



Cumberland Piedmont Network Water Quality Report

Shiloh National Military Park



ON THE COVER

Marcus Johnson samples Owl Creek, August 3, 2005
Photograph by: Joe Meiman

Cumberland Piedmont Network Water Quality Report

Shiloh National Military Park

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U.S. Department of the Interior
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Southeast Regional Office
Atlanta, Georgia

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Introduction

In early Fiscal-Year 2003, a water quality monitoring effort began in the Cumberland Piedmont Network (CUPN). For all intents and purposes, park managers and program directors can think of this initial sampling effort as a water quality inventory, as for many parks in the CUPN, little was known regarding water quality. Each park, sampled in rotation, underwent a water quality inventory sampling period which also served as a proving-ground for water quality monitoring protocols and logistics. The report that follows is a park-specific document that describes the monitoring sites, parameters tested, results in graphic form, a brief interpretation of the results, and recommendations of parameters to be measured for the long-term.

Sampling sites were chosen following site visits by then Mammoth Cave National Park (MACA) hydrogeologist Joe Meiman, and with consultation with park staff. Some sites were chosen to coincide with past inventories and monitoring efforts. In most cases sites were chosen at the downstream end of a watershed to serve as an integrator of the basin, and should yield characteristics and contributions from the entire watershed.

The NPS Water Resources Division (WRD) requires each Network water quality program to monitor four core field parameters – water temperature, pH, specific conductance, and dissolved oxygen. Any additional parameters of park interest will be considered through the CUPN Vital Signs selection process. As little was known about water quality in most CUPN parks – exceptions being MACA, Little River Canyon National Preserve (LIRI) and Cumberland Gap National Historical Park (CUGA) – a wide net of water quality parameters was cast during the first two years. Furthermore, as much was known about the water quality of these three parks, they were placed near the end of the park rotation allowing full inventories of parks with little data. In addition to the four core parameters, acid neutralizing capacity (ANC) and fecal coliform tests were performed in the field. Samples were taken and analyzed for a variety of ions and constituents at the WATERS Laboratory (a joint venture between MACA and Western Kentucky University (WKU)).

The CUPN Science and Technical Committee (STC) reviewed field and laboratory quality in January 2005 and made their recommendations to the CUPN Board of Directors. Data quality was reviewed based upon the Relative Percent Difference (RPD) between a field sample and its duplicate. In general the STC found the RPD values of the core four parameters to be of acceptable quality (less than 10% duplicate pairs lying outside a +/- 10% RPD tolerance level), although the fecal coliform and ANC tests need attention. Specifically, ANC results were of poor quality below 10 mg/l as CaCO_3 and fecal coliform results were generally poor throughout its entire range. New protocols for ANC and bacteria were developed and initiated in the spring of 2005.

In addition, the STC reviewed RPD values from laboratory analysis. Overall, eleven of the seventeen lab parameters had greater than 10% of duplicate pairs falling outside a +/- 20% RPD tolerance level. Although data generated from the lab are of questionable quality, they are still of use in a basic inventory of water quality for the park.

The CUPN STC also reviewed the relevance of data collected during the inventory round. In addition to poor laboratory performance and costs, it was determined that a full two-year inventory of ionic and associated parameters were not needed to further quantify the waters of

SHIL. Therefore, the data presented in this report consists of one full year (FY05) of laboratory data and two full years of an expanded set of field parameters (FY05 and FY06).

Sampling Sites

Below is a map of water quality sampling sites at SHIL. During each monthly sampling round each site was visited and an additional Quality Assurance-Quality Control sample was extracted. Monthly sampling commenced in October 2004 and continued until September 2006, for a total of 24 sampling events.

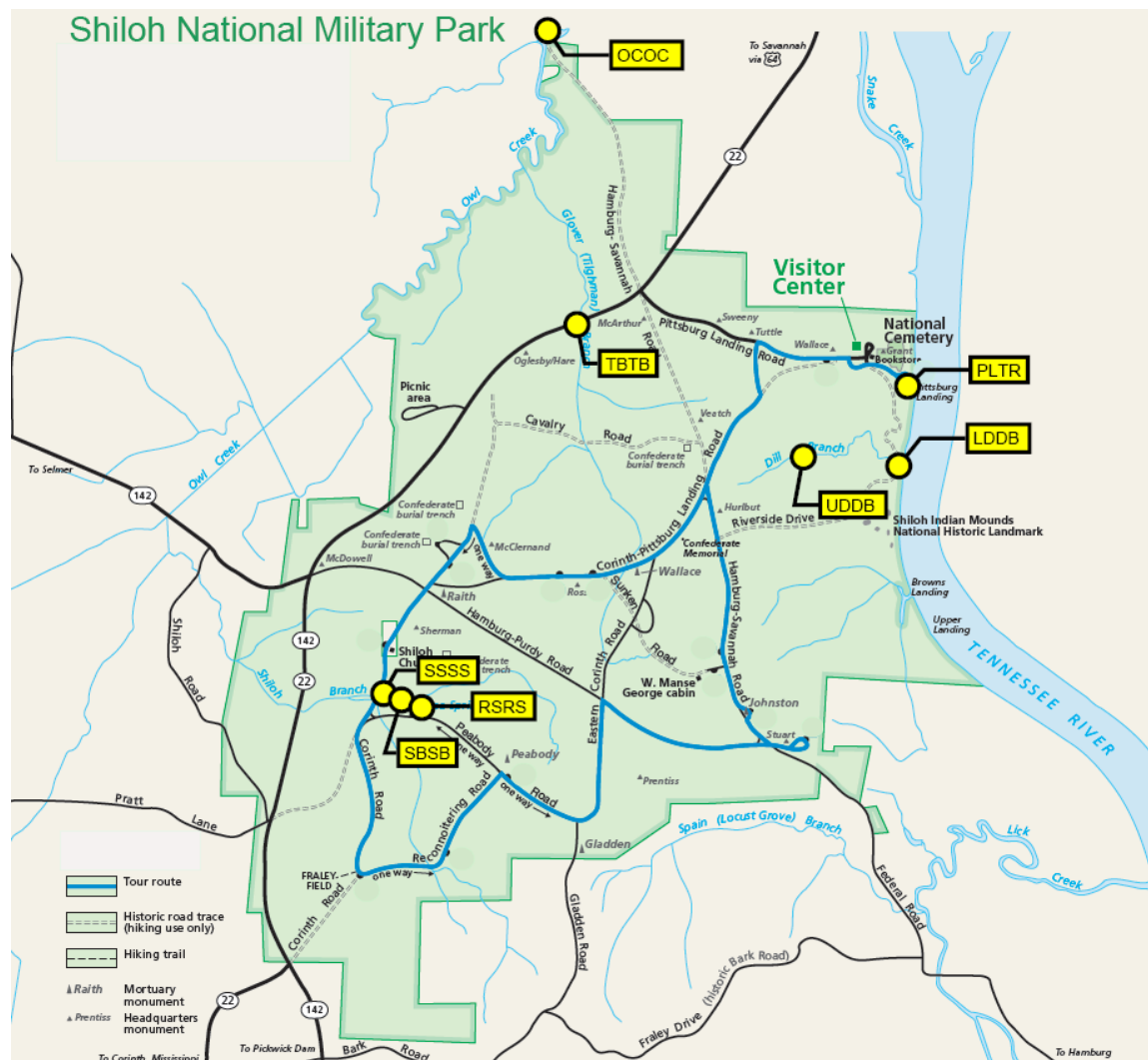


Figure 1. Map of water quality sampling sites at SHIL

Description of Sampling Sites

Lower Dill Branch (LDDB)

Located near the mouth of Dill Branch, just upstream of Brown's Landing Road. Back-flooding from river is possible. Rainfalls prior to the 12-08-2004 sampling event cause the Tennessee River to rise over seven meters over base, back-flooding the entire section of Lower Dill Branch.



Figure 2. Lower Dill Branch as photographed July 18th, 2001 by Joe Meiman

Upper Dill Branch (UDDB)

This site is located in the headwaters of Dill Branch at the confluence of two unnamed tributaries.



Figure 3. Upper Dill Branch as photographed July 18th, 2001 by Joe Meiman

Shiloh Spring (SSSS)

Located just south of Shiloh Church and east of Corinth Road. Little was known about this small, perennial limestone spring. It is a tributary of Shiloh Creek and has not been sampled in past monitoring efforts.



Figure 4. Shiloh Spring as photographed October 5th, 2004 by Joe Meiman

Rea Spring (RSRS)

Located just north of Rea Springs Road. Little was known about this small, perennial limestone spring. It is a tributary of Shiloh Creek and has not been sampled in past monitoring efforts.



Figure 5. Rea Spring as photographed July 17th, 2001 by Joe Meiman

Shiloh Branch (SBSB)

Located just downstream from the confluence of Rhea Spring, this site is sampled 10-15 meters downstream of the footbridge. It is likely that this site will be moved further downstream (downstream of the park's Corinth Road) for future sampling.



Figure 6. Shiloh Branch as photographed October 5th, 2004 by Joe Meiman

Tighman Branch (TBTB)

Located just upstream of the park boundary at the crossing of TN 22. Samples are taken just before the stream enters the box culvert.



Figure 7. Tighman Branch as photographed October 5th, 2004 by Joe Meiman

Owl Creek (OCOC)

Forms the northwest border of the park and is accessed by the Hamberg-Savannah Road. This creek was included in both fish and amphibian inventories.



Figure 8. Owl Creek as photographed October 5th, 2004 by Joe Meiman

Tennessee River (Kentucky Lake) at Pittsburg Landing (PLTR)

The original bounds of the park were marked by a low-water mark along the western bank of the Tennessee River. Currently, Kentucky Lake has elevated the water level onto previously sub-aerially exposed lands. In effect, the park boundary is well under water today. This reach of the lake/river may contain significant mussel populations and is met with a wide variety of water quality issues, including upstream pulp mills and proposed coal-fired power plants.



Figure 9. Pittsburg Landing as photographed October 5th, 2004 by Joe Meiman

Parameters for Water Quality Inventory

Field Measures

The following text is adapted from the USGS Techniques of Water-Resources Investigations Book 9, Chapters A1-A9 (2001). All equipment specifications and calibration procedures are outlined in this document.

Temperature

Measurements of water and air temperatures at the field site are essential for water-data collection. Determinations of dissolved-oxygen concentrations, conductivity, pH, rate and equilibria of chemical reactions, biological activity, and fluid properties rely on accurate temperature measurements. Accurate water- and air-temperature data are essential to document thermal alterations to the environment caused by natural phenomena and by human activities. A thermistor thermometer is an electrical device made of a solid semiconductor with a large temperature coefficient of resistivity. An electrical signal processor (meter) converts changes in resistance to a readout calibrated in temperature units. Thermistors commonly are incorporated in instruments used for surface-water and groundwater measurements.

Specific Conductance

Electrical conductance is a measure of the capacity of water (or other media) to conduct an electrical current. Basically, Specific Conductance (SpC) is a quick and reliable estimation of the dissolved solids in the water. Electrical conductance of water is a function of the types and quantities of dissolved substances in water, but there is no universal linear relation between total dissolved substances and conductivity. A dip-cell electrode sensor was used.

pH

The pH of an aqueous solution is controlled by interrelated chemical reactions that produce or consume hydrogen ions. Water pH is a useful index of the status of equilibrium reactions in which water participates. The pH of water directly affects physiological functions of plants and animals, and it is, therefore, an important indicator of the health of a water system. The electrometric measurement method uses a hydrogen ion electrode.

Dissolved oxygen

Accurate data on concentrations of dissolved oxygen (DO) in water are essential for documenting changes to the environment caused by natural phenomena and human activities. Sources of DO in water include atmospheric reaeration and photosynthetic activities of aquatic plants. Many chemical and biological reactions in ground water and surface water depend directly or indirectly on the amount of oxygen present. Dissolved oxygen is necessary in aquatic systems for the survival and growth of many aquatic organisms. The most commonly used field method for measuring DO in water is the amperometric method, in which DO concentration is determined with a temperature-compensating instrument or meter that works with a polarographic membrane-type sensor.

Acid Neutralizing Capacity

is the acid-neutralizing capacity (ANC) of solutes plus particulates in an unfiltered water sample, reported in mg/l as CaCO₃. ANC is equivalent to alkalinity for samples without titratable particulate matter. ANC is basically a measure of buffering capacity – the ability of water to buffer the effects of acid. Waters of low ANC are more susceptible to decreased pH by acid precipitation. During the January 2005 CUPN STC meeting, it was determined that the Hach ANC method was not producing reliable results. A new protocol was written and in June 2005 the CUPN began using a modified version of Standard Method 403 Alkalinity test.

Bacteria

Fecal indicator bacteria are used to assess the quality of water because they are not typically disease-causing, but are correlated to the presence of several waterborne disease-causing organisms (pathogens). The concentration of indicator bacteria (the term "indicator bacteria" is used synonymously with fecal indicator bacteria in this section) is a measure of water safety for body-contact recreation or for consumption. The most widely used indicator bacteria are of the total coliform, fecal coliform, enterococci, and fecal streptococci groups, and *E. coli*. Standard Method 9222D, membrane filtration for fecal coliform was used.

During the January 2005 CUPN STC meeting, it was determined that the 922D fecal coliform method was not producing reliable results. A new protocol was written and in June 2005 the CUPN began using the IDEXX (Standard Method 9223 – Enzyme Substrate Coliform) *Escherichia coli* and total coliform bacteria test. All three bacteria are members of the coliform group and are found in the gastrointestinal track of warm-blooded animals; *E. coli* is the most common member of fecal coliform, and fecal coliform a subset of total coliform.

Discharge

The anchor of all water quality data. Discharge data are used to compute the mass flux, or loading, of a particular constituent. Mass flux yields valuable insight as to the mode of contaminant entrainment and transport through the watershed.

Laboratory Measures

Anions

A suite of anions (fluoride, chloride, nitrite, bromide, nitrate, phosphate, and sulfate) was analyzed. Sources of anions are varied – from natural and anthropogenic contribution. Anions such as chloride and bromide are common to oil field brines, and nitrite, nitrate, and phosphate are considered nutrients, and are commonly products of animal wastes. Standard Method 300.1 (ion chromatograph) was used.

Cations

A suite of cations (sodium, potassium, magnesium, and calcium) were analyzed on the ion chromatograph, an unapproved method. Note that all data presented below were a product of the ion chromatograph. Any future cation analysis will be analyzed on a flame atomic adsorption spectrometer using Standard Method 3113. The cation sodium is paired with chloride and may indicate brine contamination. Potassium, magnesium and calcium are usually contributed to the dissolution of rock.

Total Organic Carbon

TOC is a measure of organic carbon in water, including various constituents in various oxidation states. This is a direct and easy measure of organic carbon, including components of biological and chemical oxygen demand. Standard Method 5310 B was used.

Turbidity

Turbidity measures the scattering effect that suspended solids have on light: the higher the intensity of scattered light, the higher the turbidity. Primary contributors to turbidity include clay, silt, finely divided organic and inorganic matter, soluble colored organic compounds, plankton, and microscopic organisms. The measurement is qualitative and cannot be correlated directly as micrograms per liter of suspended solids. Measurements were made in the laboratory with a nephelometer using Standard Method 214 A.

Stream Designated Uses

Each water body sampled within the CUPN has either been assigned a designated use by the state, or, by using the same ranking criteria, by this author. Each stream in SHIL has been designated by the state (see table below). The USEPA, besides mandating these rankings, also directed the states to develop water quality standards for each designated use. We can use these water quality standards as a minimum to track water quality trends in CUPN parks. By adapting the state standards, we can also track park water quality trends within the states, regions, or watersheds. New NPS nationwide GPRA goals are now tied to state water quality standards and designated uses. For more information on Tennessee water quality standards, please see:

Tennessee: Rules 1200-4-3-01, Tennessee Department of Environment and Conservation

Table 1. The table below shows the designated uses for each site.

SHIL	LDDDB	Lower Dill Branch	TN	Fish & Aquatic Life
SHIL	UDDDB	Upper Dill Branch	TN	Fish & Aquatic Life
SHIL	SSSS	Shiloh Spring	TN	Fish & Aquatic Life
SHIL	RSRS	Rea Spring	TN	Fish & Aquatic Life
SHIL	SBSB	Shiloh Branch	TN	Fish & Aquatic Life
SHIL	TBTB	Tighman Branch	TN	Fish & Aquatic Life
SHIL	OCOC	Owl Creek	TN	Fish & Aquatic Life
SHIL	PLTR	Tennessee River at Pittsburg Landing	TN	Domestic Water Supply Fish & Aquatic Life Industrial Water Supply Irrigation Livestock Watering & Wildlife Navigation Recreation

Most of the water quality parameters included in this inventory are not found in the state water quality standards. This is not to say they are unimportant to park management (a suggested list of parameters for long-term monitoring will conclude this report). If a state designated use water quality exists, it will be mentioned in the data interpretation below.

Results and Interpretation

The following graphs are a composite of 24 consecutive monthly rounds of sampling at SHIL. There are represented in the graphs below as box-plots. Here is a key to understanding the structure of a box-plot:

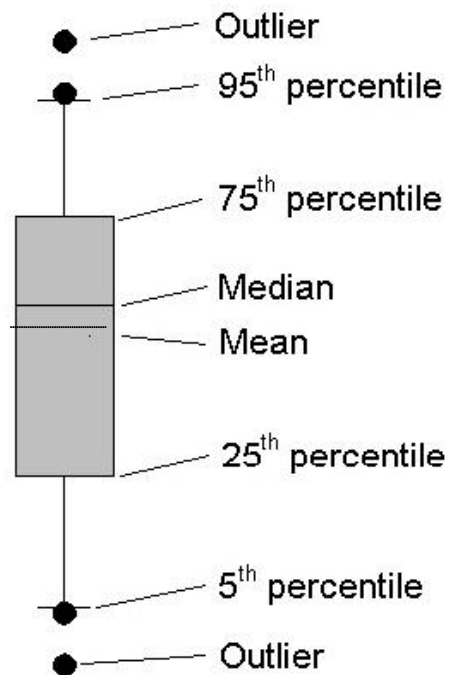


Figure 10. Structure of a box-plot

Field Measures

Water Temperature

Water temperatures of SHIL are considered to be within range to support native aquatic life. The compressed temperature ranges at Shiloh and Rhea Springs (SSSS and RSRS) are a function of long retention times of groundwater recharging these springs. This is seen to a less extent at Shiloh Branch (SBSB) as it is partially fed by Rhea Spring. One sample (August 2005) taken at Pittsburg Landing, Tennessee River (PLTR) was at the state limit of 30.5°C.

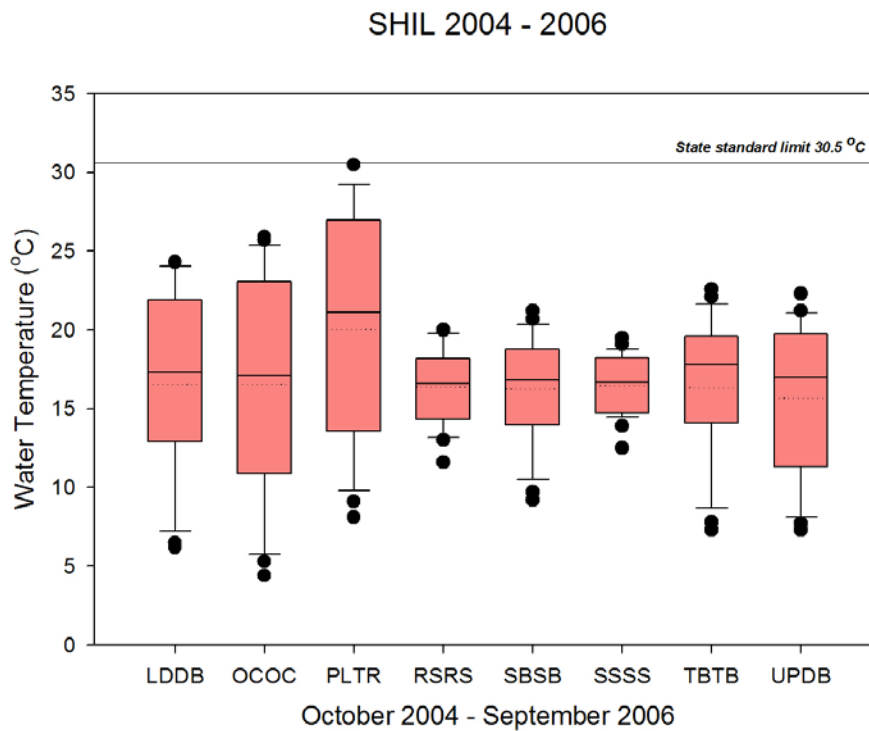


Figure 11. Water temperature at SHIL

Specific Conductance

The distribution of specific conductance (SpC) of SHIL is reflective of the amount of dissolved solids, which is primarily controlled by lithology and residence time. The tight pattern of low SpC values of both Dill Branch sites (LBDB and UPDB), Rhea and Shiloh Springs (RSRS and SSSS) and the creeks Shiloh and Tighman Branches (SBSB and TBTB) are consistent to limited contact with carbonate strata. Although the park is underlain by limestone – the two springs are issuing from limestone – there is little contact with the carbonate strata. It is likely that water recharging the springs spends the bulk of its time underground within siliclastic overburden, and makes its trip through the limestone in short order. The SpC pattern is evident in the following graphs of dissolved ions.

On the other end of the range, the Tennessee River (PLTR) and Owl Creek (OCOC) are recharged by larger watersheds and the opportunity to augment their load of dissolved solids is greatly increased. High outliers at LDDDB were due to back-flooding of the high-SpC waters of the Tennessee River.

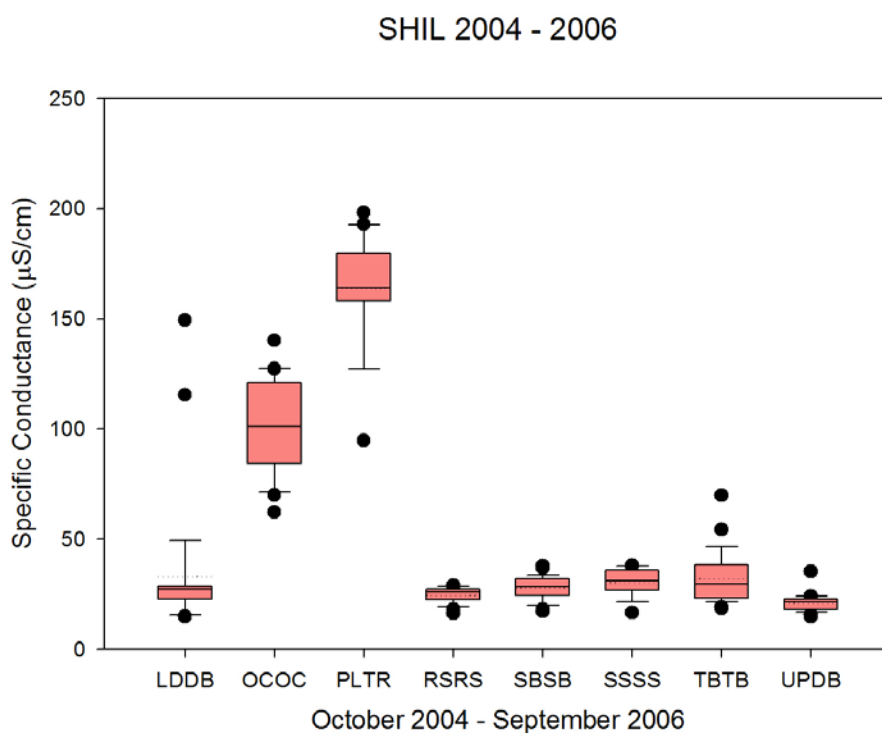


Figure 12. Specific Conductance at SHIL

pH

The pH of SHIL waters are naturally acidic. While it is apparent that, with exception of the PLTR and OCOC, these waters are almost always below the state lower pH limit of 6.0 SU. Normally this would mean that these waters are considered to be non-attainment under the Clean Water Act. However, according to Tennessee statute 1200-4-3-.05 “Where naturally formed conditions (e.g., geologic formations) or background water quality conditions are substantial impediments to attainment of the water quality standards, these natural or background conditions shall be taken into consideration in establishing any effluent limitations or restrictions on discharges to such waters.” There is no doubt, confirmed by other chemical parameters, that the waters of SHIL are naturally below the state pH lower limit.

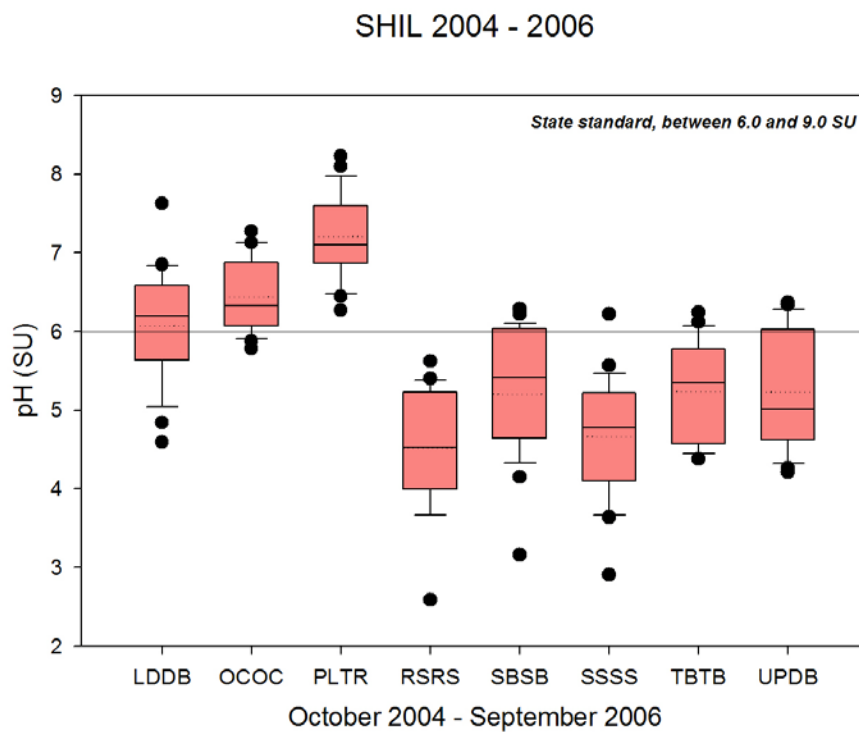


Figure 13. pH levels at SHIL

Dissolved Oxygen

Waters monitored at SHIL are usually saturated, or at least above the lower limit of 5.0 mg/l for dissolved oxygen (DO). Both spring sites (RSRS and SSSS) are typically the lowest in DO as it is not uncommon for springs which are recharged primarily by diffuse means and shallow gradients to have low DO. That is to say that there are few chances for the groundwater to be well aerated. DO levels in Tighman Branch are consistently lower than the other sites. For a detailed look at TBTB DO refer to the following figure.

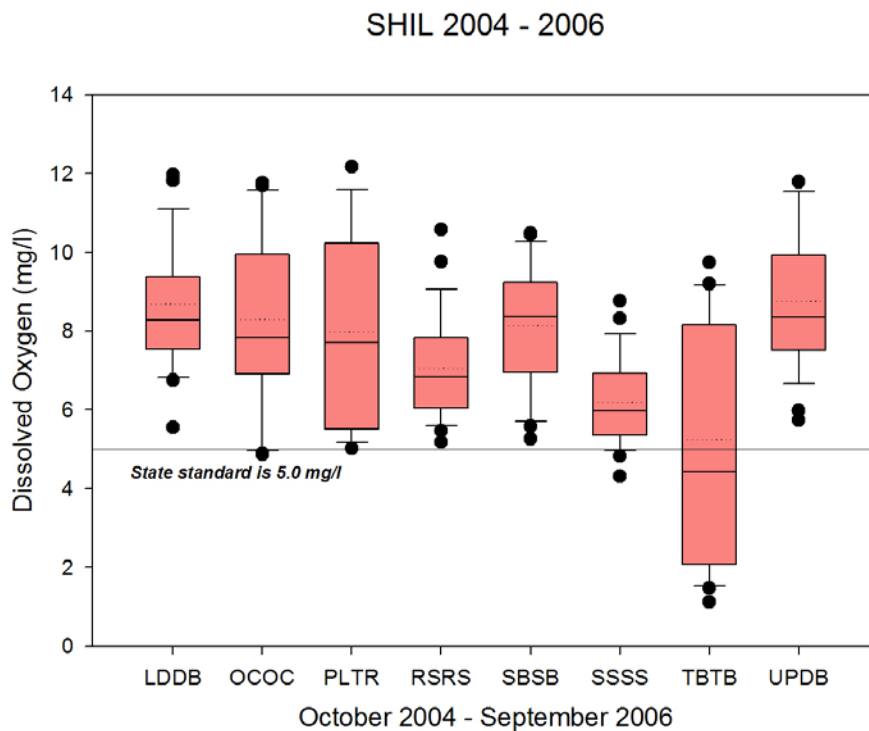


Figure 14. Dissolved Oxygen levels at SHIL

Dissolved Oxygen, Tighman Branch

It is typical that DO concentrations decreases as water temperature increases. Thus, it would be generally expected that DO levels drop in the warm summer and autumn months and increase in the winter. This pattern is seen October 2004 through October 2005 in the time-series graph below. In three consecutive months, November 2005 through January 2005, although water temperature drops, there is not a corresponding rise in DO. The exact cause of the depressed DO in Tighman Branch for these three months is not known. These data appear to be reliable and within tolerances of the protocol. Even during the summer months DO concentrations in TBTB are below the state standard of 5.0 mg/l. It will be recommended that the CUPN place a continuous-recording DO sensor in TBTB periodically over the next few years to explain these low DO conditions.

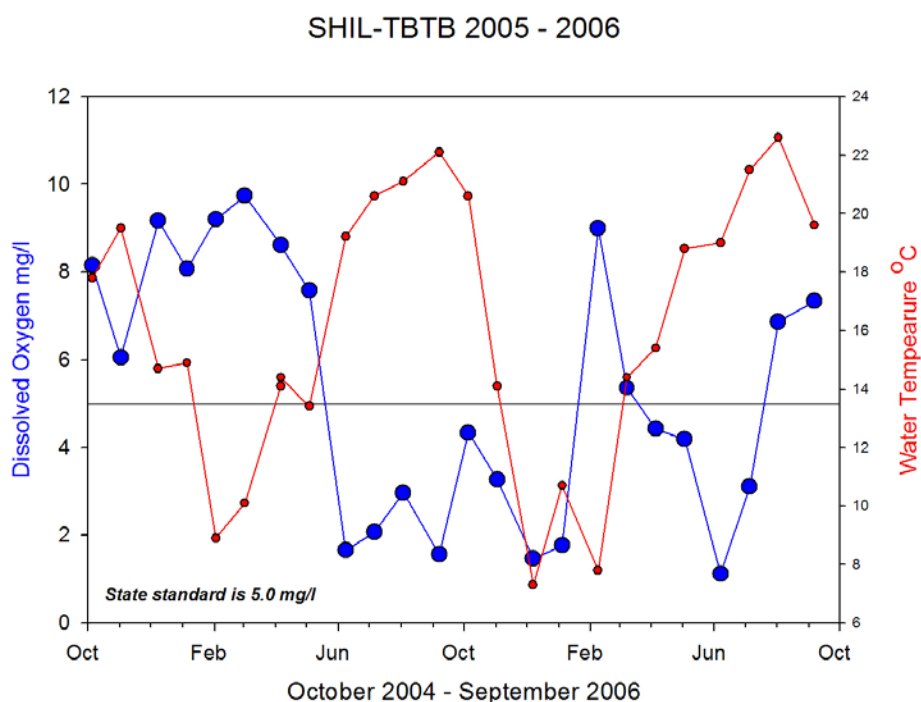


Figure 15. Dissolved Oxygen levels at Tighman Branch

Acid Neutralizing Capacity

The waters of SHIL (with exception of the Tennessee River and Owl Creek) have the lowest Acid Neutralizing Capacities (ANC) values of any CUPN park. Low ANC levels make waters more susceptible to acid precipitation as there are limited amounts of bicarbonates available to counter additional acids. ANC of SHIL waters, like the pattern seen in SpC, reflect basin lithology. Those recharged across or through carbonate strata (PLTR and OCOC) have fairly high ANC values. All other sites have very low ANC values as they have little or no contact with carbonates. Note the skewed plot of the Lower Dill Branch (LDDB) site. The two outliers that dominate the plot were the result of sampling events coincidental with flooding the Tennessee River. River water back-flooded upstream into the LDDB sampling site, but not as far upstream to affect the Upper Dill Branch site (UPDB).

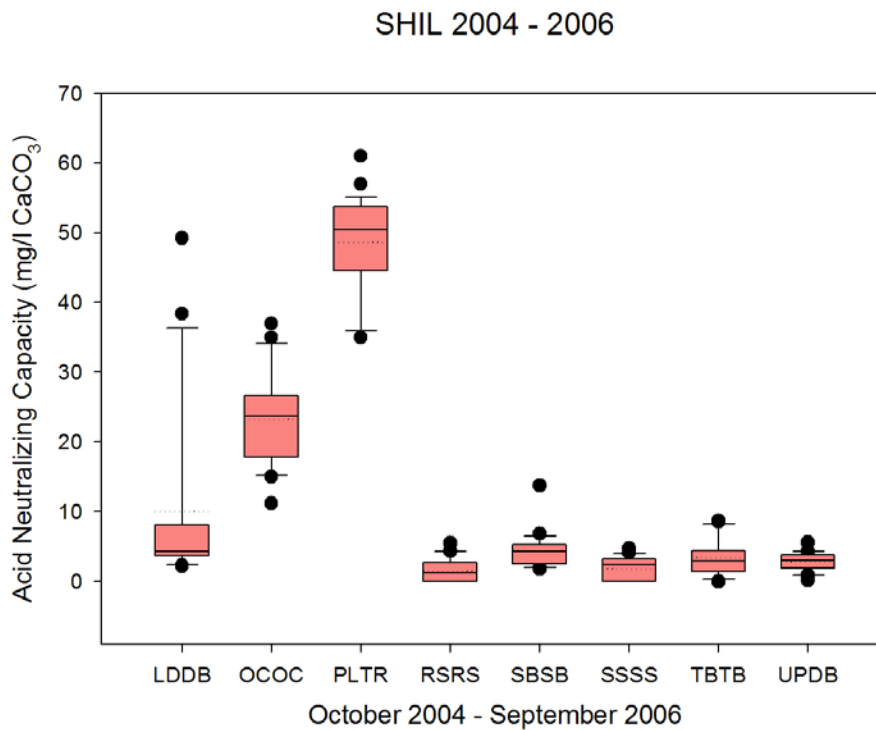


Figure 16. Acid Neutralizing Capacity at SHIL

Escherichia coli

For the most part, *E. coli* levels in SHIL waters are low. There are occasional spikes, as seen at Shiloh Tighman Branches (SBSB and TBTB), where a single elevated sample skews the plot. Sampling downstream from wildlife “activity” may cause an occasion spike as these. It is not understood why the Lower Dill Branch (LDDB) site is consistently higher than others. While below the state single sample standard of 2,880 colonies per 100 ml, LDDB is commonly high (by comparison) in *E. coli*. The Upper Dill Branch site (UPDB) is slightly elevated as well. As there is no development within the Dill Branch watershed, it may be a reflection of wildlife within the watershed.

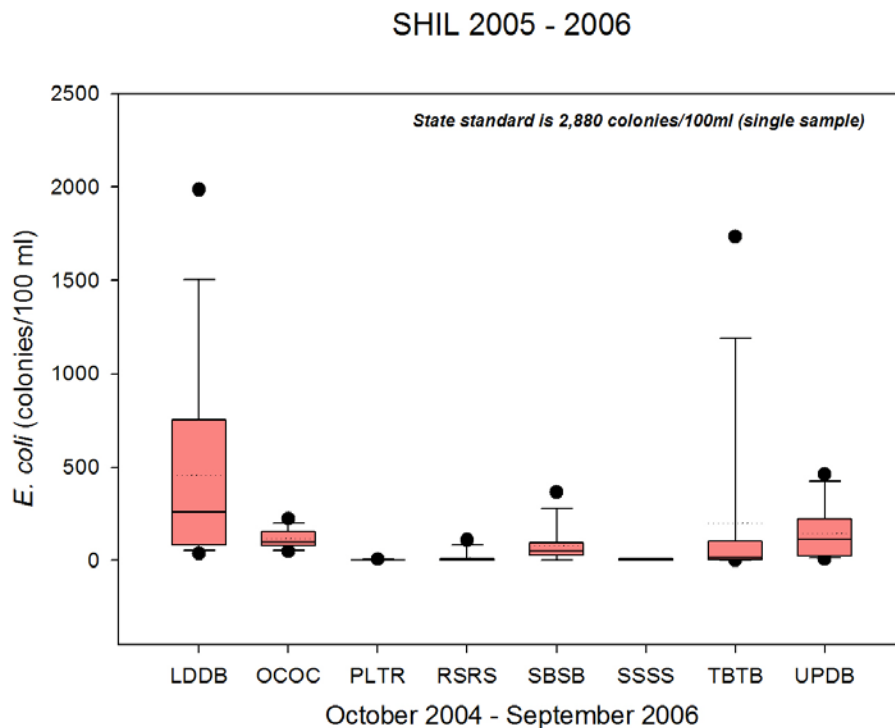


Figure 17. *E. coli* levels at SHIL

Laboratory Measures

Chloride

In general, chloride concentrations are correlative to the size of the watershed. The Tennessee River (PLTR), followed by Owl Creek (OCOC) and Dill Branch (LDDB) has the highest chloride values – the larger the watershed, the more opportunity to dissolve naturally ubiquitous ions such as chloride. There are no state standards for chloride. These levels are within natural background ranges.

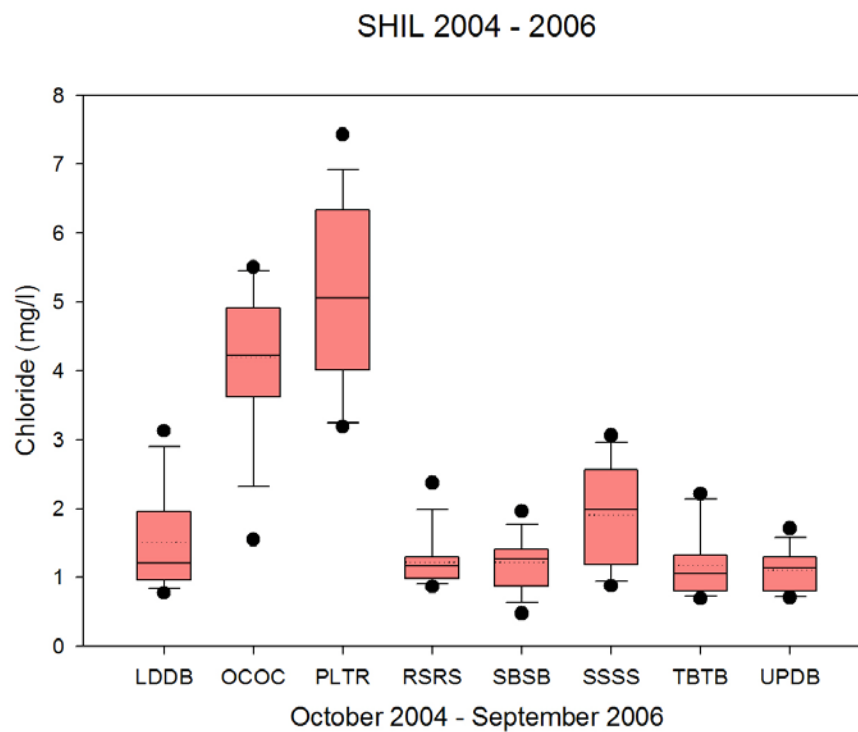


Figure 18. Chloride levels at SHIL

Nitrate

Nitrate levels in SHIL waters are consistent with natural background conditions. It must be noted that all nitrate samples from the October 5, 2005 sampling event were discarded. These results were very similar for all sites, and all approximately an order of magnitude higher than normal and are likely caused by a laboratory error. Also, there is no other supporting evidence – such as elevated SpC, turbidity, or other ions – that corroborate high nitrate levels. There are no state standards for nitrate, besides drinking water.

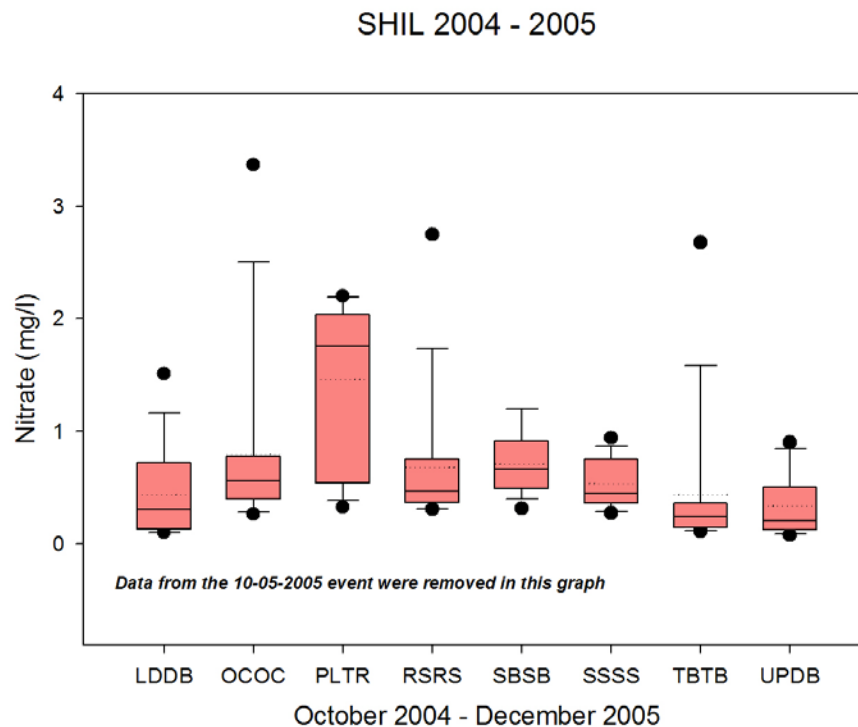


Figure 19. Nitrate levels at SHIL

Sulfate

Waters of SHIL are fairly low in sulfate. Note that the distribution and concentration of sulfate is nearly identical to that of chloride. Again, there is a correlation between watershed size and the concentration of this common dissolved ion. No sulfate standard exists for Tennessee designated use standards for the park's waters.

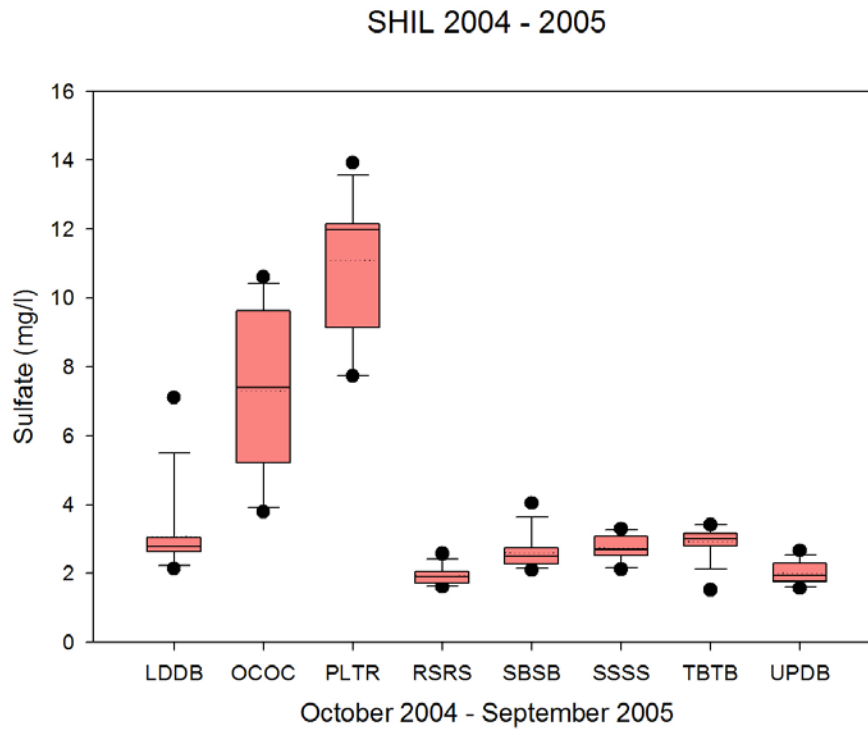


Figure 20. Sulfate levels at SHIL

Potassium

Potassium levels of waters monitored at SHIL are consistently low, and like chloride and sulfate, concentrations are correlative to watershed size. There is no potassium standard for assigned designated uses.

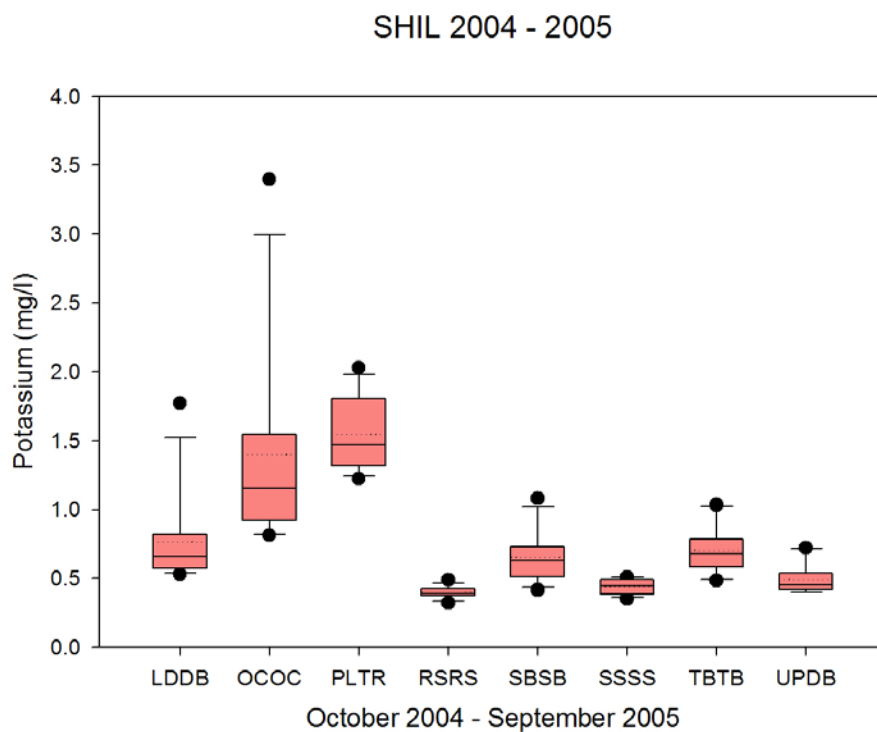


Figure 21. Potassium levels at SHIL

Sodium

The occurrence of sodium mirrors that of chloride. These two ions are commonly found in all freshwaters of the world and are primary products of oceanic evaporation of seawater – that is a small amount of NaCl is evaporated along with H₂O and precipitated across the land. This is not the only source of sodium or chloride, as many human-related land uses also liberate these ions. In any case, sodium levels are within normal ranges for waters of SHIL, and there is no sodium standards for Tennessee.

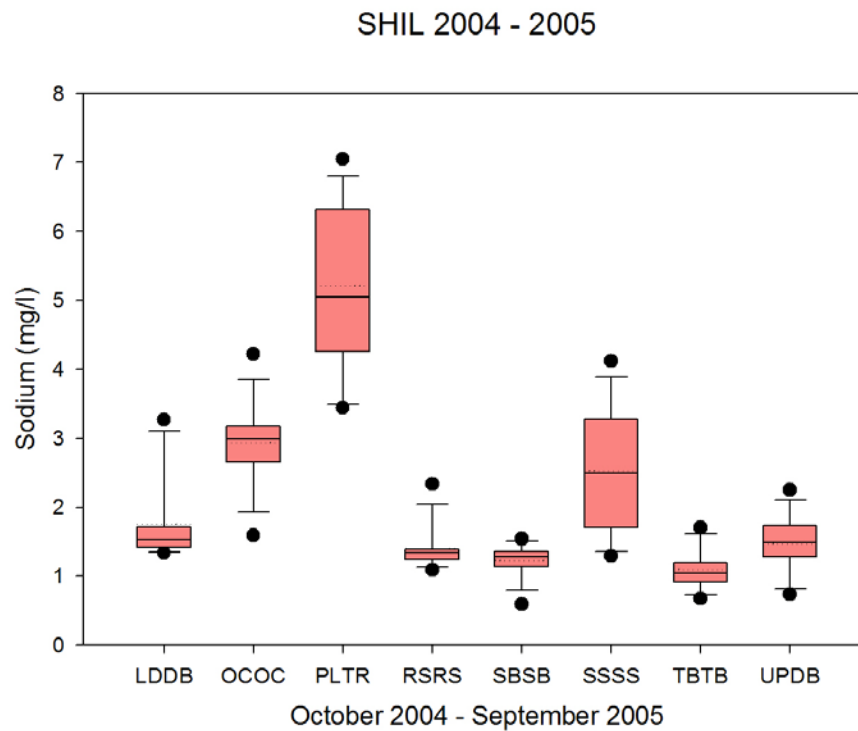


Figure 22. Sodium levels at SHIL

Magnesium

Similar to most other ionic data, the waters of SHIL are extremely reflective of the lithology of their watersheds. Those containing a large amount of carbonate strata – the Tennessee River – are higher than those that do not, as magnesium is common to limestones as the mineral dolomite. The back-flooding of the Tennessee into Dill Branch skews the LDDDB plot upward. There is no magnesium standard for Tennessee.

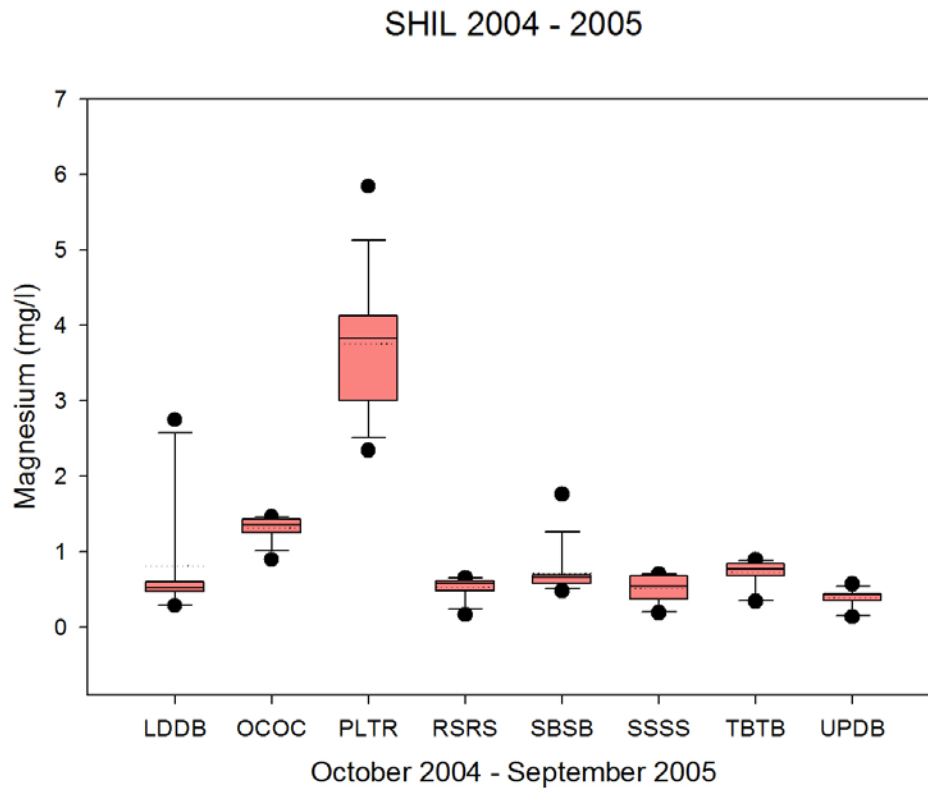


Figure 23. Magnesium levels at SHIL

Calcium

Relative concentrations of the calcium ion generally mirror that of magnesium. Both divalent cations, calcium and magnesium are often found replacing one another in mineral crystalline matrices. Recall the ANC graph earlier. The notable higher calcium levels are matched in the higher ANC values. Again, the back-flooding event at Dill Branch is seen in calcium data. There is no state standard for calcium.

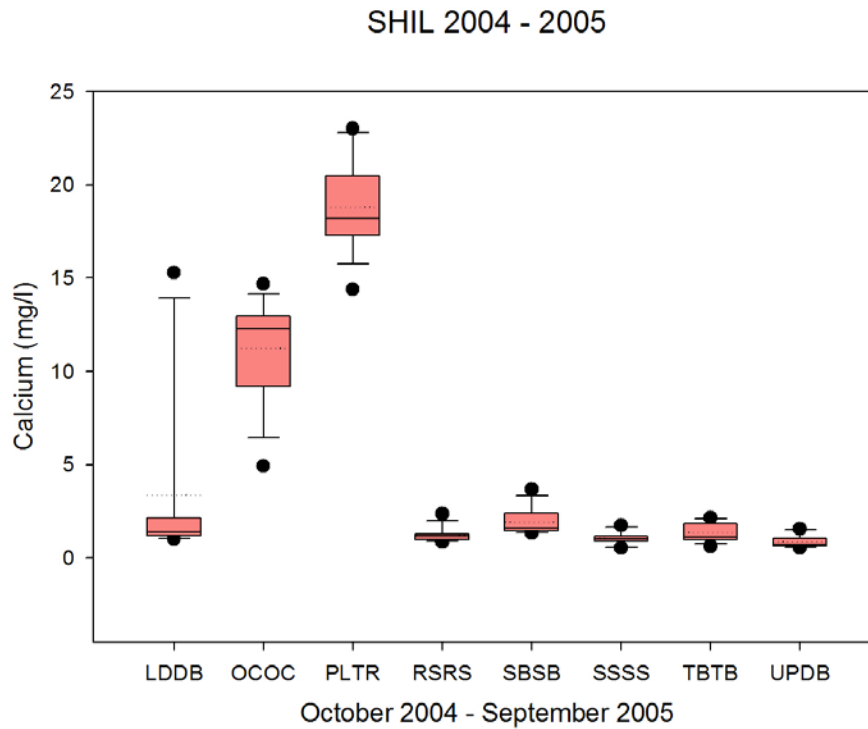


Figure 24. Calcium levels at SHIL

Total Organic Carbon

Total organic carbon, or in the case of most natural waters, non-purgeable organic carbon, is moderate to low in the waters of SHIL. The higher NPOC levels (outliers) are common to the April 6, 2005 sampling event at which time the streams were near flood flow and carrying more carbon than usual. There is no Tennessee standard for TOC.

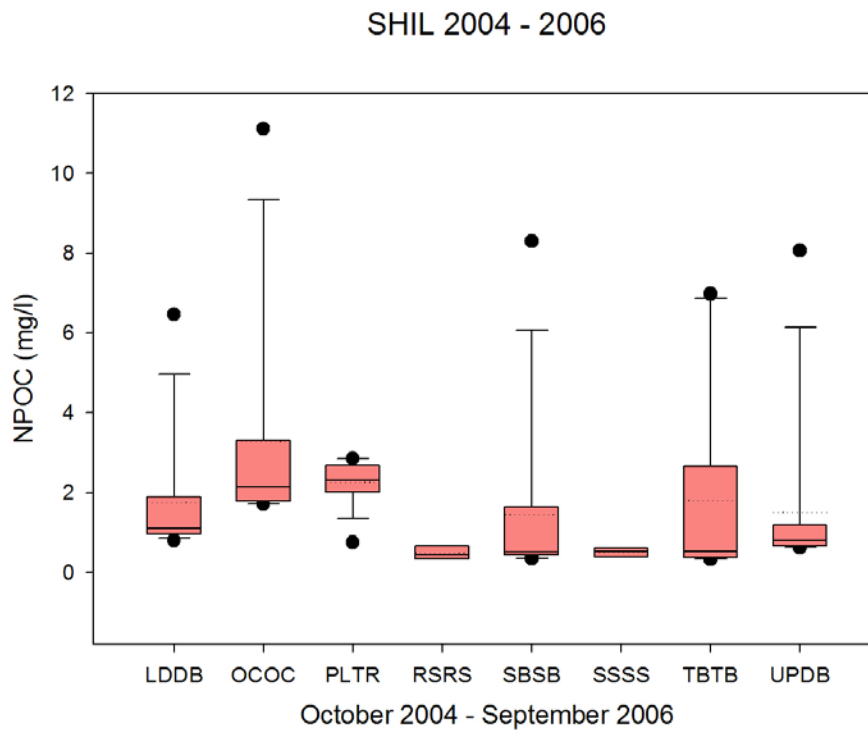


Figure 25. NPOC at SHIL

Turbidity

Turbidity is a general measure, or approximation of the amount of suspended material in the water. It is not directly correlative to suspended solids as particle size, shape and color all play a role in the transmission of light through the water column. In general, the higher turbidity values are associated with muddy or turbid waters. In general, waters of SHIL were slightly to moderately turbid. This range is primarily due to sample collection in respect to flood events – high turbidity associated with high flow. The entire graph is expanded due to the November 2, 2004 sample at Owl Creek. During this sampling event Owl Creek was in flood flow while other streams were near base – a large isolated rainfall event must have occurred within the Owl Creek Watershed. The Tennessee standard states that turbidity “should not result in visual contrast in a water body due to a man-made activity.

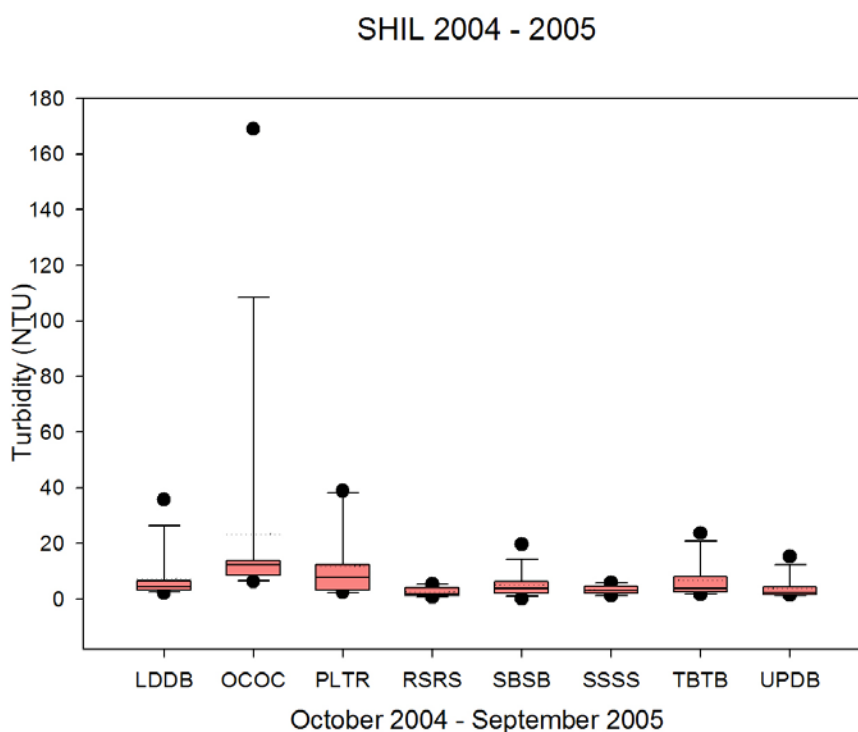


Figure 26. Turbidity at SHIL

General Water Quality Status

Water quality of the eight sites sampled at SHIL is good. The only exception would be the low dissolved oxygen at Tighman Branch. Waters of the park, with exception of the Tennessee River and Owl Creek, are naturally low in pH and acid neutralizing capacity. While pH values exceed the state pH standard, they should not be considered non-attainment to their designated uses, as they are naturally acidic. This claim is supported by ANC and dissolved ionic concentrations. The historically and naturally low ANC and pH values are not much of an issue. However, with the increase in acid precipitation over the past decades, streams with low buffering capacity and low pH, such as these are susceptible to becoming more acidic.

Future Water Quality Monitoring Recommendations

The CUPN is required in accord with the national water quality program to monitor water temperature, specific conductance, pH, and dissolved oxygen. In addition, there is sufficient reason to continue to monitor ANC, as long-term data may serve to alert the park to impending water quality issues.

The low dissolved oxygen values at Tighman Branch remains a mystery. SHIL is not scheduled for routine sampling until 2011. It would be prudent to resample Tighman Branch in these “off-years” anytime a trained CUPN water sampler is in the park. If the park would like to sample this and other streams, the CUPN would provide the equipment and training. This DO re-sampling may include the use of a continuous-recording multi-parameter sonde. This device would be left in the stream for several weeks and collect information that may explain why Tighman Branch has low DO values.

Long-Term Monitoring will include:

Water Temperature
Specific Conductivity
pH
Dissolved Oxygen
Acid Neutralizing Capacity

List of Abbreviations

ANC	Acid Neutralizing Capacity
Ca	Calcium
CaCO ₃	Calcium carbonate
Cl	Chloride
DO	Dissolved Oxygen
K	Potassium
km	kilometer
Mg	Magnesium
mg/l	milligrams per liter
NaCl	Sodium Chloride
NO ₃	Nitrate
NTU	Nephelometric Turbidity Unit
NPOC	Non-purgable Organic Carbon
RPD	Relative Percent Difference
SpC	Specific Conductance
SO ₄	Sulfate
SU	Standard Unit (pH)
TOC	Total Organic Carbon
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey

Table 2. Abbreviations used in this document