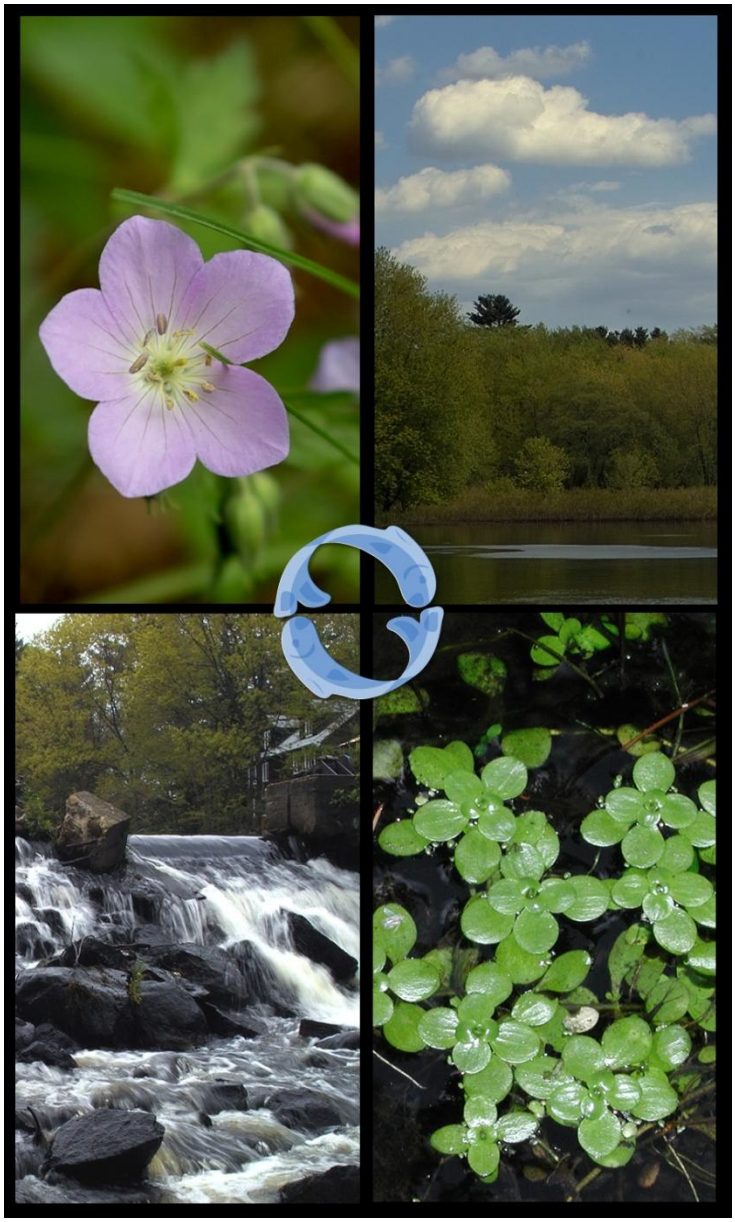
OARS

FOR THE ASSABET SUDBURY & CONCORD RIVERS

Water Quality Monitoring Program
Final Report – 2009 & 2010 Field Seasons



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Abstract

This report presents the monthly water quality and streamflow data collected on the Assabet, Sudbury, and Concord Rivers and tributary streams in 2009 (May, June, July, August, and September) and in 2010 (March, May, June, July, August, September, November).

Introduction

The combined Assabet, Sudbury, and Concord River watershed is about 399 square miles in eastern Massachusetts and is within EPA's Nutrient Ecoregion XIV subregion 59, the Eastern Coastal Plain. The mainstem rivers, particularly the Assabet, suffer from cultural eutrophication caused by excess nutrients entering the river. During the growing season these excess nutrients, phosphorus in particular, fuel nuisance algal and macrophytic plant growth which interferes with recreational use of the rivers and causes large daily variations in dissolved oxygen concentrations and pH, making poor habitat for aquatic life. When the algae and plants decay (whenever they are exposed on the river banks and/or at the end of the growing season) they generate strong sewage-like odors and can dramatically lower the dissolved oxygen levels in the rivers.

In their 2010 assessment, Massachusetts Department of Environmental Protection (MA DEP, 2010) lists all sections of the Assabet and Concord Rivers, from the Assabet River Reservoir (A1 Impoundment) in Westborough to the confluence with the Merrimack River in Lowell, as Category 5 Waters, "Waters Requiring a TMDL" for a variety of impairments. A Total Maximum Daily Loading Study (TMDL) for nutrients on the Assabet River was completed in 2004. The Sudbury River upstream of Fruit Street bridge in Hopkinton/Westborough is listed as Category 3 "No uses assessed." All sections of the Sudbury River from Fruit Street downstream to the confluence with the Assabet in Concord are listed as Category 5 for metals. Six of the tributaries in the basin, Hop Brook (in Marlborough/Sudbury), Pantry Brook, Elizabeth Brook, Nashoba Brook, and River Meadow Brook, are also listed as Category 5 Waters (MA DEP, 2010). Mill Brook in Concord is listed as Category 4c Waters, "Impairment not caused by a pollutant." Other tributaries are listed as either Category 2 ("Attaining some uses; other uses not assessed") or Category 3 ("No Uses Assessed").

The findings of the Assabet River Total Maximum Daily Loading Study (ENSR 2001, MA DEP 2004) confirmed that the majority of the nutrients entering the Assabet come from the wastewater treatment plants that discharge treated effluent to the river. In particular, treatment plants are the major source of ortho-phosphorus (the bioavailable form of phosphorus) throughout the year. While non-point sources contribute nutrients, they contribute significantly less than point sources over the growing season. The study concluded that reductions in nutrient loads from both point and non-point sources will be required to restore the Assabet River to Class B conditions. MA DEP and EPA adopted a two-phased adaptive management plan to reduce phosphorous loads in the Assabet. In Phase I, lower total phosphorus discharge limits were imposed at the four major wastewater treatment plants (WWTPs). As a part of Phase I, ways of limiting nutrient flux from the nutrient-rich sediments which accumulate in the slower moving and impounded river sections were studied. The Assabet River, Massachusetts, Sediment and Dam Removal Feasibility Study (ACOE 2010) examined sediment dredging, dam removal, and lower winter phosphorus discharge limits as ways of controlling the annual phosphorus loading from the sediments. The study concludes that dredging

would achieve, at best, short term improvements. Phosphorus discharge from the WWTPs in the winter contributes to the annual phosphorus budget for the Assabet and, therefore, decreased winter phosphorus discharge limits would be another way to control phosphorus loading to the system. Finally, the study's dam removal analysis showed that dam removal plus the Phase 1 WWTPs improvements would almost meet the 90 percent goal, achieving an estimated 80 percent reduction of sediment phosphorus load.

Upgrades to the Hudson wastewater treatment plant were completed in September 2009, and upgrades to the Maynard WWTP were completed in spring 2011, allowing those plants to meet summer total phosphorus discharge limits of 0.1 mg/L. Upgrades to the remaining two major wastewater treatment plant discharging to the Assabet River and to the Marlborough Easterly plant discharging to Hop Brook (tributary to the Sudbury River) are expected to be coming online over the next several years (2012 to 2014).

Flow, particularly baseflow, is critical to supporting fish and other aquatic life in the mainstem river and tributaries and is essential to diluting the effluent discharged to the river. For the nutrient load reductions proposed in the state's TMDL to be effective in restoring water quality in the mainstem, the existing baseflow in the river and its tributaries must be preserved and, if possible, augmented. The water resources of the area are under the strain of an increasing demand for water supply and centralized wastewater treatment, which results in the net loss of water from many sub-basins and reduced baseflow in the mainstem and tributaries.

Because of these problems, OARS (formerly the Organization for the Assabet River) conducts a water quality, streamflow, and biomass monitoring program on the mainstems and large tributaries of the Assabet, Sudbury, and Concord. The summer of 2010 was OARS' nineteenth consecutive summer collecting data at mainstem Assabet River sites, including the longest standing sites below each major wastewater treatment plant, its nineth year collecting data at tributary sites, its seventh year collecting data at mainstem Concord River sites, its second summer collecting Sudbury River data, and its sixth year assessing aquatic plant biomass in the large impoundments of the Assabet River. Water quality data collected under OARS' Quality Assurance Program Plan for the Assabet & Concord (OAR 2009a, approved 7/20/2009) or Sudbury (OAR 2009b, approved 8/14/09) may be used by EPA and DEP in making regulatory decisions. The goals of OARS' monitoring program remain: to understand long-term trends in the condition of the river and its tributaries, provide sound scientific information to evaluate regulatory decisions that affect the river, and to promote stewardship of the river through volunteer participation in the project.

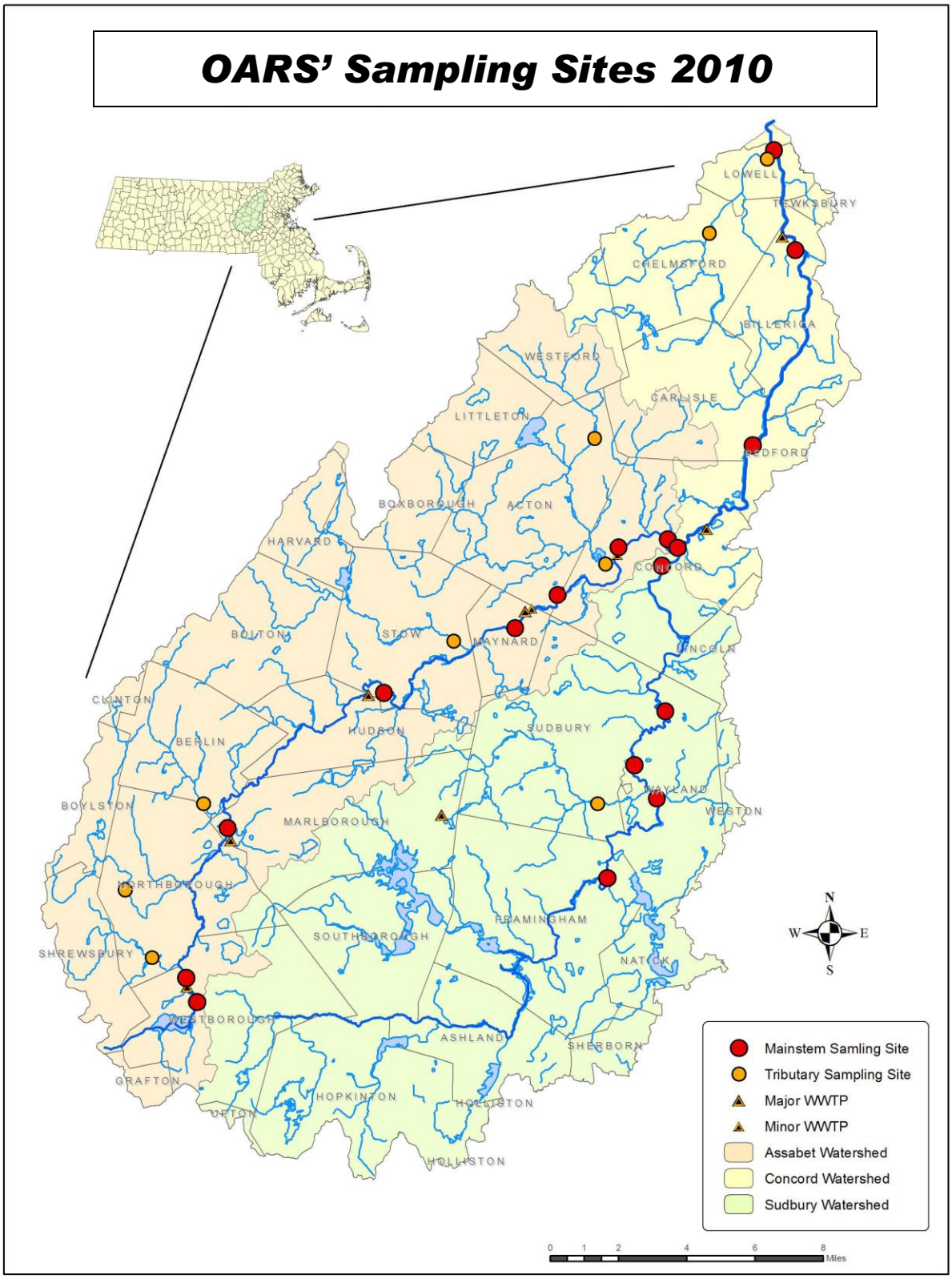
The data collected also support the goals of the StreamWatch project: to characterize fish habitat conditions in the main tributary sub-basins. Streamflow and habitat availability data were collected at nine tributary sites (Assabet headwaters, Hop Brook, Cold Harbor Brook, North Brook, Fort Meadow Brook, Elizabeth Brook, Danforth Brook, Nashoba Brook, and River Meadow Brook) to calculate "Stream Health Index" readings for those streams (described at http://www.oars3rivers.org/our-work/monitoring/interpret-data). This report covers the water quality and streamflow data collected between March 2009 and November 2010. Water quality reports and data for 1999 – 2008 (OAR 2000b, OAR 2001, OAR 2002, OAR 2003b, OAR 2004, OAR 2005, OAR 2006b, OAR 2007, OAR 2009) and 2005 biomass sampling project (OAR 2006a) are available on OARS' website (http://www.oars3rivers.org/river/waterquality/reports).

Table 1: Sampling Sites 2009 & 2010

Waterbody	**Site Location**	Town	Years Sampled	OARS Site #	SARIS #	Lat/Long (d/m/s)	Measurements	
							WQ	Flow
Concord River	Rogers Street	Lowell	2004-2010	CND-009	46500	42°38' 08.89" / -71°18' 06.45"	√	(USGS)
Concord River	Lowell Street	Billerica	2008-2010	CND-045	46500	42°35'35.5"/ -71°17' 20.04"	√	
Concord River	Rte 225	Bedford	2008-2010	CND-110	46500	42°30' 33.0"/ -71°18' 48.6"	√	
Concord River	Lowell Rd. Bridge	Concord	2004-2010	CND-161	46500	42°27' 58.56"/- 71°21' 20.43"	√	
Sudbury River	Rte 62 / Boat House	Concord	2008-2010	SUD-005	47650	42°27' 29.8"/ -71°21' 58.8"	√	
Sudbury River	Sherman Bridge Rd.	Wayland	2009-2010	SUD-064	47650	42°23' 47.21" /- 71°21' 50.00"	√	
Sudbury River	River Road	Wayland	2009-2010	SUD-086	47650	42°22' 25.26"/ -71°22' 55.17"	√	
Sudbury River	Pelham Island Road	Wayland	2009-2010	SUD-098	47650	42°21' 33.3" / - 71°22' 09.1"	√	
Sudbury River	Danforth Court	Framingham	2009-2010	SUD-144	47650	42°19' 32.1" /- 71°23' 50.8"	√	√
Assabet River	Lowell Road	Concord	1999-2010	ABT-010	46500	42°28' 12.43"/- 71°21' 44.65"	√	
Assabet River	Route 2	Concord	1992-2010	ABT-026	46775	42°27' 56.96"/ -71°23' 27.92"	√	
Assabet River	Rte 62 / Pump Stn.	W. Concord	1992-2009 [a]	ABT-033	46775	42°27' 22.58"/ -71°23' 23.39"	√	
Assabet River	Rte 62 / Canoe access	Acton	1999-2010	ABT-063	46775	42°26' 28.29"/ -71°25' 48.65"	√	
Assabet River	Rte 62/ USGS Gage	Maynard	1992-2010	ABT-077	46775	42°25' 56.00"/ -71°26' 58.55"	√	(USGS)
Assabet River	Rte 62 / Gleasondale	Stow	1992-2010	ABT-144	46775	42°24' 16.26"/ -71°31' 34.70"	√	
Assabet River	Cox Street	Hudson	1992-2009 [a]	ABT-162	46775	42°23' 59.83"/ -71°32' 44.74"	√	
Assabet River	Robin Hill Road	Marlborough	2006-2010	ABT-238	46775	42°20' 42.61"/ -71°36' 50.92"	√	
Assabet River	Boundary Street	Marlborough	1992-2009 [a]	ABT-242	46775	42°20' 29.70"/ -71°36' 58.25"	√	
Assabet River	School Street	Northborough	1997-2009 [a]	ABT-280	46775	42°18' 16.94"/ -71°37' 42.44"	√	
Assabet River	Route 9	Westborough	1992-2010	ABT-301	46775	42°16' 59.61"/ -71°38' 19.44"	√	
Assabet River	Maynard Street	Westborough	1992-2010	ABT-311	46775	42°16' 26.07"/ -71°37' 57.34"	√	
River Meadow Brook	Thorndike Street	Lowell	2004-2010	RVM-005	46525	42°37' 54.54"/ -71°18' 30.70"	√	
River Meadow Brook	Route 129	Chelmsford	2004-2009[a]	RVM-038	46525	42°35' 56.10"/ -71°20' 19.85"	√	√
Nashoba Brook	Commonwealth Ave.	Concord	1995-2010	NSH-002	unnamed	42°27' 32.05"/ -71°23' 49.35"	√	√
Nashoba Brook	Wheeler Lane	Acton	2008 - 2010	NSH-047	46875	42°30' 46.71"/ -71°24' 15.83"	√	(USGS)
Elizabeth Brook	White Pond Road	Stow	2002-2010	ELZ-004	47125	42°25' 36.96"/ -71°29' 07.01"	√	√
Danforth Brook	Rte 85	Hudson	2002-2010	DAN-013	47275	42°24' 13.65"/ -71°34' 28.64"	√	√
North Brook	Pleasant St.	Berlin	2002-2010	NTH-009	47375	42°21' 25.67"/ -71°37' 45.48"	√	√
Cold Harbor Brook	Church Street	Northborough	2002-2010	CLD-012	47550	42°19' 12.33"/ -71°40' 24.91"	√	√
Hop Brook	Otis Street	Northborough	2002-2010	HOP-011	47600	42°17' 31.27"/ -71°39' 27.04"	√	√
Hop Brook	Landham Road	Sudbury	2009-2010	HBS-016	47825	42°21' 26.5" / -71°24' 11.7"	√	

[a] Site discontinued in 2010.

Figure 1: Sudbury, Assabet, and Concord River Watershed and 2009/2010 Sampling Sites



Water Quality Sampling Methods

Trained volunteers and OARS staff monitored water quality at sites along the mainstem Assabet, Sudbury, and Concord rivers and on the major tributaries to those rivers (Table 1, Figure 1). Each site is assigned a three letter prefix for the waterbody name plus a three number designation indicating rivermiles above its confluence with the next stream. For example, the Cold Harbor Brook site at Cherry Street in Northborough, 3.0 miles upstream of the confluence of the brook with the Assabet River, is designated "CLD-030." Water quality monitoring (bottle samples, *in-situ* measurements, and observations) was conducted one weekend (5:00 am - 9:00 am) each month in May (headwater and tributary sites only in May), June, July, August, September, October (2009 only), and November (2010 only). Streamflow was calculated from the stage readings using stage/discharge rating curves developed in cooperation with USGS. Sites discontinued in 2010 were: mainstem Assabet River sites above the wastewater treatment plants (ABT-280, ABT-242, ABT-162, and ABT-033) and the upper River Meadow Brook site (RVM-038). Sites in the lower Sudbury River watershed were added in August 2009 (SUD-064, SUD-096, SUD-086, SUD-144, and HBS-016).

Samples for nutrients and suspended solids were taken using bottles supplied by the laboratory under contract with OARS and were stored in the dark on ice during transport from the field to the lab. Samples were delivered to the laboratory within four hours of collection. *In-situ* readings of temperature, dissolved oxygen, pH, and conductivity were taken using multi-function YSI 6000-series meters. To ensure that samples were representative of the bulk flow of the river in wadeable free-running sections, bottle samples and YSI readings were taken from the main flow of the river at mid-depth where possible. Ten percent of the samples taken were duplicate field samples and 10% were field blanks of distilled water. Table 2, below, summarizes the parameters measured, laboratory methods and equipment used. Detailed descriptions of sampling methods and quality control measures are available in the Quality Assurance Project Plan for StreamWatch: OAR's Water Quality and Quantity Monitoring Program (OAR 2009a, approved 7/20/09) and Quality Assurance Project Plan for OAR's Lower Sudbury River Water Quality Monitoring Program (OAR 2009b, approved 8/14/09).

Table 2: Sampling and Analysis Methods

Parameter	Analysis Method #	Equipment Range/ Reporting Limits	Sampling Equipment	Laboratory
Temperature	---	-5 – 45 degrees C	YSI 6000-series	---
pH	---	0 to 14 units	YSI 6000-series	---
Dissolved oxygen	---	0 - 50 mg/L	YSI 6000-series	---
Conductivity	---	0 to 1000 microS/cm	YSI 6000-series	---
Total Suspended Solids	SM 2540D	1 mg/L	bottle	Nashoba Analytical
Total phosphorus	SM4500-P-E	0.01 mg/L	bottle	Nashoba Analytical
ortho-Phosphate	SM4500-P-E	0.01 mg/L	bottle	Nashoba Analytical
Total Kjeldahl Nitrogen (discontinued in 2010)	SM4500-NH3-D	0.1 mg/L	bottle	Premier Laboratories
Nitrates	EPA 300.0	0.05 mg/L	bottle	Nashoba Analytical
Ammonia	SM4500-NH3-D	0.1 mg/L	bottle	Nashoba Analytical

Water quality measurements were compared with the Massachusetts Water Quality Standards for Class B waters (MA DEP, 2007). All segments of the Assabet are designated Class B/warm water fisheries. All segments of the Concord River are designated Class B warm water fisheries except the last segment (below the last sampling site) from Rogers Street, Lowell, to its confluence with the

Merrimack which is designated Class B (CSO)/warm water fishery. The Sudbury River from the outlet of Cedar Swamp Pond to Fruit Street, Hopkinton (not monitored as part of this project) is designated Class B/Outstanding Resource Water. From Fruit Street to the outlet of Saxonville Pond, Framingham, the Sudbury is designated Class B/warm water fishery. From the outlet of Saxonville Pond to its confluence with the Assabet, the Sudbury is designated Class B/aquatic life. All of the tributary streams assessed in this project are designated Class B waters. Although the tributary streams of the basin are not designated as cold water fisheries, most of the streams support or have supported cold water fisheries and it is, therefore, useful to compare dissolved oxygen and water temperature measurements on the tributaries with cold water fisheries standards. For nutrient concentrations (where the Massachusetts standard is narrative) results were compared with the EPA "Gold Book" total phosphorus criteria of 0.05 mg/L TP (US EPA, 1986) (Table 4) and with summertime data for Ecoregion XIV subregion 59 streams (US EPA, 2000) (Table 5).

Table 3: Water Quality Standards and Guidance for Use Support (MA DEP 2007)

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
pH	6.5 – 8.3 inland waters	
Nutrients	"control cultural eutrophication" / Gold Book standard TP < 0.05mg/L	
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 $\Delta \leq$ 2.8° C
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.	

Table 4: Reference Conditions for Ecoregion XIV (59) Streams (US EPA 2000)

Parameter	Reference condition (25th percentile based on summer data for Nutrient Ecoregion XIV subregion 59)
Total Phosphorus (mg/L)	0.025
Total Nitrogen (mg/L)	0.44
NO2 + NO3 (mg/L)	0.34

River Reaches and Tributaries

All the sites tested were in relatively free-flowing sections. For data analysis, the sites are divided into sections: (1) the upper Assabet mainstem from ABT-301 (Route 9, Westborough) to ABT-144 (Gleasondale, Stow), (2) the lower Assabet mainstem, from ABT-077 (Route 62, Maynard) to ABT-010 (near Lowell Road, Concord), (3) the Concord River mainstem from CND-161 (below the confluence of the Assabet and Sudbury) to CND-009 (at Rogers Street in Lowell), (4) the Sudbury River mainstem from SUD-144 (Danforth Ct, Framingham) to SUD-005 (Rte 62, Concord), and (4) the Assabet headwater and all tributary sites (Table 1). Because the headwaters site ABT-311 (Maynard Street, Westborough) is upstream of the first wastewater treatment plant discharge, it is

reported separately from the other Assabet River mainstem sites. Sites HOP-011 (Hop Brook), CLD-030 (Cold Harbor Brook), NTH-009 (North Brook), DAN-013 (Danforth Brook), ELZ-004 (Elizabeth Brook), NSH-047 (Nashoba Brook in Acton), and NSH-002 (Nashoba Brook) are all on tributaries to the Assabet River. RVM-038 (River Meadow Brook at Chelmsford) and RVM-005 (River Meadow Brook at Lowell) are on the largest tributary to the Concord River. Table 6 lists tributary and mainstem basin characteristics calculated using USGS's StreamStats program.

Table 5: StreamStats Drainage Basin Statistics

	Statistics at Mouth of Tributary[a]				
Headwater & Tributary Streams	Latitude/Longitude at Mouth of Tributary	Drainage Area (sq.mi.)	Stratified Drift Area (sq.mi.)	% area stratified drift	Slope [b] (%)
Assabet at Maynard St., Westboro	42.2741/-71.6322	6.79	1.64	24.15	3.61
Cold Harbor Brook, Northborough	42.3238/-71.6413	6.86	1.97	28.72	5.01
Danforth/ Mill Brook, Hudson	42.3897/-71.5666	7.17	2.06	28.73	3.58
Elizabeth Brook, Stow	42.4217/-71.4776	19.09	6.93	36.30	3.73
Fort Meadow Brook, Hudson	42.3975/-71.5169	6.25	1.76	28.16	3.77
Hop Brook, Northboro/Shrewsbury	42.2887/-71.6449	7.87	2.09	26.56	3.57
Hop Brook, Sudbury	42.3627/-71.3733	22.0	13.4	61.14	2.44
Nashoba Brook, Concord	42.4592/-71.3942	48.05	19.05	39.65	2.29
North Brook, Berlin	42.3576/-71.6188	16.89	4.12	24.39	4.38
River Meadow Brook, Lowell	42.6318/-71.3087	26.32	16.18	61.47	1.91
Mainstem Rivers	**Statistics near Mouth of River[a]**				
Assabet River, Concord	42.4652/-71.3596	177.81	73.00	41.06	3.01
Sudbury River, Concord	42.4637/-71.3578	162	49.13	30.33	2.52
Concord River, Lowell	42.6351/-71.3015	400.0	197.97	49.49	2.63

[a] Calculated using USGS's StreamStats program (http://ststdmamrl.er.usgs.gov/streamstats/)
[b] Slope is the mean basin slope calculated from the slope of each grid cell in the designated subbasin.

Results and Discussion

Reach and tributary statistics are summarized in Table 6, below. Full monthly summaries of the water quality data are attached in the Appendix II. Individual parameters are discussed below.

Table 6: Mainstem Reach and Tributary Statistics – 2009 & 2010

	Reach Statistics 2009 (calculated on 1/2 detection level where sample is below method detection levels)														
	Reach	# sites	Statistic	Time	Temp (°C)	DO % Sat	DO Conc (mg/L)	Cond (µS/cm)	pH	TSS (mg/L)	TP (mg/L)	ortho-P (mg/L)	NO3 (mg/L)	NH3 (mg/L)	TKN (mg/L)
26/27 Feb-09	Assabet Mainstem	1	Single reading	na	na	na	na	na	na	na	na	na	na	na	na
	Concord Mainstem	1	Single reading	11:40 AM	0.73	98.9	14.14	300	7.15	1.5	0.03	0.03	0.77	0.05	0.25
	Headwater & Tribs	10	Median	10:59 AM	1.13	94.5	13.33	260	7.08	1	0.02	0.010	0.59	<0.1	<0.5
19-Apr-09	Assabet Mainstem	1	Single reading	8:11 AM	12.41	98.8	10.54	328	7.02	1	0.11	0.05	1.2	<0.1	<0.5
	Concord Mainstem	1	Single reading	8:15 AM	12.41	93.3	9.95	313	7.24	3	0.07	0.02	0.4	0.13	0.61
	Headwater & Tribs	10	Median	7:40 AM	10.58	92.2	10.02	285	6.88	0.5	0.05	0.01	0.44	<0.1	<0.5
21-Jun-09	Upper Assabet Mainstem	6	Median	7:59 AM	18.92	74.9	6.99	451.5	6.82	2.5	0.20	0.11	2.5	<0.1	<0.5
	Lower Assabet Mainstem	5	Median	7:05 AM	20.04	89.7	8.18	402	7.09	6	0.15	0.07	1.5	<0.1	0.7
	Sudbury Mainstem	1	Single reading	6:10 AM	20.21	53.1	4.82	357	7.06	2	0.04	<0.01	<0.05	<0.1	<0.5
	Concord Mainstem	4	Median	7:17 AM	20.03	84.1	7.63	355	7.045	5	0.11	0.03	0.5	<0.1	<0.5
	Headwater & Tribs	10	Median	7:53 AM	18.68	83.5	7.86	293	7.05	2	0.06	0.02	0.2	<0.1	<0.5
19-Jul-09	Upper Assabet Mainstem	6	Median	7:59 AM	20.70	81.3	7.23	347	6.85	4.5	0.13	0.08	0.7	<0.1	<0.5
	Lower Assabet Mainstem	5	Median	7:20 AM	22.91	89.2	7.68	395	7.17	9	0.09	0.06	0.9	<0.1	<0.5
	Sudbury Mainstem	1	Single reading	6:25 AM	23.68	15.8	1.33	326	6.75	2	0.07	0.01	0.03	<0.1	<0.5
	Concord Mainstem	4	Median	7:27 AM	23.37	63.2	5.43	335	6.875	6	0.08	0.03	0.18	<0.1	0.41
	Headwater & Tribs	10	Median	8:04 AM	20.36	79.9	7.13	283	6.94	3	0.07	0.02	0.23	<0.1	<0.5
16-Aug-09	Upper Assabet Mainstem	6	Median	8:02 AM	21.77	68.7	5.9	543	6.87	3	0.14	0.08	1.60	<0.1	0.25
	Lower Assabet Mainstem	5	Median	7:00 AM	23.44	88.8	7.54	423	7.32	6	0.09	0.05	0.71	<0.1	0.25
	Sudbury Mainstem	5	Median	7:07 AM	24.28	30.1	2.53	393	6.77	3	0.03	0.02	0.15	<0.1	0.25
	Concord Mainstem	4	Median	7:14 AM	24.15	66.8	5.59	408	6.88	6	0.07	0.04	0.31	<0.1	0.25
	Headwater & Tribs	10	Median	7:48 AM	21.76	85.0	7.31	440	6.89	3	0.06	0.02	0.25	<0.1	0.25
20-Sept-09	Sudbury Mainstem	5	Median	7:13 AM	16.12	79.1	7.78	310	6.95	2.5	0.03	0.02	0.14	<0.1	nr
	Sudbury Tributary	1	Single reading	7:55 AM	12.19	41.8	4.48	355	6.83	4	0.06	0.03	0.63	<0.1	nr
18-Oct-09	Assabet Mainstem	1	Single reading	8:40 AM	8.74	99.1	11.49	362	7.23	2	0.18	0.05	1.70	<0.1	0.87
	Sudbury Mainstem	1	Single reading	12:32 PM	10.19	99.2	11.13	261	7.63	2.5	0.03	0.02	0.09	<0.1	0.67
	Concord Mainstem	1	Single reading	7:20 AM	9.11	94.5	10.88	314	7.22	4	0.06	0.04	0.98	<0.1	0.90
	Headwater & Tribs	10	Median	7:43 AM	7.33	87.9	10.29	280	7.05	2	0.04	0.02	0.24	<0.1	0.80

Table 6 (continued)

	Reach Statistics 2010 (calculated on 1/2 detection level where sample is BDL)														
	Reach	# Sites	statistic	Time	Temp (°C)	DO % Sat	DO Conc (mg/L)	Cond (µS/cm)	pH	TSS (mg/L)	TP (mg/L)	ortho-P (mg/L)	NO3 (mg/L)	NH3 (mg/L)	Chl (mg/L)
28-Mar-10	Upper Assabet			nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr
	Lower Assabet			nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr
	Sudbury Mainstem	2	Median	7:52 AM	6.53	103.0	12.64	248	7.25	1	0.010	<0.01	0.35	<0.1	nr
	Concord Mainstem	2	Median	8:27 AM	7.64	92.3	11.05	225	6.72	1	0.010	<0.01	0.24	<0.1	nr
	Headwater & Tribs	9	Median	9:40 AM	4.50	96.5	12.23	226	6.72	<1	0.020	<0.01	0.4	<0.1	nr
16-May-10	Upper Assabet Mainstem	1	Single reading	7:06 AM	15.60	81.0	8.22	786	6.68	4	0.26	0.19	7.80	<0.1	nr
	Lower Assabet Mainstem	2	Median	7:43 AM	16.57	94.0	9.15	409	6.98	6	0.08	0.03	1.45	<0.1	nr
	Sudbury Mainstem	5	Median	6:39 AM	17.27	84.1	8.07	366	6.96	5	0.06	0.015	0.16	<0.1	nr
	Concord Mainstem	2	Median	7:16 AM	16.58	93.9	9.15	370	7.19	6	0.06	<0.01	0.27	<0.1	nr
	Headwater & Tribs	8	Median	7:34 AM	15.27	89.8	9.00	270	6.94	4	0.04	<0.01	0.33	<0.1	nr
13-Jun-10	Upper Assabet Mainstem	3	Median	7:40 AM	17.96	93.1	8.70	393	7.20	7	0.103	0.06	1.20	<0.1	nr
	Lower Assabet Mainstem	4	Median	6:55 AM	18.54	87.8	8.23	381	7.09	6	0.13	0.07	2.59	<0.1	nr
	Sudbury Mainstem	5	Median	6:52 AM	18.87	53.6	4.97	347	6.80	13	0.04	<0.01	0.13	<0.1	nr
	Concord Mainstem	4	Median	7:13 AM	19.04	73.5	6.80	350	6.92	8	0.05	0.02	0.37	<0.1	nr
	Headwater & Tribs	9	Median	7:35 AM	16.77	87.7	8.55	324	7.00	3	0.04	0.01	0.38	<0.1	nr
18-Jul-10	Upper Assabet Mainstem	3	Median	7:30 AM	23.35	73.3	6.32	989	6.86	3	0.15	0.11	9.90	<0.1	nr
	Lower Assabet Mainstem	4	Median	6:43 AM	26.42	85.0	6.86	853	7.50	2	0.05	0.01	1.75	<0.1	nr
	Sudbury Mainstem	5	Median	7:20 AM	26.97	58.3	4.65	535	7.03	7	0.05	0.02	0.11	<0.1	0.016
	Concord Mainstem	4	Median	7:04 AM	27.77	77.1	6.12	622	7.42	7	0.07	0.02	0.69	<0.1	nr
	Headwater & Tribs	9	Median	7:36 AM	24.09	75.5	6.36	377	7.18	5.5	0.05	0.01	0.14	<0.1	nr
22-Aug-10	Upper Assabet Mainstem	3	Median	7:35 AM	21.59	80.4	6.87	843	7.31	1	0.06	0.03	2.0	<0.1	nr
	Lower Assabet Mainstem	4	Median	6:51 AM	21.76	66.9	6.05	1165	7.20	1.5	0.10	0.04	11.7	<0.1	nr
	Sudbury Mainstem	5	Median	6:52 AM	23.36	70.1	5.96	554	7.30	11	0.09	0.01	0.03	<0.1	0.013
	Concord Mainstem	4	Median	7:14 AM	23.71	86.7	7.41	638	8.05	8	0.08	<0.01	0.7	<0.1	nr
	Headwater & Tribs	9	Median	7:25 AM	20.05	53.8	4.65	482	7.04	4	0.06	0.02	0.16	0.15	nr

Table 6 Continued

	Reach Statistics 2010 (calculated on 1/2 detection level where sample is BDL)														
	Reach	# Sites	statistic	Time	Temp (°C)	DO % Sat	DO Conc (mg/L)	Cond (µS/cm)	pH	TSS (mg/L)	TP (mg/L)	ortho-P (mg/L)	NO3 (mg/L)	NH3 (mg/L)	Chl (mg/L)
19-Sep-10	Upper Assabet Mainstem	1	Single reading	7:55 AM	19.13	76.2	7.03	841	6.83	3	0.53	0.48	21.6	<0.1	nr
	Lower Assabet Mainstem	2	Median	7:47 AM	16.49	80.0	7.93	665	7.34	4	0.08	0.05	3.35	<0.1	nr
	Sudbury Mainstem	5	Median	7:18 AM	16.34	78.0	7.50	449	7.11	8	0.04	0.02	0.23	<0.1	nr
	Concord Mainstem	2	Median	7:33 AM	17.40	84.3	8.05	535	7.34	9	0.07	0.03	1.90	<0.1	nr
	Headwater & Tribs	8	Median	7:50 AM	15.43	71.7	7.17	364	6.91	2	0.04	0.02	0.06	<0.1	nr
14-Nov-10	Upper Assabet Mainstem	1	Single reading	8:45 AM	9.24	88.8	9.92	558	6.50	4	0.35	0.33	12.6	0.2	nr
	Lower Assabet Mainstem	2	Median	8:24 AM	6.00	107.0	13.38	308	7.04	2	0.04	0.02	1.75	<0.1	nr
	Sudbury Mainstem	2	Median	7:46 AM	6.80	89.7	10.92	272	7.08	2	0.03	0.01	0.12	<0.1	nr
	Concord Mainstem	2	Median	8:17 AM	6.52	92.4	11.32	279	7.03	3	0.03	0.02	0.55	<0.1	nr
	Headwater & Tribs	7	Median	9:00 AM	5.39	94.3	11.87	205	6.87	1	0.02	0.01	0.06	<0.1	nr

nr = not sampled / not recorded

Precipitation and Streamflow

Precipitation, and the associated increased stormwater runoff and streamflow changes, are correlated with concentrations of total suspended solids, total phosphorus, and nitrate/nitrites. For the purposes of this project, sampling dates were classified by visual inspection of the hydrograph of the nearest available real-time USGS gage as rising, falling, or flat hydrograph (Table 7). Samples collected on a rising hydrograph are likely to include stormwater runoff and the associated pollutants. Rainfall data was downloaded from the National Weather Service's Worcester Airport station (http://www7.ncdc.noaa.gov/CDO/cdo) (Figures 2 & 3; Table 8).

Table 7: Hydrograph and precipitation on sampling days 2009 & 2010

	Hydrograph at USGS gage			
Sampling Date	Assabet River at Maynard	Sudbury at Framingham	Concord at Lowell	2-day precip. (inches) before sampling day (NWS data)
26&27-Feb-09	falling	rising	rising	0
19-Apr-09	falling	falling	falling	0.01
21-Jun-09	**start of fall**	**falling**	**rising**	**0.24**
19-Jul-09	**rising**	falling	falling	0.86
16-Aug-09	falling	falling	falling	0
20-Sep-09	falling	falling	falling	0
18-Oct-09	falling	falling	rising	0.17
28-Mar-10	falling	falling	falling	0.13
16-May-10	falling	falling	falling	0.22
13-Jun-10	**rising**	**rising**	**start of fall**	**0.87**
18-Jul-10	flat	falling	flat	0.31
22-Aug-10	start of rise	start of rise	flat	0
19-Sep-10	flat	flat	flat	0.02
14-Nov-10	falling	falling	falling	0

Figure 2: NWS rainfall data (2009)

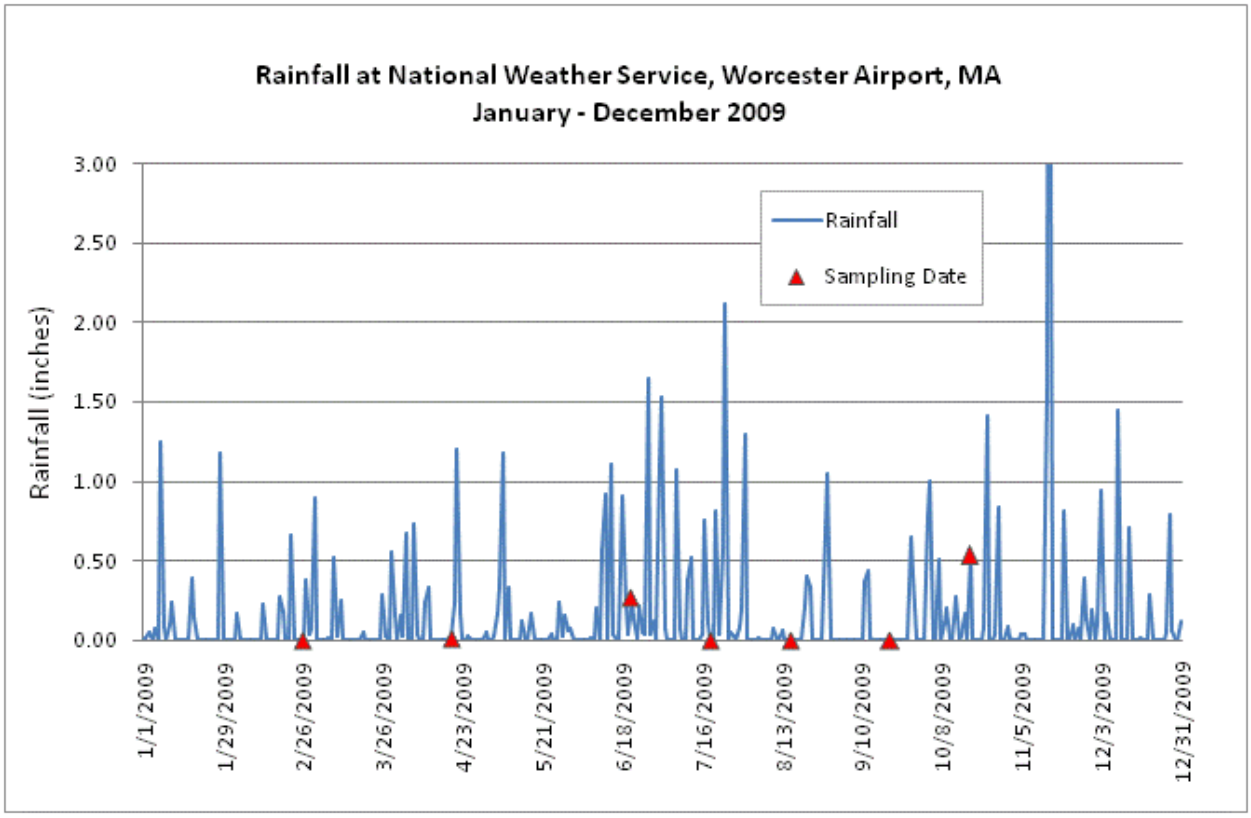


Figure 3: NWS rainfall data (2010)

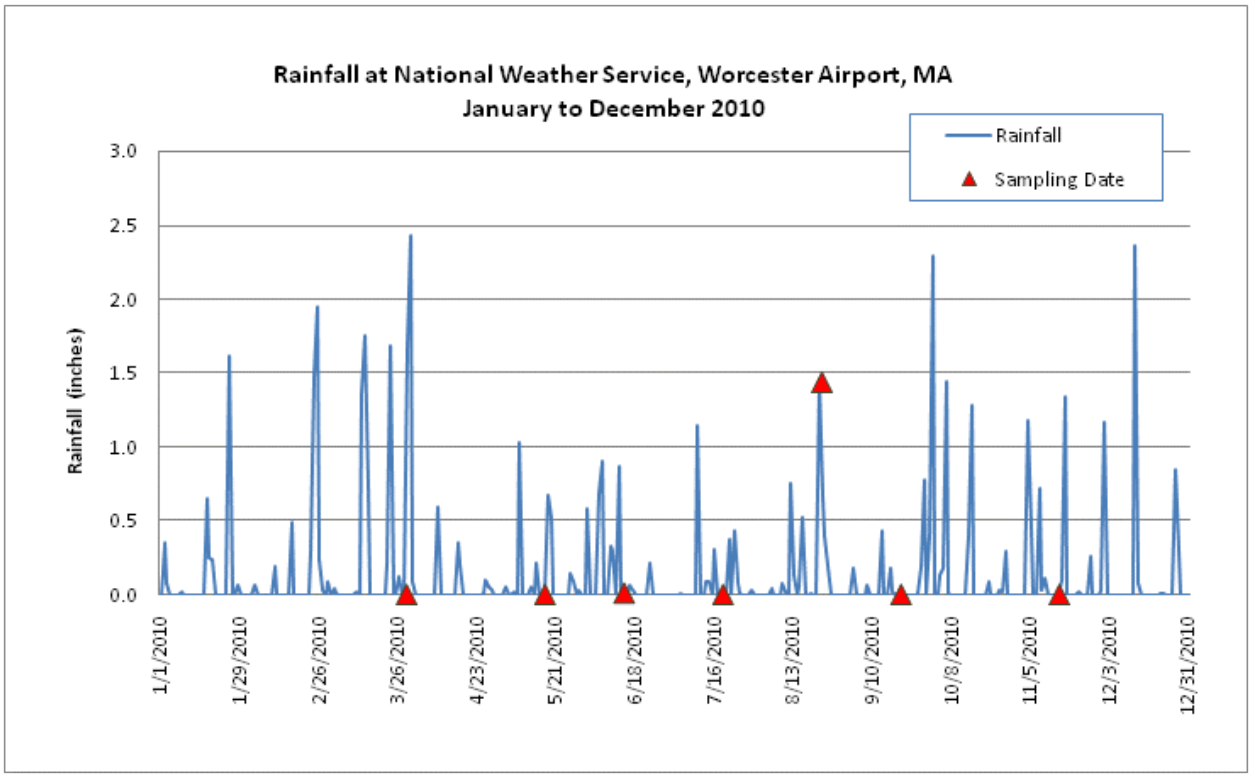


Table 8 shows composite monthly rainfall for the Central Region of Massachusetts as reported by the Department of Conservation and Recreation. In 2009, April, June and July were wetter than average, with July 237% of normal for the month. In 2010, March was wetter than average, but the following summer months were drier than average.

Table 8: Composite Rainfall Data for Sampling Months 2009 & 2010

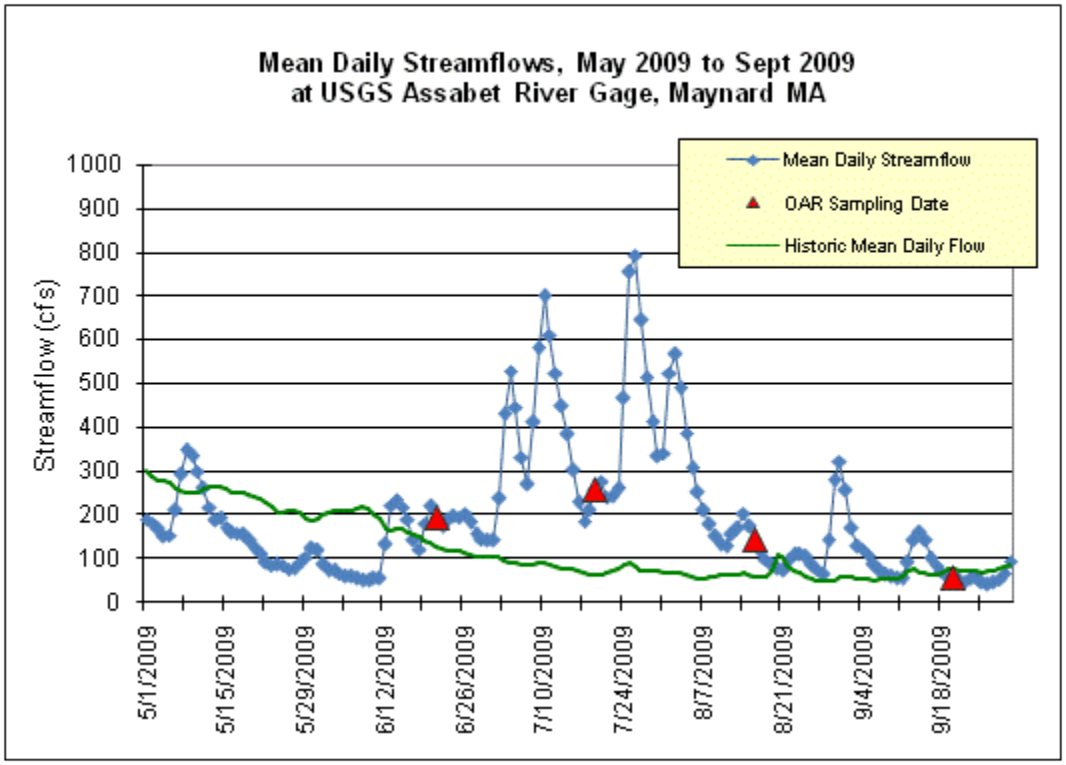
2007 & 2008 Rainfall Data from DCR Rainfall Program – Central Region *			
Sampling Month	Rainfall (inches)	Normal (inches)	Percent of normal for the month (%)
Feb 2009	1.79	3.30	54
April 2009	4.12	3.98	104
June 2009	5.99	3.91	153
July 2009	9.10	3.84	237
Aug 2009	3.15	3.91	81
Sept 2009	1.54	3.99	39
Oct 2009	4.79	3.89	123
March 2010	6.33	3.75	169
May 2010	3.37	3.90	96
June 2010	3.53	3.94	90
July 2010	4.01	3.91	103
Aug 2010	3.58	3.91	92
Sept 2010	2.48	3.95	63
Nov 2010	3.92	4.18	94

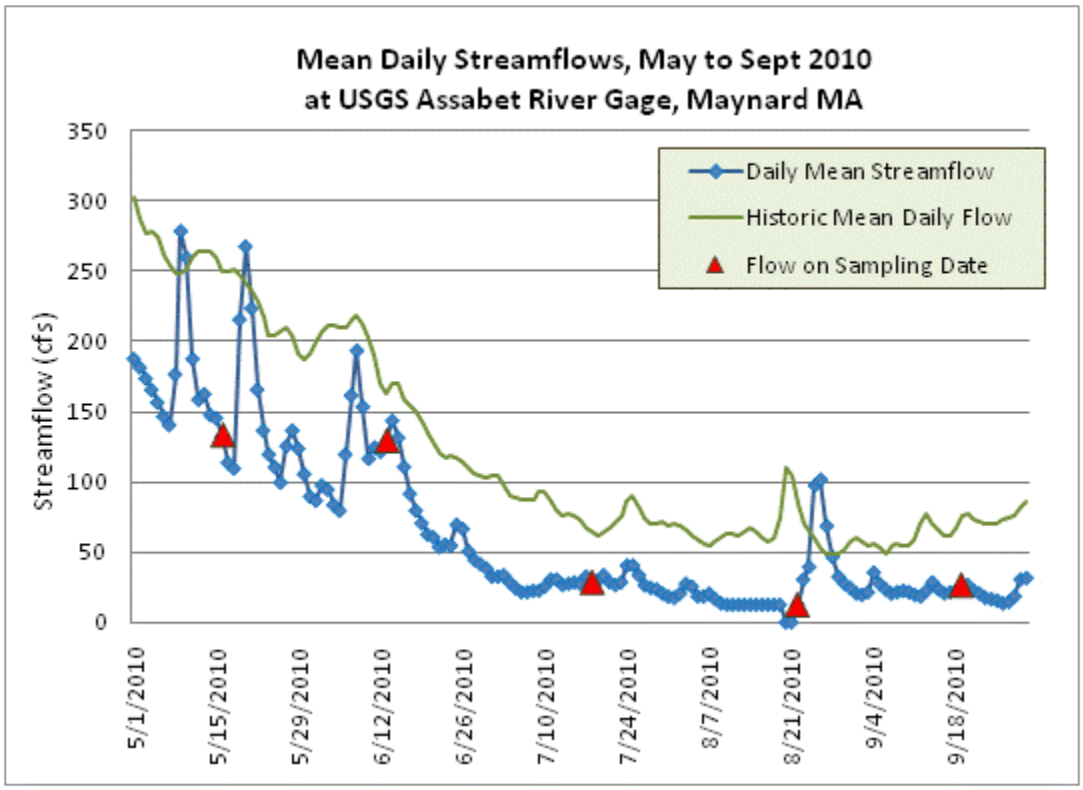
* Accessed April 2011, http://www.mass.gov/dcr/waterSupply/rainfall/

Streamflow has a direct impact on the concentration of nutrients and suspended solids in the water column and the availability of aquatic habitat and an indirect impact on water temperature, dissolved oxygen concentration, pH, and conductivity. Note that streamflows measured at the Assabet River gage in Maynard include effluent discharges from three of the four municipal wastewater treatment plants on the river. For example, Figure 4 shows summer mean daily streamflows at the Assabet River gage in Maynard compared with the historic mean of the daily streamflows (calculated on the period of record for the gage). In general, May to September in 2009 was wetter than average; in 2010 there were floods in March followed by drier than average conditions in May to September. Summer hydrographs for the Concord River gage in Lowell, the Sudbury River gage in Saxonville/Framingham, and the Nashoba Brook gage in Acton (see Appendix I) are similar to the Assabet River's for 2009 and 2010.

Monthly streamflows were also recorded at six tributary monitoring sites and near the Assabet River headwaters, above the first wastewater discharge (data in Appendix I).

Figure 4: Mean Daily Streamflows Assabet River: May – Sept 2009 and May – Sept 2010



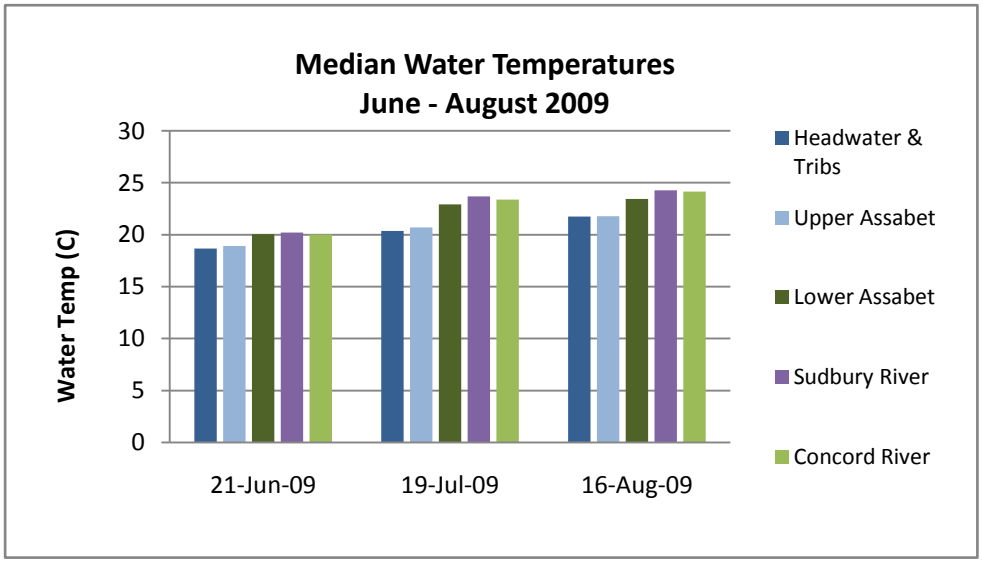


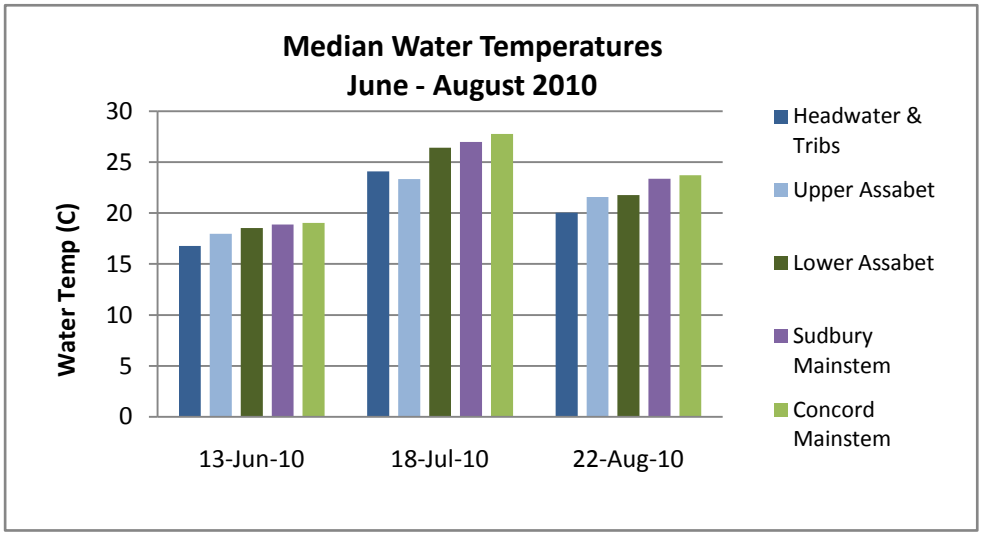
Water Temperature, pH, and Conductivity

In-situ readings (including dissolved oxygen, water temperature, pH, and conductivity) in the summer months (May to Sept) were taken between about 5:30 am and 9:00 am, when dissolved oxygen concentrations are expected to be at their lowest for the day. Readings during the non-growing season (November and March) were taken between 7:00 am and 1:00 pm. Summary statistics for all in-situ readings are in Table 6 (above) and full data is in Appendix A.

Figure 5 shows median water temperatures by river section for summer 2009 and 2010. Water temperatures at both mainstem and tributary sites met Class B warm water fisheries standard on all dates tested in 2009 and 2010. Because the tributary streams support or have supported cold water fisheries, tributary and headwater temperature readings were also compared with the cold water standard (20.0°C). Exceeding 20.0°C among the tributary stream readings were: 5 sites in July 2009, all eight sites in July 2010, and four sites in August 2010. The recommended single-reading maxima for brook trout is 20.0°C and for brown trout is 23.9°C.

Figure 5: Water temperature readings (Summer 2009 & 2010)

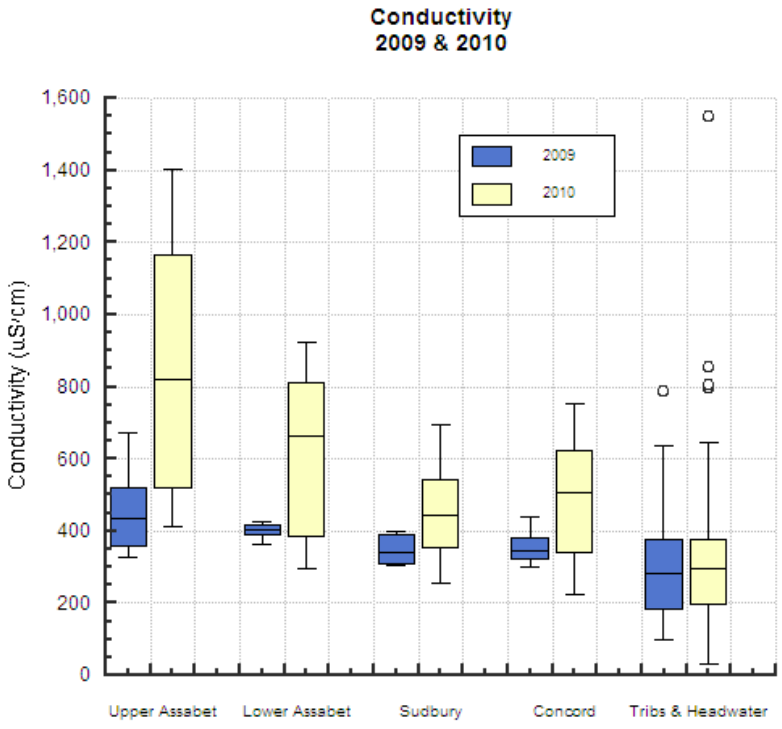




pH readings in the mainstem ranged from 6.12 to 7.52 in 2009, and from 6.50 to 8.14 in 2010. Sites not meeting standards: Assabet at Rte 9, Westborough, and Sudbury at River Road, Wayland, were below 6.5 in August 2009. Tributary pH readings ranged from 4.78 to 7.63 in 2009, and from 6.55 to 7.71 in 2010. Sites not meeting standards were: Cold Harbor Brook in Northborough was less than 6.5 in June and August 2009 and Hop Brook in Northborough were less than 6.5 in August 2009.

Conductivity is an indirect indicator of pollutants such as effluent, non-point source runoff (especially road salts) and erosion. The range of mainstem conductivity readings was from 261 µS/cm to 671 µS/cm in 2009 and 33 µS/cm to 1551 µS/cm in 2010. The lowest reading (33 µS/cm) was recorded at Danforth Brook in June 2010, when flows were very low. The highest readings (greater than 1000 µS/cm) were recorded in the upper Assabet mainstem sites and at River Meadow Brook in Lowell, in July and August in 2010. (Figure 6).

Figure 6: Conductivity readings (Summers 2009 & 2010)



Dissolved Oxygen

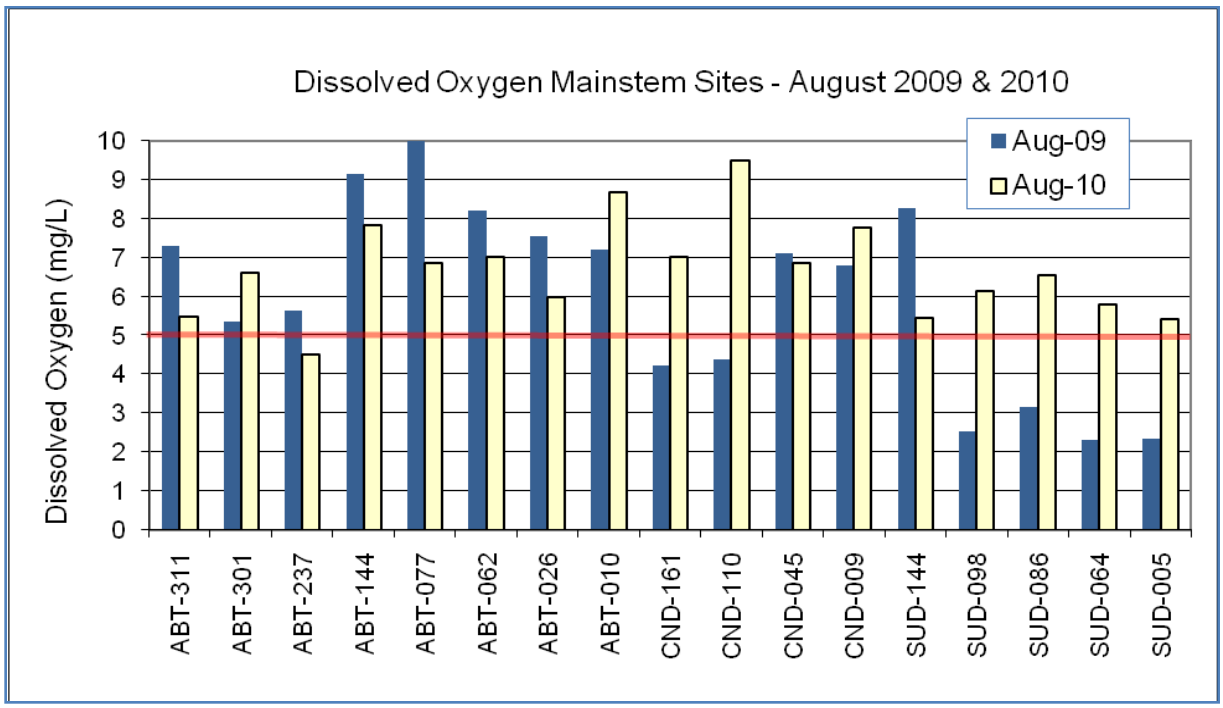
Dissolved oxygen (DO) concentrations during the growing season are generally lowest between 5am and 8am after plant and microbial respiration has removed oxygen from the water column overnight. Low minimum DO concentrations and large diurnal variations in DO can indicate eutrophic conditions. Summary statistics for DO readings are in Table 6 and full data are in Appendix I. Water quality standards (WQS) violations (<5.0 mg/L for Class B; < 3.0 mg/L for Class B Aquatic Life for mainstem Sudbury sites) are listed in Table 9. Note that low DO measurements may not constitute a violation of WQS if it is caused by natural conditions.

Table 9: Dissolved Oxygen Violations

Date	Site	Dissolved Oxygen (mg/L)
July 2009	CND-161	4.22
	CND-110	3.30
	SUD-005	1.33
	DAN-013	4.88
	HOP-011	4.92
August 2009	CND161	4.23
	CND-110	4.37
	SUD-098	2.53
	SUD-064	2.32
	SUD-005	2.33
	HBS-016	0.79
September 2009	HBS-016	4.48
May 2010	HBS-016	4.39
June 2010	SUD-064	2.93
	HBS-016	3.13
July 2010	ABT-237	4.45
	ELZ-004	0.77
	HBS-016	0.19
August 2010	ABT-237	4.50
	ELZ-004	2.24
	HBS-016	1.09
	HOP-011	3.04
	NSH-002	4.65
September 2010	HBS-016	3.33

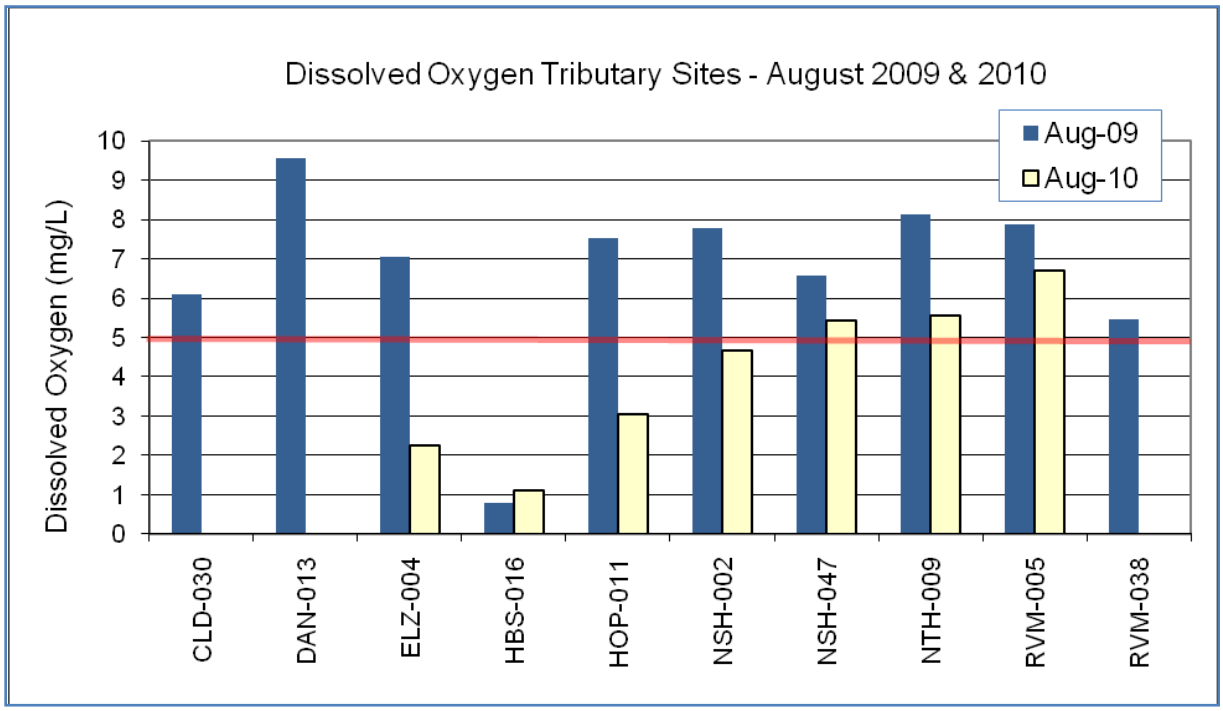
For comparison between years, it is useful to look at conditions in August (generally the lowest flow and poorest water quality conditions for the year). Figures 7 and 8 show August dissolved oxygen measurements for mainstem and tributary sites in 2009 and 2010. DO readings were lower in August 2010 than in August 2009 in most of the Assabet mainstem (except ABT-301 and ABT-010) and at the tributary sites. At Sudury River sites from Pelham Island Road (SUD-098) to the confluence (SUD-005) and the upper Concord River sites (CND-161 and CND-110) dissolved oxygen was higher in 2010, when streamflows were generally lower. Hop Brook at Landham Road, Sudbury, has consistently low dissolved oxygen concentrations.

Figure 7: Dissolved Oxygen Measurements at mainstem sites (Aug 2009 & Aug 2010)



Red line indicates the Class B water quality standard (5.0mg/l)

Figure 8: Dissolved Oxygen Measurements in tributary streams (Aug 2009 & Aug 2010)



Nutrients and Suspended Solids

Summary statistics for nutrient concentrations are in Table 6, above. Median nutrient concentrations (Table 10) over the summer were calculated for the upper and lower Assabet mainstem reaches (see Table 1 for reach definitions), Sudbury mainstem sites, Concord mainstem sites, combined Assabet headwaters and tributary sites, and Hop Brook in Sudbury.

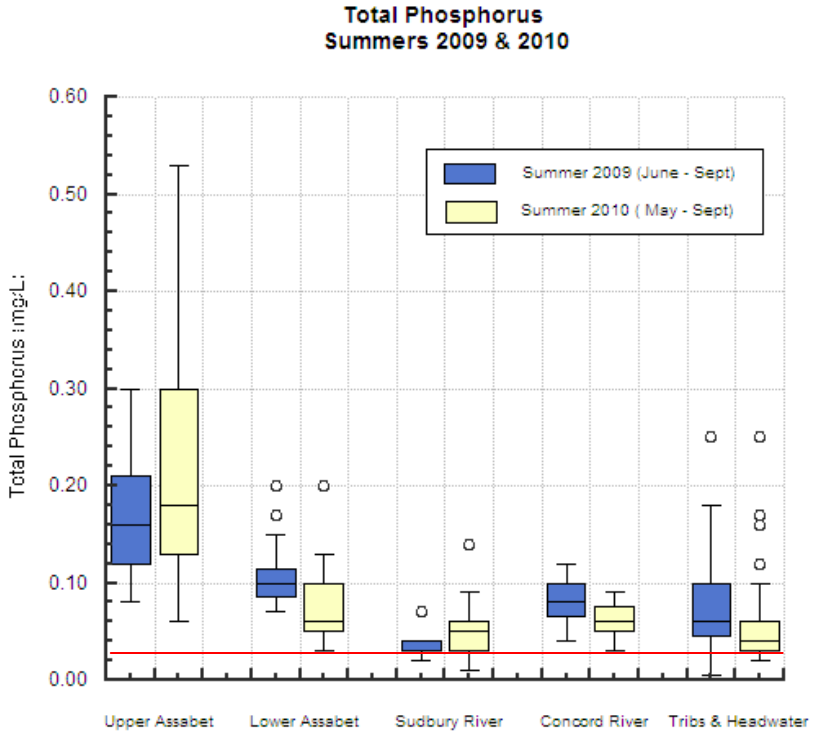
Figures 9 – 11 show summertime (June – Sept) nutrient concentrations in the various river sections, displayed as box plots to readily compare between sections. Median nutrient concentrations along the Assabet River mainstem below the first wastewater discharge (Westborough WWTP) were well above Ecoregion reference conditions (25th percentile of the summertime data) for both total phosphorus (TP) and nitrates in 2009 and 2010. Median nutrient concentrations in the Concord River mainstem were generally lower than Assabet River concentrations, but still exceeded Ecoregion reference conditions for TP in 2009 and 2010 and for nitrates in 2010. Median TP in the Sudbury River were lower than in either the Assabet or Concord Rivers, but exceeded reference conditions in 2009 and 2010. Total phosphorus concentration in the tributaries except Hop Brook in Sudbury, were slightly elevated. Hop Brook, Sudbury, which is affected by the wastewater discharge from Marlborough Easterly WWTP, and has total phophorus concentrations 6-7 times the recommended concentrations (Table 10). In Figures 9 - 11, Hop Brook, Sudbury, is included in the "Headwaters and Tribs" statistics. Nitrates were very high (median 9.9 mg/L) in the upper Assabet in summer 2010; the highest reading was 24.8 mg/L at the Assabet River at Rte 9 Westborough (ABT-301) site in August 2010, when streamflows were lowest.

Table 10: Summer (June - August) medians compared with recommended criteria

	Summer Median TP [Exceeds TP criteria (0.025 mg/L) by]		**Summer Median NO3 [Exceeds NO3/NO2 criteria (0.34 mg/L) by]**	
Section	**2009**	**2010**	**2009**	**2010**
Upper Assabet	**0.16 mg/L [6.4x]**	**0.15 mg/L [6.0x]**	**1.45 mg/L [4.3x]**	**9.9 mg/L [29.1x]**
Lower Assabet	**0.10 mg/L [4.0x]**	**0.06 mg/L [2.4x]**	**0.90 mg/L [2.7x]**	**1.65 mg/L [4.9x]**
Sudbury River *	**0.04 mg/L [1.6x]**	**0.05 mg/L [2.0x]**	**0.09 mg/L [below]**	**0.1 mg/L [below]**
Concord River	**0.07 mg/L [2.8x]**	**0.06 mg/L [2.0x]**	**0.27 mg/L [below]**	**0.49 mg/L [1.4x]**
Assabet Headwaters & Tributaries (except Hop Brook, Sudbury)	**0.06 mg/L [2.4x]**	**0.05 mg/L [1.8x]**	**0.23 mg/L [below]**	**0.21 mg/L [below]**
Hop Brook, Sudbury*	**0.18 mg/L [7.2x]**	**0.16 mg/L [6.4x]**	**0.18 mg/L [below]**	**0.08 mg/L [below]**

*** In 2009 Sudbury River sites and Hop Brook, Subury, were only sampled in August.**

Figure 9: Total Phosphorus Concentrations (Summers)



(Red line indicates 0.025mg/L; EPA Ecoregion XIV recommended TP concentrations.)

Figure 10: Ortho-Phosphorus Concentrations (Summers)

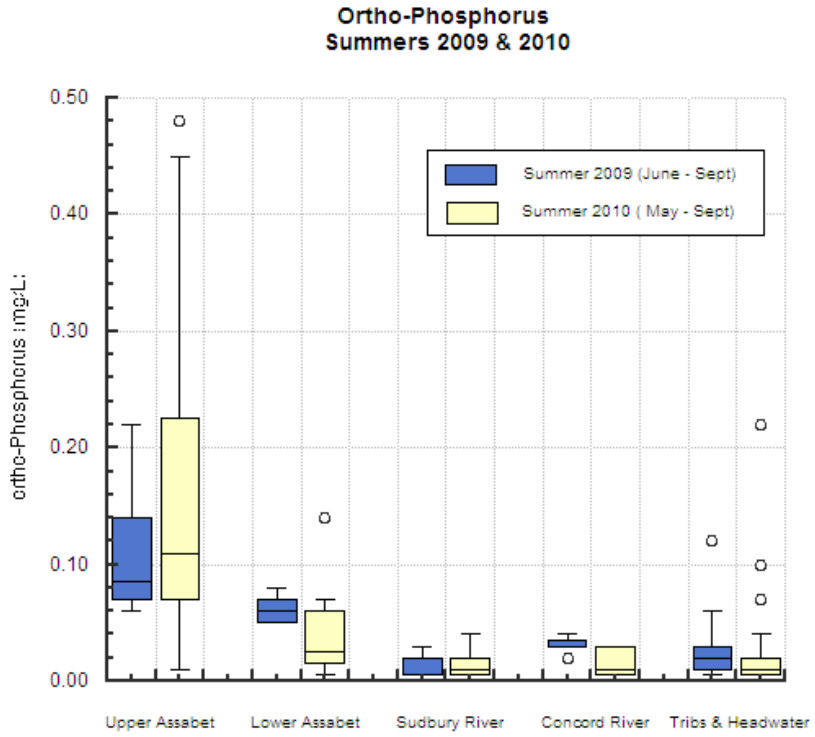
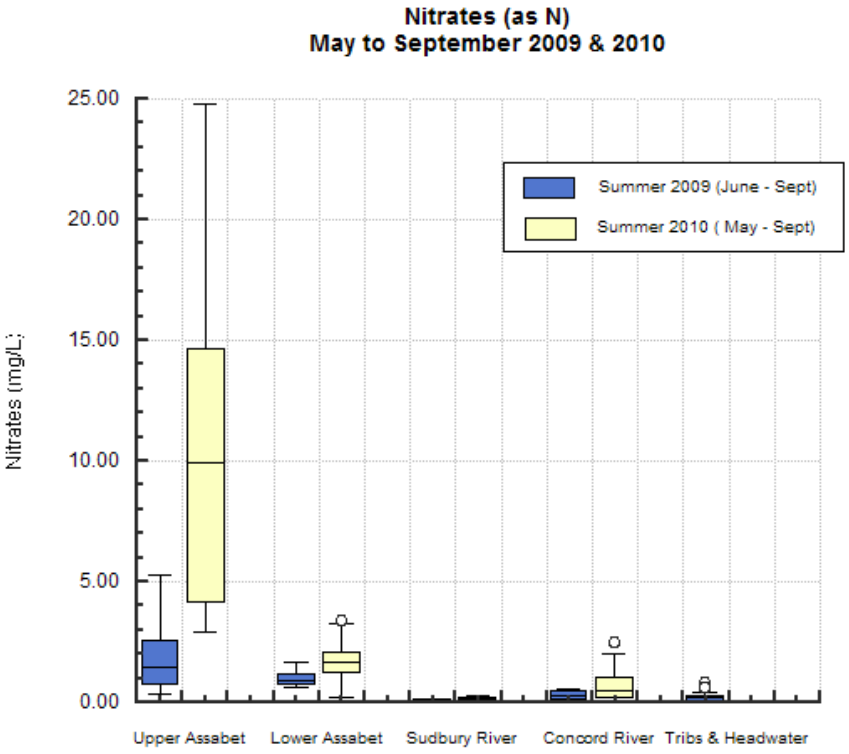
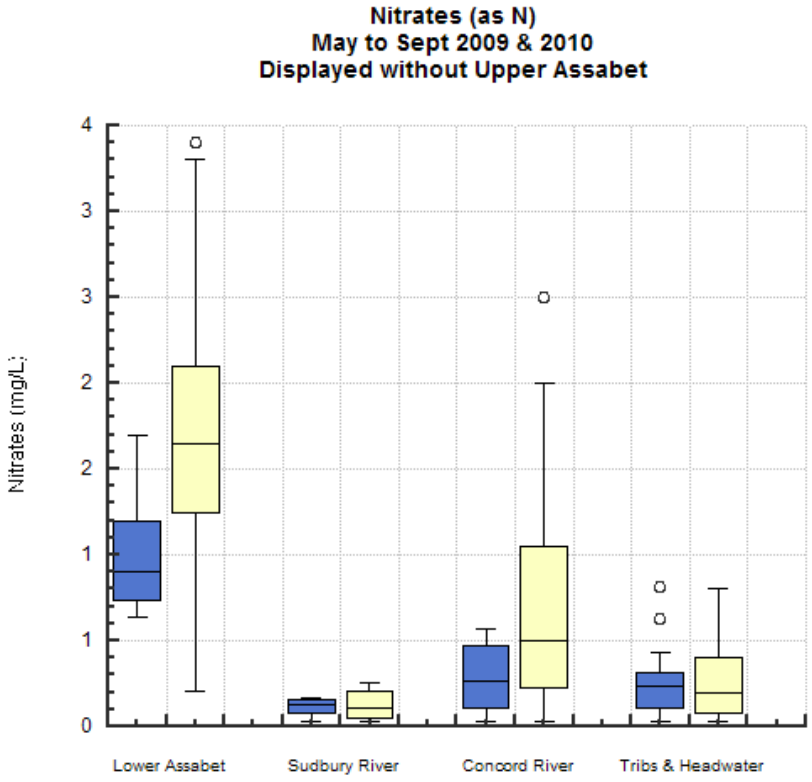


Figure 11: Nitrate Concentrations (Summers)





Water Quality and Stream Health Index Calculations

The Stream Health Index was used to assess conditions at seven of the tributary stream sites for each of the monthly sampling results (Table 11). The Water Quality Index (a sub-index of the overall Stream Health Index) was also used to assess water quality at selected mainstem sites (Table 12) and Hop Brook, Sudbury, which don't have streamflow data available.

OARS' Stream Health Index is designed to characterize summertime fish habitat conditions in the small streams of the watershed. A full description of the index is available on the OARS webpage. Briefly, an index brings information from multiple data sources together into a single number, like a grade, that can be understood at a glance. As such, an index is a useful tool in making water quality, habitat and streamflow data accessible to the public and in assessing spatial and temporal trends.

For the Stream Health Index, measurements of streamflow, groundwater levels, channel flow status, dissolved oxygen, temperature, pH, total phosphorus, nitrates, and total suspended solids are scored from 1 (worst) to 100 (best). In 2009, the index calculation was updated to use nitrates (instead of total nitrogen, since TKN is no longer being analysed) and to include Class B "Aquatic Life" standards for dissolved oxygen and temperature in the Water Quality Index for the Sudbury River mainstem sites. Streamflow data are scored against minimum summertime streamflow recommendations of several standard-setting methods. Water quality metrics are scored against published fish tolerances, Massachusetts surface water quality standards, and EPA criteria. Nutrient concentrations are scored against expected conditions for Ecoregion XIV. Channel flow status is scored using EPA's Rapid Bioassessment Protocol. For tributary stream sites, which support or have supported cold-water fish populations, temperature and dissolved oxygen readings were compared with Class B cold water standards. For mainstem Assabet and Concord sites, temperature and DO readings were compared with Class B warm water standards and Sudbury sites were compared with Class B "Aquatic Life" standards. These parameter scores are aggregated to give streamflow, water quality and habitat availability index scores; these three index scores are then aggregated into an overall stream health index. For postings the index score was converted to a description: excellent (81 – 100), good (61 – 80), fair (41 – 60), poor (21 – 40), and very poor (1 – 20).

Stream Health Index: The tributary Stream Health Index readings were generally "excellent" to "good" in 2009. In 2010, with drier summer conditions, SHI readings were "excellent" to "good" in May and June, but dropped to "poor" to "very poor" with low summer flows. The lowest subindex readings were generally for flow. Danforth Brook was not sampled in July, August or September 2010 because the sampling site was dry.

Water Quality Index: Table 12 shows Water Quality Index readings for selected sites on the mainstem Assabet, Sudbury and Concord Rivers and on Hop Brook in Sudbury. Total phosphorus and nitrates were the lowest scoring parameters, driving the overall WQI score, at the Assabet River sites. Total phosphorus and dissolved oxygen were the lowest scoring parameters at the Hop Brook site in Sudbury. Dissolved oxygen was the lowest scoring parameter at the three Sudbury River sites below Saxonville in August 2009 and June 2010.

Table 11: Stream Health Index Readings – Summers 2009 & 2010

	Stream Health Index Readings – 2009 & 2010								
	21-June-09	19-July-09	16-Aug-09		16-May-10	13-June-10	18-July-10	22-Aug-10	19-Sept-10
Assabet River Headwater, Maynard St., Westborough									
Water Quality Index	78	50	37		80	73	56	70	84
Flow Index	91	90	91		92	96	10	8	10
Habitat Index	100	90	80		95	85	40	15	25
Stream Health Index	89	71	59		89	83	22	15	19
Danforth Brook, Rte 85, Hudson									
Water Quality Index	82	68	67		86	83	na	na	na
Flow Index	91	90	88		78	63	8	7	7
Habitat Index	90	95	85		90	80	20	10	5
Stream Health Index	88	83	79		84	74	na	na	na
Elizabeth Br., near White Pond Road, Stow									
Water Quality Index	62	60	61		76	71	53	6	80
Flow Index	91	90	83		100	96	62	<26	33
Habitat Index	90	95	90		100	100	80	45	85
Stream Health Index	79	78	76		91	87	63	<13	55
Hop Brook, Otis Street, Northborough									
Water Quality Index	65	57	55		69	70	20	36	73
Flow Index	91	90	91		100	96	40	19	38
Habitat Index	95	95	80		100	100	60	30	45
Stream Health Index	81	77	72		87	87	33	27	48
Nashoba Br., Commonwealth Ave, W. Concord									
Water Quality Index	66	54	54		na	75	77	56	77
Flow Index	91	90	91		na	96	78	na	54
Habitat Index	95	95	90		na	90	55	40	35
Stream Health Index	82	75	74		na	86	68	na	50
Nashoba Brook, Wheeler Ave, Acton									
Water Quality Index	59	59	51		62	63	39	65	66
Flow Index	91	90	85		98	91	31	29	21
Habitat Index	90	90	100		100	90	75	50	35
Stream Health Index	77	77	72		82	79	42	43	33
North Brook, Whitney Ave, Berlin									
Water Quality Index	85	70	54		78	64	43	56	na
Flow Index	91	90	90		100	95	71	39	43
Habitat Index	100	100	90		95	90	65	30	75
Stream Health Index	91	85	74		90	80	57	39	na

Key:	81 – 100 = Excellent	61 – 80 = Good	41 – 60 = Fair	21 – 40 = Poor	1 – 20 = Very Poor
	na: data not available				

Table 12: Water Quality Index Readings – Selected Mainstem Sites Summers 2009 & 2010

Assabet at Rte 9 Westboro (ABT-301)	Water Quality Parameter Reading						Water Quality Index Reading
	NO3	TP	TSS	DO	pH	Temp	
21-June-2009	5.3	0.21	2	6.33	6.76	19.94	22
19-July-2009	1.4	0.18	3	7.30	6.72	22.02	50
16-Aug-2009	3.0	0.30	5	5.35	6.41	23.21	33
16-May-2010	7.8	0.26	3.5	8.22	6.68	15.60	8
13-June-2010	3.7	0.18	12	7.74	6.82	18.62	32
18-July-2010	16.1	0.49	3	6.32	6.70	22.37	5
22-Aug-2010	24.8	0.34	<1	6.60	6.89	21.59	5
19-Sept-2010	21.6	0.53	3	7.03	6.83	19.13	5

Assabet at Rte 27 Maynard (ABT-077)	Water Quality Parameter Reading						Water Quality Index Reading
	NO3	TP	TSS	DO	pH	Temp	
21-June-2009	1.7	0.20	6	8.04	6.96	20.41	47
19-July-2009	0.90	0.07	5	8.15	7.17	23.39	62
16-Aug-2009	0.64	0.12	6	9.99	7.34	23.27	62
16-May-2010	1.6	0.07	6	9.33	6.80	17.08	55
13-June-2010	1.3	0.06	4	8.50	7.24	18.70	60
18-July-2010	1.7	0.03	1.5	7.23	7.50	26.66	55
22-Aug-2010	2	0.05	<1	6.87	7.24	23.06	53
19-Sept-2010	3.4	0.05	5	na	7.43	17.33	na

Concord at Rte 225 Bedford (CND-110)	Water Quality Parameter Reading						Water Quality Index Reading
	NO3	TP	TSS	DO	pH	Temp	
21-June-2009	0.57	0.11	7	6.16	6.97	20.01	61
19-July-2009	0.20	0.09	2	3.30	6.81	23.38	57
16-Aug-2009	0.30	0.07	6	4.37	6.85	23.99	62
13-June-2010	0.34	0.05	8.5	5.92	6.90	18.93	68
18-July-2010	0.57	0.07	10.5	7.42	7.49	28.19	58
22-Aug-2010	0.38	0.09	16	114%	8.01	24.54	61

Concord at Rogers Street Lowell (CND-009)	Water Quality Parameter Reading						Water Quality Index Reading
	NO3	TP	TSS	DO	pH	Temp	
21-June-2009	0.55	0.10	1	7.52	7.18	20.05	69
19-July-2009	0.24	0.08	6	6.64	6.95	23.32	69
16-Aug-2009	0.50	0.07	5	6.80	6.92	24.30	65
16-May-2010	0.44	0.07	7	9.47	7.19	16.59	70
13-June-2010	0.67	0.06	8	7.84	7.03	19.18	65
18-July-2010	1.1	0.08	12	5.86	7.43	27.25	51
22-Aug-2010	2.0	0.07	5	7.78	8.14	23.58	49
19-Sept-2010	2.5	0.06	8	8.00	7.38	17.71	45

Key:	81 – 100 = Excellent	61 – 80 = Good	41 – 60 = Fair	21 – 40 = Poor	1 – 20 = Very Poor
	na: data not available				

Sudbury at Saxonville Framingham (SUD-144)	Water Quality Parameter Reading						Water Quality Index Reading
	NO3	TP	TSS	DO	pH	Temp	
16-Aug-2009	0.17	0.02	2	8.26	7.25	24.44	86
20-Sept-2009	0.16	0.03	<1	103.9%	7.34	17.23	91
16-May-2010	0.26	0.03	2.5	9.25	7.02	16.84	84
13-June-2010	0.24	0.01	8.5	8.67	7.20	19.05	83
18-July-2010	0.20	0.02	2	5.94	7.08	24.61	81
22-Aug-2010	0.21	0.02	1	5.45	7.18	20.88	84
19-Sept-2010	0.23	0.04	1.5	8.03	7.09	15.70	84

Sudbury at Pelham Island Rd, Wayland (SUD-098)	Water Quality Parameter Reading						Water Quality Index Reading
	NO3	TP	TSS	DO	pH	Temp	
16-Aug-2009	0.16	0.03	3	2.53	6.66	24.16	59
20-Sept-2009	0.13	0.03	<1	8.06	7.05	15.95	91
16-May-2010	0.21	0.04	5	8.06	6.89	17.50	79
13-June-2010	0.15	0.06	7	4.82	6.73	19.00	70
18-July-2010	0.13	0.03	3.5	5.09	6.93	26.14	75
22-Aug-2010	<0.05	0.09	10	6.13	7.31	22.83	69
19-Sept-2010	0.25	0.04	7.5	7.44	7.11	16.00	76

Sudbury at River Rd, Wayland (SUD-086)	Water Quality Parameter Reading						Water Quality Index Reading
	NO3	TP	TSS	DO	pH	Temp	
16-Aug-2009	0.15	0.04	3	3.17	6.83	24.35	65
20-Sept-2009	0.14	0.03	3	8.68	7.02	16.02	87
16-May-2010	0.14	0.05	5.5	6.41	6.79	17.46	77
13-June-2010	0.14	0.03	29	3.29	6.67	18.67	55
18-July-2010	0.11	0.06	7	4.65	6.96	26.97	67
22-Aug-2010	<0.05	0.08	12	6.55	7.29	23.36	69
19-Sept-2010	0.24	0.04	8	7.27	7.09	16.34	75

Sudbury at Sherman Bridge Rd, Wayland (SUD-064)	Water Quality Parameter Reading						Water Quality Index Reading
	NO3	TP	TSS	DO	pH	Temp	
19-July-2009	0.09	0.03	5	2.32	6.77	24.28	55
16-Aug-2009	0.12	0.03	3	7.22	6.84	15.82	85
16-May-2010	0.11	0.04	6.5	7.56	6.87	17.97	80
13-June-2010	0.06	0.05	13	2.93	6.57	18.76	58
18-July-2010	0.10	0.07	11	4.54	7.03	28.20	62
22-Aug-2010	<0.05	0.14	18	5.79	7.32	23.97	59
19-Sept-2010	0.05	0.06	13	7.50	7.21	17.13	73

Key:	81 – 100 = Excellent	61 – 80 = Good	41 – 60 = Fair	21 – 40 = Poor	1 – 20 = Very Poor
	na: data not available				

Sudbury at Rte 62, Concord (SUD-005)	Water Quality Parameter Reading						Water Quality Index Reading
	NO3	TP	TSS	DO	pH	Temp	
21-June-2009	<0.05	0.04	2	4.82	7.06	20.31	80
19-July-2009	<0.05	0.07	2	1.33	6.75	23.68	24
16-Aug-2009	0.06	0.04	5	2.33	6.72	24.23	55
20-Sept-2009	0.10	0.03	6	7.51	6.88	16.23	83
16-May-2010	0.10	0.14	5.5	9.07	7.22	16.57	71
13-June-2010	0.05	0.03	7	5.14	6.81	18.86	76
18-July-2010	<0.05	0.05	7	4.08	7.19	27.42	65
22-Aug-2010	<0.05	0.06	9	5.40	7.28	24.18	70
19-Sept-2010	<0.05	0.05	18	7.80	7.43	17.40	71

Hop Brook at Landham Road, Sudbury (HBS-016)	Water Quality Parameter Reading						Water Quality Index Reading
	NO3	TP	TSS	DO	pH	Temp	
16-Aug-2009	0.18	0.18	6	0.79	6.74	21.71	5
20-Sept-2009	0.63	0.06	4	4.48	6.83	12.19	57
16-May-2010	0.51	0.05	2.5	4.39	6.59	15.18	58
13-June-2010	0.52	0.07	5	3.13	6.70	17.27	52
18-July-2010	0.08	0.25	14	0.19	7.71	24.09	5
22-Aug-2010	<0.05	0.16	5.5	1.09	6.83	20.05	6
19-Sept-2010	0.26	0.10	2	3.33	6.78	14.25	46

Key:	81 – 100 = Excellent	61 – 80 = Good	41 – 60 = Fair	21 – 40 = Poor	1 – 20 = Very Poor
	na: data not available				

Summary

This report presents the monthly water quality and streamflow data OARS collected on the Assabet, Sudbury, and Concord Rivers and tributary streams in 2009 (February, April, June, July, August, September, and October) and in 2010 (March, May, June, July, August, September, and November). All sites are sampled in June, July, and August; a subset of the sites are sampled in other months. Between 2009 and 2010 the number Assabet River mainstem sites was decreased and new sites were added on the Sudbury River mainstem.

In general, May to September in 2009 was wetter than average; in 2010 there were floods in March followed by drier than average conditions in May to September.

Mainstem dissolved oxygen readings failed to meet Water Quality Standards at: 5 sites in July 2009, 6 sites in August 2009, 1 site in September 2009, 1 site in May 2010, 2 sites in June 2010, 3 sites in July 2010, 5 sites in August 2010, and 1 site in September 2010. The lowest mainstem reading was taken on the Sudbury River at Rte 62, Concord, in July 2009 (1.09 mg/L). The lowest tributary readings were consistently at Hop Brook at Landham Road, Sudbury, in both 2009 and 2010, with the lowest reading of 0.19 mg/L in July 2010.

Water temperatures at both mainstem and tributary sites met Class B warm water fisheries standards on all dates tested. Because the tributary streams support or have supported cold water fisheries, tributary temperature readings were also compared with cold water standards. Exceeding 20.0°C among the tributary stream readings were: 5 sites in July 2009, all eight sites in July 2010, and four sites in August 2010.

pH readings in the mainstem ranged from 6.12 to 7.52 in 2009, and from 6.50 to 8.14 in 2010. Sites not meeting standards: Assabet at Rte 9, Westborough, and Sudbury at River Road, Wayland, were below 6.5 in August 2009. Tributary pH readings ranged from 4.78 to 7.63 in 2009, and from 6.55 to 7.71 in 2010. Sites not meeting standards were: Cold Harbor Brook in Northborough was less than 6.5 in June and August 2009 and Hop Brook in Northborough were less than 6.5 in August 2009.

Conductivity is an indirect indicator of pollutants such as effluent, non-point source runoff (especially road salts) and erosion. The range of mainstem conductivity readings was from 261 µS/cm to 671 µS/cm in 2009 and 33 µS/cm to 1551 µS/cm in 2010. The lowest reading (33 µS/cm) was recorded at Danforth Brook in June 2010, when flows were very low. The highest readings (greater than 1000 µS/cm) were recorded in the upper Assabet mainstem sites and at River Meadow Brook in Lowell, in July and August in 2010 (Figure 6).

Median nutrient concentrations along the Assabet River mainstem (both upper and lower sections) were well above Ecoregion reference conditions (25^{th} percentile of the summertime data) for both total phosphorus (TP) and nitrates in 2009 and 2010. Nitrates were very high (median 9.9 mg/L) in the upper Assabet in summer 2010; the highest reading was 24.8 mg/L at the Assabet River at Rte 9 Westborough (ABT-301) site in August 2010, when streamflows were lowest. Median nutrient concentrations in the Concord River mainstem were generally lower than Assabet River concentrations, but still exceeded Ecoregion reference conditions for TP in 2009 and 2010 and for nitrates in 2010. Median TP in the Sudbury River were lower than in

either the Assabet or Concord Rivers, but exceeded reference conditions in 2009 and 2010. Total phosphorus concentration in the tributaries except Hop Brook in Sudbury, were slightly elevated. Hop Brook, Sudbury, which is affected by the wastewater discharge from Marlborough Easterly WWTP, and has total phophorus concentrations 6-7x the recommended concentrations.

The Stream Health Index was used to assess conditions at seven tributary stream sites for each of the summer sampling results. The Water Quality Index (a sub-index of the overall Stream Health Index) was also used to assess water quality in at selected mainstem sites. In general, with higher precipitation and streamflows, Stream Health Index readings in the tributaries were higher in 2009 than in 2010. On the mainstem sites calculated, Water Quality subindex readings were higher in 2009 and readings generally improved from upstream to downstream along the Assabet and Concord mainstem sites, but decreased from upstream to downstream on the Sudbury River (with dissolved oxygen generally the lowest scoring parameter for the Sudbury sites).

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Glossary of Terms

Adaptive Management: the process by which new information about a watershed is incorporated into the watershed management plan. Ideally, adaptive management is a combination of research, monitoring, and practical management that allows "learn by doing." It is a useful tool because of the uncertainty about how ecosystems function and how management affects ecosystems. More: http://www.epa.gov/owow/watershed/wacademy/wam/step5.html

Ammonia (NH_3): a form of nitrogen available for uptake by plants and microorganisms. Sources include the breakdown of organic nitrogen in sediments and untreated sewage. Other sources of ammonia include: fertilizer, home cleaning products and food processing. While ammonia can be readily utilized by plants, high concentrations of ammonia are directly toxic to aquatic life. A secondary effect of increased ammonia occurs when bacteria oxidize the NH_3 to NO_3, a process called nitrification, consuming four atoms of oxygen for every atom of nitrogen converted. This process can dramatically lower dissolved oxygen in the water.

Baseflow: the flow of water from aquifers into the streambed. In natural systems in New England baseflow makes up most of the river flow during the summer.

Biochemical oxygen demand (BOD): oxygen required to break down organic matter and to oxidize reduced chemicals (in water or sewage). BOD provides a direct measure of the decomposition or oxidation processes in the water column. The more difficult-to-perform **sediment oxygen demand (SOD)** test measures the decomposition processes in the sediments.

Box plots: (also known as a box-and-whisker diagrams) are a convenient way of representing data with several statistics: the lower quartile (Q1), median (Q2), upper quartile (Q3), confidence intervals, and outliers. Each box (from Q1 to Q3) encloses 50% of the data with the median value of the variable displayed as a line. The top and bottom of the box mark the limits of ± 25% of the variable population. The lines extending from the top and bottom of each box mark the minimum and maximum values within the data set that fall within an acceptable range (often 1.5 times the size of the box). Any value outside of this range, called an outlier, is displayed as an individual point. More: http://www.resample.com/xlminer/help/Boxplot/Box_Intro.htm

Channel Flow Status: an estimation of the amount of the streambed that is covered with water. Method from the EPA Rapid Bioassessment Protocol.

Class B: Massachusetts Class B, sometimes referred to as "fishable, swimable," is one of the state's designations of "appropriate water uses to be achieved and protected" under the federal Clean Water Act. For more information about the federal requirements on water quality standards: http://water.epa.gov/scitech/swguidance/standards/index.cfm. For the Massachusetts Surface Water Quality Standards: http://www.mass.gov/dep/service/regulations/314cmr04.pdf.

Conductivity: the ability of the water to conduct an electrical charge. Conductivity is a rough indicator of the presence of pollutants such as: wastewater from wastewater treatment plants or septic systems; non-point source runoff (especially road salts); and soil erosion. Reported in microSiemens per centimeter (µS/cm), conductivity is measured by applying a constant voltage

to one nickel electrode and measuring the voltage drop across 1 cm of water. The flow of electrical current (I) through the water is proportional to the concentration of dissolved ions in the water - the more ions, the more conductive the water and the higher the "conductivity." Since conductivity in water is also temperature dependent the results are often reported as "specific conductivity," which is the raw conductivity measurement adjusted to 25° C.

Dissolved Oxygen: the presence of oxygen gas molecules (O_2) in the water, reported as percent saturation (% sat) or in milligrams per liter (mg/L). The concentration of dissolved oxygen (DO) in the water column provides a direct indication of the water's ability to support aquatic life like fish and macroinvertebrates. Aquatic plants and bacteria in the sediments remove dissolved oxygen from the water when they respire (plants respire mainly at night). Therefore, the lowest dissolved oxygen concentrations of the day occur in the early in the morning. During the day plants add oxygen to the water column through photosynthesis. Both extreme (low or high) DO concentrations and large changes in DO concentrations over the day (diurnal variation) are damaging to the habitat.

Ecoregion: An area over which the climate is sufficiently uniform to permit development of similar ecosystems on sites that have similar properties. According to EPA, the ecoregions are "designed to serve as a spatial framework for the research, assessment, management, and monitoring of ecosystems and ecosystem components." More information on the New England Ecoregions: http://www.epa.gov/wed/pages/ecoregions/new_eng_eco.htm

Eutrophic: abundant in nutrients and having high rates of productivity frequently resulting in oxygen depletion below the surface layer.

Hydrograph: A graph showing stage, flow, velocity, or other property of water with respect to time. More hydrographic definitions: http://water.usgs.gov/wsc/glossary.html#TOC

Gold Book: EPA's 1986 publication of recommended water quality standards. http://water.epa.gov/scitech/swguidance/standards/criteria/aqlife/upload/2009_01_13_criteria_goldbook.pdf

Impoundment: A body of water contained by a barrier such as a dam; characterized by an inlet and an outlet stream.

Mainstem: The main channel of a river, as opposed to the streams and smaller rivers that feed into it.

Mesotrophic: having a nutrient loading resulting in moderate productivity.

Nitrogen: a major nutrient supporting plant growth. Nitrogen is measured in its various forms as **nitrate (NO_3)**, **ammonia (NH_3)**, and **total Kjeldahl nitrogen (TKN**). **Total nitrogen** is calculated as the sum of TKN and nitrates. **Available nitrogen**, calculated as the sum of nitrate and ammonia, gives a measure of the nitrogen readily available for absorption by plants. Once absorbed, nitrogen is incorporated into proteins, amino acids, nucleic acids, and other molecules.

Although most aquatic plant growth in rivers is limited by the availability of phosphorus, increased nitrogen availability can also lead to algal blooms.

Oligotrophic: having a small supply of nutrients, low production of organic matter, low rates of decomposition, and high dissolved oxygen in the lower layers of the water column.

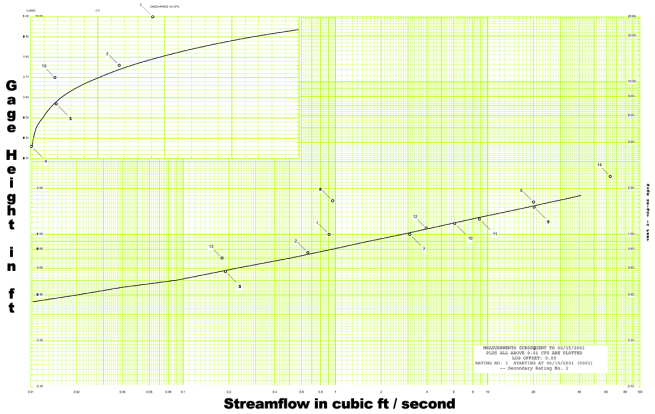
Oxidation/reduction potential provides a measure of the condition of the suspended solids: to what extent the organic material in them has been degraded by microorganisms.

Phosphorus: Plants need nutrients to grow; in particular they need a balance of phosphorus (P) and nitrogen (N). Phosphorus is measured as **total phosphorus** (TP) and **ortho-phosphate** (ortho-P; soluble inorganic phosphate, the form required by plants). In most fresh waters, the concentration of phosphorus available to plants is low enough that the plants cannot grow at their maximum rate. But in water bodies like the Assabet, where human activities add phosphorus to the environment, the added phosphorus allows much greater growth of aquatic plants (eutrophic conditions).

pH: the negative log of the hydrogen ion concentration in water, a measure of the acidity of water. pH is measured on a scale from 1 to 14, with 1 being very acidic, 7 being neutral, and 14 being very basic. Extreme pHs, in either direction, can be toxic to fish and other aquatic life and play a role in the behavior of other pollutants such as heavy metals in the environment. Changes in pH can be the result of acid rain/snow, chemicals entering the waterways, or algal blooms.

Stage and streamflow measure the amount of water in the river. Stage is the height of the water above the riverbed, and is read at staff gages at several points along the mainstem river and at sites on eight tributaries. Streamflow (also called discharge) is the volume of water passing a given point in the river (reported in cubic feet per second, "cfs"). Streamflow is measured on the mainstem Assabet and Concord Rivers at the USGS gages in Maynard and Lowell, respectively, and reported on the USGS web page. Streamflow on the tributary streams is calculated using a rating curve from staff gage readings taken by OARS volunteers.

Stage-discharge rating (aka "rating curve"): the relationship between stage (water height) and discharge (streamflow). The rating curve is determined empirically by making a series of streamflow measurements at different stages and analyzing the graphed results (figure below).



Temperature affects the ecosystem in a number of ways: many organisms, especially cool water fish, are sensitive to high temperatures; the solubility of oxygen is lower in warmer water, decreasing the supply of dissolved oxygen; algae, weeds, and pathogenic microorganisms can all grow faster in warmer water.

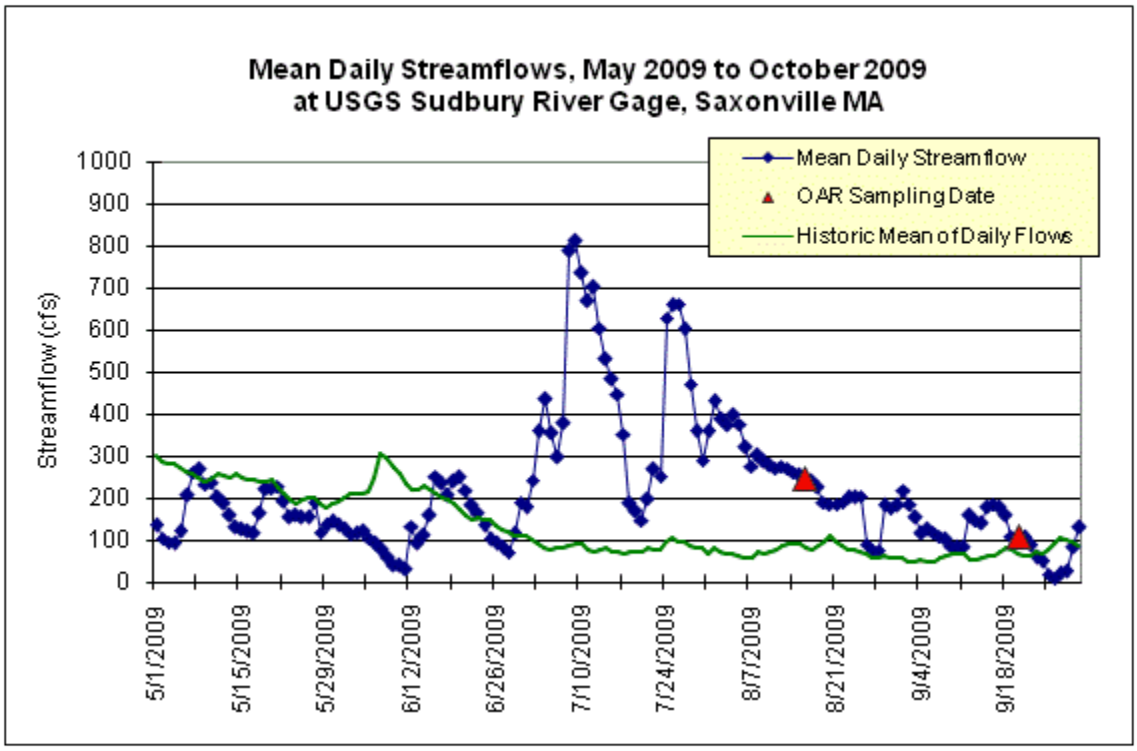
TMDL: Total Maximum Daily Loading, defined under the federal Clean Water Act, is a calculation of the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards, and an allocation of that load among the various sources of that pollutant. More: http://www.epa.gov/owow/tmdl/overviewoftmdl.html

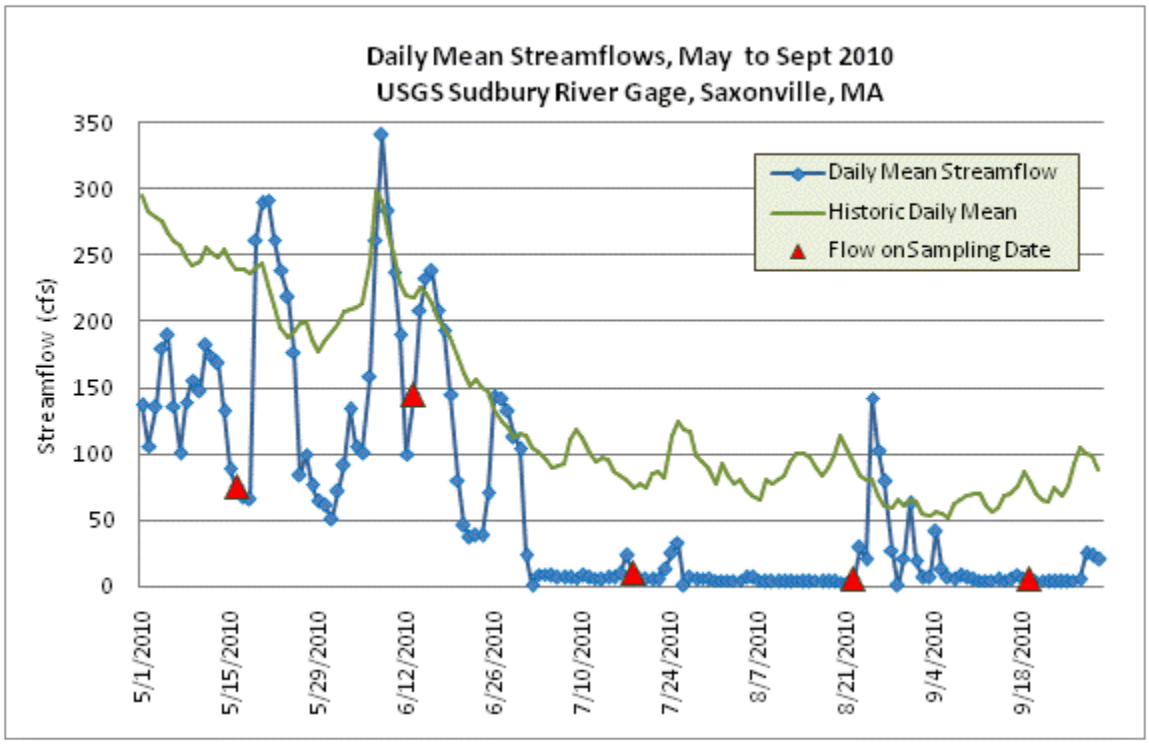
Total suspended solids (TSS): the amount of silt, clay, organic material and algae in the water. Sources include erosion and the solids in effluent. Once in the water column, suspended solids are transported downstream and settle gradually, along with decaying plant matter, to form thick organic-rich sediments in the slower sections of the river.

Tributary: A stream or river whose water flows into a larger stream, river, or lake.

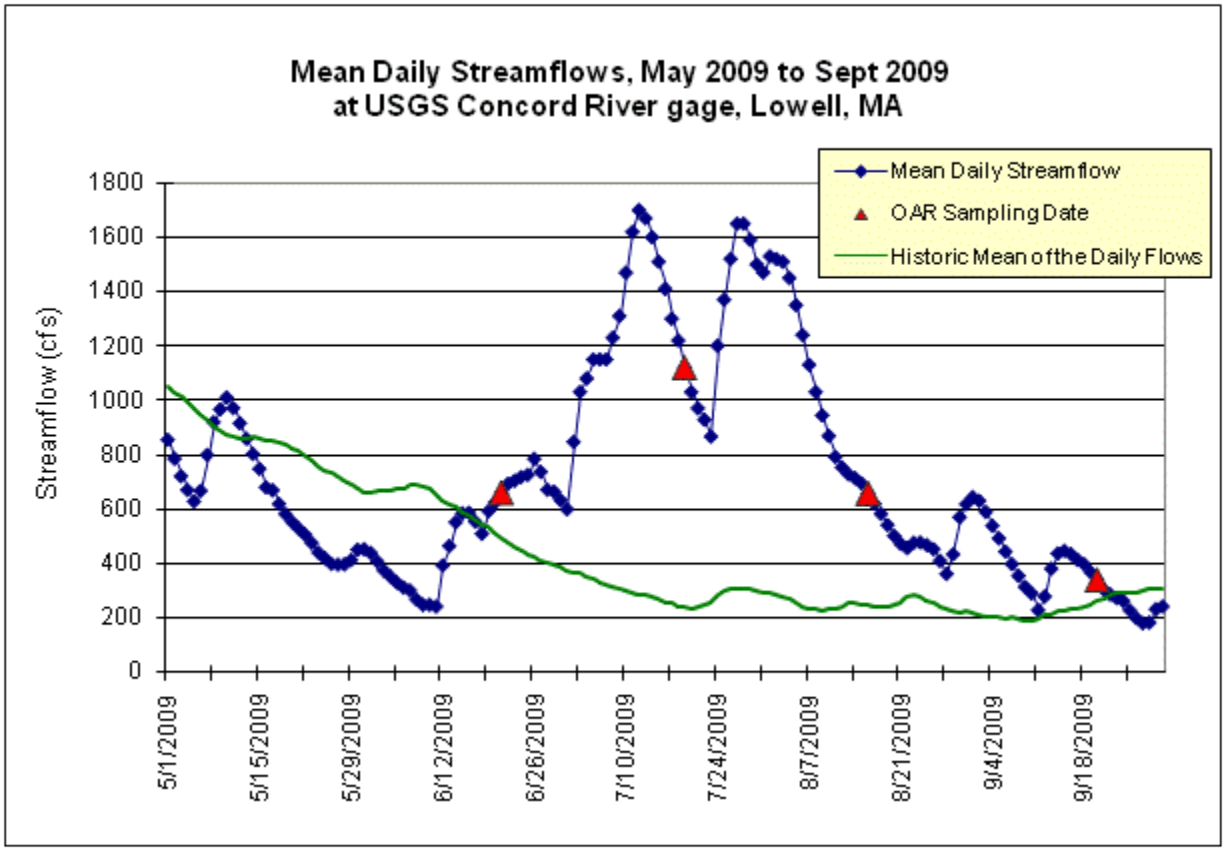
Appendix I: Streamflow Data from USGS Gages

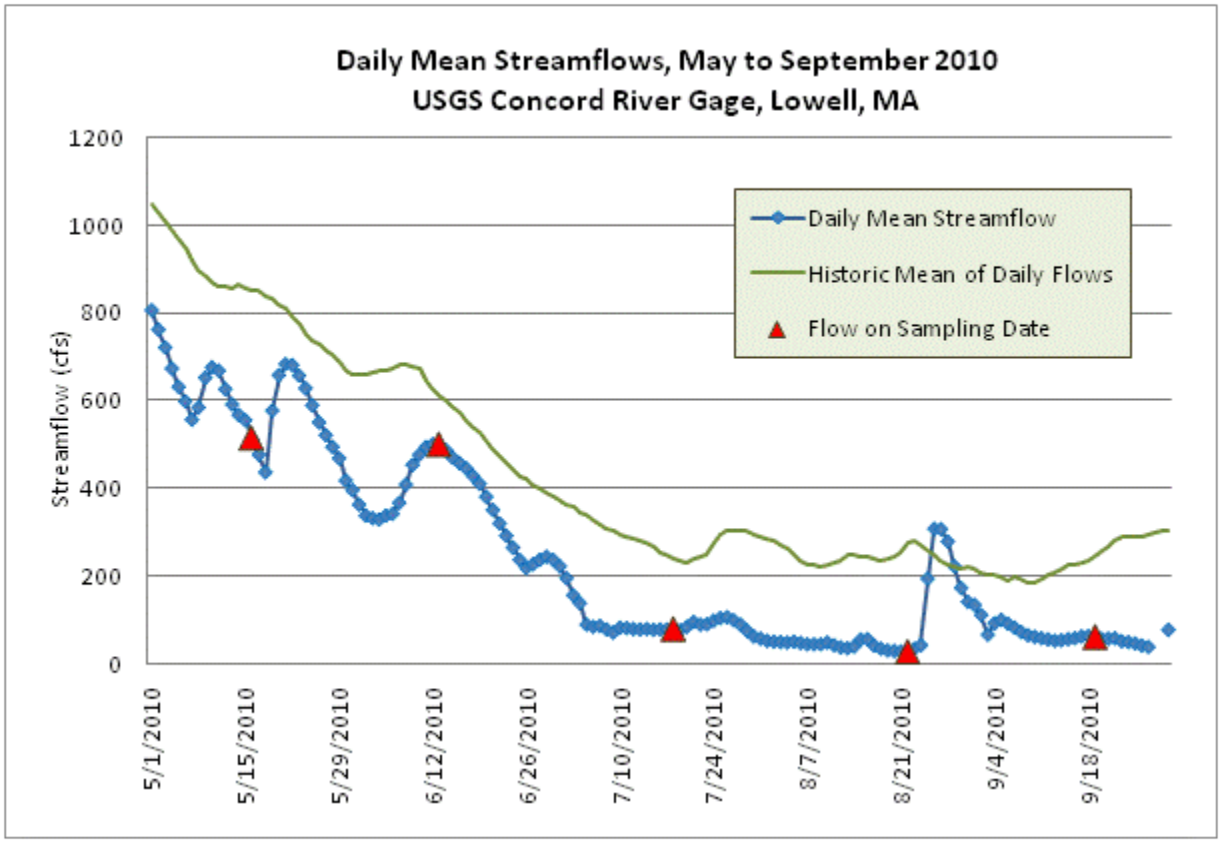
Mean Daily Streamflows: Sudbury River USGS gage, Saxonville, MA



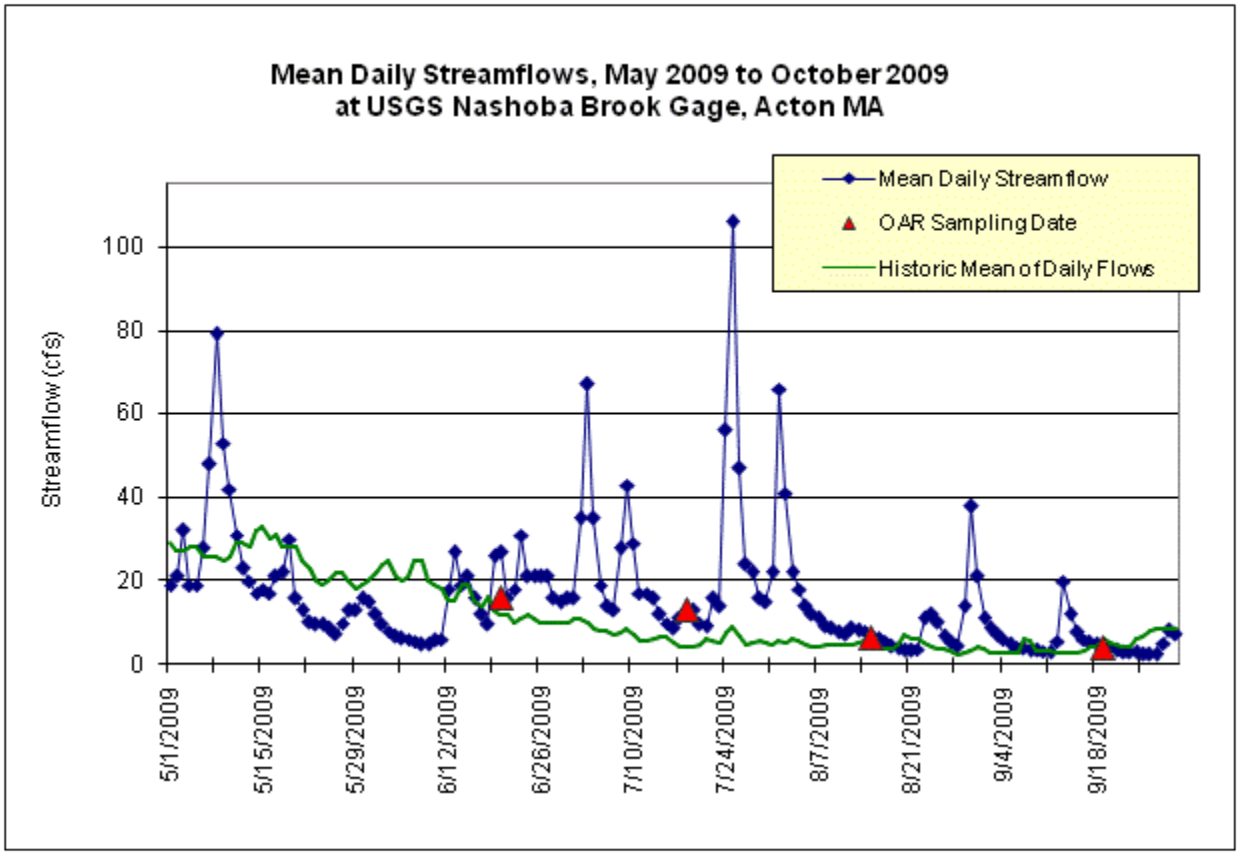


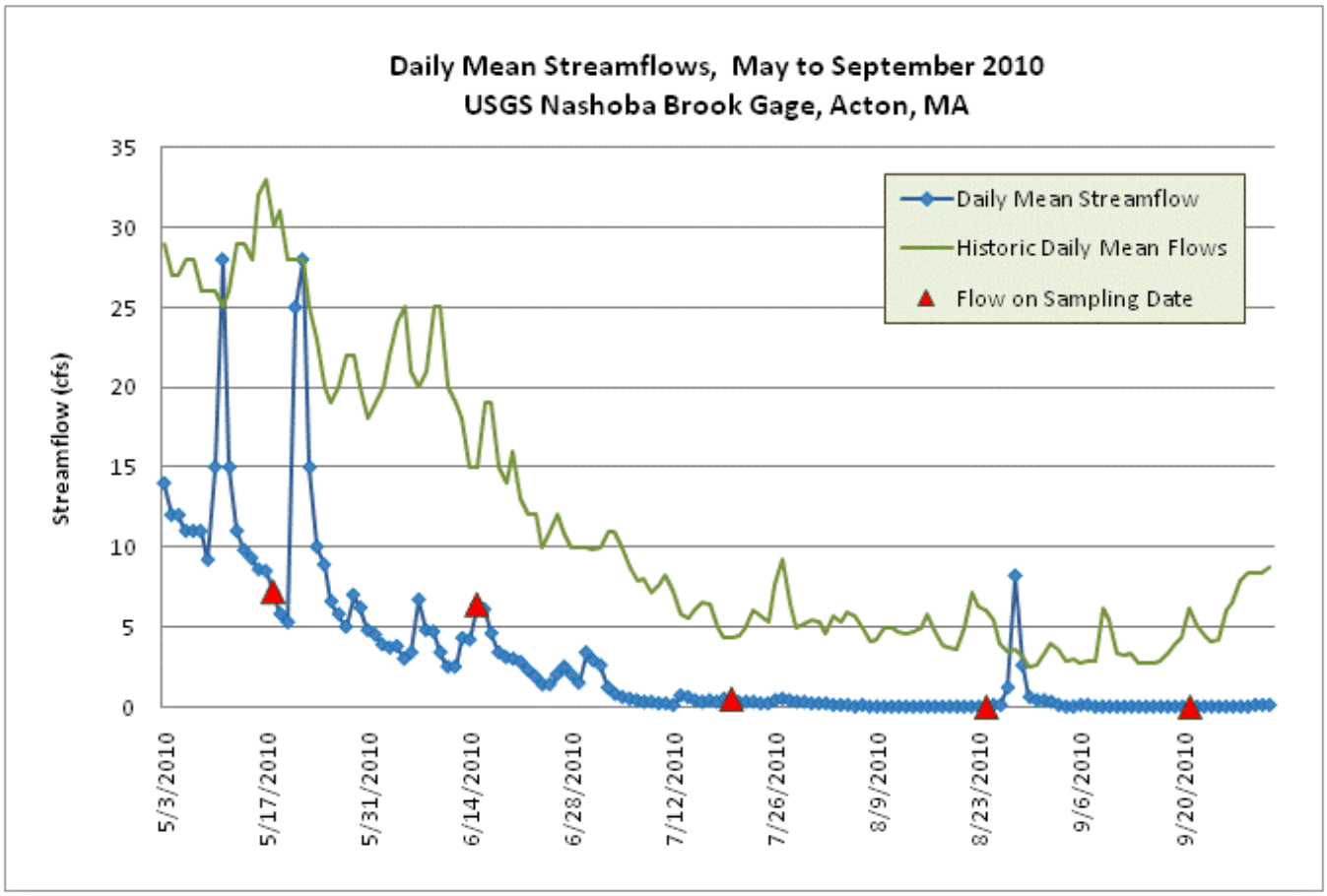
Mean Daily Streamflows: Concord River USGS gage, Lowell, MA





Mean Daily Streamflows: Nashoba Brook USGS gage, Acton, MA





Appendix II: Water Quality Data