

Cumberland Piedmont Network Water Quality Report

February 2005

Carl Sandburg Home National Historic Site

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Based on the field work of Sheppard McAninch,
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Introduction

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 work as a water quality inventory, as for many parks in the CUPN, little, if anything, was known regarding water quality. This two-year period 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 the 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.

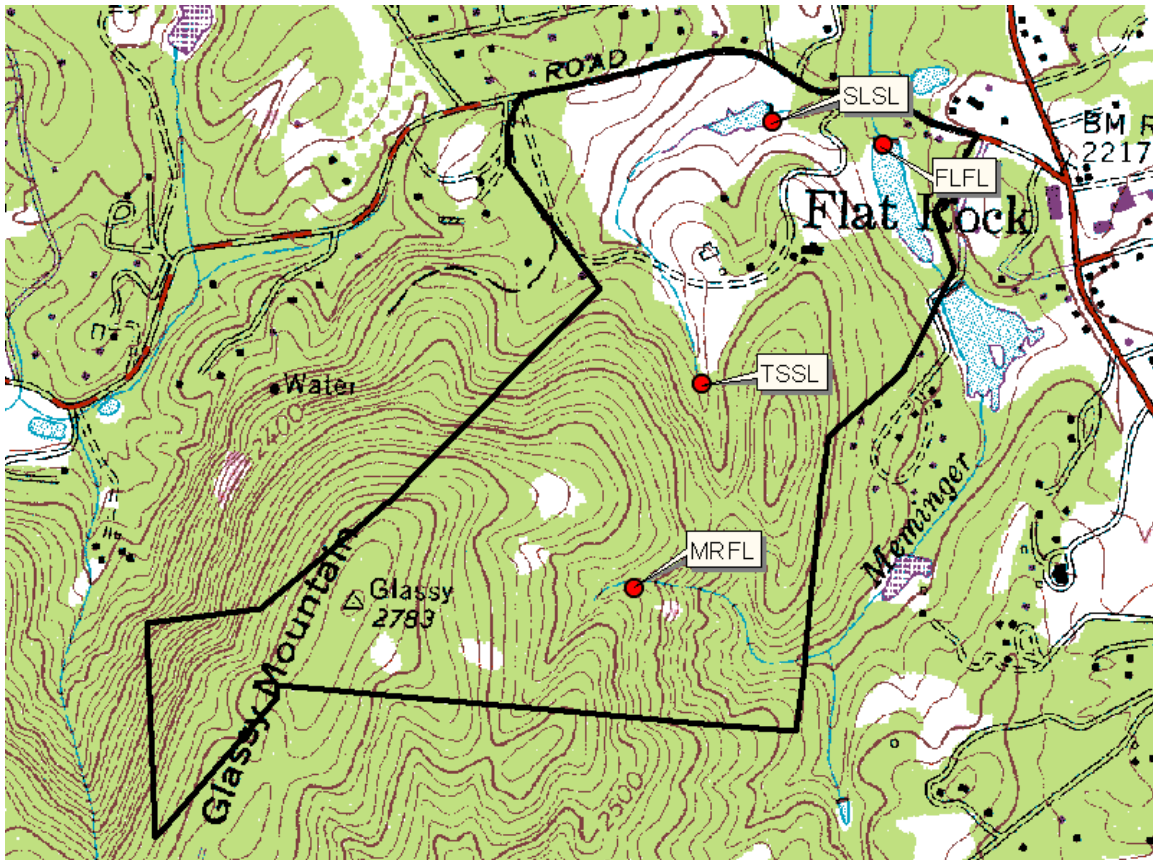
The NPS Water Resources Division (WRD) requires each Network water quality program to monitor four core field parameters – water temperature, pH, specific conductance, and dissolved oxygen. Any additional parameters of park interest will be considered through the CUPN Vital Signs selection process. As 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 MACA Water Quality Laboratory and the WATERS Laboratory (a joint venture between MACA and Western Kentucky University WKU). The MACA laboratory moved to the WKU campus in July 2004.

The CUPN Science and Technical Committee (STC) recently reviewed field and laboratory quality and has 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. The STC has been tasked with developing new protocols for ANC and fecal coliform.

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.

Sampling Sites

Below is a map of water quality sampling sites at CARL. During each quarterly sampling round each site was visited and an additional Quality Assurance-Quality Control sample was extracted. Monthly sampling commenced in December 2002 and continued until September 2003, for a total of four sampling events. Additional field parameters were taken during one round as laboratory samples were mis-shipped, necessitating a repeat sampling.



Description of Sampling Sites

Trout Pond Spring (TSSL): Located approximately 100 meters upstream of the Trout Pond. This small, perennial spring is the headwater of the Side Lake watershed. The spring was “improved” several years ago by the NPS. The spring was buried under rubble and a spring-box was constructed with an 8,000 gallon underground supply tank that feeds the barn operation via a buried pipe. Access to the spring, through the spring box (upstream from the tank), is easy and safe in all conditions.



Side Lake (SLSL): Located on the northern edge of the park, this man-made lake is the extreme downstream end of the Side Lake watershed. The lake is fed in part by waters of Trout Pond Spring and an unnamed non-park tributary. Access to the lake is easy and safe in all conditions.



Mountain Reservoir (MRFL): Located in the southern uplands of the park, this small pond is fed by a small stream originating from small springs in undeveloped woodlands both in and adjacent to the park. This site represents the headwaters of the Front Lake watershed. Access is easy and safe in all conditions.



Front Lake (FLFL): Located on the northeastern edge of the park, this man-made lake is the extreme downstream end of the Front Lake watershed. The lake is fed in part by the waters of the Mountain Reservoir which flows as Meminger Creek through the Ravenswood community before entering Front Lake. Access is easy and safe in all conditions.



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.

ANC: is the acid-neutralizing capacity of solutes plus particulates in an unfiltered water sample, reported in mg/l as CaCO_3 . 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.

Fecal coliform 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.

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.

Total Suspended Solids: While turbidity measures are a quick and simple estimation of suspended solid loads, it cannot be directly correlated to TSS, which is a true measure of suspended solids due to particle size and color characteristics. Standard Method 2540 E was used.

Chlorophyll-a: Since chlorophyll-containing organisms are the first step in most food chains, the health and /or abundance of these primary producers will have cascading effects to all higher organisms. Therefore, the determination of chlorophyll concentration is one of the key indices in monitoring the health of any natural system. EPA Method 445.0 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.

Atrazine: Atrazine, a triazine-class herbicide, represents the most common and durable pesticides used in the United States. They are commonly found after peak applications periods (spring), closely associated with storm pulses (attached to fine particulate matter), and have been found persisting in the water column for six months. The immuno-assay screening technique was used for this analysis.

Stream Designated Uses

As discussed below, 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. 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. For more information on North Carolina water quality standards, please see:

North Carolina: Subchapter 2B – Surface Water and Wetland Standards, 15A NCAC 02B .0100 - .0510.

The table below shows that none of the park’s four sites are officially listed – a state is not required to list designated uses for all waters. The author, using the same criteria used by the state process, “listed” designated uses for each site for purposes of water quality comparison.

<i>Park</i>	<i>Code</i>	<i>Site</i>	<i>State</i>	<i>Designated Use</i>
CARL	TSSL	Trout Pond Spring	NC	HQW
CARL	SLSL	Side Lake	NC	Class WS-II
CARL	MRFL	Mountain Reservoir	NC	HQW
CARL	FLFL	Front Lake	NC	Class WS-II

HQW is the designation for “High Quality Waters” which are rated as excellent based upon biological or physical/chemical characteristics through monitoring or studies. Class WS-II includes waters that may be protected as water supplies and are within primarily undeveloped watersheds.

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 four quarterly rounds of sampling at CARL. With only four data points per site, it was not possible to create box-plots (a easy graphic way to show basic statistics), water quality data are displayed as simple scatter plots.

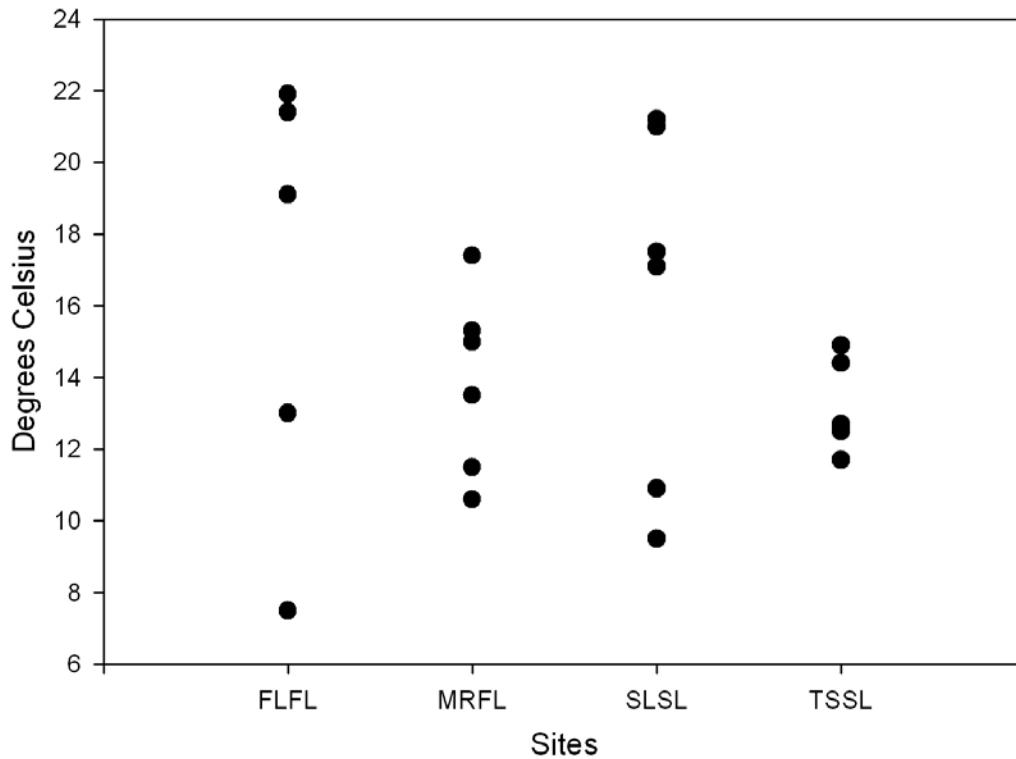
In addition to state water quality standards (where applicable), laboratory “Practical Quantitation Limits” (PQL) will be denoted. The PQL is five times the “Minimum Detection Limit” set by the laboratory. The PQL can be used as a means of determining if a particular parameter is worth monitoring in the future. For example, if samples continually come in well under the PQL value, and there is no known reason to continue that analyte, it would be a candidate to discontinue. The laboratory used the ion chromatograph (unapproved method) for all cation analysis below and did not provide PQL limits. For the cations of calcium, potassium, magnesium, and sodium, PQLs for the flame atomic adsorption method were used. There is also no PQL provided for Chlorophyll-a analysis.

Field Parameters

Water Temperature

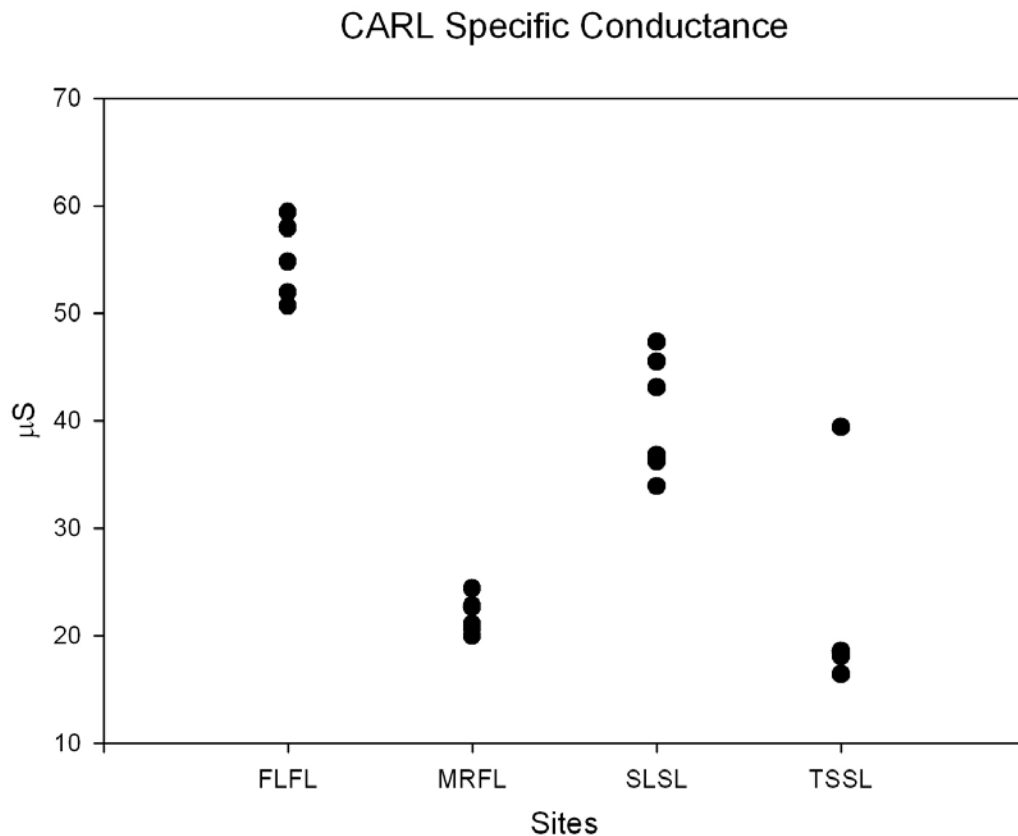
Water temperatures at CARL are considered to be within range to support native aquatic life. The compressed temperature range at Trout Spring (TSSL) is a function of longer retention times of groundwater recharging the spring. This attenuation is seen to a less extent at Mountain Reservoir (MRFL). North Carolina designated use standards for both HQW and WS-II waters state that temperature cannot exceed natural conditions by more than 2.8°C. Although it will take time to establish “natural conditions” for these waters, there is no reason to believe that temperature is an issue with respect to compliance.

CARL Water Temperature



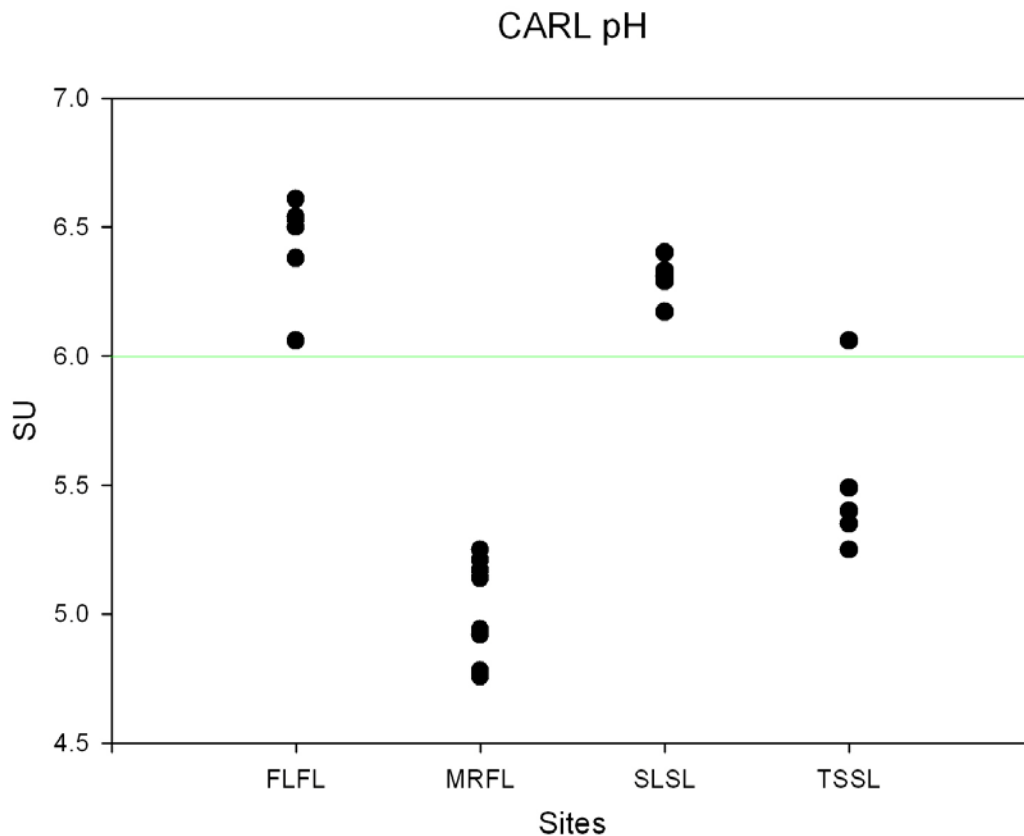
Specific Conductance

The distribution of specific conductance (SPC) at CARL, like anywhere, is a function of the amount of dissolved ions in the water. The very low SPC values at TSSL and MRFL represent the emergence of groundwater (springs) flowing through relatively insoluble rock. There is not much of an opportunity to dissolve mineral species into the water. As the streams flow down to their lakes, Side (SLSL) and Front (FLFL), they pick up a moderate amount of dissolved ions. With the exception of one “high” SPC value at Trout Spring, SPC is rather consistent and predictable. As will be seen in ionic graphs later, there is not much dissolved solids in the waters of CARL, which is very typical for the stratigraphy found in the park.



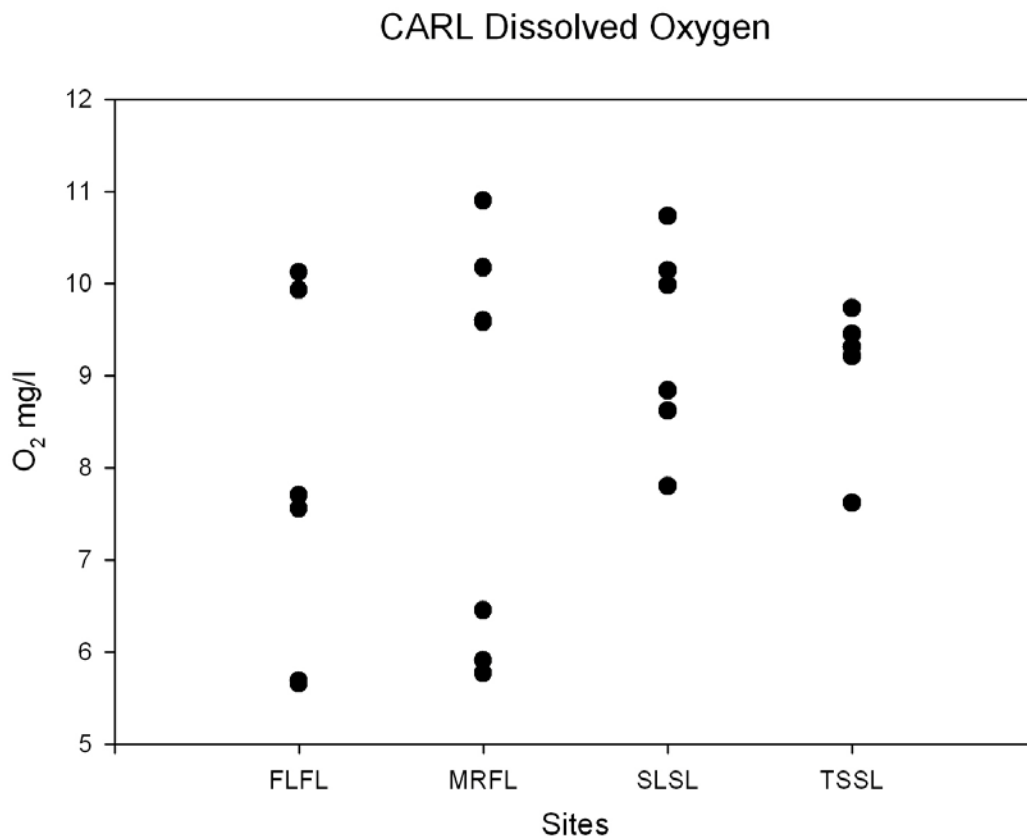
pH

Waters of CARL are slightly to moderately acidic. The sites higher within a particular watershed tend to a bit more acidic than lower sites. This may be an effect of contributing basin size – that is, sites like TSSL and MRFL are at their headwaters and as they emerge from the granitic bedrock are naturally acidic and have little or no contact with buffering agents. The less acidic waters of FLFL and SLSL, as will be seen in the forthcoming ANC graph, is due to a higher load bicarbonates, which buffer the effects of the acids. State standard for freshwater pH is between 6.0 and 9.0 SU. We can see that both spring sites are below the lower state pH limit. As these springs are recharged in a buffering-limited environment, this low pH is most likely natural.



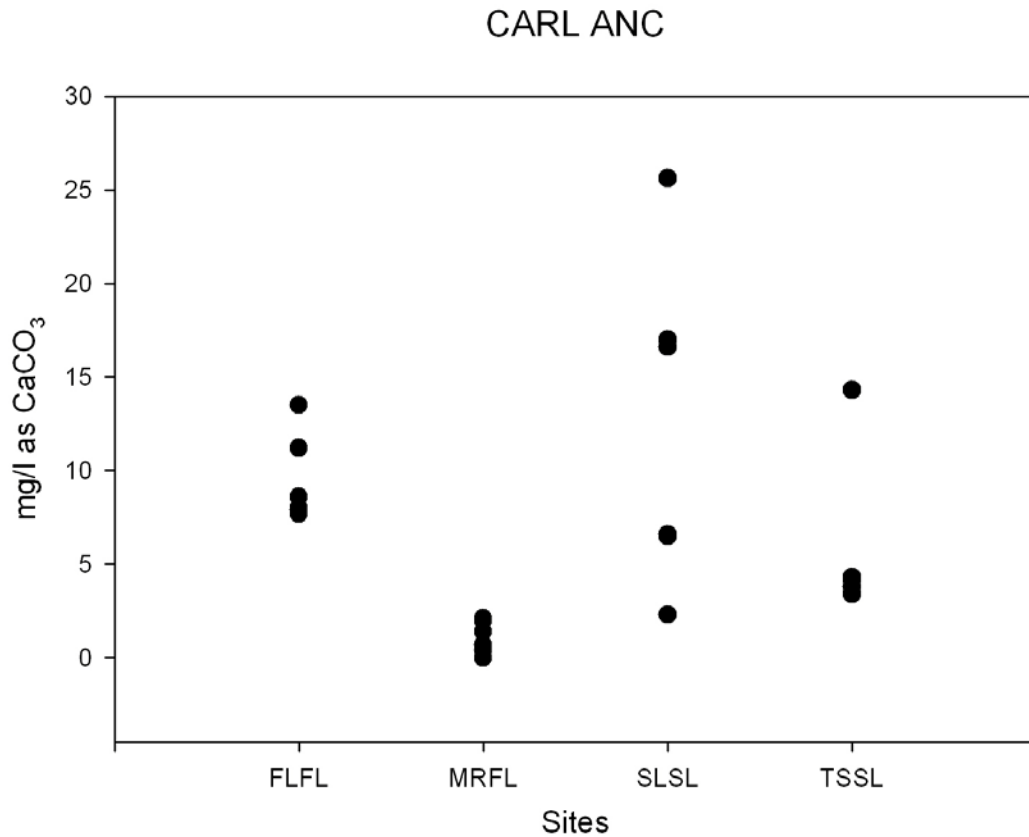
Dissolved Oxygen

Dissolved oxygen, in all samples, was above the state limit of 5.0 mg/l. There were a few readings at MRFL and one at FLFL that approach this limit. These low readings all occurred during the warmer summer months when water cannot dissolve as much oxygen as when it is cold. In general, the waters of CARL are well oxygenated – well enough to support aquatic life.



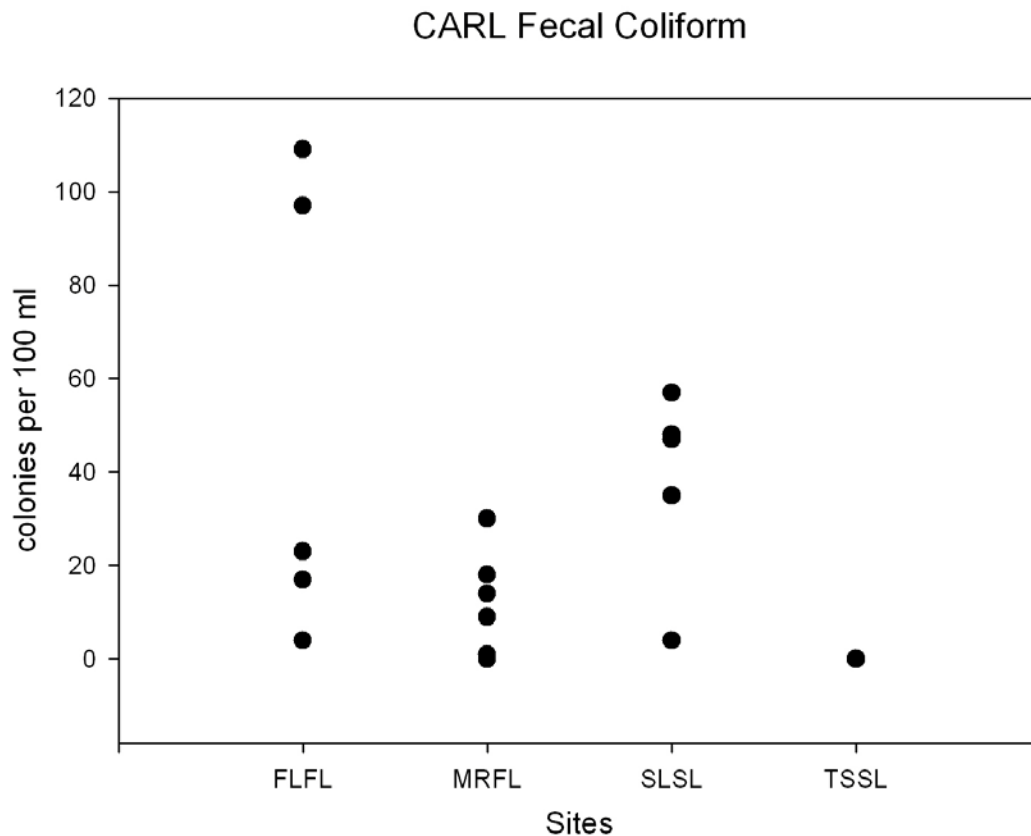
Acid Neutralizing Capacity

A nearly identical signature as was seen with SPC. Acid neutralizing capacity (ANC) of CARL waters is fairly low to very low, indicating a lack of contact with carbonate strata or other sources of the bicarbonate ion. As the streams flow to the lakes a small amount of bicarbonates are acquired and the ANC increases. Low ANC levels make waters more susceptible to acid precipitation as there are limited amounts of bicarbonates available to counter additional acids.



Fecal Coliform

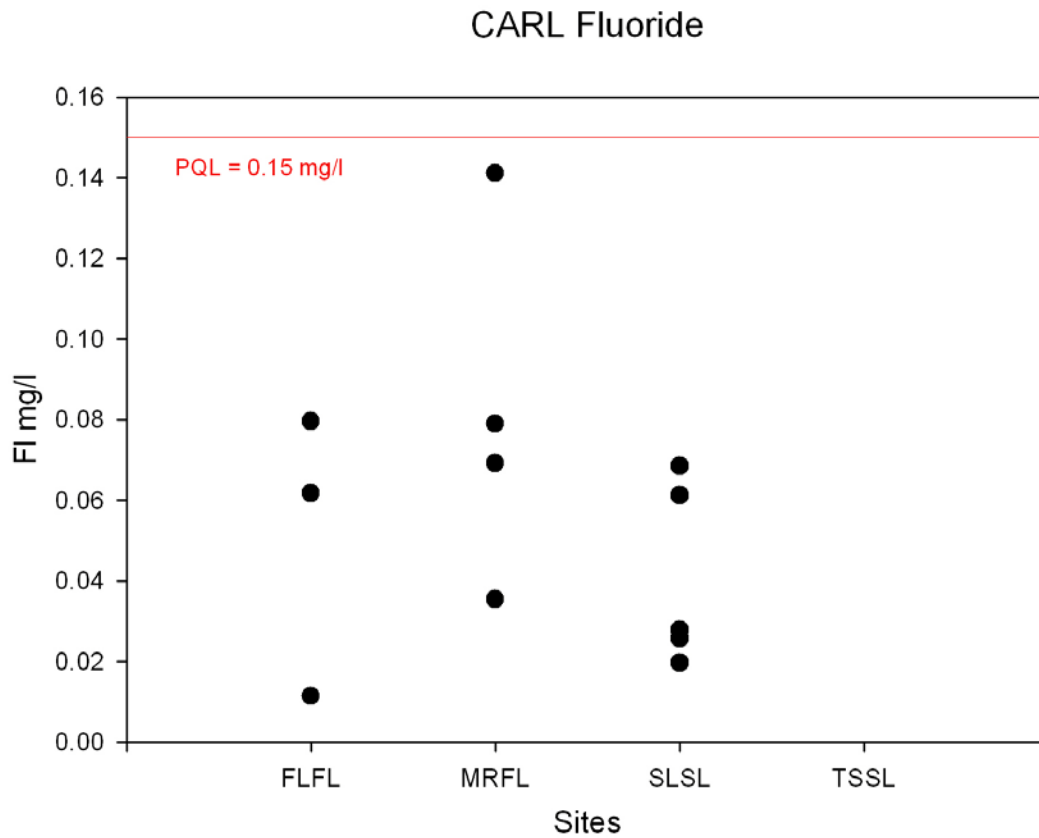
Fecal coliform levels at CARL are among the lowest within the CUPN. Not one colony was counted in any of the samples taken at Trout Spring – the Sandburgs could not have chosen a better drinking water supply, at least in terms of fecal contamination. Similar to dissolved ions, the upper-basin sites (the springs) were low in fecal coliform, as additional bacteria was added to the streams as they made their ways to the lakes. The higher levels at Front Lake (FLFL) are either derived from Meminger Creek outside the park, or possible by domestic animal waste runoff into the lake. A simple set of grab samples can easily be taken to determine the source. It is likely that the coliforms seen at MRFL are due to wildlife. This is not seen at TSSL as the spring is fully capped by a structure. In any case, the fecal coliform standards for WS-II and HQW is 200 colonies per 100 ml, based on a geometric mean of a series of 5 samples taken within a 30 day period. The waters of CARL represent pristine or near-pristine conditions with respect to fecal coliform.



Laboratory Measures

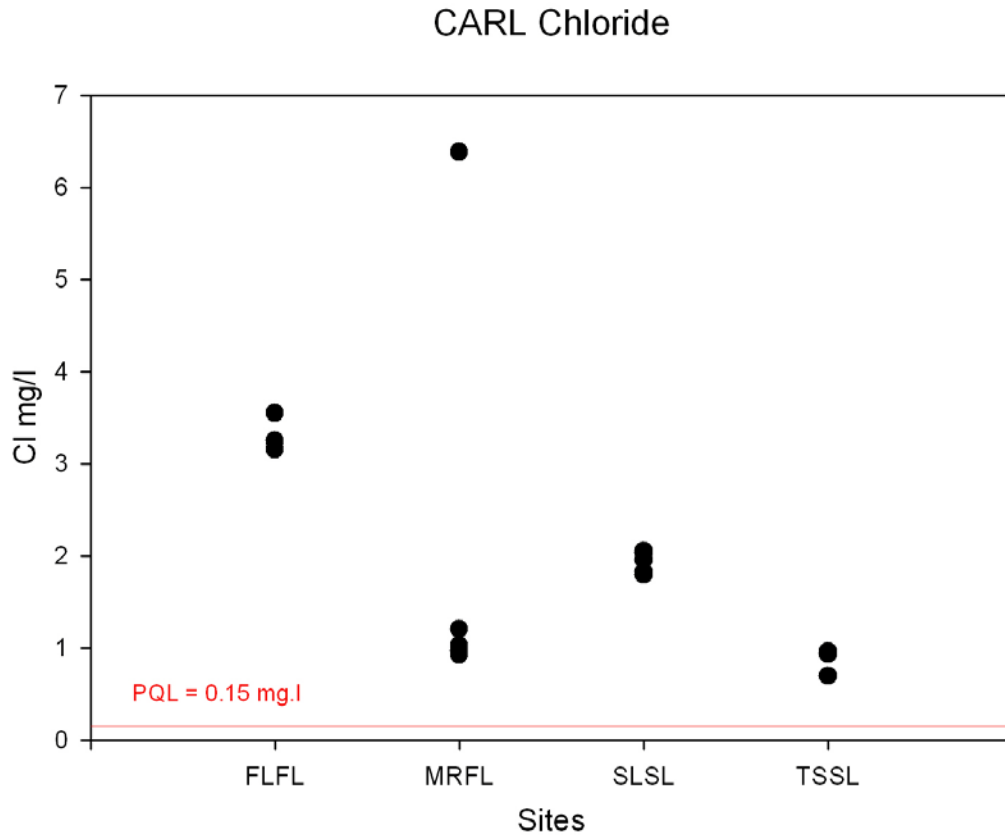
Fluoride

Fluoride concentrations of CARL waters are very low; so low that all samples registered lower than the PQL of 0.15 mg/l. The state standard is 1.8 mg/l, over an order of magnitude higher than the PQL.



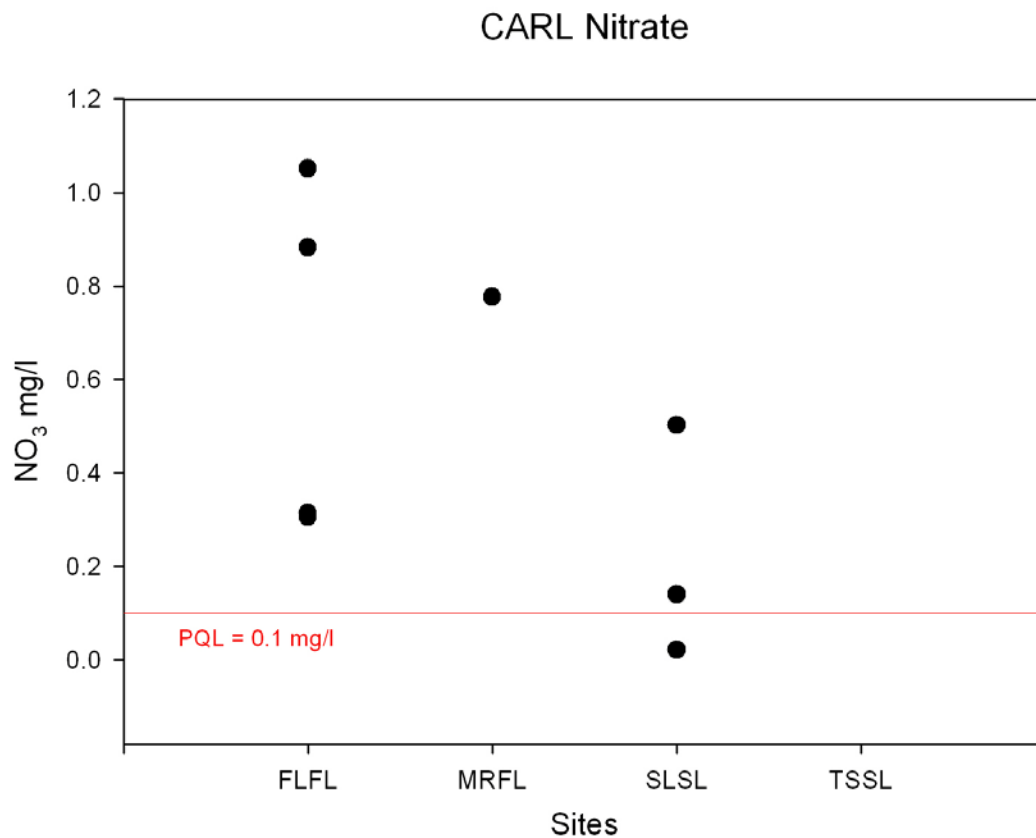
Chloride

While all samples were above the PQL of 0.15 mg/l, no samples exceeded the state standard for chloride, set at 250 mg/l. Chloride is found as natural background ion, a leftover of evaporation and evapotranspiration processes. These levels are within what is expected as natural concentrations.



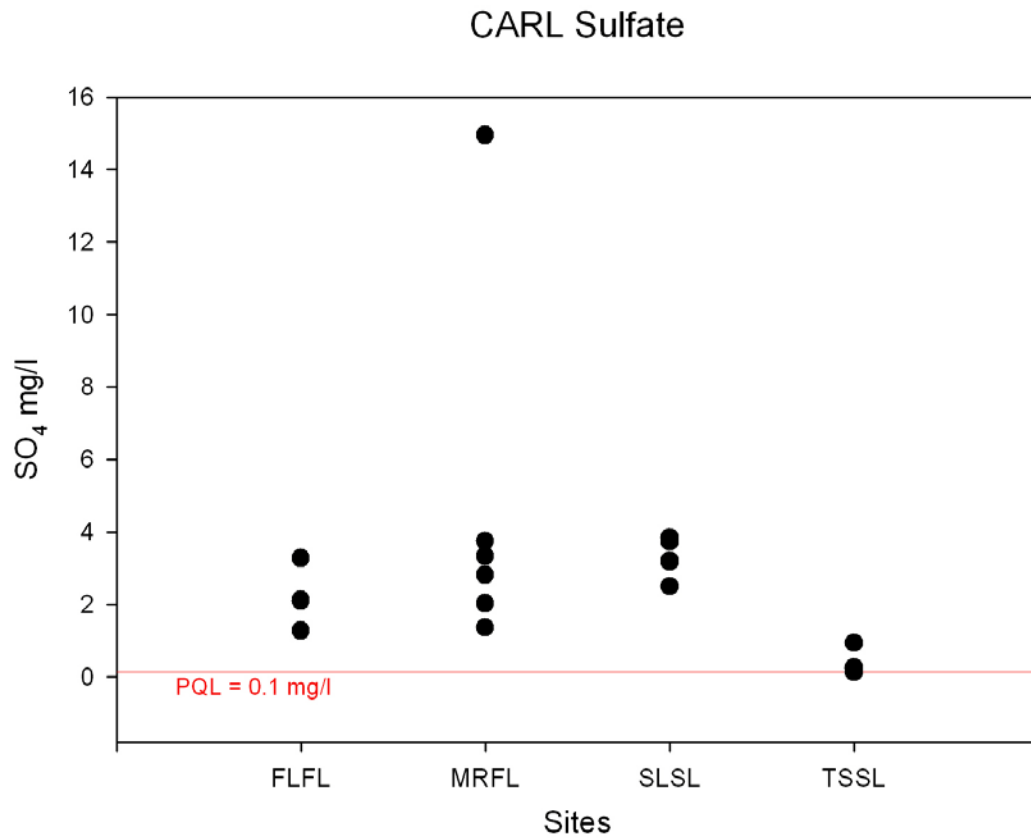
Nitrate

Nitrate levels at CARL are very low. The state standard for both water classes is 10 mg/l as N-NO₃ (as commonly expressed, or 45 mg/l as NO₃ as graphed below – 40 to well over one hundred times higher than found at the four sites. All samples taken at Trout Spring were non-detectable for nitrate. Again, the Sandburgs could not have found a better water supply.



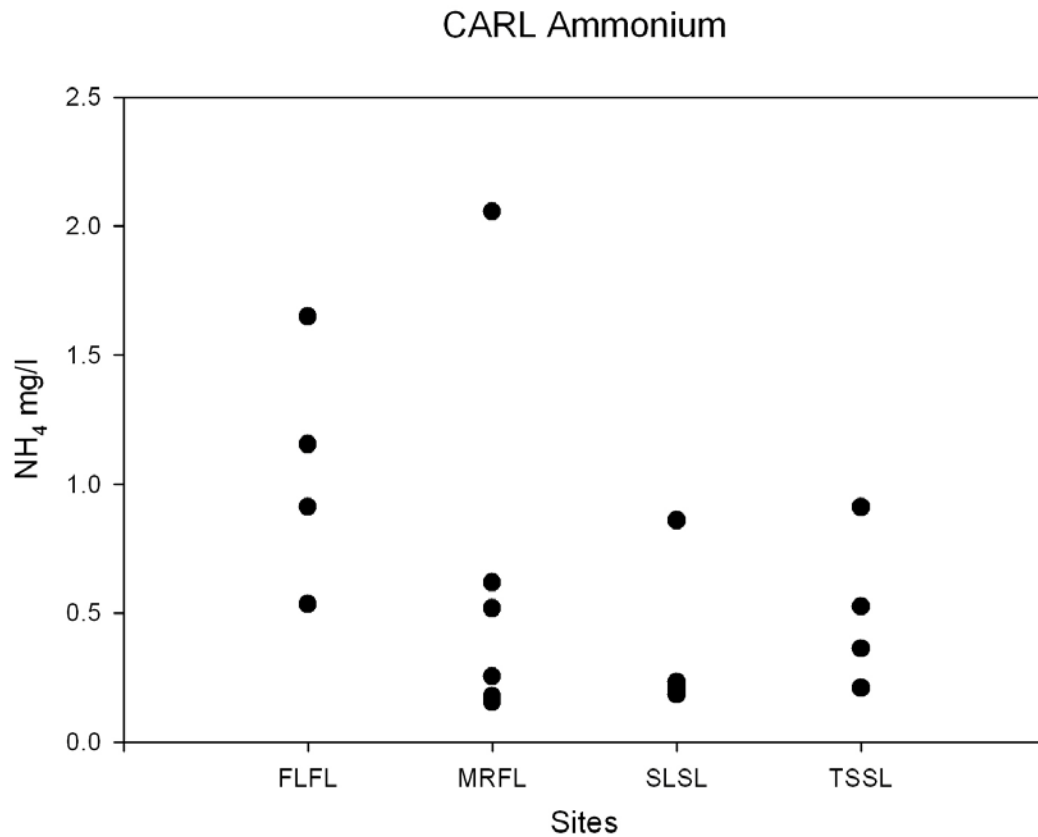
Sulfate

Waters of CARL have low sulfate concentrations. With exception of the lone outlier of MRFL, there are no concerns with sulfate concentrations, and even that outlier concentration is not high enough to cause harm to aquatic life. For comparison, the state standard is 250 mg/l.



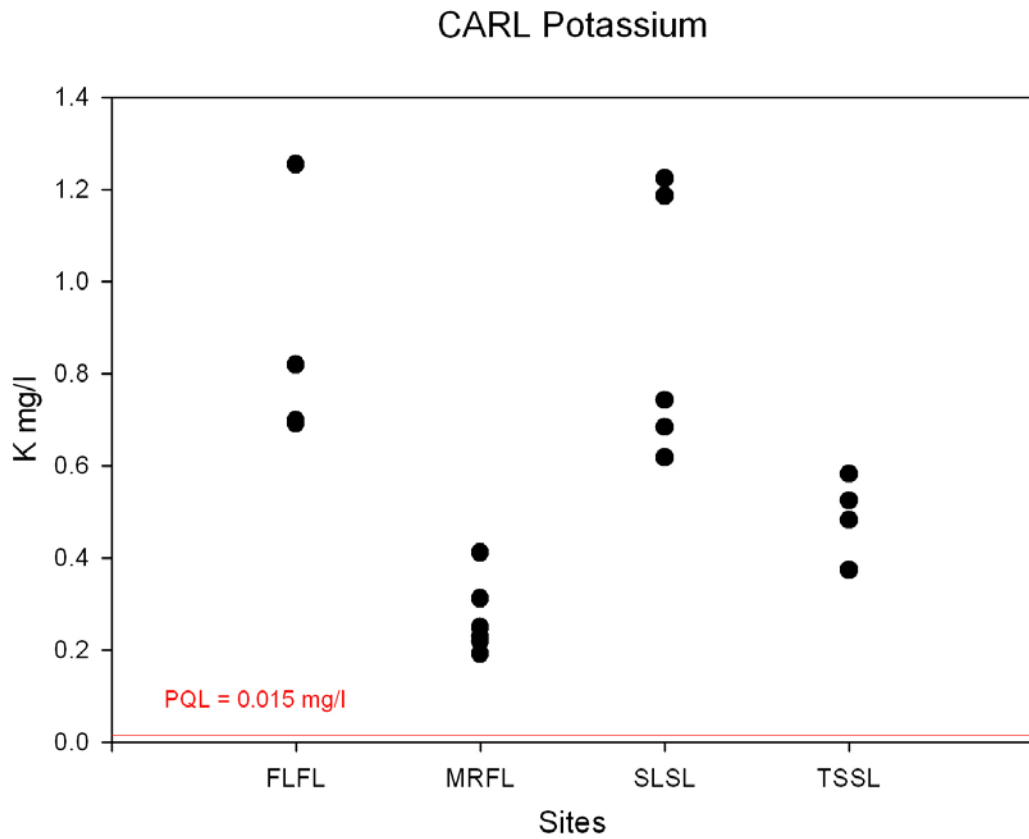
Ammonium

Ammonium levels at all sites are low. It should be noted that the laboratory did not perform ammonium analysis by an approved method. General ammonium reproducibility from the lab is considered unacceptable, and these data are presented in this light and not for management actions or decisions. As dissolved oxygen levels indicate well-aerated stream conditions, there is no reason to believe ammonium values to be of any significant levels – even at MRFL and FLFL where DO readings were sometimes depressed.



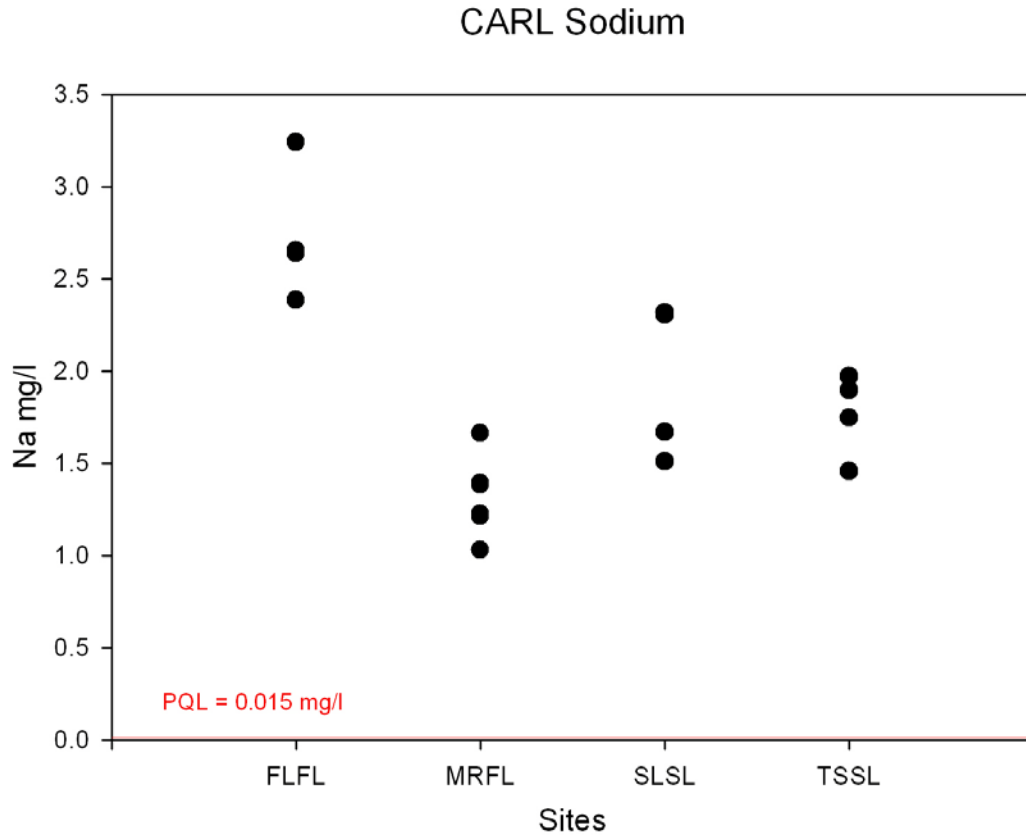
Potassium

Potassium levels of waters monitored at CARL are consistently low. There are no potassium standards for WS-II or HQW designated uses.



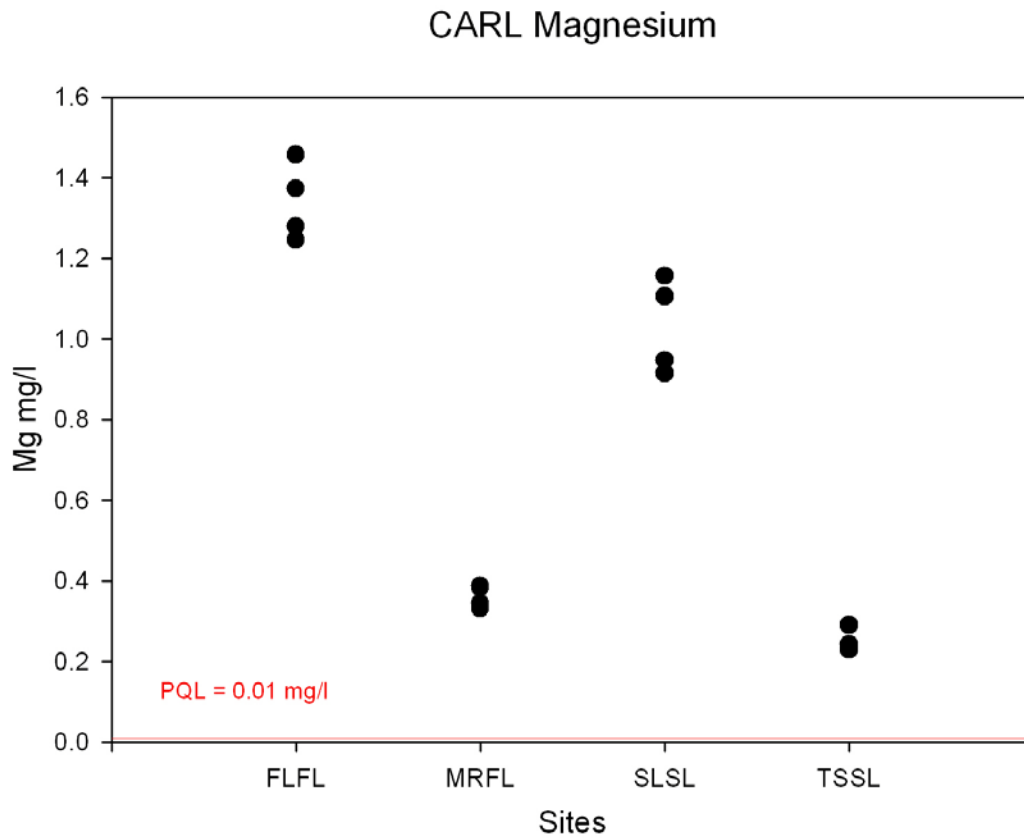
Sodium

The occurrence of sodium approximates 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 CARL, and there is no sodium standard for WS-II or HQW waters.



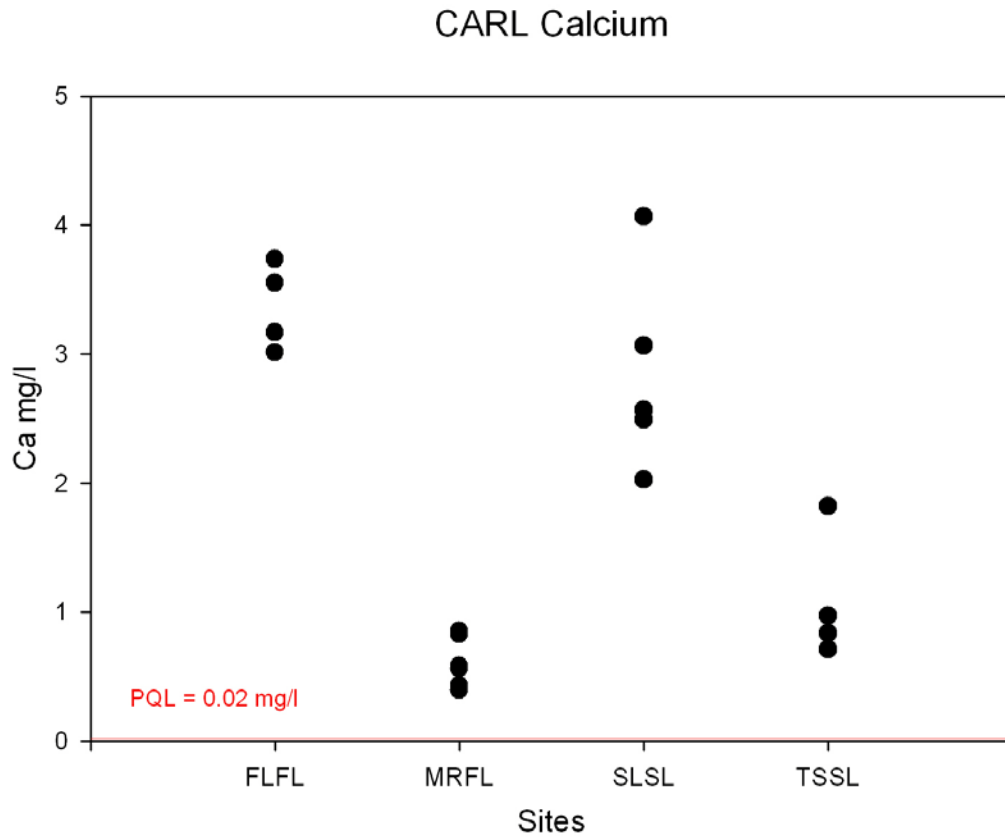
Magnesium

Magnesium levels at CARL are very low and common to granitic watersheds. There are no magnesium standards for WS-II or HQW waters.



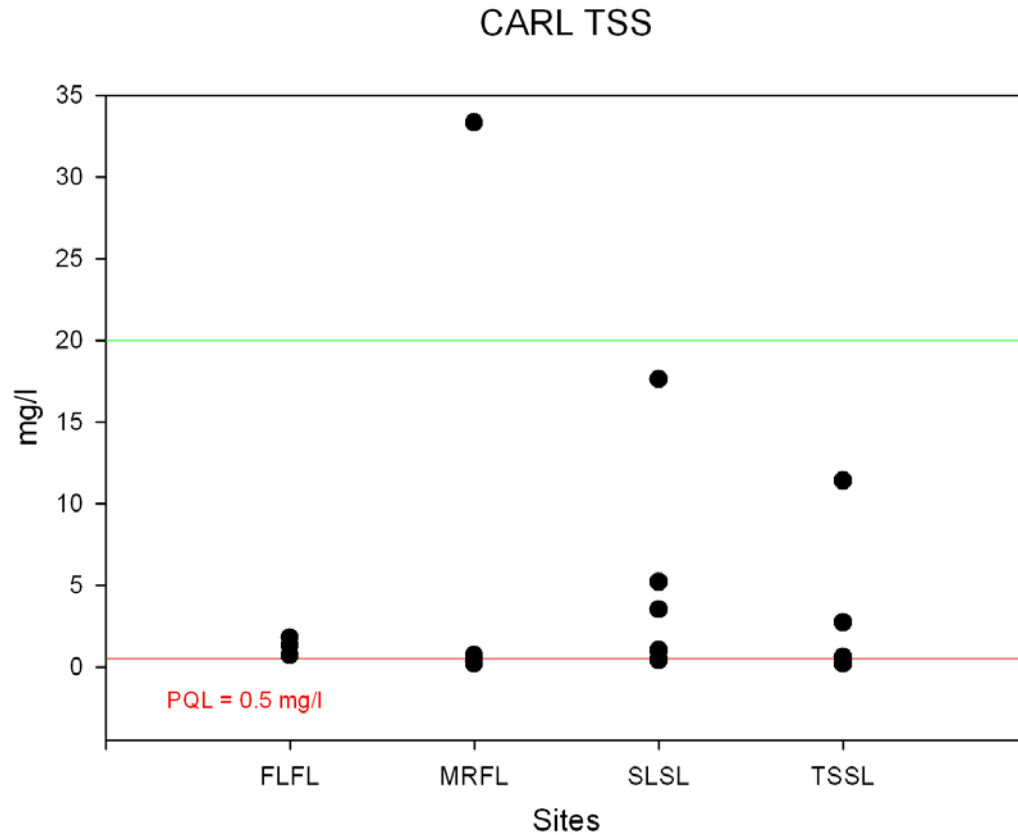
Calcium

Relative concentrations of the calcium ion generally mirror that of magnesium, and are quite low. Both divalent cations, calcium and magnesium are often found replacing one another in mineral crystalline matrices. There is no state standard for calcium.



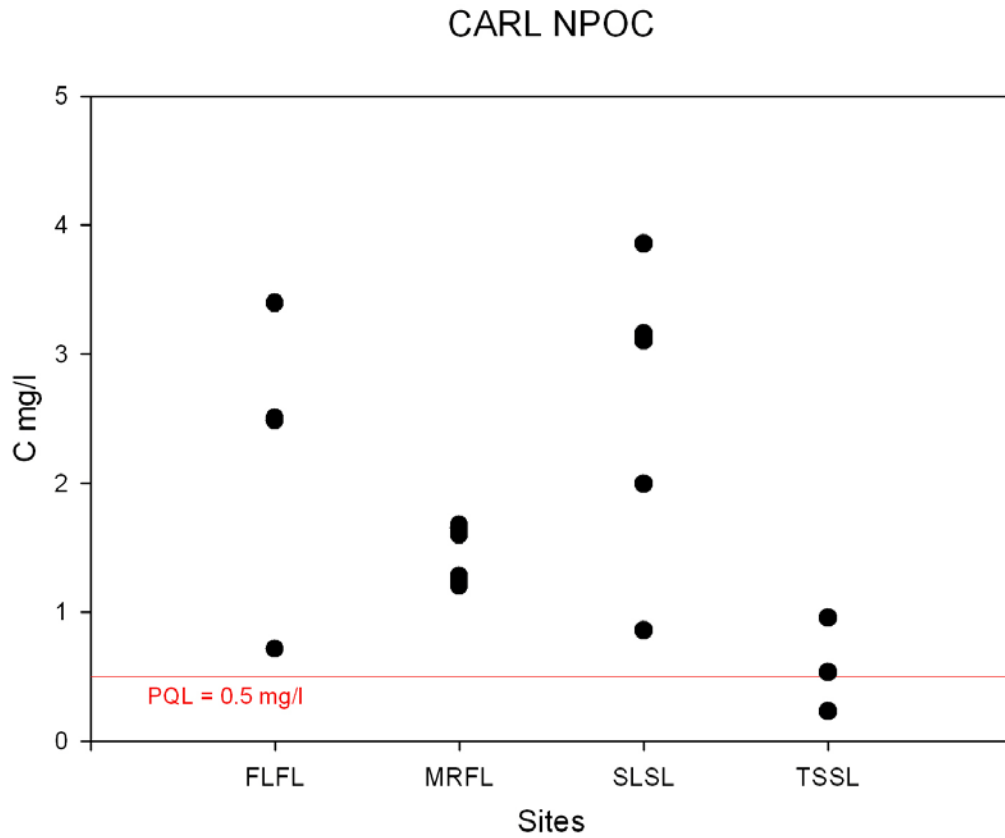
Total Suspended Solids

The laboratory reproducibility for suspended solids was not very good. The lab also reduced solids data into two subsets, fixed and volatile solids. Results are not worth presenting here. While the state standard for TSS is 20 mg/l, the data are of such questionable quality that it should not cause alarm.



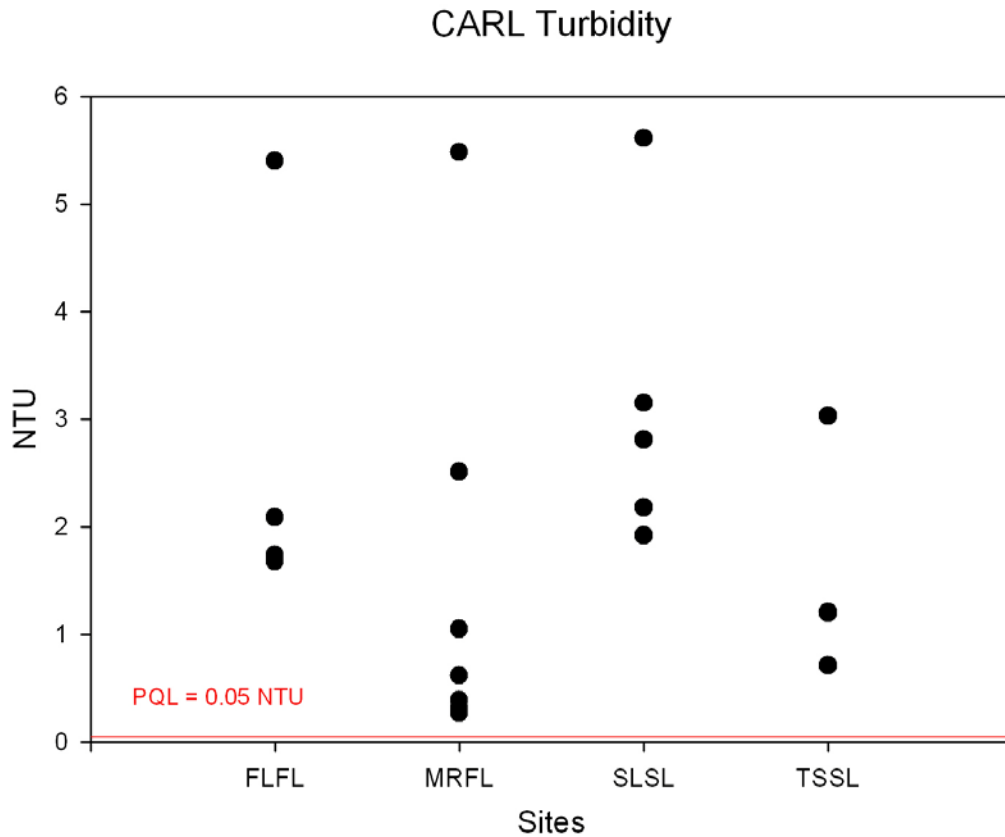
Total Organic Carbon

Total organic carbon, or in the case of most natural waters, non-purgeable organic carbon, is moderate in the waters of CARL. There is no standard for TOC in either designated use category.



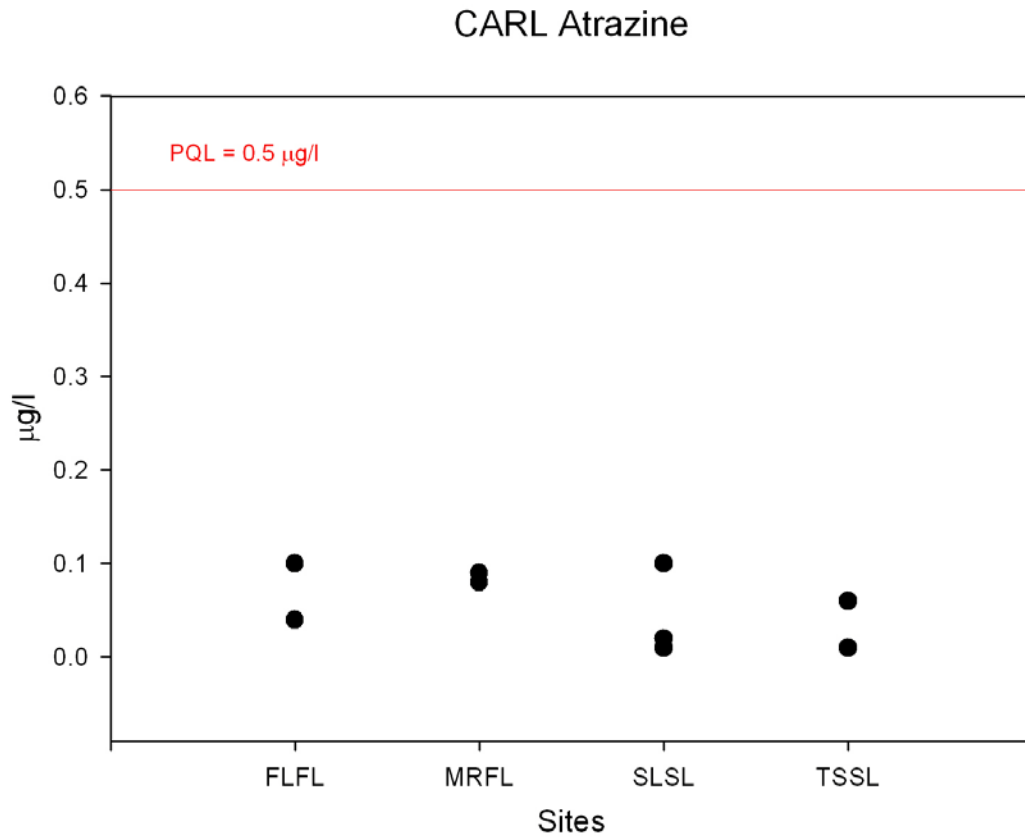
Turbidity

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. Waters of CARL are exceptionally clear. This is due to a limited amount of sediments being washed into park waters. Turbidity limits in both designated use categories is 50 NTU.



Atrazine

All atrazine samples were well below the PQL of 0.5 µg/l. There is no state standards for atrazine in the designated use categories. Some studies have seen a hermaphrodization of amphibians at concentrations of one part per billion. A national drinking water standard of 3.0 µg/l can be used as a general comparison to what was found at CARL.



General Water Quality Status

The water quality of the four sites sampled at CARL is very good. Without a doubt it is the highest quality water found in the CUPN. During the course of the water quality inventory, Shepard McAninch took a sample was taken in the Front Lake near where an old boat landing existed. The sample was taken as an oily scum appeared on the water – the same product was found oozing from the soils adjacent to the lake. Tests were not conclusive. There are two likely possibilities. First, if the scum is actually an oil, there may be buried hydrocarbons in the soils at this location. Second, if the iridescent scum is of bacterial origin (several iron-reducing bacteria produce a similar scum) it is possible that old pieces of iron are buried at this location. In either case, with archeological compliance, the site should be dug and the cause determined, if the park is interested.

Shepard also observed an oily sheen being delivered from the parking lot runoff into Front Lake on at least one occasion. If the park wishes to greatly reduce parking lot runoff, a filtration system should be installed. Prior to taking such measures first-flush runoff samples should be taken, with park assistance, where the culvert empties into the lake. With approval of the CUPN – as sample analysis will cost a few dollars, perhaps in the range of \$200 to \$400, a runoff event after at least two weeks on no precipitation during the peak visitation period (to determine maximum contamination) could be sampled and analyzed for oil/grease and total petroleum hydrocarbons.

The park has expressed concerns regarding animal waste (dog) into Front Lake. At nominal costs to the CUPN WQ Program, and with park assistance, samples could be taken from; the parking lot culvert, the Meminger Creek at the head of the lake, the usual sampling location near the dam, and any ephemeral flow into the lake. The samples would be kept on wet ice and transferred to the KIMO field station and plated within 24 hours of collection. This topical sampling could occur soon after the new bacterial protocols are in place, hopefully by the end of March 2005.

Future Water Quality Monitoring Recommendations

This inventory of water quality greatly reduces the number of parameters that need long-term monitoring for the Vital Signs program. Nitrite, bromide, and phosphate ions, and chlorophyll-a (only one sample for the latter was found to contain quantifiable levels) were also analyzed but all samples were found to be below detection limits. It is recommended that the core four field parameters should be continued for the long-term.

Long-Term Monitoring will include:

Water Temperature
Specific Conductivity
pH
Dissolved Oxygen
Acid Neutralizing Capacity

List of Abbreviations

ANC	Acid Neutralizing Capacity
Br	Bromide
C	Carbon
Ca	Calcium
CaCO ₃	Calcium carbonate
Cl	Chloride
DO	Dissolved Oxygen
Fl	Fluoride
K	Potassium
km	kilometer
l/s	liters per second
MDL	Minimum Detection Limit
Mg	Magnesium
mg/l	milligrams per liter
µg/l	micrograms per liter
NaCl	Sodium Chloride
NH ₄	Ammonium
NO ₃	Nitrate
NTU	Nephelometric Turbidity Unit
PQL	Practical Quantitation Limit
NPOC	Non-purgable Organic Carbon
RPD	Relative Percent Difference
SPC	Specific Conductance
SO ₄	Sulfate
SU	Standard Unit (pH)
TOC	Total Organic Carbon
TSS	Total Suspended Solids
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey