Quality Assurance Project Plan

Rhode Island Wadeable Streams Biomonitoring and Habitat Assessment

PREPARED FOR:
Rhode Island Department of Environmental Management
Office of Water Resources
235 Promenade Street
Providence, Rhode Island 02908

PREPARED BY:
ESS Group, Inc.
10 Hemingway Drive, 2nd Floor
East Providence, Rhode Island 02915

ESS Project No. R298-011

Revised December 2, 2014

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US EPA-NE Worksheet 1 Title and Approval Page

QUALITY ASSURANCE PROJECT PLAN
RHODE ISLAND WADEABLE STREAMS
BIOMONITORING AND HABITAT ASSESSMENT

Revised December 2, 2014

CONTRACT OFFICER, RIDEM

2/4/15
DATE

Sue Kiernan
Rhode Island Department of Environmental Management
Office of Water Resources, 235 Promenade Street
Providence, RI 02908
Phone: 401-222-4700 Ext. 7600
sue.kiernan@dem.ri.gov

PROJECT OFFICERS, RIDEM

2/4/15
DATE

Katie DeGoosh
Rhode Island Department of Environmental Management
Office of Water Resources, 235 Promenade Street
Providence, RI 02908
Phone: 401-222-4700 Ext. 7211
katie.degoosh@dem.ri.gov

2/4/15
DATE

Jane Sawyers
Rhode Island Department of Environmental Management
Office of Water Resources, 235 Promenade Street
Providence, RI 02908
Phone: 401-222-4700 Ext. 2032
jane.sawyers@dem.ri.gov

PROJECT MANAGER, ESS GROUP, INC.

2/3/15
DATE

Carl Nielsen
ESS Group, Inc.
10 Hemingway Drive, 2nd Floor
East Providence, Rhode Island 02915
Phone: 401-330-1224
cnielsen@essgroup.com

QAPP PREPARER AND QUALITY ASSURANCE OFFICER, ESS GROUP, INC.

2/3/15
DATE

Matt Ladewig
ESS Group, Inc.
10 Hemingway Drive, 2nd Floor
East Providence, Rhode Island 02915
Phone: 401-330-1204
mladewig@essgroup.com

RHODE ISLAND DEPARTMENT OF HEALTH LABORATORY

2/4/2015
DATE

Henry Leibovitz
Rhode Island Department of Health
Rhode Island State Health Laboratories
50 Orms Street
Providence, RI 02904
Phone: 401-222-5578
henry.leibovitz@health.ri.gov

US EPA QA OFFICER

02/05/15
DATE

Steve DiMattei
QA Chemist, US EPA, 11 Technology Drive
North Chelmsford, MA 01863
Phone: 617-918-8369
DiMattei.Steve@epamail.epa.gov

US EPA PROJECT OFFICER

2/5/15
DATE

Margherita Pryor
US EPA
Region 1 New England
5 Post Office Square
Boston, MA 02109
Phone: (617) 918-1597
pryor.margherita@epa.gov

List of Abbreviations

Abbreviation	Definition
CAS	Chemical Abstracts Service
cm	Centimeter
DQI	Data Quality Indicators
DQO	Data Quality Objectives
ft	Foot
HEALTH	Rhode Island Department of Health
L	Liter
m	Meter
mg	Milligram
mL	Milliliter
mm	Millimeter
MDL	Method Detection Limit
NA	Not Applicable
NNC	Numeric Nutrient Criteria
NPS	Nonpoint Source
NTU	Nephelometric Turbidity Unit
QAPP	Quality Assurance Project Plan
QA/QC	Quality Assurance/Quality Control
RIDEM	RI Department of Environmental Management
RPB	Rapid Bioassessment Protocols
RPD	Relative Percent Difference
SFS	Society for Freshwater Science (formerly North American Benthological Society)
SOG	Standard Operating Guideline
SOP	Standard Operating Procedure
SU	Standard Unit
µg	Microgram
µm	Micron
µS	Microsiemen
US EPA	U.S. Environmental Protection Agency
US EPA-NE	U.S. Environmental Protection Agency – New England Region (Region 1)

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1.0 PURPOSE AND DESCRIPTION

1.1 Quality Assurance Project Plan Objectives

This Quality Assurance Program Plan (QAPP) for Rhode Island Wadeable Streams Biomonitoring and Habitat Assessment outlines the personnel management organization, program objectives, data quality requirements, experimental design and sampling methodology. This QAPP also provides instruction for required data and sampling review actions in order to facilitate consistent data collection, and to ensure data quality and program objectives are met. This QAPP is the periodic revision of the previous program QAPP prepared in 2007 entitled "Taxonomic Identification of Benthic Macroinvertebrates – Biomonitoring for Wadeable Streams" as available online: http://www.dem.ri.gov/pubs/qapp/taxbenth.pdf. The 2007 program QAPP was a revision of the original program methods document, the 2002 "QAPP for Taxonomic Identification of Benthic Macroinvertebrates, RI" (ESS, 2002). This document is written in accordance with US EPA New England Quality Assurance Project Plan Program Guidance (US EPA 2010) and Guidance for Quality Assurance Project Plans (US EPA 2002) and the location of all required information is given in Table A. QA/QC criteria, sampling and analysis procedures, and method documentation for laboratory and field analyses are summarized in Section 3.0 and associated SOPs/SOGs (Appendix A).

Wadeable Stream Biomonitoring and Habitat Assessments are an integral part of Rhode Island's Water Quality Monitoring Strategy (RIDEM/OWR 2005a). The RIDEM/OWR Water Quality Standards and Water Quality Assessment Programs analyze, assess, and report the water quality status of rivers and streams across the state. The data collected using the methods described herein are used to characterize the health of wadeable streams to determine if the stream adequately supports fish and wildlife habitat (its Aquatic Life Use). These assessments are published in the Integrated Water Quality Monitoring and Assessment Report (http://www.dem.ri.gov/pubs/305b/index.htm) that is issued by RIDEM to US EPA as required under Sections 305(b) and 303(d) of the Clean Water Act (CWA).

The objective of the Rhode Island Wadeable Streams Biomonitoring and Habitat Assessment Program is to characterize benthic macroinvertebrate communities and overall habitat in wadeable streams throughout in Rhode Island. Because benthic macroinvertebrates are relatively sedentary within a stream and spend much of their life cycle in the water, health of the macroinvertebrate community reflects local ambient environmental conditions. The macroinvertebrates sampled are good indicators of stream water quality and can be used to evaluate the biological integrity of a stream--its ability to support and maintain healthy aquatic communities. These biological communities integrate the effects of different stressors providing a broad measure of aggregate impacts and also assimilate the effects of these stressors over time, providing an ecological measure of fluctuating environmental conditions. Lack of invertebrates that are sensitive to pollution or invertebrate communities dominated by pollution tolerant organisms may indicate "impaired" waters that do not support healthy aquatic communities ("aquatic life use"). Because invertebrate communities reflect water quality over time and are relatively easy to collect and identify, biomonitoring is often regarded as a more cost-effective ambient monitoring technique to identify problems than intensive water sampling for multiple toxic pollutants that are highly variable over time. These biomonitoring methods are based on US EPA's Rapid Bioasssessment Protocols (RBP III; Barbour et al. 1999) to measure local habitat features (e.g., physical structure, flow regime), water quality parameters and biological indicators to infer aquatic ecosystem quality from a relatively "rapid" assessment of the prevailing biologic conditions. Biological monitoring can provide information about past and/or episodic pollution and readily gives an accurate representation of relative health of aquatic ecosystems. Data collected under this QAPP will be finalized in a data report submitted to RIDEM. RIDEM/OWR Water Quality Standards and Water Quality Assessment Programs will then analyze this data in accordance with the RI CALM to make assessment determinations.

Table A provides a summary of US EPA-NE QAPP Worksheets locations in this document. This table also provides the rationale for omission of any worksheets.

Table A. Required Information Checklist

US EPA-NE Worksheet No.	Worksheet Title	Location in QAPP
1	Title and approval	Prior to narrative
2	Table of contents & document format	Prior to narrative
3	Distribution list	Prior to narrative
4	Project personnel sign-off sheet	All relevant personnel are included on the approval page
5a	Organizational chart	Figure 1
5b	Communication pathway	Section 2.0 in narrative
6	Personnel responsibilities and qualifications	Section 2.1 in narrative and Appendix B
7	Special personnel training requirements	Section 2.2 in narrative
8a	Project scoping meeting attendance sheet, agenda	Section 1.1 in narrative
8b	Problem definition/site history & background	Section 1.2 in narrative
9a	Project description	Section 1.1 in narrative
9b	Contaminants of concern	Section 3.5.1
9c	Field & QC sample summary	Section 3.5.2
10	Project schedule timeline	Section 1.4 in narrative
11a	Project quality objectives/decision statements	Section 3.0 in narrative
11b	Measurement performance criteria	Section 3.5.3
12a	Sampling design & rationale	Section 1.2 in narrative
12b	Sampling locations, methods, SOP requirements	Sections 1.2 and 3.5.4
13	Project sampling SOP references	Section 3.5.5
14	Field sampling equipment calibration	Section 3.5.6
15	Field equipment maintenance, testing and inspection	Section 3.5.7
16	Sample handling, tracking, custody	Section 1.3 in narrative and Section 3.5.12
17	Field analytical method/SOP references	See Worksheets 12b and 13
18	Field calibration	See Worksheet 14
19	Field maintenance	See Worksheet 15
20	Fixed lab. analytical method/SOP references	See Worksheets 12b and 13
21	Fixed lab. instrument maintenance & calibration	See Worksheet 14
22a	Field sampling QC	See Worksheet 24a
22b	Field sampling QC continued	NA – not needed
23a	Field analytical QC	Sections 3.5.8, 3.5.9, and 3.5.10
23b	More field QC	NA – not needed
24a	Fixed laboratory analytical QC	Section 3.5.11
24b	More lab analytical QC	No multiple analytes
25	Non-direct measurement criteria	NA
26	Project documentation and records	Section 4.0 in narrative

Table A. Required Information Checklist

US EPA-NE Worksheet No.	Worksheet Title	Location in QAPP
27a	Assessment and response	Section 4.0 in narrative
27b	Project assessment	Section 4.0 in narrative
27c	Project assessment plan	Section 4.0 in narrative
28	QA management reports	Section 4.0 in narrative
29a	Data evaluation process	Section 4.0 in narrative
29b	Data validation summary	Section 4.0 in narrative
29c	Data validation modifications	Section 4.0 in narrative
30	Data usability assessment	Section 4.0 in narrative

1.2 Sampling Design: Background and Rationale

RIDEM's macroinvertebrate program has designed its current sampling approach as an adaptive response to its changing data needs. As the Biomonitoring program has evolved over the years, the sampling design has changed from a fixed station network to a rotating basin approach and also was modified when needed to fill newly identified data gaps (for water quality assessment purposes or refinements to the biotic index). The following background information is provided to illustrate how and why the sampling approach has been modified from 2002 to its current design.

Since first implementing biological monitoring for the state's wadeable streams in 1991, RIDEM has refined the methods used for monitoring and assessment of the aquatic life use. RIDEM has historical biological monitoring data from 1991-2001 for 45 intermittently sampled, fixed station ambient monitoring sites on wadeable streams (Table 1). The data was collected under cooperative agreement with a Roger Williams University (RWU) professor (1991-2000). Not all sites were sampled each year between 1991 and 2001; however, at least six years of biomonitoring data are available for most sites. These data were benthic macroinvertebrate kick samples identified to family-level taxonomy. The macroinvertebrate data was summarized into community metrics, and metrics from a station were compared to a previously assigned reference station within the same ecoregion. Stations located in the Southern New England Coastal Plains and Hills (as defined by Griffith et. al. 1994) were compared to a reference station on the Wood River, and stations located in the Narragansett-Bristol Lowland (NBL) were compared to Adamsville Brook. To manage this data, RIDEM contracted Tetra Tech in 2000 and again in 2002 to develop and populate an EDAS-based Access database (called BioQual) with the Rhode Island biomonitoring data, automatically calculate macroinvertebrate metrics, and also to provide guidance for developing the biomonitoring program. Results of preliminary data analysis with BioQual highlighted how the family level taxonomic resolution did not provide data sensitive enough to accurately discriminate between macroinvertebrate communities nor indicate appropriate tolerance levels. This project resulted in recommendations for improving the program such as increasing taxonomic resolution, collecting more data at new stations as well as resampling stations to estimate annual variability.

Therefore, beginning in 2002, RIDEM contracted ESS Group Inc. to conduct collections using the US EPA RBP III (1999) for sampling benthic macroinvertebrates, at 40-50 sites per year selected by RIDEM and to identify macroinvertebrates at a higher taxonomic resolution (typically genus/species). ESS developed a QAPP (Quality Assurance Project Plan) for the program, which was approved by US EPA (ESS 2002). In 2002 and 2003, the 45 stations previously sampled by RWU were resampled by ESS, in addition to a few other targeted locations (Tables 2 & 3).

In 2003, as part of the overall effort to develop a comprehensive statewide water monitoring strategy, RIDEM/OWR contracted an outside consultant, Midwest Biodiversity Institute (MBI) to review and make recommendations for establishing a river monitoring strategy based on a sampling design that would better fulfill all the state water quality management needs for the next several years (MBI 2003a). The resulting MBI report recommended the use of a rotating basin approach and a geometric sampling design to select station locations and to incorporate biological, chemical and physical data collection (MBI, 2003b). The geometric sampling design provides robust spatial coverage to allow comparison over larger areas and reveal patterns of stressor effects when streams are grouped by size class, geographic position, or biological quality. The strategy aids water quality management like TMDL development and implementation, ecosystem restoration and protection (MBI 2003a). Therefore, further refinements were made to the overall sampling design to expand the scope of biomonitoring from the initial 45 biomonitoring stations to a more intensive statewide sampling program to sample and assess more river miles in the state.

In cooperation with the Rhode Island Environmental Monitoring Collaborative, RIDEM published the state's Water Monitoring Strategy that was subsequently approved by the Rhode Island Bays, Rivers and Watersheds Coordination Team (RIDEM 2005a). The Monitoring Strategy incorporated the rotating basin approach and recommended a five-year rotational cycle for collection of physical, chemical, and biological data. Having assumed the recommended three to four person monitoring team would be available, the monitoring strategy identified an initial rotating basin schedule that, if fully implemented, would enable RIDEM to thoroughly sample and assess all watershed basins within Rhode Island in a five-year timeframe. In 2004, RIDEM proceeded to implement a pilot rotating basing program using the geometrically selected stations while working within the constraints of existing resources.

This new rotating basin approach to river monitoring included the regular, systematic and intensive data collection (including multiple sites located on multiple rivers) within specific watershed basins to aid monitoring and assessment. Monitoring of targeted watershed basins (at the HUC-10 and HUC 12 digit watershed size) would typically be done on a regular rotating schedule every three to five years (MBI, 2003a). Under this approach, station locations were selected using the geometric sampling design to locate monitoring stations intensively in a specified basin by positioning sites successively in a stratified pattern within the watershed. The first station was located at the mouth of the mainstem river, the next station was located at a point that drains ½ of the drainage basin area, and subsequent stations were located at ¼, then at $^1/_8$ and $^1/_{16}$ the size of the area. Targeted stations were also selected to address gaps in coverage for specific pollution sources or sections of interest.

The pilot rotating basin program began with the 2004 sampling season, and, for the biological monitoring component of this program, RIDEM/OWR contracted with ESS to continue to collect and analyze macroinvertebrate samples from 32 stations in the Wood River Basin (~90 mi^2), with 13 additional targeted stations around the state (Table 4). In the Wood River Basin, stations were selected using the geometric sampling design (to a resolution of 1 mi^2 regardless of presence of riffle habitat) and certain supplemental stations were added to bracket known or potential pollution sources.

In the second year (2005) of the rotating basin cycle, ESS sampled in the Pawcatuck River Basin (covering approximately 117 mi^2 including the Chipuxet and Beaver River HUC-12 basins). Stations were located at 40 sites using the geometric sampling design to a resolution of 1 mi^2 regardless of the presence riffle habitat and an additional 6 targeted stations outside of the basin were also selected (Table 5). Two stations, PAW16 and PAW34, could not be sampled because they did not have any flowing water.

In the third year (2006) of the rotating basin cycle, ESS sampled in five HUC-12 basins: Queen River basin, Flat River basin, Big River basin, Lower Pawcatuck River basin and South Branch of the Pawtuxet River basin (covering ~109 mi^2 in total; Table 6). Samples were collected at 48 stations sited using the

geometric sampling design, also to a resolution of 1 mi^2 (regardless of riffle habitat presence) and 5 supplemental stations were added to bracket known or potential pollution sources. Also, the QAPP for this program was revised and approved by US EPA (ESS 2007).

During planning of the 2007 sampling season, RIDEM refined station selection by instituting a drainage size restriction on station placement and eliminated biomonitoring streams that drained less than 5 mi^2. It has been documented that these small streams often undergo periods of zero flow and/or complete desiccation in the summer (noted in previous years when sampling). Through development of the Rhode Island Aquatic Base Flow (ABF) standards, review of historical USGS data demonstrated that, during the summer, streams draining less than 5 mi^2 had significantly lower flows than those that drained greater than 5 mi^2 throughout Rhode Island. This was attributed to the inclusion of data from streams in the smaller drainage group that were intermittent or dry streams (zero flow; RIDEM, 2005b). A supplemental project conducted by RIDEM/OWR involving stream flow monitoring of several small, first order streams draining less than 5 mi^2, also indicated most study streams were intermittent, experiencing periods of zero flow during the summer. The new drainage size restriction ensured macroinvertebrate samples would be collected at perennial streams that most likely maintained the Rhode Island aquatic base flow throughout the year. RIDEM then prioritized the focus of biomonitoring toward these perennial streams. Establishment of this station placement criterion also improved the spatial efficiency of the rotation cycle by increasing the proportion of area covered in Rhode Island over the course of a year. Further, RIDEM placed increased scrutiny on the habitats selected to be sampled, as the most appropriate place to conduct RBP sampling is in a riffle, therefore riffle habitats were prioritized as a criteria in station selection. Note: Streams not meeting the selection criteria for biomonitoring may be monitored for other indicators by other RIDEM programs. In 2007, 34 stations were selected in the Scituate Reservoir watershed and Pawtuxet River basin in riffle habitats (avoiding most locations just below impoundment dams) using the geometric sampling design (with the drainage size restriction at 5 mi^2), and 20 supplemental stations were added to bracket pollution sources (Table 7). The stations sampled in the targeted basins covered approximately 158 mi^2 improving the sampling efficiency/frequency of the rotating basin program to cover more area per year, and reducing the number of years between sampling a station.

In the 2008 sampling was conducted at 49 stations throughout the Clear, Branch, Woonasquatucket, Moshassuck, Blackstone, Abbott Run (Mill River), Upper Moosup, Hunt, and Saugatucket River HUC-12 basins (covering approximately 355 mi^2, Table 8). Additionally, ESS began collecting duplicate field samples to estimate the reproducibility (precision) of sample collection and processing methods as well as the reliability (precision) of biological metrics for quality assurance purposes. At the end of the 2008 season, biomonitoring was completed at most rivers and streams with riffle habitats within Rhode Island which drain greater than 5mi^2, thereby completing the first statewide rotation.

In 2008, RIDEM received results of a biomonitoring program review they were invited to participate in by the Midwest Biodiversity Institute with support from US EPA (MBI 2008). The review process evaluated the program against predetermined Critical Technical Elements of Bioassessment Programs (Barbour et al, 2006). The program review documented strengths and opportunities for improvement, providing recommendations such as expanding data management activities, use of additional fish or periphyton assemblage monitoring (for biocriteria or nutrient criteria development), and further enhancing bioassessment methods through better characterization of a reference condition and biological condition gradient. From the beginning of RIDEM's Bioassessment program in 1991, the reference station approach had been used to assess the data, in which macroinvertebrate metrics for streams within each ecoregion were compared to one reference station, respectively. However, this method of comparing data against just one station did not account for the natural variability inherent in riverine systems. Ambient conditions at one stream station may have been naturally different from the reference station due to variable factors such as geology, slope, elevation, stream order, catchment area, or surrounding

landscape (farmland, pine forests, deciduous tree cover etc.) in the watershed. This method of comparing a station to just one reference location can result in a misinterpretation of metric dissimilarities and result in Type 1 assessment errors (wrongly assigned as impaired). Conversely, an unexpected, isolated stressor at the reference station causing temporary degradation of the macroinvertebrate community may result in Type 2 assessment errors (mischaracterizing a degraded station as non-impaired). Therefore, RIDEM began moving toward development of biocriteria and a new assessment method using a biotic index to compare stations against a reference *condition.* The reference condition uses data to characterize multiple reference stations to represent more diverse reference scenarios and a wide spectrum of biological conditions. This allows for a wider range of acceptable circumstances (accounting for natural variability) and more accurately classifies stations when making impairment decisions. Based on the results of the MBI program review, in 2009 RIDEM contracted Tetra Tech to update the Rhode Island BioQual Access database with the data collected by ESS since 2002 (TetraTech 2009). Additionally, to expand the amount of data available to develop the biological condition gradient, ESS sampled 46 biomonitoring stations in 2009 (Table 9) at stations that had only been sampled once or twice in the past, targeting riffle habitats (avoiding most locations just below impoundment dams, with the drainage size restriction at 5 mi^2). Again, ESS collected duplicate field samples for quality assurance purposes.

In 2010, RIDEM targeted 32 biomonitoring stations (Table 10) for ESS to sample to enhance the biological condition gradient development and include any reference type stations that had only been sampled once or twice (and may have been overlooked in 2009 due to small drainage sizes less than 5 mi^2). For these stations, reconnaissance was completed at each station to evaluate evidence of flow, ensure streams were perennial, and had riffle areas. However, three stations (WON11, WRB19 and ESS12) had flow insufficient to collect samples at the time ESS visited them for sampling. Regardless, ESS collected duplicate samples for quality assurance purposes at other stations.

The biological sampling ESS completed in 2009 and 2010 was helpful to increase the number of samples available for use in a calibration set to characterize the biological condition gradient in Rhode Island spanning a range of reference and stressed sites. In 2011, RIDEM contracted with Tetra Tech again to incorporate the new data into the database and analyze the relationships between physical, chemical, hydrological and biological factors that account for natural classification of sites (group sites to reduce natural variability—highland verses lowland areas, for example). This factor analysis utilized the new Level IV Ecoregions (Griffith et al. 2009), introducing an area delineated as the Long Island Sound Coastal Lowland (LISCL) that was formerly classified under the Southern New England Coastal Plains and Hills (SNECPH). Further, they used physical, chemical and landuse factors to provide an objective assessment of stressor exposure and human disturbance to classify the calibration stations into stressed and reference stations to characterize the biological condition gradient. Using these calibration stations, they were able to identify the macroinvertebrate metrics that best distinguished reference stations, and created a multimetric biological condition index--MBCI for the upland areas within the Southern New England Coastal Plains and Hills (Tetra Tech, 2012) to further biocriteria development. Analysis of the data revealed RIDEM does not have sufficient stations in either lowland ecoregions (NBL or LISCL) to develop a statistically valid reference condition for streams in this area. Therefore, data collection should only be targeted towards stations in the upland region of the state until an alternative monitoring/assessment method for the lowland areas can be developed.

For the 2011 sampling season, biomonitoring station selection returned to a rotating basin strategy. The overall strategy was revised by reducing the density of stations along a river and/or within a watershed where the data suggested extrapolation of assessment information would be appropriate. For example, eliminating stations where extrapolation of a supporting bioassessment from a downstream station located in a similar landscape area. In addition, stations previously located in non-riffle areas were removed. This revision also allowed for a shortening of the five year rotation due to the consolidation of

stations. Therefore, in 2011, ESS was able to sample stations in the Wood and Pawcatuck River basins in the same season (previously sampled in 2004 and 2005) as well as the Queen River basin and Lower Pawcatuck River basins (previously sampled in 2006). This revision allowed ESS to sample macroinvertebrates at 21 appropriate riffle locations covering 259 square miles, decreasing the number of years between site visits and increasing sampling frequency (Table 11). Additionally, to better estimate reliability (precision) of biological metrics for quality assurance purposes, ESS picked each sample to both 100 and 300 organism sub-samples, and again, duplicates were taken at a few stations for quality assurance purposes. Further, to investigate addition of a second assemblage and develop numeric nutrient criteria for streams, RIDEM began considering the utility of benthic algae biomonitoring into its statewide wadeable stream monitoring program by evaluating different methods and timing of benthic algae collection. Results of this methodological research are being used to refine future biomonitoring data collection, nutrient criteria development and water quality assessments.

In 2012, the macroinvertebrate biomonitoring program continued to target stations within the condensed statewide rotating basin schedule, moving northward in the state where ESS sampled 38 stations in the greater Scituate Reservoir basin, entire Pawtuxet River basin, Upper Moosup and Hunt River basins (Table 12). These basins span 291 square miles, and again ESS took field duplicates at a few stations for quality assurance purposes. RIDEM continued to evaluate and refine benthic algae field methods for future incorporation into the biomonitoring program.

In 2013, continuing along the condensed rotating basin schedule, targeted stations were located within the greater Blackstone River basin, including the Clear, Chipuxet, Branch, and Mill River basins as well as the Moshassuck River HUC-12 basins. ESS sampled 32 stations in riffle areas spanning approximately 217 square miles and also included 3 field duplicates for quality assurance purposes (Table 13). In addition, ESS began to incorporate some of the field methods to aid in Numeric Nutrient Criteria (NNC) Development (i.e., densiometer, pebble count, and benthic algae collection) that have been developed by RIDEM to assess the reproducibility and accuracy of the collection methods (see section 1.3.1.3 for SOPs). Results of this effort will be analyzed to determine the feasibility of incorporating these new methods and new assemblage as a permanent fixture of the Rhode Island Wadeable Biomonitoring Program for numeric nutrient criteria (NNC) development and refinement, as well as assessments.

With the exception of sampling the Woonasquatucket River Basin, RIDEM was able to condense the statewide rotating basin cycle from a five year schedule (2004-2009) to a three year schedule (2011-2013). In 2014, samples will be taken in the Woonasquatucket River Basin to complete the statewide assessment. However, it is anticipated that this basin will be incorporated into future three year sampling cycles. Other stations were included to collect data for NNC (Table 14).

1.3 Project Sampling Overview

1.3.1 Field Sampling:

Full descriptions of sampling procedures and datasheets to be used for each of the elements below are available in the appropriate SOP or SOG document (Appendix A); however a short description follows in each section. Wadeable stream field sampling anticipated under this QAPP includes each of the following elements:

- Stream habitat assessment/physical characterization and measurement of water quality parameters recommended by the US EPA RBPs;
- Macroinvertebrate sample collection;
- Benthic algae sample collection and filtering (includes collection of natural substrate samples for diatoms and chlorophyll *a*);

- Pebble count; and
- Densiometer (canopy cover) sampling.

1.3.1.1 Stream Habitat Assessment/Physical Characterization

Habitat quality is sampled within each selected stream segment by completing a Habitat Assessment Field Data Sheet for High Gradient Streams, which was similar to data sheets recommended by the US EPA in Appendix 1 (Barbour et al., 1999). The approach weighs various habitat parameters to emphasize those that are the most biologically significant, thus supporting interpretation of macroinvertebrate results. All parameters are evaluated for each stream segment studied and rated on a numerical scale of 0 to 20 (highest) for each stream segment. The individual parameter scores are added together to calculate the overall Habitat Score. Scores increase as habitat quality increases.

The habitat assessment process involves rating ten habitat parameters as optimal, sub-optimal, marginal, or poor based on the US EPA-developed criteria. A brief summary of the parameters evaluated and the criteria upon which the assessment is based, follows:

1. Instream Cover – Assesses the quantity and variety of natural structures in the stream such as cobbles, large rocks, fallen trees, logs, snags and undercut banks, which serve as shelter, nursery or feeding areas to aquatic organisms.
2. Epifaunal Substrate – Assesses the extent and quality of riffle and run habitat, which offers a diversity of habitat, through variety of particle sizes, to aquatic organisms.
3. Embeddedness – Assesses the extent to which rocks (gravel, cobbles and boulders) and snags are covered or sunken into the fine sediments of the stream bottom, which impacts the surface area available to macroinvertebrates.
4. Channel Alteration – Assesses the extent of change to the shape of a stream channel, such changes can include channelization, dredging and artificial embankments, which affects the quantity and quality of natural habitat for aquatic organisms.
5. Sediment Deposition – Assesses the amount of sediment that has accumulated in pools and other changes that have occurred to the stream bottom as a result of deposition.
6. Frequency of Riffles/Velocity-Depth Combinations – Assesses the presence or absence of four depth patterns, namely slow-deep, slow-shallow, fast-deep, fast-shallow. Variety of habitat is key, the more of these depth patterns present in a stream reach the more stable the aquatic environment.
7. Channel Flow Status – Assesses the degree to which the channel is filled with water, which affects the amount of suitable substrate and other habitat available to aquatic organisms.
8. Bank Vegetative Protection – Assesses the amount of vegetative protection afforded to the right and left banks of the stream. The greater the percentage of the stream bank covered with a variety of native vegetation at a variety of growth heights, the greater the ability of the bank to resist erosion, the greater the control of instream scouring and the more shading for the stream. Each bank is evaluated separately and the cumulative score is used.
9. Bank Stability – Assesses the extent of and potential for bank erosion. Each bank is evaluated separately and the cumulative score is used.
10. Riparian Vegetative Zone Width – Assesses the width of natural vegetation from the edge of the stream bank out through the riparian zone. A relatively undisturbed riparian zone supports a healthy system; narrow riparian zones occur when roads, parking lots fields, lawns and

buildings are near the stream bank. Each bank is evaluated separately and the cumulative score is used.

As specified within the US EPA methodology, the habitat assessment also includes physical characterization and in-field measurement of water quality parameters. This information is not incorporated into habitat assessment scores but serves as further insight into the ability of the stream to support a healthy aquatic community. In addition, a map depicting the entire sampling reach and in-stream physical features such as riffles, falls, fallen trees, pools, bends and other important structures is sketched in the field for each stream segment.

Physical characterization includes documenting:

- Surrounding land use; and subsystem classification; presence or absence of dams;
- Local water erosion & potential non-point source (NPS) pollution;
- Width, depth and flow;
- Inorganic and organic substrate types; and
- Presence of odors, oils and deposits.

Water quality parameters measured in the field included:

- Dissolved oxygen (mg/L and % Saturation);
- pH (SU);
- Specific conductance (µS/cm);
- Turbidity (NTU); and
- Temperature (^{o}C).

A summary of QA/QC procedures for the collection and analysis of the above target analytes are provided as sub-appendices in Appendix A, as follows:

- Temperature - Appendix A2
- pH – Appendix A3
- Flow rate – Appendix A4
- Dissolved oxygen – Appendix A5
- Specific conductance – Appendix A6
- Turbidity – Appendix A7

1.3.1.2 Macroinvertebrate Sampling

The single habitat assessment approach to sampling as detailed by the US EPA (Barbour et al. 1999) will be used for this study. This approach entailed sampling benthic macroinvertebrates from riffle/run communities at each selected stream segment. Sampling will be conducted in accordance with the methods detailed in the SOG (Appendix A1) including the following key tasks:

- Selection of a representative 100-meter section of stream at each stream segment;
- Kick sampling within a series of riffles (working upstream) for a total cumulative duration of 3-minutes using a 500um-mesh D-net (kick net);

- Transfer of sample to a glass jar;
- Preservation of sample in 70% ethanol solution;
- Labeling inside and outside of sample jar accordingly; and
- Completion of the relevant section of the US EPA "Benthic Macroinvertebrate Log-In Sheet" (Barbour et al. 1999), which details the date the sample was collected and by whom, number of containers filled by the sample, preservative used, identification code for the stream segment and name and location of the stream.

Collection of freshwater macroinvertebrates in Rhode Island requires a scientific collection permit issued by the RIDEM Division of Fish and Wildlife. This permit is available for no fee to RIDEM/OWR and its contractors and should be obtained on an annual basis. A copy of the scientific collection permit application and approval for 2014 is included as Appendix D.

1.3.1.3 Benthic Algae Sampling

To aid numeric nutrient criteria development in wadeable streams, ESS will collect benthic algae samples from natural substrates for analysis of chlorophyll *a* in accordance with RIDEM SOP WR-W-37 (Appendix A8). RIDEM/OWR is evaluating benthic chlorophyll *a* at sites across the state in order to determine whether a relationship is present between water nutrient concentrations and benthic chlorophyll *a*. Chlorophyll *a* is one of the parameters proposed by the U.S. Environmental Protection Agency (US EPA) as a nutrient criteria response parameter. Sampling by ESS will allow for more sites to be sampled and for evaluation of data collection reproducibility and variability.

Sampling includes scraping algae (and rinsing) from several natural substrates (rocks and wood), compositing the scrapings from the natural substrates, and then filtering the slurry of algae and rinse water. Natural substrates should be completely submerged in the water and can be rocky substrates (>2cm – 25 cm in diameter), woody branches or sticks (greater than 2 cm in diameter or surface area) or aquatic vegetation. A combination of three different substrates will be selected to represent the condition of the benthic algae growing in stream, and a circular area (2.5 inches in diameter) of benthic algae/periphyton will be scraped off of each substrate using a brush. These algae will be rinsed into an opaque, light-resistant sampling container with DI rinse water and taken to the laboratory on ice for filtration (see Section 1.2.2.2). After filtration, the filters are frozen and then brought to the Rhode Island Department of Health Laboratory (HEALTH) for analysis.

1.3.1.4 Pebble Count

A semi-quantitative measurement of algal growth will be completed for a sample of 100 grains (pebble count) along the stream reach in accordance with RIDEM SOP WR-W-36 (Appendix A9). Grains will be assessed and ranked for size, the amount of non-vascular and attached vascular plant growth, and microalgae and macroalgae covering the pebble. The plant growth and marcroalgae percent coverage of the substrate are ranked on a scale from 0—3, and the microalgae accumulation depth will be ranked on a scale from 0—6 (Table B, RIDEM 2014). Microalgae will include all forms completely attached to the substrate, such as globular diatom or cyanobacteria patches. Macroalgae will include plant-like algae, such as *Cladophora* spp, *Nitella* spp, or *Tolypella* spp, or any filamentous algal growth.

Table B. Pebble Count Ranks for Substrate, Plants, Macroalgae, and Microalgae

Rank	Substrate	Plants	Macroalgae	Microalgae
0		No visual evidence	No visual evidence	No visual evidence

1	<2 mm	<5% coverage	<5% coverage	Substrate slimy, biofilm not visible; green coloration
2	2-16 mm	5-25% coverage	5-25% coverage	Thin layer present
3	16-64 mm	>25% coverage	>25% coverage	0.5-1 mm
4	64-256 mm			1-5 mm
5	>256 mm			5-20 mm
6				2 cm

1.3.1.5 Densiometer (Canopy Cover) Sampling

Due to ease and low cost, canopy cover measured by densiometer is often used as a surrogate for light availability in streams, which can play a large role in the response of primary production to nutrients. A semi-quantitative measurement of canopy cover will be taken using a densiometer in accordance with Rhode Island SOP WR-W-35 (Appendix A10). The densiometer used for this study is using a convex mirror etched with lines to form twenty-four quarter-inch squares and then modified as described in Strickler (1959) by covering a known area of the mirror. The resulting 17 observable points are where the inscribed lines intersect. A measurement is taken by lowering the densiometer to approximately 1 ft above the water surface and observing the number of points that are obscured by canopy vegetation or other items blocking the light from reaching the stream (e.g. large boulders). This reading will be done at 18 locations within a stream segment (at each of three transects; one measurement will be taken at the left bank, four measurements in the middle—one facing each compass direction, and one measurement on the right bank).

1.3.2 Laboratory Analysis

Full descriptions of sampling procedures and datasheets to be used for each of these elements are available in the appropriate SOP or SOG document (Appendix A). Laboratory analysis anticipated under this QAPP includes each of the following elements;

1.3.2.1. Macroinvertebrate Identification

Laboratory analysis of wadeable stream macroinvertebrate samples is also anticipated. This includes sorting, taxonomic identification, and enumeration of collected macroinvertebrates (Appendix A1).

1.3.2.2 Chlorophyll *a* filtration

Additionally, ESS can provide RIDEM with sample filtration and handling for chlorophyll *a* samples they collect under the QAPP for Rhode Island Ambient River Monitoring (RIDEM 2010). Samples will be collected and composited by RIDEM/OWR staff from natural (rocks, sticks) and artificial (glass slides) substrates. Chlorophyll *a* analytical samples will be directly delivered from RIDEM to ESS for filtration. After filtration, ESS will deliver frozen filters directly to the HEALTH laboratory for analysis. All required holding times and preservation requirements will be maintained during transport and storage. A chain-of-custody form, including volume filtered and total volume of the sample, will accompany each batch of samples.

1.4 Schedule/Timeline

Stream habitat assessment, macroinvertebrate sampling, densiometer sampling, and pebble count will be targeted to occur during the summer low-flow period (August through September). This period is expected to be the one of greatest environmental stress on stream organisms due to typical hydrologic and weather conditions.

Benthic algae and chlorophyll *a* samples collected by ESS will also be obtained during the summer low-flow period. However, RIDEM may collect additional chlorophyll *a* samples for ESS to filter and deliver to HEALTH as part of the development of NNC as noted above in section 1.3.2.2. These additional samples will be collected by RIDEM and provided to ESS between June and September.

ESS macroinvertebrate laboratory work, data entry, and reporting will be completed between October of the sampling calendar year and June of the following calendar year.

2.0 PROJECT ORGANIZATION

Carl Nielsen will act as the project manager responsible for coordinating all tasks completed by ESS. Sue Kiernan will serve as contract officer to ensure that all deliverables are completed in a manner consistent with contract expectations. Communication between project staff is also anticipated in order to coordinate day-to-day sampling activities, arrange sample transfers, provide or review project deliverables, or initiate discussion on proposed project changes. However, substantive project alterations or changes to the QAPP and its appendices will be made only after review and acceptance by both Ms. Kiernan and Mr. Nielsen.

The organization chart describes the principal personnel associated with the project and illustrates the chain of communication and authorization (Figure 1). Full resumes for primary ESS project personnel are provided in Appendix B.

2.1 ESS Personnel Roles and Qualifications

Carl Nielsen – Project Manager. Mr. Nielsen has over 21 years of experience in the assessment and evaluation of marine and freshwater ecosystems. He has worked extensively in identifying and understanding the ecology of most aquatic organisms including aquatic plants, algae, zooplankton, aquatic invertebrates, fish, reptiles and amphibians. Mr. Nielsen has been Senior Project Scientist for nearly 200 aquatic resource studies that have been performed for numerous clients including: federal, state and local governments, municipal water districts, local lake and watershed associations, industrial facilities, property developers, major corporations, utilities, golf courses, ski areas, and airports. He has served as Project Manager since ESS first began working with RIDEM as the prime contractor for the statewide wadeable stream macroinvertebrate biomonitoring program in 2002.

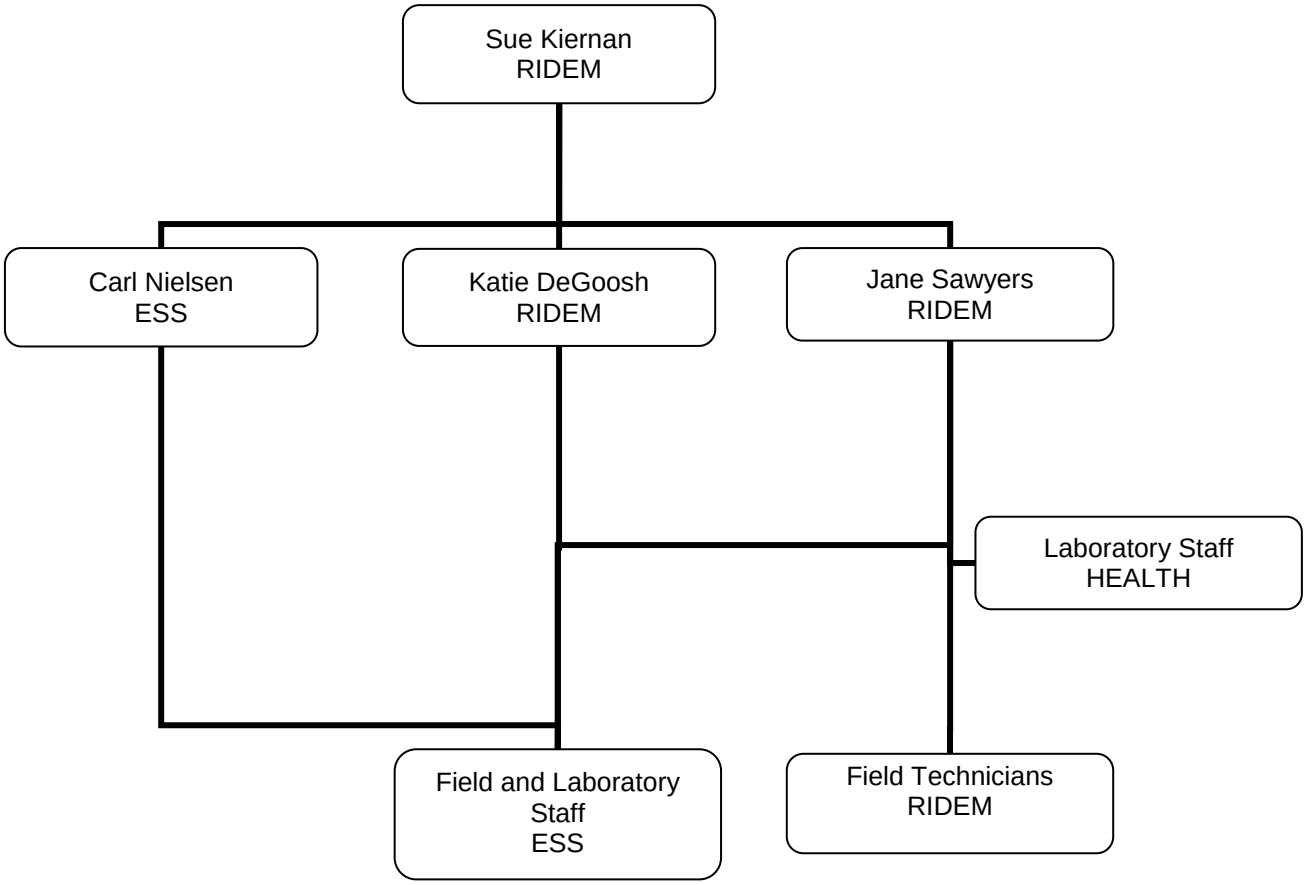

Figure 1. Project Organizational Chart

Matt Ladewig – Senior Taxonomist and QA Officer. Mr. Ladewig has significant experience developing and implementing marine and freshwater biological monitoring and assessment programs, including nearly seven years of direct experience with statewide wadeable stream biomonitoring and habitat assessment on behalf of RIDEM. He also maintains taxonomic certifications through SFS for the identification of freshwater macroinvertebrate organisms. Mr. Ladewig will oversee implementation of the field and laboratory portions of this project and will serve as the senior taxonomist and QA officer.

Eliza Moore – Staff Taxonomist. Ms. Moore is an experienced macroinvertebrate taxonomist and field biologist. She will assist Mr. Nielsen and Mr. Ladewig with taxonomic identifications of macroinvertebrate samples. Ms. Moore will also assist with implementation of the field program, macroinvertebrate sample sorting, and filtration of chlorophyll *a* samples.

Alex Patterson, Matt Robertson, Collin Smythe, Jessica LaJoie and James Treacy are ESS technical staff that may also assist with sample collection, handling, filtration, sorting, and data entry. Additional staff may be incorporated into the project with appropriate training and oversight (Section 2.2).

2.2 Training

As a company, ESS has been RIDEM's prime contractor for wadeable stream biomonitoring and habitat assessment each year since 2002. As such, ESS is highly familiar with the methods used to complete these tasks.

Training requirements are included in SOPs/SOGs. However, staff responsible for field or laboratory tasks receive, at a minimum, training from ESS staff that have experience on proper sample collection technique, use of field instrumentation, and laboratory methods. Training consists of hands-on training with sampling or laboratory equipment and review of written SOPs/SOGs. Many of the staff also received prior training through university coursework, research assistantships, or prior employment.

ESS staff responsible for field sample collection, habitat assessment, and macroinvertebrate sample sorting have received training by experienced ESS staff specific to this project. ESS staff responsible for macroinvertebrate identification have received additional training to develop this skill to the level necessary to achieve the targeted taxonomic level. Carl Nielsen, Matt Ladewig, and Eliza Moore each have previous academic study and professional experience in macroinvertebrate taxonomy. Matt Ladewig maintains active certifications for freshwater macroinvertebrate taxonomy with the Society for Freshwater Science.

Laboratory filtration of chlorophyll *a* samples is a new task for this project and current ESS staff that may be responsible for receiving, handling, filtering, or transporting these samples received training before June 17, 2013 (the earliest date for sample receipt).

Other new tasks include densiometer, pebble count, and collection of benthic algae from natural substrates. Field staff will receive training by experienced ESS staff on proper implementation of the methods used to perform these tasks prior to performing these tasks in addition to any training they may already have received.

3.0 DATA QUALITY OBJECTIVES AND MEASUREMENT PERFORMANCE CRITERIA

The quality of an environmental monitoring program can be evaluated in three steps: (1) Establishing scientific assessment quality objectives; (2) Evaluating program design for whether the objectives can be met; and (3) Establishing assessment and measurement quality objectives that can be used to evaluate the appropriateness of the methods being used in the program. The process of establishing Data Quality Objectives (DQOs) involves identifying the allowable uncertainty of a data set that may lead to two types of error: *false positives* (Type I error: a problem is found to exist when in fact it does not) and *false negatives* (Type II error: a problem is not found when in fact it does exist). The acceptance probabilities of those errors as established by the data users are the DQOs. The DQO process entails establishing action-triggering values and selecting rates of false positives and false negatives that are acceptable to the data user (decision maker). The quality of a particular data set is some measure of the types and amount of error associated with the data.

Sources of error or uncertainty associated with variables and indicators include the following:

1. Sampling error: The difference between actual representative values and sampling values that are related to error in sampling design. Sampling error consists of station specific natural variability due to unknown stream characteristics (may produce adequate living conditions in an isolated area) and anthropogenic variability associated with the impact of unknown recent disturbance events (may result in temporary loss of adequate living conditions).
2. Analytical error (e.g., identification error): The difference between sample values and *in situ* "true" values associated with the sorting and identification process. Identification error includes bias and imprecision associated with sample labeling, handling, storage, sorting and taxonomic classification.

The data requirements for this project encompass aspects of field sampling, laboratory analysis, and database management to reduce sources of errors and uncertainty in the use of the data. Methods and procedures described in this document are intended to reduce the magnitude of measurement error sources and frequency of occurrence. Project quality objectives include the following:

- Use of standardized, repeatable sample collection procedures

- Use of trained scientists to perform the sample collection and analyses
- Calibration of measurement equipment
- Analysis of duplicate samples
- Use of Chains-of-Custody when transferring samples or sample material between ESS, any outside QA/QC laboratories or experts, and RIDEM or HEALTH
- A QA/QC check on a percentage of samples analyzed during sorting and identification.
- Maintenance of a taxonomic reference collection

Data generated under this QAPP may be used to inform the state's assessments of wadeable streams or develop specific criteria or policies. Therefore, it is of utmost importance that the data are of sufficient quality to permit these actions.

If data are not accepted during review they will not be used in the project. Therefore, no specific project action limits or if/then statements are required.

DQOs are qualitative and quantitative statements that clarify the intended use of the data, define the type of data needed to support the decision, identify the conditions under which the data should be collected, and specify tolerable limits on the probability of making a decision error because of uncertainty in the data. To ensure the collection of high-quality data, specific DQOs have been set for laboratory and field analytical procedures on a method basis for precision, accuracy, comparability and completeness.

3.1 Precision

Precision is a measure of the degree to which two or more measurements of the same sample are in agreement as well as a measurement of random error. Precision will be assessed through the measurement of duplicate samples (one sample split into two replicates) and subsequent calculation of the relative percent difference (RPD) as follows:

$$RPD = \frac{|\text{Result of Replicate 1} - \text{Result of Replicate 2}|}{\text{Average of Result of Replicate 1 and Result of Replicate 2}} \times 100$$

Objectives for precision are located in the SOGs/SOPs (Appendix A) as well as worksheet 11b (Section 3.5.3).

3.2 Accuracy

Accuracy is an evaluation of the degree to which a measured value and a known reference value or true value are in agreement. This is a measurement of systematic error and is often referred to as "bias". Accuracy is determined by the analysis of reference material and comparison of the resulting value to that of the accepted value. The difference between the accepted and reference value is the percent difference. The percent difference is calculated as follows:

$$\% \text{ Difference} = \frac{|\text{Known Value of Reference Material} - \text{Calculated Value of Reference Material}|}{\text{Known Value of Reference Material}} \times 100$$

Objectives for accuracy are located in the SOGs/SOPs (Appendix A) as well as worksheet 11b (Section 3.5.3).

3.3 Comparability

Comparability is a measure of how comparable proposed methods are to accepted methods. All of the SOPs that will be implemented here are based on approved and established protocols. ESS field and laboratory SOGs are based on US EPA methods and protocols, where available. The RIDEM SOP for densitometer measurements is also based on US EPA methods. The RIDEM SOP for pebble count is

based on methods used by the Vermont Department of Environmental Conservation, modified from methods used by the US Forest Service. The RIDEM benthic algae sampling SOP is based on a number of state and research lab methods.

Laboratory filtration procedures for chlorophyll *a* are based upon known and accepted methods. For this project, filtration will meet the requirements specified by HEALTH SOP TO32 and be consistent with US EPA Method 446.0 (1997).

3.4 Completeness

Completeness is a measure of the amount of valid data obtained compared to the amount that was expected to be obtained under normal conditions. Greater than 90% completeness of samples accepted into the laboratory is expected. Greater than 90% completeness of field analytical procedures and collection of valid samples is expected. Completeness is calculated as follows:

$$\text{Completeness} = \frac{\text{Number of Valid Measurements}}{\text{Number of Measurements Planned}} \times 100$$

3.5 Quality Assurance/Quality Control Tables

Summaries of the QA/QC objectives for the analysis and collection of samples for this project are provided in the tables on subsequent pages. These tables specifically address the Data Quality Indicators (DQIs) or the procedures to be followed to provide assurance that an analytical procedure is returning valid results. Each DQI has a specific result that must be met before the data are considered acceptable. Maintenance and calibration procedures for equipment and instrumentation are also provided along with sample collection methods. Analyte-specific tables provide information on the number of QA/QC samples to be prepared (replicates, etc.) and the expected result as well as the person(s) responsible for assessing any problems and determining the proper course of action, if necessary.

3.5.1 Contaminants of Concern and Other Target Analytes Table – Worksheet #9b

US EPA-NE QAPP Worksheet #9b - Rev. 10/99 Contaminants of Concern and Other Target Analytes Table (Reference Limit and Evaluation Table)				
Analyte	**CAS Number**	**Reporting Units**	**Project Action Limit (Units)**	**Project Quantitation Limit (Units)**
Specific Conductance	NA	µS/cm	NA	0.1
Dissolved Oxygen	NA	mg/L O_2	NA	0.1
Temperature	NA	°C	NA	0.1
Turbidity	NA	NTU	NA	1
pH	NA	SU	NA	0.1
Canopy Cover	NA	# of dots	NA	1
Pebble Count	NA	Categorical	NA	NA

3.5.2 Field and Quality Control Sample Summary Table – Worksheet #9c

US EPA-NE QAPP Worksheet #9c - Rev. 10/99 Field and Quality Control Sample Summary Table						
Medium/ Matrix	**Analytical Parameter**	**Conc. Level**	**Analytical Method/ SOP Reference**	**No. of Sampling Locations**	**No. of Field Duplicate Pairs**	**Total No. of Samples to Lab per sampling event**
Surface Water	Specific Conductance	Ambient	ESS Specific Conductance SOG	35	4 (10% rate)	Variable – dependent upon the number of sites sampled per day
	Dissolved Oxygen		ESS Dissolved Oxygen SOG			
	Temperature		ESS Temperature SOG			
	Turbidity		ESS Turbidity SOG			
	pH		ESS pH SOG			
NA	Canopy Cover		RIDEM SOP WR-W-35			
Natural Substrate	Pebble Count		RIDEM SOP WR-W-36 (part)			
	Macroinvertebrates		ESS Macroinvertebrate SOG			
	Benthic Algae		RIDEM SOP WR-W-37 (part)			

Note:
Due to the nature of the analyses performed by the laboratory there is no need to collect sample blanks or additional sample volume for matrix spike and duplicate analyses. Therefore, these columns have been eliminated from this table.

3.5.3 Measurement Performance Criteria Table – Worksheet #11b

US EPA-NE QAPP Worksheet #11b - Rev. 10/99 Measurement Performance Criteria Table (field collection, field analysis and lab analysis)					
Sampling Procedure	**QC Sample and/or Activity Used to Assess Measurement Performance**	**Measurement Performance Criteria**	**DQIs**	**QA Samples Address Sample (S) or Analytical (A) Error**	**Analytical Method/SOP/SOG**
Field Analysis					
Specific Conductance	Calibration and post calibration check Field duplicate at 10% rate	Calibrate before each use, post cal. reading ± 20% Field duplicate ± 10 RPD	Accuracy/Precision	A	ESS Conductivity SOG
Dissolved Oxygen	Calibration and post calibration check Field duplicate at 10% rate	Calibrate before each use, post cal. reading ± 20% Calibration value ≤5% from ideal dissolved oxygen value in mg/L Field duplicate ± 10 RPD	Precision/Accuracy	A	ESS Dissolved Oxygen SOG
Temperature	Field duplicate at 10% rate	Thermometer standardized by manufacturer and checked against NIST thermometer before sampling season begins Field duplicate ± 0.5 °C	Accuracy/Precision	NA	ESS Temperature SOG
Turbidity	Calibration and post calibration check Field duplicate at 10% rate	Calibrate before each use, post cal. reading within 1.0 NTU Field duplicate ± 10 RPD	Accuracy/Precision	A	ESS Turbidity SOG
pH	Calibration and post calibration check Field duplicate at 10% rate	Calibrate before each use, post cal. reading within 0.2 SU Field duplicate ± 10 RPD	Accuracy/Precision	A	ESS pH SOG
Canopy Cover	Repeated measurement by second analyst at 10% of stream segments	NA	Precision	S	RIDEM SOP WR-W-35

US EPA-NE QAPP Worksheet #11b - Rev. 10/99 Measurement Performance Criteria Table (field collection, field analysis and lab analysis)					
Sampling Procedure	**QC Sample and/or Activity Used to Assess Measurement Performance**	**Measurement Performance Criteria**	**DQIs**	**QA Samples Address Sample (S) or Analytical (A) Error**	**Analytical Method/SOP/SOG**
Pebble Count	Repeated measurements of entire procedure by second analyst at 10% of stream segments	NA	Precision	S	RIDEM SOP WR-W-36 (part)
Field Collection					
Macroinvertebrates	Field duplicate at 10% rate	Biological assessment score ± 20 RPD	Precision	S	ESS Macroinvertebrate SOG
Benthic Algae	Field duplicate at 10% rate	NA	Precision	S	RIDEM SOP WR-W-37 (part)
Lab Analysis					
Macroinvertebrate Sorting, ID and Enumeration	Sorting efficiency check ID/enumeration validation	Sorting efficiency >90% ID ± 10% different Enumeration ± 10% different	Accuracy	A	ESS Macroinvertebrate SOG
Chlorophyll *a*	None – filtration only	NA	NA	NA	HEALTH SOP TO32

3.5.4 Sampling Locations, Sampling and Analysis Method/SOP Requirements Table – Worksheet #12b

Parameter	Matrix	No. Samples Per Site	Field Sampling SOP	Lab SOP	Sample Volume	Containers (no., size and type)	Preservation	Max Holding Time
Specific Conductance, Dissolved Oxygen, & Temperature	Surface Water	1	ESS Dissolved Oxygen, Conductivity and Temperature SOGs	NA_1	NA_1	NA_1	NA_1	NA_1
Turbidity	Surface Water	1	ESS Turbidity SOG 2012	NA_1	NA_1	NA_1	NA_1	NA_1
pH	Surface Water	1	ESS pH SOG 2012	NA_1	NA_1	NA_1	NA_1	NA_1
Canopy Cover	NA	1	RIDEM SOP WR-W-35	NA_1	NA_1	NA_1	NA_1	NA_1
Pebble Count	Natural Substrate	1	RIDEM SOP WR-W-36 (part)	NA_1	NA_1	NA_1	NA_1	NA_1
Benthic Algae (Diatom taxonomy)	Natural Substrate	1	RIDEM SOP WR-W-37 (part)	NA_2	Variable	1 - 250mL amber HDPE bottle	10% buffered formalin and refrigeration at 4° C	Preserve within 8 hours
Benthic Algae (Chlorophyll *a*)	Natural Substrate	1	RIDEM SOP WR-W-37 (part)	HEALTH SOP $TO32_2$	Variable	1 - 250mL amber HDPE bottle	Refrigeration at 4° C followed by freezing at -20° C	24 hours in bottle 21 days after filtration
Macroinvertebrates	Natural Substrate	1	ESS Macroinvertebrate SOG	ESS Macroinvertebrate SOG	Variable	Quantity as needed - quart jar	70% EtOH	Preserve within 8 hours

Notes:
$_1$ In-situ field measurement – no sample retained for laboratory analysis.
$_2$ Collection, preparation, and/or preservation of sample only. Laboratory analysis will not be conducted under this QAPP.

3.5.5 Project Sampling SOP Reference Table – Worksheet #13

US EPA-NE QAPP Worksheet #13 - Rev. 10/99 Project Sampling SOP Reference Table				
SOP	**Title, Revision Date and/or Number**	**Originating Organization**	**Equipment Identification**	**Modified for Project Work (Y or N)**
Field Analysis				
ESS Dissolved Oxygen, Conductivity and Temperature SOGs	Standard Operating Guidelines for the Measurement of Dissolved Oxygen, Temperature, and Specific Conductance, 2012	ESS Group, Inc.	YSI Model 85 or similar	N
ESS Turbidity SOG	Standard Operating Guidelines for Measurement of Turbidity, 2012	ESS Group, Inc.	LaMotte 2020 Nephelometric Turbidity Meter or similar	N
ESS pH SOG	Standard Operating Guidelines for Measurement of pH, 2012	ESS Group, Inc.	Hanna pHep5 pH Tester or similar	N
RIDEM SOP WR-W-36 (part)	Standard Operation Procedure for Measurement of Benthic Algae and Non-vascular Plant Cover by Viewing Bucket and Modified Pebble Count, 2011	RIDEM	Ruler	N
RIDEM SOP WR-W-35	Standard Operating Procedure for Stream Canopy Measurements by Densiometer, 2011	RIDEM	Densiometer	N
Field Collection				
ESS Macroinvertebrate SOG	Standard Operating Guidelines for Freshwater Macroinvertebrate Sampling and Analysis, 2013	ESS Group, Inc.	SOG-specific Sampling Equipment	N
RIDEM SOP WR-W-37 (Part)	Standard Operating Procedure for Collection of Benthic Algae from Natural and Artificial Substrates, 2011	RIDEM	SOP-specific Sampling Equipment	N
Lab Analysis				
ESS Macroinvertebrate SOG	Standard Operating Guidelines for Freshwater Macroinvertebrate Sampling and Analysis, 2013	ESS Group, Inc.	SOG-specific Laboratory Equipment	N
HEALTH SOP TO32 (Part)	Determination of Chlorophylls and Pheopigments in Algae by Visible Spectrophotometry by EPA Method 446.0 Rev 1.2	HEALTH	SOP-specific Filtration Equipment	N

3.5.6 Field Sampling Equipment Calibration Table – Worksheet #14

US EPA-NE QAPP Worksheet #14 - Rev. 10/99 Field Sampling Equipment Calibration Table						
Equipment	**Procedure**	**Frequency of Calibration**	**Acceptance Criteria**	**Corrective Action**	**Person Responsible for Corrective Action**	**SOP Reference**
YSI 85 Multi-parameter Meter	Calibration and post-calibration	At beginning and end of each sampling day	Calibration and post-calibration reading agree ± 10% Calibration value ≤5%from ideal dissolved oxygen value in mg/L	Flag data as suspect and attempt re-calibration. If errors persist send instrument out for repair	Field personnel performing work	ESS Dissolved Oxygen, Conductivity and Temperature SOGs
Turbidity Meter	Calibration and post-calibration	At beginning and end of each sampling day	Calibration and post-calibration reading agree ± 1.0 NTU	Flag data as suspect. Clean instrument and attempt re-calibration. If errors persist send instrument out for repair	Field personnel performing work	ESS Turbidity SOG
pH Meter	Calibration and post-calibration	At beginning and end of each sampling day	Calibration and post-calibration reading agree ± 0.2 SU	Flag data as suspect and attempt re-calibration. Clean instrument and attempt re-calibration. If errors persist send instrument out for repair	Field personnel performing work	ESS pH SOG

3.5.7 Field Equipment Maintenance, Testing and Inspection Table – Worksheet #15

US EPA-NE QAPP Worksheet #15 - Rev. 10/99 Field Equipment Maintenance, Testing and Inspection Table								
Sampling Equipment/ Instrument	**Maintenance Activity**	**Testing Activity**	**Inspection Activity**	**Responsible Person**	**Frequency**	**Acceptance Criteria**	**Corrective Action**	**SOP Reference**
YSI 85 Multi-parameter meter	Rinse with clean water after use. Keep Dissolved Oxygen membrane moist during storage.	Calibration	Look for wear in cables and check to be sure probes are not damaged	Person(s) collecting sample	Before each use	Instrument is not damaged and calibration acceptable	If calibration will not hold throughout sampling day as evidenced by problems with post-calibrations, then send to licensed maintenance company.	ESS Dissolved Oxygen, Conductivity and Temperature SOGs
Turbidity Meter	Clean and thoroughly dry cuvettes	Calibration	Look for damage to instrument or scratching on cuvettes	Person(s) collecting sample	Before each use	Instrument is not damaged and calibration acceptable	If acceptable calibration cannot be achieved, send instrument to manufacturer or licensed dealer for repair.	ESS Turbidity SOG
pH Meter	Rinse with tap water after use. Keep pH electrode bulb moist during storage.	Calibration	Look for damage to instrument	Person(s) collecting sample	Before each use	Instrument is not damaged and calibration acceptable	If acceptable calibration cannot be achieved, send instrument to manufacturer or licensed dealer for repair.	ESS pH SOG

3.5.8 Field Analytical QC Table – Worksheet #23a

US EPA-NE QAPP Worksheet #23a - Rev. 10/99 Field Analytical QC Table – pH					
Sampling SOP	ESS pH SOG		Analytical Method/SOP Reference	NA – Field Measurement	
Medium/Matrix	Surface Water		Sampler's Name	Various	
Analytical Parameter	pH		Field Sampling Organization	RIDEM (or designee) or ESS	
Concentration Level	0 to 14 SU		No. of Sample Locations	35	
Field QC:	**Frequency/Number**	**Method/SOP QC Acceptance Limits**	**Corrective Action**	**Person(s) Responsible for Corrective Action**	**DQI**
Calibrate	At the beginning and end of each field day	pH post-calibration values ±0.2 SU from calibration value	Flag data, try and recalibrate instrument, send instrument out for repair if continues to be in error	Field staff	Accuracy
Field duplicate pair	10%	±0.2 SU	Flag data, try and recalibrate instrument, send instrument out for repair if continues to be in error	Field staff	Precision

3.5.9 Field Analytical QC Table – Worksheet #23a (Continued)

US EPA-NE QAPP Worksheet #23a - Rev. 10/99 Field Analytical QC Table – Turbidity					
Sampling SOP	ESS Turbidity SOG		Analytical Method/SOP Reference	NA – Field Measurement	
Medium/Matrix	Surface Water		Sampler's Name	Various	
Analytical Parameter	Turbidity		Field Sampling Organization	RIDEM (or designee) or ESS	
Concentration Level	0 to 1000 NTU		No. of Sample Locations	35	
Field QC:	**Frequency/Number**	**Method/SOP QC Acceptance Limits**	**Corrective Action**	**Person(s) Responsible for Corrective Action**	**DQI**
Calibrate	At the beginning and end of each field day	Turbidity post-calibration values ±2% from calibration value	Flag data, try and recalibrate instrument, send instrument out for repair if continues to be in error	Field staff	Accuracy
Field duplicate pair	10%	±2% below 100 NTU ±3% at or above 100 NTU	Flag data, try and recalibrate instrument, send instrument out for repair if continues to be in error	Field staff	Precision

3.5.10 Field Analytical QC Table – Worksheet #23a (Continued)

US EPA-NE QAPP Worksheet #23a - Rev. 10/99 Field Analytical QC Table – Temperature, Dissolved Oxygen and Specific Conductance					
Sampling SOP	ESS Dissolved Oxygen, Conductivity and Temperature SOGs		Analytical Method/SOP Reference	NA – Field Measurement	
Medium/Matrix	Surface Water		Sampler's Name	Various	
Analytical Parameter	Temperature, dissolved oxygen and specific conductance		Field Sampling Organization	ESS	
Concentration Level	Temp: 1-30 °C Dissolved oxygen 0-20 mg/L Specific conductance 0-2,000 µS/cm		No. of Sample Locations	35	
Field QC:	**Frequency/Number**	**Method/SOP QC Acceptance Limits**	**Corrective Action**	**Person(s) Responsible for Corrective Action**	**DQI**
Field duplicate pair	10%	Specific conductance and dissolved oxygen: ±2%	Flag data, try and recalibrate instrument, send instrument out for repair if continues to be in error	Field staff	Precision
Calibrate	At the beginning and end of each field day	Specific conductance and dissolved oxygen: Post-calibration values <10 RPD from calibration value	Flag data, try and recalibrate instrument, send instrument out for repair if continues to be in error	Field staff	Accuracy

3.5.11 Fixed Laboratory Analytical QC Sample Table – Worksheet #24a

US EPA-NE QAPP Worksheet #24a - Rev. 10/99 Fixed Laboratory Analytical QC Sample Table – Macroinvertebrates					
Medium/Matrix	Natural Substrate Biological Sample		Analytical Method/ SOP Reference	NA	
Sampling SOP	ESS Macroinvertebrate SOG		Laboratory Name	ESS Group, Inc.	
Concentration Level	NA		No. of Sample Locations	35	
Laboratory QC:	**Frequency/ Number**	**Method/SOP QC Acceptance Limits**	**Corrective Action**	**Person(s) Responsible for Corrective Action**	**DQI**
Duplicate Pair	10%	<20 RPD	NA	NA	Precision
Sorting Efficiency Check	10%	Efficiency ≥90%	Provide guidance to sorter, re-sort additional sample(s), re-sort all samples completed by the sorter if sorting efficiency check is outside limits on four samples.	ESS Taxonomists	Accuracy
Identification and Enumeration Check	10%	≥90% correctly identified Enumeration within ±10%	Provide guidance to taxonomist, re-identify/ enumerate additional sample(s), re-identify/enumerate all samples completed by the taxonomist if outside limits on four samples.	ESS Taxonomists	Accuracy

3.5.12 Sample Handling System – Worksheet #16

US EPA-NE QAPP Worksheet #16 - Rev. 10/99 Sample Handling System
SAMPLE COLLECTION, PACKAGING AND SHIPMENT
Sample Collection: ESS and RIDEM personnel
Sample Packing: ESS and RIDEM personnel
Coordination of Shipment: ESS and RIDEM personnel
Type of Shipment: Ground shipment by ESS and RIDEM personnel
SAMPLE RECEIPT AND ANALYSIS
Responsible Organizations: ESS, RIDEM, and HEALTH
Sample Receipt: ESS and RIDEM personnel. HEALTH laboratory staff
Sample Custody and Storage: ESS and RIDEM personnel. HEALTH laboratory staff
Sample Preparation: ESS personnel
Sample Determinative Analysis: ESS personnel
SAMPLE ARCHIVAL
Field Sample Storage (Time from sample collection): Chlorophyll *a* – 24 hours refrigerated; Macroinvertebrates – 12 hours unpreserved, indefinitely with preservation; Benthic algae – 12 hours unpreserved, indefinitely with preservation
Sample Extract/Digestate Storage (Time from extraction/digestion): Chlorophyll *a* – 21 days frozen; Macroinvertebrates – Indefinitely with preservation; Benthic algae – indefinitely with preservation
SAMPLE DISPOSAL
Responsible Organizations: ESS, RIDEM, and HEALTH

4.0 PROJECT DOCUMENTATION, RECORDS AND VALIDATION

4.1 Project Records

Field personnel will record data in a bound, weatherproof field notebook or on weatherproof field sheets consistent with the requirements set forth by the SOPs/SOGs in Appendix A. Habitat assessment and physical characterization data, including temperature, specific conductance, dissolved oxygen, pH, and turbidity data will be recorded on the field sheets in Appendix C. All field data will be retained by ESS. Copies of field sheets and final data tables will be provided to RIDEM in the final report.

All laboratory data will be recorded in a laboratory notebook or on laboratory log-in and bench sheets consistent with the requirements set forth by the SOPs/SOGs in Appendix A. All laboratory data will be retained by ESS. Copies of laboratory sheets and final data results tables will be provided to RIDEM in the final report.

Field and laboratory data may also be stored electronically consistent with the requirements set forth by the SOPs/SOGs in Appendix A. Macroinvertebrate data are stored in the format required by RIDEM for uploading into the state's BioQual database. Details on the fields used are provided in Appendix C. In summary, a final data report will be submitted to RIDEM which includes all final data tables, copies of all field and laboratory sheets, pictures as well as electronic copies of the data.

4.2 Assessment and Response Actions

Field data collection efforts, field notes, laboratory data, and maps generated as part of this project will be periodically assessed by the ESS Project Manager to ensure that data collected is usable for the purposes of the study.

- The Project Manager will provide oversight for each field data collection effort to ensure that protocols described in the QAPP are being followed. This duty includes: ensuring that field equipment is properly calibrated, data are recorded in a consistent manner, sampling methodology is being conducted in accordance with SOGs, and samples are being properly distributed to laboratories.
- The Project Manager will review field and laboratory data to ensure that appropriate methodology is adhered to and reported data is within the accepted range for each parameter. If inconsistencies are detected or perceived, the Project Manager will discuss field instrument calibration and data collection with field personnel. Any "outlier" data discovered will be reported in the final report, and potential sources of error will be described.

4.3 Quality Management Reports

Quality management reports serve to ensure that the management organization (ESS) and the review agency (RIDEM) are regularly informed on the project status. To accomplish this goal, the following will be conducted.

- ESS will verbally inform the appropriate RIDEM personnel upon commencement of field sampling. Any factors significantly impacting the ability of ESS to complete field work at a given location (e.g., stream is not flowing) will be verbally communicated to RIDEM as soon as possible.
- ESS will internally review all field and laboratory results. Reviewed and amended (if necessary) results will be sent to RIDEM for review. Any problems detected in the data will be verbally discussed between ESS and RIDEM.
- Any "non-conformance" of field or laboratory data will be verbally discussed with RIDEM.

4.4 Verification and Validation Requirements

Data review, validation, and verification provide methods for determining the usability and limitations of data, as well as a standardized data quality assessment. ESS will be responsible for reviewing field data, laboratory data, data entries, and transmittals for completeness, correctness, and adherence to QC requirements.

4.5 Verification and Validation Procedures

All field entries, chain-of-custody forms, laboratory notebooks or sheets, and other records will be reviewed by the ESS Project Manager for completeness and correctness. Data will be reviewed and validated internally to provide information on whether they are acceptable or should be flagged or rejected.

Data packages will include, to the extent possible, sample receipt and tracking information, chain-of-custody forms, tabulated data summary forms, and raw analytical data for all field samples, standards, QC checks, and other project-specific documents. Data quality will be assessed by comparing entered data to original data or by comparing results with the measurement performance criteria summarized in Section 3.5.3 (Worksheet #11b) to determine whether to accept, reject, or qualify the data.

Results of the verification and validation processes will be reported to RIDEM, who will make the final determination to reject and remove any unusable data. If less than 90% of the data are judged valid (completeness requirement), best professional judgment will be applied to verify whether the remaining data will make it possible to draw the correct conclusions. Limitations in the data set will be communicated to RIDEM through quality management reports and, as necessary, in the draft and final project reports.

4.6 Data Usability/Reconciliation with Project Quality Objectives

Following completion of each year's effort, the precision, accuracy, and completeness measures will be assessed and compared with the criteria discussed in Section 3.5.3 (Worksheet #11b). If data collected meet the DQOs for the study, then the data are considered to meet the objectives of the study. Uncertainties and limitations in the use of these data and interpretation of results will be provided to RIDEM and will be reconciled, as possible.

5.0 REFERENCES

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Tables

Table 1. Biomonitoring stations sampled by Roger Williams University 1991-2000 for RIDEM (2001 samples were collected by a Master's student from the University of Rhode Island)

Station Name	River Name	Station Location	1991	1992	1995	1996	1997	1998	1999	2000	2001	Total times visited
RWU01	Abbott Run Brook North & Tribs	Route 120	1	1		1	1	1	1	1	1	8
RWU02	Abbott Run Brook South & Tribs	Valley Road	1	1		1	1	1	1	1	1	8
RWU03	Adamsville Brook & Tribs	At USGS gage on Rt. 81 (Crandall Rd.)	1	1	1	1	1	1	1	1	1	9
RWU04	Ashaway River & Tribs	At Rt. 216 below bridge	1	1		1	1	1	1	1	1	8
RWU05	Bailey's Brook & Tribs	Kempenaar's Clambake	1	1	1	1	1	1	1	1	1	9
RWU06	Beaver River & Tribs	Shannock Hill Road	1	1		1	1	1	1	1	1	8
RWU07	Big River & Tribs	South side of Rt. 3	1	1		1	1	1	1	1	1	8
RWU08	Blackstone River	Below Manville Dam			1	1	1	1	1	1	1	7
RWU09	Buckeye Brook & Tribs	Rt. 117A at Lockwood Corner	1	1	1	1	1	1	1	1	1	9
RWU10	Bucks Horn Brook & Tribs	At Lewis Farm Road	1			1	1	1	1	1	1	7
RWU11	Canonchet Brook & Tribs	Woodville/Alton Road	1	1		1	1	1	1	1	1	8
RWU12	Carr River & Tribs	Burnt Saw Mill Road	1			1	1	1	1	1	1	7
RWU13	Chipuxet River & Tribs	Wolf Rocks Road	1			1	1	1	1	1	1	7
RWU14	Clear River	Victory Highway	1	1		1	1	1	1	1	1	8
RWU15	Cold (Cole) Brook & Tribs	Pottersville Road	1	1	1	1	1	1	1	1	1	9

Table 1. Biomonitoring stations sampled by Roger Williams University 1991-2000 for RIDEM (2001 samples were collected by a Master's student from the University of Rhode Island)

Station Name	River Name	Station Location	1991	1992	1995	1996	1997	1998	1999	2000	2001	Total times visited
RWU16	Congdon River & Tribs	At south side of bridge near old foundation	1	1		1	1	1	1	1	1	8
RWU17	Dolly Cole Brook & Tribs	Old Danielson Pike	1	1		1	1	1	1	1	1	8
RWU18	Dundery Brook	Swamp Road	1	1	1	1	1	1	1	1	1	9
RWU19	Falls River & Tribs	North of Route 165	1	1		1	1	1	1	1	1	8
RWU20	Hardig Brook & Tribs	Toll Gate Rd. near Little Gorton Pond	1	1		1	1	1	1	1	1	8
RWU21	Hemlock Brook & Tribs	150m west of Hemlock Road bridge	1	1								2
RWU22	Hunt River	Route 1	1	1	1	1	1	1	1	1	1	9
RWU23	Jamestown Brook	Watson Farm Road	1		1	1	1	1			1	6
RWU24	Keach Brook & Tribs	At covered bridge in George Washington Mgmt. Area	1	1		1	1	1	1	1	1	8
RWU25	Upper Kickemuit River	At Poverty Corner Road			1	1	1	1	1	1	1	7
RWU26	Lawton Brook	Below Newport Res. Off Rt. 114		1	1	1	1	1		1	1	7
RWU27	Maidford River	Prospect Avenue	1	1	1	1	1	1	1	1	1	9
RWU28	Meadow Brook & Tribs	Pine Hill Road (Carolina Mgmt. Area)	1	1		1	1	1	1	1	1	8
RWU29	Moosup River & Tribs	At Rt. 14 Bridge			1	1	1	1	1	1	1	7
RWU30	Moswansicut Stream	Near Rt. 116, west 80m - below old stone bridge	1	1								2

Table 1. Biomonitoring stations sampled by Roger Williams University 1991-2000 for RIDEM (2001 samples were collected by a Master's student from the University of Rhode Island)

Station Name	River Name	Station Location	1991	1992	1995	1996	1997	1998	1999	2000	2001	Total times visited
RWU31	Nipmuc River & Tribs	South of Brook Road - Top Bk. Below pool	1	1		1	1	1	1	1	1	8
RWU32	Nooseneck River & Tribs	West side of Rt. 3	1	1	1	1	1	1	1	1	1	9
RWU33	Palmer River (Rehoboth, MA)	At County Street			1	1	1	1				4
RWU34	Parris Brook & Tribs	Blitzkreig Trail	1	1		1	1	1	1	1	1	8
RWU35	Pascoag River	Grove St. bridge	1	1		1	1	1	1	1	1	8
RWU36	Pawcatuck River & Tribs	Below White Rock Bridge			1	1	1	1	1	1	1	7
RWU37	Pawtuxet River Main Stem	At USGS gage in Cranston	1	1		1	1	1	1	1	1	8
RWU38	Queens River & Tribs	Liberty Road	1				1	1	1	1	1	6
RWU40	Runnins River & Tribs	At Rt. 44 bridge			1	1	1	1	1	1	1	7
RWU41	Rush Brook & Tribs	100m west of Elmdale Bk.	1	1	1							3
RWU42	Saugatucket River & Tribs	Rt. 1A bridge	1		1	1	1	1	1	1	1	8
RWU43	Silver Creek	At Chesnut Street			1	1	1	1	1	1	1	7
RWU44	Swamp Brook	15m NW of inflow pt. of Ponaganset Riv. Into Scituate Reservoir	1	1	1							3
RWU45	Ten Mile River & Tribs	Broadway Bridge	1		1	1	1	1		1	1	7
RWU46	Tomaquag Brook & Tribs	Chase Hill Road	1	1	1	1	1	1	1	1	1	9

Table 1. Biomonitoring stations sampled by Roger Williams University 1991-2000 for RIDEM (2001 samples were collected by a Master's student from the University of Rhode Island)

Station Name	River Name	Station Location	1991	1992	1995	1996	1997	1998	1999	2000	2001	Total times visited
RWU47	Wilbur Hollow Brook & Tribs	3m north of culvert crossing on Old Plainfield Pike	1		1							2
RWU48	Wood River	North of Skunk Hill Rd. off Old Nooseneck Road	1	1		1	1	1	1	1	1	8
RWU49	Woonasquatucket River	Eagle Street Bridge	1		1	1	1	1	1	1	1	8
Total			40	32	24	42	43	43	39	41	42	346

Table 2. Biomonitoring stations sampled by ESS in 2002

Station Name	Alter-native Station Names	Official State River Name	Rhode Island Waterbody ID Number	Watershed Basin Name	Town	Water-shed Size (mi^2)	Elevation (ft)
ESS01	MLL10near BSN02 ESS01 BL01	Abbott Run Brook North & Tribs	RI0001006R-01A	Abbott Run Brook & Tribs	Cumberland	18.1	129
ESS02	CLR06 ESS02 BL23	Clear River	RI0001002R-05D	Branch River & Tribs	Burrillville	45.4	318
ESS03	CLR02 ESS03 BL20	Pascoag River	RI0001002R-09	Branch River & Tribs	Burrillville	8.5	374
ESS04	ESS04	Croff Farm Brook	RI0005047R-04	Tribs to the Five Mile	Burrillville	2.3	538
ESS05	ESS05	Leland Brook & Tribs	RI0001002R-17	Branch River & Tribs	Burrillville	2.0	454
ESS06	CLR01 ESS06	Brandy Brook & Tribs	RI0001002R-02	Branch River & Tribs	Glocester	3.4	462
ESS07	CLR11 DRY09 ESS07	Mowry Brook & Tribs	RI0001002R-18	Branch River & Tribs	Burrillville	1.4	419
ESS08	ESS08	Chepachet River & Tribs	RI0001002R-03	Branch River & Tribs	Burrillville	19.4	343
ESS09	BNC09 ESS09	Tucker Brook & Tribs	RI0001002R-21	Branch River & Tribs	Burrillville	0.9	304
ESS10	BNC03 ESS10	Tarkiln Brook & Tribs	RI0001002R-13B	Branch River & Tribs	Burrillville	9.2	279
ESS11	BSN06 ESS11	Cherry Brook & Tribs	RI0001003R-02	Blackstone River & Tribs	Woonsocket	4.6	176
ESS12	ESS12	Catamint Brook	RI0001006R-07	Abbott Run Brook & Tribs	Cumberland	3.5	169
ESS13	ESS13	West Sneech Brook & Tribs	RI0001003R-06	Blackstone River & Tribs	Cumberland	2.3	96
ESS14	ESS14 BL11	Dundery Brook	RI0010048R-02C	Southeast Coastal Ponds	Little Compton	2.2	9
ESS15	ESS15 BL05	Bailey's Brook & Tribs	RI0007035R-01	Aquidneck Water Supply Tribs	Middletown	2.4	23
ESS16	BB05 ESS16	Buckeye Brook & Tribs	RI0007024R-01	Upper Narragansett Bay	Warwick	3.0	31
ESS17	ESS17	Hardig Brook & Tribs	RI0007025R-01	Greenwich Bay	Warwick	5.6	9
ESS18	ESS18 BL13	Hunt River	RI0007028R-03C	Potowomut River	Warwick	16.8	43
ESS19	ESS19 BL14 RWU23	Jamestown Brook	RI0007036R-01	Jamestown Water Supply	Jamestown	0.8	62
ESS20	AI01near ESS20	Lawton Brook	RI0007035R-04	Aquidneck Water Supply Tribs	Portsmouth	2.7	92

Table 2. Biomonitoring stations sampled by ESS in 2002							
Station Name	**Alter-native Station Names**	**Official State River Name**	**Rhode Island Waterbody ID Number**	**Watershed Basin Name**	**Town**	**Water-shed Size (mi^2)**	**Elevation (ft)**
ESS21	ESS21 BL16	Maidford River	RI0007035R-02A	Aquidneck Water Supply Tribs	Middletown	1.9	70
ESS22	PAW12 ESS22 BL03 RWU04	Ashaway River & Tribs	RI0008039R-02A	Pawcatuck River & Tribs	Hopkinton	28.2	50
ESS23	PAW28 ESS23 BL06	Beaver River & Tribs	RI0008039R-03	Pawcatuck River & Tribs	Richmond	11.9	95
ESS24	WRB04 ESS24 BL08	Canonchet Brook & Tribs	RI0008040R-04B	Wood River & Tribs	Hopkinton	6.6	71
ESS25	PAW05 ESS25 BL09	Chipuxet River & Tribs	RI0008039R-06B	Pawcatuck River & Tribs	Exeter	7.1	103
ESS26	WRB17 ESS26	Falls River & Tribs	RI0008040R-07	Wood River & Tribs	Exeter	35.2	171
ESS27	PAW20 ESS27 BL17	Meadow Brook & Tribs	RI0008039R-13	Pawcatuck River & Tribs	Richmond	5.1	79
ESS28	WRB18 ESS28 BL19	Parris Brook & Tribs	RI0008040R-13	Wood River & Tribs	Exeter	6.6	136
ESS29	QNAB ESS29 BL21	Queens River & Tribs	RI0008039R-21C	Pawcatuck River & Tribs	Exeter	19.3	133
ESS30	PAW04 ESS30 BL24	Tomaquag Brook & Tribs	RI0008039R-24	Pawcatuck River & Tribs	Hopkinton	6.7	38
ESS31	WRB15 ESS31 PAW47 WD-REF	Wood River	RI0008040R-16B	Wood River & Tribs	Hopkinton	54.6	125
ESS32	WRB-E ESS32	Canonchet Brook & Tribs	RI0008040R-04A	Wood River & Tribs	Hopkinton	0.1	91
ESS33	ESS33	Grassy Brook & Tribs	RI0008040R-09	Wood River & Tribs	Hopkinton	1.0	314
ESS34	ESS34	Mile Brook	RI0008039R-14	Pawcatuck River & Tribs	Hopkinton	1.2	31
ESS35	LPK03 ESS35	Mastuxet Brook & Tribs	RI0008039R-11	Pawcatuck River & Tribs	Westerly	1.3	34
ESS36	WRB02 ESS36	Wood River & Tribs	RI0008040R-16C	Wood River & Tribs	Hopkinton	88.3	48
ESS37	ESS37	White Brook	RI0008039R-26	Pawcatuck River & Tribs	Richmond	2.3	55
ESS38	ESS38	Taney Brook	RI0008039R-23	Pawcatuck River & Tribs	Richmond	1.8	63
ESS39	ESS39	Glen Rock Brook & Tribs	RI0008039R-09	Pawcatuck River & Tribs	South Kingstown	3.9	135

Table 2. Biomonitoring stations sampled by ESS in 2002

Station Name	Alter-native Station Names	Official State River Name	Rhode Island Waterbody ID Number	Watershed Basin Name	Town	Water-shed Size (mi^2)	Elevation (ft)
ESS40	PAW35 ESS40	Chipuxet River	RI0008039R-06C	Pawcatuck River & Tribs	South Kingstown	10.0	93
ESS41	ESS41	Chipuxet River & Tribs	RI0008039R-06A	Pawcatuck River & Tribs	Exeter	4.0	127
ESS42	BGR10 BL07 ESS42	Big River & Tribs	RI0006012R-02	Big River & Tribs	West Greenwich	22.5	250
ESS43	UMR03 ESS43 BL22	Bucks Horn Brook & Tribs	RI0005011R-01	Moosup River & Tribs	Coventry	8.4	408
ESS44	UFM01near ESS44 BL15	Keach Brook & Tribs	RI0005047R-02	Tribs to the Five Mile	Burrillville	0.6	549
ESS45	ESS45	Adamsville Brook & Tribs	RI0009041R-01	Adamsville Brook & Tribs	Tiverton	8.1	21

Table 3. Biomonitoring stations sampled by ESS in 2003

Station Name	Alter-native Station Names	Official State River Name	Rhode Island Waterbody ID Number	Watershed Basin Name	Town	Water-shed Size (mi^2)	Elevation (ft)
ESS01	MLL10near BSN02 ESS01 BL01	Abbott Run Brook North & Tribs	RI0001006R-01A	Abbott Run Brook & Tribs	Cumberland	18.1	129
ESS02	CLR06 ESS02 BL23	Clear River	RI0001002R-05D	Branch River & Tribs	Burrillville	45.4	318
ESS03	CLR02 ESS03 BL20	Pascoag River	RI0001002R-09	Branch River & Tribs	Burrillville	8.5	374
ESS06	CLR01 ESS06	Brandy Brook & Tribs	RI0001002R-02	Branch River & Tribs	Glocester	3.4	462
ESS07	CLR11 DRY09 ESS07	Mowry Brook & Tribs	RI0001002R-18	Branch River & Tribs	Burrillville	1.4	419
ESS08	ESS08	Chepachet River & Tribs	RI0001002R-03	Branch River & Tribs	Burrillville	19.4	343
ESS09	BNC09 ESS09	Tucker Brook & Tribs	RI0001002R-21	Branch River & Tribs	Burrillville	0.9	304
ESS10	BNC03 ESS10	Tarkiln Brook & Tribs	RI0001002R-13B	Branch River & Tribs	Burrillville	9.2	279
ESS12	ESS12	Catamint Brook	RI0001006R-07	Abbott Run Brook & Tribs	Cumberland	3.5	169
ESS14	ESS14 BL11	Dundery Brook	RI0010048R-02C	Southeast Coastal Ponds	Little Compton	2.2	9
ESS15	ESS15 BL05	Bailey's Brook & Tribs	RI0007035R-01	Aquidneck Water Supply Tribs	Middletown	2.4	23
ESS16	BB05 ESS16	Buckeye Brook & Tribs	RI0007024R-01	Upper Narragansett Bay	Warwick	3.0	31
ESS17	ESS17	Hardig Brook & Tribs	RI0007025R-01	Greenwich Bay	Warwick	5.6	9
ESS18	ESS18 BL13	Hunt River	RI0007028R-03C	Potowomut River	Warwick	16.8	43
ESS19	ESS19 BL14 RWU23	Jamestown Brook	RI0007036R-01	Jamestown Water Supply	Jamestown	0.8	62
ESS21	ESS21 BL16	Maidford River	RI0007035R-02A	Aquidneck Water Supply Tribs	Middletown	1.9	70
ESS22	PAW12 ESS22 BL03 RWU04	Ashaway River & Tribs	RI0008039R-02A	Pawcatuck River & Tribs	Hopkinton	28.2	50
ESS23	PAW28 ESS23 BL06	Beaver River & Tribs	RI0008039R-03	Pawcatuck River & Tribs	Richmond	11.9	95

Table 3. Biomonitoring stations sampled by ESS in 2003							
Station Name	**Alter-native Station Names**	**Official State River Name**	**Rhode Island Waterbody ID Number**	**Watershed Basin Name**	**Town**	**Water-shed Size (mi^2)**	**Elevation (ft)**
ESS24	WRB04 ESS24 BL08	Canonchet Brook & Tribs	RI0008040R-04B	Wood River & Tribs	Hopkinton	6.6	71
ESS25	PAW05 ESS25 BL09	Chipuxet River & Tribs	RI0008039R-06B	Pawcatuck River & Tribs	Exeter	7.1	103
ESS26	WRB17 ESS26	Falls River & Tribs	RI0008040R-07	Wood River & Tribs	Exeter	35.2	171 (121 GE)
ESS27	PAW20 ESS27 BL17	Meadow Brook & Tribs	RI0008039R-13	Pawcatuck River & Tribs	Richmond	5.1	79
ESS28	WRB18 ESS28 BL19	Parris Brook & Tribs	RI0008040R-13	Wood River & Tribs	Exeter	6.6	136
ESS29	QNAB ESS29 BL21	Queens River & Tribs	RI0008039R-21C	Pawcatuck River & Tribs	Exeter	19.3	133
ESS30	PAW04 ESS30 BL24	Tomaquag Brook & Tribs	RI0008039R-24	Pawcatuck River & Tribs	Hopkinton	6.7	38
ESS31	WRB15 ESS31 PAW47 WD-REF	Wood River	RI0008040R-16B	Wood River & Tribs	Hopkinton	54.6	125
ESS32	WRB-E ESS32	Canonchet Brook & Tribs	RI0008040R-04A	Wood River & Tribs	Hopkinton	0.1	91
ESS34	ESS34	Mile Brook	RI0008039R-14	Pawcatuck River & Tribs	Hopkinton	1.2	31
ESS35	LPK03 ESS35	Mastuxet Brook & Tribs	RI0008039R-11	Pawcatuck River & Tribs	Westerly	1.3	34
ESS36	WRB02 ESS36	Wood River & Tribs	RI0008040R-16C	Wood River & Tribs	Hopkinton	88.3	48
ESS37	ESS37	White Brook	RI0008039R-26	Pawcatuck River & Tribs	Richmond	2.3	55
ESS38	ESS38	Taney Brook	RI0008039R-23	Pawcatuck River & Tribs	Richmond	1.8	63
ESS39	ESS39	Glen Rock Brook & Tribs	RI0008039R-09	Pawcatuck River & Tribs	South Kingstown	3.9	135
ESS40	PAW35 ESS40	Chipuxet River	RI0008039R-06C	Pawcatuck River & Tribs	South Kingstown	10.0	93
ESS41	ESS41	Chipuxet River & Tribs	RI0008039R-06A	Pawcatuck River & Tribs	Exeter	4.0	127
ESS42	BGR10 BL07 ESS42	Big River & Tribs	RI0006012R-02	Big River & Tribs	West Greenwich	22.5	250
ESS43	UMR03 ESS43 BL22	Bucks Horn Brook & Tribs	RI0005011R-01	Moosup River & Tribs	Coventry	8.4	408

Table 3. Biomonitoring stations sampled by ESS in 2003							
Station Name	**Alter-native Station Names**	**Official State River Name**	**Rhode Island Waterbody ID Number**	**Watershed Basin Name**	**Town**	**Water-shed Size (mi^2)**	**Elevation (ft)**
ESS44	UFM01near ESS44 BL15	Keach Brook & Tribs	RI0005047R-02	Tribs to the Five Mile	Burrillville	0.6	549
ESS45	ESS45	Adamsville Brook & Tribs	RI0009041R-01	Adamsville Brook & Tribs	Tiverton	8.1	21
ESS50	ESS50	Mosquitohawk Brook & Tribs	RI0006015R-18	Scituate Reservoir	Scituate	3.0	362
ESS51	WRB03 ESS51	Wood River & Tribs	RI0008040R-16C	Wood River & Tribs	Richmond	84.6	50
ESS52	QN01 ESS52	Usquepaug River	RI0008039R-25	Pawcatuck River & Tribs	South Kingstown	36.0	90
ESS53	ESS53	White Horn Brook & Tribs	RI0008039R-27B	Pawcatuck River & Tribs	South Kingstown	3.9	98
ESS54	ESS54	Mill River	RI0001003R-03		Woonsocket	33.4	140
ESS55	ESS55	Indian Run Brook & Tribs	RI0010045R-02	Saugatucket River & Tribs	South Kingstown	1.9	34

Table 4. Biomonitoring stations sampled by ESS in 2004 (Wood River Basin)							
Station Name	**Alter-native Station Names**	**Official State River Name**	**Rhode Island Waterbody ID Number**	**Watershed Basin Name**	**Town**	**Water-shed Size (mi^2)**	**Elevation (ft)**
ESS02	CLR06 ESS02 BL23	Clear River	RI0001002R-05D	Branch River & Tribs	Burrillville	45.4	318
ESS03	CLR02 ESS03 BL20	Pascoag River	RI0001002R-09	Branch River & Tribs	Burrillville	8.5	374
ESS14	ESS14 BL11	Dundery Brook	RI0010048R-02C	Southeast Coastal Ponds	Little Compton	2.2	9
ESS15	ESS15 BL05	Bailey's Brook & Tribs	RI0007035R-01	Aquidneck Water Supply Tribs	Middletown	2.4	23
ESS16	BB05 ESS16	Buckeye Brook & Tribs	RI0007024R-01	Upper Narragansett Bay	Warwick	3.0	31
ESS19	ESS19 BL14 RWU23	Jamestown Brook	RI0007036R-01	Jamestown Water Supply	Jamestown	0.8	62
ESS20	AI01near ESS20	Lawton Brook	RI0007035R-04	Aquidneck Water Supply Tribs	Portsmouth	2.7	92
ESS21	ESS21 BL16	Maidford River	RI0007035R-02A	Aquidneck Water Supply Tribs	Middletown	1.9	70
ESS35	LPK03 ESS35	Mastuxet Brook & Tribs	RI0008039R-11	Pawcatuck River & Tribs	Westerly	1.3	34
ESS40	PAW35 ESS40	Chipuxet River	RI0008039R-06C	Pawcatuck River & Tribs	South Kingstown	10.0	93
ESS41	ESS41	Chipuxet River & Tribs	RI0008039R-06A	Pawcatuck River & Tribs	Exeter	4.0	127
ESS45	ESS45	Adamsville Brook & Tribs	RI0009041R-01	Adamsville Brook & Tribs	Tiverton	8.1	21
ESS54	ESS54	Mill River	RI0001003R-03	Blackstone River & Tribs	Woonsocket	33.4	140
WRB01	WRB01 PAW46	Wood River & Tribs	RI0008040R-16D	Wood River & Tribs	Richmond	88.4	59
WRB02	WRB02 ESS36	Wood River & Tribs	RI0008040R-16D	Wood River & Tribs	Hopkinton	88.3	48
WRB03	WRB03 ESS51	Wood River & Tribs	RI0008040R-16C	Wood River & Tribs	Richmond	84.6	50
WRB04	WRB04 ESS24 BL08	Canonchet Brook & Tribs	RI0008040R-04B	Wood River & Tribs	Hopkinton	6.6	66
WRB05	WRB05	Canonchet Brook & Tribs	RI0008040R-04B	Wood River & Tribs	Hopkinton	5.8	74
WRB06	WRB06	Canonchet Brook & Tribs	RI0008040R-04B	Wood River & Tribs	Hopkinton	5.0	77
WRB07	WRB07	Canonchet Brook & Tribs	RI0008040R-04A	Wood River & Tribs	Hopkinton	0.4	112

Table 4. Biomonitoring stations sampled by ESS in 2004 (Wood River Basin)							
Station Name	**Alter-native Station Names**	**Official State River Name**	**Rhode Island Waterbody ID Number**	**Watershed Basin Name**	**Town**	**Water-shed Size (mi^2)**	**Elevation (ft)**
WRB08	WRB08	Wood River & Tribs	RI0008040R-16C	Wood River & Tribs	Hopkinton	73.5	70
WRB09	WRB09	Brushy Brook & Tribs	RI0008040R-03C	Wood River & Tribs	Hopkinton	11.8	97
WRB10	WRB10	Moscow Brook & Tribs	RI0008040R-12	Wood River & Tribs	Hopkinton	3.9	291
WRB11	WRB11	Moscow Brook & Tribs	RI0008040R-12	Wood River & Tribs	Hopkinton	5.5	208
WRB12	WRB12	Brushy Brook & Tribs	RI0008040R-03A	Wood River & Tribs	Hopkinton	3.0	155
WRB13	WRB13	Canob Brook	RI0008040R-23	Wood River & Tribs	Richmond	0.4	137
WRB14	WRB14	Wood River	RI0008040R-16B	Wood River & Tribs	Richmond	57.1	107
WRB15	WRB15 ESS31 PAW47 WD-REF	Wood River	RI0008040R-16B	Wood River & Tribs	Hopkinton	54.6	125
WRB16	WRB16	Baker Brook	RI0008040R-18	Wood River & Tribs	Richmond	1.6	196
WRB17	WRB17 ESS26	Wood River & Tribs	RI0008040R-16A	Wood River & Tribs	Exeter	35.2	162
WRB18	WRB18 ESS28 BL19	Parris Brook & Tribs	RI0008040R-13	Wood River & Tribs	Exeter	6.6	136
WRB19	WRB19	Woody Hill Brook & Tribs	RI0008040R-17	Wood River & Tribs	Exeter	0.9	237
WRB20	WRB20	Parris Brook & Tribs	RI0008040R-13	Wood River & Tribs	Exeter	2.8	268
WRB21	WRB21	Parris Brook & Tribs	RI0008040R-13	Wood River & Tribs	Exeter	1.6	313
WRB22	WRB22 BL12	Falls River & Tribs	RI0008040R-07	Wood River & Tribs	Exeter	19.1	144
WRB23	WRB23	Breakheart Brook & Tribs	RI0008040R-02	Wood River & Tribs	Exeter	6.6	192
WRB24	WRB24	Roaring Brook	RI0008040R-15	Wood River & Tribs	Exeter	2.7	351
WRB25	WRB25	Roaring Brook	RI0008040R-15	Wood River & Tribs	Exeter	1.4	352
WRB26	WRB26	Breakheart Brook & Tribs	RI0008040R-02	Wood River & Tribs	West Greenwich	2.4	361
WRB27	WRB27	Phillips Brook & Tribs	RI0008040R-14	Wood River & Tribs	West Greenwich	1.8	260
WRB28	WRB28	Acid Factory Brook & Tribs	RI0008040R-01	Wood River & Tribs	West Greenwich	1.2	265
WRB29	WRB29	Phillips Brook & Tribs	RI0008040R-14	Wood River & Tribs	West Greenwich	0.7	424
WRB30	WRB30	Coney Brook & Tribs	RI0008040R-05	Wood River & Tribs	West Greenwich	0.5	429

Table 4. Biomonitoring stations sampled by ESS in 2004 (Wood River Basin)							
Station Name	**Alter-native Station Names**	**Official State River Name**	**Rhode Island Waterbody ID Number**	**Watershed Basin Name**	**Town**	**Water-shed Size (mi^2)**	**Elevation (ft)**
WRB31	WRB31	Coney Brook & Tribs	RI0008040R-05	Wood River & Tribs	West Greenwich	2.4	346
WRB32	WRB32	Falls River & Tribs	RI0008040R-07	Wood River & Tribs	West Greenwich	9.3	343

Table 5. Biomonitoring stations sampled by ESS in 2005 (Pawcatuck River Basin)							
Station Name	**Alter-native Station Names**	**Official State River Name**	**Rhode Island Waterbody ID Number**	**Watershed Basin Name**	**Town**	**Water-shed Size (mi^2)**	**Elevation (ft)**
BR01	BR01	Blackstone River	RI0001003R-01B	Blackstone River & Tribs	Pawtucket	474.2	43
BR02	BR02	Blackstone River	RI0001003R-01B	Blackstone River & Tribs	Central Falls	445.2	49
ESS16	BB05 ESS16	Buckeye Brook & Tribs	RI0007024R-01	Upper Narragansett Bay	Warwick	3.0	31
PAW01	PAW01	Pawcatuck River & Tribs	RI0008039R-18E	Pawcatuck River & Tribs	Westerly	292.0	15
PAW02	PAW02	Pawcatuck River & Tribs	RI0008039R-18C	Pawcatuck River & Tribs	Richmond	99.3	56
PAW03	PAW03	Pawcatuck River	RI0008039R-18A	Pawcatuck River & Tribs	Richmond	72.3	94
PAW04	PAW04 ESS30 BL24	Tomaquag Brook & Tribs	RI0008039R-24	Pawcatuck River & Tribs	Hopkinton	6.7	38
PAW05	PAW05 ESS25 BL09	Chipuxet River & Tribs	RI0008039R-06B	Pawcatuck River & Tribs	Exeter	7.1	103
PAW07	PAW07	Beaver River & Tribs	RI0008039R-03	Pawcatuck River & Tribs	Richmond	0.5	177
PAW08	PAW08	Tomaquag Brook & Tribs	RI0008039R-24	Pawcatuck River & Tribs	Hopkinton	5.5	44
PAW09	PAW09	Chickasheen Brook & Tribs	RI0008039R-05B	Pawcatuck River & Tribs	South Kingstown	3.9	111
PAW10	PAW10	Beaver River & Tribs	RI0008039R-03	Pawcatuck River & Tribs	Richmond	4.7	258
PAW11	PAW11	Mile Brook	RI0008039R-14	Pawcatuck River & Tribs	Hopkinton	1.1	35
PAW12	PAW12 ESS22 BL03 RWU04	Ashaway River & Tribs	RI0008039R-02A	Pawcatuck River & Tribs	Hopkinton	28.2	50
PAW13	PAW13	Parmenter Brook & Tribs	RI0008039R-37	Pawcatuck River & Tribs	Hopkinton	2.5	104
PAW14	PAW14	Aguntaug Brook	RI0008039R-35	Pawcatuck River & Tribs	Westerly	9.2	33
PAW15	PAW15	Tomaquag Brook & Tribs	RI0008039R-24	Pawcatuck River & Tribs	Hopkinton	2.9	85
PAW17	PAW17	Perry Healy Brook & Tribs	RI0008039R-19	Pawcatuck River & Tribs	Charlestown	2.4	72
PAW18	PAW18	Cedar Swamp Brook & Tribs	RI0008039R-04	Pawcatuck River & Tribs	Charlestown	4.8	48
PAW20	PAW20 ESS27 BL17	Meadow Brook & Tribs	RI0008039R-13	Pawcatuck River & Tribs	Richmond	5.1	79
PAW23	PAW23	Meadow Brook & Tribs	RI0008039R-13	Pawcatuck River & Tribs	Richmond	0.8	253
PAW25	PAW25	Taney Brook	RI0008039R-23	Pawcatuck River & Tribs	Richmond	1.6	66

Table 5. Biomonitoring stations sampled by ESS in 2005 (Pawcatuck River Basin)							
Station Name	**Alter-native Station Names**	**Official State River Name**	**Rhode Island Waterbody ID Number**	**Watershed Basin Name**	**Town**	**Water-shed Size (mi^2)**	**Elevation (ft)**
PAW26	PAW26	Pasquiset Brook	RI0008039R-17	Pawcatuck River & Tribs	Charlestown	6.0	96
PAW27	PAW27	Pasquiset Brook	RI0008039R-17	Pawcatuck River & Tribs	Charlestown	5.2	94
PAW28	PAW28 ESS23 BL06	Beaver River & Tribs	RI0008039R-03	Pawcatuck River & Tribs	Richmond	11.9	94
PAW29	PAW29	Beaver River & Tribs	RI0008039R-03	Pawcatuck River & Tribs	Richmond	9.2	116
PAW30	PAW30	Beaver River & Tribs	RI0008039R-03	Pawcatuck River & Tribs	Richmond	1.8	331
PAW31	PAW31	Chickasheen Brook & Tribs	RI0008039R-05B	Pawcatuck River & Tribs	South Kingstown	4.8	98
PAW32	PAW32	Chickasheen Brook	RI0008039R-05A	Pawcatuck River & Tribs	Exeter	0.8	143
PAW35	PAW35 ESS40	Chipuxet River	RI0008039R-06C	Pawcatuck River & Tribs	South Kingstown	10.0	93
PAW36	PAW36	Chipuxet River & Tribs	RI0008039R-06B	Pawcatuck River & Tribs	Exeter	6.4	113
PAW37	PAW37	Chipuxet River & Tribs	RI0008039R-06A	Pawcatuck River & Tribs	North Kingstown	3.6	129
PAW38	PAW38	Pawcatuck River & Tribs	RI0008039R-18C	Pawcatuck River & Tribs	Westerly	217.0	54
PAW39	PAW39	Pawcatuck River & Tribs	RI0008039R-18E	Pawcatuck River & Tribs	Westerly	238.9	51
PAW41	PAW41	Pawcatuck River & Tribs	RI0008039R-18B	Pawcatuck River & Tribs	Richmond	91.5	62
PAW42	PAW42	Pawcatuck River & Tribs	RI0008039R-18C	Pawcatuck River & Tribs	Charlestown	95.2	63
PAW43	PAW43	Pawcatuck River & Tribs	RI0008039R-18C	Pawcatuck River & Tribs	Charlestown	107.3	58
PAW44	PAW44	Pawcatuck River & Tribs	RI0008039R-18C	Pawcatuck River & Tribs	Charlestown	204.3	44
PAW45	PAW45	White Brook	RI0008039R-26	Pawcatuck River & Tribs	Richmond	1.9	57
PAW46	WRB01 PAW46	Wood River & Tribs	RI0008040R-16D	Wood River & Tribs	Hopkinton	88.4	59
PAW47	WRB15 ESS31 PAW47 WD-REF	Wood River	RI0008040R-16B	Wood River & Tribs	Hopkinton	54.6	125
WRB10	WRB10	Moscow Brook & Tribs	RI0008040R-12	Wood River & Tribs	Hopkinton	3.9	291
WRB11	WRB11	Moscow Brook & Tribs	RI0008040R-12	Wood River & Tribs	Hopkinton	5.5	208
WRB26	WRB26	Breakheart Brook & Tribs	RI0008040R-02	Wood River & Tribs	West Greenwich	2.4	361

Table 6. Biomonitoring stations sampled by ESS in 2006 (Flat, Queen, Big, SBP and LPK)							
Station Name	**Alter-native Station Names**	**Official State River Name**	**Rhode Island Waterbody ID Number**	**Watershed Basin Name**	**Town**	**Water-shed Size (mi^2)**	**Elevation (ft)**
ESS09	BNC09 ESS09	Tucker Brook & Tribs	RI0001002R-21	Branch River & Tribs	Burrillville	0.9	304
BGR01	BGR01	Bear Brook & Tribs	RI0006012R-01	Big River & Tribs	Coventry	3.9	263
ESS43	UMR03 ESS43 BL22	Bucks Horn Brook & Tribs	RI0005011R-01	Moosup River & Tribs	Coventry	8.4	408
FL01	FL01	Boyd Brook	RI0006013R-01	Flat River Res & Tribs	Coventry	1.6	278
FL03	FL03	Flat River & Tribs	RI0006013R-02	Flat River Res & Tribs	Coventry	9.1	276
FL05	FL05	Whaley Brook & Tribs	RI0006013R-09	Flat River Res & Tribs	Coventry	1.2	295
FL06	FL06	Negro Sawmill Brook	RI0006013R-04	Flat River Res & Tribs	Coventry	4.0	347
FL07	FL07	Quidneck Brook & Tribs	RI0006013R-08A	Flat River Res & Tribs	Coventry	0.2	569
FL08	FL08	Quidneck Brook & Tribs	RI0006013R-08A	Flat River Res & Tribs	Coventry	3.1	424
FL09	FL09	Unnamed Trib #2 to Flat River Reservoir	RI0006013R-12	Flat River Res & Tribs	Coventry	18.7	339
SBP02	SBP02	Mishnock River & Tribs	RI0006014R-02	Pawtuxet River South Branch & Tribs	Coventry	3.1	252
SBP03	SBP03	Tribs to Tiogue Lake	RI0006014R-05	Pawtuxet River South Branch & Tribs	Coventry	0.4	237
SBP04	SBP04	Pawtuxet River South Branch	RI0006014R-04A	Pawtuxet River South Branch & Tribs	Coventry	63.0	220
SBPAA	SBPAA	Unnamed Trib #3 to South Branch Pawtuxet River	RI0006014R-08	Pawtuxet River South Branch & Tribs	Coventry	0.7	214
QN05	QN05	Locke Brook & Tribs	RI0008039R-10	Pawcatuck River & Tribs	Exeter	3.0	273
QN06	QN06	Locke Brook & Tribs	RI0008039R-10	Pawcatuck River & Tribs	Exeter	4.2	158
QN07	QN07	Queens River & Tribs	RI0008039R-21C	Pawcatuck River & Tribs	Exeter	18.1	152
QN08	QN08	Sodom Brook	RI0008039R-22	Pawcatuck River & Tribs	Exeter	8.1	169
QN09	QN09	Queens River & Tribs	RI0008039R-21A	Pawcatuck River & Tribs	Exeter	3.7	160
QN10	QN10	Queens Fort Brook & Tribs	RI0008039R-31B	Pawcatuck River & Tribs	Exeter	3.6	163

Table 6. Biomonitoring stations sampled by ESS in 2006 (Flat, Queen, Big, SBP and LPK)							
Station Name	**Alter-native Station Names**	**Official State River Name**	**Rhode Island Waterbody ID Number**	**Watershed Basin Name**	**Town**	**Water-shed Size (mi^2)**	**Elevation (ft)**
QN11	QN11	Queens River & Tribs	RI0008039R-21A	Pawcatuck River & Tribs	Exeter	2.8	195
QN12	QN12	Queens River & Tribs	RI0008039R-21A	Pawcatuck River & Tribs	Exeter	1.4	308
QN13	QN13	Dutemple Brook	RI0008039R-30	Pawcatuck River & Tribs	Exeter	0.9	218
QN14	QN14	Fisherville Brook & Tribs	RI0008039R-07	Pawcatuck River & Tribs	Exeter	3.5	229
QNAA	QNAA	Queens River & Tribs	RI0008039R-21C	Pawcatuck River & Tribs	Exeter	0.8	174
QNAB	QNAB ESS29 BL21	Queens River & Tribs	RI0008039R-21C	Pawcatuck River & Tribs	Exeter	19.3	138
WD-REF	WRB15 ESS31 PAW47 WD-REF	Wood River	RI0008040R-16B	Wood River & Tribs	Hopkinton	54.6	125
ESS15	ESS15 BL05	Bailey's Brook & Tribs	RI0007035R-01	Aquidneck Water Supply Tribs	Middletown	2.4	23
ESS21	ESS21 BL16	Maidford River	RI0007035R-02A	Aquidneck Water Supply Tribs	Middletown	1.9	70
ESS20	AI01near ESS20	Lawton Brook	RI0007035R-04	Aquidneck Water Supply Tribs	Portsmouth	2.7	92
QN01	QN01 ESS52	Usquepaug River	RI0008039R-25	Pawcatuck River & Tribs	Richmond	36.1	102
FL02	FL02	Boyd Brook	RI0006013R-01	Flat River Res & Tribs	Scituate	1.2	313
QN02	QN02	Glen Rock Brook & Tribs	RI0008039R-09	Pawcatuck River & Tribs	South Kingstown	0.2	161
QN03	QN03	Glen Rock Brook & Tribs	RI0008039R-09	Pawcatuck River & Tribs	South Kingstown	2.5	211
QN04	QN04	Sherman Brook	RI0008039R-34	Pawcatuck River & Tribs	South Kingstown	1.0	152
ESS45	ESS45	Adamsville Brook & Tribs	RI0009041R-01	Adamsville Brook & Tribs	Tiverton	8.1	21
BGR03	BGR03	Nooseneck River & Tribs	RI0006012R-05	Big River & Tribs	West Greenwich	3.3	377
BGR04	BGR04	Raccoon Brook	RI0006012R-06	Big River & Tribs	West Greenwich	2.0	349
BGR05	BGR05	Congdon River & Tribs	RI0006012R-04	Big River & Tribs	West Greenwich	4.4	321
BGR06	BGR06	Congdon River & Tribs	RI0006012R-04	Big River & Tribs	West Greenwich	0.5	291
BGR07	BGR07	Carr River & Tribs	RI0006012R-03	Big River & Tribs	West Greenwich	0.6	294

Table 6. Biomonitoring stations sampled by ESS in 2006 (Flat, Queen, Big, SBP and LPK)							
Station Name	**Alter-native Station Names**	**Official State River Name**	**Rhode Island Waterbody ID Number**	**Watershed Basin Name**	**Town**	**Water-shed Size (mi^2)**	**Elevation (ft)**
BGR08	BGR08	Carr River & Tribs	RI0006012R-03	Big River & Tribs	West Greenwich	6.7	255
BGR09	BGR09	Nooseneck River & Tribs	RI0006012R-05	Big River & Tribs	West Greenwich	8.2	285
QN15	QN15	Fisherville Brook & Tribs	RI0008039R-07	Pawcatuck River & Tribs	West Greenwich	1.2	268
SBP01	SBP01	Mishnock River & Tribs	RI0006014R-02	Pawtuxet River South Branch & Tribs	West Greenwich	0.3	251
SBP05	SBP05	Hawkinson Brook & Tribs	RI0006014R-01	Pawtuxet River South Branch &	West Warwick	0.7	159
LPK01	LPK01	Pawcatuck River & Tribs	RI0008039R-18E	Pawcatuck River & Tribs	Westerly	0.3	38
LPK02	LPK02	Mastuxet Brook & Tribs	RI0008039R-11	Pawcatuck River & Tribs	Westerly	0.2	75
LPK03	LPK03 ESS35	Mastuxet Brook & Tribs	RI0008039R-11	Pawcatuck River & Tribs	Westerly	1.3	34
BGRAA	BGRAA	Big River & Tribs	RI0006012R-02	Big River & Tribs	West Greenwich	~15	251

Table 7. Biomonitoring stations sampled by ESS in 2007 (Scituate and Pawtuxet River Basins)							
Station Name	**Alter-native Station Names**	**Official State River Name**	**Rhode Island Waterbody ID Number**	**Watershed Basin Name**	**Town**	**Water-shed Size (mi^2)**	**Elevation (ft)**
BGR09	BGR09	Nooseneck River & Tribs	RI0006012R-05	Big River & Tribs	West Greenwich	8.2	285
BNC01	BNC01	Branch River & Tribs	RI0001002R-01B	Branch River & Tribs	North Smithfield	92.8	188
BNC02	BNC02	Branch River & Tribs	RI0001002R-01A	Branch River & Tribs	Burrillville	0.2	299
BNC03	BNC03 ESS10	Tarkiln Brook & Tribs	RI0001002R-13B	Branch River & Tribs	Burrillville	9.2	261
BSN01	MLL09 BSN01 BL02	Abbott Run Brook South & Tribs	RI0001006R-01B	Abbott Run Brook & Tribs	North Attleboro, MA	23.9	83
BSN02	MLL10near BSN02 ESS01 BL01	Abbott Run Brook North & Tribs	RI0001006R-01A	Abbott Run Brook & Tribs	Cumberland	18.1	129
CLR01	CLR01 ESS06	Brandy Brook & Tribs	RI0001002R-02	Branch River & Tribs	Glocester	3.4	462
CLR02	CLR02 ESS03 BL20	Pascoag River	RI0001002R-09	Branch River & Tribs	Burrillville	8.5	374
ESS45	ESS45	Adamsville Brook & Tribs	RI0009041R-01	Adamsville Brook & Tribs	Tiverton	8.1	21
FL03	FL03	Flat River & Tribs	RI0006013R-02	Flat River Res & Tribs	Coventry	9.1	276
NBP02	NBP02	Pawtuxet River North Branch	RI0006016R-06B	Pawtuxet River North Branch & Tribs	Scituate	101.0	159
PAW10	PAW10	Beaver River & Tribs	RI0008039R-03	Pawcatuck River & Tribs	Richmond	4.7	258
PAW12	PAW12 ESS22 BL03 RWU04	Ashaway River & Tribs	RI0008039R-02A	Pawcatuck River & Tribs	Hopkinton	28.2	50
PAW23	PAW23	Meadow Brook & Tribs	RI0008039R-13	Pawcatuck River & Tribs	Richmond	0.8	253
PAW32	PAW32	Chickasheen Brook	RI0008039R-05A	Pawcatuck River & Tribs	Exeter	0.8	143
PBR02	PBR02	Hemlock Brook & Tribs	RI0006015R-10	Scituate Reservoir Tribs	Foster	8.7	408
PBR03		Dolly Cole Brook	RI0006015R-08	Scituate Reservoir Tribs	Foster	4.9	359
PBR04		Windsor Brook	RI0006015R-30	Scituate Reservoir Tribs	Foster	4.3	402
PCT01	PCT01	Pocasset River & Tribs	RI0006018R-03A	Pocasset River & Tribs	Johnston	4.7	107

Table 7. Biomonitoring stations sampled by ESS in 2007 (Scituate and Pawtuxet River Basins)							
Station Name	**Alter-native Station Names**	**Official State River Name**	**Rhode Island Waterbody ID Number**	**Watershed Basin Name**	**Town**	**Water-shed Size (mi^2)**	**Elevation (ft)**
PCT02	PCT02	Pocasset River & Tribs	RI0006018R-03A	Pocasset River & Tribs	Johnston	8.6	74
PCT03	PCT03	Simmons Brook & Tribs	RI0006018R-04	Pocasset River & Tribs	Johnston	5.9	88
PCT04	PCT04	Pocasset River & Tribs	RI0006018R-03A	Pocasset River & Tribs	Johnston	15.5	81
PCT05	PCT05	Pocasset River & Tribs	RI0006018R-03B	Pocasset River & Tribs	Cranston	18.1	37
PCT06	PCT06	Pocasset River & Tribs	RI0006018R-03B	Pocasset River & Tribs	Cranston	18.8	28
PXT01	PXT01	Meshanticut Brook & Tribs	RI0006017R-02	Pawtuxet River Main Stem & Tribs	Cranston	9.0	47
PXT02	PXT02	Furnace Hill Brook & Tribs	RI0006017R-01	Pawtuxet River Main Stem & Tribs	Cranston	4.3	59
QN03	QN03	Glen Rock Brook & Tribs	RI0008039R-09	Pawcatuck River & Tribs	South Kingstown	2.5	211
QN06	QN06	Locke Brook & Tribs	RI0008039R-10	Pawcatuck River & Tribs	Exeter	4.2	158
QN08	QN08	Sodom Brook	RI0008039R-22	Pawcatuck River & Tribs	Exeter	8.1	169
QN15	QN15	Fisherville Brook & Tribs	RI0008039R-07	Pawcatuck River & Tribs	West Greenwich	1.2	268
RMR02	RMR02	Huntinghouse Brook	RI0006015R-11	Scituate Reservoir Tribs	Scituate	6.2	328
SBP04	SBP04	Pawtuxet River South Branch	RI0006014R-04A	Pawtuxet River South Branch & Tribs	Coventry	63.0	220
SCI01	SCI01	Wilbur Hollow Brook & Tribs	RI0006015R-29	Scituate Reservoir Tribs	Scituate	4.5	299
TEN01	TEN01	Ten Mile, Attleborough, MA	MA, n/a		Attleboro, MA	25.0	89
TEN02	TEN02	Ten Mile River & Tribs	RI0004009R-01A	Ten Mile River & Tribs	Pawtucket	42.1	60
UMR01	UMR01	Moosup River & Tribs	RI0005011R-03	Moosup River & Tribs	Coventry	24.5	344
UMR02	UMR02	Bucks Horn Brook & Tribs	RI0005011R-01	Moosup River & Tribs	Coventry	5.5	430
UMR03	UMR03 ESS43 BL22	Bucks Horn Brook & Tribs	RI0005011R-01	Moosup River & Tribs	Coventry	8.4	411
UMR04	UMR04	Moosup River & Tribs	RI0005011R-03	Moosup River & Tribs	Coventry	15.3	366
UMR05	UMR05	Moosup River & Tribs	RI0005011R-03	Moosup River & Tribs	Coventry	13.2	400
UMR06	UMR06	Moosup River & Tribs	RI0005011R-03	Moosup River & Tribs	Foster	4.3	445

Table 7. Biomonitoring stations sampled by ESS in 2007 (Scituate and Pawtuxet River Basins)							
Station Name	**Alter-native Station Names**	**Official State River Name**	**Rhode Island Waterbody ID Number**	**Watershed Basin Name**	**Town**	**Water-shed Size (mi^2)**	**Elevation (ft)**
WON01	WON01	Woonasquatucket River & Tribs	RI0002007R-10A	Woonasquatucket River & Tribs	Smithfield	4.9	256
WON02	WON02	Woonasquatucket River & Tribs	RI0002007R-10B	Woonasquatucket River & Tribs	Smithfield	34.4	143
WON03	WON03	Woonasquatucket River & Tribs	RI0002007R-10C	Woonasquatucket River & Tribs	Johnston	37.7	100
WON04	WON04	Woonasquatucket River & Tribs	RI0002007R-10C	Woonasquatucket River & Tribs	Johnston	44.3	62
WON05	WON05	Woonasquatucket River	RI0002007R-10D	Woonasquatucket River & Tribs	Providence	48.5	4
WRB04	WRB04 ESS24 BL08	Canonchet Brook & Tribs	RI0008040R-04B	Wood River & Tribs	Hopkinton	6.6	66
WRB05	WRB05	Canonchet Brook & Tribs	RI0008040R-04B	Wood River & Tribs	Hopkinton	5.8	74
WRB12	WRB12	Brushy Brook & Tribs	RI0008040R-03A	Wood River & Tribs	Hopkinton	3.0	155
WRB15	WRB15 ESS31 PAW47 WD-REF	Wood River	RI0008040R-16B	Wood River & Tribs	Hopkinton	54.6	125
WRB17	WRB17 ESS26	Wood River & Tribs	RI0008040R-16A	Wood River & Tribs	Exeter	35.2	162
WRB18	WRB18 ESS28 BL19	Parris Brook & Tribs	RI0008040R-13	Wood River & Tribs	Exeter	6.6	136
WRB22	WRB22 BL12	Falls River & Tribs	RI0008040R-07	Wood River & Tribs	Exeter	19.1	144
WRB23	WRB23	Breakheart Brook & Tribs	RI0008040R-02	Wood River & Tribs	Exeter	6.6	192

Table 8. Biomonitoring stations sampled by ESS in 2008 (CLR, BNC, WON MSK, BSN, MLL, UMR and SAU)

Station Name	Alter-native Station Names	Official State River Name	Rhode Island Waterbody ID Number	Watershed Basin Name	Town	Water-shed Size (mi^2)	Elevation (ft)
BNC01	BNC01	Branch River & Tribs	RI0001002R-01B	Branch River & Tribs	North Smithfield	92.8	188
BNC02	BNC02	Branch River & Tribs	RI0001002R-01A	Branch River & Tribs	Burrillville	0.2	299
BNC03	BNC03 ESS10	Tarkiln Brook & Tribs	RI0001002R-13B	Branch River & Tribs	Burrillville	9.2	261
BR02	BR02	Blackstone River	RI0001003R-01B	Blackstone River & Tribs	Central Falls	445.2	49
BSN01	MLL09 BSN01 BL02	Abbott Run Brook South & Tribs	RI0001006R-01B	Abbott Run Brook & Tribs	North Attleboro, MA	24.0	83
BSN02	MLL10near BSN02 ESS01 BL01	Abbott Run Brook North & Tribs	RI0001006R-01A	Abbott Run Brook & Tribs	Cumberland	18.1	129
BSN03	BSN03	Emerson Brook (Uxbridge, MA)	MA, n/a	Greater Blackstone River Basin	Uxbridge, MA	5.8	311
BSN04	BSN04	Emerson Brook (Uxbridge, MA)	MA, n/a	Greater Blackstone River Basin	Uxbridge, MA	7.5	272
BSN05	BSN05	Bacon Brook (Uxbridge, MA)	MA, n/a	Greater Blackstone River Basin	Uxbridge, MA	5.8	219
BSN06	BSN06 ESS11	Cherry Brook & Tribs	RI0001003R-02	Blackstone River & Tribs	Woonsocket	4.6	176
BSN07	BSN07	Crookfall Brook & Tribs	RI0001004R-01	Woonsocket Res #3 & all Tribs	Lincoln	5.7	207
BSN08	BSN08	Blackstone River	RI0001003R-01A	Blackstone River & Tribs	Lincoln	431.4	93
BSN09	BSN09	Blackstone River	RI0001003R-01A	Blackstone River & Tribs	Lincoln	433.8	87
CLR01	CLR01 ESS06	Brandy Brook & Tribs	RI0001002R-02	Branch River & Tribs	Glocester	3.4	462
CLR02	CLR02 ESS03 BL20	Pascoag River	RI0001002R-09	Branch River & Tribs	Burrillville	8.5	374
ESS45	ESS45	Adamsville Brook & Tribs	RI0009041R-01	Adamsville Brook & Tribs	Tiverton	8.1	21
HNT01	HNT01	Frenchtown Brook & Tribs	RI0007028R-01	Potowomut River	East Greenwich	6.5	139
HNT02	HNT02	Hunt River	RI0007028R-03A	Potowomut River	East Greenwich	5.8	57
HNT03	HNT03	Frenchtown Brook & Tribs	RI0007028R-01	Potowomut River	East Greenwich	7.0	78
HNT06	HNT06	Hunt River	RI0007028R-03C	Potowomut River	East Greenwich	16.8	60

Table 8. Biomonitoring stations sampled by ESS in 2008 (CLR, BNC, WON MSK, BSN, MLL, UMR and SAU)

Station Name	Alter-native Station Names	Official State River Name	Rhode Island Waterbody ID Number	Watershed Basin Name	Town	Water-shed Size (mi^2)	Elevation (ft)
MLL01	MLL01	Burnt Swamp Brook & Tribs	RI0001006R-06	Abbott Run Brook & Tribs	Cumberland	4.7	236
MLL02	MLL02	East Sneech Brook	RI0001006R-03	Abbott Run Brook & Tribs	Cumberland	7.9	167
MLL03	MLL03	Abbott Run Brook South & Tribs	RI0001006R-01B	Abbott Run Brook & Tribs	North Attleboro, MA	22.8	94
MLL04	MLL04	Millers River	RI0001006R-08	Abbott Run Brook & Tribs	Cumberland	1.1	98
MSK01	MSK01	Moshassuck River & Tribs	RI0003008R-01A	Moshassuck River & Tribs	Lincoln	4.8	109
MSK02	MSK02	Moshassuck River & Tribs	RI0003008R-01B	Moshassuck River & Tribs	Lincoln	7.8	48
MSK03	MSK03	Moshassuck River & Tribs	RI0003008R-01C	Moshassuck River & Tribs	Pawtucket	8.9	40
MSK04	MSK04	Moshassuck River & Tribs	RI0003008R-01C	Moshassuck River & Tribs	Pawtucket	10.6	32
MSK05	MSK05	Moshassuck River & Tribs	RI0003008R-01C	Moshassuck River & Tribs	Providence	22.9	17
MSK06	MSK06	West River & Tribs	RI0003008R-03C	Moshassuck River & Tribs	Providence	11.0	21
MSK07	MSK07	West River & Tribs	RI0003008R-03B	Moshassuck River & Tribs	North Providence	4.6	106
SAU01	SAU01	Saugatucket River & Tribs	RI0010045R-05B	Saugatucket River & Tribs	South Kingstown	15.1	20
TEN01	TEN01	Ten Mile, Attleborough, MA	MA, n/a		Attleboro, MA	25.0	89
TEN02	TEN02	Ten Mile River & Tribs	RI0004009R-01A	Ten Mile River & Tribs	Pawtucket	42.1	60
UMR01	UMR01	Moosup River & Tribs	RI0005011R-03	Moosup River & Tribs	Coventry	24.5	344
UMR02	UMR02	Bucks Horn Brook & Tribs	RI0005011R-01	Moosup River & Tribs	Coventry	5.5	430
UMR03	UMR03 ESS43 BL22	Bucks Horn Brook & Tribs	RI0005011R-01	Moosup River & Tribs	Coventry	8.4	411
UMR04	UMR04	Moosup River & Tribs	RI0005011R-03	Moosup River & Tribs	Coventry	15.3	366
UMR05	UMR05	Moosup River & Tribs	RI0005011R-03	Moosup River & Tribs	Coventry	13.2	400
UMR06	UMR06	Moosup River & Tribs	RI0005011R-03	Moosup River & Tribs	Foster	4.3	445
WON01	WON01	Woonasquatucket River & Tribs	RI0002007R-10A	Woonasquatucket River & Tribs	Smithfield	4.9	256

Table 8. Biomonitoring stations sampled by ESS in 2008 (CLR, BNC, WON MSK, BSN, MLL, UMR and SAU)

Station Name	Alter-native Station Names	Official State River Name	Rhode Island Waterbody ID Number	Watershed Basin Name	Town	Water-shed Size (mi^2)	Elevation (ft)
WON02	WON02	Woonasquatucket River & Tribs	RI0002007R-10B	Woonasquatucket River & Tribs	Smithfield	34.4	143
WON03	WON03	Woonasquatucket River & Tribs	RI0002007R-10C	Woonasquatucket River & Tribs	Johnston	37.7	100
WON04	WON04	Woonasquatucket River & Tribs	RI0002007R-10C	Woonasquatucket River & Tribs	Johnston	44.3	62
WON05	WON05	Woonasquatucket River	RI0002007R-10D	Woonasquatucket River & Tribs	Providence	48.5	4
WON06	WON06	Stillwater River & Tribs	RI0002007R-09	Woonasquatucket River & Tribs	Smithfield	8.7	275
WON10	WON10	Nine Foot Brook & Tribs	RI0002007R-11	Woonasquatucket River & Tribs	Smithfield	1.9	405
WON11	WON11	Latham Brook & Tribs	RI0002007R-05	Woonasquatucket River & Tribs	Smithfield	0.2	400
WRB15	WRB15 ESS31 PAW47 WD-REF	Wood River	RI0008040R-16B	Wood River & Tribs	Hopkington	54.6	125

Table 9. Biomonitoring stations sampled by ESS in 2009 (resamples for biocriteria development)							
Station Name	**Alter-native Station Names**	**Official State River Name**	**Rhode Island Waterbody ID Number**	**Watershed Basin Name**	**Town**	**Water-shed Size (mi^2)**	**Elevation (ft)**
BGR09	BGR09	Nooseneck River & Tribs	RI0006012R-05	Big River & Tribs	West Greenwich	8.2	285
BNC01	BNC01	Branch River & Tribs	RI0001002R-01B	Branch River & Tribs	North Smithfield	92.8	188
BSN01	MLL09 BSN01 BL02	Abbott Run Brook South & Tribs	RI0001006R-01B	Abbott Run Brook & Tribs	North Attleboro, MA	23.9	83
BSN03	BSN03	Emerson Brook (Uxbridge, MA)	MA, n/a	Greater Blackstone River Basin	Uxbridge, MA	5.8	311
BSN04	BSN04	Emerson Brook (Uxbridge, MA)	MA, n/a	Greater Blackstone River Basin	Uxbridge, MA	7.5	272
BSN05	BSN05	Bacon Brook (Uxbridge, MA)	MA, n/a	Greater Blackstone River Basin	Uxbridge, MA	5.8	219
BSN07	BSN07	Crookfall Brook & Tribs	RI0001004R-01	Woonsocket Res #3 & all Tribs	Lincoln	5.7	207
ESS17	ESS17	Hardig Brook & Tribs	RI0007025R-01	Greenwich Bay	Warwick	5.6	9
ESS45	ESS45	Adamsville Brook & Tribs	RI0009041R-01	Adamsville Brook & Tribs	Tiverton	8.1	21
FL03	FL03	Flat River & Tribs	RI0006013R-02	Flat River Res & Tribs	Coventry	9.1	276
HNT01	HNT01	Frenchtown Brook & Tribs	RI0007028R-01	Potowomut River	East Greenwich	6.5	139
HNT02	HNT02	Hunt River	RI0007028R-03A	Potowomut River	East Greenwich	5.8	57
HNT03	HNT03	Frenchtown Brook & Tribs	RI0007028R-01	Potowomut River	East Greenwich	7.0	78
HNT06	HNT06	Hunt River	RI0007028R-03C	Potowomut River	East Greenwich	16.8	60
MLL02	MLL02	East Sneech Brook	RI0001006R-03	Abbott Run Brook & Tribs	Cumberland	7.9	167
MLL03	MLL03	Abbott Run Brook South & Tribs	RI0001006R-01B	Abbott Run Brook & Tribs	North Attleboro, MA	22.8	94
MSK02	MSK02	Moshassuck River & Tribs	RI0003008R-01B	Moshassuck River & Tribs	Lincoln	7.8	48
MSK03	MSK03	Moshassuck River & Tribs	RI0003008R-01C	Moshassuck River & Tribs	Pawtucket	8.9	40
MSK04	MSK04	Moshassuck River & Tribs	RI0003008R-01C	Moshassuck River & Tribs	Pawtucket	10.6	32
MSK05	MSK05	Moshassuck River & Tribs	RI0003008R-01C	Moshassuck River & Tribs	Providence	22.9	17

Table 9. Biomonitoring stations sampled by ESS in 2009 (resamples for biocriteria development)							
Station Name	**Alter-native Station Names**	**Official State River Name**	**Rhode Island Waterbody ID Number**	**Watershed Basin Name**	**Town**	**Water-shed Size (mi^2)**	**Elevation (ft)**
MSK06	MSK06	West River & Tribs	RI0003008R-03C	Moshassuck River & Tribs	Providence	11.0	21
PAW02	PAW02	Pawcatuck River & Tribs	RI0008039R-18C	Pawcatuck River & Tribs	Richmond	99.3	56
PAW29	PAW29	Beaver River & Tribs	RI0008039R-03	Pawcatuck River & Tribs	Richmond	9.2	116
PBR02	PBR02	Hemlock Brook & Tribs	RI0006015R-10	Scituate Reservoir Tribs	Foster	8.7	408
PCT02	PCT02	Pocasset River & Tribs	RI0006018R-03A	Pocasset River & Tribs	Johnston	8.6	74
PCT03	PCT03	Simmons Brook & Tribs	RI0006018R-04	Pocasset River & Tribs	Johnston	5.9	88
PCT04	PCT04	Pocasset River & Tribs	RI0006018R-03A	Pocasset River & Tribs	Johnston	15.5	81
PCT05	PCT05	Pocasset River & Tribs	RI0006018R-03B	Pocasset River & Tribs	Cranston	18.1	37
PCT06	PCT06	Pocasset River & Tribs	RI0006018R-03B	Pocasset River & Tribs	Cranston	18.8	28
PXT01	PXT01	Meshanticut Brook & Tribs	RI0006017R-02	Pawtuxet River Main Stem & Tribs	Cranston	9.0	47
QN08	QN08	Sodom Brook	RI0008039R-22	Pawcatuck River & Tribs	Exeter	8.1	169
RMR02	RMR02	Huntinghouse Brook	RI0006015R-11	Scituate Reservoir Tribs	Scituate	6.2	328
TEN01	TEN01	Ten Mile, Attleborough, MA	MA, n/a		Attleboro, MA	25.0	89
TEN02	TEN02	Ten Mile River & Tribs	RI0004009R-01A	Ten Mile River & Tribs	Pawtucket	42.1	60
UMR01	UMR01	Moosup River & Tribs	RI0005011R-03	Moosup River & Tribs	Coventry	24.5	344
UMR04	UMR04	Moosup River & Tribs	RI0005011R-03	Moosup River & Tribs	Coventry	15.3	366
UMR05	UMR05	Moosup River & Tribs	RI0005011R-03	Moosup River & Tribs	Coventry	13.2	400
WON03	WON03	Woonasquatucket River & Tribs	RI0002007R-10C	Woonasquatucket River & Tribs	Johnston	37.7	100
WON04	WON04	Woonasquatucket River & Tribs	RI0002007R-10C	Woonasquatucket River & Tribs	Johnston	44.3	62
WON06	WON06	Stillwater River & Tribs	RI0002007R-09	Woonasquatucket River & Tribs	Smithfield	8.7	275
WRB05	WRB05	Canonchet Brook & Tribs	RI0008040R-04B	Wood River & Tribs	Hopkinton	5.8	74
WRB08	WRB08	Wood River & Tribs	RI0008040R-16C	Wood River & Tribs	Hopkinton	73.5	70

Table 9. Biomonitoring stations sampled by ESS in 2009 (resamples for biocriteria development)							
Station Name	**Alter-native Station Names**	**Official State River Name**	**Rhode Island Waterbody ID Number**	**Watershed Basin Name**	**Town**	**Water-shed Size (mi^2)**	**Elevation (ft)**
WRB11	WRB11	Moscow Brook & Tribs	RI0008040R-12	Wood River & Tribs	Hopkinton	5.5	208
WRB15	WRB15 ESS31 PAW47 WD-REF	Wood River	RI0008040R-16B	Wood River & Tribs	Hopkinton	54.6	125
WRB22	WRB22 BL12	Falls River & Tribs	RI0008040R-07	Wood River & Tribs	Exeter	19.1	144
WRB23	WRB23	Breakheart Brook & Tribs	RI0008040R-02	Wood River & Tribs	Exeter	6.6	192

Table 10. Biomonitoring stations sampled by ESS in 2010 (resamples for biocriteria development)							
Station Name	**Alter-native Station Names**	**Official State River Name**	**Rhode Island Waterbody ID Number**	**Watershed Basin Name**	**Town**	**Water-shed Size (mi^2)**	**Elevation (ft)**
AI01	AI01 ESS20near	Lawton Brook	RI0007035R-04	Aquidneck Water Supply Tribs	Portsmouth	2.7	92
BGR05	BGR05	Congdon River & Tribs	RI0006012R-04	Big River & Tribs	West Greenwich	4.4	321
BSN01	MLL09 BSN01 BL02	Abbott Run Brook South & Tribs	RI0001006R-01B	Abbott Run Brook & Tribs	North Attleboro, MA	23.9	83
BSN06	BSN06 ESS11	Cherry Brook & Tribs	RI0001003R-02	Blackstone River & Tribs	Woonsocket	4.6	176
ESS12	ESS12	Catamint Brook	RI0001006R-07	Abbott Run Brook & Tribs	Cumberland	3.5	169
ESS45	ESS45	Adamsville Brook & Tribs	RI0009041R-01	Adamsville Brook & Tribs	Tiverton	8.1	21
GNB17	GNB17	Hardig Brook & Tribs	RI0007025R-01	Greenwich Bay	East Greenwich	not calculated	47
LC01	LC01	Tribs East of Cold Brook	RI0010048R-03	Southeast Coastal Ponds	Little Compton	not calculated	29
MLL02	MLL02	East Sneech Brook	RI0001006R-03	Abbott Run Brook & Tribs	Cumberland	7.9	167
MLL20	BSN23 MLL20 ESS47near	Monastery Brook & Tribs	RI0001003R-07	Blackstone River & Tribs	Cumberland	not calculated	71
PAW09	PAW09	Chickasheen Brook & Tribs	RI0008039R-05B	Pawcatuck River & Tribs	South Kingstown	3.9	111
PAW10	PAW10	Beaver River & Tribs	RI0008039R-03	Pawcatuck River & Tribs	Richmond	4.7	258
PAW11	PAW11	Mile Brook	RI0008039R-14	Pawcatuck River & Tribs	Hopkinton	1.1	35
PAW20	PAW20 ESS27 BL17	Meadow Brook & Tribs	RI0008039R-13	Pawcatuck River & Tribs	Richmond	5.1	79
PAW25	PAW25	Taney Brook	RI0008039R-23	Pawcatuck River & Tribs	Richmond	1.6	66
PAW32	PAW32	Chickasheen Brook	RI0008039R-05A	Pawcatuck River & Tribs	Exeter	0.8	143
PXT02	PXT02	Furnace Hill Brook & Tribs	RI0006017R-01	Pawtuxet River Main Stem & Tribs	Cranston	4.3	59
QN04	QN04	Sherman Brook	RI0008039R-34	Pawcatuck River & Tribs	South Kingstown	1.0	152
QN06	QN06	Locke Brook & Tribs	RI0008039R-10	Pawcatuck River & Tribs	Exeter	4.2	158

Table 10. Biomonitoring stations sampled by ESS in 2010 (resamples for biocriteria development)							
Station Name	**Alter-native Station Names**	**Official State River Name**	**Rhode Island Waterbody ID Number**	**Watershed Basin Name**	**Town**	**Water-shed Size (mi^2)**	**Elevation (ft)**
RMR20	RMR20	Moswansicut Stream	RI0006015R-16	Scituate Reservoir Tribs	Scituate	not calculated	307
SAU04	SAU04 ESS55	Indian Run Brook & Tribs	RI0010045R-02	Saugatucket River & Tribs	South Kingstown	2.0	30
SBP02	SBP02	Mishnock River & Tribs	RI0006014R-02	Pawtuxet River South Branch & Tribs	Coventry	3.1	252
UFM01	UFM01 ESS44 near BL15	Keach Brook & Tribs	RI0005047R-02	Tribs to the Five Mile	Burrillville	0.7	549
UMR02	UMR02	Bucks Horn Brook & Tribs	RI0005011R-01	Moosup River & Tribs	Coventry	5.5	430
WON11	WON11	Latham Brook & Tribs	RI0002007R-05	Woonasquatucket River & Tribs	Smithfield	0.2	400
WRB05	WRB05	Canonchet Brook & Tribs	RI0008040R-04B	Wood River & Tribs	Hopkinton	5.8	74
WRB11	WRB11	Moscow Brook & Tribs	RI0008040R-12	Wood River & Tribs	Hopkinton	5.5	208
WRB15	WRB15 ESS31 PAW47 WD-REF	Wood River	RI0008040R-16B	Wood River & Tribs	Hopkinton	54.6	125
WRB18	WRB18 ESS28 BL19	Parris Brook & Tribs	RI0008040R-13	Wood River & Tribs	Exeter	6.6	136
WRB19	WRB19	Woody Hill Brook & Tribs	RI0008040R-17	Wood River & Tribs	Exeter	0.9	237
WRB26	WRB26	Breakheart Brook & Tribs	RI0008040R-02	Wood River & Tribs	West Greenwich	2.4	361
WRB27	WRB27	Phillips Brook & Tribs	RI0008040R-14	Wood River & Tribs	West Greenwich	1.8	260
WRB40	WRB40	Roaring Brook	RI0008040R-15	Wood River & Tribs	West Greenwich	not calculated	362
WRB41	WRB41	Baker Brook	RI0008040R-18	Wood River & Tribs	Richmond	1.0	166

Table 11. Biomonitoring stations sampled by ESS in 2011 (Wood, Pawcatuck & Queen Basins)							
Station Name	**Alter-native Station Names**	**Official State River Name**	**Rhode Island Waterbody ID Number**	**Watershed Basin Name**	**Town**	**Water-shed Size (mi^2)**	**Elevation (ft)**
ESS37	ESS37	White Brook	RI0008039R-26	Pawcatuck River & Tribs	Richmond	2.3	55
ESS41	ESS41	Chipuxet River & Tribs	RI0008039R-06A	Pawcatuck River & Tribs	Exeter	4.0	127
LPK03	LPK03 ESS35	Mastuxet Brook & Tribs	RI0008039R-11	Pawcatuck River & Tribs	Westerly	1.3	34
PAW09	PAW09	Chickasheen Brook & Tribs	RI0008039R-05B	Pawcatuck River & Tribs	South Kingstown	3.9	111
PAW12	PAW12 ESS22 BL03 RWU04	Ashaway River & Tribs	RI0008039R-02A	Pawcatuck River & Tribs	Hopkinton	28.2	50
PAW20	PAW20 ESS27 BL17	Meadow Brook & Tribs	RI0008039R-13	Pawcatuck River & Tribs	Richmond	5.1	79
PAW25	PAW25	Taney Brook	RI0008039R-23	Pawcatuck River & Tribs	Richmond	1.6	66
PAW26	PAW26	Pasquiset Brook	RI0008039R-17	Pawcatuck River & Tribs	Charlestown	6.0	96
PAW29	PAW29	Beaver River & Tribs	RI0008039R-03	Pawcatuck River & Tribs	Richmond	9.2	116
PAW41	PAW41	Pawcatuck River & Tribs	RI0008039R-18B	Pawcatuck River & Tribs	Richmond	91.5	62
QN04	QN04	Sherman Brook	RI0008039R-34	Pawcatuck River & Tribs	South Kingstown	1.0	152
QN08	QN08	Sodom Brook	RI0008039R-22	Pawcatuck River & Tribs	Exeter	8.1	169
QN09	QN09	Queens River & Tribs	RI0008039R-21A	Pawcatuck River & Tribs	Exeter	3.7	160
QNAB	QNAB ESS29 BL21	Queens River & Tribs	RI0008039R-21C	Pawcatuck River & Tribs	Exeter	19.3	138
WRB05	WRB05	Canonchet Brook & Tribs	RI0008040R-04B	Wood River & Tribs	Hopkinton	5.8	74
WRB08	WRB08	Wood River & Tribs	RI0008040R-16C	Wood River & Tribs	Hopkinton	73.5	70
WRB09	WRB09	Brushy Brook & Tribs	RI0008040R-03C	Wood River & Tribs	Hopkinton	11.8	97
WRB15	WRB15 ESS31 PAW47 WD-REF	Wood River	RI0008040R-16B	Wood River & Tribs	Hopkinton	54.6	125
WRB17	WRB17 ESS26	Wood River & Tribs	RI0008040R-16A	Wood River & Tribs	Exeter	35.2	162
WRB18	WRB18 ESS28 BL19	Parris Brook & Tribs	RI0008040R-13	Wood River & Tribs	Exeter	6.6	136
WRB22	WRB22 BL12	Falls River & Tribs	RI0008040R-07	Wood River & Tribs	Exeter	19.1	144

Table 11. Biomonitoring stations sampled by ESS in 2011 (Wood, Pawcatuck & Queen Basins)							
Station Name	**Alter-native Station Names**	**Official State River Name**	**Rhode Island Waterbody ID Number**	**Watershed Basin Name**	**Town**	**Water-shed Size (mi^2)**	**Elevation (ft)**
WRB23	WRB23	Breakheart Brook & Tribs	RI0008040R-02	Wood River & Tribs	Exeter	6.6	192

Table 12. Biomonitoring stations sampled by ESS in 2012 (Scituate, Pawtuxet, Hunt, & Upper Moosup Basins)

Station Name	Alter-native Station Names	Official State River Name	Rhode Island Waterbody ID Number	Watershed Basin Name	Town	Water-shed Size (mi^2)	Elevation (ft)
BB05	BB05 ESS16	Buckeye Brook & Tribs	RI0007024R-01	Upper Narragansett Bay	Warwick	3.0	31
BB05A	BB05near ESS16near	Buckeye Brook & Tribs	RI0007024R-01	Upper Narragansett Bay	Warwick	3.1	31
BGR01	BGR01	Bear Brook & Tribs	RI0006012R-01	Big River & Tribs	Coventry	3.9	263
BGR05	BGR05	Congdon River & Tribs	RI0006012R-04	Big River & Tribs	West Greenwich	4.4	321
BGR08	BGR08	Carr River & Tribs	RI0006012R-03	Big River & Tribs	West Greenwich	6.7	255
BGR09	BGR09	Nooseneck River & Tribs	RI0006012R-05	Big River & Tribs	West Greenwich	8.2	285
FL01	FL01	Boyd Brook	RI0006013R-01	Flat River Res & Tribs	Coventry	1.6	278
FL03	FL03	Flat River & Tribs	RI0006013R-02	Flat River Res & Tribs	Coventry	9.1	276
FL06	FL06	Negro Sawmill Brook	RI0006013R-04	Flat River Res & Tribs	Coventry	4.0	347
FL08	FL08	Quidneck Brook & Tribs	RI0006013R-08A	Flat River Res & Tribs	Coventry	3.1	424
HNT03	HNT03	Frenchtown Brook & Tribs	RI0007028R-01	Potowomut River	East Greenwich	7.0	78
HNT05	HNT05	Fry Brook & Tribs	RI0007028R-02	Potowomut River	East Greenwich	3.1	98
HNT07	HNT07	Scrabbletown Brook	RI0007028R-06	Potowomut River	North Kingstown	1.3	97
HNT08	HNT08	Mawney Brook & Tribs	RI0007028R-04	Potowomut River	East Greenwich	not calculated	193
NBP02	NBP02	Pawtuxet River North Branch	RI0006016R-06B	Pawtuxet River North Branch & Tribs	Scituate	101.0	159
NBP06	NBP06	Pawtuxet River North Branch	RI0006016R-06B	Pawtuxet River North Branch & Tribs	West Warwick	not calculated	51
PBR02	PBR02	Hemlock Brook & Tribs	RI0006015R-10	Scituate Reservoir Tribs	Foster	8.7	408
PBR04	PBR04	Windsor Brook & Tribs	RI0006015R-30	Scituate Reservoir Tribs	Foster	4.3	402
PBR06	PBR06	Shippee Brook & Tribs	RI0006015R-23	Scituate Reservoir Tribs	Foster	not calculated	534

Table 12. Biomonitoring stations sampled by ESS in 2012 (Scituate, Pawtuxet, Hunt, & Upper Moosup Basins)

Station Name	Alter-native Station Names	Official State River Name	Rhode Island Waterbody ID Number	Watershed Basin Name	Town	Water-shed Size (mi^2)	Elevation (ft)
PBR07	PBR07	Ponaganset River & Tribs	RI0006015R-20B	Scituate Reservoir Tribs	Foster	not calculated	354
PCT02	PCT02	Pocasset River & Tribs	RI0006018R-03A	Pocasset River & Tribs	Johnston	8.6	74
PCT03	PCT03	Simmons Brook & Tribs	RI0006018R-04	Pocasset River & Tribs	Johnston	5.9	88
PCT07	PCT07	Pocassett River & Tribs	RI0006018R-03B	Pocasset River & Tribs	Cranston	19.9	18
PCT08	PCT08	Dry Brook & Tribs	RI0006018R-02A	Pocasset River & Tribs	Johnston	2.6	252
PXT01	PXT01	Meshanticut Brook & Tribs	RI0006017R-02	Pawtuxet River Main Stem & Tribs	Cranston	9.0	47
PXT02	PXT02	Furnace Hill Brook & Tribs	RI0006017R-01	Pawtuxet River Main Stem & Tribs	Cranston	4.3	59
PXT07a	PXT07near	Pawtuxet River Main Stem	RI0006017R-03	Pawtuxet River Main Stem & Tribs	Warwick	not calculated	18
RMR02	RMR02	Huntinghouse Brook	RI0006015R-11	Scituate Reservoir Tribs	Scituate	6.2	328
RMR03a	RMR03 near	Rush Brook & Tribs	RI0006015R-22	Scituate Reservoir Tribs	Scituate	not calculated	293
RMR04	RMR04	Peeptoad Brook & Tribs	RI0006015R-19B	Scituate Reservoir Tribs	Scituate	5.0	329
SBP02	SBP02	Mishnock River & Tribs	RI0006014R-02	Pawtuxet River South Branch & Tribs	Coventry	3.1	252
SBP04	SBP04	Pawtuxet River South Branch	RI0006014R-04A	Pawtuxet River South Branch & Tribs	Coventry	63.0	220
SCI01	SCI01	Wilbur Hollow Brook & Tribs	RI0006015R-29	Scituate Reservoir Tribs	Scituate	4.5	299
SCI03	SCI03	Westconnaug Brook & Tribs	RI0006015R-27	Scituate Reservoir Tribs	Scituate	not calculated	345
UMR01	UMR01	Moosup River & Tribs	RI0005011R-03	Moosup River & Tribs	Coventry	24.5	344
UMR03	UMR03 ESS43 BL22	Bucks Horn Brook & Tribs	RI0005011R-01	Moosup River & Tribs	Coventry	8.4	411

Table 12. Biomonitoring stations sampled by ESS in 2012 (Scituate, Pawtuxet, Hunt, & Upper Moosup Basins)

Station Name	Alter-native Station Names	Official State River Name	Rhode Island Waterbody ID Number	Watershed Basin Name	Town	Water-shed Size (mi^2)	Elevation (ft)
UMR04	UMR04	Moosup River & Tribs	RI0005011R-03	Moosup River & Tribs	Coventry	15.3	366
UMR06	UMR06	Moosup River & Tribs	RI0005011R-03	Moosup River & Tribs	Foster	4.3	445
UMR07	UMR07	Roaring Brook & Tribs	RI0005011R-04	Moosup River & Tribs	Coventry	not calculated	359

Table 13. Biomonitoring stations to be sampled in 2013 (Blackstone, Mill & Moshassuck)

Station Name	Alter-native Station Names	Official State River Name	Rhode Island Waterbody ID Number	Watershed Basin Name	Town	Water-shed Size (mi^2)	Elevation (ft)	Macro-invert Sample	NNC Sample[1]
BNC01	BNC01	Branch River & Tribs	RI0001002R-01B	Branch River & Tribs	North Smithfield	92.8	188	Yes	Yes
BNC03	BNC03 ESS10	Tarkiln Brook & Tribs	RI0001002R-13B	Branch River & Tribs	Burrillville	9.2	261	Yes	Yes
BNC06	BNC06	Unnamed Trib to Confluence with Branch River	RI0001002R-38	Branch River & Tribs	Burrillville	not calculated	398	Yes	No
BNC08	BNC08	Tarkiln Brook & Tribs	RI0001002R-13C	Branch River & Tribs	Burrillville	not calculated	345	Yes	Yes
BNC09	BNC09 ESS09	Tucker Brook & Tribs	RI0001002R-21	Branch River & Tribs	Burrillville	0.9	304	Yes	No
BSN06	BSN06 ESS11	Cherry Brook & Tribs	RI0001003R-02	Blackstone River & Tribs	Woonsocket	4.6	176	Yes	Yes
BSN16	BSN16	Mill River	RI0001003R-03	Blackstone River & Tribs	Woonsocket	not calculated	114	Yes	Yes
BSN18	BSN18	Scott Brook & Tribs	RI0001003R-05	Blackstone River & Tribs	Cumberland	not calculated	113	Yes	Yes
BSN19	BSN19	West Sneech Brook & Tribs	RI0001003R-06	Blackstone River & Tribs	Cumberland	not calculated	140	Yes	Yes
BSN20	BSN20	Unnamed Tribs to Blackstone River #1	RI0001003R-08	Blackstone River & Tribs	Woonsocket	not calculated	186	Yes	Yes
BSN21	BSN21	Unnamed Tribs to Blackstone River #2	RI0001003R-09	Blackstone River & Tribs	Woonsocket	not calculated	164	Yes	No
BSN23	BSN23 MLL20 ESS47near	Monastery Brook & Tribs	RI0001003R-07	Blackstone River & Tribs	Cumberland	not calculated	71	Yes	No
BSN24	BSN24	Mussey Brook	RI0001003R-16	Blackstone River & Tribs	Lincoln	not calculated	112	Yes	Yes
CHP02	CHP02	Saunders Brook & Tribs	RI0001002R-12	Branch River & Tribs	Glocester	not calculated	438	Yes	Yes
CLR01	CLR01 ESS06	Brandy Brook & Tribs	RI0001002R-02	Branch River & Tribs	Glocester	3.4	462	Yes	Yes
CLR02	CLR02 ESS03 BL20	Pascoag River	RI0001002R-09	Branch River & Tribs	Burrillville	8.5	374	Yes	Yes
CLR07	CLR07	Dry Arm Brook & Tribs	RI0001002R-06	Branch River & Tribs	Burrillville	not calculated	542	Yes	No
CLR08	CLR08	Nipmuc River & Tribs	RI0001002R-08	Branch River & Tribs	Burrillville	not calculated	338	Yes	Yes
CLR09	CLR09	Clear River & Tribs	RI0001002R-05B	Branch River & Tribs	Burrillville	not calculated	445	Yes	Yes

Table 13. Biomonitoring stations to be sampled in 2013 (Blackstone, Mill & Moshassuck)

Station Name	Alter-native Station Names	Official State River Name	Rhode Island Waterbody ID Number	Watershed Basin Name	Town	Water-shed Size (mi^2)	Elevation (ft)	Macro-invert Sample	NNC Sample[1]
CLR10	CLR10	Leland Brook & Tribs	RI0001002R-17	Branch River & Tribs	Burrillville	not calculated	447	Yes	Yes
CLR11	CLR11 DRY09 ESS07	Mowry Brook & Tribs	RI0001002R-18	Branch River & Tribs	Burrillville	not calculated	409	Yes	No
CLR12	CLR12	Tribs to Wilson Reservoir	RI0001002R-29	Branch River & Tribs	Burrillville	not calculated	456	Yes	No
MLL04	MLL04	Millers River	RI0001006R-08	Abbott Run Brook & Tribs	Cumberland	1.1	98	Yes	Yes
MLL09	MLL09 BSN01 BL02	Abbott Run Brook South & Tribs	RI0001006R-01B	Abbott Run Brook & Tribs	North Attleboro, MA	23.9	83	Yes	Yes
MLL10	MLL10 BSN02 near ESS01 near BL01	Abbott Run Brook North & Tribs	RI0001006R-01A	Abbott Run Brook & Tribs	Cumberland	18.1	129	Yes	Yes
MSK01	MSK01	Moshassuck River & Tribs	RI0003008R-01A	Moshassuck River & Tribs	Lincoln	4.8	109	Yes	Yes
MSK02	MSK02	Moshassuck River & Tribs	RI0003008R-01B	Moshassuck River & Tribs	Lincoln	7.8	48	Yes	Yes
MSK03	MSK03	Moshassuck River & Tribs	RI0003008R-01C	Moshassuck River & Tribs	Pawtucket	8.9	40	Yes	Yes
MSK04	MSK04	Moshassuck River & Tribs	RI0003008R-01C	Moshassuck River & Tribs	Pawtucket	10.6	32	Yes	Yes
MSK05	MSK05	Moshassuck River & Tribs	RI0003008R-01C	Moshassuck River & Tribs	Providence	22.9	17	Yes	Yes
MSK06	MSK06	West River & Tribs	RI0003008R-03C	Moshassuck River & Tribs	Providence	11.0	21	Yes	Yes
MSK07	MSK07	West River & Tribs	RI0003008R-03B	Moshassuck River & Tribs	North Providence	4.6	106	Yes	Yes

NNC Sample[1] Includes samples collected for: Chlorophyll, Diatom Taxonomy, Pebble Count, Densiometer

Table 14. Biomonitoring stations to be sampled in 2014 (Woonasquatucket Basin)

Station Name	Alternative Station Names	Official State River Name	Rhode Island Waterbody ID Number	Watershed Basin Name	Town	Water-shed Size (mi^2)	Elevation (ft)	Macro-invert Sample	NNC Sample[1]	Latitude	Longitude
SAU03	SAU03	Fresh Meadow Brook	RI0010045R-01	Saugatucket River & Tribs	South Kingstown	not calculated	61	No	Yes	41.47908	-71.48243
SAU04	SAU04 ESS55	Indian Run Brook & Tribs	RI0010045R-02	Saugatucket River & Tribs	South Kingstown	2.0	30	No	Yes	41.44983	-71.49554
SAU05	SAU05	Rocky Brook & Tribs	RI0010045R-04	Saugatucket River & Tribs	South Kingstown	not calculated	29	No	Yes	41.45158	-71.50143
TLC08	TLC08	Tribs East of Cold Brook	RI0010048R03	Southeast Coastal Ponds	Little Compton	not calculated	11	No	Yes	41.51664	-71.12908
TLC09	TLC09	Dundery Brook	RI0010048R-02C	Southeast Coastal Ponds	Little Compton	not calculated	13	No	Yes	41.48835	-71.17143
WON01	WON01	Woonasquatucket River & Tribs	RI0002007R-10A	Woonasquatucket River Basin	Smithfield	4.9	256	Yes	Yes	41.92085	-71.55265
WON03	WON03	Woonasquatucket River & Tribs	RI0002007R-10C	Woonasquatucket River Basin	Johnston	37.7	100	Yes	No	41.8592	-71.4874
WON04	WON04	Woonasquatucket River & Tribs	RI0002007R-10C	Woonasquatucket River Basin	Johnston	44.3	62	Yes	No	41.83286	-71.47033
WON05	WON05	Woonasquatucket River	RI0002007R-10D	Woonasquatucket River Basin	Providence	48.5	4	Yes	No	41.82652	-71.43583
WON06	WON06	Stillwater River & Tribs	RI0002007R-09	Woonasquatucket River Basin	Smithfield	8.7	266	Yes	No	41.87452	-71.55488
WON11	WON11	Latham Brook & Tribs	RI0002007R-05	Woonasquatucket River Basin	Smithfield	0.2	400	Yes	No	41.91943	-71.56013
WON12	WON12	Woonasquatucket River & Tribs	RI0002007R-10D	Woonasquatucket River Basin	Providence	46.6	41	Yes	No	41.8214	-71.4547
WON13	WON13	Unnamed Tribs to Stillwater Pond	RI0002007R-12	Woonasquatucket River Basin	Smithfield	not calculated	205	Yes	Yes	41.91089	-71.52803
WON15	WON15	Harris Brook & Tribs	RI0002007R-03	Woonasquatucket River Basin	Smithfield	not calculated	204	No	Yes	41.90139	-71.50945
WON16	WON16	Tribs to Georgiaville Pond	RI0002007R-16	Woonasquatucket River Basin	Smithfield	not calculated	169	Yes	Yes	41.89473	-71.50713
WON17	WON17	Cutler Brook & Tribs	RI0002007R-02	Woonasquatucket River Basin	Glocester	not calculated	354	No	Yes	41.88452	-71.6000
WON19	WON19	Hawkins Brook & Tribs	RI0002007R-04	Woonasquatucket River Basin	Smithfield	not calculated	127	Yes	Yes	41.87344	-71.50132
WON21	WON21	Assapumpset Brook & Tribs	RI0002007R-01	Woonasquatucket River Basin	Johnston	not calculated	91	Yes	No	41.84303	-71.48194
WONWR3A	WONWR3A	Woonasquatucket River & Tribs	RI0002007R-10B	Woonasquatucket River Basin	Smithfield	not calculated	114	Yes	No	41.87368	-71.49713

NNC Sample[1] Includes samples collected for: Chlorophyll, Diatom Taxonomy, Pebble Count, Densiometer

Appendix A

Standard Operating Procedures
Standard Operating Guidelines

Appendix A1

Standard Operating Guidelines for Freshwater Macroinvertebrate Sampling and Analysis

STANDARD OPERATING GUIDELINES FOR FRESHWATER MACROINVERTEBRATE SAMPLING AND ANALYSIS

1.0 INTRODUCTION

The following guidelines are to be used by ESS Group, Inc. (ESS) for freshwater macroinvertebrate sampling within a single stream habitat type. They are appropriate for sampling wadeable rivers and streams, as outlined by US EPA (1999). The laboratory analysis procedures outlined below specify critical techniques and quality assurance and quality control procedures.

2.0 REQUIRED MATERIALS

The following materials are likely to be necessary for this procedure:

Field Equipment

- Standard D-frame kick-net, 500 µm mesh, ~0.3 meter (~1.0 ft) frame width
- Stopwatch
- ≥70% ethanol for sample preservation
- White tray for retaining or examining sample debris
- Sample containers (liter- or quart-sized jars preferred)
- Fine point permanent marker for labeling outside of sample jars
- Weatherproof paper for internal sample lables
- Wash bottle or similar container for dispensing water and ethanol
- Fine forceps for picking macroinvertebrates from net
- Pencils
- Field data sheets on weatherproof paper
- Clipboard
- Measuring tape, ruler, or stick
- Meters, probes, and other devices necessary for making field measurements (use of these is covered under separate SOGs)
- Chest or hip waders
- Arm length protective gloves
- Digital camera
- Site list
- Sieve bucket, 500 µm mesh (Optional)
- Driving directions (Optional)
- Global Positioning System (GPS) Unit (Optional)

Laboratory Equipment

- Log in sheet for samples
- 70% ethanol for storage of specimens
- Forceps – ultrafine or superfine gauge (straight or angled per staff preference)
- Gridded sorting sieve (at least 16 grid cells) with mesh size of 500 µm or less
- Sorting sieve tray (dimensions sufficient to fit sieve)
- Scoop for removing sample material
- Specimen vials with caps or stoppers
- Sample labels
- Archival pen/pencil
- Dissecting microscope for organism identification
- Compound microscope for slide-mounted organism identification
- External light source (fiber optic gooseneck lamp ideal)
- Petri dishes – sectional preferred
- Regionally appropriate macroinvertebrate taxonomic keys
- Standard laboratory bench sheets for sorting and identification
- Holding wells (Optional)
- Lab notebook (Optional)

3.0 HABITAT ASSESSMENT AND MACROINVERTEBRATE COLLECTION

The details provided below assume that the "single habitat sampling approach" will be taken, as referred to by US EPA (Barbour et al. 1999), in order to standardize assessments among streams. Sampling the riffle habitat (run habitat where riffle not available) is anticipated to provide a representative sample of the stream reach.

Summary of Requirements:

- All kick samples to be taken with a standard D-frame net, working upstream along a representative 100 meter (m) reach.
- Conduct kick sampling for a three-minute duration, removing organisms from larger substrate particles by hand.
- All samples must be preserved in the field on the day of collection with ethanol solution in a leak proof container. Samples ma be diluted with water as necessary to bring preservative level to about 70%.
- Complete physical characterization and habitat assessment field sheets, as necessary.
- Complete sample log-in sheet upon returning samples to the laboratory.

- Clearly label all sample containers with sample identification code, date, stream name, sampling location, and collector name.

Specific Requirements:

1. A 100-m reach representative of the characteristics of the stream will be selected. If not specified by the client/project, the sampling reach should be sufficiently downstream from any road crossing to minimize its effect on stream velocity, depth, and overall habitat quality, with no major tributaries discharging to the stream in the study area. If access restrictions, available habitat, or other site constraints prevent this, areas upstream of or near bridges and/or culverts may be included.
2. Before sampling, any required physical characterization field sheets should be completed to document water quality prior to disturbing stream sediments. Sheet entries will be reviewed after sampling.
3. A map of the sampling reach should be drawn to characterize key in-steam and riparian corridor attributes (e.g., riffles, falls, fallen trees, pools, bends, undercut banks, areas or erosion, vegetation, possible pollutant sources, etc.). An arrow will indicate the direction of flow. Take care not to disturb portions of the stream that will be sampled for macroinvertebrates.
4. Sampling should begin at the downstream end of the reach and proceed upstream to avoid disturbing targeted in-stream habitat. Using a D-frame kick net, sampling will be conducted at various locations in a riffle or series of riffles for a total active sampling time of three minutes. The area sampled should be representative of available habitat. Therefore, if multiple areas of riffle habitat are available, the sample should be composited from multiple riffles within the stream reach. If only one area of appropriate habitat is available, the sample should be composited from multiple locations within this area. If no riffle habitat is available, sampling should be done in the most similar habitat available (i.e., higher velocities with hard substrates).

   In general, sampling should last for no more than 30 seconds at any one net location. Cobbles should be picked up, placed at the lip of the net, and rubbed by hand to remove attached organisms. Boulders or exposed bedrock may be sampled by placing the net downstream and rocking and/or rubbing the surface of the rock to dislodge organisms into the net. Areas of gravel may be sampled by standing upstream of the net and gently disrupting the substrate with the toe and heel of wader boots. The goal of sampling is to dislodge burrowing, clinging, or attached organisms. Therefore, it is not desirable to violently disturb or kick substrate into the water column; this may result in damage to sampled organisms and excessive accumulation of sand and gravel in the net. Before moving to a new sampling location within the reach, collected material should be rinsed by splashing or running clean stream water through the net two to three times. If clogging does occur, the material in the net should be emptied into a sampling tray before returning to the stream to continue sampling.

   If field duplicate samples are required, these should be collected simultaneously by a second trained staff member. Each staff member should sample the same habitat features and switch sides of the stream halfway through the duration of the sampling event. This will help to counter potential sampling bias.
5. Once a complete sample has been collected,, larger debris (e.g., cobbles, twigs, large leaves) may be carefully rinsed with stream water to remove any macroinvertebrates and discarded. Sample material should be transferred from the net to sample container(s) and preserved in enough ethanol to cover the sample. Forceps may be needed to remove organisms from the net. Ethanol should not

be diluted below 70%. A label should be placed into the sample container indicating the sample identification code, date, stream name, sampling location, and collector name. The outside of the container will include the same information and indicate that the sample is preserved in ethanol. If more than one container is needed for a sample, each container label will contain all the information for the sample and should be numbered (e.g., 1 of 2, 2 of 2, etc.).

6. Sample container information as noted in step (5) will be recorded, on the US EPA "Sample Log-In Sheet" or comparable form.
7. Walking the reach, an assessment of the surrounding habitat will be conducted by completing a US EPA "Habitat Assessment Field Data Sheet" or comparable form. The sheet should be appropriate to the gradient of the stream being assessed (i.e., low or high).
8. Complete any other required tasks at this time.

4.0 PROTOCOL FOR LABORATORY ANALYSIS

Summary of Requirements:

- Samples will be rinsed to remove preservatives and fine sediments.
- Large, unique, or rare species will be removed prior to sub-sampling.
- Sub-samples will be taken using a grid-marked sorting sieve tray and metal frame.
- Sub-samples will be sorted under a dissecting microscope until the target number of organisms has been removed.
- Organisms will be preserved with ethanol in small, appropriately labeled, vials or jars.
- Unsorted residue and sorted residue should be preserved with ethanol in appropriately labeled jars.
- Midges and worms may be mounted on labeled slides, as necessary, for identification.
- Identification to genus/species level or the lowest practicable taxonomic level using a compound microscope for mounted slides and a dissecting microscope for other organisms.

Specific Requirements:

1. The sample log-in sheet will be reviewed and annotated, as necessary, to verify that all samples have arrived and are in proper condition for processing.
2. Sample processing begins by rinsing the sample material in a 500-µm mesh sieve to remove preservative and fine sediment. A sieve tray should be placed under the sieve to capture all rinseate. Take care to ensure that direct flow of water does not impinge and damage organisms against the mesh screen. Large organic material (whole leaves, twigs. algal or macrophyte mats, etc.) not removed in the field may be carefully rinsed, visually inspected, and discarded once organisms have been removed and placed in the sieve. If the samples have been preserved in alcohol, it may be necessary to soak the sample contents in water for about 15 minutes to hydrate the benthic organisms, which will prevent them from floating on the water surface during sorting.
3. After washing, the sub-sample will be evenly spread across the sorting sieve by immersing in water and then quickly removing from the water once organisms and debris are evenly distributed. Cover the sieve to keep sample material moist during sorting.

4. Large, rare or unique organisms should be picked out, identified and reported as supplemental information for each location prior to sub-sampling.

5. Use a random number table to select a grid cell from the tray for sub-sampling. Debris overhanging the grid may be cut with scissors. A scoop will be used to remove all debris and organisms from the grid. The sub-sample will then be transferred to a small container or Petri dish for temporary holding and sorting.

6. The sub-sample will be sorted under a dissecting microscope or other magnifying device sufficient to pick out organisms as small as 500 µm. All organisms from the sub-sampled material should be sorted from sample debris. If fewer than the target number of organisms is removed from the sub-sampled material, then another random grid from the sorting sieve must be selected and steps (4) and (5) repeated. These steps should be repeated until the whole sample has been sorted or the target number of organisms has been removed. On most projects, sorting may be stopped if the number of sub-sampled organisms is within 10% of the target value. However, this should be confirmed with the project manager on a project-by-project basis.

7. The sorted organisms should be placed into glass vials and preserved in 70% ethanol. The vials will be labeled inside and out with the sample identifier or lot number, date, stream name, sampling location and taxonomic group. If more than one vial is needed, each will be labeled separately and numbered (e.g., 1 of 2, 2 of 2). Most projects will require sorting into at least three vials, by taxonomic classification. Typically, these three vials will be labeled “Chironomidae/Oligochaeta”, “Mollusca/Crustacea” and “Others”, unless otherwise indicated by the project manager. An additional vial, called “Supplemental” may be used where supplemental organisms have been removed from the sample material.

8. The sorted debris residue will be saved in a separate container (sealable plastic bag is acceptable, as long as it is placed within a sealed jar) and labeled as “sorted residue”. The label will also include all prior sample label information and indicate preservation in 70% ethanol. The remaining unsorted sample debris residue will be saved in the original sample container when possible.

9. Oligochaete worms (Oligochaeta) and non-biting midge (Chironomidae) larvae and pupae may be mounted on slides, as necessary for identification. These should be mounted in an appropriate medium (e.g., CMC-9 or -10) using a method consistent with Epler (2001). Slides should be labeled with the project name, site identifier, and date collected. Multiple mounts may be completed on each slide but the slide label should be marked to index the location of each on the slide. As with midges, may also be mounted on slides and will be appropriately labeled.

10. The sorter will fill out the laboratory bench sheet, noting sub-sampling/sorting information, the number of grids picked, time expenditure, and number of organisms. QC checks performed on a particular sample should be indicated on the reverse of this sheet or in a QA/QC logbook. The sorter will record the date of sorting and slide monitoring, if applicable, on log-in sheet as documentation of progress and status of completion of the sample lot.

11. Identification and enumeration for sorted organisms within each sample will be determined through the use of a dissecting microscope (up to 45X magnification), a fiber optic lamp, standard dissecting tools, and using appropriate taxonomic keys. Midges and oligochaete worms mounted on slides will be identified using a compound microscope. Each taxon found in a sample will be recorded and enumerated on a lab bench sheet or be transcribed to the laboratory bench sheet from a lab notebook. Any difficulties encountered during identification (e.g.. missing anatomical features, degraded condition, early instar) should be noted on these sheets.

12. Any sample material that is released to the client or to an outside laboratory must be accompanied by a signed chain-of-custody form. Copies of all chains-of-custody should be retained on file, as needed.
13. For archiving samples, specimen vials will be placed in labeled jars with a small amount of denatured 70% ethanol and tightly capped.

5.0 QUALITY ASSURANCE/QUALITY CONTROL (QA/QC)

The QA/QC protocol for the benthic monitoring program will be comparable to procedures outlined for other similar assessment programs. In the field, after sampling has been completed at a given site, all nets, pans, etc. that have come into contact with the sample will be rinsed thoroughly examined carefully and picked free of debris or organisms. Also, a duplicate sample will be taken at 10% of the sites to evaluate the precision or repeatability of the sampling technique or the collection team.

In the lab, ESS will randomly perform a quality check on a minimum of 10% of the samples analyzed. This quality check will cover both the sorting and the identification phases of the analysis.

For the sorting phase, if more than 10 % error (calculated by dividing the number found in the quality check by the total number of individuals) is found between the sorter and the quality assurance check, 4 additional samples will be reprocessed. If the percent error in those samples is more than 10% in those samples, then all samples sorted by that individual will be reprocessed.

For identification, a second ESS staff member trained in macroinvertebrate identification will randomly check a minimum of 10% of the samples analyzed. The purpose of this check will be to validate the identifications made on the individuals comprising the sample. In addition, ESS will confirm the identifications made with other regional experts as necessary.

A reference collection of samples will be maintained. These specimens will be labeled and preserved in 70% ethanol and stored for future reference and/or for study by other regional experts as necessary

Records of the results of each of the various quality assurance checks described above will be kept in a laboratory analysis log.

6.0 QUALIFICATIONS

Habitat Assessment and Physical Characterization

Staff responsible for habitat assessment and physical characterization must be familiar with the protocols and requirements necessary to complete field sheets and meet project needs. In-house training with the QA officer or field crew leader is required to minimize bias among individual staff completing the habitat assessment scoring.

Macroinverterbrate Sample Collection

Staff responsible for macroinvertebrate sample collection must be familiar with the protocols and requirements necessary to collect a representative single-habitat sample from wadeable streams. In-house training with the QA officer or field crew leader is required to ensure sampling methods and effort are consistent among individual staff. In-house training in proper sample preservation techniques is also required.

Macroinvertebrate Sorting and Identification

To properly conduct the taxonomic identification of aquatic macroinvertebrates, the taxonomist and QC officer must be familiar with the protocols stated in this SOG, have confidence in the appropriate use of aquatic macroinvertebrate keys and be familiar with the organisms from the area in question.

Staff responsible for slide mounting of Chironomidae and Oligochaeta must be familiar with the protocols stated in this SOG and be proficient in the methods outlined by Epler (2001).

In-house training with an experienced aquatic macroinvertebrate taxonomist is required for all staff responsible for entering taxonomic data into a project database. The staff member responsible for data entry must be familiar with the structure of the database and nature of the calculated metrics in order to ensure accuracy of the data and any associated calculations.

7.0 REFERENCES

Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling. 1999. Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish, Second Edition. EPA 841-B-99-002. Washington, D.C.: U.S. Environmental Protection Agency; Office of Water;

Epler, J.H. 2001. Identification Manual for the Larval Chironomidae (Diptera) of North and South Carolina. Special Publication SJ2001-SP13. North Carolina Department of Environment and Natural Resources, Raleigh, NC and St. Johns River Water Management District, Palatka FL.

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BENTHIC MACROINVERTEBRATE SAMPLE LOG-IN SHEET

Date Collected	Collected By	Number of Containers	Preservation	Station #	Stream Name and Location	Date Received by Lab	Lot Number	Date of Completion		
								sorting	mounting	identification

Serial Code Example: B0754001(1)
B = Benthos (F = Fish; P = Periphyton)**#** 0754 = project number **#** 001 = sample number **#** (1) = lot number (e.g., winter 1996 =1; summer 1996 = 2)

BENTHIC MACROINVERTEBRATE LABORATORY BENCH SHEET (FRONT)

page _____ of _____

STREAM NAME	LOCATION
STATION #_____ RIVERMILE_____	STREAM CLASS
LAT _____ LONG _____	RIVER BASIN
STORET #	AGENCY
COLLECTED BY DATE_____	LOT #
TAXONOMIST DATE_____	SUBSAMPLE TARGET ❑ 100 ❑ 200 ❑ 300 ❑ Other ____

Enter Family and/or Genus and Species name on blank line.

Organisms		No.	LS	TI	TCR	Organisms		No.	LS	TI	TCR
Oligochaeta						Megaloptera					
Hirudinea						Coleoptera					
Isopoda											
Amphipoda						Diptera					
Decapoda											
Ephemeroptera											
						Gastropoda					
						Pelecypoda					
Plecoptera											
						Other					
Trichoptera											
Hemiptera											

Taxonomic certainty rating (TCR) 1-5:1=most certain, 5=least certain. If rating is 3-5, give reason (e.g., missing gills). LS= life stage: I = immature; P = pupa; A = adult TI = Taxonomists initials

Total No. Organisms _____ **Total No. Taxa _____**

BENTHIC MACROINVERTEBRATE LABORATORY BENCH SHEET (BACK)

SUBSAMPLING/SORTING INFORMATION

Sorter _____

Date _____

Number of grids picked: _____

Time expenditure _____ No. of organisms _____

Indicate the presence of large or obviously abundant organisms:

QC: ❑ YES ❑ NO **QC Checker** _____

$$\frac{\text{\# organisms originally sorted}}{\square} \div \left(\frac{\text{\# organisms recovered by checker}}{\square} + \frac{\text{\# organisms originally sorted}}{\square} \right) = \text{\% sorting efficiency } \square$$

≥90%, sample passes _____

<90%, sample fails, action taken _____

_____

TAXONOMY

ID _____

Date _____

Explain TCR ratings of 3-5:

Other Comments (e.g. condition of specimens):

QC: ❑ YES ❑ NO **QC Checker** _____

Organism recognition ❑ pass ❑ fail

Verification complete ❑ YES ❑ NO

Appendix A2

Standard Operating Guidelines for Measurements of Temperature

STANDARD OPERATING GUIDELINES FOR MEASUREMENT OF TEMPERATURE

1.0 INTRODUCTION

1.1 Purpose and Applicability

These Standard Operating Guidelines (SOG) provide basic instructions for routine measurement of temperature using any high quality mercury-filled thermometer or thermistor with analog or digital read-out device such as the Hydac Multimeter Probe and YSI Model 55. Multimeter instruments used for temperature measurement may measure additional parameters (e.g., dissolved oxygen, conductivity, pH, etc.). This SOG addresses temperature measurement only (other capabilities are outlined in the appropriate SOG). This SOG is designed specifically for the measurement of temperature in accordance with EPA Method 170.1 and Standard Method 2550 B which address thermometric temperature measurement of drinking, surface, and saline waters, and domestic and industrial wastes.

1.2 Quality Assurance Planning Considerations

The end use of the data will determine the quality assurance requirements that are necessary to produce data of acceptable quality. These quality assurance requirements will be defined in the site-specific workplan or Quality Assurance Project Plan (QAPP) (hereafter referred to as the project plan) or laboratory Quality Assurance Manual (QAM) and may include duplicate or replicate measurements or confirmatory measurements.

2.0 RESPONSIBILITIES

2.1 The analyst is responsible for verifying that the temperature measuring device is in proper operating condition prior to use and for implementing the calibration and measurement procedures in accordance with this SOG and the project plan.

2.2 The project manager is responsible for ensuring that project-specific requirements are communicated to the project team and for providing the materials, resources, and guidance necessary to perform the measurements in accordance with this SOG and the project plan.

3.0 REQUIRED MATERIALS

The following materials are necessary for this procedure:

- Thermometer or thermistor with analog or digital read-out device
- Manufacturer's instruction manual for the instrument
- National Institute of Standards and Technology (NIST)-traceable thermometer
- Laboratory or field data sheets or logbooks

4.0 METHOD

4.1 Sample Handling, Preservation, and General Measurement Procedures

To achieve accurate temperature measurements, samples should be analyzed immediately upon collection (preferably within 15 minutes). Samples should be collected in glass or plastic containers.

4.2 Calibration and Measurement Procedures

4.2.1 ESS-owned temperature measuring devices will, at a minimum, be checked annually as described in Section 5.0 or more frequently, as may be required by specific projects. The device will be checked against a NIST-traceable thermometer and the necessary

compensation made for the difference in temperature between the two. Rental equipment will be checked by the manufacturer and documentation provided to ESS.

4.2.2 Immerse the thermometer or temperature measuring device into the sample.

4.2.3 Swirl and take a reading when the value stabilizes.

4.2.4 Record the temperature reading to the nearest 0.50 for a thermometer or 0.10 for digital meter-type instruments. Compensate for any difference with the NIST-traceable thermometer.

4.2.5 Temperature data may be post-calibrated using any of a variety of calibration data including, but not limited to, field calibration points, manufacturer calibration data, and analytical results from samples collected during field deployment of the sensors. The decision criteria for post calibration, and the technique used, will be specified in the project plan, and will be consistent with the manufacturer's recommendations.

4.3 Troubleshooting Information

If there are any performance problems with any of the meter-type temperature measuring devices, consult the appropriate section of the meter instruction manual for the checkout and self-test procedures. If the problem persists, consult the manufacturer's customer service department immediately for further instructions. If a performance problem exists with the thermometer, discard the thermometer and replace it.

4.4 Maintenance

Instrument maintenance for meter-type temperature measuring devices should be performed according to the procedures and frequencies required by the manufacturer.

5.0 QUALITY CONTROL

5.1 The temperature measuring devices will, at a minimum, be checked against a NIST-traceable thermometer at the frequency stated in Section 4.2.1. This verification procedure will be performed as follows:

- Immerse the thermometer or temperature sensor and the NIST-traceable thermometer into a sample.
- Allow the readings to stabilize.
- Record the readings and document the difference.
- Label the thermometer or temperature sensor with the correction value/adjustment and the date the accuracy check was performed.
- Compensate for the difference when sample measurements are taken.

5.2 Duplicate measurements of a single sample will be performed at the frequency stated in the project plan. In the absence of project-specific criteria, duplicate measurements should agree within $\pm$ 0.50C or approximately $\pm$ 1.00F.

6.0 DOCUMENTATION

6.1 Records for checking the accuracy of the thermometer or temperature measuring device (where applicable) will include:

- Date
- Thermometer or meter-type temperature measuring device checked
- Reference thermometer number
- Readings for reference thermometer and thermometer being checked
- Adjustment made for difference in readings
- Initials of analyst

6.2 Documentation for recorded data must include a minimum of the following:

- Date and time of analysis
- Signature or initials of person performing the measurement
- Thermometer ID # or instrument identification number/model
- Sample identification/station location
- Temperature of sample (including units and duplicate measurements) compensated for any difference with the reference thermometer if applicable
- Comments

7.0 TRAINING/QUALIFICATIONS

To properly perform temperature measurements, the analyst must be familiar with the calibration and measurement techniques stated in this SOG. The analyst must also be experienced in the operation of the meter.

Certain state certification programs require that temperature measurements in the field be taken by, or in the presence of, personnel that are qualified under the certification program.

8.0 REFERENCES

Standard Methods for the Examination of Water and Wastewater, 17th Edition, 1989.

Methods for the Chemical Analysis of Water and Wastes, EPA 600/4-79-020, Revised 1983.

Appendix A3

Standard Operating Guidelines for Measurements of pH

STANDARD OPERATING GUIDELINES FOR MEASUREMENT OF PH

1.0 INTRODUCTION

1.1 Purpose and Applicability

These Standard Operating Guidelines (SOG) provide basic instructions for routine calibration and operation of a variety of pH meters, including the YSI Model 55, Hydac Multimeter Probe and the pHep pH Testers. Although these meters may measure additional parameters (e.g., temperature, specific conductivity, etc.), this SOG addresses pH measurement only (other capabilities are outlined in the appropriate SOG and manufacturer's individual instrument manuals). This SOG is designed specifically for the measurement of pH in accordance with EPA Method 150.1 and Standard Method 4500-H B which address electrometric pH measurements of drinking, surface, and saline waters, domestic and industrial wastes, and acid rain.

1.2 Quality Assurance Planning Considerations

The end use of the data will determine the quality assurance requirements that are necessary to produce data of acceptable quality. These quality assurance requirements will be defined in the site-specific workplan or Quality Assurance Project Plan (QAPP) (hereafter referred to as the project plan) or laboratory Quality Assurance Manual (QAM) and may include duplicate or replicate measurements or confirmatory analyses.

2.0 RESPONSIBILITIES

- The analyst is responsible for verifying that the pH meter is in proper operating condition prior to use and for implementing the calibration and measurement procedures in accordance with this SOG and the project plan.
- The project manager is responsible for ensuring that project-specific requirements are communicated to the project team and for providing the materials, resources, and guidance necessary to perform the measurements in accordance with this SOG and the project plan.

3.0 REQUIRED MATERIALS

The following materials may be necessary for this procedure:

- pH meter
- pH meter manufacturer's instruction manual
- Deionized water
- 4.0, 7.0, and 10.0 buffer solutions
- Lint-free tissues
- Mild detergent
- 10% hydrochloric acid
- National Institute of Standards and Technology (NIST)-traceable thermometer
- Calibration sheets or logbook
- Laboratory or field data sheets or logbooks

4.0 METHOD

4.1 Sample Handling, Preservation, and General Measurement Procedures

4.1.1 To achieve accurate pH measurements, samples should be analyzed in the field (preferably within 15 minutes), or as soon as possible after collection. Sample should be collected in plastic or glass containers.

4.1.2 After measuring a sample containing oily material or particulate matter, the electrode must be cleaned by carefully wiping with a lint-free cloth, or washing gently in a mild detergent, followed by a deionized water rinse. If this does not suffice, an additional rinse with 10% hydrochloric acid (followed by deionized water) may be needed.

4.1.3 As temperature can affect the pH measurements obtained, both the pH and the temperature of the sample must be recorded. Both the Hydac Multimeter and the pHep Tester that will be used in this study have the ability to compensate for temperature.

4.1.4 Calibration must include a minimum of two points that bracket the expected pH of the samples to be measured. Calibration measurements must be recorded in logbook.

4.1.5 Primary standard buffer salts available from NIST can be purchased and are necessary for situations where extreme accuracy is required. Secondary standard buffers may be purchased as a solution from commercial vendors and are recommended for routine use. Buffers should not be used after their expiration dates as provided by the manufacturer. An expiration date of one year should be used if the manufacturer does not supply an expiration date or if the buffers are prepared from pH powder pillows, etc.

4.1.6 When using the meter in the laboratory, always place the buffer/sample beaker on the magnetic stirrer, and make sure the stirring bar is rotating during measurements. Rinse the stirring bar as well as the beaker between buffers/samples.

EXCEPTION: Do not use the magnetic stirrer for acid rain samples. It is crucial not to induce dissolved gases into the sample to be absorbed or desorbed, as this will alter the pH. Stir the sample gently for a few seconds after introducing the electrode, then allow the electrode to equilibrate prior to recording temperature and pH readings.

4.1.7 When the meter is being used in the field, move the probe in a way that creates sufficient sample movement across the sensor; this insures homogeneity of the sample and suspension of solids. If sufficient movement has occurred, the readings will not drift (<0.l pH units). Rinse the electrode with deionized water between samples and wipe gently with a lint-free tissue.

4.1.8 When measuring the pH of hot liquids, wait for the liquid to cool to 160°F or below.

4.1.9 Fluctuating readings may indicate more frequent instrument calibrations are necessary.

4.2 Calibration and Measurement Procedures

4.2.1 The pH meter must be calibrated daily before any analyses are performed. The meter should be re-calibrated every 12 hours or at the frequency specified in the project plan.

4.2.2 Connect the electrode to the meter. Choose either 7.0 and 10.0 (high range) or 4.0 and 7.0 (low range) buffers, whichever will bracket the expected sample range. Place the buffer in a

clean glass beaker. If the pH is being measured in a laboratory, place the beaker on the magnetic stirrer and place the stirring bar in the beaker. Measure and record the temperatures of the buffers using a calibrated thermometer or automatic temperature compensation (ATC).

4.2.3 Place the electrode into the 10.0 buffer or into the 7.0 buffer.

4.2.4 Adjust the instrument calibration according to the manufacturer's instructions. Discard the buffer and rinse the beaker and stirring bar thoroughly with deionized water.

4.2.5 Refill the beaker with the 7.0 buffer or the 4.0 buffer. Rinse the electrode, gently wipe with a lint-free tissue, and place it in the selected buffer solution. If the pH is being measured in a laboratory, place the beaker on the magnetic stirrer and place the stirring bar in the beaker. Continue adjusting the instrument calibration according to the manufacturer's instructions. Record the electrode slope (if provided by the instrument) on the calibration sheet (an acceptable slope is between 92 and 102 percent). Measure and record the temperature of the buffer using a calibrated thermometer or ATC. Discard the buffer and rinse the beaker and stirring bar thoroughly with deionized water.

4.2.6 An additional check may be performed, if required by the project plan, by placing the electrode into an additional buffer solution. This buffer should be from a different source than the buffers used for the initial calibration. This buffer should read within +0.2 pH units of the buffer's true pH value.

4.2.7 Verify the calibration every 15 samples and at the end of the day. Recalibrate the instrument if the check value varies more than 0.2 pH units from the true value.

4.2.8 The electrode will be rinsed with deionized water and wiped gently with a lint-free tissue between sample analysis.

4.2.9 Recalibrate the instrument if the buffers do not bracket the pH of the samples.

4.2.10 The meter must be re-calibrated following any maintenance activities and prior to the next use.

4.3 Troubleshooting Information

If there are any performance problems with any of the pH meters which result in the inability to achieve the acceptance criteria presented in Section 5.0, consult the appropriate section of the meter instruction manual for the checkout and self-test procedures. If the problem persists, consult the manufacturer's customer service department immediately for further instructions.

4.4 Maintenance

4.4.1 Instrument maintenance should be performed according to the procedures and frequencies required by the manufacturer.

4.4.2 The electrode must be stored and maintained according to the manufacturer's instructions.

4.4.3 If an instrument with ATC is being used, the device should be checked on a quarterly basis for accuracy with an NIST thermometer.

5.0 QUALITY CONTROL

5.1 Duplicate measurements of a single sample will be performed at the frequency specified in the project plan. In the absence of project-specific criteria, duplicate measurements should agree within ±0.l pH units.

5.2 The temperature readout of the meter will be checked annually against an NIST-traceable thermometer. If the difference is greater than 0.2°C, the instrument manufacturer will be consulted for instructions. Temperature measurements will be compensated for any difference with the reference thermometer.

5.3 Some regulatory agencies may require the analysis of USEPA Water Supply (WS) or Water Pollution (WP) performance evaluation samples. These performance evaluation samples will be analyzed as required.

6.0 DOCUMENTATION

6.1 All pH meter calibration, temperature check, and maintenance information will be recorded on the daily calibration sheet (Figure 1). pH data may be recorded on the appropriate laboratory or field data sheets or logbooks.

6.2 Calibration documentation must be maintained in a thorough and consistent manner. At a minimum, the following information must be recorded:

- Date and time of calibration
- Signature or initials of person performing the measurement
- Instrument identification number/model
- Expiration dates and batch numbers for all buffer solutions
- Reading for pH 7.0 buffer before and after meter adjustment
- Reading for pH 4.0 or 10.0 buffer before and after meter adjustment
- Readings for all continuing calibration checks
- Temperature of buffers (corrected for any difference with reference thermometer), including units
- Comments

6.3 Documentation for recorded data must include a minimum of the following:

- Date and time of analysis
- Signature or initials of person performing the measurement
- Instrument identification number/model
- Sample identification/station location
- Temperature (corrected for any difference with reference thermometer) and pH of sample (including units and duplicate measurements)
- Comments

7.0 TRAINING/QUALIFICATIONS

To properly perform pH measurements, the analyst must be familiar with the calibration and measurement techniques stated in this SOG. The analyst must also be experienced in the operation of the meter.

Certain state certification programs require that pH measurements in the field be taken by, or in the presence of, personnel that are qualified under the certification program.

8.0 REFERENCES

Standard Methods for the Examination of Water and Wastewater, 17th Edition, 1989.

Methods for the Chemical Analysis of Water and Wastes, EPA 600/4-79-020, Revised 1983.

Appendix A4

Standard Operating Guidelines for Measurements of Flow Rate

STANDARD OPERATING GUIDELINES FOR MEASUREMENT OF FLOW RATE

1.0 INTRODUCTION

1.1 Purpose and Applicability

These Standard Operating Guidelines (SOG) provide basic instructions for routine measurement of flow rate in bodies of running water. The two techniques under consideration are the Time of Travel Method and the Global Flow Probe Procedure.

1.2 Quality Assurance Planning Considerations

The end use of the data will determine the quality assurance requirements that are necessary to produce data of acceptable quality. These quality assurance requirements will be defined in the site-specific workplan or Quality Assurance Project Plan (QAPP) (hereafter referred to as the project plan) or laboratory Quality Assurance Manual (QAM) and may include duplicate or replicate measurements or confirmatory measurements.

2.0 RESPONSIBILITIES

The analyst is responsible for verifying that the instrumentation is in proper operating condition prior to use and for implementing the calibration and measurement procedures in accordance with this SOG and the project plan.

The project manager is responsible for ensuring that project-specific requirements are communicated to the project team and for providing the materials, resources, and guidance necessary to perform the measurements in accordance with this SOG and the project plan.

3.0 REQUIRED MATERIALS

The following materials are necessary for the Global Flow Probe Procedure:

- Global Flow Probe FP101, Global Water, Gold River, CA
- LCD computer display
- Radio Shack 675 HP or equivalent batteries
- Manufacturer's instruction manual for the instrument
- Laboratory or field data sheets or logbooks

The following materials are necessary for the Time of Travel Method:

- A neutral buoyancy floating object, such as a cracked ping-pong ball
- Twine or other heavy-duty string material
- Water proof yard-stick to measure stream depth
- Stop-watch
- Permanent marker (e.g., sharpie)
- Laboratory or field data sheets or logbooks

4.0 METHOD

4.1 General Measurement Procedures For Global Flow Probe Procedure

To achieve accurate flow measurements samples must be analyzed in the field. Flow measurements may be taken in small and large streams, rivers and within pipes.

- The average velocity of stream flow multiplied by the cross-sectional area is equal to the flow rate (Q=VxA). The cross sectional area is determined manually by measuring the depth of the water at

several points across the channel. The cross section in square feet times the average velocity in feet per second gives the cubic feet per second (c.f.s.).

- When sampling within round pipes, one needs only to measure the water depth and then refer to the tables in the Global Flow Probe Instruction Manual to determine the cross-sectional area.

4.2 Calibration and Measurement Procedures for Global Flow Probe Procedure

The Flow Probe is set up and calibrated at the factory. The calibration sequence is entered automatically when the batteries are changed or by holding down both Right and Left buttons simultaneously for 8 seconds. Calibration should be checked annually.

- To change between English and Metric units and to enter the calibration sequence, hold down both Left and Right buttons simultaneously for 8 seconds. The Left button scrolls between English “mi” and Metric “km”.
- To check the calibration push the Right button to “CAL”. For “mi” calibration set Probe calibration to 33.31. For “km” calibration set Probe calibration to 1603. The Left button increases the number when the arrow points up and decreases the number when the arrow points down.
- The Flow Probe computer has a simple 2 – button operation. The Right button changes between Function and the Left button picks the Option. Pushing both buttons simultaneously for 1 second zeros the displayed value.
- By pushing the Right button you may scroll through the following functions. Velocity Function: “V” is instantaneous velocity to the nearest 0.1 feet per second. Push the Left button to scroll between “AV” (average velocity) and “MX” (maximum velocity) which reads out to the nearest 0.01 feet per second. Stop Watch / Clock Function: Push the Left button to start and stop watch.
- Make sure the prop turns freely and point the prop directly into the flow with the arrow on the bottom of the probe pointing down-stream.
- Press the Right button until the “V” for velocity appears and select the desired velocity parameters to be measured by pushing the Left button. Average velocity readings “AV” must be collected for flow rate measurements (c.f.s.).
- Put the probe at your measuring point and press both Right and Left buttons simultaneously and release to re-zero and begin recording. Hold in the flow for several seconds until you have steady average velocity.
- When sampling in small streams and within pipes, the probe should be moved slowly and smoothly along a vertical plane throughout the flow to ensure that the probe evenly samples the cross-sectional area of the flow.
- When sampling larger streams and rivers divide the stream into subsections (e.g. 2-3 feet in width). At the center of each subsection, insert the probe and sample vertically from the surface to the bottom smoothly to obtain a vertical average velocity profile. The Average Velocity times the Area of the subsection is the Flow for the subsection. Add all the subsection flows to obtain the Total Stream Flow.
- Repeat procedure three times in at least three different locations, recording data in field notebook. The flow rate should be calculated as an average of the three measurements taken at different locations within the channel or pipe.
- Calculate discharge (Q) from the measured data, as follows:

- Measure and calculate the cross-sectional area of your flow stream in square feet and multiply this by the average velocity in feet / second to obtain discharge in cubic feet per second (c.f.s.).
- Cross-sectional area (ft^2) x AV (ft/sec) = Q (ft^3/sec)

4.3 Calibration and Measurement Procedures for the Time of Travel Method

To measure travel time, the length of time taken for the floating object to travel 3 feet will be measured as follows:

1. Select an appropriate stream cross section with relatively uniform and uninterrupted flow
2. Securely attach 3 feet of string to floating object (i.e., cracked ping-pong ball)
3. Release floating object in the water and activate timer
4. Record time (T) from when the floating object is released to the time when the string goes taut, indicating that the object has traversed 3 feet
5. Repeat procedure three times at three different locations, recording data in a field notebook. The flow rate should be calculated as an average of the three measurements taken at different locations within the stream channel. Flow rate = 3 feet/T (seconds) = X feet / second
6. Measure stream average width and average depth at sampling location

- Calculate discharge (Q) from the measured data, as follows:

1. Calculate cross-sectional area (A) of the stream, by multiplying average width and average depth
2. Select a coefficient or correction factor (C): 0.8 for rocky bottom streams, 0.9 for muddy bottom streams. The coefficient allows correction for the fact that water travels faster at the surface than at the stream bottom, due to resistance from bottom materials
3. $Q = \frac{A*C*L}{T}$ Where L= 3 feet and T= time of travel (seconds)

   Units of Q are typically cubic feet per second

4.4 Troubleshooting Information for Global Flow Probe Procedure

If there are any performance problems with the Global Flow Probe, consult the appropriate section of the instruction manual for the checkout and self-test procedures. If the problem persists, consult the manufacturer's customer service department at (916) 638-3429 immediately for further instructions.

4.5 Maintenance for Global Flow Probe Procedure

Instrument maintenance for the Global Flow Probe should be performed according to the procedures and frequencies required by the manufacturer.

5.0 QUALITY CONTROL

5.1 Quality Control for Global Flow Probe Procedure

The Global Flow Probe calibration should be checked annually to ensure that the Flow Probe is operating up to factory specifications.

5.2 Quality Control for the Time of Travel Method

To ensure a quality measurement, a minimum of three times of travel measurements will be obtained and recorded at each sampling point. An average value will be used to measure flow rate / discharge.

6.0 DOCUMENTATION

6.1 Documentation for Global Flow Probe Procedure

All Global Flow Probe calibration, checks, and maintenance information will be recorded on the daily calibration sheet or logbook. Flow data may be recorded on the appropriate laboratory or field data sheets or logbooks.

- Calibration documentation must be maintained in a thorough and consistent manner. At a minimum, the following information must be recorded:
  - Date and time of calibration
  - Signature or initials of person performing the measurement
  - Instrument identification number/model
  - Readings for all continuing calibration checks
  - Comments
- Documentation for recorded data must include a minimum of the following:
  - Date and time of analysis
  - Signature or initials of person performing the measurement
  - Instrument identification number/model
  - Sample identification/station location
  - Flow Rate in cubic feet per second (c.f.s.), average water velocity and maximum water velocity
  - Comments

6.2 Documentation for the Time of Travel Method

All data will be recorded in a field logbook. Documentation for recorded data must include a minimum of the following:

- Date, time and location of measurement
- Time of travel and distance traveled
- Comments, if any

7.0 TRAINING/QUALIFICATIONS

- To properly perform Global Flow Probe measurements, the analyst must be familiar with the calibration and measurement techniques stated in this SOG. The analyst must also be experienced in the operation of the meter.
- Certain state certification programs require that flow measurements in the field be taken by, or in the presence of, personnel that are qualified under the certification program.
- No special training is required to implement the Time of Travel Method; however, the analyst must be familiar with the calibration and measurement techniques stated in this SOG.

8.0 REFERENCES

Volunteer Stream Monitoring: A Methods Manual. EPA 841-B-97-003, November 1997.

Global Flow Probe Instruction Manual.

Appendix A5

Standard Operating Guidelines for Measurements of Dissolved Oxygen

STANDARD OPERATING GUIDELINES FOR MEASUREMENT OF DISSOLVED OXYGEN

1.0 INTRODUCTION

1.1 Purpose and Applicability

These Standard Operating Guidelines (SOG) provide basic instructions for routine measurement of dissolved oxygen using a polarographic sensor equipped dissolved oxygen meter with a digital read-out such as the YSI Model 55 Handheld Dissolved Oxygen System. Measurements are made in accordance with EPA Standard Methods that addresses dissolved oxygen measurement of drinking, surface, and saline waters, and domestic and industrial wastes.

1.2 Quality Assurance Planning Considerations

The end use of the data will determine the quality assurance requirements that are necessary to produce data of acceptable quality. These quality assurance requirements will be defined in the site-specific workplan or Quality Assurance Project Plan (QAPP) (hereafter referred to as the project plan) or laboratory Quality Assurance Manual (QAM) and may include duplicate or replicate measurements or confirmatory measurements.

2.0 RESPONSIBILITIES

The analyst is responsible for verifying that the dissolved oxygen measuring device is in proper operating condition prior to use and for implementing the calibration and measurement procedures in accordance with this SOG and the project plan.

The project manager is responsible for ensuring that project-specific requirements are communicated to the project team and for providing the materials, resources, and guidance necessary to perform the measurements in accordance with this SOG and the project plan.

3.0 REQUIRED MATERIALS

The following materials are necessary for this procedure:

- Dissolved oxygen meter with digital read-out device
- Manufacturer's instruction manual for the instrument
- YSI Model 5775 Standard Membrane Kit with KCl solution and O-rings
- NIST-traceable thermometer
- Laboratory or field data sheets or logbooks

4.0 METHOD

4.1 Sample Handling, Preservation, and General Measurement Procedures

To achieve accurate dissolved oxygen measurements, samples should be analyzed *in situ*. Measurements in flowing waters should be made in relatively turbulent free areas. Measurements in standing waters will require probe agitation to create water movement around the probe.

4.2 Calibration and Measurement Procedures

To accurately calibrate the YSI Model 55, you will need to know the approximate altitude of the region in which you are located and the approximate salinity of the water you will be analyzing. Fresh water has a salinity of approximately zero. Seawater has an approximate salinity of 35 parts per thousand (ppt). If uncertain, measure salinity with an appropriate device.

- Ensure that the sponge inside the instrument’s calibration chamber is wet then insert the probe into the chamber. Turn the instrument on and wait for readings to stabilize (approximately 15 minutes).

- To calibrate, enter the calibration menu by pressing and releasing both the up and down arrow keys at the same time. Enter the altitude (in hundreds of feet) at the prompt by using the arrow keys to increase or decrease the altitude (example: 12 = 1,200 feet). Press enter when correct altitude is shown.
- The meter should display CAL in the lower left of the display with the calibration value in the lower right of the display and the current D.O. reading (before calibration) should be on the main display. Once the D.O. reading is stable, press ENTER. Enter the salinity at the prompt by using the arrow keys. Press ENTER when finished and the instrument will return to normal operation.
- Calibration should be performed at a temperature within ± 10°C of the sample temperature. Verify the calibration every 15 samples and at the end of the day.
- If erratic readings occur, replace membrane as per the manufacturer's manual. The average replacement interval is two to four weeks.
- Replace the membrane as per the manufacturer's manual if bubbles appear (>1/8 inch diameter), or if the membrane becomes damaged, wrinkled, or fouled.
- Avoid contact with any environment which contains substances that may attack the probe materials (e.g. acids, caustics, and strong solvents).
- The meter must be re-calibrated following any maintenance activities and prior to the next use.

4.3 Troubleshooting Information

If there are any performance problems with the dissolved oxygen-measuring device, consult the appropriate section of the instruction manual for the checkout and self-test procedures. If the problem persists, consult the manufacturer's customer service department immediately for further instructions.

4.4 Maintenance

Instrument maintenance for meter-type dissolved oxygen measuring devices should be performed according to the procedures and frequencies required by the manufacturer.

5.0 QUALITY CONTROL

Duplicate measurements of a single sample will be performed at the frequency specified in the project plan. In the absence of project-specific criteria, duplicate measurements should agree within ± 0.2 mg/L.

The temperature readout of the meter will be checked regularly (at least weekly) against a NIST-traceable thermometer. If the difference is greater than 0.5°C, the instrument manufacturer will be consulted for instructions. Temperature measurements will be compensated for any difference with the reference thermometer.

6.0 DOCUMENTATION

All dissolved oxygen meter calibration, checks, and maintenance information will be recorded on the daily calibration sheet or logbook. Dissolved oxygen data may be recorded on the appropriate laboratory or field data sheets or logbooks.

- Calibration documentation must be maintained in a thorough and consistent manner. At a minimum, the following information must be recorded:
    - Date and time of calibration
    - Signature or initials of person performing the measurement
    - Instrument identification number/model

- Expiration dates and batch numbers for all standard solutions
- Readings for all continuing calibration checks
- Comments

- Documentation for recorded data must include a minimum of the following:
  - Date and time of analysis
  - Signature or initials of person performing the measurement
  - Instrument identification number/model
  - Sample identification/station location
  - Dissolved oxygen, both in mg/L and percent saturation (corrected for any difference with reference thermometer) and temperature of sample (including units and duplicate measurements)
  - Comments

7.0 TRAINING/QUALIFICATIONS

To properly perform dissolved oxygen measurements, the analyst must be familiar with the calibration and measurement techniques stated in this SOG. The analyst must also be experienced in the operation of the meter.

Certain state certification programs require that dissolved oxygen measurements in the field be taken by, or in the presence of, personnel that are qualified under the certification program.

8.0 REFERENCES

Standard Methods for the Examination of Water and Wastewater, 21st Edition, 2005.

Methods for the Chemical Analysis of Water and Wastes, EPA 600/4-79-020, Revised 1983.

Solubility of Oxygen in Water at a Specific Conductance of 0 microsiemens/cm

Dissolved oxygen instrument saturation reading should be within 0.3 mg/L of the value below for the given temperature and barometric pressure

Temp.	Barometric Pressure (mbar)															
(°C)	975	980	985	990	995	1000	1005	1010	1015	1020	1025	1030	1035	1040	1045	1050
0.0	14.1	14.1	14.2	14.3	14.4	14.4	14.5	14.6	14.7	14.7	14.8	14.9	14.9	15.0	15.1	15.2
0.1	14.0	14.1	14.2	14.2	14.3	14.4	14.5	14.5	14.6	14.7	14.8	14.8	14.9	15.0	15.0	15.1
0.2	14.0	14.1	14.1	14.2	14.3	14.4	14.4	14.5	14.6	14.6	14.7	14.8	14.9	14.9	15.0	15.1
0.3	14.0	14.0	14.1	14.2	14.2	14.3	14.4	14.5	14.5	14.6	14.7	14.7	14.8	14.9	15.0	15.0
0.4	13.9	14.0	14.1	14.1	14.2	14.3	14.3	14.4	14.5	14.6	14.6	14.7	14.8	14.8	14.9	15.0
0.5	13.9	13.9	14.0	14.1	14.2	14.2	14.3	14.4	14.4	14.5	14.6	14.7	14.7	14.8	14.9	14.9
0.6	13.8	13.9	14.0	14.0	14.1	14.2	14.3	14.3	14.4	14.5	14.5	14.6	14.7	14.8	14.8	14.9
0.7	13.8	13.9	13.9	14.0	14.1	14.2	14.2	14.3	14.4	14.4	14.5	14.6	14.7	14.7	14.8	14.9
0.8	13.8	13.8	13.9	14.0	14.0	14.1	14.2	14.3	14.3	14.4	14.5	14.5	14.6	14.7	14.8	14.8
0.9	13.7	13.8	13.9	13.9	14.0	14.1	14.1	14.2	14.3	14.4	14.4	14.5	14.6	14.6	14.7	14.8
1.0	13.7	13.8	13.8	13.9	14.0	14.0	14.1	14.2	14.2	14.3	14.4	14.5	14.5	14.6	14.7	14.7
1.1	13.6	13.7	13.8	13.9	13.9	14.0	14.1	14.1	14.2	14.3	14.3	14.4	14.5	14.6	14.6	14.7
1.2	13.6	13.7	13.7	13.8	13.9	14.0	14.0	14.1	14.2	14.2	14.3	14.4	14.4	14.5	14.6	14.7
1.3	13.6	13.6	13.7	13.8	13.8	13.9	14.0	14.1	14.1	14.2	14.3	14.3	14.4	14.5	14.5	14.6
1.4	13.5	13.6	13.7	13.7	13.8	13.9	13.9	14.0	14.1	14.2	14.2	14.3	14.4	14.4	14.5	14.6
1.5	13.5	13.6	13.6	13.7	13.8	13.8	13.9	14.0	14.1	14.1	14.2	14.3	14.3	14.4	14.5	14.5
1.6	13.5	13.5	13.6	13.7	13.7	13.8	13.9	13.9	14.0	14.1	14.2	14.2	14.3	14.4	14.4	14.5
1.7	13.4	13.5	13.6	13.6	13.7	13.8	13.8	13.9	14.0	14.0	14.1	14.2	14.3	14.3	14.4	14.5
1.8	13.4	13.5	13.5	13.6	13.7	13.7	13.8	13.9	13.9	14.0	14.1	14.1	14.2	14.3	14.3	14.4
1.9	13.3	13.4	13.5	13.6	13.6	13.7	13.8	13.8	13.9	14.0	14.0	14.1	14.2	14.2	14.3	14.4
2.0	13.3	13.4	13.4	13.5	13.6	13.7	13.7	13.8	13.9	13.9	14.0	14.1	14.1	14.2	14.3	14.3
2.1	13.3	13.3	13.4	13.5	13.5	13.6	13.7	13.8	13.8	13.9	14.0	14.0	14.1	14.2	14.2	14.3
2.2	13.2	13.3	13.4	13.4	13.5	13.6	13.6	13.7	13.8	13.9	13.9	14.0	14.1	14.1	14.2	14.3
2.3	13.2	13.3	13.3	13.4	13.5	13.5	13.6	13.7	13.7	13.8	13.9	14.0	14.0	14.1	14.2	14.2
2.4	13.2	13.2	13.3	13.4	13.4	13.5	13.6	13.6	13.7	13.8	13.8	13.9	14.0	14.0	14.1	14.2
2.5	13.1	13.2	13.3	13.3	13.4	13.5	13.5	13.6	13.7	13.7	13.8	13.9	13.9	14.0	14.1	14.1
2.6	13.1	13.2	13.2	13.3	13.4	13.4	13.5	13.6	13.6	13.7	13.8	13.8	13.9	14.0	14.0	14.1
2.7	13.1	13.1	13.2	13.3	13.3	13.4	13.5	13.5	13.6	13.7	13.7	13.8	13.9	13.9	14.0	14.1
2.8	13.0	13.1	13.2	13.2	13.3	13.4	13.4	13.5	13.6	13.6	13.7	13.8	13.8	13.9	14.0	14.0
2.9	13.0	13.1	13.1	13.2	13.3	13.3	13.4	13.5	13.5	13.6	13.7	13.7	13.8	13.9	13.9	14.0
3.0	13.0	13.0	13.1	13.2	13.2	13.3	13.4	13.4	13.5	13.6	13.6	13.7	13.8	13.8	13.9	14.0
3.1	12.9	13.0	13.1	13.1	13.2	13.3	13.3	13.4	13.5	13.5	13.6	13.7	13.7	13.8	13.9	13.9
3.2	12.9	13.0	13.0	13.1	13.2	13.2	13.3	13.4	13.4	13.5	13.6	13.6	13.7	13.8	13.8	13.9
3.3	12.9	12.9	13.0	13.1	13.1	13.2	13.2	13.3	13.4	13.4	13.5	13.6	13.6	13.7	13.8	13.8
3.4	12.8	12.9	12.9	13.0	13.1	13.1	13.2	13.3	13.3	13.4	13.5	13.5	13.6	13.7	13.7	13.8
3.5	12.8	12.8	12.9	13.0	13.0	13.1	13.2	13.2	13.3	13.4	13.4	13.5	13.6	13.6	13.7	13.8
3.6	12.7	12.8	12.9	12.9	13.0	13.1	13.1	13.2	13.3	13.3	13.4	13.5	13.5	13.6	13.7	13.7
3.7	12.7	12.8	12.8	12.9	13.0	13.0	13.1	13.2	13.2	13.3	13.4	13.4	13.5	13.6	13.6	13.7
3.8	12.7	12.7	12.8	12.9	12.9	13.0	13.1	13.1	13.2	13.3	13.3	13.4	13.5	13.5	13.6	13.7
3.9	12.6	12.7	12.8	12.8	12.9	13.0	13.0	13.1	13.2	13.2	13.3	13.4	13.4	13.5	13.6	13.6
4.0	12.6	12.7	12.7	12.8	12.9	12.9	13.0	13.1	13.1	13.2	13.3	13.3	13.4	13.5	13.5	13.6
4.1	12.6	12.6	12.7	12.8	12.8	12.9	13.0	13.0	13.1	13.2	13.2	13.3	13.4	13.4	13.5	13.6
4.2	12.5	12.6	12.7	12.7	12.8	12.9	12.9	13.0	13.1	13.1	13.2	13.3	13.3	13.4	13.5	13.5
4.3	12.5	12.6	12.6	12.7	12.8	12.8	12.9	13.0	13.0	13.1	13.2	13.2	13.3	13.4	13.4	13.5
4.4	12.5	12.5	12.6	12.7	12.7	12.8	12.9	12.9	13.0	13.1	13.1	13.2	13.3	13.3	13.4	13.5
4.5	12.5	12.5	12.6	12.6	12.7	12.8	12.8	12.9	13.0	13.0	13.1	13.2	13.2	13.3	13.4	13.4
4.6	12.4	12.5	12.5	12.6	12.7	12.7	12.8	12.9	12.9	13.0	13.1	13.1	13.2	13.3	13.3	13.4
4.7	12.4	12.5	12.5	12.6	12.6	12.7	12.8	12.8	12.9	13.0	13.0	13.1	13.2	13.2	13.3	13.3
4.8	12.4	12.4	12.5	12.5	12.6	12.7	12.7	12.8	12.9	12.9	13.0	13.1	13.1	13.2	13.2	13.3
4.9	12.3	12.4	12.4	12.5	12.6	12.6	12.7	12.8	12.8	12.9	13.0	13.0	13.1	13.1	13.2	13.3
5.0	12.3	12.4	12.4	12.5	12.5	12.6	12.7	12.7	12.8	12.9	12.9	13.0	13.1	13.1	13.2	13.2
5.1	12.3	12.3	12.4	12.4	12.5	12.6	12.6	12.7	12.8	12.8	12.9	13.0	13.0	13.1	13.1	13.2
5.2	12.2	12.3	12.4	12.4	12.5	12.5	12.6	12.7	12.7	12.8	12.9	12.9	13.0	13.0	13.1	13.2
5.3	12.2	12.3	12.3	12.4	12.4	12.5	12.6	12.6	12.7	12.8	12.8	12.9	13.0	13.0	13.1	13.1
5.4	12.2	12.2	12.3	12.4	12.4	12.5	12.5	12.6	12.7	12.7	12.8	12.9	12.9	13.0	13.0	13.1
5.5	12.1	12.2	12.3	12.3	12.4	12.4	12.5	12.6	12.6	12.7	12.8	12.8	12.9	12.9	13.0	13.1
5.6	12.1	12.2	12.2	12.3	12.4	12.4	12.5	12.5	12.6	12.7	12.7	12.8	12.9	12.9	13.0	13.0
5.7	12.1	12.1	12.2	12.3	12.3	12.4	12.4	12.5	12.6	12.6	12.7	12.8	12.8	12.9	12.9	13.0
5.8	12.0	12.1	12.2	12.2	12.3	12.4	12.4	12.5	12.5	12.6	12.7	12.7	12.8	12.8	12.9	13.0
5.9	12.0	12.1	12.1	12.2	12.3	12.3	12.4	12.4	12.5	12.6	12.6	12.7	12.8	12.8	12.9	12.9
6.0	12.0	12.0	12.1	12.2	12.2	12.3	12.4	12.4	12.5	12.5	12.6	12.7	12.7	12.8	12.8	12.9
6.1	11.9	12.0	12.1	12.1	12.2	12.3	12.3	12.4	12.4	12.5	12.6	12.6	12.7	12.8	12.8	12.9
6.2	11.9	12.0	12.0	12.1	12.2	12.2	12.3	12.4	12.4	12.5	12.5	12.6	12.7	12.7	12.8	12.8
6.3	11.9	12.0	12.0	12.1	12.1	12.2	12.3	12.3	12.4	12.4	12.5	12.6	12.6	12.7	12.7	12.8
6.4	11.9	11.9	12.0	12.0	12.1	12.2	12.2	12.3	12.3	12.4	12.5	12.5	12.6	12.7	12.7	12.8
6.5	11.8	11.9	12.0	12.0	12.1	12.1	12.2	12.3	12.3	12.4	12.4	12.5	12.6	12.6	12.7	12.7
6.6	11.8	11.9	11.9	12.0	12.0	12.1	12.2	12.2	12.3	12.3	12.4	12.5	12.5	12.6	12.7	12.7
6.7	11.8	11.8	11.9	12.0	12.0	12.1	12.1	12.2	12.3	12.3	12.4	12.4	12.5	12.6	12.6	12.7
6.8	11.7	11.8	11.9	11.9	12.0	12.0	12.1	12.2	12.2	12.3	12.3	12.4	12.5	12.5	12.6	12.7
6.9	11.7	11.8	11.8	11.9	12.0	12.0	12.1	12.1	12.2	12.3	12.3	12.4	12.4	12.5	12.6	12.6
7.0	11.7	11.7	11.8	11.9	11.9	12.0	12.0	12.1	12.2	12.2	12.3	12.3	12.4	12.5	12.5	12.6
7.1	11.7	11.7	11.8	11.8	11.9	12.0	12.0	12.1	12.1	12.2	12.3	12.3	12.4	12.4	12.5	12.6
7.2	11.6	11.7	11.7	11.8	11.9	11.9	12.0	12.0	12.1	12.2	12.2	12.3	12.3	12.4	12.5	12.5
7.3	11.6	11.7	11.7	11.8	11.8	11.9	12.0	12.0	12.1	12.1	12.2	12.3	12.3	12.4	12.4	12.5
7.4	11.6	11.6	11.7	11.7	11.8	11.9	11.9	12.0	12.0	12.1	12.2	12.2	12.3	12.3	12.4	12.5
7.5	11.5	11.6	11.7	11.7	11.8	11.8	11.9	12.0	12.0	12.1	12.1	12.2	12.3	12.3	12.4	12.4
7.6	11.5	11.6	11.6	11.7	11.7	11.8	11.9	11.9	12.0	12.0	12.1	12.2	12.2	12.3	12.3	12.4
7.7	11.5	11.5	11.6	11.7	11.7	11.8	11.8	11.9	12.0	12.0	12.1	12.1	12.2	12.3	12.3	12.4
7.8	11.5	11.5	11.6	11.6	11.7	11.7	11.8	11.9	11.9	12.0	12.0	12.1	12.2	12.2	12.3	12.3
7.9	11.4	11.5	11.5	11.6	11.7	11.7	11.8	11.8	11.9	12.0	12.0	12.1	12.1	12.2	12.3	12.3
8.0	11.4	11.5	11.5	11.6	11.6	11.7	11.8	11.8	11.9	11.9	12.0	12.0	12.1	12.2	12.2	12.3
8.1	11.4	11.4	11.5	11.5	11.6	11.7	11.7	11.8	11.8	11.9	12.0	12.0	12.1	12.1	12.2	12.3
8.2	11.3	11.4	11.5	11.5	11.6	11.6	11.7	11.8	11.8	11.9	11.9	12.0	12.0	12.1	12.2	12.2
8.3	11.3	11.4	11.4	11.5	11.5	11.6	11.7	11.7	11.8	11.8	11.9	12.0	12.0	12.1	12.1	12.2
8.4	11.3	11.3	11.4	11.5	11.5	11.6	11.6	11.7	11.8	11.8	11.9	11.9	12.0	12.0	12.1	12.2

Temp.	Barometric Pressure (mbar)															
(°C)	975	980	985	990	995	1000	1005	1010	1015	1020	1025	1030	1035	1040	1045	1050
8.5	11.3	11.3	11.4	11.4	11.5	11.6	11.6	11.7	11.7	11.8	11.8	11.9	12.0	12.0	12.1	12.1
8.6	11.2	11.3	11.3	11.4	11.5	11.5	11.6	11.6	11.7	11.8	11.8	11.9	11.9	12.0	12.0	12.1
8.7	11.2	11.3	11.3	11.4	11.4	11.5	11.6	11.6	11.7	11.7	11.8	11.8	11.9	12.0	12.0	12.1
8.8	11.2	11.2	11.3	11.4	11.4	11.5	11.5	11.6	11.6	11.7	11.8	11.8	11.9	11.9	12.0	12.0
8.9	11.2	11.2	11.3	11.3	11.4	11.4	11.5	11.6	11.6	11.7	11.7	11.8	11.8	11.9	12.0	12.0
9.0	11.1	11.2	11.2	11.3	11.4	11.4	11.5	11.5	11.6	11.6	11.7	11.8	11.8	11.9	11.9	12.0
9.1	11.1	11.2	11.2	11.3	11.3	11.4	11.4	11.5	11.6	11.6	11.7	11.7	11.8	11.8	11.9	12.0
9.2	11.1	11.1	11.2	11.2	11.3	11.4	11.4	11.5	11.5	11.6	11.6	11.7	11.8	11.8	11.9	11.9
9.3	11.0	11.1	11.2	11.2	11.3	11.3	11.4	11.4	11.5	11.6	11.6	11.7	11.7	11.8	11.8	11.9
9.4	11.0	11.1	11.1	11.2	11.2	11.3	11.4	11.4	11.5	11.5	11.6	11.6	11.7	11.8	11.8	11.9
9.5	11.0	11.0	11.1	11.2	11.2	11.3	11.3	11.4	11.4	11.5	11.6	11.6	11.7	11.7	11.8	11.8
9.6	11.0	11.0	11.1	11.1	11.2	11.2	11.3	11.4	11.4	11.5	11.5	11.6	11.6	11.7	11.8	11.8
9.7	10.9	11.0	11.1	11.1	11.2	11.2	11.3	11.3	11.4	11.4	11.5	11.6	11.6	11.7	11.7	11.8
9.8	10.9	11.0	11.0	11.1	11.1	11.2	11.3	11.3	11.4	11.4	11.5	11.5	11.6	11.6	11.7	11.8
9.9	10.9	10.9	11.0	11.1	11.1	11.2	11.2	11.3	11.3	11.4	11.5	11.5	11.6	11.6	11.7	11.7
10.0	10.9	10.9	11.0	11.0	11.1	11.1	11.2	11.3	11.3	11.4	11.4	11.5	11.5	11.6	11.7	11.7
10.1	10.8	10.9	10.9	11.0	11.1	11.1	11.2	11.2	11.3	11.3	11.4	11.5	11.5	11.6	11.6	11.7
10.2	10.8	10.9	10.9	11.0	11.0	11.1	11.1	11.2	11.3	11.3	11.4	11.4	11.5	11.5	11.6	11.7
10.3	10.8	10.8	10.9	11.0	11.0	11.1	11.1	11.2	11.2	11.3	11.3	11.4	11.5	11.5	11.6	11.6
10.4	10.8	10.8	10.9	10.9	11.0	11.0	11.1	11.2	11.2	11.3	11.3	11.4	11.4	11.5	11.5	11.6
10.5	10.7	10.8	10.8	10.9	11.0	11.0	11.1	11.1	11.2	11.2	11.3	11.3	11.4	11.5	11.5	11.6
10.6	10.7	10.8	10.8	10.9	10.9	11.0	11.0	11.1	11.2	11.2	11.3	11.3	11.4	11.4	11.5	11.5
10.7	10.7	10.7	10.8	10.9	10.9	11.0	11.0	11.1	11.1	11.2	11.2	11.3	11.4	11.4	11.5	11.5
10.8	10.7	10.7	10.8	10.8	10.9	10.9	11.0	11.0	11.1	11.2	11.2	11.3	11.3	11.4	11.4	11.5
10.9	10.6	10.7	10.7	10.8	10.9	10.9	11.0	11.0	11.1	11.1	11.2	11.2	11.3	11.4	11.4	11.5
11.0	10.6	10.7	10.7	10.8	10.8	10.9	10.9	11.0	11.1	11.1	11.2	11.2	11.3	11.3	11.4	11.4
11.1	10.6	10.6	10.7	10.8	10.8	10.9	10.9	11.0	11.0	11.1	11.1	11.2	11.2	11.3	11.4	11.4
11.2	10.6	10.6	10.7	10.7	10.8	10.8	10.9	10.9	11.0	11.1	11.1	11.2	11.2	11.3	11.3	11.4
11.1	10.6	10.6	10.7	10.8	10.8	10.9	10.9	11.0	11.0	11.1	11.1	11.2	11.2	11.3	11.4	11.4
11.2	10.6	10.6	10.7	10.7	10.8	10.8	10.9	10.9	11.0	11.1	11.1	11.2	11.2	11.3	11.3	11.4
11.3	10.5	10.6	10.6	10.7	10.8	10.8	10.9	10.9	11.0	11.0	11.1	11.1	11.2	11.2	11.3	11.4
11.4	10.5	10.6	10.6	10.7	10.7	10.8	10.8	10.9	10.9	11.0	11.1	11.1	11.2	11.2	11.3	11.3
11.5	10.5	10.5	10.6	10.7	10.7	10.8	10.8	10.9	10.9	11.0	11.0	11.1	11.1	11.2	11.3	11.3
11.6	10.5	10.5	10.6	10.6	10.7	10.7	10.8	10.8	10.9	11.0	11.0	11.1	11.1	11.2	11.2	11.3
11.7	10.4	10.5	10.5	10.6	10.7	10.7	10.8	10.8	10.9	10.9	11.0	11.0	11.1	11.1	11.2	11.3
11.8	10.4	10.5	10.5	10.6	10.6	10.7	10.7	10.8	10.9	10.9	11.0	11.0	11.1	11.1	11.2	11.2
11.9	10.4	10.4	10.5	10.6	10.6	10.7	10.7	10.8	10.8	10.9	10.9	11.0	11.0	11.1	11.1	11.2
12.0	10.4	10.4	10.5	10.5	10.6	10.6	10.7	10.7	10.8	10.9	10.9	11.0	11.0	11.1	11.1	11.2
12.1	10.3	10.4	10.5	10.5	10.6	10.6	10.7	10.7	10.8	10.8	10.9	10.9	11.0	11.0	11.1	11.2
12.2	10.3	10.4	10.4	10.5	10.5	10.6	10.6	10.7	10.8	10.8	10.9	10.9	11.0	11.0	11.1	11.1
12.3	10.3	10.4	10.4	10.5	10.5	10.6	10.6	10.7	10.7	10.8	10.8	10.9	10.9	11.0	11.0	11.1
12.4	10.3	10.3	10.4	10.4	10.5	10.5	10.6	10.6	10.7	10.8	10.8	10.9	10.9	11.0	11.0	11.1
12.5	10.3	10.3	10.4	10.4	10.5	10.5	10.6	10.6	10.7	10.7	10.8	10.8	10.9	10.9	11.0	11.1
12.6	10.2	10.3	10.3	10.4	10.4	10.5	10.5	10.6	10.7	10.7	10.8	10.8	10.9	10.9	11.0	11.0
12.7	10.2	10.3	10.3	10.4	10.4	10.5	10.5	10.6	10.6	10.7	10.7	10.8	10.8	10.9	10.9	11.0
12.8	10.2	10.2	10.3	10.3	10.4	10.4	10.5	10.6	10.6	10.7	10.7	10.8	10.8	10.9	10.9	11.0
12.9	10.2	10.2	10.3	10.3	10.4	10.4	10.5	10.5	10.6	10.6	10.7	10.7	10.8	10.8	10.9	11.0
13.0	10.1	10.2	10.2	10.3	10.3	10.4	10.5	10.5	10.6	10.6	10.7	10.7	10.8	10.8	10.9	10.9
13.1	10.1	10.2	10.2	10.3	10.3	10.4	10.4	10.5	10.5	10.6	10.6	10.7	10.7	10.8	10.9	10.9
13.2	10.1	10.1	10.2	10.3	10.3	10.4	10.4	10.5	10.5	10.6	10.6	10.7	10.7	10.8	10.8	10.9
13.3	10.1	10.1	10.2	10.2	10.3	10.3	10.4	10.4	10.5	10.5	10.6	10.6	10.7	10.8	10.8	10.9
13.4	10.0	10.1	10.2	10.2	10.3	10.3	10.4	10.4	10.5	10.5	10.6	10.6	10.7	10.7	10.8	10.8
13.5	10.0	10.1	10.1	10.2	10.2	10.3	10.3	10.4	10.4	10.5	10.5	10.6	10.7	10.7	10.8	10.8
13.6	10.0	10.1	10.1	10.2	10.2	10.3	10.3	10.4	10.4	10.5	10.5	10.6	10.6	10.7	10.7	10.8
13.7	10.0	10.0	10.1	10.1	10.2	10.2	10.3	10.3	10.4	10.4	10.5	10.6	10.6	10.7	10.7	10.8
13.8	10.0	10.0	10.1	10.1	10.2	10.2	10.3	10.3	10.4	10.4	10.5	10.5	10.6	10.6	10.7	10.7
13.9	9.9	10.0	10.0	10.1	10.1	10.2	10.2	10.3	10.4	10.4	10.5	10.5	10.6	10.6	10.7	10.7
14.0	9.9	10.0	10.0	10.1	10.1	10.2	10.2	10.3	10.3	10.4	10.4	10.5	10.5	10.6	10.6	10.7
14.1	9.9	9.9	10.0	10.0	10.1	10.2	10.2	10.3	10.3	10.4	10.4	10.5	10.5	10.6	10.6	10.7
14.2	9.9	9.9	10.0	10.0	10.1	10.1	10.2	10.2	10.3	10.3	10.4	10.4	10.5	10.5	10.6	10.6
14.3	9.9	9.9	10.0	10.0	10.1	10.1	10.2	10.2	10.3	10.3	10.4	10.4	10.5	10.5	10.6	10.6
14.4	9.8	9.9	9.9	10.0	10.0	10.1	10.1	10.2	10.2	10.3	10.3	10.4	10.4	10.5	10.5	10.6
14.5	9.8	9.9	9.9	10.0	10.0	10.1	10.1	10.2	10.2	10.3	10.3	10.4	10.4	10.5	10.5	10.6
14.6	9.8	9.8	9.9	9.9	10.0	10.0	10.1	10.1	10.2	10.2	10.3	10.3	10.4	10.4	10.5	10.6
14.7	9.8	9.8	9.9	9.9	10.0	10.0	10.1	10.1	10.2	10.2	10.3	10.3	10.4	10.4	10.5	10.5
14.8	9.7	9.8	9.8	9.9	9.9	10.0	10.0	10.1	10.2	10.2	10.3	10.3	10.4	10.4	10.5	10.5
14.9	9.7	9.8	9.8	9.9	9.9	10.0	10.0	10.1	10.1	10.2	10.2	10.3	10.3	10.4	10.4	10.5
15.0	9.7	9.8	9.8	9.9	9.9	10.0	10.0	10.1	10.1	10.2	10.2	10.3	10.3	10.4	10.4	10.5
15.1	9.7	9.7	9.8	9.8	9.9	9.9	10.0	10.0	10.1	10.1	10.2	10.2	10.3	10.3	10.4	10.4
15.2	9.7	9.7	9.8	9.8	9.9	9.9	10.0	10.0	10.1	10.1	10.2	10.2	10.3	10.3	10.4	10.4
15.3	9.6	9.7	9.7	9.8	9.8	9.9	9.9	10.0	10.0	10.1	10.1	10.2	10.2	10.3	10.3	10.4
15.4	9.6	9.7	9.7	9.8	9.8	9.9	9.9	10.0	10.0	10.1	10.1	10.2	10.2	10.3	10.3	10.4
15.5	9.6	9.6	9.7	9.7	9.8	9.8	9.9	9.9	10.0	10.0	10.1	10.1	10.2	10.2	10.3	10.3
15.6	9.6	9.6	9.7	9.7	9.8	9.8	9.9	9.9	10.0	10.0	10.1	10.1	10.2	10.2	10.3	10.3
15.7	9.6	9.6	9.7	9.7	9.8	9.8	9.9	9.9	10.0	10.0	10.1	10.1	10.2	10.2	10.3	10.3
15.8	9.5	9.6	9.6	9.7	9.7	9.8	9.8	9.9	9.9	10.0	10.0	10.1	10.1	10.2	10.2	10.3
15.9	9.5	9.6	9.6	9.7	9.7	9.8	9.8	9.9	9.9	10.0	10.0	10.1	10.1	10.2	10.2	10.3
16.0	9.5	9.5	9.6	9.6	9.7	9.7	9.8	9.8	9.9	9.9	10.0	10.0	10.1	10.1	10.2	10.2
16.1	9.5	9.5	9.6	9.6	9.7	9.7	9.8	9.8	9.9	9.9	10.0	10.0	10.1	10.1	10.2	10.2
16.2	9.5	9.5	9.6	9.6	9.7	9.7	9.8	9.8	9.9	9.9	9.9	10.0	10.0	10.1	10.1	10.2
16.3	9.4	9.5	9.5	9.6	9.6	9.7	9.7	9.8	9.8	9.9	9.9	10.0	10.0	10.1	10.1	10.2
16.4	9.4	9.5	9.5	9.6	9.6	9.7	9.7	9.8	9.8	9.9	9.9	10.0	10.0	10.1	10.1	10.2
16.5	9.4	9.4	9.5	9.5	9.6	9.6	9.7	9.7	9.8	9.8	9.9	9.9	10.0	10.0	10.1	10.1
16.6	9.4	9.4	9.5	9.5	9.6	9.6	9.7	9.7	9.8	9.8	9.9	9.9	10.0	10.0	10.1	10.1
16.7	9.4	9.4	9.5	9.5	9.6	9.6	9.7	9.7	9.7	9.8	9.8	9.9	9.9	10.0	10.0	10.1
16.8	9.3	9.4	9.4	9.5	9.5	9.6	9.6	9.7	9.7	9.8	9.8	9.9	9.9	10.0	10.0	10.1
16.9	9.3	9.4	9.4	9.5	9.5	9.6	9.6	9.7	9.7	9.8	9.8	9.9	9.9	10.0	10.0	10.0
17.0	9.3	9.3	9.4	9.4	9.5	9.5	9.6	9.6	9.7	9.7	9.8	9.8	9.9	9.9	10.0	10.0
17.1	9.3	9.3	9.4	9.4	9.5	9.5	9.6	9.6	9.7	9.7	9.8	9.8	9.9	9.9	10.0	10.0
17.2	9.3	9.3	9.4	9.4	9.5	9.5	9.5	9.6	9.6	9.7	9.7	9.8	9.8	9.9	9.9	10.0
17.3	9.2	9.3	9.3	9.4	9.4	9.5	9.5	9.6	9.6	9.7	9.7	9.8	9.8	9.9	9.9	10.0
17.4	9.2	9.3	9.3	9.4	9.4	9.5	9.5	9.6	9.6	9.7	9.7	9.8	9.8	9.8	9.9	9.9

Temp.	Barometric Pressure (mbar)															
(°C)	975	980	985	990	995	1000	1005	1010	1015	1020	1025	1030	1035	1040	1045	1050
17.5	9.2	9.3	9.3	9.3	9.4	9.4	9.5	9.5	9.6	9.6	9.7	9.7	9.8	9.8	9.9	9.9
17.6	9.2	9.2	9.3	9.3	9.4	9.4	9.5	9.5	9.6	9.6	9.7	9.7	9.8	9.8	9.9	9.9
17.7	9.2	9.2	9.3	9.3	9.4	9.4	9.5	9.5	9.5	9.6	9.6	9.7	9.7	9.8	9.8	9.9
17.8	9.1	9.2	9.2	9.3	9.3	9.4	9.4	9.5	9.5	9.6	9.6	9.7	9.7	9.8	9.8	9.9
17.9	9.1	9.2	9.2	9.3	9.3	9.4	9.4	9.5	9.5	9.6	9.6	9.7	9.7	9.7	9.8	9.8
18.0	9.1	9.2	9.2	9.3	9.3	9.3	9.4	9.4	9.5	9.5	9.6	9.6	9.7	9.7	9.8	9.8
18.1	9.1	9.1	9.2	9.2	9.3	9.3	9.4	9.4	9.5	9.5	9.6	9.6	9.7	9.7	9.8	9.8
18.2	9.1	9.1	9.2	9.2	9.3	9.3	9.4	9.4	9.4	9.5	9.5	9.6	9.6	9.7	9.7	9.8
18.3	9.1	9.1	9.1	9.2	9.2	9.3	9.3	9.4	9.4	9.5	9.5	9.6	9.6	9.7	9.7	9.8
18.4	9.0	9.1	9.1	9.2	9.2	9.3	9.3	9.4	9.4	9.5	9.5	9.6	9.6	9.6	9.7	9.7
18.5	9.0	9.1	9.1	9.2	9.2	9.3	9.3	9.3	9.4	9.4	9.5	9.5	9.6	9.6	9.7	9.7
18.6	9.0	9.0	9.1	9.1	9.2	9.2	9.3	9.3	9.4	9.4	9.5	9.5	9.6	9.6	9.7	9.7
18.7	9.0	9.0	9.1	9.1	9.2	9.2	9.3	9.3	9.4	9.4	9.4	9.5	9.5	9.6	9.6	9.7
18.8	9.0	9.0	9.1	9.1	9.1	9.2	9.2	9.3	9.3	9.4	9.4	9.5	9.5	9.6	9.6	9.7
18.9	8.9	9.0	9.0	9.1	9.1	9.2	9.2	9.3	9.3	9.4	9.4	9.5	9.5	9.6	9.6	9.6
19.0	8.9	9.0	9.0	9.1	9.1	9.2	9.2	9.3	9.3	9.3	9.4	9.4	9.5	9.5	9.6	9.6
19.1	8.9	9.0	9.0	9.0	9.1	9.1	9.2	9.2	9.3	9.3	9.4	9.4	9.5	9.5	9.6	9.6
19.2	8.9	8.9	9.0	9.0	9.1	9.1	9.2	9.2	9.3	9.3	9.4	9.4	9.4	9.5	9.5	9.6
19.3	8.9	8.9	9.0	9.0	9.1	9.1	9.1	9.2	9.2	9.3	9.3	9.4	9.4	9.5	9.5	9.6
19.4	8.9	8.9	8.9	9.0	9.0	9.1	9.1	9.2	9.2	9.3	9.3	9.4	9.4	9.5	9.5	9.5
19.5	8.8	8.9	8.9	9.0	9.0	9.1	9.1	9.2	9.2	9.3	9.3	9.3	9.4	9.4	9.5	9.5
19.6	8.8	8.9	8.9	9.0	9.0	9.0	9.1	9.1	9.2	9.2	9.3	9.3	9.4	9.4	9.5	9.5
19.7	8.8	8.8	8.9	8.9	9.0	9.0	9.1	9.1	9.2	9.2	9.3	9.3	9.4	9.4	9.4	9.5
19.8	8.8	8.8	8.9	8.9	9.0	9.0	9.1	9.1	9.1	9.2	9.2	9.3	9.3	9.4	9.4	9.5
19.9	8.8	8.8	8.9	8.9	8.9	9.0	9.0	9.1	9.1	9.2	9.2	9.3	9.3	9.4	9.4	9.5
20.0	8.7	8.8	8.8	8.9	8.9	9.0	9.0	9.1	9.1	9.2	9.2	9.3	9.3	9.3	9.4	9.4
20.1	8.7	8.8	8.8	8.9	8.9	9.0	9.0	9.0	9.1	9.1	9.2	9.2	9.3	9.3	9.4	9.4
20.2	8.7	8.8	8.8	8.8	8.9	8.9	9.0	9.0	9.1	9.1	9.2	9.2	9.3	9.3	9.4	9.4
20.3	8.7	8.7	8.8	8.8	8.9	8.9	9.0	9.0	9.1	9.1	9.2	9.2	9.2	9.3	9.3	9.4
20.4	8.7	8.7	8.8	8.8	8.9	8.9	9.0	9.0	9.0	9.1	9.1	9.2	9.2	9.3	9.3	9.4
20.5	8.7	8.7	8.8	8.8	8.8	8.9	8.9	9.0	9.0	9.1	9.1	9.2	9.2	9.3	9.3	9.3
20.6	8.6	8.7	8.7	8.8	8.8	8.9	8.9	9.0	9.0	9.1	9.1	9.1	9.2	9.2	9.3	9.3
20.7	8.6	8.7	8.7	8.8	8.8	8.9	8.9	8.9	9.0	9.0	9.1	9.1	9.2	9.2	9.3	9.3
20.8	8.6	8.7	8.7	8.7	8.8	8.8	8.9	8.9	9.0	9.0	9.1	9.1	9.2	9.2	9.2	9.3
20.9	8.6	8.6	8.7	8.7	8.8	8.8	8.9	8.9	9.0	9.0	9.0	9.1	9.1	9.2	9.2	9.3
21.0	8.6	8.6	8.7	8.7	8.8	8.8	8.8	8.9	8.9	9.0	9.0	9.1	9.1	9.2	9.2	9.3
21.1	8.6	8.6	8.6	8.7	8.7	8.8	8.8	8.9	8.9	9.0	9.0	9.1	9.1	9.1	9.2	9.2
21.2	8.5	8.6	8.6	8.7	8.7	8.8	8.8	8.9	8.9	8.9	9.0	9.0	9.1	9.1	9.2	9.2
21.3	8.5	8.6	8.6	8.7	8.7	8.7	8.8	8.8	8.9	8.9	9.0	9.0	9.1	9.1	9.2	9.2
21.4	8.5	8.6	8.6	8.6	8.7	8.7	8.8	8.8	8.9	8.9	9.0	9.0	9.0	9.1	9.1	9.2
21.5	8.5	8.5	8.6	8.6	8.7	8.7	8.8	8.8	8.8	8.9	8.9	9.0	9.0	9.1	9.1	9.2
21.6	8.5	8.5	8.6	8.6	8.7	8.7	8.7	8.8	8.8	8.9	8.9	9.0	9.0	9.1	9.1	9.1
21.7	8.5	8.5	8.5	8.6	8.6	8.7	8.7	8.8	8.8	8.9	8.9	8.9	9.0	9.0	9.1	9.1
21.8	8.4	8.5	8.5	8.6	8.6	8.7	8.7	8.8	8.8	8.8	8.9	8.9	9.0	9.0	9.1	9.1
21.9	8.4	8.5	8.5	8.6	8.6	8.6	8.7	8.7	8.8	8.8	8.9	8.9	9.0	9.0	9.0	9.1
22.0	8.4	8.5	8.5	8.5	8.6	8.6	8.7	8.7	8.8	8.8	8.9	8.9	8.9	9.0	9.0	9.1
22.1	8.4	8.4	8.5	8.5	8.6	8.6	8.7	8.7	8.7	8.8	8.8	8.9	8.9	9.0	9.0	9.1
22.2	8.4	8.4	8.5	8.5	8.6	8.6	8.6	8.7	8.7	8.8	8.8	8.9	8.9	9.0	9.0	9.0
22.3	8.4	8.4	8.4	8.5	8.5	8.6	8.6	8.7	8.7	8.8	8.8	8.8	8.9	8.9	9.0	9.0
22.4	8.3	8.4	8.4	8.5	8.5	8.6	8.6	8.7	8.7	8.7	8.8	8.8	8.9	8.9	9.0	9.0
22.5	8.3	8.4	8.4	8.5	8.5	8.5	8.6	8.6	8.7	8.7	8.8	8.8	8.9	8.9	8.9	9.0
22.6	8.3	8.4	8.4	8.4	8.5	8.5	8.6	8.6	8.7	8.7	8.8	8.8	8.8	8.9	8.9	9.0
22.7	8.3	8.3	8.4	8.4	8.5	8.5	8.6	8.6	8.6	8.7	8.7	8.8	8.8	8.9	8.9	9.0
22.8	8.3	8.3	8.4	8.4	8.5	8.5	8.5	8.6	8.6	8.7	8.7	8.8	8.8	8.8	8.9	8.9
22.9	8.3	8.3	8.4	8.4	8.4	8.5	8.5	8.6	8.6	8.7	8.7	8.7	8.8	8.8	8.9	8.9
23.0	8.3	8.3	8.3	8.4	8.4	8.5	8.5	8.6	8.6	8.6	8.7	8.7	8.8	8.8	8.9	8.9
23.1	8.2	8.3	8.3	8.4	8.4	8.5	8.5	8.5	8.6	8.6	8.7	8.7	8.8	8.8	8.8	8.9
23.2	8.2	8.3	8.3	8.3	8.4	8.4	8.5	8.5	8.6	8.6	8.7	8.7	8.7	8.8	8.8	8.9
23.3	8.2	8.2	8.3	8.3	8.4	8.4	8.5	8.5	8.5	8.6	8.6	8.7	8.7	8.8	8.8	8.9
23.4	8.2	8.2	8.3	8.3	8.4	8.4	8.4	8.5	8.5	8.6	8.6	8.7	8.7	8.7	8.8	8.8
23.5	8.2	8.2	8.3	8.3	8.3	8.4	8.4	8.5	8.5	8.6	8.6	8.6	8.7	8.7	8.8	8.8
23.6	8.2	8.2	8.2	8.3	8.3	8.4	8.4	8.5	8.5	8.5	8.6	8.6	8.7	8.7	8.8	8.8
23.7	8.1	8.2	8.2	8.3	8.3	8.4	8.4	8.4	8.5	8.5	8.6	8.6	8.7	8.7	8.7	8.8
23.8	8.1	8.2	8.2	8.3	8.3	8.3	8.4	8.4	8.5	8.5	8.6	8.6	8.6	8.7	8.7	8.8
23.9	8.1	8.2	8.2	8.2	8.3	8.3	8.4	8.4	8.5	8.5	8.5	8.6	8.6	8.7	8.7	8.8
24.0	8.1	8.1	8.2	8.2	8.3	8.3	8.4	8.4	8.4	8.5	8.5	8.6	8.6	8.7	8.7	8.7
24.1	8.1	8.1	8.2	8.2	8.3	8.3	8.3	8.4	8.4	8.5	8.5	8.6	8.6	8.6	8.7	8.7
24.2	8.1	8.1	8.2	8.2	8.2	8.3	8.3	8.4	8.4	8.4	8.5	8.5	8.6	8.6	8.7	8.7
24.3	8.1	8.1	8.1	8.2	8.2	8.3	8.3	8.3	8.4	8.4	8.5	8.5	8.6	8.6	8.6	8.7
24.4	8.0	8.1	8.1	8.2	8.2	8.2	8.3	8.3	8.4	8.4	8.5	8.5	8.5	8.6	8.6	8.7
24.5	8.0	8.1	8.1	8.1	8.2	8.2	8.3	8.3	8.4	8.4	8.4	8.5	8.5	8.6	8.6	8.7
24.6	8.0	8.0	8.1	8.1	8.2	8.2	8.3	8.3	8.3	8.4	8.4	8.5	8.5	8.6	8.6	8.6
24.7	8.0	8.0	8.1	8.1	8.2	8.2	8.2	8.3	8.3	8.4	8.4	8.5	8.5	8.5	8.6	8.6
24.8	8.0	8.0	8.1	8.1	8.1	8.2	8.2	8.3	8.3	8.4	8.4	8.4	8.5	8.5	8.6	8.6
24.9	8.0	8.0	8.0	8.1	8.1	8.2	8.2	8.3	8.3	8.3	8.4	8.4	8.5	8.5	8.6	8.6
25.0	7.9	8.0	8.0	8.1	8.1	8.2	8.2	8.2	8.3	8.3	8.4	8.4	8.5	8.5	8.5	8.6
25.1	7.9	8.0	8.0	8.1	8.1	8.1	8.2	8.2	8.3	8.3	8.4	8.4	8.4	8.5	8.5	8.6
25.2	7.9	8.0	8.0	8.0	8.1	8.1	8.2	8.2	8.3	8.3	8.3	8.4	8.4	8.5	8.5	8.5
25.3	7.9	7.9	8.0	8.0	8.1	8.1	8.2	8.2	8.2	8.3	8.3	8.4	8.4	8.4	8.5	8.5
25.4	7.9	7.9	8.0	8.0	8.1	8.1	8.1	8.2	8.2	8.3	8.3	8.3	8.4	8.4	8.5	8.5
25.5	7.9	7.9	8.0	8.0	8.0	8.1	8.1	8.2	8.2	8.2	8.3	8.3	8.4	8.4	8.5	8.5
25.6	7.9	7.9	7.9	8.0	8.0	8.1	8.1	8.2	8.2	8.2	8.3	8.3	8.4	8.4	8.4	8.5
25.7	7.8	7.9	7.9	8.0	8.0	8.1	8.1	8.1	8.2	8.2	8.3	8.3	8.3	8.4	8.4	8.5
25.8	7.8	7.9	7.9	8.0	8.0	8.0	8.1	8.1	8.2	8.2	8.2	8.3	8.3	8.4	8.4	8.5
25.9	7.8	7.9	7.9	7.9	8.0	8.0	8.1	8.1	8.1	8.2	8.2	8.3	8.3	8.4	8.4	8.4
26.0	7.8	7.8	7.9	7.9	8.0	8.0	8.1	8.1	8.1	8.2	8.2	8.3	8.3	8.3	8.4	8.4

Temp.	Barometric Pressure (mbar)															
(°C)	975	980	985	990	995	1000	1005	1010	1015	1020	1025	1030	1035	1040	1045	1050
26.1	7.8	7.8	7.9	7.9	8.0	8.0	8.0	8.1	8.1	8.2	8.2	8.2	8.3	8.3	8.4	8.4
26.2	7.8	7.8	7.9	7.9	7.9	8.0	8.0	8.1	8.1	8.1	8.2	8.2	8.3	8.3	8.4	8.4
26.3	7.8	7.8	7.8	7.9	7.9	8.0	8.0	8.0	8.1	8.1	8.2	8.2	8.3	8.3	8.3	8.4
26.4	7.7	7.8	7.8	7.9	7.9	8.0	8.0	8.0	8.1	8.1	8.2	8.2	8.2	8.3	8.3	8.4
26.5	7.7	7.8	7.8	7.9	7.9	7.9	8.0	8.0	8.1	8.1	8.1	8.2	8.2	8.3	8.3	8.3
26.6	7.7	7.8	7.8	7.8	7.9	7.9	8.0	8.0	8.0	8.1	8.1	8.2	8.2	8.3	8.3	8.3
26.7	7.7	7.7	7.8	7.8	7.9	7.9	7.9	8.0	8.0	8.1	8.1	8.2	8.2	8.2	8.3	8.3
26.8	7.7	7.7	7.8	7.8	7.9	7.9	7.9	8.0	8.0	8.1	8.1	8.1	8.2	8.2	8.3	8.3
26.9	7.7	7.7	7.8	7.8	7.8	7.9	7.9	8.0	8.0	8.0	8.1	8.1	8.2	8.2	8.2	8.3
27.0	7.7	7.7	7.7	7.8	7.8	7.9	7.9	7.9	8.0	8.0	8.1	8.1	8.2	8.2	8.2	8.3
27.1	7.6	7.7	7.7	7.8	7.8	7.9	7.9	7.9	8.0	8.0	8.1	8.1	8.1	8.2	8.2	8.3
27.2	7.6	7.7	7.7	7.8	7.8	7.8	7.9	7.9	8.0	8.0	8.0	8.1	8.1	8.2	8.2	8.2
27.3	7.6	7.7	7.7	7.7	7.8	7.8	7.9	7.9	7.9	8.0	8.0	8.1	8.1	8.1	8.2	8.2
27.4	7.6	7.6	7.7	7.7	7.8	7.8	7.8	7.9	7.9	8.0	8.0	8.1	8.1	8.1	8.2	8.2
27.5	7.6	7.6	7.7	7.7	7.8	7.8	7.8	7.9	7.9	8.0	8.0	8.0	8.1	8.1	8.2	8.2
27.6	7.6	7.6	7.7	7.7	7.7	7.8	7.8	7.9	7.9	7.9	8.0	8.0	8.1	8.1	8.1	8.2
27.7	7.6	7.6	7.6	7.7	7.7	7.8	7.8	7.8	7.9	7.9	8.0	8.0	8.0	8.1	8.1	8.2
27.8	7.6	7.6	7.6	7.7	7.7	7.8	7.8	7.8	7.9	7.9	8.0	8.0	8.0	8.1	8.1	8.2
27.9	7.5	7.6	7.6	7.7	7.7	7.7	7.8	7.8	7.9	7.9	7.9	8.0	8.0	8.1	8.1	8.1
28.0	7.5	7.6	7.6	7.6	7.7	7.7	7.8	7.8	7.8	7.9	7.9	8.0	8.0	8.0	8.1	8.1
28.1	7.5	7.6	7.6	7.6	7.7	7.7	7.8	7.8	7.8	7.9	7.9	8.0	8.0	8.0	8.1	8.1
28.2	7.5	7.5	7.6	7.6	7.7	7.7	7.7	7.8	7.8	7.9	7.9	7.9	8.0	8.0	8.1	8.1
28.3	7.5	7.5	7.6	7.6	7.6	7.7	7.7	7.8	7.8	7.8	7.9	7.9	8.0	8.0	8.0	8.1
28.4	7.5	7.5	7.6	7.6	7.6	7.7	7.7	7.8	7.8	7.8	7.9	7.9	8.0	8.0	8.0	8.1
28.5	7.5	7.5	7.5	7.6	7.6	7.7	7.7	7.7	7.8	7.8	7.9	7.9	7.9	8.0	8.0	8.1
28.6	7.4	7.5	7.5	7.6	7.6	7.6	7.7	7.7	7.8	7.8	7.8	7.9	7.9	8.0	8.0	8.0
28.7	7.4	7.5	7.5	7.6	7.6	7.6	7.7	7.7	7.8	7.8	7.8	7.9	7.9	7.9	8.0	8.0
28.8	7.4	7.5	7.5	7.5	7.6	7.6	7.7	7.7	7.7	7.8	7.8	7.9	7.9	7.9	8.0	8.0
28.9	7.4	7.4	7.5	7.5	7.6	7.6	7.6	7.7	7.7	7.8	7.8	7.8	7.9	7.9	8.0	8.0
29.0	7.4	7.4	7.5	7.5	7.6	7.6	7.6	7.7	7.7	7.7	7.8	7.8	7.9	7.9	7.9	8.0
29.1	7.4	7.4	7.5	7.5	7.5	7.6	7.6	7.7	7.7	7.7	7.8	7.8	7.9	7.9	7.9	8.0
29.2	7.4	7.4	7.4	7.5	7.5	7.6	7.6	7.6	7.7	7.7	7.8	7.8	7.8	7.9	7.9	8.0
29.3	7.4	7.4	7.4	7.5	7.5	7.6	7.6	7.6	7.7	7.7	7.7	7.8	7.8	7.9	7.9	7.9
29.4	7.3	7.4	7.4	7.5	7.5	7.5	7.6	7.6	7.7	7.7	7.7	7.8	7.8	7.9	7.9	7.9
29.5	7.3	7.4	7.4	7.4	7.5	7.5	7.6	7.6	7.6	7.7	7.7	7.8	7.8	7.8	7.9	7.9
29.6	7.3	7.4	7.4	7.4	7.5	7.5	7.6	7.6	7.6	7.7	7.7	7.7	7.8	7.8	7.9	7.9
29.7	7.3	7.3	7.4	7.4	7.5	7.5	7.5	7.6	7.6	7.7	7.7	7.7	7.8	7.8	7.9	7.9
29.8	7.3	7.3	7.4	7.4	7.4	7.5	7.5	7.6	7.6	7.6	7.7	7.7	7.8	7.8	7.8	7.9
29.9	7.3	7.3	7.4	7.4	7.4	7.5	7.5	7.6	7.6	7.6	7.7	7.7	7.7	7.8	7.8	7.9
30.0	7.3	7.3	7.3	7.4	7.4	7.5	7.5	7.5	7.6	7.6	7.7	7.7	7.7	7.8	7.8	7.8
30.1	7.3	7.3	7.3	7.4	7.4	7.4	7.5	7.5	7.6	7.6	7.6	7.7	7.7	7.8	7.8	7.8
30.2	7.2	7.3	7.3	7.4	7.4	7.4	7.5	7.5	7.6	7.6	7.6	7.7	7.7	7.7	7.8	7.8
30.3	7.2	7.3	7.3	7.3	7.4	7.4	7.5	7.5	7.5	7.6	7.6	7.7	7.7	7.7	7.8	7.8
30.4	7.2	7.3	7.3	7.3	7.4	7.4	7.4	7.5	7.5	7.6	7.6	7.6	7.7	7.7	7.8	7.8
30.5	7.2	7.2	7.3	7.3	7.4	7.4	7.4	7.5	7.5	7.6	7.6	7.6	7.7	7.7	7.7	7.8
30.6	7.2	7.2	7.3	7.3	7.3	7.4	7.4	7.5	7.5	7.5	7.6	7.6	7.7	7.7	7.7	7.8
30.7	7.2	7.2	7.3	7.3	7.3	7.4	7.4	7.4	7.5	7.5	7.6	7.6	7.6	7.7	7.7	7.8
30.8	7.2	7.2	7.2	7.3	7.3	7.4	7.4	7.4	7.5	7.5	7.6	7.6	7.6	7.7	7.7	7.7
30.9	7.2	7.2	7.2	7.3	7.3	7.3	7.4	7.4	7.5	7.5	7.5	7.6	7.6	7.7	7.7	7.7
31.0	7.1	7.2	7.2	7.3	7.3	7.3	7.4	7.4	7.4	7.5	7.5	7.6	7.6	7.6	7.7	7.7
31.1	7.1	7.2	7.2	7.2	7.3	7.3	7.4	7.4	7.4	7.5	7.5	7.6	7.6	7.6	7.7	7.7
31.2	7.1	7.2	7.2	7.2	7.3	7.3	7.3	7.4	7.4	7.5	7.5	7.5	7.6	7.6	7.7	7.7
31.3	7.1	7.1	7.2	7.2	7.3	7.3	7.3	7.4	7.4	7.4	7.5	7.5	7.6	7.6	7.6	7.7
31.4	7.1	7.1	7.2	7.2	7.2	7.3	7.3	7.4	7.4	7.4	7.5	7.5	7.6	7.6	7.6	7.7
31.5	7.1	7.1	7.2	7.2	7.2	7.3	7.3	7.3	7.4	7.4	7.5	7.5	7.5	7.6	7.6	7.7
31.6	7.1	7.1	7.1	7.2	7.2	7.3	7.3	7.3	7.4	7.4	7.4	7.5	7.5	7.6	7.6	7.6
31.7	7.1	7.1	7.1	7.2	7.2	7.2	7.3	7.3	7.4	7.4	7.4	7.5	7.5	7.6	7.6	7.6
31.8	7.0	7.1	7.1	7.2	7.2	7.2	7.3	7.3	7.3	7.4	7.4	7.5	7.5	7.5	7.6	7.6
31.9	7.0	7.1	7.1	7.1	7.2	7.2	7.3	7.3	7.3	7.4	7.4	7.4	7.5	7.5	7.6	7.6
32.0	7.0	7.1	7.1	7.1	7.2	7.2	7.2	7.3	7.3	7.4	7.4	7.4	7.5	7.5	7.5	7.6
32.1	7.0	7.0	7.1	7.1	7.2	7.2	7.2	7.3	7.3	7.3	7.4	7.4	7.5	7.5	7.5	7.6
32.2	7.0	7.0	7.1	7.1	7.1	7.2	7.2	7.3	7.3	7.3	7.4	7.4	7.4	7.5	7.5	7.6
32.3	7.0	7.0	7.1	7.1	7.1	7.2	7.2	7.2	7.3	7.3	7.4	7.4	7.4	7.5	7.5	7.5
32.4	7.0	7.0	7.0	7.1	7.1	7.2	7.2	7.2	7.3	7.3	7.3	7.4	7.4	7.5	7.5	7.5
32.5	7.0	7.0	7.0	7.1	7.1	7.1	7.2	7.2	7.3	7.3	7.3	7.4	7.4	7.4	7.5	7.5
32.6	6.9	7.0	7.0	7.1	7.1	7.1	7.2	7.2	7.2	7.3	7.3	7.4	7.4	7.4	7.5	7.5
32.7	6.9	7.0	7.0	7.1	7.1	7.1	7.2	7.2	7.2	7.3	7.3	7.3	7.4	7.4	7.5	7.5
32.8	6.9	7.0	7.0	7.0	7.1	7.1	7.2	7.2	7.2	7.3	7.3	7.3	7.4	7.4	7.4	7.5
32.9	6.9	7.0	7.0	7.0	7.1	7.1	7.1	7.2	7.2	7.3	7.3	7.3	7.4	7.4	7.4	7.5
33.0	6.9	6.9	7.0	7.0	7.1	7.1	7.1	7.2	7.2	7.2	7.3	7.3	7.4	7.4	7.4	7.5
33.1	6.9	6.9	7.0	7.0	7.0	7.1	7.1	7.2	7.2	7.2	7.3	7.3	7.3	7.4	7.4	7.4
33.2	6.9	6.9	7.0	7.0	7.0	7.1	7.1	7.1	7.2	7.2	7.3	7.3	7.3	7.4	7.4	7.4
33.3	6.9	6.9	6.9	7.0	7.0	7.1	7.1	7.1	7.2	7.2	7.2	7.3	7.3	7.4	7.4	7.4
33.4	6.9	6.9	6.9	7.0	7.0	7.0	7.1	7.1	7.2	7.2	7.2	7.3	7.3	7.3	7.4	7.4
33.5	6.8	6.9	6.9	7.0	7.0	7.0	7.1	7.1	7.1	7.2	7.2	7.3	7.3	7.3	7.4	7.4
33.6	6.8	6.9	6.9	6.9	7.0	7.0	7.1	7.1	7.1	7.2	7.2	7.2	7.3	7.3	7.4	7.4
33.7	6.8	6.9	6.9	6.9	7.0	7.0	7.0	7.1	7.1	7.2	7.2	7.2	7.3	7.3	7.3	7.4
33.8	6.8	6.8	6.9	6.9	7.0	7.0	7.0	7.1	7.1	7.1	7.2	7.2	7.3	7.3	7.3	7.4
33.9	6.8	6.8	6.9	6.9	6.9	7.0	7.0	7.1	7.1	7.1	7.2	7.2	7.2	7.3	7.3	7.4
34.0	6.8	6.8	6.9	6.9	6.9	7.0	7.0	7.0	7.1	7.1	7.2	7.2	7.2	7.3	7.3	7.3
34.1	6.8	6.8	6.9	6.9	6.9	7.0	7.0	7.0	7.1	7.1	7.1	7.2	7.2	7.3	7.3	7.3
34.2	6.8	6.8	6.8	6.9	6.9	6.9	7.0	7.0	7.1	7.1	7.1	7.2	7.2	7.2	7.3	7.3
34.3	6.8	6.8	6.8	6.9	6.9	6.9	7.0	7.0	7.0	7.1	7.1	7.2	7.2	7.2	7.3	7.3
34.4	6.7	6.8	6.8	6.9	6.9	6.9	7.0	7.0	7.0	7.1	7.1	7.1	7.2	7.2	7.3	7.3
34.5	6.7	6.8	6.8	6.8	6.9	6.9	7.0	7.0	7.0	7.1	7.1	7.1	7.2	7.2	7.2	7.3
34.6	6.7	6.8	6.8	6.8	6.9	6.9	6.9	7.0	7.0	7.0	7.1	7.1	7.2	7.2	7.2	7.3
34.7	6.7	6.7	6.8	6.8	6.9	6.9	6.9	7.0	7.0	7.0	7.1	7.1	7.1	7.2	7.2	7.3
34.8	6.7	6.7	6.8	6.8	6.8	6.9	6.9	7.0	7.0	7.0	7.1	7.1	7.1	7.2	7.2	7.2
34.9	6.7	6.7	6.8	6.8	6.8	6.9	6.9	6.9	7.0	7.0	7.1	7.1	7.1	7.2	7.2	7.2
35.0	6.7	6.7	6.7	6.8	6.8	6.9	6.9	6.9	7.0	7.0	7.0	7.1	7.1	7.1	7.2	7.2

Appendix A6

Standard Operating Guidelines for Measurements of Specific Conductance

STANDARD OPERATING GUIDELINES FOR MEASUREMENT OF SPECIFIC CONDUCTANCE

1.0 INTRODUCTION

1.1 Purpose and Applicability

These Standard Operating Guidelines (SOG) provide basic instructions for routine calibration and operation of a variety of specific conductance meters. Although this meter measures additional parameters (e.g., temperature, TDS), this SOG addresses specific conductance measurement only (other capabilities are outlined in the appropriate SOG and manufacturer's individual instrument manuals). This SOG is designed specifically for the measurement of specific conductance in accordance with EPA Method 120.1 and Standard Method 2510 B which address specific conductance measurements of drinking, surface, and saline waters, domestic and industrial wastes, and acid rain.

1.2 Quality Assurance Planning Considerations

The end use of the data will determine the quality assurance requirements that are necessary to produce data of acceptable quality. These quality assurance requirements will be defined in the site-specific workplan or Quality Assurance Project Plan (QAPP) (hereafter referred to as the project plan) or laboratory Quality Assurance Manual (OAM) and may include duplicate or replicate measurements or confirmatory analyses.

2.0 RESPONSIBILITIES

The analyst is responsible for verifying that the specific conductance meter is in proper operating condition prior to use and for implementing the calibration and measurement procedures in accordance with this SOG and the project plan.

The project manager is responsible for ensuring that project-specific requirements are communicated to the project team and for providing the materials, resources, and guidance necessary to perform the measurements in accordance with this SOG and the project plan.

3.0 REQUIRED MATERIALS

The following materials are necessary for this procedure:

- Specific conductance meter
- Specific conductance meter manufacturer's instruction manual
- Deionized water
- KCI standard at concentration that approximates sample concentrations
- Lint-free tissues
- National Institute of Standards and Technology (NIST)-traceable thermometer
- Calibration sheets or logbook
- Laboratory or field data sheets or logbooks

4.0 METHOD

4.1 Sample Handling, Preservation, and General Measurement Procedures

- Specific conductance measurements should be taken soon after sample collection since temperature changes, precipitation reactions, and absorption of carbon from the air can affect the specific conductance. If specific conductance measurements cannot be taken immediately (within 24 hours), samples should be filtered through a 0.45 μm filter, stored at 4°C and analyzed within 28 days.
- Report results as specific conductance, μmhos/cm at 25°C.

- As temperature can affect the specific conductance measurements obtained, record both the specific conductance and the temperature of the sample. The Cole-Parmer Portable Conductivity Meter and YSI Model 85 have the ability to compensate for temperature.
- Secondary standards may be purchased as a solution from commercial vendors. These standards should not be used after their expiration dates as provided by the manufacturer. An expiration date of one year should be used if the manufacturer does not supply an expiration date or if the standards are prepared from various salts (e.g., KCI).

4.2 Calibration and Measurement Procedures

- The specific conductance meter must be calibrated daily (or the calibration checked) before any analyses are performed.
- Set up the instrument according to the manufacturer's instructions.
- Rinse the probe with deionized water and dry with a lint-free tissue.
- Dip the probe into the calibration standard. Immerse the probe tip beyond the upper steel band. Stir the probe gently to create a homogenous sample.
- Record the stabilized specific conductance reading of the standard and the temperature. Enter the calibration mode (according to manufacturer's instructions) and change the value on the primary display to match the value of the calibration standard. The meter can be adjusted to $\pm$ 20% from the default setting. If the measurement differs by more than $\pm$ 20%, the probe should be cleaned or replaced as needed. If the meter does not have automatic temperature compensation (ATC), correct all measurements to 25°C by adding 2% of the reading per degree if the temperature is below 25°C or by subtracting 2% of the reading per degree if the temperature is above 25°C.
- An additional check may be performed, if required by the project plan, by placing the probe into an additional KCI standard. This standard should be from a different source than the standard used for the initial calibration. This standard should read within 5% of the true value.
- Verify the calibration every 15 samples and at the end of the day. Recalibrate or replace the instrument if the check value is not within 15% of the true value.
- The probe will be rinsed with deionized water and wiped gently with a lint-free tissue between sample analyses.
- The meter must be recalibrated following any maintenance activities and prior to the next use.
- Conductivity data may be post calibrated using any of a variety of calibration data including, but not limited to field calibration points, manufacturer calibration data, and analytical results from samples collected during field deployment of the sensors. The decision criteria for post calibration, and the technique used will be specified in the project plan, and will be consistent with the manufacturer's recommendations.

4.3 Troubleshooting Information

If there are any performance problems with any of the specific conductance meters which result in inability to achieve the acceptance criteria presented in Section 5.0, consult the appropriate section of the meter instruction manual for the checkout and self-test procedures. If the problem persists, consult the manufacturer's customer service department immediately for further instructions.

4.4 Maintenance

- Instrument maintenance should be performed according to the procedures and frequencies required by the manufacturer.
- The probe must be stored and maintained according to the manufacturer's instructions.
- If an instrument with ATC is being used, the meter should be checked annually for accuracy with an NIST thermometer.

5.0 QUALITY CONTROL

- The meter must be calibrated daily before sampling and recalibrated every 12 hours, and will not be used for sample determinations of specific conductance unless the initial check standard value is within 5% of the true value.
- Duplicate measurements of a single sample will be performed at the frequency specified in the project plan. In the absence of project-specific criteria, duplicate measurements should agree within 10%.
- The temperature readout of the meter will be checked against an NIST traceable thermometer at least quarterly. If the difference is greater than 0.2°C, the instrument manufacturer will be consulted for instructions. Temperature measurements will be compensated for any difference with the reference thermometer.
- Some agencies may require the analysis of USEPA Water Pollution (WP) performance evaluation samples. These performance evaluation samples will be analyzed as required.

6.0 DOCUMENTATION

- All specific conductance meter calibration, temperature check, and maintenance information will be recorded on the daily calibration sheet (an example is presented as Figure 1). Specific conductivity data may be recorded on the appropriate laboratory or field data sheets or logbooks.
- Calibration documentation must be maintained in a thorough and consistent manner. At a minimum, the following information must be recorded:
    - Date and time of calibration
    - Signature or initials of person performing the measurement
    - Instrument identification number/model
    - Expiration dates and batch numbers for all standards
    - Reading for standard before and after meter adjustment
    - Readings for all continuing calibration checks
    - Temperature of standards (corrected for any difference with reference thermometer)
    - Comments
- Documentation for recorded data must include a minimum of the following:
    - Date and time of analysis
    - Signature or initials of person performing the measurement
    - Instrument identification number/model
    - Sample identification/station location

- Temperature (corrected for any difference with reference thermometer) and conductance of sample (including units and duplicate measurements) Note: show all calculations for converting instrument reading to μmhos/cm if the instrument provides readings in any other units. Useful conversions are: 1 mS/m = 10 μmho/cm or 1 μmho/cm = 0.1 mS/m.
- Comments

7.0 TRAINING/QUALIFICATIONS

To properly perform specific conductance measurements, the analyst must be familiar with the calibration and measurement techniques stated in this SOG. The analyst must also be experienced in the operation of the meter.

Certain state certification programs require that specific conductance measurements be taken in the field by, or in the presence of, personnel that are qualified under the certification program.

8.0 REFERENCES

Standard Methods for the Examination of Water and Wastewater, 17th Edition, 1989.

Methods for the Chemical Analysis of Water and Wastes, EPA 600/4-79-020, Revised 1983.

Appendix A7

Standard Operating Guidelines for Measurements of Turbidity

STANDARD OPERATING GUIDELINES FOR MEASUREMENT OF TURBIDITY

1.0 INTRODUCTION

1.1 Purpose and Applicability

These Standard Operating Guidelines (SOG) provide basic instructions for routine measurement of turbidity using a nephelometric turbidity meter with a digital read-out device such as the LaMotte 2020 Turbidimeter. Measurements are made in accordance with EPA Method 180.1 that addresses nephelometeric turbidity measurement of drinking, surface, and saline waters, and domestic and industrial wastes.

1.2 Quality Assurance Planning Considerations

The end use of the data will determine the quality assurance requirements that are necessary to produce data of acceptable quality. These quality assurance requirements will be defined in the site-specific workplan or Quality Assurance Project Plan (QAPP) (hereafter referred to as the project plan) or laboratory Quality Assurance Manual (QAM) and may include duplicate or replicate measurements or confirmatory measurements.

2.0 RESPONSIBILITIES

2.1 The analyst is responsible for verifying that the turbidity measuring device is in proper operating condition prior to use and for implementing the calibration and measurement procedures in accordance with this SOG and the project plan.

2.2 The project manager is responsible for ensuring that project-specific requirements are communicated to the project team and for providing the materials, resources, and guidance necessary to perform the measurements in accordance with this SOG and the project plan.

3.0 REQUIRED MATERIALS

The following materials are necessary for this procedure:

- Turbidity meter with digital read-out device
- Manufacturer's instruction manual for the instrument
- Turbidity tubes
- Mild detergent
- Lint-free cloth
- Distilled water
- Nephelometric Turbidity Unit (NTU) calibration standards (1.00 NTU and 10.0 NTU), or as appropriate for project
- Laboratory or field data sheets or logbooks

4.0 METHOD

4.1 Sample Handling, Preservation, and General Measurement Procedures

To achieve accurate turbidity measurements, samples should be analyzed immediately upon collection (preferably within 15 minutes). Samples should be collected in glass or plastic containers.

4.2 Calibration and Measurement Procedures

4.2.1 Select a turbidity standard in the range of the samples to be tested (1.00 NTU or 10.0 NTU). Fill a turbidity tube with the standard, cap, and wipe the tube with the clean lint-free cloth.

4.2.2 Place the sample into the turbidity meter such that the indexing arrow on the turbidity tube is aligned with the indexing arrow on the meter face. Close the lid and press the “READ” button. If the displayed value is not the same as the value of the standard (within 2%), continue with the calibration procedure.

4.2.3 Follow the calibration procedures outlined by the manufacturer’s manual.

4.2.4 Verify the calibration every 15 samples and at the end of the day. Recalibrate the instrument if the check value varies more than 2% from the true value.

4.2.5 The turbidity tubes will be rinsed with deionized water and wiped gently with a lint-free tissue between sample analysis.

4.2.6 Recalibrate the instrument with the appropriate NTU standard if the standard is not of the same order of magnitude as the samples being tested.

4.2.7 The meter must be re-calibrated following any maintenance activities and prior to the next use.

4.2.8 Record the turbidity reading to the nearest 0.01 NTU for measurements less than 11 NTU and to the nearest 0.1 for measurements greater than 11 NTU but less than 110 NTU. For values greater than 110 NTU record to the nearest 1 NTU.

4.3 Troubleshooting Information

If there are any performance problems with any of the meter-type turbidity measuring devices, consult the appropriate section of the meter instruction manual for the checkout and self-test procedures. If the problem persists, consult the manufacturer's customer service department immediately for further instructions.

4.4 Maintenance

Instrument maintenance for meter-type turbidity measuring devices should be performed according to the procedures and frequencies required by the manufacturer.

5.0 QUALITY CONTROL

5.1 The turbidity measuring tubes will, at a minimum, be checked against NTU calibration standards at the frequency stated in Section 4.2.1. This verification procedure will be performed as follows:

- Insert the turbidity tube with distilled water into the turbidity meter.
- Press “READ”.
- Record the readings and document the difference.
- Label each turbidity tube with its corresponding turbidity correction value.
- Record the adjustment and the date the accuracy check was performed in a logbook.

- Compensate for the difference when sample measurements are taken.

5.2 Duplicate measurements of a single sample will be performed at the frequency stated in the project plan. In the absence of project-specific criteria, duplicate measurements should agree within ± 2% for readings below 100 NTU and ± 3% for readings above 100 NTU.

6.0 DOCUMENTATION

All turbidity meter calibration, checks, and maintenance information will be recorded on the daily calibration sheet or logbook. Turbidity data may be recorded on the appropriate laboratory or field data sheets or logbooks.

6.1 Calibration documentation must be maintained in a thorough and consistent manner. At a minimum, the following information must be recorded:

- Date and time of calibration
- Signature or initials of person performing the measurement
- Instrument identification number/model
- Expiration dates and batch numbers for all standard solutions
- Reading for 1.00 NTU standard before and after meter adjustment
- Reading for 10.0 NTU standard before and after meter adjustment
- Readings for all continuing calibration checks
- Comments

6.2 Documentation for recorded data must include a minimum of the following:

- Date and time of analysis
- Signature or initials of person performing the measurement
- Instrument identification number/model
- Sample identification/station location
- Turbidity of sample (including units and duplicate measurements)
- Comments

7.0 TRAINING/QUALIFICATIONS

To properly perform turbidity measurements, the analyst must be familiar with the calibration and measurement techniques stated in this SOG. The analyst must also be experienced in the operation of the meter.

Certain state certification programs require that turbidity measurements in the field be taken by, or in the presence of, personnel that are qualified under the certification program.

8.0 REFERENCES

Standard Methods for the Examination of Water and Wastewater, 17th Edition, 1989.

Methods for the Chemical Analysis of Water and Wastes, EPA 600/4-79-020, Revised 1983.

Appendix A8

Standard Operating Procedure for Collection of Benthic Algae from Natural Substrates

Standard Operating Procedure for Collection of Benthic Algae from Natural and Artificial Substrates

SOP-WR-W-37

APPROVALS:

Deputy Chief of Water Resources:

Sue Kiernan	Sue Kiernan	8/4/12
Printed Name	Signature	Date

Quality Assurance Manager:

Connie Carey	Connie Carey	8/9/12
Printed Name	Signature	Date

DISTRIBUTION

(x) Surface Water Monitoring & Assessment (Connie Carey) ..... By:_____Date :_____

(x) TMDL Program (Elizabeth Scott) ..... By:_____Date :_____

(x) Quality Assurance Manager (Terrence Gray, P.E.)..... By:_____Date :_____

Title: Standard Operating Procedure for Collection of Benthic Algae from Natural and Artificial Substrates
Originator Name: Jane Sawyers

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Standard Operating Procedure for Collection of Benthic Algae from Natural and Artificial Substrates

1. APPLICABILITY

This SOP applies to all Office of Water Resources (OWR) staff involved in collecting benthic algae in wadeable streams from natural and artificial substrates. Exemption from the use of this SOP for project work shall be allowed for reasons of inapplicability determined by management discretion.

2. PURPOSE

This SOP establishes a standardized method for performing quantitative field collection of benthic algae in wadeable streams from natural and artificial substrates. It sets a consistent protocol to ensure the quality of OWR's data collection—resulting in improved uniformity, reproducibility, verifiability, and defensibility of the data, as well as increased program credibility.

3. DEFINITIONS

3.1 RIDEM – Rhode Island Department of Environmental Management

3.2 OWR – RIDEM Office of Water Resources

3.3 SOP – Standard Operating Procedures

3.4 Benthic algae – Micro- and macroalgae growing on the bottom of a stream or lake.

3.5 Periphytometer – A piece of equipment designed to hold glass slides for colonization of benthic algae

3.6 Artificial substrate – Any substrate not naturally occurring in streams, such as clay tiles, glass slides, trash, or human-made structures.

3.7 Natural substrate – Any substrate that naturally occurs in streams, such as logs, rocks, or aquatic vegetation

3.5 QA – Quality Assurance refers to a systematic process to ensure production of valuable, accurate, reliable, reproducible and defensible environmental data

3.6 QC – Quality Control refers to the activities performed to affirm production of valuable, accurate, reliable, reproducible and defensible environmental data

3.7 QI – Quality Improvement refers to any act or process performed to enhance the value, accuracy, reliability, reproducibility or defensibility of environmental data collected by RIDEM OWR

4. RESPONSIBILITIES

4.1 TRAINING

Any RIDEM/OWR personnel collecting benthic algae for a RIDEM project or program should have completed RIDEM's Quality System Awareness Training Program with appropriate documentation from the Quality Assurance Manager. This training ensures the field analyst recognizes the importance of proper data collection and management and he/she comprehends the significance of the environmental decisions that may be made with the data. It is suggested that field analysts have also completed the USEPA Water Quality Standards Academy Basic Course and Supplemental Topic Modules online, but it does not require any additional special training or certification.

4.2 RESPONSIBILITIES OF FIELD ANALYST

To properly collect benthic algae, the field analyst must be familiar with and comply with the data collection techniques stated in this SOP. The field analyst is required to read and understand this SOP. The field analyst should complete and submit any required training forms and/or field assessments for project and/or program QAPPs to document proficiency with this procedure. Any field analyst not familiar with the collection of benthic algae should be assisted by OWR staff who are accustomed to collecting benthic algae.

The field analyst is responsible for checking the required equipment in the Sampling Center at the beginning of deployment and retrieval of artificial substrates and collection from natural substrates. The field analyst is responsible for verifying that the periphytometers are in proper operating condition prior to use (i.e. floats are properly attached; glass slides not cracked and locked into place) and communicating to the project manager when equipment is in need of repair or replacement. The field analyst is also responsible for ensuring that all supplementary equipment (trays, brushes, waders, hip boots, etc.) is present and in working condition. The field analyst is responsible for cleaning and storing the field equipment before and after deployment and before winter storage.

The field analyst is also responsible for using best professional judgment to determine if site conditions are safe for performing the procedure. The field analyst is accountable for employing proper measurement procedures and data recording in accordance with this SOP.

4.3 RESPONSIBILITIES OF PROJECT OR PROGRAM MANAGER

The project or program manager is responsible for providing the materials, resources, and/or guidance necessary to perform the measurements in accordance with this SOP. The project manager is responsible for ensuring that the field analyst collects benthic algae correctly in accordance with this SOP and that any additional, project-specific requirements are communicated to the project team.

The project manager is responsible for ensuring the periphytometers are maintained in proper operating condition annually. This includes ensuring the floats are properly attached to the periphytometers, glass slides are cleaned and

not cracked, and the supplementary equipment is present. The project manager is also responsible for repairing the periphytometers or reordering equipment when necessary.

The project manager will determine and communicate with field analysts what procedures and the order of procedures during deployment and retrieval of artificial substrates and collection from natural substrates. The project manager will determine the dates of deployment and retrieval and communicate the schedule to the field staff. The project manager will also monitor stream gages in the area during deployment to determine the schedule for retrieval of the periphytometers. The project manager will communicate with other OWR field staff sampling the stream segment about the potential for high flows. The project manager will communicate with other OWR staff, contractors, and departments the location of deployed substrates. Further, the project manager shall ensure annual review and periodic updates to this SOP as necessary to reflect current needs and standards as well as revise this SOP every five years.

5. GUIDELINES AND PROCEDURES

5.1 PROPER COLLECTION OF BENTHIC ALGAE

5.1.1 REQUIRED MATERIALS

The following materials are necessary for this procedure:

- Datasheet or field notebook printed on waterproof paper (Figure 1; paper similar to Grainger Item Number 3XFR7)
- Clipboard
- Pencil or Rite in the Rain Pen (similar to Forestry Suppliers Item Number 49237)
- Waders or hip boots
- Periphytometers (Figure 2, similar to Wildco model 156-D30)
- 10% buffered formalin (similar to Fisher item 23245684)
- Disposable dropper (similar to Grainger item 3TRD2)
- Backpack containing (Figure 3):
    - Periphyton brush (similar to Wildco model 156-F40)
    - Sample sorting tray (similar to Wildco model 182-F20)
    - 2 - 250ml amber HDPE Nalgene® bottles per site (similar to Fisher item 02 923 103), pre-labeled with each the site name, date, collectors, and time.

  - Algae sampling frame (made from LDPE plastic similar to Grainger item 1YZU4, with circle cut out measuring 2.5 inches in diameter)
  - 8 Whirl-Pak® bags per site; labeled with the site name/ID, location(s) and a letter A-H
  - Rope (similar to Grainger item 2ELD3)
  - Multi-tool with knife (similar to Grainger item 3FRA8)
  - Black electrical tape
  - Tape measure
  - GPS or ArcPad
  - Infrared thermometer (similar to Forestry Suppliers item 89642)
- Secchi disk attached to tape measure
- Bricks or concrete blocks
- Bleach
- Acetone (90%)
- Pressure sprayer filled with hot tap water
- 2.5 L jug filled with distilled water
- Graduated cylinder

5.1.2 COLLECTION OF BENTHIC ALGAE IN THE FIELD

For most purposes, benthic algae collection will be completed in the field with samples taken from artificial or natural substrates in streams. This method does require sample containers and preservation.

5.1.3 RECORDING PARAMETER UNITS

The following units should be used when recording measurements taken with the artificial samplers and plastic algae frame:

Area sampled.....cm^2

5.2 FIELD MEASUREMENT PROCEDURES

5.2.1 DETERMINE FIELD PROCEDURE SCHEDULE

Prior to departure, the project manager will communicate with the field analysts what procedures should be accomplished for each sampling event to the sampling location and the order in which the field procedures should be completed. Prior to performing these analyses, the field analyst should ensure the benthic algae collection is completed in the correct order. This procedure may disrupt fish and microscopic organisms, such as benthic macroinvertebrates, fish, and algae. This disruption can interfere with other field procedures and sample collections in streams. Furthermore, this procedure can dislodge sediment, which can interfere with water quality sample collections. Benthic algae collection should preferably be completed on days when these samples are not being collected. If other sampling activities must occur on the same day, benthic algae collection should be undertaken after other water quality sampling has been completed. This procedure will typically take place late July through September to capture low flow conditions and maximum algal growth. Other seasons may be sampled as dictated by project goals. This will also highlight a time period in Rhode Island when streams may go dry. It is important that this procedure take place in streams that have continuous flow throughout the deployment of the artificial substrates.

5.2.3 BENTHIC ALGAE COLLECTION

Depending on the individual project goals, benthic algae collection can be taken from natural and/or artificial substrates. This method describes the procedure for collecting from both types of substrates. After collection of the artificial substrates and natural substrates in the field, all samples should be kept on ice and out of the light to prevent degradation of the samples. After compositing of samples, the samples will be stored in amber bottles that prevent light penetration. Any further preparation of the samples for preservation, shipping, or analysis should prevent exposure to light and hot temperatures.

5.2.4 ARTIFICIAL SUBSTRATE PREPARATION

Prior to departure from the sampling center, the field analyst will prepare the appropriate number of periphytometers for placement in the stream, as communicated by the project manager. If the periphytometers and concrete blocks have been deployed in previous years and not cleaned, the field analyst will need to scrub the artificial substrate equipment with warm, soapy water prior to the field season. Artificial substrates are sprayed with bleach prior to winter storage, so this wash will remove any bleach residue.

A scrubbing pad or toothbrush can be gently used on the periphytometers and deployment equipment to dislodge any remaining debris or biological

growth. The artificial substrate equipment will then need to be rinsed free of soap and allowed to dry. New rope should be used every year. Once dry, the periphytometers are prepared by sliding open the locking pieces on the top of the sampling tray (Figure 2).

Prior to the sampling event, the field analyst will prepare the periphytometers for deployment in the sampling center. The field analyst will then attach a rope on both sides of the periphytometer to the cement blocks, which will act as anchors. The field analyst will tie a rope around a concrete block or brick. The block should be tied so that the rope is looped around the block twice, with one end extending a little more than 1.5 feet to allow for manipulation of the concrete block placement to ensure the periphytometer is below the surface of the water (Figure 4B, 5). The field analyst will repeat this with a second concrete block or brick. The field analyst will securely tie the rope from one block to one ring on the periphytometer (Figure 4C). The field analyst will then use black electrical tape to secure the loose end of rope (Figure 4C). The field analyst will tie the other block to the ring on the other side of the periphytometer, securing the end with black electrical tape (Figure 4D). The field analyst will place the required number of periphytometers in separate boxes to prevent any contamination from other field equipment in the vehicle.

5.2.5 ARTIFICIAL SUBSTRATE PLACEMENT CONSIDERATIONS

Artificial substrates should be placed in the stream at least 3 weeks prior to collection to allow for maximum colonization and growth of benthic algae. The periphytometer will be left at the location for at least 3 weeks, preferably 4 weeks. Previous research has shown that maximum accrual in enriched and unenriched streams is reached at 4 weeks (Biggs 1988), but the potential for sloughing of materials from high flows and maximum growth could become an issue near the end of the deployment. The project manager will determine the pick up schedule.

The field analyst will observe the stream and canopy conditions at the sampling location. Several factors should be considered when determining the location of the periphytometer placement:

- The artificial substrate should be preferably placed in an area with continuous flow. The field analyst should make sure that the flow is not back flow (upstream flow) or from backwaters of the main channel. To maintain similar flow conditions across the periphytometer, it should not be placed in bends of the stream where flow will be directed in an arc across the side of the periphytometer.

- The periphytometer should be placed in an area where light is penetrating to the bottom of the stream.

    - The field analyst will ensure that light is penetrating to the bottom by lowering a Secchi disk to the bottom of the stream. The field analyst will say aloud whether the Secchi disk is visible on the

stream bottom, and this data will be recorded on the field data sheet (Figure 1) by the recording field analyst.

- The periphytometer should not be placed in areas with excessively turbulent flow conditions (i.e. areas with large amounts of spray-off from flow striking rocks or other substrate).

- The periphytometer should be placed in an area that receives some sunlight at some point through the day.

    - NOTE: Some sites may have extremely dense canopy cover. Every effort should be made to locate the periphytometer in a place with some sunlight to keep light from becoming the limiting factor to growth. If a lighted area is not available at the sampling location, the field analyst should alert the recording field analyst to make a note on the datasheet or appropriate field notebook.

- To minimize disturbance and vandalism, the periphytometer should be placed in areas that are inconspicuous (away from public roadways, bridges, or walking paths).

    - NOTE: The periphytometer will be submerged just under the surface of the water to mimic light conditions of natural substrate, which should also assist in minimizing disturbance and vandalism.

5.2.6 ARTIFICIAL SUBSTRATE PLACEMENT

Both analysts should wear gloves throughout the entire procedure to minimize the possibility of contact with the glass slides. Using gloves, the field analyst will handle the edges of the slides and place a single slide in each of eight (8) slots (Figure 4A). It is important to wear gloves because skin contact with the glass slides can inhibit the growth of the algae due to oils that naturally occur on the skin. The field analyst will slide the locking piece closed to prevent the slides from slipping out.

The artificial substrate slides will be used to composite one sample for chlorophyll *a* analysis and one sample for diatom identification from each stream site.

- Once the placement location has been selected, the recording field analyst will record the sampling station name and number, date, time, and collectors at the top of the datasheet or field notebook (Figure 1). The recording field analyst will note any observations about stream condition, riparian area, benthic algae growth, or sampling trip and record this information on the datasheet. (Figure 1).

- To minimize disruption of the sediment, both analysts will enter the stream at a point downstream of the selected placement location. Sediment can obscure the view and coat the slides with a source of nutrients other than the flowing water. The recording field analyst will assist with carrying and handing materials to the field analyst. The recording field analyst will carry the backpack containing the supplies.

The field analyst will carry the concrete blocks or bricks and the attached periphytometer.

- Both analysts will travel upstream to the selected location of the artificial substrate placement.

- The field analyst will hand one concrete block or brick connected to the periphytometer to the recording field analyst.

- The field analyst will observe the direction of flow and orient the flow guard of the periphytometer to face into the direction of flow.

    - The flow guard is the clear, curved plastic piece in between one of the floats and the plastic case containing the glass slides on the periphytometer (Figure 2).

- The field analyst will hold the periphytometer in one hand and the brick or concrete block in the other hand. Using the rope tied to the brick or concrete block, the field analyst will gently lower the brick or concrete block to the bottom of the stream. The field analyst will continue to hold onto the periphytometer with the other hand.

- The field analyst will then slowly lower the periphytometer to a depth 0.2 feet below the surface of the water. The recording field analyst will take their concrete block and stretch the length of rope until it is gently taut. The recording field analyst will slowly lower the concrete block to the bottom of the stream bed using the rope. The periphytometer should remain at least 0.2 feet below the surface of the water. If the periphytometer is less than 0.2 feet below the surface of the water, the recording field analyst should grasp the rope of the concrete block and bring it upstream. The recording field analyst will then move the other concrete block downstream until the 0.2 feet depth is achieved.

- Using the tape measure attached to the Secchi disk, the field analyst will measure the depth of periphytometer from the stream substrate to the top of the plastic tray (Figure 6) and read the measurement aloud to the recording field analyst, who will record the value on the datasheet or field notebook.

    - NOTE: The field analyst should make sure the depth is measured from the stream substrate and not the top of the brick or concrete block.

- The field analyst will measure the depth of periphytometer from the water surface to the top of the plastic tray (Figure 6). The field analyst will read the measurement aloud to the recording field analyst, who will record the value on the datasheet or field notebook.

- The recording field analyst will hand a GPS unit or ArcPad to the field analyst. The field analyst will take a waypoint at the location of the periphytometer. The recording field analyst will retrieve the GPS unit

or ArcPad and record the location of the waypoint. The recording field analyst will also note any major landmarks or features on the datasheet or field notebook to identify the location of the periphytometer.

- The recording field analyst will hand the infrared thermometer to the field analyst. The field analyst will point the thermometer at the water surface and press and release the gray button on the front. The field analyst will read the measurement aloud to the recording field analyst, who will record the value on the datasheet or appropriate notebook.
    - NOTE: A water quality sonde may also be used to take this reading.
- Both analysts will exit the stream at the periphytometer location or another location that is safe for them to exit.
- The field analyst should communicate the location of the periphytometer with project manager. Other field personnel can avoid disturbing the equipment and also provide notification if the equipment is damaged or missing. This will also ensure that field staff are not injured by becoming entangled in the ropes attached to the concrete blocks or bricks.
- The project manager will check any available stream gages (http://ri.water.usgs.gov/) in the area and communicate with other field staff sampling area regarding the potential for high flows. The project manager will communicate with the field analyst and recording field analyst when the periphytometers should be retrieved from the sampling location.

5.2.7 RETRIEVING THE ARTIFICIAL SUBSTRATE

- Using the GPS location and the major landmarks or features, the analysts will return to the location of the periphytometer. Both analysts should wear gloves to retrieve the periphytometers to avoid contamination of the samples.
    - NOTE: If the periphytometer is not located, the recording field analyst should note this on the datasheet. Section 5.2.7 will not be completed, and the analysts should continue with Section 5.2.8 Sampling the Natural Substrate. The field analyst will notify the project manager if any periphytometers were not recovered.
    - NOTE: If site conditions have deteriorated (i.e. high flows, bank erosion) significantly since placement of the periphytometer, the field analysts should not retrieve the periphytometer or sample the natural substrate. Photographs of the site conditions should be taken to document the issue for the project manager. The field analyst will communicate with the project manager any lost equipment or inaccessible sites. The project manager will

determine any follow-up action to retrieve the artificial substrates or sample the natural substrates.

- To minimize sediment disruption, the analysts will enter the stream at a location downstream of the periphytometer and travel upstream to the location of the periphytometer. The recording field analyst will assist with carrying and handing materials to the field analyst. The recording field analyst will carry the backpack containing the supplies.

- At the stream bank, the recording field analyst will remove 8 Whirl-Pak® bags from the backpack, each labeled with the site location and a letter A-H.

- The field analyst will observe the location and condition of the periphytometer. The field analyst should relay to the recording field analyst any unusual circumstances of the periphytometer (plants caught on the periphytometer, periphytometer is out of the water, etc.). The recording field analyst should record this information on the datasheet or appropriate field notebook (Figure 1).

- Using the tape measure attached to the Secchi disk, the field analyst will then measure the depth of periphytometer from the stream substrate to the top of the plastic tray (Figure 6) and read the measurements aloud to the recording field analyst, who will record the value on the datasheet or field notebook. The field analyst will then measure from the water surface to the top of the plastic tray (Figure 6) and read aloud the recording field analyst, who will record the value on the datasheet or appropriate field notebook.

    - NOTE: The field analyst should make sure the depth is measured from the stream substrate and not the top of the brick or concrete block.

- The field analyst will carefully grasp the rope of the upstream cement block or brick just under the periphytometer. The field analyst will gently hold the periphytometer by a float or plastic sides in the other hand. The field analyst will then gently pull on the rope attached to the brick or concrete block. The field analyst should pull the rope until the brick or concrete block is exposed from the water. The recording field analyst will repeat this with the downstream concrete block or brick.

    - NOTE: Do not use the periphytometer to pull up the brick or concrete block. This risks ripping off the floats or cracking the plastic tray holding the glass slides.

    - NOTE: Depending on the site conditions, the field analysts may cut the ropes to retrieve the periphytometer. The field analysts will then need to retrieve the concrete blocks or bricks by pulling on the floating rope.

- Both analysts will move to the stream bank. The field analyst will place the upstream concrete block or brick on the stream bank near the recording field analyst. The recording field analyst will then place the downstream concrete block or brick on the stream bank. The field analyst will then hand the periphytometer to the recording field analyst.

- The recording field analyst will slide open the locking mechanism to remove the glass slides from the periphytometers (Figure 2). Carefully avoiding touching the face of each slide, the recording field analyst will remove a single slide from each slot and place one slide in each of the 8 Whirl-Pak® bags. The recording field analyst will add some distilled water to each of the Whirl-Pak® bags. The recording field analyst will roll the top of the bag and close with the imbedded twist-tie.

- The field analyst will observe the amount of aquatic macrophyte and duckweed (*Lemna* sp) and/or watermeal (*Wolffia* sp) growth in the visible 25m reach of stream upstream and 25m downstream of the periphytometer location. If necessary, the field analyst can hike or wade around overhanging vegetation or bends in the stream. If this cannot be accomplished (due to deep water or impassable vegetation), the recording field analyst will estimate how far they can see, and record that visible distance on the field sheet (Figure 1).

- The field analyst will estimate and say aloud the percent cover of all macrophyte growth and duckweed and/or watermeal. The recording field analyst will circle the percent cover of macrophytes and duckweed and/or watermeal growth on the datasheet or appropriate field notebook.

5.2.8 SAMPLING THE NATURAL SUBSTRATE

The field analyst will typically collect two composite samples. One sample will be analyzed for chlorophyll *a*, and the second sample will be sent to a contractor for diatom identification. During the collection of the natural substrates, the field analyst will need to keep 2 amber Nalgene® HDPE bottles in their wader pocket.

- Following retrieval of the artificial substrates, the field analyst will observe the location of natural substrates in the stream. Natural substrate will need to be completely submerged in the water. The natural substrate should be fixed at the location but easy to remove for sampling. Natural substrate will be collected with the following decreasing preference:

    1. Rocky substrate (>2cm – 25cm in diameter)

    2. Woody substrate (branches or sticks greater than 2cm in diameter or surface area)

3. Aquatic vegetation (such as wild celery (Figure 7)) or other broad leafed vegetation with some portion under the water)

    - NOTE: Do not sample any vegetation that is skin irritant, such as poison ivy or stinging nettle (Figure 7).

    - NOTE: Aquatic vegetation should only be used when rocky or woody substrate is not available. Broad-leafed vegetation can be sampled in the process described below, but the field analyst will need to scrub gently to avoid rupturing the cells of the vegetation.

    - NOTE: It is important to sample the same species of vegetation or a species of the same growth type. The recording field analyst should record on the datasheet or field notebook when a growth form other than broad-leafed vegetation is used.

- The field analyst should observe the amount of growth in the stream. The field analyst will use best professional judgment to select substrates that are representative of the benthic algal growth conditions. The field analyst will attempt to only sample the algal growth when possible. The field analyst will avoid heavy non-vascular plant growth

    - For example, in a stream with a single green rock or branch the field analyst should not sample the only rock or branch with growth, or in the case of a stream with large amounts of growth, the field analyst should not sample the only clean rock and woody substrate.

- The field analyst will randomly collect seven pieces of natural substrate representative of algal growth and bring them to a relatively flat surface. The field analyst will attempt to get a mix of different types of substrate.

    - For example, the field analyst should collect 5 rocks and 2 branches or sticks. The chlorophyll *a* analysis will use 2 rocks and 1 stick and diatom taxonomy will use 3 rocks and 1 branch.

- The field analyst will retrieve the backpack of sampling materials from the recording field analyst. The field analyst will remove the periphyton brush, sample sorting tray, algae sampling plastic, and wash bottle filled with distilled water.

- Using DI water, the field analyst will rinse the bottom of the substrate to be scraped over the ground to ensure that only scrubbed material is rinsed into the sample. This rinse will remove large debris adhered to the bottom of rocks.

- The field analyst will sit on the stream bank with their feet directly in front of them and knees slightly bent to make a 45º angle. The field analyst will place the sampling tray on their thighs with the pour spout closest to their body or in a position to not spill the contents while

scraping (Figure 8). All rinse water should be collected in the sampling tray. The field analyst should also take care to minimize the amount of rinse water to avoid overfilling the bottles for processing and shipment.

- NOTE: Do not sit with knees bent in more than a 45º angle. This can promote spilling of the rinse water.

- The field analyst will place the plastic algae sampling frame on the surface of the natural substrate exposed to sunlight. If the circle cut into the plastic is not filled by the surface of the natural substrate, the field analyst will need to observe and estimate the amount of the circle filled.

- Using the periphyton brush, the field analyst will scrub the surface of the natural substrate over the sorting tray. The field analyst will remove the plastic algae sampling frame and place it next to the natural substrate. The field analyst will use a small amount of water to rinse the scrubbed circle on the substrate, and if necessary, any debris on the frame. The field analyst will repeat the scrubbing and rinsing until a clear circle is apparent on the surface of the natural substrate (Figure 9).

  - NOTE: If the circle was not filled by the surface being scrubbed, the field analyst will select another location on the surface and scrub the appropriate area to complete the surface area encompassed by the circle.

- After the circle is scrubbed and rinsed clean, the field analyst will rinse any debris remaining on the plastic algae sampling frame into the tray. The field analyst will select another substrate and repeat the scrubbing and rinsing of the surface until a clear circle is apparent on the surface of the natural substrates.

  - NOTE: Again, at least one of the selected natural substrates should be different than the other selected natural substrates (i.e. 1 rocks, 3 sticks or 3 rocks, 1 stick). The preferred division is 2 rocks and 1 stick for chlorophyll *a* and 3 rocks and 1 stick for diatom taxonomy, but if this is not possible at a site, the field analyst will sample the same natural substrates.

- When the field analyst has scrubbed the preferred number of natural substrates, the field analyst will rinse the periphyton brush and plastic algae sampling frame until a clear rinse has been achieved. If spray from scrubbing the samples has gotten on the field analyst's hands, the field analyst will then rinse their hands, with a small amount of DI water, into the sorting tray.

- The field analyst will then take and open 1 of the amber Nalgene® HDPE bottles and place it at the bottom of the pour spot. The field analyst will then pour the rinse water into the Nalgene® bottle and

rinse the entire sampling tray into the bottle. The field analyst will then tightly replace the lid.

- The field analyst will announce to the recording field analyst the types of substrate sampled for the first sample. The recording field analyst will record this information on the appropriate datasheet or field notebook.

- The field analyst will then rinse the sampling tray, periphyton brush, and plastic algae sampling frame with distilled water. This is to ensure that all debris from scraping has been rinsed clean.

- The field analyst will then select another substrate. The field analyst will again place the sampling tray on their thighs at a 45º angle with the pour spout closest to their body or in a manner to not spill the contents. Using the periphyton brush, the field analyst will scrub the surface of the natural substrate over the sorting tray. The field analyst will remove the plastic algae sampling frame and place it next to the natural substrate. The field analyst will use a small amount of water to rinse the scrubbed circle on the substrate, and if necessary, any debris on the frame. The field analyst will repeat the scrubbing and rinsing until a clear circle is apparent on the surface of the natural substrate.

    - NOTE: If the circle was not filled by the surface being scrubbed, the field analyst will select another location on the surface and scrub the appropriate area to complete the surface area encompassed by the circle.

- After the circle is scrubbed and rinsed clean, the field analyst will rinse any debris remaining on the plastic algae sampling frame into the tray. The field analyst will select another substrate and repeat the scrubbing and rinsing of the surface until a clear circle is apparent on the surface of all the natural substrates.

    - NOTE: Again, at least one of the selected natural substrates should be different than the other selected natural substrates (i.e. 1 rocks, 3 sticks or 3 rocks, 1 stick). The preferred division is 2 rocks and 1 stick for chlorophyll *a* and 3 rocks and 1 stick for diatom taxonomy, but if this is not possible at a site, the field analyst will sample the same natural substrates.

- When the field analyst has scrubbed the preferred number of natural substrates, the field analyst will rinse the periphyton brush and plastic algae sampling frame until a clear rinse has been achieved. If spray from scrubbing the samples has gotten on the field analyst's hands, the field analyst will then rinse their hands, with a small amount of DI water, into the sorting tray.

- The field analyst will then take and open 1 of the amber Nalgene® HDPE bottles and place it at the bottom of the pour spot. The field analyst will then pour the rinse water into the Nalgene® bottle and

rinse the entire sampling tray into the bottle. The field analyst will then tightly replace the lid.

- The field analyst will announce to the recording field analyst the types of substrate sampled for the first sample. The recording field analyst will record this information on the appropriate datasheet or field notebook.

- The field analyst will then rinse the sampling tray, periphyton brush, and plastic with deionized water. This is to ensure that all debris from scraping has been rinsed clean.

- The analysts will exit the stream at the periphytometer location or another location that is safe to exit.

- The benthic algae samples collected will be placed in a cooler on ice.

- Upon return to the vehicle, the field analyst will spray the sampling equipment with pressurized hot tap water to minimize potential transfer of contaminants and invasive species. It will also ensure that sampling equipment is clean between sites to minimize cross-contamination of samples.

- Samples for diatom taxonomy will need to be preserved upon return to the Sampling Center. See Section 5.2.10. All chlorophyll *a* will need to remain in a cooler or refrigerator until filtering.

5.2.9 PROCESSING THE ARTIFICIAL SUBSTRATES IN THE SAMPLING CENTER

The compositing of samples should be done within 24 hours of collection, preferably immediately upon return to the sampling center after retrieval or the artificial substrates. Four slides will be composited for analysis of chlorophyll *a*. The other 4 slides will be composited for diatom taxonomic identification and analysis. All parts of the artificial substrate processing should be done wearing gloves.

- Once back in the sampling center, the field analyst will remove one set of artificial substrate samples from one site for a total of 8 Whirl-Pak® bags. The field analyst will then place two amber Nalgene® bottles on the counter. The field analyst should attempt to minimize light in the sampling center, but the field analyst should not dim the lights to a point where safety will be a concern.

- Using a book or other equipment, the field analyst will set the sampling tray at a 45º angle on the counter.

- The field analyst will put on gloves and unwhirl Whirl-Pak® bag A from the site. The field analyst will carefully remove the glass slide, handling only the sides of each slide.

- Using a periphyton brush or razor blade, the field analyst will carefully scrub or scrape only the surface of each side of the glass slide over

the sampling tray. The field analyst will not scrub the edges of the slide. The field analyst will rinse the scrubbed area into the tray and repeat the scrubbing and rinsing until the slide surface is clean. The field analyst will then place slide A in a wash tub filled with warm, soapy water.

- The Whirl-Pak® bag A should then be rinsed with distilled water into the sampling tray. The Whirl-Pak® bag A should then be discarded in the trash.

- The field analyst will then unwhirl Whirl-Pak® bag B, C and D and repeat the above procedure.

- The field analyst will then rinse the periphyton brush or razor blade into the sorting tray until the rinse is clean. The field analyst will then rinse their hands if spray is apparent on the gloves. The field analyst will then place one of the empty, labeled amber Nalgene® bottles under the pour spout. The field analyst will then rinse the sorting tray into the amber Nalgene® bottle. The field analyst will then recap the bottle and place it back in the refrigerator.

- The field analyst will set the sampling tray at a 45º angle on the counter.

- The field analyst will then unwhirl Whirl-Pak® bag E for the site. The field analyst will carefully remove the glass slide, handling only the sides of the slides.

- The field analyst will carefully scrub only the surface of each side of the glass slide over the sampling tray using a periphyton brush or razor blade. The field analyst will not scrub the edges of the slide. The field analyst will rinse the scrubbed area and repeat the scrubbing and rinsing until the slide surface is clean. The field analyst will then place slide E in a wash tub filled with warm, soapy water.

- The field analyst will then then unwhirl Whirl-Pak® bags F, G, and H for the site. The field analyst will then rinse the periphyton brush until the rinse is clean. The field analyst will then rinse their hands if spray is apparent on the gloves. The field analyst will then place the second empty amber Nalgene® bottles for the site under the pour spout. The field analyst will then rinse the sorting tray into the amber Nalgene® bottle.

5.2.10 DIATOM TAXONOMY SAMPLE PRESERVATION AND MEASUREMENT

- In the hood, the field analyst will add 3 mL of 10% buffered formalin to each bottle being sent for diatom analysis.

    - NOTE: Most algal preservatives contains acid, which will interfere with the analysis of chlorophyll *a*. To ensure that chlorophyll *a* samples are not exposed to acid, preservative should only be

added at the end of compositing all sample sites processed at the end of the day.

- In the hood, the field analyst will gently swirl each bottle being sent for diatom analysis. The contents of the bottle will be poured into a graduated cylinder. The field analyst will note the volume of the sample on the chain of custody (Figure 10). The contents of the bottle will then be poured back into the amber sample bottle. The graduated cylinder will be rinsed with a very small amount of DI water. The bottle will then be placed in the refrigerator until shipping to the contractor.

5.2.11 EQUIPMENT MAINTENANCE

Periphytometers are designed to be reused over many years and sampling sites. In order to minimize cross-contamination of sites and years, the periphytometers and all equipment deployed in the stream must be cleaned and decontaminated after deployment. This process will use bleach, so the field analyst will need to wear clothes or a lab coat that can be exposed to bleach. The field analyst should also consult the MSDS and safety sticker on the bottle of bleach to determine whether safety glasses or other protective equipment is required. The field analyst should wear gloves when cleaning the glass slides.

- After deployment, the field analyst will need to prepare a bucket of warm, soapy water. The field analyst will use scrubbing pads and toothbrushes to gently scrub and clean any debris or growth from the periphytometers and deployment equipment.

- The field analyst will need to prepare a dilute solution of bleach (10%). The field analyst will spray the periphytometers with the bleach solution. The bleach should not be washed off to allow for all current growth to be killed and to discourage any growth over the winter. The periphytometer should be allowed to air dry then placed in the sampling center for winter storage.

- Discard any broken slides in the appropriate glass disposal container in the sampling center. It is preferable to use new slides, but slides that are going to be reused should be scrubbed in warm, soapy water. The slides should then be soaked in 90% acetone overnight. The slides will then be rinsed with distilled water and allowed to dry. The slides can then be stored in the Sampling Center for the winter.

6. QUALITY CONTROL

6.1 QUALITY CONTROL

Quality control of the artificial substrate procedure will be assessed by placing a second periphytometer at 10% of stream segments. Quality control of natural substrate procedure will be assessed by collection of a second set of bottles by the field analyst at 10% of stream segments. This will give a measure of precision for both procedures.

6.2 QUALITY ASSURANCE PLANNING CONSIDERATIONS

The end use of the data will determine the quality assurance requirements that are necessary to produce data of acceptable quality. Unless specified otherwise in a site or project-specific work plan, Quality Assurance Project Plan (QAPP), Quality Assurance Program Plan (QAPP) or laboratory Quality Assurance Manual (QAM), all data collected following the protocols set forth in this document will be collected in accordance with the minimum QAQC requirements of Section 6.1. Further quality assurance requirements will be defined in project specific work plans and may include duplicate or replicate measurements or confirmatory analyses.

7. REFERENCES

Biggs, B.J.F. 1988. Artificial substrate exposure times for periphyton biomass estimates in rivers. New Zealand J. Marine Freshw. Res. 22:507-515.

Danielson, T. 2006. Protocols for Sampling Benthic Algae in Streams, Wetlands, and Freshwater Wetlands. Maine Department of Environmental Protection. DEPLW-0634

Danielson, T. 2009. Description of Nutrient Criteria for Fresh Surface Waters (Chapter 583). Maine Department of Environmental Protection. DEPLW-0974A.

Potapova, M. and D.F. Charles. 2005. Choice of substrate in algae-based water-quality assessment. J. N. Am. Benthol. Soc. 24:415-427.

Figure 1. Benthic Algae Collection Datasheet for Monitoring Section Sampling Events

	Benthic Algae Collection Datasheet						
Stream Segment :	_____				**Town:**	_____	
Site Number:	_____	**Deploy**	**Stream Depth:**	_____ ft	**Periphytometer #**		_____
		Pick-up	**Stream Depth:**	_____ ft			
Deployment Date:	_____	**Time:**	_____	**Pictures:**	_____	**Collectors:**	_____
Retrieval Date:	_____	**Time:**	_____	**Pictures:**	_____	**Collectors:**	_____
Lat/Long of Art Sub:	_____				**QA Site?**	**Yes**	**No**
Lat/Long of Art Sub Dup:	_____						
Major Landmarks of Art Sub:	_____				**Secchi?**	**Yes**	**No**
Major Landmarks of Art Sub Dup:	_____				**Secchi?**	**Yes**	**No**
Comments/Notes:							
Percent Macrophyte Cover (Circle 1)	0	10 - 20	21 - 30	31 - 40	41 - 50	51 - 60	
	61 - 70	71 - 80	81 - 90	91 - 100			
Percent Duckweed and/or Watermeal (Circle 1)	0	10 - 20	21 - 30	31 - 40	41 - 50	51 - 60	
	61 - 70	71 - 80	81 - 90	91 - 100			
	Deploy	**Pickup**			**Deploy**	**Pickup**	
Art Sub Depth Below Surface	_____	_____	ft	**Depth to Bottom**	_____	_____	ft
Art Sub Depth Below Surface Dup	_____	_____	ft	**Depth to Bottom**	_____	_____	ft
Art Sub Retrieved?	**Yes**	**No**		**Intact Glass Slides**		_____	
Art Sub Retrieved Dup?	**Yes**	**No**		**Intact Glass Slides Dup**		_____	
# of Nat Sub Sampled (Chl)	**Rocks**	_____	**Wood**	_____	**Vegetation Type:**	_____	
Total Area (Circles*31.6531)	_____	cm^2					
# of Nat Sub Sampled (Tax)	**Rocks**	_____	**Wood**	_____	**Vegetation Type:**	_____	
Total Area (Circles*31.6531)	_____	cm^2					

Figure 2. <u>Periphytometer</u>

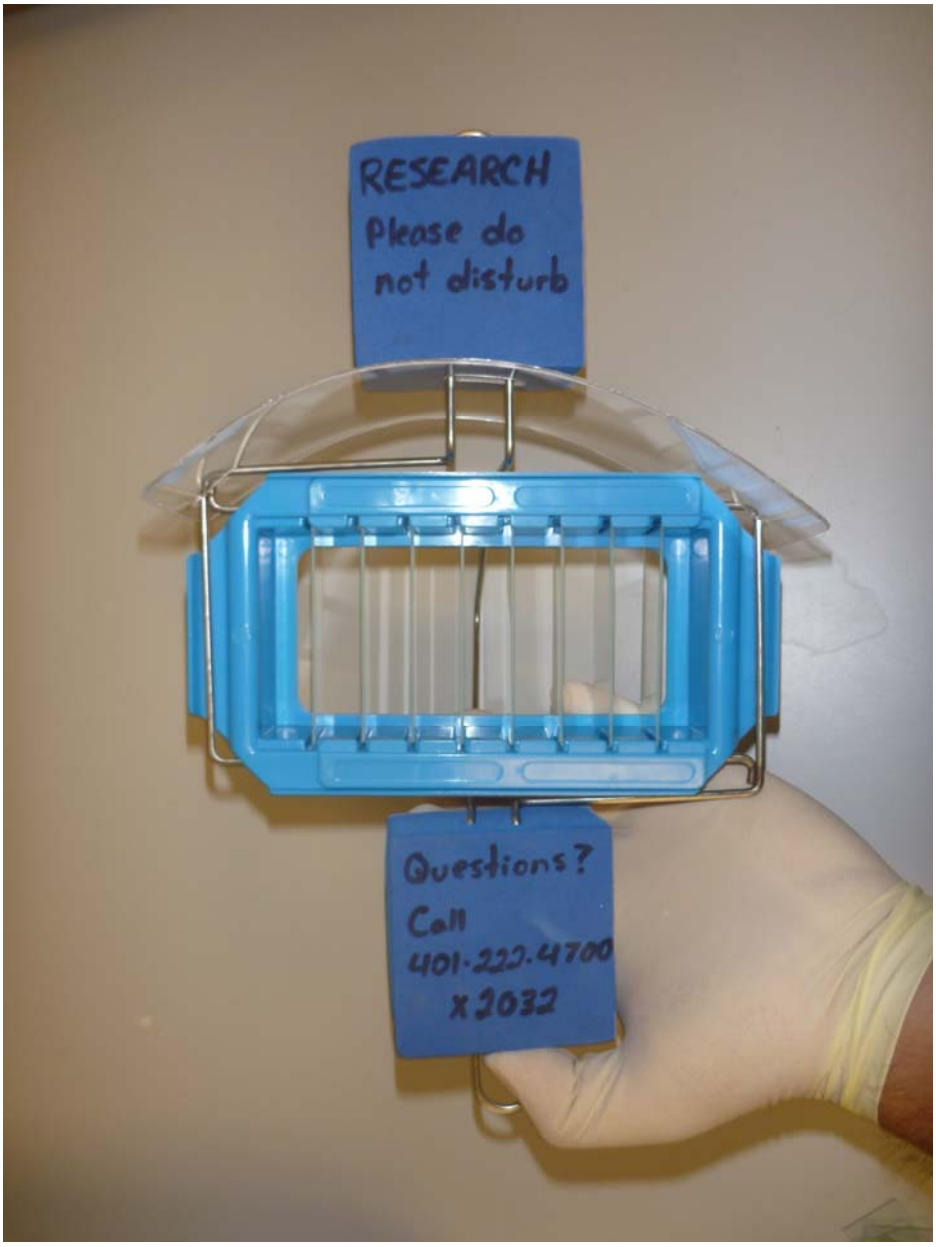

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Figure 3. <u>Supplementary Equipment</u>

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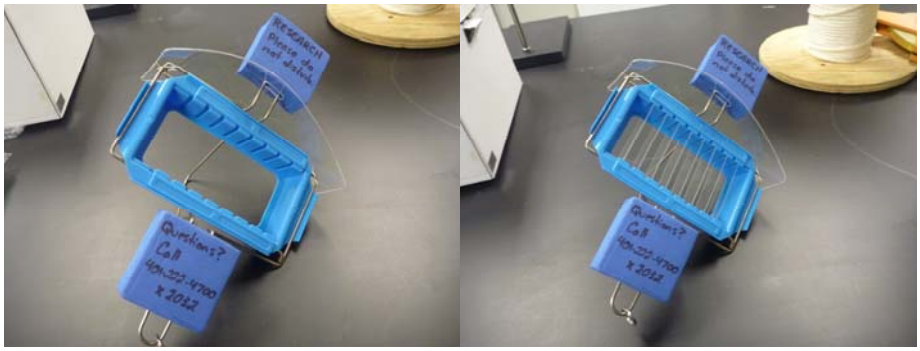
Figure 4. Preparation of the Artificial Substrates

A



B

C

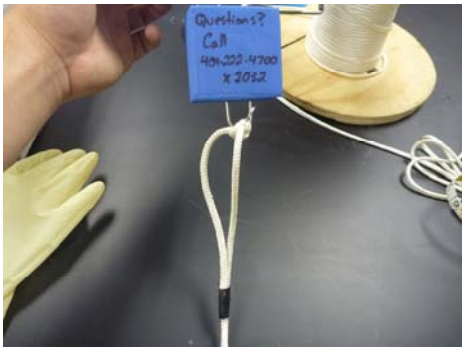


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Figure 5. Deployed Artificial Substrate

Figure 6. Measurements of Periphytometer Depths

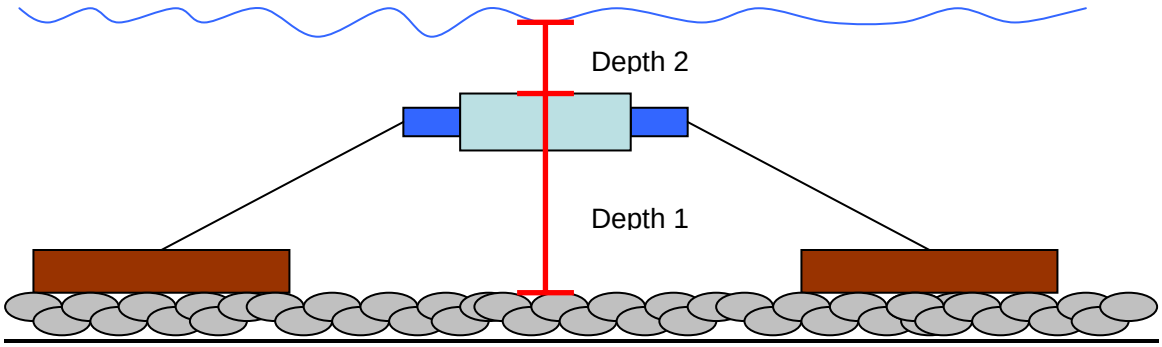


Figure 7. Vegetation Pictures

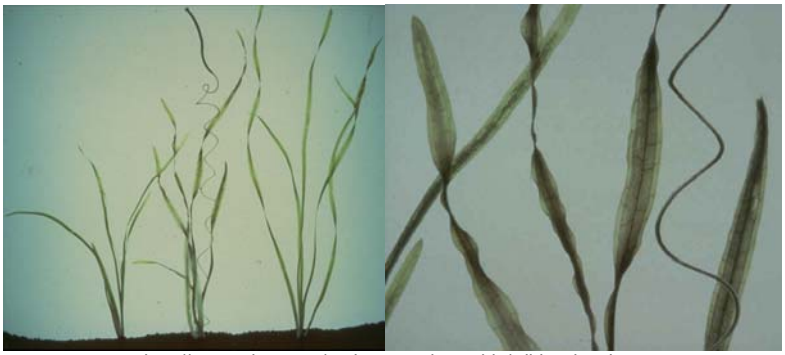
Poison Ivy
(*Toxicodendron radicans* (L.) Kuntze)

http://greatermd.bbb.org/watch-out-for-poison-ivy-/

Stinging Nettle
(*Urtica dioica* L.)

http://www.wildmanstevebrill.com/Plants.Folder/Nettle.html

Wild Celery
(*Apium graveolens* L.)



http://www.mlswa.org/underwaterplantguide/wild_celery.htm

Figure 8. Cleaning of the natural substrate

Figure 9. Example of clean scrubbed circle

Figure 10. Diatom Taxonomy Chain of Custody

Rhithron Associates Inc.
29 Fort Missoula Road
Missoula, MT 59804
406 721 1977

Periphyton Chain of Custody

Sample ID #	Sample Date Collected	Site Name/Waterbody	Station ID	# of Jars	Collection Procedure	Latitude	Longitude	Comments
		Project Name:						
		Contact Person:			Phone:		Email:	
		Relinquished by:				Date:		
		Received by:				Date:		
						page_____of_____		

Appendix A9

Standard Operating Procedure for Pebble Count

Standard Operating Procedure for Measurement of Benthic Algae and Non-Vascular Plant Cover by Viewing Bucket and Modified Pebble Count

SOP-WR-W-36

APPROVALS:

Deputy Chief of Water Resources:

Sue Kiernan	Sue Kiernan	8/4/12
Printed Name	Signature	Date

Quality Assurance Manager:

Connie Carey	Connie Carey	8/9/12
Printed Name	Signature	Date

DISTRIBUTION

(x) Surface Water Monitoring & Assessment (Connie Carey) ..... By:_____Date :_____

(x) TMDL Program (Elizabeth Scott) ..... By:_____Date :_____

(x) Quality Assurance Manager (Tom Getz) ..... By:_____Date :_____

Title: Standard Operating Procedure for Measurement of Benthic Algae and Non-Vascular Plant Cover by Viewing Bucket and Modified Pebble Count
Originator Name: Jane Sawyers

TABLE OF CONTENTS

Standard Operating Procedure for Measurement of Benthic Algae Cover by Viewing Bucket and Modified Pebble Count

1. APPLICABILITY

This SOP applies to all Office of Water Resources (OWR) staff involved in collecting benthic algae and non-vascular cover measurements in shallow, wadeable stream reaches using a viewing bucket and modified pebble count. Exemption from the use of this SOP for project work shall be allowed for reasons of inapplicability determined by management discretion.

2. PURPOSE

This SOP establishes a standardized method for performing semi-quantitative field measurements of benthic algae and non-vascular plant coverage in wadeable streams using a viewing bucket and modified pebble count. It sets a consistent protocol to ensure the quality of OWR's data collection—resulting in improved uniformity, reproducibility, verifiability, and defensibility of the data, as well as increased program credibility.

3. DEFINITIONS

3.1 RIDEM – Rhode Island Department of Environmental Management

3.2 OWR – RIDEM Office of Water Resources

3.3 SOP – Standard Operating Procedures

3.4 Benthic algae – Micro- and macroalgae growing on the bottom of a stream or lake

3.4.1 Macroalgae – Algae that have either a large colonial structure or a plant like structure visible to the naked eye

3.4.2 Microalgae – Algae that are either unicellular or colonial without structure visible to the naked eye

3.5 Non-vascular plants – Plants lacking vascular tissue to transport water and materials, which limits their size to less than 20 cm. Plants appear leafy but lack true stems, roots, and leaves. Includes mosses, liverworts, and hornworts.

3.6 Wadeable stream – Perennial streams 1st through 3rd order draining a watershed area of at least 0.5mi^2 and with a maximum depth less than or equal to 1.0m.

3.6.1 Perennial stream – A stream with continuous flow year-round under typical conditions

3.7 Riffle – A section of stream characterized by shallow, fast-flowing water with the water surface broken by the presence of rocky substrate

3.8 Pool – A section of stream characterized by deep, slow-moving water with the surface not broken by the presence of rocky substrate

3.9 Run – A section of stream that is characterized by fast-flowing water with the surface not broken by the presence of rocky substrate

3.10 Riparian area – The area of land immediately adjacent to the stream

3.11 QA – Quality Assurance refers to a systematic process to ensure production of valuable, accurate, reliable, reproducible and defensible environmental data.

3.12 QC – Quality Control refers to the activities performed to affirm production of valuable, accurate, reliable, reproducible and defensible environmental data.

3.13 QI – Quality Improvement refers to any act or process performed to enhance the value, accuracy, reliability, reproducibility or defensibility of environmental data collected by RIDEM OWR.

4. RESPONSIBILITIES

4.1 TRAINING

Any RIDEM/OWR personnel collecting benthic algae and non-vascular plant cover measurements with a viewing bucket and modified pebble count for a RIDEM project or program should have completed RIDEM's Quality System Awareness Training Program with appropriate documentation from the Quality Assurance Manager. This training ensures the field analyst recognizes the importance of proper data collection and management and he/she comprehends the significance of the environmental decisions that may be made with the data. It is suggested that field analysts have also completed the USEPA Water Quality Standards Academy Basic Course and Supplemental Topic Modules online, but additional special training or certification is not required.

To properly employ the viewing bucket and perform the modified pebble count, the field analyst must be familiar with and comply with the data collection techniques stated in this SOP. The field analyst is required to read and understand this SOP. The field analyst should complete and submit any required training forms and/or field assessments for project and/or program QAPPs to document proficiency with this procedure. Any field analyst not familiar with the use of the viewing bucket or performing the modified pebble count should be assisted by OWR staff who are accustomed to using the equipment and performing the procedure.

4.2 RESPONSIBILITIES OF FIELD ANALYST

The field analyst is responsible for checking the required equipment in the Sampling Center at the beginning of the sampling event before taking measurements in the field. The field analyst is responsible for verifying that the

viewing bucket is in proper operating condition prior to use (i.e. no cracks in the acrylic sheet; white dot pattern apparent; silicon seal water-tight) and communicating to the project manager when equipment is in need of repair or replacement. The field analyst is also responsible for ensuring that all supplementary equipment (waders/hip boots, etc.) is present and in working condition. The field analyst is also responsible for using best professional judgment to determine if site conditions are safe for performing the procedure. The field analyst is accountable for employing proper measurement procedures and data recording in accordance with this SOP.

4.3 RESPONSIBILITIES OF PROJECT OR PROGRAM MANAGER

The project or program manager is responsible for providing the materials, resources, and/or guidance necessary to perform the measurements in accordance with this SOP. The project manager is responsible for ensuring that the field analyst operates the viewing bucket correctly and performs the modified pebble count in accordance with this SOP and that any additional, project-specific requirements are communicated to the project team. The project manager is responsible for ensuring the viewing bucket is maintained in proper operating condition annually. This includes ensuring the acrylic sheet is not cracked, the dot pattern is apparent, and the silicon seal is water-tight. The project manager is also responsible for repairing the viewing bucket or reordering equipment when necessary. The project manager will determine and communicate with field analysts what procedures and order of procedures are to be accomplished during each sampling event to a sampling location. Further, the project manager shall ensure annual review and periodic revisions to this SOP as necessary to reflect current needs and standards as well as renew this SOP every five years.

5. GUIDELINES AND PROCEDURES

5.1 REQUIRED MATERIALS

The following materials are necessary for this procedure:

- Viewing Bucket (Figure 1)
- Metric Ruler (Similar to Fisher Scientific Item S40641P)
- Datasheet (Figure 2)
- Clipboard
- Pencil or Rite in the Rain Pen (Similar to Forestry Suppliers Item 49237)
- Waders, hip or knee boots
- 2 - Handheld Tally Counter (Similar to Grainger Item 2PAU4)
- Arm-length puncture resistant gloves (Similar to Grainger 1AHG1)
- Tape Measure

Figure 1. Viewing Bucket

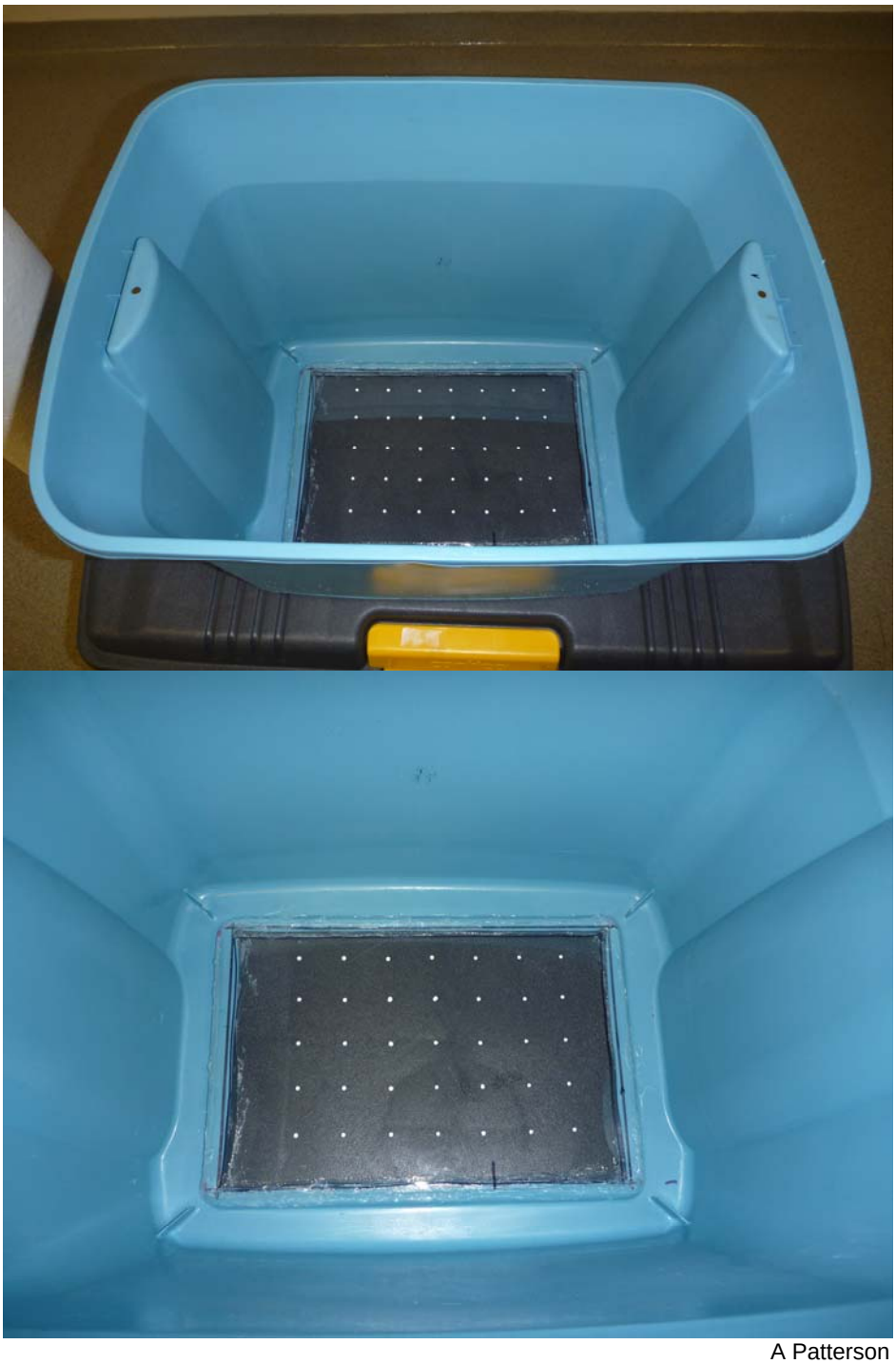


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Figure 2. Viewing Bucket Datasheet for Monitoring Section Sampling Events

Page 1

Viewing Bucket Sampling Datasheet

Stream Segment :	_____		**Town:**	_____	
Site Number:	_____				
		Military			
Date:	_____	**Time:**	_____	**Collectors:**	_____
Meter #	_____			**Pictures:**	_____
Max Depth:	_____	ft	**Lat/Long**	_____	
Weather:	**Clear**		**Partly Cloudy**	**Overcast**	
(Circle)					
	Raining		**Windy**	**Sunny**	

Comments/Notes:

VIEWING BUCKET

	# of dots 1A	1B	1C	2A	2B	2C	3A	3B	3C
Woody Substrate									
Rocky Substrate									
Total									
Macroalgae									
Macroalgae Length (1/sampling point)									

Page 2

Stream Segment: _____

VIEWING BUCKET MICROALGAE

Rank	Description	1A	1B	1C	2A	2B
0	No visual evidence					
1	Thin layer evident					
2	0.5 - 1mm thick					
3	1.01 - 5mm thick					
4	5.01mm - 2cm thick					
5	> than 2.01cm thick					

Rank	Description	2C	3A	3B	3C
0	No visual evidence				
1	Thin layer evident				
2	0.5 - 1mm thick				
3	1.01 - 5mm thick				
4	5.01mm - 2cm thick				
5	> than 2.01cm thick				

Page 3

Stream Segment: _____

PEBBLE COUNT PARTICLE SIZE

Particle S	Descriptio	Tally	Total
Sand	<2mm		
Gravel	2-16mm		
Course Gr	16-64mm		
Cobble	64-256mm		
Boulder	>256		

100?	YES	NO

PEBBLE COUNT NON-VASCULAR

Rank	Description	Tally	Total
0	No visual evidence		
1	Some <5% coverage		
2	5-25% coverage		
3	>25% coverage		

Page 4

Stream Segment: _____

PEBBLE COUNT MACROALGAE

Rank	Description	Tally	Total
0	No visual evidence		
1	Some <5% coverage		
2	5-25% coverage		
3	>25% coverage		

PEBBLE COUNT MICROALGAE

Rank	Description	Tally	Total
0	No visual evidence		
1	Substrate slimly, biofilm not visible; Green coloration		
2	Thin layer present		
3	0.5-1mm		
4	1-5mm		
5	5-20mm		
6	2cm		

5.2 PROPER USE OF VIEWING BUCKET AND PERFORMANCE OF PEBBLE COUNT

For most purposes, the viewing bucket are modified pebble count are used specifically for in situ benthic algae cover measurements taken directly in the field, in wadeable streams. This method does not require sample containers or preservation.

5.2.1 RECORDING PARAMETER UNITS

The following units should be used when recording measurements taken with the viewing bucket:

Macroalgae length.....millimeter

Microalgae mat depth……..rank tally

Non-vascular plant matter mat depth…….....rank tally

Suitable substrate……count of dots; rank tally

Macroalgal coverage……..count of dots; rank tally

5.3 FIELD MEASUREMENT PROCEDURES

5.3.1 DETERMINE FIELD PROCEDURE SCHEDULE

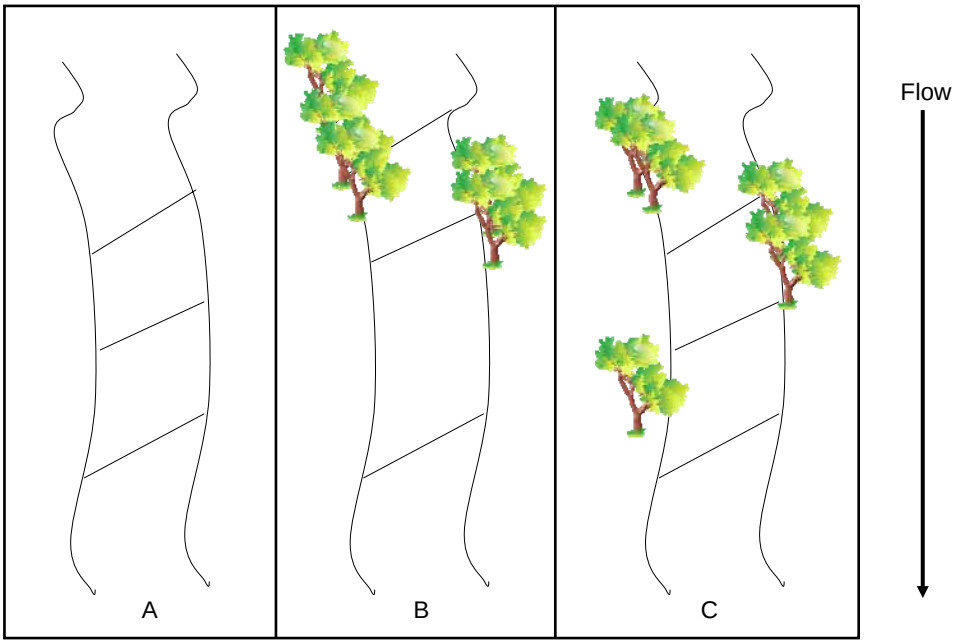
Prior to departure, the project manager will communicate with the field analysts what procedures should be accomplished for each sampling trip to the sampling location and the order the field procedures should be completed. Prior to performing this analysis, the field analyst should ensure the viewing bucket measurement is taken in the correct order. This procedure may disrupt sediment, fish and benthic organisms, which can interfere with other field procedures and sample collections in streams. Viewing bucket measurements should be measured after these samples have been collected. However, viewing bucket measurements should be taken before any sampling procedure or activity that may disturb bottom sediments to avoid increasing turbidity at the location. The field analyst should note any disturbance to the bottom sediment in the Comment/Notes section of the field datasheet (Figure 2) or appropriate field notebook.

5.3.2 ESTABLISH TRANSECTS

The field analyst will establish three (3) transects running diagonal across the stream. The field analyst should observe the location of riffles, runs, and pools along the stream segment. The field analyst should locate transects in areas with runs and riffle, if present, and avoid locations with large pools.

The transects should be approximately at a 45º angle to the right bank (Figure 3A). The field analyst should observe the amount of shade and, using best professional judgment, locate the transects to capture the range of shade conditions available (Figure 3B,3C). The location of the transects should not overlap another transect on any part of the transect.

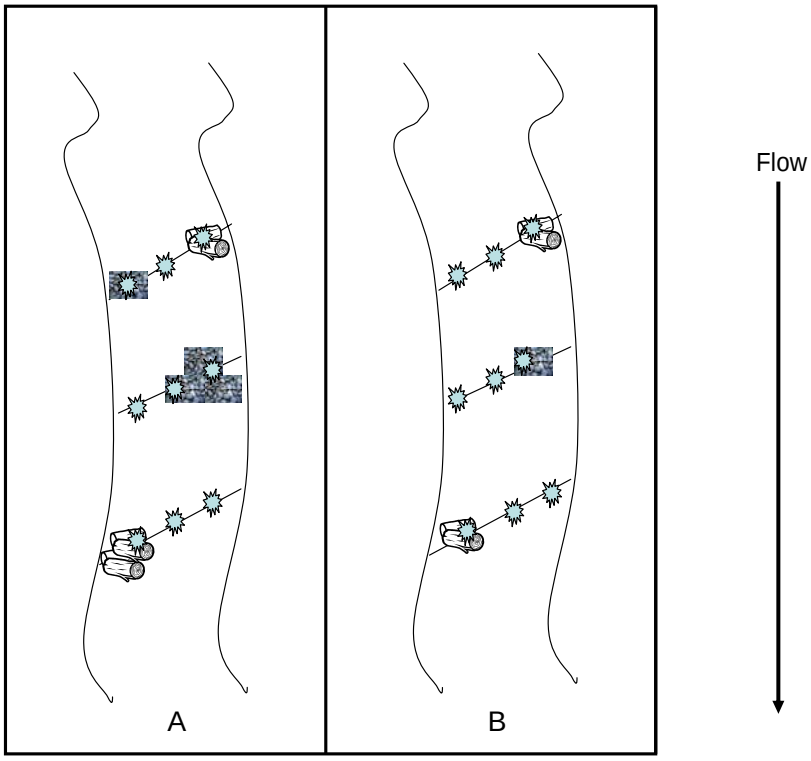
Figure 3. Appropriate establishment of transects



5.3.3 ESTABLISH SAMPLING POINTS

The field analyst will establish three (3) viewing bucket sampling points along each transect for a total of nine (9) viewing bucket sampling points for the stream reach. The field analyst should observe the different available habitat and stream conditions and, using best professional judgment, locate the viewing bucket sampling stations to capture the range of available habitats and stream conditions (Figure 4A, 4B).

Figure 4. Appropriate establishment of sampling points



5.3.4 TAKING SUBSTRATE AND BENTHIC ALGAE MEASUREMENTS WITH THE VIEWING BUCKET

The field analyst will take measurements of available rocky substrate, available woody substrate, amount of macroalgae cover, maximum length of macroalgae, and amount and rank of microalgae cover.

- Record the stream segment station name and number, date, time, and collectors at the top of the datasheet or field notebook. Note any observations about stream condition, riparian area, benthic algae growth, or sampling trip.

- Carefully enter the stream at the most downstream transect at the left bank. Locate the left bank sampling point. It is important to begin at the left bank, because it is the most downstream station. By starting at the most downstream sampling point, the possibility for disruption of sediment and obscuring the bottom of the stream will be minimized.

- Immerse the viewing bucket into the stream so that approximately 4 inches of the bottom of the bucket is underwater. The viewing bucket should be oriented with the longest length perpendicular to flow, and the field analyst should be downstream of the viewing bucket to

minimize sediment disruption obscuring visibility of the bottom. The field analyst should bend over or squat in the water to view the bottom of the stream without interference. If glare or floating is a problem, add a little water to the viewing bucket.

- The field analyst will observe a grid of white dots painted on the clear acrylic sheet in the bottom of the viewing bucket. The dots will be used as locations to estimate and measure the amount of benthic algae growth at the nine sampling stations as described in the following sections.

5.3.5 MEASUREMENT OF AVAILABLE WOODY AND ROCKY SUBSTRATE WITH THE VIEWING BUCKET

- Using the handheld tally-counter, the field analyst will count the number of dots under which suitable rocky substrate is present. Read aloud the number of dots to the recording field analyst. Reset the handheld tally-counter.
    - Suitable rocky substrate is >2cm in length
- Using the handheld tally-counter, the field analyst will count the number of dots under which suitable woody substrate is present. Read aloud the number of dots to the recording field analyst. Reset the handheld tally-counter.
    - Suitable woody substrate is woody branches or logs that are stationary.

5.3.6 MEASUREMENT OF MACROALGAE COVER AND MAXIMUM LENGTH WITH THE VIEWING BUCKET

- Using the handheld tally-counter, the field analyst will count the number of dots that occur over macroalgae growth. Read aloud the number of dots to the recording field analyst. Reset the handheld tally-counter (Macroalgae Examples Figure 6).
- Using the metric ruler, measure the length of the longest macroalgae growth. Read aloud the measurement to the recording field analyst.

5.3.7 MEASUREMENT OF MICROALGAE COVER AND RANK OF GROWTH WITH THE VIEWING BUCKET

- For microalgae, the field analyst should locate the lower left-hand corner of the viewing bucket. Beginning in the lower left-hand corner should allow the field analyst to minimize movement of viewing bucket for measurement, which will help to keep the viewing bucket over the sampling station.
- At each white dot, using the metric ruler, the field analyst will measure the depth of the microalgae layer, if one is present, on the available woody or rocky substrates. The field analyst should read aloud the

measurement to the recording field analyst. If no algae layer is present, the field analyst will say zero to the recording field analyst.

- Note: The recording field analyst should review the chart on the datasheet to rank the amount of growth (0-5) on the substrate based on the measurement taken by the field analyst, and make a tally mark in appropriate row on the chart (Figure 2).

- The recording field analyst will add up the number of tally marks. The recording field analyst will ensure that the number of recorded data for tally marks equal the total number of white dots.

5.3.8 COMPLETING THE VIEWING BUCKET MEASUREMENTS AT ALL SAMPLING POINTS AND UPSTREAM TRANSECTS

- The field analyst will move to the sampling point in the middle of the stream on the transect and repeat the counts and measurements of substrate, macroalgae growth, and microalgae growth described in Sections 5.2.5, 5.2.6, and 5.2.7.

- The field analyst will move to the sampling point at the right bank of the stream on the transect and repeat the counts and measurements of substrate, macroalgae growth, and microalgae growth described in Sections 5.2.5, 5.2.6, and 5.2.7.

- After completing all viewing bucket sampling points on the downstream transect, the field analyst will move to the next transect upstream. The field analyst will repeat the counts and measurements for all transect viewing bucket sampling points beginning at the left bank as described in Sections 5.2.5, 5.2.6, and 5.2.7. The field analyst will then move upstream to the next transect and repeat all counts and measurements at all transect viewing bucket sampling points beginning at the left bank as described in Sections 5.2.5, 5.2.6, and 5.2.7.

- After completing measurements on all transects, the recording field analyst will check that nine (9) viewing bucket sampling points have been assessed.

- The field analyst will exit the stream, if possible, at the final sampling station or another location that is accessible.

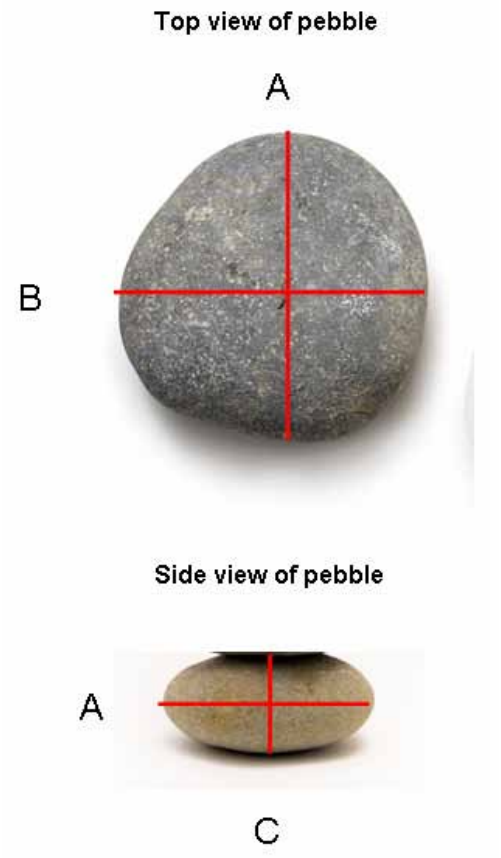
5.3.9 TAKING SUBSTRATE AND BENTHIC ALGAE MEASUREMENTS WITH THE MODIFIED PEBBLE COUNT METHOD

As the field analyst is traveling the transects established for the viewing bucket, the modified pebble count procedure will be executed. This procedure will only be completed if site conditions allow. Sites with sharp objects, especially trash, or particularly murky water will not be sampled using the modified pebble count method. The goal is to assess a minimum of 100 pebbles. If 100 pebbles are not encountered during the viewing bucket procedure, additional transects will be established

upstream using the guidelines in Section 5.3.2 and traveled until 100 pebbles are encountered and assessed. If 100 pebbles are not encountered after 50 m of the stream reach have been assessed, then the procedure will be discontinued. For every pebble measured by the field analyst, the record field analyst will count the total number of pebbles assessed using the second handheld tally counter.

- After completing the first viewing bucket sampling point, the field analyst should take one pace upstream along the established viewing bucket transect.
- The field analyst should visually check the stream bottom for any sharp items or trash. If any dangerous items are encountered, the field analyst should move another pace upstream.
- If the stream bottom conditions are safe, the field analyst should avert their eyes, select a randomly-sized pebble from the stream bottom, and remove it from the stream bottom.
- The field analyst will measure the intermediate axis of the pebble with the ruler (Figure 5, Axis B). The field analyst will say aloud the measurement. The recording field analyst will mark a tally in the substrate size column.

Figure 5. Intermediate axis of pebble



- If the measurement is less than 2 cm, then the field analyst will take another pace, pick up another pebble, and repeat the measurement above. If the measurement is greater than 2 cm, then the field analyst will observe the growth of non-vascular growth (Figure 8), macroalgae, and microalgae.

- The moss and macroalgae will be ranked using the scale below. A separate rank for each type of growth will be observed by the field analyst and said aloud for the recording analyst to mark on the field sheet.

    - 0=no moss or macroalgae present
    - 1=some (<5% coverage) present
    - 2=5-25% coverage of the substratum
    - 3=>25% coverage of substratum

- The microalgae will be ranked using the scale below. The rank for will be observed by the field analyst and said aloud for the recording analyst to mark on the field sheet.

    - 0=substratum is rough with no apparent growth
    - 1=substrate slimy, but biofilm is not visible (tracks CAN NOT be drawn with fingernail or edge of ruler or greenish color to surface)
    - 2=thin layer visible (tracks CAN be draw in biofilm)
    - 3=accumulation to thickness of 0.5-1mm
    - 4=accumulation to thickness of 1-5mm
    - 5=accumulation to thickness of 5-20mm
    - 6=accumulation to thickness of >2cm

- After ranking the growth, the field analyst will take another pace upstream and repeat the above procedure along the entire viewing bucket transects.

    - NOTE-As the field analyst encounters a viewing bucket sampling point, the field analyst will stop to take the viewing bucket measurements as described in Sections 5.2.5, 5.2.6, and 5.2.7. Once the viewing bucket sampling point is complete, the field analyst will continue the modified pebble count.
    - NOTE-If the field analyst reaches 100 pebbles before all viewing bucket sampling points are completed, then field analyst will discontinue the modified pebble count but continue to conduct the viewing bucket survey.

6. QUALITY CONTROL

6.1 QUALITY CONTROL

Quality control will be assessed by the recording field analyst repeating the measurements of the entire procedure at 10% of stream segments. This will give a measure of bias for the procedure.

6.2 QUALITY ASSURANCE PLANNING CONSIDERATIONS

The end use of the data will determine the quality assurance requirements that are necessary to produce data of acceptable quality. Unless specified otherwise in a site or project-specific work plan, Quality Assurance Project Plan (QAPP), Quality Assurance Program Plan (QAPP) or laboratory Quality Assurance Manual (QAM), all data collected following the protocols set forth in this document will be collected in accordance with the minimum QAQC requirements of Section 6.1. Further quality assurance requirements will be defined in project specific work plans and may include duplicate or replicate measurements or confirmatory analyses.

7. REFERENCES

Charles, D., D. Winter, and M. Hoffman. 2000. Field sampling procedures for the New Jersey Algae Indicators Project. Patrick Center for Environmental Research, Academy of Natural Sciences. Procedure No. P-13-64.

Danielson, T. 2006. Protocols for Sampling Benthic Algae in Streams, Wetlands, and Freshwater Wetlands. Maine Department of Environmental Protection. DEPLW-0634

Danielson, T. 2009. Description of Nutrient Criteria for Fresh Surface Waters (Chapter 583). Maine Department of Environmental Protection. DEPLW-0974A.

Stevenson, R.J. and L.L. Bahls. 1999. Periphyton protocols. In: Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling. 1999. *Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish, Second Edition*. EPA 841-B-99-002. U.S. Environmental Protection Agency; Office of Water; Washington, D.C.

VTDEC. 2012. Modified Pebble Count – RIFFLE Habitat. Vermont Department of Environmental Conservation.

Wetzel, R.G. 2001. *Limnology: Lake and River Ecosystems*, 3rd ed. San Diego: Academic Press, 1006 pp.

Figure 6. Macroalgae Examples

Tolypella sp.

http://www.globaltwitcher.com/photo_info.asp?photoid=31466

Nitella sp.

http://www.awc-america.com/plant_id_utility/plants/nit.html

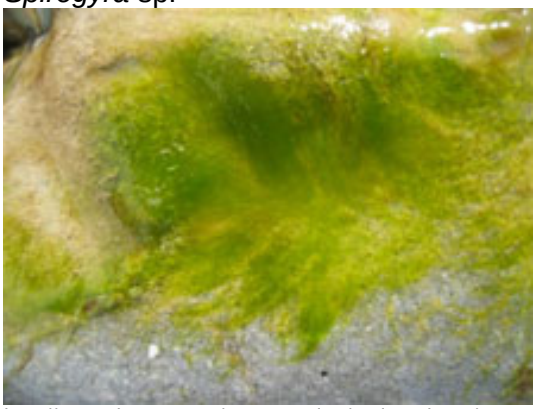
Chara sp.

http://images.mitrasites.com/chara-(alga).html

Spirogyra sp.

http://www.buzzle.com/articles/what-is-spirogyra.html

Spirogyra sp.



http://www.doc.govt.nz/conservation/native-plants/freshwater-algae/

Vaucheria sp.

http://www.keweenawalgae.mtu.edu/gallery_pages/xanthophytes.htm

Figure 7. Microalgae Examples

Didymosphenia geminata (INVASIVE-NOT FOUND IN RI)

http://blogs.app.com/enviroguy/2012/05/03/
damaging-rock-snot-infesting-the-delaware-river/

Gomphoneis sp

http://www.doc.govt.nz/conservation/
native-plants/freshwater-algae/

Microalgae

http://www.darbynelson.com/blog/whats-in-your-lake-lake-ecology-101-periphyton/

Figure 8. Examples of Non-vascular Plant Growth

http://www.jimmccormac.blogspot.com

http://www.squirrelsview.blogspot.com

Fontinalis sp.

http://www.ecy.wa.gov/programs/wq/plants/plantid2/photopages/fontinalis.html

Fontinalis sp.

http://www.aphotoflora.com/moss_fontinalis_squamosa_alpine_water_moss.html

Fontinalis sp.

http://www.aphotoflora.com/moss_fontinalis_squamosa_alpine_water_moss.html

Appendix A10

Standard Operating Procedure for Stream Canopy Measurements by Densiometer

Standard Operating Procedure for Stream Canopy Measurements by Densiometer

SOP-WR-W-35

APPROVALS:

Deputy Chief of Water Resources:

Sue Kiernan	Sue Kiernan	8/12/11
Printed Name	Signature	Date

Quality Assurance Manager:

Connie Carey	Connie Carey	8/1/2011
Printed Name	Signature	Date

DISTRIBUTION

(x) Surface Water Monitoring & Assessment (Connie Carey) ..... By: cgc Date : 8/1/11

(x) TMDL Program (Elizabeth Scott) ..... By:_____Date :_____

(x) Quality Assurance Manager (Tom Getz) ..... By:_____Date :_____

Title: Standard Operating Procedure for Densiometer Canopy Measurements
Originator Name: Jane Sawyers

TABLE OF CONTENTS

Standard Operating Procedure for Stream Canopy Measurements by Densiometer

1. APPLICABILITY

This SOP applies to all Office of Water Resources (OWR) staff involved in collecting canopy cover measurements in streams using a densiometer. Exemption from the use of this SOP for project work shall be allowed for reasons of inapplicability determined by management discretion.

2. PURPOSE

This SOP establishes a standardized method for performing semi-quantitative field measurements of canopy cover in streams using a densiometer. It sets a consistent protocol to ensure the quality of OWR's data collection—resulting in improved uniformity, reproducibility, verifiability, and defensibility of the data, as well as increased program credibility.

3. DEFINITIONS

3.1 RIDEM – Rhode Island Department of Environmental Management

3.2 OWR – RIDEM Office of Water Resources

3.3 SOP – Standard Operating Procedures

3.4 Densiometer – A convex or concave mirror with twenty-four ¼" square engraved on the surface.

3.5 QA – Quality Assurance refers to a systematic process to ensure production of valuable, accurate, reliable, reproducible and defensible environmental data.

3.6 QC – Quality Control refers to the activities performed to affirm production of valuable, accurate, reliable, reproducible and defensible environmental data.

3.7 QI – Quality Improvement refers to any act or process performed to enhance the value, accuracy, reliability, reproducibility or defensibility of environmental data collected by RIDEM OWR.

4. RESPONSIBILITIES

4.1 TRAINING

Any RIDEM/OWR personnel collecting canopy cover measurements for a RIDEM project or program should have completed RIDEM's Quality System Awareness Training Program with appropriate documentation from the Quality Assurance Manager. This training ensures the field analyst recognizes the importance of

proper data collection and management and he/she comprehends the significance of the environmental decisions that may be made with the data. It is suggested that field analysts have also completed the USEPA Water Quality Standards Academy Basic Course and Supplemental Topic Modules online, but it does not require any additional special training or certification.

To properly employ the densiometer, the field analyst must be familiar with and comply with the data collection techniques stated in this SOP. The field analyst is required to read and understand this SOP. The field analyst should complete and submit any required training forms and/or field assessments for project and/or program QAPPs to document proficiency with this procedure. Any field analyst not familiar with the use of the densiometer should be assisted by OWR staff who are accustomed to using the equipment.

4.2 RESPONSIBILITIES OF FIELD ANALYST

The field analyst is responsible for checking the required equipment in the Sampling Center at the beginning of the sampling event before taking measurements in the field. The field analyst is responsible for verifying that the densiometer is in proper operating condition prior to use (i.e. no cracks in the mirror or level; taped areas covered) and communicating to the project manager when equipment is in need of repair or replacement. The field analyst is also responsible for ensuring that all supplementary equipment (hand-held tally counter, waders, hip boots, etc.) is present and in working condition. The field analyst is also responsible for using best professional judgment to determine if site conditions are safe for performing the procedure. The field analyst is accountable for employing proper measurement procedures and data recording in accordance with this SOP.

4.3 RESPONSIBILITIES OF PROJECT OR PROGRAM MANAGER

The project or program manager is responsible for providing the materials, resources, and/or guidance necessary to perform the measurements in accordance with this SOP. The project manager is responsible for ensuring that the field analyst operates the densiometer correctly in accordance with this SOP and that any additional, project-specific requirements are communicated to the project team. The project manager is responsible for ensuring the densiometer is maintained in proper operating condition annually. This includes ensuring the densiometer mirror and level are not cracked and the taped areas are covered. The project manager is also responsible for repairing the densiometer or reordering equipment when necessary. The project manager will determine and communicate with field analysts what procedures and order of procedures are to be accomplished during each sampling event to a sampling location. Further, the project manager shall ensure annual review and periodic revisions to this SOP as necessary to reflect current needs and standards as well as renew this SOP every five years.

5. GUIDELINES AND PROCEDURES

5.1 PROPER USE OF DENSIOMETER

5.1.1 REQUIRED MATERIALS

The following materials are necessary for this procedure:

- Densiometer – convex, modified as described in Strickler (1959) (Figure 1, similar to Forestry Suppliers Item Number 43887)
- Datasheet or field notebook printed on waterproof paper (Figure 2; paper similar to Grainger Item Number 3XFR7)
- Hand-held tally counter (Similar to Grainger Item #2PAU4)
- Clipboard
- Pencil or Rite in the Rain Pen (similar to Forestry Suppliers Item Number 49237)
- Waders or hip boots

5.1.2 USING THE DENSIOMETER IN THE FIELD

For most purposes, the densiometer is used specifically for in situ canopy cover measurements taken directly in the field in streams. This method does not require sample containers or preservation.

5.1.3 RECORDING PARAMETER UNITS

The following units should be used when recording measurements taken with the densiometer:

Canopy cover.....# of dots

5.2 FIELD MEASUREMENT PROCEDURES

5.2.1 DETERMINE FIELD PROCEDURE SCHEDULE

Prior to departure, the project manager will communicate with the field analysts what procedures should be accomplished for each sampling trip to the sampling location and the order the field procedures should be completed. Prior to performing this analysis, the field analyst should ensure the densiometer measurement is taken in the correct order. This procedure may disrupt fish and microscopic organisms, such as benthic macroinvertebrates, fish, and algae, which can interfere with other field procedures and sample collections in streams. Furthermore, this procedure can dislodge sediment, which can interfere with water quality

sample collections. Densiometer measurements should be measured after these samples have been collected.

5.2.2 DETERMINE THE LOCATION OF TRANSECTS AND SAMPLING POINTS

This procedure will typically occur in conjunction with SOP-WR-W-36 Standard Operating Procedure for Measurement of Benthic Algae Cover by Viewing Bucket. The procedure for determining the location of transects and sampling points are described in Sections 5.2.2 and 5.2.3 of SOP WR-W-36. Densiometer measurements should be taken at the same time as viewing bucket measurements.

5.2.3 TAKING THE CANOPY COVER MEASUREMENT

Each transect will have a left bank, middle, and right bank sampling point. At each of three transects, the field analyst will take measurements at all sampling points along each transect. At each transect, the field analyst will take one canopy measurement at the left bank sampling point, four canopy measurements at the middle sampling point, and one canopy measurement at the right bank sampling point (Figure 3). A total of 18 canopy cover measurements will be taken at each stream segment.

- The field analyst will enter the stream at the most downstream transect at the left bank sampling point (1A). Standing at the left bank sampling station, the field analyst will face the left bank. It is important to begin at the left bank, because it is the most downstream station. By starting at the most downstream station, the possibility for disruption of sediment will be minimized for other analyses.

- The field analyst will hold the densiometer 12”-18” in front of them with the mirrored surface closest to their body.

- The field analyst should raise or lower the densiometer’s height until it is 0.3m (a little less than 1ft) above the surface of the water.

- The field analyst should note the position of the bubble level in the lower right-hand corner of the densiometer face. The field analyst should rotate the densiometer until the air bubble is in the middle of the gray circle to indicate the densiometer is level. The field analyst should ensure that the densiometer stays level by observing the air bubble is in the middle of the gray circle throughout the procedure.

- The field analyst will move their head until it is just outside the field of view at the bottom of the triangle area of visible mirrored surface.

- The field analyst will observe and count the number of dots on the mirror obscured by canopy vegetation. The field analyst will use the hand-held tally counter to keep track of the number of dots obscured. The field analyst will read aloud the number of dots obscured by canopy vegetation. The recording field analyst will record the number of dots on the datasheet or in the appropriate field notebook.

  - Note: The dots are not marked on the face of the mirrored surface. The field analyst must observe the etched lines on the mirrored surface. The corners of the squares formed by the etched lines are the location of dots imagined by the field analyst (Figure 4).

  - Note: There are 17 available points. The field analyst will observe and report to the recording field analyst a number between 0 (no points covered) to 17 (all points covered).

- The field analyst move to the middle sampling station (1B). The field analyst will face upstream and repeat the above procedure to determine the number of dots obscured by canopy vegetation.

  - The field analyst will turn to face the left bank. The field analyst will repeat the above procedure to determine the number of dots obscured by canopy vegetation.

  - The field analyst will turn to face downstream. The field analyst will repeat the above procedure to determine the number of dots obscured by canopy vegetation.

  - The field analyst will turn to face the right bank. The field analyst will repeat the above procedure to determine the number of dots obscured by canopy vegetation.

- The field analyst move to the right bank sampling station (1C). The field analyst will face the right bank and repeat the above procedure to determine the number of dots obscured by vegetation.

- The field analyst will move to the next transect upstream. The field analyst will locate and move to the left bank sampling station (2A). The field analyst will repeat the above procedure for all sampling points located on transect 2.

- The field analyst will then move upstream to transect 3 and locate the left bank sampling station (3A). The field analyst will repeat the above procedure for all sampling stations located on transect 3.

- Sampling is complete when 18 canopy measurements have been recorded by the recording field analyst.

6. QUALITY CONTROL

6.1 QUALITY CONTROL

Quality control will be assessed by the recording field analyst repeating the measurements at 10% of stream segments. This will give a measure of bias for the procedure.

6.2 QUALITY ASSURANCE PLANNING CONSIDERATIONS

The end use of the data will determine the quality assurance requirements that are necessary to produce data of acceptable quality. Unless specified otherwise in a site or project-specific work plan, Quality Assurance Project Plan (QAPP), Quality Assurance Program Plan (QAPP) or laboratory Quality Assurance Manual (QAM), all data collected following the protocols set forth in this document will be collected in accordance with the minimum QAQC requirements of Section 6.1. Further quality assurance requirements will be defined in project specific work plans and may include duplicate or replicate measurements or confirmatory analyses.

7. REFERENCES

Kaufmann, P.R., P. Levine, E.G. Robinson, C. Seeliger, and D.V. Peck. 1999. *Quantifying Physical Habitat in Wadeable Streams*. EPA/620/R-99/003. U.S. Environmental Protection Agency, Washington, D.C.

OWEB. 1999. “Chapter 14: Stream Shade and Canopy Cover Monitoring Methods.” *Water Quality Monitoring: Technical Guide Book*. Oregon Watershed Enhancement Board. http://www.oregon.gov/ODF/privateforests/docs/ShadeProt.pdf?ga=t

Strickler, G.S. 1959. Use of the densiometer to estimate density of forest canopy on permanent sample plots. Forest Service, U.S. Department of Agriculture, Research Note No. 180.

Figure 1. <u>Densiometer Modification from Strickler (1959)</u>

J. Sawyers

Figure 2. Densiometer Datasheet for Monitoring Section Sampling Events

Densiometer Canopy Measurements

Stream Segment : _____ Town: _____

Site Number: _____

Date: _____ Military Time: _____ Collectors _____

Sampling Point	Upstream	Left bank	Downstream	Right bank
1A				
1B				
1C				
2A				
2B				
2C				
3A				
3B				
3C				

Figure 3. Canopy Measurements Taken at Each Sampling Station

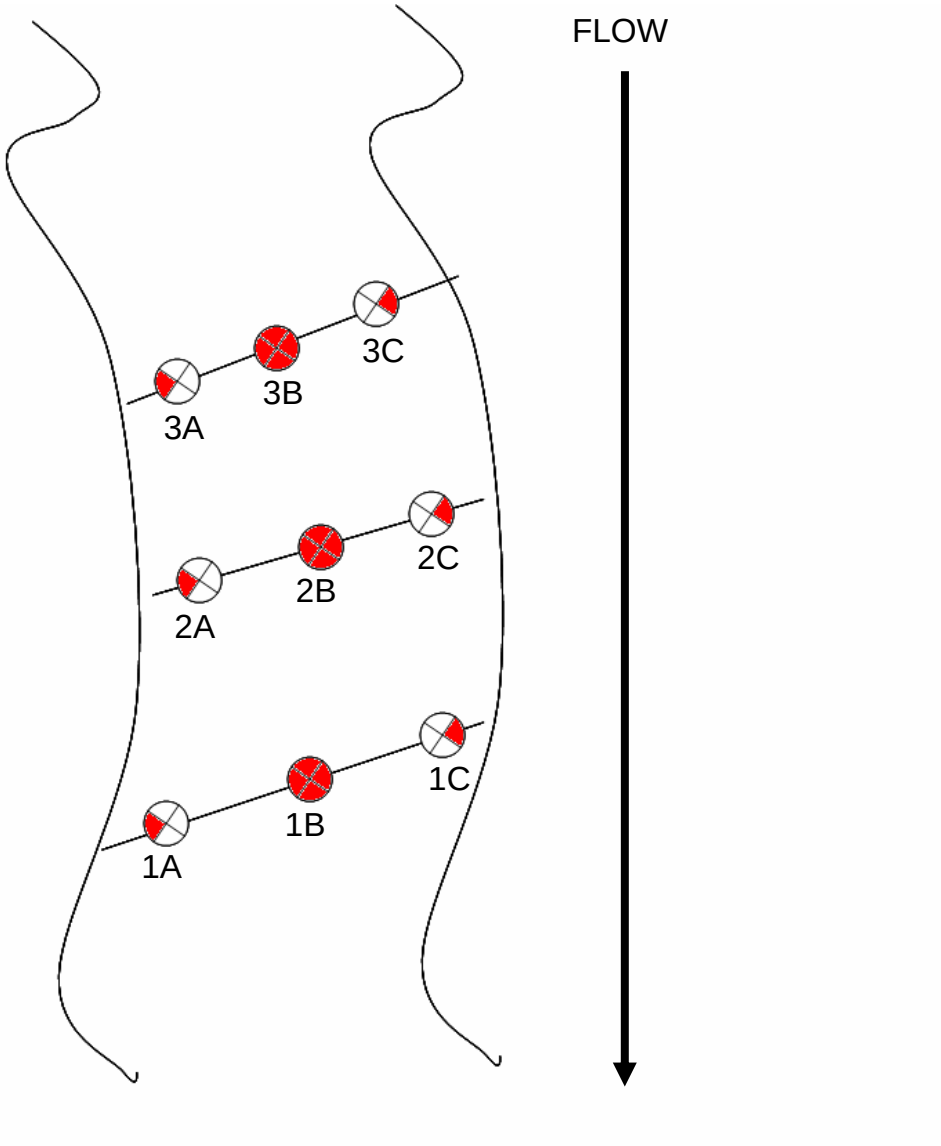


Figure 4. Location of Coverage Points on Densiometer

J. Sawyers

Appendix B

ESS Key Personnel Resumes

CARL D. NIELSEN, CLM
Vice President and Senior Water Resources Scientist

Experience
ESS Group, Inc.:1998 to present

Years of Prior Related Experience: 8

Education
MS, Fisheries and Wildlife, University of Missouri - Columbia, 1994

BA, Biology, Colgate University, 1990

Tufts University, Water Quality Modeling for TMDLs, 40-hr. Workshop, 2001

Professional Registrations and Affiliations
North American Lake Management Society – Certified Lake Manager (CLM)

New England Chapter – North American Lake Management Society

Society for Freshwater Science

Northeast Aquatic Plant Management Society

NAUI Open Water SCUBA Diver Certification

American Heart Association – CPR and First Aid

Qualifications

Mr. Nielsen has over 21 years of experience in the assessment and evaluation of marine and freshwater ecosystems. Mr. Nielsen uses his knowledge of water chemistry and biology to go beyond basic assessments that just identify whether a waterbody is meeting the regulatory standards. Mr. Nielsen has worked extensively in identifying and understanding the ecology of most aquatic organisms including aquatic plants, algae, zooplankton, aquatic invertebrates, fish, reptiles and amphibians. By understanding the ecological needs of the organisms present in an aquatic system Mr. Nielsen is able to tailor management recommendations and mitigation strategies that are appropriate and viewed favorably by the community and most permitting authorities. Mr. Nielsen is also actively involved in the restoration of aquatic systems and has worked to improve water quality and aquatic habitat conditions in numerous lake and river systems throughout New England. As part of these efforts, Mr. Nielsen regularly uses water quality data collected to develop customized scientific watershed models to assist in locating sources of pollution and to evaluate the potential effectiveness of a variety of watershed management strategies. Mr. Nielsen has been Senior Project Scientist for more than 150 aquatic resource studies which have been performed for numerous clients including: federal, state and local governments, municipal water districts, local lake and watershed associations, industrial facilities, property developers, major corporations, utilities, golf courses, ski areas, and airports.

Representative Project Experience

Wilcox & Barton, Inc., Water Quality and Biomonitoring Surveys and Ongoing Monitoring Reporting to Inland Wetlands Commission in Support of Major Retail Development. Guilford, CT. Mr. Nielsen was responsible for designing and implementing a comprehensive biomonitoring program in Spinning Mill Brook adjacent to the construction site for a 155,000 square foot retail development. Work included sampling the fish community, benthic invertebrate community, aquatic habitat, and water quality. Work has been performed for two-baseline years of assessment and is likely to continue annually throughout the construction and operation of the proposed development.

Glendale Power Station, Housatonic River Freshwater Mussel Survey. Stockbridge, MA. Mr. Nielsen designed and implemented a comprehensive survey for rare mussels for the Glendale Power Station in Stockbridge, MA in support of a Federal Energy Regulatory Commission (FERC) re-licensing of their hydro-power facility on the Housatonic River. Field survey was performed in the bypass channel of the hydro-power station on the Housatonic River. In addition, Mr. Nielsen was responsible for filing a Rare Animal Observation Form with the Massachusetts Natural Heritage and Endangered Species Program when evidence of a state-listed mussel species was found in the channel. Summarized the findings of the survey in a report supporting the FERC application.

United States Army Corps of Engineers (USACE), Mill Pond Pre-Dredging Assessment. Littleton, MA. Mr. Nielsen was responsible for designing and implementing an assessment of the biological resources of Mill Pond in order to support the USACE with the dredging of Mill Pond. Work by Mr. Nielsen included the assessment of fish and macroinvertebrates in Mill Pond and its tributaries (Reedy

Meadow Brook and Beaver Brook) which are all located within the Merrimack River watershed. Fish sampling was performed using boat and back-pack electo-shocking equipment.

Narragansett Bay Commission, Midge Larvae Monitoring, Dye Flushing Study and Management Recommendations for Bishop Cove. Seekonk River, RI. Mr. Nielsen was responsible for the design and implementation of a study to identify the issues regarding a nuisance midge population associated Bishop Cove in the Seekonk River. The study included extensive sampling of midge larvae and their associated habitat over the 28 acre cove. In addition, a dye study was conducted to evaluate the patterns of tidal and river flushing within the cove to gain an understanding of how the water movement may be contributing to habitat conditions that were deemed favorable to midge production. Based on the study, Mr. Nielsen developed a list of recommendations for the Commission that have since been implemented and have resulted in the control of the nuisance midge issues that had formerly plagued the residents along the shore of the cove.

Town of Norton, Massachusetts, Diagnostic and Feasibility Assessment for Management of Lake Winnecunnet. Norton, MA. Mr. Nielsen was responsible for conducting an assessment of Lake Winnecunnet and its watershed which are located within a Massachusetts ACEC (Area of Critical Environmental Concern). The deep-water habitat associated with the lake is threatened by the invasive and exotic plant *Cabomba caroliniana* (fanwort) which has spread throughout the lake to the detriment of native plants and potentially native fauna. The need to manage this situation while protecting the potentially rare or threatened species that exist within the lake required extensive survey of the lake shoreline, the major tributaries to the lake (Canoe River and Mulberry Meadow Brook), and the lake outlet (Snake River). Mr. Nielsen conducted a survey of freshwater mussels, aquatic macroinvertebrates, minnows and young-of-the-year fish, aquatic and semi-aquatic plants, reptiles, and amphibians. Based on these detailed surveys, Mr. Nielsen developed a comprehensive lake and watershed management plan for the Town.

Massachusetts Department of Conservation and Recreation, Assessment and Permitting for In-lake Weed Control. Lake Cochituate, MA. Mr. Nielsen prepared Notices of Intent for submittal to the Towns of Framingham, Wayland, and Natick, Massachusetts for the control of nuisance aquatic vegetation at Lake Cochituate. Proposed measures included the use of herbicides, hand-pulling, diver suctioning, milfoil weevils, water circulation, and benthic barriers to control milfoil and curly-leaf pondweed in the lake.

Club Motorsports, Inc., 401 Water Quality Certificate and Baseline Monitoring. Tamworth, NH. Mr. Nielsen was the lead investigator tasked with designing and implementing a complete baseline monitoring program for the Club Motorsports, Inc.'s proposed racetrack development in New Hampshire. Mr. Nielsen worked closely with NHDES to design and implement a program that would be protective of the aquatic resources of the State on-site and down stream of the property. This program was accepted and the client received their 401 Water Quality Certificate. A long-term monitoring program including water quality, macroinvertebrates, and stream habitat quality is ongoing.

Massachusetts Department of Conservation and Recreation, Diagnostic and Feasibility Assessment of Big Pond. Otis, MA. Mr. Nielsen designed and conducted an investigation of Big Pond and its watershed to gather baseline information on water quality, stormwater quality, macroinvertebrate community composition, aquatic and wetland plants, fish, and wildlife. Mr. Nielsen made recommendations for monitoring and preserving the ecological integrity of this relatively healthy aquatic system.

MATTHEW D. LADEWIG
Project Scientist

Experience
ESS Group, Inc.: 2006 to present

Years of Prior Related Experience: 3

Education
MS, Aquatic Resource Ecology and Management, University of Michigan, 2006

BA, Geography, University of Illinois at Urbana-Champaign, 2000

Professional Registrations and Affiliations
North American Lake Management Society – Certified Lake Manager

Society for Freshwater Science – Certified Taxonomist for Chironomidae and Ephemeroptera, Plecoptera and Trichoptera

Rhode Island Natural History Survey

Qualifications

Mr. Ladewig is a Certified Lake Manager and ecologist with ten years of experience in the monitoring, modeling, and management of aquatic ecosystems. He has completed studies on over 50 lakes and ponds, including water suppliers, state and municipal governments, lake associations, and private landowners. Mr. Ladewig has also developed and implemented numerous surface water sampling, sediment testing, and biomonitoring programs for a wide variety of water resource projects. He regularly conducts stormwater mapping, sampling, and compliance programs.

Mr. Ladewig is an experienced taxonomist who has analyzed thousands of macroinvertebrate samples collected from freshwater and marine habitats in the Northeast, the Mid-Atlantic and the Bahamas. He holds certifications from the Society for Freshwater Science and oversees the ESS invertebrate taxonomy lab. Mr. Ladewig's taxonomic experience extends to a wide variety of other biological resources, including fish, birds, aquatic plants and a number of rare species.

Representative Project Experience

Rhode Island Department of Environmental Management (RIDEM), Cyanobacteria Monitoring and Statewide Stream Habitat Assessment and Biomonitoring. Assists with management and execution of the state's new lake and pond cyanobacteria monitoring program. Manages the field effort for the annual collection and identification of macroinvertebrates from 50 sites across the state of Rhode Island. Analyzes the habitat, water quality and macroinvertebrate community data. Additionally, participated in an August 2007 review of Rhode Island's stream biomonitoring program. The program is a multi-year assessment of all of the waters of the state and the data reports prepared by the ESS team are used to support the state's routine water quality reporting requirements (305 (b) Assessment) to U.S. EPA.

West Point Partners, LLC, New York State Article VII. Hudson River, NY. Completed an assessment of existing water quality, sediment quality, and benthic and shellfish resources in the Hudson River for a proposed power transmission project between Athens and Buchanan, New York. As part of this assessment, identified and enumerated benthic macroinvertebrates from baseline benthic samples collected along the Proposed Subaquatic Route. This is being used to help identify potential impacts of the electric transmission line for the New York Article VII permit filing.

Town of Weymouth, Whitman's Pond Vegetation Management Action Plan. Weymouth, MA. Completed a comprehensive Vegetation Management Action Plan for the Whitman's Pond Working Group, a town-appointed committee charged with task of identifying a restoration strategy for the 190-acre pond. Although Whitman's Pond suffers from excessive growth of invasive plants, sedimentation, and water quality impairments, it supports a significant run of anadromous alewife (*Alosa pseudoharengus*), provides diverse recreational opportunities for the public, and serves as a backup water supply for the town. The Vegetation Management Action Plan was developed to address the problems in Whitman's Pond while being protective of the multiple resources it provides to a diverse group of stakeholders. Bathymetric and sediment isopach mapping, biological surveys (plants, fish, birds, and invertebrates), sediment sampling, water quality sampling, and hydrologic assessments were conducted to support the development of the Vegetation Management Action Plan. The final plan was presented to the town at a public meeting.

Brooks Pond Conservation Association – Development of a Lake Management Plan; North Brookfield, New Braintree, Oakham, and Spencer, MA. Led field program at Brooks Pond, including

water quality sampling and aquatic macrophyte mapping. Developed a lake management plan with short and long term recommendations for maintaining the recreational and ecological assets of the pond. Also assisted the Brooks Pond Conservation Association and Town of North Brookfield with submittal of a proposal for grant funding under Section 319 of the Clean Water Act.

Massachusetts Water Resources Authority (MWRA), Aquatic Invasive Macrophyte Surveys. MA. Managed field effort and reporting tasks for a comprehensive survey of aquatic macrophytes at ten source and emergency reservoir areas jointly managed by MWRA and the Massachusetts Department of Conservation and Recreation (DCR). This survey provided the first comprehensive update to baseline macrophyte surveys completed in 2006 and 2007. Developed aquatic macrophyte monitoring and management plan that included an assessment of climate change impacts on macrophyte communities in the MWRA/DCR reservoirs. Compiled the first comprehensive field guide to the aquatic macrophytes of the entire MWRA/DCR reservoir system.

Providence Water, Limnological Studies of Ponaganset and Regulating Reservoirs. Glocester and Scituate, RI. Conducted watershed assessments, water quality surveys, groundwater seepage surveys, bathymetric mapping, and aquatic macrophyte mapping for two reservoirs in the City of Providence's public water system as part of a limnological study to address water quality issues. These issues stem mainly from concerns over aquatic invasive species (AIS), land use density in the watershed, and shoreline encroachment.

Confidential Client, Stream and Pond Monitoring Program. Guilford, CT. Conducts field work including habitat assessment, water quality sampling and biomonitoring at three in-stream sites as well as plant and bathymetry mapping of a small pond in line with the stream. The biomonitoring design employs quantitative methods for sampling macroinvertebrates, periphyton and fish within the brook. Baseline conditions have been established for the stream and will permit the evaluation of post-construction water quality, sedimentation and biological conditions in the stream, as needed.

Massachusetts Department of Conservation and Recreation, Lakes and Ponds Program, Quagga and Zebra Mussel Education, Monitoring and Outreach. Western MA. Managed project designed to help prevent the spread of invasive quagga and zebra mussels into the waters of western Massachusetts. Also presented a workshop to volunteers on methods of collection, preservation, and screening of early life stage samples. The approach of this project was multifaceted and incorporated education, monitoring and outreach activities. On the monitoring front, volunteers were trained to collect and process samples using kits developed by ESS that focus on early life stage detection. The project team also developed educational materials, including brochures for outreach to boaters and anglers as well as metal signs for posting at strategically targeted water bodies. A concerned citizen relied on information in the educational brochure to detect the first occurrence of zebra mussels in the state.

Housatonic River Natural Resource Damage (NRD) Fund, Enhancement of Housatonic River Public Access. Western MA. Assessed hydrologic, geomorphic, and biological conditions at potential public access points along the Housatonic River to select five sites (from a total of 41 locations) for construction of public access improvements. Conducted cross section surveys and discharge measurements at sites with the highest priority for public access. Also assessed high priority locations for the presence of rare, threatened, and endangered fish, mussel, and invertebrate species and their habitats. The assessment was based mainly on feasibility of access, ecological constraints and distance to the nearest existing river access point. Each site has been permitted and is ready for construction.

Gomez and Sullivan, Housatonic River Freshwater Mussel Survey. Glendale Power Station, Stockbridge, MA. Assisted with a field survey for mussels in the bypass channel of a hydro power station on the Housatonic River. In addition, was responsible for filing a Rare Animal Observation Form with the Massachusetts Natural Heritage and Endangered Species Program when evidence of a state-listed mussel species was found in the channel. Summarized the findings of the survey in a report to the client for compliance with Federal Energy Regulatory Commission (FERC) relicensing procedures.

ELIZA C. MOORE
Invertebrate Taxonomist

Experience
ESS Group, Inc.: 2012 to present

Years of Prior Related Experience: 6

Education
MS, Biology, San Diego State University, 2008

BS, Biology, magna cum laude, Northeastern University, 2005

Three Seas Program – East West Marine Biology, Northeastern University – Jamaica, West Indies, & Nahant, MA, 2003

Professional Registrations
NMFS Certified Protected Species Observer

Qualifications

Ms. Moore is an accomplished taxonomist and marine ecologist. Her training and work experience have allowed her to become familiar with fish and invertebrate fauna from a wide variety of marine habitats including the coastal waters of New England, southern California, and Hawaii. In addition to her taxonomic skills, Ms. Moore also possesses a great deal of expertise in statistical analysis (including PRIMER-E v6), database management, technical writing, and field applications.

Representative Project Experience

West Point Partners, LLC, New York State Article VII. Hudson River, NY. Prepared an assessment of existing benthic, shellfish, and finfish resources in the Hudson River for a proposed power transmission project between Athens and Buchanan, New York. This is being used to help identify potential impacts of the electric transmission line for the New York Article VII permit filing. The assessment included evaluation of sensitive habitat areas (including Essential Fish Habitat and Significant Coastal Fish and Wildlife Habitat) and any threatened or endangered species present along the Proposed Construction Route. As part of this assessment, also identified and enumerated benthic macroinvertebrates from baseline benthic samples collected along the Proposed Subaquatic Route.

Rhode Island Department of Environmental Management (RIDEM), Statewide Stream Habitat Assessment and Biomonitoring. Collects benthic invertebrates from wadeable streams throughout the state of Rhode Island as part of the annual monitoring efforts in these environments. Taxonomically identifies invertebrates and performs data QA/QC for other sorter staff. Assisted in preparation of the QAPP report for this project.

Town of Holliston, Massachusetts, Lake Winthrop Aquatic Plant Mapping and Sediment and Mussel Surveys – Holliston, MA. Assisted with a field survey to identify mussel species and map the distribution of native and invasive aquatic plants in Lake Winthrop. Also took bathymetry measurements and sediment grabs for chemical analysis. Survey results were used to make recommendations to the town on how best to manage aquatic plant overgrowth.

Haskell – Recapitalize U.S. Coast Guard Buoy Tender Waterfront at Naval Station Newport Project, Newport, RI. Taxonomic identification of benthic invertebrates collected as part of sediment monitoring in the designated dredge area between Pier One and Pier Two. This design/build Project consists of both shore and waterfront improvements including dredging a portion of waterfront to provide deeper water for the maneuvering and berthing of U.S. Coast Guard (USCG) buoy tender vessels whose homeport is NAVSTA Newport.

Massachusetts Department of Conservation and Recreation, Ponkapoag Golf Course, Water Supply Development and Ecological Monitoring. Canton, MA. Monitored water levels in Ponkapoag Pond and Bog in compliance with an Order of Conditions and Water Level Monitoring Plan issued by the Canton Conservation Commission. Conducted biological surveys for several species of insects and mosses. These efforts were conducted to monitor the impacts of nearby irrigation to the fragile Atlantic white cedar/emergent/scrub-shrub wetland.

Cape Wind Associates, LLC, Cape Wind Offshore Renewable Energy Generation and Submarine Cable Project Geophysical and Geotechnical Surveys. Nantucket Sound, MA. Processed vibracore sediment samples collected from the seabed within the proposed 130-turbine Cape Wind offshore wind project area. Analyzed sediments for grain size and material type, color, and presence of organic material

and objects of cultural significance. Once completed, Cape Wind will be the largest offshore wind power generation facility in the United States and among the largest worldwide.

United Water Company, Midge Larvae Monitoring and Management Recommendations. Bucklin Point, East Providence, RI. Conducts invertebrate monitoring efforts in order to identify non-biting midge larvae "hot spots" in the mud flats of the area of concern. Monitoring involves sampling set locations within the mud flats several times throughout the season for midge larvae. Monitoring efforts provide data to guide implementation of a site-specific management program.

Northeast Utilities, Long Island Submarine Cable Replacement Project. Norwalk, CT. Provided quality assurance/quality control and identified and enumerated benthic macroinvertebrates collected as part of the submarine cable post-construction monitoring program conducted under a Connecticut Department of Environmental Protection approved protocol. Assisted with data analysis and Final Summary Reports to monitor the impacts, if any, to benthic and shellfish resources near the submarine replacement cables.

City of San Diego Ocean Monitoring Program. San Diego, CA. Collected oceanographic and biological samples from research vessels (e.g., CTD, Niskin, & Van Dorn bottles, benthic grabs, otter trawls, SCUBA) as part of an ongoing ocean monitoring program in the areas surrounding two municipal wastewater outfalls to the Pacific Ocean. This monitoring is in compliance with NPDES permits. Provided taxonomic identification of macroinvertebrates sorted from benthic sediment grab samples, as well as fish and invertebrates obtained through trawl-sampling. Prepared annual ocean monitoring reports, including data analysis, QA/QC, presentation, summary of findings, and technical and production editing. Managed city ocean monitoring lab's participation in the ISO 14001 program for document control and environmental impact management.

San Diego State University, Macroinvertebrate Community Dynamics in Seagrass Habitats. San Diego, CA. Collected epifaunal samples in seagrass habitat and performed taxonomic identification of macroinvertebrates from these samples. Responsible for conducting all data entry, QA/QC, and analysis and managing support staff in the field and laboratory.

San Diego State University, Spiny Lobster and Grass Shrimp Behavioral Studies. San Diego, CA. Conducted field studies of California Spiny Lobster behavior in kelp forests including diving, lobster tagging, and active and passive acoustic tracking. Managed and conducted experiments on grass shrimp movement in lab mesocosms and in eelgrass beds.

Northeastern University Marine Science Center, Marine Invertebrate Ecological Studies. Nahant, MA. Conducted ecological experiments on invertebrate ecology, behavior, and physiology in the rocky intertidal zone and lab mesocosms. Also collected colonial ascidians from dive sites throughout northern Massachusetts for lab studies of fouling community ecology. Responsible for management of lab space and equipment.

Research Technician (summer) – Hawaii Institute of Marine Biology – Oahu, HI. Conducted field and lab research including measurement of flow patterns over coral heads in a seawater flume and sampling of coral reefs in Kaneohe Bay.

Publications

Moore, E.C. and K.A. Hovel. 2010. Relative influence of habitat complexity and proximity to patch edges on seagrass epifaunal communities. Oikos 119: 1299–1311.

Appendix C

Additional Data Forms and Instructions

HABITAT ASSESSMENT FIELD DATA SHEET

SARIS NO. _____ RIVER BASIN _____

RIVER MILE _____ ECOREGION REFERENCE SITE _____

DATE _____ INVESTIGATOR _____

DESCRIBE SITE LOCATION _____

Comments:

Riffle/Run Prevalent Streams are those in moderate to high-gradient landscapes that sustain water velocities of approximately 30 cm/sec or greater. Natural streams have substrates primarily composed of coarse sediment particles (i.e., gravel or larger) or frequent coarse particulate aggregations along stream reaches.

Habitat Parameter	Category			
	Optimal	**Suboptimal**	**Marginal**	**Poor**
1. Instream Cover (Fish)	A mix of snags, submerged logs, undercut banks, rubble, or other stable habitat in greater than 50% of the sample area	30-50% of area with a mix of stable habitat; adequate habitat for maintenance of populations.	10-30% of area with a mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 10% of area with a mix of stable habitat; lack of habitat is obvious; substrate unstable or lacking.
SCORE _____	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
2. Epifaunal Substrate	Well-developed riffle and run; riffle is as wide as stream and length extends two times the width of stream; abundance of cobble. (Boulders prevalent in headwater streams).	Riffle is as wide as stream but length is less than two times width; abundance of cobble; boulders and gravel common.	Run area may be lacking; riffle not as wide as stream and its length is less than 2 times the stream width; gravel or bedrock prevalent; some cobble present.	Riffles or runs virtually nonexistent; bedrock prevalent; cobble lacking.
SCORE _____	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
3. Embeddedness	Gravel, cobble, and boulder particles are 0-25% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 25-50% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 50-75% surrounded by fine sediment.	Gravel, cobble, and boulder particles are more than 75% surrounded by fine sediment.
SCORE _____	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
4. Channel Alteration	Channelization or dredging absent or minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e., dredging, (greater than past 20 yr) may be present, but recent channelization is not present.	New embankments present on both banks; and 40 to 80% of stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted.
SCORE _____	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
5. Sediment Deposition	Little or no enlargement of islands or point bars and less than 5% of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 5-30% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 30-50% of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 50% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
SCORE _____	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
6. Frequency of Riffles (or bends) / Velocity-Depth Combinations	Occurrence of riffles relatively frequent; ratio of distance between riffles divided by width of the stream <7:1 (generally 5 to 7); variety of habitat is key. In streams where riffles are continuous, placement of boulders or other large, natural obstruction is important; All 4 velocity/depth patterns present.	Occurrence of riffles infrequent; distance between riffles divided by the width of the stream is between 7 to 15. Only 3 of 4 velocity/depth patterns present (i.e., slow [<0.3 m/s]-deep [>0.5 m]; slow-shallow; fast-deep; fast-shallow).	Occasional riffle or bend; bottom contours provide some habitat; distance between riffles divided by the width of the stream is between 15 to 25. Only 2 velocity/depth patterns present; usually lacking deep areas.	Generally all flat water or shallow riffles; poor habitat; distance between riffles divided by the width of the stream is a ratio of >25. Dominated by one velocity/depth pattern.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
7. Channel Flow Status	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
SCORE _____	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

Habitat Parameter	Category			
	Optimal	**Suboptimal**	**Marginal**	**Poor**
8. Bank Vegetative Protection (score each bank) Note: determine left or right side by facing downstream.	More than 90% of the streambank surfaces covered by native vegetation, including trees, understory shrubs, or nonwoody macrophytes; vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of the streambank surfaces covered by native vegetation, but one class of plants is not well-represented; disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.	50-70% of the streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; vegetation has been removed to 5 centimeters or less in average stubble height.
SCORE ___ (LB)	Left Bank 10 9	8 7 6	5 4 3	2 1 0
SCORE ___ (RB)	Right Bank 10 9	8 7 6	5 4 3	2 1 0
9. Bank Stability (score each bank)	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems. <5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
SCORE ___ (LB)	Left Bank 10 9	8 7 6	5 4 3	2 1 0
SCORE ___ (RB)	Right Bank 10 9	8 7 6	5 4 3	2 1 0
10. Riparian Vegetative Zone Width (score each bank riparian zone)	Width of riparian zone >18 meters; human activities (i.e., parking lots, roadbeds, clear-cuts, lawns, or crops) have not impacted zone.	Width of riparian zone 12-18 meters; human activities have impacted zone only minimally.	Width of riparian zone 6-12 meters; human activities have impacted zone a great deal.	Width of riparian zone <6 meters: little or no riparian vegetation due to human activities.
SCORE ___ (LB)	Left Bank 10 9	8 7 6	5 4 3	2 1 0
SCORE ___ (RB)	Right Bank 10 9	8 7 6	5 4 3	2 1 0

Total Score:

___

Physical Characterization/Water Quality Field Data Sheet

STATION: _____ STREAM NAME:_____ RIVER MILE: _____ DATE:_____

RIVER BASIN:_____ STREAM CLASSIFICATION:_____INVESTIGATORS:_____

DESCRIBE LOCATION:_____

STREAM CHARACTERIZATION

■ Subsystem Classification
___ Tidal
___ Lower Perennial
___ Upper Perennial
___ Intermittent

■ Stream Type
___ Coldwater
___ Warmwater

RIPARIAN ZONE/INSTREAM FEATURES

■ Predominant Surrounding Land Use
___ Forest
___ Field/Pasture
___ Agricultural
___ Residential
___ Commercial
___ Industrial
___ Other
■ Channelized ___Y ___N
■ Dam Present ___Y ___N

■ Local Water Erosion
___ None
___ Moderate
___ Heavy
■ Local Watershed NPS Pollution
___ No evidence
___ Some potential sources
___ Obvious sources
■ High Water Mark ___m
■ Velocity ___m/sec

■ Estimated Stream Width ___m
■ Estimated Stream Depth
Riffle___ m
Run___ m
Pool___ m
■ Est. Fish Reach Length___ m
■ Canopy Cover
___ Partly open
___ Partly shaded
___ Shaded

SEDIMENT/SUBSTRATE

■ Odors
___ Normal
___ Sewage
___ Petroleum
___ Chemical
___ Anaerobic
___ None
___ Other

■ Oils
___ Absent
___ Slight
___ Moderate
___ Profuse
___ Relict shells
___ Other

■ Deposits
___ Sludge
___ Sawdust
___ Paper fiber
___ Sand

■ Are the underside of stones not deeply embedded black?
___Y ___N

INORGANIC SUBSTRATE COMPONENTS			ORGANIC SUBSTRATE COMPONENTS		
Substrate Type	Diameter	Percent Composition in Sampling Area	Substrate Type	Characteristic	Percent Composition in Sampling Area
Bedrock			Detritus	sticks, wood, coarse plant materials (CPOM)	
Boulder	>256mm (10 in)				
Cobble	64-256mm (2.5-10 in)				
Gravel	2-64mm (0.1-2.5 in)		Muck-mud	black, very fine organic (FPOM)	
Sand	0.06-2mm (gritty)				
Silt	0.004-0.06mm		Marl	grey, shell fragments	
Clay	<0.004mm (slick)				

WATER QUALITY

■ Temperature _____
■ Specific Conductance ___
■ Dissolved Oxygen ___
■ pH ___
■ Turbidity ___

■ Water Odors
___ Normal/None
___ Sewage
___ Petroleum
___ Chemical
___ Fish

■ Water Surface Oils
___ Slick
___ Sheen
___ Globs
___ Flecks
___ None

■ Turbidity (if not measured)
___ Clear
___ Slightly turbid
___ Turbid
___ Opaque
___ Water color

Appendix C Macroinvertebrate Data Entry Fields and Instructions

1. Re-orgnize your raw data to fit in BIO_Template work sheet template. You must keep the BIO_Template as the first worksheet in this workbook when uploading the data.

Station Name must match a Station Name that already exists in BioQual and WQual.
This import function only works for stations associated with three projects: ESS, RIDEMAS, NWAS

2. All the fields with blue header backgrounds MUST be completed (others are optional). There are drop down lists for some fields.

Station Name	Must be complete with a Station existing in BioQual
CollDate	Required
Deployment Date	Optional
Sample Type	Required, pull-down menu available
Field Method	Required, pull-down menu available
Taxa Group	Optional, pull-down menu available
Final ID	Required, pull-down menu available based on entires in Taxa Group
Life Stage	Optional; if blank, it will be set to "X" on import
Count	Required
Supplemental Bug	Optional; if blank, it will be set to "0" on import
Fraction Sorted	Optional; if blank, it will be set to "1" on import
Comments	Optional

NOTE:
ProjectID is assumed to be:
19 RIDEM Artificial Substrate Stations
20 Environmental Science Services Biological Stations
25 Non-wadeable River Biomonitoring - Artificial Substrate
This import assumes that the station is already associated with one of these projects.

3. Sample Type:

Sample:	(Rountine Sample)
Replicate	(Replicate Sample)

Only use "Replicate1", "Replicate2"... when there are more than one Replicate; If there are more than 10 Replicate, name the rest accordingly, such as Replicate11, Replicate12, etc.

4. Field method: methods are extracted from SampleCollectionProcedures in database

5. Taxa Group: major taxonomic groups.
This must be selected before the FinalID drop-down menu will function.
Some oddball taxa are in the group called 'Other'.
If 'Undefined' is selected, then the whole taxa list will appear in the FinalID pull-down menu.

6. Final ID: The reference list (in the FinalID worksheet) is from from Benthics_Master_Taxa table in BioQual
The FinalID field can be completed with copy/paste operations from other eletronic sources (the association with Taxa Group will be ignored)

7. Life Stage:

X:	default; no stage was noted
Adult	
Larvae	
Pupae	

8. Supplemental Bug

0:	no, default
1:	yes

9. Please Validate Data before import by using Excel data validation function (Data/Data Validation/Circle Invalid Data)
Invalid data are those which do not appear in drop-down lists on the BIO_template sheet
1) If the invalid data are in field "Sample Type", "Field method", "Life Stage", "Suplementary Bug", fix it by only selecting options from the drop down list.
2) If the invalid data is in field "Taxa Group" or "Final ID" field, fix the spelling error, if there is any.

New Taxa

If there are new taxa in your import list that are not in the drop-down lists, add the new taxa names in three places.
1. to 'FinalID' work sheet, column "FinalID"
2. to 'FinalID' work sheet, in the appropriate column for the new taxon's group
3. To the 'Benthics_Master_Taxa' table of Bioqual. This will occur automatically on import after prompting for confirmation of validity.
Taxa attributes should also be added to the Benthics_Master_Taxa table

Appendix D

Scientific Collection Permit

MASSACHUSETTS
100 Fifth Avenue, 5th Floor
Waltham, Massachusetts 02451
p 781.419.7696

RHODE ISLAND
10 Hemingway Drive, 2nd Floor
East Providence, Rhode Island 02915
p 401.434.5560

VIRGINIA
999 Waterside Drive, Suite 2525
Norfolk, Virginia 23510
p 757.777.3777

August 1, 2014

Ms. Christine Dudley
Rhode Island Department of Environmental Management
Division of Fish and Wildlife
277 Great Neck Road
West Kingston, Rhode Island 02892

Re: RIDEM Annual Stream Biomonitoring
Statewide, Rhode Island
ESS Project No. R298-013

Dear Ms. Dudley:

I have attached an application for a scientific collector's permit for the remainder of the year 2014. ESS Group, Inc. will be conducting annual stream biomonitoring efforts on behalf of the Rhode Island Department of Environmental Management Office of Water Resources, which includes sampling benthic stream invertebrates from 12 sites throughout the state. The sampling locations for 2014 are attached.

Sampling will be completed using methods consistent with the Rhode Island Wadeable Streams Biomonitoring and Habitat Assessment Quality Assurance Project Plan. Macroinvertebrate samples are collected from wadeable stream substrates using kick-nets. Samples are preserved in ethanol in the field, and analyzed and housed at the ESS East Providence office until turned over to the Office of Water Resources for long-term archival.

I have not enclosed the $25 application fee at this time. In the past, the fee has been waived since the application is being submitted on behalf of the Office of Water Resources. Please let me know if you have any questions or concerns.

Sincerely,

ESS GROUP, INC.

Eliza Moore
Environmental Scientist

Attachment: Scientific Collector's Permit Application
Proposed Sampling Locations for 2014

MASSACHUSETTS
100 Fifth Avenue, 5th Floor
Waltham, Massachusetts 02451
p 781.419.7696

RHODE ISLAND
10 Hemingway Drive, 2nd Floor
East Providence, Rhode Island 02915
p 401.434.5560

VIRGINIA
999 Waterside Drive, Suite 2525
Norfolk, Virginia 23510
p 757.777.3777

Proposed Sampling Locations for 2014.

Official State River Name	Rhode Island Waterbody ID Number	Watershed Basin Name	Town	Latitude	Longitude
Woonasquatucket River & Tribs	RI0002007R-10A	Woonasquatucket River Basin	Smithfield	41.92085	-71.55265
Woonasquatucket River & Tribs	RI0002007R-10C	Woonasquatucket River Basin	Johnston	41.8592	-71.4874
Woonasquatucket River & Tribs	RI0002007R-10C	Woonasquatucket River Basin	Johnston	41.83286	-71.47033
Woonasquatucket River	RI0002007R-10D	Woonasquatucket River Basin	Providence	41.82652	-71.43583
Stillwater River & Tribs	RI0002007R-09	Woonasquatucket River Basin	Smithfield	41.87452	-71.55488
Latham Brook & Tribs	RI0002007R-05	Woonasquatucket River Basin	Smithfield	41.91943	-71.56013
Woonasquatucket River & Tribs	RI0002007R-10D	Woonasquatucket River Basin	Providence	41.8214	-71.4547
Unnamed Tribs to Stillwater Pond	RI0002007R-12	Woonasquatucket River Basin	Smithfield	41.91089	-71.52803
Tribs to Georgiaville Pond	RI0002007R-16	Woonasquatucket River Basin	Smithfield	41.89473	-71.50713
Hawkins Brook & Tribs	RI0002007R-04	Woonasquatucket River Basin	Smithfield	41.87344	-71.50132
Assapumpset Brook & Tribs	RI0002007R-01	Woonasquatucket River Basin	Johnston	41.84303	-71.48194
Woonasquatucket River & Tribs	RI0002007R-10B	Woonasquatucket River Basin	Smithfield	41.87368	-71.49713

No. 2012 - 37

Rhode Island Department of Environmental Management
DIVISION OF FISH AND WILDLIFE
277 Great Neck Road
West Kingston, RI 02892 (401) 789-0281

SCIENTIFIC COLLECTOR'S PERMIT APPLICATION

1. Name: ELIZA MOORE 2. Date: 8/1/2014
3. Home address: 41 B CONSTITUTION ST BRISTOL, RI 02809 4. Tel.# 508-932-6111
5. Occupation: ENVIRONMENTAL SCIENTIST
6. Business Address: ESS GROUP, INC., 10 HEMINGWAY Dr. 7. Tel.# 401-330-1209
8. Education: MS - BIOLOGY 2ND FLOOR EAST PROVIDENCE, RI 02915
9. Species to be collected: BENTHIC STREAM INVERTEBRATES
10. Federal Permit #, if applicable:
11. In which specific locations in R.I. will this collecting be done? (Attach additional sheet if necessary) _____
12. Will you collect sub-legal size? If so, what species:
13. Purpose of collection:
    RIDEM ANNUAL STREAM BIOMONITORING
14. Collecting technique: KICK-NET
15. Numbers required:
16. Period Required: AUGUST - DECEMBER 2014
17. Where collection housed? 10 HEMINGWAY DR, 2ND FLOOR, EAST PROVIDENCE RI 02915
18. If animals are for experimental purposes, attach a statement or outline of research protocol. N/A
19. If collecting molluscan shellfish from any marine waters designated as polluted, you must notify the Division of Enforcement by phone (222-2284) indicating the exact date, time, and place you plan to sample. N/A
20. Any collecting gear that is left untended, must have identification on it indicating your name and permit number.
21. This permit expires on December 31 of each year. An annual report of specimens collected is required.
22. SPECIAL PERMIT CONDITIONS:

Signature of Applicant: _____ 8/13/14

Approved: Christie A. Judge - Deputy Chief Disapproved:
Chief, R.I. Division of Fish & Wildlife for Catherine Sparks.

Fee ~~$25.00~~ - check made payable to: RIDEM/Div. of Fish & Wildlife

cc: Division of Enforcement Waived

RHODE ISLAND DEPARTMENT OF ENVIRONMENTAL MANAGEMENT
DIVISION OF FISH AND WILDLIFE

PERMIT

Issued to:

Eliza Moore

To RI DEM Annual Stream Biomonitoring

Under the rules and regulations established by the Division

Expires December 31, 2014

Chief