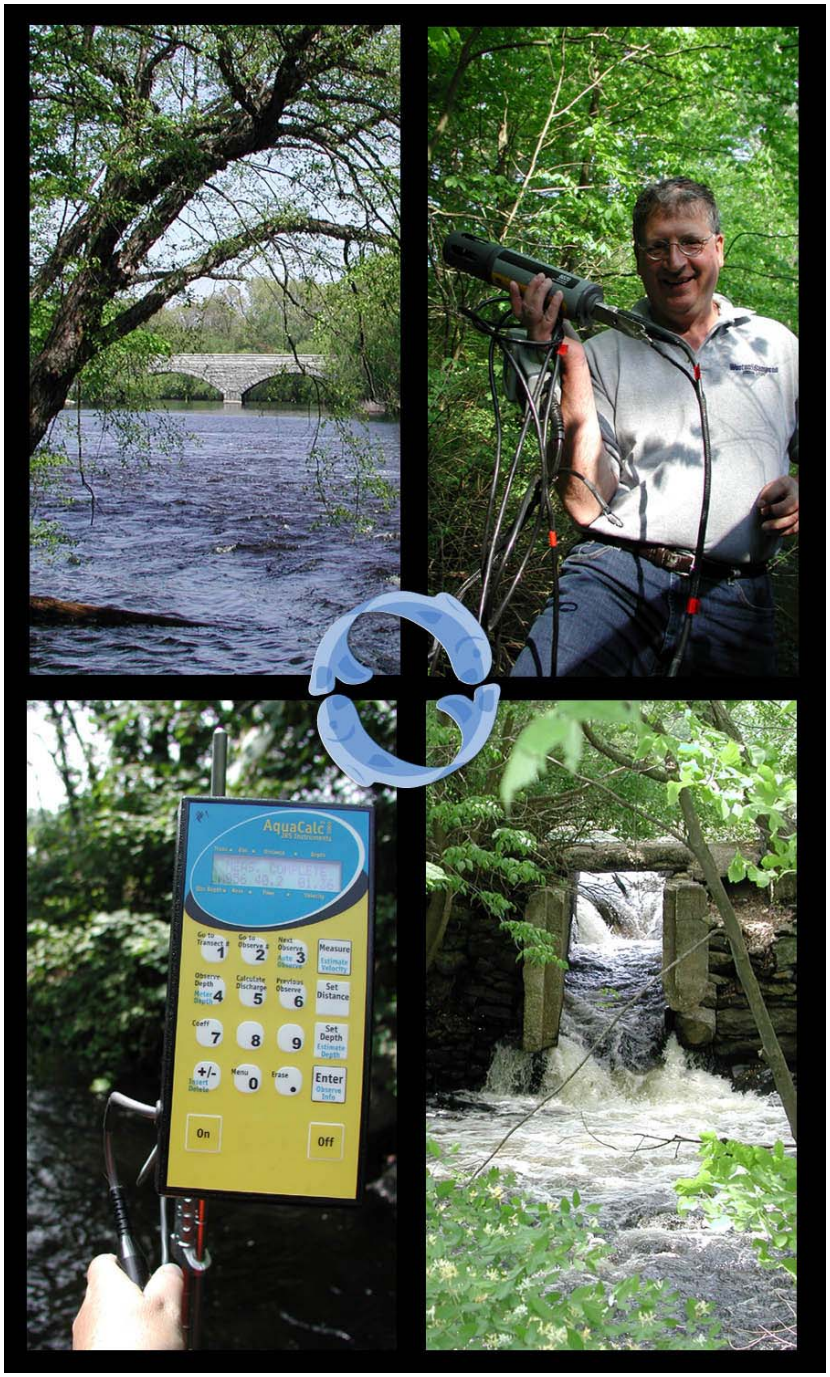
# Organization for the Assabet River

StreamWatch and Water Quality Monitoring Program
Final Report – May to October 2003

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Cover (clockwise from top left): Concord River in Lowell, Len Rappoli sampling, data logger for flow meter, outlet of Wheeler Pond on North Brook, Berlin.

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## Abstract

In the summer of 2003, the Organization for the Assabet River collected water quality and streamflow data once a month on the mainstem of the Assabet River and on eight tributary streams. The goals of OAR's 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: to characterize fish habitat in the main tributaries of the Assabet, and to provide timely, accurate information to the public. This report covers the water quality and streamflow data collected on both the mainstem and tributaries in 2003 for the period May to September.

With near-normal rainfall and streamflows in the watershed during the summer of 2003, streamflow and dissolved oxygen conditions in both the mainstem Assabet and tributary streams were generally above the state's water quality standard ( $\geq$ 5.0 mg/L and 60% saturation). Dissolved oxygen concentrations on the mainstem failed to meet water quality standards only once on the mainstem (Robin Hill Road in August). DO concentrations at tributary sites failed to meet standards criteria at two sites: Cold Harbor Brook (July, August, September) and Elizabeth Brook (July, August, September, and October). The low DO readings at these two sites were likely influenced by upstream swampy conditions or upstream beaver dams. Nutrient concentrations along the mainstem below the first wastewater discharge were well above maximum recommended levels for total phosphorus, total nitrogen, and nitrates. In headwaters and the tributaries, median TP, TN, and NO3 concentrations were significantly lower than in the mainstem reaches, although still above recommended maximum levels in more than half the measurements taken.

Weekly streamflow and habitat availability data were collected at six tributary sites (Hop Brook, Cold Harbor Brook, Fort Meadow Brook, Elizabeth Brook, Danforth Brook, and Nashoba Brook) to calculate "Stream Health Index" readings for those streams as part of the StreamWatch project. (A full description of the development of the Stream Health index is available separately at www.assabetriver.org/streamwatch/howindex.html.). The stream health was rated "excellent" or "good" for most of the 15 weeks assessed: Hop Brook (15 of 15 weeks), Cold Harbor Brook (10 of 15 weeks), Danforth Brook (8 of 15 weeks), Fort Meadow Brook (13 of 15 weeks), Elizabeth Brook (12 of 15 weeks), and Nashoba Brook (12 of 15 weeks). The lowest stream health readings for each stream occurred in late September, when streamflows were at their lowest for the season.

## 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 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 river and causes large daily variations in the concentration of dissolved oxygen in the water, and makes the river 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 dramatically lower the 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. While non-point sources also contribute nutrients, but these sources contribute 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 Assabet River are currently being studied.

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 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 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 major tributaries of the Assabet. The summer of 2003 was OAR's twelfth consecutive summer collecting data at 12 mainstem sites, including the longest standing sites above and below each major wastewater treatment plant, and its second year collecting data at eight tributary sites. Water quality data collected under OAR's Water Quality Monitoring Program QAPP (OAR 2000a), and the Quality Assurance Program Plan for the StreamWatch Project (OAR 2003a) 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 six tributary sites (Hop Brook, Cold Harbor Brook, Fort Meadow Brook, Elizabeth Brook, Danforth Brook, and Nashoba Brook) to calculate "Stream Health Index" readings for those streams as part of the StreamWatch project. (A full description 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. Water quality reports and data from 1999 – 2002 (OAR 2000b, OAR 2001, OAR 2002, OAR 2003b) are available on OAR's website (www.assabetriver.org/wq/) .

**Methods**

Twenty-six trained volunteers, one summer intern, and two OAR staff members monitored water quality at 12 sites along the mainstem and eight sites on the main tributaries of the Assabet (Figure 1, Table 2). Sites are 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 (all tributary sites and five mainsteam sites), June, July, August, September, and October. Staff gage readings and habitat availability estimates at the tributary stream sites were made once a week and reported to the OAR office. Streamflow was calculated from the stage readings using stage/discharge rating curves developed in cooperation with USGS.

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 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. At ten percent of the sites during each sampling event, duplicate field samples and field blanks of distilled water were taken. 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 Water Quality Monitoring Program QAPP (OAR, 2000a) and the QAPP for the StreamWatch Project (OAR, 2003a).

**Table 1: OAR Sampling Sites - Summer 2003**

| 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 | by Rte 62 bridge nr. Acton Ford, Acton | X | X | |
| | ABT-033 | 3.3 | by Rte 62 bridge nr. pump station, 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 2003**

**Figure 2: Assabet River Profile - Elevation vs. Rivermile**

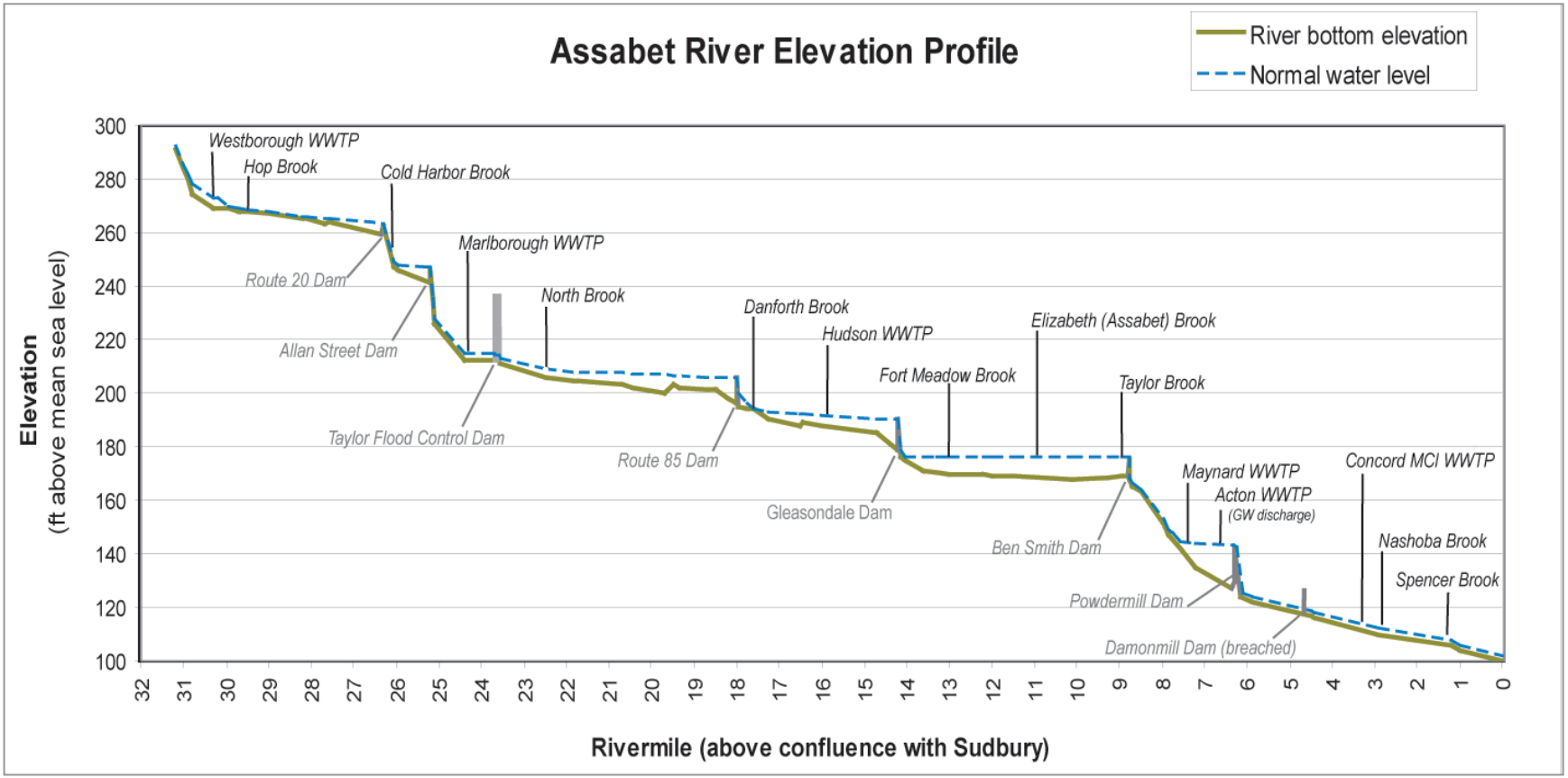


**Table 2: Sampling and Analysis Methods**

| Parameter | Sample Type | Analysis Method # | Equipment Range/ 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 300.0 | 0.01mg/L | bottle | Thorstensen Laboratory |
| Ammonia | bottle | EPA 350.3 | 0.03 mg/L | 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 (MA DEP, 1997) and the guidance for determining use support (MA DEP, 2002a) (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 the EPA "Gold Book" total phosphorus criteria of 0.05 mg/L TP (US EPA, 1986) (Table 3) and with summertime data for Ecoregion XIV subregion 59 streams (US EPA, 2000) (Table 4).

**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<br>6.0 mg/l and 75% saturation in cold water fisheries |
| pH | 6.5 – 9.0 for freshwater aquatic life [b]<br>6.5 – 8.3 inland waters (upper limit is a swimming standard) [a] |
| Nutrients[a] | "control cultural eutrophication" |
| Total phosphorus[b] | 0.050 mg/L total phosphorus |
| Temperature[a] | 28.3° C and $\Delta$ < 2.8° C for warm water fisheries<br>20.0° C and $\Delta$ < 1.7° C for cold water fisheries |
| Suspended Solids [c] | Aquatic life: 25 mg/L maximum, $\Delta$ 10 mg/L due to a discharge |
| Aesthetics<br>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] MA DEP. 1997.
[b] US EPA. 1986.
[c] MA DEP. 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.

## *Reaches and Tributaries*

All the sites tested 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 (Table 1). 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 on 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 |
| 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 (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 (see Table 1 for reaches) 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 I. Individual parameters are discussed below.

### *Flow*

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.

Figure 3 shows daily mean streamflows recorded at the USGS gage in Maynard for the sampling period, May through October 2003, compared with the daily means for the period of record (1941 to 2003). Daily mean streamflows over the sampling period in 2003 were generally near or above the daily means for the period of record. Precipitation, as measured at the National Weather Service (NWS) Worcester station, in the area was slightly higher than average (104%) for the May to October period (Table 6).

Precipitation and the consequent stormwater runoff preceeding a sampling affects water quality. Because increased stormwater runoff is correlated with increased concentrations of total suspended solids, total phosphorus, and nitrate/nitrites, it is worthwhile noting precipitation before and during the sampling. For the purposes of this project a "dry weather" sampling is considered that which is preceeded by at least 48 hours with less than 0.1" of rain. In 2003, the May and October sampling days were dry weather; June, July, August, and September sampling days were wet weather. Figure 4 shows daily rainfall as recorded at the USGS gage in Maynard for May to October with the sampling days indicated.

**Table 6: Rainfall Data (May - Oct 2003 )**

| **2003 Rainfall Data from NWS Worcester Station*** | | | | |
|---|---|---|---|---|
| Month | Monthly precip (in.) | 30-year average (in.) | Departure from average (in.) | % of average |
| May | 4.13 | 4.35 | -0.22 | 95 |
| June | 6.16 | 4.02 | 2.14 | 153 |
| July | 3.05 | 4.19 | -1.14 | 73 |
| Aug | 2.96 | 3.37 | -0.41 | 88 |
| Sept | 4.26 | 4.27 | -0.01 | 100 |
| Oct | 5.42 | 4.67 | 0.75 | 116 |
| May – Oct | 25.98 | 24.87 | 1.11 | 104 |

* http://www.erh.noaa.gov/box/MonthlyClimate2.shtml

Once a week streamflow was calculated from stage readings and stage-discharge rating curves for six of the tributary monitoring sites: Hop Brook, Cold Harbor Brook, Danforth Brook, Fort Meadow Brook, Elizabeth Brook, and Nashoba Brook. Stage-discharge rating curves are being developed for another 3 sites. These streamflow readings were used, along with water quality results and habitat availability readings, to calculate weekly Stream Health Index readings for the tributaries. The Stream Health Index readings are discussed below; the full data set and index readings are attached in Appendix III.

**Table 7: Mainstem Reach and Tributary WQ Statistics**

| | | | | Mainstem Reach and Tributary Statistics (morning readings between 5:30 – 8:30 am) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | Reach | Sites | 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) | Total N |
| 19 & 20-May-03 | Assabet Mainstem (4 sites) | ABT-280 - ABT-077 | Minimum | n/a | n/a | n/a | n/a | n/a | <1 | 0.060 | 0.035 | 1.1 | <0.03 | 0.16 | 1.27 |
| | | ABT-280 - ABT-077 | Maximum | n/a | n/a | n/a | n/a | n/a | 5 | 0.289 | 0.149 | 3.0 | 0.06 | 0.61 | 3.16 |
| | | ABT-280 - ABT-077 | Median | n/a | n/a | n/a | n/a | n/a | 4.5 | 0.160 | 0.096 | 2.1 | <0.03 | 0.21 | 2.53 |
| | Headwater & Tribs ( 9 sites) | ABT-311 & Tribs | Minimum | 12.00 | 75.3 | 8.00 | 127 | 6.59 | <1 | 0.013 | <0.006 | <0.01 | <0.03 | 0.12 | 0.13 |
| | | ABT-311 & Tribs | Maximum | 15.57 | 102.1 | 10.62 | 473 | 7.14 | <1 | 0.046 | 0.018 | 0.57 | <0.03 | 0.55 | 1.05 |
| | | ABT-311 & Tribs | Median | 14.05 | 96.6 | 9.93 | 327 | 7.00 | <1 | 0.029 | 0.010 | 0.38 | <0.03 | 0.20 | 0.58 |
| 14-June-03 | Assabet Mainstem (11 sites) | ABT-301 - ABT-010 | Minimum | 14.67 | 75.5 | 7.48 | 323 | 6.57 | 3 | 0.122 | <0.006 | 0.79 | 0.07 | 0.72 | 1.5 |
| | | ABT-301 - ABT-010 | Maximum | 17.75 | 98.6 | 9.38 | 353 | 6.94 | 13 | 0.237 | 0.178 | 1.9 | 0.21 | 1.8 | 3.7 |
| | | ABT-301 - ABT-010 | Median | 17.52 | 88.5 | 8.63 | 338 | 6.78 | 7 | 0.160 | 0.085 | 0.90 | 0.13 | 1.0 | 1.9 |
| | Upper Assabet Mainstem (6 sites) | ABT-301 - ABT-144 | Median | 16.14 | 79.2 | 7.74 | 338 | 6.76 | 6 | 0.178 | 0.109 | 1.10 | 0.11 | 1.2 | 2.3 |
| | Lower Assabet Mainstem (5 sites) | ABT-077 - ABT-010 | Median | 17.67 | 90.8 | 8.65 | 344 | 6.85 | 9 | 0.142 | 0.071 | 0.84 | 0.14 | 0.83 | 1.7 |
| | Assabet Head & Tributaries (9 sites) | ABT-311 & Tribs | Minimum | 14.41 | 63.8 | 6.17 | 108 | 6.34 | <1.0 | 0.022 | <0.006 | 0.23 | 0.06 | 0.59 | 1.0 |
| | | ABT-311 & Tribs | Maximum | 18.72 | 97.5 | 9.70 | 433 | 7.10 | 9 | 0.074 | 0.040 | 0.50 | 0.16 | 1.3 | 1.8 |
| | | ABT-311 & Tribs | Median | 16.65 | 89.0 | 8.33 | 286 | 6.70 | 7 | 0.049 | 0.021 | 0.36 | 0.11 | 0.73 | 1.1 |
| 12-July-03 | Assabet Mainstem (11 sites) | ABT-301 - ABT-010 | Minimum | 18.36 | 73.1 | 6.80 | 424 | 6.83 | 2 | 0.073 | 0.068 | 1.0 | 0.08 | 0.21 | 1.28 |
| | | ABT-301 - ABT-010 | Maximum | 22.26 | 94.3 | 8.49 | 567 | 7.20 | 9 | 0.216 | 0.205 | 2.2 | 0.13 | 0.36 | 2.49 |
| | | ABT-301 - ABT-010 | Median | 20.41 | 83.2 | 7.48 | 517 | 7.07 | 6 | 0.117 | 0.096 | 1.2 | 0.10 | 0.28 | 1.45 |
| | Upper Assabet Mainstem (6 sites) | ABT-301 - ABT-144 | Median | 19.36 | 77.4 | 7.17 | 538 | 7.03 | 6 | 0.132 | 0.113 | 1.8 | 0.12 | 0.31 | 2.10 |
| | Lower Assabet Mainstem (5 sites) | ABT-077 - ABT-010 | Median | 21.42 | 85.8 | 7.57 | 468 | 7.10 | 7 | 0.106 | 0.095 | 1.1 | 0.09 | 0.28 | 1.38 |
| | Assabet Head & Tributaries (9 sites) | ABT-311 & Tribs | Minimum | 17.80 | 49.5 | 4.70 | 127 | 6.65 | 2 | 0.007 | <0.006 | 0.34 | 0.05 | 0.14 | 0.54 |
| | | ABT-311 & Tribs | Maximum | 22.17 | 94.3 | 8.86 | 596 | 7.65 | 12 | 0.051 | 0.042 | 2.4 | 0.11 | 0.27 | 2.58 |
| | | ABT-311 & Tribs | Median | 18.87 | 76.5 | 7.01 | 349 | 6.89 | 4 | 0.022 | 0.019 | 0.44 | 0.08 | 0.20 | 0.61 |

* calculated as ½ detection level where samples are BDL

Table 7: Mainstem Reach and Tributary Statistics - Continued

| | 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) | Total N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9-August-03 | Assabet Mainstem (11 sites) | ABT-301 - ABT-010 | Minimum | 22.45 | 58.4 | 5.06 | 332 | 6.44 | 1 | 0.091 | 0.055 | 0.6 | 0.03 | 0.26 | 0.9 |
| | | ABT-301 - ABT-010 | Maximum | 24.10 | 92.8 | 7.81 | 481 | 7.01 | 13 | 0.173 | 0.114 | 1.8 | 0.1 | 0.58 | 2.2 |
| | | ABT-301 - ABT-010 | Median | 23.37 | 78.4 | 6.68 | 444 | 6.68 | 6 | 0.128 | 0.080 | 1.1 | 0.08 | 0.42 | 1.56 |
| | Upper Assabet Mainstem (6 sites) | ABT-301 - ABT-144 | Median | 22.97 | 76.0 | 6.48 | 455 | 6.61 | 3.5 | 0.155 | 0.104 | 1.4 | 0.09 | 0.45 | 1.83 |
| | Lower Assabet Mainstem (5 sites) | ABT-077 - ABT-010 | Median | 23.93 | 83.4 | 7.00 | 390 | 6.77 | 10 | 0.098 | 0.066 | 0.64 | 0.07 | 0.37 | 1.06 |
| | Assabet Head & Tributaries (9 sites) | ABT-311 & Tribs | Minimum | 21.67 | 40.9 | 3.60 | 147 | 6.26 | <1.0 | <0.006 | <0.006 | <0.01 | <0.03 | 0.23 | 0.23 |
| | | ABT-311 & Tribs | Maximum | 25.31 | 92.8 | 8.12 | 513 | 7.09 | 2 | 0.086 | 0.039 | 0.37 | 0.09 | 0.47 | 0.77 |
| | | ABT-311 & Tribs | Median | 22.46 | 79.9 | 6.92 | 266 | 6.37 | 1.0 | 0.034 | 0.011 | 0.20 | 0.07 | 0.36 | 0.56 |
| 20-September-03 | Assabet Mainstem (11 sites) | ABT-301 - ABT-010 | Minimum | 18.59 | 71.2 | 6.61 | 409 | 6.63 | <1.0 | 0.046 | 0.016 | 1.3 | <0.03 | 0.22 | 1.52 |
| | | ABT-301 - ABT-010 | Maximum | 20.25 | 96.6 | 8.88 | 568 | 7.10 | 18 | 0.408 | 0.332 | 3.5 | 0.05 | 0.5 | 4.00 |
| | | ABT-301 - ABT-010 | Median | 19.45 | 78.2 | 7.24 | 502 | 6.96 | 2 | 0.08 | 0.033 | 1.9 | 0.04 | 0.34 | 2.33 |
| | Upper Assabet Mainstem (6 sites) | ABT-301 - ABT-144 | Median | 19.09 | 75.5 | 6.94 | 520 | 6.88 | 0.8 | 0.187 | 0.078 | 2.55 | 0.04 | 0.36 | 2.86 |
| | Lower Assabet Mainstem (5 sites) | ABT-077 - ABT-010 | Median | 19.94 | 80 | 7.28 | 479 | 6.98 | 2 | 0.058 | 0.021 | 1.8 | 0.04 | 0.28 | 2.08 |
| | Assabet Head & Tributaries (9 sites) | ABT-311 & Tribs | Minimum | 17.73 | 48.9 | 4.55 | 145 | 6.19 | <1.0 | <0.006 | <0.006 | 0.23 | <0.03 | 0.12 | 0.43 |
| | | ABT-311 & Tribs | Maximum | 20.47 | 97.8 | 9.26 | 571 | 7.24 | 16 | 0.045 | 0.025 | 0.44 | 0.05 | 0.24 | 0.64 |
| | | ABT-311 & Tribs | Median | 18.72 | 77.9 | 7.26 | 292 | 6.94 | 3.0 | 0.028 | 0.007 | 0.36 | 0.03 | 0.20 | 0.56 |
| 18-October-03 | Assabet Mainstem (11 sites) | ABT-301 - ABT-010 | Minimum | 10.52 | 76.0 | 8.20 | 314 | 6.63 | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | | ABT-301 - ABT-010 | Maximum | 13.14 | 98.1 | 10.60 | 441 | 7.06 | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | | ABT-301 - ABT-010 | Median | 11.40 | 87.4 | 9.62 | 383 | 6.87 | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | Upper Assabet Mainstem (6 sites) | ABT-301 - ABT-144 | Median | 10.97 | 83.5 | 9.12 | 393 | 6.82 | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | Lower Assabet Mainstem (5 sites) | ABT-077 - ABT-010 | Median | 11.72 | 91.5 | 9.90 | 378 | 6.89 | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | Assabet Head & Tributaries (9 sites) | ABT-311 & Tribs | Minimum | 9.22 | 56.6 | 6.35 | 126 | 6.29 | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | | ABT-311 & Tribs | Maximum | 12.13 | 95.2 | 10.51 | 389 | 7.14 | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | | ABT-311 & Tribs | Median | 10.25 | 82.8 | 9.41 | 233 | 6.69 | n/a | n/a | n/a | n/a | n/a | n/a | n/a |

* calculated as ½ detection level where samples are BDL

**Figure 3: Mean daily streamflows (May 2003 – Oct 2003)**

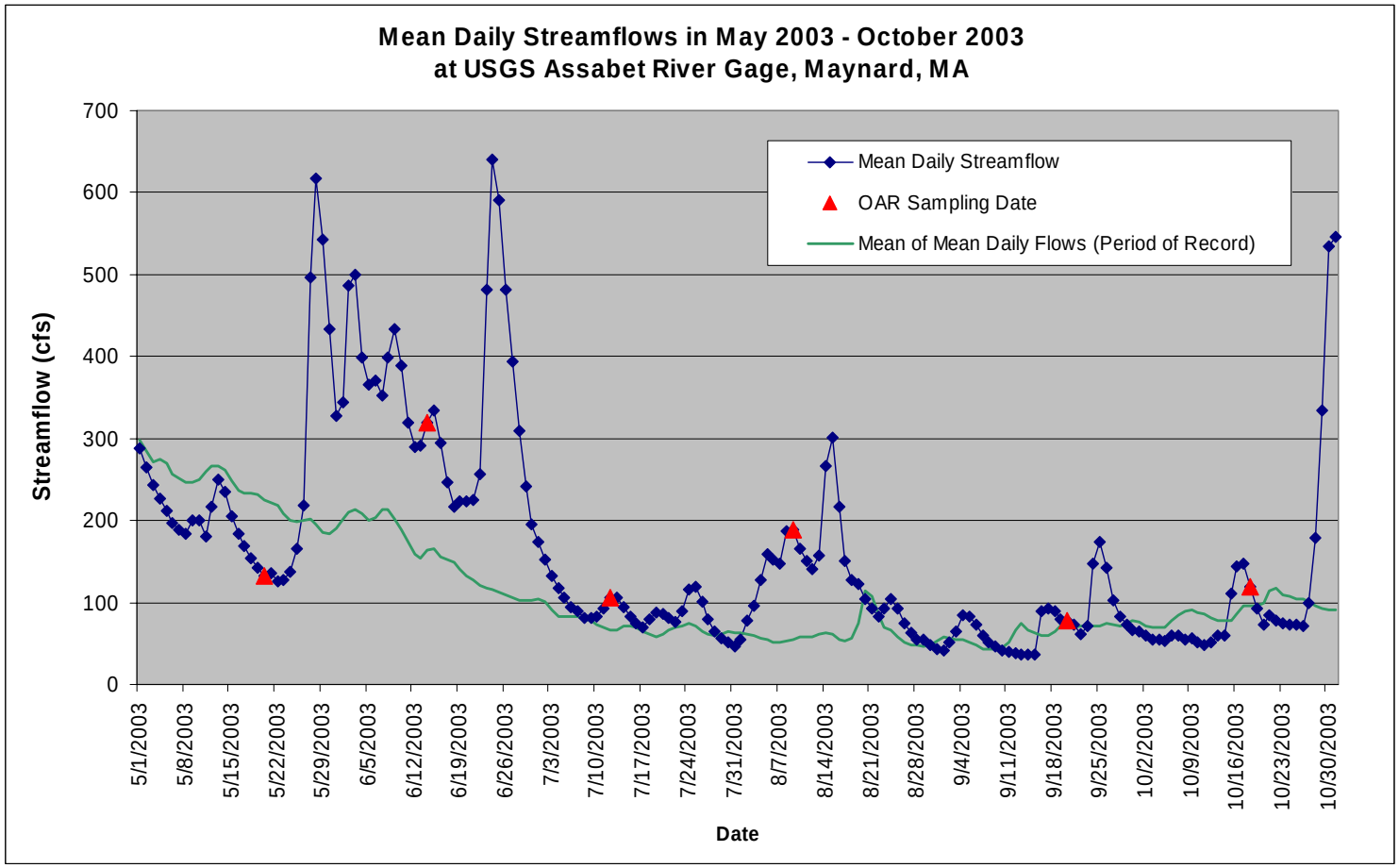
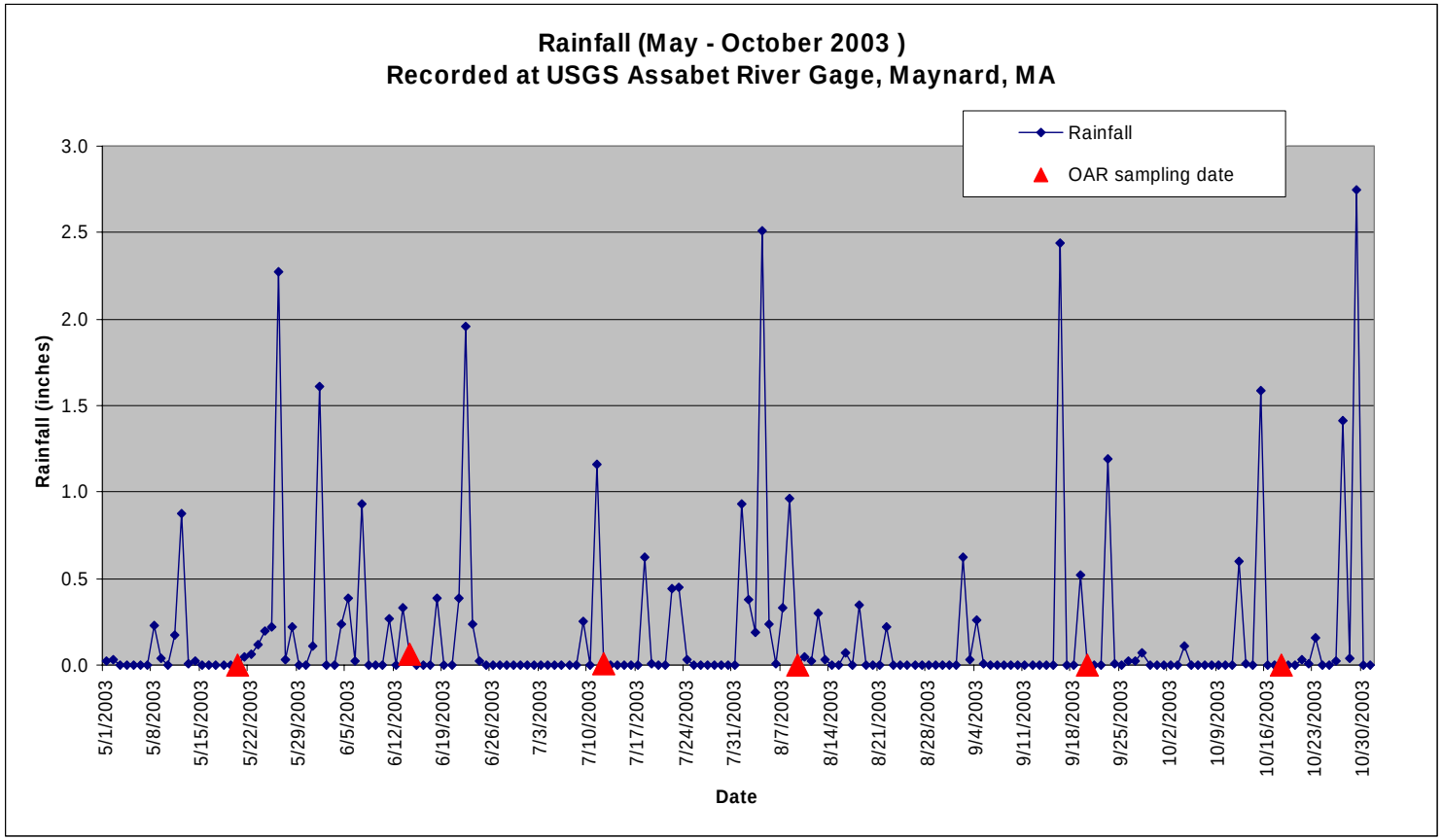


**Figure 4: Rainfall data (May – October 2003) at USGS Assabet River Gage, Maynard**



### Water Temperature, pH, and Conductivity

Dissolved oxygen (DO), water temperature, pH, and conductivity measurements were taken in May, 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 6, above.

Water temperatures in the mainstem and tributaries met water quality temperature standards on all dates tested. Temperatures in the mainstem ranged from 10.52 – 24.10 °C, with the lowest readings in October and the highest in August. Temperatures in the tributaries ranged from 9.22– 25.31 °C, with the lowest reading in October and the highest in August.

pH in the mainstem met water quality pH standards at all mainstem sites on all dates tested except for ABT-238 in August (pH 6.44); pHs in the mainstem ranged from 6.44 – 7.20. In the tributaries, pH's ranged from 6.19 - 7.65. Measurements of pH below the WQS (6.5) were recorded in Cold Harbor Brook (June, August, September, and October), Elizabeth Brook (June, August, and October), Spencer Brook (June and August), Nashoba Brook (August), and North Brook (August). In the case of at least two of the streams the low pH readings may be associated with natural conditions: the Cold Harbor Brook site is below a long swampy area, and the Elizabeth site is below a beaver dam.

Conductivity ranged from 314 - 568 μS/cm in the mainstem, with readings generally higher in the upper reach than in the lower reach. In the tributaries conductivity ranged from 108 – 596 μS/cm, with highest readings in Cold Harbor and Fort Meadow Brooks.

### 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 readings were taken between 5:30 a.m. and 10:00 a.m.

DO concentrations on the mainstem were generally good this summer, failing to meet standards criteria ( $\geq$ 5.0 mg/L and 60% saturation) only once on the mainstem (Robin Hill Road in August) (Figure 5). DO concentrations in the mainstem ranged from 5.06 – 10.43 mg/L with the lowest concentrations generally in August (Fig. 7) and the highest in October.

DO concentrations at tributary sites ranged from 3.60 – 10.51 mg/L and failed to meet standards criteria at two sites: Cold Harbor Brook (July, August, September) and Elizabeth Brook (July, August, September, and October) (Figure 6). The low DO readings at these two sites were likely a result of upstream swampy conditions or upstream beaver dams. Figure 8 shows tributary site dissolved oxyen concentrations in August.

**Figure 5: Histogram of Mainstem DO Measurements (May to Oct)**

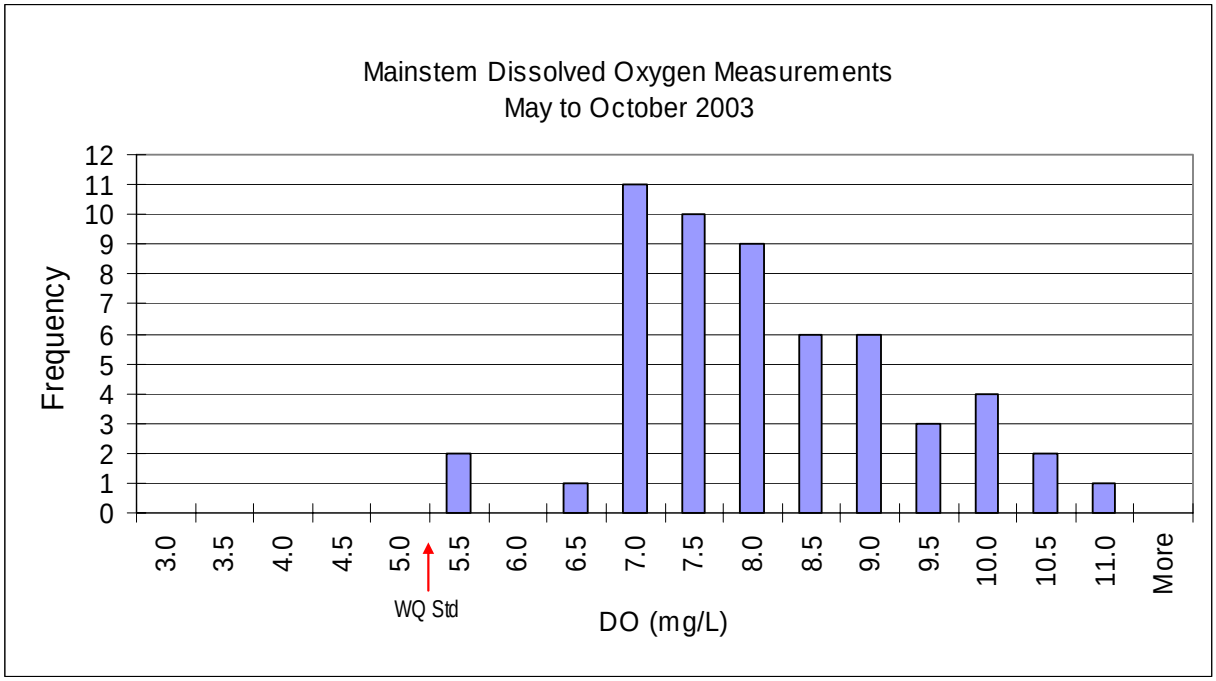



**Figure 6: Histogram of Headwater & Tributary DO Measurements (May to Oct)**

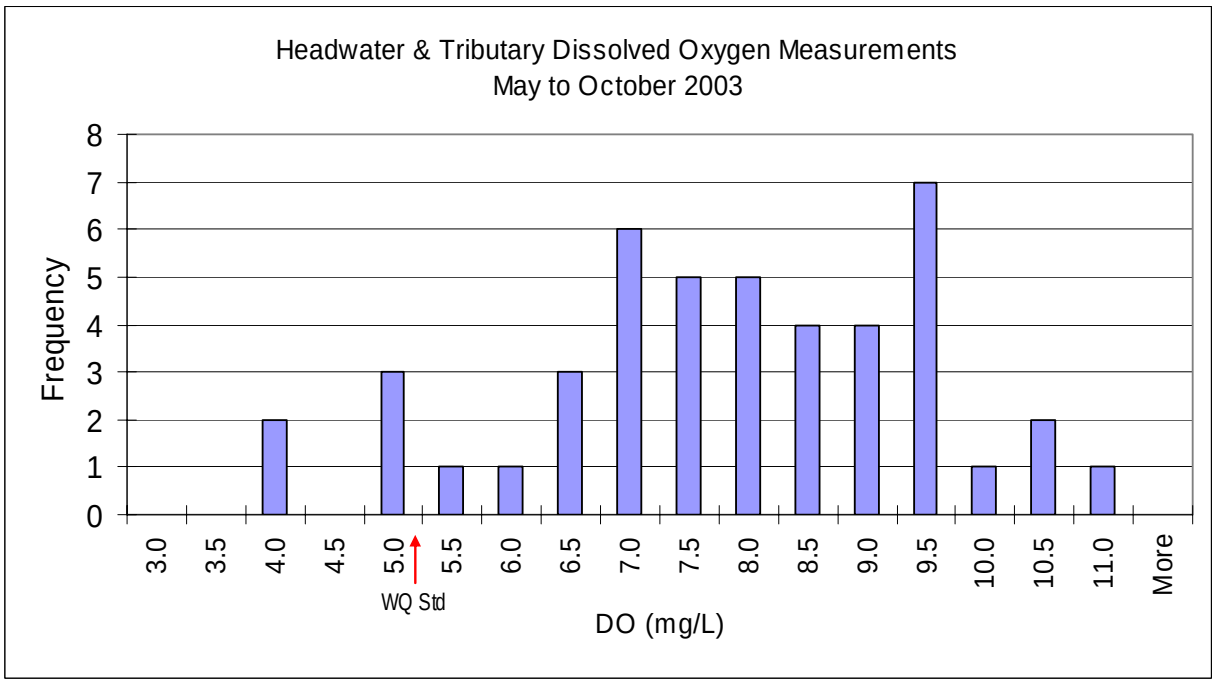


**Figure 7: Mainstem Dissolved Oxygen Concentrations - Aug 2003**

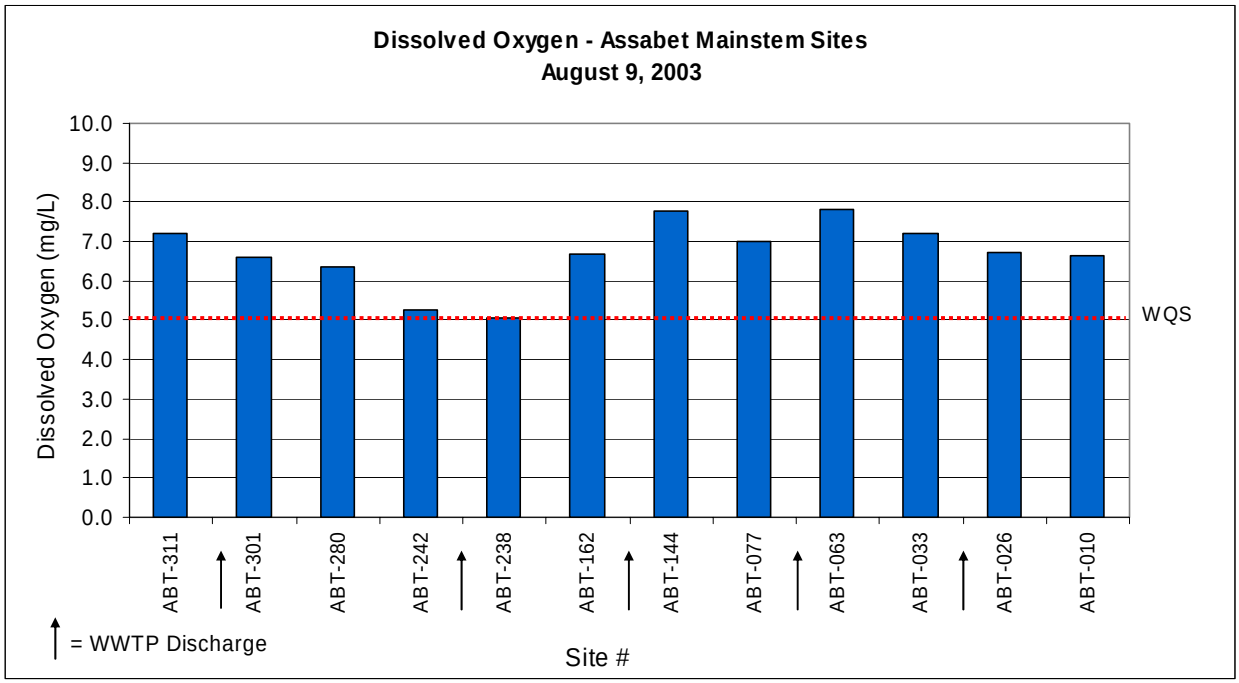
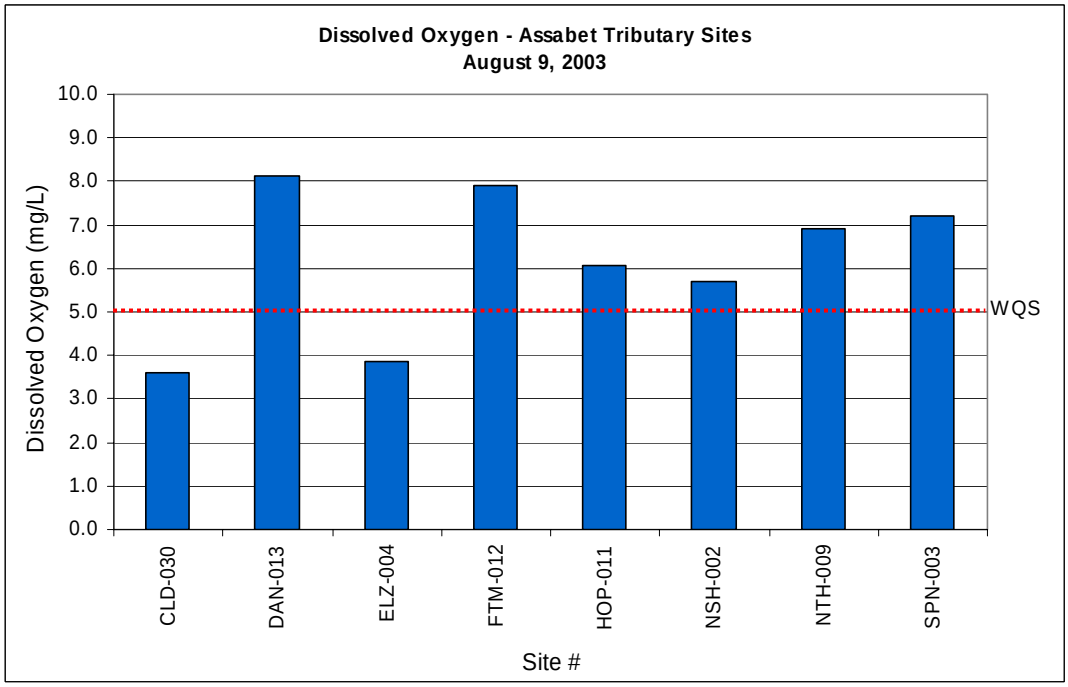



**Figure 8: Tributary Dissolved Oxygen Concentrations – Aug 2003**



### *Nutrients and Suspended Solids*

Summary statistics for nutrient concentrations are in Table 7, above. Median nutrient concentrations were calculated for the upper and lower mainstem reaches (see Table 1 for reach definitions) and for the combined headwater and tributary sites. Figures 7 – 11 show nutrient concentrations at mainstem vs. headwater/tributary sites.

In general, nutrient concentrations along the mainstem below the first wastewater discharge (Westborough WWTP) 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 (Fig. 7) ranged from 0.046 mg/L to 0.408 mg/L, exceeding the Ecoregion reference condition (0.025 mg/L) in 49 of 49 measurements, and exceeding the EPA "Gold Book" criteria (0.050 mg/L) in 48 of 49 measurements. Ortho-phosphorus concentrations in the mainstem (Fig. 8) ranged from 0.016 mg/L to 0.332 mg/L. Mainstem total nitrogen concentrations (Fig. 9) ranged from 0.90 mg/L to 4.00 mg/L, exceeding the reference condition (0.44 mg/L) in 49 of 49 measurements. Nitrate concentrations (Fig. 10) ranged from 0.60 mg/L to 3.50 mg/L (as nitrate-N), exceeding the reference condition (0.34 mg/L NO3 + NO2-N) in 49 of 49 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 (Fig. 11) ranged from 0.03 mg/L to 0.21 mg/L ammonia-N, with similar median concentrations in the upper and lower reaches each month. Total suspended solids in the mainstem ranged from <1 mg/L to 18 mg/L.

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 (Fig. 9) ranged from <0.006 mg/L – 0.086 mg/L TP, with 23 of 42 total phosphorus readings greater than 0.025 mg/L TP. Median total phosphorus concentrations (Fig. 10) in the headwater and tributaries were below the median TP concentrations for both the upper and lower mainstem reaches. Total nitrogen (TN) concentrations (Fig. 11) in the headwater and tributaries ranged from 0.23 mg/L to 2.58 mg/L, exceeding 0.34 mg/L in 36 of 42 measurements. Nitrate concentrations (Fig. 12) ranged from <0.01 mg/L to 2.40 mg/L. Median TN and nitrate concentrations at the headwater and tributary sites were lower than median concentrations in the mainstem. Ammonia (ammonia as N) concentrations (Fig. 13) ranged from <0.03 mg/L to 0.16 mg/L. Median ammonia concentrations were similar in the mainstem reaches and headwater and tributary sites. Total suspended solids in the headwaters and tributaries ranged from <1 mg/L to 16 mg/L with the highest concentrations measured in Cold Harbor Brook in June and September.

**Figure 9: Total Phosphorus Concentrations (2003)**

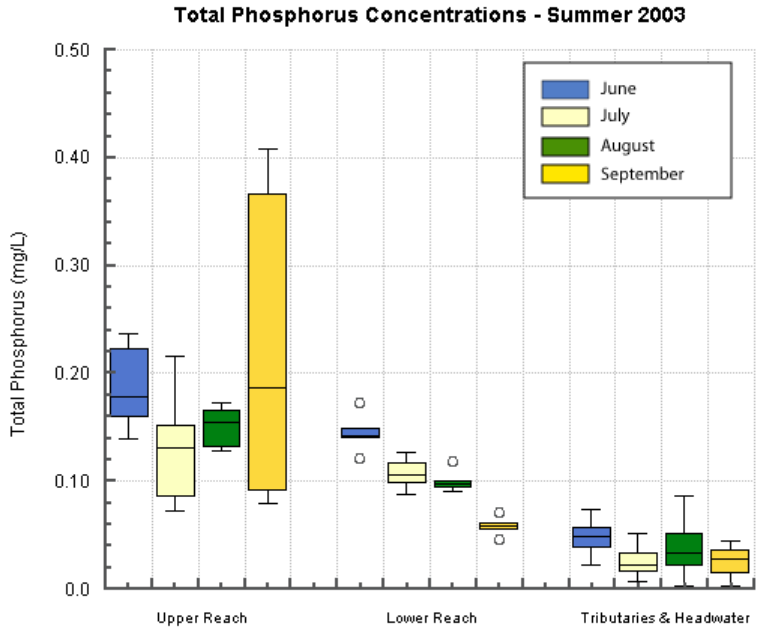



**Figure 10: Ortho-Phosphorus Concentrations (Summer 2003)**

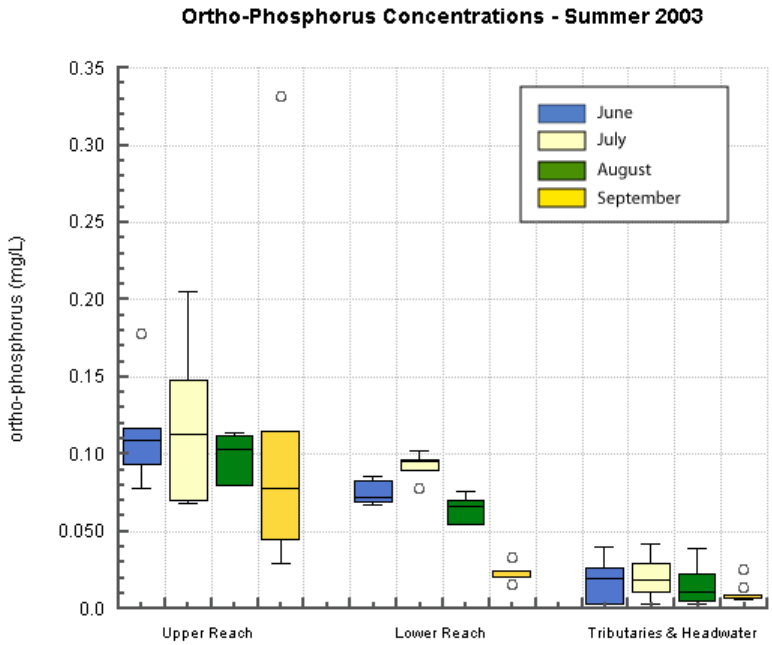


**Figure 11: Total Nitrogen Concentrations (2003)**

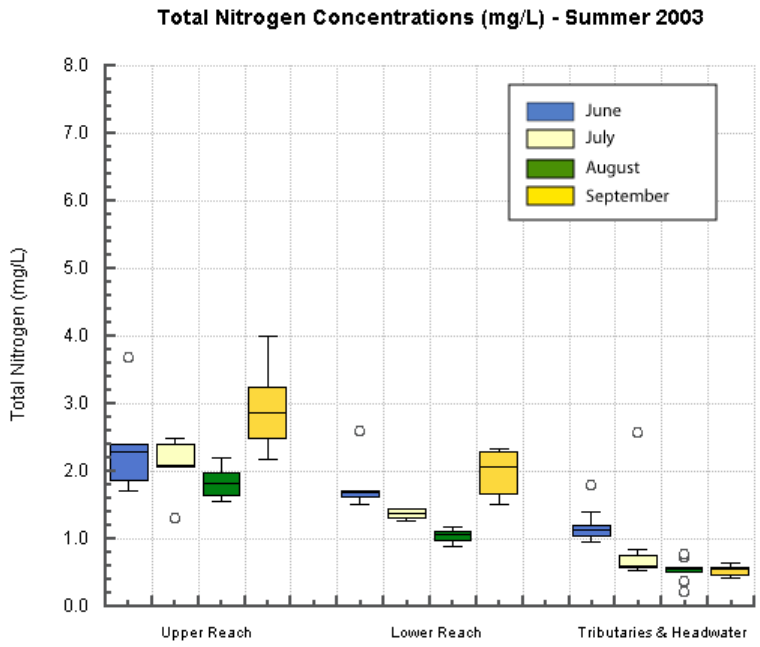



**Figure 12: Nitrate Concentrations (2003)**

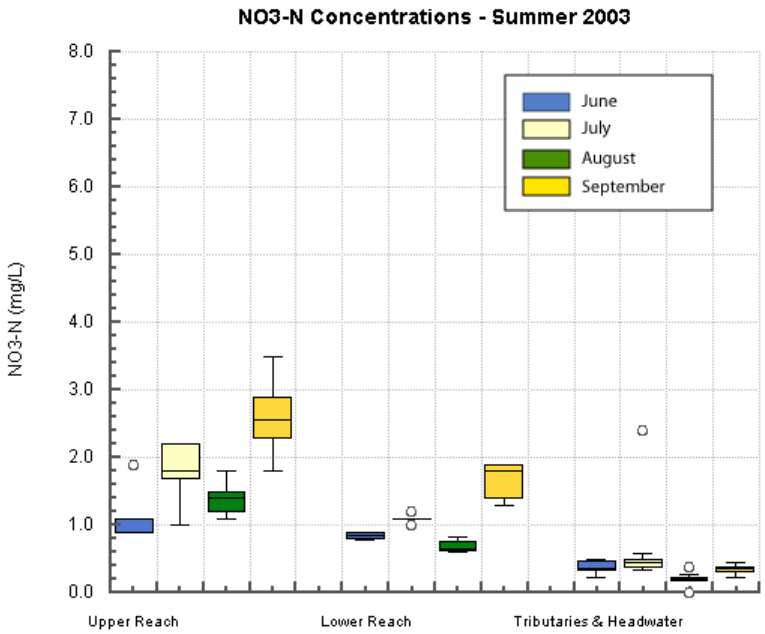
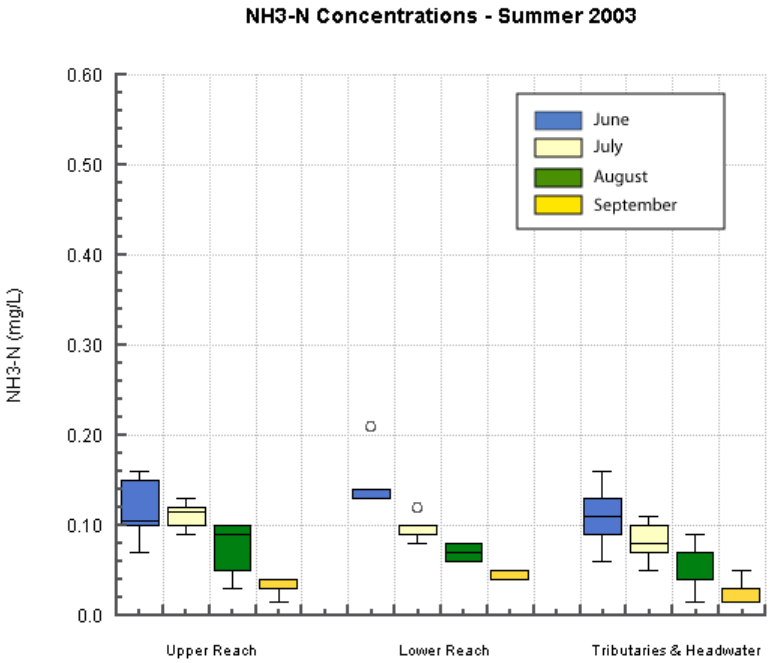


**Figure 13: Median Ammonia (as N) Concentrations (2003)**




## *Stream Health Index Readings*

The Stream Health Index was used to assess conditions in six of the tributary streams from June to September in 2003. The 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 project webpage (www.assabetriver.org/streamwatch/howindex.html). 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, total nitrogen, and total suspended solids are scored from 1 (worst) to 100 (best). Streamflow data is scored against minimum streamflow recommendations of several standard-setting methods. Groundwater levels are scored against expected conditions from long-term records. 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. 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 posting on curbside signs the index score was converted to a description: excellent (81 – 100), good (61 – 80), fair (41 – 60), poor (21 - 40), or very poor (1 – 20).

Figures 14 – 20 show Stream Health Index readings and streamflow over the summer for each of the six streams. The full data set is presented in Appendix III. The stream health was rated "excellent" or "good" for most of the 15 weeks that the six tributaries were assessed: Hop Brook (15 of 15 weeks), Cold Harbor Brook (10 of 15 weeks), Danforth Brook (8 of 15 weeks), Fort Meadow Brook (13 of 15 weeks), Elizabeth Brook (12 of 15 weeks), and Nashoba Brook (12 of 15 weeks). The lowest overall stream health readings for each stream occurred in late September, when streamflows were at their lowest for the season. The lowest-scoring parameters over the summer were, in order of frequency: total nitrogen, water temperature, dissolved oxygen, streamflow, and total phosphorus. Earlier in the summer the lowest-scoring parameter tended to be TN; by mid-August, the lowest-scoring parameters were streamflow and water temperature.

Stream health index readings were calculated last summer for only the project pilot, conducted on Danforth Brook. Streamflows and index readings in Danforth Brook were higher this summer than in 2002 when a mild drought affected the region (Fig 14 &15).

**Figure 14: Stream Health & Streamflow – Hop Brook (2003)**

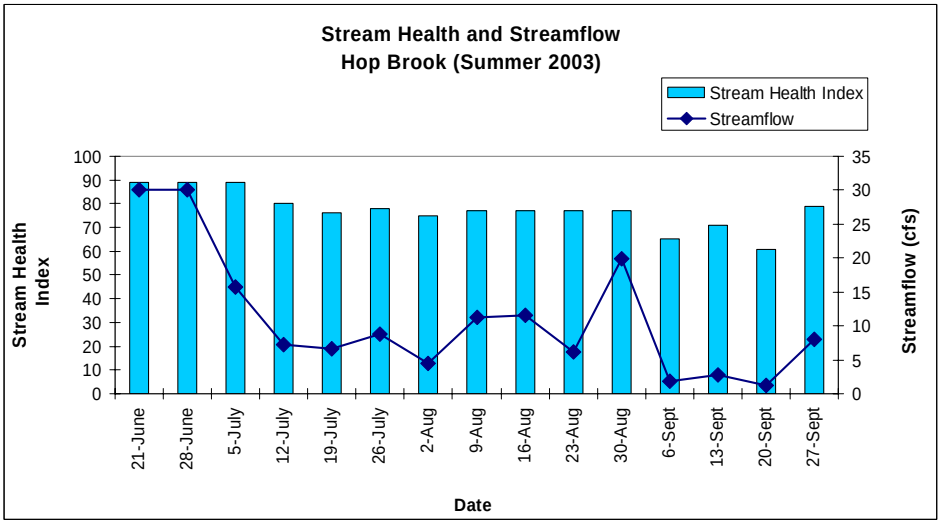
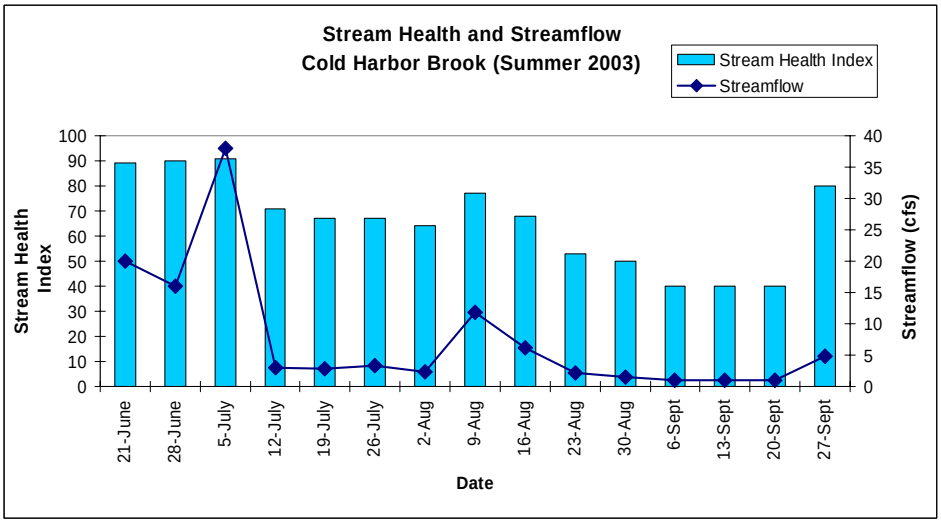



**Figure 15: Stream Health & Streamflow – Cold Harbor Brook (2003)**



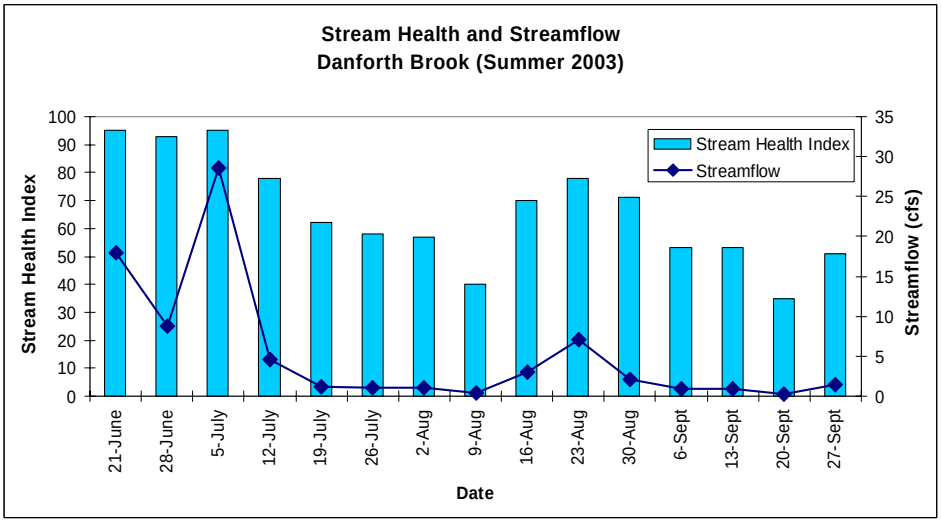



**Figure 16: Stream Health & Streamflow – Danforth Brook (2003)**

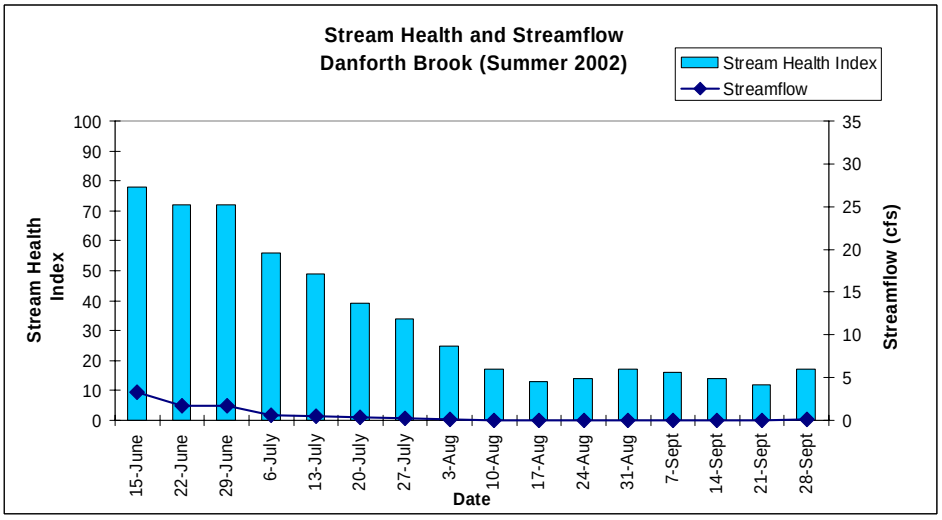



**Figure 17: Stream Health & Streamflow - Danforth Brook (2002)**

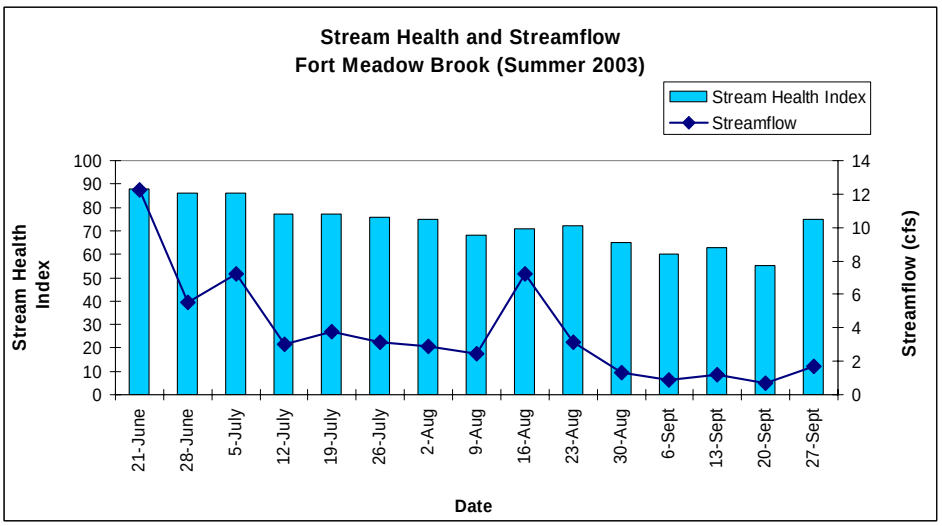



**Figure 18: Stream Health & Streamflow – Fort Meadow Brook (2003)**

**Figure 19: Stream Health & Streamflow - Elizabeth Brook (2003)**

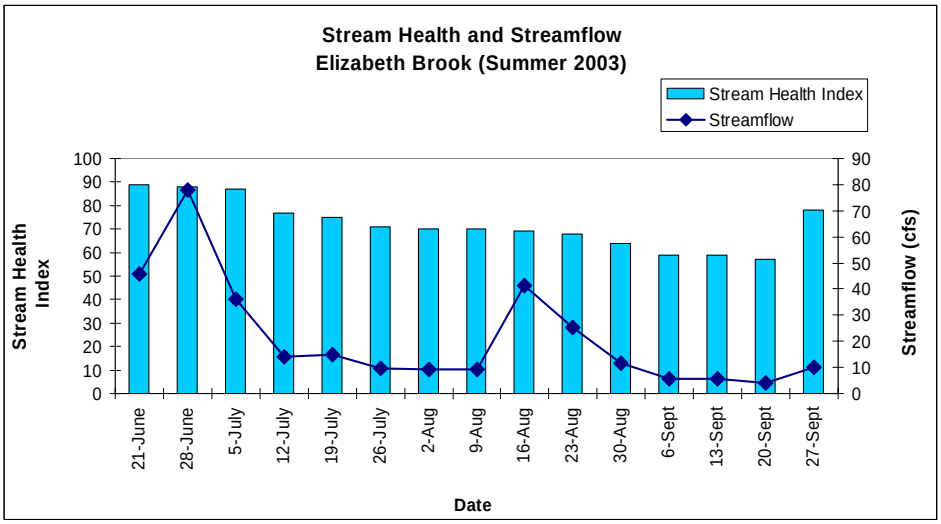
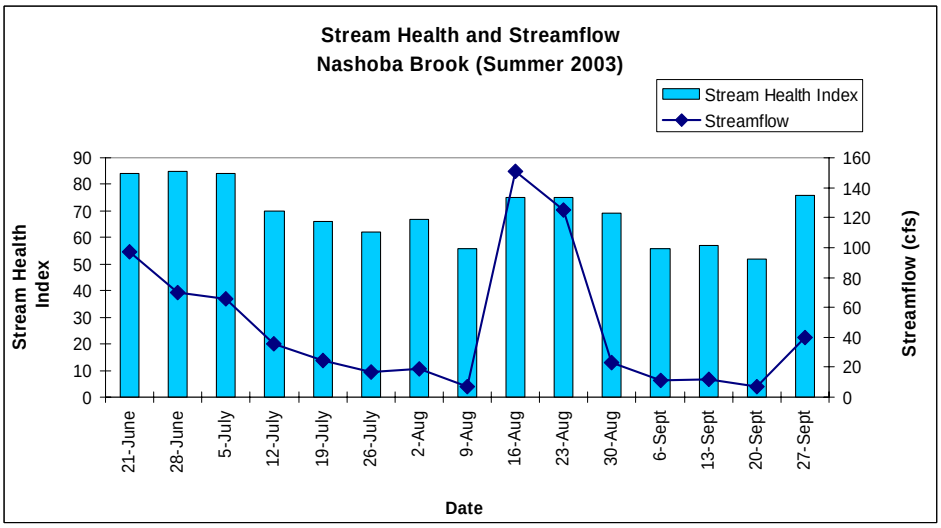



**Figure 20: Stream Health & Streamflow - Nashoba Brook (2003)**



## Conclusions

Rainfall (as measured at the NWS Worcester station) and streamflows (as measured at the USGS gage in Maynard) were near or above average for the sampling period, May to October 2003. With near-normal rainfall and streamflows in the watershed during the summer of 2003, streamflow and dissolved oxygen conditions in both the mainstem Assabet and tributary streams were better than last year. Weekly streamflows were calculated from stage readings for six of the tributary monitoring sites: Hop Brook, Cold Harbor Brook, Danforth Brook, Fort Meadow Brook, Elizabeth Brook, and Nashoba Brook.

Dissolved oxygen concentrations on the mainstem were generally good this summer, failing to meet water quality standards ( ≥ 5.0 mg/L and 60% saturation) only once on the mainstem (Robin Hill Road in August). DO concentrations at tributary sites failed to meet standards criteria at two sites: Cold Harbor Brook (July, August, September) and Elizabeth Brook (July, August, September, and October). The low DO readings at these two sites were likely a result of upstream swampy conditions or upstream beaver dams.

Nutrient concentrations along the mainstem below the first wastewater discharge (Westborough WWTP) were well above maximum recommended levels for total phosphorus, total nitrogen, and nitrates. Total phosphorus concentrations in the mainstem ranged from 0.046 mg/L to 0.408 mg/L, exceeding the Ecoregion reference condition (0.025 mg/L) in 49 of 49 measurements and exceeding 0.050 mg/L in 48 of 49 measurements. Mainstem total nitrogen concentrations ranged from 0.90 mg/L to 4.00 mg/L, exceeding the reference condition (0.44 mg/L) in 49 of 49 measurements. Nitrate concentrations ranged from 0.60 mg/L to 3.50 mg/L nitrate-N, exceeding the reference condition (0.34 mg/L NO3 + NO2-N) in 49 of 49 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 mg/L to 0.21 mg/L ammonia-N, with similar median concentrations in the upper and lower reachs each month.

In headwaters and the tributaries, median TP, TN, and NO3 concentrations were significantly lower than in the mainstem reaches, although still above recommended maximum levels in more than half the measurements taken. Total phosphorus concentrations ranged from <0.006 mg/L – 0.086 mg/L TP, with 23 of 42 total phosphorus readings exceeding the reference condition (0.025 mg/L) and 7 of 42 measurements exceeding 0.050 mg/L. Total nitrogen (TN) concentrations in the headwater and tributaries ranged from 0.23 mg/L to 2.58 mg/L, exceeding the reference condition (0.44 mg/L) in 36 of 42 measurements. Nitrate concentrations ranged from <0.01 mg/L to 2.40 mg/L, exceeding the reference condition for nitrate+nitrite (0.34 mg/L) in 24 of 42 measurements. Ammonia concentrations ranged from <0.03 mg/L to 0.16 mg/L. Median ammonia concentrations were similar in the mainstem reaches and headwater and tributary sites.

A weekly Stream Health Index was calculated for each of six tributary streams. The stream health was rated "excellent" or "good" for most of the 15 weeks assessed: Hop Brook (15 of 15 weeks), Cold Harbor Brook (10 of 15 weeks), Danforth Brook (8 of 15 weeks), Fort Meadow Brook (13 of 15 weeks), Elizabeth Brook (12 of 15 weeks), and Nashoba Brook (12 of 15 weeks). The lowest stream health readings for each stream occurred in mid-September, when streamflows were at their lowest for the season. Early in the summer, June through early-August, the lowest-scoring parameters were total nitrogen and total phosphorus. Later in the summer, from early-August through September, the lowest-scoring parameters were temperature, dissolved oxygen, and streamflow.

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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.

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

**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.

**Ecoregion**: An area over which the climate is sufficiently uniform to permit development of similar ecosystems on sites that have similar properties. Ecoregions contain many landscapes with different spatial patterns of ecosystems.

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

**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.

**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 plays 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 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 is calculated from the 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.

**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: 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<br>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

**Appendix III: Stream Health Index Readings & Tributary Data**