Water Resources Research Institute of the University of North Carolina
Annual Technical Report
FY 2002

Introduction

During 2002-2003 (FY 2002), the Water Resources Research Institute (WRRI) of The University of North Carolina added to its research and technology transfer efforts new programs funded by the N.C. General Assembly. The General Assembly established the N.C. Water Quality Workgroup in 1999 and charged it with selecting collaborative studies between the N.C. Department of Environment and Natural Resources and constituent institutions of The University of North Carolina that collectively close knowledge policy gaps with regard to the States water quality. Also in 1999 the General Assembly appropriated to the N.C. Sedimentation Control Commission monies to fund research aimed at evaluating and improving erosion and sedimentation control technology and application. During 2002, WRRI took on administration and management of both these programs, including providing support for meetings of the Water Quality Workgroup, issuing the call for proposals, coordinating peer review, facilitating project selection, and managing contracts. These new programs added significantly to WRRIs impact across North Carolina, resulting in 14 research projects in addition to those supported by USGS, State appropriations through the university system, and the N.C. Urban Water Consortium and Stormwater Group.

During 2002, WRRI continued its regular program of fostering research, training, and information transfer responsive to water issues of the state and region. Research priorities continue to be identified by the WRRI Advisory Committee, composed of federal, state, and local agency personnel and representatives of the business, industry, and environmental communities. High on the list of priorities identified for inclusion in the 2002-2003 call for proposal were topics related to sediment pollution, water supply in the N.C. Coastal Plain, water conservation, drinking water, and riparian buffers.

The information transfer program continued to focus on disseminating results of sponsored research and providing information on emerging water issues, regulations, and problems. Results of research are disseminated by publication of technical completion reports, summaries in the WRRI newsletter, publication of summaries on the WRRI website, and presentations by investigators at WRRI seminars and the Annual Conference. During this year, WRRI was approved as a sponsor of continuing education credits by the N.C. Board of Examiners of Engineers and Surveyors. This allows WRRI to offer Professional Development Hours for attendance at WRRI seminars and the Annual Conference.

Research Program

Hydrolgical and Biogeochemical Investigations of Riparian Buffers in the Piedmont and Blue Ridge Regions of North Carolina

Basic Information

Title:	Hydrolgical and Biogeochemical Investigations of Riparian Buffers in the Piedmont and Blue Ridge Regions of North Carolina
Project Number:	2002NC1B
Start Date:	3/1/2002
End Date:	2/28/2003
Funding Source:	104B
Congressional District:	12
Research Category:	Water Quality
Focus Category:	Groundwater, Water Quality, Solute Transport
Descriptors:	Riparian Buffer, Nutrients, Fecal Coliform Bacteria, Sediments, Water Quality, Surface-Groundwater Flowpaths, Groundwater Modeling
Principal Investigators:	Craig J. Allan, Jy S Wu

Publication

1. Allen, Donna, Craig J. Allan and Jy Wu, 2003, Hydrological and Biogeochemical Investigations of Riparian Buffers in the Piedmont and Blue Ridge Regions of North Carolina, in NC WRRI Annual Meetings, Raleigh, NC, ww2.ncsu.edu/ncsu/cil/wrri.allen.pdf.

Title: Hydrological and Biogeochemical Investigations of Riparian Buffers in the Piedmont and Blue Ridge Regions of North Carolina

Problem and Research Objectives: The ongoing research project is quantifying the pollutant removal efficiency and hydrologic characteristics of vegetated riparian buffers in the western Piedmont and the Blue Ridge physiographic regions of the North Carolina. Data from the project will be used to help determine the effectiveness of riparian buffers in reducing Non Point Source (NPS) pollutant loadings to surface waters in hydrogeologic regions of the state where their use has not been fully investigated. The research will also be used to evaluate the potential of riparian buffers in controlling the NPS loadings of bacteriological contaminants to surface waters. Both aspects of the project will provide information with regard to the water quality benefits associated with vegetated riparian buffers to assist planners and resource managers when faced with decisions regarding development within floodplains. The objectives are to: 1) Define the subsurface hydrogeologic conditions at each study site through the construction of flow nets to identify subsurface flow paths, 2) Quantify subsurface flow inputs of nutrients to the receiving stream channel, and finally 3) Measure the attenuation of groundwater transported pollutants moving from field edge through the riparian buffer; and parameterize the numerical flow model.

Methodology: Two transects running from the field edge to the center of the stream channel have been instrumented at each of the two study sites. Transects at each site were sited in areas representing average slope, width and vegetative cover. Surface flow is sampled and quantified through samplers consisting of plastic bottles inserted in the ground with an opening at ground level. The objective is to quantify surface water inputs into the streamside buffer and monitor the attenuation of pollutants as they pass through the buffer. Two to three samplers are installed along each sampling transect.

Piezometers and groundwater wells have been installed at various locations along each transect including the streambed. Each piezometer is screened and water levels determined manually with an electronic depth sensor. Hydraulic conductivity is determined through Hvorslev water level recovery method (Freeze and Cherry 1979). Groundwater levels are continuously recorded at select sites with Druck Pressure transducers logged by a Campbell Scientific (CS) data logging system. Cl^- (a conservative element) and dissolved O_2 concentrations will be measured along with the pollutants of concern to delineate zones where conditions are favorable for pollutant removal. Groundwater flow through the riparian buffers will be calculated by three different methods to bracket our flow estimates. Firstly, two-dimensional flow nets will be constructed from the piezometric head data and combined with the hydraulic conductivity data to measure ground water flow (Freeze and Cherry 1979, Roulet 1990). Secondly, a series of detailed dilution gauging measurements will be made at different groundwater stages along each channel to directly quantify net ground water inputs to the stream channel. A third approach involves the use of the numeric model to predict hydrochemical transport at each site. The utility of this final approach is dependent upon a sufficient length of field data to both calibrate and test the model.

Infiltration rates are being determined with flooding ring infiltrometers. Hydraulic conductivity (K_u) in the unsaturated zone is profiled through the unsaturated zone with a Guelph Permeameter and relations established between soil moisture content and hydraulic conductivity (Reynolds and Elrick 1985). Soil moisture levels are being continuously recorded at each site with logged CS soil moisture reflectometry probes. Tension lysimeters have been installed at two

depths at each site to monitor soil solution chemistry. The purpose of this phase of the project is to quantify the transport of water and pollutants through the vadose zone of the riparian buffer and assess changes in volumetric soil moisture content to aid in the solution of the water balance. Stream flow through each buffer is monitored with an automatic water sampler/flow meter below each study area. Streamflow and water samples are recorded at the EPA downstream gauging station at the Kiser Dairy site. Stage discharge relationships are being established for the Blue Ridge site through manual gauging at different stream stages**.** All chemical and bacteriological analyses are performed at UNC Charlotte. NO_3^-, NH_4^+, Cl^- and ortho-P analyses are performed on a Dionex IC system. Total P determinations are performed colormetrically after sample digestion. Suspended sediment concentrations are determined gravimetrically after filtration. Dissolved O_2 is measured in the field with a portable O_2 meter. Dissolved organic carbon (DOC) and TN is analyzed with a Shimadzu TOC/TN analyzer. Fecal coliform are determined by method 9221 E (APHA 1998).

Progress Report: Year 1

1. Selection of Piedmont (Kiser Dairy) and Blue Ridge (Brevard) study sites (April 2002)
2. Installation of Piezometer and GW Wells at Kiser (June 2002) and (Nichols Branch (Septptember 2003)
3. Initiation of regular monitoring of Gaston County (July) and Brevard (September) sites. Monitoring is continuing on a regular schedule.
4. Analysis of Brevard and Kiser Dairy samples for major ions by IC, pH conductivity and total phosphorus is ongoing. Analyses of total nitrogen on archived subsamples will begin in June 2003.
5. Sedimentological and mineralogical analysis of Core Samples from Kiser Dairy and Brevard sites has been completed (May 2003).
6. Topographic surveys at the Kiser Dairy and the Brevard Piezometer networks have been completed and monitoring network templates have been developed.
7. The field measurement of hydraulic conductivity (K_{sat}) are ongoing at the Kiser dairy site and will begin later this summer at the Brevard site.
8. Initial results from the project were presented at the April 1, 2003 Annual NC WRRI meetings in Raleigh.

We have had a successful first year and the project is running with a regular two out of three week sampling schedule both study sites. Beyond the regular sampling the remaining field tasks involve the measurement of hydraulic conductivity for each piezometer at the Brevard location and the sampling for fecal coliform bacteria at both sites. We will also install additional piezometers at both sites to “flesh-out” our monitoring network. Sample analyses are ongoing and we expect all backlogged analyses to be completed by August 2003.

Reduced Cost Strategies for Regional Integration of Surface and Groundwater Use

Basic Information

Title:	Reduced Cost Strategies for Regional Integration of Surface and Groundwater Use
Project Number:	2002NC2B
Start Date:	3/1/2002
End Date:	2/28/2003
Funding Source:	104B
Congressional District:	4th
Research Category:	Water Quality
Focus Category:	Water Quality, Models, Management and Planning
Descriptors:	Water Resources Development, Groundwater Management, Water Treatment Facilities, Resource Planning
Principal Investigators:	Gregory W Characklis

Publication

1. Kirsch, B. R. and G. W. Characklis (2002). An Analysis of Water Supply Alternatives in the Central Coastal Plain Capacity Use Area: A Regional Supply Model, Annual Meeting of the American Water Works Association(AWWA)/Water Environment Association (WEA), North Carolina Section, Winston-Salem, NC, November 2002. [2nd prize, Graduate Research Competition]
2. Kirsch, B. R. and G. W. Characklis (2003). An Integrated Analysis of Water Use Alternatives in the Central Coastal Plain Capacity Use Area, Proceedings of the Annual Conference of the North Carolina Water Resources Research Institute, Raleigh, NC, April 2003

Problem and Research Objectives: A fifteen county region in eastern North Carolina has been classified as a "Capacity Use Area", a designation that provides the legal framework for regulation of groundwater withdrawals. This region, the Central Coastal Plain Capacity Use Area (CCPCUA), has traditionally been dependent on groundwater for much of its water supply, however, increasing usage has led to reductions in aquifer levels and saltwater intrusion. Rules recently approved by the State call for communities within the CCPCUA to be issued groundwater pumping permits, while also establishing a plan to limit groundwater withdrawals by as much as 75% over a 16 year period ending in 2017. New water sources are available to the region, but will be expensive to develop. Cost effectively complying with the pumping reduction schedule will require a combination of new supplies and more efficient use of existing resources. In order to foster greater efficiency, the CCPCUA rules also make provisions for the transfer of groundwater pumping permits amongst regional users, thereby laying the foundation for the state's first water market. Surface water sources (e.g., Neuse and Tar rivers) will be developed and involve substantial capital expenditures on treatment facilities as well as conveyance infrastructure for communities not located near the rivers. Current estimates of the regional cost associated with each community individually attempting to meet its future water demand total over $100 million in capital costs alone, a figure that would be very burdensome to these 15 counties, several of which rank among the poorest in the state. Research is required to evaluate more cost effective means of meeting future water demand in the region. The primary contribution of this work is estimating the reduction in regional cost achievable through a combination of approaches that involve the development of regional drinking water treatment facilities and the use of transferable groundwater pumping permits. While regionalization of wastewater treatment has been explored, little evidence of similar research exists in the drinking water literature. The central theme of the regionalization analysis involves identifying minimum cost scenarios while balancing the economies of scale inherent in water treatment with the diseconomies of scale associated with distribution over larger service areas. The additional consideration of tradable groundwater permits provides for greater supply flexibility and is likely to further reduce regional costs.

Methodology: A regional water supply and treatment model is developed for the CCPCUA. The model identifies regional scenarios that minimize the costs of meeting regional water demand in the CCPCUA by providing the affected communities with three supply choices: (1) join a regionalized surface water treatment system, (2) purchase groundwater pumping permits, or (3) tap a "tertiary" source (e.g., unregulated aquifer) which can vary based on the community. As each community is responsible for the costs associated with its choice (i.e. few state or federal funds are available) each community is assumed to select the alternative that results in the lowest cost for its customers. This is an important distinction as it contrasts with studies of wastewater regionalization in which large federal grants motivated the search for approaches that provided the lowest *aggregate* cost, with less attention to the expense incurred by individual communities. It is interesting to note that in the framework developed here, an individual community's selection of either (1) or (2) will impact the costs experienced by other communities, as each choice implies a change in either surface water system capacity or groundwater permit demand. Those joining the regional system are assumed to pay their share of treatment and conveyance costs, with these expenses mitigated somewhat by revenues from the sale of groundwater permits. Capital and operational costs for surface water treatment and conveyance are calculated using established cost functions from the literature which are calibrated with regional data

gleaned from state records and consulting reports. Those choosing to remain on groundwater already have the required infrastructure in place and will therefore incur additional costs through the purchase of sufficient permitted capacity to compensate for groundwater pumping reductions. The price for these permits is a function of demand, which is, in turn, related to the number of communities joining the regional surface water system. A simplified description of the modeling framework involving only alternatives (1) and (2) can be described as beginning with an initial input for groundwater permit price. This is set arbitrarily high to start, such that all communities are assumed to find it less expensive to join a regional surface water system. Several potential sites for regional treatment facilities are preselected. Each community is then assigned to a regional site based on which provides it with the least expensive source. The cost to each community is determined through use of the treatment and conveyance cost functions, in combination with a minimum spanning tree algorithm that calculates the shortest pipe network that will serve each regional system. At the end of this first iteration, unused groundwater capacity exists, and market theory indicates that the price for groundwater permits should decline. Therefore, a new lower groundwater price is selected and translated to a cost for each community, which is then compared against each community's anticipated costs for joining the regional surface water system. As the price of groundwater continues to decline more communities choose to use groundwater, thereby resulting in an increase in surface water costs as the capacity of the regional system declines. This iterative process continues with successive reductions in the groundwater input price until total groundwater use (i.e. the sum of the amount retained by the original owners and the amount sold) is equal to the total available groundwater capacity. At this point, two additional conditions prevail, (1) all communities are using the source that results in the lowest cost at the tap for their customers, and (2) the costs associated with either groundwater or surface water in the "marginal" community (i.e. the last to join the regional facility) have converged toward equality. This is a substantial, but illustrative, simplification of the methodology that does not include discussion of how one considers all the possible regional permutations arising from discrete community decisions (e.g., what happens when the second community on a multi-city pipeline decides to convert to groundwater), the existence of tertiary supply alternatives, or changes in consumption with variable price. Results provide information on each community's supply choice, the costs incurred by each, and aggregate regional costs.

Principal Findings and Significance: Preliminary results indicate that approximately half of the 36 affected communities within the CCPCUA would find it economically attractive to join a regionalized surface water system. The remaining communities would either purchase groundwater pumping permits from surface water users, or tap tertiary alternatives (e.g., unregulated aquifers). Total capital cost to the region using this approach is $81 million, substantially lower than the $95 to $145 million range estimated if each community were to pursue water supply solutions in isolation. The annualized purchase price for groundwater permits is ~2.00/Kgal/yr, or a one time cost of $27.50/Kgal (amortized over 30 yrs at 6%). This translates to a cost increase that ranges from a few pennies to $1.00/Kgal at the tap, depending on the community. The total regional cost of meeting the proposed pumping restrictions is also being investigated to determine whether the choice of the 75% level places a substantially higher cost burden on regional communities than a lower level. Results indicate a relatively moderate, linear increase in costs if the cutback level is varied between 25% and 75%. Lastly, an exploration is currently underway to examine the relative cost reduction attributable to

regionalized systems and tradable permit schemes independent of one another. These results, combined with those described above, should prove useful to decision makers in North Carolina, as well as those in other states, that seek sustainable strategies for managing groundwater resources.

A Systematic Evaluation of Polyacrylamide for Sediment and Turbidity Control

Basic Information

Title:	A Systematic Evaluation of Polyacrylamide for Sediment and Turbidity Control
Project Number:	2002NC3B
Start Date:	3/1/2002
End Date:	2/28/2003
Funding Source:	104B
Congressional District:	2nd
Research Category:	Not Applicable
Focus Category:	Non Point Pollution, Surface Water, Water Quality
Descriptors:	
Principal Investigators:	Richard A McLaughlin

Publication

1. Bartholomew, Nathaniel, 2003, Polyacrylamide to Reduce Turbidity in Runoff as Affected by Soil and Polyacrylamide Properties, "MS Dissertation," Soil Science, College of Agriculture and Life Science, North Carolina State University, Raleigh, NC. In review.
2. N. Bartholomew, R. A. McLaughlin, and D.L. Hesterberg, 2002. Polyacrylamide to Reduce Turbidity in Runoff. Agronomy Society of America Annual Meetings.
3. S. A. Hayes, R. A. McLaughlin, N. Bartholomew, and D. L. Osmond. 2002. Polyacrylamide Use for Erosion and Turbidity Control. Agronomy Society of America Annual Meetings.
4. R. A. McLaughlin, S. A. Hayes, N. Bartholomew, and D. L. Osmond. 2002. Testing Polyacrylamides for Erosion and Turbidity Control. Soil and Water Conservation Society Annual Meetings.
5. McLaughlin, R. A. and J. W. Gilliam. 2002. Using Natural and Landscaped Buffers to Reduce Pollutant Loading from Agricultural Runoff. Water Res. Research Inst. Of the U. of N. C. Report # 340. 53 pages.
6. McLaughlin, R. A. 2002. Measures to Reduce Erosion and Turbidity in Construction Site Runoff. N. C. Dept. of Trans. & Ctr. For Trans. & Environ. Joint Project 2001-05 Final Report. 131 pages

Title: A Systematic Evaluation of Polyacrylamide for Sediment and Turbidity Control

Problem and Research Objectives:

We evaluated the effectiveness of a series of sediment and turbidity control systems that can be used as part of a typical sediment trap as well as innovative modifications. The objectives are:

1. Determine the effects of modifications to a typical sediment trap to optimize the effectiveness of PAM in reducing turbidity at the outlet.
2. Evaluate combinations of PAM and an electrolyte source for synergistic effects.
3. Evaluate the effects of moisture condition and temperature on PAM release from logs

Methodology:

1. Determine the range of modifications necessary to a typical sediment trap to optimize the effectiveness of PAM in reducing turbidity at the outlet. The experimental design involved three factors: baffles, outlet, and PAM. The baffle treatments included no baffles, standard silt fence baffles with weirs, and the proposed jute fence baffles. The outlet treatments were either standard rock dam or a skimmer with retention times of 10-12 hours. The PAM treatment was either none or a combination of two PAM logs (Applied Polymer Systems, Norcross, GA) proven to work well in our preliminary tests. The tests involved simulated storm flows that are changed every five minutes over a course of 25 minutes. Flows ranged up to a peak of 0.9 cfs at 10 minutes, for a total of approximately 800 cu ft (full basin). Soil was added manually at a constant rate at each flow rate, peaking at 120 lb/min at 10 minutes, for a total of 900 lb during the test. After each test, large deposits were removed from the basin and it was relined with filter fabric, which in turn was completely removed every 3-5 tests to maintain basin geometry.

2. Evaluate PAM and electrolyte combinations for synergistic effects:
   We tested different PAM products from different sources. Current work in another project has suggested a number of products with a relatively wide range of activity over different sediment sources. Each was tested at a range of concentrations which are at or below where they are most effective at flocculation. This was combined with a range of gypsum at or below where it begins to flocculate the sediment. Turbidity was measured 30 seconds after mixing.

3. Evaluate the effects of moisture condition and temperature on PAM release from logs.
   The tests were conducted at SECREF as described in 1. We conducted identical tests using APS Floc Logs either allowed to dry to the touch between tests or maintained under water. These were replicated during cold weather and warm weather.

Principal Findings and Significance:

Basin Design:

- The outlet type does not appear to be important under conditions where the PAM is effectively reducing turbidity in the basin. While the skimmer has been shown to be effective in improving sediment retention under typical conditions, the flocculation process may be successful enough to eliminate outlet effects. Our rock outlets are not new and do pool water for the first 0.2 – 0.4 m in the basin, so most of the water exiting the basin is from near the top of the water column. This is probably typical of rock outlets after several storms.
- Under conditions where PAM is effective, the jute/coir baffles were successful in reducing turbidity compared to no baffles in skimmer basins, but not always for rock outlet basins.

Electrolyte Interactions

- Gypsum reduced the effectiveness of PAM under most conditions, with greater concentrations hindering PAM more.
- When PAM concentrations exceed 1 mg/L, the turbidity actually rises for many soils. The addition of gypsum reduced or eliminated this effect.

PAM Log Conditions

- Turbidity is significantly more difficult to control under cold conditions. PAM was much less effective in the winter compared to the summer. This may be due to a combination of increased water viscosity and less PAM being eroded from the logs. We are currently conducting experiments to determine the cause.
- Pre-wetted logs are much more effective than logs which were initially dry.

Reuse of Wastewater from Septic Systems

Basic Information

Title:	Reuse of Wastewater from Septic Systems
Project Number:	2001NC801B
Start Date:	3/1/2002
End Date:	2/28/2003
Funding Source:	104B
Congressional District:	2th
Research Category:	Not Applicable
Focus Category:	Irrigation, Waste Water, Water Use
Descriptors:	Septic Tanks, Hydraulic Conductivity, Wastewater Irrigation
Principal Investigators:	Aziz Ammozegar, Wayne P. Robarge, Stuart L. Warren

Publication

Problem and Research Objectives: Approximately twenty-five percent of the US population and 50% of the people living in North Carolina use septic systems for managing their household sewage on-site. Assuming an average of 225 L (60 gallons) of wastewater flow per individual per day, and the estimated number of people using septic systems (4.15 million), the annual amount of wastewater added to North Carolina soils through septic systems exceeds 340 billion L. Reuse of treated wastewater from sewer treatment plants is not a new idea. However, limited research has been conducted on the use of graywater (wastewater generated from a dwelling excluding toilet, and kitchen sink/garbage disposal) for irrigation. According to the EPA, 21.7% and 1.4% of the volume of wastewater from residential dwellings are generated by washing machines and dishwashers, respectively. Assuming similar values for North Carolina, approximately 74 billion L of graywater generated annually by laundry facilities within individual residential dwellings can potentially be used for irrigation of landscape plants on-site. The specific objectives of the study were: (1) to assess the effect of wastewater from laundry and kitchen facilities of residential dwellings on soil hydraulic conductivity, and to determine the impact of surfactants and sodium hypochlorite present in laundry products on soil hydraulic conductivity and water retention, and 2) to evaluate the effects of untreated household wastewater generated by kitchen and laundry facilities plus a calcium amendment on growth and appearance of selected ornamental plants.

Methodology: The impact of wastewater from laundry and dishwashing machines on the saturated hydraulic conductivity (K_{sat}) of two soils and one saprolite was assessed in a laboratory. More than 60 intact cores, 6 cm in diameter and 10 cm long, were collected from each of a sandy soil, the Bt of a clayey soil, and one saprolite. Using the entire volume of wastewater generated by individual events from the laundry and dishwashing machines of the homes of a number of volunteers and tap water from the City of Raleigh, K_{sat} of each of the soils and the saprolite was measured using five replications. In two other sets of measurements, K_{sat} of each of the soils and saprolite was determined using three different solutions containing 150, 500, and 1000 mg/L sodium; and three different surfactant solutions containing 40 mg/L, 1 g/L, and 2 g/L of Biosoft S-120 neutralized with sodium hydroxide. In the greenhouse, the effects of untreated household wastewater generated by kitchen and laundry facilities on growth and appearance of eight ornamental plants planted in two different soils were investigated. The experiment was a 2 by 4 by 8 factorial in a completely random design with six replications. The main factors consisted of two soils, four irrigation treatments, and eight plants. The two soils were a Cecil (a clayey soil) and Norfolk (a loamy sand soil) from the Piedmont and Coastal Plain regions of North Carolina, respectively. The irrigation treatments were wastewaters from dishwashing machine and laundry facility of residential dwellings, laundry wastewater amended with $CaCl_2$, and tap water from the City of Raleigh. The amount of Ca amendment was based on the Na content of the laundry wastewater. The eight plants were 'Super Olympia Red' begonia, 'Celebrity Neon' petunia, 'Honeybells' hosta (*Hosta fortunei* 'Honeybells'), 'Compacta' Japanese holly (*llex crenata* 'Compacta'), 'Sunglow' azalea (*Rhododendron* sp. 'Sunglow'), willow oak (*Quercus phellos*), and loblolly pine (*Pinus taeda*). Plants were grown in a greenhouse in 3.8-L containers. The irrigation treatments were applied manually to plants every other day.

Principal Findings and Significance: Saturated hydraulic conductivity of the soils and saprolite measured using water remained relatively unchanged. Using graywater from laundry and dishwashing machines, on the other hand, resulted in substantial reduction in the measured K_{sat} within a few days. Saturated hydraulic conductivity of the Bt samples decreased for all sodium solutions, while K_{sat} of the saprolite samples showed a substantial increase during 12 days of measurements, and K_{sat} of the sand initially increased before declining. Using the 2-g/L and 1-g/L surfactant solutions resulted in substantial decreases in K_{sat} of the two soils and saprolite. For the 40-mg/L surfactant solution, K_{sat} of the sand gradually decreased to approximately 50% of the initial conductivity value, whereas the K_{sat} of the saprolite increased slightly. Thus, it appears the surfactants and not sodium reduce soil hydraulic conductivity following application of laundry or dishwashing graywater. Plant response to irrigation treatments was similar in both soils. The kitchen wastewater killed or severely injured every plant in the study. Plant response to the laundry wastewater and the $CaCl_2$ amended laundry wastewater was plant specific. Growth (final dry weight) of begonia, petunia, azalea, and loblolly pine irrigated with laundry wastewater and the $CaCl_2$ amended laundry wastewater was not significantly different from tap water. Growth of hosta, holly, and willow oak were significantly reduced by both laundry wastewater treatments compared to tap water. Growth of plants irrigated with $CaCl_2$ amended laundry wastewater was not significantly better than laundry wastewater. Compared to tap water, visual appearance of all plants except hosta was reduced by both laundry wastewater treatments. Visual appearance of most plants irrigated with $CaCl_2$ amended laundry wastewater was significantly greater than plants irrigated with laundry wastewater. Results of this study suggest that laundry wastewater has potential for use in irrigating landscape plants in North Carolina, whereas wastewater from dishwashing machine does not seem suitable as irrigation water.

Awards, Honors, promotions: None

Effect of Riparian Buffers on Removal of Nutrients and Sediment in Urban Streams

Basic Information

Title:	Effect of Riparian Buffers on Removal of Nutrients and Sediment in Urban Streams
Project Number:	2001NC1441B
Start Date:	3/1/2002
End Date:	2/28/2003
Funding Source:	104B
Congressional District:	6th
Research Category:	Water Quality
Focus Category:	Non Point Pollution, Nutrients, Sediments
Descriptors:	Riparian buffer, nutrients, sediments, Water Quality, Surface groundwater flowpaths
Principal Investigators:	Anne Hershey, Paul P Mou

Publication

1. Ulseth, A. J., 2003, The use of the natural abundance of 15N to evaluation the effects of anthropogenic N on the components of a headwater urban stream, MS Thesis," Department of Biology, College or Arts and Sciences, University of North Carolina at Greensboro, Greensboro, NC, 70 pages.
2. Mou, Paul P., Blair Bishop, and Anne E. Hershey. 2003. Effects of riparian buffers on removal of nutrients and sediment in urban streams. North Carolina Water Resources Research Institute, North Carolina State University, Raleigh, NC, 31 pages.
3. Bishop, B. B., P. P. Mou, A. E. Hershey. Urban Riparian Zones: Mitigation and Retention of Three Nutrient Species Known to Affect Water Quality. Water Resources Research Institute 2003 Annual Conference, NCSU, Raleigh, NC. (Oral presentation).
4. Hershey, A. E., A. J. Ulseth, and K. Fortino. Use of Stable Isotopes to Trace Sewage Effluent through a Forested Low-Order Stream in the Vicinity of Greensboro, NC. Water Resources Research Institute 2003 Annual Conference, NCSU, Raleigh, NC. (Oral presentation).
5. Ulseth, A.J., and A.E. Hershey. 2003. The use of the natural abundance of 15N and 13C to trace food web and anthropogenic nitrogen in an urban stream. Water Resources Research Institute 2003 Annual Conference, NCSU, Raleigh, NC. (Poster presentation).

6. Ulseth, A., K. Fortino, and A. E. Hershey. 2003. The use of the natural abundance of 13C and 15N to determine trophic differences between two coexisting species of crayfish.
7. Hershey, A. E., A. J. Ulseth, and K. Fortino. Use of Stable Isotopes to Trace Sewage Effluent through a Forested Low-Order Stream in the Vicinity of Greensboro, NC. Annual Meeting of the North American Benthological Society

Problem and Research Objectives:

Urban riparian zones are underutilized for removing anthropogenic nutrients derived from storm water. These areas have the potential to function similarly to riparian buffers in forested or agricultural areas, where they are recognized for their importance in protecting water quality in receiving systems.

Methodology:

We studied the effectiveness of urban grassy and forested riparian buffers by conducting an experimental addition of nutrient enriched (NH_4^+, NO_3^-, PO_4^{+2}) water and by sampling natural rainfall events along 50m riparian zone transects perpendicular to North Buffalo Creek, an urban stream in Greensboro, NC, that drains a headwater watershed of the Cape Fear River basin.

Principal Findings and Significance: (Please provide a progress report if the project is to be continued)

Due to drought conditions, sampling of rainfall events was not informative; there was no surface runoff and no downslope movement of nutrients through soil water. However, the experimental application of nutrient enriched water allowed us to examine the effect of season, sampling time (pre-addition, and days 1 and 2 post addition), location along the 50 m downslope transect, soil depth, and vegetation type. All nutrients showed a decrease in concentration along a down slope gradient across the riparian zone. Concentrations of all nutrients decreased significantly with soil depth. Treatment responses indicated that all nutrients showed greater changes in concentrations in the forested compared to the grassy sites. NO_3^- and PO_4^{+2} exhibited progressively greater changes with progression of seasons from winter to spring, but NH_4^+ did not change significantly with season. Patterns in nutrient retention during summer were more difficult to interpret because we experienced a severe drought. These results show that urban riparian zones are underutilized in removing nutrients from storm water, as well as for moderating storm water hydrology. Although forested riparian zones are more effective, grassy riparian zones also have considerable potential for retaining water and nutrients from storm water.

Information Transfer Program

In addition to activities related to specific research projects, WRRI maintains a strong information transfer program by cooperating with various state agencies and professional organizations to sponsor workshops and other events and by seeking grants for relevant activities. During the current fiscal year, WRRI was designated by the N.C. Board of Examiners for Engineers and Surveyors as an Approved Sponsor of Continuing Professional Competency activities for Professional Engineers and Surveyors licensed by the State of North Carolina. This allows WRRI to offer Professional Development Hours to engineers and surveyors for attending our water resources research seminars and our Annual Conference.

During the period March 1, 2002, to February 28, 2003, WRRI accomplished the following technology transfer activities:

Information transfer activities on 104 projects

Richard A. McLaughlin

Project summary published in WRRI Annual Program and online:
http://www2.ncsu.edu/ncsu/CIL/WRRI/annual/0203turbidity.html

Summary of recent research of erosion, sediment and turbidity control systems: Good, bad and ugly Presentation to WRRI Advisory Committee May 2002

Evaluations of Polyacrylamide for Erosion and Sediment Control Presentation at WRRI Annual Conference April 9, 2002

Innovative Technologies in Sediment and Erosion Control Presentation at Advanced Erosion and Sedimentation Control Workshops September and October 2002

Sediment and Erosion Control Research and Education Presentation at N.C. Erosion and Sedimentation Control Local Programs Workshop January 2002

Greg Characklis

Project summary published in WRRI Annual Program and online:
http://www2.ncsu.edu/ncsu/CIL/WRRI/annual/0203CCPCUA.html

Craig Allen

Project summary published in WRRI Annual Program and online:
http://www2.ncsu.edu/ncsu/CIL/WRRI/annual/0203buffers.html

Setting the Agenda for Water Resources Research

Basic Information

Title:	Setting the Agenda for Water Resources Research
Project Number:	2002NC36O
Start Date:	4/1/2002
End Date:	4/1/2002
Funding Source:	Other
Congressional District:	4th
Research Category:	Not Applicable
Focus Category:	None, None, None
Descriptors:	
Principal Investigators:	Kenneth H. Reckhow

Publication

Convened the Annual WRRI Conference, “Setting the Agenda for Water Resources Research in April 2002. Robert Hirsch of USGS, Laura Ahlers of the National Research Council, and Ken Reckhow, WRRI Director, delivered plenary addresses. Investigators from universities, agencies, industry, and consulting firms presented results of work on topics ranging from erosion and sedimentation control technologies to air borne water pollutants. Some 300 people participated in the conference. Participants had 48 technical presentations in 9 concurrent sessions from which to choose, as well as 37 technical posters to view. A booklet of abstracts was produced and distributed to participants. Abstracts were also made available on the WRRI website.

Erosion and Sediment Control for Construction Sites Seminar

Basic Information

Title:	Erosion and Sediment Control for Construction Sites Seminar
Project Number:	2002NC37B
Start Date:	9/24/2002
End Date:	10/24/2002
Funding Source:	104B
Congressional District:	
Research Category:	Not Applicable
Focus Category:	None, None, None
Descriptors:	
Principal Investigators:	Kenneth H. Reckhow

Publication

Organized and co-sponsored with the N.C. Division of Land Resources “Erosion and Sediment Control for Construction Sites Seminar” in September 2002 in Hickory, NC, and October in New Bern, NC. One hundred sixty-eight design professionals attended the Hickory seminar ; 158 attended the New Bern seminar.

Advanced Erosion and Sedimentation Control Workshops

Basic Information

Title:	Advanced Erosion and Sedimentation Control Workshops
Project Number:	2002NC38B
Start Date:	2/18/2003
End Date:	3/20/2003
Funding Source:	104B
Congressional District:	
Research Category:	Not Applicable
Focus Category:	None, None, None
Descriptors:	
Principal Investigators:	, Kenneth H. Reckhow

Publication

Organized and co-sponsored with the N.C. Division of Land Resources “Advanced Erosion and Sedimentation Control Workshops” March 2002 in Hickory and February 2003 in Raleigh, NC. One hundred seventy-four attended the Hickory workshop; 169 attended the Raleigh workshop.

Workshop for Local Erosion & Sediment Control Programs

Basic Information

Title:	Workshop for Local Erosion & Sediment Control Programs
Project Number:	2002NC39B
Start Date:	2/4/2003
End Date:	2/5/2003
Funding Source:	104B
Congressional District:	
Research Category:	Not Applicable
Focus Category:	None, None, None
Descriptors:	
Principal Investigators:	, Kenneth H. Reckhow

Publication

Organized and co-sponsored with the N.C. Division of Land Resources a “Workshop for Local Erosion and Sediment Control Programs” in February. One hundred eleven plan reviewers, inspectors, and managers of local programs attended.

Low-Impact Development (LID) Summit

Basic Information

Title:	Low-Impact Development (LID) Summit
Project Number:	2002NC40B
Start Date:	1/29/2003
End Date:	1/30/2003
Funding Source:	104B
Congressional District:	
Research Category:	Not Applicable
Focus Category:	None, None, None
Descriptors:	
Principal Investigators:	, Amy (Jeri) B Gray

Publication

Secured funding and organized a “Low-Impact Development (LID) Summit” in January 2003. With funding from a CWA 319 grant through the N.C. Department of Environment and Natural Resources (DENR) and a grant from the N.C. Urban Water Consortium Stormwater Group, WRRI cooperated with N.C. DENR and the NC State University College of Design to convene a group of technical experts from across the state to study and make recommendations on technical design considerations, regulatory issues, and research, demonstration and outreach needs for implementing LID in Piedmont North Carolina.

Southeastern Regional Small Drinking Water Technical Assistance Center

Basic Information

Title:	Southeastern Regional Small Drinking Water Technical Assistance Center
Project Number:	2002NC41B
Start Date:	2/1/2003
End Date:	2/28/2003
Funding Source:	104B
Congressional District:	
Research Category:	Not Applicable
Focus Category:	None, None, None
Descriptors:	
Principal Investigators:	Amy (Jeri) B Gray

Publication

Completed a project funded by the Southeastern Regional Small Drinking Water Technical Assistance Center to provide information to rural churches operating transient non-community public water systems to help them comply with sampling, monitoring, and reporting requirements under the Safe Drinking Water Act. Cooperating on the project were the N.C. Public Water Supply Section and the N.C. Rural Water Association

NC Water Resources Association Luncheon Forums

Basic Information

Title:	NC Water Resources Association Luncheon Forums
Project Number:	2002NC42B
Start Date:	4/1/2002
End Date:	2/1/2003
Funding Source:	104B
Congressional District:	
Research Category:	Not Applicable
Focus Category:	None, None, None
Descriptors:	
Principal Investigators:	Greg Jennings

Publication

Organized and coordinated the following luncheon-forums for the N.C. Water Resources Associations:

- April 2002 – Total Maximum Daily Loads (TMDLs)
- September 2002 - Drought
- December 2002 –Air Borne Water Pollutants
- February 2003 – Geographic Information Systems

WRRI Research Seminar Series

Basic Information

Title:	WRRI Research Seminar Series
Project Number:	2002NC43B
Start Date:	4/1/2002
End Date:	2/1/2003
Funding Source:	104B
Congressional District:	
Research Category:	Not Applicable
Focus Category:	None, None, None
Descriptors:	
Principal Investigators:	Greg Jennings

Publication

Organized and sponsored the following seminars by investigators working under WRRI grants:

- April 2002 – Tracking Drought Impact on Managed and Unmanaged Ecosystems of NC by Dr. Lawrence E. Band and Dr. Aaron Moody, UNC-Chapel Hill
- May 2002 Role of Sediment Processes in Regulating Water Quality of the Cape Fear River by Dr. P.V. Sundareshwar, Nicholas School of the Environment, Duke University
- September 2002 Effect of Riparian Buffers on Removal of Nutrients and Sediment in Urban Streams by Dr. Anne E. Hershey, UNC-Greensboro
- October 2002 Effectiveness of Four Best Management Practices for Reducing Nonpoint Pollution from Piedmont Tobacco Fields by Dr. E. Carlyle Franklin, NC State University
- November 2002 Predicting Long-Term Wetland Hydrology Using Hydric Soil Field Indicators by Dr. Michael J. Vepraskas, NC State University
- January 2003 Technical, Economic and Environmental Evaluation of Alternatives for Animal Waste Management in North Carolina by Dr. Michael R. Overcash, NC State University
- February 2003 Ultraviolet-based Processes for Meeting Water Quality Goals: Microbial and Chemical Contaminants by Dr. Karl G. Linden, Duke University

The Institute NEWS

Basic Information

Title:	The Institute NEWS
Project Number:	2002NC44B
Start Date:	3/1/2002
End Date:	2/1/2003
Funding Source:	104B
Congressional District:	
Research Category:	Not Applicable
Focus Category:	None, None, None
Descriptors:	
Principal Investigators:	Amy (Jeri) B Gray

Publication

Published the *WRRI News* six times during the reporting period. The WRRI News is a 16-page newsletter that covers a wide range of water-related topics from current federal and state legislation and regulatory activities to new research findings, water-related workshops and conferences, and reviews of water-related publications. The WRRI News is sent to nearly 4,300 federal and state agencies, university personnel, multi-county planning regions, city and local officials, environmental groups, consultants, businesses and individuals.

The Sediments News

Basic Information

Title:	The Sediments News
Project Number:	2002NC45B
Start Date:	3/1/2002
End Date:	2/1/2003
Funding Source:	104B
Congressional District:	
Research Category:	Not Applicable
Focus Category:	None, None, None
Descriptors:	
Principal Investigators:	Amy (Jeri) B Gray

Publication

Published four issues of the *Sediments* newsletter. WRRI publishes this newsletter for the N.C. Sedimentation Control Commission to provide information and assistance to the regulated community and to facilitate communication among personnel of state and local erosion and sediment control programs. Current circulation is about 5,800.

WRRI Website

Basic Information

Title:	WRRI Website
Project Number:	2002NC46B
Start Date:	3/1/2002
End Date:	2/1/2003
Funding Source:	104B
Congressional District:	
Research Category:	Not Applicable
Focus Category:	None, None, None
Descriptors:	
Principal Investigators:	Amy (Jeri) B Gray

Publication

Maintained the WRRI website (http://www2.ncsu.edu/ncsu/CIL/WRRI). The website provides on-line access to the WRRI News, the WRRI Annual Program, technical report summaries, the schedule of water research seminars, a water resources research expertise directory, and information on workshops, conferences, calls for papers, and public hearings.

WRRI Annual Program

Basic Information

Title:	WRRI Annual Program
Project Number:	2002NC47B
Start Date:	3/1/2002
End Date:	2/1/2003
Funding Source:	104B
Congressional District:	
Research Category:	Not Applicable
Focus Category:	None, None, None
Descriptors:	
Principal Investigators:	Amy (Jeri) B Gray

Publication

Published the 2002-2003 WRRI Annual Program. This 16-page publication includes synopses of all new research projects and updates on continuing projects, a review of technology transfer activities, and the announcement of the upcoming year's research seminars. It is sent to all newsletter subscribers.

New WRRI Research Reports

Basic Information

Title:	New WRRI Research Reports
Project Number:	2002NC48B
Start Date:	3/1/2002
End Date:	2/1/2003
Funding Source:	104B
Congressional District:	
Research Category:	Not Applicable
Focus Category:	None, None, None
Descriptors:	
Principal Investigators:	Kenneth H. Reckhow

Publication

New WRRI Research Reports – A strong demand for Institute reports continues. During the year, the Institute published the following reports for distribution to users throughout the state and nation.

WRRI-337 - Assessment of Trace Elements Concentrations in Municipal Wastewater Treatment Plant Discharges in North Carolina.

WRRI-338 - Occurrence of Bacterial Regrowth and Nitrification in the Raleigh Distribution System and Development of an Epanet Model for Future Assessments.

WRRI-339 – Biologically Mediated Nitrogen Dynamics in Eutrophying Estuaries. Assessing Dentrification N2 Fixation and Primary Productivity Responses to Proposed N Loading Reductions in the Neuse River Estuary.

WRRI-340 – Using Natural and Landscaped Buffers to Reduce Pollutant Loading from Agricultural Runoff.

WRRI-342 – Predicting Long-Term Wetland Hydrology From Hydric Soil Field Indicators.

Student Support

Student Support					
Category	**Section 104 Base Grant**	**Section 104 RCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	3	0	0	0	3
Masters	2	0	1	0	3
Ph.D.	1	0	1	0	2
Post-Doc.	1	0	0	0	1
Total	7	0	2	0	9

Notable Awards and Achievements

Publications from Prior Projects

1. 2000NC10B ("Predicting Long-term Wetland Hydrology Using Hydric Soil Field Indicators") - Articles in Refereed Scientific Journals - He, X.; M.J. Vepraskas, R.W. Skaggs, and D.L. Lindbo. 2002. Adapting a drainage model to simulate water table levels in coastal plain soils. Soil Science Society America Journal 66(5):1722-1731.