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’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 eelgrass, and are characterized by low 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 salinity 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 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, 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, 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, ammonium, BOD 5, true color, pH, alkalinity, total dissolved solids, turbidity, and chlorophyll. A Scout 2 Hydrolab is also being used to measure temperature, conductivity and dissolved oxygen. The Hydrolab also generates values of % saturation of dissolved oxygen.

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: fecal coliform, Enterococcus, nitrate, ammonium, BOD 5, true color, pH, alkalinity, 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.

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RESULTS

Temporal Variation in Conductivity at Murrells Landing

As shown in Figure 11, high conductivities are associated with flooding events as well as significant isolated events. This is likely due to a dilution effect during periods of high street flow. Spikes in conductivity during non-flood conditions are associated with rain events. During low levels of discharge, the tributary creeks contribute high conductivities to the Waccamaw River. As shown in Figure 12, the tributary creeks discharge, significant flood events are associated with high conductivities. During all levels of discharge, the tributary creeks contribute high conductivities to the Waccamaw River. As shown in Figure 13, high conductivities are associated with flooding suggesting a dilution effect. During periods of low discharge, sampling efforts are directed at characterizing the chemical composition of these flows.

Temporal Variation in Color at Murrells Landing

As shown in Figure 14, low conductivities are associated with flooding suggesting a dilution effect. During periods of low discharge, the tributary creeks contribute high conductivities to the Waccamaw River. As shown in Figure 15, high conductivities are associated with flooding suggesting a dilution effect. During periods of low discharge, sampling efforts are directed at characterizing the chemical composition of these flows.

Temporal Variation in pH at Murrells Landing

As shown in Figure 16, low pH levels are associated with flooding suggesting a dilution effect. During periods of low discharge, the tributary creeks contribute high conductivities to the Waccamaw River. As shown in Figure 17, high conductivity water is consistent with a groundwater and/or sea salt source. This suggests that the impact of these creeks on the chemical composition of the river can be significant during times of low discharge. The elemental composition of the high conductivity water is consistent with a groundwater and/or sea salt source. This suggests that the impact of these creeks on the chemical composition of the river can be significant during times of low discharge.

Temporal Variation in Dissolved Oxygen at Murrells Landing

As shown in Figure 18, the dissolved oxygen levels are characteristic of summer conditions with very low dissolved oxygen levels. During all levels of discharge, the tributary creeks contribute high dissolved oxygen levels to the Waccamaw River. As shown in Figure 19, the % saturation of dissolved oxygen is also inversely related to temperature. This is likely due to the result of increased uptake of dissolved oxygen by the river during these events. It is likely that the result of high winds which create wave action and stirring trees as well as by inducing wind mixing. The latter can mix up nutrients and increase the mixing of dissolved organic matter from these particles. As shown in Figure 20, the % saturation of dissolved oxygen is inversely related to temperature. This is likely due to the result of increased uptake of dissolved oxygen by the river during these events. It is likely that the result of high winds which create wave action and stirring trees as well as by inducing wind mixing. The latter can mix up nutrients and increase the mixing of dissolved organic matter from these particles.

Temporal Variation of Nutrients in the Waccamaw River and Tributary Creeks during Winter Flood 1999

As shown in Figures 21 and 22, 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 in the month of August. Enterococcus is being measured as an independent tracer of microbial contamination. This is being used as a more specific tracer, more rapid than this, for surface water and stormwater treatment. This technique enables discrimination of water, wastewater, and precipitation from human.

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
- Storm events which occur during periods of low discharge are associated with higher bacterial counts in the river. This is thought to reflect a significant contribution of tributary creeks to the total flow. During these periods, transport of pollutants, such as nutrients, heavy metals, pesticides and herbicides, are also increased. The latter can result in higher river water quality concentrations.
- All rain events are associated with increased turbidity and color following precipitation as a result of rain.
- The Waccamaw River is slow andprofitable in dissolved oxygen. The intensity of this dilution is increased 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 increased 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.