QUALITY ASSURANCE PROJECT PLAN FOR
OARS' Water Quality and Quantity Monitoring Program
(including Bacteria)

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A4 PROJECT/TASK ORGANIZATION

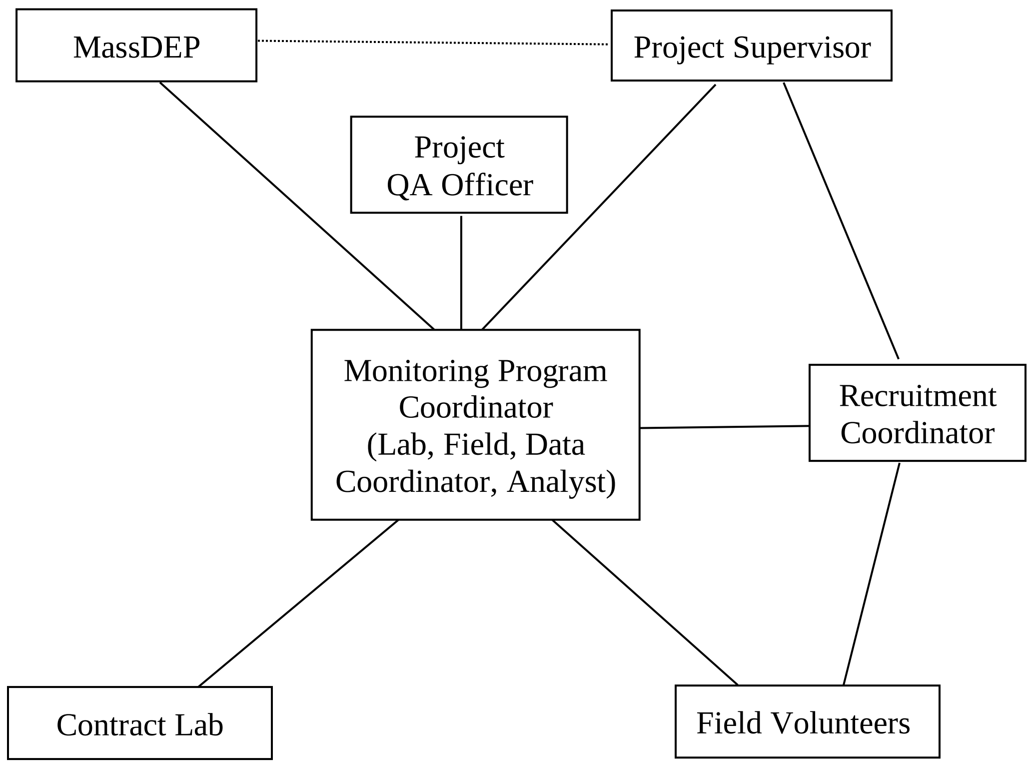
Founded in 1986 as the Organization for the Assabet River (OAR), OARS officially expanded its mission in April 2011 to include the entire Sudbury, Assabet, and Concord river watersheds and changed its name to OARS, Inc. OARS' Water Quality and Quantity Monitoring Program was established in 1992, and involves about 25 trained volunteers each year, who monitor water quality and read staff gages. OARS' Bacteria Monitoring Program was established in 2019 to monitor the recreational health safety of the rivers, and involves about 20 volunteers each year, who collect bacteria samples. The two programs are being combined into a single QAPP in 2022.

Table 1: Project Organization

Name(s)	Project Title/Responsibility
Alison Field-Juma, OARS Executive Director	**Project Supervisor**—Oversees all aspects of project including: fiscal management, project objectives, data uses, program changes, etc.
Peter Shanahan, Project QA/QC Officer, Senior Lecturer, MIT (ret.)	**QA Officer**—Reviews project data and QC reports to ensure that project follows QA measures.
Benjamen Wetherill, OARS Water Quality Scientist	**Monitoring Program Coordinator (Project Manager)** – Volunteer recruitment and training, coordination with TAC. Produces monitoring report. Produces or oversees outreach efforts in coordination with project manager.
Benjamen Wetherill, OARS Water Quality Scientist	**Lab Coordinator**—Makes arrangements with contract lab to perform analyses according to QAPP. Ensures correct procedures are used, holding times are met, and adequate documentation is provided.
Benjamen Wetherill, OARS Water Quality Scientist	**Field Coordinator**—Responsible for training and supervising volunteers in field work; ensures field procedures are properly followed, and performs QC checks to confirm or correct procedures as needed.
Benjamen Wetherill, OARS Water Quality Scientist	**Data Analyst**—Makes discharge measurements to create and maintain stage/discharge rating curves.
Benjamen Wetherill, OARS Water Quality Scientist	**Data Management Coordinator**—Maintains the data systems for the program, performs/oversees data entry, and checks entries for accuracy against field and lab forms.
Citizen Scientists	**Volunteers**—Conduct sampling, perform field analyses, and assist in laboratory analyses and/or data entry.
Nathalie Lewis, Alpha Analytical, Inc.	**Contract Analytical Lab Manager—**Responsible for analytical procedures performed under contract with monitoring organization.
Maria Braun, Nashoba Analytical LLC	**Contract Analytical Lab Manager—**Responsible for analytical procedures performed under contract with monitoring organization.

Name(s)	Project Title/Responsibility
Suzanne Flint, MassDEP Watershed Planning Program	**MassDEP Quality Assurance Officer**—Reviews QAPP.

Figure 1: Project Organization



Previous QAPP Documentation

OARS' ongoing monitoring program was developed in several parts: the baseline water quality monitoring program started in 1992, the Assabet River StreamWatch project (with sampling on tributary streams) started in 2002, sampling on the Concord River started in 2004, Sudbury River sampling started in 2009, and the Bacteria Monitoring Program started in 2019. This QAPP covers the continuing combined program for the Sudbury, Assabet, and Concord rivers. Table 2 lists the previous QAPP documentation for OARS' various sampling programs since 2000.

Table 2: Previous QAPP Documentation

QAPP Title	EPA Ref. #	Approval Date
Quality Assurance Project Plan for the Volunteer Water Monitoring Program	RFA#03296	April 2000 (updated 2003 and 2007)
Quality Assurance Project Plan for Assabet River StreamWatch Project	RFA# 03327	June 2003 (updated 2004 and 2007)

Quality Assurance Project Plan for StreamWatch: OAR’s Water Quality and Quantity Monitoring Program	---	June 2009
Quality Assurance Project Plan for OAR’s Lower Sudbury River Water Quality Monitoring Program	---	August 2009
Quality Assurance Project Plan for OARS’ Water Quality and Quantity Monitoring Program	RFA#13095	May 2013
Quality Assurance Project Plan for OARS’ Water Quality and Quantity Monitoring Program	RFA# 16067	March 2016
Quality Assurance Project Plan for OARS’ Water Quality and Quantity Monitoring Program	---	December 2018 (updated 2019)
Quality Assurance Project Plan for OARS’ Bacteria Monitoring Program	---	June 2019 (updated 2020)

A5 PROBLEM DEFINITION / BACKGROUND

The Sudbury, Assabet, and Concord rivers, parts of which are federally designated Wild and Scenic Rivers, flow from the headwaters of the Assabet and Sudbury in Westborough, joining in Concord to become the Concord River, and continuing to the confluence of the Concord River with the Merrimack River in Lowell. Beloved of Hawthorne and Thoreau, they are lovely, scenic rivers, and popular among recreational boaters and anglers. However, like most New England rivers, the Assabet, Sudbury, and Concord rivers flow through a landscape that bears the imprint of human activity. Roads, houses, dams, businesses, and other human uses of the land affect both the river water quality and its flow. Home to a growing human population, the rivers, and the aquifers beneath, provide both wastewater disposal and water supply for watershed residents and businesses. As the business, industrial, and residential population grows, the demands on the rivers increase, affecting water quality, streamflow, and ability to support natural plant and animal populations. OARS, the towns of the watershed, and the regulatory agencies (MA DEP, US EPA) face the scientific, political, and practical challenges of measuring the effectiveness of water management practices in the SuAsCo watershed. The information collected in this project will continue building a long-term database of water quality and quantity in the watershed, with which trends in water quality and quantity can be assessed on all three rivers and their tributaries.

Table 3 lists the MA DEP water quality designations for the three rivers (MA DEP, 2013). All rivers are varying designations of Class B. All of the tributary streams assessed in this project are also designated Class B waters. Table 4 lists the tributary streams of the basin that are designated as cold-water fisheries by MA Division of Fisheries and Wildlife (MA DFW, 2016). More streams supported cold-water fisheries in the past (Schlotterbeck, 1954).

OARS monitors bacteria because the demand for primary and secondary contact recreation has significantly increased over the past decades. OARS stakeholders have clearly expressed the need for an indicator of public health and safety for recreational activities. The MA DEP 2018-2020 Integrated List of Waters (MA DEP, 2019) shows Category 5 impairment due to bacteria in nine segments of the three rivers (Table 5). Consequently, OARS includes bacteria monitoring as a key parameter in this water quality monitoring project. And, with the Clean Water Act Class B goal of “swimmable”, monitoring for bacteria will be particularly useful to determine the possibility of establishing public bathing in the future.

Table 3: MA DEP major river water quality designations

River	Section	Designation
Assabet	Headwaters to Westborough Wastewater Treatment Plant	Class B, Warm Water, High Quality Water
Assabet	Westborough Wastewater Treatment Plant to confluence with the Sudbury	Class B, Warm Water
Concord	Confluence of the Assabet and Sudbury to the Billerica drinking water withdrawal	Class B, Warm Water, Treated Water Supply
Concord	Billerica withdrawal to Roger’s St. in Lowell	Class B, Warm Water
Concord	Rogers St. to confluence with the Merrimack	Class B, Warm Water, CSO

Sudbury	Headwaters at Cedar Swamp Pond to Fruit St. in Hopkinton	Class B, Warm Water, Outstanding Resource Water
Sudbury	Fruit St. to the outlet of Saxonville Pond in Framingham	Class B, Warm Water, High Quality Water
Sudbury	Saxonville Pond to Hop Brook	Class B, Aquatic Life, High Quality Water
Sudbury	Hop Brook to confluence with the Assabet	Class B, Aquatic Life

Table 4: MA DFW Cold-Water Fish Resources List for Concord Basin

Stream Name	SARIS #
Cranberry Brook	8247885
Danforth Brook	8247275
Flagg Brook	8247225
Great Brook	8247175
Hayward Brook	8248000
Hog Brook	8247325
Hop Brook (1)	8247600
Hop Brook (2)	8247825
Howard Brook	8247525
Jackstraw Brook	8248475
Landham (Allowance) Brook	8247900
Nagog Brook	8246900
North Brook	8247375
Piccadilly Brook	8248450
Pine Brook	8247950
Rawson Hill Brook	8247575
Run Brook	8247875
Second Division Brook	8247075

Stream Name	SARIS #
Sheepsfall Brook	8247250
UNT to A-1 Site (1) (Nourse Brook)	8247627
UNT to A-1 Site (2)	8247628
UNT to Assabet River	8247260
UNT to Cranberry Brook	8247886
UNT to Great Brook	8247180
UNT to Hog Brook	8247327
UNT to Hop Brook	8247879
UNT to Hop Brook (2, 1; Trout Brook)	8247830
UNT to Hop Brook (2, 3)	8247855
UNT to Nashoba Brook	8246876
UNT to North Brook	8247435
UNT to Pine Brook	8247965
UNT to Second Division Brook	8247076
UT(NOURSE BROOK)	8248530
Wrack Meadow Brook	8247440

Table 5: MA DEP waters impaired due to pathogens

River	Impaired Sections
Assabet	MA82B-02, MA82B-03, MA82B-04, MA82B-05, MA82B-07 (Westborough WWTP → Confluence, except MA82B-06 Maynard → Acton)
Sudbury	MA82A-25 (Fruit St., Hopkinton → Reservoir #2 inlet, Ashland), MA82A-03 (Saxonville Dam outlet, Framingham → Hop Brook, Wayland)
Concord	MA82A-07 (Confluence → Billerica water intake), MA82A-09 (Roger’s St., Lowell → Merrimack River)

OARS monitors water quality because wastewater has impaired the rivers’ water quality and caused eutrophication. High-priority water quality issues have been identified as eutrophication, stormwater impacts, low baseflow, and recreational health safety. The following discusses the water quality of each of the three rivers.

Assabet River

The primary cause of eutrophication in the mainstem Assabet has been the nutrient-rich effluent discharged to the river by five wastewater treatment facilities serving the communities of Westborough/Shrewsbury, Marlborough, Northborough, Hudson, and Maynard. Starting in 1999, a total phosphorus TMDL study of the Assabet River was conducted by ENSR International (ENSR, 2001) under contract to the US Army Corps of Engineers (ACOE) and the Massachusetts Department of Environmental Protection (MA DEP). MA DEP issued the final total phosphorus TMDL for the Assabet River in 2004, proposing to achieve water quality goals in the Assabet River through a two-phased, adaptive management strategy (MA DEP, 2004). Based on modeling, best professional judgment, and weight of evidence, the state determined that a combination of stringent point-source phosphorus controls and sediment remediation would be necessary to reduce eutrophication and restore designated uses in the Assabet River.

In Phase 1, the four municipal wastewater treatment plants (WWTPs) that discharge directly to the Assabet River were required to meet a summer discharge limit of 0.1 mg/L total phosphorus by the end of the NPDES permit period (2005–2011), and plans were made to further investigate the feasibility of remediating sediments to reduce phosphorus flux. Prior to the facility upgrades, the WWTPs were required to continue meeting the 2000 interim NPDES permit limits for total phosphorus of 0.75 mg/L during the summer, and were required to meet winter limits of 1.0 mg/L starting on November 1, 2007. Upgrades to the wastewater treatment plants were completed as follows: Hudson in October 2009, Maynard in March 2011, Westborough in March 2012, and Marlborough Westerly in February 2012. (Upgrades to the Marlborough Easterly plant, which discharges to Hop Brook, a tributary of the Sudbury River, were completed in January 2015.) In 2010, the Army Corps of Engineers issued final results of a sediment and dam study (US ACOE, 2010):

- Dam removal was deemed the best option for improving water quality and habitat:
  - Removal of all six Assabet dams would result in improved water quality and habitat.
  - Removal of the Ben Smith dam alone would result in significant improvements in the lower Assabet River.
- Sediment dredging/treatment would result in only short-term benefits in controlling aquatic plant and algae growth and were deemed expensive and ineffective.
- Winter limits: reducing the winter loading (winter TP discharge concentrations) would have significant benefit to the river.
- Summer limits: further reducing the summer TP discharge limits (without other improvements) would have little benefit.

In Phase 2, DEP and the U.S. Environmental Protection Agency (EPA) were tasked with jointly deciding what additional phosphorus treatment would be needed for the Assabet to meet water quality standards, based on the towns' actions, on the recommendations of the sediment evaluation, and the effects of the first round of WWTP upgrades. No action was taken on the sediment recommendations. As of 2017, the median summer TP concentration (0.02 mg/L) of all the Assabet River mainstem sites below the Westborough wastewater discharge was below the EPA "Gold Book" recommendation (0.05 mg/L) and below the Ecoregion reference condition for TP

(0.025 mg/L), while the median summer NO_3 concentration (1.15 mg/L) of all the Assabet mainstem sites was more than three times the Ecoregion reference condition (0.34 mg/L). However, the total aquatic plant biomass in the impounded sections of the river remained high. Between 2019 and 2021, the EPA and DEP took the next step of reducing the winter phosphorus discharge limits to 0.2 mg/L: the permits for Hudson and Maynard were updated in 2019, Marlborough Westerly was updated in 2021 (with a 12-month implementation period), Westborough was updated in Feb. 2022, and Marlborough Easterly is in draft form as of late Feb. 2022.

Sudbury River

Sources of impairment to the Sudbury River include: Nyanza Superfund Site in Ashland (mercury), the Natick Laboratory Army Research Center superfund site in Natick (volatile organic chemicals and metals), the Wayland wastewater treatment plant discharge (nutrients), and the Marlborough Easterly wastewater treatment plant discharge via Hop Brook (nutrients). EPA completed a "Restoration Plan and Environmental Assessment for the Nyanza Chemical Waste Dump Superfund Site" in July 2012, proposing to place a thin-layer sand cap on the contaminated sediments of Framingham Reservoirs 1 and 2 and proposing restoration projects in other parts of the system. The sand cap has never been installed. The Sudbury River is also impacted by invasive aquatic plants, particularly water chestnut (*Trapa natans*) in the sections of the river from the Framingham Reservoirs downstream. Other potential sources of pollution include non-point source runoff from urbanized areas (particularly the heavily urbanized areas of the upper watershed in Westborough, Ashland, and Framingham) and from sub-standard septic systems. Much of the Sudbury watershed relies on local septic systems for wastewater treatment.

Concord River

While nutrient concentrations have been lower in the Concord River than in the Assabet River, levels are still slightly elevated and the Concord is listed as Category 5 (impaired) for metals, nutrients, and pathogens. A nutrient TMDL Assessment Study of the Concord River was completed in 2003 (ENSR, 2003), but a final TMDL has not been issued for the Concord. The Concord River receives wastewater discharges from municipal WWTPs in Concord and Billerica. Both WWTPs were upgraded to meet total phosphorus discharge limits of 0.2 mg/L by 2009. The Concord also suffers heavy infestations of water chestnut in sections, particularly in the impoundment above the Faulkner Mill Dam in Billerica. The Faulkner Mill Dam is considered a major barrier for migratory fish, as it is the first impassable dam travelling upstream from the ocean. Billerica draws water for public water supply from the Concord.

Tributaries

The major tributaries of the watershed are affected by both streamflow depletion and non-point-source pollution. The Marlborough Easterly Wastewater Treatment Plant (mentioned above) is located on the largest tributary of the Sudbury River, Hop Brook. Local water supplies are under the combined strain of the increasing demand of a rapidly growing population (MTC/MAPC, 1998) and water management practices that result in the net transfer of water out of the sub-basins and decreased baseflow in the tributaries (Carlson, 2008 and Zarriello, 2010). Water use projections for the years 2000 to 2030 (MAPC, 2005) show increased usage due to population increases of 10-20% in some towns (Westborough, Hudson, Maynard, Acton) and more than 20% in others (Shrewsbury, Northborough, and Littleton).

A6 PROJECT / TASK DESCRIPTION

Project Goals of the Combined Program

OARS' overall monitoring strategy, guided in part by the goals of the Assabet River TMDL, includes water quality monitoring on the mainstem Assabet, Sudbury, and Concord rivers and their major tributaries, streamflow monitoring on the major tributary streams of the basin, and total and floating aquatic plant biomass monitoring on the major impoundments of the Assabet mainstem. This document addresses water quality and streamflow monitoring. Bacteria monitoring has been added more recently.

The main goals of OARS Water Quality and Quantity Monitoring program are:

- Assessing whether the Sudbury, Assabet, and Concord rivers meet Massachusetts Surface Water Quality Standards.
- Assessing long-term trends in water quality and streamflow.
- Assessing the effect of changes in the management of point and non-point pollution sources as the state's TMDL recommendations are implemented.
- Comparing water quality conditions among the rivers.
- Identifying problem spots for further investigations.
- Communicating the data and findings at several levels of detail to the lay public, local decision makers, and scientists to build the capacity across the watershed for making short- and long-term management decisions.
- Through volunteer participation, increasing the personal connection of the community to the rivers and fostering better river stewardship.
- Evaluating the health safety of the rivers for swimming and recreation.

Program Overview

OARS' monitoring program includes monthly summer sampling (to evaluate eutrophication in the summer growing season), sampling in March and November (to get additional data about annual nutrient loadings), and mid-month sampling (to collect higher-frequency bacteria data). To be able to assess long-term trends, sampling and analysis methods have been kept the same, as much as possible, since 1999. The core of OARS' mainstem Assabet sampling sites, six of the sites originally selected in 1992, have also been kept constant. About 20-25 volunteers participate in the program each summer, taking water quality readings, collecting samples, and reading staff gages.

Monitoring will be conducted one Sunday each month, regardless of weather conditions, in June/July/August at all sites and in March/May/September/November at a smaller set of sites. Bacteria monitoring will be conducted on the Monday following the Water Quality monitoring plus mid-month during the summer. See Table 8 and Table 9 for the list of sites with location coordinates and sampling schedules by site. Water quality parameters measured include: dissolved oxygen, pH, water temperature, conductivity, total phosphorus, ortho-phosphorus, nitrate, ammonia, total suspended solids, and *E. coli*. Concurrent with the water quality monitoring, staff gage readings will be taken at five sampling sites with rated staff gages, and streamflow readings will be downloaded from the NWIS webpage for United States Geological Survey (USGS) real-time gages at an additional four sites. OARS staff is responsible for overall organization, coordination, and training of volunteers, equipment calibration and maintenance, data management and QA/QC, and maintaining the staff gage stage/discharge rating curves.

To assess stream conditions, water quality data will be used to calculate a "Water Quality Index" according to methods developed by OARS for the Assabet River StreamWatch project to compare measured conditions with ideal conditions for native fish. (A full description of the Stream Health Index is available on the OARS webpage at https://oars3rivers.org/our-work/monitoring/interpret-data/stream-health-index.) Parts of this index are used for OARS' Rivers Report Card (https://ecoreportcard.org/report-cards/sudbury-assabet-concord-rivers/). Water quality findings will also be compared with Massachusetts Water Quality Standards (MA DEP, 2013) for dissolved oxygen, pH, temperature, and *E. coli* (Table 6). For nutrient concentrations (where the Massachusetts standard is narrative) results will be compared with the EPA "Gold Book" total phosphorus national criterion (EPA, 1986) and with summertime data for Ecoregion XIV subregion 59 (EPA, 2000) (Table 7). Chloride concentrations will be compared with EPA's National Recommended Water Quality Criteria (EPA, 2002).

Table 6: MA DEP Class B Water Quality Standards

Parameter	Standard / Guidance Class B	Standard / Guidance Class B "Aquatic Life"
Dissolved oxygen	≥ 5.0 mg/l for warm water fisheries ≥ 6.0 mg/l for cold water fisheries	≥5.0 mg/l at least 16 hours of any 24-hour period and ≥ 3.0 mg/l at any time
Temperature	≤28.3° C and Δ < 2.8° C for warm water fisheries ≤20.0° C and Δ < 1.7° C for cold water fisheries	≤29.4 ° C and Δ ≤ 2.8° C
pH	6.5–8.3 inland waters	
Nutrients	"control cultural eutrophication" / Gold Book** standard TP < 0.05 mg/L for rivers entering a lake or impounded section	
Suspended Solids	"free from floating, suspended and settleable solids in concentrations and combinations that would impair any use assigned to this Class"	
Aesthetics	All surface waters shall be free from pollutants in concentrations or combinations that settle to form objectionable deposits; float as debris, scum or other matter to form nuisances; produce objectionable odor, color, taste or turbidity; or produce undesirable or nuisance species of aquatic life.	
E.coli	Geometric Mean 126 cfu/100ml and Single Sample 235 cfu/100ml for primary contact Geometric Mean 630 cfu/100ml and Single Sample 1260 cfu/100ml for secondary contact	
Chloride	EPA Recommended Criteria*** 230 mg/L chronic exposure, 860 mg/L acute exposure	

MASS DEP. 2013. Massachusetts Surface Water Quality Standards—314 CMR 4.00 2013
** EPA, 1986 ("Gold Book"); *** EPA, 2002 National Recommended Water Quality Criteria

Table 7: EPA Ambient Water Quality Recommendations (EPA, 2000)

Parameter	Nutrient Ecoregion XIV Reference Conditions (25th percentile of summer data)	Nutrient Ecoregion XIV Reference Conditions (50th percentile of summer data)
Total Phosphorus (Ecoregion XIV Subregion 59)	25 μg/L	50 μg/L
Ortho-Phosphorus (Ecoregion XIV Subregion 59)	10 μg/L	25 μg/L

Parameter	Nutrient Ecoregion XIV Reference Conditions (25th percentile of summer data)	Nutrient Ecoregion XIV Reference Conditions (50th percentile of summer data)
Total Nitrogen (Ecoregion XIV Subregion 59)	0.44 mg/L	0.74 mg/L
NO2 + NO3 (Ecoregion XIV Subregion 59)	0.34 mg/L	0.43 mg/L
Chlorophyll *a* Spec A method (Ecoregion XIV Subregion 63)	2.00 μg/L	4.00 μg/L

EPA, 2000. Ambient Water Quality Criteria Recommendations—Rivers and Streams in Nutrient EcoRegion XIV

At the end of each sampling season: the data and QC data will be reviewed by the program QA Officer and the fully-QCed data will be submitted to MassDEP through the National Water Quality portal (WQX). A project report will be submitted to DEP by the Project Manager with a summary of data submitted and QC results. An annual water quality report will be posted on OARS' project webpage as soon as it is available. The reports are also available in hardcopy.

Special Personnel or Equipment Requirements
No special personnel or additional equipment are required for this project. OARS owns three YSI multi-parameter water meters (one 6-series, two Pro-series) and rents YSI Pro-series meters as needed. For instrument calibration, OARS owns a NIST-traceable digital thermometer and purchases fresh calibration fluids several times per year. OARS also owns Pygmy and Price AA current meters, wading rods, AquaCalc data recorders, and all of the ancillary equipment needed to take instantaneous discharge measurements.

Assessment Techniques
OARS will be responsible for QA/QC activities related to water quality measurements, staff gage readings, and instantaneous discharge measurements. Any data posted will be labeled as provisional until it has been reviewed for compliance with quality objectives.

Overall project success may be gauged by the delivery of timely, accurate environmental information and the ability to detect long-term trends. Success of the information delivery system will be judged by tracking use of the web page: timing, source, and frequency of web page visitors. Success may also be demonstrated through the active collaboration with members of the Assabet/Sudbury/Concord River watershed communities, presentation of OARS' projects at scientific conferences, and utilization of the data for advocacy and regulatory purposes.

Schedule
This is an ongoing program; the general schedule is shown in Table 10.

Figure 2: OARS Water Quality Sampling Sites

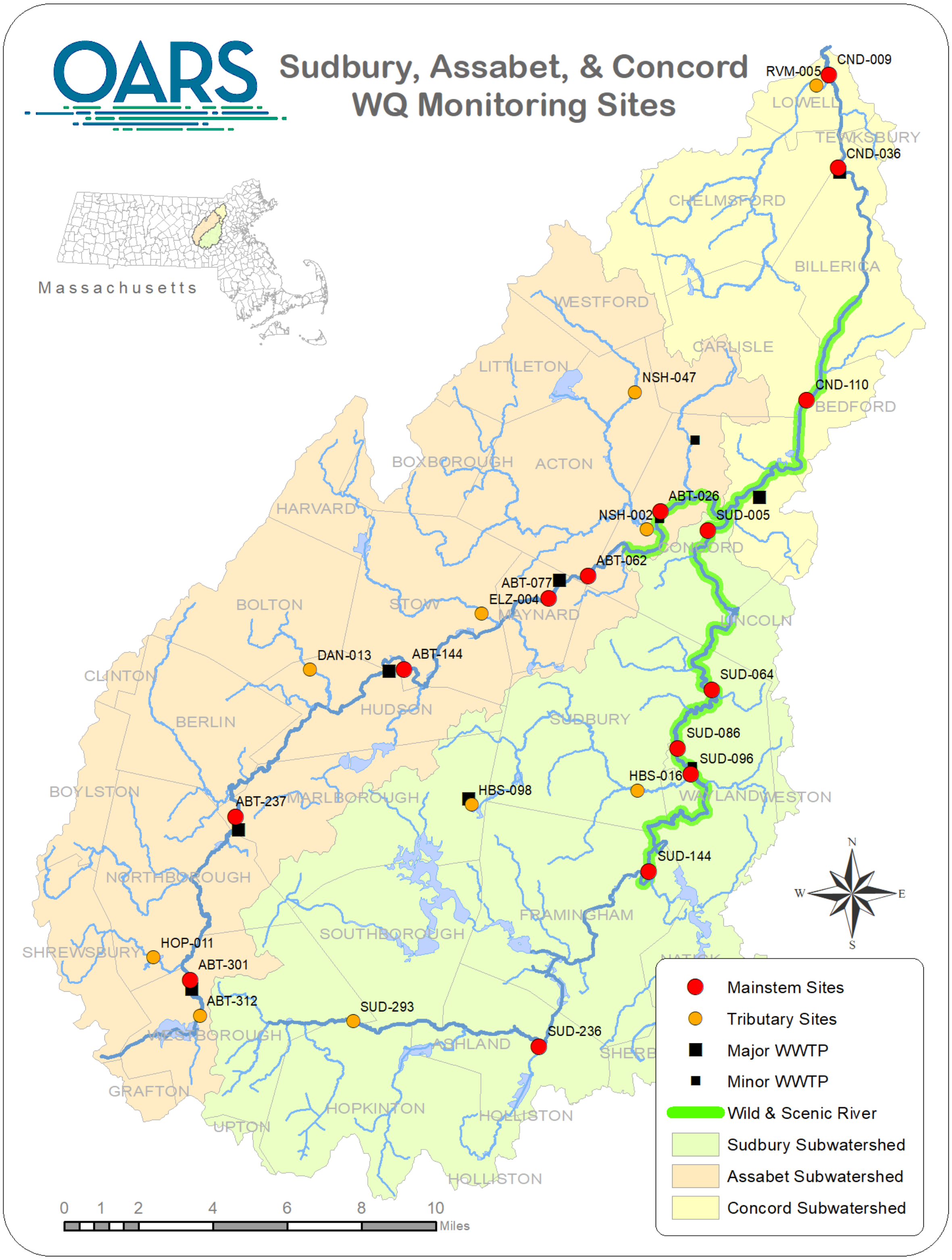


Figure 3: OARS Bacteria Sampling Sites

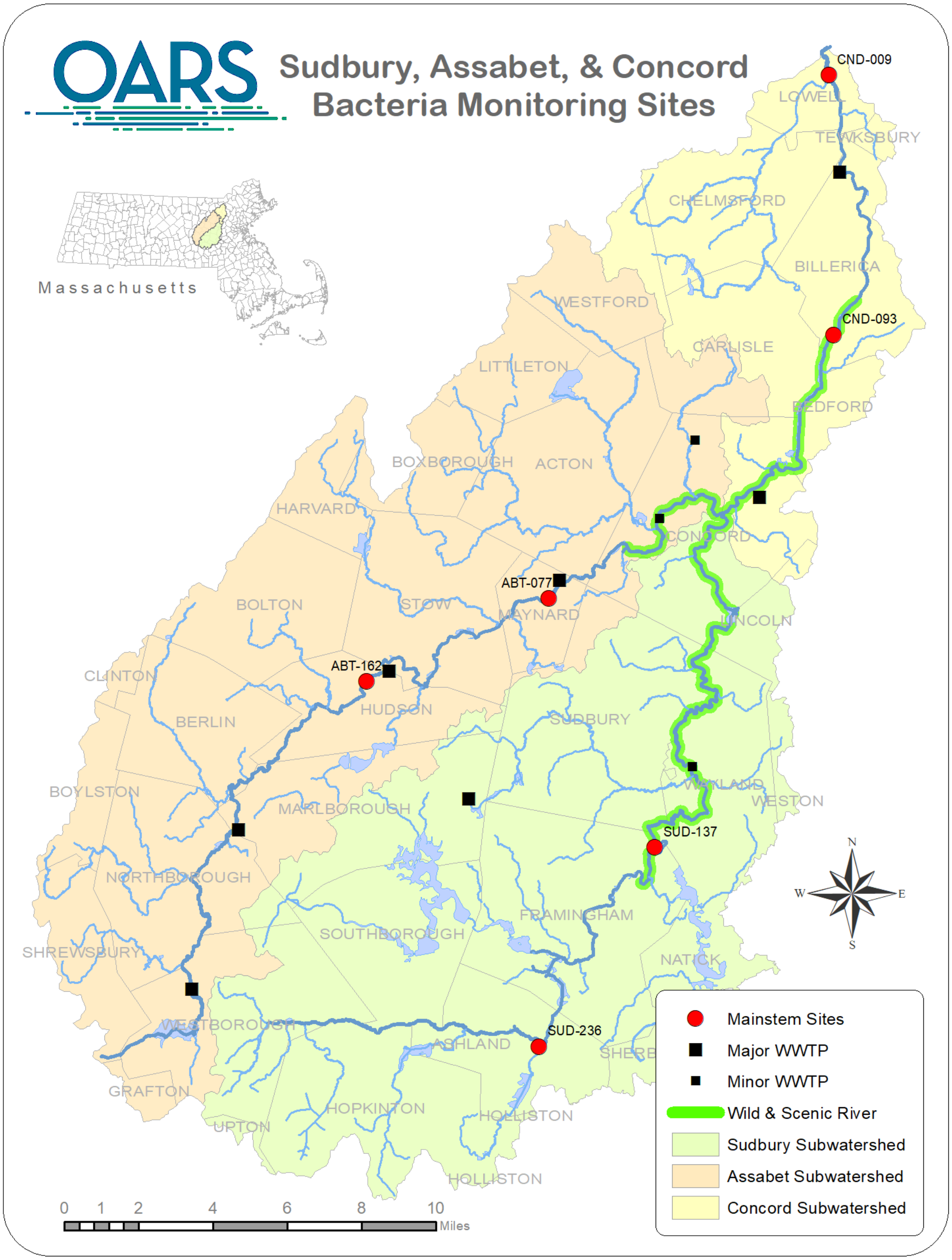


Table 8: Water Quality Monitoring Sites

Waterbody	**Sites**	Town	OARS Site #	SARIS #	Lat/Long	Sampling Dates			Gage reading /streamflow*
						June/Jul/ Aug	May/ Sept	Nov/ March	
Concord River	Rogers Street	Lowell	CND-009	46500	42°38' 11"/ -71°18' 05"	√	√	√	(USGS Gage)
Concord River	Bristol & Amherst Streets	Billerica	CND-036	46500	42°35' 59"/ -71°17' 49"	√			
Concord River	Route 225	Bedford	CND-110	46500	42°30' 33"/ -71°18' 48"	√			
Assabet River	Route 2	Concord	ABT-026	46775	42°27' 56"/ -71°23' 28"	√	√	√	
Assabet River	Route 62 (Canoe access)	Acton	ABT-062	46775	42°26' 27"/ -71°25' 46"	√			
Assabet River	USGS Maynard Gage	Maynard	ABT-077	46775	42°25' 56"/ -71°26' 58"	√	√	√	(USGS Gage)
Assabet River	Route 62 (Gleasondale)	Stow	ABT-144	46775	42°24' 18"/ -71°31' 35"	√			
Assabet River	Robin Hill Road	Marlborough	ABT-237	46775	42°20' 44"/ -71°36' 50"	√			
Assabet River	Route 9	Westborough	ABT-301	46775	42°16' 59"/ -71°38' 18"	√	√	√	
Assabet River	Mill Road	Westborough	ABT-312	46775	42°16' 26"/ -71°37' 56"	√	√	√	√
Sudbury River	Route 62 (Boat House)	Concord	SUD-005	47650	42°27' 30"/ -71°21' 58"	√	√	√	
Sudbury River	Sherman Bridge Road	Wayland	SUD-064	47650	42°23' 47" / -71°21' 52"	√	√		
Sudbury River	River Road	Wayland	SUD-086	47650	42° 21' 48"/-71° 22'28"	√	√		
Sudbury River	Route 20	Wayland	SUD-096	47650	42° 22' 24"/-71° 22' 56"	√	√		
Sudbury River	Sudbury Landing	Framingham	SUD-144	47650	42° 19' 32"/ -71° 23' 50"	√	√	√	(USGS Gage)
Sudbury River	Chestnut Street	Ashland	SUD-236	47650	42°15' 27" / -71°27' 18"	√			
Sudbury River	Fruit Street	Southborough	SUD-293	47650	42°16' 3" / -71°33' 9"	√	√	√	√
Danforth Brook	Route 85	Hudson	DAN-013	47275	42°23' 59"/ -71°33' 57"	√	√	√	√
Elizabeth Brook	White Pond Road	Stow	ELZ-004	47125	42°25' 21"/ -71°28' 38"	√	√	√	
Hop Brook N'boro	Otis Street	Northborough	HOP-011	47600	42°17' 31"/ -71°39' 27"	√	√	√	√
Hop Brook Sudbury	Landham Road	Sudbury	HBS-016	47825	42° 21' 26"/ -71° 24' 11"	√	√	√	
Hop Brook Sudbury	Rt 20 Above Hager Pond	Marlborough	HBS-098	47825	42° 21' 3"/ -71° 29'26"	√			
Nashoba Brook	Commonwealth Ave.	Concord	NSH-002	unnamed	42°27' 32"/ -71°23' 49"	√	√	√	√
Nashoba Brook	Wheeler Lane	Acton	NSH-047	46875	42°30' 37"/ -71°24' 24"	√	√	√	(USGS gage)
River Meadow	Thorndike Street	Lowell	RVM-005	46525	42°37' 54"/ -71°18' 31"	√	√	√	

* (USGS Gage) indicates that data is collected from USGS real-time gaging stations via the USGS NWS website. Check mark indicates gage readings by OARS volunteers at staff gages maintained by OARS as described in this document. USGS Gage at Mill Road, Westborough, is no longer available on the real-time USGS NWS website; gage is read by OARS volunteers and maintained by OARS staff.

Table 9: OARS Bacteria Monitoring Sites

Waterbody	**Site Description**	Town	OARS Site #	Latitude	Longitude
Concord River	Rogers Street bridge	Lowell	CND-009	42.63595037	-71.30148697
Concord River	Route 4 bridge	Billerica	CND-093	42.53472222	-70.70055556
Assabet River	Route 27/62 bridge near USGS gage #01097000	Maynard	ABT-077	42.43206352	-71.44974106
Assabet River	Cox Street bridge	Hudson	ABT-162	42.39979789	-71.54598569
Sudbury River	Little Farms Road	Framingham	SUD-137	42.33500791	-71.39450489
Sudbury River	Route 135 bridge upstream of Cold Spring Brook	Ashland	SUD-237	42.25849843	-71.45547229

Additional sites may be added for special studies, following all the same protocol.

Table 10: Annual Task Calendar

Activity	J	F	M	A	M	J	J	A	S	O	N	D
Equipment preparation, inspection, and testing		X	X									
Volunteer training sessions				X								
Water Quality Sampling			*X		X	X	X	X	X		X	
Bacteria Sampling					X	X	X	X	X			
Data entry				X		X	X	X	X	X		X
Data review and validation	*X											X
Data uploads to WQX		*X										
Annual report			*X	*X								

* This is an annual repeating calendar. Some items should be thought of as happening in the following year.

A7 DATA QUALITY OBJECTIVES AND CRITERIA

Data Users

The primary data users will be OARS and the Massachusetts Department of Environmental Protection (DEP). Secondary data users may include the Massachusetts Department of Conservation and Recreation (DCR), U.S. EPA Region 1, the National Park Service, municipal officials, and residents and managers of the Sudbury, Assabet, and Concord river watershed municipalities.

Data Usage

The primary use of the data will be to document the long-term water quality and streamflow conditions of the Sudbury, Assabet, and Concord rivers and their tributaries with sufficient sensitivity to detect changes due to management and distinguish those from natural variation. The bacteria data will also be used to evaluate the suitability for recreation of the rivers. The data inform OARS' advocacy for the river and must be of sufficient quality to be used by OARS in appealing regulatory decisions affecting the river. The data may be used by local, state, and federal agencies for regulatory purposes and be included in the state's Integrated List of Waters reports to the EPA and water quality assessments. A secondary, and less stringent, use of the data is for education and outreach to the municipalities and residents of the watershed.

Data Type Needed

See Table 11 below for a list of parameters.

Data Quality

The data quality objectives are listed below in Table 11.

Table 11. Data Quality Objectives

Parameter	Units	Accuracy [1]	Overall Precision [2] (RPD)	Approx. Expected Range [3]
Stage	ft	± 0.01 ft	< 10% RPD	0–6 feet
instantaneous flow	cfs	± 0.01 ft on rating curve	± 15% of rating curve or within estimated error bars for measurements <0.1cfs	varies by gage
air temperature	degrees C	± 2 °C	± 2 °C	-5 to 45° C
water temperature	degrees C	± 1 °C	± 1 °C	-5 to 45° C
pH	S.U.	± 0.2 S.U. at pH 7.00	± 0.5 S.U.	0 to 14 units
DO	% and mg/L	± 5% at 100% DO sat	< 10% RPD or < 20% RPD if <4 mg/L	0 to 20 mg/L
Conductivity	µS/cm	± 50 µS at 0 and 1000 µS/cm	< 20% RPD or <30% RPD if <250 µS/cm	0 to 5000 µS/cm
TSS	mg/L	Blanks show below detection limit	< 30% RPD or ± 1 mg/L if ≤ 3mg/L (< 20% or ± 1 mg/L for lab duplicates)	1.0 mg/L–100 mg/L
TP	mg/L	85-115% recovery of lab fortified blank	< 30% RPD or ± 0.01 mg/L if <0.05 mg/L (<20% or ± 0.01 mg/L for lab duplicates)	0.01 mg/L–1.0 mg/L
ortho – P	mg/L	85-115% recovery of lab fortified blank	< 20% RPD or ± 0.01 mg/L if <0.05 mg/L	0.01 mg/L–1.0 mg/L
NO3	mg/L	85-115% recovery of lab fortified blank	< 30% RPD (< 20% for lab duplicates)	0.05 mg/L–10 mg/L
NH3	mg/L	85-115% recovery of lab fortified blank	< 30% RPD (< 20% for lab duplicates)	0.1 mg/L–10 mg/L
chloride	mg/L	85-115% recovery of lab fortified blank	< 30% RPD (< 20% for lab duplicates)	1 mg/L–1000 mg/L
Chl-*a*	µg/L	Blanks show below detection limit	< 20% RPD or ± 2µg/L if <15µg/L	2 µg/L–100 µg/L
E. coli	MPN/100 ml	Blanks and negatives show zero MPN, positives show MPN>0	For log10 transformed data: <30% RPD (<50 MPN) <20% RPD (50-500 MPN) <10% RPD (500-5000 MPN) < 5% RPD (>5000 MPN)	0–1,000,000 MPN

1) Accuracy is the confidence in a measurement. For analytical samples, it is measured with field and lab blanks and percent recovery of lab spike samples.

2) Precision is the degree of agreement among repeated measurements of the same analyte under the same condition, indicating how constant and reproducible the field sampling or analytical procedures have been. For analytical samples, the objective for overall precision is typically based on the relative percent difference (RPD) of co-located, simultaneous duplicates.

3) If measurement exceeds detection range then an appropriate dilution is done and the test is repeated.

Stage-discharge rating curves: A stage-discharge rating curve will be considered acceptable if all measured points used to establish the curve fall within 15% of the curve (or within the estimated error bars for poor-quality low-flow discharge estimates). Accuracy of established rating curves will be checked at least once every three years by OARS' Staff Scientist by taking instantaneous flow measurements and confirming that they fall within 15% of the curve.

Additional discharge measurements will be taken to check the rating curve if changes are observed to the staff gage position or channel morphology near the gage or gage control. Digital pictures will be taken of the gaging sites when discharge measurements are taken to help with data interpretation.

Amount of Data Needed

Table 12 lists the number of samples required to meet the annual completeness objectives. To ensure that samples and field data were properly collected, all field information will be reviewed by OARS immediately after the samples are analyzed. If sample data do not meet the data completeness objectives, appropriate corrective actions will be determined, for example, re-sampling if feasible.

Table 12: Expected Data Completeness

Parameter	Valid Samples Anticipated	Valid Samples Needed	Percent Completeness
Temperature	138 / year	124 / year	>90%
pH	138 / year	124 / year	>90%
DO	138 / year	124 / year	>90%
Sp. Conductance	138 / year	124 / year	>90%
TSS	138 / year	124 / year	>90%
TP	138 / year	124 / year	>90%
ortho – P	138 / year	124 / year	>90%
NO_3	138 / year	124 / year	>90%
NH_3	138 / year	124 / year	>90%
E. coli	48 / year	41 / year	>85%
Chloride	TBD	TBD	>90%
Chlorophyll-a	18 / year	16 / year	>90%
stage reading	35 / year	28 / year	>80%
USGS streamflow	28 / year	28 / year	100%

Representativeness and Comparability

Data must be representative of conditions existing at the time of sample collection and must be comparable with measurements of the same parameters taken in other years and/or by other organizations. OARS aims to keep sampling and analysis methods as consistent as possible over time and to keep a core of mainstem sampling sites the same. Standard collection and analysis methods are used for all parameters so that the data will be comparable with data from other studies. For water quality parameters it is assumed that the bulk flow of the river is representative of conditions at that location on the river. To ensure that the sample is representative of the bulk flow of the stream and is not contaminated by surface debris or bottom sediments, all grab samples are taken from the main flow of the stream, 6-12 inches below the surface (or mid-depth where the depth is less than 6 inches), upstream of where the sampler is standing (if the sampler is in the water). Field and laboratory conditions that may affect sample integrity are to be documented on the field collection forms or laboratory logs. Standard USGS methods are used for measuring streamflow to ensure that the data collected will be comparable with that collected by other organizations.

A8 SPECIAL TRAINING/CERTIFICATION

OARS staff will provide training for and oversee volunteers taking water quality measurements/samples and staff gage readings. Both new and returning volunteers are required to participate in an annual training session at the beginning of the monitoring season and their most recent training date is recorded in the project files. Training consists of instruction, demonstration, and hands-on experience with the sampling techniques. Each volunteer receives copies of OARS' Water Quality Monitoring Manual and Bacteria Monitoring Manual (both updated yearly; Appendices A and B). Trainers review the contents of the manual thoroughly, demonstrate the sampling techniques, and provide safety training, and the volunteers practice the sampling techniques. Samples and field forms will be checked as they are collected and obvious problems will be brought to the volunteer's attention and corrected on the spot if possible. If a problem is detected, OARS staff will discuss the problem with the volunteer and, if necessary, meet with the volunteer in the field on a sampling day to check their procedures and correct any problems. If necessary, refresher training will be conducted. Extra meter use training will be conducted immediately prior to sampling for new volunteers using a bucket of water. In addition, if COVID-19 social distancing standards allow, sampling teams will be rotated regularly to allow volunteers to check each other's technique and align on common practices.

OARS' staff scientist, Benjamen Wetherill, has had graduate school level training in the procedures for taking instantaneous flow measurements according to USGS standard methods for wadeable streams. The staff scientist will review the training materials provided by USGS annually before conducting spring measurements, particularly: Rantz, S.E., and others, 1982a; Rantz, S.E., and others, 1982b; Buchanan and Somers, 1969; Smoot and Novak, 1968. Any questions on technique or results will be referred to the USGS contact, Richard Verdi.

A9 DOCUMENTATION AND RECORDS

Table 13: Program Documents

Document	Generated by	Purpose	Archived
Water Quality Monitoring Manual	OARS	Document sampling site descriptions, maps, sampling methods/instructions	OARS office, off-site server (weekly backup)
Bacteria Monitoring Manual	OARS	Document sampling site descriptions, maps, sampling methods/instructions	OARS office, off-site server (weekly backup)
Sample Labels	OARS	Label each sample bottle with site name, date, and time to avoid mixing up samples	NA
Calibration report for lab thermometer	Cooper-Atkins	Document NIST-traceable certificate	OARS office
Field Observation Sheets	OARS	Record time, date, site number & name, sample number, site observations, sampling method, samplers, qc samples taken, in-situ readings	OARS office

Document	Generated by	Purpose	Archived
Chain of Custody Forms	OARS	Record sample chain of custody	OARS office; copies off-site, Nashoba Analytical LLC
Calibration forms	OARS	Record instrument calibration and performance; record calibration solution expiration dates/inspection	OARS office, copies off-site
Sample analysis and QC reports	Nashoba Analytical / Alpha Analytical	Summaries of sample analysis results and QC	OARS office; copies off-site, Nashoba Analytical, Alpha Analytical
Discharge measurement field sheets	OARS	Record field notes for instantaneous discharge measurements	OARS office, electronic copies off-site server
Database	OARS	Record all sampling data in a single easily retrievable electronic location	OARS office, off-site server (weekly backup)
QA/QC data package	OARS	Review all field data and QC data; reviewed by project QC officer	OARS office, off-site server (weekly backup)
Final Monitoring Report	OARS	Report data and findings for the season	OARS office, off-site server (weekly backup), webpage

Field Data

Standardized field observation sheets will be used to record all field data. All field records will contain at a minimum the following information: (1) project name, (2) site name, (3) site number, (4) date and time of work, (5) site condition, (6) persons performing work, and (7) pre- and post-field instrument performance checks where applicable. Field notes will be completed on-site at the time measurements occur. Field records will be recorded using permanent pen; for any corrections needed, the error will be crossed out with a single line and the change initialed by the responsible person. All forms will be reviewed annually and updated as needed; the date of the most recent revision will be in the form's footnote. All instrument calibration/performance documents will be archived indefinitely at the OARS office in West Concord, MA, and are available on request.

Reports and Database

Laboratory data:

All analysis and quality control documents for the laboratory analysis of water samples will be recorded and archived by the laboratories, according to their QA/QC Manuals (Appendix D/F) and their addendum SOPs (Appendix E/G). Summaries of sample analyses and quality control measures for those samples (laboratory duplicates, laboratory blanks, and laboratory media spikes) will be sent to OARS and archived indefinitely at the OARS office in West Concord, MA, and are available upon request.

Database:

All data will be collected in a Microsoft Access database maintained by OARS staff. The database is designed to handle field data, laboratory data, instrument calibration/performance records, quality control data, water quality criteria, flow recommendations, and meta-data for each site on each sampling date. Each data point is uniquely identified by the combined sampling location and date. Fully quality-controlled data will also be submitted to MassDEP through the National Water Quality portal (WQX).

Backups:
Backup copies of all computer data are made weekly or as needed on an automatic on-line backup system (Backblaze Online Backup).

Reports:
Raw data and quality control reports will be submitted annually to the project's Quality Control Officer for review. Reports will include a summary of field sample results, field quality control results, laboratory quality control results, and instrument calibration check results for all sampling dates. The QC Officer's review and recommendations will be signed and a hard copy filed with the data. Final data, after QC check, will be submitted to MA DEP along with a QC Report summarizing all findings of the QC review. Final data will also be reported in an annual or biannual monitoring report and may be included in the reports on other projects. All reports are archived indefinitely at the OARS office in West Concord, MA, and are available upon request. Final reports are available at http://www.oars3rivers.org/river/waterquality/reports.

QAPP:
The Quality Assurance Project Plan will be reviewed annually and updated if there are significant changes. The document will be identified by title and date listed on the header of each page. All persons listed in the distribution list will receive updated electronic copies.

B1 SAMPLING PROCESS DESIGN

Scheduled Ongoing Data Collection Activities

The overall project schedule is shown in Table 10 above. Data collection analytes, frequency of collection, number of sites sampled, and sampling matrices are summarized in Table 15 below.

Water Quality data collection

Once each month in March, May, June, July, August, September, and November, volunteers and/or OARS staff will test water quality at monitoring sites (Table 8). Grab samples for nutrients and solids will be taken concurrently with meter readings (for dissolved oxygen, pH, water temperature, and conductivity). In June, July, and August, chlorophyll-a will be sampled during the workweek as soon as possible after the nutrient sampling in order to get samples to the lab within the specified holding time (6 hours). May through September, *E. coli* will be sampled at defined sites (Table 9) on the Monday following sampling events and on a second Monday halfway between sampling events (two samples per month), also in order to get samples to the lab within the specified holding times (6 hours). During the summer (May-Aug), all sampling that includes dissolved oxygen (DO) will be conducted between 6:00 and 9:00 AM barring unusual circumstances. In September, the target will be 10:00 AM, since the sun rises later. There is no DO time constraint in March and November, because they are not in the summer growing season. Based on an examination of continuous DO measurements collected on the Sudbury (ENSR, 2004) and Assabet Rivers (ENSR, 2001), DO concentrations measured before 8:30 AM in the summer should be near the lowest of the day. Water quality sampling methods are also detailed in OARS' Water Quality Monitoring Manual (Appendix A) and Bacteria Monitoring Manual (Appendix B).

Streamflow data collection

Concurrent with water quality sampling, volunteers or OARS staff will take stage readings at five sampling locations (see Table 8). Staff gages were installed by USGS (Massachusetts-Rhode Island Water Science Center, Northborough) or Massachusetts Division of Ecological Restoration (River Instream Flow Stewards project). Staff gage readings of stage will be taken according to USGS standard procedures and OARS Water Quality Monitoring Manual (Appendix A). Stage readings will be converted to discharge measurements using a stage/discharge rating curve developed for each site. OARS volunteers will take duplicate staff gage readings periodically for quality control purposes. For sites with USGS real-time gages (Table 14), stage and discharge readings will be downloaded from the USGS National Water Information System web interface for the sampling date/time.

Table 14: USGS Gage and Groundwater IDs

Waterbody	OARS Site #	Location	USGS Gage Identification
Assabet River	ABT-077	Rte 27 Maynard, MA	01097000
Nashoba Brook	NSH-047	Wheeler Lane, Acton, MA	01097300
Concord River	CND-009	below River Meadow Brook, at Lowell, MA	01099500
Sudbury River	SUD-144	Sudbury Landing	01098530
Groundwater	n/a	MA-ACW 158 Acton, MA	422812071244401

OARS staff will be responsible for instantaneous discharge measurements taken to confirm the accuracy of established stage-discharge curves and/or establish new curves as needed (as described above in A7 Data QUALITY OBJECTIVES AND CRITERIA). Stage-discharge ratings were originally established by USGS at the five gaged sites in accordance with standard USGS methods (Rantz, S.E., and others, 1982a; Rantz, S.E., and others, 1982b; and Smoot and Novak, 1968) based on at least six instantaneous flow measurements over a range of summertime flows. Any new rating curves will be established using the same methods. For very low flows, where precise velocity measurements are more difficult, OARS will use the USGS protocol for assigning a data quality (good, fair, poor) to each discharge estimate to indicate its precision. The technical feasibility of making discharge measurements at each site will be judged based on the following favorable criteria: laminar flow, straight channel segment, sufficient water depths for velocity meter to function properly (at least 0.1 ft for the Pygmy current meter, 0.5 feet for the Price AA current meter), and safety and accessibility of the river segment. Stage-discharge rating curves may be extended to include the normal range of winter flows based on at least three additional instantaneous flow measurements over a range of winter flows.

Precipitation data collection
Precipitation values will be retrieved from the CoCoRaHS Network (https://www.cocorahs.org/ViewData/) for 24 and 48-hour time periods prior to sampling and recorded with the data—in particular for bacteria data. The CoCoRaHS QC documentation is available at https://media.cocorahs.org/docs/CoCoRaHS_QA_QC_April_2019.pdf .

Groundwater data collection
Groundwater levels at the USGS groundwater monitoring well in Acton, MA, (USGS 422812071244401) will be recorded from the relevant USGS webpage (https://waterdata.usgs.gov/monitoring-location/422812071244401/#parameterCode=72019&period=P7D).

Design of the Sampling Network
Water Quality Network
Mainstem water quality sampling sites were selected over the years to assess the impact of wastewater treatment plant discharges and to get a synoptic view of water quality and streamflow in the watershed. All sites were selected in running river sections where the water column is likely to be well mixed. In general, mainstem sites are distributed along the rivers (including sites near the headwaters and mouths and downstream of wastewater discharges) to give a representative picture of conditions on the rivers. The OARS Water Quality Monitoring program started with the Assabet River, with sites above and below the four major wastewater treatment plant discharges. In 2004 and 2009, when OARS extended its sampling program to the Concord and Sudbury rivers, the number of Assabet sites was reduced to re-allocate resources.

In 2002, tributaries were added to the program to raise awareness of the tributaries of the basin, to assess habitat conditions for native fish over the expected low-flow summer period, and to help assess instantaneous nutrient loading from the tributary streams. The tributary sub-basins were chosen to represent the main tributaries in the towns of Lowell, Concord, Acton, Stow, Hudson, Berlin, Northborough, Shrewsbury, Westborough, and Sudbury. The chosen tributaries represent the range of hydraulic conditions of tributaries in the basin, from the steeper streams in the upper watershed (3.5–5.0% slope and 24–29% area stratified drift) to the flatter streams of the lower watershed (1.3–1.7% slope and 58–78% area stratified drift) (statistics from USGS StreamStats, https://streamstats.usgs.gov/ss/). The tributary sites were selected, where possible, in the lower part of the drainage to capture water quality conditions entering the mainstem of the rivers, but were also constrained to locations where a staff gage likely to have a stable rating curve could be installed. In general, the gage site must provide an adequate size gaging pool and a stable control to be able to develop a relatively stable stage/discharge curve (Rantz and others, 1982a).

Following is the current logic for specific Water Quality sites by month:

- All months:
    - major tributaries and Sudbury/Assabet headwaters (for nonpoint contributions)
    - at the mouth of each of the three rivers
    - at the four USGS gage sites
    - one site downstream of Westborough WWTP
- Summer only (Jun/Jul/Aug):
    - below each of the six WWTPs of concern
    - at midpoint of each river (to capture sub-watersheds)
- May–Sep:
    - five Sudbury River sites (to support Wayland—DEP agreement)

Water Quality Sampling sites are listed in Table 8 above, and a watershed level map of the locations is presented in Figure 2.

Bacteria Network

Bacteria sampling sites were intended to be able to provide water health safety information to recreational users of the rivers in the future. Recreational users include boaters (canoes, kayaks, paddleboards, rowing shells) and swimmers. Sites were chosen from a list of sites with historical DEP bacteria monitoring data (Appendix H). One site was selected in each of the six reporting segments in the OARS River Report Card (Upper Assabet, Lower Assabet, Upper Sudbury, Lower Sudbury, Upper Concord, Lower Concord). When possible, sites were selected to coincide with the OARS existing water quality sampling sites. And, most importantly, all sites were selected to be geographically relevant for recreational areas of the river—upstream of, or indicative of water quality in recreational sections. Bacteria sampling sites are listed in Table 9, and a watershed level map of the locations is presented in Figure 3.

Safety considerations

Sites for water quality sampling and staff gage reading by volunteers must provide safe parking nearby, must be near a road, must be either on a public right-of-way or on private property for which permission for access has been obtained, and should be safe for wading under summer flow conditions. Driving directions to sampling locations and maps of the locations are available in OARS' Water Quality Monitoring binders given out to all volunteer samplers and are available as electronic PDFs and on Google Maps (via links provided in the Manual).

Analyte Selection Rationale
The sampling parameters selected are relevant to the high-priority water quality issues identified: eutrophication, stormwater impacts, low baseflow, and recreational health safety. Sampling parameters were also chosen to provide information on habitat conditions for native fish in the tributaries and to provide information on conditions with respect to Massachusetts water quality standards for dissolved oxygen, pH, and temperature and EPA regional guidance on nutrient concentrations in rivers. If chloride is being sampled, it is sampled only in March (to capture peak road salt effects) and in August (to capture the baseline for the sites sampled in March). Chlorophyll-a is sampled only on the Sudbury River mainstem sites, per agreement with the Town of Wayland and MA DEP, to assess eutrophication in the Sudbury River.

B2 SAMPLING METHODS

For Water Quality sampling, OARS volunteers will be organized into teams of two to three people. If necessary to meet COVID protocols, each team may be assembled from a single family. Teams will sample four to six stations each in an assigned geographic section of watershed. For Bacteria and Chlorophyll sampling, volunteers will be organized into teams of one or two people and each team will sample two sites along one of the three rivers. All active team members will have completed a training course. Untrained team members may be present for safety and accompaniment purposes or to record data on the field sheet but they will not take active part in the sample collection.

Sampling methods are detailed in the attached Water Quality Monitoring Manual (Appendix A) and Bacteria Sampling Manual (Appendix B). Detailed instructions for backup plans in case of equipment failure or loss are included in the manuals. Volunteers will be supplied with backup sampling bottles, spare batteries for the YSI data loggers, and instructions to call the OARS office in case of problems. OARS staff will always be available during a sampling event to help resolve issues. Table 15 provides a summary of the sampling requirements, sample volumes, preservation methods, analytical methods, and holding times.

Water Quality Sampling
Observations taken at each sampling site include: date and time of sampling, sampler names, weather observations, air temperature, water color and odor, gage height (if a gage is present), and estimated "channel flow status" (based on the EPA Rapid Bioassessment Protocol). Parameters measured in-situ with hand-held meters are water temperature, pH, DO, and conductivity. Grab samples are collected in two bottles. One 500 ml bottle contains 2 ml of 18-N H_2SO_4 as a preservative, and is analyzed for total phosphorus and ammonia-N. The second 1000 ml bottle has no preservative and is analyzed for total suspended solids, nitrate-N, and ortho-phosphate. Samples will be collected either by hand or with a sampling pole. If using a pole, samplers will submerge the bottle upside-down to a depth of 6 inches, turn it horizontal to fill it with water, and remove it right-side-up. If sampling by hand, samplers will hold the bottle at a depth of 6 inches below the surface, remove the cap, allow it to fill with water, replace the cap underwater, and then remove the bottle from the water. Samplers will always collect water in a non-preserved bottle and pour from that into the preserved bottle. Samplers have also been instructed to watch for particulate matter in the bottles. If particulate matter is seen, then they

are to discard the sample and use a provided 1L bottle to decant samples so as to minimize particulate matter.

Bacteria Sampling
Observations taken at each sampling site include: date and time of sampling, sampler names, weather observations, water temperature, water color and odor, and estimated "channel flow status." Grab samples will be collected in sterile bottles provided by the lab. Samples will be collected either by hand or with a sampling pole. If using a pole, samplers will submerge the bottle upside-down to a depth of 6 inches, turn it horizontal to fill it with water, and remove it right-side-up. If sampling by hand, samplers will hold the bottle at a depth of 6 inches below the surface, remove the cap with a gloved hand, allow it to fill with water, replace the cap underwater, and then remove the bottle from the water. After collecting the sample, samplers will pour out approximately ½ inch of water from the top to facilitate mixing (leaving at least 100mL of sample). Latex gloves will be worn on the hand which touches the cap for the entire procedure. We do not use a preservative (such as sodium thiosulfate) because chlorine levels in the mainstem of the rivers are not sufficient to limit bacteria growth.

If hand or pole sampling is unsafe (for example, at a bridge), grab samples will be taken with a basket (also described in the sampling manuals).

B3 SAMPLE HANDLING AND CUSTODY

Sample sizes, containers, preservation, and holding times are summarized in Table 15. Sample containers are supplied by the labs and are new (bacteria containers are sterile). All sample containers will be labeled before hand-off to the volunteer samplers with the OARS site ID or replicate identification, any preservative used, and the date. In the field, the samplers check the pre-labeled information against the chain of custody form, add their initials and time of collection to the bottle label, and record the time of collection on the chain of custody form. Samples are put immediately on ice in a cooler. Each cooler is supplied with a clearly labeled "temperature blank" (a sample bottle with water that is placed in the cooler at the start of the sampling). Using a temperature blank avoids the possibility of thermometer breakage from being placed directly in the cooler or the possibility of sample contamination by checking the temperature of an actual sample. Samples are transported to the OARS office by a designated member of the sampling team and are surrendered to an OARS staff member or another designated check-in person. At the office, samples are checked and returned to coolers for transport to the laboratory. Sampling times on the bottles, field sheets, and chain-of-custody are checked to make sure they match. If the samples are transferred from one cooler to another, the temperature blank is transferred with the samples (unless samples are being consolidated to a cooler that already has other samples and an at-temperature blank). Nutrient samples are delivered to the lab for analysis within 26 hours of collection by OARS staff or designated volunteer. Chain-of-custody forms will be used to record time of collection and all transport and storage information. Completed Chain of Custody forms are permanently archived at the OARS office.

Bacteria and Chlorophyll samples are delivered to the lab for analysis within 6 hours of collection. Bacteria samples should remain below 6°C[1] for the duration of time between collection and analysis at the lab.

For samples that require preservative in the field, the lab supplies sample bottles with 2 ml of 18-N H_2SO_4 in each 500-ml bottle to ensure that the samples are acidified immediately upon collection. Samplers are instructed to check the bottles for preservative before use and to collect the grab sample using the bottle without preservative to ensure that the acid is not lost during sampling. Sample preservation is later checked in the laboratory and adjusted with 18-N H_2SO_4 to pH < 2.0 if necessary. Laboratory staff will notify OARS if samples were not adequately preserved in the field.

Samples are identified by OARS site number: three letter designation for the stream and three-digit number designating river miles of the site above stream confluence with the next largest mainstem river. For example: the sampling site at the Cox Street Bridge, 16.2 mi upstream from the confluence with the Sudbury River, will be ABT-162. Field replicate and field blank sample sites are chosen randomly for each sampling date and are designated by QC-xx (e.g. QC-01 for the first quality control sample). The record of sample identification, QC type (field duplicate or field blank), and sites where the QC samples were collected will be kept at the OARS office with the list of samples for each sampling date and entered in the database accordingly. The QC-xx code ensures that the lab does not know where the replicates and blanks came from.

B4 ANALYTICAL METHODS

Analytical methods and sampling equipment required are listed in Table 15 below.

The water samples analyzed by the contract lab Alpha Analytical, Inc. (Massachusetts State Certified Testing Laboratory # MA-M086) include: total suspended solids (TSS), total phosphorus (TP), orthophosphate (ortho-P), nitrate-N (NO_3), ammonia-N (NH_3), chlorophyll-a, and chloride. *E. coli* samples are analyzed by Nashoba Analytical LLC (MA State Certified Testing Laboratory # MA1118). Note that MA does not certify the chlorophyll-*a* method.

[1] The target bacteria sample temperature for this QAPP as requested by MA DEP is <6°C. However, the Colilert SOP specifies the temperature as <10°C for up to 1 hour and <8°C for up to 8 hours. Therefore, it is not necessary to qualify samples if they are held between 6°C and 10°C for less than 1 hour.

Table 15: Sampling and Analytical Methods Requirements

Matrix	**Parameter**	**Sample Type**	**Annual Sample Frequency per Site**	**Sampling Equipment**	**Sample Volume**	**Sample Container**	**Sample Preservative**	**Analytical Method #**	**MDL**	**Holding Time**
Air	Temperature	*in-situ*	3-7 per year	alcohol thermometer	----	----	----	----	----	----
River water	Temperature	*in-situ*	3-7 per year	YSI Pro series	----	----	----	----	----	----
River water	pH	*in-situ*	3-7 per year	YSI Pro series	----	----	----	----	----	----
River water	DO	*in-situ*	3-7 per year	YSI Pro series	----	----	----	----	----	----
River water	Conductivity	*in-situ*	3-7 per year	YSI Pro series	----	----	----	----	----	----
River water	TSS	grab	3-7 per year	bottle	1000-ml	plastic bottle	4°C in dark	SM 2540D	5 mg/L	7 days
River water	TP	grab	3-7 per year	bottle	500-ml	plastic bottle	H_2SO_4 to pH < 2.0, 4°C in dark	SM 4500-P-E	0.01 mg/L	28 days
River water	ortho–P	grab	3-7 per year	bottle	500-ml	plastic bottle	4°C in dark	SM 4500-P-E	0.005 mg/L	48 hours
River water	NO_3-N	grab	3-7 per year	bottle	500-ml	plastic bottle	4°C in dark	SM 4500-NO3-F	0.1 mg/L	48 hours
River water	NH_3-N	grab	3-7 per year	bottle	500-ml	plastic bottle	H_2SO_4 to pH < 2.0, 4°C in dark	SM 4500-NH3-BH	0.075 mg/L	28 days
River water	*E. coli*	grab	8 per year	bottle	100mL	sterilized HDPE/PP bottle	6°C in dark	SM 9223-B (IDEXX Colilert 2000)	1 MPN/100ml	6 hours (+2 at lab)
River Water	Chloride	grab	TBD	bottle	500-ml	plastic bottle	4°C in dark	EPA 300.0	1 mg/L	28 days
River water	Chlorophyll-*a*	grab	3 per year	bottle	500-ml	opaque brown plastic bottle	4°C in dark	SM 10200-H(3)	2 µg/L	24 hours

Matrix	**Parameter**	**Sample Type**	**Annual Sample Frequency per Site**	**Sampling Equipment**	**Sample Volume**	**Sample Container**	**Sample Preservative**	**Analytical Method #**	**MDL**	**Holding Time**
River water	Stage	*in-situ*	7 per year	staff gage	----	----	----	----	----	----
River water	instantaneous discharge	*in-situ*	1x per three years (minimum)	Pygmy / Price AA flow meter	----	----	----	---	---	---

B5 QUALITY CONTROL PROCEDURES

Field QC Checks

Table 16 lists the frequency of QC checks. Replicate sampling provides data to assess the precision of the method, the volunteer, and the lab analyst. Field blanks check for contamination from the sample bottles and for field sampling techniques. Volunteers will take at least 10% replicate field samples and 10% field blanks (distilled water for nutrients or sterile DI water for bacteria) at sites selected randomly for grab samples. This 10% will be calculated over the entire season, so in cases where there are a small number of sites sampled, there might be some sampling dates without any QC samples. An effort will be made to ensure that QC samples are distributed evenly among the sites and sampling teams throughout the year. QC records will be kept in the water quality database.

Lab replicate readings for *in-situ* measurements (DO, pH, conductivity, and temperature) will be taken by placing all instruments in a common bucket of water to assess the precision of the instruments. Field replicate readings will be conducted by each team with one instrument by taking repeated measurements to assess the precision of the recording. Each sampling team will choose a site and readings will be taken in the same spot by two different volunteers. Replicate staff gage readings will be taken by having two volunteers take independent readings at the gage locations.

To evaluate discharge measurements and the repeatability of cross-section measurements, discharge surveys shall include one duplicate discharge measurement taken immediately after the original measurement for every ten measurements. The relative percent difference (% RPD) between the two calculated flow estimates will measure the overall precision of the flow data.

Table 16: Minimum Frequency of Replicate, Blank, and Spiked QC Samples

Parameter	Field Duplicates	Field Blanks	Lab Duplicates	Lab Blanks	Lab Spikes
Air temperature	10% [a]	-	10% [b]	-	-
Water temperature	10% [a]	-	10% [b]	-	-
pH	10% [a]	-	10% [b]	-	10%
Dissolved Oxygen	10% [a]	-	10% [b]	10%	10%
Conductivity	10% [a]	-	10% [b]	10%	10%
Total Phosphorus	10%	10%	5–10 %	5–10 %	5–10 %
Ortho-Phosphorus	10%	10%	5–10 %	5–10 %	5–10 %
Nitrate	10%	10%	5–10 %	5–10 %	5–10 %
Ammonia	10%	10%	5–10 %	5–10 %	5–10 %
Total Suspended Solids	10%	10%	5–10 %	5–10 %	-
Bacteria (*E. coli*)	10%	10%	5–10 %	5–10 %	-
Chloride	10%	10%	5–10 %	5–10 %	5–10 %
Chlorophyll-a	10%	10%	5–10 %	5–10 %	-

Parameter	Field Duplicates	Field Blanks	Lab Duplicates	Lab Blanks	Lab Spikes
Staff gage readings	10% [a]	-	-	-	-
Discharge measurements	10% [a]	-	-	-	-

[a] Meter and thermometer field duplicates are taken as separate readings at the same location, repeated by different team members.
[b] Meter and thermometer lab duplicates are conducted as measurements with all available instruments in the same water.

Laboratory QC Checks
Laboratory QC checks include duplicates, blanks, and spikes. Attached as appendices are laboratory QA/QC manuals and standard operating procedures (SOPs) from Nashoba Analytical (Appendix D and E) and Alpha Analytical (Appendix F and G). Laboratory QC results will be reported to OARS and archived with the season's sampling data.

Completeness
Completeness is the number of measurements that have been judged valid compared to the number of samples expected. See Table 12 for completeness expectations. Measures taken to ensure sampling accuracy and completeness include:

(1) Volunteers are supplied with pre-labeled bottles for each sampling site and a set of spare bottles for their section.
(2) The bottle sets for each sampling are assembled by OARS staff before the sampling event and are re-checked before the bottles are delivered to the volunteers.
(3) Chain of custody forms, pre-printed with the samples required for each site, are used as an extra check that all required samples are taken.
(4) The YSI meters go into the field with extra batteries and volunteers are instructed to call OARS staff if there are problems.
(5) OARS staff is available during every sampling event to troubleshoot problems or resample if needed.
(6) Field sampling kits are supplied with sponges for cleaning staff gages as needed, and volunteers are instructed to clean any gage that is difficult to read due to algae or scum.
(7) Current meters and data loggers for discharge measurements go into the field with spare parts and batteries. A spare set of equipment for discharge measurements is available in the office: Pygmy meter, wading rod, tape measure, data logger.

Acceptance Criteria
Acceptance criteria for all quality control samples and calibration checks are specified in Table 11. If the QC samples do not meet acceptance criteria the data will be checked with the laboratory for transcription errors, flagged as questionable, or censored (based on the severity of the non-conformity and best professional judgment). QA steps will be taken (e.g. re-training, equipment checks and service) to assure acceptable results. The handheld meters will be calibrated before use in the field and calibration will be rechecked after each sampling event to ensure that the instrument has remained calibrated throughout use.

QC Calculations
For all water quality data, the following Data Quality Indicators (DQIs) will be calculated and recorded with the associated data in the project database: absolute difference and relative

percent difference (RPD) between field duplicates and laboratory duplicates, percent recovery from field and laboratory blanks, percent recovery from laboratory spikes, RPD between instrument duplicates, instrument drift, and percent completeness.

Relative Percent Difference between field duplicate samples or laboratory duplicate samples will be calculated as follows (using log10 transformed measurements for bacteria):

$$RPD = \frac{|\text{original measurement - duplicate measurement}|}{0.5\ x\ (\text{original measurement + duplicate measurement})}\ x\ 100$$

The percent recovery (%R) for media spike samples will be determined according to the following equation:

$$\%R = \frac{\text{measured concentration in spiked sample - amount in sample}}{\text{known concentration added}}\ x\ 100$$

Completeness is the ratio of the number of valid sample results to the total number of samples analyzed with a specific matrix and/or analysis. At the end of each sampling season, the percent completeness will be calculated by the following equation:

$$Completeness = \frac{\text{number of valid measurements}}{\text{number of planned measurements}}\ x\ 100$$

Corrective Actions
If measurements are determined to be out of QC acceptance range those measurements will be flagged "qualified" and/or may be excluded from reports. Corrective actions may include: repeat sampling when feasible, recalibration of instruments, and retraining of volunteer water quality samplers.

Discharge measurements outside of QC acceptance range will be repeated. If more than two consecutive or three non-consecutive discharge measurement are outside the acceptance range, the rating curve will be reviewed to determine corrective actions, which may include re-doing the rating curve, re-surveying the gage height, re-checking the point-of-zero-flow (PZF), or moving the staff gage to a better location.

Documenting QC Results
All QC results for water quality measurements will be recorded in the project database. Flow measurement QC results will be recorded and stored in Excel spreadsheets. QC results will be summarized at the end of each year in a QC report, approved by the QC Officer. The QC Report will be submitted to MA DEP along with the annual data submission.

B6 INSTRUMENT/EQUIPMENT TESTING, INSPECTION, AND MAINTENANCE

YSI Pro-series or 6-series Water Monitoring Meters

YSI water monitoring meters used during this project will be visually inspected prior to use and stored and maintained according to the manufacturer's recommendations. Standard spare parts are supplied by the manufacturer with the instrument's repair kit. Other spare parts are readily available from YSI Inc. If an instrument fails in the field, the operator is instructed to contact OARS staff for corrective action. Corrective actions may include doing simple repairs in the field or completing the sampling using a different instrument. If the 6-series DO membrane needs to be replaced, the sensor must be operated in "Run Mode" for 15 to 30 minutes to break in the membrane (YSI operations manual Section 2.9.2), and then the sensor must be recalibrated against 100% water-saturated air. OARS' three meters will be maintained by OARS. Other meters will be rented as needed for each sampling weekend from US Environmental Rental Corporation, 166 Riverview Avenue, Waltham, MA. The contact is Gregg Gazza (781-899-1560). US Environmental Rental Corp. maintains their instruments in good working order, pre-calibrates the instruments before each rental, and provides support. Although the rented instruments are pre-calibrated, they are calibrated alongside the OARS instruments before field use.

Current Meters

Current meters and wading rods will be inspected prior to use and tested by conducting a "free-spin" test to ensure that the rotating current meter cups are free of obstruction and move freely during operation. Current meters will be maintained according to Smoot and Novak (1968). Spare parts are readily available from the manufacturer through Rickly Hydrological Co. Major repairs will be done by Rickly Hydrological Co.

Alcohol Thermometers and Sampling Kits

Alcohol thermometers, each identified with an inventory code, will be inspected visually each year for any breaks in the glass or separations in the column and checked for accuracy against a NIST-traceable certified thermometer. A correction factor is calculated if needed and the results of the check and any correction factors are recorded in the project database. Using the correction factors, temperatures readings are modified and the corrected values recorded in the water quality database. At the start of each sampling event thermometers are checked again for cracks or separations in their fluid column.

NIST-traceable digital thermometer

The NIST-traceable digital thermometer used for laboratory calibration checks (Cooper TM99A), which is owned by OARS and kept in the OARS office, is supplied with a certified calibration report. The thermometer will be returned to the supplier (Cooper Atkins, Middlefield, CT) for re-calibration once every five years.

Sampling Kits

Once a year (usually in May), the sampling kits given to volunteers will be inspected and refurbished as needed by OARS staff. Kits include thermometers, scrubbies for cleaning gages, a screwdriver, pens, markers, manuals, maps, clipboards, and spare sampling bottles.

B7 INSTRUMENT CALIBRATION AND FREQUENCY

See Table 17 for instrument calibration frequencies. YSI meters will be calibrated according to the manufacturer's recommended procedures immediately prior to and after each sampling session. Instrument drift over the sampling period should be less than the acceptance criteria listed in Table 17. Before each field use, the YSI meters are calibrated or checked against commercially available standard solutions for pH (4, 7, and 10 S.U.), dissolved oxygen (0%), and conductivity (1000 µS/cm) according to the manufacturer's instructions. Dissolved oxygen is also calibrated against saturated air (100% saturation) and conductivity against distilled water (0 µS/cm). Temperature probes will be checked against readings from the NIST-traceable thermometer. True barometric pressure (used in calibrating YSI dissolved-oxygen probes) will be measured using the OARS-owned YSI Pro-series barometers, which in turn will be calibrated against the Blue Hill Observatory[2] barometer once every two years. After each use, the meters are re-checked against the standard solutions and any drift in the readings is recorded. All calibration and repair records are kept at the OARS office. Standard solutions cannot be reused. The solutions are replaced as needed or before their expiration date and are stored, tightly capped, at room temperature. The "Zero Oxygen Solution" (sodium sulfite) used in calibration of YSI-meter dissolved oxygen probes is returned to U.S. Environmental Rental Corp. for proper disposal after use.

Current meters and wading rods will be visually checked before each field use for any damage to the cups, wear on the pin, or damage to the wading rod. A spin test will be conducted before and after each field use to ensure that the meter is spinning freely.

Table 17: Instrument Inspection and Calibration Specifications

Parameter	Equipment Type	Inspection Activity	Calibration Frequency	Standard or Calibration Instrument	Acceptance Criteria	Corrective Action
Air temp.	Alcohol thermometer	Visual inspection	Annually before field season	thermometer, NIST traceable	± 2.0 °C	Assign correction factor; replacement
Water temp.	YSI temperature probe	Calibration and visual check	Before and after use in the field	thermometer, NIST traceable	± 1.0 °C	Assign correction factor; replacement
Temperature calibration check	NIST-traceable thermometer	Visual inspection	Visual check for defects at use; factory calibration every 5 years	Factory	± 0.1 °C	Factory service as necessary
Dissolved Oxygen	YSI DO probe	Calibration and visual check	Before and after use in the field	water-saturated air (100%); sodium sulfite solution (0%)	± 10 % saturation, or ± 1.0 mg/L	Replace membrane or service as necessary and recalibrate
pH	YSI pH probe	Calibration and visual check	Before and after use in the field	pH standards: 4, 7 and 10	± 0.10 S.U.	Clean probe or replace as necessary and recalibrate

[2] The Blue Hill Weather Observatory, Readville, MA.

Parameter	Equipment Type	Inspection Activity	Calibration Frequency	Standard or Calibration Instrument	Acceptance Criteria	Corrective Action
Conductiv-ity	YSI conductivity probe	Calibration and visual check	Before and after use in the field	Conductivity standards: 1,000µS/cm, 0 µS/cm	± 50 µS /cm	Clean probe or service as necessary and recalibrate
Barometric pressure (for DO calibration)	YSI Pro-series barometer	Compariso n between multiple units	Every 2 years	NWS weather station (Blue Hill Observatory)	± 5 mmHg	Factory service
Flow	Pygmy current meter	Spin test	Before and after each use	free spin	0.5 – 1.5 minutes	Lubricate all bearings with instrument oil
Flow	Price AA current meter	Spin test	Before and after each use	free spin	> 2. 0 minutes	Lubricate all bearings with instrument oil

B8 INSPECTION/ACCEPTANCE OF SUPPLIES AND CONSUMABLES

New, unused sample bottles are supplied by the labs. All sample bottles are inspected visually by OARS staff before use and must be clean and free of cracks. Sample bottles with preservative are inspected visually for the presence of preservative. Bacteria sample bottles must be sealed for sterility. Sample bottles must be correctly labeled prior to sampling. Appropriate corrective actions will be taken for supplies and consumables not meeting acceptance criteria, e.g., replacement, return to vendor.

Calibration solutions are inspected for proper labeling, expiration dates, and appropriate grade. Solutions will be labeled with date received/inspected and will be replaced before they exceed the manufacturer's recommended shelf life. Solution lot numbers and expiration dates will be recorded in the instrument calibration sheet.

B9 DATA ACQUISITION REQUIREMENTS

Precipitation values will be retrieved from rain gages as described in Section B1. Precipitation will be recorded in Excel spreadsheets for data analysis.

USGS real-time discharge readings will be downloaded from the USGS NWIS website for four sampling locations concurrent with water quality samplings as described in section B1. Groundwater levels at the USGS groundwater monitoring well in Acton, MA, (USGS 422812071244401) will also be recorded from the relevant USGS webpage. Discharge and groundwater values will be recorded in the Water Quality database.

B10 DATA MANAGEMENT

Data Recording

Field observations, sampling methods, *in-situ* water quality readings, and stage measurements will be recorded using permanent pen or marker on appropriate data sheets or logbooks for each sampling site. *In-situ* water quality readings will also be logged in the handheld data logger. Corrections on original field sheets or logs will be made by crossing out the error and writing in the correct value. All corrections are initialed. All instrument calibration information will be recorded on calibration sheets. River observation field sheets taken by OARS volunteers will be reviewed by OARS staff for legibility, errors, and questionable values. Any questions are referred to the collector for clarification.

Analytical and *in-situ* sampling results and instrument calibration information will be entered from lab reports, data loggers, or field sheets into the OARS Access database for storage and into Excel spreadsheets for analysis. Discharge measurements will be downloaded from the AquaCalc data loggers to spreadsheets using "AquaCalc Data Link" software supplied by the manufacturer. Data quality control steps will be taken at several stages, as outlined in Table 20. DQI's will be calculated and entered in the database as described in Section B5.

Data Transformation/Data Reductions/Data Analysis

The only data transformation needed before raw data are entered in the project database will be: application of thermometer correction factors to water temperature measurements. For reporting, streamflow, water quality, and habitat indices will be calculated from water quality and streamflow data using a customized Access database. All calculations made during data transformation will be checked 100% prior to dissemination of the transformed information.

Data Tracking, Storage, and Retrieval

OARS will be responsible for data storage, management, and retrieval. Data will be stored in a central project file and stored and managed using a Microsoft Access database held on the Monitoring Coordinator's computer. The database is designed to handle field data, quality control data, and meta-data for sites, parameters, methods, and instruments. The database will be backed up weekly using an on-line backup service (Backblaze Online). Monthly copies of the database will be stored locally on the same computer and the database will be backed up to an external hard drive for replicate storage annually.

Data Delivery

Data will be provided on the OARS webpage and in annual written reports. Full Quality Control Reports will be available upon request. Data upload to the web page (run on a commercial server) is password protected and the web interface itself uses industry standard components (HTML, Java, JavaScripts). Fully Quality Controlled data will also be submitted to MA DEP through the National Water Quality portal (WQX). After submitting these data, a "Statement of Data Integrity" will also be submitted to MA DEP as per the instructions at https://www.mass.gov/guides/external-data-submittals-to-the-watershed-planning-program .

C1 ASSESSMENTS AND RESPONSE ACTIONS

Table 18: Planned Project Assessments

Assessment Type	Frequency	Internal/ External	Organization	Person(s) Responsible
Project surveillance	Ongoing	Internal	OARS	Ben Wetherill
Laboratory Technical systems	Annually	External	Nashoba Analytical	Maria Braun
Laboratory Technical systems	Annually	External	Alpha Analytical	Nathalie Lewis
Data Validation	Annually	External	OARS	Ben Wetherill
Peer review of project	Annually	External	MA DEP	Suzanne Flint
Data Quality Assessment	Annually	External	OARS	Peter Shanahan

Assessment of Subsidiary Organizations
Nashoba Analytical and Alpha Analytical, as part of their internal QA Programs, will conduct laboratory performance and system audits. As state-certified laboratories, Nashoba Analytical (M-MA1118) and Alpha Analytical (M-MA086) undergo the state inspection and audits needed to maintain their certification. An assessment of the reported laboratory QC sample results will be conducted when data is received, and the laboratory's state-certification will be checked on-line annually (http://eeaonline.eea.state.ma.us/DEP/Labcert/Labcert.aspx).

Assessment of Project Activities
Project surveillance and periodic review of the monitoring/sampling activities will be the responsibility of the project manager. For water sampling, each volunteer team's performance will be reviewed (for completeness of sampling, quality of samples, completeness of data recorded, completeness of chain of custody forms) by OARS staff when the day's samples are checked in. Replicate samples are used to check volunteers' performance and laboratory performance. If errors in sampling technique are detected, retraining is conducted prior to or during the next sampling event.

Equipment performance, data entry, and data management are evaluated on an ongoing basis. When results from QC samples fall outside acceptable ranges, OARS staff will review the available data. Some or all of the following actions may be applied: review of the system in question, re-sampling, schedule replicate sampling of the site during the next sampling event, reconsideration of acceptable limits, rejection of the data and exclusion from the report, rejection or relocation of the sampling site. Field and laboratory activities may be reviewed by state and EPA quality assurance officers as requested.

Reporting and Resolution of Issues
If it is found that there are QAPP deviations or project deficiencies, appropriate response to address non-conformances will be chosen in consultation with the project QC officer and external reviewers. Appropriate corrective action responses to ensure that the data quality is adequate for its intended use can include: (1) flagging of data with written explanation of the action, (2) rejection of data and exclusion from reports with written explanation,

(3) reconstruction of acceptable limits with written explanation of action, (4) rejection of the entire site location with recommendation of relocation of the sample site, (5) revision of SOPs, (6) checking staff gage rating, height, and/or PZF, and (7) moving staff gage or abandoning gaging site.

The corrective actions decided upon will be implemented and directed by the project manager. Because many of these actions involve modification of the original QAPP, all modifications will be documented and submitted for approval in the same manner as the original QAPP. All amendments/changes to the original QAPP will be incorporated in a revision of the QAPP as needed. Only after the modification has been approved can the change be implemented. Modifications may be documented in an addendum letter per approval of the MA DEP QA Officer.

C2 REPORTS

Table 19: QA Management Reports

Type of Report	Frequency	Delivery Date	Person(s) Responsible	Report Recipient
QC reports	Annually	February	Ben Wetherill	QA Officer, and available upon request
Final report	Annually	April	Ben Wetherill	MA DEP, general public, towns, other funders

The written QC report will include: project quality objectives, summary of major/critical problems encountered and their resolution, raw QC data, QC data summary, and reconciliation of QC data with project quality objectives.

D1 DATA REVIEW, VALIDATION, AND VERIFICATION REQUIREMENTS

The Monitoring Coordinator (Project Manager) will review field and laboratory data after each sampling run and take corrective actions as described in Table 20. At least once during the season, at the end of the season and if questions arise, the Monitoring Coordinator will share the data with the QA Officer to determine if the data appear to meet the objectives of the QAPP. Together, they will decide on any actions to take if problems are found.

Table 20: Data Management, Review, Validation, Verification Process

Activity	By whom	Corrective action, if needed
Check labels just prior to sampling, to ensure correct labeling of container.	Field sampler	Correct label or change container
At time of sampling, record data, sign field sheets.	Field sampler	Coordinate with sampler on missing/unclear information; correct sheets
Fill out and sign chain of custody (COC) forms for any samples going to lab.	Field sampler	Coordinate with sampler on missing/unclear information; correct sheets
Upon receipt of field sheets, recheck for reasonableness to expected range, completeness, accuracy, and legibility. Sign COC form.	Field/Monitoring Coordinator	Confer with field sampler(s) immediately or within 24 hours. Resample if feasible; otherwise, flag suspect data.
Upon receipt of samples, field sheets, and COC forms, check to see that sheets and forms correspond to number of samples and condition of samples as stated on COC forms. Confirm that times match on bottles, COC forms, and field sheets. Sign COC forms.	Lab Coordinator	Confer with field/monitoring coordinator Request resample if feasible; otherwise, flag suspect data.
Upon completion of laboratory analyses, fill out lab sheets, including data on QC tests. Review for reasonableness to expected range, completeness.	Lab Coordinator.	Re-analyze if possible. If not, confer with monitoring coordinator. Flag all suspect data.
Upon receipt of lab sheets, review for completeness and enter data in database.	Monitoring Coordinator	Confer with lab coordinator.
Upon receipt of field sheets, compare written in-situ measurements with logged data.	Data Entry Coordinator	Confer with field sampler to identify correct values.
Upon completion of data entry, print out raw data. Compare with field/lab sheets for accuracy.	Data Entry Coordinator	Re-enter data.
Translate raw data printouts into preliminary data reports: run statistical analyses and/or prepare graphical summaries of data. Check for agreement with QC objectives and for completeness.	Monitoring Coordinator	Confer with QA Officer. Flag or discard suspect data.

D2 VALIDATION AND VERIFICATION METHODS

The goal of data verification is to ensure that the data are what they purport to be, that is, that the reported results reflect what was actually done, and to document that the data fulfill applicable requirements. The goal of data validation is to identify and evaluate the impact of any technical non-compliance or quality control non-conformances on the complete data set. Data verification and validation for all water quality data will be the combined responsibility of the Monitoring Program Coordinator and the project QA Officer.

The Monitoring Program Coordinator (Project Manager) will conduct the initial verification and validation checks and generate the initial data package, including field sheets, raw data and data summaries, chain-of-custody forms, analytical results, and DQI calculations for review by the project QA Officer. The procedures used to verify and validate field data will include: checking field procedures and sampling locations, evaluating the field documents for consistency, ensuring that holding times were met, ensuring that field measurement equipment was properly calibrated and performance checks were within acceptable ranges, checking for transcription errors and outliers, comparing the DQI calculations with data quality objectives (DQOs), and checking the data for reasonableness. The project QA Officer will review the verified data packages following the steps recommended in EPA QA/G-8, "Guidance on Environmental Data Verification and Validation." The QA Officer will review QC information and prepare a signed QC Review letter summarizing deviations and the impact on data quality. The Monitoring Program Coordinator will review the QC Review letter, determine corrective actions, assign data qualifiers as necessary (Table 21), and assemble the final QC Report.

Table 21: Data Qualifiers

Data qualifiers	Description
P	provisional data (QA/QC not yet performed)
Q	data met most but not all QA/QC requirements
--- (don't submit)	data censored

Completeness checks will be administered on all data to determine whether data packages specified in the QAPP are present. At a minimum, data packages will include field sheets, raw data and data summaries, chain-of-custody forms, analytical results, QC summaries, and a narrative summary of QC corrective actions. If verification and validation checks identify a corrective action situation, it is the Project Supervisor's responsibility to approve the implementation of corrective action. All corrective actions will be documented by the Monitoring Program Coordinator.

D3 RECONCILIATION WITH DATA QUALITY OBJECTIVES

As soon as possible after each sampling event, calculations and determinations will be made for precision, completeness, and accuracy. The Project Manager and QA Officer will review the data to determine if the data quality objectives (DQOs) have been met. If the DQOs are not met, the cause of the failure will be evaluated and the following actions may be applied: review of the system in question, re-sample, schedule replicate sampling of the site during the next sampling event, rejection of the data and exclusion from the report, rejection or relocation of the sampling site, or reconsideration of DQOs. Deviations from SOPs, failure to meet DQOs, questionable data, and any limitations to the use of the data will be noted in the QC sheet for each data package. Limitations to the use of the data will be noted in the project web page and final reports. All water quality data presented will be marked as “provisional” until the data has undergone verification and validation. Any revisions to the QAPP DQOs will be submitted to MA DEP for review.

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APPENDIX A:
WATER QUALITY MONITORING MANUAL
SUDBURY, ASSABET, AND CONCORD RIVERS

(APPENDICES IN SEPARATE FILES)

APPENDIX B:
BACTERIA SAMPLING MANUAL
SUDBURY, ASSABET, AND CONCORD RIVERS

(APPENDICES IN SEPARATE FILES)

APPENDIX C: OARS FIELD DATA SHEETS

(APPENDICES IN SEPARATE FILES)

APPENDIX D: NASHOBA ANALYTICAL QUALITY ASSURANCE/QUALITY CONTROL MANUAL

(APPENDICES IN SEPARATE FILES)

APPENDIX E:
NASHOBA ANALYTICAL – SOPS

(APPENDICES IN SEPARATE FILES)

APPENDIX F: ALPHA ANALYTICAL QUALITY ASSURANCE/QUALITY CONTROL MANUAL

(APPENDICES IN SEPARATE FILES)

APPENDIX G:
ALPHA ANALYTICAL – SOPS

(APPENDICES IN SEPARATE FILES)

APPENDIX H:
PRIOR DEP BACTERIA MONITORING SITES

(APPENDICES IN SEPARATE FILES)