Organization for the Assabet River

StreamWatch and Water Quality Monitoring Program
Final Report - Summer 2002

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Acknowledgments

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Cover (clockwise from top left): sensors of a YSI water quality meter, Danforth Brook, StreamWatch sign, Assabet River passing Gleasondale Industries in Stow.

Table of Contents

List of Figures and Tables

Abstract

In 2002, The Organization for the Assabet River's long standing water quality monitoring program was expanded to form the monitoring portion of the Assabet River StreamWatch project. StreamWatch is a cooperative project of the Assabet River Consortium, the Organization for the Assabet River (OAR), USGS, the Massachusetts Division of Fisheries and Wildlife, and the Massachusetts Audubon Society. The goals of the water quality monitoring program are to understand long-term water quality trends, provide sound scientific information to evaluate regulatory decisions, and promote stewardship of the watershed. Data collected by the program also support StreamWatch project goals. Specifically they help characterize fish habitat conditions in the main tributaries of the Assabet and provide timely, accurate information to the public.

Water quality data was collected at 12 mainstem and, for the first time, nine tributary sites in the Assabet River watershed. Weekly streamflow and habitat availability data was also collected at one tributary site, Danforth Brook, to help develop and pilot a Stream Health index for the StreamWatch project. (A full description of the development of the Stream Health index is available separately at www.assabetriver.org/streamwatch/howindex.html.) This report covers the water quality and streamflow data collected on both the mainstem and tributaries in 2002 for the period June to October.

The mean monthly streamflows in 2002 were low from July to the beginning of October at the USGS gage on the Assabet in Maynard as compared with the period of record; daily mean flows were below the 7Q10 for nine consecutive days in late August. Flows in Danforth Brook were very low, dropping from 1.7 cfs when weekly monitoring started in mid-June to <0.05 cfs by the third week of August and remained very low through the middle of October. Dissolved oxygen (DO) concentrations at mainstem Assabet sites below the Westborough wastewater treatment plant discharge (the first wastewater discharge on the river) failed to meet the Massachusetts Class B Water Quality Standards (WQS) DO criteria 5 of 48 measurements from June to September. DO concentrations at tributary and headwater sites failed to meet WQS 14 of 45 measurements; the low DO concentrations on the tributaries appeared to be related to low flows and/or to natural conditions such as upstream marshy conditions or beaver dams.

Total phosphorus (TP) and total nitrogen (TN) concentrations on the mainstem Assabet River below the Westborough wastewater treatment plant discharge were consistently above recommended maximum concentrations. TP concentrations at mainstem sites ranged from <0.01 to 0.46 mg/L, exceeding the EPA "Gold Book" criteria, 0.050 mg/L, in 33 of 44 measurements. Median total phosphorus and total nitrogen concentrations in the headwater and tributary sites were lower than median TP and TN concentrations in the mainstem. TP concentrations in the headwater and tributary sites ranged from <0.01 to 0.47 mg/L, equal to or lower than 0.050 mg/L in 34 of 40 measurements. The highest TP concentrations in the tributaries were measured on Elizabeth Brook downstream of a beaver dam that was breached during the summer.

Introduction

The Assabet River has a watershed of about 177 square miles in eastern Massachusetts and is within EPA's Ecoregion XIV subregion 59, the eastern coastal plain. The Massachusetts Department of Environmental Protection (DEP, 2002b) lists all sections of the Assabet River, from the Assabet River Reservoir (A1 Impoundment) in Westborough to the river's confluence with the Sudbury River in Concord, as Category 5 Waters: "Waters Requiring a TMDL." The tributaries of the Assabet River are largely unassessed (DEP, 2002b).

The mainstem river suffers primarily from eutrophication caused by excess nutrients entering the river. During the growing season, these excess nutrients, phosphorus in particular, fuel nuisance algal and aquatic plant growth which interfere directly with recreational use of the river and cause large daily variations in the concentration of dissolved oxygen in the water, making the river poor habitat for aquatic life. When the algae and plants decay, whenever they are exposed on the river banks and at the end of the growing season, they generate strong sewage-like odors and lower dissolved oxygen levels in the river.

The findings of the Assabet River TMDL Phase One Study (ENSR 2001) confirm that the majority of the nutrients entering the river 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. Non-point sources also contribute nutrients, but, overall, significantly less than the point sources over the growing season. Sediments, which tend to accumulate in the impoundments behind dams, are currently a minor source of nutrients to the river compared with other sources. Sediment quantity and quality in the main impoundments of the river is currently being studied.

Flow, particularly baseflow, is critical to supporting fish and other aquatic life in the river and tributary themselves and is essential to diluting the effluent being discharged to the river. For the nutrient load reductions needed to restore water quality in the mainstem to be effective, 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 combined strain of the increasing demand for water supply and wastewater treatment that results in the net loss of water from many sub-basins, and low baseflow in the mainstem and tributaries.

For these reasons the Organization for the Assabet River (OAR) conducts a water quality monitoring program aimed at understanding water quality and quantity in the mainstem and tributaries of the Assabet. The summer of 2002 was OAR's eleventh consecutive summer collecting data at 12 mainstem sites, including the longest standing sites above and below each major wastewater treatment plant, and its first year collecting data at nine tributary sites. Water quality data collected under OAR's Water Quality Monitoring Program QAPP, approved by the EPA in 2000, may be used by EPA and DEP in making regulatory decisions. The goals of OAR's water quality 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.

In addition, the data collected supports the goals of the StreamWatch project: to characterize fish habitat conditions in the main tributary sub-basins of the Assabet River and provide timely, accurate information to the public, local decision makers, and scientists. Weekly streamflow and habitat availability data was collected at one tributary site, Danforth Brook, to develop and pilot a Stream Health index for the StreamWatch project. (A full description of the development of the Stream Health index is available at www.assabetriver.org/streamwatch/howindex.html.) This report covers the water quality and streamflow data collected on both the mainstem and tributaries.

Methods

Twenty-eight trained volunteers and two OAR staff members monitored water quality at 12 sites along the mainstem and nine sites on the main tributaries of the Assabet (Figure 1, Table 2). Sites are designated a three letter prefix for the waterbody name plus three number designation of 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 June, July, August, and September. In October, only *in-situ* measurements were taken. Staff gage readings were taken weekly at Danforth Brook; pictures of Danforth Brook were taken periodically throughout the summer. Flow and stage readings from the USGS gage at Maynard were downloaded from the USGS web page once a week.

Samples for nutrients and suspended solids were taken using bottles supplied by the laboratories and were stored in the dark on ice during transport from the field to the lab. Samples to be analyzed by Thorstensen Laboratory were delivered to the laboratory within 4 hours. *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. At ten percent of the sites during each sampling event, duplicate field samples were taken. At ten percent of the sites during each sampling event, field blanks of distilled water were taken. Table 2, below, summarizes the parameters measured, laboratory methods and equipment used. A detailed description of sampling methods and quality control measures is available in the QAPP (OAR, 2000a).

Table 1: OAR Sampling Sites - Summer 2002

Reach	New Site #	Old Site #	Site Description	Data Collected		
				In-situ	Bottle Samples	Staff gage
Headwater	ABT-311	31.0	Assabet at Maynard Street, Westboro	X	X	X
Upper Mainstem	ABT-301	30.1	by Rte 9 East bridge, Westboro	X	X	
	ABT-280	28.0	by School St. bridge, Northboro	X	X	
	ABT-242	24.2	by Boundary Rd. bridge, Northboro	X	X	
	ABT-238	23.8	upstream of dam off Robin Hill Rd., Marlboro	X	X	
	ABT-162	16.2	by Cox Street bridge, Hudson	X	X	X
	ABT-144	14.4	downstream of Gleasondale dam, Rte 62, Stow	X	X	
Lower Mainstem	ABT-077	7.7	by USGS gage, Rte 27/62, Maynard	X	X	
	ABT-063	6.3	upstream of Rte 62 nr. Acton Ford, Acton	X	X	
	ABT-033	3.3	by Rte 62 bridge nr. Donut Shop, W. Concord	X	X	
	ABT-026	2.6	by Rte 2 bridge, Concord	X	X	
	ABT-010	1.0	nr Lowell Road, Concord (previously “nr. Dakins Brook”)	X	X	
Tributaries	HOP-011	--	Hop Brook, nr Otis Street, Northboro	X	X	X
	CLD-030	--	Cold Harbor Brook, Cherry Street bridge, Northboro	X	X	X
	NTH-009	--	North Brook, Whitney Ave. bridge, Berlin	X	X	X
	DAN-013	--	Danforth Brook, nr. Rte 85 bridge, Hudson	X	X	X
	FTM-012	--	Fort Meadow Brook, Shay Road bridge, Hudson	X	X	X
	ELZ-004	--	Elizabeth Brook, nr. White Pond Rd., Stow	X	X	X
	NSH-002	T2.9	Nashoba Brook, Commonwealth Ave. bridge, W. Concord	X	X	X
	SPN-003	--	Spencer Brook, Barrett’s Mill Rd bridge, Concord	X	X	X

[a] *In-situ*: temperature, DO, pH, and conductivity
[b] Bottle Samples: TSS, TP, ortho-P, TKN, nitrates, and ammonia

Figure 1: Assabet River Watershed and Sampling Sites 2002

Figure 2: Assabet River Profile - Elevation vs. Rivermile

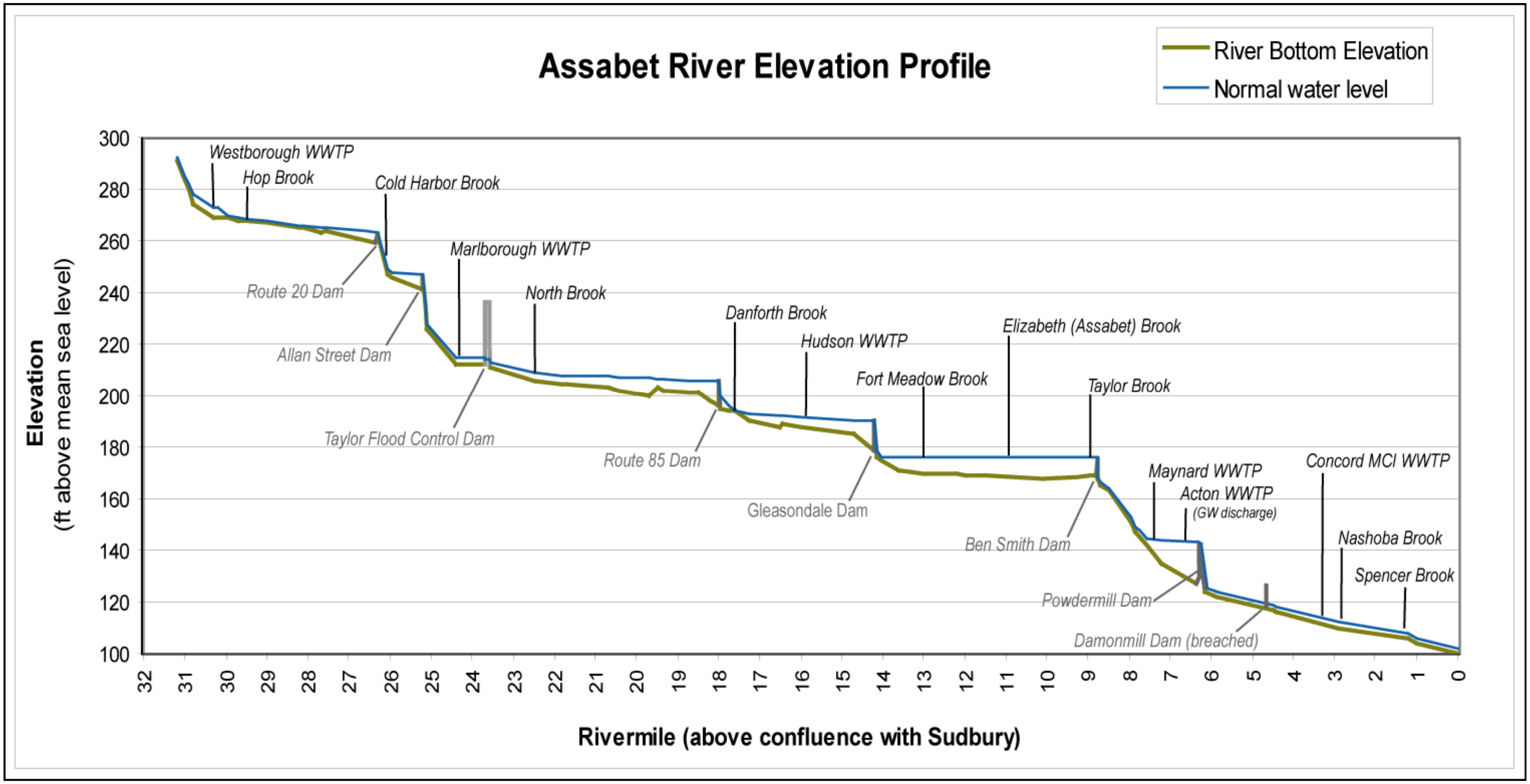


Table 2: Sampling and Analysis Methods

Parameter	Sample Type	Analysis Method #	Detection Limits	Sampling Equipment	Laboratory
Temperature	*in-situ*	---	-5 - 45° C	YSI 6000-series	---
pH	*in-situ*	---	0 to 14 units	YSI 6000-series	---
Dissolved oxygen	*in-situ*	---	0 - 50 mg/L	YSI 6000-series	---
Conductivity	*in-situ*	---	0 to 1000 μS/cm	YSI 6000-series	---
Total Suspended Solids	bottle	EPA 160.2[a]	1.0 mg/L	bottle	Thorstensen Laboratory
Total phosphorus	bottle	EPA 365.2	0.01 mg/L	bottle	Thorstensen Laboratory
ortho-Phosphate	bottle	EPA 365.2	0.01 mg/L	bottle	Thorstensen Laboratory
Total Kjeldahl Nitrogen	bottle	EPA 351.3	0.05 mg/L	bottle	Thorstensen Laboratory
Nitrates	bottle	EPA 352.1	0.01mg/L	bottle	Thorstensen Laboratory
Ammonia	bottle	EPA 350.3	0.03 mg/L	bottle	Thorstensen Laboratory
Fecal Coliforms	bottle	SM 9222D[b]	0 / 100ml	bottle	Thorstensen Laboratory

[a] USEPA, 1983.
[b] American Public Health Association, 1995.

Water quality measurements were compared with the Massachusetts Water Quality Standards for Class B waters (MADEP, 1997) and the guidance for determining use support (MADEP, 2002a) and with the EPA "Gold Book" total phosphorus criteria of 0.05 mg/L TP (USEPA, 1986) (Table 3). All segments of the Assabet are designated Class B warm waters; all of the tributary streams assessed in this project are designated Class B waters. For nutrient concentrations (where the Massachusetts standard is narrative) results were compared with summertime data for Ecoregion XIV subregion 59 streams (Table 4) (USEPA, 2000).

Table 3: Water Quality Standards and Guidance for Use Support

Parameter	Standard
Dissolved oxygen[a]	5.0 mg/l and 60% saturation in warm water fisheries 6.0 mg/l and 75% saturation in cold water fisheries
pH[a]	6.5 – 8.3 for inland waters
Nutrients[a]	"control cultural eutrophication"
Total phosphorus[b]	0.050 mg/L total phosphorus
Temperature[a]	28.3° C and Δ < 2.8° C for warm water fisheries 20.0° C and Δ < 1.7° C for cold water fisheries
Suspended Solids [c]	Aquatic life: 25 mg/L maximum, Δ 10 mg/L due to a discharge
Fecal Coliforms [c]	Primary contact recreational use Dry weather guidance: (<5 samples taken) <400cfu/100ml Wet weather guidance: dry weather samples meet and wet samples ≤ 2000 cfu/100ml Secondary contact recreational use Dry weather guidance: (< 5 samples taken) ≤ 2000 cfu/100ml Wet weather guidance: dry weather samples meet and wet samples ≤ 4000cfu/100ml
Aesthetics Biocommunity [c]	Primary or secondary contact recreational use: no nuisance organisms that render the water aesthetically objectionable or unusable, BPJ; Cover of macrophytes <50% within any portion of the lake area at maximum extent of growth.

[a] MADEP. 1997.
[b] US EPA. 1986.
[c] MADEP. 2002.

Table 4: Reference conditions for aggregate Ecoregion XIV subregion 59 streams [a]

Parameter	Reference condition (25th percentile based on summer data for Ecoregion XIV subregion 59)
Total Phosphorus (mg/L)	0.025
Total Nitrogen (mg/L)	0.44
NO2 + NO3 (mg/L)	0.34
TKN (mg/L)	0.30

[a] USEPA. 2000.

Note that the EPA recommendations for total phosphorus and total nitrogen water quality standards in river systems changed between the draft and final recommendations. In 2000 our results (OAR 2000b) were compared with the draft recommendations (USEPA 1999).

Reaches and Tributaries

All the sites tested this year were in relatively free-flowing sections of the river and tributaries. For the purposes of data analysis, the sites are divided into an upper reach, a lower reach, and the headwater and tributary sites. The upper reach of the river is from site ABT-301 (Route 9, Westborough) to site ABT-144 (Gleasondale, Stow). The lower reach of the river is from site ABT-077 (Route 62, Maynard) to site ABT-010 (near Lowell Road, Concord). For comparison with the mainstem reaches, the headwaters site ABT-311 (Maynard Street, Westborough) is either reported separately or analyzed with the tributary sites. ABT-311 is upstream of the first wastewater treatment plant discharge. Sites HOP-011 (Hop Brook), CLD-030 (Cold Harbor Brook), NTH-009 (North Brook), DAN-013 (Danforth Brook), FTM-012 (Fort Meadow), ELZ-004 (Elizabeth Brook), SPN-003 (Spencer Brook), and NSH-002 (Nashoba Brook) are all tributaries to the Assabet River. Table 5 lists tributary and mainstem basin characteristics calculated using USGS's StreamStats program.

Table 5: StreamStats drainage basin statistics

	Statistics at Mouth of Tributary[a]				
Tributary Streams	Latitude/Longitude at Mouth of Tributary	Drainage Area (sq.mi.)	Stratified Drift Area (sq.mi.)	% area stratified drift	Slope [b] (%)
Cold Harbor Brook, Northboro	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
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
Spencer Brook, Concord	42.4714/-71.3731	7.16	2.16	30.17	2.09
Taylor Brook, Maynard	42.4248/-71.4695	4.15	3.27	78.80	1.38
Mainstem Assabet	Statistics at Mainstem Assabet River Sites[a]				
mouth Assabet, Concord	42.4652/-71.3596	177.81	73.00	41.06	3.01
Boundary St., Marlboro/Northboro	42.3416/-71.6163	34.93	13.70	39.22	3.45
Maynard St., Westboro	42.2741/-71.6322	6.79	1.64	24.15	3.61
outlet of A1 Impound., Westboro	42.2672/-71.6354	6.51	1.53	23.50	3.65

[a] Calculated using USGS's StreamStats program.
[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 for the summer in Table 7, below. Full monthly summaries of the water quality data are attached in the Appendix. Individual parameters are discussed below.

Flow

Streamflow has a direct impact on the concentration of nutrients in the water column and the availability of aquatic habitat and an indirect impact on water temperature, dissolved oxygen concentration, pH, and conductivity. The mild drought that affected New England starting in late 2001 and over the summer of 2002 affected streams throughout the Assabet watershed. According to Mass Department of Environmental Management's Drought Management Task Force, although all areas of the state were downgraded from a drought "warning" to a drought "advisory" in May, monthly rainfalls in July, August, and September were below average and the drought advisory remained in effect until mid-December 2002.

In Table 6 and Figure 3 monthly mean streamflows on the mainstem Assabet for 2002, as measured at the UGSG gage in Maynard (USGS 01097000), are compared with the monthly means for the three previous years and for the period of record (1941 to 2002). Streamflows on the mainstem in 2002 were below 7Q2 flows (20.1 cfs; Wandle and Fontaine, 1984) for 20 consecutive days in August and below 7Q10 flows (15.1 cfs; Wandle and Fontaine, 1894) for nine of those days. Mean monthly streamflows were also below the long-term monthly means in September and October.

Once a week streamflow was calculated from the stage-discharge rating curve for the monitoring site on Danforth Brook (the pilot site for the StreamWatch project). When monitoring started in mid-June, flow in Danforth Brook was 1.7 cubic feet per second (cfs). Streamflows in Danforth dropped steadily during July and August to < 0.05 cfs by the third week of August and remained very low through the middle of October (Figure 4). Streamflows also appeared low at the other tributary sampling sites from July to October and the site at Spencer Brook was completely dry in September.

Table 6: Mean Monthly Streamflows (USGS Gage, Maynard)

	Mean Monthly Streamflows at USGS Gage, Maynard (cfs)				
Time Period	1999	2000	2001	2002	Period of Record [a]
June	29	246	234	151	153
July	20	72	85	37	73
August	19	81	27	19	62
September	95	46	18	25	63
October	92	60	31	54	92

[a] period of record: 1941 – present.
(http://waterdata.usgs.gov/ma/nwis/monthly/?site_no=01097000&agency_cd=USGS)

Figure 3: Mean Monthly Streamflows (USGS Gage, Maynard)

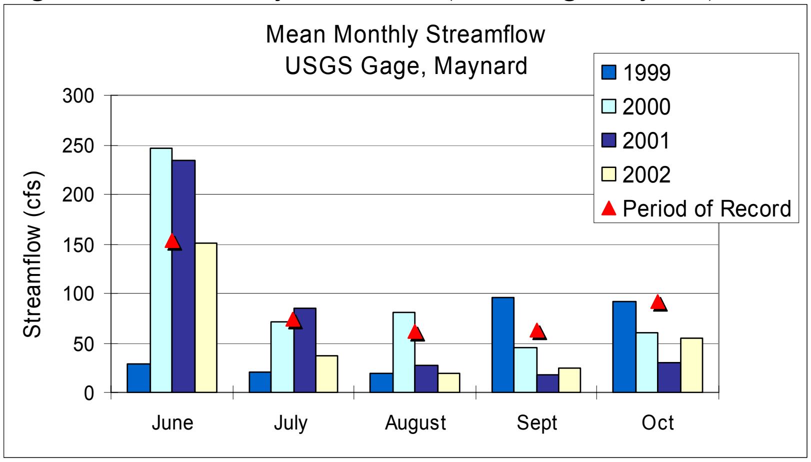


Figure 4: Flow in Danforth Brook - Summer 2002

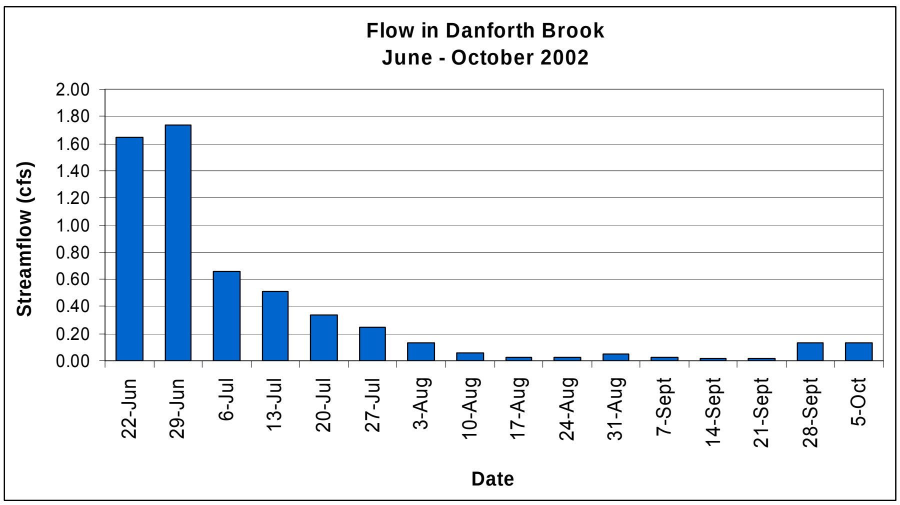


Figure 5: Danforth Brook, Hudson, August 24, 2002 (Flow = <0.05cfs)

Table 7: Reach Statistics

Date	Sites	Reach	Statistic	Water Temp (°C)	DO (mg/L)	DO % Sat.	Cond. (µS/cm)	pH	TSS (mg/L)	Total P (mg/L)	ortho-P (mg/L)	NO3 (mg/L)	NH3 (mg/L)	TKN (mg/L)	Avail. N	Total N
				Mainstem Reach and Tributary Statistics (morning readings between 5:30 – 8:30 am)												
15-June-02	ABT-301 to ABT-010	Mainstem	Minimum	15.18	7.42	76.0	324	6.58	1.0	<0.01	<0.01	0.9	0.06	0.50	0.99	1.43
	ABT-301 to ABT-010	Mainstem	Maximum	17.29	9.32	94.8	414	7.08	8.0	0.31	0.10	2.3	0.21	0.73	2.38	2.72
	ABT-301 to ABT-010	Mainstem	Median	16.43	8.43	87.0	374	6.97	3.0	0.09	0.05	1.4	0.13	0.56	1.50	2.16
	ABT-301 to ABT144	Upper Mainstem	Median	15.47	8.44	84.2	385	6.98	3.5	0.17	0.07	2.0	0.10	0.54	2.03	2.51
	ABT-077 to ABT-010	Lower Mainstem	Median	17.23	8.43	87.7	347	6.96	3.0	0.09	0.04	0.9	0.14	0.56	1.05	1.56
	ABT-311 & Tributaries	Headwater & Tributaries	Minimum	13.92	1.31	14.0	105	5.87	<1.0	<0.01	<0.01	0.01	0.03	0.03	0.04	0.56
	ABT-311 & Tributaries	Headwater & Tributaries	Maximum	17.36	9.38	92.2	386	7.17	6.0	0.25	0.11	0.69	0.14	1.20	0.82	1.51
	ABT-311 & Tributaries	Headwater & Tributaries	Median	16.20	8.84	87.9	176	6.80	2.0	0.005	0.005	0.31	0.06	0.55	0.36	1.10
20-July-02	ABT-301 to ABT-010	Mainstem	Minimum	20.76	5.09	57.2	565	6.37	<1.0	<0.01	<0.01	1.1	0.07	0.15	1.19	1.26
	ABT-301 to ABT-010	Mainstem	Maximum	24.12	7.97	94.0	867	7.38	5.0	0.46	0.12	8.7	0.23	1.40	8.84	9.31
	ABT-301 to ABT-010	Mainstem	Median	22.66	6.34	74.0	679	7.12	1.0	0.01	0.01	2.5	0.11	0.78	2.61	3.37
	ABT-301 to ABT144	Upper Mainstem	Median	21.23	5.78	64.9	738	6.85	1.0	0.21	0.09	4.0	0.13	0.84	4.17	5.11
	ABT-077 to ABT-010	Lower Mainstem	Median	22.99	6.52	75.6	595	7.20	1.0	0.01	0.01	1.1	0.10	0.66	1.20	1.76
	ABT-311 & Tributaries	Headwater & Tributaries	Minimum	18.60	0.74	8.4	63	5.85	<1.0	<0.01	<0.01	<0.01	0.06	0.18	0.09	0.29
	ABT-311 & Tributaries	Headwater & Tributaries	Maximum	23.52	8.42	92.4	704	7.38	27.5	0.47	0.10	1.1	0.70	0.84	1.17	1.28
	ABT-311 & Tributaries	Headwater & Tributaries	Median	20.99	5.84	67.9	361	6.88	1.3	0.01	0.01	0.29	0.08	0.31	0.39	0.59
17-August-02	ABT-301 to ABT-010	Mainstem	Minimum	23.55	1.47	18.2	702	6.51	<1.0*	<0.01*	<0.01*	1.1*	0.03*	0.25*	1.13*	1.55*
	ABT-301 to ABT-010	Mainstem	Maximum	27.27	7.37	93.1	1031	7.52	17.0*	0.42*	0.16*	10.3*	0.34*	1.10*	10.37*	10.82*
	ABT-301 to ABT-010	Mainstem	Median	25.48	6.47	77.6	880	7.16	1.0*	0.10*	0.08*	3.7*	0.07*	0.49*	3.77*	4.14*
	ABT-301 to ABT144	Upper Mainstem	Median	24.46	5.52	65.3	964	6.84	0.8*	0.22*	0.10*	6.8*	0.08*	0.51*	6.87*	7.25*
	ABT-077 to ABT-010	Lower Mainstem	Median	26.12	6.81	84.3	732	7.32	1.0*	0.09*	0.07*	1.3*	0.03*	0.35*	1.33*	1.78*
	ABT-311 & Tributaries	Headwater & Tributaries	Minimum	18.32	1.14	13.3	102	5.94	<1.0*	<0.01*	<0.01*	0.2*	0.02*	0.13*	0.35*	0.54*
	ABT-311 & Tributaries	Headwater & Tributaries	Maximum	27.36	7.90	91.9	831	7.45	18.0*	0.28*	0.19*	1.4*	0.41*	1.70*	1.56*	2.60*
	ABT-311 & Tributaries	Headwater & Tributaries	Median	22.89	4.77	55.5	394	6.78	5.0*	0.005*	0.005*	0.3*	0.12*	0.96*	0.44*	1.40*

* August nutrient data not for regulatory use; data did not pass QC.

Table 7: Reach and Tributary Statistics - Continued

	Sites	Reach	Statistic	Water Temp (ºC)	DO (mg/L)	DO % Sat.	Cond. (µS/cm)	pH	TSS (mg/L)	Total P (mg/L)	ortho-P (mg/L)	NO3 (mg/L)	NH3 (mg/L)	TKN (mg/L)	Avail. N	Total N
21-September-02	ABT-301 to ABT-010	Mainstem	Minimum	18.88	3.44	38.1	572	6.64	<1.0	0.07	0.04	1.4	0.08	0.15	1.77	1.90
	ABT-301 to ABT-010	Mainstem	Maximum	21.14	9.47	106.7	927	7.52	17.0	0.46	0.38	10.5	0.42	0.82	10.69	10.82
	ABT-301 to ABT-010	Mainstem	Median	20.29	7.24	79.4	763	7.17	1.0	0.10	0.08	6.2	0.09	0.32	6.47	6.60
	ABT-301 to ABT144	Upper Mainstem	Median	20.21	6.13	67.4	848	6.88	0.5	0.32	0.29	7.5	0.17	0.30	7.57	7.64
	ABT-077 to ABT-010	Lower Mainstem	Median	20.32	8.56	95.4	634	7.32	2.0	0.08	0.06	1.7	0.25	0.36	1.95	2.02
	ABT-311 & Tributaries	Headwater & Tributaries	Minimum	15.25	1.80	19.2	70	6.22	<1.0	<0.01	<0.01	0.15	0.06	0.18	0.27	0.37
	ABT-311 & Tributaries	Headwater & Tributaries	Maximum	21.28	8.51	91.3	716	7.25	51.0	0.08	0.04	1.1	1.00	1.20	1.70	1.91
	ABT-311 & Tributaries	Headwater & Tributaries	Median	18.68	5.77	62.4	331	7.01	1.0	0.02	0.01	0.21	0.27	0.40	0.54	0.59
19-October-02	ABT-301 to ABT-010	Mainstem	Minimum	10.08	7.19	70.7	344	6.62								
	ABT-301 to ABT-010	Mainstem	Maximum	14.49	10.23	91.3	733	7.31								
	ABT-301 to ABT-010	Mainstem	Median	11.22	9.40	85.4	448	7.12								
	ABT-301 to ABT144	Upper Mainstem	Median	11.08	9.36	84.4	421	6.92								
	ABT-077 to ABT-010	Lower Mainstem	Median	11.27	9.40	86.0	451	7.25								
	ABT-311 & Tributaries	Headwater & Tributaries	Minimum	7.67	3.06	27.2	43	6.21								
	ABT-311 & Tributaries	Headwater & Tributaries	Maximum	11.48	10.71	93.0	423	7.46								
	ABT-311 & Tributaries	Headwater & Tributaries	Median	9.23	9.43	81.8	233	7.02								

Temperature and pH

Dissolved oxygen (DO), water temperature, pH, and conductivity measurements were taken in June, July, August, September, and October between 5:30am – 8:30am, when daily dissolved oxygen concentrations are expected to be at their lowest. Summary statistics for all *in-situ* readings are in Table 7, above.

Water temperatures in the mainstem and tributaries met standards criteria on all dates tested. Temperatures in the mainstem ranged from 7.67 – 27.27 °C, with the lowest readings in October and the highest in August. Temperatures in the tributaries ranged from 8.35 – 27.36 °C, with the lowest reading in October and the highest in August.

pH in the mainstem met standards criteria at all mainstem sites on all dates tested except for ABT-301 in July; pHs in the mainstem ranged from 6.37 – 7.52. In the tributaries, pH's below the WQS (6.5) were measured in Taylor Brook (June, July, and August), Cold Harbor Brook (July, August, September, and October), and Danforth Brook (August and September). The low pH readings were generally associated with dissolved oxygen readings below 5.0 mg/L. The low DO and pH readings were likely a result of stagnant conditions or natural conditions: the flow in Danforth Brook site was virtually stagnant (<0.5 cfs) in August and September; the Cold Harbor Brook site is below a long swampy area (Figure 6); both the Elizabeth and Taylor Brook sites are below beaver dams.

Figure 6: Cold Harbor Brook, near West Street, Northborough, upstream of sampling site.

Dissolved Oxygen

Dissolved oxygen concentrations are generally lowest between 5am – 8am after plant and microbial respiration has been removing oxygen from the water column overnight. Low minimum DO concentrations and large diurnal variations in DO indicate eutrophic conditions. Summary statistics for DO readings are in Table 7, above.

DO concentrations on the mainstem failed to meet standards criteria (≥ 5.0 mg/L and 60% saturation) at one site in July, three sites in August, and one site in September. DO concentrations in the mainstem ranged from 7.42 – 9.32 mg/L in June, 5.09 – 7.97 mg/L in July, 1.47 – 7.37 mg/L in August, 3.44 – 9.47 mg/L in September, and 7.19 – 10.23 mg/L in October. Figures 7 and 8, below, show DO concentrations in August.

DO concentrations at tributary sites failed to meet standards criteria at two sites in June, three sites in July, seven sites in August, three sites in September, and one site in October. The low DO readings were likely a result of upstream swampy conditions, beaver dams, or stagnant conditions at the site. The low DO readings at Elizabeth Brook were investigated further (see "Elizabeth Brook in September," below).

Figure 7: Mainstem Dissolved Oxygen Concentrations - Aug 2002

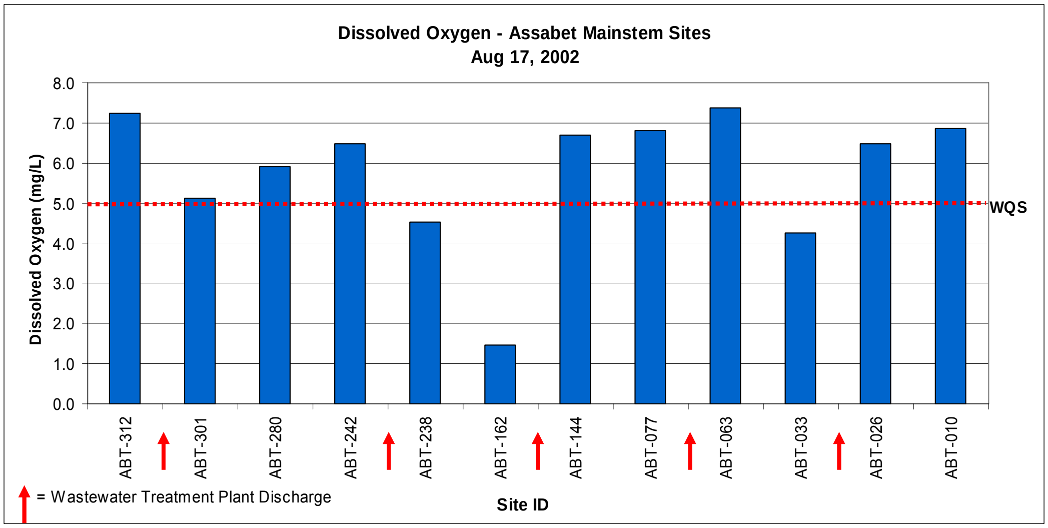
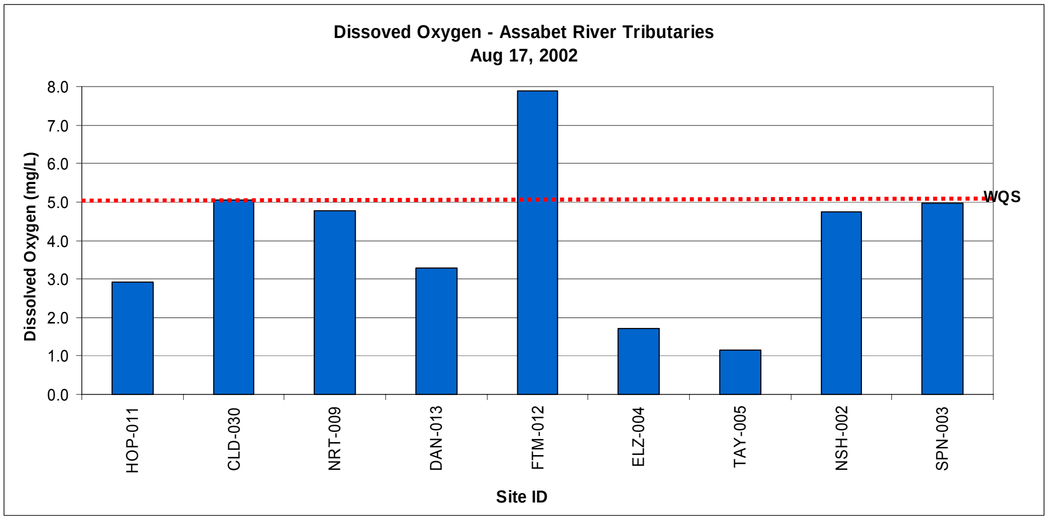


Figure 8: Tributary Dissolved Oxygen Concentrations – Aug 2002



Nutrients

Summary statistics for nutrient concentrations are in Table 7, above. Median nutrient concentrations were calculated for the upper (sites ABT-301 to ABT-144) and lower (sites ABT-077 to ABT-010) mainstem reaches and for the combined headwater and tributary sites. (Figures 9 – 12 show nutrient concentrations in the mainstem vs. the headwater and tributary sites.)

In general, nutrient concentrations along the mainstem below the first wastewater discharge were well above Ecoregion reference conditions (25^{th} percentile of the summertime data) for total phosphorus, total nitrogen, and nitrates. Total phosphorus concentrations in the mainstem ranged from <0.01 – 0.46 mg/L, exceeding the Ecoregion reference condition, 0.025 mg/L, and the EPA "Gold Book" criteria, 0.050 mg/L, in 33 of 44 measurements. Total nitrogen concentrations ranged from 2.16 – 10.82 mg/L, exceeding the reference condition, 0.44 mg/L, in 40 of 40 measurements. Nitrate concentrations ranged from <0.01 mg/L to 10.5 mg/L nitrate-N, exceeding the reference condition, 0.34 mg/L nitrate + nitrite-N, in 44 of 44 measurements. Median nutrient concentrations in the mainstem river were higher in the upper reach than in the lower reach for total phosphorus, ortho-phosphorus, total nitrogen, and nitrate concentrations. Ammonia concentrations ranged from 0.03 – 0.42 mg/L ammonia-N, with median concentrations lower in the upper reach than the lower reach in June and September.

In headwaters and the tributaries, total phosphorus (TP) and ortho-phosphate (ortho-P) concentrations were significantly lower than in the mainstem reaches. Total phosphorus concentrations ranged from <0.01 mg/L – 0.47 mg/L TP, with 29 of 40 total phosphorus readings below 0.025 mg/L TP. Median total phosphorus concentrations in these sites were below the median TP concentrations for both the upper and lower mainstem reaches. The highest total phosphorus concentrations were measured in Elizabeth Brook (see discussion below). Total nitrogen (TN) concentrations in the headwater and tributaries ranged from 0.29 – 2.60 mg/L, exceeding 0.34 mg/L in 27 of 34 measurements. The median TN and nitrate concentrations at the headwater and tributary sites were also lower than median concentrations in the mainstem. Ammonia concentrations ranged from 0.02 – 1.00 mg/L, with the highest measurement at Elizabeth Brook. Median ammonia concentrations were higher in the tributaries than in either mainstem reach in August and higher than in the upper mainstem reach in September.

Figure 9: Total Phosphorus Concentrations (2002)

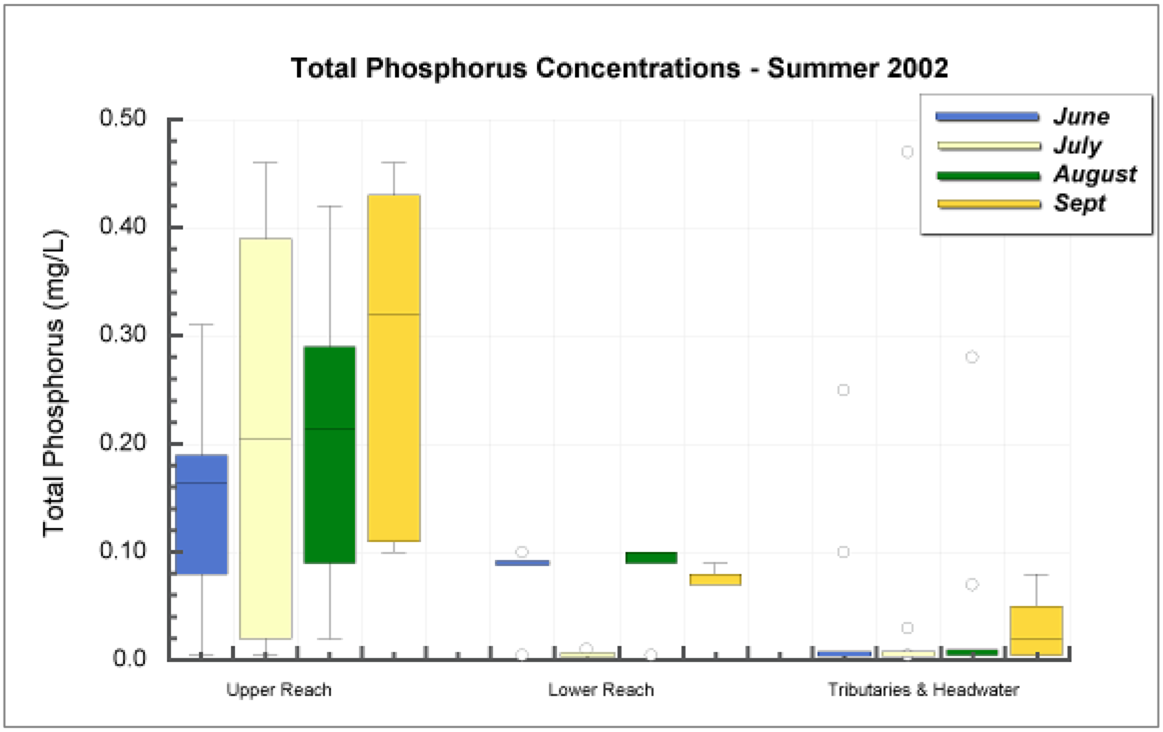


Figure 10: Total Nitrogen Concentrations (2002)

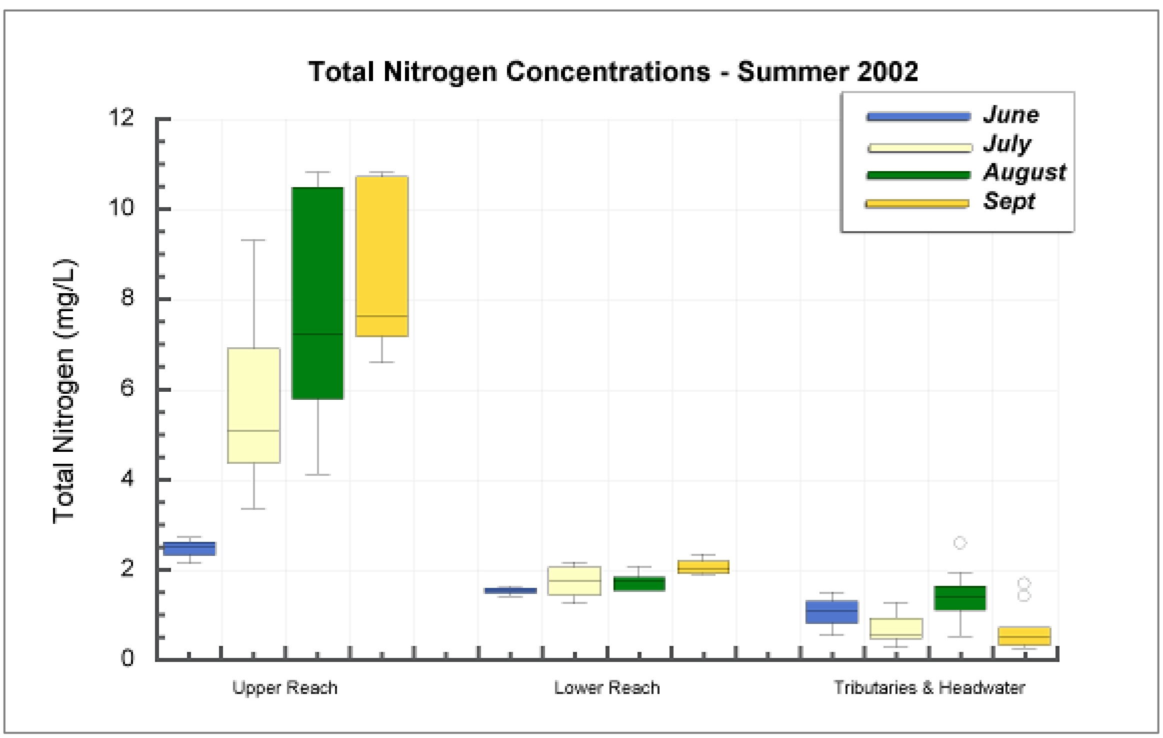


Figure 11: Nitrate Concentrations (2002)

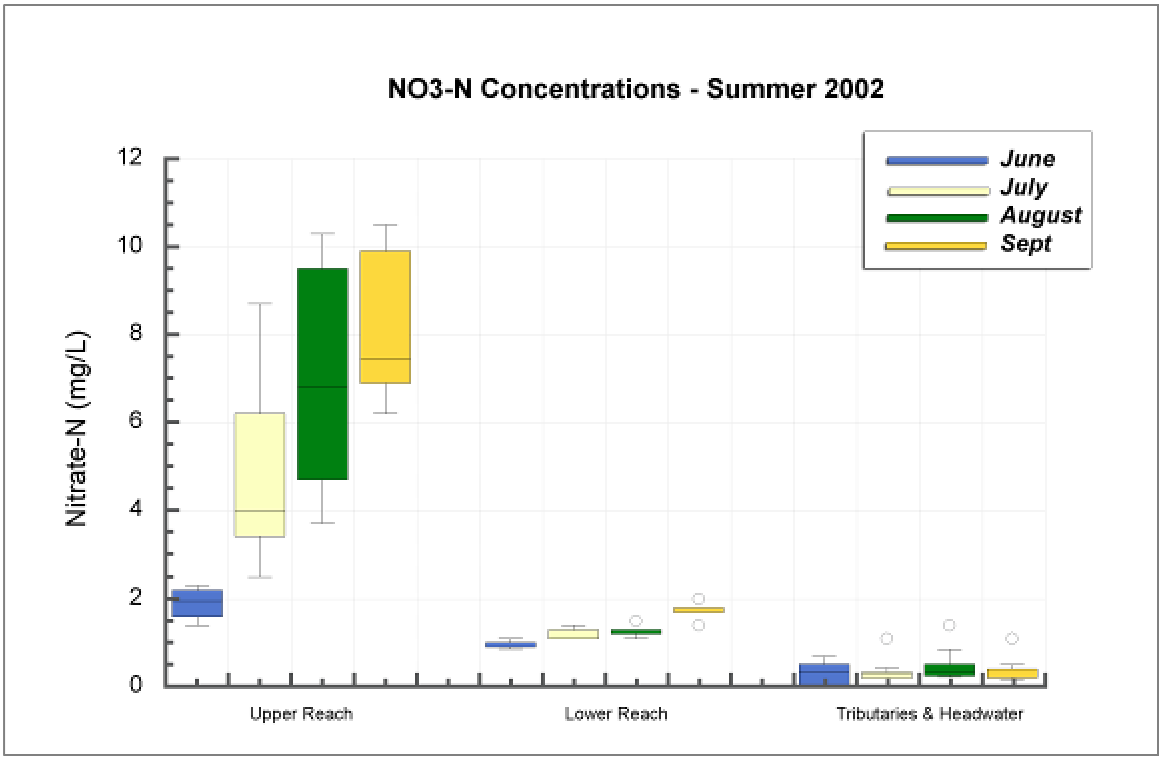
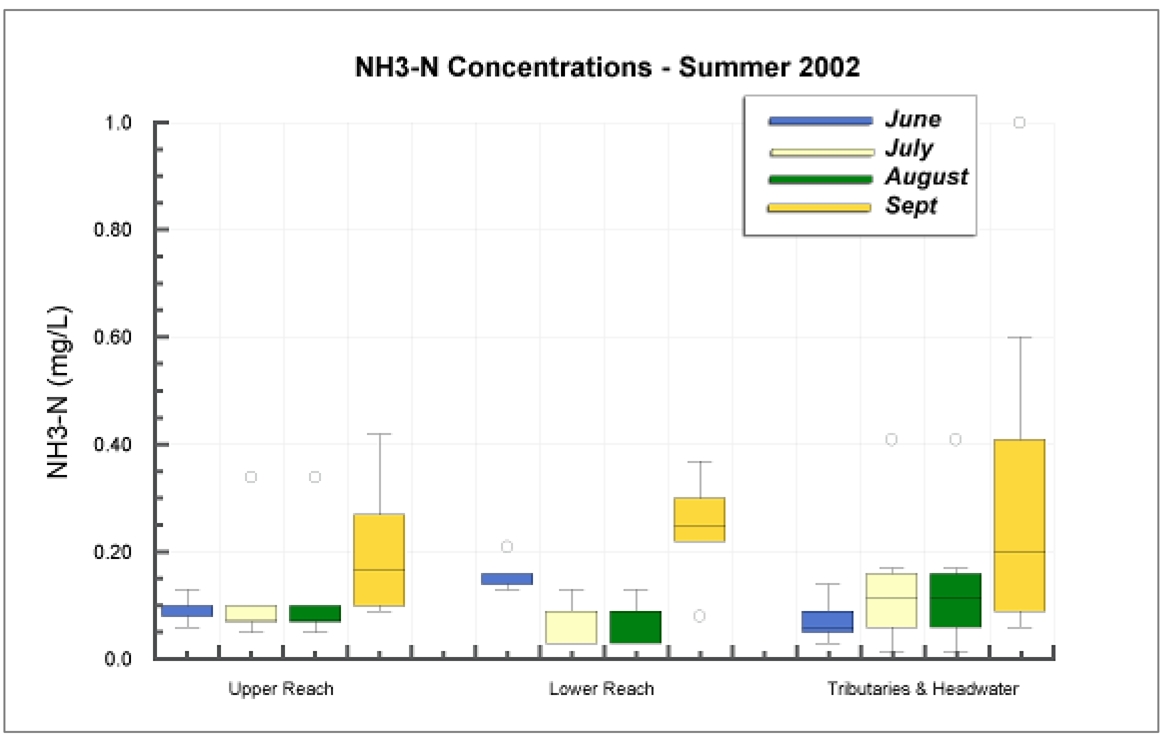


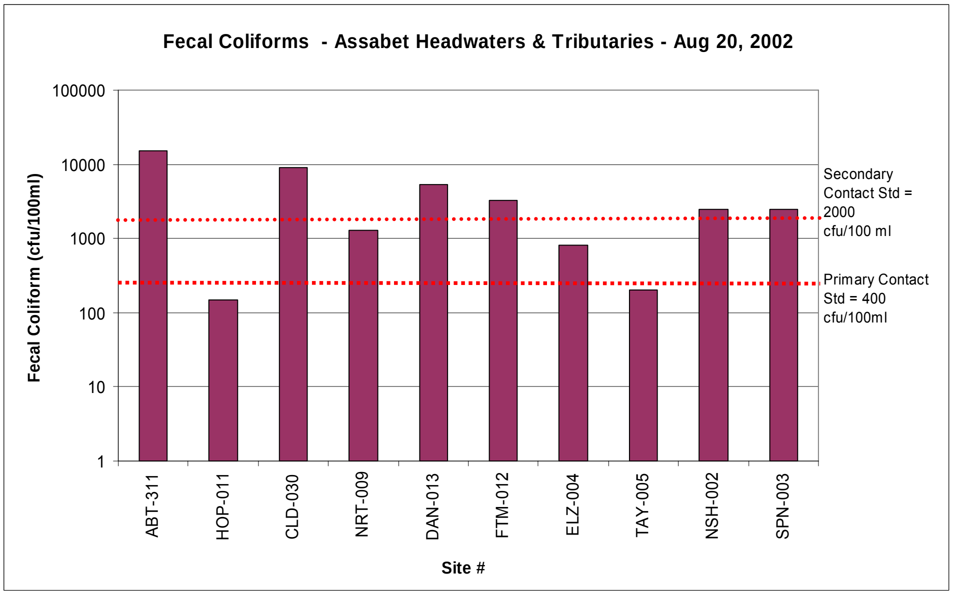
Figure 12: Median Ammonia Concentrations (2002)



Fecal Coliforms

Headwater and tributary sites were tested for fecal coliforms on August 20th in the first six hours after 0.44 inches of rainfall following 14 days with trace or no precipitation. Fecal coliform counts at six of the ten sites tested (Figure 13) exceeded the recommended secondary contact standard (2000cfu/100ml; MADEP 2002a). These results suggest the need for further wet and dry weather sampling on the tributaries.

Figure 13: Fecal coliforms (August 20, 2002)



Elizabeth Brook in September

Because total phosphorus concentrations (Figure 14) in Elizabeth Brook had been higher than in any of the other tributaries over the summer and dissolved oxygen concentrations (Figure 15) in the brook were very low, the brook was surveyed visually on August 20th and further *in-situ* readings were taken upstream on September 25th.

Figure 14: Total Phosphorus Concentrations in Tributaries

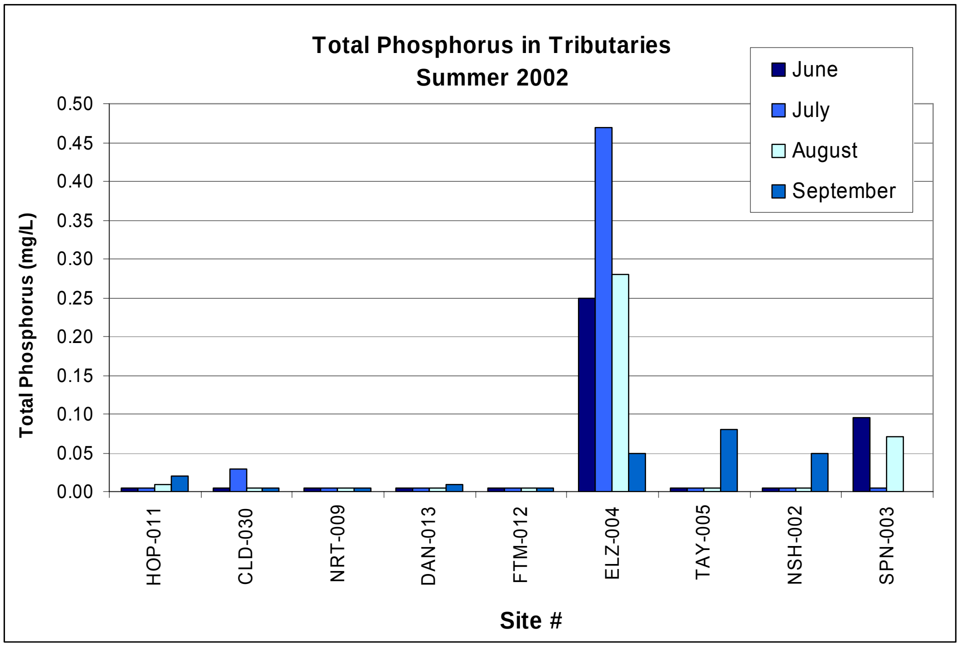
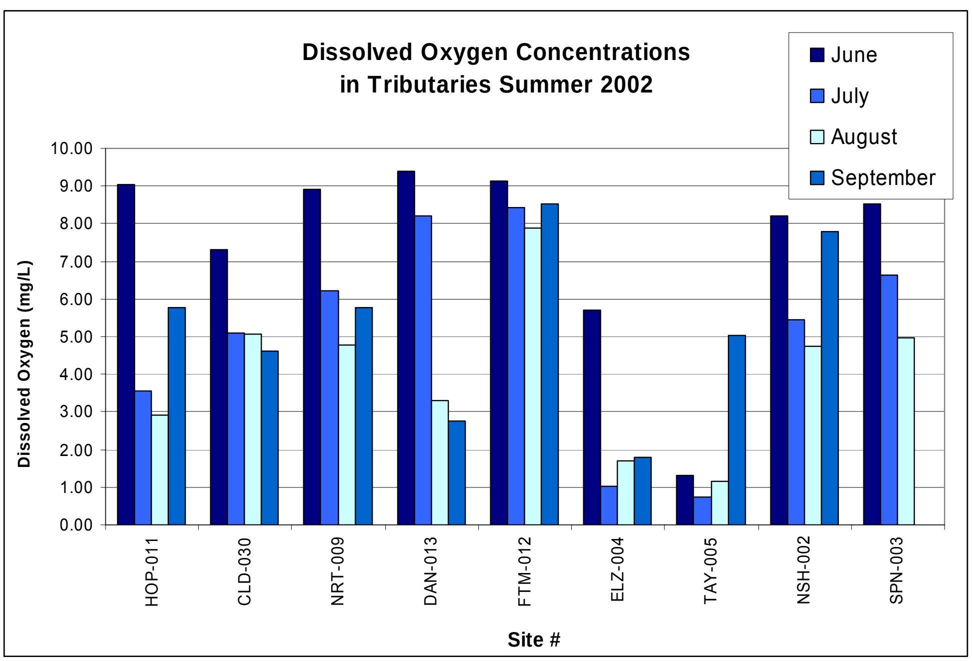


Figure 15: Dissolved Oxygen Concentrations in Tributaries



About 0.6mi upstream from the regular sampling site a beaver dam was found blocking a culvert in the Stow Town Forest (Gardner Hill Conservation Area). When the stream was initially surveyed on August 20th, the beaver dam had been partially breached and was, apparently, releasing stored water from the impounded section above the dam. By September 25th, when the *in-situ* measurements were taken, the beaver dam had been completely removed and grating installed under the culvert. (Figures 16 & 17). *In-situ* measurements were taken at seven sites (Table 8, Figs. 18 & 19) starting at the regular sampling site (ELZ-004) and working upstream. Dissolved oxygen readings in the free-flowing sections of the stream upstream of the area impacted by the beaver dam were over 100% saturation (Table 8); in comparison, DO readings at the two sites downstream of the beaver dam were 32.2% and 41.6%. DO concentrations in Fletcher Pond were also very low (1.18%). It is likely that the low DO concentrations and high nutrient readings at ELZ-004 over the summer reflected the impact of upstream the beaver dam on water quality.

Similarly, the Taylor Brook sampling site is just downstream of a beaver dam blocking a culvert under Old Patrol Road on the Assabet River National Wildlife Refuge, although that dam remained undisturbed through the summer and there was little flow over or through the dam. Dissolved oxygen measurements at Taylor Brook over the summer were very low but, unlike Elizabeth Brook, total phosphorus concentrations (and other nutrients concentrations measured) were low.

Table 8: In-situ readings on Elizabeth Brook, Sept 25, 2002

Elizabeth Brook – September 25, 2002									
Site/Sample ID #			*In-situ* Readings						
Site ID #	Site Name	Town	Time	Water Temp (°C)	DO (mg/L)	DO % Sat	Cond. (µS/cm)	pH
ELZ-051	US* of Delaney Rd bridge	Stow	1:40 PM	19.21	9.81	106.3	338	6.76
ELZ-039	DS* of Rte 117 bridge	Stow	1:28 PM	16.64	9.87	101.4	289	6.82
ELZ-025	US of Wheeler Rd bridge	Stow	1:18 PM	20.22	9.67	106.9	261	6.98
ELZ-019	in Fletcher Pond	Stow	12:57 PM	20.31	1.18	13.1	290	6.65
ELZ-018	Box Mill Rd. DS of dam	Stow	1:04 PM	19.31	7.71	83.7	280	6.82
ELZ-010	DS of culvert at town forest	Stow	12:41 PM	16.50	3.14	32.2	235	6.53
ELZ-004	DS of culvert nr. White Pond Rd.	Stow	12:21 PM	16.62	4.05	41.6	245	6.57

* US = upstream; DS = downstream

Figure 16: Partially-breached beaver dam at Stow Town Forest (August 20, 2002)

Figure 17: Breached beaver dam at Stow Town Forest (September 25, 2002)

Figure 18: Elizabeth Brook Downstream Sampling Sites, Stow MA (Sept 02)

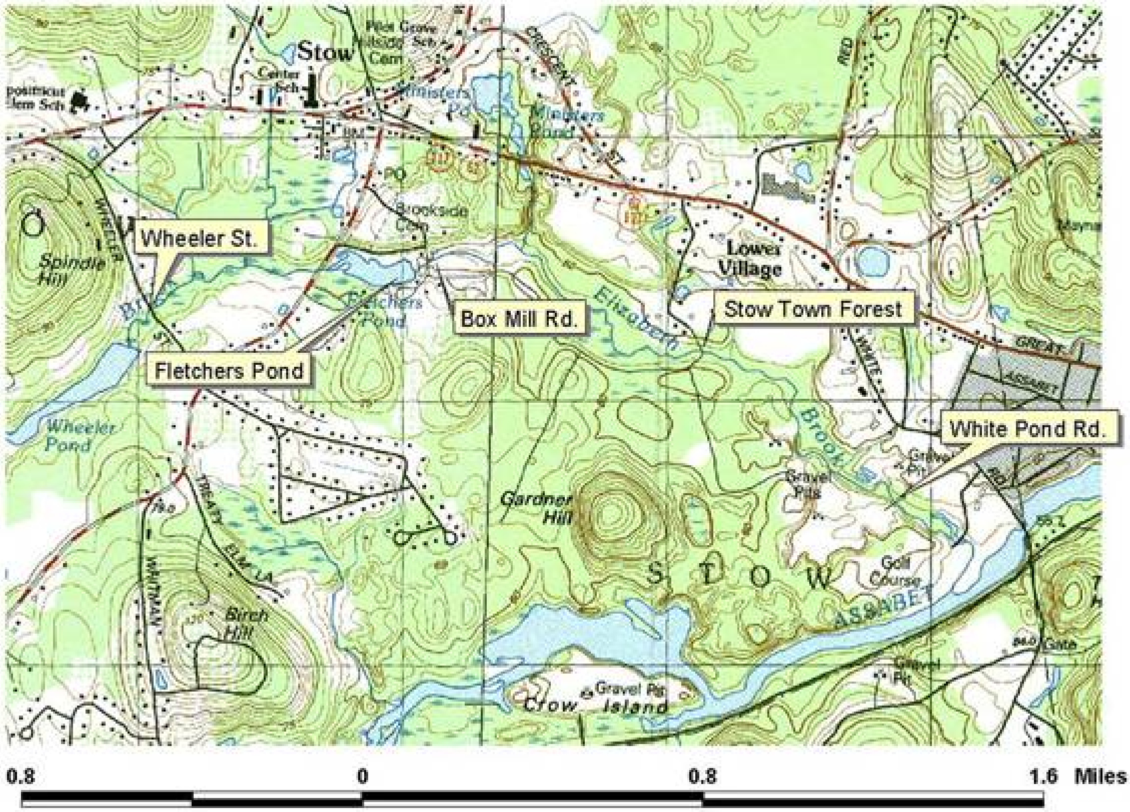
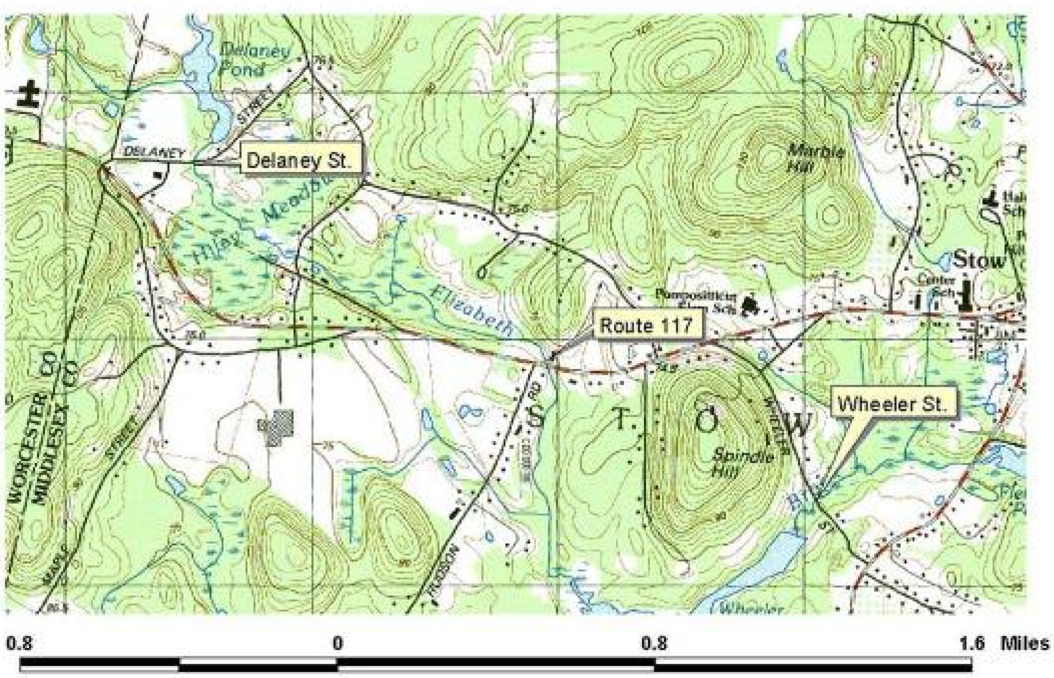


Figure 19: Elizabeth Brook Upstream Sampling Sites, Stow MA (Sept 02)



Conclusions

The mild drought that affected New England over the summer of 2002 affected streams throughout the Assabet watershed. The mean monthly streamflows at the USGS gage on the Assabet in Maynard were near normal in June 2002, but low from July to the beginning of October as compared with the period of record. Flows in Danforth Brook were very low, dropping from 1.7 cfs when monitoring started in mid-June to <0.05 cfs by the third week of August and remaining very low through the middle of October. The sampling site at Spencer Brook was dry in September.

Dissolved oxygen (DO) concentrations at mainstem Assabet sites below the first wastewater treatment plant discharge failed to meet the Massachusetts Class B dissolved oxygen criteria in 5 of 48 measurements (10.4%) from June to September. DO concentrations at tributary and headwater sites failed to meet DO criteria in 14 of 45 measurements (31.1%); the main problems on the tributaries appeared to be related to low flows in the late summer or natural conditions such as upstream marshy conditions or beaver dams.

On the mainstem Assabet River starting below the first wastewater treatment plant discharge, nutrient concentrations, both phosphorus and nitrogen species, were consistently above maximum recommended levels. Total phosphorus concentrations on the mainstem ranged from <0.01 to 0.46 mg/L. Total nitrogen concentrations on the mainstem below the first wastewater discharge ranged from 1.26 to 10.82 mg/L. Median total phosphorus and total nitrogen concentrations in both the upper and lower mainstem reaches were higher than in the headwater and tributary sites.

Nutrient concentrations in the Assabet headwater (upstream of the first wastewater treatment plant discharge) and tributary sites were generally lower than on the mainstem. Total phosphorus concentrations at these sites were generally below the EPA reference condition (25th percentile of the Ecoregion summer data) of 0.025 mg/L TP, ranging from <0.01 – 0.47 mg/L with median concentrations below 0.025 mg/L. The highest TP readings were on Elizabeth Brook in July and August when the upstream beaver dam was likely being breached and releasing the water impounded behind the dam.

Total nitrogen concentrations on the tributaries ranged from 0.29 to 2.60 mg/L. Median total nitrogen concentrations were lower in the headwater and tributaries than in the mainstem. Median ammonia concentrations in headwater and tributary sites varied over the summer with the highest ammonia concentration (1.00 mg/L) measured at the Elizabeth Brook site in September when that site was likely still affected by the breaching of the upstream beaver dam. The median ammonia concentration in the headwaters and tributaries was lower than the mainstem median concentrations in June and July, but higher in August and similar to the mainstem concentrations in September.

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Glossary of Terms

Ammonia (NH3): a form of nitrogen available to 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.

Conductivity: the ability of the water to conduct a charge, which increases with increasing concentrations of charged ions in the water. Conductivity is a rough indicator of pollutants, such as untreated waste, entering the stream.

Dissolved Oxygen: the presence of oxygen gas molecules (O2) in the water. 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.

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

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.

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.

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.

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. pH plays role in the behavior of other pollutants such as heavy metals in the environment. High or low pH levels can be the result of acid rain/snow, chemicals entering the waterways, or algal blooms.

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.

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 measures the volume of water passing a given point in the river. Flow is measured by the USGS at their gage in Maynard and reported on the USGS web page; flow at the Danforth Brook site is calculated from the Danforth rating curve.

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.

Appendix I: Massachusetts Proposed Listing of Individual Categories of Waters

Appendix I: Massachusetts Proposed Listing of Individual Categories of Waters (MADEP 2002)

Massachusetts Category 2 Waters: "Attaining some uses; other uses not assessed"			
Name	Segment ID	Description	Uses Attained
Fort Meadow Brook (8247220)	MA82B-11_2002	Outlet of Fort Meadow Reservoir (Marlboro/Hudson) to confluence with Assabet River, Hudson. Miles 2.8 – 0.0	Aquatic Life Aesthetics
Massachusetts Category 3 Waters: "No Uses Assessed"			
Name	Segment ID	Description	No uses assessed
Elizabeth Brook (8247150)	MA82B-12_2002	From outlet of unnamed pond (Delaney Project) west of Harvard Road to inlet Fletchers Pond, Stow. Miles 3.8 – 0.0	
Nashoba Brook (8246875)	MA82B-14_2002	Source just south of Route 110 in Westford to confluence with Fort Pond Brook, Concord. Miles 9.0 – 0.0	
Spencer Brook (8246825)	MA82B-15_2002	Outlet of unnamed pond, Carlisle north of Bellows Hill to inlet Angiers Pond, Concord. Miles 4.0 – 0.0	
Taylor Brook (8247100)	MA82B-08_2002	Outlet Puffer Pond to confluence with Assabet River, Maynard. Miles 1.80 – 0.0	
Massachusetts Category 4c Waters: "Impairment not caused by a pollutant"			
Name	Segment ID	Description	Impairment Cause
Unnamed tributary (8246805)	MA82B-16_2002	Outlet of Angiers Pond to confluence with Assabet River, Concord. Miles 0.5 – 0.0	Flow alternation
Massachusetts Category 5 Waters: "Waters requiring a TMDL"			
Name	Segment ID	Description	Pollutant Needing TMDL
Assabet River Reservoir (82004)	MA82004_2002	Westborough	Metals; Noxious aquatic plants; Turbidity; (Exotic species)
Warner's Pond (82110)	MA82110_2002	Concord	Metals; Noxious aquatic plants; (Exotic species)
Assabet River (8246775)	MA82B-01_2002	Outlet Flow Augmentation Pond to Westborough WWTP, Westborough. Miles 31.8 – 30.4	Nutrients; Organic enrichment/Low DO; Pathogens
Assabet River (8246775)	MA82B-02_2002	Westborough WWTP, Westborough to Route 20 Dam, Northborough. Miles 30.4 – 26.7	Metals; Nutrients; Organic enrichment/Low DO; Pathogens
Assabet River (8246775)	MA82B-03_2002	Route 20 Dam, Northborough to Marlborough West WWTP, Marlborough. Miles 26.7 – 24.3	Nutrients; Pathogens
Assabet River (8246775)	MA82B-04_2002	Marlborough West WWTP, Marlborough to Hudson WWTP, Hudson. Miles 24.3 – 16.4	Cause unknown; Metals; Nutrients; Organic enrichment/Low DO; Pathogens
Assabet River (8246775)	MA82B-05_2002	Hudson WWTP Hudson to Routes 27/62 at USGS Gage, Maynard. Miles 16.4 – 7.6	Nutrients; Organic enrichment/Low DO; Pathogens
Assabet River (8246775)	MA82B-06_2002	Routes 27/62 at USGS Gage, Maynard to Powdermill Dam, Acton. Miles 7.6 – 6.4	Priority organics; Metals; Nutrients; Organic enrichment/Low DO; Thermal modifications; Taste, odor and color; Suspended solids; Noxious aquatic plants
Assabet River (8246775)	MA82B-07_2002	Powdermill Dam, Acton to confluence with Sudbury River, Concord. Miles 6.4 – 0.0	Nutrients; Organic enrichment/Low DO; Pathogens

Appendix II: Data Summaries