EXECUTIVE SUMMARY
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RIVERNET: Continuous Monitoring of Water Quality in the Neuse River Basin

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Agricultural and urban land use has increased the fluxes of nutrients, sediments and different organic/inorganic chemicals into surface water and ground waters. As a consequence, many estuaries and wetlands are under various levels of environmental pressure as a result of diminished water quality (e.g., high nutrient concentrations, sediment loading, low levels of dissolved oxygen). The increased nitrogen flux to estuaries and coastal waters has affected water quality by enhancing phytoplankton blooms as part of the overall eutrophication process. This enhanced production modifies coastal food webs, reduces commercial species abundance, and in extreme cases produces zones of hypoxia and anoxia. The threat of agricultural chemicals to groundwater supplies has focused attention on the mobility of solutes such as nitrates and pesticides in shallow groundwater systems. Although extensive research has been done to understand nitrate contamination and attenuation processes in ground water, discharge rates of nitrate in streams are commonly not matched to different types of land use or to field application rates. To promote the long-term sustainability of natural and managed watersheds, fundamental processes that control water quality on a watershed scale must be investigated.

RiverNet is a study that addresses fundamental water quality processes on a watershed scale with new state-of-the-art technology. Remote water quality monitoring systems (Figure 1) have been developed

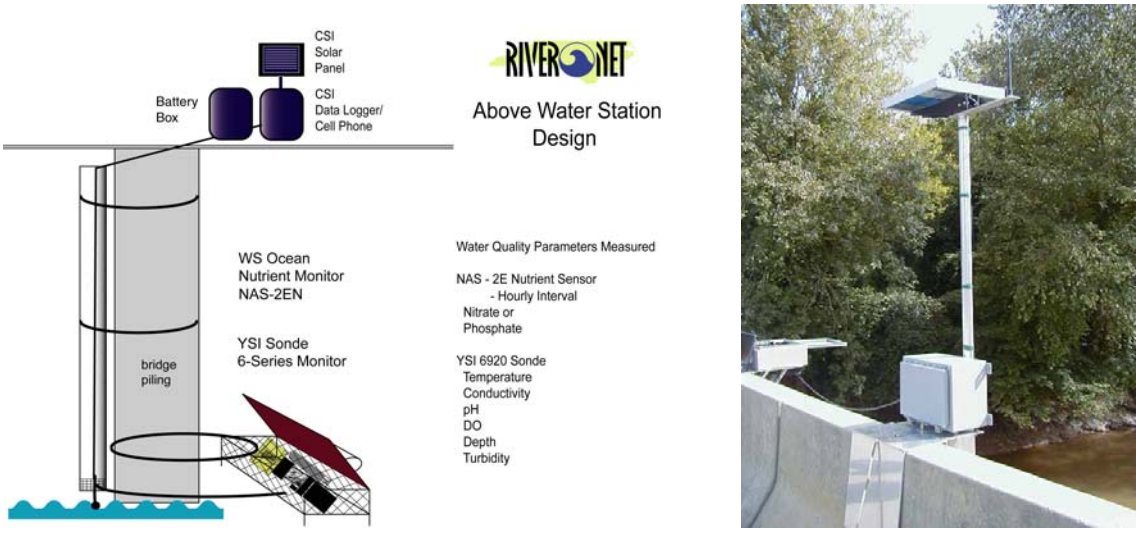

Figure 1. RiverNet automated continuous water quality monitoring station with solar panel. 10 water quality parameters are measured at 15 to 60 minute intervals, and the data is transmitted every 24 hours to NC State University (rivernet.ncsu.edu). These stations will collect and transmit water quality data during extreme events, such as hurricanes, when areas are inaccessible by normal means.

and have been installed at six locations in the Neuse River Basin (Figure 2). Monthly water samples for nutrient and isotopic analysis are collected at the RiverNet sites and at 22 other stations in the Neuse River Basin. RiverNet stations are designed so that water quality data can be monitored continuously in

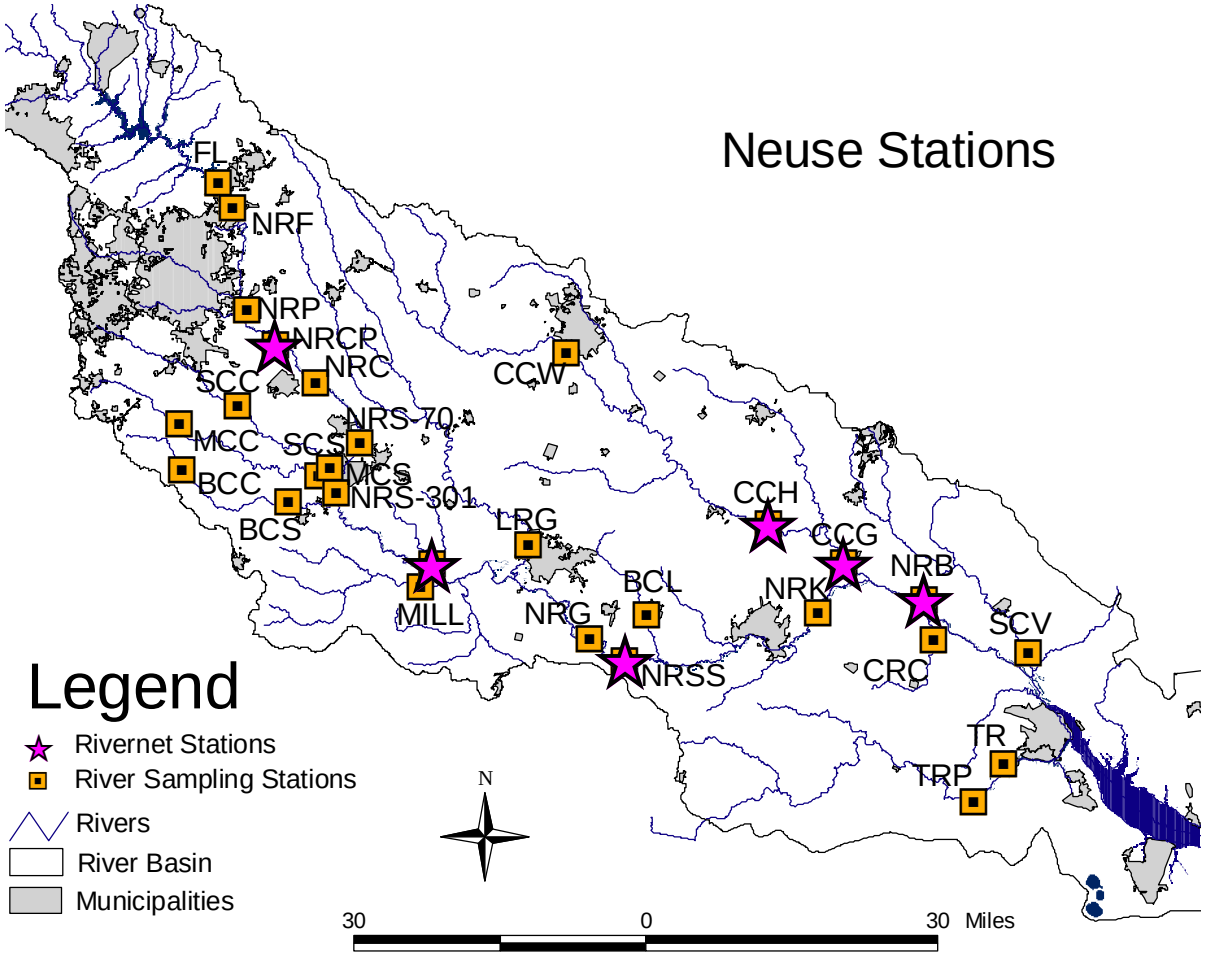

Figure 2. RiverNet Monitoring Stations (stars) are attached to highway bridges. Water quality data is transmitted to NCSU by cell phones and put on a web page for public access. Water quality and isotope measurements are also made at the river sampling stations.

real time during any unusual event. During normal operations, water quality data are downloaded via cell phones to NCSU every 24 hours where the data are organized, checked for measurement accuracy, and disseminated to the user and stakeholders groups via the RiverNet web site {**http://rivernet.ncsu.edu/**}. Through this web site, near real time access to water quality data are provided to state and national agencies, the research community, educators, co-operative groups, citizen environmental groups, and public policy makers.

Objectives: To provide better assessment of nutrient loading in the impaired waters of eastern North Carolina.

- Assessment of dissolved and particulate nutrient loading variability on different time scales.
- Assessment of dissolved and particulate nutrient loading variability during different discharge states.
- Assessment of variability of nutrient loading in areas of different land use, geology and hydrogeology.
- To provide better water quality data during crisis management and extreme storm events.
- To provide better estimates of the spatial and temporal variations in nutrient flux that contribute to the impairment of water quality
- To assess the role of groundwater in surface water quality through high resolution time-series monitoring

RiverNet: Results

Initial results of the RiverNet program indicated that the nitrate and sediment concentrations in the Neuse mainstem change rapidly with and without stage changes. Documentation of the high frequency concentration and flux changes is possible because of the innovative design of the RiverNet stations. Isotopic monitoring of riverine nitrogen using ^{15}N indicates that the non-point nutrient sources have changed over the past decade. These changes are related to groundwater-surface water interactions and the hydrologic links between nitrogen intensive land use (cultivated and waste application fields) and river channels.

The RiverNet stations have been operated over the past year in low flow conditions. Under these conditions the stage/nitrate concentration profiles change for stations located in different geological formations (Figure 3). The stage/nitrate relationship is steep in the upper basin indicating that upper aquifer ground waters contaminated with nitrate are being discharged into the streams with rainfall events. The stage/nitrate relationship at Seven Springs in the central basin Black Creek formation aquitard is flat, indicating little groundwater enters the river in this area. In the lower portion of the basin the stage/nitrate relationship are invariant indicating that deep aquifers that are depleted in nitrogen are discharging into the river. Nutrient concentrations in general are low in the upper parts of the basin, highest in the central portion of the basin and then decrease in the lower portion of the basin. It is important from a nutrient management perspective to understand what are the fundamental process controlling nutrient concentrations. The decreased concentrations in the lower basin could result from denitrification and in-

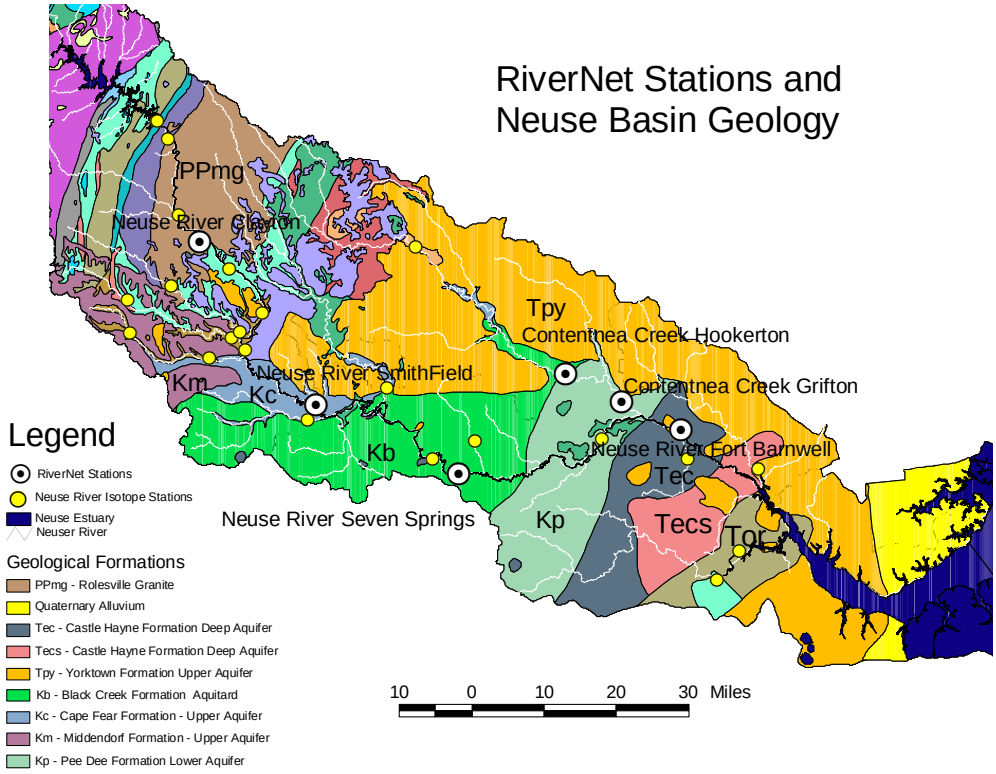

Figure 3. Geological map of the Neuse Basin with the RiverNet station locations. The upper basin is composed of crystalline basement rocks, the central portion of the basin has an aquitard (Black Creek formation –green) and an surficial aquifer (Yorktown formation – orange), and the lower basin has several deep aquifers (Pee Dee – light green and Castle Hayne – grey & pink). RiverNet Stations were placed in different geological formations.

stream consumption, or from the dilution of surface waters from deep aquifer ground waters with low nitrate concentrations.

We have used two innovative new isotope tracer techniques to investigate the cause of down stream concentration changes. Analysis of the nitrogen (^{15}N) and oxygen (^{18}O) isotopic variations in nitrate in the Neuse mainstem and smaller tributaries shows that little or no denitrification occurs in the mainstem, but does occur in smaller streams. The isotopic measurements and monitoring data from the Neuse agree with recent findings of the USGS in the Mississippi River Basin, where in-stream consumption is related to stream depth on a much larger scale. Our data suggest that once nitrogen enters the larger river channels, it is transported directly to the estuary with little denitrification or photosynthetic uptake. The addition of the deep aquifer ground waters to the lower Neuse can be demonstrated by simultaneously measuring the oxygen (^{18}O) and hydrogen (^{2}H) isotopic composition of rainfall in the basin, surface waters and ground waters. The isotopic composition of the upper and middle Neuse is similar to the isotopic composition of rainfall. Once the river crosses the deep aquifers in the lower basin, the isotopic composition of the river water shifts from the rainfall composition towards the deep ground water composition, indicating the addition of deep ground water in these geological formations. Decreased concentrations of nutrients in the lower basin result from ground water dilution from nitrate depleted deep aquifers.

These results indicate that the nutrient transport model used by NC DENR to manage the Neuse River Basin (NCDENR 1993, 1998) may need to be reevaluated, because those models primarily focus on in-stream consumption as an explanation for the diminished nitrate concentrations in the lower basin. While the ground waters in the lower basin may dilute nutrient concentrations, ground water in the central basin in the surficial aquifers accumulate nitrate. Isotope characterization helps identify how this surficial aquifer nitrogen then moves into streams. The movement of the surficial aquifer nitrogen is controlled by the size and land use in groundwater discharge zones. Groundwater discharge zones on the coastal plain have been mapped by the USGS (Figure 4). The Neuse River basin has a greater percentage of land covered by groundwater discharge areas than other Coastal Plain river basins. The central portion of the Neuse River Basin has the greatest proportion of land area covered by groundwater discharge areas, up to 30% in some watersheds. The isotopic composition of nitrogen that is discharged from these watersheds is

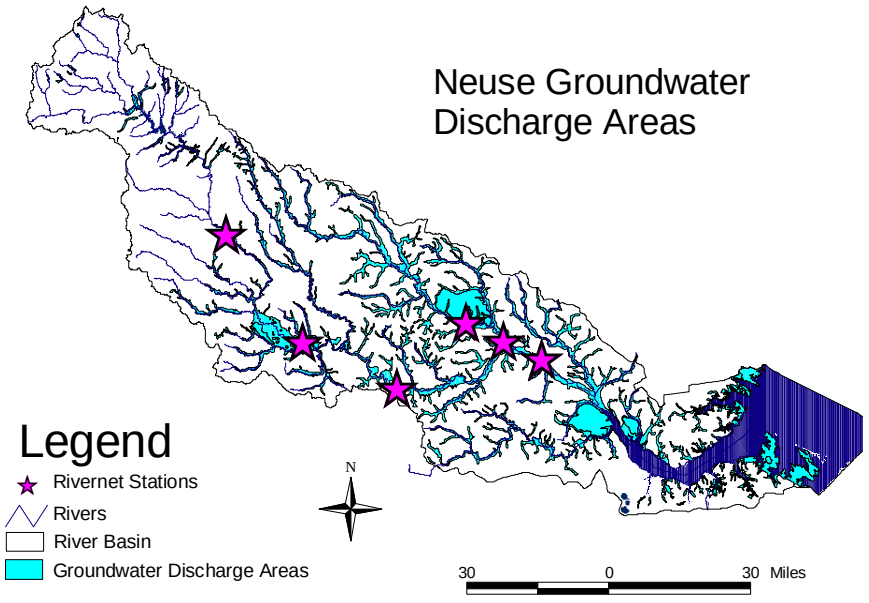

Figure 4. Groundwater discharge zones in the Neuse River basin after Heath (1994). These areas (in blue) are where groundwater flows into surface streams during wet and dry periods. The Neuse River Basin has several large groundwater discharge areas. Nutrient transport from these areas may be enhanced into local streams by the groundwater flow regime.

related to land use in these groundwater discharge zones and not land use in the watershed as a whole. The implication for management strategies is that buffer requirements may have to be scaled to river channel size or stream order, and that land use within the groundwater discharge area needs to be regulated like land use in a flood zone to protect water quality.

Summary:

RiverNet is a monitoring system that has given researchers and water quality regulators a new understanding of fundamental processes affecting water quality on a watershed scale. At the present time we have obtained $255k in matching funds for the RiverNet program and have applied for $325k in additional federal funds. Major findings of the program to date include:

- Nitrate and sediment concentrations in the Neuse River Basin change rapidly with and without stage changes. These variations are being measured with the innovative RiverNet *in situ* monitoring design.
- Nitrate and sediment concentration variations are related to the geology and hydrogeology at the site of the river station. Nutrient concentrations and isotopic composition are related to land use within the groundwater discharges zones.
- Innovative stable isotope techniques indicate that in-stream attenuation of nitrogen is not significant in large channels. Denitrification and in-stream consumption only occur in wetlands and smaller channels. Once nitrogen enters the mainstem of the Neuse, it is transported directly to the estuary.
- New stable isotope techniques indicate that significant amount of deep nitrogen depleted groundwater is entering the Neuse River in the lower basin. This explains the decreased concentrations in the lower basin.
- Groundwater in the central part of the basin from the upper aquifers enter the river in groundwater discharge zones. The land use in these groundwater discharge zones have a direct effect upon surface water quality in these regions.

By wisely using state and national resources and by emphasizing results focused on the systematic application of research-based knowledge, we can expedite the timely resolution of our water quality problems and protect our invaluable water resources. By combining research efforts with educational outreach programs, we can improve the public's understanding of water resource issues and the essential social, economic, and environmental value of local water resources for all persons and sectors of society.