Metropolitan Council Environmental Services

Quality Assurance Program Plan: Stream Monitoring

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1 INTRODUCTION

1.1 *MCES STREAM MONITORING PROGRAM BACKGROUND AND PURPOSE*

Stormwater runoff in both urban and rural areas carries nonpoint source pollutants from diverse and widely scattered sources to Metropolitan Area streams and rivers. Stream monitoring is conducted to: 1) determine the extent of nonpoint source pollutant loading from tributaries to the Mississippi, Minnesota, and St. Croix Rivers, 2) provide the information necessary for development of target pollutant loads and/or total maximum daily load (TMDL) plans for these tributary watersheds, and 3) evaluate the effectiveness of watershed best management practices for reducing nonpoint source pollution and improving water quality in streams and rivers. Automated measurements of water stage, in conjunction with site-specific rating curves, are used to estimate flow rates in all streams. During runoff events, automated water samples and occasional grab samples are obtained for laboratory analysis of a variety of nonpoint source pollutants. During baseflow conditions, grab samples are obtained for laboratory analysis of water quality variables. The stream monitoring program is comprised of two sub-programs as described below.

1.1.1 Streams – Nonpoint Source Pollution Monitoring Program

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

1.1.2 Streams – Watershed Outlet Monitoring Program

The watershed outlet monitoring program (WOMP) has been in place in the Metropolitan Area since 1995. The purpose of the program is to collect data to assess nonpoint source pollution impacts on Metropolitan Area watersheds. The data are used to evaluate current watershed conditions, to develop target pollution loads and/or TMDL plans for Metropolitan Area watersheds, and to measure progress toward achieving pollutant reductions and improving water quality. Since 1997, this program has been supported in part with funding provided by the Minnesota Pollution Control Agency (MPCA). WOMP monitoring is conducted by watershed management organizations, watershed districts, soil and water conservation districts, and other government agencies, through a cooperative cost-share arrangement with the Metropolitan Council. The sampling program includes baseflow and storm (runoff) event sampling at 15 Metropolitan Area stream sites. Event-based monitoring is conducted during the March – November period and baseflow sampling is conducted year round. Water samples are analyzed for conventional and toxic pollutants. Streamflow information is continuously collected year-round at all 15 monitoring sites.

Precipitation, temperature, and conductivity information are continuously collected year-round at most of the monitoring sites, while continuous turbidity information is obtained seasonally (March-November) at one of the monitoring sites.

1.2 RELATIONSHIP OF QAPP TO OTHER GUIDANCE DOCUMENTS

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

2 PROGRAM ORGANIZATION AND RESPONSIBILITY

2.1 OVERVIEW

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

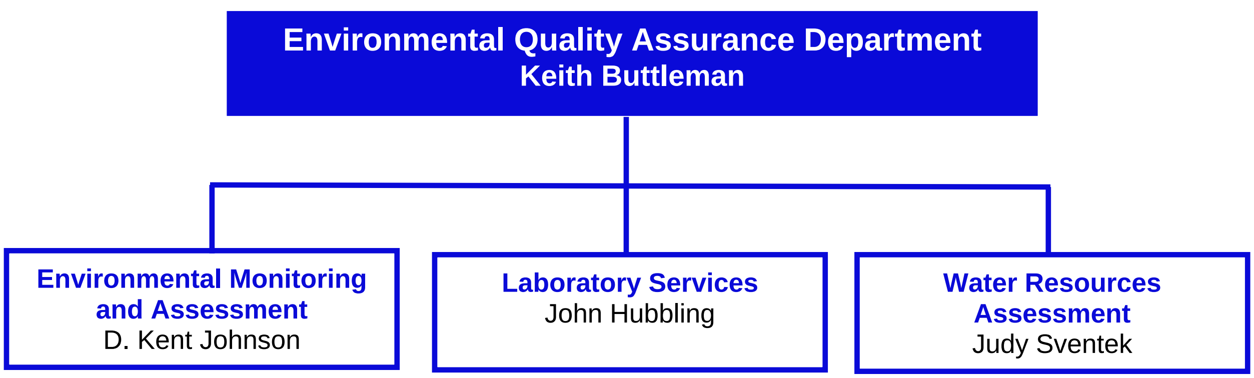


Figure 2.1. MCES Business Units Involved with the Stream Monitoring Program

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

Member	Business Unit	Responsibility
Kent Johnson	Environmental Monitoring and Assessment	Business Unit Manager
Tim Pattock	Environmental Monitoring and Assessment	NPS Monitoring
Mike Ahlf	Environmental Monitoring and Assessment	NPS Monitoring
Cassie Champion	Environmental Monitoring and Assessment	WOMP1 Coordinator
Leigh Harrod	Environmental Monitoring and Assessment	WOMP2 Coordinator
John Hubbling	Laboratory Services	Business Unit Manager
Lam Sanouvong	Laboratory Services	Laboratory QA Officer
Judy Sventek	Water Resources Assessment	Business Unit Manager
Terrie O'Dea	Water Resources Assessment	Water Quality DB Administrator
Terrie O'Dea	Water Resources Assessment	EIMS Administrator

2.2 *ENVIRONMENTAL MONITORING AND ASSESSMENT*

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

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

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

2.3 *LOCAL COOPERATORS*

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

2.4 LABORATORY SERVICES

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

2.5 WATER RESOURCES ASSESSMENT

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

3 MONITORING PROGRAM DESCRIPTION

3.1 STUDY AREA

This program monitors the water quality and quantity of streams tributary to three large Minnesota rivers: 1) the Mississippi River, 2) the Minnesota River, and 3) the St. Croix River. Monitoring of these large rivers is conducted under a different EMA program and is covered by a separate QAPP. The extent of the study area covered by the stream monitoring program includes much of central Minnesota, with most sites located in the seven-county Metropolitan Area. This area straddles two ecoregions: the North Central Hardwood Forest and the Western Cornbelt Plains. About half the land within the Metropolitan Area is agricultural or undeveloped, while the remaining half is predominantly urban.

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

3.2 *SITE SELECTION / PROGRAM DESIGN*

The number of sites in the MCES stream monitoring program has varied over the years, as dictated by management objectives and the availability of funding. As of 2011, the stream monitoring program includes 22 active sites, eight historical sites that are no longer in the program, and four sites that were transferred to the Water Resource Center at Minnesota State University, Mankato in 2005 (Figure 3.1). Monitoring sites have been selected based upon a number of criteria that have varied slightly over the years.

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

Figure 3.1. Location of MCES Stream Monitoring Sites

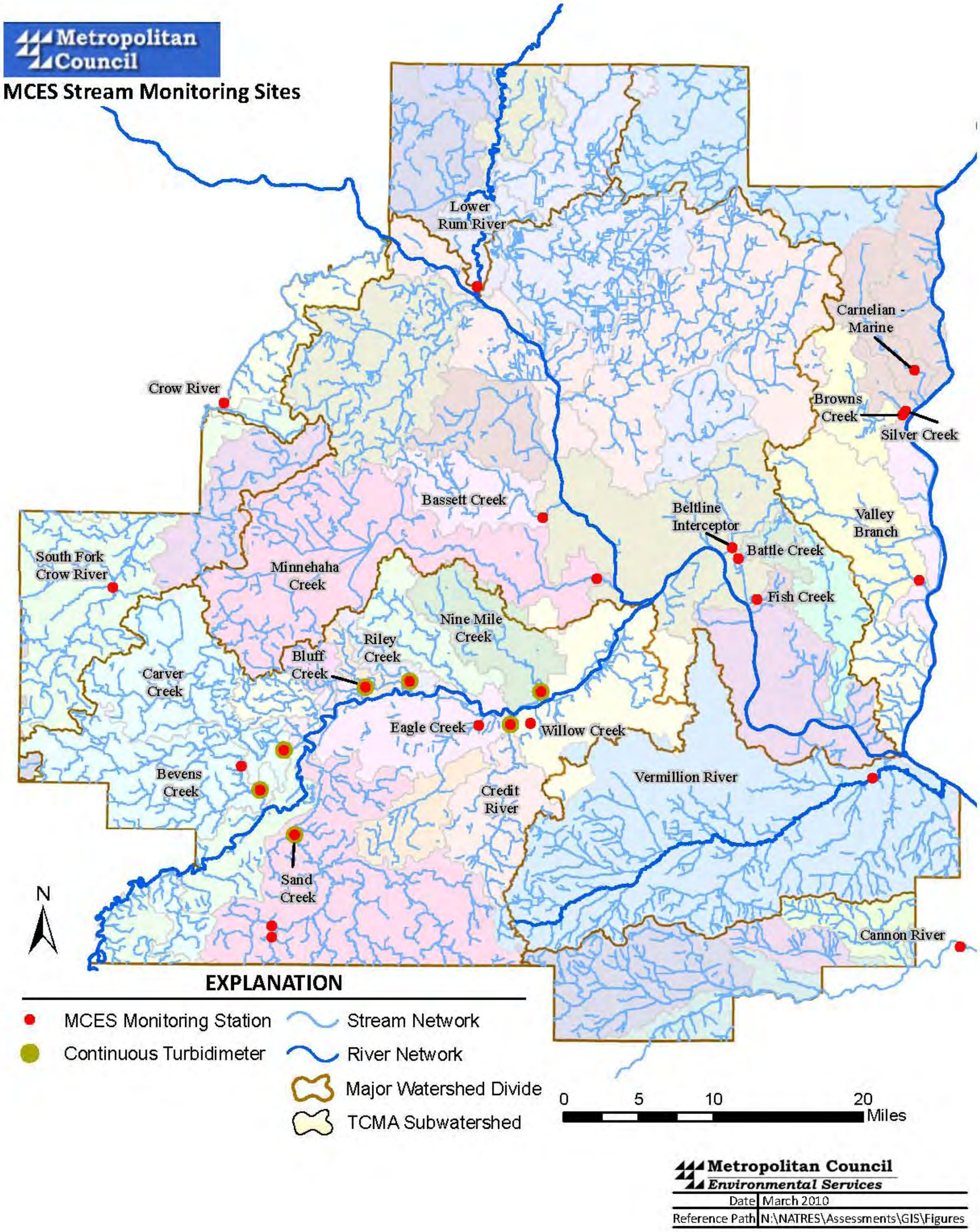


Table 3.1 MCES Stream Monitoring Sites

Monitoring Site	Major Basin	Dominant Land Use	Year Initiated	Watershed Size (miles^2)
Beauford Ditch	Minnesota - Middle	Agricultural	Transferred	7.0
Blue Earth River	Minnesota - Middle	Agricultural	Transferred	1550
LeSueur River	Minnesota - Middle	Agricultural	Transferred	1100
Little Cobb River	Minnesota - Middle	Agricultural	Transferred	130
Bevens Creek - Lower	Minnesota - Lower	Agricultural	1989	131
Bevens Creek - Upper	Minnesota - Lower	Agricultural	1992	90.2
Bluff Creek	Minnesota - Lower	Rural/Transitional	1990	8.9
Carver Creek	Minnesota - Lower	Agricultural	1989	83.5
Credit River	Minnesota - Lower	Rural/Transitional	1989	51.4
Eagle Creek	Minnesota - Lower	Urban/Transitional	1999	3.4
Nine Mile Creek	Minnesota - Lower	Urban	1989	38.3
Riley Creek	Minnesota - Lower	Rural/Transitional	1999	13.1
Sand Creek	Minnesota - Lower	Agricultural	1989	255
Scott County Ditch 10	Minnesota - Lower	Agricultural	Discontinued	16.5
West Raven Creek	Minnesota - Lower	Agricultural	Discontinued	14.9
Willow Creek	Minnesota - Lower	Urban	Discontinued	10.2
Battle Creek	Mississippi - Lower	Urban	1996	11.4
Beltline Interceptor	Mississippi - Lower	Urban	1995	28.0
Cannon River	Mississippi - Lower	Agricultural	1999	1340
Fish Creek	Mississippi - Lower	Urban/Transitional	1995	5.1
Vermillion River	Mississippi - Lower	Agricultural	1995	327
Bassett Creek	Mississippi - Upper	Urban	2000	42.8
Coon Creek	Mississippi - Upper	Rural/Transitional	Discontinued	91.1
Crow River	Mississippi - Upper	Agricultural	1999	2620
Crow River - South Fork	Mississippi - Upper	Agricultural	2001	1137
Elm Creek	Mississippi - Upper	Urban/Transitional	Discontinued	106
Minnehaha Creek	Mississippi - Upper	Urban/Transitional	1999	181
Rice Creek	Mississippi - Upper	Urban/Transitional	Discontinued	180
Rum River	Mississippi - Upper	Rural	1996	1552
Shingle Creek	Mississippi - Upper	Urban	Discontinued	41.6
Browns Creek	St. Croix	Rural/Transitional	1998	34.1
Carnelian-Marine Outlet	St. Croix	Rural/Transitional	Discontinued	30.0
Silver Creek	St. Croix	Mixed/Transitional	1998	7.6
Valley Creek	St. Croix	Mixed/Transitional	1999	62.1

3.3 *MONITORING VARIABLES AND FREQUENCY*

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

Table 3.2 MCES Stream Monitoring Variables

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

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

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

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

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

Table 3.3 MCES Stream Monitoring Frequency

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

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

4 QUALITY ASSURANCE OBJECTIVES

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

4.1 Precision and Variability

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

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

4.2 Accuracy and Bias

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

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

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

4.3 REPRESENTATIVENESS

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

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

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

4.4 COMPLETENESS

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

4.5 COMPARABILITY

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

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

4.6 ANALYTICAL SENSITIVITY

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

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

Laboratory Variable	LRL	Units	Laboratory Variable	LRL	Units
Aluminum, Filtered	5	ug/L	Magnesium, Unfiltered	10	ug/l
Aluminum, Unfiltered	5	ug/L	Manganese, Filtered	0.5	ug/L
Ammonia Nitrogen, Unfiltered	60	ug/L	Manganese, Unfiltered	0.5	ug/L
Bicarbonate Alkalinity, Unfiltered			Mercury, Methyl	0.5	ng/L
BOD 5-day, Unfiltered	1	mg/L	Mercury, Unfiltered	0.5	ng/L
BOD Ultimate, Unfiltered	1	mg/L	Nickel, Filtered	0.5	ug/L
Cadmium, Filtered	0.5	ug/L	Nickel, Unfiltered	0.5	ug/L
Cadmium, Unfiltered	0.5	ug/L	Nitrate N, Unfiltered	50	ug/L
Calcium, Unfiltered	20	ug/L	Nitrite N, Unfiltered	30	ug/L
Carbonate Alkalinity, Unfiltered			Ortho Phosphate, Filtered	10	ug/L
CBOD 5-day, Unfiltered	1	mg/L	Ortho Phosphate, Unfiltered	10	ug/L
CBOD Ultimate, Unfiltered	1	mg/L	pH (resolution)	0.1	pH unit
Chloride, Unfiltered	2	mg/L	Pheophytin-a	1	ug/L
Chlorophyll-a, Pheo-Corrected	1	ug/L	Potassium, Unfiltered	20	ug/L
Chlorophyll-a, Trichromatic	1	ug/L	Sodium, Unfiltered	20	ug/L
Chlorophyll-b, Trichromatic	1	ug/L	Sulfate, Unfiltered	0.5	mg/L
Chlorophyll-c, Trichromatic	1	ug/L	Total Alkalinity, Unfiltered	10	mg/L
Chromium, Filtered	5	ug/L	Total Dissolved Solids	10	mg/L
Chromium, Unfiltered	5	ug/L	Total Kjeldahl Nitrogen, Filtered	0.2	mg/L
COD, Filtered	15	mg/L	Total Kjeldahl Nitrogen, Unfiltered	0.2	mg/L
COD, Unfiltered	15	mg/L	Total Organic Carbon, Unfiltered	1	mg/L
Copper, Filtered	0.5	ug/L	Total Phosphorus, Filtered	10	ug/L
Copper, Unfiltered	0.5	ug/L	Total Phosphorus, Unfiltered	10	ug/L
Dissolved Oxygen	0.05	mg/L	Total Suspended Solids	1	mg/L
Escherichia coli Bacteria	1	mpn/100 ml	Turbidity	1	NTRU
Fecal Coliform Bacteria	1	#/100 ml	Volatile Suspended Solids	1	mg/L
Hardness, Unfiltered	5	mg/L	Zinc, Filtered	5	ug/L
Iron, Unfiltered	6	ug/L	Zinc, Unfiltered	5	ug/L
Lead, Filtered	0.1	ug/L			
Lead, Unfiltered	0.1	ug/L			

5 SAMPLING METHODS

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

5.1 SAMPLING PROCEDURES

5.1.1 Grab Sampling Procedures

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

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

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

5.1.1.1 Wading and Hand Collection

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

5.1.1.2 Reach Pole Collection

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

5.1.1.3 Bridge and Rope Collection

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

5.1.1.4 Autosampler Pump Collection

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

5.1.2 Flow-Weighted Composite Sampling Procedure

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

5.2 FIELD EQUIPMENT USED

5.2.1 Grab Sampling Equipment

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

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

5.2.2 Composite Sampling Equipment

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

- 24 Clean, 1000-ml Plastic Sample Bottles
- Clean, Labeled Five-Gallon Composite Sample Bottle
- Automatic Sampler (either Sigma® or ISCO®)

- Polypropylene Sample Tubing
- Campbell CR10X Datalogger
- Cooler and Ice

5.3 Sample Bottle Preparation and Equipment Cleaning

5.3.1 Grab Sample Bottles and Equipment Cleaning

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

5.3.2 Composite Sample Bottles and Equipment Cleaning

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

6 FIELD AND SAMPLE CUSTODY DOCUMENTATION

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

6.1 FIELD DATA SHEETS

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

6.2 FIELD NOTES

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

6.3 SAMPLE LABELING

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

6.4 SAMPLE SHIPPING

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

6.5 SAMPLE CHAIN-OF-CUSTODY PROCEDURE

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

7 FIELD MEASUREMENT PROCEDURES

7.1 PERMANENT IN-SITU MONITORING EQUIPMENT

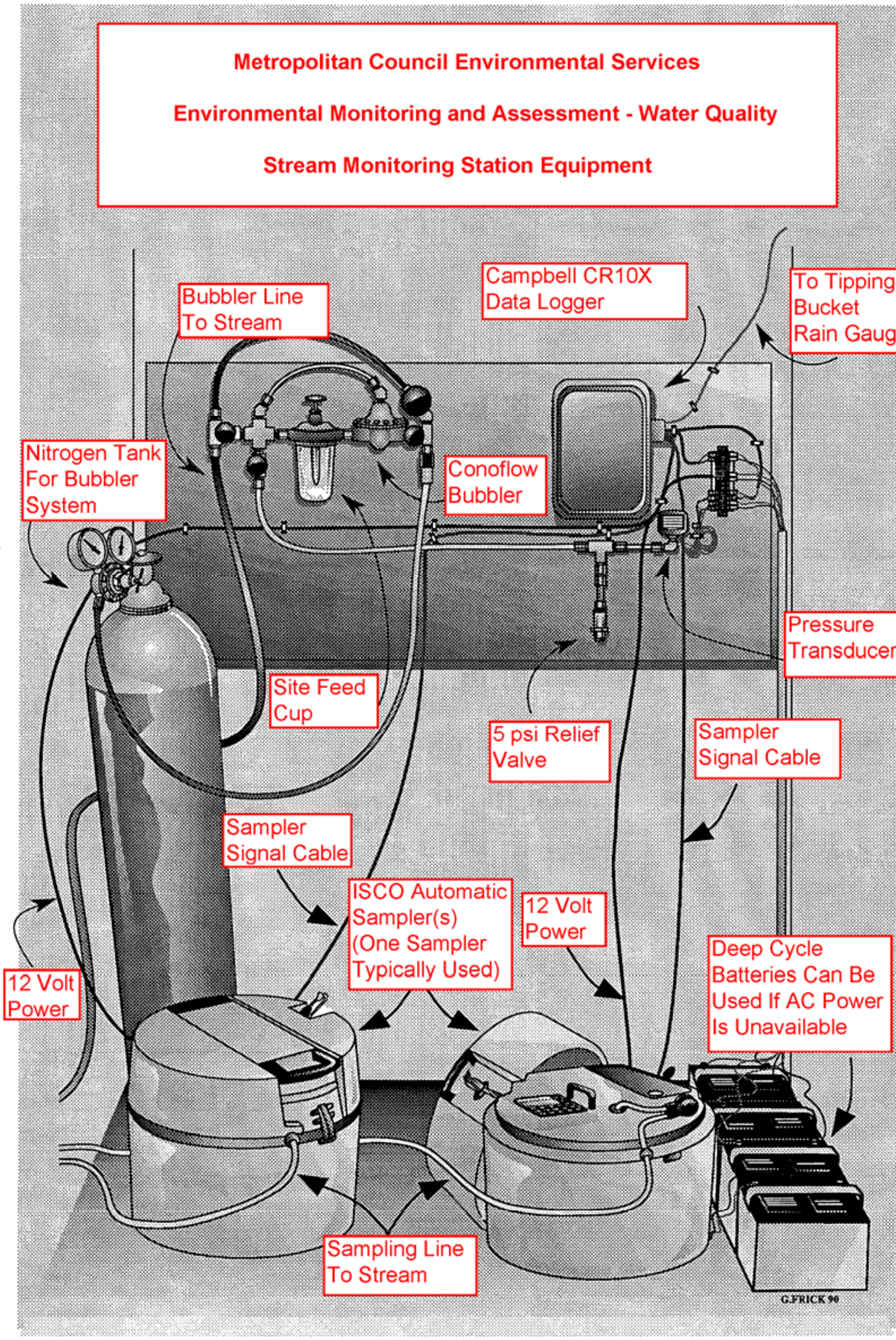
The typical stream monitoring station is designed to continuously monitor stage, flow, temperature, and conductivity at 15-minute intervals. Precipitation (rainfall) is measured in 0.01-inch increments via a tipping-bucket rain gauge. At seven monitoring stations, continuous turbidity information is obtained at 15-minute intervals during the open-water season (March-November).

The standard equipment layout is:

- A walk-in shelter equipped with AC power, a phone line, and modem for data transmission.
- A Campbell Scientific® TE525 tipping-bucket rain gauge for collection of rainfall data, in 0.01-inch increments. The rain gauge is situated at a location that is free from overhanging vegetation.
- A stage reference guide, usually a staff gauge or a wire weight gauge.
- A stage measurement device, usually a bubbler/pressure transducer system. Stations without this system are equipped with an ultrasonic sensor, a radar sensor, or a shaft encoder.
- A Sigma® or ISCO® automatic sampler, with either 24 1000-ml sample bottles or 1 5-gallon composite sample bottle. At monitoring stations where extended hydrographs and sampling times are possible after storm events, a refrigerated automatic sampler is used to maintain sample integrity.
- A Campbell Scientific® Model 247 or Model 547 combined temperature/conductivity probe, for continuous measurement of temperature and conductivity at 15-minute intervals.
- A Forest Technology Systems ® DTS-12 turbidimeter (at seven monitoring stations), for continuous measurement of turbidity at 15-minute intervals during the open-water season (March-November).
- A Campbell Scientific® CR10X datalogger, which activates/deactivates the automatic sampler and writes a data record every fifteen minutes for stage, flow, temperature, conductivity, and turbidity (where applicable), and at 0.01-inch increments for rainfall.
- A conduit which runs from the shelter to the stream. The conduit contains autosampler tubing, heat tape, a temperature/conductivity probe, a turbidimeter cable (where applicable), and a bubbler line. At several stations, a separate conduit it used to house the turbidimeter cable. The end of the conduit is securely anchored to a solid surface (typically a fence post) in the stream, at a representative monitoring location. The remainder of the conduit, between the shelter and the stream, is typically buried or covered with rip-rap.

A schematic drawing of the interior of a typical MCES stream monitoring station is provided in Figure 7.1.

Figure 7.1. Typical MCES Stream Monitoring Station



7.1.1 Permanent In-Situ Monitoring Equipment: Operation and Calibration

7.1.1.1 Precipitation

Precipitation (rainfall) is measured in 0.01-inch increments via a Campbell Scientific® TE525 tipping bucket rain gauge. The rain gauge is situated at a location that is free from overhanging vegetation, typically on the monitoring shelter, where it can be readily connected to the Campbell CR10X datalogger which records and stores the rainfall data. The TE525 is an adaptation of the standard National Weather Service tipping bucket rain gauge. The rain gauge funnel and bucket mechanism must be kept clean. Routinely check for and remove any foreign material, dust, insects, etc. The gauge is factory calibrated, but a field calibration check is recommended every 12 months, as described in the instruction manual (http://www.campbellsci.com/documents/manuals/te525.pdf). If factory calibration is required, contact Campbell Scientific to obtain a Returned Materials Authorization (RMA).

7.1.1.2 Stage

Measurements of water stage (level) are recorded at 15-minute intervals by the Campbell CR10X datalogger. Water stage measurements are typically made using a bubbler/pressure transducer system, but an ultrasonic sensor, a radar sensor, or a shaft encoder is used at some stations. The bubbler/pressure transducer system detects water stage by using a pressure transducer to measure the pressure needed to force a gas (air or nitrogen) bubble from the end of the submerged bubbler line. The higher the water stage, the greater the pressure necessary to force a gas bubble out of the bubbler line. The gas source (either a compressed nitrogen gas cylinder or an air pump) is located in the monitoring shelter, along with the pressure transducer. The bubbler line extends from the shelter to the stream (or stilling well), through a conduit. The end of the bubbler line is securely mounted in a fixed position under the water surface. The bubbling rate, controlled by a needle valve in the shelter, is typically set at one to three bubbles per second.

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

The radar sensor detects water stage by emitting short microwave pulses and measuring the travel time to the water surface and back. The radar sensor is installed in a fixed position above the water surface, typically on the side or underside of a bridge or culvert.

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

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

7.1.1.3 Flow

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

At two monitoring stations (Eagle Creek and Valley Creek), acoustic Doppler current meters are used to directly measure stream flow at 15-minute intervals. YSI Incorporated's SonTek Argonaut®-SW is used at Eagle Creek, and YSI Incorporated's SonTek Argonaut®-SL is used at Valley Creek. Using pulsed acoustic Doppler technology, both units combine velocity and water level data with channel geometry to compute total flow in real time.

7.1.1.4 Autosamplers

During storm runoff events, flow-weighted composite samples are collected using ISCO® Model 6712 and Sigma® Model 900 automated samplers. At several monitoring stations where extended hydrographs and sampling times are possible after storm events, Sigma® Model 900 refrigerated automatic samplers are used to maintain sample integrity. The flow-weighted composite sampling procedure is described in Section 5.1.2. Directions for operating, maintaining, and calibrating the autosamplers are found in the ISCO and Sigma instruction manuals, at http://www.isco.com/products/manuals.asp?PL=20110 and http://www.hach.com/hc/static.template/templateName=HcBridgePage.HcSigma.htm, respectively.

7.1.1.5 Temperature

Measurements of water temperature are recorded at 15-minute intervals by the Campbell CR10X datalogger. A Campbell Scientific® Model 247 or Model 547 combined temperature/conductivity probe, connected to the datalogger, extends from the shelter to the stream (or stilling well), through a conduit. A thermistor at the end of the temperature probe is encapsulated in a protective housing. Thermistors are thermally sensitive resistors that exhibit a large change in electrical resistance with a small change in temperature. Temperature measurements are manually calibrated by comparing the instrument measurement to a manual field temperature measurement obtained with an independently-calibrated portable meter or thermometer. See Section 7.2.1.3 for information on manual field measurement of water temperature.

7.1.1.6 Conductivity

Conductivity is the inverse of electrical resistance. In water, conductivity is related to ionic strength, or the amount of ions in solution, including calcium, magnesium, sodium, potassium, chloride, sulfate and others. Measurements of water conductivity are recorded at 15-minute intervals by the Campbell CR10X datalogger. A Campbell Scientific® Model 247 or Model 547 combined temperature/conductivity probe, connected to the datalogger, extends from the shelter to the stream (or stilling well), through a conduit. The end of the conductivity probe consists of two or more metal plates separated by a gap through which water can flow. An electrical voltage is then applied across the plates and the resulting electrical resistance is measured. Conductivity measurements are manually calibrated by comparing the instrument measurement to a manual field conductivity measurement obtained with an independently-calibrated conductivity meter. If an adjustment is needed, the conductivity probe is assigned an appropriate offset (via the datalogger keypad) to match the conductivity meter measurement. See Section 7.2.1.4 for information on manual field measurement of conductivity.

7.1.1.7 Turbidity

Turbidity in water is caused by suspended matter, such as clay, silt, finely divided organic and inorganic matter, soluble colored organic compounds, and plankton and other microscopic organisms. Turbidity is an expression of the optical property that causes light to be scattered and absorbed rather than transmitted in straight lines through a water sample.

At seven stream monitoring stations, in-stream turbidity is continuously measured using the Forest Technology Systems (FTS) ® DTS-12 turbidity sensor. This sensor employs an optical back-scatter method, with the detector aligned at 90 degrees to the incident light beam (780 nm). The measurement range of the DTS-12 is 0-1600 Nephelometric Turbidity Units (NTUs). The turbidity sensor is placed inside of a protective housing made of perforated 4” PVC pipe, which is secured in the stream channel. The turbidity sensor is positioned inside of the PVC pipe so that it maintains an adequate viewing area (4” axial end clearance and 2” radial side clearance), yet remains submerged at low stream levels. The turbidity sensor transmits turbidity data to the Campbell CR10X datalogger by a direct wire connection, which runs from the stream to the monitoring station through a protective conduit. The DTS-12 makes 100 turbidity measurements at 20 measurements per second, and then performs statistical calculations which include: mean, variance, median, best easy systematic (BES) value, minimum, and maximum values, which are sent to final storage and recorded by the Campbell CR10X datalogger at 15-minute intervals. A wiper blade at the end of the DTS-12 sensor operates at 10-minute intervals, to help keep the optic interface clean. The DTS-12 turbidity sensors are only deployed during the open-water season, typically from March-November. While the DTS-12 requires no field calibration, it must be sent to FTS annually for factory calibration and maintenance.

7.1.2 Permanent In-Situ Monitoring Equipment: Maintenance

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

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

- Check for loose wires,
- Check the dessicant indicators and replace if needed (when color changes from blue to pink),
- Make sure that the in-stream turbidimeter is set to the correct depth to allow adequate viewing area and stay submerged,
- Clear any debris from the turbidimeter's in-stream protective housing, as the debris could interfere with the sensor,
- Inspect the turbidity sensor's optical face for fouling and correct wiper function; if fouled, clean with a soft cloth, and replace the wiper blade.

7.2 PORTABLE MONITORING EQUIPMENT

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

Table 7.1 MCES Portable Stream Monitoring Equipment

Variable	Equipment Used
Dissolved Oxygen	YSI 650/6820 Multiparameter Meter
Dissolved Oxygen	Hydrolab Quanta Multiparameter Meter
pH	YSI 650/6820 Multiparameter Meter
pH	Hydrolab Quanta Multiparameter Meter
Temperature	YSI 650/6820 Multiparameter Meter
Temperature	Hydrolab Quanta Multiparameter Meter
Temperature	Fisher Scientific Digital Thermometer
Conductivity	YSI 650/6820 Multiparameter Meter
Conductivity	Hydrolab Quanta Multiparameter Meter
Conductivity	Oakton C 100, 300, 410, 440 Meters
Flow	Dye Drip Pump and Fluorometer (Laboratory)
Flow / Velocity	SonTek/YSI FlowTracker Handheld ADV Meter
Flow/ Velocity	USGS Price Meter and Aqua Calc 5000
Transparency	Transparency Tube

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

7.2.1 Portable Monitoring Equipment: Operation, Calibration, and Maintenance

7.2.1.1 Dissolved Oxygen

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

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

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

7.2.1.2 pH

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

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

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

7.2.1.3 Temperature

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

7.2.1.4 Conductivity

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

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

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

7.2.1.5 Stream Flow

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

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

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

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

7.2.1.6 Transparency

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

8 LABORATORY ANALYTICAL PROCEDURES

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

Table 8.1 MCES Laboratory Analytical Methods for Stream Monitoring Variables

Laboratory Variable	MCES LIMS ID	Certified Reference	Laboratory Variable	MCES LIMS ID	Certified Reference
Aluminum, Filtered	MET-MSV	EPA 200.8	Lead, Filtered	MET-MSV	EPA 200.8
Aluminum, Unfiltered	MET-MSV	EPA 200.8	Lead, Unfiltered	MET-MSV	EPA 200.8
Ammonia Nitrogen, Unfiltered	NH3N-AV	EPA 350.1	Magnesium, Unfiltered	MET-MSV	EPA 200.8
Bicarbonate Alkalinity, Unfiltered	ALK-AV	EPA 310.2	Manganese, Filtered	MET-MSV	EPA 200.8
BOD 5-day, Unfiltered	BOD5	SMEWW 5210 B-01	Manganese, Unfiltered	MET-MSV	EPA 200.8
BOD Ultimate, Unfiltered	BODU70-DN	SMEWW 5210 C	Nickel, Filtered	MET-MSV	EPA 200.8
Cadmium, Filtered	MET-MSV	EPA 200.8	Nickel, Unfiltered	MET-MSV	EPA 200.8
Cadmium, Unfiltered	MET-MSV	EPA 200.8	Nitrate Nitrogen, Unfiltered	N_N-AV	SMEWW 4500-NO3 H-00
Calcium, Unfiltered	MET-MSV	EPA 200.8	Nitrite Nitrogen, Unfiltered	N_N-AV	SMEWW 4500-NO3 H-00
Carbonate Alkalinity, Unfiltered	ALK-AV	EPA 310.2	Ortho Phosphate, Filtered	ORTHO_P	SMEWW 4500-P E
CBOD 5-day, Unfiltered	BOD5C	SMEWW 5210 B-01	Ortho Phosphate, Unfiltered	ORTHO_P	SMEWW 4500-P E
CBOD Ultimate, Unfiltered	BODUC70-DN	SMEWW 5210 C	pH		NA (Field Probe)
Chloride, Unfiltered	CL-AV	SMEWW 4500-Cl-E	Pheophytin-a	CLA-TR-CS	ASTM D3731-87
Chlorophyll-a, Pheo-Corrected	CLA-TR-CS	ASTM D3731-87	Potassium, Unfiltered	MET-MSV	EPA 200.8
Chlorophyll-a Trichromatic Uncorrected	CLA-TR-CS	ASTM D3731-87	Sodium, Unfiltered	MET-MSV	EPA 200.8
Chlorophyll-b	CLA-TR-CS	ASTM D3731-87	Sulfate (SO4), Unfiltered	SO4-ICV	EPA 300.0
Chlorophyll-c	CLA-TR-CS	ASTM D3731-87	Total Alkalinity, Unfiltered	ALK-AV	EPA 310.2
Chromium, Filtered	MET-MSV	EPA 200.8	Total Dissolved Solids	TDS-180	SMEWW 2540 C
Chromium, Unfiltered	MET-MSV	EPA 200.8	Total Kjeldahl Nitrogen, Filtered	NUT-AV	EPA 351.2
COD, Filtered	COD-A2	EPA 410.4	Total Kjeldahl Nitrogen, Unfiltered	NUT-AV	EPA 351.2
COD, Unfiltered	COD-A2	EPA 410.4	Total Organic Carbon, Unfiltered	TOC-WO	SMEWW 5310 A/C
Copper, Filtered	MET-MSV	EPA 200.8	Total Phosphorus, Filtered	P-AV	EPA 365.4
Copper, Unfiltered	MET-MSV	EPA 200.8	Total Phosphorus, Unfiltered	NUT-AV	EPA 365.4
Dissolved Oxygen	DOX-W	ASTM D888-92(A)	Turbidity	TRB-NTRUN2	SMEWW 2130 B
Escherichia coli Bacteria	ECOLI-MPNT	IDEXX 2000	Total Suspended Solids	TSSVSS-GF	SMEWW 2540 E
Fecal Coliform Bacteria	FCOLI-MF	EPA-600/8-78-071	Volatile Suspended Solids	TSSVSS-GF	SMEWW 2540 E
Hardness, Unfiltered	HARD-HL	SMEWW 2340 C	Zinc, Filtered	MET-MSV	EPA 200.8
Iron, Unfiltered	MET-MSV	EPA 200.8	Zinc, Unfiltered	MET-MSV	EPA 200.8

9 QUALITY ASSURANCE PROCEDURES

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

9.1 DATA REVIEW AND VALIDATION

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

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

All field, laboratory, continuous monitoring, and biological data for a given calendar year are reviewed, flagged, and approved by the EMA data owners (currently Cassie Champion, Leigh Harrod, and Tim Pattock) by the end of the first quarter of the following calendar year. This process ensures that quality-assured data are available in the EDW in a timely manner.

9.2 QUALITY ASSURANCE AUDITS AND REPORTING

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

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

9.3 CORRECTIVE ACTION

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

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

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

10 DATA REPORTING

10.1 AUTOMATED, ELECTRONIC DATA REPORTING

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

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

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

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

10.2 ANNUAL ASSESSMENT REPORT

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