



Water Quality Monitoring at Saugus Iron Works National Historic Site

Northeast Temperate Network 2014 Summary Report

Natural Resource Data Series NPS/NETN/NRDS—2016/1027



ON THE COVER

Turning Basin, May 2014

Photograph by: Liza McElroy

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The Natural Resource Data Series is intended for the timely release of basic data sets and data summaries. Care has been taken to assure accuracy of raw data values, but a thorough analysis and interpretation of the data has not been completed. Consequently, the initial analyses of data in this report are provisional and subject to change.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner.

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Executive Summary

This report on the water quality of Saugus Iron Works National Historic Site (SAIR) includes data gathered by the Northeast Temperate Network (NETN) in the 2014 monitoring season and displays these results in graphic form, accompanied by a brief interpretation. The data address the NETN objective to detect change in the status of physical, chemical, or biological attributes of park freshwater bodies.

The NETN Freshwater Monitoring Protocol calls for a total of two stream sites at SAIR to be sampled twice annually in May and August. Staff 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.

Sampling parameters included in-situ water quality measures (pH, specific conductance, temperature, and dissolved oxygen, turbidity), weather, stream flow (discharge), and stream stage. In May and August, water samples were obtained and analyzed for acid neutralizing capacity (ANC), color, nutrients, dissolved organic carbon (DOC), chloride, and sulfate.

All 2014 water quality parameters monitored in Saugus Iron Works National Historic Site were within state standards, where applicable, and total phosphorus and nitrogen measures were above the EPA Ecoregion 14 nutrient criteria.

Phosphorus concentrations were high, but within the range of past measurements. ANC measurements showed that all sites were very well-buffered. NETN plans to establish a stage datum point (or preferably an automated water level logger) at the Turning Basin in 2015. This will enable a better understanding of the relationship between Turning Basin water levels and the discharge measurements from the USGS gage. A continuous data logger was installed in the Turning Basin in August of 2014 to collect conductivity data.

Introduction

This report on the water quality of Saugus Iron Works National Historic Site (SAIR) generated by the Northeast Temperate Network (NETN) Water Quality Monitoring Program includes data gathered in the 2014 monitoring season and displays these results in graphic form, accompanied by a brief interpretation. Appendix A contains data collected in 2014 in tabular form.

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 two stream sites at SAIR to be sampled twice annually in May and August. Two NETN Student Conservation Association (SCA) interns measured physical and in-situ water chemistry parameters and 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 water quality monitoring sites have been selected at SAIR for the long-term monitoring program (Table 1). The Saugus River site (SAIRSA) is at the U.S. Geological Survey (USGS) continuous-record streamflow-gage on the Saugus River just upstream of the park boundary (USGS 01102345 Saugus River at Saugus, MA) which has been in operation since 1994. Although the station is upstream of the park, this station adequately represents water quality where the river enters the park (Lombard et al. 2006). This station is useful because it is immediately upstream of the upper limit of tidal influence. Data from this station can be accessed at:

http://waterdata.usgs.gov/ma/nwis/uv/?site_no=01102345&agency_cd=USGS. The Saugus River is classified as a warm water fishery (Lombard et al. 2006), capable of supporting bass, pickerel, sunfish, and similar species.

Table 1. Water quality monitoring sites at Saugus Iron Works NHS.

Water Body	NETN Site Code	USGS Station Number	Latitude	Longitude	Site Remarks
Saugus River	SAIRSA	01102345	42.4693861	-71.0071722	Warm water fisheries
Turning Basin	SAIRSB	n/a	42.4688833	-71.0077000	

The second sample site is located at the Turning Basin (SAIRSB). The Turning Basin is a modified tidal basin, first used by the original iron works from 1650-1679 as a location for boats to turn around at the head of the estuary. Brackish water intrudes into the basin during high (spring) tides and affects the water quality. The river channel within and below the Turning Basin, including the benthic zone, intertidal surface, and floodplain was the subject of a major restoration project between the 2007 and 2008 sampling years.

Nutrient chemistry samples and in-situ water quality sonde measurements are scheduled to be taken twice a year at the location of the USGS gage and in the Turning Basin (Figure 1). No in-situ water quality measurements were taken in 2006 and May and August nutrient chemistry samples were collected from SAIRSA only. From 2007 through 2011 nutrient chemistry samples were taken from both sites, although sonde measurements were collected only at the Turning Basin, likely due to misinterpretation of protocol instructions. Monitors collected in situ measurements and nutrient samples at both sites beginning in 2012.

In addition, water chemistry, sediment pollutants, channel morphology, and tidal hydrology data have been collected as part of the Turning Basin restoration project monitoring program in 2008, 2010 and 2012 (CH2MHill 2011). Additional data collection is expected through 2017.

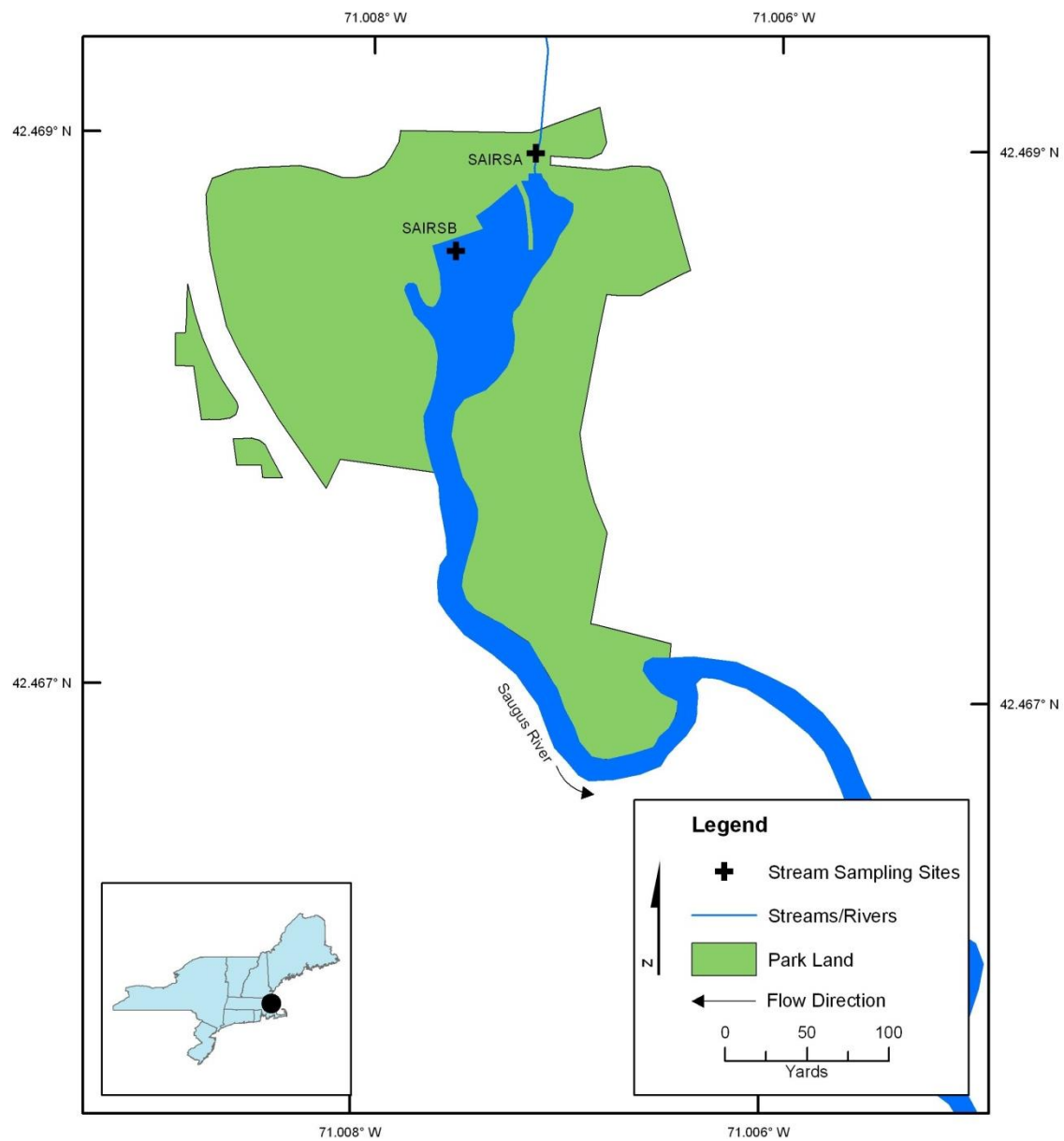


Figure 1. NETN water monitoring sites at Saugus Iron Works NHS.

Methods

Detailed descriptions of all monitoring methods are found in the original protocol (Lombard et al. 2006) and the most recent protocol update (Gawley et al. 2014). In-situ water quality measures (pH, specific conductance, temperature, and dissolved oxygen) were determined with a YSI 600XL sonde. Turbidity was measured with a LaMotte 2020e meter. In May and August, water samples were obtained and analyzed for acid neutralizing capacity (ANC), color, and nutrients. Nutrient chemistry parameters were analyzed from a grab sample.

Stream discharge is measured continuously by the gage at the Saugus River (SAIRSA) site. Instantaneous discharge data are available on the USGS website and are summarized in annual USGS data reports. No discharge or stage measurements are collected at the Turning Basin.

In-situ stream water chemical and physical measurements and water samples at SAIRSA were collected within 5 meters of the location of the USGS gage. Sonde measurements were taken in the main stream flow with care taken that the sonde was not resting directly on the stream bottom. Grab samples were obtained by submerging the sample bottle directly in the stream with a gloved hand. Identical procedures were used in the Turning Basin's (SAIRSB) standing water.

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 2013). ORW is used to denote those waters, other than Public Water Supplies, designated for protection as outstanding resources. The DO concentrations of Class A waters “shall not be less than 6.0 mg/l in cold water fisheries and not less than 5.0 mg/l in warm water fisheries. Where natural background conditions are lower, DO shall not be less than natural background conditions.” Temperature “Shall not exceed 68° F (20° C) based on the mean of the daily maximum temperature over a seven day period in cold water fisheries, unless naturally occurring... Temperature shall not exceed 83°F (28.3°C) in warm water fisheries... pH shall be in the range of 6.5 through 8.3 standard units but not more than 0.5 units outside of the natural background range... These waters shall be free from color and turbidity in concentrations or combinations that are aesthetically objectionable or would impair any use assigned to this class.” (Table 2; Massachusetts Department of Environmental Protection 2013).

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 2. Massachusetts stream water quality standards.

Water quality classification code	MaxTemp (°C)	Min Dissolved Oxygen (mg/L)	pH Range (standard units)	Maximum Total Nitrogen (µg/L)	Maximum Total Phosphorus (µg/L)	Color (color units, platinum-cobalt method)	Turbidity (NTU)
A	28.3	5.0	6.5-8.3	As naturally occurs	As naturally occurs	Not objectionable and does not impair use	Not objectionable and does not impair use

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 Saugus Ironworks NHS, Minute Man NHP, 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 2014 are displayed in scatter-plot graphs showing all data for each site for a given parameter. The scatter plots of 2014 data are overlaid on box plots representing the overall range and distribution of data values collected from 2006 through 2014 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. At least nine data points are required to compute the 5th, 10th, 90th and 95th percentiles. If a percentile point cannot be computed, that set of points is not drawn. If EPA or other water quality criteria exist for a particular parameter they are displayed on the graphs as specification lines.

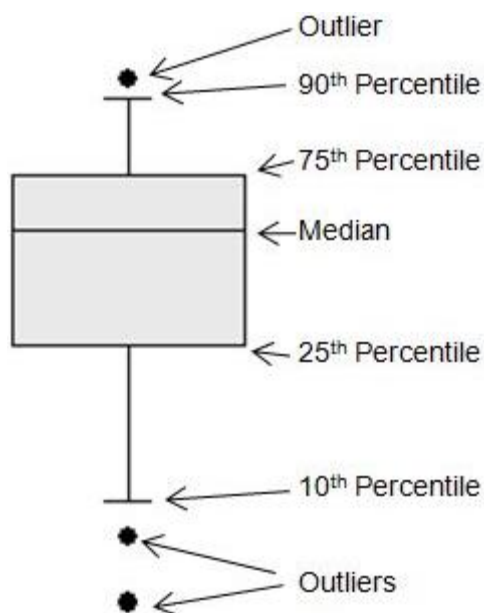


Figure 2. Explanation of box plot graph

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 for fresh waters range from less than 20 to more than 1,000 microsiemens per centimeter ($\mu\text{S}/\text{cm}$), while salt water can have specific

conductance as high as 55,000 $\mu\text{S}/\text{cm}$. Specific conductance values from 2014 were within the appropriate range for moderate ionic strength waters (Appendix A).

Two high outlier values from the Turning Basin (26,801 $\mu\text{S}/\text{cm}$ on 20 August 2009 and 35,588 $\mu\text{S}/\text{cm}$ on 10 August 2010) that are included on the graph in Figure 3 are likely due to saltwater intrusion from storm events or high tides. According to the USGS 2009 Water-Data report for Station 01102345 (U.S. Geological Survey 2011), no corresponding high conductance values were recorded at the SAIRSA station (which is above the range of tidal influence) on 20 August 2009. Specific conductance values are unavailable from SAIRSA on 10 August 2010.

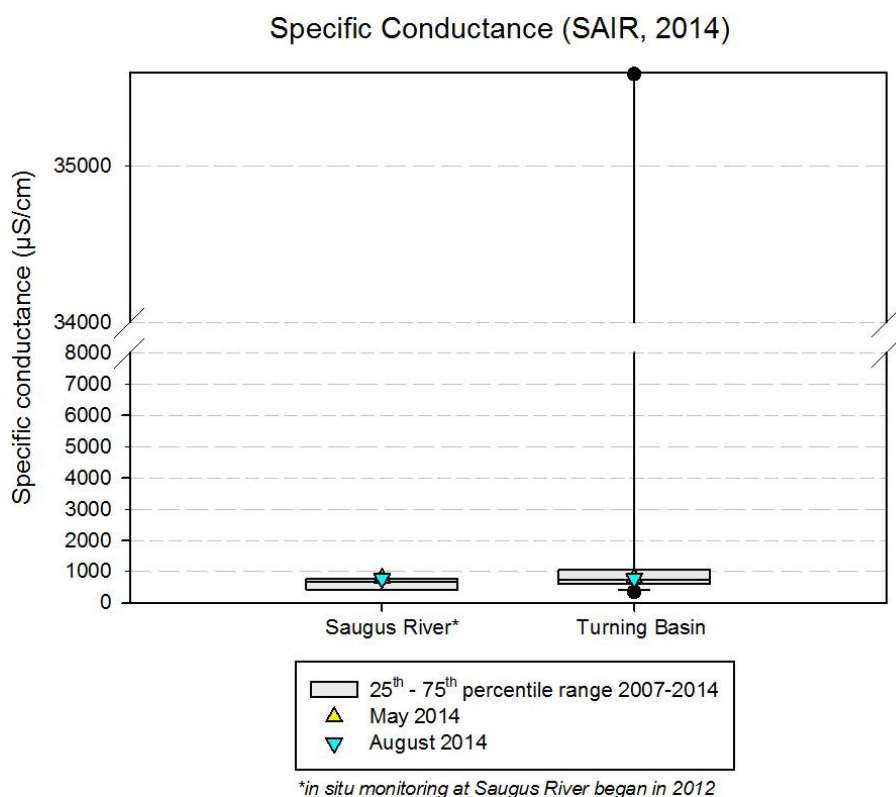


Figure 3. Specific conductance from 2014 YSI sonde in-situ measurements overlaid on a box plot of measurements taken from 2007-2014.

A continuous data logger was installed in the Turning Basin in August of 2014 to collect conductivity (*not* temperature compensated to 25°C) data at hourly intervals. These readings, displayed with hourly water temperature in Figure 4, illustrate the wide variability of conductivity at the site, which is driven by tidal cycles. The sharp drop in conductivity occurring around October 24th continued until the logger was removed in early January, and is possibly attributed to low battery voltage.

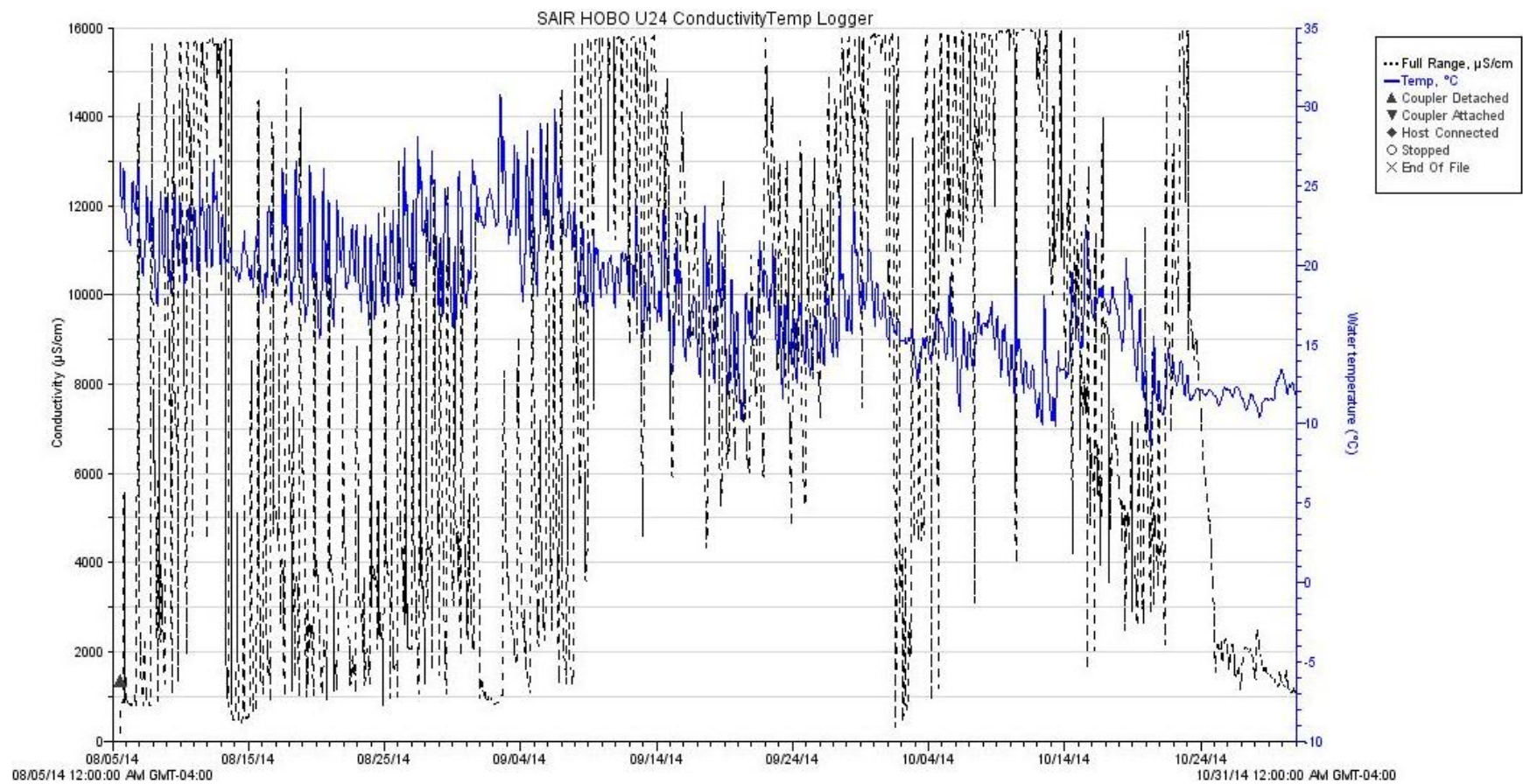


Figure 4. Hourly conductivity and temperature from the Turning Basin, August through October 2014.

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 2014 monitoring season (Figure 5) were slightly basic, and were between the upper and lower Massachusetts water quality standards.

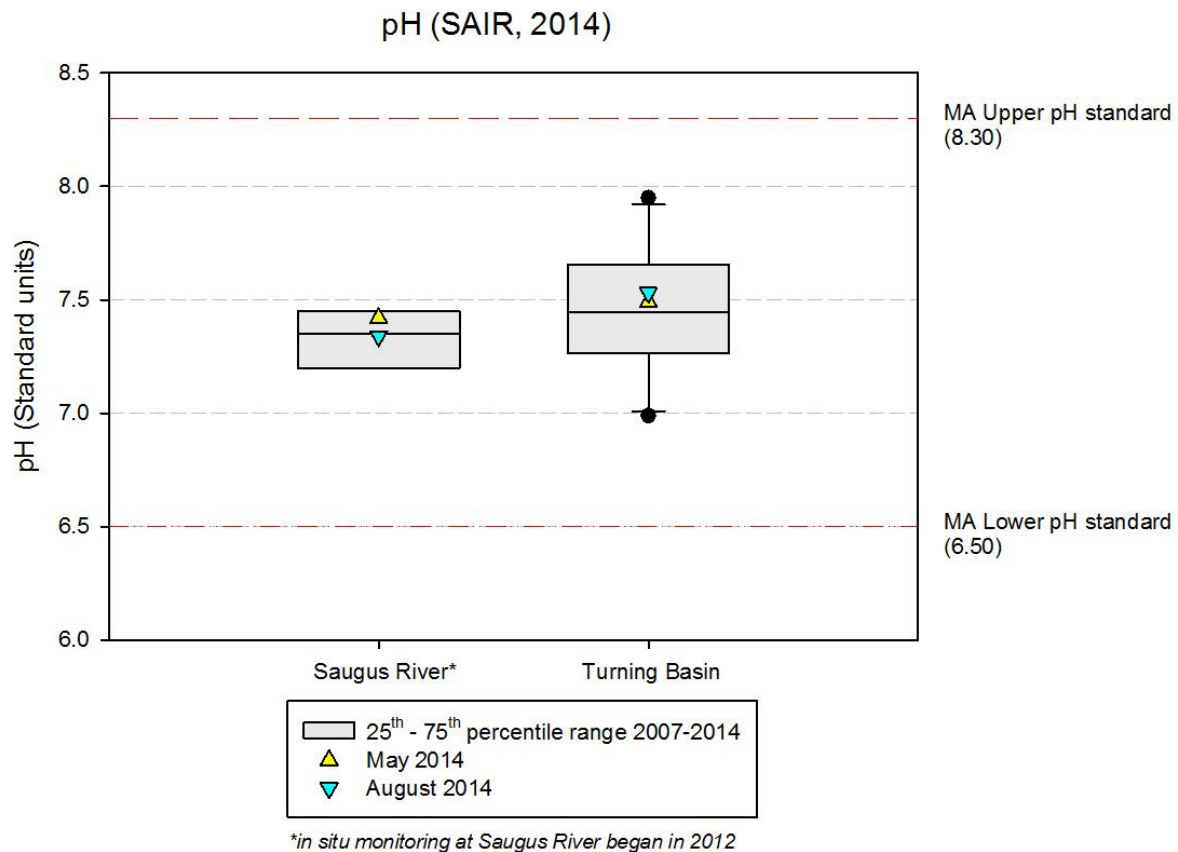


Figure 5. pH from 2014 YSI sonde in-situ measurements overlaid on a box plot of measurements taken from 2007-2014.

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. In 2014, surface water temperatures (Figure 6) for May were within the normal range of variability while August readings were above the 75th percentile. All 2014 temperature measurements were below the state maximum temperature standard

for warm water fisheries, and the May temperature measurements were also below the more restrictive state cold water standard.

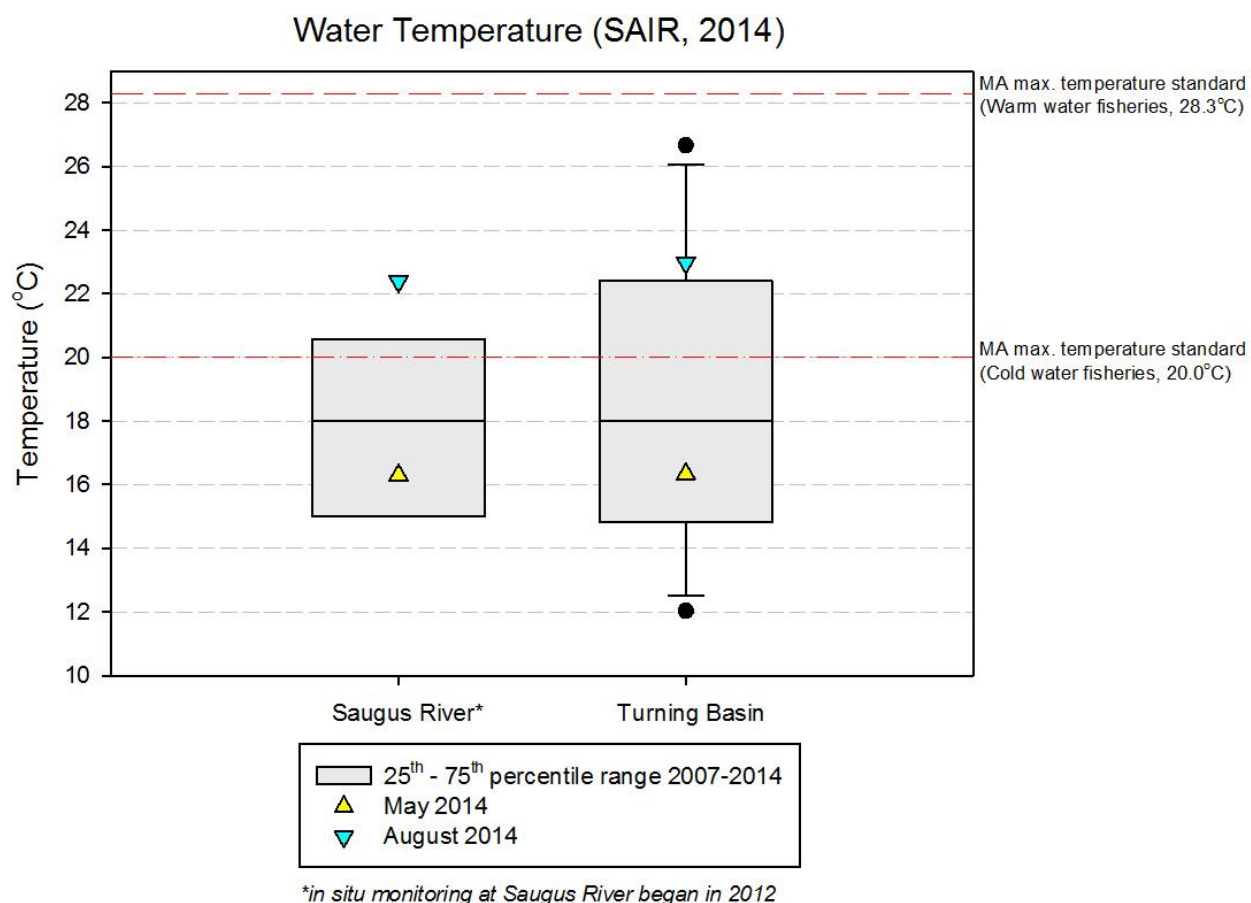


Figure 6. Water temperature (surface) from 2014 YSI sonde in-situ measurements overlaid on a box plot of measurements taken from 2007-2014.

Dissolved Oxygen

Dissolved oxygen is a critical indicator of water quality because aquatic life generally needs it in 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 DO concentrations less than 1 part per million (ppm) is considered anoxic (no oxygen present). All SAIR DO measurements in 2014 (Figure 7) were above the 5 mg/L state warm-water stream DO standard and were consistent with the long-term historic range.

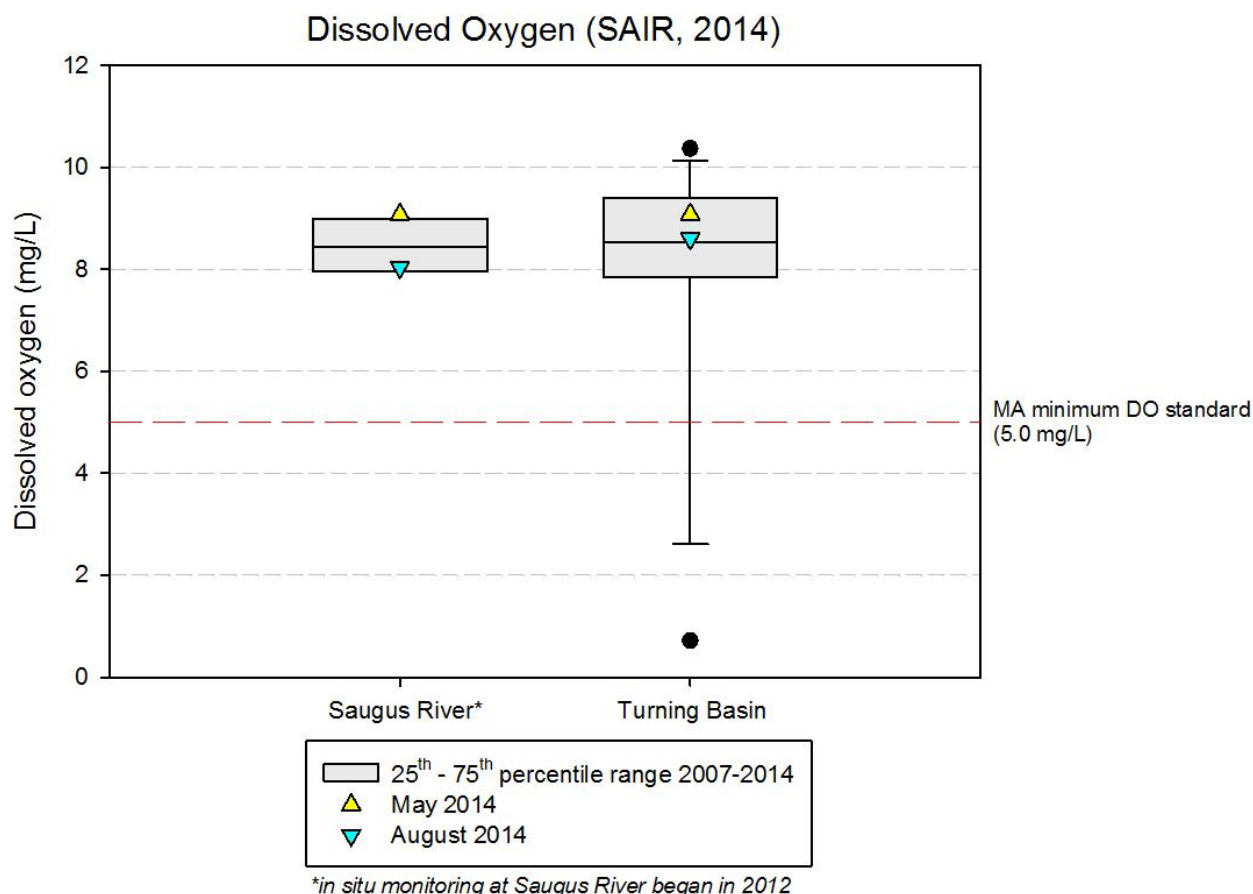
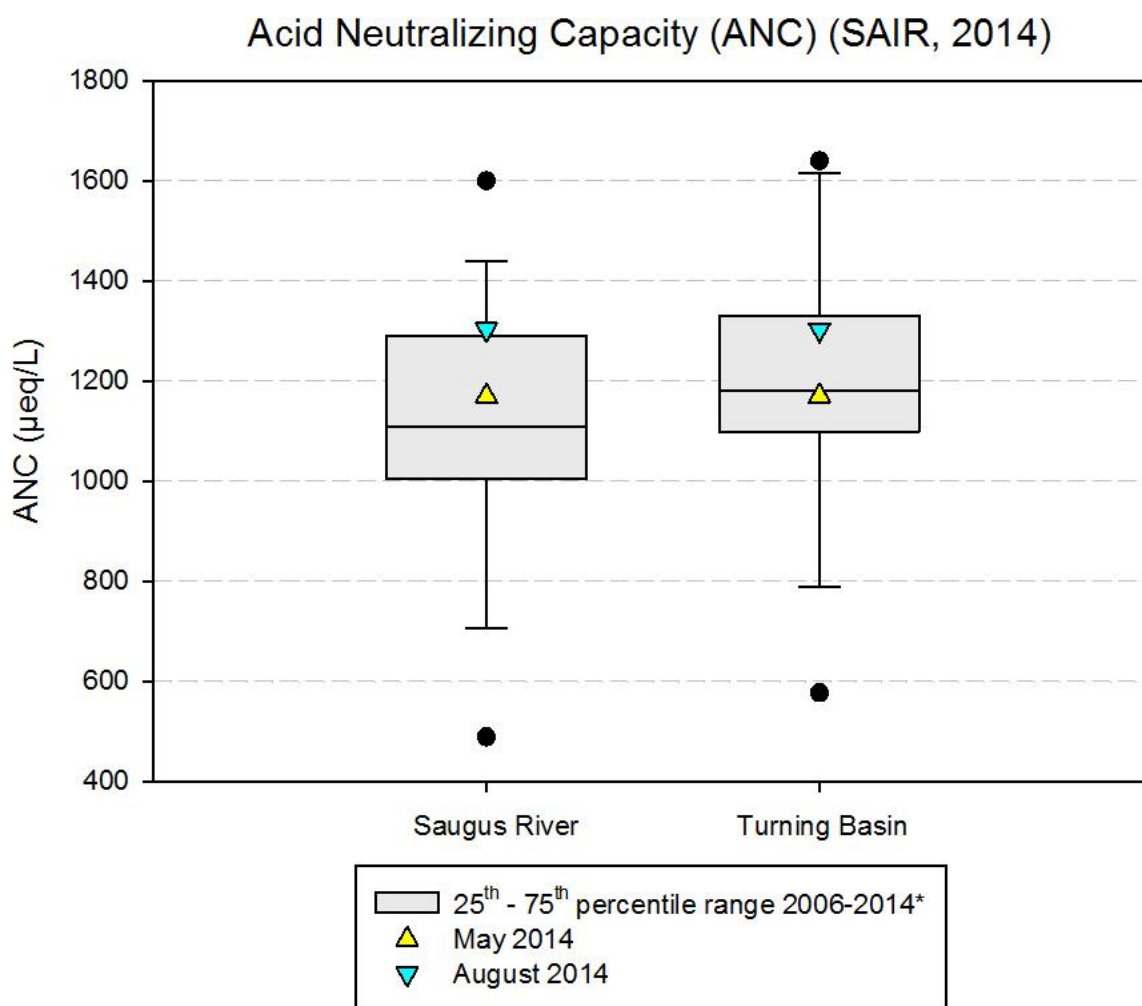


Figure 7. Dissolved oxygen (surface) from 2014 YSI sonde in-situ measurements overlaid on a box plot of measurements taken from 2007-2014.

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 measurements from the 2014 samples (Figure 8) show the SAIR waters to be well-buffered, likely due to the underlying geology.



**Turning Basin data ranges from 2007-2014*

Figure 8. Acid neutralizing capacity from 2014 May and August water samples overlaid on a box plot of measurements taken from 2006-2014 (Saugus River) and 2007-2014 (Turning Basin).

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, and 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.” Measurements during 2014 (Figure 9) indicate that water at the two SAIR sampling locations was highly colored. Three of the four measures were below the long-term median values, with the spring Saugus River measure just above the long-term median.

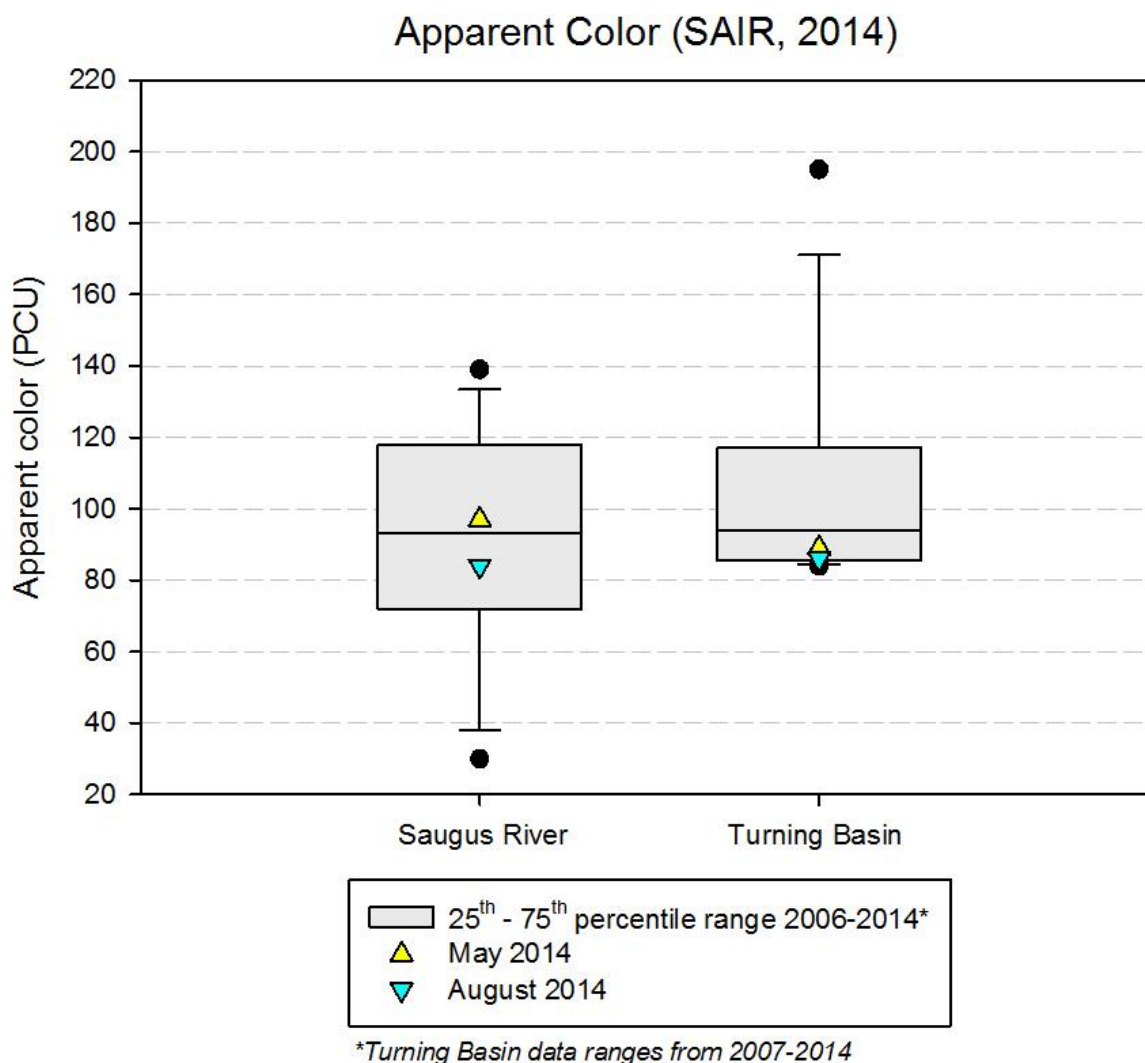


Figure 9. Apparent color from 2014 May and August water samples overlaid on a box plot of measurements taken from 2006-2014 (Saugus River) and 2007-2014 (Turning Basin).

Dissolved Organic Carbon

NETN began measuring dissolved organic carbon in 2012. Carbon is a nutrient required for biological processes. Sources of organic carbon in water include humic substances from plant and soil organic matter, wetland peat deposits, and atmospheric deposition. Certain forms of DOC can contribute to “tea” color in water, which can affect light attenuation. DOC is also an important part of the energy balance and acid-base chemistry in many freshwater systems. It also affects the transport (solubility and bioavailability) of metals, including mercury, in aquatic systems.

DOC concentrations in most streams in temperate zones range from 1 mg/L to 20 mg/L, with a worldwide mean of 5.75 mg/L (Meybeck 1982). SAIR DOC concentrations (Figure 10) were moderate in 2014, reflecting the surrounding marsh and wetland systems. The values were between the median and 75th percentile of the historic NETN measurements, and also within the range of the monitoring results from USGS studies from 1994-2004 (mean = 7.0 mg/L, maximum = 11.1 mg/L,

minimum = 4.3 mg/L) cited in the SAIR Natural Resources Condition Assessment (James-Pirri et al. 2011).

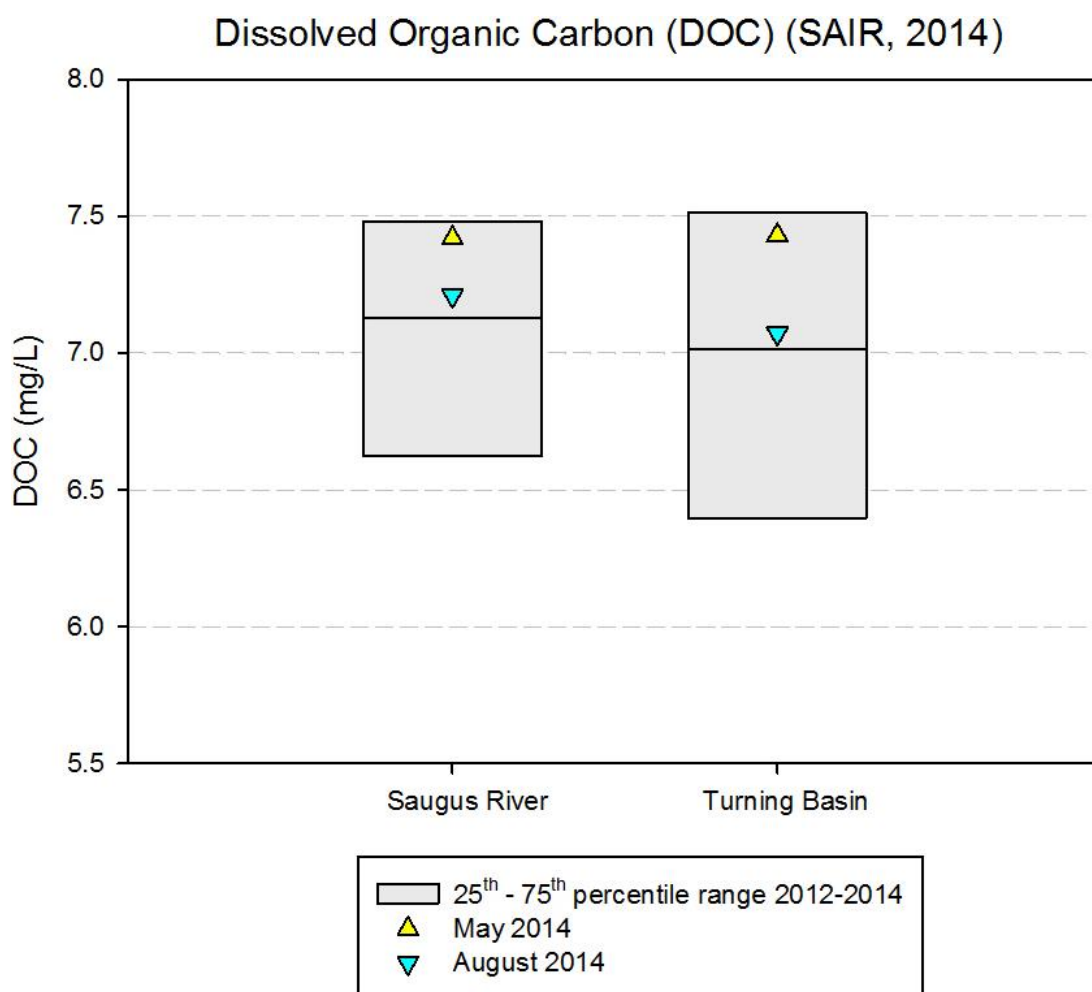


Figure 10. Dissolved organic carbon (DOC) from 2014 spring and summer water samples. The data are overlaid on a box plot of measurements taken from 2012-2014.

Turbidity

Turbidity is the measure of the relative clarity of a liquid. It is measured by passing light through a water sample to determine how much light is scattered, and the results are reported in nephelometric turbidity units (NTU). Turbidity is caused by suspended matter or impurities that interfere with the clarity of the water. These impurities may include clay, silt, finely divided inorganic and organic matter, soluble colored organic compounds, and plankton and other microscopic organisms. In natural waters, turbidity is often used as an indicator of water quality and productivity. Turbidity is measured in the field using an electronic meter.

Turbidity in the water can create aesthetic, ecological, and health issues. Turbid water may indicate runoff from construction, roads, agriculture or other types of pollution. Suspended sediment can carry nutrients and pesticides throughout the water system. Suspended particles near the surface

absorb additional heat from sunlight, raising the water temperature. High turbidity levels can reduce the amount of light reaching lower depths of lakes and streams, which can inhibit growth of submerged aquatic plants, and reduce dissolved oxygen levels. Suspended materials can clog fish gills, affecting fitness, growth, and reproduction (U.S. Environmental Protection Agency 1997). Turbidity values measured at SAIR during 2014 (Figure 11), the third year of NETN turbidity testing, were all less than 3.5 NTU, in the low range of dry-weather turbidity of surface waters, which normally ranges from 0 to 10 NTU (U.S. Environmental Protection Agency 1999). The spring Saugus River turbidity values were also less than the 25th percentile of the long-term range.

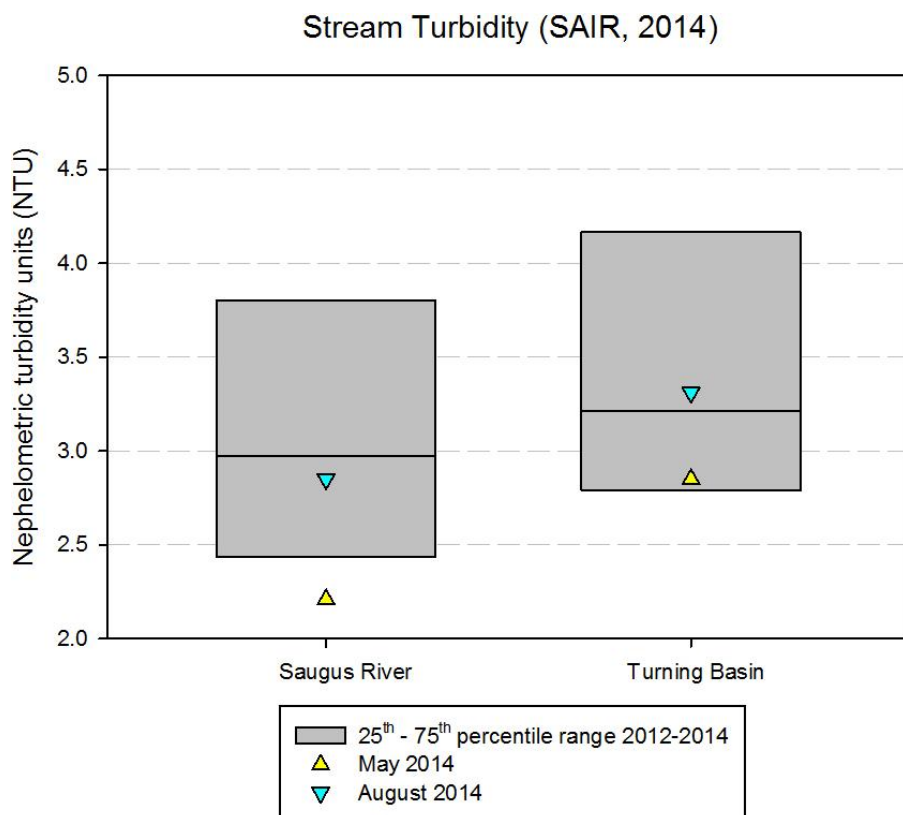


Figure 11. Stream turbidity from 2012-2014 monthly measurements. The data are overlaid on a box plot of measurements taken from 2012-2014.

Nutrient Enrichment

Nutrient enrichment and the acceleration of eutrophication have been identified in most NETN parks as one of the stressors of greatest concern. Total phosphorus and several forms of 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 in natural systems and limits the plant growth in streams and ponds. Total phosphorus (TP) is a measure of both inorganic and organic forms of phosphorus, and is the common water quality

standard or criteria metric. Although several forms of phosphorus have been tested individually since 2006, tests for total dissolved phosphorus (TDP) and soluble reactive phosphorus (SRP) were discontinued in 2012 in favor of TP.

In 2014, total phosphorus concentrations (Figure 12) were high but at or below the long-term median for both sampling locations. All values were above the EPA Ecoregion 14 criteria of 31.25 µg/L for streams. As described above (“Water Quality Standards”), the EPA criteria do not have any regulatory meaning.

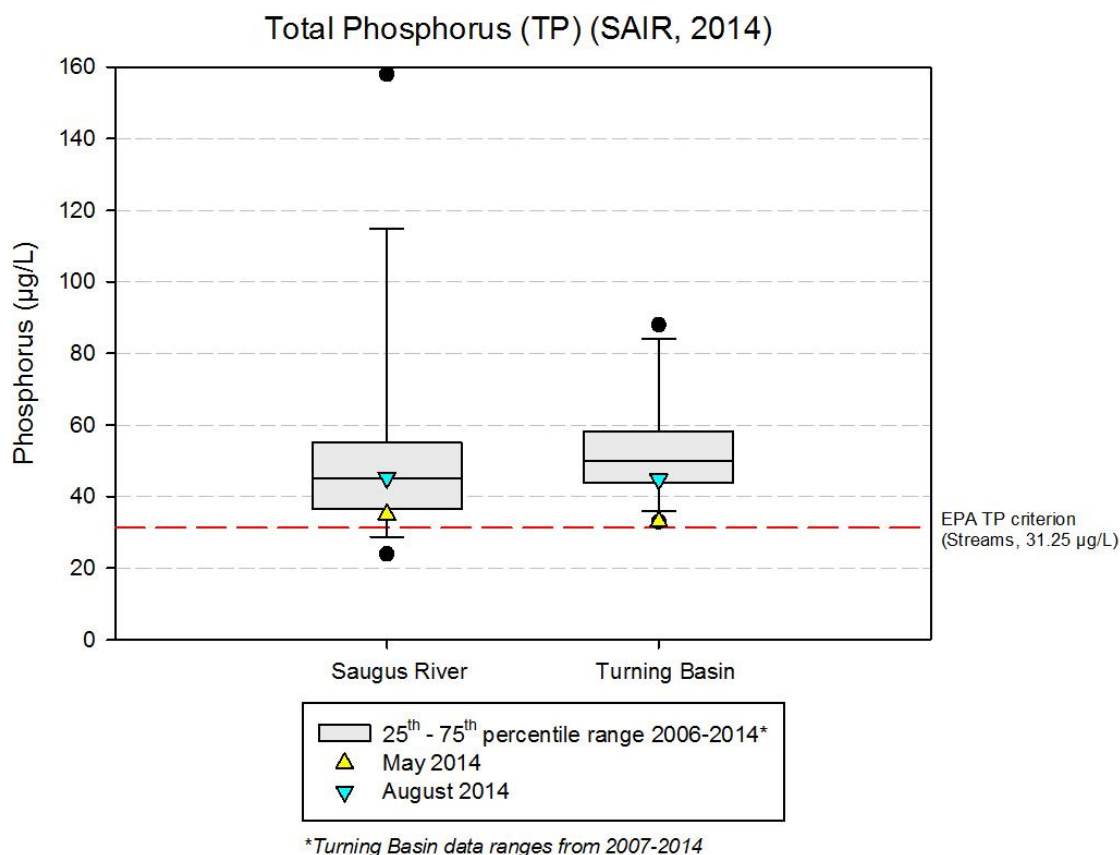


Figure 12. Total phosphorus (TP) from May and August water samples. The data are overlaid on a box plot of measurements taken from 2006-2014 (Saugus River) and 2007-2014 (Turning Basin). There is no numeric Massachusetts state water quality TP standard.

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. 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. Nitrate (NO₃) 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 (NO₂) is an unstable form of nitrogen that is either rapidly oxidized to nitrate (nitrification) or reduced to nitrogen gas (de-nitrification). This form of nitrogen can also be used as a source of nutrients for plants. Ammonia (NH₃) is generated by bacteria

as a decomposition product of nitrogenous organic compounds, and is also readily assimilated by plants. Results of NO_3 , NO_2 , and NH_3 tests are all reported as the concentrations of the N component of these compounds, expressed in mg/L.

Test results for several forms of nitrogen are shown in Figure 13. All 2014 TN measurements were below 2.0 mg/L, the value used as a TN standard in several northeast states (Massachusetts has no numeric TN standard). TN values exceeded the EPA Ecoregion 14 criterion of 0.71 mg/L, although as with TP this criterion does not have regulatory meaning. Nitrate nitrogen values were moderate, nitrite concentrations were very low, and 2014 ammonia test results were moderately low. May TN results were above the EPA criterion but all were below the long-term historical data range.

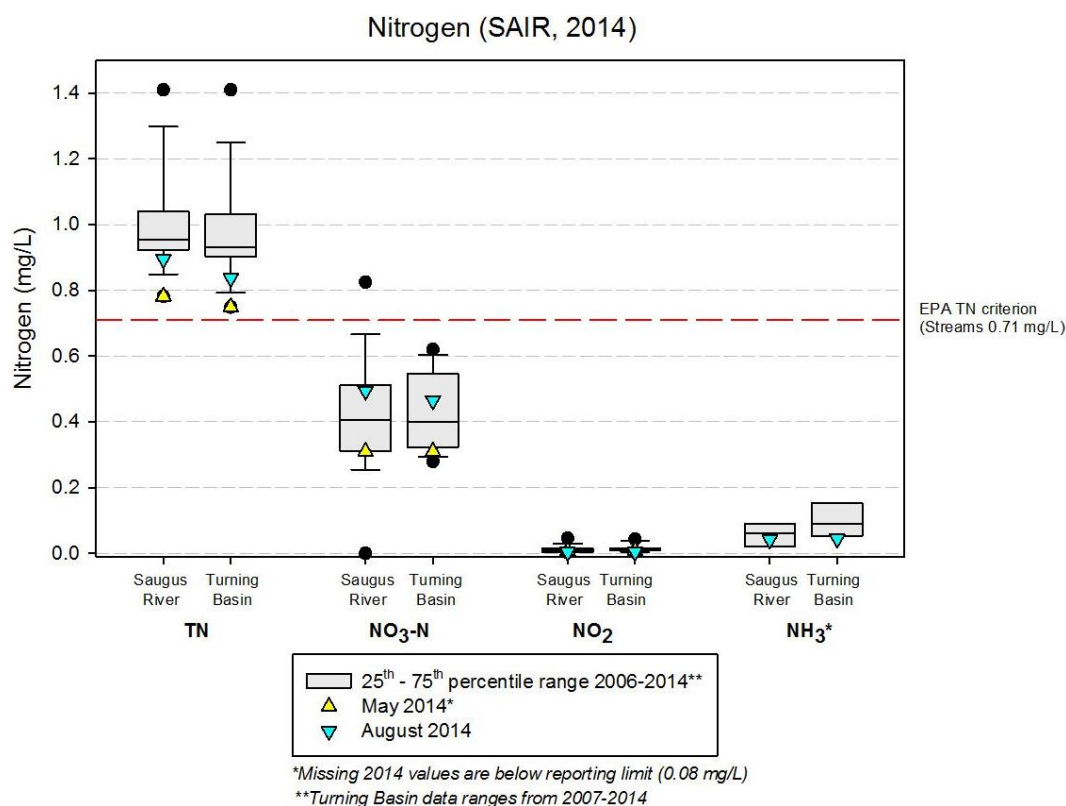


Figure 13. Total nitrogen (TN), nitrate (NO_3), nitrite (NO_2), and ammonia (NH_3) from 2014 May and August water samples. The data are overlaid on a box plot of measurements taken from 2006-2014 (Saugus River) and 2007-2014 (Turning Basin).

Other Analytes

Chloride

Chloride is one of the major negatively-charged ions in fresh water systems. The chloride content of natural surface waters will depend to a great extent on the geology of the area. Concentrations are generally greater in lakes that are in proximity to marine regions. Another source of chloride is road run-off from de-icing materials. Chloride is important in terms of metabolic processes, as it influences osmotic salinity balance and ion exchange.

Average chloride concentration in natural fresh water is 234.1 μ eq/L (Wetzel 1983). Chloride values in SAIR samples were very high in 2014 (Figure 14). These elevated concentrations are largely a result of tidal influences and deposition of marine aerosols, though there is likely some influence from runoff effects of winter road salting. (James-Pirri et al. 2011).

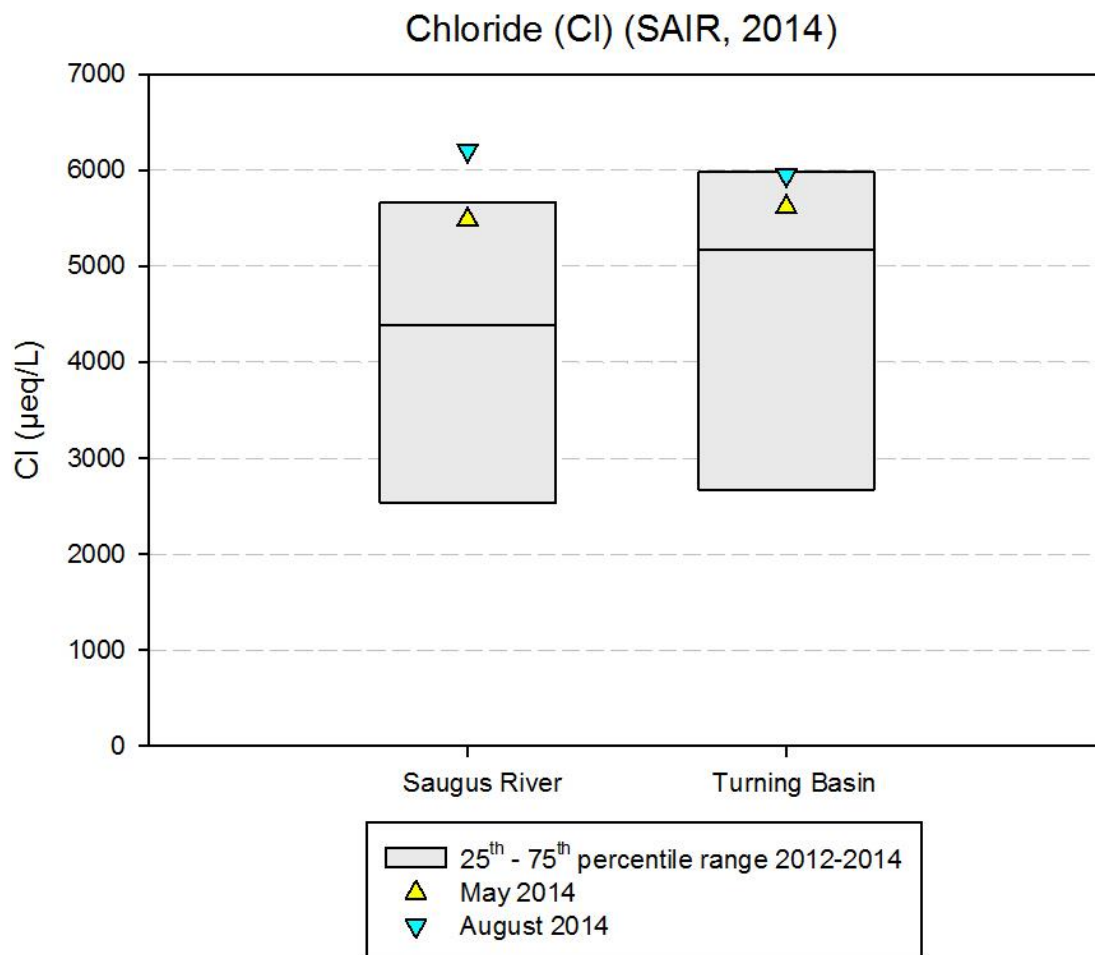


Figure 14. Chloride from 2014 spring and summer water samples. The data are overlaid on a box plot of measurements taken from 2012-2014.

Sulfate

Sulfate is found in most natural waters, originating from watershed geology and soils, and also from atmospheric transport and deposition (in precipitation) of by-products from the combustion of fossil fuels. Sulfate can play a major role in acidification of lakes and streams. Sulfate concentrations in atmospheric deposition have declined significantly since 1982, in part due to the 1995 implementation of Phase I controls of the Clean Air Act Amendments and in part to other long-term pollution reduction efforts (Kahl 1999).

The usual range of sulfate concentration in natural water is 104 μ eq/L to 695 μ eq/L (Wetzel 1983). Sulfate concentrations at SAIR were moderately high in 2014 (Figure 15) and within the range of the

NETN monitoring results to date, as well as those from 1994-2004 USGS studies (mean = 277.0 $\mu\text{eq/L}$, maximum = 477.0 $\mu\text{eq/L}$, minimum = 131.2 $\mu\text{eq/L}$) cited in James-Pirri, et al (2011).

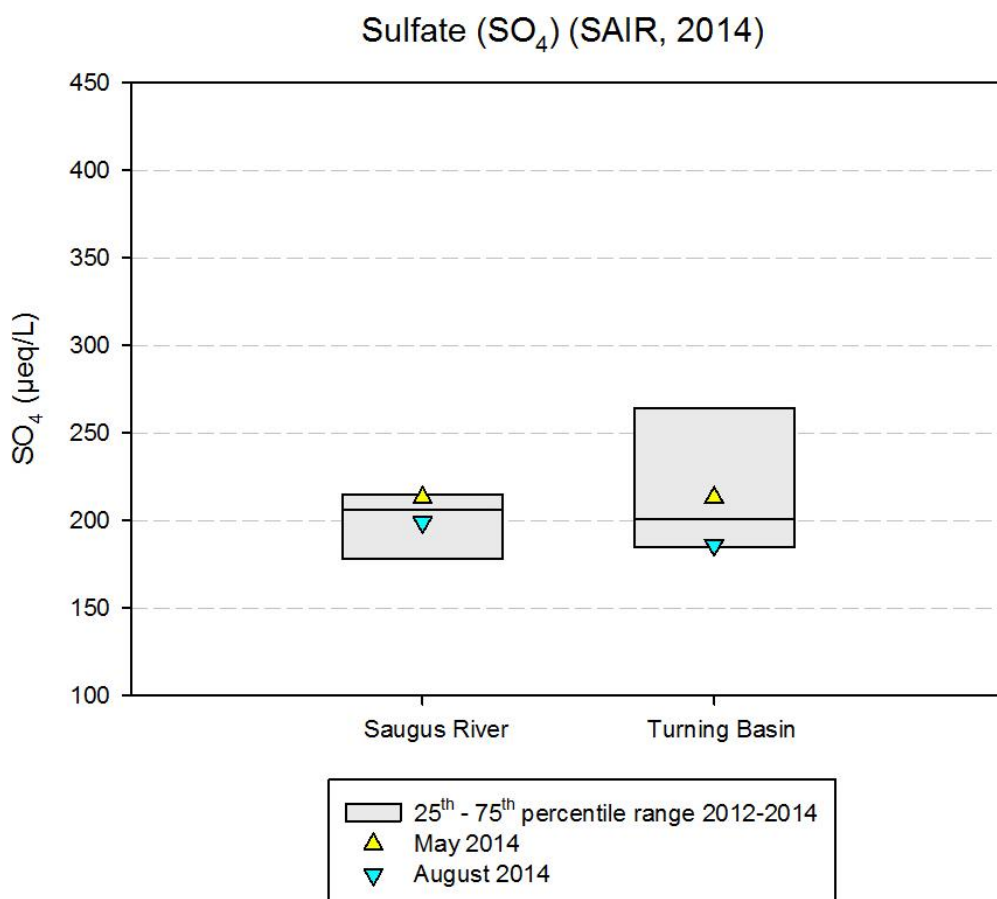


Figure 15. Sulfate from 2014 spring and summer water samples. The data are overlaid on a box plot of measurements taken from 2012-2014.

Water Quantity

Stream Discharge

Stream discharge measurements can be used to calculate loading of nutrient chemical constituents (flow times concentration), and also provide a record of variations in stream flow. Mean daily discharge values from dates in 2014 in which water chemistry measurements were made are listed in Table A3 in Appendix A.

Streamflow in 2014 (Figure 16) followed the expected seasonal sequence of high discharge in the spring to minimal flow in July and August, with 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.

Recommendations were made in 2011 to measure stage (water level) in the Turning Basin to document changes over time and to develop a relationship between Turning Basin stage and the discharge measurements from the USGS gage. Due to staff and scheduling constraints, the NETN

was unable to install a continuous water level logger at this site, but will revisit this option during the 2015 season.

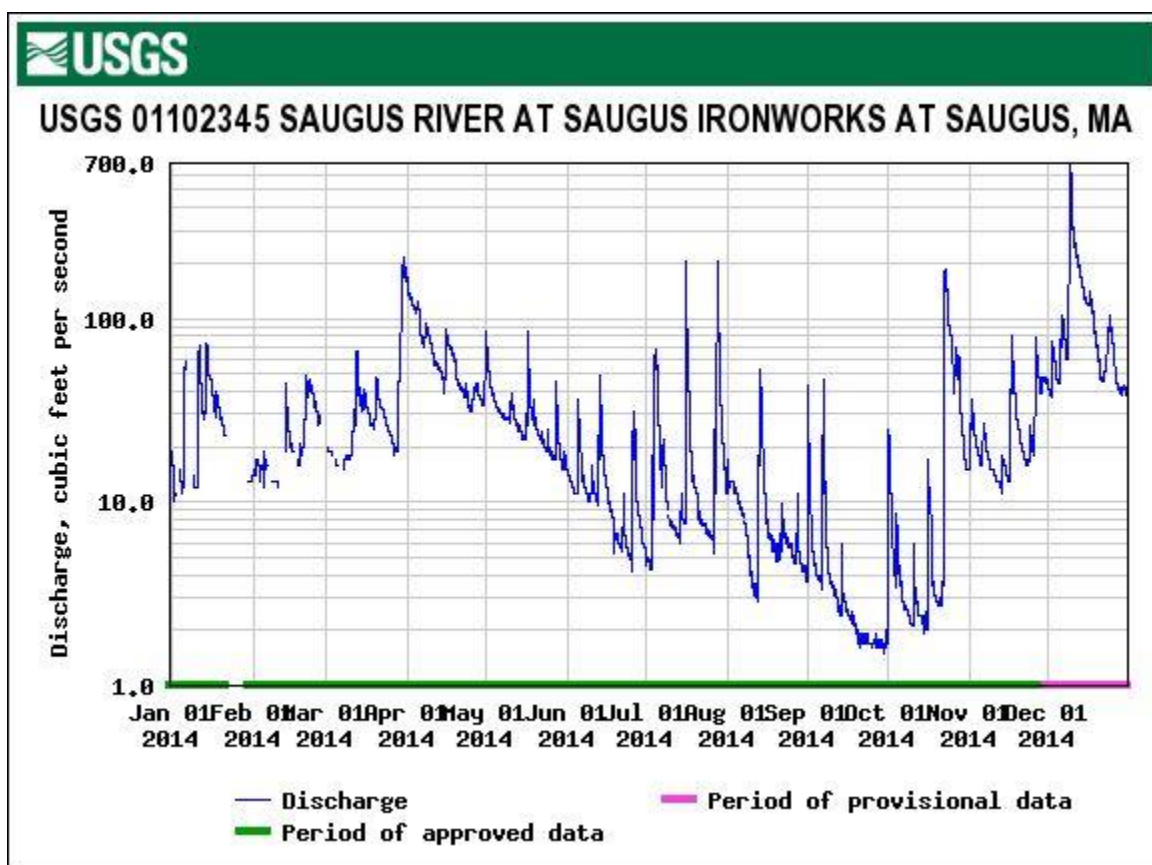


Figure 16. 2014 stream discharge from U.S. Geological Survey continuous-record streamflow-gage on the Saugus River.

Invasive Aquatic Plants

Invasive aquatic plant monitoring was not conducted at SAIR during the 2014 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 algae species that has recently invaded the northern reaches of the Connecticut River in New Hampshire and the White River and Battenkill Rivers 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 can easily be spread by waders and potentially by water monitoring equipment and other gear that touches the bottoms of streams in infested areas. Just one cell breaking off and drifting downstream can spread the algae. Enhanced equipment cleaning and decontamination procedures are being included in the latest NETN monitoring protocol revision (Gawley et al. 2014).

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.

Quality Assurance and Quality Control (QA/QC)

QA/QC is important to the success of a long-term data collection and trend detection program. Quality assurance (QA) is achieved through the establishment and use of the NETN Freshwater Monitoring Protocol. Specific procedures are used to control critical components of a project such as sampling at the right place with the right equipment and using the right methods. Over the years, staff will change, equipment may be updated, and methods may evolve. Although these changes will be kept to a minimum, changes are inevitable and therefore following an established and well-documented protocol will ensure that the data remain valid.

QA requirements incorporated in the protocol include consistency and low turnover in project leaders and staff, consistency in staff training and oversight, consistency in equipment used and calibration methods, the selection of a well-established chemical laboratory with a proven track record, and a robust sample design that includes an adequate number of field and laboratory quality control (QC) samples.

QC includes the assessment of bias and variability through the use of additional samples such as blank and replicate samples. QC samples are an objective assessment of whether or not QA protocols are adequate. The protocol calls for the collection of two blank and two replicate samples (one each from lakes/ponds and streams, respectively) during both the spring and summer nutrient sampling months at Acadia NP, and the same number, distribution, and schedule at the combined eight “Lower NETN” parks. Sample collection sites are selected at random from both monitoring groups.

The latest (2014) protocol revision requires in situ measurements, including Secchi transparency, sonde water quality, and stream discharge, to be periodically replicated to ensure that field equipment and observers are performing within the required precision standards. Water quality sonde temperature, pH and specific conductance measurements are to be compared monthly in the laboratory with similar measurements made with a NIST-traceable thermometer and benchtop pH and conductivity meters. Sonde dissolved oxygen measurements will be compared in the field to measurements made using a LaMotte dissolved oxygen test kit (Winkler titration method). These additional procedures will begin network-wide in the 2015 monitoring season.

Nutrient QC Sample Results

Analysis results of all 2014 blank samples collected from Lower NETN ponds and streams (Appendix B, Table B1) were near or below the method reporting limits, indicating little or no contamination was introduced during the sampling, handling and analysis processes. However, new instrumentation utilized at the analytical lab in June and August provided lower detection and reporting limits for several analytes (NO₂, NH₃, SO₄), allowing quantification of some levels of possible contamination not detected in the past. Replicate sample analysis results (Appendix B, Table B2) showed that most Lower NETN samples were in the acceptable range of precision (relative percent difference or precision objective in units, depending on sample concentration).

Summary

All 2014 water quality parameters monitored in Saugus Iron Works National Historic Site were within state standards, where applicable while TP and TN concentrations were above the EPA Ecoregion 14 nutrient criteria. TP values were within the ranges of the historic NETN monitoring data from SAIR, whereas TN values were below the 25th percentile (though still above the EPA criterion).

ANC measurements showed that all sites were very well-buffered, sufficient to avoid severely depressed pH values from episodic acid deposition. Sulfate, DOC, and chloride values were moderate to high in 2015, though typical for marine-influenced systems. A continuous data logger was installed in the Turning Basin in August of 2014 to collect hourly temperature and conductivity data. Preliminary data from this logger showed a wide variability in conductivity levels coupled to tidal cycles. There are plans to install a similar logger to measure water level in the Turning Basin in 2015. This will enable a better understanding of the relationship between Turning Basin water levels and the discharge measurements from the USGS gage.

Monitoring under the NETN protocol builds on the historic water quality monitoring by the National Park Service and other agencies to provide critical baseline information on the chemical and physical status of the water resources of Saugus Iron Works National Historic Site. Several changes were 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 May and August water chemistry testing. Test results for all of these new analytes were within the range of historic data collected by other agencies. The revised analytical parameters 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. Saugus Iron Works National Historic Site (SAIR) Water Monitoring Data, 2014.

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

Site	NETN Code	Date	Depth (m)	Temp (C)	DO (mg/L)	pH	Specific Conductance (μS/cm)
Saugus River	SAIRSA	5/13/2014	0.08	16.30	9.08	7.42	786.00
Saugus River	SAIRSA	8/5/2014	0.39	22.38	8.04	7.34	777.00
Turning Basin	SAIRSB	5/13/2014	0.05	16.34	9.08	7.49	787.00
Turning Basin	SAIRSB	8/5/2014	0.19	22.97	8.60	7.53	777.00

Appendix A. Saugus Iron Works National Historic Site (SAIR) Water Monitoring Data, 2014 (continued).

Table A2. Laboratory nutrient chemistry data for SAIR. “<MRL” indicates the result was below the method reporting limit (0.1 for TN, 1.0 for NO₃, 0.005 for NO₂, and 0.08 for NH₃). *Missing values indicate data are unavailable.*

Site	Date	ANC (µeq/L)	A Color (PCU)	DOC (mg/L)	TP (µg/L)	TN (mg/L)	NO ₃ (µeq/L)	NO ₃ -N (mg/L Calc)	NO ₂ (mg/L)	NH ₃ (mg/L)	Cl (µeq/L)	SO ₄ (µeq/L)
Saugus River	5/13/2014	1170.00	97	7.42	35.0	0.782	22	0.310	0.0076	<MRL 0.080	5486	213
Saugus River	8/5/2014	1303.02	84	7.21	45.3	0.895	35	0.494	0.0030	0.041	6207	199
Turning Basin	5/13/2014	1170.00	89	7.43	33.0	0.749	22	0.310	0.0077	<MRL 0.080	5615	213
Turning Basin	8/5/2014	1302.75	86	7.07	44.8	0.837	33	0.465	0.0040	0.044	5950	186

Appendix A. Saugus Iron Works National Historic Site (SAIR) Water Monitoring Data, 2014 (continued).

Table A3. Instantaneous stream discharge data for water monitoring visit days at SAIR. Complete data available from USGS at http://waterdata.usgs.gov/ma/nwis/uv/?site_no=01102345&agency_cd=USGS.

Site	Date	Time	Stage (ft)	Discharge (cfs)
Saugus River	5/13/2014	11:16	2.13	25
Saugus River	5/13/2014	11:40	2.12	25
Saugus River	8/5/2014	14:54	1.66	10
Saugus River	8/5/2014	14:58	1.66	10

Appendix B. Saugus Iron Works National Historic Site (SAIR) Blank and Replicate Water Samples, 2014 (continued).

Appendix B. Saugus Iron Works National Historic Site (SAIR) Blank and Replicate Water Samples, 2014.

Table B1. 2014 Blank sample analysis results (Lower NETN).

Site	Date	ANC (µeq/L)	A Color (PCU)	DOC (mg/L)	Chla (µg/L)	Cl (µeq/L)	SO ₄ (µeq/L)	TP (µg/L)	TN (mg/L)	NO ₂ (mg/L)	NO ₃ (µeq/L)	NH ₃ (mg/L)
SARA	5/20/2014	-1.70	1	<MRL 0.5		<MRL 2	<MRL 2	<MRL 1	<MRL 0.100	<MRL 0.005	<MRL 1	<MRL 0.080
WEFA	6/11/2014	-2.12	1	<MRL 0.5	<MRL 1	<MRL 2	<MRL 2	<MRL 1	0.017	<MRL 0.005	<MRL 1	<MRL 0.080
MABI	8/4/2014	-2.95	1	<MRL 0.5		<MRL 2	<MRL 2	<MRL 1	0.018	<MRL .001	<MRL 1	<MRL 0.003
MABI	8/4/2014	-1.44	1	<MRL 0.5	0.2	<MRL 2	<MRL 2	<MRL 1	<MRL 0.100	<MRL .001	<MRL 1	0.010

Table B2. Replicate sample analysis results and measurement quality analysis (Lower NETN).

Site	Date	Color Reg	Color Rep	Diff (PCU)	% Diff	DOC Reg	DOC Rep	Diff (mg/L)	% Diff	ANC Reg	ANC Rep	Diff (µeq/L)	% Diff
MIMASA	5/22/2014	207	204	3.0	1.4%	8.85	8.62	0.23	2.60%	755.0	749.0	6.0	0.8%
MABIPA	6/3/2014	26	26	0.0	0.0%	2.30	2.39	-0.09	3.91%	1632.6	1628.9	3.7	0.2%
WEFAPA	8/12/2014	30	32	-2.0	6.7%	5.00	5.00	0.00	0.00%	379.8	378.4	1.3	0.4%
MORRSB	8/12/2014	19	22	-3.0	15.8%	2.00	1.85	0.15	7.50%	789.7	791.6	-1.9	0.2%

Site	Date	Chla Reg	Chla Rep	Diff (µg/L)	% Diff	TP Reg	TP Rep	Diff (µg/L)	% Diff	TN Reg	TN Rep	Diff (mg/L)	% Diff
MIMASA	5/22/2014					124	136.0	-12.0	9.7%	0.77	0.87	-0.11	13.7%
MABIPA	6/3/2014	6.1				10.3	10.3	0.0	0.0%	0.28	0.30	-0.02	7.8%
WEFAPA	8/12/2014	3.4				15.3	15.0	0.3	2.0%	0.54	0.45	0.09	16.5%
MORRSB	8/12/2014					28.4	30.3	-1.9	6.7%	0.49	0.48	0.01	2.1%

Site	Date	NO ₃ Reg	NO ₃ Rep	Diff (µeq/L)	% Diff	NH ₃ Reg	NH ₃ Rep	Diff (mg/L)	% Diff	SO ₄ Reg	SO ₄ Rep	Diff (µeq/L)	% Diff
MIMASA	5/22/2014	8.9	8.4	0.50	5.6%	< MRL	< MRL			213	199	14.0	6.6%
MABIPA	6/3/2014	< MRL	< MRL			< MRL	< MRL			88	88	0.0	0.0%
WEFAPA	8/12/2014	< MRL	< MRL			0.032	0.03	0.002	6.3%	92	89	3.0	3.3%
MORRSB	8/12/2014	28.0	28.0	0.00	0.0%	0.024	< MRL			291	300	-9.0	3.1%

Site	Date	SO ₄ Reg	SO ₄ Rep	Diff (µeq/L)	% Diff	Cl Reg	Cl Rep	Diff (µeq/L)	% Diff
MIMASA	5/22/2014	213	199	14.0	6.6%	4330	3985	345.0	8.0%
MABIPA	6/3/2014	88	88	0.0	0.0%	17	17	0.0	0.0%
WEFAPA	8/12/2014	92	89	3.0	3.3%	932	932	0.0	0.0%
MORRSB	8/12/2014	291	300	-9.0	3.1%	170	175	-5.0	2.9%

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