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. 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 and to develop successful remediation strategies, fundamental processes that control water quality on a watershed scale must be investigated. RiverNet is a program that is designed to understand nitrogen fluxes in watersheds with different land uses.

BACKGROUND

The 2001 Session of the General Assembly appropriated $300,000 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. Due to budget reductions, $285,000 was available to operate the RiverNet program in 2006. The RiverNet Monitoring network has been operated over the past six 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 began to monitor groundwater nutrient flux from the Raleigh WWTP near Clayton, NC. During the fourth year we have applied a new tracer to measure the transfer of atmospheric deposition of nitrogen into surface waters (^{17}O). During the fifth year we developed and applied a new technology that will permit nutrient watershed mapping to investigate where groundwater inputs are entering the river system. During the six year we begain a co-operative program with the USGS and DENR 319 program to quantify biosolid nitrogen being transported by surface streams into the Neuse River adjacent to the NRWWTP (Neuse River Waste Water Treatment Plant). Six stations are operating in the basin from Raleigh to Fort Barnwell, one station is in the Contentnea watershed, and five are along the Neuse Mainstem (Figure 1). Physical water quality property measurements are made every 15 minutes and nitrate analyses are made once an hour. The data is transferred to a server at the NCSU Raleigh campus once a day via a cell phone network, and mounted 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.

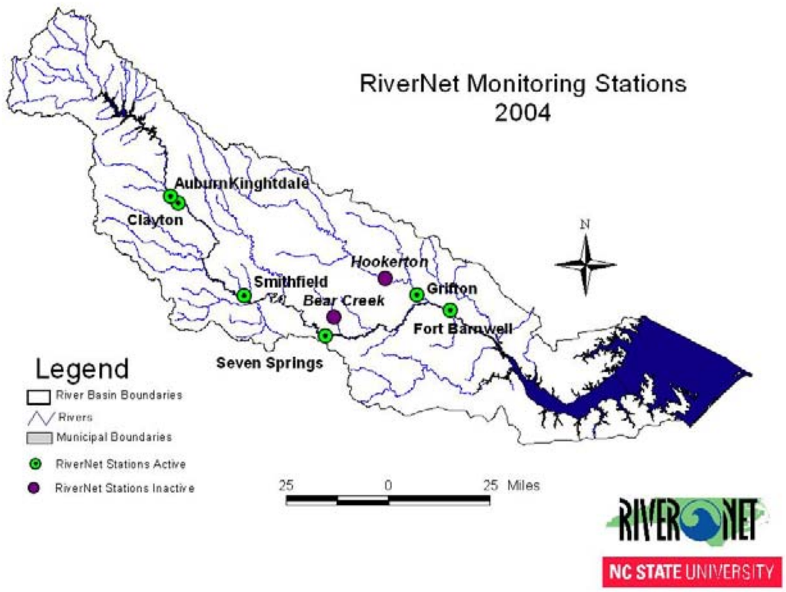

Figure 1. The RiverNet monitoring network with a new station located above the Raleigh Waste Water Treatment Plant (WWTP) to investigate the relationship of groundwater flux from this large Waste Application Field (WAF) in the piedmont. Due to continued budget restrictions, two lower basins stations were temporarily closed down.

RiverNet: Results 2006

Previous years results have shown that there are very rapid nitrate concentration changes in the Neuse River in the upper, middle and lower basin. In 2006 a weak El Nino began to build in the equatorial Pacific, similar in magnitude to the El Nino observed in 2003. At the end of 2006 the N flux in the Neuse Basin increased with discharge levels similar to the fluxes observed in 2003 (Figure 1). The overall long term six year trend is of increased N flux, but the inter-annual N flux variation is significant and is related to large scale climate oscillations. Nitrate concentration in the river is a poor predictor of water quality trends (Figure 2). During low flux intervals the nitrate concentrations tend to be higher that during high flux intervals due to the dilution effect. Flux measurements are better indicators of potential eutrophication events in the estuary and coastal waters.

The two large scale climate oscillations that affect North Carolina precipitation and hydrology are El Nino and the North Atlantic Oscillation. Nitrate flux increases with positive El Nino oscillations. Warmer waters in the equatorial Pacific intensify the southern jet stream, which brings Gulf of Mexico moisture to North Carolina. This causes increased precipitation and N flux in watersheds. North Carolina precipitation is also affected by the North Atlantic Oscillation. The North Atlantic oscillation (NAO) is a climatic phenomenon in the North Atlantic Ocean of fluctuations in the difference of sea-level pressure between the Icelandic Low and the Azores high. This difference controls the strength and direction of westerly winds and storm tracks across the North Atlantic. When the North Atlantic Oscillation Index is positive, the westerly flow across the North Atlantic and western Europe is enhanced, warm ocean waters occur off the eastern US and rainfall is enhanced in our region. During the negative phase storm tracks are forced further south and northern Europe and the eastern coast of the US are dry.

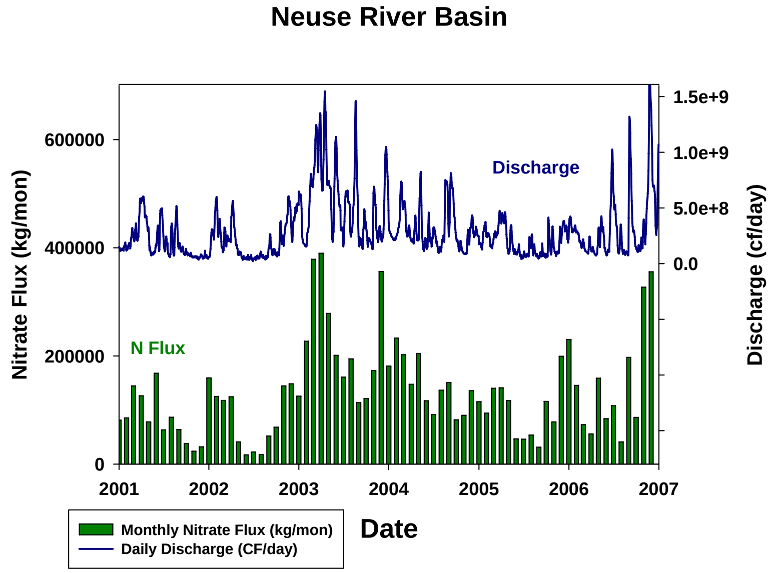

Figure 1. Daily discharge and Monthly N flux at Fort Barnwell North Carolina at the bottom of the Neuse River Basin.

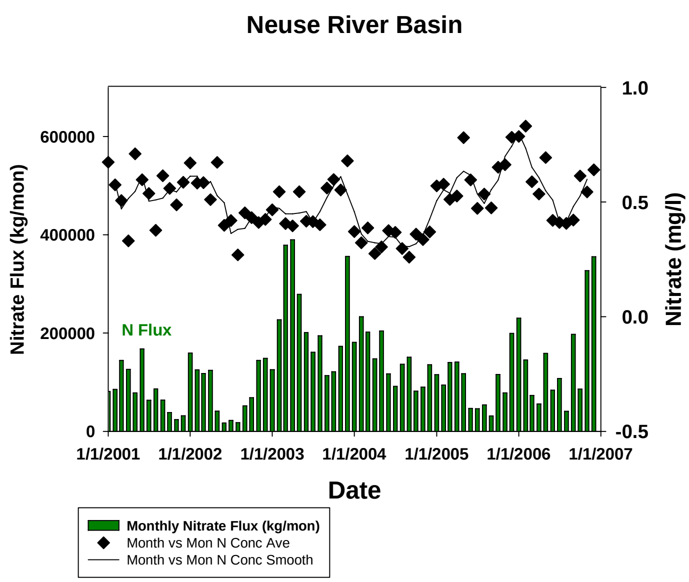

Figure 3. Monthly N flux at Fort Barnwell North Carolina versus nitrate concentration. Nitrate concentration is a poor predictor of water quality trends, during high flux periods concentrations tend to be lower that during low flux intervals.

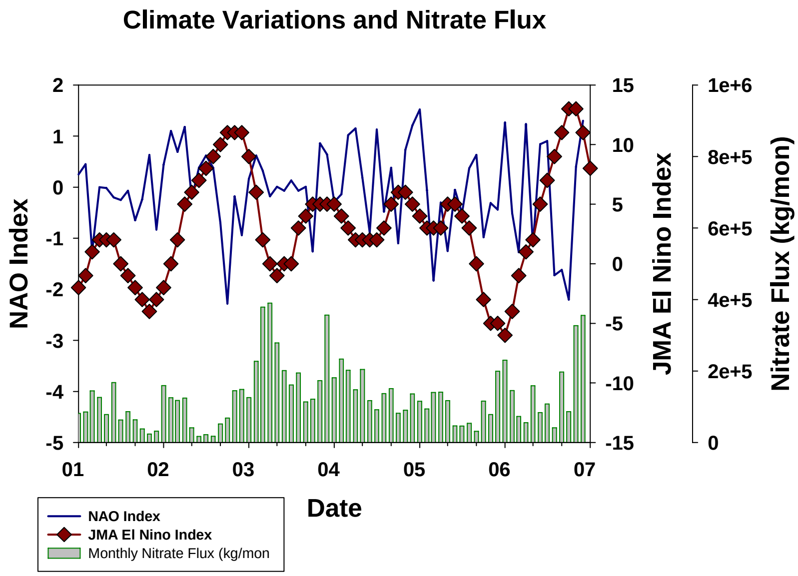

Figure 3. Monthly N flux at Fort Barnwell North Carolina versus two climate oscillations, El Nino and the North Atlantic Oscillation.

During the two periods of positive El Nino oscillations (2003 and 2006), enhanced rainfall and nutrient fluxes were moderated by a negative North Atlantic Oscillation index. Nutrient flux did not increase until the NOA became positive. In these two periods of moderate El Nino, the increased flux of nitrate was modulated by the negative NOA phase. During the hypoxic and anoxic events of the 1990's this was not the case. Positive El Nino and NAO phases occurred together which would have enhanced nutrient transport in the basin and led to the negative water quality events in the Neuse River Estuary (Figure 4).

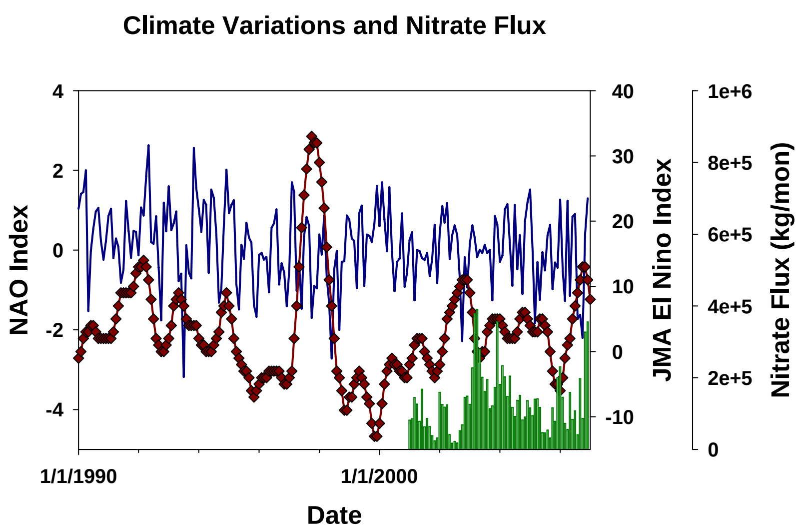

Figure 4. Monthly N flux at Fort Barnwell North Carolina versus two climate oscillations, El Nino and the North Atlantic Oscillation were both positive during the 1992, 1995 and 1998 periods of high nutrient fluxes..

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 investigated the movement of groundwater nitrate from under the Battle Bridge Road treatment plant operated by the City of Raleigh into the Neuse River over the past three years with two RiverNet Stations above and below the plant. Biosolids have been land applied at this site for the past 24 years. The amount of nitrate entering the river from contaminated groundwater is 51% the flux of nitrate released from the plant via the discharge pipe over a three year period (Figure 5, Table 1). This contaminated groundwater flux is significant to river nitrate flux, and is event driven. To evaluate the effect of groundwater or surface water drainages into the river, NC DENR, USGS, and NCSU have installed a groundwater observatory at the Neuse River Waste Water Treatment Plant with co-operation by the City of Raleigh, Public Utilities Division.

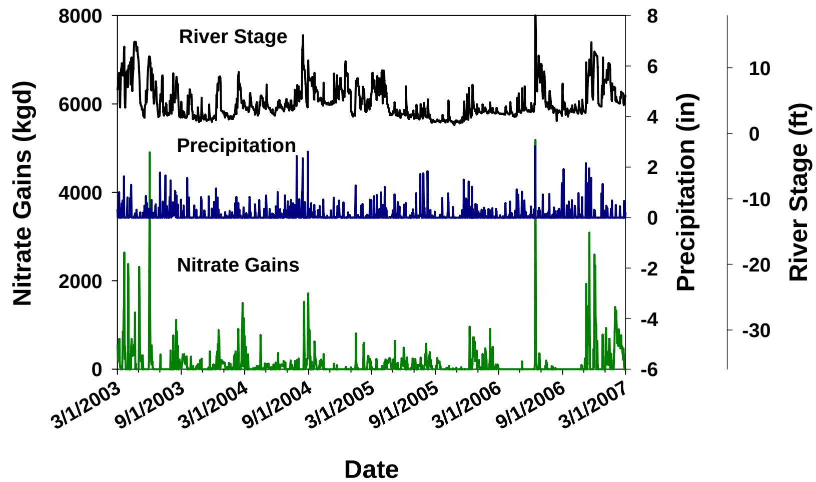

Figure 5. River stage and Nitrate gains at the Neuse River Wastewater Treatment Plant near Clayton, NC. Nitrate gains are not related to precipitation trends or river stage.

TABLE 1. Nitrate gains in the Neuse River Reach next to the NRWWTP

Monitoring Year	Daily Integrated NO3 Gains	% Total NO3 Output (NRCP)	% Total NO3 Output NRWWTP	Clayton & RDU Precipitation Average (in)
2003	70,098	13	58	44.15
2004	27,876	9	26	45.45
2005	29,943	10	30	35.04
2006	60984	16	89	54.11
Average	**47,225**	**12**	**51**	**45**

Monitoring the stream nitrate flux at the NRWWTP has shown that the nitrate concentrations in the streams are related to the groundwater levels in the mid-slope well cluster. The lower well cluster groundwater levels are tied to the river stage and do not correlate to nitrate flux in the streams (Figure 6). This seasonal variation will require spatially distributed models to predict biosilid nitrate flux to the Neuse River. The present static mudflow models can not accurately predict surface drainage nitrate flux from the biosolid application fields with this type of seasonal and interannual climatic variations.

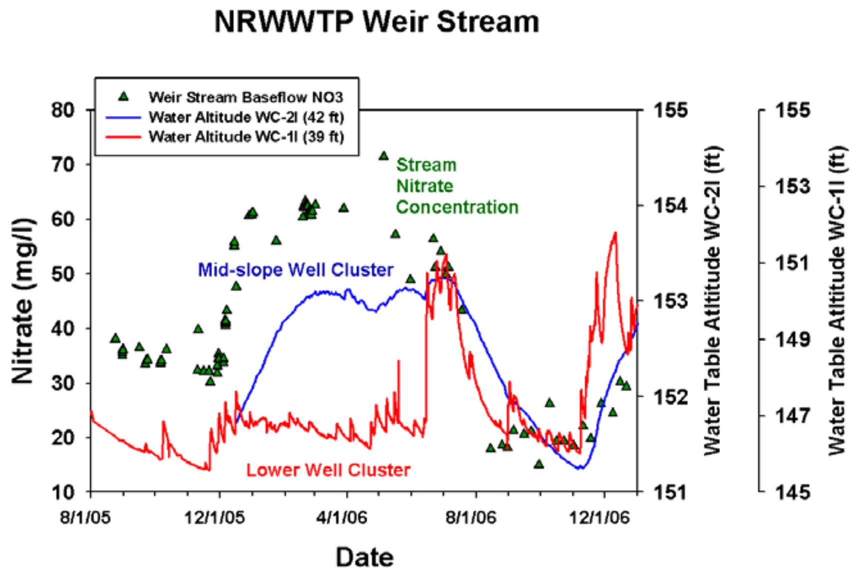

Figure 6. Stream nitrate concentration and water levels at the Neuse River Wastewater Treatment Plant near Clayton, NC. Concentrations and nitrate flux to the Neuse vary with mid-slope water levels.

Summary:
RiverNet is a monitoring system that has significantly evolved and given researchers and water quality regulators a new understanding of fundamental processes affecting water quality on a watershed scale. At the present time we are combining RiverNet monitoring efforts with a new Piedmont Groundwater Observatory being installed at the Neuse River Waste Water Treatment Plant near Clayton NC. We are also mapping where contaminated groundwater enters the river with a new ISUS UV nitrate sensor. These efforts have so far proven to be very successful. These efforts will help design a remediation effort to protect river water quality.

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 modulated by the NAO (North Atlantic Oscillation) which has a 1-2 year cycle..
- Hourly RiverNet flux measurements are significantly more accurate than flux estimates made from daily concentration measurements. Daily flux estimates have a 10 to 40% error depending upon the location in the river basin.
- Measurement of groundwater nitrate fluxes with the RiverNet technology has shown that groundwater N additions are episodic with time periods of hours to days.
- Groundwater nitrate flux at the Raleigh WWTP is about 51% the nitrogen flux from the discharge pipe over a three year period, demonstrating that N

groundwater flux is important and cannot be ignored.

- New optical measurement techniques are less expensive than the chemical measurement techniques and will allow the RiverNet program to expand statewide for reasonable costs.
- Nutrient mapping on a watershed scale can identify where groundwater nitrate fluxes enter the river. The groundwater quality in these groundwater discharge zones has a direct effect upon surface water quality in these regions.
- Identification of the location and processes that discharge contaminated groundwater into the river is the crucial first step towards remediation of contaminated surface and ground waters.

The progress towards watershed N flux and N mapping that the RiverNet program made this year is an important next step in evaluating and designing remediation strategies to protect our surface, estuarine and coastal water quality.

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.