



Rice Creek Watershed District Monitoring Program Plan

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Table of Contents

1	Introduction.....	1-1
1.1	Description of Watershed and Resources	1-1
1.2	Purpose and Scope of Document	1-1
2	Purpose and Scope of Data Collection	2-1
2.1	Surface Water Monitoring	2-1
2.1.1	Fixed Site (Long-Term) vs. Synoptic (Project-Specific) Sampling.....	2-1
2.1.2	One-Time (Investigative) Sampling	2-2
2.1.3	Seasonal vs. Year-Round Sampling.....	2-2
2.2	Ground Water Monitoring	2-4
2.3	Biological Monitoring.....	2-6
2.4	Geomorphology	2-7
2.5	Precipitation Monitoring.....	2-8
3	Monitoring Program.....	3-1
3.1	Surface Water.....	3-1
3.1.1	General Criteria for Site Selection.....	3-1
3.1.1.1	Streams.....	3-1
3.1.1.2	Lakes	3-2
3.2	Evaluation of the RCWD Current Monitoring Network.....	3-4
3.2.1	Monitoring Sites.....	3-4
3.2.2	Water Quality Parameters	3-6
3.2.3	Equipment	3-7
3.2.4	Data Coordination and Cooperation	3-10
3.2.4.1	Stream Monitoring.....	3-10



3.2.4.2	Lake Monitoring	3-10
3.2.5	Site-Information	3-10
3.2.6	Site-naming Conventions.....	3-11
3.2.7	Site-numbering Conventions	3-11
3.3	Water-Level Monitoring	3-12
3.3.1	Elevations.....	3-13
3.3.2	Reference Point and Stage Readings	3-13
3.3.3	Recording Stage and Streamgaging	3-14
3.4	Groundwater Monitoring	3-14
3.5	Biological Monitoring.....	3-14
3.6	Geomorphologic Monitoring	3-15
3.7	Precipitation Monitoring.....	3-15
4	Data Management.....	4-1
4.1	Data-quality Objectives	4-1
4.1.1	Sampling Design.....	4-1
4.1.2	Concentration, Loads, and Yields.....	4-3
4.2	Storage and Maintenance of Data.....	4-4
4.2.1	Data-storage Systems.....	4-4
4.2.1.1	Discrete Data.....	4-4
4.2.1.2	Time-series Data	4-5
4.2.1.3	Data-storage Plans	4-5
5	Quality Assurance and Management Procedures.....	5-1
5.1	Quality Control Sampling and Objectives	5-1
5.1.1	Considerations.....	5-1



5.1.2	Errors in Data.....	5-1
5.1.3	Types of Quality-Assurance Samples.....	5-1
5.2	Quality Management Procedures.....	5-2
5.2.1	Documentation.....	5-3
5.2.2	Quality Management of Equipment.....	5-5
5.2.3	Reagents.....	5-6
5.3	Data Integrity.....	5-6
5.4	Sample Containers, Preservation, Transportation, and Holding Times.....	5-7
5.5	Laboratory Analytical Methods.....	5-8
5.5.1	Analyses.....	5-8
5.5.2	Review of results.....	5-9
6	Summary of Recommended Enhancements to the Present Monitoring Network and Probable Costs.....	6-1
6.1	Surface water.....	6-1
6.2	Groundwater Monitoring.....	6-2
6.3	Biological Monitoring.....	6-3
6.4	Geomorphologic Monitoring.....	6-3
6.5	Precipitation Monitoring.....	6-4
6.6	General Recommendations.....	6-4
7	References.....	7-1



List of Tables

- Table 1 Surface-Water Sites Recently Sampled in the Rice Creek Watershed District
- Table 2 Lakes Sites Sampled in the RCWD

List of Figures

- Figure 1 Surface Water Sampling Sites (2009)
- Figure 2 Proposed Precipitation Monitoring Sites

List of Appendices

- Appendix A General Guidance: Health and Safety
- Appendix B Stream Site Information
- Appendix C Annual Data-Review Form
- Appendix D Monitoring Procedures
- Appendix E Quality-Assurance Objectives
- Appendix F Quality-Assurance Data Types
- Appendix G Field Forms Used by the Rice Creek Watershed District
- Appendix H Field Supplies Checklist
- Appendix I Standard Operating Procedures (SOPs) Used by the District
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1 INTRODUCTION

1.1 Description of Watershed and Resources

The Rice Creek Watershed District (RCWD) is a local unit of government working to solve and prevent water related problems. The watershed is a 186 square mile area including portions of Anoka, Hennepin, Ramsey and Washington Counties within the northeast portion of the Minneapolis – St. Paul Metropolitan area. Rice Creek is the primary watercourse within the RCWD. Rice Creek originates at Clear Lake in Forest Lake, MN, meanders southwest through a series of lakes, and joins the Mississippi River in Fridley, MN. Hardwood Creek and Clearwater Creek (both legal drainage systems) are the two most prominent tributaries to Rice Creek draining the eastern part of the watershed.

The RCWD includes many lakes and wetlands. Many of the lakes within the RCWD historically served as a source of potable water for the City of Saint Paul and the suburban communities served by the St. Paul Regional Water Services. These lakes now serve almost exclusively as an emergency supply of potable water and are used primarily for recreation.

1.2 Purpose and Scope of Document

The latest watershed management plan being prepared by the RCWD discusses developing a monitoring plan to ensure collection and management of uniform and reliable monitoring data. These data are needed to monitor the movement of water and constituents carried by that water throughout the District. Accurate data are needed to determine constituent loadings and to calibrate hydraulic and water quality models that will be used to better manage water resources in the District. The monitoring network is operated under direction of the Lake and Stream program of the RCWD.

When collecting data, it is important to follow a clearly-defined set of established methods and techniques. This results in data that are of reliable and consistent quality across all the sites monitored as part of the sampling network. Consistent, reliable, high-quality data also will be defensible should the data be called into question. These data



could be critical not only from the standpoint of water volume, but also as the primary component of loads and yields; this makes them a critical component of Minnesota's Impaired Waters (Total Maximum Daily Load) program. These procedures are discussed in more detail in subsequent sections of this document.

This document is intended to provide guidance on developing, maintaining, and operating a network of water-monitoring sites in the RCWD that will provide reliable data that is representative of flows and constituent loads moving through the RCWD. It is not meant to be all encompassing, but instead provides general guidance and recommendations on data-collection methods and sampling networks. Additional guidance, training, and mentoring is advised to ensure the best quality data. It is expected that this document will be periodically reviewed and updated as data-quality needs evolve.

During the development of this document, the existing network of sampling sites was reviewed. The data collected were not reviewed to determine variability and identify potential redundancy. That is something that needs to be done as part of an annual review of the network.

There is only very general guidance on ground water sampling included within this document, although that likely will be an important focus of data collection in the future. The guidance for that sampling network will be largely dependent on the needs of the sampling program. That will dictate not only how samples are collected, but also how groundwater wells are designed, installed, and maintained. Other special-purpose sampling also is discussed only briefly. The District should be prepared to collect special samples as the needs and capabilities of the District evolve.



2 PURPOSE AND SCOPE OF DATA COLLECTION

2.1 Surface Water Monitoring

The Rice Creek Watershed District is continuing an ongoing program to sample streams and lakes in order to establish baseline conditions and detect trends in water quality, runoff volumes, and peak flow rates. Surface water sampling is, and will continue to be, the primary focus of the District. The sampling network generally is driven by a variety of concerns including documenting the quality of water resources or compliance with regulations such as discharge restrictions. These basically require monitoring the concentration of constituents. Some of the sampling sites are maintained with the goal of better defining pollutant loading, in support of Total Maximum Daily Load (TMDL) studies. This requires measurement of both the constituent concentration and the volume of flow. Aquatic chemistry in natural waters varies substantially throughout time. The chemistry often varies greatly even at different times of the day. This can be observed in field measurements of temperature, dissolved oxygen, pH, and even conductance and chemical concentrations that are measured at different times of the day or night. Because concentrations and flow change over time, both measurements need to be made frequently and across a range of expected values so they may be integrated over time using some sort of averaging, estimating, or modeling technique.

2.1.1 Fixed Site (Long-Term) vs. Synoptic (Project-Specific) Sampling

The present RCWD sampling network consists primarily of fixed sampling sites. However, there often is need to collect samples from groups of sites across a broader area over a relatively short time period. This synoptic sampling may be used to detect areal differences in constituent concentrations, but ignores the important temporal component of water quality. These efforts often are driven by some concern about the distribution of a contaminant. Studies of this nature require careful planning to optimize resources.

Detecting, assessing, and analyzing long-term trends is the primary purpose for establishing fixed monitoring sites. These sites generally will be operated for several years and the data evaluated annually using statistically-acceptable techniques to



determine whether a trend is evident. Synoptic sampling sites are generally “project specific” sites, established to assess, evaluate and resolve local or regional water quality issues and problems (e.g., for completing mass balance for a TMDL study). Synoptic sites are generally operated for a few years and generally do not provide enough data for trend analysis. Rather, the sites are meant to evaluate the short-term changes, perhaps as the result of a management activity, or large-scale but temporally short environmental event such as a sudden discharge or flood. Whether or not the management activity or environmental event actually *caused* or resulted in a measured change in flow or water quality must be assessed carefully, and with detailed knowledge of possible confounding factors.

2.1.2 One-Time (Investigative) Sampling

One-time (i.e., investigative) sampling consists of collecting one or two samples, usually upon the request of a citizen or Board member, as a result of perceived transient or short-term water quality problem. The likelihood of identifying or quantifying a transient occurrence using a grab sample is challenging – sample collection must occur at the same time as the problem is manifested. Substances introduced to a stream or lake may rapidly dissipate or otherwise become undetectable making them difficult to trace to a particular source or cause. The data generated do not confirm whether there is a problem, and generally is of low value. However, a recurring or persistent problem, or the detection of a “spike” in the pollutant of concern, may justify initiating a special study to identify and better quantify the problem.

2.1.3 Seasonal vs. Year-Round Sampling

Many sites monitored in the RCWD are operated only during the open-water season. This primarily is because streamgaging is extremely difficult in Minnesota winters when the streams become ice-covered, and equipment that is not properly protected may be damaged. A secondary reason is that the normal stage-streamflow relation relied upon during open water is almost useless because of backwater effects from ice. However, there may be justification in maintaining the operation of selected sites throughout the winter months.



Many streams stop flowing during the winter because there is no runoff to maintain flow or they freeze to the bottom effectively damming the water. Streams that continue to flow often are fed by baseflow from groundwater discharge or the outflow from lakes. Winter flows may be greater than late summer flows because evaporation and transpiration no longer draw water from the hydrologic system allowing it to flow in the streams. Also, the weight of precipitation accumulating on the surface of lake ice pushes the underlying water through the lake outlet.

The steady stream of water flowing for the many months of winter can move considerable amounts of material through the system, although most is in the dissolved form. An exception occurs when ice forces the stream to cut a channel into the stream bottom.

Under winter conditions the stream water can become hostile to living organisms even though they are adapted to the cold water. Oxygen may become depleted during winter, especially in organically-enriched streams, because it is not replaced by contact with the air and photosynthesis is severely reduced. Under anoxic conditions, potentially toxic concentrations of ammonia and sulfides may build up in the ice-covered streams.

Sodium chloride is a common contaminant in streams during the winter because of its use during road de-icing. Winter sampling for chloride in potentially-affected streams will be used to assess possible toxicity, assess seasonality, and determine whether concentrations meet or exceed water-quality criteria. The occurrence of road deicing chemicals in natural waters is presented in Mullany and others (2009).

It is advised that the RCWD conduct winter sampling and flow measurement at selected stream sites that are considered important. This would apply particularly to streams such as Hardwood Creek that already is listed as being impaired for habitat and low dissolved oxygen concentrations. The sampling would be conducted when streams are likely to be stressed when flows are low, light penetration is minimal, and re-aeration is not occurring. This typically will be during late January to early February.



2.2 Ground Water Monitoring

The need grows to better understand groundwater and its interaction with surface waters, the need for ground water monitoring is expected to increase. The District may not be able to fully rely on other agencies such as the USGS, the DNR, or the MPCA to conduct routine groundwater-level and quality monitoring because they have reduced their monitoring networks in response to budget declines. This has resulted in reduced measurement frequency and discontinuing some sites.

As resources allow, the District could provide support for groundwater monitoring as part of the data-collection program. The primary groundwater monitoring is expected to be related to evaluating wetland hydrology as a component of a wetland restoration project or Wetland Conservation Act (WCA) compliance monitoring. The second possible component of a groundwater monitoring program is monitoring the surface water – groundwater interaction for groundwater sensitive resources as defined by the Watershed Management Plan and lakes and stream with a surface water – groundwater connection. Establishing groundwater levels and direction of the groundwater gradient is the expected focus of groundwater monitoring.

A groundwater monitoring program is presented in the Groundwater Management & Planning Program Final Report prepared by Emmons and Olivier Resources (January 2009). Per the recommendations of that document, bi-weekly, or at least monthly, level measurements would provide appropriate data resolution. Better resolution would be provided using submersible pressure transducers that would document diel fluctuations in groundwater levels that can be caused by evapotranspiration or earthtides. Because the watershed is a complex hydrologic system that involves lakes and wetlands that probably are interconnected with shallow groundwater, knowledge of that system likely will aid in the understanding of the hydrologic system. However, that is an undertaking that would be done only when the District is willing to make a long-term commitment to invest time and resources into that program.



That document also recommends installing new wells in selected locations, but this can be an expensive undertaking. That effort needs to support the goals of the RCWD, or be part of a long-term study or project. It also recommends that existing wells be maintained as part of a trend network and measured at least once each year. However, seasonal and more frequent measurements would provide better resolution. As the Hardwood Creek TMDL process continues, those wells should be maintained and measured, and could be sampled for field parameters and nutrients to determine how groundwater influences streamflow quantity and quality. If opportunities arise, the RCWD could acquire state and federal wells that would otherwise be dropped from monitoring programs. Monitoring groundwater would only be done in shallow aquifers that could interact with lakes, streams, and wetlands. Monitoring water in deeper aquifers, including those that typically supply public drinking water, are the responsibility of water suppliers, state, and federal agencies; not the RCWD.

Basic equipment to measure ground water levels includes a steel tape that costs about \$100 with some chalk to see where the water cuts a line on the tape. Electric tapes are more expensive at about \$500 and have advantages as well as shortcomings.

An effort to sample groundwater chemistry will require considerably more investment in equipment and training. Shallow wells (less than about 20 feet) can be sampled with suction pumps that vary widely in cost, but deeper wells require submersible pumps costing hundreds of dollars that push the water to the surface. Bailers are inexpensive, often less than \$50, but can churn the water in wells and disturb sediments accumulated at the bottom of the well. The bailer also requires considerable effort to remove the stagnant water inside the well so that any sample that is collected actually represents what is in the aquifer.

Because the RCWD is in a metropolitan suburban area, it is possible that a broad range of contaminants may have been dumped that might be worth monitoring. However, most have been documented and are being monitored as needed by state and federal authorities.



In most cases, the RCWD will need to sample for typical field values including conductance and pH, nutrients, and chloride as an indicator of urban inputs. These are intended to document the relation between groundwater the expansive surface-water resource in the District. The nutrients to be sampled will include phosphorus and soluble forms of nitrogen; ammonia plus organic (previously called Kjeldahl) and nitrite plus nitrate. If unexpectedly high concentrations are found or there is concern for changing concentrations, one sample to document concentrations may be sufficient. Quarterly or more frequent sampling is advised when a concern is identified because concentrations can vary seasonally or with recharge events. Additional measurements could be made, but that should not be done without considering the cost and whether the added information is important. Consultation with hydrogeologists may be advisable.

Groundwater sampling guidance can be found in MPCA's Field Guidance Manual (Stockinger, 1998), and the USGS (U.S. Geological Survey) Techniques of Water-Resources Investigations (TWRI): National field manual for the collection of water-quality data.

2.3 Biological Monitoring

The District has had success working with state agencies, contractors, and volunteers to conduct biological monitoring, and will continue to support those efforts. The District has cooperated with the MPCA, for example, in assessing the biological condition along portions of Hardwood Creek and Rice Creek. Although beyond the scope of this document, the District could adopt established protocols (e.g. MPCA, 2009) and conduct their own biological sampling. This would provide data that are more consistent and would have a known quality than much of what is presently available. A simple place to start might be microbiological sampling for indicator bacteria such as fecal coliform or *Escherichia coli*. This type of sampling requires minimal equipment and training, but may require the RCWD to work with different laboratories, thus adding time and expense. The Upper Mississippi River Bacteria TMDL (2009, in progress) is expected to produce "local partner" monitoring protocols for bacteria, including sampling frequency and timing.



The WMP identifies future biological monitoring to establish reference conditions for wetland systems and as one component of evaluating the ecological integrity of rivers and streams in the District. Use of MPCA's Rapid Biological Assessment Protocol (also known as the MPCA Stream Habitat Assessment, or MSHA) is the most economical method for completing this type of monitoring. Initial monitoring locations would include high quality wetlands and those locations along the Trunk system where restoration projects are underway to reconnect meanders and improve the habitat (e.g., middle Rice Creek, lower Clearwater Creek, and Hardwood Creek).

Several volunteer biological monitoring programs have been sponsored by the RCWD in recent years. The Stream Health Evaluation Program (SHEP), which is run by the Friends of the Mississippi River (FMR), collects invertebrate data from each of the trunk systems. Although these data will not be utilized by MPCA for standards assessment, they do provide a valuable long-term record of invertebrate populations, which serves as a general indicator of overall stream health. Since volunteer invertebrate monitoring programs are often criticized for lack of QA/QC, SHEP invertebrate identification accuracy was evaluated by specialists at the MPCA. This assessment found that SHEP volunteers were correct in approximately 98% of their IDs. The RCWD also works with Anoka County and local high school science classes to monitor stream invertebrate populations. This program does not have a QA/QC procedure; the main value in this program is educational.

2.4 Geomorphology

The District has worked with state agencies, contractors, and volunteers to assess stream geomorphology, primarily at the channel restoration areas shown in **Figure 1**. Monitoring at these locations shall continue on an annual and post-runoff-event basis to assess effectiveness and adjust strategies, as necessary, for future projects. Additional sites could be located along lower Rice Creek where runoff may be causing increased erosion of stream banks resulting in sediment deposition in Long and Locke Lakes. The District could adopt established protocols and assess stream geomorphology on their own if the current assessments were not adequate or are discontinued. Existing protocols



include Rosgen's WARSSS, the USDA's ARS approach, and a series of protocols adopted as part of USGS National Water-Quality Assessment (NAWQA) program including biological sampling, habitat, and laboratory protocols that can be found at <http://water.usgs.gov/nawqa/protocols/bioprotocols.html>. Choosing specific portions of existing protocols may be an appropriate way to assess certain aspects of stream stability or sediment transport, and could save time and resources. For example, a combination of the "Pfankuch" Channel Stability Evaluation and Rosgen's Bank Erosion Hazard Index (BEHI) may be sufficient for evaluating stream stability, as opposed to following the entire WARSSS protocol.

The District already has the capability to make detailed measurements of stream and overbank area cross-sections. By installing bank pins, bed chains, or permanent cross sections along stream transects that typically span the length 20 times the bank-full width, the rates of aggradation and degradation could be assessed. These data would be used to evaluate stream geomorphology and evaluate changes in channel configuration resulting from runoff events or stream-channel restoration. These measurement tools are needed near and below the channel restoration areas shown in **Figure 1**. They also are needed at other areas along critical-resource areas where bank-instability is known to be a problem.

The USGS, in conjunction with their streamgaging site discussed elsewhere, has proposed sampling sediment bedload at that site. Although this might be an expensive undertaking that provides only semi-quantitative data, the USGS has proposed to share the cost as part of a larger monitoring effort. These data will be helpful evaluating the transport of bed material downstream of a recently-restored section of Rice Creek and may provide an indication of the amount of material delivered to Long Lake which is slightly more than a mile downstream.

2.5 Precipitation Monitoring

Precipitation and related weather information is a critical component of runoff models and most hydrologic models, including those that simulate the movement of constituents in surface water. A rain gage network operated by the RCWD can provide



helpful information because it generally would be a much denser network than anything presently available. The District has operated a network of tipping-buck rain gages co-located at selected sites with equipment used to monitor stream stage. The location of those sites is variable and the operation of the network is tentative because of the time needed to operate and maintain the network within the existing stream and lake monitoring program.

Existing sources of precipitation and related weather information include the Minnesota Climatology Working Group (<http://climate.umn.edu/>) and the Weather Underground (<http://www.wunderground.com/>). The Minnesota Climatology Working Group is supported by the State of Minnesota and provides historical and up-to-the-minute weather data. The data are quality assured and generally can be used to estimate weather conditions for almost any point in the state extrapolated or interpolated from the existing network. Much of the data provided for the District would be based on data collected near Forest Lake and St. Paul, MN, effectively spanning the watershed. The Weather Underground is an on-line, near real-time, volunteer-operated, automated weather-information network. The quality of the data provided by the Weather Underground is uncertain and may be reliant entirely upon the commitment of the weather-station operator. The Weather Underground data can be quality assured by the end user by comparing results from adjacent stations. However, the density of that network appears sparse in the RCWD area. The newly-established USGS streamflow gage on the lower Rice Creek includes a tipping bucket rain gage that provides data in near real time. Although the placement of that gage near trees is not ideal, the information is still useful.



3 MONITORING PROGRAM

3.1 Surface Water

3.1.1 General Criteria for Site Selection

The RCWD has an established network of fixed surface water monitoring sites. The District also operates several synoptic sites. As the fixed network matures, the District needs to re-evaluate the network and determine whether sites can be discontinued, sampled at a reduced frequency, or moved to more relevant locations. This section describes considerations about site locations that will be considered for existing sites and for the location of new monitoring sites.

3.1.1.1 Streams

Stream sites will be located with consideration of a number of different factors. Unfortunately, achieving all of these factors may be difficult, when the location of the site is so critical that the network operator has to settle for less than ideal conditions. The key in this situation is understanding the quality of the data generated.

The stream site must have steady, tranquil flow. It will have few or no riffles and may be pooled at the gaging site. The site should have a good hydraulic control at all stages which usually is the first riffle below the gage. A culvert opening often makes a good control. As the flow changes the control may change to become the stream banks or channel. Streamflow measurements made over a range of water levels (stages) and flow values is used to establish a rating (often a log-log relation) that defines the relation between stage and streamflow. Once this has been established a rating may be usable for many years until a flood or other channel-changing event alters the relation. Temporary adjustments to the rating may be needed as vegetation or debris alter the channel configuration. Routine measurements of streamflow are needed because they will identify how that relation changes resulting in the need to apply a shift in the stage-streamflow relation. This often is a seasonal condition at sites where vegetation temporarily causes backwater. Formation of an ice cover can result in several feet of backwater making the open water rating almost useless and may be evident when a hole



is opened and the stream water rises through that opening begins flowing over the ice surface. Debris also is an issue with controls as it may block the control and cause erratic stage changes that are not always evident when reviewing the data. Rantz and others (1982) provide details about streamgaging and rating curves and also provide forms used to document details of streamflow measurements and how they relate to the established stage-streamflow rating. It is also suggested that persons working with the streamflow ratings periodically prepare plots of residual values to identify trends in how the anomalous data values may change over time.

Good access to the sites at all stages is important. If the access is blocked by flood waters or other conditions, an alternative needs to be available to avoid a missed opportunity to collect some of the most critical data obtained at a site.

Some installations may need to be hidden or otherwise protected from vandals. Providing a description of the equipment inside the shelter and its purpose can deter vandalism. (“There is nothing useful in here”)

3.1.1.2 Lakes

Lake monitoring is quite different than stream monitoring because a shelter with dedicated equipment generally is not needed unless lake stage or field measurements are recorded. However, good access is needed and may only be practical when a public or private boat launch is available. Some lakes may require remote access from another lake or stream, or may require carrying in a smaller craft such as a canoe.

The typical sample location within the lake is usually the deepest point, often near the center of the lake. Getting to that point may be a problem and may have to be postponed if strong winds, the threat of lightning strikes or other conditions present a hazard. It is important to visit the same location on each sampling trip; shoreline samples are not an acceptable substitute for the standard sampling location. Refer to the sections on safety and hazards discussed in **Appendix A**.

Shallow lakes may require different sampling protocols than deep lakes. Although shallow lakes tend to remain well mixed vertically by wind action, the quality



of the lake may vary laterally. Aquatic vegetation, islands, and flow through the lakes can result in considerable heterogeneity, so compositing samples from multiple points might be considered. A basic approach to document variations in water quality without collecting multiple samples is to use a multi-parameter meter to measure whether there is variability in water quality or establish that the lake is well mixed.

Placement of a water-level monitoring gage on a lake also must be carefully considered. A gage mounted on a dock could be difficult to read accurately unless the reader positions themselves away from the dock. Year-to-year variations can result when the gage is placed on a dock that is taken out each winter and replaced, or one that is subject to heaving from ice or ice floes; staff gages mounted in the lake bottom also are subject to heaving. When ice is a concern, elevations must be verified each spring. Often a reading taped down from an object suspended over the water or taped up from a submerged object such as a boulder is most reliable. Staff gages mounted to water control structures are found in the District and are reliable.

Wind direction is another consideration when recording lake stage. This tendency of the water to pile up on the downwind side of the lake will cause temporary falsely-high or falsely-low readings depending on the direction of the wind relative reading location. In some lakes a seiche will occur where the level will oscillate ('slosh') for hours after the wind has stopped.

The lake sampling that is ongoing needs to be maintained to monitor trophic status and identify trends in lake-water quality. It is advisable to rotate low-priority lakes so they are sampled periodically rather than many years in a row. Lakes that are important resources should be sampled at least 2-3 times yearly during the summer using the sampling programs that are in place. Winter sampling also should be done in selected lakes to determine whether low dissolved oxygen or other adverse conditions might result in fish kills. This may not have to be done every year except in lakes where a threat to the aquatic ecosystem is known or suspected.



3.2 Evaluation of the RCWD Current Monitoring Network

3.2.1 Monitoring Sites

Figure 1 shows surface-water sites in the RCWD that have been routinely sampled during 2007-09. Generally, these sites are part of the Districts fixed (long-term) sampling network. **Table 1** provides pertinent information about the stream sites including a subjective categorization of the sites as indicators or integrators (see below), or both. The lake sites, including those sampled by other agencies, are listed in **Table 2**. Additional information about the stream-sampling sites is also available in **Appendix B**. Although some of the sites are difficult to monitor, they all are at important locations within the District. Many are indicative of the outflow from major areas called planning regions including Hardwood Creek, Clearwater Creek and middle and lower parts of Rice Creek, and integrate the variety of hydrologic influences present in those areas. These sites are important to maintain and operate as they provide baseline and trend information for important parts of the watershed. They provide a reference for other short-term or small scale studies that are likely to develop as needs arise.

Other sites are located near important points in the system and are used to evaluate or indicate local conditions or resource issues. They are located at the outlets of minor watersheds to monitor the effectiveness of best management practices (BMPs) that are being employed, near the inlets of lakes that have water-quality concerns, or downstream of areas that are suspected of contributing excessive contaminants to the stream system.

While the RCWD focuses primarily on monitoring surface waters, including streams and lakes, during the open-water season, other agencies also conduct studies in collaboration with the District, its activities, and interests. These efforts focus primarily on lakes that are listed in **Table 2**. Ramsey County has an active sampling network and much of it overlaps the southern portions of the RCWD. The Metropolitan Council of the Twin Cities Area manages a lake water quality data collection program called the Citizen-Assisted Monitoring Program (CAMP) that is conducted primarily by volunteers



on selected lakes. Recently, the USGS has established a streamflow monitoring gage on the main stem of Rice Creek that will be operated year round.

Table 1 provides a qualitative description of the value on each of the sampling sites. The present sampling network appears to be functioning well and is providing good coverage of the watershed. Because many of the sites have been operated for only a few years or less, and the personnel operating the network are developing a better understanding of the network, it is advisable to make no changes until the existing network can be evaluated in more detail.

The new USGS site and site R-5 are redundant for streamflow record, except for probable intervening stormwater and groundwater inflows. The streamflow records will be run concurrently for one year to verify redundancy before streamflow records at site R-5 are discontinued. Site R-5 is an important water-quality sampling site to monitor the effects of channel restoration immediately upstream, but could be co-located at the USGS site with only minor effects on the water-quality record.

Based on information available, it appears that two sites in the northern part of the District that had been sampled are not being sampled during 2009. These sites on the main stem of upper Rice Creek represent important contributions to Peltier and the remaining Chain of Lakes. The most upstream site, R9 represents Clear, Mud, and Howard Lake outflow and provide background water quality information as the creek passes through considerable wetlands before flowing into Peltier Lake. The next downstream site, R-8.5, appears to have discontinued after 2007 and can be used to evaluate the water flowing into Peltier Lake. This contribution to Peltier Lake is important when evaluating the mass balance of constituents moving into and through this lake.

There is a need to evaluate the data that have been collected and learn how those data are meeting the information needs of the District. Annually compiling the information requested in the form shown in **Appendix C**, which compares the distribution of recent compared to historical data, will meet that need. Assessment of the quality of those data is the first priority to determine whether the network needs to be



more robust. Potential shortfalls could be the operation of those sites only during the open-water season, the difficulty in collecting reliable data during extreme events, and the potential for bias. Bias could result from any number of factors including the gage location and equipment configuration, the seasonal nature of the data collection, and other factors that may be poorly understood.

The monitoring network has to provide information that leads to a comprehensive understanding of water movement in the watershed in order to support the District-wide hydraulic and hydrologic modeling effort. Once developed, this model will route flows through the hydrological system focusing on nodes at critical points where major tributaries of the watershed converge. As part of that need, the elevation of the sites relative to one another is important. Local benchmarks need to be established at each location, so the elevation of equipment can be related throughout the District. Because most sites may not be robust enough to reliably measure flows during major runoff events, detailed measurements of stream and overbank area cross-sections would be helpful. These data also could be used to evaluate stream geomorphology and evaluate changes in channel configuration resulting from runoff events.

3.2.2 Water Quality Parameters

The present sampling protocol provides for field measurements of streamflow, water temperature, specific conductance (SC), pH, and dissolved oxygen. Samples are analyzed for total and soluble-reactive phosphorus, total and organic particulate matter (total and volatile suspended solids), total ammonia plus organic nitrogen (formerly described as Kjeldahl nitrogen), and chloride. These provide a useful overview of constituent concentrations throughout the watershed and their variability over time and space. They also are important for addressing the distribution, sources, and transport of contaminants. The nutrient concentrations are important in relation to nutrient enrichment in lakes and streams. SC and the chloride concentration can be indicators of anthropogenic influences, especially road-deicing salts.

Adding additional constituents to the fixed sampling network during routine sampling may be needed to address special considerations such as known contaminant



problems or other issues. Some constituents to add include dissolved solids to establish the relation with measurements of SC and chloride concentrations. The addition of turbidity measurements will help establish a relation with other measures indicative of suspended material as well as define stream impairments in relation to state standards.

The parameters evaluated at synoptic sites are specific to the water quality issue. Special issues such as the low dissolved oxygen TMDL study for Hardwood Creek may require special data collection. The RCWD needs to determine whether the cause is excessive temperatures resulting in low oxygen solubility, high loadings of oxygen-demanding substances (that may be naturally occurring), excessive nutrient loads that cause wide swings in plant productivity and respiration that cause diurnal extremes in oxygen concentrations, or other factors. These all require a specially-designed sampling program that can determine the cause of the listed impairment. It is suggested that diurnal monitoring occur for dissolved oxygen using a deployed monitor. Monitoring of biological oxygen demand (BOD) on Hardwood Creek would provide data to support the TMDL; periodic monitoring of BOD on Clearwater and Rice Creeks would be useful if dissolved oxygen concentrations are a concern (i.e. non-support of MN standards). However, BOD measurement results are complicated by the analytical methods used and may not be comparable to studies performed in other areas.

3.2.3 Equipment

There is a wide range in the quality of environmental sampling equipment available on the market with some equipment lacking the range, precision, and reproducibility of higher-end models. Some instruments will provide values that lack precision making the results difficult to qualify when the results are stored without extensive remarks. This may result in wasted personnel time and lack of confidence in the data. Precision, quality of data, service and dependability all must weigh-in to the decision of what equipment to purchase. Unfortunately, cost is not always a good indicator of the best equipment to buy, so it is helpful to rely on others having experience using various makes and models.



The RCWD uses a variety of different types of monitoring equipment. For measuring level, the District uses submerged bubblers (gas-pressure), submerged pressure transducers, and ultrasonic transducers mounted above the water surface. Each of these technologies has advantages and disadvantages; particularly because they have different maintenance requirements. When working correctly, they all can collect high-quality data.

For measuring streamflow, the District primarily uses an acoustic-doppler velocity meter brand-named a “FlowTracker”. At some sites, an electromagnetic velocity meter marketed by Marsh McBirney is used. For measuring physical characteristics, a portable multimeter is used to measure temperature, pH, specific conductance, and dissolved oxygen (using optical technology). All equipment are maintained to manufacturer specifications, and calibrated regularly using recommended methods and standards.

The RCWD needs to acquire a uniform set of monitoring equipment as older equipment is replaced. An annual budget of at least \$5-10,000 per year is recommended. This will simplify servicing of equipment, especially when more than one person is visiting the sites. This may not be entirely possible because different sites may require different technology to make the needed measurements and interface with other equipment.

Another concern is having back-up equipment for use and deployment when operating equipment fails. An older working unit could be used as a backup, but needs to be maintained and serviced for when it is needed. Backup equipment also will allow bench tests on field units that are providing questionable data.

One of the greatest challenges with data collection is obtaining extreme-event samples. Because samples are routinely grabbed and remote-sampling equipment (wands, weighted bottles, etc.) are available, high-flow sampling equipment may not be an important concern. However, they may not collect a representative sample of materials including phosphorus that may be associated with the suspended particulate matter that may not be evenly distributed in the stream. Because streams in the RCWD



generally are small, they generally are well mixed so vertical and lateral stratification is not a concern. However, during extreme flow conditions, personnel will collect samples from as near the stream centroid as possible to assure that the sample is representative of the material being carried by the stream and not what water is near the stream bank. Incomplete vertical or horizontal mixing may be a concern under certain flow regimes, multiple cross-sectional measurements of pH and SC will document variability, but compositing samples from multiple verticals using a depth-integrating sampler is the best method of assuring a representative stream-water sample.

A critical problem with grab sampling is the relation to flow regime. When streamflow is increasing following a runoff event, the concentration (and load) of suspended solids is higher than when the streamflow is declining. This effect is termed hysteresis and can seriously affect the results of monitoring and the interpretation of results from that monitoring program. The load of constituents associated with solids, generally including phosphorus, may be biased by the timing of sample collection. If the samples are collected as the streamflow is receding (as often happens because of delays getting out to collect environmental samples), the solids concentration typically will be much less than if the samples are collected as the streamflow is increasing. This emphasizes the need to have a sampling program that is focused on the timing of sample collection. At sites where sediment (and phosphorus) loading to downstream sites is important, personnel need to be mobilized to collect samples as the stream is rising and possibly again as it is falling to quantify the differences. Fortunately, automatic samplers (discussed in **Appendix D**) can fill those gaps in a complex sampling network where persons are not able to get to all sampling sites at the most opportune time.

The District presently does not have the capability to measure streamflow at some sites during high-flow events. There is at least one site, H-1.3, where conditions prevent even making a routine streamflow measurement without additional equipment. The investment would not be great (possibly only \$1,000 depending on the configuration and compatibility with existing equipment) and well worth the satisfaction that the data collected there can reliably be used to compute loads and applied to hydraulic models. It



is recommended that the District acquire a set of streamflow-measuring equipment that could be equipped for measuring off of bridges and other locations where and when wading is not possible, and that also could be used for quality-assurance (e.g. check measurements). The District could contract with the local USGS office to collect non-wadable measurements, but this may not be a reliable alternative because personnel may not be available for small-stream measurements when runoff events occur.

3.2.4 Data Coordination and Cooperation

Various agencies and organizations will, at times, be involved in the collection of data. These groups are expected to coordinate their field activities with other organizations to minimize duplication of similar efforts or to use those related sampling efforts to supplement the data already being collected. These coordinated sampling efforts also provide quality assurance of the data being collected.

3.2.4.1 Stream Monitoring

The RCWD is the primary organization conducting stream-monitoring in the Rice Creek Watershed. The District will continue to work with other organizations collecting flowing-water samples in the Watershed. The District recently entered into a cooperative agreement with the USGS to monitor streamflow on the lower Rice Creek year-round that will supplement and provide quality-assurance of data being collected by the District.

3.2.4.2 Lake Monitoring

Lake-monitoring is conducted by a number of organizations including the RCWD, the Metropolitan Council of Environmental Services, Ramsey County, and local organizations. The RCWD is coordinating data-collection efforts to avoid duplication.

3.2.5 Site-Information

Because sites are monitored for a variety measurements that may be stored in different data bases, an electronic look-up file that may be called a 'Site' file will be maintained. This would include all important information for a site no matter where the collected data are stored. This file would include primary look-up keys such as site identifier and site number. Additional information that would be stored includes the site



name, the elevation, latitude-longitude and/or Universal Transverse Mercator (UTM) coordinates, and other relevant information that may include descriptive site information.

3.2.6 Site-naming Conventions

The RCWD is encouraged to adopt a uniform site-naming convention that is understandable by most of the people that may encounter the data. Lake names are reasonably uniform because they generally have commonly accepted names on official maps. The list of stream-sampling sites in **Table 1** shows site names that are efficient for routine field personnel that are familiar with the sites, and is convenient to write on forms or sample containers. However, the names often mean little to other users. A suggested approach is to use a stream name followed by a nearby legal feature such as a town or city. This will work with mixed success in the RCWD as many of the sampled sites are parts of legal drainage systems that do not have common names.

An example would be the name for the important site labeled CEP1. **Table 1** lists this site identifier and describes the site (Waterbody / Location) as Anoka County Ditch 53-62 at Carl Eck Park in Circle Pines, MN. This name is inconvenient to use routinely, but provides detailed information that gives the casual user a close approximation of the sampling site location. Many of the descriptions provided in Table 1 may be a good start at providing meaningful names for sites in the RCWD sampling network. Further guidance for more detailed site naming is provided in the companion document describing specifications for hydraulic modeling in the RCWD.

3.2.7 Site-numbering Conventions

The USGS, in cooperation with the NRCS, created 12-digit (or 6-level) hydrologic units down to approximately 10,000-acre or 15 square-mile drainage areas. They were based upon the existing 8-digit (or 4-level) hydrologic units completed by the USGS in the 1970's. The Minnesota DNR has developed their own hydrologic boundaries within the state known as the Major and Minor Watersheds and is currently in the process of updating the boundaries as part of its Lakeshed Mapping Project. The RCWD is further delineating the Rice Creek watershed into 19-digit hydrologic units using topography from LIDAR (Light Detection and Ranging) data which allows delineation to a finer



scale than the 12-digit watersheds. The 19-digit hydrologic unit codes are an extension of the existing 12-digit unit codes. They follow the standards established by the USGS Federal Guidelines, Requirements and Procedures for the National Watershed Boundary Dataset (<http://pubs.usgs.gov/tm/tm11a3/>, accessed July 9, 2009). Although the District will maintain the current site-identification system, it would help to add a field in the sitefile (described elsewhere) to allow persons to sort sampling sites in a downstream order. This would simplify the routing of water and constituent loads.

The Minnesota DNR maintains Lake-identification codes for most lakes in the state. The numbering format contains 6 digits; the template is XX-XXXX or XXXXXX. The first two digits represent the county in which the lake is primarily located, and remaining digits are sequentially assigned. The database, called 'Lakefinder', contains much of the available data for lakes including location, bathymetry, and water quality. The database is available at:

<http://www.dnr.state.mn.us/lakefind/index.html>

3.3 Water-Level Monitoring

Monitoring water levels is needed for both streams and lakes, and similar equipment may be used for each. However, the purpose of the data collection is quite different. Lake levels generally are recorded to determine the volume contained, while streams are monitored to determine the volume flowing past a point. High water information is also especially useful for calibrating hydraulic models. The volume of water flowing in a stream is related to the depth (water level) by making a series of streamflow measurements and developing a rating based on that relationship -- greater volume is accompanied by greater depth. Recent technology has allowed determination of the volume passing a point in a stream by measuring the velocity of particles moving past a Doppler sensor, but this still requires information about the cross section of the stream including the depth or water-level of the stream. That technology generally has been expensive and not suited for small streams, but newer equipment is available that may be applicable for difficult sites such as CD-25 where velocities are slow, reverse flow may occur, and stream stage does not relate well to streamflow.



3.3.1 Elevations

Each of the RCWD monitoring sites are part of a broader monitoring network that will be evaluated as part of a larger system. Water at a given location arrives from upstream at a higher elevation and continues down-gradient to another location. It is important to have the elevation of these sites referenced relative to one another via a common system. The RCWD is in the process of determining elevations relative to the National Geographic Vertical Datum at each of the sites in the watershed. It is not certain whether this was done in the past, but it is wise to verify older readings using newer technology that combines global-positioning system readings with reference to precisely-maintained base-station elevations.

3.3.2 Reference Point and Stage Readings

A primary, highly stable, reference point must be established very near the gaging location that is tied into this network elevation. This point is available for use when GPS or other surveying equipment is not available. An identified point on a paved surface, a spike near the base of an established tree, or other stable object is recommended. Secondary reference points may be advisable if construction, washout, or some other calamity could disturb the primary reference point.

Relative to the elevation of that fixed reference point a measuring point for stage readings is established at a point near the water surface that presumably will not dry up. This may be a point on a bridge, culvert, rock, or other structure that can be related (vertically) to the water-surface elevation. The structure may be above or below the water surface. A vertical staff gage, a horizontal cantilever gage, or other device may be installed. Staff gages mounted in the bottom of the water body being measured are unreliable because ice and other factors may alter its elevation giving inaccurate readings. Frequent verification of the elevation will document whether the gage is subject to disturbances causing changes in elevation.

Care must be taken when making a tape-down reading. Staff gages and submersed or bubbler-assisted transducers typically provide a higher reading at higher stages. A tape-down is opposite and needs to be subtracted from the elevation of the



measuring point to provide the elevation of the water surface. This will be recorded on the field-notes to document possible subtraction errors.

3.3.3 Recording Stage and Streamgaging

Information about recording stream stage, streamgaging, and computing records of streamflow is provided in **Appendix D**. More detailed information and guidance, including rating-curve development, is provided in Rantz and others (1982)

3.4 Groundwater Monitoring

A successful District-wide groundwater monitoring program requires a considerable long-term financial commitment. Because the primary responsibility for groundwater resources rests with other state agencies, groundwater monitoring undertaken by the RCWD should be related to and focused on the specific project needs of the District. These needs are expected to focus on shallow groundwater levels as a component of wetland restorations, establishing water budgets for lakes, determining the extent of interaction between groundwater and streamflow and assessing impacts to groundwater sensitive resources. The District may on a case-by-case basis decide to financially support long-term aquifer monitoring in support of other agencies like the Minnesota Department of Natural Resources.

3.5 Biological Monitoring

The RCWD should continue to support biological monitoring as a component of their educational program. The feasibility and financial commitment associated with implementing biological monitoring at the outlet of each of the five (5) planning regions should be evaluated and, if possible, implemented. Biological monitoring at these locations would be expected to consist of collecting data on fish assemblages and aquatic macroinvertebrate-population data sufficient to estimate species diversity and compute Indices of Biotic Integrity. Monitoring should be long-term and associated with a long-term surface water quality monitoring locations in order to correlate physical and chemical data with biological data. The locations selected are expected to integrate the



upstream water quality condition. Modification of the SHEP program could perhaps serve this function.

3.6 Geomorphologic Monitoring

The geomorphologic monitoring conducted by the RCWD should be related to and focused on the specific project needs of the District. These needs are expected to primarily be monitoring the changes in stream stability associated with restoration projects on Hardwood Creek downstream of Highway 61 and Middle Rice Creek. Long-term geomorphologic monitoring locations should also be established for assessing long-term stream stability near the outlet of each major planning region, and co-located with the biological monitoring locations. The protocols should be reviewed to determine what is most appropriate. Geomorphic surveys of the stream cross section can be made periodically (typically every other year). Creating a photographic record of condition would augment other qualitative indices.

Because of the interest in sediment sources and sinks along Rice Creek and the District's obligation to maintain portions of Locke and Long Lake, sediment monitoring sufficient to assess and estimate total sediment loads at multiple locations along Rice Creek, should be implemented. The monitoring locations should be strategically placed to understand the inputs from Hardwood Creek and Clearwater Creek and the affect of the lakes (e.g., Peltier) located in the middle portion of the District. Possible monitoring locations are: 1) Rice Creek below the ACD 15 / JD 4 outlet; 2) outlet from Hardwood Creek; 3) outlet from Clearwater Creek; 4) below Peltier Lake; 5) middle Rice Creek; 6) Upstream of Long Lake; and 6) between Long Lake and Locke Lake; and 7) Downstream of Locke Lake. The number and intensity of monitoring should be adjusted based on the resources of the District. The goal of the monitoring would be to establish a sediment mass balance for Rice Creek.

3.7 Precipitation Monitoring

The RCWD has a number of tipping-bucket rain gages that are in reasonably good working condition that were part of a 10-station network operated as recently as 2007.

Those gages could continue to be operated as part of a network, but a rain-gage network



of that type is labor intensive and requires a commitment to operate and maintain. A rain gage network needs to be serviced on a regular basis. When it does not rain, debris including bird droppings can accumulate in the funnel and bucket and interfere with performance and accuracy of the unit.

Rain-gage placement is important and needs to be based on professional guidance. They must be placed away from trees. To be meaningful in understanding the relation between rainfall and runoff, rain gages need to be placed upstream from the stream gage approximately in the middle or near the headwaters of the contributing watershed.

Tipping-bucket rain gages are prone to recording occasional false readings and often under-measure heavy rainfall. In addition to routine cleaning, the units need to be calibrated at least once each year, typically before spring deployment. Like any other data collected, the recorded data needs to be quality-assured as soon after collection as possible. On-site review can be accomplished readily with the laptop-computer interface.

A rain gage network can provide useful information, especially for modeling, but because of the amount of time required to maintain a high-density network it may hinder, rather than enhance, the data-collection program. The data presently collected are not used to understand directly how precipitation relates to runoff and contaminant transport, and are not timely enough to help direct sample collection.

No more than 5 rain gages strategically placed in the watershed could provide supplemental information that might be helpful in understanding runoff. Rainfall in the upper watershed is adequately monitored by the Forest Lake weather station, but a District-operated rain gage could be located at or near site ACD-46 to monitor precipitation in that part of the watershed. The southwest is adequately covered by the St. Paul weather station and the USGS gaging station. The rain gage at site R-5 is very close to the existing USGS site and may not provide much additional information about rainfall, although technically it is a better rainfall-measurement site and could be operated concurrently to develop a statistical relation between the two gages. Rain gages installed near the middle of Hardwood Creek, probably at site H-1.3, and near the middle of Clearwater Creek, possibly near the outlet of Bald Eagle Lake, could provide useful



information about the relation between precipitation and runoff in those major tributaries. A rain gage could be operated at one of the monitoring sites along the middle Rice Creek, particularly those monitoring drainage from some of the western ditched areas. The present headquarters of the District at the intersection of Lexington Avenue and Interstate Highway 35-W is a good rain-gage location near the middle Rice Creek that provides easy access to District personnel. **Figure 2** shows the locations of the proposed precipitation monitoring sites.

Most of the rain gages owned by the RCWD will be reserved for use in smaller-scale studies of local watershed runoff. They also may be used to supplement data as gaps are identified in the existing precipitation network. At the present level of data collection, the RCWD does not have personnel time available to operate a rain gage network effectively enough to provide meaningful information throughout the watershed.



4 DATA MANAGEMENT

4.1 Data-quality Objectives

When designing and operating a data-collection network, it is important to evaluate the data-quality objectives. This will dictate the quality of the data collected, and may influence the intensity of the network operations. Stable flows and constituent concentrations will require less frequent monitoring while unstable systems will require more frequent visits across a range of hydrologic conditions. Similarly, regulatory compliance may require meeting an established set of quality (and frequency) standards.

These data will be part of an important network that will be modeled using hydraulic and water-quality transport models such as Flux or Loadest. As part of model development and documentation, it is important to be able to quantify the error associated with the models. The streamflow data used in those models will have an error associated with them that needs to be quantified.

Data quality can be described by the accuracy, precision and percent completeness for both sample collection and laboratory analysis. **Appendix E** is a table showing preliminary data quality objectives for the RCWD surface water monitoring network. This type of table will be consulted annually during the data-review process to characterize both the field and laboratory components of the data analysis process.

4.1.1 Sampling Design

The RCWD will continue to operate the existing network and review the data on a routine basis to identify where gaps in the data may exist. For streams, this can be done by using a simple plot showing the return period for the flow, when water quality samples were collected. The intent is to sample through the entire flow range, especially when those data will be used to develop long-term models of chemical transport using tools such as Flux or Loadest. Some gaps likely will be during events that were not sampled. Automatic samplers are being used to fill those gaps and will continue to be used. When an automatic sampler is tripped and collects a set of samples, judgment needs to be made to decide whether the event sampled fills a gap in the range of events sampled for that



site. A sample that was collected does not have to be used if it does not contribute substantial information about the constituent-transport characteristics at that site. Unfortunately, the bottles still need to be cleaned and the sampler reset.

The RCWD presently composites automatic samples using a bulk-composite approach that provides a sample of the event, but does not provide much information about the transport of constituents as streamflow changes during the event. When streamflow is increasing following a runoff event, the concentration (and load) of suspended solids is higher than when the streamflow is declining. This effect is termed hysteresis and can seriously affect the results of monitoring and the interpretation of results from that monitoring program. The load of constituents associated with solids, generally including phosphorus, may be biased by the timing of sample collection.

Alternate approaches to compositing samples that better represent the transport of constituents during runoff events are discussed in **Appendix D**. At important sites such as R-1 and R-5 where sediment-transport is a concern, discrete samples collected by the automatic sampler over the hydrograph analyzed separately would provide information about changing sediment concentrations during the runoff event. Only selected samples from selected storms events would be analyzed this way because doing this routinely would provide little additional information and would get expensive.

The errors in each of the measurements will be considered when operating and evaluating a network because when results are multiplied, as in load calculations, the errors also are multiplied. An important part of sampling programs is to try to minimize those errors and to quantify them in order to provide an estimate of the reliability of the results. Sampling error can best be quantified by maintaining a high frequency of data collection, including both streamflow and concentration, and reviewing those data to ensure that they are defining the variability of data at that site. Once that variability is defined, the data-collection program for that site can be evaluated to decide whether measuring or sampling frequency can be reduced, maintained, or enhanced because of high variability.



The RCWD is using an approach to stream gaging that relates the need for flow measurements to gaps in the rating curve. Although that approach seems to be working, it is based on the assumption that rating curves are stable from season-to-season. Because these are small streams, that may be a safe assumption, but growth of aquatic plants or other factors generally result in changing backwater conditions that require the hydrographer to apply seasonal shifts to the streamflow rating. Any type of channel-forming event, including a tree falling across the channel, can substantially alter an existing rating curve. Also, many of these sites are located where the control (discussed in **Appendices B** and **D**) is unstable. Frequent streamflow measurements must be made at all sites unless the stability of the control has been documented, because the user may not realize that the relation between stage and streamflow has been altered until several weeks or months have passed. The time needed to make a streamflow measurement is minimal compared to the time already invested in field trips and the time required to correct historical data.

Generally, sample collection and analysis error can be controlled by ensuring that the sample is as representative as possible and ensuring that the laboratory analyzing the samples has a rigorous quality-assurance program and can ensure the quality of their results. An increased quantity of samples collected also can provide a clearer definition of the central tendency of the data and its variability.

4.1.2 Concentration, Loads, and Yields

Streamflow generally is one of the most time-consuming field measurements made, but it also is very important because it is needed to compute constituent loads and yields:

$$\text{Concentration} \times \text{flow (volume)} = \text{mass transported (load)}$$

$$\text{Yield} = \text{mass per unit area.}$$

Because the quality of the data is so critical to the operation of a sampling network, a streamgaging site must be located where a reliable record can be collected. There will be situations, especially in the RCWD because of flat topography and



numerous lakes and streams, where a reliable relation between stream stage and the streamflow cannot be maintained, but the streamflow record from that site is too important to locate the site anywhere else. Sites such as H-1.3 and some ditches including CD-25 are examples of these important, but difficult, sites. This lack of quality stream-stage data often has to be compensated with more frequent manual measurements of streamflow and determining the streamflow records using a high-tech version of connect-the-dots. An advantage of flat topography and numerous lakes and streams is that streams tend to have stable flows and generally do not respond quickly to precipitation events.

4.2 Storage and Maintenance of Data

4.2.1 Data-storage Systems

The RCWD collects field data in a variety of formats. Site information, including location information, elevation, and drainage area, is the most basic and may have several other formats of data associated with it. Discrete (instantaneous) samples that will include detailed notes including field measurements and observations that likely will include textual comments will be stored with the results of laboratory analyses. Stage data from lakes and streams, and water-quality monitor data typically are time-series measurements that generally are measured at 15-minute intervals and may require a special storage format. Discrete water quality samples can be stored in a typical database table. Vertical-profile data from lakes are challenging because they often need individual entries with unique times for each depth that was sampled. That is easy for a typical spreadsheet, but challenging when working with a public-access data base like STORET or its equivalent.

4.2.1.1 Discrete Data

Field data for the RCWD presently are being stored in a local data base which typically is an MS-Excel workbook or an MS-Access data base. From there the data are submitted to the MPCA.. The MPCA then uploads its data to STORET, which is the national water-quality data base maintained by the U.S. Environmental Protection Agency. STORET is scheduled for replacement during 2010 with a database called



Water-Quality Exchange (WQX) and a quasi-regional database to be named H2inf0. The availability and capability of these data base systems are uncertain as they still are being designed. The data presently are accessed by the general population using the EDA (Electronic Data Access) data base that contains most of the water quality data collected in Minnesota.

4.2.1.2 Time-series Data

The existing state and national data base systems have no efficient means to store time series data such as stage and streamflow data, or data from continuous monitors that record water temperature, SC, or other values. It is uncertain whether the new version of these data bases will handle time-series data, but it is not expected in the first release of the software.

The Minnesota Department of Natural Resources (DNR) stores time-series data as part of their Stream Hydrology Program

(http://www.dnr.state.mn.us/waters/surfacewater_section/stream_hydro/index.html,

accessed June 8, 2009). It is based on a proprietary system called Hydstra

(<http://www.kisters.de/english/html/au/homepage.html>) that is used to store stage and streamflow time-series data collected by the DNR and the MPCA. Access to those data is limited. Also, it is not understood whether that system is configured to handle other types of continuous data such as water-quality monitor readings. It is not understood if DNR or MPCA are planning on accepting “local” data into these databases.

4.2.1.3 Data-storage Plans

The RCWD expects to continue maintaining their data base locally and employ routine back-ups and other quality-assurance measures to assure that those data are not lost or compromised. These quality assurance measures include visually inspecting a minimum of 10% of the records for transcription errors, and obtaining data electronically from the laboratory to avoid manual data entry. This will continue long after H2inf0 is available until it is determined to be a reliable primary storage facility for water-quality data. The RCWD will continue to store time-series data using their own system, presently Microsoft Access, for the foreseeable future because most open-access water-



quality data bases are not presently equipped to efficiently store time series data. The RCWD will continue to submit water quality data to state or regional databases (STORET, and in the future, H2infO). Time-series (continuous) and vertical-profile data also should be stored in those legacy data bases when that becomes possible.

Because data bases generally are based on commercial, often proprietary software they are subject to changes and periodic updates that may cause old data-storage systems to become obsolete. This has resulted in the loss of a great deal of historical data that might have proved useful for time series analyses or to better understand how current conditions relate to baseline data.

One option that is software independent is the RDB: Relational DataBase data-management system. RDB is a fast, portable, tab-delimited, relational database management system without arbitrary limits (other than memory and processor speed), that runs under, and interacts with, the UNIX Operating system. Being similar to the CSV data-format, simple comma-delimited ASCII files with header lines that define the column contents, it is compatible with most software including MS-Excel and MS-Access. This likely will be a preferred format to use when the RCWD shares data with other users that may not have access to commercially-available software.



5 QUALITY ASSURANCE AND MANAGEMENT PROCEDURES

5.1 Quality Control Sampling and Objectives

5.1.1 Considerations

The purpose of obtaining QC samples is to (1) assess the adequacy of the cleaning procedures and the level of contamination in the environment in which samples are collected and processed, and (2) to assess the quality, reliability, and precision (reproducibility) of the data generated. Quality-control data also can be used to determine if the difference between chemical concentrations measured for different samples are statistically significant. QC samples are a requisite for any sampling and analysis program because without quality-control information, the quality of collected environmental data can neither be evaluated nor qualified. If data quality can not be evaluated, then the data must be viewed as uninterpretable, or at best only marginally interpretable, because the user has no means of knowing the associated errors. Thus, what appear to be differences between samples obtained at the same location over a period of time, or differences between samples collected at about the same time but from different locations, may actually represent errors introduced by the method and the application of the methods for sampling, sample processing, or laboratory analysis.

5.1.2 Errors in Data

The types of errors associated with chemical data produced from environmental samples come from a number of sources. For simplicity, these errors can be divided into three general categories: (1) contamination (field or laboratory), (2) sampling error, and (3) analytical error (A.J. Horowitz, and others, 1994).

5.1.3 Types of Quality-Assurance Samples

The types of quality-assurance (QA) samples to be considered for sampling in the RCWD are listed and described in **Appendix F**. The RCWD routinely submits blank and sequential-duplicate grab samples to the laboratory. It is understood that most laboratories, including those used by the RCWD, recognize blank and replicate samples that are submitted, and many laboratories welcome them. There generally is no need to



disguise QA samples submitted to the laboratory. It often is advantageous to work with the analytical laboratory when submitting QA samples because they may look more closely at the data to identify potential problems.

The addition of equipment blanks will ensure that sample collection methods, equipment cleaning, and sample handling are not introducing contamination. This may be especially important when using automatic samplers where equipment storage, cleaning, and cross contamination may be a concern. Any new sampling equipment also must be thoroughly cleaned and checked with equipment blanks to ensure it is not a source of contamination or possibly cross contamination. Be aware that some off-the-shelf deionized and distilled waters that are used for cleaning also may contain contaminants. Quality-assurance protocols dictate that these rinsing waters need to be tested (typically by lot number) periodically for contaminants. However, the blank samples that the RCWD has submitted to the laboratory have shown no reportable detections, suggesting that the water used is acceptable for routine use.

An annual report documenting the results of quality assurance will be provided to interested persons. It would include a series of graphs showing results of blank-sample results during the sampling year and plots showing the variability of replicate sample results. These might be shown as X-Y plots and may need to be converted to logarithmic values depending on the range of the data being plotted. The analytical laboratory also will be able to provide data and graphics showing their internal quality-assurance results that will add to the report. Detailed statistical analysis generally is not needed, but can be provided if desired.

5.2 Quality Management Procedures

Ensuring the quality of data collected for any network includes documentation about sites, the methods used, detailed descriptions of how data were collected, and the conditions under which they were collected. Techniques manuals, field procedures, some of which are conveyed in this document, training and experience all add to the quality of the data collected. Maintaining those data in a secure data storage system also constitute part of the quality management.



5.2.1 Documentation

Information about the sites being sampled can be critical, especially when someone unfamiliar with the sites has to substitute for routine personnel. This information will be stored in paper form and/or an electronic data base, as well as having a copy that can be carried into the field. **Table 1** shows the minimum amount of information which will be maintained for a monitoring location. Needed information includes the site name and field identifier, directions to the site, reference points and elevations, and helpful information about the site including preferred measuring and sampling locations. Other helpful information might warn about traffic hazards or other special considerations. The RCWD needs to ensure that these files are kept current when substitute personnel are called upon to help with data collection.

Field note sheets can be adapted from other projects and many examples are available, but the best field note sheets often evolve to fit the individual needs of the data-collection program. The RCWD has prepared water-quality sampling field note sheets, shown in **Appendix G**, that meet their needs and can be modified as those needs change. The District plans to convert those field forms into a computerized version that will eliminate the need to use paper forms in the field. The streamflow-measurement sheet output by the paperless Flow Tracker ® instrument provides detailed information about each streamflow measurement and provides useful quality-assurance information.

Different field sheets may be needed to fit the particular application at a given site or for a particular event. Forms are needed to describe the details of a basic site visit, instrument servicing, a streamflow measurement, or information about sample collection. A different form may be needed depending of the type of sample collected, be it a stream, lake, or some other media. All forms likely will need a space for recording field measurements, field observations such as water and weather conditions, and any special notations that will later help interpreting the data. Field note sheets will be completed in the field before leaving the site so as not to rely on memory to add information later. Presently these completed forms are stored in paper file cabinets in the office, but the District is developing an electronic field form that could result in a paperless data-



recording system. This will result in automated data entry that will reduce transcription errors, but will bypass one level of data checking that occurs during manual entry of field data into the data base.

Sample labeling is an important part of maintaining quality because a mixed up or mislabeled sample can result in lost data or incorrect results. The container will be labeled with indelible marker or waterproof-tape label while it is clean and dry before the sample is added. A unique identifier including the date and time will be clearly and prominently marked on the container. A paired tape-labeling system with one label for the container and its pair for the field form is ideal and could be based on a laser-read bar-code system. The RCWD uses the paired tape-labeling system effectively minimizing sample mix-up errors. Neither the RCWD nor the laboratory is equipped to use a bar-coded labeling system.

Log books of equipment maintenance, calibration, storage, and servicing can be helpful by providing a history of that instrument and will be maintained by the District. The log book is needed for each instrument and filled out every time some type of work, including calibration or off-site repairs, is performed on the instrument. The RCWD has established and routinely uses log books for their equipment and will continue to expand that program as needed.

Checklists of equipment and supplies needed for field work can be useful for people new to the sampling program, but also are useful for experience field personnel. This is especially applicable at the beginning of the sampling season or when a change in the sampling program is initiated. As a sampling program increases in complexity, the value of a checklist increases. An example checklist is included as **Appendix H**. Other examples of checklists also are available from a number of places including the Internet.

Chain of custody is used routinely by the RCWD for submission of samples to the laboratory although it is not specifically required. Chain of custody provides a method of tracking who handled a set of samples and can be used to track down suspect samples that might have been mixed up. It also helps locate lost samples.



5.2.2 Quality Management of Equipment

Equipment selection is important because rugged equipment may last longer, but that ruggedness often could compromise sensitivity of the instrument as typically occurs with glass pH electrodes and dissolved oxygen membranes. Newer models are designed to work in a variety of conditions including slow velocities that otherwise could affect readings of dissolved oxygen. Maintaining, cleaning, and proper storage of equipment also will extend its life and the reliability of data provided. The manufacturer usually provides the most reliable guidance for maintaining, cleaning, and proper storage of equipment.

The RCWD has an up-to-date multiparameter instrument for making field measurements. It includes an optical dissolved oxygen probe that is more reliable than predecessors that used older technology. If an upgrade is desired, a new unit for about \$6,000 that also measures turbidity could be considered because state standards often cite turbidity as an impairment. Adding turbidity adds considerably to the cost of an upgrade because it requires another optical port on the sonde unit. This upgrade is not recommended because the transparency tube presently being used meets state guidelines and the state has not determined what automated form of turbidity measurement will be the accepted standard.

The remaining field equipment for the RCWD appears to be in reasonably good shape and functions well under the conditions encountered. The equipment must be inventoried and assessed at least every year before seasonal deployment to determine what needs to be replaced. At least one, and possibly more back up units, including EDLs and automatic samplers, must be available and maintained in good operating condition in case the existing units fail. It has not been determined whether the individual parts on the different units are interchangeable or compatible. That may be an important consideration. Rental units may be available for some temporary applications. Costs vary widely depending on the features needed or desired.



5.2.3 Reagents

Preservatives, standards, and reagents generally have marked on them an expiration date and a lot number that can provide useful quality-assurance information. Although expiration dates are useful for rotating stock and keeping it fresh, they are not an absolute cutoff date and the product may be usable for a considerable time beyond that date. In other words: don't cancel a field trip because the reagents have expired. However, fresh reagents must be ordered as soon as possible.

Lot numbers may be helpful in tracking down a problem with a given container of reagent. Recently, a national vendor changed the formula of their conductance standard from potassium chloride to sodium chloride which resulted in the change in the calibration-correction factors. Had the lot numbers been recorded on field sheets or the instrument log book, considerable time tracking down questionable data would have been saved.

The RCWD is careful in using fresh reagents and keeps track of expiration dates. It might be wise to document reagent conditions and lot numbers as part of the daily calibration procedure, recording that information in the equipment log books.

5.3 Data Integrity

Data integrity is an aspect of quality assurance that may be overlooked. Paper files are still used, but have been supplemented with computerized data bases. Modern computerized data bases keep the data accessible except when in the field, although newer technology, including wireless communications, may be bridge that gap. It is helpful, but not always feasible, to have experienced personnel in the field with knowledge of the history of a site and the sampling network. Experienced or not, having field information from previous site visits including the streamflow-stage relationship for a site is helpful. It is not advisable to bring originals in the field; only copies that may be discarded unless they are used to record new information.

It is advisable to take time soon after returning to the office to review field notes to see if anything was not recorded or was incorrectly recorded. This may be coincident



with entering the sample information into the data base. This is equivalent to logging the sampling into the data base where-by a template is created that will have to be matched with the laboratory results when they are received.

The RCWD does a good job of keeping pertinent data available during field trips. Office time needs to be provided to compile data from previous site visits and ensure that the data carried in the field are current. This may be more important when less-experienced substitute personnel are sent to monitor field sites.

5.4 Sample Containers, Preservation, Transportation, and Holding Times

The RCWD staff presently collect stream samples using a trademarked plastic bag called a Whirl Pak® (<http://www.enasco.com/whirlpak/>, accessed June 8, 2009). These containers have passed the RCWD quality-assurance tests. Because the bags are inexpensive, RCWD staff is able to collect two samples, using the second container for a backup or replicate. The RCWD immediately chills collected samples and delivers them to the laboratory for time-dependent processing and preservation the same day they were collected. This procedure conforms with Standard Methods for the Examination of Water and Wastewater (Standard Methods), and the laboratory immediately adds the reagents needed to ensure the stability of the intended analytes.

The methods currently employed by the RCWD are appropriate for routine sample collection, but the District needs to purchase or fabricate a weighted bottle sampler to collect samples from streams when they are unwadable. The sampling wand presently being used generally is adequate, but must be kept clean because it directly contacts the sample water.

When it is decided that other sample types will be collected (as described in **Appendix D**), different protocols, containers, and preservation methods may need to be considered depending on the sample being collected. Methods manuals such as Standard Methods, analytical laboratories, and other sources may be consulted to provide advice on the appropriate method for sampling, sample containers, and preservation for the materials being sampled. It might be advisable to contract-out specialized sampling unless the methods will be routinely employed.



5.5 Laboratory Analytical Methods

5.5.1 Analyses

The RCWD has been using the Ramsey County Department of Public Works laboratory for routine sample analyses. They have been using that laboratory since at least 2006 and anticipate using them for the foreseeable future. The quality of the data provided, their responsiveness, and turn-around times all have met the needs of the RCWD. It is understood that most of their analytical methods are consistent with those published in Standard Methods. An up-to-date copy of their quality assurance plan will be maintained on file in the District and reviewed periodically to ensure that the data continue to meet the needs of the RCWD. The laboratory must provide to the District an annual report showing laboratory performance for the requested analyses. The report will include tables showing the accuracy, precision, and bias of those analytes; it also will include charts showing analytical performance over time based on internal quality assurance testing. The results of any inter-laboratory comparison ('round robin') studies also will be provided.

Because the Ramsey County laboratory does not provide a broad range of analytical services, other laboratories may be used as needed by the RCWD. This could include the Minnesota Department of Health environmental laboratory other commercial laboratories.

As time allows, the RCWD could consider performing some analyses in house. These would provide rapid turn-around times and allow the processing of a larger number of non-routine samples less expensively than typically is possible with current procedures. An example application might be along Hardwood Creek where the impairment might be identified with a series of nutrient analyses at selected sites along the impaired length of the stream. There are many test kits marketed that provide high-quality results with almost immediate results. Others are relatively simple techniques that require inexpensive equipment and minimal training. A good example might be microbiological sampling for indicator bacteria such as fecal coliform or *Escherichia coli*.



5.5.2 Review of results

Laboratory analytical results are reviewed within 2 weeks of receipt to assure that the data are consistent with what is expected for that hydrologic system. If questionable data are found, the laboratory is contacted to request a rerun or a verification of the results. This checking is in addition to the checking already done internally at the laboratory.



6 SUMMARY OF RECOMMENDED ENHANCEMENTS TO THE PRESENT MONITORING NETWORK AND PROBABLE COSTS

6.1 Surface water

- The existing network of sampling sites will be maintained until the network and data collected from those sites has been critically reviewed. No cost.
- At least one of two sites on upper Rice Creek (R-9 and R-8.5) should be restarted or continued because they represent an important contribution to Peltier Lake, unless it can be shown that contributions from that watershed are well defined and stable. Cost: about \$12,000 per site.
- The RCWD needs to purchase equipment allowing them to measure and sample un-wadable streams. This could consist of a handline assembly, an extended wading rod, or other device that may be used off bridges or culverts in the RCWD. The cost of these items would start at about \$1,000 but could be higher depending on the configuration and compatibility with existing equipment.
- All the integrator sites listed in Table 1 including C-2, H-2, R-8.5, R-5, and R-1 should be operated indefinitely. However, the new USGS site and site R-5 are somewhat redundant. No, or reduced cost.
- The present frequency of approximately monthly sampling is appropriate and will continue. However, collected data will be evaluated and may show that sites having minimal variability do not need to be sampled as often as sites showing high variability in the concentration of constituent of interest. No cost.
- Following an event, the most upstream sites as they will respond much more quickly to precipitation than more downstream integrator sites. No cost.



- The District needs to be prepared with equipment and trained personnel to sample any major flow events and/or service automatic samplers. This may require training plus the cost of equipment described elsewhere.
- It is important to sample a range of flows focusing on the difficult to catch high-flow events to define a relation between streamflow and the constituent of concern that may be suspended solids, turbidity, or phosphorus. This relates to the earlier discussion of hysteresis, but also provides data that may be used to develop a constituent-transport curve (similar to a stage-streamflow rating curve as described in Tornes, 1984 for suspended sediment).
- The District shall collect at least 3 routine stream water samples during December, January, and February (typically under ice) with field measurements including streamflow at each of the integrator sites. These would be analyzed for the same suite of constituents as the routine open-water samples. This would fill a major gap in the understanding of constituent transport and possible anoxia during the winter. Cost: approximately \$1,500, excluding labor.
- The District could consider installing velocity-sensing (Doppler) instruments at one or more selected sites such as CD-25 in the watershed on a trial basis. These units cost about \$6,000, not including personnel time to install and operate them.

6.2 Groundwater Monitoring

Groundwater monitoring undertaken by the RCWD should be related to and focused on project-specific needs. These needs are expected to primarily be monitoring shallow groundwater levels as a component of wetland restorations, establishing water budgets for lakes, and assessing ground water dependent resources. The cost of these efforts will vary depending on the level of effort needed to acquire the desired amount of information. For planning purposes, typical costs are \$125 per foot for installation of a



well or piezometer and assuming bi-monthly site visits an estimate \$500 per month per location for measuring and recording water levels.

6.3 Biological Monitoring

The RCWD should continue to support biological monitoring as a component of their educational program. Biological monitoring at the outlet of each of the five planning regions should be implemented, if possible. Biological monitoring at these locations would consist of collecting fish and aquatic macroinvertebrate population data to estimate species diversity and compute Indices of Biotic Integrity. The cost will vary depending on the level of effort and whether RCWD staff would do the work. For planning purposes, electrofishing equipment and nets would cost approximately \$6,000 and macroinvertebrate collection equipment will cost approximately \$500. Sampling both at 5 locations will require approximately 9 staff days to complete the work. The lab costs for macroinvertebrate identification would be approximately \$200 to \$400 per sample.

6.4 Geomorphologic Monitoring

The geomorphologic monitoring conducted by RCWD should be related to specific project needs. Currently, these locations would coincide with restoration projects on Hardwood Creek and Middle Rice Creek. Long-term geomorphologic monitoring locations should be established at the outlet of each major planning region, and co-located with the biological monitoring locations. Given adequate resources, the District could use geomorphologic monitoring to identify sediment sources and sinks along Rice Creek, especially in areas related to Long and Locke Lakes. Possible locations are listed in section 3.6. The cost of these efforts will depend on the level of effort needed to employ them. For planning purposes, typical costs are:

- Cross-section GPS survey per location (\$600 to \$1,000 per site at a frequency of every 3 to 5 years)
- Geomorphic condition assessment and data reduction (\$600 to \$900 per site)
- Installation of bank pins / chains, establish local elevation control and pin elevations (\$1,000 to \$1,500 per site)

These costs exclude data reduction, analysis and reporting.



6.5 Precipitation Monitoring

The rain gages will be operated at only a few locations to fill gaps. Unneeded rain gages will be maintained and used for special, localized studies of runoff. Operating a comprehensive network takes time from other important tasks. No cost

6.6 General Recommendations

- The streamflow and stage sites (including lakes) all need to be surveyed and benchmarks established to a common datum to aid in basin-wide modeling efforts. Requires only personnel time because the equipment is already available.
- The RCWD also needs to purchase a full set of backup equipment, including stage measuring and recording devices. This could be part of an annual \$5-10,000 commitment to upgrade equipment.
- The District will not collect samples to identify or quantify a transient occurrence that probably cannot be measured by a grab sample. However, a recurring or persistent problem may justify initiating a special study to identify the problem. No, or reduced cost.
- The monitoring network and data will be reviewed at least annually to identify bias, trends, or bad data values. This will provide an opportunity to assess whether sampling and/or network configuration needs modification. This typically requires about 1 week of personnel time and should include consultation with other technical professionals.
- The analytical laboratory must provide a current copy of their quality-assurance plan and annually provide a report summarizing their performance on quality assurance samples for the analyses performed for the District. No direct cost.
- The District should consider monitoring surficial groundwater to better understand its interaction with lakes, streams, and wetlands. The cost of this undertaking could be quite variable, but likely would require at least one-quarter of a person's annual staff time.



7 REFERENCES

American Public Health Association (APHA), the American Water Works Association (AWWA), and the Water Environment Federation (WEF), 2006, Standard Methods for the Examination of Water and Wastewater, variously paged

Buchanan, T.J. and Somers, W.P., 1969, Discharge measurements at gaging stations, U.S. Geological Survey, Techniques of Water-Resources Investigations, Book 3, Chapter A8, 65 p.

Horowitz, Arthur J.; Demas, C. R.; Fitzgerald, K. K.; Miller, T. L.; Rickert, D. A., 1994, U.S. Geological Survey protocol for the collection and processing of surface-water samples for the subsequent determination of inorganic constituents in filtered water, USGS Open-File Report 94-539

Minnesota Pollution Control Agency, 2007, Guidance Manual for Assessing the Quality of Minnesota Surface Waters For Determination of Impairment. 305(b) Report and 303(d) List, <http://www.pca.state.mn.us/publications/wq-iw1-04.pdf>

Minnesota Pollution Control Agency, 2009, Standard Operating Procedures for Monitoring Fish and Macroinvertebrates in Streams, February 2009, URL: <http://www.pca.state.mn.us/water/biomonitoring/bio-streams.html>

Mullaney, John R.; Lorenz, David L.; Arntson, Alan D., 2009, Chloride in Groundwater and Surface Water in Areas Underlain by the Glacial Aquifer System, Northern United States, USGS Scientific Investigations Report 2009-5086, 43 p.

Rantz, S.E. and others, 1982, Measurement and Computation of Streamflow; Volume 1. Measurement of Stage and Discharge, Volume 2. Computation of Discharge, U.S. Geological Survey, Water Supply Paper 2175

Stockinger, James, 1998, Field Guidance Manual, Minnesota Pollution Control Agency, Ground Water and Solid Waste Division, Program Development Section, Ground Water Unit, St. Paul, Minnesota.



Tornes, L. H, 1986, Suspended sediment in Minnesota streams, USGS Water-Resources Investigations Report 85-4312, 33 p

U.S. Geological Survey, variously dated, National field manual for the collection of water-quality data: U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chaps. A1-A9, available online at <http://pubs.water.usgs.gov/twri9A>.

Tables

Table 1 Surface-Water Sites Recently Sampled in the Rice Creek
Watershed District

Table 2 Lakes Sites Sampled in the RCWD

Table 1 Surface-Water Sites Recently Sampled in the Rice Creek Watershed District [Int, Integrator; Ind, Indicator]

Stream sites monitored by the RCWD				Recent Year Sampled				
SITE_ID	Site Type	Waterbody / Location	Historical Sampling Record	2008	2007	2006	Type	Value of Sampling Site
ACD31	Tributary Ditch	Anoka County Ditch 31 at Kettle River Blvd in Columbus, MN		Yes	Yes	Yes	Ind.	Unique north drainage indicator, primary Howard Lake trib.
ACD46	Tributary Ditch	Anoka County Ditch 46 at Lake Drive in Columbus, MN		Yes	Yes	Yes	Ind.	Northwestern drainage indicator, needs evaluation whether needed for long-term
C-2	Major Tributary	Clearwater Creek S of County Road 14 in Centerville, MN	1990-92; 1996-present)	Yes	Yes	Yes	Int.	Near mouth of creek; represents majority of CWC drainage. Integrator
CD2	Tributary Ditch	Ramsey County Ditch 2 in Hanson Park in New Brighton, MN	1999 to present	Yes	Yes	Yes	Ind.	Indicator of SW urban areas
CD25	Tributary Ditch	Anoka County Ditch 25 at Black Duck Drive in Lino Lakes, MN	1999	Yes	Yes	Yes	Ind.	Indicator of Reshanau Lake nutrient loading
H1.3	Major Tributary	Hardwood Creek at Harrow Ave in Forest Lake, MN	2002	Yes	Yes	Yes	Ind.	Indicator of Ag/low developed reference area
H-2	Major Tributary	Hardwood Creek at 20 th Avenue (CR21) crossing in Lino Lakes, MN	1991, 1994, 1999 - 2000	Yes	Yes		Both	Mouth of HWC drainage. Monitors sediment transported from a degraded and restored section of creek channel. – both Indicator and integrator site
JD1.1	Tributary Ditch	Ramsey/Washington Judicial Ditch 1 at Hugo Road in White Bear Township, MN	1990-1992;2000-2001	Yes	Yes	Yes	Ind.	Headwaters of CWC, important tributary to Bald Eagle Lake. Indicator
OWS 10	Tributary Ditch	Anoka County Ditch 10-22-32 at Interstate 35W in Lino Lakes, MN	Historical	Yes	Yes	Yes	Ind.	Indicator of large area drained to middle Chain of Lakes
OWS2	Tributary Ditch	Anoka/Washington Judicial Ditch 4 on I-	Historical through	Yes	Yes	Yes	Ind.	Indicator of ag. And major drainage from northeast; tributary to Chain of Lakes.

Stream sites monitored by the RCWD				Recent Year Sampled				
SITE_ID	Site Type	Waterbody / Location	Historical Sampling Record	2008	2007	2006	Type	Value of Sampling Site
		35W frontage road in Lino Lakes, MN	1993					
R-1	Rice Creek Mainstem	Rice Creek at Mississippi St. in New Brighton, MN	1993 to present	Yes	Yes	Yes	Both	Long-term record of majority of RCWD drainage. Integrator site that also indicates sediment transport in reach from Long Lake to Locke Lake
R5	Rice Creek Mainstem	Rice Creek at County Road I in Shoreview, MN	Historical through 1993	Yes	Yes	Yes	Int.	Integrator of upper and middle Rice Creek; represents all but SW drainage. Indicator of sediment transported from a degraded and restored section of creek channel.
R9	Rice Creek Mainstem	Rice Creek at Howard Lake Outlet in Columbus, MN		Yes	Yes	Yes	Ind.	Indicator of headwaters of Rice Creek, represents Clear, Mud, and Howard Lake outflow.
CEP1	Tributary Ditch	Anoka County Ditch 53-62 at Carl Eck Park in Circle Pines, MN		Yes			Ind.	Western trib to Lower Rice Creek, (Golden Lake?)
D2	Tributary Ditch	Ramsey County Ditch 2 at Learning Center in New Brighton, MN		Yes			Ind.	Long Lake trib., Indicator of SW urban areas
P1	Rice Creek Mainstem	Peltier Lake at Anoka County Park in Lino Lakes, MN		Yes			Both	Eutrophic lake. One of the Sentinel Lakes monitored by the State; used in conjunction with weir equation to compute flow through Peltier Lake
RCD4.1	Tributary Ditch	Ramsey County Ditch 4 at Lydia Ave in Roseville, MN		Yes			Ind.	Indicator of SW urban areas
D	Tributary Ditch	Ramsey County Ditch North of I-694 at Long Lake in New Brighton, MN	Historical-1993		Yes		Ind.	Trib to Long Lake (TMDL)
H1.2	Major Tributary	Hardwood Creek at 170th St. in Hugo, MN	2002		Yes	Yes	Ind.	HWC TMDL
OWS11A	Tributary Ditch	Anoka County Ditch			Yes		Ind.	Moved to CEP

Stream sites monitored by the RCWD				Recent Year Sampled				
SITE_ID	Site Type	Waterbody / Location	Historical Sampling Record	2008	2007	2006	Type	Value of Sampling Site
		53-62 in Circle Pines, MN						
OWS11b	Tributary Ditch	Anoka County Ditch 53-62 at Golden Lake Road in Circle Pines, MN			Yes	Yes	Ind.	BMP performance
R8.5	Rice Creek Mainstem	Rice Creek at I-35W in Lino Lakes, MN	1990-1992; 2000-2001		Yes	Yes	Int.	Major trib to Chain of Lakes. Integrator
Stream site monitored by the US Geological Survey								
05-288580	Rice Creek Mainstem	Rice Creek below Old Hwy 8 in Mounds View, MN						Year-round, high-quality streamflow

Table 2 -- Lake Sites Sampled in the RCWD

[MCES, Metropolitan Council of Environmental Services Citizen-Assisted Monitoring Program (CAMP)]

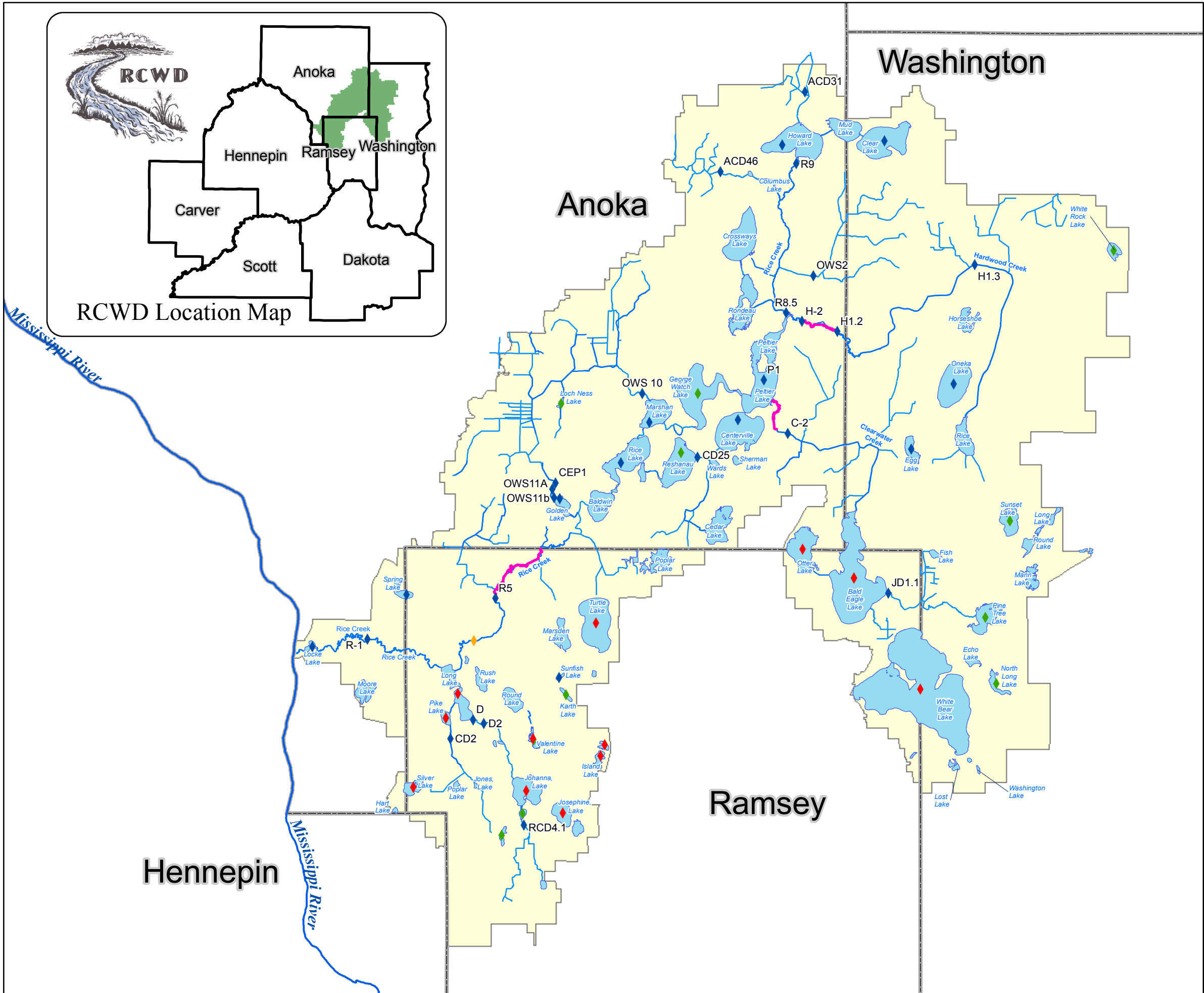
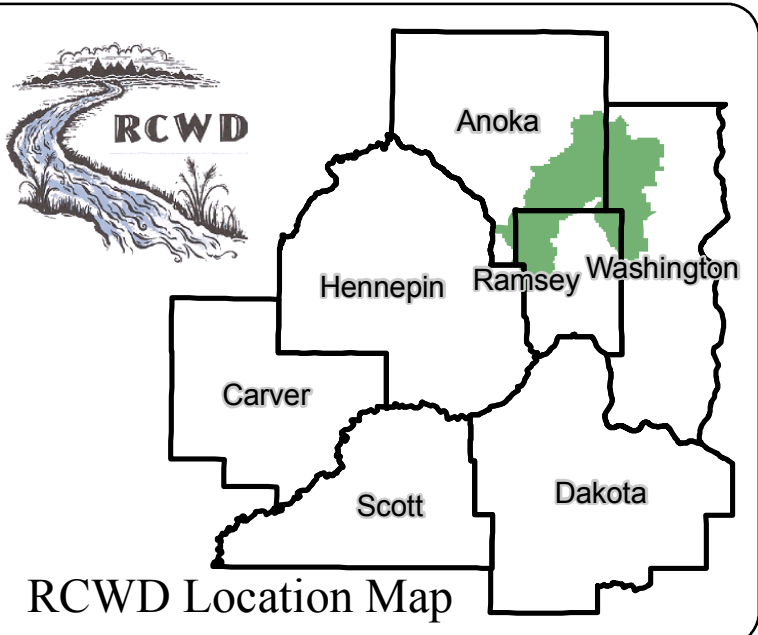
Lake Name	County	Sampling Agency
Bald Eagle Lake	Ramsey	MCES
Bald Eagle Lake	Ramsey	Ramsey County
Centerville Lake	Anoka	RCWD
Clear Lake	Washington	RCWD
Egg Lake	Washington	RCWD
George Watch Lake	Anoka	MCES
Golden Lake	Anoka	RCWD
Howard Lake	Anoka	RCWD
Island Lake	Ramsey	Ramsey County
Karth Lake	Ramsey	MCES
Lake Johanna	Ramsey	Ramsey County
Lake Josephine	Ramsey	Ramsey County
Langton Lake	Ramsey	MCES
Little Johanna Lake	Ramsey	MCES
Lochness Lake	Anoka	MCES
Locke Lake	Anoka	RCWD
Long Lake	Washington	MCES
Long Lake	Ramsey	Ramsey County
Marshan Lake	Anoka	RCWD
Oneka Lake	Washington	RCWD
Otter Lake	Ramsey	Ramsey County
Pike Lake	Ramsey	MCES
Pike Lake	Ramsey	Ramsey County
Pine Tree Lake	Washington	MCES
Reshanau Lake	Anoka	MCES
Rice Lake	Anoka	RCWD
Silver Lake	Ramsey	Ramsey County
Spring Lake	Ramsey	RCWD
Sunfish Lake	Ramsey	RCWD
Sunset Lake	Washington	MCES
Turtle Lake	Ramsey	Ramsey County
Valentine Lake	Ramsey	MCES
Valentine Lake	Ramsey	Ramsey County
White Bear Lake	Ramsey	Ramsey County
White Rock Lake	Washington	MCES

Figures

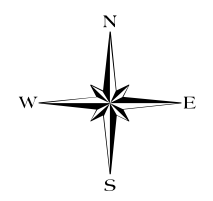
Figure 1 Surface Water Sampling Sites (2009)

Figure 2 Proposed Precipitation Monitoring Sites

Rice Creek Watershed District Surface Water Sampling Sites (2009)



- ◆ MCES Sites
- ◆ RCWD Lake & Stream Sites
- ◆ Ramsey County Sites
- ◆ USGS Site
- Channel Restoration Areas
- Stream/Waterway
- Lake
- Counties
- RCWD Legal Boundary

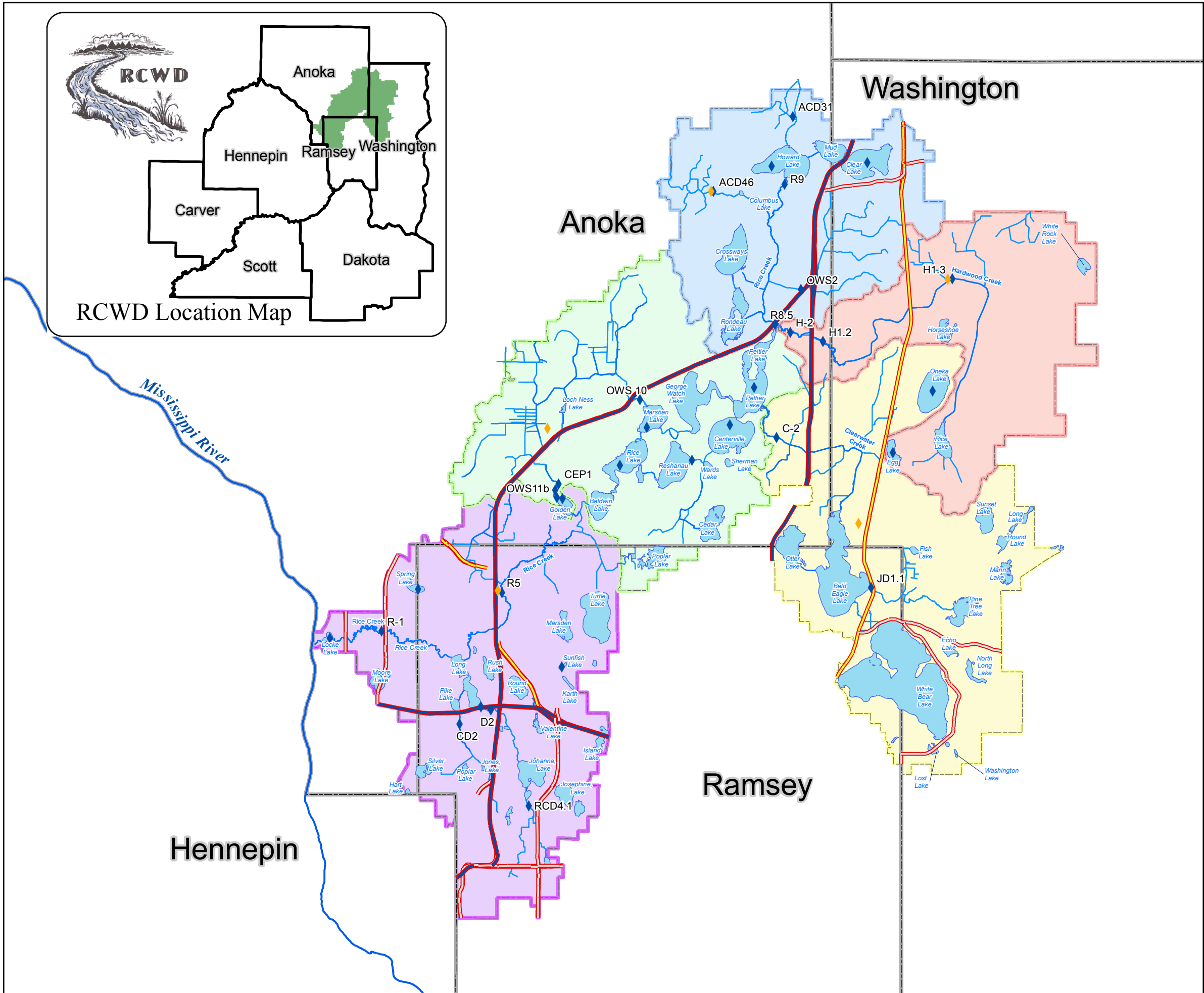
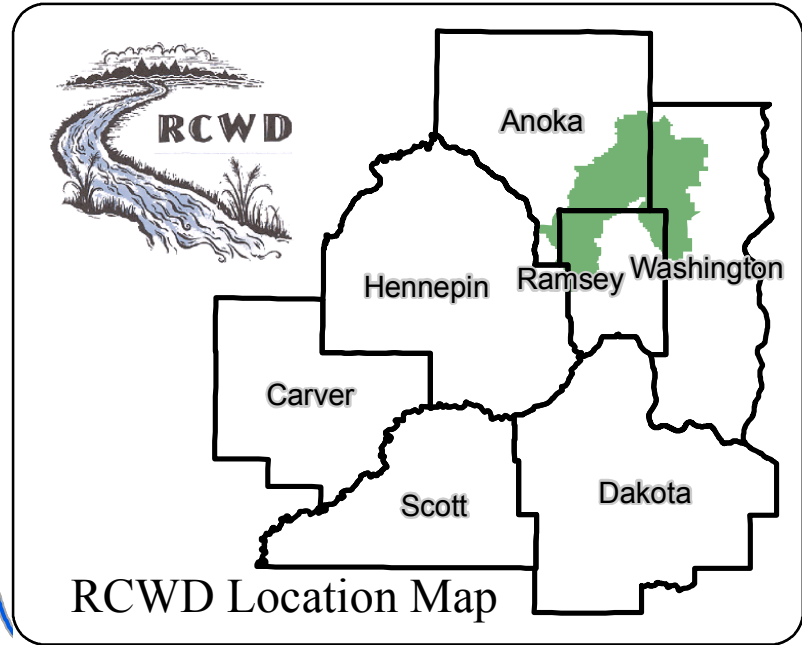


0 1.25 2.5 5 Miles
 Projection: NAD 1983 UTM Zone 15N

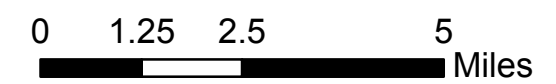
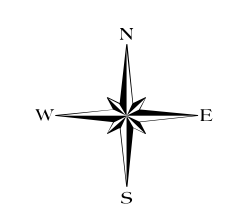
Data Sources: Rice Creek Watershed District, MN DNR Data Deli

Figure 1: Surface Water Sampling Sites (2009)					
Scale: AS SHOWN	Drawn by: KZS	Checked by:	Project No.: 5555-060.19	Date: 07/09/09	Sheet:
			Maple Grove P: 763.493.4522 F: 763.493.5572		

Rice Creek Watershed District Proposed Precipitation Monitoring Sites




- ◆ Proposed Precipitation Site
 - ◆ RCWD Lake & Stream Sites
 - Stream/Waterway
 - Lake
 - Counties
- RCWD Planning Regions**
- Clearwater Creek
 - Hardwood Creek
 - Lower Rice Creek
 - Middle Rice Creek
 - Upper Rice Creek



Data Sources: Rice Creek Watershed District, MN DNR Data Deli

Figure 2: Proposed Precipitation Monitoring Sites

Scale: AS SHOWN	Drawn by: KZS	Checked by:	Project No.: 5555-060.19	Date: 8/12/09	Sheet:
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Appendix A

General Guidance: Health and Safety

GENERAL GUIDANCE

Personnel Qualifications and Training

Personnel conducting field investigations are expected to have a reasonable working knowledge of the science and technology behind the data collection activities they are conducting. This includes understanding the limitations of the equipment so as not to damage equipment or cause injury. Knowledge and experience also will aid the person(s) to know when the data being collected are not reasonable and to investigate whether the equipment or data-collection methods are providing reasonable data.

Personnel also are expected to be provided with adequate training to properly conduct the work. Much of this can be learned from techniques and methods manuals which can be supplemented with video or Internet-based instructional courses. However, some direct, hands-on, preferably in-the-field, mentoring should be provided.

Health and Safety

Employees are expected to take reasonable care for their own safety and the safety of those affected by their acts or omissions; and to comply with health and safety arrangements. Fieldwork organizers or supervisors have responsibility to appropriately plan and manage field activities as to ensure healthy and safe working conditions. Staff participating in fieldwork, but not supervising, must ensure they follow safety instructions and use control measures properly.

It is important for safety that personnel are adequately trained in the skills required for their fieldwork, either beforehand or as part of the work. Training is discussed in more detail elsewhere.

Proper equipment includes the following types of clothing and personal protective equipment which should be considered as may be needed:

- sun protective clothing and sun screen lotion
- warm/weatherproof clothing (for cold/wet conditions)
- appropriate footwear

Appendix A – General Guidance: Health and Safety

- eye/face protection
- hearing protection
- respiratory protection
- high visibility clothing and
- life jackets.

The effect of reasonably foreseeable weather conditions should have already been considered and up to date weather forecasts obtained where practicable. Even with the best advance preparation, some refinement of the risk assessment will be needed if weather or other circumstances change, or are not as expected.

A wide range of factors that are only apparent on site may require reassessment of risks or changes to control measures, e.g.

- extremes of weather
- unstable rock, soil, ice, or snow conditions
- dangerous structures
- marshes or quicksand
- danger of forest or brush fires
- overhead or buried power lines
- swift currents
- traffic
- venomous, frisky or aggressive animals.

It may be necessary to consider additional precautions, e.g.

- appropriate protective clothing
- provision of shade or shelter
- provision of maps, compasses, GPS

Appendix A – General Guidance: Health and Safety

- first aid and medical equipment
- rescue and emergency equipment
- fixed safety lines, nets, or harnesses
- posting of lookouts
- safety boats
- increased level of supervision
- mobile or satellite phone, radio, or other communication systems
- control of sources of ignition
- permit to work systems (e.g. for confined spaces)
- gas detection equipment
- erection of barriers and warning signs.

Field staff should receive adequate instruction on the likely health hazards associated with the work, and particular attention should be given to:

- environmental hazards (e.g. hypothermia, dehydration, and sunburn)
- microbiological hazards
- insect, animal, and plant hazards
- basic personal hygiene and care of the feet
- chemical hazards
- use of insect repellents.

Appendix B

Stream Site Information

Appendix B – Stream Site Information

Rice Creek Watershed District Sampling Site Descriptions [Elevations are North American Vertical Datum of 1988 in feet above mean sea level]

Ramsey County Ditch Site CD-2.

This site is located about half a mile east of Silver Lake Road on 7th street at Hanson Park. It is at an aging dam that creates a large pond and wetland upstream. Large debris may catch on the dam causing shifts in the gage height record.

Reference point: Painted measuring point on the upstream dam wingwall at the left edge of the flowing water.

Gage: Electronic Data Logger (EDL) connected to a submersed pressure transducer.

The dam is the control, but is being considered for replacement. Samples are dip-grabbed from beneath the surface near the left edge of the dam where water is flowing. Field measurements are made with the sonde suspended from the bridge.

Rice Creek site R 1.

This most downstream routine monitoring site on the creek is located 400 feet downstream of Central Avenue (Hwy 65) in a Fridley park at a footbridge crossing the creek.

Reference point: Painted mark near center of bridge on upstream side.

Gage: EDL connected to an ultrasonic stage-measuring device attached to the underside of the bridge.

The control is a stable riffle at most stages. Streamflow is easy to measure at all except the highest stages when equipment to measure off the bridge is advisable. The grab sample is collected near the bridge and the cross section appears well mixed.

Rice Creek site R-5.

Located near the lower end of Middle Rice Creek at the St. Paul Regional Water Services aqueduct crossing, 70 feet upstream Ramsey County Road I.

Reference point: Painted mark on the top of a concrete wing wall on the left bank on the upstream side of the northernmost aqueduct.

Gage: EDL that senses water levels using an ultrasonic stage-measuring device attached to the aqueduct.

This is a well-established site with a downstream submerged riffle between the 2 aqueducts that serves as the control at all stages. This control appears stable, providing a reliable stage record. Streamflow generally should be measured at the control. Samples are dip-grabbed from beneath the surface near the center of the flow while wading..

Non-jurisdictional Ditch site D 2

This site is on a tributary to Long Lake at a footbridge at the New Brighton Learning Center.

Reference point: Painted measuring point on the upstream side of the footbridge.

Gage: EDL connected to an ultrasonic stage-measuring device attached to the underside of the bridge.

This site has a sand/gravel bottom with relatively stable banks. The channel probably is the control at all stages, although a downstream culvert may cause backwater at higher flows. Excellent measuring section downstream of bridge. Streamflow could be measured from the bridge at high stages, but may require purchasing additional equipment. Samples are dip-grabbed from beneath the surface near the center of the flow. Site may be critical for evaluating improvement of water retention in upstream wetland.

Tributary Ditch OWS10

Site is located at the outflow of ditch 10-22-32 where it passes under Lake Drive before flowing into Marshan Lake.

Benchmark elevation: 890.26

Reference point: _____

Appendix B – Stream Site Information

Gage: EDL connected to a submersed pressure transducer.

This gage probably needs frequent measurements to establish a new rating following considerable modifications to the stream channel in the vicinity of the gage.

Judicial Ditch 4 site OWS 2.

OWS2 is located at the Clear Channel road crossing of JD-4, just west of West Freeway Drive. Benchmark elevation: 889.31

Reference point: Painted measuring point on the downstream end of the northern culvert.

Gage: EDL connected to a submersed pressure transducer.

This site is located at the downstream end of three large culverts. The control is a grassy channel but the rating appears stable. Seasonal shifts should be anticipated and documented with periodic streamflow measurements. Streamflow is fairly easy to measure at three points inside each culvert – be sure to stay well upstream of where the stream surface breaks downward at the outfall. The grab sample is collected from the outfall of the culvert having the largest proportion of flow because the stream is well mixed before it enters the culverts upstream.

Clearwater Creek site C-2.

C2 is located behind the Centerville fire station south of Anoka County Road 14.

Reference point: a staff gage mounted in the stream bottom.

Gage: EDL connected to a pressure transducer that measures changes in a pressurized gas system.

This is a well-established site with a downstream riffle that serves as the control at low stages. This control appears to be stable, but floating debris may hang up on the control causing temporary shifts. At higher stages the channel probably is the control.

Hardwood Creek site H-2.

H2 is located at Hardwood Creek and 20th Avenue.

Benchmark elevation: 889.12

Reference point: Painted measuring point on the downstream end of the box culvert.

Gage: EDL that senses water levels using an ultrasonic stage-measuring device.

This is a well-established site with relatively stable banks. The channel probably is the control at all stages. The wading measurement section is a narrows about 30 feet below the gage. An alternate could be about 20 feet upstream of the box culvert. Samples are dip-grabbed from beneath the surface near the center of the flow while wading. The ultrasonic stage-measuring device misreads during temperatures near freezing.

Hardwood Creek site H-1.3.

H1.3 is located at Hardwood Creek and Harrow Avenue.

Benchmark elevation: 917.97

Reference point: Painted measuring point on the downstream end of the box culvert.

Gage: EDL connected to a submersed pressure transducer.

This is a well-established site with relatively stable banks. The channel probably is the control at all stages. This site is reportedly dangerous to wade because of a soft bottom. Because of unknown channel stability, flow at this site should be measured routinely. Samples are dip-grabbed from beneath the surface near the center of the flow using a sampling wand.

Anoka County Ditch 46 site ACD 46.

ACD 46 is located at ACD 46 and Lake Drive, near the inlet to Columbus Lake.

Reference point: _____

Gage: EDL connected to an area/velocity probe mounted to the bottom of the open channel near the upstream end of the culvert.

Appendix B – Stream Site Information

Anoka County Ditch 31 site ACD 31.

ACD 31 is located where Kettle River Blvd. crosses ACD 31 near the inlet to Howard Lake.

Benchmark Elevation: 889.81

Reference point: _____

Gage: EDL connected to an area/velocity probe mounted at the downstream end of the 36-inch corrugated metal pipe culvert.

The culvert typically is half full of sediment all season long. A new rating curve was developed for this site at the downstream end of the culvert, just above the sediment surface.

County Ditch CD 25.

CD 25 is located where Black Duck Road crosses ACD 25, near the inlet to Reshanau Lake.

Reference point: Painted mark on the concrete culvert inlet.

Gage: EDL connected to a submersed pressure transducer.

The culvert opening is the control at all stages. This site is located downstream of Wards Lake with an intervening wetland and above Reshanau Lake, with slope and flow that is barely perceptible. Extremely slow velocities and variable backwater make this a difficult site to gage. Reverse flow likely occurs when the wind blows strongly from the west. Heavy rains in the lower watershed also could cause flow reversals. Tracer-dilution could be used to measure the flow, but would be a very slow process because of slow velocities and poor mixing. If the culvert has a uniform shape inside and is not filled with debris, its slope and geometry could be used to determine the flow. Samples are dip-grabbed from beneath the surface near the center of the flow upstream from the culvert. The shelter at this site is an awkward metal barrel that is planned for replacement.

Judicial Ditch 1 site JD-1.1.

JD1.1 is located at JD1 and Hugo Road, near the inlet to Bald Eagle Lake.

Benchmark elevation: 915.15

Reference point: Painted measuring point on the upstream end of the culvert.

Gage: EDL connected to a submersed pressure transducer.

This site is located downstream of a box culvert and upstream of a county road culvert. The control is a relatively stable gravel riffle that may become inundated by backwater from Bald Eagle Lake when the lake is high and the wind is out of the west. Samples are dip-grabbed from beneath the surface near the center of the flow while wading.

Anoka County Ditch 53-62 site CEP-1.

CEP-1 is located in Carl Eck Park north of Lake Drive on Fire Barn Road. It is a ditched western tributary to Golden Lake and middle Rice Creek.

Benchmark elevation: 896.05

Reference point: Painted mark on top of the CMP culvert inlet.

Gage: EDL connected to a submersed pressure transducer.

The gage installation at this site is subject to vandalism: the transducer was recently dislodged by persons pulling on the protective cable.

This site has a fine sand bottom that is constantly moving. Although the primary control is the culvert opening, it is partially submerged and the shifting sand could alter the control; especially at low stages. This is a very flashy stream site because of upstream impervious surfaces, so accurate streamflow records will rely on a good streamflow rating.

Rice Creek at Howard Lake outlet site R9.

R9 is located near the outlet of Howard Lake.

Reference point: _____

Gage: EDL connected to a flow meter.

Peltier Lake site P1.

Appendix B – Stream Site Information

P1 is located on Peltier Lake for measuring elevation and provides an indication of the lake outflow volume. One of the Sentinel Lakes monitored by the State

Reference point: _____

Gage: unknown.

Ramsey County Ditch 4 site RCD-4.1

RCD-4.1 is located west of Snelling Ave. on north side of W. Lydia Ave. at Northwestern Business College.

Reference point: Painted measuring point on the top left downstream end of the box culvert.

Gage: EDL connected to a submersed pressure transducer.

This ditch appears to be a natural stream, but was partially enhanced with boulders, cobbles, and concrete. The control is a stable riffle that may catch debris and is subject to modification by people. The wading measurement section is in the downstream end of each of two box culverts. Samples are dip-grabbed from beneath the surface near the center of the flow while wading.

Appendix C

Annual Data-Review Form

Appendix C – Annual Data-Review Form

The following chart provides some guidance as to the method that could be used annually to evaluate the data collected from each of the sampling sites. It is likely that the information suggested by this form would be done electronically using a software package such as MS-Excel and archived electronically as a group of spreadsheets within a workbook.

Annual review of data from Rice Creek Watershed District Sampling Sites.											
Site ID:		Site Name:					Year:				
	Period of record	Historical					Recent				
		N	Min	Max	Median	StdDev	N	Min	Max	Median	StdDev
Streamflow											
Water temperature											
Specific conductance (SC)											
pH											
Dissolved oxygen.											
Total phosphorus											
Soluble-reactive phosphorus											
Total particulate matter											
Organic particulate matter											
Total ammonia plus organic nitrogen											
Chloride											

Analysis of some constituents also might be helped by charting the data, determining a simple trend line, and computing a slope for that line. Typically, any trend observed (upward or downward) suggests the need for further monitoring to verify that the trend is real and sustained. The trend may be indicative of either degradation or improvement in the measured resource.

Appendix D

Monitoring Procedures

RECORDING STAGE

There are a variety of methods used to record stream stage in an effort to determine nearly-continuous records of streamflow. Most of the established methods are described in Rantz and others (1982). These may be a float-based system dampened from wave action (e.g. a stilling well), a submersible transducer (usually vented to the atmosphere), a pneumatic (bubbler) system, or an ultrasonic (non contact) system. Non-contact, ultra-sonic devices also may be used. A variety of media are used to record the data, but most modern systems incorporate some type of electronic data logger (EDL) that is environmentally protected and provided with memory and/or battery backup.

The RCWD primarily uses pressure transducers that are vented to the atmosphere. Non-vented systems have been used but they also respond to changes in barometric pressure such as the passage of weather systems which complicates interpretation of the record. The vented systems avoid this problem, but need to have the vent tube protected from moisture using a desiccant chamber that ‘filters’ water from the air. These desiccant chambers need to be serviced routinely to avoid moisture damage to the sensors.

Some of the transducers are attached to a fixed point beneath the water surface, and directly measure the change in the pressure of the water as it changes depth. Others are attached to a pressurized system that bubbles gas from a fixed point beneath the stream surface and responds to changes in the water depth using a non-submersible pressure transducer to measure the change in back pressure. The bubbler system keeps the sensitive and delicate transducer out of the water providing more protection, but also is more complex requiring an active source of pressurized gas to produce continuous backpressure on the transducer.

Some sites are equipped with a non-contact ultrasonic stage-measuring device that is mounted directly over the stream. It reliably measures the height of the water by determining the distance to the water surface. It appears to have problems during cold weather, but otherwise meets the data-quality stage-measurement needs of the RCWD.

The RCWD typically uses an assortment of EDLs to record data. These are downloaded using a laptop computer and proprietary software to interrogate the EDL. Laptop use can be challenging during inclement weather, which may include direct sunlight. EDL systems

generally are more reliable than historically-used systems described in Rantz (1982) as long as volatile memory is not compromised.

Doppler systems are becoming more common as the technology improves and the price lowers. They measure the movement of water in addition to the stream stage providing more information about the flowing-water system. They also can measure flow in slow velocities and measure flow reversal. With present technology, Doppler systems have difficulty in small streams. However, they may be needed where other systems are inadequate and the expense of installation, operation, and maintenance is justified. Doppler systems do not replace the need for streamflow measurements to calibrate the streamflow they record.

An important addition to the RCWD data-collection program includes the use of high-water marks to document stream stage when the capabilities of the equipment are exceeded or when no equipment is on site to record peak water elevations during an important event, particularly during snowmelt runoff. These high-water elevations will be used to calibrate the flow models that are being developed and used for the District-wide modeling effort. Inexpensive peak-stage recording devices called crest stage gages (Rantz, 1982) may be installed in anticipation of extreme events. These devices should be installed at all or most of the critical streamflow sites.

Peak stream stage also can be estimated by measuring the elevation of debris that is left on fixed objects (trees, posts, bridge abutments, buildings) at the peak stage. Often called the ‘seed line’, it may be composed of many different, small floatable materials. The peak stage must be determined quickly after the event as rain will easily wash away the seed line.

MEASURING STREAMFLOW

The RCWD is collecting streamflow data at all of their stream-monitoring sites using reasonably good protocols. Most of the actual streamflow measurements are considered good, although the flow conditions measured may be limited by slow velocities and poorly-defined channels. The primary concern is that measurements are not being made at some of the sites where it is most difficult to measure streamflow. These also may be sites where channel instability frequently changes the relation between streamflow and stream stage. This will lead to uncertainty about the quality of the computed streamflow record. As described elsewhere in this document, additional equipment may be needed to ensure collection of good-quality

Appendix D – Monitoring Procedures

streamflow data. This section describes important aspects of collecting good-quality streamflow data using a variety of methods under a variety of conditions.

Streamflow (sometimes called discharge) generally is measured manually near the control (measuring on the control should be avoided because it could cause temporary backwater conditions) to establish a rating curve. A rating curve is the relation between stream stage and streamflow. Streamflow measurement sites generally should have uniform, laminar flow (no riffles or pools at most stages) with minimal interferences from debris including aquatic vegetation. Streamflow can be measured by determining the stream width, average depth, and the average velocity using a variety of velocity meters and multiplying the values. Streamflow also can be measured by dilution of a solute such as a dye, or using constricted-opening equations. The later often are employed as an indirect measurement of streamflow after a flood has passed.

The simplest, quickest, but generally least accurate measurement is an estimate. The hydrographer uses some device to measure or guesstimate the width, average depth, and the time it takes for a partially-submerged object near the center of flow to travel a known distance in relation to the streambank. Because the velocity is fastest at the top and center of the stream, streamflow is usually overestimated. However, indirect width and depth estimates also add uncertainty.

Most streamflow measurements are completed by extending a measuring device such as a measuring tape across the stream perpendicular to the flow, then measuring the depth and velocity at known points along the stream cross section using a velocity meter. Each of these measured sections or ‘cells’ of water are added together to provide the total flow. More specifically, the velocity in each section should be measured at a point 0.60 units of depth from the stream bottom to the surface of the water, which is where the average velocity for the stream vertical typically is found. When the depth exceeds a predetermined level, sometimes 2.5 feet, the velocity is measured at depths of 0.2 and 0.8 units of depth. A top-setting wading rod has been developed to assist the hydrographer with setting the velocity meter at the correct depth from the stream bottom. Ideally, at least 20 sections are chosen so that each section contains no more than 5 percent of the total flow, with narrower sections near the middle where the velocity and depths are greatest and wider sections near the shore where the velocity and depths are less.

Appendix D – Monitoring Procedures

More information about making streamflow measurements can be found from Buchanan and Somers, 1969, which is available at <http://pubs.usgs.gov/twri/twri3a8/html/pdf.html>.

Various meters are used to measure velocity and factors including accuracy at different flows, ruggedness, and cost all important considerations. Vertical axis current meters that spin at a rate relative to the velocity of the water historically were considered the most reliable, but newer meters with no moving parts that measure the movement of particles in the water are becoming more acceptable. The RCWD uses a Flow Tracker® that provides good-quality data and useful quality-assurance information.

Some stream environments lend themselves to the installation of devices that allow direct calculation of the streamflow from the stream stage. Flumes, weirs, and often culverts work in this fashion. They can be expensive to install, but require minimal maintenance. They may fail to work when their capacity is exceeded, when they become clogged, or when their outflow becomes flooded by backwater.

In systems that are difficult to gage, the amount of water can be determined by measuring how much it dilutes a known concentration of a conservative substance sometimes called a tracer. For this purpose a salt with an easy to measure ion or a fluorescent dye is injected into the stream and its concentration is sampled and measured far enough downstream for the tracer to be well mixed. The volume of water in the stream is determined by how much it diluted the tracer. Although this is effective in several aquatic systems, it is fraught with potential errors. If done incorrectly it can provide erroneous and misleading results.

When major events exceed the capacity of recording equipment but knowing the peak streamflow is critical, an indirect measurement can be made. This is a highly labor-intensive effort that entails measuring the surface profile of a flood based on high-water marks, the shape of the channel that held the water, and the slope of the flood waters that moved through the system. By computing the upstream and downstream volumes and the velocity as determined by the slope, the person(s) calculate the amount of water that was flowing through the channel at the time the high-water marks were deposited. Generally, it is advisable to have the assistance of an experienced hydrographer when making indirect measurements because debris or other obstructions in the channel can give false readings of the stream stage and the slope, and the calculations can be cumbersome.

STREAMFLOW COMPUTATIONS

The RCWD has been doing a good job of developing streamflow ratings and performing computations. Although several methods of computing streamflow have been considered, these streams generally allow application of relatively simple, spreadsheet-based streamflow-stream stage regression equations to records of stream stage to compute continuous records of streamflow.

Measurements and Ratings

Streamflow rating curves are created and maintained based on several measurements over a range of flows and stream stages. The water-surface elevation at the point the stream stops flowing, called the point of zero flow (PZF), can be helpful in defining the rating by providing the lowest point or anchor point for the rating. The RCWD is actively working to determine PZF at as many streamgaging stations as possible. Once a rating is established, shifts may need to be applied based on time (season), or stage (control obstruction). Ultimately, a new rating may be needed when shifts of similar magnitude are routinely needed.

Logarithmic transformations or plotting the rating on a logarithmic grid can provide a straight-line relation that averages some of the noise in the rating. On small streams having a small range in flows, this transformation often is not advantageous.

New ratings often are started when a similar shift is applied routinely. New ratings typically are built on the rating-shifted measurements plus newer measurements when they become available. Even a reliable rating (including flumes and weirs) should be checked occasionally because a variety of factors including frost heaves and other subtle occurrences can affect the relation.

Processing Records of Streamflow

Streamflow values are computed by applying gage-height recordings to the stream rating, but need to be checked for accuracy and consistency. A record may look reasonable, but should be compared to nearby stream hydrographs and precipitation records to determine whether variations in flow look reasonable. This also is a useful approach when equipment malfunction or other incidents result in missing record.

WATER QUALITY SAMPLING PROCEDURES

An important part of collecting any sample is to ensure that your sample does not become contaminated during any phase of the sample-collection process. This entails careful consideration of what is being sampled and understanding that all foreign objects that may come in contact with the sample containers or the sample itself could compromise the sample. Examples: some detergents used during cleaning may contain phosphates that could contaminate a sample analyzed for phosphorus. Many snack foods that a person handles could add salts to the sample including sodium and chloride. Rain dripping from dirty surfaces could add a variety of unknown chemicals to the sample. The addition of the rain itself might dilute to sample. Clean hands, clean equipment, and proper sample handling will help ensure sample integrity. Disposable gloves can help reduce contamination concerns, but also may contain compounds that can contaminate a sample.

Staff of the RCWD do a good job collecting grab samples while minimizing the opportunity for sample contamination. Samples typically are collected from the stream directly into a Whirl Pak® that is opened immediately before and resealed immediately after sample collection. No other processing is done in the field beyond chilling the sample.

It is assumed that lake samples are processed using this same level of care. However, some type of sampling device such as a Kemmerer or Van Dorn type sampler generally needs to be used, and care should be taken to ensure that the sampler is rinsed between sites.

Streams

Streams range from poorly-mixed to well-mixed. When point sources, including tributary streams enter the main channel it can require several times the width of the stream for complete lateral mixing to occur downstream. The morphometry of the stream including riffles and meanders can affect how efficiently the stream mixes. Particulate material often is distributed unevenly in the stream both vertically and laterally with the largest concentrations and densest particles occurring near the center and bottom. Unless it can be assured that the stream is well mixed for the constituents being sampled at the sample location, special sampling protocols need to be employed to ensure that the collected sample is representative of the stream cross section.

Appendix D – Monitoring Procedures

Sample collection using isokinetic, depth-integrating samplers ensures that the most representative stream-water sample is being collected. The shape of the sampling device results in an unsampled area about 12 centimeters near the stream bottom where coarse sediments typically are transported. Another concern is that the sampler and container material does not contaminate the sample.

The most convenient sample to collect is the streambank grab. No one has to get their feet wet and the equipment needed is minimal. However, this also is the least reliable sample because it is not known how that water represents what is truly being carried by the stream. Point sources upstream, shoreline debris, and streambank ground-water seeps could be sampled rather than the material being transported by the stream.

The method used by the RCWD provides a more representative sample. It is a sample taken from beneath the stream surface near the centroid of the flow. This is taken facing upstream and avoiding sampling sediments that may have been disturbed while wading into the stream. When wading is not practical or possible, a remote device such as a sampling wand, a weighted bottle, or a cable suspension may be employed. If the mixing of the stream is uncertain, the sample is composited from multiple points in the cross section.

The preferred method to collect a representative sample is use the depth-integrated, isokinetic method endorsed by the USGS. It is described in more detail in several publications, but the most pertinent can be accessed at:

http://water.usgs.gov/owq/FieldManual/chapter4/pdf/Chap4_v2.pdf

Field measurements typically are made when the analytical sample is collected. Like the sample that is collected, the location in the stream cross section where the field measurements are made can be important. This may be verified by occasionally making measurements at several points in the stream cross section under a variety of flow conditions.

Field observations written down on the notes may be useful when the data are evaluated at some later date. Weather observations are helpful, but unusual things such as people or pets playing nearby, flocks of wildlife, or evidence of runoff events all can be helpful when interpreting the results of sampling.

Lakes

When sampling lakes it is important to consider the purpose of the sampling program. Field measurements, typically water temperature, specific conductance, pH, and dissolved oxygen, from top-to-bottom in the vertical to be sampled will give an indication whether the lake has become stratified. Many deep lakes in northern climates will stratify with warmer water near the surface and cooler water near the bottom. Finding stratification will suggest that a surface sample will not be representative of the overall condition of the lake. A vertical composite may be needed or the surface waters, epilimnion, and the bottom waters, hypolimnion, should be sampled separately.

The most common measurements made in lakes include the field measurements mentioned above, especially the dissolved oxygen concentration, and the transparency of the lake. Transparency typically is measured using a Secchi-disk and clearly-defined protocols, including taking the measurement near the middle of the day when the sun is overhead. Total phosphorus and chlorophyll also are sampled near the surface in the epilimnetic waters, when applicable. Chlorophyll is unstable, so collecting, processing, and analyzing the sample quickly is important. It generally is preferred to filter the chlorophyll sample on site and freeze the filter on dry ice in the field. The summertime measurements of transparency, total phosphorus, and chlorophyll can be used to evaluate the trophic status (productivity) of the lake.

Unattended samplers

Automatic samplers

The RCWD is equipped to automatically collect samples at many of their most important sites. This allows them to collect event-based samples to supplement the limited personnel available to service the large number of sampling sites. The automatic samplers also provide the opportunity to composite samples over the storm-runoff hydrograph while constituent concentrations may be changing as a result of hysteresis or other influences.

The automatic samplers are installed at select locations where sampling the storm hydrograph is most critical because of changes in constituent transport. These locations are subject to change as limited equipment are needed elsewhere.

Appendix D – Monitoring Procedures

The samplers are locked inside secure metal boxes, usually with the stage recorder from which a buried sampling tube leading to a metal post or other solid point in the stream where the tubing intake is fastened. The open end of the tubing is protected by a strainer to prevent clogging from debris as it collects a sample. When a strainer is not available the tubing is pointed downstream because tests have shown that this configuration still allows collection of a representative sample of suspended as well as dissolved constituents. The automatic sampler generally is set to start collecting samples with input from the stage recorder when a predetermined stage is attained, based on prior experience with storm runoff at a given site, and to continue collecting samples until all bottles are filled.

The sampling sequence and timing may be programmed for any number of configurations including rate-of-change in stage or flow, or a predetermined time interval. The sample is then composited for a single analysis using one of several sample-compositing protocols which may include flow-weighted, timed sequence, or a bulk composite. Presently, the RCWD prepares a bulk composite by combining all the water from all sample bottles into one large container, mixing the composite, and then subsampling from that composite.

The present RCWD automatic-sample collection and compositing protocols are adequate for the sampling program. However, consideration should be given to enhancing the information provided using those samplers, especially at critical sites where the composition of runoff is important. Most newer automatic samplers can be programmed to collect water proportional to the volume of flow carried by the stream over the runoff hydrograph. The persons processing the samples can accomplish the same by subsampling water that is proportional to the water carried by the stream from each of the sample bottles and compositing those into a bulk sample. Both approaches require considerable effort, and the time committed has to be weighed against the information obtained. At present, this approach should not be a high priority for the District except on a site-by-site basis.

Another approach to enhancing the information from automatic samplers is to analyze selected samples from the runoff hydrograph individually to provide discrete values and learn how concentrations change as a result of hysteresis. This should not be a high priority, but could be considered to better understand the transport of constituents during runoff events.

Appendix D – Monitoring Procedures

Passive Samplers

The RCWD may miss sampling during high-flow events, especially during snowmelt runoff when automatic samplers have not been deployed or at sites where installation of an automatic sampler is not practical. Passive samplers including the US SS-59 single-stage sampler are devices that have been used successfully to collect un-attended samples in many remote sampling locations. They are designed to collect a sample by filling a container and stopping after a previously-determined stage has been reached. Because they are inexpensive, many of them can be deployed to sample at many locations or many stages at a single location.

Water-quality Monitors

The RCWD has the capability to deploy water-quality monitors that can operate unattended to record water temperature, dissolved oxygen, pH, and specific conductance. Turbidity may also be added to that list. These units typically are deployed for only a few days because of concerns about loss or damage to these expensive pieces of equipment. During longer-term deployments a routine site-visiting and calibration protocol needs to be established. The record for any deployment needs to be reviewed to determine whether instrument drift or fouling occurred. The record may need to be adjusted to compensate for drift or errors, or part of the record for one or more constituents may have to be discarded.

Water-quality monitors are available for rent from several vendors. These will be useful when presently-available equipment fails or when deployment at multiple sites is required. These would be useful for special studies such as evaluating diurnal fluctuations in concentrations of dissolved oxygen at sites on impaired streams such as Hardwood Creek.

Seasonal Sampling Considerations

Concerns about water-quality during winter under ice were discussed earlier, but each of the seasons has certain characteristics that make collecting samples during different time of the year important. The RCWD should consider how seasonal variations need to be addressed in their sampling program. The following caveats are presented to foster discussion about enhancing the existing monitoring network.

During the spring, snowmelt runoff brings water through the system that has been accumulating atmospheric deposition, road salt and sand, and other debris that has accumulated

Appendix D – Monitoring Procedures

for several months. Spring flooding also may inundate areas that had not been underwater for years, bringing in other new material. Considerable transport of material occurs during the high flows of spring. However, this also is a time when operating streamgaging and automatic sampling equipment can be a problem because of frequent temperatures below freezing. This often has to be supplemented with intensive manual samples in order to define constituent loads in the streams.

During the summer high temperatures increase evapotranspiration causing decreased streamflow. However, storms and persistent rainfall can cause runoff events that can be important contributors of undesirable constituents to streams and lakes.

Late summer into early fall generally results in low flows with few runoff events. However, as trees start to change colors flows often will increase because evapotranspiration becomes insignificant and moisture that had been drawn from the ground to the atmosphere instead goes into the streams.

As described above, little happens during the winter and freezing conditions make sampling difficult. However, anoxia can cause stressful conditions under the ice in some water bodies and it may be worth putting forth the effort to document these conditions.

Other Sample Types

It is beyond the scope of this document to explain the variety of methods that should be used to collect all the special samples that may be collected. However, it is important to explain that at some time there is likely to be a need or an event that will require staff of the RCWD to collect some of these samples. Fortunately, there are a number of good sources detailing methods that can be used to collect these samples. Standard Methods for the Examination of Water and Wastewater is primarily a description of laboratory methods, but also contains some guidance on field sampling protocols. The USEPA also has extensive lists of laboratory and field methods. The USGS has an extensive series of publications called Techniques of Water Resources Investigations (TWRI). RCWD staff should be aware of special sampling considerations because the need to implement them often arises with minimal advance notice as in the case of major chemical spills. Fortunately, many fire departments are equipped and trained to respond to spills of hazardous materials and can be called into action on short notice.

Appendix D – Monitoring Procedures

Ground water likely will be sampled by the RCWD in the future as the need to understand the relation between ground and surface waters grows. The methods employed typically will depend on what is sampled and how deep the wells are. Guidance and advice from experienced persons should be included in any new groundwater sampling program until the sampling becomes routine. In many cases an experienced contractor should be hired to collect some of the more complex samples.

Chemical spills are likely to occur in the watershed and a plan to monitor their effect on resources should be available. The behavior of the spill will depend on the nature of the material spilled, the media into which the spill is introduced, and the conditions, such as weather, that may influence the movement of the contaminant.

Bacteria have occasionally been sampled in various parts of the RCWD, particularly in areas where human contact with the water is anticipated. This includes primarily public beaches and waterways where people and pets may spend time in the water. Much of the required sampling has been done by health department officials, and that responsibility probably will remain with those organizations. If the RCWD determines that additional sampling for bacteria is needed, some training or guidance of personnel will be needed and some equipment such as incubators and possibly an autoclave should be purchased. Bacteria sampling and analysis is not a complicated endeavor, but considerable time and care should be exercised to ensure the results of sampling are meaningful.

Bottom Sediment sampling also is reasonably straightforward, but the methods used are directly influenced by the purpose of the sampling. Sampling and analyzing nutrient concentrations in bottom sediment is challenging because the purpose of the sampling usually is to determine whether the nutrients will be biologically available under typical environmental conditions. Trace element sampling and analysis typically present similar concerns. The particle size and organic content of the sediments also should be measured to understand their interaction with the constituent being measured and the environment surrounding the sediments.

Mercury is a contaminant of concern in many aquatic environments including the RCWD. Several lakes in the RCWD have fish-consumption advisories directly related to elevated concentrations of mercury in fish tissue. At the present time, investing in any mercury study probably is beyond the scope of the RCWD. This type of sampling generally is most

Appendix D – Monitoring Procedures

effective when performed under the guidance of researchers having an understanding of the behavior of mercury in the environment.

Ecological Monitoring can be complicated and typically requires training and experience. The RCWD is fortunate to have many external organizations that are willing to volunteer their time and knowledge to better understand ecological resources at selected points in the watershed. As with many data-collection programs, ecological monitoring may be more art than science so the data may be of limited quality at any given time; especially if the site has been perturbed by outside influences such as a runoff event.

The RCWD may consider including other types of data collection within their sampling network. This generally is useful to broaden the set of data collected by the District, but should not dilute the work already being done.

Appendix E

Quality-Assurance Objectives

Appendix E – Quality – Assurance Objectives

Field and Laboratory Quality-Assurance Objectives			
Measurement	Precision (Standard Deviation)	Accuracy	Completeness (Percent of useable measurements)
Water level (stage)	+/- 5 percent	0.02 feet	95 percent
Streamflow	+/- 5 percent	0.1 cubic feet per second	100 percent
Water temperature	+/- 0.1 degrees Celsius	0.2 degrees Celsius	100 percent
Specific conductance	+/- 5 percent	5 uS/cm	100 percent
pH	+/- 0.1 units	0.05 units	100 percent
Dissolved oxygen.	+/- 0.05 mg/L	0.05 mg/L	100 percent
Transparency	+/- 5 percent	0.5 feet	100 percent
Precipitation depth (recorder)	+/- 0.05 inches	0.01 inches	90 percent
Total phosphorus	< 10 percent	95 percent recovery	95 percent
Soluble-reactive phosphorus	< 10 percent	95 percent recovery	95 percent
Total particulate matter	< 10 percent	95 percent recovery	95 percent
Organic particulate matter	< 10 percent	95 percent recovery	95 percent
Total ammonia plus organic nitrogen	< 10 percent	95 percent recovery	95 percent
Chloride	< 10 percent	95 percent recovery	95 percent

Appendix F

Quality-Assurance Data Types

Quality assurance data types [From Horowitz, and others 1994]

Equipment blank (sampler + splitter + pump + filter) - a blank solution subjected to the same aspects of sample collection, processing, preservation, transportation, and laboratory handling as an environmental sample, but is processed and shipped from the relatively controlled environment of an office or laboratory.

Sequential equipment blanks - a series of blank samples (sampler blank, followed by splitter blank, followed by pump blank) collected in order after each step in the generation of an equipment blank.

Field blank - a blank solution that is generated under actual field conditions and is subjected to the same aspects of sample collection, field processing, preservation, transportation, and laboratory handling as the environmental samples.

Sequential field blanks - a series of blank samples (sampler blank, followed by splitter blank, followed by pump blank--see above) collected in order after each step in the generation of a field blank.

Source-solution blank - solution that is considered free of analyte(s) of interest and is stock solution used to develop other blank samples; source-solution blank is collected in a relatively protected area and used to verify the composition of the stock solution.

Sampler blank - a blank solution that is poured through the same sampler to be used for collecting environmental samples.

Splitter blank (sampler + splitter) - a blank solution that is poured into the same sampler and then processed through the same splitter to be used for environmental samples.

Pump blank (sampler + splitter + pump) - a blank solution that is poured through the same sampler, then processed through the same field splitter, and then is pumped by a peristaltic system through the same tubing to be used for environmental samples.

Replicate (duplicate/triplicate/split) samples - a set of environmental samples collected in a manner such that the samples are thought to be essentially identical in composition.

Replicate is the general case for which a duplicate is the special case consisting of two sequentially-collected samples and for which a split is the special case in which two or more samples are generated from one. Different types of replicate samples may yield somewhat different results because they are collected in dynamic hydrologic settings.

Split field sample - a type of replicate sample in which one sample is split into two or more subsamples contemporaneous in time and space.


Concurrent field sample - a set of replicate samples which are composed of alternating subsamples composited contemporaneously in two or more collection containers.

Standard/Reference material sample - a solution or material prepared by a laboratory whose composition is certified for one or more properties so that it can be used to assess a measurement method or for assigning concentration values of specific analytes.

Appendix G

Field Forms Used by the Rice Creek Watershed District

Appendix G - Field note sheets used by the Rice Creek Watershed District

	RICE CREEK WATERSHED DISTRICT STREAM FIELD DATASHEET	<i>NEVER USE RED INK!</i>		
Station ID	Station Name	Date	Time (24 hr)	Personnel
WATER QUALITY: LAB PARAMETERS				
Sample Type (circle one)				
Lab ID _____	<input type="radio"/> Grab <input type="radio"/> Storm Composite <input type="radio"/> Depth Composite (integrated)			
Lab _____	QA / QC Sample			
Lab ID _____	<input type="checkbox"/> Blank <input type="checkbox"/> Replicate <input type="checkbox"/> Spike Spike Type/Value: _____			
STAGE/DISCHARGE				
BM to WS/Gage: _____		Meas. Stage: _____		Logger Stage: _____
Stage Conversion:	<input type="checkbox"/> Correction applied <input type="checkbox"/> Logger downloaded		Battery _____ V <input type="checkbox"/> Batteries changed	
Q collected:	<input type="checkbox"/> Flow Trk <input type="checkbox"/> MMcB		Total Q = _____ cfs Width = _____ ft Max. Depth = _____ ft	
Q quality:	<input type="checkbox"/> good <input type="checkbox"/> fair <input type="checkbox"/> poor		Stage at Zero Flow _____	
DON'T FORGET TO CHECK THE DESICCANT!				
FIELD PARAMETERS				
Temp: _____ (°F/°C) DO: _____ (mg/ DO %: _____ pH: _____ sp.con: _____ (uS/cm)				
Turbidity: _____ (ntu) T-tube: _____ (cm) Multimeter type/SN: _____ <input type="checkbox"/> Calibrated?				
FIELD NOTES				
Weather:				
Air Temp (approx): _____ (°F/°C)				
Field Observations:				
RAIN GAUGE				
<input type="checkbox"/> Downloaded <input type="checkbox"/> Obstructed <input type="checkbox"/> Damaged battery status _____				
Notes:				

Appendix H

Field Supplied Checklist

Field sampling checklist

Item	Location	OK	Verify
Fully-charged laptop computer w/ appropriate software			
Cellular phone			
Streamgaging equipment			
Wading rod			
Field note sheets			
Analytical request forms			
Chain of Custody forms			
Site information / directions			
Spare batteries			
Spare desiccant			
Hip boots / Chest waders			
Personal floatation device			
Insect repellent			
Coolers with ice			
Clean sample containers			
Sample preservative			
Sample labels			
Marking pens			
Pens / pencils			
Sample Bags			
Weighted-bottle sampler			
Detergent, phosphate free			
Deionized water			
Squirt bottles			
Multi-parameter field meter:			
Thermistor, electronic thermometer			
Specific conductance			
pH			
Dissolved oxygen			

Appendix H – Field Supplies Checklist

Standards, specific conductance, 100 to 1,000 $\mu\text{S}/\text{cm}$			
Buffers, pH 4, 7, & 10			
Meter log book			
Tools			
First aid kit			
Roadway warning devices			

Appendix I

Standard Operating Procedures (SOPs) Used by the District

Watershed Monitoring
RICE CREEK WATERSHED DISTRICT
STANDARD OPERATING PROCEDURE (S.O.P.) No. 1

WATER GRAB SAMPLING

Watershed Monitoring
Standard Operating Procedure No. 1
WATER GRAB SAMPLING

Table of Contents

1.0	SCOPE AND APPLICABILITY	
1.1	Overview of Water Grab Sampling Required	3
1.2	Scope of the S.O.P.	3
2.0	DEFINITIONS	
2.1	Discrete Grab Sample.....	3
2.2	Duplicate Samples	3
3.0	EQUIPMENT AND MATERIALS	3
4.0	PROCEDURES	
4.1	General Procedural Requirements	4
4.2	Collecting Discrete Grab Samples	5
4.3	Field Documentation	5
4.4	Sample Labeling and Identification	6
4.5	Sample Handling.....	6
4.6	Sample Transport and Chain of Custody	7
4.7	Submission to the Laboratory	7
5.0	HEALTH AND SAFETY	8
6.0	PERSONNEL	
6.1	Field Sampling Personnel	8
6.2	Quality Assurance Personnel.....	8
7.0	QUALITY ASSURANCE AND CONTROL (QA/QC)	
7.1	Data Management and Records Management	8
7.2	Submission of Duplicate Samples.....	9
7.3	Quality Assurance Audits.....	9

1.0 SCOPE AND APPLICABILITY

.1 Overview of Water Grab Sampling Required

Water grab sampling refers to the collection of water samples from specific locations at specific times, without the use of automated sampling equipment. Grab sampling is done manually by a field crew. Samples are submitted to a laboratory for analysis for selected parameters.

For the Rice Creek Watershed District (RCWD), grab sampling is typically used for collecting lake water samplings and stream samples. Grab samplings for stream flows is only employed for base flow stream conditions and where flow or time weighted compositing is not desired.

.2 Scope of the S.O.P.

This SOP describes procedures and requirements for collecting water grab samples, recording the necessary field data, and transmitting the collected samples to laboratory facilities for analysis. This includes requirements regarding sample handling and chain-of-custody records, along with requirements for quality assurance and quality control (QA/QC).

2.0 DEFINITIONS

.1 Discrete Grab Sample

A "discrete" grab sample is one that is taken at a selected location, depth and time.

.2 Duplicate Samples

Duplicate samples are obtained by dividing one sample into two or more identical sub-samples. This should be done periodically to obtain information on the magnitude of errors owing to contamination, random and systematic errors, and any other variabilities that are introduced from the time of sampling until samples arrive at the lab. The typical objective for watershed sampling is to collect duplicate samples from 5% of all samples.

3.0 EQUIPMENT AND MATERIALS

Equipment and supplies that are needed for water grab sampling include:

- Field log book
- Hip waders to allow sampling personnel to wade into the stream if necessary
- First-aid kit
- Sample bottles or containers
- Blank sample bottle labels (as provided by the laboratory to which samples will be submitted)

- Chain-of-custody and laboratory sample submission forms
- Sampling pole or rod to which sample bottles can be easily and securely attached
- Intermediate sample container, if necessary
- Decontamination water (deionized or distilled water) for intermediate sampler rinsing

4.0 PROCEDURES

.1 General Procedural Requirements

Only the recommended type of sample bottle for each parameter should be used. The parameters analyzed for each watershed monitoring program vary. Refer to Table SOP1-1 for the general requirements for the parameters analyzed for typical RCWD programs.

**Table SOP1-1
 Recommended Sample Containers and Sample Preservation**

Parameter	Container	Preservation	Maximum Storage/ Holding Time
Total Suspended Solids	Polyethylene or glass	Refrigerate to 4°C	7 days
Carbonaceous Biochemical Oxygen Demand	Polyethylene or glass	Refrigerate to 4°C	48 hours
Fecal Coliform, <i>E. coli</i>	Sterilized polyethylene or glass	Refrigerate to 4°C; (add Na ₂ S ₂ O ₇)	6-8 hours
Ammonia	Polyethylene or glass	Add H ₂ SO ₄ until pH <2; refrigerate to 4°C	48 hours
Chloride	Polyethylene or glass	None	28 days
Nitrate + Nitrite	Polyethylene or glass	Refrigerate to 4°C	48 hours
Soluble Reactive Phosphorus	Polyethylene or glass	Filter upon arrival at laboratory using 0.45 µm membrane filter	48 hours
Chemical Oxygen Demand	Polyethylene or glass	Add H ₂ SO ₄ until pH <2; refrigerate to 4°C	28 days
Phosphorus	Polyethylene or glass	Add H ₂ SO ₄ until pH <2; refrigerate to 4°C	28 days
Chlorophyll-a	Polyethylene or glass	Keep in the dark	30 days
Total Kjeldahl Nitrogen	Polyethylene or glass	Add H ₂ SO ₄ until pH <2; refrigerate to 4°C	28 days
Total Dissolved Solids	Polyethylene or glass	Refrigerate to 4°C	7 days

The inner portion of sample bottles and caps should not be touched with bare or gloved hands.

Sample bottles for fecal coliform must be pre-sterilized and sealed. Sample bottles must be kept in a clean environment away from dust, dirt, fumes and grime. Vehicle cleanliness is important to eliminating contamination problems.

Samples must be delivered to the laboratory as soon as possible and within the holding times specified in Table SOP1-1. Fecal coliforms, with a maximum holding time of 6-8 hours, is the most time-sensitive parameter for delivery to the laboratory. Samples must never be allowed to stand in the sun. They should be stored in a cool place. Ice chests are required for this purpose.

.2 Collecting Discrete Grab Samples

When collecting discrete grab samples:

- Do not include large non-homogeneous particles or detritus in the sample.
- To collect the sample, clamp the bottle onto a properly designed sampling rod or pole. If samples can be gathered within arm's reach, a pole need not be used.
- To gather water samples from a creek or other watercourse, dip the sample bottle into the flow being careful not to draw in bottom sediments or detritus.
- Face the sampling bottle upstream to avoid contamination.
- If an intermediate sample container is used for sample collection, a dedicated intermediate container must be used for each sample site. The intermediate container must be rinsed before and after use with laboratory supplied distilled/deionized water. Also, the intermediate container must be rinsed at least three times with the stream, creek, or effluent water being sampled before collection of the sample for analysis.
- Be certain to completely fill bottles and leave as little headspace as possible
- Once the sample bottle has been filled, quickly cap it and place it in a suitable storage container (i.e., ice chest) for transportation to the laboratory facility.

.3 Field Documentation

During each sampling run, field notes will be taken using waterproof field notebooks and pens with waterproof ink (e.g., ballpoint pens). These notes will describe field conditions, weather, procedures followed, any problems encountered, and any modifications to standard procedures. The field notes will include:

- Date and time of sample collection at sample sites visited, and sample ID numbers
- Sampling team initials
- Sampling team assignments (e.g., sample collector, forms completion, field notes)
- Weather conditions (temperature, wind, cloud cover)
- General observations regarding flow, water clarity, odors at sampling sites
- Description of any problems that occur
- Modifications to established procedures

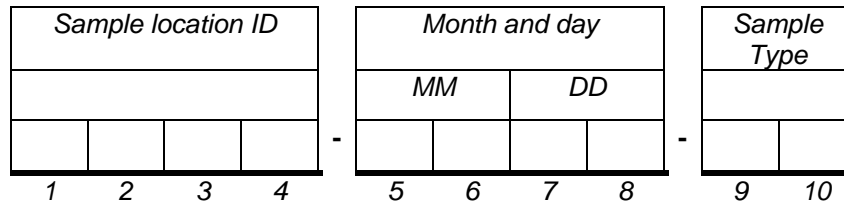
Complete and accurate field logbook notes are an essential part of the QA/QC process (see below). Proper attention must therefore be given to completing the field notes during the course of each sampling trip.

.4 Sample Labeling and Identification

The labels must be legibly and completely filled out and placed firmly on the bottle when samples are collected.

All samples will be assigned a unique 10-character sample ID number, as shown below. The sample number will be clearly written on the sample label. Information on parameters to be analyzed and preservatives added to the sample will also be clearly indicated on the sample label.

Sample ID coding:



Character(s)	Description
1 to 4	Sample site and location ID code (alphanumeric)
5 and 6	Month of the year (e.g., March = 03, Oct = 10)
7 and 8	Day (e.g., 1 st = 01, 10 th =10, 23 rd =23)
9 and 10	Sample type: FC – Flow Composite TC – Time Composite GG – Grab QC – Field Duplicate
11 (if needed)	Sample sequence number (used if time-sequenced grab samples are gathered at a sampling location)
Top right hand corner of label	Bottle analysis/preservative description (for bottle labels only) G - General N - Nutrient+Acid F - Fecal Coliforms

Example Bottle Label: 00S1-AP19-GG-B

Site S-1, sampled on April 19, a discrete grab sample, preserved for biological analysis (BOD, Chl-a)

.5 Sample Handling

When samples are collected, careful handling is required to minimize risk of contamination. Samples should be handled as little as possible and by as few people as possible.

- Sample containers should remain sealed/capped until used
- The inner portion of sample bottles and caps should not be touched with bare or gloved hands
- Sample bottles must be kept in a clean environment away from dust, dirt, fumes and grime. Vehicle cleanliness is important to eliminating contamination problems.
- Samples must never be allowed to stand in the sun. They should be stored in a cool place. Ice chests are recommended.

.6 Sample Transport and Chain of Custody

The field sampling crew will initiate a chain-of-custody form for all samples. An example of a chain-of-custody form is shown in Figure SOP1-1.

Chain-of-custody forms will include information on project name, date and time of sample collection, sample description, sample ID number, date and time of sample custody transfer, and the names of persons from and to whom custody was transferred.

The chain-of-custody form will be signed and dated each time custody is changed.

If commercial couriers are used to transport samples to the laboratory, copies of the custody form will be made by field sampling personnel before samples are shipped to the laboratory. (The commercial courier does not sign the custody form.) The original custody form will be sealed in a plastic bag and sealed in the shipping container. Once received by the laboratory, the sample custodian at the lab will inspect the samples for damage, sign the custody form, make a copy for the laboratory file, and then forward the original form to the project's field program manager for filing in the project files.

.7 Submission to the Laboratory

Blank copies of laboratory submission forms are to be provided by the laboratory to which samples will be submitted for analysis.

The laboratory submission forms will be completed by the field sampling crew and will accompany the chain-of-custody forms when the samples are delivered to the laboratory.

The laboratory sample submission forms must include information on the identification numbers for all samples submitted, which parameter analysis is required on each sample, and the method of sample preservation used at the time of sample collection.

5.0 HEALTH AND SAFETY

Gathering of water samples may result in exposure to sewage and bacteriologically contaminated water. All field sampling personnel must therefore be adequately protected against risk of exposure to such contaminants.

- Field personnel shall wear rubber gloves or suitable hand protection during the collection and handling of samples.
- Before embarking on any sample collection activities, field personnel shall acquire adequate medical protection against risk of infectious disease, including (as a minimum) protection against tetanus, polio, pertussis, diphtheria, and hepatitis A. Hepatitis B protection is also recommended.
- While working in the field, the field crew shall carry a complete first-aid kit that provides materials for disinfection and protection of any skin cuts or abrasions. Personnel will promptly attend to any such cuts or abrasions and seek medical attention if appropriate. Any need for first aid or medical attention shall be recorded in the field logbook, including information on time and location of any injury to personnel and description of first-aid treatment applied.

6.0 PERSONNEL

.1 Field Sampling Personnel

The field personnel responsible for sample collection should be technical personnel with experience in conducting this type of work.

All field personnel must have acquired recommended medical preventatives and inoculations to guard against risks associated with sampling of contaminated waters. The specific requirements are set out above, under "Health and Safety."

.2 Quality Assurance Personnel

Field quality assurance reviews and auditing requirements (described below) will be the responsibility of the sampling team leader. This person must have experience in water sampling and environmental monitoring programs, and be familiar with sample handling, preservation, chain of custody, and laboratory submission requirements.

7.0 QUALITY ASSURANCE AND CONTROL (QA/QC)

.3 Data Management and Records Management

Field sampling personnel will be responsible for maintaining copies of all chain-of-custody forms and laboratory sample submission forms.

Field sampling personnel will be responsible for maintaining the field logbook.

Field sampling personnel will be responsible for providing the sampling team leader with the above materials after each grab sampling run, to allow the QA personnel to carry out QA review and audit.

The QA personnel will also keep copies of all chain-of-custody and laboratory submission forms, and will be responsible for maintaining a record of the results of reviews and audits of the individual sampling runs (see below).

.4 Submission of Duplicate Samples

Duplicate samples are obtained by dividing one sample into two or more identical sub-samples. This should be done on 5% of samples and on each sampling run. The purpose is to obtain information on the magnitude of errors owing to contamination, random and systematic errors, and any other variabilities that are introduced from the time of sampling until samples arrive at the lab.

.5 Quality Assurance Audits

Immediately after completion of a sampling run, the sampling team leader will carry out a review and audit of the sampling run. This will include:

- Review of the field log book
- Review of copies of chain-of-custody forms and lab submission forms
- Interview with field sampling personnel

The purpose is to determine whether or not all grab sample collection, handling, transmission, and laboratory submission procedures were properly executed.

If this review determines that there were errors or deficiencies in the procedures used, then the quality assurance personnel will review the matter in detail with the field sampling crew to ensure that any necessary corrective action is taken to ensure that the problems do not recur. The QA personnel will make records of the errors or deficiencies and take any other corrective action that may be appropriate or necessary to avoid errors in data that may result from the sampling run.

Watershed Monitoring
RICE CREEK WATERSHED DISTRICT
STANDARD OPERATING PROCEDURE (S.O.P.) No. 2

AUTOMATED WATER SAMPLING

Watershed Monitoring
Standard Operating Procedure No. 2
AUTOMATED WATER SAMPLING

Table of Contents

1.0	SCOPE AND APPLICABILITY	
2.0	DEFINITIONS	
2.1	Stream Site	3
2.2	Composite Sample	3
2.3	Automated Sampler (or Auto-Sampler).....	3
3.0	EQUIPMENT AND MATERIALS	4
4.0	PROCEDURES	
4.1	Sampler Installation	4
4.1.1	General	4
4.1.2	Installing Suction Intake Tubing and Intake Strainer	4
4.1.3	Securing the Automated Sampler	5
4.2	Initiating Sampling	5
4.3	Sample Handling, Transportation and Chain of Custody	6
4.3.1	Sample Removal from the Automated Sampler	6
4.4	Sample Labeling and Identification	6
4.5	Sample Chain of Custody	7
4.6	Submission to the Laboratory	8
4.7	Maintenance of Automated Samplers	8
4.8	Field Documentation	8
5.0	HEALTH AND SAFETY	
5.1	Health of Personnel	9
5.2	Confined Space Operations.....	10
6.0	PERSONNEL	
6.1	Field Sampling Personnel	10
6.2	Quality Assurance Personnel.....	10
7.0	QUALITY ASSURANCE AND CONTROL (QA/QC)	
7.1	Data Management and Records Management	10
7.2	Quality Control	11
7.2.1	Submission of Duplicate Samples	11
7.3	Quality Assurance Audits.....	11

1.0 SCOPE AND APPLICABILITY

This S.O.P. describes the procedure to be followed in installing automated sampling equipment, and operating and maintaining the equipment. This S.O.P. also addresses handling of samples collected by the automated samplers, sample transportation and chain-of-custody tracking, and submission to the laboratory for analysis. QA/QC requirements are also described.

This S.O.P. does NOT provide detailed instructions on how to program, trigger and troubleshoot automated sampling equipment, since these aspects are unique to the specific make and model of automated sampler in use. Field personnel responsible for installing, operating and maintaining automated samplers must therefore make reference to the relevant equipment user manuals. Furthermore, this S.O.P. does NOT provide detailed instructions for confined space installations. Projects requiring confined space entry should follow confined space entry permitting procedures and personnel should have confined space entry training.

For Twin Cities watersheds automated sampling is typically used to gather wet weather water samples from streams and storm water collection systems.

2.0 DEFINITIONS

.1 Stream Site

A stream site is a location along an open watercourse at which automated sampling is required.

.2 Composite Sample

A composite sample is a single mixed sample that is collected over time by an automated sampler. It may be time-composite (where a specific volume of water is added to the composite sample at regular time intervals) or flow-composite (where the rate of sampling is proportional to the measured rate of flow at the sampling location).

.3 Automated Sampler (or Auto-Sampler)

A portable sampler unit that can be programmed to collect discrete sequential samples, time-composite samples or flow-composite samples. (See EQUIPMENT section below for further details).

3.0 EQUIPMENT AND MATERIALS

The following equipment and materials will be required.

- Field log book
- First-aid kit
- Automated samplers and associated materials such as batteries and sampling tubing. Samplers should include the following features:
 - Initiation (triggering) of sampling may be accomplished manually or via a control signal generated by an external device such as a flow meter or timer.
 - Samples are drawn into the sampler by peristaltic pump.
 - Sample delivery is through a suction line of vinyl tubing.
 - The suction line should be equipped with a stainless steel intake strainer.
- Sample bottles
- Sample bottle labels
- Chain-of-custody forms and laboratory submission forms
- Flashlights
- Tools, hardware, and other materials needed for securing sampling equipment at the installation site

4.0 PROCEDURES

.1 Sampler Installation

.1.1 General

The manufacturer's instructions and recommendations should be followed. Refer to equipment manuals provided with the automated samplers.

.1.2 Installing Suction Intake Tubing and Intake Strainer

At the designated sampling location, the intake strainer should be placed parallel to the flow, facing upstream. The strainer is to be secured to a length of PVC pipe of suitable diameter. The PVC pipe is mounted to the bottom or walls of the conduit using steel strapping or some other method that will secure the assembly in place. Alternatively, it may be necessary to secure the PVC pipe/strainer assembly to a heavy object (e.g., piece of steel plate) and place the entire assembly within the flow.

The minimum amount of tubing to reach the sampler should be used. Make sure to measure the entire length of the tubing since this information is needed when programming the automated sampler. Strapping or clips should be used to secure the tubing in place. There must be no kinks or dips in the tubing.

.1.3 Securing the Automated Sampler

Outfall Site Installations

Outfall site installations will typically be within open effluent or stormwater channels.

In these situations, the automated sampler can be secured to the wall of the channel at locations above the expected high water level.

Suitable strapping, chains, ropes or other methods may be used to secure the auto-sampler in place. The sampler should be situated to facilitate routine access to the operational switches and programming keypad. The sampler should also be situated and secured in a manner that does not impede the ability to access, remove, and replace sample bottles.

Stream Site Installations

At stream site installations, the same procedures and requirements apply. However, it will likely be necessary to provide secure housing for the sampler. This can be accomplished in a number of ways, depending on site conditions and site location.

In some situations, it may be possible to secure the sampler at or within a bridge or culvert crossing of the watercourse. In such cases, it may be necessary to construct a platform on which the sampler is mounted. In other cases, it may be necessary to construct a platform and housing for the sampler on the banks or shore of the watercourse.

In these cases, efforts must be made to minimize risk of equipment vandalism and theft by suitably locating and securing the equipment.

.2 Initiating Sampling

Following instructions provided in the equipment manuals, the sampler must be programmed to sample at regular time intervals, or according to a flow-proportional signal generated by a nearby flow meter. For the Twin Cities watersheds the first sample taken at a site is typically time composited. Once a good stage discharge curve is established subsequent samples should be collected by flow proportion.

Sampling can be initiated either by manually triggering the sampler, or by programming the sampler to respond to changes in flow or water level that are indicated by changes in control

signal generated by a nearby flow meter or water-level sensor. Again, the equipment manuals must be referred to for instructions on how these various types of operation are accomplished.

Automated samplers must be provided with fully charged batteries immediately prior to initiating sampling.

If samples are to be refrigerated between the time of sample collection and submission to the laboratory, then immediately prior to initiation of sampling, the sampler's bottle carousel should be iced.

.3 Sample Handling, Transportation and Chain of Custody

.3.1 Sample Removal from the Automated Sampler

At the end of the sampling period, the sample distributed to appropriate bottles for the required analyses, preserved, and delivered to the laboratory where they will be analyzed for the required parameters. If any of the bottles were not filled or if spillage occurred during sampling or during sample bottle removal, make appropriate notes in the field logbook.

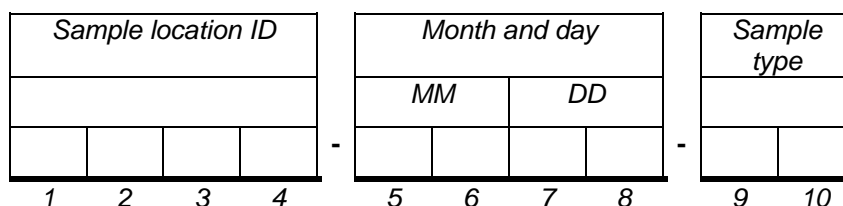
When samples are removed from the sampler, careful handling is required to minimize risk of contamination. Samples should be handled as little as possible and by as few people as possible.

- The inner portion of sample bottles and caps should not be touched with bare or gloved hands
- Sample bottles must be kept in a clean environment away from dust, dirt, fumes and grime. Vehicle cleanliness is important to eliminating contamination problems.
- Samples must never be allowed to stand in the sun. They should be stored in a cool place. Ice chests are recommended

.4 Sample Labeling and Identification

The labels must be legibly and completely filled out and placed firmly on the bottle when samples are collected.

All samples will be assigned a unique 12-character sample ID number, as shown below. The sample number will be clearly written on the sample label. Information on parameters to be analyzed and preservatives added to the sample will also be clearly indicated on the sample label.



Character(s)	Description
1 to 4	Sample site and location ID code (alphanumeric)
5 and 6	Month of the year (e.g., March = 03, Oct = 10)
7 and 8	Day (e.g., 1 st = 01, 10 th =10, 23 rd =23)
9 and 10	Sample type: FC – Flow Composite TC – Time Composite GG – Grab QC – Field Duplicate
11 (if needed)	Sample sequence number (used if time-sequenced grab samples are gathered at a sampling location)
Top right hand corner of label	Bottle analysis/preservative description (for bottle labels only) G - General N - Nutrient+Acid P - Soluble Reactive Phosphorous (SRP) B - BOD and Chlorophyll-a F - Fecal Coliforms

Example Bottle Label: OST1-API9-TC-B

Site ST-1, sampled on April 19, a time composited sample, taken during a wet weather event (single sample sequence), preserved for biological analysis (BOD, Chl-a)

Example Sample Label: ST1-API9-CT1

.5 Sample Chain of Custody

The field sampling crew will initiate a chain-of-custody form for all samples.

Chain-of-custody forms will include information on project name, date and time of sample collection, sample description, sample ID number, date and time of sample custody transfer, and the names of persons from and to whom custody was transferred.

The chain-of-custody form will be signed and dated each time custody is changed.

If commercial couriers are used to transport samples to the laboratory, copies of the custody form will be made by field sampling personnel before samples are shipped to the laboratory. (The commercial courier does not sign the custody form.) The original custody form will be sealed in

a plastic bag and sealed in the shipping container. Once received by the laboratory, the sample custodian at the lab will inspect the samples for damage, sign the custody form, make a copy for the laboratory file, and then forward the original form to the project's field program manager for filing in the project files.

.6 Submission to the Laboratory

Blank copies of laboratory submission forms are to be provided by the laboratory to which samples will be submitted for analysis.

The laboratory submission forms will be completed by the field sampling crew and will accompany the chain-of-custody forms when the samples are delivered to the laboratory.

The laboratory sample submission forms must include information on the identification numbers for all samples submitted, which parameter analysis is required on each sample, and the method of sample preservation used at the time of sample collection.

.7 Maintenance of Automated Samplers

In general, manufacturer's instructions and recommendations regarding routine maintenance are to be followed.

Sampler pump head and intake tubing will be inspected after each sampling period. Intake strainer will be cleaned or replaced as necessary. Tubing will be replaced if necessary. Cleaning and replacements must be noted in the field logbook.

.8 Field Documentation

During automated sampler installations, field notes will be made in the field log book including

- Time, date and specific location of installation
- Flow conditions during installation
- Weather conditions
- Any problems encountered
- Details of installation including length and diameter of sampler intake tubing, method used to secure intake strainer and tubing, method used to secure sampler, and results of checks on sampler operation and battery condition.

On each occasion that sampling is initiated, field notes will be made regarding the following:

- Date and time of sampling start-up
- Flow conditions at start-up

- Type and details of auto-sampler programming set-up, indicating if sampling is intended as discrete sequential, time-composite or flow-composite.
- Details on programmed sampling interval.
- If sampler operation is being controlled by signals from nearby flow meters or water-level sensors, include notes on how the sampler has been programmed to react to changing level or flow.
- Any problems encountered

When sampling is completed and samples are being removed from the samplers, make field log notes regarding:

- Condition of sampler including information on whether all bottles were filled or if any spillage appeared to have occurred.
- Condition of intake strainer and intake tubing, noting any cleaning or replacements undertaken.
- Weather conditions
- Date and time of sample removal from the sampler
- General observations regarding flow, water clarity, odors at sampling sites
- Description of any apparent problems with the sampler

Complete and accurate field logbook notes are an essential part of the QA/QC process (see below). Proper attention must therefore be given to completing the field notes during the course of fieldwork.

5.0 HEALTH AND SAFETY

.1 Health of Personnel

Gathering of water samples may result in exposure to sewage and bacteriologically contaminated water. All field-sampling personnel must therefore be adequately protected against risk of exposure to such contaminants.

- Field personnel shall wear rubber gloves or suitable hand protection during the collection and handling of samples.
- Before embarking on any sample collection activities, field personnel shall acquire adequate medical protection against risk of infectious disease, including (as a minimum) protection against tetanus, polio, pertussis, diphtheria and hepatitis A. Hepatitis B protection is also recommended.
- While working in the field, the field crew shall carry a complete first-aid kit that provides materials for disinfection and protection of any skin cuts or abrasions. Personnel will promptly attend to any such cuts or abrasions, and seek medical attention if appropriate. Any need for first aid or medical attention shall be recorded in the field logbook, including

information on time and location of any injury to personnel and description of first-aid treatment applied.

.2 Confined Space Operations

No confined space installations are to be attempted without proper on-site permits, safety equipment and applicable training.

6.0 PERSONNEL

.1 Field Sampling Personnel

The field personnel responsible for installing and operating automatic samplers should be technical personnel with experience in installing, operating and maintaining the specific equipment to be used.

All field personnel must have acquired recommended medical protections to guard against risks associated with sampling of contaminated waters. The specific requirements are set out above, under "Health and Safety:"

.2 Quality Assurance Personnel

Quality assurance reviews and auditing requirements (described below) will be the responsibility of the sampling team leader. This person must have experience in water sampling and environmental monitoring programs, and be familiar with sample collection, handling, preservation, chain of custody, and laboratory submission requirements.

7.0 QUALITY ASSURANCE AND CONTROL (QA/QC)

.1 Data Management and Records Management

Field sampling personnel will be responsible for maintain copies of all chain-of-custody forms and laboratory sample submission forms.

Field sampling personnel will be responsible for maintaining the field logbook.

Field sampling personnel will be responsible for providing the quality assurance personnel with the above materials after each sampling period, to allow the QA personnel to carry out QA review and audit.

The QA personnel will also keep copies of all chain-of-custody and laboratory submission forms, and will be responsible for maintaining a record of the results of reviews and audits of the individual sampling periods (see below).

.2 Quality Control

.2.1 Submission of Duplicate Samples

.3 Duplicate samples are obtained by dividing one sample into two or more identical sub-samples. This should be done on 5% of samples and each sampling run. The purpose is to obtain information on the magnitude of errors owing to contamination, random and systematic errors, and any other variabilities which are introduced from the time of sampling until samples arrive at the lab.

.4 Quality Assurance Audits

Immediately after completion of a sampling run, the designated quality-assurance personnel will carry out a review and audit of the sampling run. This will include

- Review of the field log book
- Review of copies of chain-of-custody forms and lab submission forms
- Interview with field sampling personnel

The purpose will be to determine whether or not automated sampling operations, sample handling, transportation, chain of custody and laboratory submission procedures were properly executed.

If this review determines that there were errors or deficiencies in the procedures used, then the quality-assurance personnel will review the matter in detail with the field sampling crew to ensure that any necessary corrective action is taken to ensure that the problems do not recur. The QA personnel will make records of the errors or deficiencies and take any other corrective action that may be appropriate or necessary to avoid errors in data that results from the sampling run.

Watershed Monitoring
RICE CREEK WATERSHED DISTRICT
STANDARD OPERATING PROCEDURE (S.O.P.) No. 3

FLOW MONITORING

Watershed Monitoring
Standard Operating Procedure No. 3
FLOW MONITORING

Table of Contents

1.0	SCOPE AND APPLICABILITY	
1.1	Overview of Streamflow Gauging Requirements	4
1.2	Summary of Procedure.....	4
1.3	Scope of the S.O.P.....	5
2.0	DEFINITIONS	5
3.0	EQUIPMENT AND MATERIALS	5
4.0	PROCEDURES	
4.1	Procedure for Selecting Gauging Locations	6
4.1.1	Reconnaissance Survey	6
4.1.2	Criteria for Gauging Site Selection.....	6
4.2	Procedure for Stage-Discharge Measurements	7
4.2.1	Required Number of Measurements at Each Gauging Station	7
4.2.2	Discharge Measurement Procedure	8
4.2.3	Procedure for Computing Discharge from Depth-Velocity Data	9
4.3	Methods and Procedures for Continuous Water Level Monitoring.....	10
4.3.1	Continuous Water-level Sensor and Data Recorder	10
4.3.2	Staff Gauge and Vertical Reference Benchmark.....	11
4.4	Data Acquisition, Calculations and Data Reduction.....	11
4.4.1	Field Log Book.....	11
4.4.2	Water Depth and Velocity Data for Rating Curve Development	11
4.4.3	Rating Curve Development.....	12
4.4.4	Continuous Water Level Data.....	12
5.0	HEALTH AND SAFETY	12
6.0	PERSONNEL	
6.1	Field Personnel for Stream Gauging	13
6.2	Quality Assurance and Approval	13

7.0	QUALITY ASSURANCE AND CONTROL (QA/QC)	
7.1	Data Management and Records Management.....	14
7.2	Quality Control for Continuous Water-level Recorder.....	14
7.3	Calibration of Current Meter (Water Velocity Meter).....	14
7.4	Validation of Rating Curve Data	15
7.4.1	Data Review, Audit and Approval.....	15
7.4.2	Maintaining Approved Rating Curve Data	15
8.0	REFERENCES	15
9.0	FORMS AND FIGURES	16

1.0 SCOPE AND APPLICABILITY

.1 Overview of Streamflow Gauging Requirements

An open-channel streamflow gauging station is established by developing a relationship between stage (water level) and discharge at a selected watercourse cross section. The relationship is developed by taking discharge measurements over the expected range of discharge and stage. Each discharge measurement and corresponding water level is plotted and a smooth curve is drawn. The stage-discharge curve is used with a continuous water level record to produce a time series of discharge for the period during which water level has been recorded.

.2 Summary of Procedure

The streamflow gauging procedure can be summarized as follows:

1. Reconnaissance survey is conducted to gather information on the physical characteristics of the locations where streamflow-gauging sections are to be established.
2. Hydrologic and hydraulic calculations are carried out to estimate the expected range of flowrates and flow depth variations at each gauging site.
3. Continuous water level recorder, staff gauge, and if necessary, a velocity meter is installed at each gauging site.
4. During the course of the monitoring program, a series of stage-discharge measurements are made at each gauging section. Discharge is measured by measuring flow depth and flow velocity at selected points across the gauging cross section. This is done on a number of occasions in order to obtain stage-discharge measurements over the range of flows of interest.
5. For each section a "rating curve" is then developed from the stage-discharge measurements. The rating curve represents the relationship between water level (i.e., stage) at the gauging section and discharge at the section. The rating curve allows a time series of discharge rates to be computed using the data acquired from the station's continuous water-level recorder.

.3 Scope of the S.O.P.

This SOP describes required procedures for establishing streamflow-gauging stations in Twin Cities watersheds. This SOP describes:

- Selection of gauging station location and cross sections for discharge measurement.
- Methods and procedures for discharge measurement using velocity and depth measurements.
- Computation of discharge from velocity/depth data.
- Installation and maintenance of continuous water level recorder.
- Installation of staff gauge for on-going verification of water-level recorder operation and accuracy.

2.0 DEFINITIONS

Streamflow, discharge or flowrate is the volume of water passing through a given cross section of the watercourse during a specific period of time. Typical units are cubic feet per second (cfs).

A **current meter** is an instrument used to measure water velocity at a point. This procedure recommends that vertical-axis bucket-wheel current meters be used; for example, the Price Type AA current meter and the Pygmy type current meter.

3.0 EQUIPMENT AND MATERIALS

The following equipment and materials will be required:

- Field log book
- First-aid kit
- Survey tape measure, survey level and survey rod
- Current meter (Price Type AA and/or Pygmy vertical-axis meters) and associated instrument rod
- Hip waders for personnel wading into the watercourse
- Staff gauge for installation at each gauging site (for visual monitoring of water level)
- Water-level sensor (e.g., pressure-transducer sensor) for providing continuous measurement of water level at each gauging site
- Data logger compatible with velocity sensor
- Data logger compatible with water-level sensor
- Laptop computer to allow for setup of and real-time interrogation of data logger and water level sensor, and data retrieval from the data logger
- Hardware, tools, and miscellaneous materials needed for installation of staff gauge and water level sensor

Specific requirements for hardware and materials needed for staff gauge, water level and velocity sensor/data logger installations will be determined during site reconnaissance survey.

4.0 PROCEDURES

.1 Procedure for Selecting Gauging Locations

The following procedures are to be applied to the process of selecting the specific locations (i.e., stream cross sections) where gauging will be carried out.

.1.1 Reconnaissance Survey

An initial reconnaissance survey will be carried out to establish suitable monitoring locations. This will also provide information on local turbulence and other factors that may affect the flow-gauging program and gauging site selection.

During the reconnaissance survey, proposed gauging site locations will be examined in detail to select specific locations for cross sections at which stage-discharge measurements will be taken and water level recorders and staff gauges installed.

.1.2 Criteria for Gauging Site Selection

The following criteria will be used to select gauging cross sections:

1. The cross section is to be located where stream bed and banks are reasonably straight and uniform for a distance of approximately five times the section's width upstream, and two times the section's width downstream
2. The streambed and banks appear to be stable and not subject to scour (e.g., bank erosion), deposition (e.g., sand bar formation), or debris accumulation.
3. The stream bed cross section is as uniform as possible and free from vegetal growth or any large rocks or protruding obstructions
4. The cross section should be perpendicular to the general direction of flow and should not be subject to highly turbulent conditions that would make point velocity measurements difficult or inaccurate.
5. The cross section should be located such that there is a "control" situated downstream of the cross section that ensures a stable stage-discharge relationship at the cross section. The control is a physical condition in the stream that controls or determines the discharge that passes the cross section for a given upstream water level. It may be a natural phenomenon

such as a stretch of rapids, a weir or other artificial structure. In the absence of a prominent feature, it may be a less obvious condition such as convergence of the channel or the resistance to flow through a downstream reach. Care must be taken during selection of properly controlled cross sections for stream gauging. In particular, consideration must be given to the possibility of backwater effects during high-flow conditions that could result from downstream flow restrictions (e.g., culverts or bridges) or incoming tributary flows.

6. The gauging location should be situated where there is a suitable and convenient location for secure installation of a continuous water-level recorder and electronic data logger. As well, there should be a suitable location for installation of a staff gauge that will allow for routine visual checks on water level.
7. The gauging cross section should be located where there are suitable on-shore reference points to assist with repeated measurement of flow velocities at locations across the cross section. As well, on-shore reference points are needed to serve as elevation benchmarks. These horizontal/vertical reference points should be well-defined immovable objects.

.2 Procedure for Stage-Discharge Measurements

Once gauging sites have been selected, discharge measurements will be carried out during the course of the monitoring program, to establish the relationship between water level and discharge at each of the gauging sites. The measurements must be done over a range of flows, so that the rating curve will be valid over the full range of flows encountered during the monitoring period.

.2.1 Required Number of Measurements at Each Gauging Station

The accuracy of the rating curve developed for each flow gauging station will depend in part on the number of stage-discharge measurements made at each location, and the range of those measurements. The minimum requirement is that ten stage-discharge measurements be made at each location, consisting of:

- 3 measurements under relatively low flow conditions (e.g., dry weather)
- 4 measurements under moderate flow conditions (e.g., shortly after a runoff peak, during hydrograph recession)
- 3 measurements under high flow conditions (e.g., during the peak of a significant runoff episode)

The rating curve for each station is developed by plotting the stage-discharge pairs on graph paper, and then fitting a smooth curve over the range of the data. Visual or mathematical curve fitting techniques can be used.

Once a good rating curve has been established for sites where monitoring is continued over multiple years, gauging during subsequent years can be completed on an as needed basis. This should include at least three new points per year distributed between low, medium and high

flows; and additional measurements targeting areas on the rating curve where the uncertainty and variability are highest. However, whenever there is a change in channel cross section occurs near the monitoring site (i.e., from construction, new bridge crossings, erosion, etc.) a completely new rating curve needs to be developed.

.2.2 Discharge Measurement Procedure

The general approach will be to take point velocity readings at evenly spaced stations across the cross section, and at the same time record the water depth at each station. Flowrate can then be computed using the method described below. Paired water level/discharge values can then be used to develop the station's rating curve.

The following procedures will be used to carry out stage-discharge measurements at selected cross sections:

1. The cross section is first divided into a number of vertical subsections or "panels" of equal width. As a general rule, there should be at least 10 panels to properly account for velocity variations across the cross section. See Figure SOP3-1.
2. Using an on-shore reference object, the distance to the mid-point of each panel should be measured using a surveyor's tape or other suitably accurate method. Distances should be expressed as distance from the on-shore reference point.
3. A tag line should then be strung across the cross section. The tag line will have markers indicating the locations where depth and flow velocity are to be measured (i.e., the midpoints of each of the panels).
4. The tag line is used to determine where velocity and depth measurements are taken.
5. On each occasion when stage-discharge measurement is made, first make notes on conditions at the gauging site, including information on any scour, deposition, and aquatic vegetation growth or debris accumulation. Make particular note of any apparent changes since the previous measurement visit. Take photos of the site and stream conditions.
6. Record the start time and current water level and begin the panel-by-panel depth and velocity measurements.
7. Flow depth at the midpoint of each panel is measured using a suitable rod or weighted cable. The rod or weighted cable is lowered vertically into the water until it reaches the bed or bottom of the creek. Take care that the rod is not pushed into the bed of the creek.

8. Flow velocity is also measured at the midpoint of each panel. Velocity measurements will be taken with a reliable and calibrated velocity probe, such as a Price 622 Type AA vertical-axis bucket wheel meter.
 - If water depth is greater than 30 inches, measure velocity at 20% and 80% of water depth. These measurements are to be made along a vertical line at the mid-point of the panel.
 - If water depth is less than 30 inches, measure velocity at 60% of water depth.
 - When measuring velocity, hold the probe steady for at least 30 seconds to allow a stable reading.
 - Ensure that all velocity readings are within the measurement range of the probe. If low velocities (e.g., less than 0.1 fps) are being encountered, it may be necessary to use a different probe (e.g., a Pygmy meter) to provide accurate velocity measurements.
1. If wading across the section, use a suitable pole or rod to check streambed conditions. Check for any scour holes, boulders, cobbles, or other conditions that could make for unsafe footing.
2. When taking velocity measurements, place the current meter in a position that least affects the flow passing the current meter.
3. Record water depth and velocity readings as they are taken. These can be relayed to on-shore personnel for recording. Use Form SOP3-1 or equivalent.
4. Once all readings have been taken, record the stop time and the water level. Then compute the discharge using the method described below. If any of the individual depth or velocity measurements or the computed discharge appear questionable, take additional readings to confirm the results.

.2.3 Procedure for Computing Discharge from Depth-Velocity Data

The method used to compute discharge makes the following assumptions:

- The measured depth at the mid-point of each panel is considered to be the mean depth for the panel
- The mean velocity at an observation vertical is assumed to be the mean velocity for the respective panel

For each panel, the discharge is the mean depth multiplied by the mean velocity. The panel discharges are then summed to obtain the total discharge through the gauging cross section.

For panels where velocity was measured at 20% and 80% of depth, the mean velocity is computed as the arithmetic average of the two readings: $V_{\text{mean}} = (V_{0.2} + V_{0.8}) / 2$. Where velocity was measured at only 60% of depth, that velocity will be considered the mean velocity.

.3 Methods and Procedures for Continuous Water Level Monitoring

.3.1 Continuous Water-level Sensor and Data Recorder

At each gauging station, a water level sensor and data logger will be installed to provide continuous electronic logging of water levels during the monitoring period.

1. The water level probe will be an ultrasonic, pressure-transducer sensor or bubbler system, capable of measuring water depth to within 2.0% precision. It will be capable of measuring depth over the full range of expected depths. Hydraulic calculations should be made to estimate the range of depths that might be encountered at the gauging site.
2. The water level measurements will be recorded on an electronic data-logger. The data-logger will be of a type and design that allows real-time data access and graphical review of stored data using a laptop computer.
3. The water level sensor must be installed in a secure location that ensures that the sensor will not be moved by the flow or any debris carried by the flow. Sensor and data logger must be installed in a location that minimizes risk of vandalism and minimizes the possibility of damage by debris carried by the flow.
4. The water level sensor and data-logger system will be set up to provide water level readings every 5 minutes. This setting can be adjusted if watershed response times and hydrograph recession times prove to be shorter or longer than expected.
5. Water level sensor operation and accuracy shall be verified at least once every five to ten calendar days. At each check, the water level sensor accuracy will be verified by comparing the sensor reading with a water level measurement taken from the gauging site's staff gauge (see below). The time and results of each of these checks shall be recorded in the field logbook.
6. During each check, data-logger operation will also be verified. The stored data will be accessed and reviewed to determine if there has been any drift or unexplained variation in recorded water levels.
7. If the check reveals that the water-level sensor is in error by more than 5% of water depth at the sensor, then the sensor is to be removed and inspected. Time of sensor removal must be recorded in the field logbook. If no reason for the error can be found, the sensor should

be immediately replaced by a calibrated sensor. Time of any such replacement must be recorded in the log book.

.3.2 Staff Gauge and Vertical Reference Benchmark

To assist with routine checks on the accuracy and operation of the water level sensor and datalogger, a staff gauge or reference point will be installed at each gauging site. The staff gauge will consist of a vertical weather-resistant staff marked at even depth increments that allow visual measurement of water level within 0.25 inches. The staff gauge will be installed in a secure location and in a manner that ensures that it will not be moved by the flow, debris carried by the flow, wind or other forces that might be expected to act on the staff gauge.

At each gauging station, an on-shore vertical reference benchmark shall be established, and all water levels shall be measured relative to this vertical benchmark. The on-shore benchmark must be an immovable object that is expected to remain above the water level at all times. The staff gauge should be designed and installed such that water levels read from the staff gauge can be readily expressed as distance below the on-shore benchmark. The staff gauge must therefore be installed using proper level surveying techniques.

.4 Data Acquisition, Calculations, and Data Reduction

.4.1 Field Log Book

A field logbook will be maintained during the course of the streamflow gauging program. It will contain notes and observations on each visit to each gauging station site. On each visit during which depth-discharge measurements are made, notes will be made regarding

- Flow conditions
- Extent of floating debris carried by the flow
- Streambank and streambed erosion, deposition or debris accumulation
- Weather conditions
- Upstream and downstream conditions
- Condition of staff gauge and water level sensor and datalogger
- Any other pertinent information

Water levels (from staff gauge readings and the water level recorder) and clock times at the start and end of the depth-velocity measurement period should be recorded in the field log book.

.4.2 Water Depth and Velocity Data for Rating Curve Development

As noted above, water depth and velocity data are to be recorded as they are gathered at individual gauging stations. Form SOP3-1 should be used to record the data by on-shore personnel as values are measured by personnel wading across the gauging section.

Form SOP3-1 includes columns for computation of discharge for each vertical sub-section or panel of the gauging section, and for then computing total discharge at the section. These computations and tabulations shall be made in the field immediately after completing the depth and velocity measurements, to allow for immediate assessment of the reasonableness of the results.

.4.3 Rating Curve Development

A rating curve is developed for each gauging station by plotting the stage-discharge measurements on graph paper, and then fitting a smooth curve to the data.

A variety of techniques can be used to fit a rating curve to observed stage-discharge data, or alternatively, to develop a rating table (i.e., a table that describes the relationship between water level and total discharge at the gauging station). Mathematical techniques or visual curve fitting can be applied.

The methods and techniques presented the U.S. Geological Survey manual entitled, "Discharge Ratings at Gauging Stations" (E.J. Kennedy, 1984), should be applied to this task with the assistance of computer-based computations for curve fitting.

.4.4 Continuous Water Level Data

Continuous water level data will be retrieved from the datalogger once every seven to fifteen calendar days, and in no case shall the interval between site visits exceed three weeks. The data will be reviewed by field personnel for any apparent anomalies or water-level sensor malfunctions. If problems are suspected, then the data will be immediately reviewed with the QA personnel. Refer to QA/QC requirements below for more information on data review requirements.

5.0 HEALTH AND SAFETY

If flow velocity and depth measurements are taken by wading across the gauging section, the following safety practices must be followed:

- Stage-discharge measurements must be made by a team of at least two personnel except during low flows when velocities are less than 2 fps and water depth is 1.5 feet or less. During the measurement procedure, only one team member is in the water at any time, with the other assisting by recording data and otherwise assisting and ensuring the safety of the person wading in the stream.

- If flow is high, make an estimate of maximum flow depth and flow velocity before wading into the water. Floating debris can be used to estimate velocity. The staff gauge reading can be used to determine depth. As a general rule, if the product of velocity (in feet per second) and depth in feet is 7 or greater (for example, velocity of 3 fps and depth of 2.5 feet gives a product of 7.5), then wading into the flow is not likely to be safe and should not be attempted.
- When wading across the section, use a rod to check the stream bed conditions when advancing across the section. Check for scour holes, obstructions, or any other conditions that could make for unsafe footing.
- While personnel are wading in the watercourse, all team members should be attentive to flow conditions. In particular, watch for floating debris or other hazards that could damage equipment or cause problems for the in-water personnel.

If flow velocity and depth measurements are taken from a bridge crossing, the following safety practices must be followed:

- Stage-discharge measurements must be made by at least two personnel except where vehicle traffic is low and there is a sidewalk or shoulder area providing a separation distance from traffic.
- Field personnel should use appropriate clothing, including orange reflective vests, while engaged in velocity measurements from a bridge crossing.
- If necessary, traffic cones should be placed curb-side to warn approaching traffic.

6.0 PERSONNEL

.1 Field Personnel for Stream Gauging

The team responsible for field activities related to stream gauging will consist of at least two personnel, except during low flows when velocities are less than 2 fps and water depth is 1.5 feet or less.

At least one member of the stream gauging team should be familiar with theory of open-channel hydraulics and should have experience with open-channel flow measurement.

All team members should be physically fit and healthy at the time of stream flow measurement and equipment installation.

.2 Quality Assurance and Approval

Quality assurance requirements (see below), including in-progress review of the stream gauging activity, will be the responsibility of a qualified professional. The professional must have expertise in hydrology, open-channel hydraulics, flow measurement techniques and procedures, and data reduction techniques.

7.0 QUALITY ASSURANCE AND CONTROL (QA/QC)

.1 Data Management and Records Management

Maintenance of the field logbook will be the responsibility of the stream gauging field team. The field logbook will be routinely reviewed and audited as part of the QA/QC procedures (see below).

Continuous water-level data will be stored in computer data files. All raw data files extracted from the field data logger will be stored in a central office location.

.2 Quality Control for Continuous Water-level Recorder

- Water level sensor operation and accuracy shall be verified at least once every 7 to 14 calendar days. At each check, the water level sensor accuracy will be verified by comparing the sensor reading with a water level measurement taken from the gauging site's staff gauge. The time and results of each of these checks shall be recorded in the field log book.
- During each check, data-logger operation will also be verified. The stored data will be accessed and reviewed to determine if there has been any drift or unexplained variation in recorded water levels.
- If the check reveals that the water-level sensor is in error by more than 5% of water depth at the sensor, then the sensor is to be removed and inspected. Time of sensor removal must be recorded in the field log book. If no reason for the error can be found, the sensor should be immediately replaced by a calibrated sensor. Time of any such replacement must be recorded in the log book.

.3 Calibration of Current Meter (Water Velocity Meter)

Maintenance and calibration of vertical-axis type current meters shall be carried out in accordance with the U.S. Geological Survey manual entitled, "Calibration and Maintenance of Vertical-Axis Type Current Meters" (Smoot and Novak, 1968).

.4 Validation of Rating Curve Data

.4.1 Data Review, Audit and Approval

Immediately after completion of a stage-discharge measurement at a gauging station, results of that measurement will be reviewed to determine the adequacy of each measurement for use in developing the station's rating curve. This will consist of review and audit of the field log book, data records and data reduction tabulations (i.e., tabulations on Form SOP3-1), along with interview with the personnel that undertook the measurement.

If results are judged acceptable, then the data acquisition/reduction form (Form SOP3-1) will be approved.

If any deficiencies are found, then they will be reviewed in detail with the personnel that carried out the measurements so that appropriate corrective action is taken to ensure that adequacy of future measurements.

.4.2 Maintaining Approved Rating Curve Data

The project engineer will maintain a copy of all approved stage-discharge measurements for all stations, and will be responsible for developing each station's rating curve according to the requirements of this S.O.P.

8.0 REFERENCES

Smoot, G.F., and C.E. Novak, 1968. "Calibration and maintenance of Vertical-axis Type Current Meters," published by US Geological Service (Department of the Interior) as part of series entitled, "Techniques of Water Resources Investigations of the United States Geological Survey," Book 8, Chapter B2. First printing 1968. Second printing 1977.

Kennedy, E.J., 1984. "Discharge Ratings at Gauging Stations," published by US Geological Service (Department of the Interior) as part of series entitled "Techniques of Water Resources Investigations of the United States Geological Survey," Book 3, Chapter A10.

10.0 FORMS AND FIGURES

FIGURE SOP3-1:

