The Impact of Flooding on Water Quality in the Waccamaw River

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Introduction

The Waccamaw River is a black water river located in the coastal plain of northern South Carolina and southern North Carolina (Figure 1). The river water's dark color reflects high concentrations of humic materials produced by the decomposition of organic matter derived from terrestrial plants. Black water rivers typically contain a vast expanse of swamps and are characterized by slow water flow, high levels of dissolved organic matter and low levels of dissolved oxygen. The latter is caused by aerobic respiration of dissolved organic matter by native microbes. Dissolved oxygen (DO) levels, pH and alkalinity are low throughout the Waccamaw River. As a result, the South Carolina Department of Health and Environmental Control (SC DHEC) has set a special minimum DO limit of 4 ppm that applies only to the Waccamaw River. Nevertheless, DO levels frequently fall below these limits during summer and flood events.

Variations in river stage and discharge are driven by seasonal differences in rainfall. The average annual rainfall is approximately 50 inches. Rainfall is lowest in the summer and highest in the winter. Deviations from this general trend are caused by flood events usually associated with hurricanes during late summer and fall. As shown in Figure 2, during the sampling period, discharges were highest as a result of Hurricanes Bonnie, Dennis, Harvey, Floyd and Irene as well as a stationary cyclonic storm which occurred in April 1999. Rain during the winters of 1998 and 1999 was copious enough to also cause sustained periods of flooding.

The Waccamaw River is located in a watershed currently under intense development due to the rapid growth occurring in Horry and Georgetown Counties. Stormwater runoff draining developed areas could have significant effects on water quality in the river. To test this hypothesis, we are conducting several studies on the Waccamaw River. The results presented herein are based on samples collected on alternating days since September 1998 at one site located north of Conway. Also included are some results obtained by synpotically sampling the river and its adjacent tributary creeks from the NC-SC state line to Bucksport, SC at conditions of low and high flow. Also presented are results of bacterial contamination measurements collected from tributary creeks draining the city of Conway and environs as part of an ongoing U.S. EPA funded 319 Program project entitled "Identification and Mitigation of Non-Point Sources of Fecal Coliform Bacteria and Low Dissolved Oxygen in Kingston Lake and Crabtree Creek (Waccamaw River Watershed)". More information about this project is available at: **http://www.coastal.edu/science/eql/319/index.html.**

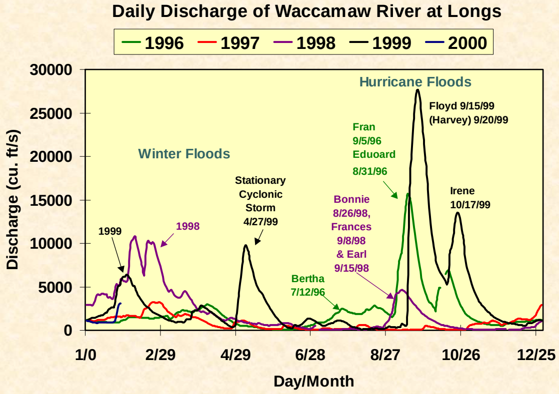


Figure 2. Discharge at USGS Gauging Station located at Longs, SC in the Waccamaw River.

Figure 1. South Carolina Portion of Waccamaw River and Pee Dee Watershed

Methods

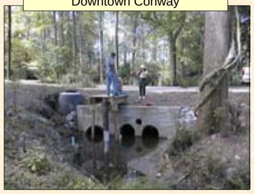
Grab samples of surface water were collected from Murrells Landing, which is located 4 miles north of the city of Conway, on alternating days from September 1998 to present. As shown in Figure 3, daily sampling was done during flood events. The following analytes were measured in the lab using U.S. EPA methods: true color, pH, alkalinity, turbidity, and chlorophyll. A Scout 2 Hydrolab was used to make in-situ measurements of temperature, conductivity and dissolved oxygen. The Hydrolab also generates values of % saturation of dissolved oxygen.

Grab samples of surface water were similarly collected at the heads of 19 tributary creeks during three dates selected to represent average high flow, low flow and flooding conditions. Also collected were samples from the river spaced equidistantly between the NC-SC state line and Bucksport. These were analyzed as above. Elemental analyses of the major ions were also performed. A Hydrolab was used to make in-situ measurements as described above.

Grabs samples of surface water are also being collected on alternating weeks from three tributary creeks and the Waccamaw River adjacent to the City of Conway in conjunction with an ongoing U.S. EPA 319 Program Project. The following analytes are being measured in the lab using U.S. EPA methods: fecal coliform, Enterococcus, nitrate, nitrite, phosphate, ammonium, BOD_5, true color, pH, alkalinity, total dissolved solids, turbidity, and chlorophyll. A Hydrolab is also being used to make in-situ measurements.

Flooding at Conway Marina from Hurricane Floyd

U.S. EPA 319 Program Project Stormwater Sampling Site in Downtown Conway



Water Sampling

Acknowledgements

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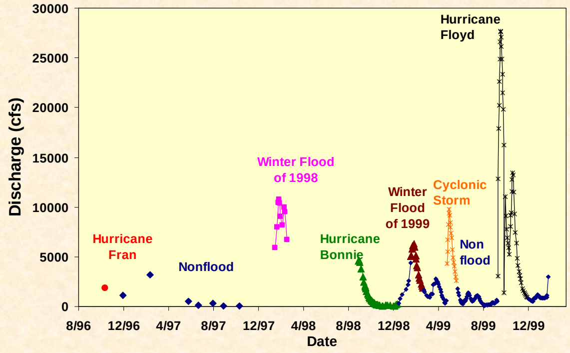


Figure 3. Discharge at USGS Gauging Station located at Longs, SC in the Waccamaw River on Sampling Dates.

RESULTS

Figure 4.

Temporal Variation in Turbidity at Murrells Landing

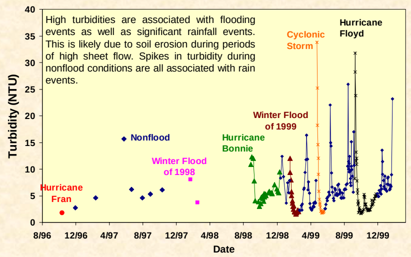


Figure 5.

Temporal Variation in Color at Murrells Landing

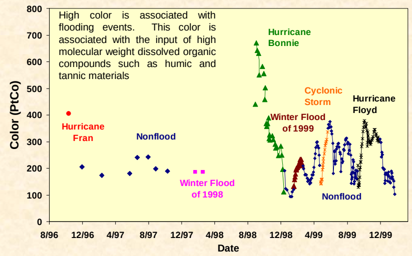
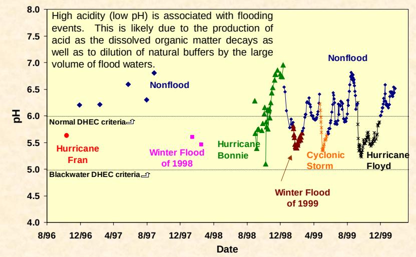


Figure 6.

Temporal Variation in pH at Murrells Landing



Dissolved Oxygen

As shown in Figure 7, low dissolved oxygen levels are characteristic of summer conditions as well as flood events. These levels frequently drop below special criteria established by S.C. DHEC for blackwater rivers. During the summer, dissolved oxygen levels are influenced by the effect of temperature, as this gas is less soluble at higher temperatures. To eliminate this influence, the dissolved oxygen concentrations are also reported as % saturations. The % saturation of dissolved oxygen is defined as the percentage of dissolved oxygen that is present relative to the amount which should be in the water if equilibrium with the atmospheric oxygen reservoir had been attained at the in-situ temperature. Values less than 100% represent a net deficiency in dissolved oxygen.

The waters in the Waccamaw River are always deficient in dissolved oxygen relative to the atmosphere (Figure 8). Even during the winter, the surface waters never exceed 80% saturation. This suggests the presence of a very large and persistent dissolved oxygen sink. This sink is likely associated with the microbially mediated decomposition of dissolved organic matter. Hence, as shown in Figure 10, high loads of dissolved organic matter (as represented by color) are associated with low % saturations of dissolved oxygen. As flooding intensifies this effect, fresh organic matter appears to be delivered into the river during these events. This is likely the result of high winds which create new leaf litter by stripping trees as well as by inducing wind mixing. The latter can churn up swamp sediments and increase the leaching of dissolved organic matter from these particles.

As shown in Figure 9, the % saturation of dissolved oxygen is also inversely related to temperature. This is likely the result of enhanced microbial activity at higher temperatures as well as the occurrence of organic matter loading during warm weather, i.e. hurricane season. It is interesting to note that even during the winter, flooding is associated with marked oxygen deficiencies relative to non-flooding conditions during this time of year.

Figure 7.

Temporal Variation in Dissolved Oxygen at Murrells Landing

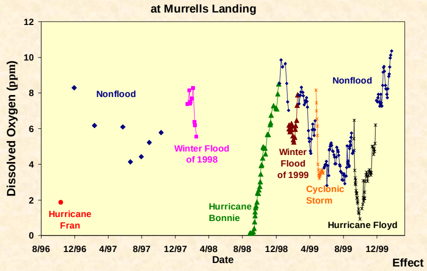


Figure 8.

Temporal Variation in % Saturation of Dissolved Oxygen at Murrells Landing

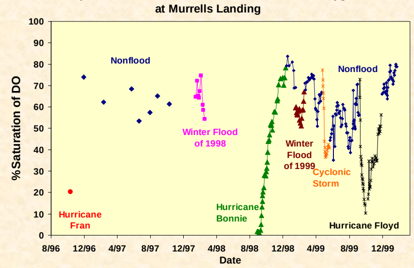


Figure 9.

Effect of Temperature on % Saturation of DO at Murrells Landing

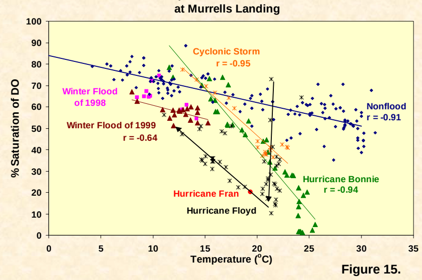


Figure 10.

Effect of Color on % Saturation of DO at Murrells Landing

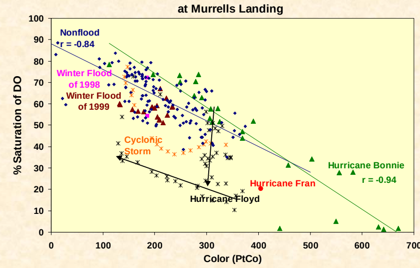


Figure 11.

Temporal Variation in Conductivity at Murrells Landing

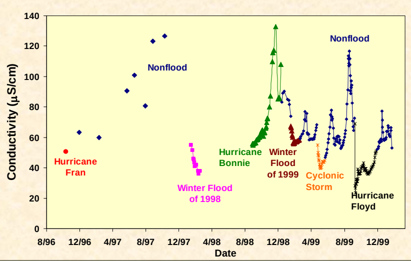


Figure 15.

Fecal Coliforms

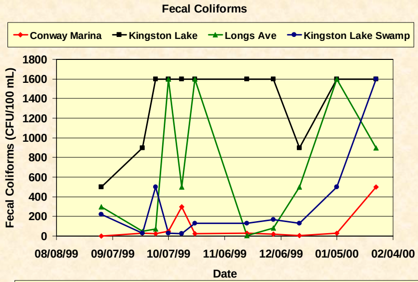


Figure 16.

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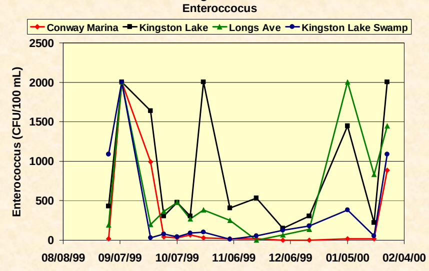


Conductivity

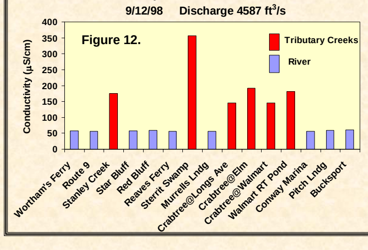
As shown in Figure 11, low conductivities are associated with flooding suggesting a dilution effect. During periods of low discharge, significant flood events are associated with high conductivities. During all levels of discharge, the tributary creeks along the Waccamaw River are sources of high conductivity water (with the exception of Tilly Swamp) (Figure 12, 13 and 14). This suggests that the impact of these creeks on the chemical composition of the river can be significant during times of low river flow. The elemental composition of the high conductivity water is consistent with a groundwater and/or sea salt source. The likely source of the groundwater are irrigation wells, especially those associated with golf courses. The seasalt is likely the result of atmospheric transport from the sea surface. While conductivity is not a pollutant, it appears to be a tracer of stormwater runoff via the River's tributaries. This suggests the potential for significant pollutant transport, such as of nutrients, heavy metals, pesticides and herbicides via these tributaries. Interestingly, these creeks are not sources of dissolved organic matter and have higher dissolved oxygen concentrations than the river. This suggests that the major sources of dissolved organic matter to the river are from adjacent swamps, transported by either sheet flow or shallow groundwater seeps. Current sampling efforts are directed at characterizing the chemical composition of these flows.

Bacterial Contamination

As shown in Figures 15 and 16, high levels of bacterial contamination are consistently observed in several tributaries draining the city of Conway and environs. Flooding associated with Hurricane Floyd (9/15/99) appears to have had a diluting effect, if any, probably because it was preceded by a lesser event (Hurricane Dennis on 8/29/99) and several very heavy rain events on 9/5/99 through 9/9/99. This likely flushed the land surfaces prior to Hurricane Floyd. Similar results were observed at other sites on the Waccamaw and the Pee Dee Rivers. Enteroccocus is being measured as an independent tracer of microbial contamination. We are also adapting a more specific tracer, multiple antibiotic resistance, to further ascertain sources of *E. coli* which we are also measuring. This technique enables discrimination of wildlife, livestock, and pet sources from humans.

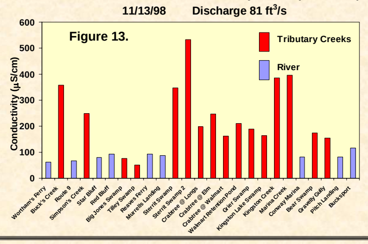
Geographic Variation in Conductivity in the Waccamaw River and Tributary Creeks after Hurricane Bonnie

9/12/98 Discharge 4587 ft^3/s



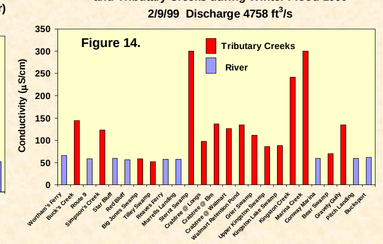
Geographic Variation in Conductivity in the Waccamaw River and Tributary Creeks (Low water)

11/13/98 Discharge 81 ft^3/s



Geographic Variation in Conductivity in the Waccamaw River and Tributary Creeks during Winter Flood 1999

2/9/99 Discharge 4758 ft^3/s



Conclusions

The following are observed impacts of flooding on the water quality of the Waccamaw River:

- Increased turbidity and color (dissolved organic matter)
- Decreased pH, alkalinity, dissolved oxygen and conductivity

Rain events which occur during periods of low discharge are associated with periods of high conductivity in the river. This is thought to reflect a significant contribution of tributary creek water to the total river flow. During these periods, transport of pollutants, such as nutrients, heavy metals, pesticides and herbicides, could result in high river water concentrations.

All rain events are associated with surges in turbidity suggesting particle loading as a result of soil erosion.

The Waccamaw River is always deficient in dissolved oxygen. The intensity of this deficiency is intensified by high temperatures as well as increased loading of dissolved organic matter. Flooding appears to bring a different type of dissolved organic matter into the river which has a high oxygen demand.

Flooding was not observed to cause sustained levels of bacterial contamination probably due to the dilution of sources by the large volume of water in the river as well as prior flushing.