Water Resources Research Institute of the University of North Carolina
Annual Technical Report
FY 2004

Introduction

During the Fiscal Year 2004 reporting period, the Water Resources Research Institute of The University of North Carolina supported research from five universities for seven related projects. Research priorities, as directed by the WRRI (Water Resources Research Institute) Advisory Committee included the following: Existing and emerging contaminants; Water supply/drought issues, Erosion and sediment control/stormwater, Nutrients and water quality, Agronomic issues, Water/wastewater financing and funding, Economic and regulatory issues, Basin management, Infrastructure issues, On-site wastewater management, and Monitoring and data analysis. The research projects reported herein provide relevant data within the WRRI priority constraints.

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 reearch are disseminatee 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 Annual Conference. WRRI continues to be a sponsor of continuing education credits by the NC 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

The Water Resources Research Institute of The University of North Carolina is responsible for fostering and developing a research training and information dissemination program responsive to the water problems of the State and region. To develop its' programs, the Institute maintains an aggressive effort to interact and communicate with federal, state, and local water managers. The close contact with water managers is a basis for determining the ever-changing water research priorities.

Priority water research needs for the FY 2004 program were developed in close consultation with the Institutes' Advisory Committee. Following their annual meeting a statement of priority research needs was developed. The proposal solicitation, as in the past, is sent to all presidents and relevant department heads of senior colleges and universities in North Carolina to apprise them of the opportunity to submit proposals. The call for proposals is also sent to an email distributuion list of about 130 university faculty across North Carolina. A special mailing is also sent to the historically black colleges and universities in North Carolina. The proposals received are sent to the Technical Committee and to external peer reviewers to determine the relevancy, need for the proposed research and relative strength and weaknesses. Federal and state agency representatives, local government officials, and other water resources leaders are also sent proposals for their comment. The Technical Committee meets to review all comments made by reviewers and to make recommendations regarding proposal funding. Factors

considered in the review of proposals are: (1) scientific quality of the proposed work; (2) need for the results of the research in North Carolina and the region; (3) the probability that useful results can be obtained in one-year; and (4) the potential for the continued support from other funding sources.

The only change that has taken place during the FY 2004 program is the priority research needs. The highest priorities focus on the areas of: existing and emerging contaminants; water supply/drought issues; erosion and sediment control/stormwater; nutrients and water quality; agronomic issues; water/wastewater financing and funding; economic and regulatory issues; basin management; infrastructure issues; on-site wastewater management; and monitoring and data analysis.

Is There a Relationship Between Phosphorus and Fecal Microbes in Aquatic Sediments?

Basic Information

Title:	Is There a Relationship Between Phosphorus and Fecal Microbes in Aquatic Sediments?
Project Number:	2004NC36B
Start Date:	3/1/2004
End Date:	8/31/2005
Funding Source:	104B
Congressional District:	7
Research Category:	Water Quality
Focus Category:	Non Point Pollution, Nutrients, Sediments
Descriptors:	Phosphorus, Bacteria, River Beds, Stormwater Mgmt.
Principal Investigators:	Lawrence B. Cahoon, Michael A. Mallin

Publication

1. 1. Articles in Refereed Scientific Journals: One manuscript in preparation.
2. 2. Book Chapters: None to report.
3. 3. Dissertations: Five M.S. theses will eventually acknowledge this project for all or part of the work.
4. 4.Water Resources Research Institute Reports: One will be produced later this year in 2005.
5. 5.Conference Proceedings: None to report.
6. 6.Other Publications: Cahoon, L.B., Michael A. Mallin, Byron R. Toothman, Michelle L. Ortwine, Renee N. Harrington, Rebecca S. Gerhart, Shannon L. Alexander, and Tara D. Blackburn, 2005, Presentation at WRRI Annual Conference: Fecal Contamination of Tidal Creek Sediments Relationships to Sediment Phosphorus and Among Indicator Bacteria, WRRI Annual Conference, April 5, 2005, http://www.ncsu.edu/wrri/events/conference/2005ac/index.html#annconf . Cahoon, L.B., Michael A. Mallin, Byron R. Toothman, Michelle L. Ortwine, Renee N. Harrington, Rebecca S. Gerhart, Shannon L. Alexander, and Tara D. Blackburn, 2005, Presentation at WRRI Annual Conference: Fecal Contamination of Tidal Creek Sediments Relationships to Sediment Phosphorus and Among Indicator Bacteria, N.C. Academy of Science, March 19, 2005.

Title

Is There a Relationship Between Phosphorus and Fecal Microbes in Aquatic Sediments?

Problem and Research Objectives

Phosphorus (P) pollution is well known to contribute to eutrophication problems in North Carolina's waters. A phosphate detergent ban in 1989 and other measures to limit point and non-point source discharges of pollutants have implicitly recognized the potential for phosphorus to cause water quality problems. Recent increases in soil P levels in much of eastern North Carolina, caused by application of animal manures and use of commercial fertilizers, have resulted in a stronger emphasis on agricultural P management, evidenced by North Carolina's promulgation of a Phosphorus Loss Assessment Tool (PLAT). However, the rationale for these management measures has been control of algal blooms. Only recently has the importance of P limitation of bacteria in aquatic ecosystems been recognized.

Recent research, including some of our work in estuarine ecosystems, shows that sediments frequently support concentrations of fecal bacteria high enough to close the overlying waters for human uses if resuspended. A number of studies have now shown that P may be particularly important in supporting the persistence and re-growth of fecal bacteria in sediments. Phosphorus has a strong affinity for particulates, so most P in aquatic ecosystems is associated with sediments. We propose to test the hypothesis that P loading to aquatic sediments supports survival and growth of fecal microbes in aquatic sediments. The project proposed here is relevant to WRRI priority research needs in the areas of "Nutrients and water quality", "Agronomic issues", "Erosion and sediment control/stormwater", and "Monitoring and data analysis".

This project will address the hypothesized linkage between P and microbial contamination of aquatic sediments. If P loading enhances the importance of aquatic sediments as a reservoir of microbial contaminants, then measures to limit P loading to surface waters take on added urgency. Appropriate measures might include P discharge standards for WWTP, robust measures to limit P loading from agricultural operations, efforts to reduce P pollution from residential sources, and better non-point source pollution control measures.

The field (observational) component of this project will generate estimates of sediment P and sediment fecal microbe concentrations from a wide variety of aquatic habitats, spanning undeveloped, agricultural, residential, and urbanized watersheds across the Coastal Plain region of North Carolina. There are few data on these parameters, yet the bulk of P and fecal microbes in shallow aquatic habitats may be associated with sediments. Findings may be useful in identifying land uses and potential sources associated with high levels of these contaminants. Findings may also be useful in adjusting the focus of ongoing monitoring programs, perhaps by adding measurement of sediment parameters.

Microbial contamination of surface waters, particularly by fecal material, is one of the most challenging problems facing environmental managers, necessitating closures of large areas of otherwise economically valuable waters to shellfishing and recreational uses. North Carolina currently has over 300,000 acres of estuarine waters closed to shellfishing, and 40,000 acres conditionally closed to shellfishing following rain events.

It can be argued that the sources and mechanisms of loading of fecal microbial contamination and P in watersheds are sufficiently similar that correlations between these parameters are not evidence of causality. However, evidence of P stimulation of bacterial growth and the relatively greater requirements for P by microbial populations in comparison to the Redfield ratio for microalgae argue strongly for a causal connection between P pollution of sediments and fecal microbial persistence and re-growth in sediments. Consequently, the researchers propose to test the hypothesis that phosphorus concentrations limit fecal microbial concentrations in aquatic sediments.

Both observational and experimental approaches will be used to test the main hypothesis. Two objectives are proposed:
1. To determine the relationship between sediment phosphorus levels and sediment concentrations of fecal indicator bacteria (fecal coliforms and fecal enterococci) in several different watersheds in eastern NC. Several considerations apply to this objective. First, we will sample in a wide range of habitats to provide a sufficient range of parameter values to detect a relationship if one exists. Second, the inherent variability in fecal microbial concentrations is significant. Third, a rectilinear relationship likely exists between sediment fecal microbial concentrations and P levels, meaning that some other factor limits microbial populations above a certain P level, so we will measure a variety of other potentially relevant parameters. Fourth, “sediment P” must be defined by the measurement techniques utilized.
2. To determine experimentally the response of fecal microbial concentrations in sediments to manipulated variations in phosphorus availability. Observational studies alone are insufficient to establish causal relationships in this situation, so experimental manipulations of the key variable(s) are necessary.

Methodology

The researchers will employ: 1) an observational field sampling effort that will seek evidence of statistical relationships between sediment P and sediment fecal microbe concentrations, as well as values of related parameters. Determination of statistical relationships in the field will be vital for further use of our results and may identify patterns that provide additional insights. Estimates of natural variability will determine the predictive power of relationships our analyses disclose; 2) an experimental approach in which we will manipulate phosphate concentrations and examine the responses of sediment fecal microbes. Manipulation is essential to distinguish covariation and independent effects.

We will sample at sites that are monitored routinely for various water quality parameters as part of the Lower Cape Fear River Monitoring Program, the Wilmington Watersheds

Program, or the New Hanover County Tidal Creeks Program, some but not all shown here. These sites (a total of 93 that are regularly sampled) encompass a variety of undeveloped, agricultural, residential, and urbanized watersheds. Excluding deep-water sites in the river and lower tidal creeks we will sample over 60 locations, providing a robust data set for statistical analysis of field data. Preliminary sediment persulfate-P data from a subset of these sites range from 0 to ~45 ug P(g sediment)$^{-1}$.

Sediment parameters may exhibit inherently high variability among replicate samples. The statistical challenge is to determine the magnitude of variability among replicate samples from the same location so that the power of statistical distinctions can be determined. Consequently, we will analyze the response of variability to replicate numbers for samples from a selected set of locations in order to have a sound statistical basis for subsequent sampling designs. The analytical parameters of interest are sediment P and [fecal microbes]. Sediment organic content, grain size distribution, carbohydrate and protein content are also of interest, the latter as indices of biological properties of the sediment. Some sediment parameters must be analyzed for fresh, wet sediment, while others can be analyzed using lyophilized sediment samples, as described below. LBC's lab has a Virtis Benchtop 3.3 Lyophilizer.

Laboratory fecal microbial growth experiments will also test the hypothesis. Sediment cores collected from selected locations (based on watershed type and observed sediment P concentrations) will be returned to the laboratory and incubated in sterile 2.5 cm diam cylindrical tubes to which filter-sterilized ambient water and supplemental phosphate have been added. The concentrations of added phosphate will be 0 (control), 10, 100, or 1000 ug P L^{-1}. Replicate tubes will be incubated for an additional 24 h at 30^{o}C and analyzed for sediment fecal coliforms and fecal enterococci as described above. This design will initially employ 6 replicates of each treatment for a total of 24 sediment tubes per location/experiment, pending preliminary experiments and statistical power analysis. This experiment will be repeated in at least 4 areas with watersheds of differing character and in summer and winter to allow investigation of the effects of these factors on responses. Statistical analysis of the overall data set, following expected log transforms of the fecal microbial concentration data, will employ a 3-way analysis of variance for effects of the variables phosphate concentration, season, and location on [fecal coliforms] and [fecal enterococci]. We will use SNK or Tukey-Kramer *a posteriori* tests to distinguish among levels of each significant treatment effect.

Principal Findings

Field sampling of sites throughout the Wilmington watersheds, New Hanover County tidal creeks, and Lower Cape Fear River project areas is continuing into the summer season. Sampling includes sediment sample collection for analysis of fecal coliforms, fecal enterococcus, phosphorus forms, carbohydrate content and protein content. Water column sampling has continued in conjunction with sediment sampling, with measures of salinity, temperature, turbidity, and DO. Additionally, benthic chlorophyll a samples continue to be taken at all sites. Total sites sampled exceed 30, with a combination of

fresh water and estuarine sites, natural waters and man-made features, and remote and heavily used locations.

We have completed sequential phosphorus extractions of a large number of sediment samples according to the modified procedure described earlier. This procedure involves Mehlich III extraction of reactive phosphorus, acid extraction of authigenic phosphorus, and combustion/acidification extraction of particulate organic phosphorus. This work complements alternate analysis of the same samples for sediment phosphorus by persulfate digestion.

Mehlich III and total phosphorus data show that the lowest sediment phosphorus values (<20 ug P/g sediment) are associated with drainage features in areas with no anthropogenic impacts (forested drainages) and that the highest values (>50 ug P/g sediment) are associated with proximal agricultural activities that include fertilization, either by conventional fertilizers or animal waste applications. Sediments in natural drainages typically have phosphorus values in the low-moderate range of values (20-50 ug P g sediment), but are not as low as expected. Sediments in tidal creeks and near boat ramps typically have sediment phosphorus in the moderate or even high range of values we have seen.

Preliminary analysis of our data shows several patterns. First, the investigators continue to find no significant correlation between fecal bacteria (coliforms, streptococcus, or enterococcus) and any measures of sediment phosphorus in any set of habitats, contrary to our primary hypothesis. This result may reflect the generally high values of sediment phosphorus we have measured in almost all aquatic habitats we are sampling now, compared to the low, and apparently limiting, levels of sediment phosphorus previous study showed to be important for sediment fecal coliform bacteria. Thus, some other factor(s) may be limiting these indicator bacteria populations. Consequently, we have now begun field experiments in which very low and very high (1 ug P/L 100 ug P/L) P concentrations in combination with low and high values of organic carbon will be provided in interstitial waters to compare fecal indicator bacteria responses. We also directed more sampling effort at habitats that presented the likelihood of low sediment phosphorus and/or low fecal indicator bacteria concentrations to improve the resolution of our statistical analysis. These efforts showed very low bacteria numbers (zero coliforms at all sites, <5 CFU/cm^2 Enterococcus) but moderate P values (6 to 45 *u*g P/g sediment), suggesting some other limiting factor as well.

Analyses of sediment carbohydrate contents (a measure of organic carbon availability) are almost completed for samples in hand. Results so far indicate a large range of values (73 to 25,000 *u*g total carbohydrate/g sediment, mean = 7200), suggesting that appropriate statistical analyses may provide interesting information about relationships to bacterial numbers when the analyses are complete. Sediment protein analyses are about to begin.

Analysis of the fecal indicator bacteria data to date also have yielded some interesting results. As reported previously, ranges of these bacteria concentrations are large, from

zero to counts in the $10^3 – 10^4$ CFU cm^{-2} sediment. These higher values are potentially indicative of threats to human health if resuspension and human exposure occur. The summer values we are now collecting should provide the most relevant assessment of human risk. It should be noted that our data on fecal streptococcus and fecal enterococcus concentrations ion sediments are the first such measures of which we are aware, certainly in NC aquatic habitats. We have examined these data first by analyzing correlations among the bacteria types. Fecal coliforms and enterococcus correlate significantly with moderate predictability ($r = 0.56$), coliforms correlate significantly but with relatively poor predictability ($r = 0.28$) with streptococcus, but enterococcus and streptococcus do not correlate significantly, an odd result, as streptococcus is a subset of the enterococcus group. In order to save resources and focus effort more profitably, we discontinued streptococcus analyses in April.

Benthic microalgal samples have been collected and processed from the tidal creek locations for summer and fall 2004 and spring 2005. The latest group, as before, shows generally highest benthic chlorophyll a concentrations in Bradley Creek, the most urbanized creek. Second highest were found in Hewletts Creek, also very urbanized. Collections are now underway to obtain early summer benthic microalgae from the tidal creek sites. Along with allowing us to examine benthic microalgae abundance in relation to nutrient levels and bacteria concentrations, We will be able to compare them with water column chlorophyll a to determine if there is an inverse relationship between these groups of primary producers.

Significance

Findings may be useful in identifying land uses and potential sources associated with high levels of these contaminants. Findings may also be useful in adjusting the focus of ongoing monitoring programs, perhaps by adding measurement of sediment parameters.

Arsenic and Heavy Metal Leaching Potential from Broiler Litter Stockpiled on Bare Soil

Basic Information

Title:	Arsenic and Heavy Metal Leaching Potential from Broiler Litter Stockpiled on Bare Soil
Project Number:	2004NC41B
Start Date:	3/1/2004
End Date:	6/30/2005
Funding Source:	104B
Congressional District:	2 & 4
Research Category:	Ground-water Flow and Transport
Focus Category:	Toxic Substances, Solute Transport, Groundwater
Descriptors:	poultry, copper, mananese, zinc, nitrate, phosphate
Principal Investigators:	Sanjay B. Shah, Garry L. Grabow, David H. Hardy, Dean Hesterberg, Rodney L Huffman, James Parsons

Publication

1. 1.Articles in Refereed Scientific Journals: None to report.
2. 2.Book Chapters: None to report.
3. 3.Dissertations: None to report.
4. 4.Water Resources Research Institute Reports: None to report.
5. 5.Conference Proceedings: None to report.
6. 6.Other Publications: Shah, S.B., G. Grabow, D. Hesterberg, R. Huffman, J. Parsons, K. Hutchison, D. Hardy, and B. Jackson, 2005, Poster Abstract: Arsenic and Heavy Metal Leaching Potential from Turkey Litter Stockpiled on Bare Soil, in process for 2005 ASAE Annual International Meeting, Tampa, Florida, USA.

Title

Arsenic and Heavy Metal Leaching Potential from Broiler Litter Stockpiled on Bare Soil (70208)

Problem and Research Objectives

Poultry production generates large amounts of waste in the form of poultry litter, a mixture of bedding material, manure, feathers, feed, and water. Frequently, poultry litter is stockpiled on bare soil close to the poultry houses or farmstead. Depending on management practice, soil and weather conditions, and crop cycle, the producer may stockpile the litter for months at the same location before land application. Soluble constituents of poultry litter stockpiled on bare soil may be transported by rainfall into the soil, both beneath and in the vicinity of the stockpile. Litter stockpiling duration and frequency, litter properties, soil properties, rainfall, and depth to the groundwater are some factors that could affect the transformation, mobility, and toxicity of poultry litter constituents, and could thus increase the potential for groundwater contamination, with potential adverse health and environmental effects. Risk of groundwater contamination by soluble poultry litter constituents is high in the Coastal Plain of North Carolina and Delaware where there are coarse-textured soils with high water tables and large poultry industries.

North Carolina ranks fourth, behind Georgia, Arkansas, and Alabama in broiler production, with >735 million broilers produced in 2002. After raising broilers for 6 weeks, the producer empties the broiler house and brings in a fresh batch of broiler chicks. Depending on the recommendations of the broiler integrator and farm management practices, some producers will replace the litter every grow-out, remove only the crusted litter after every grow-out or reuse the old litter for a number of grow-outs. While some producers employ custom applicators to remove and land-apply the litter, others will use farm labor to remove and land-apply the litter. However, due to soil and crop conditions as well as time and equipment constraints, a large number of producers stockpile litter for long durations before land-applying the litter. While storing litter in covered sheds with concrete floors reduces the potential for nutrient losses in rainfall-induced runoff and leaching, many producers stockpile litter on bare soil without any cover due to cost and flexibility considerations. Steve Rackley of Nash Johnson and Sons (poultry integrator) estimated that 95% of broiler producers stockpiled litter on bare soil (personal communication, Kenansville, N.C., 9 September 2003). In North Carolina, broiler litter is generally stockpiled over the winter months and then applied to corn ground in spring. While some producers apply broiler litter to hayfields during summer, in the absence of disposal alternatives, many producers will stockpile broiler litter for application to winter wheat in fall. Litter constituents in the stockpile could be transformed into more mobile and toxic species due to favorable litter (e.g., high dissolved organic C and microbial concentrations) and environmental (e.g., high temperature and moisture content) conditions, resulting in leaching of the compounds out of the litter stockpile. Because of the high localized concentrations of potentially-toxic

As and metals in a poultry litter stockpile, a plume of leached constituents could move through the soil and possibly impact groundwater.

While NO_3^--N leaching from animal waste application and turkey manure piles has been identified as a source of concern to groundwater quality, no work on the impact of leaching of metals from litter stockpiles could be located. However, there is evidence of As leaching into irrigation wells due to organic As herbicides in cotton (Bednar et al., 2002). Further, litter constituents such as phosphate, NO_3^--N, and organic C could increase transformation of As and its mobility in the soil. In the Coastal Plain, the surficial, unconfined aquifer which is usually within 6 m of the soil surface and much higher during the wetter months, could be used as a water supply source. Broiler litter stockpiling, combined with litter characteristics, and soil and environmental conditions, could result in contamination of groundwater resources by litter constituents, including metals. While this study will focus on broiler litter stockpiling, its impacts would also extend to turkey production (NC is the second largest turkey producer behind Minnesota), since management practices and litter quality are similar for broilers and turkey. Hence, the proposed study will be used to monitor transformations of As, Cu, Mn, Zn, N, and P species, and changes in total C concentrations in the litter stockpile. Further, the study will be used to evaluate leaching of As species, NO_3^--N, ammoniacal-N, phosphate, Cu, Mn, and Zn from broiler litter stockpiled on bare soil.

The scope of the proposed research is to monitor As, N, and P transformations, and total C (for C/N ratios) concentrations within the litter stockpile and movement of litter constituents in the upper 0.9 m (3 ft) of soil beneath and adjacent to stockpiled broiler litter under both, natural and simulated rainfall. Two batches of litter will be stockpiled during the 12-month study on a site that has not been previously contaminated with animal waste or metal containing compounds. Each batch will remain on the site for ~5 months and the site will be bare for 2-3 weeks between the two batches of litter stockpiles.

The goal of the proposed research is to evaluate the potential of constituents in broiler litter stockpiled on bare soil to contaminate groundwater. The specific research objectives are:

1. to evaluate transformations of As, N, and P species and changes in total C concentrations at different depths within the stockpiled broiler litter, and
2. to monitor movement of As species, NO_3^--N, ammoniacal-N, phosphate, Cu, Mn, and Zn beneath and around the litter stockpile.

Methodology

The project will involve field research and laboratory analyses. Field research will be conducted at NCSU's Horticultural Crops Research Station in Clinton and laboratory analyses will be performed at the Environmental Analysis Laboratory (Bio. & Ag. Engineering Dept., NCSU), Soil Physical Properties Laboratory (Bio. & Ag. Engineering Dept., NCSU), Analytical Services Laboratory (Soil Science Dept., NCSU), and NCDACS's Testing Laboratories.

Temporal changes in constituent (As species, N species, P species, carbon, Cu, Mn, and Zn) concentrations in broiler litter stockpiles as well as in underlying and adjacent soil at various depths will be investigated. Four broiler litter stockpiles will be monitored during summer through fall and four more during fall through spring; in each batch, two stockpiles will be monitored under natural rainfall and two more under simulated rainfall. Litter analyses at the beginning and end of stockpiling will provide information on the impact of stockpiling and environmental conditions on the transformation and mobility of constituents. Soil sampling in the upper 0.9 m (3 ft) of soil in different depth increments, before and after stockpiling, will provide information on the leaching of litter constituents in the soil and its potential impact on groundwater quality over time. Further information related to As mobility as influenced by soil phosphate concentrations will also be obtained.

This research will determine whether leaching of potentially-toxic groundwater contaminants, particularly As is a concern when broiler litter is stockpiled on bare soil. Environmental conditions favoring transformations of potentially harmful litter constituents into more mobile forms will be assessed. Such information could be used by state and federal agencies concerned about groundwater quality to evaluate measures to safeguard public health and the environment. If necessary, measures for reducing or eliminating any harmful impacts of poultry feed additives could be developed based on the study results.

The risk of leaching of harmful poultry litter constituents into the soil and its potential impact on groundwater would be obtained. Such information could be used in developing preventative and/or remedial measures to protect groundwater quality. State and federal agencies could work with producers currently stockpiling poultry litter on bare soil as well as those who stockpiled in the past to reduce/eliminate the potential threat to groundwater.

Correlations between plant-available constituent (P and metals) concentrations obtained with the less expensive Mehlich III extraction method vs. total concentrations obtained with more expensive methods would be developed. While correlations would only be developed for a limited number of soils, this relationship between plant-available concentrations and total concentrations may better help NC Department of Agriculture and Consumer Services (NCDACS) use Mehlich III data as an indicator of adverse environmental impacts.

Principal Findings

All soil and turkey litter samples obtained during the November 2004 sampling are being analyzed. The four new turkey litter stockpiles established in November 2004 are under observation at the field site in Clinton, NC. They could not apply simulated rainfall to two of the four stockpiles as originally proposed since the irrigation system had been winterized and there was reluctance at the Research Station to apply irrigation since the

system would again require winterization. The stockpiles were dismantled the last week of April 2005. The turkey litter and soil will be sampled as was done in November 2004.

Significance

Measures for reducing or eliminating any harmful impacts of poultry feed additives could be developed based on the study results. This information could also be used to develop preventative and/or remedial measures to protect groundwater quality. While correlations would only be developed for a limited number of soils, this relationship between plant-available concentrations and total concentrations may better help NC Department of Agriculture and Consumer Services (NCDACS) use Mehlich III data as an indicator of adverse environmental impacts.

Integration of High Resolution Imagery in Cost-effective Assessment of Land Use Practices Influencing Erosion and Sediment Yield

Basic Information

Title:	Integration of High Resolution Imagery in Cost-effective Assessment of Land Use Practices Influencing Erosion and Sediment Yield
Project Number:	2004NC42B
Start Date:	3/1/2004
End Date:	6/30/2005
Funding Source:	104B
Congressional District:	4
Research Category:	Water Quality
Focus Category:	Water Quality, Sediments, Non Point Pollution
Descriptors:	remote sensign, land use/land cover, water quality
Principal Investigators:	Siamak Khorram, Stacy Nelson

Publication

Title

Integration of High Resolution Imagery in Cost-effective Assessment of Land Use Practices Influencing Erosion and Sediment Yield (70207)

Problem and Research Objectives

National concerns have increasingly focused on the degradation of this nation's water quality and associated resources. As the Nation's population increases, so does society's ability to continuously alter the landscape leading to amplified surface loadings from storm and watershed overflow, increased suspended sediments in runoff, and agricultural and industrial drainage problems. Monitoring land use has become critically important as best management controls must now directly contend with the need for additional agricultural, industrial and urban growth and the desire to protect water quality. Improving degraded watersheds and streams require accurate and current land use and land cover (LU/LC) data. The Center for Earth Observation's previous study showed that, state-of-the-art, IKONOS imagery provides an effective means of obtaining LU/LC data within an urban watershed. IKONOS is particularly effective at delineating impervious surfaces prevalent in urban areas. However, IKONOS classifications based on single date imagery have some limitations with regard to other LU/LC classes. The delineation of bare and disturbed soils proved problematic. Bare and disturbed soils are a small part of the total proportion of the area within a watershed but these areas play a critical role in water quality and sediment load. Bare and disturbed soils are nearly identical spectrally and are often misclassified with fallow agriculture. Additionally, grass and open space which are commonly a significant part of an urban/suburban watershed, are often confused with agriculture. Due to the seasonal nature of agriculture, using multi-date imagery could be effective in distinguishing agriculture from the grass/open space class and from the bare/disturbed soil class.

Quantifying accurate LU/LC change within a watershed is an important component of monitoring watershed quality. During our previous study, IKONOS proved to be an effective means to quantify land use composition within an urban watershed. However, our initial analysis of LU/LC only provided a snapshot of the watershed land use composition at a single point in time. To completely understand the impact land use has on water quality, it is also important to accurately assess the type and position of changes occurring within the watershed. This can be accomplished through change detection using remotely sensed imagery. Currently, most LU/LC change detection studies have used lower resolution imagery. However, lower resolution imagery may be incapable of accurately detecting small-scale or mixed LU/LC classes that fall below the resolution of the imagery but still may be significant contributors of upland sediment load.

The objectives of this research were to evaluate the effectiveness of mapping detailed urban LU/LC categories which have the greatest potential for influencing the water quality by taking full advantage of high-resolution Quickbird imagery through the utilization of: (1) data fusion techniques, (2) supervised and unsupervised classification, and (3) post-processing filters. "Treatments" within each of the objective were to be

assessed so as to isolate variables of interest for each objective. Results were to be evaluated in terms of final land use and land cover map as compared with the GPS-assisted reference data collected in the field for determining accuracy.

Methodology

The study area, originally the Hominy Creek watershed, North Carolina, was revised, with WRRI approval, to include highly active and continuously changing watersheds in Northeast Raleigh, North Carolina. The level and scale of change occurring in the North Raleigh area would provide greater indications of the water quality, impervious surface areas, high-growth indices, and their linkages produced through the techniques being developed for this study. The North Raleigh study area contains primarily urban and suburban land uses interspersed with large forested clusters. The study area totals 71.5 km^2 and is located just northeast of the capital city of Raleigh, and has been sited as one of the areas of highest growth from 2000 to 2004.

The general approach for this study consisted of four steps: (1) pre-processing of the data; (2) evaluation of different data fusion, classification and post processing techniques; (3) final classification procedure based on the results from evaluation process; and (4) accuracy assessment. The pre-processing step involved accurate geometric registration of the images, atmospheric corrections, etc. The evaluation process consisted of applying the three different data processing tools (data fusion, classification method, and post processing filter) to assess their effect on the classified maps. Any differences in map accuracy should be largely explained by the effect of these tools. Consequently, the third step was the determination of the final classification procedure based on the input from the evaluation process. In the final step, accuracy assessment of the final thematic map was performed.

It is important to distinguish the terms “classification method” and “classification procedure”. Classification method describes the choice of a specific algorithm to assign raw image values to pre-determined land use/land cover (LU/LC) types. On the other hand, classification procedure is a much broader term involving pre-processing of the images, selection of the classification algorithm, post-processing, and the accuracy assessment.

Principal Findings

Six distinct LU/LC categories having the greatest impact on water quality were determine from our classification analysis; Deciduous Trees, Evergreen Trees, Herbaceous Vegetation, Bare/Disturbed Soil, Water, Impervious. Image classification performed using a supervised classification procedure and a 3x3 majority filter algorithm, yielding an overall classification accuracy of 80.29% (Kappa 0.73). The users’ accuracy for the impervious surface category was 94% (Kappa 0.89). The results suggest the classification accuracy and level of detail produced from high-resolution imagery, using the procedures detailed in this study, can be used to accurately identify and quantify levels of LU/LC which influence water quality within highly urbanized watersheds, particularly impervious surfaces.

Significance

The development of a historic dataset, in which to base current and future changes, may then be used to estimate projected rates of LU/LC change and rates of land use stability in the watershed. These calculations may then be used to model sediment source contributions as a result of land use type variations within the watershed.

Hydrological and Biogeochemical Investigation of Riparian Buffer Function in the Piedmont and Blue Ridge Regions of North Carolina

Basic Information

Title:	Hydrological and Biogeochemical Investigation of Riparian Buffer Function in the Piedmont and Blue Ridge Regions of North Carolina
Project Number:	2004NC51B
Start Date:	3/1/2002
End Date:	9/15/2004
Funding Source:	104B
Congressional District:	7
Research Category:	Climate and Hydrologic Processes
Focus Category:	Solute Transport, Water Quality, Solute Transport
Descriptors:	riparian buffer, nutrients, fecal coliform bacteria
Principal Investigators:	Craig J. Allan

Publication

1. Allan, C.J., M.J. Thomasson, J.S. Wu, and D.R. Allen, Hydrological and Biogeochemical Investigation of Riparian Buffer Function in the Piedmont and Blue Ridge Regions of North Carolina, Journal of the American Water Resources Association (In prep)
2. Thomasson, J.J., C.J. Allan, J.S. Wu, and B. Butchart, Application of the Riparian Ecosystem Management Model (REMM) to Restored Piedmont and Blue Ridge Riparian Buffers in North Carolina, Journal of the Amrican Water Resources Association (In prep).
3. Alen, D.R., C.J. Allan, J. S. Wu, 2003, Hydrogeochemical investigations of riparian zone function in the Piedmont and Blue Ridge Regions of NC, WRRI Annual Conference, Raleigh, NC.
4. Allen, D.R., C.J. Allan, J.Wu, M. Thomasson, 2003, Hydrogeochemical investigations of riparian zone function in th ePiedmont and Blue Ridge Regions of NC, Stream Restoration Annual Meeting, Cincinnati, OH.
5. Butchart, B., D.R. Allen, C.J. Allan, J.S. Wu, and M. Thomasson, 2004, Hydrological and Biogeochemical Investigations of Riparian Buffers in the Piedmont and Blue Ridge Regions of North Carolina, WRRI Annual Meeting, Raleigh, NC.
6. Allan, C.J., M. Thomasson, J. Wu, and D. Allen, 2005, Examination of Nutrient Removal

Efficiencies in Piedmont and Blue Ridge Riparian Systems, WRRI Annual Conference, Raleigh, NC.

Title

Hydrological and Biogeochemical Investigations of Riparian Buffers in the Piedmont and Blue Ridge Regions of North Carolina (70194)

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**.**

Principal Findings

Analysis of field data is continuing for incorporation into a peer reviewed journal manuscript. Parameterization of the numeric flow model for both the Brevard and Kiser study sites is ongoing and will be incorporated into a thesis by a UNC Charlotte Master's degree student. The hydrologic and chemical data analysis from the Brevard High School site has been completed and the analysis of the data from the Kiser site is ongoing. The modeling exercise for the Kiser site has been completed.

Significance

Results can be used to design and manage stream buffers to most effectively protect water quality in Piedmont and Blue Ridge regions.

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:	8/31/2004
Funding Source:	104B
Congressional District:	4th
Research Category:	Water Quality
Focus Category:	Water Quality, Models, Management and Planning
Descriptors:	
Principal Investigators:	Gregory W Characklis

Publication

1. Kirsch, B.R. and G.W. Characklis, April 2003, An Integrated Analysis of Water Use Alternatives in the Central Coastal Plain Capacity Use Area, Annual Conference North Carolina Water Resources Research Institute, Raleigh, NC.
2. Kirsch, B.R. and G.W. Characklis, November 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/Water Environment, Winston-Salem, NC.
3. Characklis, G.W., September 2003, Interface of Water Resource Engineering with Economics and Public Policy, Frontiers on Engineering Symposium, National Academy of Engineering, National Academics Beckman Center, Irvine, CA.
4. Characklis, G.W. and B.R. Kirsch, January 2004, Regional Water Supply Management in North Carolina, North Carolina Water Resources Research Institute Seminar Series, Raleigh, NC.

Title

Reduced Cost Strategies for Regional Integration of Surface and Ground-Water Use

Problem and Research Objectives

Fifteen counties in the eastern part of North Carolina have been classified as a “Capacity Use Area”, a designation that provides the legal framework for regulation of groundwater pumping withdrawals. This region, collectively known as 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 concerns over reductions in aquifer levels and saltwater intrusion. Under rules recently put forth by the State, communities within the CCPCUA will be issued groundwater pumping permits and will subsequently be required to reduce their withdrawals by as much as 75% over the next 16 years. In order to meet this goal, new water sources must be developed and current sources used more efficiently. Conservation will play some role in improving efficiency, but conservation alone will not compensate for the severe reductions in regional groundwater pumping. Regional supply could be augmented via groundwater from the unregulated surficial aquifers, as well as the more distant Castle Hayne formation, however, the surficial aquifers are unlikely to be more than a stopgap measure for most communities, while the location of the Castle Hayne implies high conveyance costs. Surface water (e.g., Neuse, Tar, and Roanoke rivers) is likely to be the primary means of meeting future water demand in the region, but treatment and distribution of surface water is more expensive than that of groundwater and will involve vast amounts of new capital spending. Significant expenditures will also be required for conveyance infrastructure to transport surface water to those communities not in close proximity to surface sources.

This project focuses on the development of a model that minimizes water supply and treatment costs for regional groups of communities. The central contribution of this work is in estimating the cost savings achievable through development of regional drinking water treatment facilities. Results will specify a water asset “portfolio” for each community, composed of a combination of groundwater, surface water, and the yield from conservation activities. The objective of this work is the development of a model that will return combinations of these assets that minimize water supply and treatment costs over a multi-period time horizon as constrained by supply reliability.

Methodology

The model developed in this project will consider:
(a) Source water(s) (i.e. groundwater, surface water);
(b) Source water availability (and changes due to pumping restrictions);
(c) Source water quality;
(d) Municipal conservation activities;
(e) Transfers of groundwater pumping permits;
(f) Distance and elevation difference between source(s) and treatment plant(s);
(g) Water demand;
(h) Reliability targets;

(i) Treatment plant capacity;
(j) Treatment technology process chain;
(k) Community characteristics (e.g., size, location, elevation).

Specifically, the model will:
(1) Compute the *total cost and average cost ($/1000 gallons) of water supply* for a community or group of communities based on specification of parameters (a)-(k).
(2) Compute the *minimum total cost and minimum average cost of water supply* for an individually specified community or group of communities based on selection of an optimal combination from given sets of choice variables for (a), (d), (e), and (i).

The model consists of the treatment cost functions and a minimal spanning tree algorithm that optimizes pipeline network configuration. The costs of water supply and treatment for communities acting individually are compared with situations in which some or all of these communities participate in a regional approach.

Principal Findings

The equilibrium approach developed in this work can be an effective tool for exploring the potential advantages of using regionalized surface water treatment and tradable groundwater permits in the pursuit of sustainable groundwater management strategies. The model's recognition of the interdependencies between individual decisions and their collective impact on costs, as well as the assumption that cities act as individuals, may provide a more representative means of modeling many regional scenarios. The approach used also allows for some flexibility in exploring various policy options related to alternative cutback scenarios and localized pumping restrictions in areas of sever aquifer damage. Beyond the methodology itself, it appears that the combined strategy of regionalized surface water and tradable groundwater permits has the potential to yield considerable savings to regions that seek to reduce groundwater withdrawals to sustainable levels. In the case of the CCPCUA, results suggest a potential savings of 35 percent relative to a base case scenario in which all communities act independently.

Significance
Results can be used by Coastal Plain water suppliers to optimize their regional growth plans to most cost-effectively provide water to their users. The modeling framework can be adopted for application in other regions to evaluate water supply scenarios for optimizing water supplies.

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:	7/31/2004
Funding Source:	104B
Congressional District:	2
Research Category:	Ground-water Flow and Transport
Focus Category:	Non Point Pollution, Surface Water, Water Quality
Descriptors:	soil erosion, runoff, suspended sediments
Principal Investigators:	Richard A McLaughlin

Publication

1. Thaxton,Christopher S. and Richard A. McLaughlin, Baffle design effect on sediment retention and distribution in a sediment detention pond, Trans. Am. Soc. Ag. Eng. (conditionally accepted with revisions - underway)
2. Thaxton, Christopher S., Joseph Calantoni, and Richard A. McLaughlin, 2004, Hydrodynamic assessment of various types of baffles in a sediment detention pond, Transaction of the ASAE, Vol. 47(3),741-749.
3. Thaxton, Christopher A., 2004, Investigations of Grain Size Dependent Sediment Transport Phenomena on Multiple Scales, Ph.D. Dessertation, Department of Physics, College of Physical & Mathematical Sciences, North Carolina State University, Raleigh, NC, 194 pages.
4. Bartholomew, Nathanael, 2002, Polyacrylamide for Turbidity Control in Runoff: Effects of Polyacrylamide, Soil, and Solution Properties, MS Dissertation, Department of Soil Science, College of Agriculture & Life Sciences, North Carolina State University, Raleigh, NC, 136 pages.
5. Thaxton, Christopher S. and Richard A. McLaughlin, 2004, Optimal hydraulic permeability of composite geotextiles as baffles in a sedimentation basin, Proc. ASAE/CSAE Annual International Meeting, Ottawa, ON, Canada, Paper 218 (SW-224)
6. McLaughlin, Richard A., 2005, SoilFacts: Using Baffles to Improve Sediment Basins, NCSU Extension Publication AGW, 429-59.
7. McLaughlin, Richard A., 2003, Potential improvements in sediment and turbidity controls at

construction sites, 2nd Conf. Watershed Mgmt. to Meet Emerging TMDL Environmental Regulations, Albuquerque, NM, Am. Soc. Ag. Eng., Stl Joseph, MI.

Title

A Systematic Evaluation of Polyacrylamide for Sediment and Turbidity Control (70196)

Problem and Research Objectives

Properly installed and maintained sediment control devices, such as silt fences and sediment traps, are intended to remove the sand and coarse silt fractions from sediment in runoff. Although they may retain the majority of the sediment carried by runoff, a substantial portion of the silt and clay fractions are not retained and contribute to high turbidity in streams, lakes, and estuaries. None of the devices currently required provide turbidity control. Polyacrylamide (PAM) has been proven to reduce erosion and turbidity under agricultural conditions. Our current laboratory and field tests have shown that PAM can also substantially reduce turbidity in sediment basins and traps, even to or near the current 50 NTU standard. Under the current WRRI grant, we are determining a number of factors involved in maximizing PAM effectiveness: sediment trap modifications, electrolyte interactions, and environmental conditions. These are primarily using the log format to introduce PAM into runoff. However, there are many other methods to introduce PAM into runoff which may be more reliable and effective. Further testing on these is needed to determine the optimal configuration for reducing turbidity.

We will evaluate 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. Compare the relative effectiveness 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

Most of the work will be conducted at the Sediment and Erosion Control Research and Education Facility at the NCSU Lake Wheeler Road Field Laboratory. This site is ideally located as it is convenient to campus for research and it is centrally located for training and demonstrations. We have already installed the infrastructure for testing sediment and erosion control systems under controlled conditions. Some of the work will be conducted under laboratory conditions in the NCSU Soil Science Department. We have three sediment traps with dimensions of 10’ x 20’, 15’ x 30’, and 20’ x 40’. Each has a rock outlet consisting of large stone (Class B) with a 2:1 slope and a 1’ layer of gravel (1/2”– ¾” dia.) on the inside face, which is the “typical” outlet in the North Carolina DENR Land Quality Section Design Manual. The dewatering times are 1-2 hours once the trap is full to the top of the outlet dam (3-4’), or 0.1-0.3 cubic feet per second (cfs). The rock outlets can be closed off and sealed in order to dewater the basin through a skimmer (or other device) attached to 6” PVC pipes buried within the outlet dam. Dewatering times are 10-20 hours for the basins fitted with skimmers. Water for generated storm events is provided from a 10,000 cubic foot pond located 200’ uphill from the testing area. The storage pond is in turn supplied through the farm irrigation system which taps into a large source pond. A 12” pipe brings the water downslope to the testing area by gravity flow, with an overall drop of 8-10’ depending on where the tests are conducted, and flows of up to five cfs are

possible. A “T” is located in the pipe at 140’ from the pond with the open end up. Soil is added manually to the water flowing through the pipe at this point. Stockpiles of two different sediment types are presently available for our experiments, including a sandy loam surface soil and a clay subsoil. The soil is first screened through a 1” coarse screen to remove large rocks and debris before it is used for experiments. Water flow in the pipe is regulated manually by a valve between the source pond and the “T” and measured by an Isco Area Velocity flow module attached to an Isco 6700 sampler. The sampler obtains samples at set intervals from the head of the sediment basin near the pipe outlet. The water leaving the basins is channeled into either 1.5 or 2.0’ H-flumes fitted with an Isco bubbler flow meter and sampler. Water sampling occurs at set intervals, usually 5-10 minutes depending on dewatering times, at the head of the flume. The discharged water is then dispersed using a level spreader into relatively flat areas of either pine plantation or grass cover. These areas generally retain the discharge, but there is a three-cell constructed wetland below these areas if the flow exceeds their capacity.

Principal Findings

The results indicate that the PAM logs were usually much less effective when initially dry at the start of the 25 minute simulated storm event. The turbidity was higher with lower water temperatures, most likely due to increased water viscosity as opposed to reduced PAM release from the logs. The optimal basin configuration for maximum turbidity reduction using PAM included porous baffles made of a jute/coir combination. The outlet type did not significantly change the turbidity reduction by PAM. Sediment bags were tested with and without PAM injected as a solution and always had reduced turbidity with PAM. Less porous bag materials had lower turbidity in discharge but also clogged more quickly. For a Piedmont soil, the addition of gypsum generally increased turbidity at low PAM concentrations (< 1 mg L^{-1}) for five PAMs with varying properties. The optimal PAM concentration was usually close to 1 mg L^{-1} and higher doses tended to increase turbidity, but this effect was dampened when gypsum was added. This combination of effects suggests that the gypsum was competing with suspended sediment for binding sites on the PAM molecules. In contrast, several Coastal Plan soils responded to PAM only in the presence of gypsum. There was no soil property which correlated with this gypsum response in all soils, but sand content and extractable Fe were the most highly correlated.

Significance

Although not widely used yet, the approach currently available is primarily using PAM logs to dispense the material into the runoff stream and then use various filtering and settling systems to remove the flocs. This research provides information to expand the current application of PAM to reduce turbidity in construction site runoff. This is expected to add flexibility and reliability to the use of PAM in these applications.

The Role of Flood Flows on the Lead Isotopic Composition of Stream Waters, Suspended Sediments, and Rainbow Trout Downstream of Lead Contaminated Soils in Barber's Orchard

Basic Information

Title:	The Role of Flood Flows on the Lead Isotopic Composition of Stream Waters, Suspended Sediments, and Rainbow Trout Downstream of Lead Contaminated Soils in Barber's Orchard
Project Number:	2003NC25B
Start Date:	3/1/2003
End Date:	6/1/2004
Funding Source:	104B
Congressional District:	11
Research Category:	Water Quality
Focus Category:	Non Point Pollution, Geochemical Processes, Water Quality
Descriptors:	fisheries, isotopes, water quality
Principal Investigators:	Jerry R Miller, Peter F Galbreath

Publication

1. Miller, Jerry R., Jamie B. Anderson, Paul J. Lechler, Shannon L. Kondrad, Peter F. Galbreath and Emory B. Salter, Influence of temporal variations in water chemistry on the Pb isotopic composition of rainbow trout (Oncorhynchus mykiss), Science of the Total Environment, (In press).

Title

The Role of Flood Flows on the Lead Isotopic Composition of Stream Waters, Suspended Sediments, and Rainbow Trout Downstream of Lead Contaminated Soils in Barber's Orchard.

Problem and Research Objectives

Lead (Pb) is a toxic element that can severely affect human health, especially that of children. Unfortunately, there are numerous anthropogenic sources of Pb to the environment including industrial complexes, paint, automotive exhaust, mining and milling operations, wastewater treatment plants, and agricultural chemicals. In North Carolina, a commonly overlooked source of lead to the environment is lead arsenate, a pesticide utilized on fruit orchards from 1890 through the 1960s. In the fall of 2001, Barber's Orchard (Waynesville, NC) was added to the U.S. National Superfund Priorities List, increasing concerns of the potential impacts of lead arsenate contamination on both human and ecosystem health. Although the magnitude of lead arsenate contamination in North Carolina is currently unknown, recent studies in other areas have demonstrated that it can be significant. For example, in Washington State, another major fruit producing region, lead arsenate has contaminated an estimated 70-100 thousand acres. Given the number of possible sources of Pb to the environment, contaminated aquatic ecosystems often possess multiple Pb sources, and the determination of the significance of each source in a given water body has proven problematic. Historically, the identification of major Pb sources has relied on spatial patterns in total Pb concentrations within water, sediments, biota, and other media. However, the use of total Pb concentrations for these purposes is plagued by numerous confounding factors within aquatic environments. This has prompted some investigators to capitalize on recent advances in analytical chemistry to fingerprint specific Pb sources on the basis of their isotopic composition. Pb isotopes have been found to be excellent tracers of Pb contamination in a wide range of media types (e.g., air, soils, sediments, water, ice, and tree-rings). Nevertheless, Pb isotopic fingerprinting studies have been applied to relatively few contaminants, and the accumulation of Pb isotopes in aquatic biota, including fish, is poorly understood. As a result, the benefits of using Pb isotopes as a tracer of metal contamination in freshwater systems has yet to be fully realized. This is particularly true of non-point source contaminants, such as lead arsenate.

The project will determine the effectiveness of using Pb isotopes to track the movement of lead arsenate from Barber's Orchard into waters and sediments of Richland Creek, and ultimately into rainbow trout. The investigation will concentrate on Pb isotopic variations in suspended sediments and waters that result from fluctuating discharges, the role of changing isotopic ratios on Pb accumulation in trout, and the partitioning of Pb isotopes between bone and fleshy tissues. An understanding of these processes is critical to the use of Pb isotopes as biogeochemical tracers in aquatic systems and the design of monitoring programs. The primary objectives of this investigation are to quantify the variations in Pb isotopic values in water and suspended sediments in Richland Creek located downstream of Barber's Orchard, and to use Pb isotopic ratios to determine differences in the rate at which Pb is incorporated into and dissipates from different tissues in trout. More specifically, field and laboratory data will be combined to test four hypotheses generated from our previous work. These hypotheses include (1) that short-term shifts in the isotopic composition of water and sediments within Richland Creek occurs during

floods as a result of erosion and transport of contaminated soils from Barber's Orchard, (2) that Pb is sequestered in bone of trout, whereas it is readily excreted by fleshy tissues, (3) that the bone reflects the contaminant Pb because of the relatively high concentrations and bioavailability of the metal to which the fish are subjected during flood events, and (4) that the bone provides a long-term record of Pb loadings and can be used as a stable biomarker of contamination to the aquatic system, whereas the liver and muscle reflect the isotopic composition of the water within a few days of sampling.

Methodology

The objectives will be accomplished by combining field data that characterize the isotopic variations in water and suspended sediment in Richland Creek as a function of flow conditions, with laboratory studies that more precisely document tissue-specific patterns of accumulation and partitioning of Pb isotopes in rainbow trout. A permanent monitoring site will be established on Richland Creek immediately downstream of Barber's Orchard. Both water and sediment samples will be collected at the site during low, moderate, and high discharge conditions. A limited number of samples may also be obtained approximately 10 km downstream of the Orchard, near the eastern edge of Waynesville. The quantity of samples that can be collected will depend on the number of rainfall/runoff events that occur. However, it is anticipated that it will be possible to collect at least 30 to 40 sets of water and suspended sediment samples over a wide-range of discharge values. Also, an effort will be made to collect samples over the entire hydrograph of at least 1 to 2 flood events. Once analyzed, total Pb and selected Pb isotopic ratios will be related to the discharge conditions at the time of sampling to determine if systematic changes in Pb concentrations and isotopic values occur. If changes in isotopic values are identified, the nature of the changes will be compared with the isotopic composition of known Pb sources in the area (e.g., lead arsenate, sediments within the modern channel bed, and uncontaminated sediments within the floodplain and terrace deposits) to determine the probable cause for the changes in isotopic abundances. In addition, these geochemical data will be compared to suspended sediment concentrations that existed at the time of sampling to evaluate whether the variations in isotopic values are consistent with erosion of upland soils.

Fertilized eggs of rainbow trout (Erwin X Arlee strain) pooled from multiple pairings were obtained from Erwin National Fish Hatchery, Erwin, TN in September 2002. The eggs were transported to facilities at the Mountain Aquaculture Research Center (MARC), WCU, Cullowhee, NC, where they are currently being incubated. At first feeding, the fry will be transferred to a common tank and reared following standard hatchery practices using commercial trout diets to a large fingerling size (approx. 50 g/fish) by the time experimentation begins in the summer of 2003. Two experiments to test tissue-specific rates of Pb uptake and depuration will be conducted simultaneously. One test will involve exposure to a constant low (0.025 mg/L) concentration of Pb in the rearing water, and the other to a pulsed exposure (twice-a-week for 6 hours) to Pb at a relatively high (0.350 mg/L) concentration. The low concentration is similar to dissolved Pb concentration levels measured in Richland Creek during low flow periods (Kondrad 2002).

Principal Findings

Stream waters are characterized by relatively low Pb concentrations during periods of base flow exceeding 10 days in length. Greater than 65% of the Pb is derived from orchard soils located upstream of the monitoring site which are contaminated by lead arsenate. During small to moderate floods, the dissolved load exhibited Pb concentrations more than twice as high as those measured during base flow, but the contribution of Pb from lead arsenate was relatively low and varied directly with discharge. In contrast to smaller events, Pb from lead arsenate in an 8-10 year (overbank) event in May 2003 was minimal during peak flow conditions, suggesting that discharge-source relations are dependent on flood magnitude. The hydrologic and geochemical data demonstrate that aquatic biota in Richland Creek are subjected to short-term variations in Pb concentrations and isotopic composition of the dissolved load ranging from a few hours to a few weeks. Laboratory studies demonstrated that when rainbow trout were exposed to elevated Pb concentrations with a distinct isotopic fingerprint, the bone and liver rapidly acquire isotopic ratios similar to that of the water. Following Pb treatments, the bone retains Pb from the contaminant source for a period of months, while the liver excreted approximately 50 percent of the accumulated Pb within a few days and nearly all of the Pb within a few weeks. Differences in the rates of excretion resulted in contrasting isotopic ratios between the organs. It seems plausible, then, that previously observed differences between the isotopic composition of bone and liver in rainbow trout from Richland Creek could result from their short-term exposure to Pb from soils contaminated with Pb arsenate that result from fluctuating hydrologic conditions. If these trends prove to be common in other contaminated aquatic environments, it may be possible to use the Pb isotopic composition of bone as an indicator of the long-term sources of Pb to the systems, and liver as a biomarker for short-term Pb exposures.

Significance

Results indicate that it may be possible to the Pb isotopic composition of bone as an indicator of the long-term sources of Pb to the systems, and liver as a biomarker for short-term Pb exposures.

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 continued to be 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.

WRRI's Information Technology Program includes workshops and seminars supported by the NC Department of Environment and Natural Resources (DENR), Land Quality Section as follows: Erosion and Sedimentation Control Local Programs Workshop. March 2-3, 2004, Mid Pines Inn, Southern Pines, NC. With NC Sedimentation Control Commission (SCC) and NC Land Quality Section (LQS), Division of Land Resources.

Stormwater: Emerging Issues for Local Communities. April 19-21, 2004. Asheville, NC. With USEPA, NC State University, and NC Dept of Environment and Natural Resources. Erosion and Sedimentation Control Basic Planning and Design Workshop. October 5-6, 2004, Holiday Inn Select, Hickory, NC. With NC Sedimentation Control Commission (SCC) and NC Land Quality Section (LQS), Division of Land Resources. Erosion and Sedimentation Control Basic Planning and Design Workshop. October 5-6, 2004, Holiday Inn Select, Hickory, NC. With NC Sedimentation Control Commission (SCC) and NC Land Quality Section (LQS), Division of Land Resources. Erosion and Sedimentation Control Basic Planning and Design Workshop. November 9-10, 2004, Sheraton Grand, New Bern, NC. With NC Sedimentation Control Commission (SCC) and NC Land Quality Section (LQS), Division of Land Resources. Erosion and Sedimentation Control Local Programs Workshop. February 2-3, 2005, Mid Pines Inn, Southern Pines, NC. With NC Sedimentation Control Commission (SCC) and NC Land Quality Section (LQS), Division of Land Resources.

Another way WRRI provides Information Technology is through the NC Water Resources Association Luncheon and Forums: Advanced Wastewater Treatment and TMDLsMeeting the Challenges: A Charlotte-Mecklenburg Utilities Perspective. September 13, 2004, Jane S. McKimmon Center, NC State University, Raleigh, NC. With the NC Water Resources Association (NCWRA). The Impact of TMDLs on Stormwater Programs. December 6, 2004, Jane S. McKimmon Center, NC State University, Raleigh, NC. With the NCWRA.

Convened the Preconference Sysmposium, Watershed Management in North Carolina: Successes and Challenges on March 30, 2004 and the Annual WRRI Conference, Watershed Assessment and Restoration: Lessons Learned and Future Directions on March 31, 2004. Drs. David Moreau, Ph.D., Chair, Dept of City & Regional Planning, UNC Chapel Hill, Ron Ferrell, Director of Operations, Ecosystem Enhancement Program, 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 420 people participated in the conference. Participants had 36 technical presentations in 9 concurrent sessions from which to choose, as well as 25 technical posters to view. Abstracts were made available on the WRRI website.

Miscellaneous seminars and workshops supported by WRRI: Southeastern Regional Conference on Stream Restoration. June 21-24, 2004, Winston-Salem, NC. With the NC Stream Restoration Institute. Southeastern Estuarine Research Society (SEERS) Fall Meeting. October 14-16, 2004, Cape Fear Coast Convention Center, Wilmington, NC. With SEERS and the Center for Marine Science of the University of North Carolina at Wilmington.

Maintained the WRRI website (http://www.ncsu.edu/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.

Maintain two electronic mail lists (listserves): Water Research list and WRRI-News list. The Water Research list is used to inform water researchers from North Carolina universities about calls for papers, grants, upcoming conferences, student internship opportunities, EPA news, etc. There are approximately 130 subscribers to this list. The WRRI-News list is used to distribute an electronic version of the WRRI-News publication as well as inform subscribers about upcoming conferences and workshops, water-related research in North Carolina. There are approximately 635 subscriptions to the WRRI-News list.

WRRI Research Seminar Series

Basic Information

Title:	WRRI Research Seminar Series
Project Number:	2004NC53B
Start Date:	3/1/2004
End Date:	2/28/2004
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:

Dr. Craig Allan, UNC-Charlotte
March 5, 2004, 1132 Jordan Hall
"Hydrology and Water Quality Associated with Restored Riparian Forests in the Piedmont and Blue Ridge of North Carolina"

Dr. Larry Band, UNC-Chapel Hill
April 23, 2004, NC State University
"Land Use & Water Quality"

Dr. Curtis Richardson, Duke University
“Wetlands of Mass Destruction: How the Hussein Regime Destroyed the Mesopotamian Marshes and Their 5,000-year-old Ma’dan Culture”
Tuesday, September 21, 2004, 3:00 pm 2010 Biltmore Hall, NC State University

Dr. David Genereux, NC State University
"Groundwater Ages in the Black Creek and Upper Cape Fear Aquifers"
Monday, October 11, 2004, 2:00 pm, Groundfloor Hearing Room, Archdale Building, Downtown Raleigh

Dr. Phil Berke, UNC-Chapel Hill
"Greening Development to Protect Watersheds: Is the New Urbanist Version of Compact Urban Forms an Answer?"
Tuesday, November 23, 2004, 3:00 pm 1132 Jordan Hall, NC State University

Dr. Randy Kramer, Duke University
"Wetland Restoration by North Carolina Landowners: Incentives, Choices and Attitudes"
Tuesday, January 18, 2005, 3:00 pm 1132 Jordan Hall, NC State University

Dr. Richard McLaughlin, NC State University
“Dirty Secrets of Construction Site Runoff and Technologies for Cleaning It Up”
Tuesday, February 15, 2005, 3:00 pm 1132 Jordan Hall, NC State University

The WRRI Institute NEWS

Basic Information

Title:	The WRRI Institute NEWS
Project Number:	2004NC54B
Start Date:	3/1/2004
End Date:	2/28/2004
Funding Source:	104B
Congressional District:	
Research Category:	Not Applicable
Focus Category:	None, None, None
Descriptors:	
Principal Investigators:	Kelly A Porter, Amy (Jeri) B Gray

Publication

Published the *WRRI News* five 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.

New WRRI Rearch Reports

Basic Information

Title:	New WRRI Rearch Reports
Project Number:	2004NC55B
Start Date:	3/1/2004
End Date:	2/28/2004
Funding Source:	104B
Congressional District:	4
Research Category:	Not Applicable
Focus Category:	None, None, None
Descriptors:	
Principal Investigators:	Greg Jennings

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. In addition, the new Journal Article Series (JA) was started in which journal articles are submitted to peer reviewed journals in lieu of institute final reports. This new series is the Journal Article Series.

WRRI-343-E - Monitoring and Modeling of the Neuse River Estuary, Phase 2: Functional Assessment of Environmental Phenomena Through Network Analysis.

WRRI-349 – Episodic Nutrient Loading Impacts on Eutrophication of the Southern Pamlico Sound: The Effects of the 1999 Hurricanes.

WRRI-JA06 – Effect of Graywater on Soil Hydraulic Properties; Effect of Graywater on Growth & Appearance of Ornamental Landscape Plants.

WRRI-JA07-1 – Predicting the Frequency of Water Quality Standard Violations: A Probabilistic Approach from TMDL Development.

WRRI-JA07-2 – A Bayesian Network of Eutrophication Models for Synthesis, Prediction, and Uncertainty Analysis.

WRRI-JA08 – Consequences of Hypoxia on Estuarine Ecosystem Function: Energy Diversion from Consumers to Microbes.

WRRI-JA09 – Modified Serial Analysis of Gene Expression Method for Construction of Gene Expression Profiles of Microbial Eukaryotic Species.

WRRI-JA10 – Construction of Platinum-Tipped Redox Probes for Determining Soil Redox Potential.

Special Report Series Publications during the reporting period:

SRS-24 - Mathematical Modeling of Nutrient Removal in Wet Detention Ponds

Student Support

Student Support					
Category	**Section 104 Base Grant**	**Section 104 RCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	4	0	1	0	5
Masters	10	0	0	0	10
Ph.D.	3	0	1	0	4
Post-Doc.	1	0	0	0	1
Total	18	0	2	0	20

Notable Awards and Achievements

As a result of Richard McLaughlin's research, Polyacrylamide (PAM) is being adopted as a turbidity control system for construction runoff and borrow pit pumping. Several fact sheets have been drafted and PAM will be included in an updated version of the state erosion and sediment control design manual. Porous baffles will also be included in the new manual and a fact sheet has been published on their use.

Publications from Prior Projects