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

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PURPOSE OF PROGRAM

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.

BACKGROUND

The 2003 Session of the General Assembly appropriated $285,000 to the Department of Environment and Natural Resources (DENR) for transfer to North Carolina State University (NCSU) for the continued operation of the RiverNet Program. The RiverNet Monitoring network has been developed over the past three years. During the first year several technological problems were solved. During the second year the system monitored nitrogen flux during a severe drought. During the third year the system monitored nitrogen flux as the drought ended and the RiverNet research group began to work with the City of Raleigh monitoring nutrient flux from the Raleigh WWTP near Clayton, NC. During this past year the RiverNet Program has measured groundwater and nitrogen flux from the Raleigh Waste Water Treatment Facility into the Neuse River and developed a new tracer (^{17}O) to measure the transfer of atmospherically deposited nitrogen into surface waters. We have also developed a new technology that will permit nutrient watershed mapping to investigate where groundwater inputs are coming into the river system. Seven stations are operating in the basin from Raleigh to Fort Barnwell, two stations are in the Contentnea watershed, and five are along the Neuse Mainstem (Figure 1). Nitrate analyses are made once an hour, whereas other water quality properties (e.g., depth, temperature, pH, turbidity, oxygen) are made every 15 minutes. The data are transferred to a server at the NCSU Raleigh campus once a day via a cell phone network and posted on a web site for public access (http://rivernet.ncsu.edu). This monitoring will continue for the next year with nutrient watershed mapping and groundwater monitoring at the Raleigh WWTP.

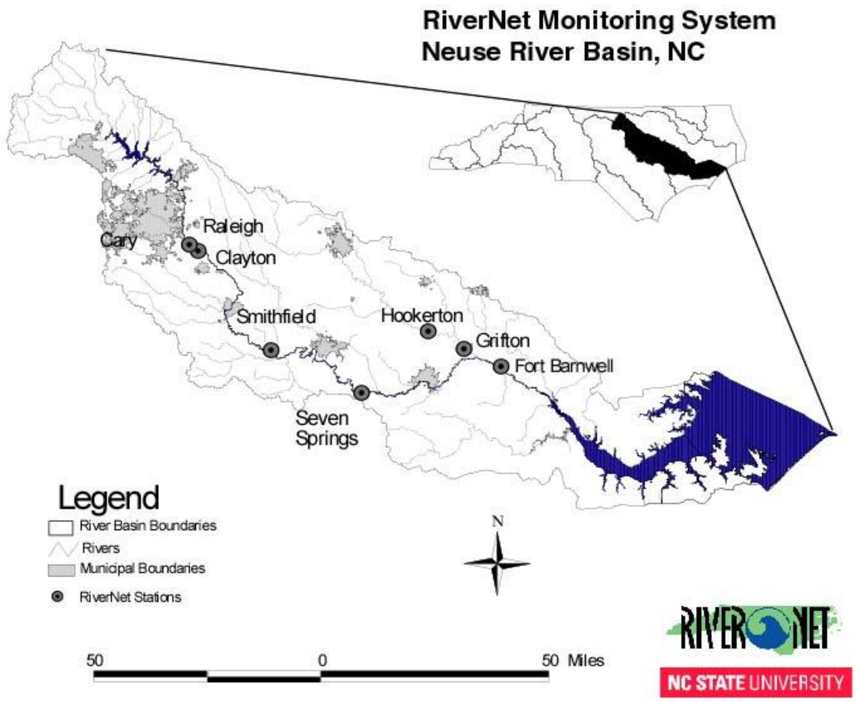

Figure 1. The RiverNet monitoring network with a new station located above the Raleigh Waste Water Treatment Plant (WWTP) to investigate the contributions of nitrogen from the associated large Waste Application Field (WAF) in the piedmont.

RiverNet: Results 2004

Results from previous years have shown that there are significant nitrate concentration variations in the Neuse River. These variations occur on time scales that vary from an hourly to daily basis (Figure 3). These variations are found in drought and non-drought conditions and are associated with large NPDES dischargers. These nitrate variations are found in the upper, middle and lower portions of the basin. Without a RiverNet program, nitrogen flux estimates are

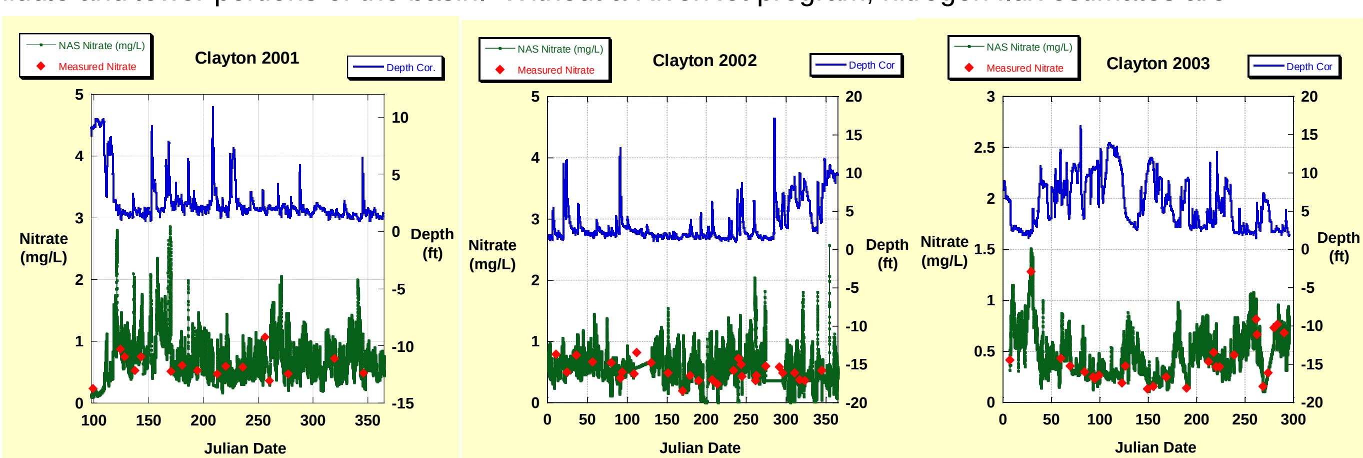

Figure 2. River nitrate variations during the 2001 to 2003 period. Notice the high frequency variations are not related to drought

based on 15-minute discharge measurements and daily nitrogen concentration measurements. Large errors are associated with daily flux estimates when compared to the RiverNet hourly flux estimates (Figure 3). These errors can be as large as 30% of the total flux. On an annual basis the flux of nitrogen to the estuary is underestimated by at least 10% without a RiverNet program. Over the long-term, nitrogen flux is controlled by rainfall and river discharge (Figure 4). Rainfall in North Carolina is related to the El Nino / Southern Oscillation cycle which is 5-7 years in length. At the present time we have captured about 50% of this cycle. However, when the flux of nitrogen is weighted for the ENSO controlled water discharge variations, the weighted

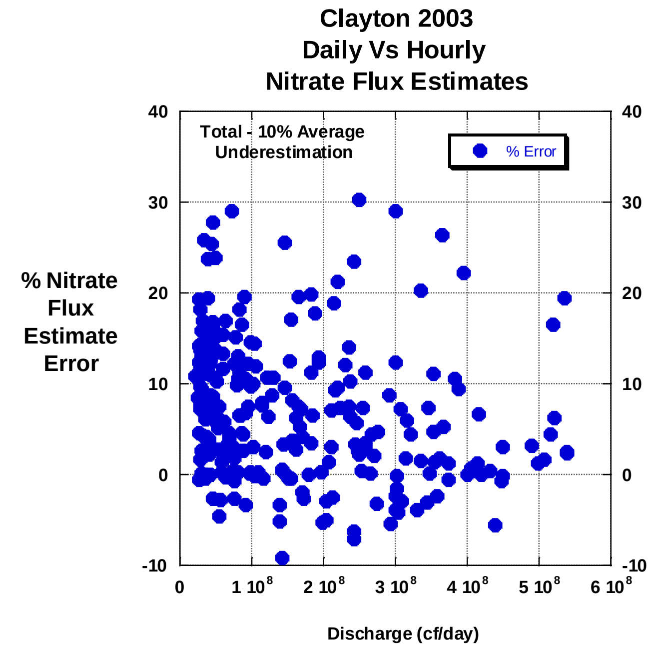

Figure 3. Daily versus hourly flux measurements at Clayton on the Neuse River, NC. The error without a RiverNet program is –10 to + 30 per cent. Over the year the nitrate flux in the Neuse Basin is underestimated by~ 10% without a high-frequency monitoring system such as RiverNet..

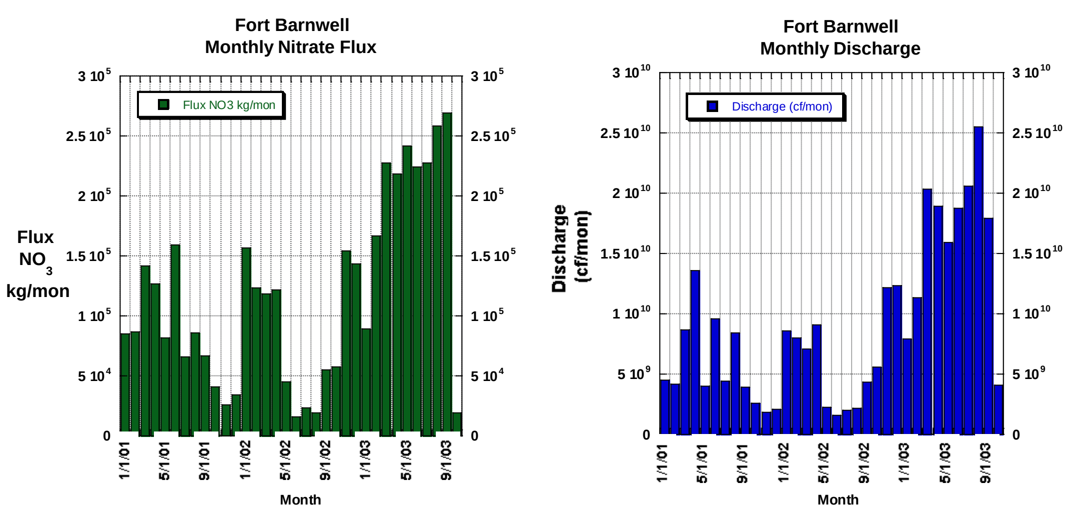

Figure 4. From 2001 to 2003 the flux of water and nitrate in the Neuse Basin has varied with the El Nino Southern Oscillation cycle (ENSO). This cycle has a frequency of 5-7 years, so with three years of monitoring we have captured approximately 50% of the cycle.

flux of nitrate in the Neuse River basin has dropped about 20%. This indicates that the regulations put in place by the NC General Assembly and enforced by NC DENR are currently reducing the flux of nitrogen to the Neuse River Estuary (Figure 5).

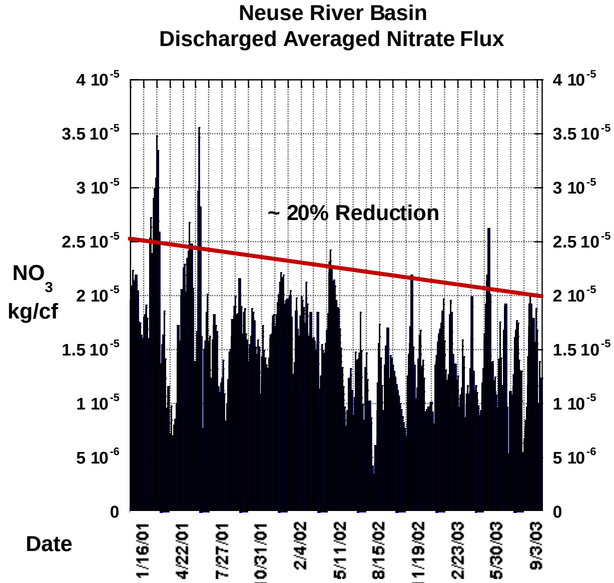

Figure 5. From 2001 to 2003 the flux of water and nitrate in the Neuse Basin normalized for discharge variations.

CONTAMINATED GROUNDWATER FLUX OF NITRATE TO THE NEUSE RIVER

Waste application fields accumulate nitrate, but the movement of nitrate from under these fields to surface waters is not well understood. We have worked with the City of Raleigh Public Works

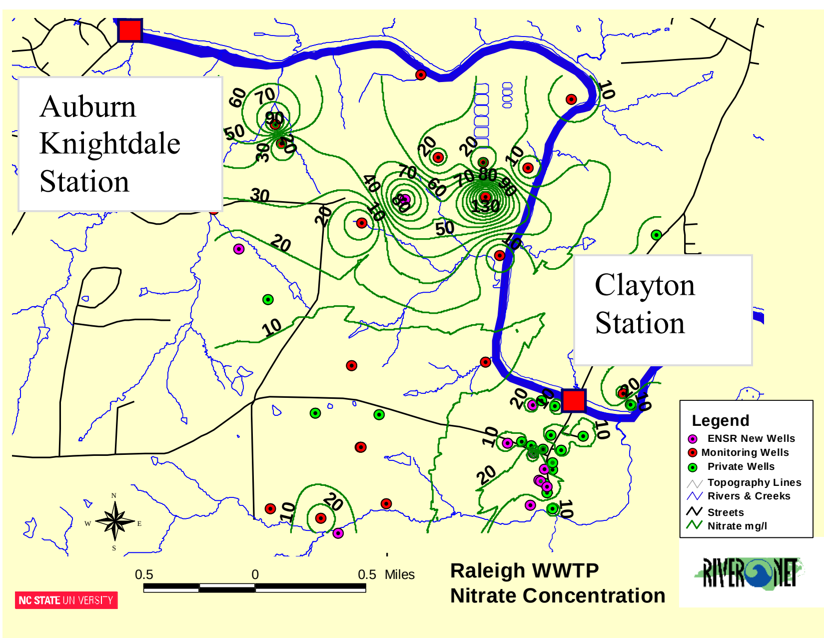

Figure 6. Two RiverNet stations monitor groundwater additions and nitrate flux at the Raleigh WWTP

Division and UNC WRRI over the past year to measure the flux of groundwater nitrate from the waste application fields at the Battle Bridge Road treatment plant in southern Wake County. Groundwater nitrate flux to the Neuse River is event driven and the peak flux occurs over a ~1 to 5 day period after heavy rainfalls (Figure 6). On an annual basis the groundwater flux of

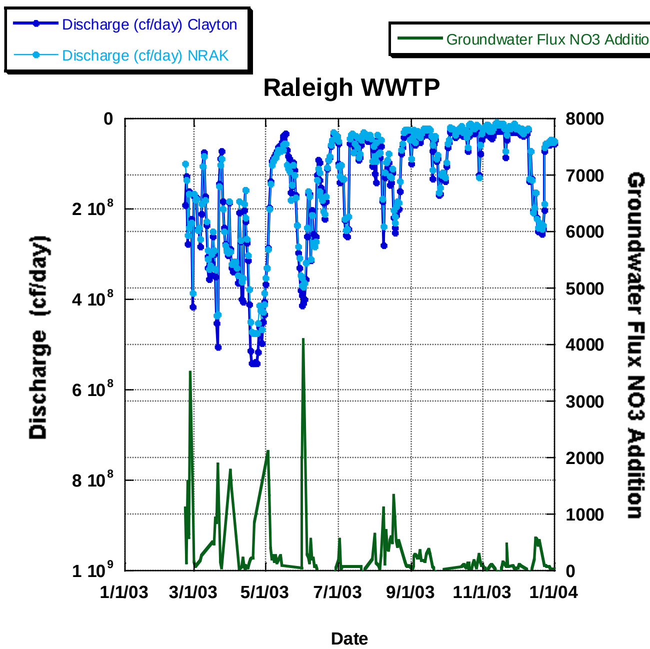

Figure 6. Groundwater additions of nitrate at the Raleigh WWTP are episodic with a typical period of 1-3 days These nitrate fluxes are related to river stage and not rainfall, which indicates a predominant hydrologic control.

nitrate represents about 50% of the flux of nitrogen out of the plant through the discharge pipe (Table 1) and 15% of the surface nitrogen flux coming down the river. This agrees with an estimate made by an environmental consultant (ENSR) hired by the City of Raleigh with groundwater models, but the RiverNet data show how episodic the groundwater additions can

Table 1. Nitrate Fluxes at the Raleigh WWTP for 2003

	% Norm Flux
Surface Flux NO3 Input % Clayton	**68.48**
RWWTP Flux NO3 % Clayton	**21.27**
Groundwater Flux NO3 % Clayton	**10.26**
Total Inputs NO3	**100.00**
Surface Flux Water Input % Clayton	**90.81**
RWWTP Flux Water % Clayton	**4.40**
Groundwater Flux Water % Clayton	**4.80**
Total Inputs Q	**100.00**

be. Groundwater flux of nitrate is important to river water quality, but is currently poorly understood and not measured. The large number of industrial and agricultural waste application fields on the coastal plain suggests that we need to develop a reliable methodology to recognize, measure and remediate contaminated groundwater nitrate flux to surface waters.

Future Directions for RiverNet: Watershed Nutrient Mapping
This year we have successfully tested a new optical UV nitrate sensor just developed by Satlantic Inc. This UV sensor has the ability to make nitrate measurements of extremely short duration over the period of seconds to minutes. Correlation with our chemical underwater sensors is excellent (Figure 7). With this rapid-fire nitrate sensor, we can map nutrient distributions in rivers on a watershed scale and determine where contaminated groundwaters are entering the river. Once the location is determined, hydrogeology and remediation efforts can be undertaken to stop the flux of nitrate with accepted current practices. With future capital equipment funds, the RiverNet program can be converted from a chemical measurement program to an optical measurement program and many more stations can be operated for the same cost. This will make expansion of the program to a statewide system possible so that water quality can be measured in river basins other than just the Neuse.

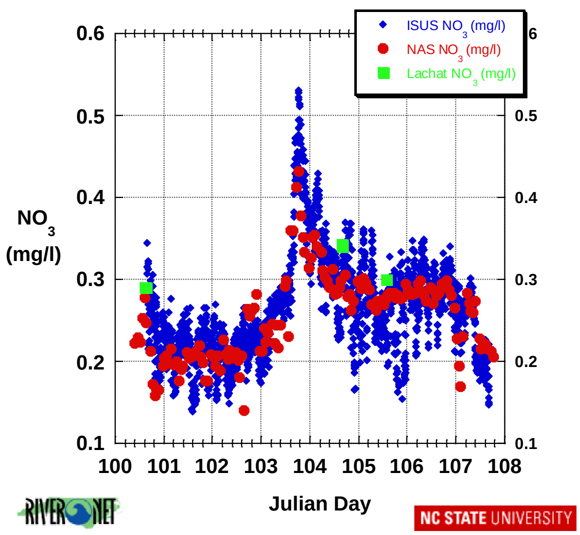

Figure 7. Isus optical nitrate measurements compared to NAS chemical nitrate measurements in the Neuse River above the Raleigh WWTP. With the optical system three measurements are made every 15 minutes as opposed to 1 per hour with the chemical system.

EDUCATION AND OUTREACH EFFORTS
The Department of MEAS, at NCSU has been awarded $517k in federal funds from NSF for a program enhancement project entitled "Enhancing Diversity in Geosciences in North Carolina". This is a three-year collaborative effort between NCSU and NCA&T to recruit minority graduate students to Geosciences graduate programs. RiverNet is a central research program in this federally funded education effort, and the program will be working with minority students from NCA&T as well as Robeson Community College this summer and next fall.

SUMMARY:
RiverNet is a monitoring system that has significantly evolved and given researchers and water quality regulators a new understanding of the fundamental processes affecting water quality on a watershed scale.

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 correlated to discharge and precipitation variations that are controlled by the ENSO (El Nino Southern Oscillation) cycle, which has a 5-7 year time period.

- Hourly RiverNet flux measurements are significantly more accurate than flux estimates made from daily concentration measurements.
- Discharge normalized nitrate flux measured by the RiverNet program indicates that there has been approximately a 20% reduction of nitrate flux since 2001.
- Measurement of groundwater nitrate fluxes with the RiverNet technology has shown that groundwater additions are episodic with time periods of hours to days.
- Groundwater nitrate flux at the Raleigh WWTP is about 50% the nitrogen flux from the discharge pipe.
- New optical measurement techniques are less expensive than the current chemical measurement techniques and will allow the RiverNet program to expand statewide for reasonable costs.
- Nutrient mapping on a watershed scale will be possible with this new optical nitrate measurement technology, which can be used to understand nitrate fluxes entering the river in groundwater discharge zones. The groundwater flux in these groundwater discharge zones has a direct effect upon surface water quality in these regions, but at present this impact is poorly understood.

The lack of understanding concerning the importance of groundwater additions to overall watershed water quality hinders our efforts of regulation, mitigation and remediation and allows undocumented blame to be placed on NC industries, which can have severe economic consequences. The development of new technologies and methodologies to address these environmental and economic concerns will be a central issue for the RiverNet program over the next monitoring year.

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 without economic impairment. By combining research efforts with educational outreach programs, we can train the scientists, regulators and policy makers of the future. In the end we will 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.