



Water Quality Monitoring at Minute Man National Historical Park

Northeast Temperate Network 2011 Summary Report

Natural Resource Data Series NPS/NETN/NRDS—2012/333



ON THE COVER

Concord River, September 2011

Photograph by: Brian Schuetz

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Introduction

This report on the water quality of Minute Man National Historical Park (MIMA) generated by the Northeast Temperate Network (NETN) Water Quality Monitoring Program includes data gathered in the 2011 monitoring season and displays these results in graphic form, accompanied by a brief interpretation. Appendix A contains data collected from 2006 through 2011.

The vital signs for freshwater bodies included in the NETN Freshwater Monitoring Protocol (Lombard et al 2006) are water chemistry, nutrient enrichment, water quantity, and the detection of invasive plant species. These metrics were chosen to address the NPS Inventory and Monitoring Program objective to detect change in the status of physical, chemical, or biological attributes of the ecosystem.

The NETN Freshwater Monitoring Protocol calls for a total of 3 park streams to be sampled monthly from May through October. A cooperator from the University of Vermont or a NETN hydrologic technician measured physical and in-situ water chemistry parameters each month and periodically collected water samples for analysis at the University of Maine's Sawyer Environmental Chemistry Research Laboratory. All monitoring data are incorporated into a series of comprehensive databases that ultimately feed the U.S. Environmental Protection Agency's "STORET" data system, the repository for all NPS water quality and quantity data.

Sampling Sites

Two streams, Mill Brook and Elm Brook, and one river, the Concord River, cut through MIMA (Figure 1). One water quality monitoring site was selected on each of these water bodies for the NETN monitoring program (Table 1). The monitoring site on Mill Brook (MIMASA) is located upstream of Lowell Road with a tape-down point on the bridge. The Mill Brook monitoring site is not located within park boundaries because the brook is intermittent where it flows through the Wayside Unit, and it becomes a wetland where it flows through the North Bridge Unit (Lombard et al 2006).

The site on Elm Brook (MIMASB) is within park boundaries at State Route 2A, 4.3 miles upstream from the confluence of Elm Brook with the Shawsheen River. The sampling results represent water quality conditions in Elm Brook within the park's Battle Road Unit (Lombard et al 2006).

The Concord River site (MIMASC) is at the Old North Bridge, 0.49 miles downstream from the confluence of the Sudbury and Assabet Rivers. The site is within the Minute Man NHP boundary and sampling results are intended to represent water quality conditions in the Concord River within the park's North Bridge Unit. Discharge measurements cannot be made by wading because of the size of the river, and this site also requires specialized techniques to obtain water quality sonde samples.

Mill Brook and Elm Brook are classified as capable of supporting cold water fisheries (National Park Service 1993), loosely defined as waters that can support, on a year-round basis, wild and stocked brook trout (*Salvelinus fontinalis*) or other species requiring similar conditions. The Concord River is considered capable of supporting warm water fish (bass, pickerel, sunfish).

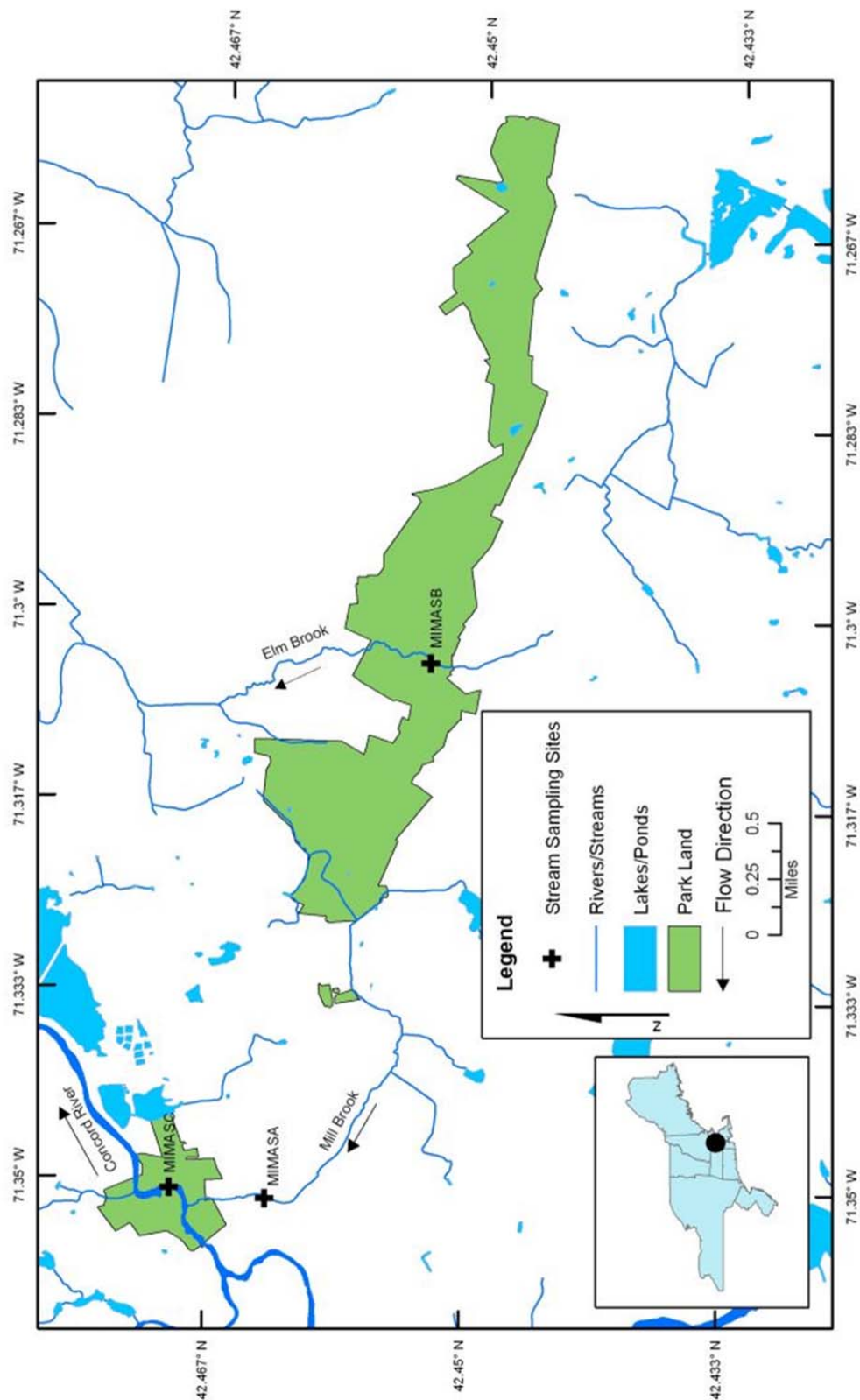


Figure 1. Map of water monitoring sites at Minute Man NHP

Table 1. Water quality monitoring sites at Minute Man NHP.

Waterbody	NETN Site Code	Latitude	Longitude	Site Remarks
Mill Brook (Stream A)	MIMASA	42.4628000	-71.3514167	Cold water fisheries
Elm Brook (Stream B)	MIMASB	42.4529333	-71.3042167	Cold water fisheries
Concord River (Stream C)	MIMASC	42.4690166	-71.3506333	Warm water fisheries

Methods

Detailed descriptions of all monitoring methods are found in the protocol (Lombard et al 2006). Monthly sampling parameters included in-situ water quality measures (pH, specific conductance, temperature, and dissolved oxygen) determined with a YSI 600XL sonde, weather, stream flow (discharge), and stream stage (water level). Water samples obtained in May and August were analyzed for acid neutralizing capacity (ANC), color, and nutrients. Nutrient chemistry parameters were analyzed from a grab sample.

Stream discharge was measured using U.S. Geological Survey protocols (Rantz et al 1982), employing a measuring tape, wading rod, and SonTek FlowTracker current meter or a Price Pygmy current meter to measure a particular cross-sectional area of the stream and the velocity of the water at that cross section. Discharge measurements of the Concord River could potentially be made off of the Old North Bridge, although bridge measurements are too expensive for NETN to cover at this time.

In-situ stream water chemical and physical measurements and water samples were collected within 5 meters from the location of the discharge measurement. Sonde measurements were taken in the main stream flow with care taken that the sonde was not resting directly on the stream bottom. In the Concord River, two-point sonde measurements were taken from the bridge (at pylons 2 and 4) at each monitoring visit to better characterize river conditions. A seven-point set of cross-sectional measurements is taken (at varied depths) once each year to confirm that the two-point measurement strategy is still representative.

Grab samples were obtained by submerging the sample bottle directly in the stream with a gloved hand. A peristaltic pump and Tygon tubing were used to collect samples if water levels were too low to completely submerge a bottle.

Water Quality Standards

Massachusetts surface-water quality standards designate Class A waters as “excellent habitat for fish, other aquatic life and wildlife, and suitable for primary and secondary contact recreation” (Massachusetts Department of Environmental Protection 2007). Outstanding Resource Waters (ORW) is used to denote those waters, other than Public Water Supplies, designated for protection as outstanding resources. “Class A waters shall have DO concentrations of not less than 6 mg/L unless background conditions are lower. Temperatures shall not exceed 68° F [20° C] in cold water fisheries or 83° F [28.3° C] in warm water fisheries, and natural and seasonal

variations shall be maintained. The pH shall range from 6.5 to 8.3 standard units but not more than 0.5 units outside of the background range. Class A waters shall be free from color in concentrations or combinations that are aesthetically objectionable or would impair any use assigned to this class”.

Table 2. Massachusetts stream water quality standards.

Water quality classification code	Minimum Dissolved Oxygen (mg/L)	pH range (standard units)	Maximum Total Nitrogen (µg/L)	Maximum Total Phosphorus (µg/L)
A	6.0	6.5 – 8.3	As naturally occurs	As naturally occurs

EPA Ecoregion 14 water quality criteria (Table 3; U.S. Environmental Protection Agency 2000) are also used as a benchmark in this report. EPA water quality criteria for nutrients help translate narrative criteria within State or Tribal water quality standards by establishing values for causal variables (e.g., total nitrogen and total phosphorus) and response variables (e.g., turbidity and chlorophyll *a*). Causal variables are necessary to provide sufficient protection of designated uses before impairment occurs and to maintain downstream uses. Early response variables are necessary to provide warning signs of possible impairment and to integrate the effects of variable and potentially unmeasured nutrient loads (U.S. Environmental Protection Agency 2002).

Table 3. EPA Ecoregion 14 nutrient criteria for streams.

Nutrient Criteria	Value
Total Phosphorus	31.25 µg/L
Total Nitrogen	0.71 mg/L

These criteria were developed specifically for Ecoregion 14 (which includes Minute Man NHP, Saugus Iron Works NHS, and Weir Farm NHS) and are designed to represent conditions of surface waters that are minimally impacted by human activities and thus protect against the adverse effects of nutrient over-enrichment from cultural eutrophication. The values are EPA’s scientific recommendations regarding ambient concentrations of nutrients that protect aquatic resource quality. They do not have any regulatory impact or meaning.

The criteria were established based on the lower 25th percentile of streams for which the EPA found data. This percentile of all streams is expected to approximately correspond to the 75th percentile of reference (undisturbed) streams. In other words, 75% of streams in the ecoregion do not meet the criteria, nor do roughly 25% of reference streams. (U.S. Environmental Protection Agency 2000).

Results

Monitoring results for 2011 are displayed in scatter-plot graphs showing all data for each site for a given parameter. The scatter plots of 2011 data are overlaid on box plots representing the overall range and distribution of data values collected from 2006 through 2011 for the specified parameter and site (Appendix A contains all data in tabular form). A box plot (Figure 2) is a summary plot that graphs data as a box representing statistical values. The boundary of the box closest to zero indicates the 25th percentile, a line within the box marks the median, and the boundary of the box farthest from zero indicates the 75th percentile. Whiskers (error bars) above and below the box indicate the 90th and 10th percentiles respectively. Outliers are displayed as black filled circles. If EPA or other water quality criteria exist for a particular parameter they are displayed on the graphs as specification lines.

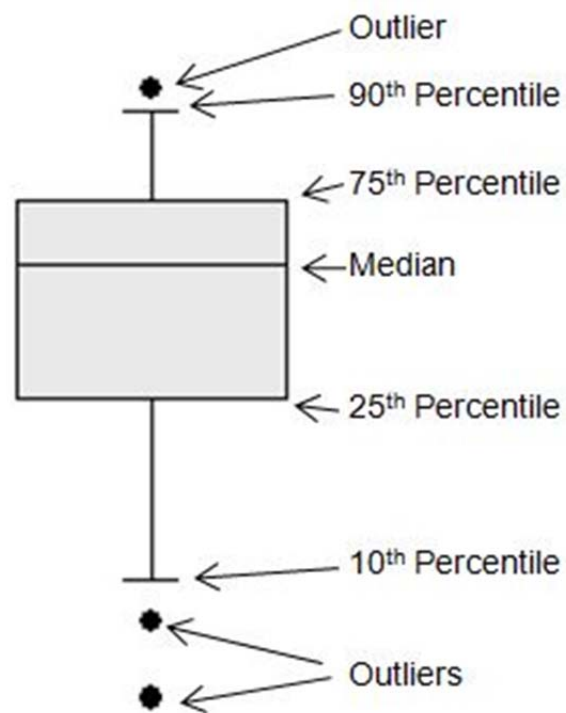


Figure 2. Explanation of box plot graph.

Water Quality

Measures of water quality include specific conductance, pH, water temperature, dissolved oxygen (DO), acid neutralizing capacity (ANC), and apparent color. Assessment of water quality data aids in the interpretation of the biotic condition and ecological processes of surface water resources.

Specific Conductance

Specific conductance (Figure 3) is a measure of the ability of water to carry an electrical current, and is directly related to the level of dissolved ions in the water. An increase in specific conductance can be an indicator of pollutants in the water. Naturally occurring values range from less than 20 to more than 1,000 microsiemens per centimeter ($\mu\text{S}/\text{cm}$). Specific conductance values from 2011 were within the appropriate range for moderate to high ionic strength waters, and were generally within the range of values shown on the box plot depicting historic data.

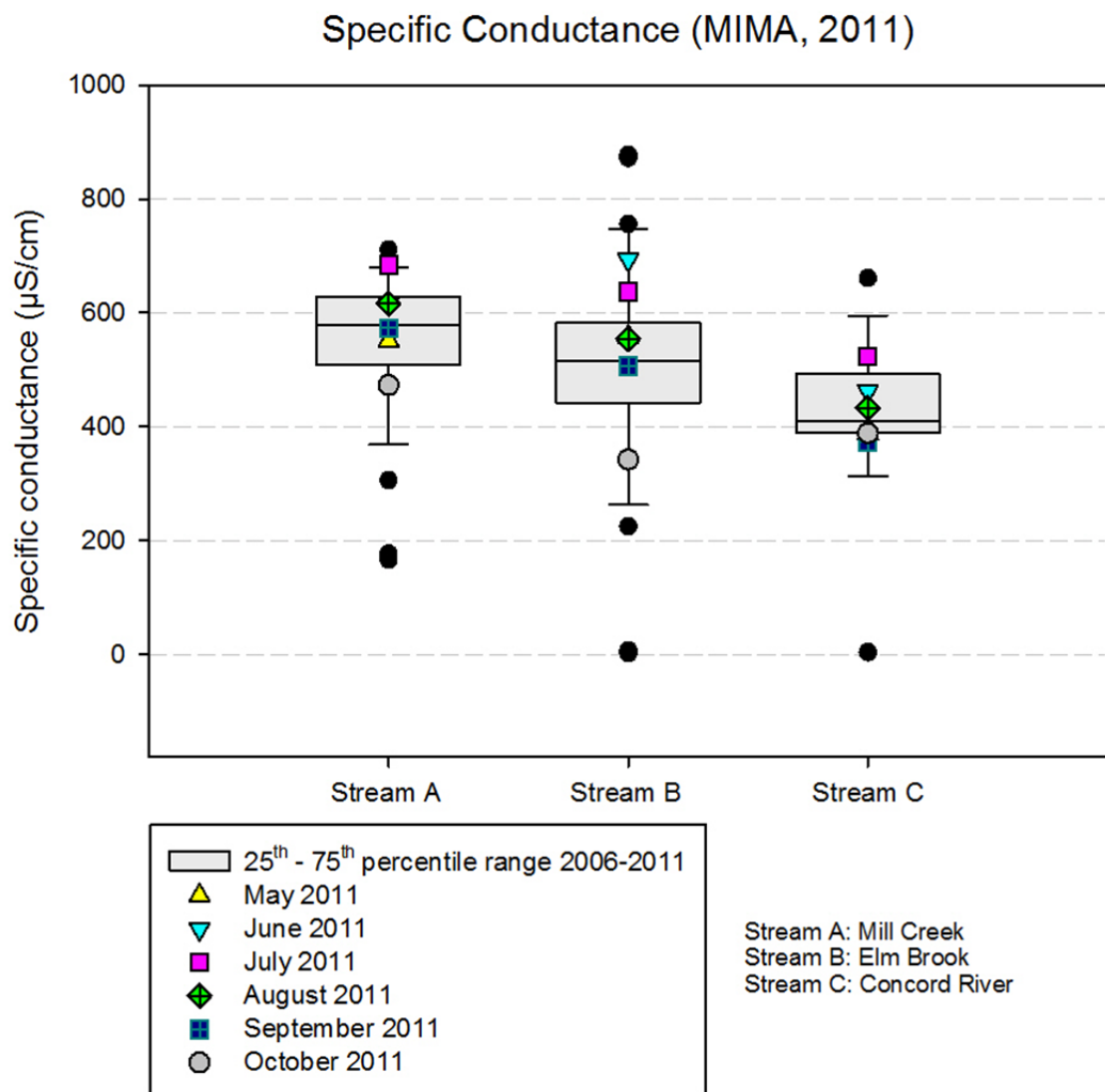


Figure 3. Specific conductance from 2011 YSI sonde in-situ measurements overlaid on a box plot of measurements taken from 2006-2011.

pH Level

The pH of a water body reflects how acidic or basic the water is, measured on a scale of 1 to 14, with 7 being neutral. Acid waters are below 7, and alkaline waters are above 7. A one unit change in pH represents a 10-fold change in acidity or alkalinity. Massachusetts standards, similar to those of most northeast states, indicate that a pH between 6.5 and 8.3 is within the acceptable range. pH values from the 2011 monitoring season (Figure 4) were circumneutral, and were all between the upper and lower Massachusetts water quality standards.

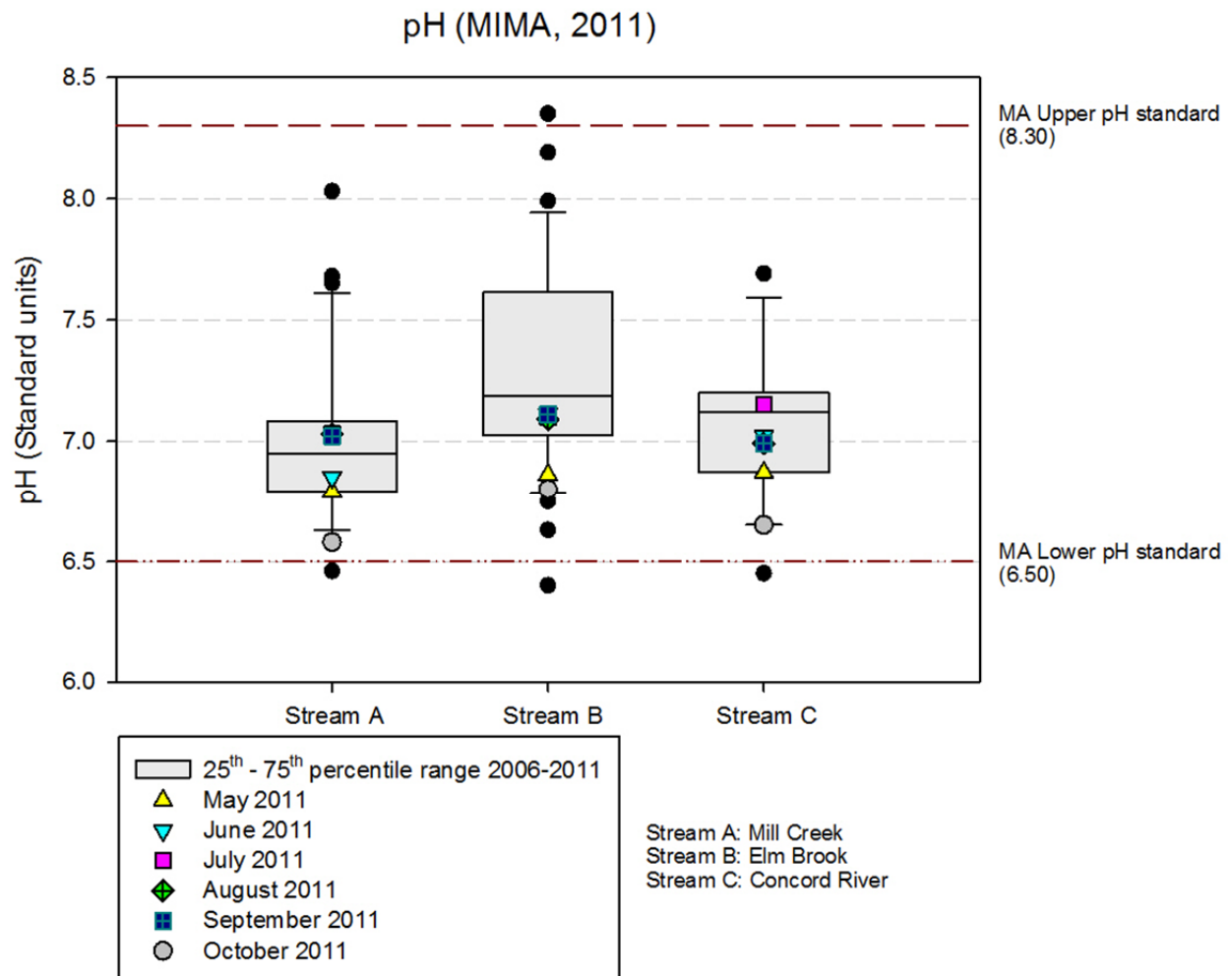


Figure 4. pH from 2011 YSI sonde in-situ measurements overlaid on a box plot of measurements taken from 2006-2011.

Temperature

Temperature can affect water chemistry and biology. For example, the amount of oxygen that water can hold is directly related to the temperature of the water. The higher the temperature, the less oxygen water can hold, which can be observed in both diel (day and night) and seasonal shifts. Oxygen will naturally decline during the summer months as water temperatures rise. Temperature can also determine the kinds of plants and animals found in the lake or pond. Certain species of fish, insects, and algae will predominate during the cooler temperatures of the spring and fall, yet be less apparent during the warmer temperatures of summer. Surface water temperatures in 2011 (Figure 5) were generally within the state water quality standards for the appropriate stream types, excepting the July Mill Creek measurement of 22.43°C. The July and August values reflected the contributions of high air temperature and solar radiation.

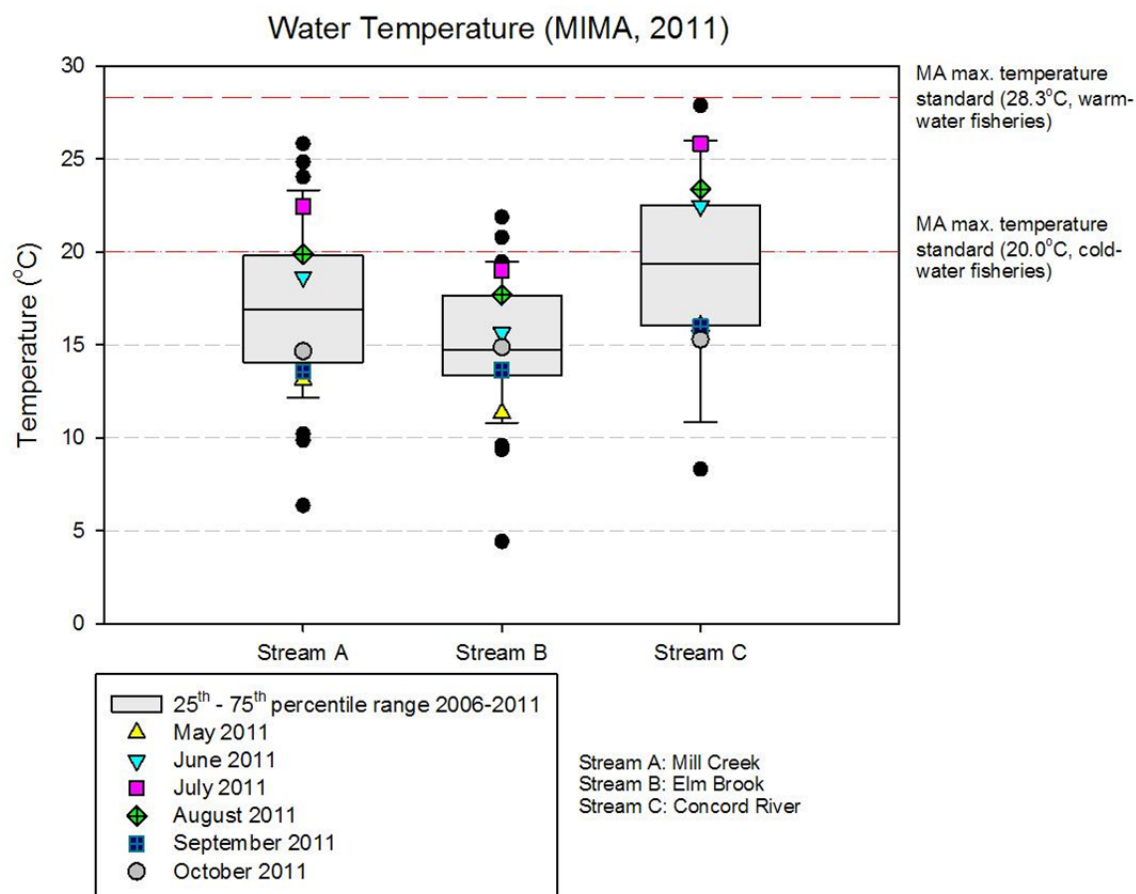


Figure 5. Water temperature (surface) from 2011 YSI sonde in-situ measurements overlaid on a box plot of measurements taken from 2006-2011.

Dissolved Oxygen

Dissolved oxygen (DO) is a critical indicator of water quality because aquatic life generally needs DO concentrations at or above 5 mg/L to thrive. Low oxygen can directly kill or stress organisms such that they will not be able to successfully reproduce or grow. Water with less than 1 part per million (ppm) of oxygen is considered anoxic (no oxygen present). Elm Brook (Stream B) was well oxygenated throughout 2011 (Figure 6), and most measurements from the two other sites were above the (6 mg/L) state DO standard. June, July and October measurements from Mill Brook (Stream A) and the September measurement from the Concord River (Stream C) were slightly below the state DO standard.

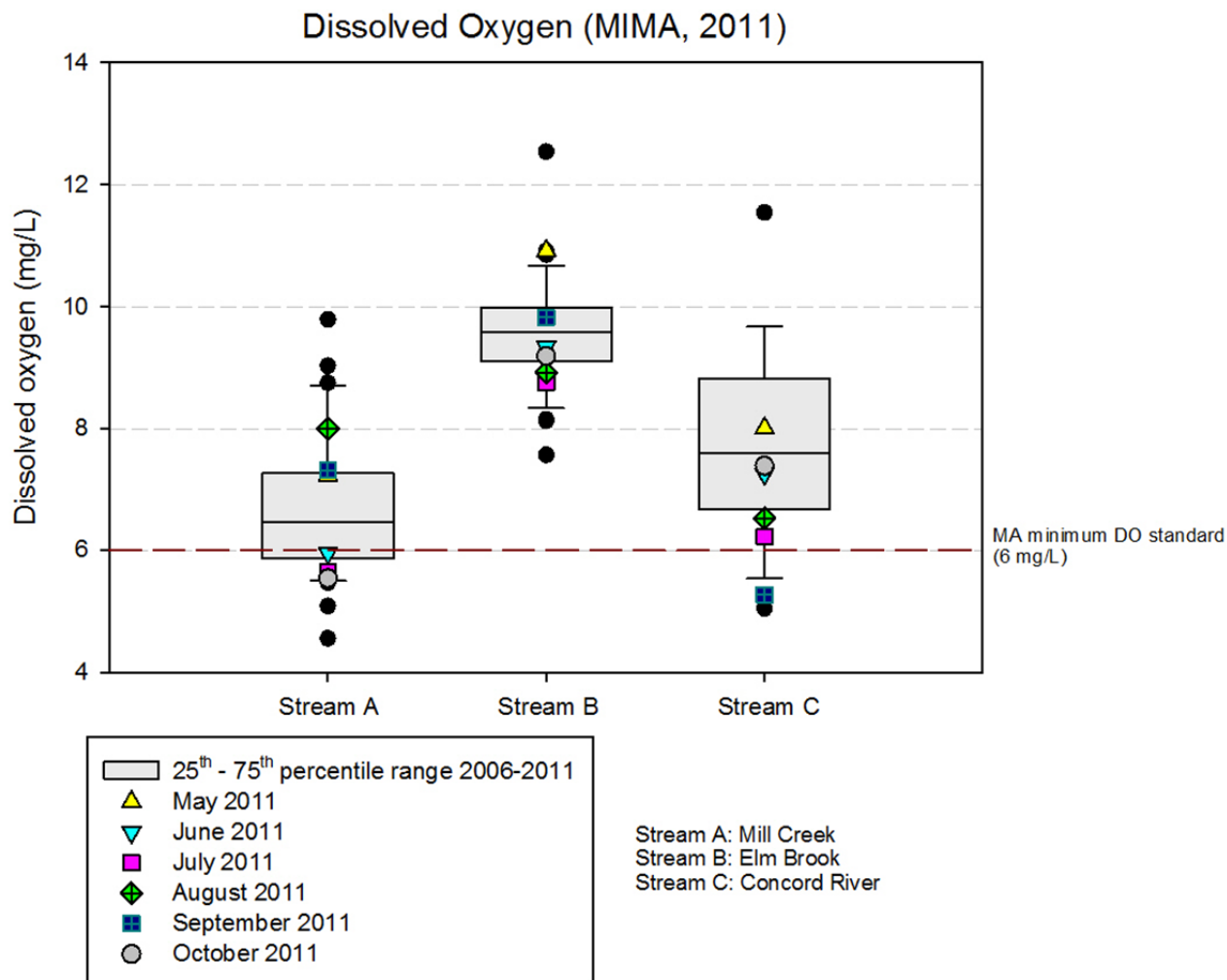


Figure 6. Dissolved oxygen (surface) from 2011 YSI sonde in-situ measurements overlaid on a box plot of measurements taken from 2006-2011.

Acid Neutralizing Capacity

Acid neutralizing capacity (ANC) is also known as alkalinity, or buffering capacity. It is due primarily to the presence of naturally available bicarbonate, carbonate, and hydroxide ions, with bicarbonate being the major form. Most states do not have numerical criteria for ANC in their water-quality standards. ANC values greater than 100 $\mu\text{eq/L}$ are considered well-buffered, while values less than zero typify acidic waters (Stoddard et al. 2003). Acid neutralizing capacity measured in the 2011 samples (Figure 7) illustrates that MIMA streams were well-buffered, likely due to the underlying geology. May (spring) 2011 ANC measurements follow the typical seasonal pattern of being lower than August (summer) values. This effect is likely due to the contribution of episodic acidification from spring snowmelt and runoff (and also illustrates the ability of the robust ANC to counteract the acidification pulses).

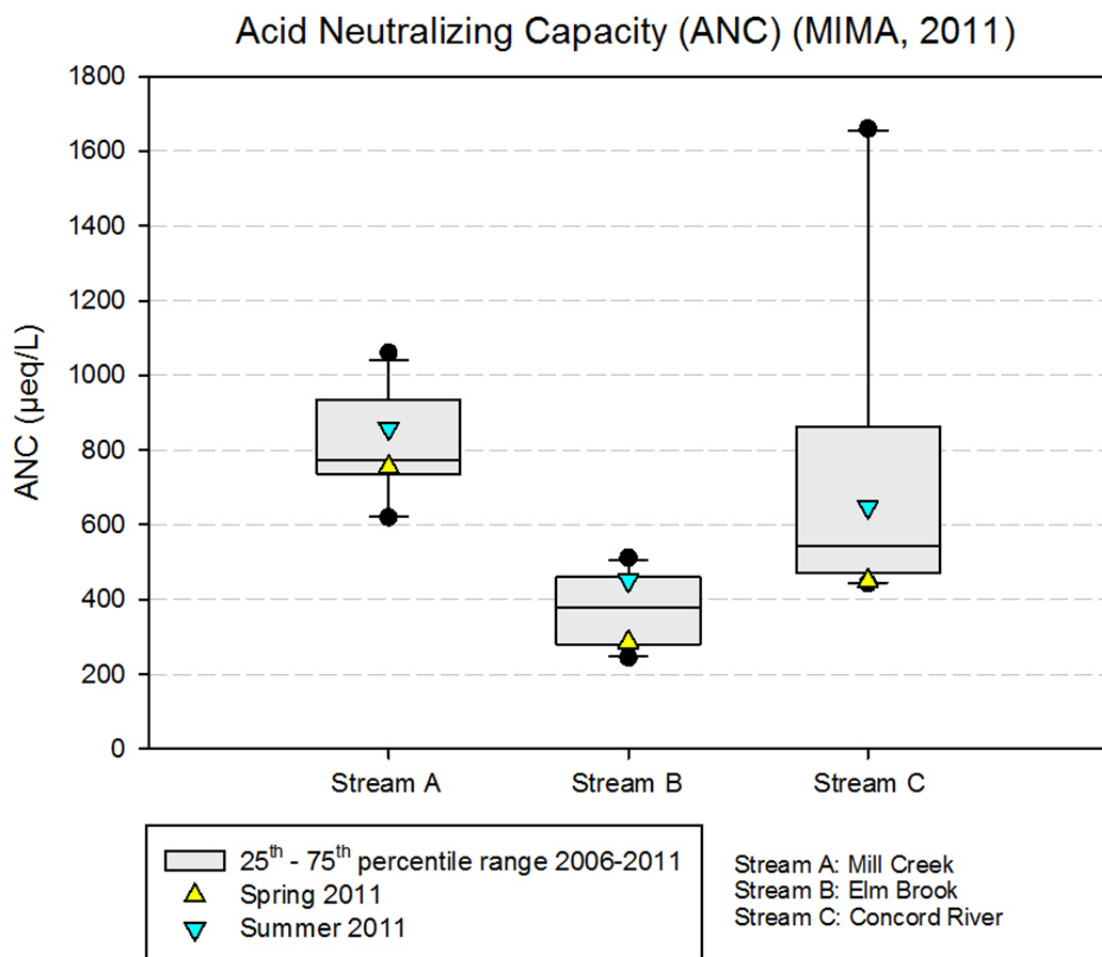


Figure 7. Acid neutralizing capacity from 2011 spring and summer water samples overlaid on a box plot of measurements taken from 2006-2011.

Apparent Color

Color in pond and stream water is caused by natural metallic ions, humus and peat materials, plankton, weeds, and industrial wastes. Color is reported in Pt-Co units (PCU). True color is the color measurement of water from which suspended particles have been removed by filtration. Apparent color (the measurement method utilized by NETN) is determined on original samples without filtration. Color can be a rough indicator for organic acidity.

Water bodies with apparent color values of greater than 25 PCU are considered to be highly colored, and often exhibit reduced water clarity and high phosphorus concentrations. Values of color are usually not included in water quality standards, except to note that they should be as naturally occurs.

Median color values from 2006 to 2011 monitoring (Figure 8) show that MIMA streams tend to be highly colored. 2011 measurements from Mill Brook (Stream A) and the Concord River (Stream C) were above the median value, and the Elm Brook color was below the 2006-2011 median. Much of the color is likely due to runoff and sediment input to the streams, rather than dissolved constituents, since the samples were not filtered before analysis. Monthly turbidity measurements, which will begin in 2012, may provide additional information on the impacts to MIMA streams from episodic runoff events.

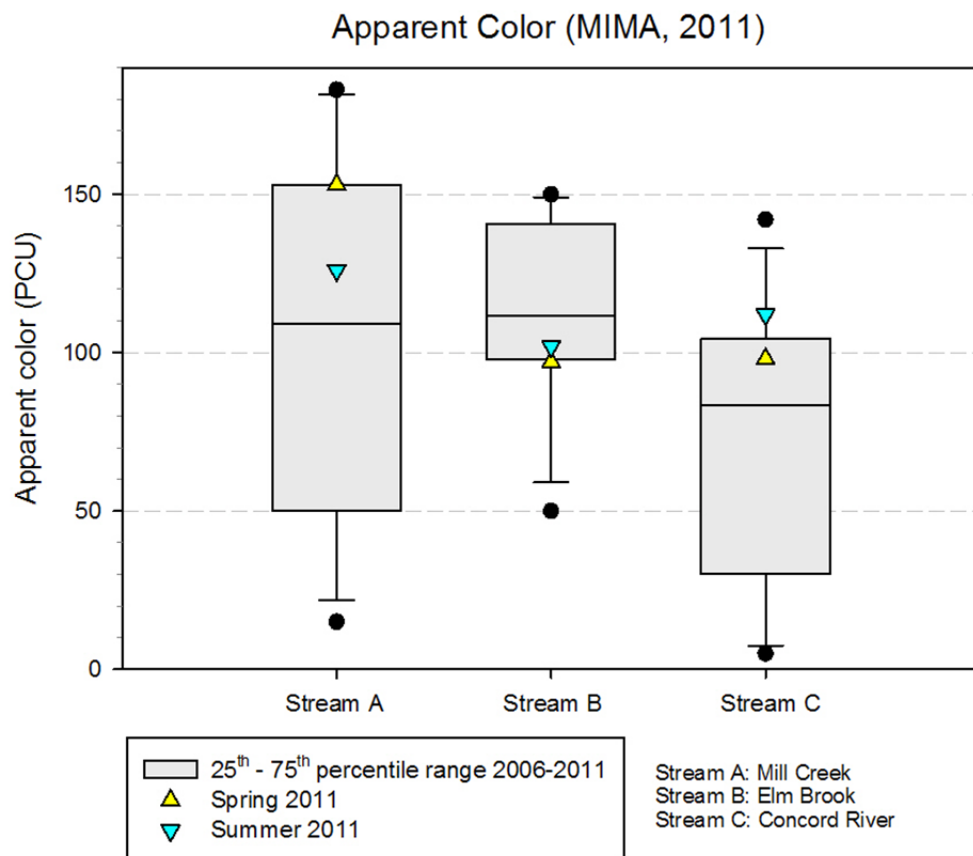


Figure 8. Apparent color from 2011 spring and summer water samples overlaid on a box plot of measurements taken from 2006-2011.

Nutrient Enrichment

Nutrient enrichment and the acceleration of eutrophication have been identified in most NETN parks as one of the stressors of greatest concern. Several forms of total and dissolved phosphorus and nitrogen are measured to give managers information regarding the trophic status and productivity of freshwater systems.

Phosphorus

Phosphorus (P) is one of the major nutrients needed for plant growth. It is generally present in small amounts and limits the plant growth in streams and ponds. Several forms of phosphorus were tested individually. Total phosphorus (TP) is a measure of both inorganic and organic forms of phosphorus, and is the common water quality standard or criteria metric. Phosphorus can be present as dissolved or particulate matter, and filtered samples were analyzed for total dissolved phosphorus (TDP). Soluble reactive phosphorus (SRP, or “orthophosphate”) is a measure of the inorganic oxidized form of soluble phosphorus. This form of phosphorus is the most readily available for uptake during photosynthesis. High concentrations of SRP generally occur in conjunction with algal blooms.

In 2011, most phosphorus concentrations (Figure 9) were in the moderate to high range, and generally showed the expected seasonal variation of lower spring values. All TP values were well above the EPA Region 14 criterion of $31.25\mu\text{g/L}$. As described above (“Water Quality Standards”), the EPA criteria do not have any regulatory meaning.

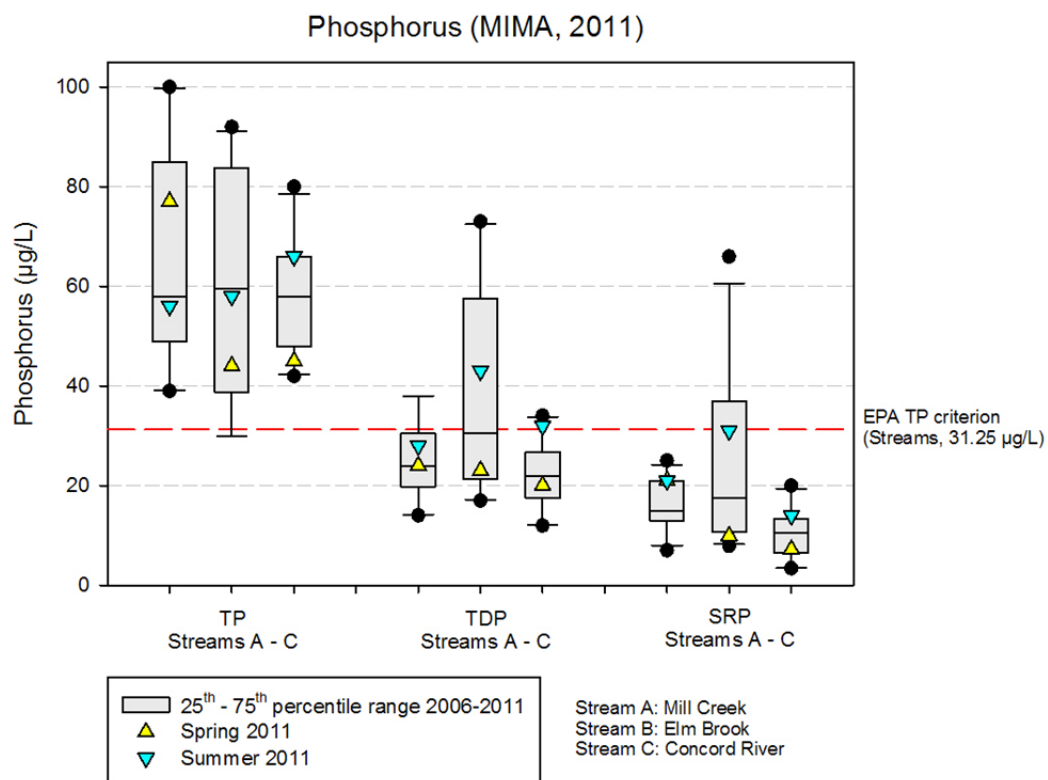


Figure 9. Total phosphorus (TP), total dissolved phosphorus (TDP), and soluble reactive phosphorus (SRP) from spring and summer water samples. The data are overlaid on a box plot of measurements taken from 2006-2011. There is no numeric Massachusetts state water quality TP standard.

Nitrogen

Total nitrogen (TN) is a measure of all forms of nitrogen (organic and inorganic). Nitrogen is an essential plant element and is often the limiting nutrient in marine waters, and it can also limit some freshwater systems. Filtered samples were analyzed for total dissolved nitrogen (TDN). The importance of nitrogen in the aquatic environment varies according to the relative amounts of the forms of nitrogen present, including nitrate, nitrite, and ammonia.

Test results for several forms of nitrogen are shown in Figure 10. All but one of the 2011 TN values exceeded the EPA Region 14 criterion of 0.71 mg/L, although as with TP this criterion does not have regulatory meaning. All of the TN and TDN results were below 2.0 mg/L, the value used as a TN standard in several northeast states (Massachusetts has no numeric TN standard). Nitrate (NO_3) is the most oxidized and stable form of nitrogen in a water body, and is the primary form of nitrogen used by plants as a nutrient. Nitrite (NO_2) is an unstable form of nitrogen that is either rapidly oxidized to nitrate (nitrification) or reduced to nitrogen gas (denitrification). This form of nitrogen can also be used as a source of nutrients for plants. NETN water samples were analyzed with a combined test for nitrate and nitrite, and most of the N detected in this test was in the form of nitrate, since individual nitrite test results in all streams were very low, with several below the method reporting limit of 0.005 mg/L. All 2011 ammonia (NH_3 , another inorganic, bioavailable form of concern) test results were below the method reporting limit of 0.08 mg/L.

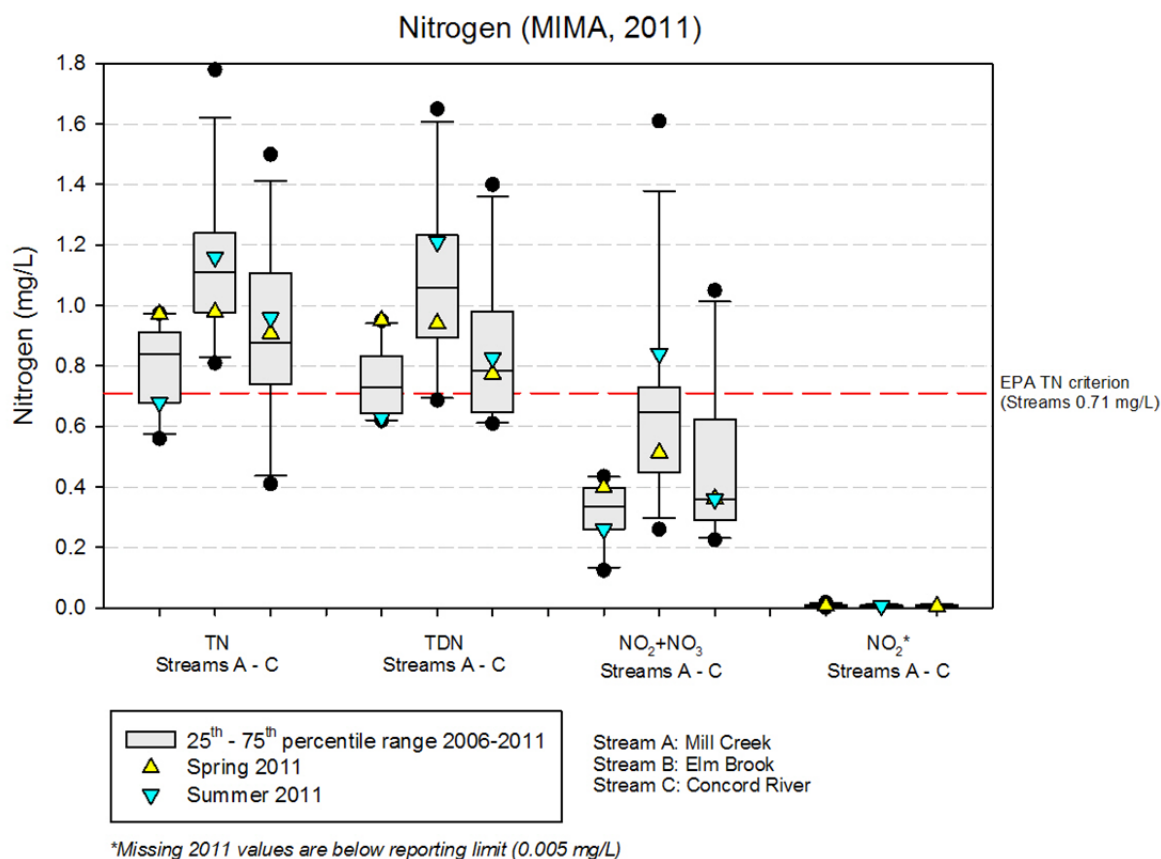


Figure 10. Total nitrogen (TN), total dissolved nitrogen (TDN), nitrite + nitrate ($\text{NO}_2 + \text{NO}_3$), and nitrite (NO_2) from 2011 spring and summer water samples. The data are overlaid on a box plot of measurements taken from 2006-2011.

Water Quantity

Monthly stream discharge measurements, taken with a current meter and wading rod, can be used to calculate loading of nutrient chemical constituents (flow times concentration), and also provide a record of variations in stream flow. Stream stage (height of water) measurements can be paired with discharge values and over time a stage to discharge relationship can be calculated. Once this relationship is established, investigators can interpolate the stream discharge from the stage measurement alone. Numerous discharge measurements at all ranges of streamflow are required to establish and maintain an accurate stage to discharge relationship. Stream stage measurements from 2011 are graphed in Figure 11. Discharge and stage measurements from 2006 to 2011 are listed in Table A3 in Appendix A. No stage or discharge measurements are available for the Concord River (Stream C).

Streamflow followed the expected seasonal sequence of high discharge in May to minimal flow in July and August, with gradual recovery in September and October. NETN staff are currently reviewing discharge and stage measurement methodology and quality assurance/quality control procedures in order to enhance the quality and utility of the water quantity data. A stage to discharge relationship graph will be produced once sufficient data are collected.

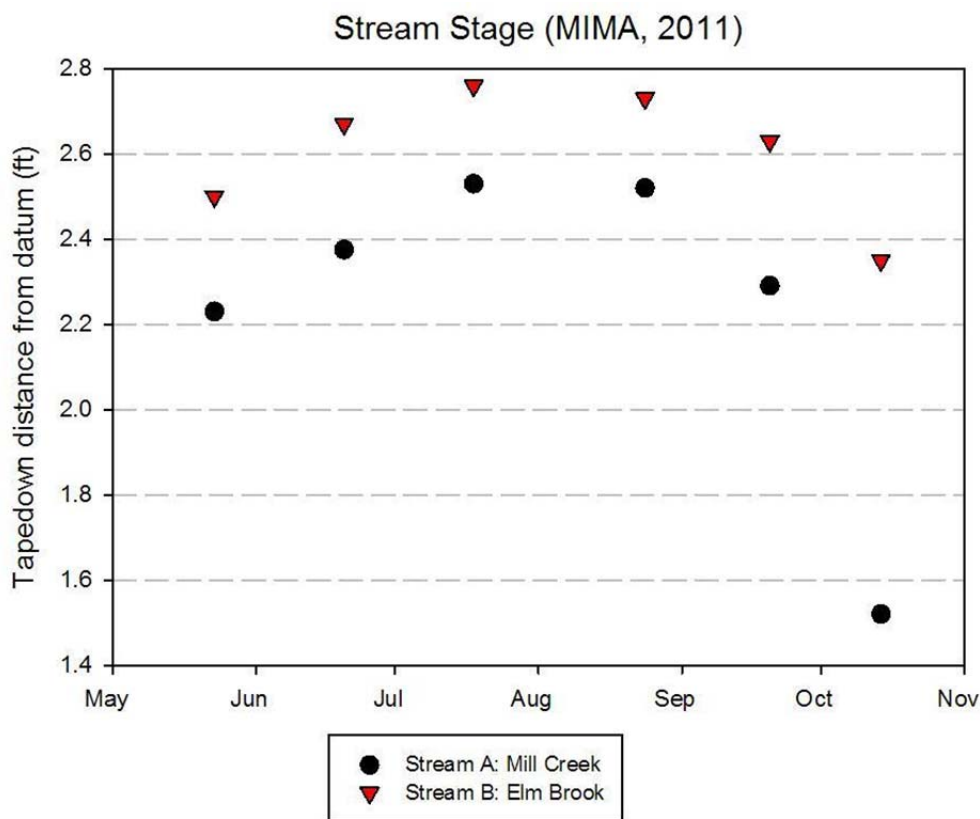


Figure 11. Stream stage obtained in 2011 by measuring from a permanent datum point down to the water surface. *Note: Larger tapedown distances indicate LOWER water levels.*

Invasive Aquatic Plants

Invasive aquatic plant monitoring was not conducted at MIMA during the 2011 monitoring season, since the protocol specifies that targeted invasive aquatic plant monitoring is only conducted at pond and lake sites. However, during future visits to all NETN parks, monitoring crews will be increasingly attentive for the presence of Didymo (*Didymosphenia geminata*), also known as “rock snot”, a highly invasive alga that has recently invaded the northern reaches of the Connecticut River in New Hampshire and in the White River and Battenkill River in Vermont. This species has a great potential to alter habitats and displace native species, and is of great concern to officials in regions where infestations have been established.

Didymo is easily spread by even just one cell of the alga breaking off and drifting downstream in infested reaches. It is also very easily spread by waders, and potentially, water monitoring equipment and other gear that touches the bottoms of streams in infested areas. Enhanced equipment cleaning and decontamination procedures are being included in the latest NETN monitoring protocol revision.

The early detection of an invasive plant infestation can make eradication or control more feasible, and it can lead to efforts that reduce the spread of the plant to neighboring water bodies. Designating the early detection of these plants as a NETN vital sign and the ongoing partnership with state and local monitoring and eradication efforts are highly effective prevention strategies.

Summary

Most water quality parameters for the streams monitored in Minute Man National Historical Park are within state standards, and are generally within the range of EPA criteria, where applicable. The majority of values are within the ranges of the historic NETN monitoring data from MIMA. ANC measurements showed that all streams had sufficient buffering to avoid severely depressed pH values from spring snowmelt and runoff that can contribute acidity and sediment to the stream water.

Test results for TN, TDN, and NO₃ were moderately high in most 2011 samples. Results for NO₂ were low at all sites. All ammonia (NH₃) test results were below the method reporting limit of 0.08 mg/L. All total phosphorus results for 2011 were significantly above the EPA Region 14 criterion of 31.25 µg/L, and TDP and SRP values were in the moderate range in all streams. These results indicate that some nutrient enrichment is occurring in MIMA streams.

Monitoring under the NETN protocol builds on the historic water quality monitoring by park staff and other agencies to provide critical baseline information on the chemical and physical status of the water resources Minute Man National Historical Park. Several changes will be implemented in the 2012 monitoring season, including taking monthly stream turbidity measurements, and the addition of sulfate, chloride, and dissolved organic carbon (DOC) analyses to the spring and summer water chemistry testing. These changes will expand the scope and usefulness of the monitoring data. As more data are collected, the ability to detect changes outside this natural range of variability will increase, which in turn will more clearly indicate the status of the vital signs of water quality, nutrient enrichment, water quantity, and the detection of invasive plant species.

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Appendix A. Minute Man National Historical Park (MIMA) Water Monitoring Data, 2006-2011.

Table A1. YSI sonde in-situ water quality measurements collected at MIMA.

Site	Date	Depth (m)	Temp (C)	DO (mg/L)	pH	Specific Conductance (μ S/cm)
Mill Creek (Stream A)	5/15/2006	0.1	9.88	7.35	6.46	166
Mill Creek (Stream A)	6/12/2006	0.5	17.95	6.38	6.99	306
Mill Creek (Stream A)	7/17/2006	0.2	21.74	5.62	6.79	574
Mill Creek (Stream A)	8/21/2006	0.1	20.01	6.34	7.68	630
Mill Creek (Stream A)	9/26/2006	0.2	13.84	7.61	7.10	643
Mill Creek (Stream A)	10/10/2006	0.0	13.96	8.68	8.03	177
Mill Creek (Stream A)	10/10/2006	0.3	12.64	7.71	7.95	645
Mill Creek (Stream A)	4/2/2007	0.3	6.36	8.75	7.09	508
Mill Creek (Stream A)	5/7/2007	0.8	14.37	9.79	7.45	511
Mill Creek (Stream A)	6/6/2007	0.1	16.84	5.47	6.83	395
Mill Creek (Stream A)	7/3/2007	0.2	15.63	6.80	7.26	456
Mill Creek (Stream A)	8/13/2007	0.3	20.90	6.45	7.59	595
Mill Creek (Stream A)	10/11/2007	0.1	14.31	6.86	7.65	679
Mill Creek (Stream A)	5/19/2008	0.2	14.61	7.17	6.85	576
Mill Creek (Stream A)	6/16/2008	0.1	17.14	5.83	6.94	650
Mill Creek (Stream A)	7/21/2008	0.2	23.01	6.96	6.94	542
Mill Creek (Stream A)	8/20/2008	0.5	18.76	6.07	6.73	487
Mill Creek (Stream A)	9/22/2008	0.3	14.88	6.48	6.89	545
Mill Creek (Stream A)	10/15/2008	0.1	13.84	9.03	7.02	608
Mill Creek (Stream A)	5/8/2009	0.4	16.22	6.15	6.63	458
Mill Creek (Stream A)	6/17/2009	0.2	17.57	6.21	6.68	579
Mill Creek (Stream A)	7/22/2009	0.5	18.51	6.02	6.69	577
Mill Creek (Stream A)	8/19/2009	0.2	25.82	7.04	6.96	658
Mill Creek (Stream A)	9/30/2009	0.2	14.71	5.51	6.94	610
Mill Creek (Stream A)	10/23/2009	0.3	10.21	7.06	6.89	585
Mill Creek (Stream A)	5/24/2010	0.4	19.60	6.83	6.63	562
Mill Creek (Stream A)	6/14/2010	0.1	16.93	7.28	7.05	587
Mill Creek (Stream A)	7/9/2010	0.1	24.84	5.09	7.01	681
Mill Creek (Stream A)	8/10/2010	0.3	24.02	4.56	7.40	644
Mill Creek (Stream A)	9/7/2010	0.3	19.05	6.04	7.03	711
Mill Creek (Stream A)	10/4/2010	0.3	12.98	5.57	6.68	625
Mill Creek (Stream A)	5/23/2011	0.3	13.11	7.24	6.79	551
Mill Creek (Stream A)	6/20/2011	0.2	18.66	5.95	6.85	616
Mill Creek (Stream A)	7/18/2011	0.3	22.43	5.64	7.03	684
Mill Creek (Stream A)	8/24/2011	0.4	19.87	8.00	7.03	616
Mill Creek (Stream A)	9/20/2011	0.3	13.56	7.32	7.02	573
Mill Creek (Stream A)	10/14/2011	0.3	14.65	5.54	6.58	473
Elm Brook (Stream B)	5/15/2006	0.2	9.59	10.58	6.40	225
Elm Brook (Stream B)	6/12/2006	0.2	14.63	9.68	7.21	394
Elm Brook (Stream B)	7/17/2006	0.2	19.46	8.82	7.06	522
Elm Brook (Stream B)	8/21/2006	0.0	18.35	9.02	7.66	552
Elm Brook (Stream B)	9/26/2006	0.2	13.49	9.62	8.35	502

Appendix A. Minute Man National Historical Park (MIMA) Water Monitoring Data, 2006-2011 (continued).

Table A1. YSI sonde in-situ water quality measurements collected at MIMA (continued).

Site	Date	Depth (m)	Temp (C)	DO (mg/L)	pH	Specific Conductance (µS/cm)
Elm Brook (Stream B)	10/10/2006	0.2	13.23	9.51	7.72	482
Elm Brook (Stream B)	4/2/2007	0.2	4.42	12.54	6.97	434
Elm Brook (Stream B)	5/7/2007	0.8	14.12	10.30	7.41	485
Elm Brook (Stream B)	6/6/2007	0.2	13.53	9.94	7.19	334
Elm Brook (Stream B)	7/3/2007	0.1	12.76	10.31	7.70	495
Elm Brook (Stream B)	8/13/2007	0.2	18.17	9.08	7.92	489
Elm Brook (Stream B)	9/10/2007	0.2	15.78	9.16	8.19	393
Elm Brook (Stream B)	10/11/2007	-0.1	13.68	9.65	7.99	511
Elm Brook (Stream B)	5/19/2008	0.2	12.47	10.00	6.95	756
Elm Brook (Stream B)	6/16/2008	0.1	14.95	9.52	7.12	872
Elm Brook (Stream B)	7/21/2008	0.1	20.78	8.41	7.10	680
Elm Brook (Stream B)	8/20/2008	0.5	16.53	9.32	7.25	584
Elm Brook (Stream B)	9/22/2008	0.3	14.26	9.55	7.69	562
Elm Brook (Stream B)	10/15/2008	0.1	12.76	9.39	7.18	527
Elm Brook (Stream B)	5/8/2009	0.2	14.42	10.01	6.75	877
Elm Brook (Stream B)	6/17/2009	0.2	14.98	9.77	6.93	743
Elm Brook (Stream B)	8/19/2009	0.1	21.88	8.15	7.01	567
Elm Brook (Stream B)	9/30/2009	0.0	13.30	9.48	7.47	522
Elm Brook (Stream B)	10/23/2009	0.2	9.37	10.85	7.24	606
Elm Brook (Stream B)	5/24/2010	0.2	16.00	9.61	7.31	509
Elm Brook (Stream B)	6/14/2010	0.1	14.90	9.74	7.24	465
Elm Brook (Stream B)	7/9/2010	0.2	20.60	8.47	7.05	490
Elm Brook (Stream B)	8/10/2010	0.2	19.45	7.57	7.37	279
Elm Brook (Stream B)	9/7/2010	0.3	17.91	8.13	7.18	577
Elm Brook (Stream B)	9/7/2010	0.3	17.89	8.55	7.24	573
Elm Brook (Stream B)	10/4/2010	0.3	12.08	9.59	7.02	596
Elm Brook (Stream B)	5/23/2011	0.3	11.34	10.91	6.86	558
Elm Brook (Stream B)	6/20/2011	0.2	15.64	9.34	7.11	693
Elm Brook (Stream B)	7/18/2011	0.2	19.02	8.75	7.10	637
Elm Brook (Stream B)	8/24/2011	0.4	17.68	8.92	7.09	554
Elm Brook (Stream B)	9/20/2011	0.2	13.64	9.82	7.11	506
Elm Brook (Stream B)	10/14/2011	0.3	14.88	9.19	6.80	342
Concord River (Stream C)	4/2/2007	0.1	8.30	11.57	6.88	342
Concord River (Stream C)	4/2/2007	0.1	8.27	11.58	6.90	343
Concord River (Stream C)	4/2/2007	0.1	8.28	11.57	6.90	342
Concord River (Stream C)	4/2/2007	0.1	8.31	11.54	6.86	348
Concord River (Stream C)	4/2/2007	0.2	8.24	11.58	6.90	341
Concord River (Stream C)	4/2/2007	0.3	8.29	11.50	6.75	352
Concord River (Stream C)	4/2/2007	0.3	8.32	11.54	6.82	349
Concord River (Stream C)	4/2/2007	0.4	8.23	11.56	6.91	340
Concord River (Stream C)	5/7/2007	1.3	15.57	10.18	7.63	354
Concord River (Stream C)	6/6/2007	0.5	19.24	6.49	6.90	313
Concord River (Stream C)	6/6/2007	0.7	19.37	6.67	6.96	313
Concord River (Stream C)	6/6/2007	0.8	19.31	6.59	6.97	316
Concord River (Stream C)	6/6/2007	0.9	19.36	6.66	6.93	313
Concord River (Stream C)	6/6/2007	0.9	19.33	6.60	6.90	314

Appendix A. Minute Man National Historical Park (MIMA) Water Monitoring Data, 2006-2011 (continued).

Table A1. YSI sonde in-situ water quality measurements collected at MIMA (continued).

Site	Date	Depth (m)	Temp (C)	DO (mg/L)	pH	Specific Conductance (µS/cm)
Concord River (Stream C)	6/6/2007	1.0	19.36	6.59	6.91	313
Concord River (Stream C)	6/6/2007	1.4	19.33	6.59	6.90	314
Concord River (Stream C)	6/6/2007	1.4	19.32	6.62	6.89	313
Concord River (Stream C)	7/3/2007	0.0	22.51	7.27	7.17	391
Concord River (Stream C)	7/3/2007	0.1	21.60	7.01	7.31	396
Concord River (Stream C)	7/3/2007	0.2	21.36	6.97	7.50	396
Concord River (Stream C)	7/3/2007	0.4	21.92	7.07	7.16	391
Concord River (Stream C)	7/3/2007	0.7	21.70	6.98	7.18	393
Concord River (Stream C)	7/3/2007	0.9	21.73	7.00	7.16	392
Concord River (Stream C)	7/3/2007	0.9	21.67	6.99	7.24	394
Concord River (Stream C)	7/3/2007	1.0	21.69	7.00	7.23	393
Concord River (Stream C)	8/13/2007	0.1	25.73	9.51	7.73	489
Concord River (Stream C)	8/13/2007	0.1	25.66	7.94	7.51	490
Concord River (Stream C)	8/13/2007	0.2	25.24	7.58	7.51	489
Concord River (Stream C)	8/13/2007	0.3	25.48	7.79	7.63	492
Concord River (Stream C)	8/13/2007	0.5	25.48	7.82	7.59	492
Concord River (Stream C)	8/13/2007	0.6	25.22	7.56	7.52	489
Concord River (Stream C)	8/13/2007	0.7	25.24	7.70	7.52	489
Concord River (Stream C)	8/13/2007	0.8	25.30	7.76	7.55	489
Concord River (Stream C)	9/10/2007	0.0	20.99	6.28	7.38	603
Concord River (Stream C)	9/10/2007	0.1	21.10	5.17	7.38	605
Concord River (Stream C)	9/10/2007	0.1	20.55	6.84	7.69	595
Concord River (Stream C)	9/10/2007	0.2	20.99	6.52	7.57	601
Concord River (Stream C)	9/10/2007	0.4	20.94	6.26	7.41	601
Concord River (Stream C)	9/10/2007	0.7	20.96	6.31	7.51	602
Concord River (Stream C)	9/10/2007	0.7	20.94	6.24	7.43	601
Concord River (Stream C)	9/10/2007	1.0	20.95	6.30	7.50	602
Concord River (Stream C)	10/11/2007	0.1	16.30	7.78	7.46	567
Concord River (Stream C)	10/11/2007	0.1	16.09	7.92	7.67	566
Concord River (Stream C)	10/11/2007	0.2	16.40	7.38	7.47	570
Concord River (Stream C)	10/11/2007	0.3	16.30	7.51	7.61	573
Concord River (Stream C)	10/11/2007	0.5	16.35	7.05	7.50	570
Concord River (Stream C)	10/11/2007	0.6	16.35	7.61	7.51	571
Concord River (Stream C)	10/11/2007	0.6	16.32	7.59	7.57	573
Concord River (Stream C)	10/11/2007	0.8	16.34	7.57	7.53	572
Concord River (Stream C)	5/19/2008	0.2	16.52	8.98	7.21	421
Concord River (Stream C)	6/16/2008	1.5	21.17	6.04	7.06	495
Concord River (Stream C)	7/21/2008	0.5	25.99	5.54	7.00	418
Concord River (Stream C)	8/20/2008	1.0	21.63	3.94	6.65	314
Concord River (Stream C)	9/22/2008	1.6	16.98	5.74	6.91	370
Concord River (Stream C)	6/17/2009	0.6	20.19	8.47	6.97	400
Concord River (Stream C)	7/22/2009	1.5	22.16	4.57	6.65	368
Concord River (Stream C)	8/19/2009	0.7	27.87	5.05	6.82	411
Concord River (Stream C)	9/30/2009	0.7	17.20	8.45	7.20	454
Concord River (Stream C)	10/23/2009	0.5	10.85	9.67	7.12	392
Concord River (Stream C)	5/24/2010	1.3	22.04	7.90	6.85	378

Appendix A. Minute Man National Historical Park (MIMA) Water Monitoring Data, 2006-2011 (continued).

Table A1. YSI sonde in-situ water quality measurements collected at MIMA (continued).

Site	Date	Depth (m)	Temp (C)	DO (mg/L)	pH	Specific Conductance (µS/cm)
Concord River (Stream C)	5/24/2010	1.5	22.04	7.98	6.86	376
Concord River (Stream C)	6/14/2010	0.2	19.28	6.60	7.07	403
Concord River (Stream C)	6/14/2010	0.4	19.28	6.62	7.15	405
Concord River (Stream C)	7/9/2010	0.3	28.80	5.74	7.24	506
Concord River (Stream C)	8/10/2010	1.3	26.41	8.67	7.42	580
Concord River (Stream C)	8/10/2010	1.3	26.32	8.84	7.48	580
Concord River (Stream C)	9/7/2010	1.4	21.86	7.06	7.34	574
Concord River (Stream C)	9/7/2010	1.4	21.83	6.98	7.32	573
Concord River (Stream C)	10/4/2010	0.8	16.05	8.82	7.16	661
Concord River (Stream C)	10/4/2010	0.8	16.05	8.80	7.20	661
Concord River (Stream C)	10/4/2010	0.8	15.98	8.76	7.11	661
Concord River (Stream C)	10/4/2010	0.9	16.08	8.79	7.25	662
Concord River (Stream C)	10/4/2010	0.9	16.07	8.80	7.23	661
Concord River (Stream C)	5/23/2011	0.4	16.02	8.01	6.87	388
Concord River (Stream C)	5/23/2011	0.4	16.05	8.01	6.86	388
Concord River (Stream C)	6/20/2011	0.6	22.47	7.26	7.02	462
Concord River (Stream C)	6/20/2011	0.7	22.46	7.27	7.01	462
Concord River (Stream C)	7/18/2011	0.5	25.82	6.22	7.15	523
Concord River (Stream C)	7/18/2011	0.5	25.84	6.22	7.15	524
Concord River (Stream C)	7/18/2011	1.2	25.83	5.82	7.13	525
Concord River (Stream C)	7/18/2011	1.2	25.85	5.87	7.15	524
Concord River (Stream C)	8/24/2011	1.0	23.37	6.52	6.99	433
Concord River (Stream C)	8/24/2011	1.0	23.36	6.53	7.03	433
Concord River (Stream C)	9/20/2011	1.1	15.97	5.27	6.99	373
Concord River (Stream C)	9/20/2011	1.1	15.96	4.95	7.07	374
Concord River (Stream C)	10/14/2011	0.6	15.29	7.39	6.65	389
Concord River (Stream C)	10/14/2011	0.7	15.30	7.38	6.65	388

Appendix A. Minute Man National Historical Park (MIMA) Water Monitoring Data, 2006-2011 (continued).

Table A2. Laboratory nutrient chemistry data for Minute Man National Historical Park. “<MRL” indicates the result was below the method reporting limit (provided after the abbreviation). *Missing values indicate data are unavailable.*

Site	Date	ANC (µeq/L)	Apparent Color (PCU)	TP (µg/L)	TDP (µg/L)	SRP (µg/L)	TN (mg/L)	TDN (mg/L)	NO2+NO3 (mg/L)	NO2 (mg/L)	NH3 (mg/L)
Mill Creek (Stream A)	8/21/2006	620.0	50	40		13.0	0.560		0.169	0.002	0.030
Mill Creek (Stream A)	5/7/2007	736.8	50	39	14	7.0	0.840	0.710	0.338	0.003	0.014
Mill Creek (Stream A)	8/13/2007	961.9	15	49	16	14.0	0.630	0.620	0.316	0.008	0.072
Mill Creek (Stream A)	5/19/2008	772.0	183	99	25	17.0	0.912	0.746	0.367	0.009	
Mill Creek (Stream A)	8/20/2008	793.0	131	100	38	25.0	0.974	0.859	0.435	0.006	<MRL 0.08
Mill Creek (Stream A)	5/8/2009	632.0	175	85	38	16.0	0.706	0.650	0.124	0.007	<MRL 0.08
Mill Creek (Stream A)	8/19/2009	936.0	107	54	23	14.0	0.683	0.701	0.315	0.008	0.094
Mill Creek (Stream A)	5/24/2010	761.0	109	67	24	15.0	0.866	0.797	0.334	0.010	0.170
Mill Creek (Stream A)	8/10/2010	1060.0	99	58	21	12.0	0.887	0.824	0.429	0.018	0.160
Mill Creek (Stream A)	5/23/2011	754.0	153	77	24	21.0	0.971	0.950	0.398	0.006	<MRL 0.08
Mill Creek (Stream A)	8/24/2011	858.0	126	56	28	21.0	0.679	0.628	0.260	<MRL 0.005	<MRL 0.08
Elm Brook (Stream B)	6/12/2006	300.0	100	30		15.0	1.210		0.646	0.003	0.014
Elm Brook (Stream B)	8/21/2006	400.0	80	30		20.0	0.810		0.386	0.003	0.023
Elm Brook (Stream B)	8/13/2007	512.1	150	92	73	66.0	1.250	1.230	0.656	0.006	0.016
Elm Brook (Stream B)	5/7/2007	277.0	50	37	17	9.0	1.080	1.060	0.648	0.003	<MRL 0.02
Elm Brook (Stream B)	8/20/2008	490.0	117	77	54	39.0	1.130	1.060	0.754	0.014	<MRL 0.08
Elm Brook (Stream B)	5/19/2008	254.0	111	52	19	13.0	0.875	0.751	0.428	<MRL 0.005	
Elm Brook (Stream B)	5/8/2009	245.0	144	89	22	7.9	0.978	0.687	0.260	<MRL 0.005	<MRL 0.08
Elm Brook (Stream B)	8/19/2009	459.0	131	86	68	48.0	1.250	1.240	0.659	0.008	<MRL 0.08
Elm Brook (Stream B)	8/10/2010	461.0	147	61	24	13.0	1.780	1.650	1.610	0.010	<MRL 0.08
Elm Brook (Stream B)	5/24/2010	356.0	112	66	37	20.0	1.090	1.010	0.532	0.006	<MRL 0.08
Elm Brook (Stream B)	5/23/2011	286.0	97	44	23	9.9	0.978	0.941	0.513	<MRL 0.005	<MRL 0.08

Appendix A. Minute Man National Historical Park (MIMA) Water Monitoring Data, 2006-2011 (continued).

Table A2. Laboratory nutrient chemistry data for MIMA (continued).

Site	Date	ANC (µeq/L)	Apparent Color (PCU)	TP (µg/L)	TDP (µg/L)	SRP (µg/L)	TN (mg/L)	TDN (mg/L)	NO ₂ +NO ₃ (mg/L)	NO ₂ (mg/L)	NH ₃ (mg/L)
Elm Brook (Stream B)	8/24/2011	451.0	102	58	43	31.0	1.160	1.210	0.840	0.007	<MRL 0.08
Concord River (Stream C)	6/13/2006	1640.0	5	<MRL 20		<MRL 6	0.410		<MRL 0.06	0.001	0.006
Concord River (Stream C)	8/23/2006	1660.0	13	<MRL 20		E, <MRL 6	0.500		<MRL 0.06	<MRL 0.002	0.068
Concord River (Stream C)	5/7/2007	461.2	30	42	12	4.0	0.740	0.610	0.282	0.004	<MRL 0.02
Concord River (Stream C)	8/13/2007	806.5	30	59	19	8.0	1.210	1.000	0.686	0.004	<MRL 0.02
Concord River (Stream C)	5/19/2008	500.0	82	54	24	11.0	1.100	0.783	0.602	0.009	
Concord River (Stream C)	8/20/2008	517.0	142	66	34	20.0	0.772	0.653	0.225	<MRL 0.005	<MRL 0.08
Concord River (Stream C)	5/8/2009	443.0	105	58	24	12.0	1.110	0.973	0.603	0.010	<MRL 0.08
Concord River (Stream C)	8/19/2009	572.0	85	58	20	13.0	0.746	0.623	0.292	0.006	<MRL 0.08
Concord River (Stream C)	5/24/2010	504.0	72	49	13	3.4	0.846	0.784	0.359	0.007	<MRL 0.08
Concord River (Stream C)	8/10/2010	883.0	103	80	25	10.0	1.500	1.400	1.050	0.012	<MRL 0.08
Concord River (Stream C)	8/24/2011	648.0	112	66	32	14.0	0.959	0.826	0.359	<MRL 0.005	<MRL 0.08
Concord River (Stream C)	5/23/2011	450.0	98	45	20	7.2	0.908	0.774	0.361	0.006	<MRL 0.08

Table A3. Stream stage and discharge data for Minute Man National Historical Park. *Missing values indicate data are unavailable.*

Site	Date	Tapedown from datum (ft)	Total cross section area (sqft)	Average velocity (f/s)	Discharge (cfs)
Mill Creek (Stream A)	7/17/2006	1.99	5.35	0.63	3.23
Mill Creek (Stream A)	8/21/2006	1.72	8.12	0.52	4.39
Mill Creek (Stream A)	9/26/2006	1.95	6.09	0.43	2.72
Mill Creek (Stream A)	10/10/2006	2.05	5.88	0.34	2.02
Mill Creek (Stream A)	4/2/2007	1.71	9.61	0.81	7.87
Mill Creek (Stream A)	5/7/2007	2.06	4.56	1.01	4.56
Mill Creek (Stream A)	6/6/2007	1.93	8.75	0.87	7.04
Mill Creek (Stream A)	7/3/2007	2.43	2.47	0.72	1.73
Mill Creek (Stream A)	8/13/2007	2.29	2.95	0.42	1.20
Mill Creek (Stream A)	5/19/2008	2.19	3.34	0.78	2.64
Mill Creek (Stream A)	6/16/2008	2.35	2.72	0.67	1.74
Mill Creek (Stream A)	7/21/2008	2.03	6.33	0.58	3.67
Mill Creek (Stream A)	8/20/2008	2.00			
Mill Creek (Stream A)	9/22/2008	2.08		0.51	
Mill Creek (Stream A)	10/15/2008	2.15	4.87	0.70	2.96
Mill Creek (Stream A)	5/8/2009	1.75	11.44	0.86	9.79
Mill Creek (Stream A)	6/17/2009	2.04	5.60	0.71	3.99
Mill Creek (Stream A)	7/22/2009	1.88	9.52	0.51	4.85
Mill Creek (Stream A)	8/19/2009	2.10	5.82	0.40	2.32
Mill Creek (Stream A)	9/30/2009	2.08	7.09	0.62	4.38
Mill Creek (Stream A)	10/23/2009	2.20	7.37	0.51	3.79
Mill Creek (Stream A)	5/24/2010	2.20	0.68	0.53	3.63
Mill Creek (Stream A)	6/14/2010	2.25	4.90	0.71	3.48
Mill Creek (Stream A)	7/9/2010	2.52	2.60	0.45	1.17
Mill Creek (Stream A)	8/10/2010	2.75	0.22	1.56	0.35
Mill Creek (Stream A)	9/7/2010	2.60	2.84	0.29	0.82
Mill Creek (Stream A)	10/4/2010	2.35	4.13	0.60	2.47
Mill Creek (Stream A)	5/23/2011	2.23	12.25	0.28	3.42
Mill Creek (Stream A)	6/20/2011	2.38	9.77	0.21	2.07
Mill Creek (Stream A)	7/18/2011	2.53	6.50	0.15	0.94
Mill Creek (Stream A)	8/24/2011	2.52	3.97	0.35	1.37
Mill Creek (Stream A)	9/20/2011	2.29	8.69	0.20	1.71
Mill Creek (Stream A)	10/14/2011	1.52	16.11	0.53	8.45
Elm Brook (Stream B)	5/15/2006		6.37	1.67	9.16
Elm Brook (Stream B)	7/16/2006				
Elm Brook (Stream B)	7/17/2006	2.54	3.76	0.13	0.45
Elm Brook (Stream B)	8/21/2006	2.56	3.17	0.10	0.22
Elm Brook (Stream B)	9/26/2006	2.73	0.19	0.77	0.16
Elm Brook (Stream B)	10/10/2006	2.73	0.34	0.39	0.14
Elm Brook (Stream B)	4/2/2007	2.35	4.50	0.53	2.26

Site	Date	Tapedown from datum (ft)	Total cross section area (sqft)	Average velocity (f/s)	Discharge (cfs)
Elm Brook (Stream B)	5/7/2007	2.46	4.06	0.43	1.60
Elm Brook (Stream B)	6/6/2007	2.54	3.63	0.37	1.01
Elm Brook (Stream B)	7/3/2007	2.77	0.43	0.61	0.25
Elm Brook (Stream B)	8/13/2007	2.82	0.21	0.74	0.17
Elm Brook (Stream B)	9/10/2007	2.85	0.09	0.36	0.04
Elm Brook (Stream B)	10/11/2007	3.10	0.10	0.52	0.05
Elm Brook (Stream B)	5/19/2008	2.52	2.97	0.35	0.98
Elm Brook (Stream B)	6/16/2008	2.71	0.79	0.49	0.36
Elm Brook (Stream B)	7/21/2008	2.67	1.97	0.21	0.28
Elm Brook (Stream B)	8/20/2008	2.65			
Elm Brook (Stream B)	9/22/2008	2.63		0.32	
Elm Brook (Stream B)	10/15/2008	2.58	1.94	0.32	0.52
Elm Brook (Stream B)	5/8/2009	2.33	4.02	0.69	2.76
Elm Brook (Stream B)	6/17/2009	2.60	2.15	0.22	0.48
Elm Brook (Stream B)	7/22/2009	2.50	2.55	0.34	0.86
Elm Brook (Stream B)	8/19/2009	2.70	1.95	0.18	0.35
Elm Brook (Stream B)	9/30/2009	2.58	1.70	0.21	0.35
Elm Brook (Stream B)	10/23/2009	2.58	2.35	0.12	0.29
Elm Brook (Stream B)	5/24/2010	2.40	1.27	0.59	0.75
Elm Brook (Stream B)	6/14/2010	2.66	0.76	0.69	0.53
Elm Brook (Stream B)	7/9/2010	2.84	0.51	0.18	0.09
Elm Brook (Stream B)	9/7/2010	2.85	0.17	0.51	0.09
Elm Brook (Stream B)	10/4/2010	2.75	0.49	0.28	0.13
Elm Brook (Stream B)	5/23/2011	2.50	0.15	0.20	0.03
Elm Brook (Stream B)	6/20/2011	2.67	0.97	0.48	0.46
Elm Brook (Stream B)	7/18/2011	2.76	0.55	0.28	0.16
Elm Brook (Stream B)	8/24/2011	2.73	0.51	0.11	0.06
Elm Brook (Stream B)	9/20/2011	2.63	0.76	0.48	0.36
Elm Brook (Stream B)	10/14/2011	2.35	2.17	0.92	1.98

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

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