Annual Report for WaterWatch

December 19, 2009

Introduction and Summary

This report summarizes the activities and results of the cooperative efforts between the University of South Carolina (USC) and Lake Wateree's WaterWatch (WW) volunteer team between January and December 2009.

All twelve of the planned monthly routine sampling trips took place, thanks to the hard work of Dick Foote and the WW volunteers. With respect to South Carolina Department of Health and Environmental Control (SCDHEC) surface water quality criteria, high pH levels and high turbidities remain an issue.

> High pH's were measured (19% of all pH samples exceeded the SCDHEC criterion of pH=8.5), almost all pH exceedances occurred in the warm months. We continued to observe the highest pH's in Singleton and Taylor Creeks. The danger of high pH's is that it increases ammonia toxicity for aquatic creatures – the extent of how high pH's affect aquatic life over the summer is at this stage not well understood.
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> High turbidities have been another concern where 31% of surface turbidity samples (i.e., samples taken at 1 ft) exceeded the SCDHEC water quality criteria of 25 Nephelometric Turbidity Units (NTU). Most of the turbidity problems occur in the cooler months and are typically associated with rain events where sediments are washed into the lake from upstream. Turbidities in the Big Wateree Creek headwaters and embayment were consistently higher than all other creeks and embayments.

A number of special sampling events took place, most of which occurred over the summer. Various USC faculty and WW volunteers took part in sampling exercises that included deep water sampling, septage and bacteria checks and checks for diurnal (day-night) swings in water quality. In addition, Sara Powell, as part of her Master's thesis work, made numerous trips to the Big Wateree creek watershed to measure turbidities at a number of locations.

The WW/USC team was able to make progress in seven out of the ten possible action items laid out in USC's 2008 report to WaterWatch. This is remarkable as all of the non-routine work was conducted on a volunteer basis, or in Sara's case, as part of student field research.

Routine Sampling

During the year, we were able to sample every month; the result is that we made twelve routine sampling trips, sampling at 20 sites for temperature, dissolved oxygen (DO), pH, specific conductivity and turbidity (See Appendix 2 for an explanation of water quality parameters and their significance). We sampled at various depths (typically 1, 4, 7, 10, 20, 30 and bottom), depending on the depth of the sample site. The result is that we acquired some 861 datasets (or data records) which contained 4731 data points from across the lake.

During the middle of the year, we experienced some problems with the Eureka sonde, first with DO and later with pH readings. After two trips to the manufacturers, the sonde was restored to good order.

We must make mention of the tireless efforts of Dick Foote who has for the last 18 months, arranged the sampling trips. The WaterWatch boat acted up for several months during the middle of the year – again, Dick worked tirelessly to get the boat back up and running. The WW skippers also did a sterling job of nursing the WW boat through a few tricky situations. The WW members who were unselfish enough to loan their boats and their skippering services to WW played a significant part in making the routine sampling runs shorter. As a result, with two boats, we were able to avoid the day-long ordeals our predecessors endured between 1999 and 2003. The long-term effect on volunteer morale and ultimate sustainability of the sampling efforts cannot be underestimated. From the USC contingent, we would also like to comment on the hospitable and generous attitude the WW volunteers displayed – this attitude certainly contributed to our enjoyment of the trips.

Results from Routine Sampling

In this section, we will focus on the three parameters namely DO, pH and turbidity as these parameters are easily compared to fixed SCDHEC water quality criteria. This also serves as an annual summary which will complement our monthly sampling reports that deal with the same three parameters.

Dissolved Oxygen (DO)

On the whole, DO concentrations behaved as expected. They were high in the colder months with lower water temperatures and dropped in the warmer months as water temperatures increased. Of the 184 DO readings taken at the surface (1ft) in 2009, only five (5) readings, or about 2.7 % of all samples showed DO concentrations below SCDHEC's 5 mg/L criterion. All four of these readings occurred on the August 18th sampling run – these were in Singleton Creek headwaters (4.74 mg/L) and embayment (3.59 mg/L), White Oak Creek headwaters (4.87 mg/L), Beaver Creek embayment (3.69 mg/L) and Channel 4 (3.38 mg/L). A summary of the DO data is shown in Table 1. Given that DO concentrations were above 5mg/L elsewhere, these conditions would not have presented a great risk to fish as they would be able to migrate to zones where oxygen concentrations are higher. In addition, the lowest DO concentration (3.38 mg/L at Channel 4) is not considered anoxic (i.e., where aquatic creatures would not be able to breathe at all).

Table 1: Dissolved Oxygen concentrations (mg/L) for Lake Wateree are presented for each site as quartiles, i.e., Q1= first quartile, Q3 = third quartile and median is the same as the 50th percentile mark. The percentages in the "% <5mg/L" column are an indication of the frequency with which the samples in each site did not attain the SCDHEC criterion of 5 mg/L DO. The blue and red bars serve as a visual reference to the reader of the relative magnitude of the values. N is the number of samples acquired during 2009.

	N	Q1	Median	Q3	% < 5 mg/L
Beaver Cr headwater	11	7.1	7.6	8.4	0%
Big Wateree Cr headwater	11	6.7	8.3	10.1	0%
Colonel Cr headwater	12	7.1	8.1	10.6	0%
Dutchman Cr headwater	11	7.3	8.2	10.7	0%
June (Fox) Cr headwater	11	6.4	7.7	9.0	0%
Singletons Cr headwater	12	7.6	9.2	9.9	8%
Taylor Cr headwater	12	8.4	9.4	11.5	0%
White Oak Cr headwater	10	7.2	8.7	10.7	10%
Beaver Cr embayment	12	7.0	8.3	9.5	8%
Big Wateree Cr embayment	12	7.4	9.1	11.4	0%
Colonel Cr embayment	9	7.3	8.0	10.5	0%
Dutchman Cr embayment	10	7.3	8.9	10.0	0%
June (Fox) Cr embayment	12	7.1	8.7	10.6	0%
Singleton Cr embayment	10	7.2	8.9	10.5	10%
Taylor Cr embayment	11	7.8	8.5	9.8	0%
White Oak Cr embayment	12	7.4	8.1	9.7	0%
Channel 1	10	7.0	8.0	10.7	0%
Channel 2	12	7.3	8.4	9.8	0%
Channel 3	12	7.3	8.1	9.3	0%
Channel 4	12	7.2	8.6	10.3	8%

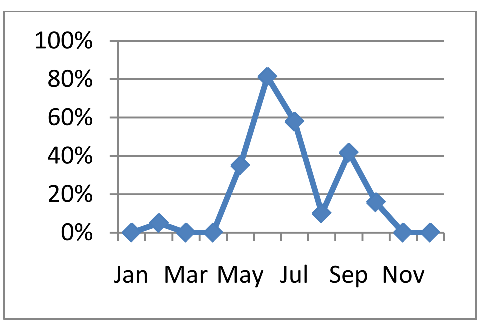
Results (cont'd) - pH

Of the 215 pH samples taken at the surface in 2009, 41 samples, or 19% of all pH samples exceeded the SCDHEC criterion of 8.5 pH units(Table 2). The pH exceedances occurred in the warmer months (Figure 1) – this is typical of the eutrophic nature of Lake Wateree. The majority of exceedances occurred in the embayments (Table 2). pH's in Singleton and Taylor Creek headwaters and embayments, reported in the 2008 annual report remained the highest for 2009 (Table 2). No pH levels fell below the SCDHEC criterion of 6.0 (which indicates acidic conditions). In December 2009 we did however observe the lowest pH levels we have since July 2008 – presumably these lower pH's (lowest pH was 6.27) were a result of the rains that fell just prior to the sampling event.

Table 2: pH levels for Lake Wateree are presented for each site as quartiles, i.e., Q1= first quartile, Q3 = third quartile and median is the same as the 50th percentile mark. The percentages in the "% >8.5" column are an indication of the frequency with which the samples in each site exceeded the SCDHEC criterion of pH = 8.5. The orange and red bars serve as a visual reference to the reader of the relative magnitude of the values. N is the number of samples acquired during 2009.

Variable	N	Q1	Median	Q3	% > 8.5
Beaver Cr headwater	10	7.2	7.4	7.8	0%
Big Wateree Cr headwater	10	7.1	7.5	7.8	0%
Colonel Cr headwater	11	7.5	7.6	7.8	9%
Dutchman Cr headwater	10	7.3	7.4	7.8	0%
June (Fox) Cr headwater	10	6.9	7.3	7.6	0%
Singleton Cr headwater	11	7.4	7.6	8.5	27%
Taylor Cr headwater	11	7.5	8.3	8.9	45%
White Oak Cr headwater	9	7.1	7.3	7.5	11%
Beaver Cr embayment	11	7.3	8.0	8.4	18%
Big Wateree Cr embayment	12	7.2	7.5	8.7	33%
Colonel Cr embayment	10	7.4	7.7	8.0	10%
Dutchman Cr embayment	11	7.6	8.1	8.6	36%
June (Fox) Cr embayment	11	7.4	7.6	8.0	18%
Singleton Cr embayment	11	7.3	8.2	9.0	45%
Taylor Cr embayment	11	7.4	7.9	8.9	45%
White Oak Cr embayment	11	7.5	7.7	8.5	18%
Channel 1	12	7.4	7.5	7.7	8%
Channel 2	11	7.5	7.7	8.5	18%
Channel 3	11	7.5	7.7	8.5	18%
Channel 4	11	7.5	7.5	8.1	9%

Figure 1: Frequency of exceedance of pH criteria by month.



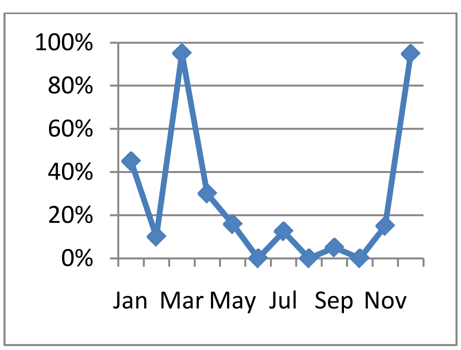
Results (cont'd) - Turbidity

Of the 199 turbidity samples taken at the surface in 2009, 62 samples (or about 31%) exceeded the SCDHEC water quality criteria of 25 NTU (Table 3); exceedances were also seasonal (Figure 2), but most occur in the cooler months where there is more runoff and where water temperatures are cooler. Figure 2 also shows that the March and December runs, both after significant rainfall events, accounted for 37 exceedances or 60% of all of the turbidity exceedances for the year. Big Wateree Creek continues to be the most turbid location (Table 3). Note that Channel 1, which is the most upstream sample site on the lake, is a good deal more turbid than Channels 2, 3 and 4 (Table 3); as such, Channel 1 is more a representative of the Catawba River than of Lake Wateree.

Table 3: Turbidities (NTU) for Lake Wateree are presented for each site as quartiles, i.e., Q1= first quartile, Q3 = third quartile and median is the same as the 50th percentile mark. The percentages in the "% >25 NTU" column are an indication of the frequency with which the samples in each site exceeded the SCDHEC criterion of 25 NTU. The brown and red bars serve as a visual reference to the reader of the relative magnitude of the values. N is the number of samples acquired during 2009.

Variable	N	Q1	Median	Q3	%>25 NTU
Beaver Cr headwater	11	10	17	23	9%
Big Wateree Cr headwater	11	23	34	75	64%
Colonel Cr headwater	12	11	15	21	17%
Dutchman Cr headwater	11	17	27	41	55%
June (Fox) Cr headwater	11	14	20	31	45%
Singleton Cr headwater	12	9	15	28	25%
Taylor Cr headwater	12	8	16	24	17%
White Oak Cr headwater	10	10	13	29	30%
Beaver Cr embayment	11	7	13	22	9%
Big Wateree Cr embayment	11	8	27	67	55%
Colonel Cr embayment	10	6	14	25	20%
Dutchman Cr embayment	11	8	16	25	27%
June (Fox) Cr embayment	12	9	16	24	17%
Singleton Cr embayment	11	6	16	26	27%
Taylor Cr embayment	10	10	18	25	20%
White Oak Cr embayment	11	7	13	31	36%
Channel 1	11	10	21	40	36%
Channel 2	11	3	11	25	18%
Channel 3	11	5	11	19	18%
Channel 4	11	4	12	18	18%

Figure 2: Frequency of exceedance of turbidity criteria by month.



Special Sampling Events

The majority of the special sampling occurred over the summer and these activities are reported in the September report. In summary however, the activities were as follows:

- Dan Tufford and a WaterWatch crew conducted a deep water sampling exercise - the results were encouraging and suggest that this method can be used to help us better understand lake eutrophication and lake management implications.
- Sara Powell made nine trips to the Big and Little Wateree Creek watersheds (before they enter the lake) to measure turbidity. The analysis is clear that on the Big Wateree Creek, turbidities upstream of a privately owned recreational area are consistently lower than turbidities downstream of the area. More work will need to be done to establish whether this recreational area is indeed fact the cause of higher turbidities.
- Buz Kloot and Gary Faulkenberry made several trips to the lake over the summer and established that DO concentrations did not drop to below critical levels in the lake in the very early (still dark) part of the morning as originally thought. Buz and Gary also tested for the presence of optical brighteners (an indicator of leaking sewage or septage) at 11 docks on Singleton Creek, but there were no positives. *Escherichia Coli* (*E. coli*) bacterial concentrations at the same 11 docks on Singleton Creek also tested extremely low (<10 *E. coli*/100mL). These results were encouraging in the sense that there were no obvious signs of leaking septic systems in the embayment.
- Three bacterial (*E. Coli)* samples were taken in September around a house boat moored in a cove on the lake's east shore, opposite the state recreational park. Once again, *E. coli* concentrations were extremely low (<10 *E. coli*/100mL), suggesting no recent discharge of raw sewage from the house boat.

Sara Powell Master's Thesis

Sara Powell completed the requirements for her Masters Degree in Environmental Health Sciences at USC's Norman Arnold School of Public Health. Sara's thesis was entitled "*Lake Wateree – getting out of the lake and into the Watershed: a Study of Volunteer Monitoring Efforts, water Quality and Community Outreach*." Sara successfully defended her thesis on December 4th of this year. An electronic copy of the thesis can be made available.

Progress Against "Possible Future Actions" Table in the 2008 Report to WW

In the 2008 *Report on Lake Wateree Sampling and Historic Water Quality – a Cooperative Exercise between Water Watch and USC*, we produced a table (Table 6, pp 29-30) that listed ten questions on lake water quality and suggested possible actions (See Appendix 1 for the questions and possible actions). We were surprised that over the last year, some kind of action has been taken on seven of the ten questions. None of the questions could be considered fully answered (Appendix 1), but given that the efforts to answer these questions stemmed from volunteer action and student thesis work, the individuals from WaterWatch and USC deserve credit for their teamwork and dedication.

Electronic Data and Information

In the last 18 months, USC has amassed a good deal of electronic information. The information includes the following:

1. MSAccess® relational database with all sampling data dating back to May 18, 1999. In all, some 3187 records of data (each record represents a sampling set containing data that include date, depth temperature, DO, pH, turbidity and conductivity) are now stored.
2. Spatial data of Lake Wateree, its surroundings and locations of the sample sites.

3. Historic water quality data (e.g., pH, Turbidity, DO, Phosphorus as P, Nitrates and Nitrites as N, Total Kjeldahl Nitrogen, Total Nitrogen, fecal colifrom and Chlorophyll-a), acquired from SCDHEC – these data (earliest data are from 1992) include data from the lake sample sites as well as the upstream sites.
4. Raw data from sample runs.
5. Reports of sample runs.
6. Quarterly and annual reports to WW.
7. Methods and protocols for data acquisition and sonde calibration.

This information will be handed over to Dan Tufford as the new project PI and we will make three CD for WW's archives and records.

Conclusion

Clearly, there is much work to be done in the future, but on the other hand, we should be proud of what the coalition has achieved in the last 18 months. On a personal note, I will miss the group, but I do look forward to seeing the progress WW and USC make in 2010.

Buz Kloot

Project Principal Investigator

Appendix 1: Some columns in the "Possible Future Actions" table in the 2008 Report (pp 29-30) and a comment on actions taken.

Question	Possible Action	Action?
What is the effect of significant storms on bacterial concentrations on Lake Wateree?	Add to current fair-weather baseline *E. coli* data and target samples specifically to coincide with and after significant storm events.	*E. coli* test reagents acquired, no samples taken.
What are the latest sample values for nutrients, chlorophyll a, fecal coliform and other parameters taken by SCDHEC in lake Wateree and key upstream stations?	Target, in conjunction with the SCDHEC watershed manager, a number of stations that SCDHEC samples on a continuous basis and set up regular Freedom of Information Act (FOIA) request to expedite data from SCDHEC. The FIOA request ought to speed up the time-consuming QA/QC process at SCDHEC to provide data that may be 2-3 months old.	Data up to April were acquired and given the WW, but no further action was taken.
What are the relative sizes of the point source nutrients reporting to upstream locations that feed into Lake Wateree?	Based on SCDHEC permit information, we know where the point sources are. NPDES permit holders need to complete monthly discharge reports (MDR's) for flow and water quality parameters that may include nutrients, biological oxygen demand and other contaminants (e.g., bacteria). A first step is to inventory all point sources upstream of the lake through the FIOA procedure where the MDR's for each upstream point source is requested.	None
Why do TN, and especially nitrate and nitrite concentrations appear to be increasing upstream of Lake Wateree and also in the lake's headwaters?	Some of the information will be related to loads from point sources (item above) but may need to extend to look at the influence of flow and modeling.	None
How does water quality on Lake Wateree vary over a 24-hour period? What other variables will affect how much water quality varies by day (e.g., no. of daylight hours? temperature? rainfall history?)	This will require some design (e.g. Where, at what depths, what times, what month/season do we measure?), and then people to monitor and record data over the given 24 hour period(s).	This was partially but not fully answered in the summer as Buz and Gary sampled in Singleton Creek. Of the samples taken in the very early morning, none indicated DO concentrations below 5 mg/L.
In 2008, why did we observe an *increase* in DO in the headwaters	The real answer may be somewhat difficult to uncover, but we do want to be sure that this is not an instrumentation error. The YSI sonde has been	None

Question	**Possible Action**	**Action?**
and a *decrease* in DO in the embayments?	measuring the headwaters while the Eureka sonde has been measuring the embayments. First order of business is to make sure that there are no biases in the instruments (is YSI over reading? Is Eureka under reading?) .	
What are the causes of the recent high pH's on the Singleton's and Taylor's Creek headwaters?	This could be initially be investigated by Water Watch members in asking questions of local people "what has changed in these two catchments?" Are there new buildings, plants? Farms that may contribute to the pH increase? The actual bounds of the relevant catchments can be determined by USC. A trip up the stream, possibly sampling the stream at various points and a windshield survey of some of the upstream features, especially new homes, businesses, farms, may be especially useful.	Tests for septage and increased bacteria (as a sign of increased nutrient loads to the embayment) were negative.
Why is the Big Wateree Creek consistently more turbid than the other creeks coming into Lake Wateree?	A trip up the stream, possibly sampling the stream at various points and a windshield survey of some of the upstream features, especially new homes, businesses, farms/pastures, may be especially useful.	This is discussed in Sara Powell's thesis.
What influences change in water quality at different depths on Lake Wateree? Are these changes in water quality something we need to be concerned about?	This is a complex issue that would require a good deal of time. The dataset, however is a treasure trove and could be an attractive subject for a talented graduate student and could provide valuable data to populate a lake water quality model.	Partially addressed by Dan's deep water sampling.
What is happening to water quality below 30ft and what is happening at the water-sediment interface?	This is a subject under discussion between Dan Tufford and Dick Foote.	Dan's deep water sampling.

Appendix 2: Water Quality Parameter Descriptions

Water quality field parameters

The water quality parameters that can be collected with a sonde are commonly known as "water quality field parameters" (also field water quality parameters) and include the following:

Water Temperature

This is a key parameter because it influences many other physical, chemical and biological activities in the water. Often summer heat can cause fish kills in ponds because high temperatures reduce available oxygen in the water. Water temperature in Lake Wateree is highly seasonal with summer temperatures averaging in the 80's and winter temperatures in the 40's.

Dissolved oxygen (DO)

This is a basic requirement for a healthy aquatic ecosystem. Most fish and beneficial aquatic insects "breathe" oxygen dissolved in the water column - most desirable fish species suffer if DO concentrations fall below 3 to 4 mg/l[1]. Prolonged episodes of depressed DO of 2 mg/l or less can result in "dead" waterbodies. Low DO also favors anaerobic bacterial activity that produces noxious gases or foul odors often associated with polluted water. Oxygen concentrations in the water column fluctuate under natural conditions, but severe oxygen depletion usually results from human activities that introduce large quantities of biodegradable organic materials into surface waters. Biodegradable organic materials contain decomposing plant and/or animal matter. Leaves, lawn clippings, sewage, manure, shellfish processing waste, milk solids, and other food processing wastes are examples of oxygen-depleting organic materials that enter our surface waters. DO is also seasonal (is highly dependent on temperature) and average summer DO concentrations in Lake Wateree can be as low as 4 mg/L while winter DO's may be as high as 14 mg/L.

The SCDHEC water quality criteria for DO are as follows:

- No *single sample* may be below **4** mg/L
- *Daily average* samples may not be below **5** mg/L.

Specific Conductivity (or Specific Conductance)

The ability of the water to conduct electricity is directly proportional to the water temperature and the concentration of dissolved ions in the water. Inorganic salts tend to ionize in solution. The main inorganic cations in most fresh and salt waters are sodium (Na^{+}), potassium (K^{+}), calcium (Ca^{+2}) and magnesium (Mg^{+2}); the major dissolved anions are carbonates (CO_3^{-2}), bicarbonates (HCO_3^{-1}), chlorides (Cl^{-1}), sulfates (SO_4^{-2}). Nitrates (NO_3^{-2}) may also contribute to the total anions in freshwater. Specific conductivity is dependent on factors like geology (and soils), catchment size (the larger the catchment, generally the higher the conductivity), urban and agricultural runoff, point source discharges, and evaporation rates.

pH

The potency of Hydrogen (or pH; also known as potential of Hydrogen) is an important variable in the biological and chemical functions in natural waters that include the following:

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[1] Larvae and juvenile fish are more sensitive and require even higher concentrations of DO.

- pH controls the dissociation of many compounds which can be toxic in less dissociated forms (HCN and H_2S) at lower pH.
- pH controls microbial transformations of mercury in natural waters; low pH favors the formation of methyl mercury, which is bioavailable and tends to bioaccumulate through the food web.
- pH controls the solubility of metals in sediments; lower pH increases solubility and the release of metals to the water.
- pH controls the equilibrium between un-ionized and ionized forms of ammonia (NH_3 vs. NH_4^+); high pH (> 9) favors the formation of NH_3, which is highly toxic.

The SCDHEC water quality criteria for pH are as follows:

- Samples should not exceed pH = **8.5** (alkaline) or be below pH=**6.5** (acidic).

Turbidity

This parameter is directly related to optical properties of the water. Standard measures of turbidity quantifies the amount of light scattered or absorbed by the particulate matter in the water and are often expressed as Nephelometric Turbidity Units (NTUs). Distilled water should have a NTU=0 and natural waters typically vary between 5-50 NTUs. Highly turbid natural waters (as in streams during storm water runoff) may measure in the hundreds of NTUs. Elevated turbidities have a negative impact on the flora and fauna of aquatic communities due to:

- Reduction in light penetration, which interferes with photosynthesis of planktonic and submerged rooted aquatic vegetation.
- interference with respiration of fish and other aquatic organisms (gill abrasion), and
- excessive sedimentation over benthic (River and Lake bottom) habitats

The SCDHEC water quality criteria for pH are as follows:

- Samples should not exceed **25** NTU in Lakes and **50** NTU in streams.