

Report as of FY2007 for 2007NC75B: "Stable Isotope Tracers to Quantify Impervious Area Effects on Baseflow to Coastal Plain Streams"

Publications

- Dissertations:
 - ◆ Hutchinson, H.W. 2007. Hydrologic and isotopic response of low-order Coastal Plain streams to urban land-use. Department of Geological Sciences (MS), East Carolina University. 126 p.
 - ◆ Soban, J.R. 2007. Department of Geological Sciences (MS), East Carolina University. Stream channel response to urban land use in the inner Coastal Plain of North Carolina. 154 p.
- Conference Proceedings:
 - ◆ DeLoatch, J.P., O Driscoll, M.A., Brinson, M.M., and Hardison, E.C. 2007. Groundwater hydrology of low-order Coastal Plain streams across an urban land-use gradient. Geological Society of America National Meeting, Denver, CO. Geological Society of America Abstracts with Programs, Vol. 39, No. 6, p. 319.
 - ◆ Hardison, E., O Driscoll, M., Rheinhardt, R., and Brinson, M, 2007. Effects of urbanization on low-order riparian and stream systems in Coastal Plain North Carolina. Society of Wetland Scientists Annual Meeting 2007. June10-15, 2007. Sacramento, CA.
 - ◆ Hardison, E., Brinson, M, and O Driscoll, M. 2007. A comparison of total versus effective impervious surface area for the prediction of water quality degradation in low-order coastal plain streams. North Carolina Academy of Sciences Annual Meeting 2007. March 31, 2007.
 - ◆ Hardison, E., Brinson, M, and O Driscoll, M. 2007. Effects of Total and Effective Impervious Surfaces on Water Quality in Low-Order Coastal Plain Streams, North Carolina. ECU Research and Creative Achievement Symposium. March 26, 2007.
 - ◆ Soban, J. and O Driscoll, M. 2007. Stream channel response to urban land-use in the North Carolina Coastal Plain. Geological Society of America Abstracts with Programs Vol. 39, No. 2. p.18. SE Section, Savannah, GA. March 29, 2007.
- Other Publications:
 - ◆ O Driscoll, M.A. 2008. Streams and sprawl: Urbanization and channel enlargement in the Coastal Plain. Cypress News 33(10):3. North Carolina Chapter - Sierra Club

Report Follows

(1) **Title:** Stable isotope tracers to quantify impervious area effects on baseflow to Coastal Plain streams.

(2) **Statement of Critical Regional or State Water Problem:**

Across the globe human populations are becoming increasingly urban. Current estimates suggest that fifty percent of the world's population lives in urban areas (Cohen 2003). In the southeastern United States urban land-use is rapidly expanding. Future projections indicate that over the next 40 years there will be a 3-4 fold growth in the amount of impervious area in the southeastern US. North Carolina is one of the most rapidly growing states in the southeast (6th fastest in U.S., 1990-2000). Statewide 18.1% of watershed area is affected by greater than 5% total impervious area. In the southeast only Florida has experienced more land-use alteration (31.2%). By 2030 projections indicate that 27% of North Carolina's watersheds will have >5% total impervious area (Exum et al. 2005). Urban land-use has been shown to alter and degrade streams by changing their hydrologic response to precipitation (McBride and Booth 2005). These findings suggest that streams in North Carolina are at significant risk for degradation due to current and future land-use changes. Stream degradation associated with increased imperviousness has been referred to as the "urban stream syndrome" and symptoms include: increases in overland flow and stormwater runoff, greater peak discharges, shortened lag times to peak flow, increased water temperature variability (Krause et al. 2004), shallow ground water quality degradation (Bruce and McMahon 1996), elevated nutrients and contaminants, altered biotic assemblages, reduced biotic richness, reduced channel complexity, increased dominance of tolerant species, and altered nutrient processing and ecosystem functioning (Meyer et al. 2005). Ground water recharge in urban areas is complex because normal recharge pathways are often altered. Alteration of natural recharge pathways in urban areas leads to changes in precipitation intake at the land surface. The literature suggests variable responses of baseflow to increased urban land-use (Walsh et al. 2005a). Baseflow magnitude may decrease if impervious area results in less ground water recharge and more stormwater runoff or if interbasin transfers occur. Channel incision related to stormwater runoff may increase drainage of near stream aquifers. Leaky underground pipes transporting sewage, stormwater and drinking water may provide recharge and increase baseflow (Lerner 2002).

Currently it is not known what threshold percentage of watershed impervious area will begin to affect stream baseflow. Different physiographic regions respond differently to increases in impervious cover and stormwater stresses. The relationship between impervious area and in-stream response must be established for the common physiographic settings in North Carolina: Mountains, Piedmont, and Coastal Plain. The effects that watershed impervious area has on baseflow to Coastal Plain streams will be quantified in this study. Quantification of impacts on Coastal Plain river baseflow is important because over 50% of annual average streamflow of these rivers is derived from baseflow (McMahon and Lloyd, 1995) and the Coastal Plain comprises 45% of the land area of North Carolina. Baseflow reductions in Coastal Plain streams could cause chemical contamination problems to worsen, increased water temperatures and lowered dissolved oxygen concentrations, alterations to fresh water fluxes to estuaries and the coastal ocean, and reduced buffering of climate change. Typically, stormwater management is dealt with on a site by site basis with no measurement of the cumulative effects on the entire watershed. The value of this proposed approach is that stable isotope measurements can reveal the cumulative effects of upstream land-use changes at the watershed outlet.

(3) **Statement of Results, Benefits and/or Information**

This proposal addresses the NC WRRI 2007-2008 priority research area D.3: **Determine the percent impervious surfaces in a watershed that would affect surface water recharge by ground water.** The major contribution of this research is that it will determine the threshold at which the percentage of watershed impervious area has measurable effects on baseflow contributions to Coastal Plain streams and evaluate the effectiveness of stable isotope techniques to quantify this threshold at the watershed-scale. This work will document variations in ground water inputs to streams across an urban gradient, and determine if stable isotope techniques are effective at quantifying the watershed-scale effects of impervious area and stormwater management. Stable isotope data will be compared with physical

(discharge and water temperature) and chemical (specific conductance) measurements, to determine if lower-cost applications may also yield similar results.

The benefits of this study are two-fold. First, it will provide detailed information on the threshold levels of impervious area that result in observable changes in baseflow magnitude to Coastal Plain streams. Monitoring of the surface water-ground water interactions at 6 locations and over a range of streamflow conditions will characterize the changes in surface water-ground water interactions that occur across a gradient of impervious area. Second, it will provide a methodology for using stable isotopes to characterize the effects of watershed impervious area on stream hydrological response at the watershed scale. Such a methodology may prove to be applicable in a wide variety of river settings.

Important outcomes of this research will include:

- (i) An improved understanding of the relationship between impervious area and stormwater/ baseflow response in Coastal Plain streams.
- (ii) Determination of impact thresholds of impervious area, above which alterations in baseflow magnitude are measurable.
- (iii) Evaluation of a stable isotope technique to characterize the effects of land-use on surface water-ground water interactions. It is expected that this methodology will be applicable in the Coastal Plain and other settings.
- (iv) Comparison of stable isotope techniques with other practical approaches (physical hydrograph separation, seepage runs, specific conductance, water temperature, flashiness,) to quantify baseflow and stormwater responses to land-use alterations
- (v) The improvements to our current monitoring network and continuation of data collection may result in future funding to create a long-term Coastal Plain urban stream monitoring network.
- (vi)The urban stream monitoring network will be useful for labs and class field trips for hydrology-related courses.
- (vii) Study results can provide valuable information for stormwater managers in Greenville and similar Coastal Plain cities. This study will also provide baseline conditions, which are useful for the evaluation of land-use effects on rivers in an area that is rapidly developing.

(4) Nature, Scope, and Objectives of Research and Timeline of Activities

The study goals are to determine thresholds of impervious area, above which alterations in baseflow magnitude are measurable and to evaluate a stable isotope approach to quantify the watershed-scale effects of stormwater runoff on Coastal Plain streams. The objectives of this study are to:

- (i) Characterize seasonal variability of river-ground water interactions across an urban land-use gradient using stable isotope and physical measurements.
- (ii) Quantify the variability in isotopic composition of stream runoff during storm events across an urban gradient.
- (iii) Evaluate the effectiveness of stable isotope tracers for quantifying the hydrologic effects of impervious area on Coastal Plain streams. To determine if stable isotopes can effectively quantify the changes in hydrology due to land-use, at what level of accuracy this can be done, and at what percentage of watershed impervious area are differences in baseflow noticeable. Overall, to determine if stable

isotope tracers can accurately measure the watershed-scale effects of stormwater runoff from impervious areas.

(iv) Compare a variety of hydraulic and geochemical measurements with isotopic results to determine if other indicators of stormwater/baseflow variations can provide similar results.

Precipitation, ground water, and surface water monitoring activities will support the research objectives by providing data that captures baseflow and runoff variability across an impervious area gradient, within storm events and across the seasons. The data will show the natural variability and the magnitude of differences in baseflow due to land-use change. In order to be confident in the integrity of stable isotope evaluation of land-use effects the margin of error for this technique must be determined by evaluation of monitoring data.

Schedule of Tasks

TASK	2007					2008								
	J	F	M	A	M	J	J	A	S	O	N	D	J	F
A.			---											
B.			-----											
C.			-----											
D.												-----		
E.												-----		

A. Add monitoring equipment to the monitoring network and begin precipitation, surface water, and ground water sampling
 B. Storm event sampling (6 storms – 1-2/season)
 C. Ground water and surface water monitoring
 D. Analysis and synthesis of hydrologic, chemical, and isotopic data
 E. Write final report and manuscript

(5) Methods, Procedures, and Facilities

General Methodology

The primary way that urbanization affects streams is by altering surface flow patterns. Stable isotope tracers may be used to quantify changes in stormwater runoff and ground water inputs to streams. ¹⁸O and Deuterium (D) are naturally occurring stable isotopes that are present in rainfall, surface water, and ground water. Seasonal stable isotopic variations in precipitation have been used to study the movement and source of subsurface water in various settings (Kendall and McDonnell 1998). ¹⁸O and D provide a seasonal meteoric signal in temperate, continental systems that is often attenuated in shallow ground water (Clark and Fritz, 1997). Rainwater tends to be depleted in winter and enriched in summer and ground water tends to have an average isotopic composition that fluctuates little throughout the year. For this reason, storm event precipitation isotopic composition is quite different from baseflow composition, allowing for two component storm hydrograph separations of baseflow or “old water” and runoff or “new water” (Sklash and Fritz 1975, Buttle 1994). In this study, the ¹⁸O and D composition of precipitation, surface water, and ground water will be quantified seasonally and for storm events across an urban land-use gradient.

A field-based hydrologic and geochemical approach will be used to quantify the effects of increased impervious area on stream hydrology. The study area will consist of sub-watersheds of the Tar River from Greenville to Grimesland, North Carolina. The Tar River basin is a good location for evaluating the effects of urbanization on Coastal Plain streams; from 1982 through 1997, the major land

use changes have been a 90.1% increase in urban land-use (NCDENR 2004). In 2005, an urban runoff monitoring network was set up in the vicinity of Greenville, NC to monitor the effects of land-use on Coastal Plain streams. Currently this monitoring network is being used for an Ecosystem Enhancement Program (NC-DENR) funded project to collect detailed data on urban riparian systems in the Coastal Plain. Six sites have been selected across an urban land-use gradient within the Tar River Basin, with watersheds ranging in size from 1.19 to 3.46 km² and impervious areas have been quantified ranging from 37% to less than 5% (Figure 1). Future work will aim to quantify the effective impervious area for these watersheds and how this relates to various hydrologic metrics. All of the sites are in similar geological settings and within 5 miles of each other and should be subject to similar meteorological conditions. Therefore hydrologic differences between sites are presumably due to land-use differences.

Preliminary data suggest that urban land-use has modified stream hydrology in the Greenville area, with direct relationships between degree of alteration and percentage of watershed impervious area. Stream discharge data and hydrograph separation modeling (Lim et al. 2005) suggests that baseflow decreases and storm runoff increases with increased watershed impervious area (Figure 2). Water temperature increases during summer storm events were also correlated to watershed impervious area (Figure 3). Stable isotope composition data for a June 2006 storm indicates that ¹⁸O composition data for storm samples varies directly with watershed impervious area and that stable isotope tracers may be useful indicators of land-use effects on stream hydrology in this and other Coastal Plain settings (Figure 4). This proposed research will aim to evaluate how well this relationship holds up throughout the year and with storms of differing intensities.

East Carolina University

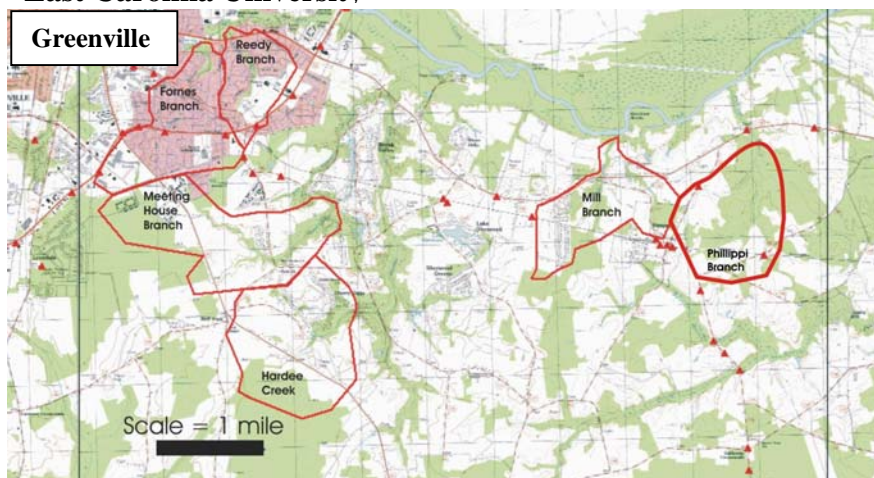


Figure 1. Location of watersheds within urban stream monitoring network, Greenville, NC.

A Comparison of Baseflow Separations for an Urban and Rural Stream

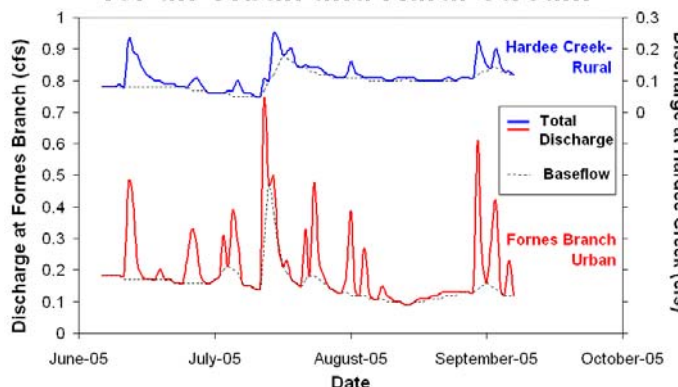


Figure 2. A comparison of baseflow separations for daily discharge during summer, 2005 for an urban stream (Fornes Branch, 37% impervious area) and a rural stream (Hardee Creek, 14% impervious area). For the summer of 2005 the urban stream had baseflow contributions of 77% whereas the rural stream had baseflow contributions of 85%. The urban stream had 8% greater stormwater runoff inputs.

Storm Temperature Surge Response

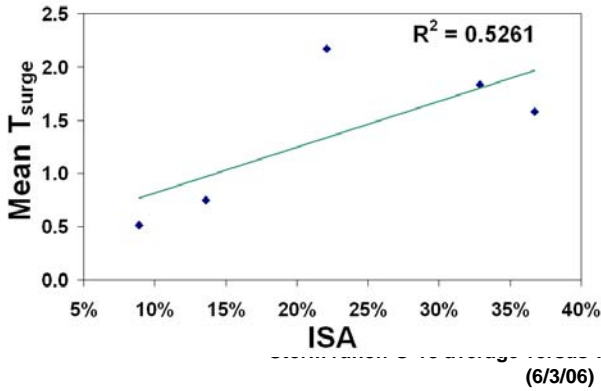


Figure 3. Stream temperature response across urban land-use gradient for storm events monitored during the summer of 2005. Temperatures are in degrees-C, n=23 storms, (ISA) impervious surface area.

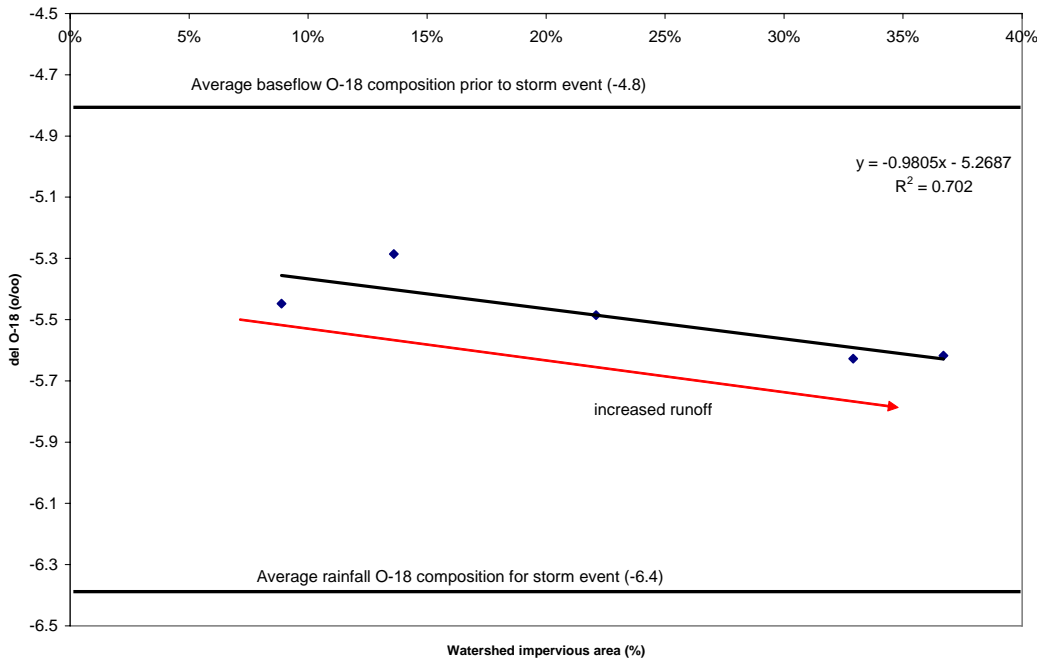


Figure 4. Stream ¹⁸O response across an urban land-use gradient for a storm event sampled on June 3, 2006. Stormwater ¹⁸O was sampled approximately 5 times during the storm event, baseflow ¹⁸O was sampled prior to the event.

Hydrologic and Isotopic Monitoring

River water will be sampled at the six sites during storm flows for six storm events throughout the year. The goal is to obtain at least 5 samples during an event to provide a composite stormwater sample (2 rising limb, 1 peak, 2 falling limb samples). Automatic water samplers will be used for storm sampling. In addition, first flush sampling will be conducted using Nalgene© first flush single sample bottles installed at similar elevations at each site. The data collected from these will indicate if first flush sampling is as effective as composite sampling for evaluating land-use effects on hydrology. Prior to storm events a stream water sample will be collected to characterize baseflow (ground water) conditions. Water samples will also be collected from floodplain ground water wells adjacent to the streams. The ground water well samples will be compared with stream baseflow and runoff samples to determine if floodplain well water composition can provide evidence of the effects of upstream impervious area on floodplain hydrology. Cross-sections of each stream will be surveyed to determine if incision due to urbanization has effects on ground water inputs. Precipitation during storm events will be collected to capture the ¹⁸O input signal. During periods between sampled storm events, baseflow and ground water well samples will be collected manually every 2-weeks. These data will be used to estimate mean residence time (Clark and Fritz 1997).

Precipitation for seasonal analysis will be collected on a bi-weekly basis in a buried bottle with a screened funnel and coiled tube. Oil will be added to prevent evaporation.

To prepare all water samples for lab analysis, water will be gravity filtered through a non-ashed carbon filter into 1 mL sample bottles. These samples will be analyzed at Duke Environmental Stable Isotope Laboratory (DEVIL) using a ThermoFinnigan Thermochemical element analyzer (TCEA) coupled to a ThermoFinnigan Delta-plus XL mass spectrometer. Isotopic composition values have a 0.1 to 0.2 per mil ^{18}O and 0.5 to 1.0 per mill Deuterium precision. Prior to analyzing all storm samples, a baseflow and a rainfall sample will be analyzed to ensure the two-components have different ^{18}O composition so the data can be analyzed using a 2-component mixing model (DeWalle and Pionke 1994). To further ensure quality control, random blind duplicates will be sent in once for every month of baseflow and rain samples. Each storm sample set analyzed will also contain a blind duplicate. After sample analysis, a two-component stable isotope mixing model will be used to determine the amount of ground water feeding rivers during storm flows at each site and for each of the monitored storm events. The percentage of ground water input for all sites and events will be compared with urban land-use category to determine if the magnitude of ground water inputs is related to land-use.

Currently stage recorders and ground water level recorders are in operation at each site and stage-discharge rating curves have been developed to determine discharge variations across watersheds. This instrumentation will continue to be used to monitor surface water and ground water stage during the study period. In addition, water temperature recorders currently in use will continue to monitor surface and ground water temperatures during the study. A weather station is being operated to monitor rainfall amounts in Greenville and this monitoring will continue for the duration of the study. For this proposed study, additions to the monitoring network will include specific conductance loggers to monitor surface water specific conductance at each site. We will use specific conductance as a surrogate for Cl. The goal is to compare storm runoff and baseflow specific conductance data with stable isotope data to verify if specific conductance behaves conservatively and is a good metric to quantify the effects of land-use on hydrology in these settings. Preliminary data collected along Green's Mill Run suggests that specific conductance may be a good tracer of surface water-ground water interactions. Hydrograph separations performed using specific conductance will be compared with those performed using stable isotopes. Additional metrics that will be compared with stable isotope data include discharge and stage daily coefficient of variation, lag time, rising stage frequency (number of time periods when stage rises at least 0.1 ft), median duration of high stage (> 90 th percentile)(McMahon et al. 2003), flashiness: fraction of the year daily discharge > annual mean discharge (Booth et al. 2004), storm temperature surge, seepage runs (1 summer, 1 winter), and physical hydrograph separations (Lim et al. 2005).

Major Research Tasks

Task 1: Characterize the variations in stable isotopic composition of rainfall, surface water, and ground water and the hydrology of the sites.

Task 2: Quantify the effects of land-use and how it relates to the threshold at which baseflow is affected by impervious cover.

Task 3: Compare isotopic results with other indicators to evaluate how well they reflect land-use effects.

Isotopic Data	Chemical Data (Specific Conductance)	Physical Data
Storm	Storm	Temperature
First flush sample	First flush sample	Air temperature (1/2 hr)
Storm composite sample	Storm composite sample	Stream and gw temperature (1/2 hr)
Baseflow	Baseflow / logger (1/2 hr)	Stage and discharge
Bi-weekly sample	Bi-weekly sample	Surface water stage (1/2 hr)
Pre-storm sample	Pre-storm sample	Ground water stage (1/2 hr)

Table 1. Storm and baseflow monitoring parameters

(6) Related Research

Watershed impervious area has been related to stream degradation in many settings (Shuster et al. 2005). Based on a review of the literature, Paul and Meyer suggest that many thresholds of stream degradation are associated with an impervious surface cover of 10-20% (2001). Little is known about the threshold at which impervious area affects baseflow to streams. Recently Brandes et al. (2005) found that baseflow response to urbanization was not consistent across three physiographic regions of the Lower Delaware River (Valley and Ridge, Piedmont, and Coastal Plain provinces). They looked at 10 watersheds (six urban and four reference) and found that only one (the Cooper River in the Coastal Plain) showed declines in baseflow over time. The decrease in baseflow was in part related to the impervious area of 21 %, but also likely due to interbasin transfers. Recent work by Brinson et al. (2006) indicates that land-use changes, specifically channelization associated with agriculture, has resulted in an alteration of groundwater flows to many low-order Coastal Plain streams. It is unknown what threshold of impervious area is likely to affect baseflow to rivers in the Coastal Plain.

Impervious area alone does not always relate directly to river condition, because some impervious surfaces may be entirely disconnected from the river network. The effective imperviousness is the proportion of a catchment covered by impervious surface and connected to the stream by stormwater drainage pipes. This measure is more directly related to stream degradation than total impervious area (Walsh et al. 2005b). Recently researchers have begun to focus on effective impervious area and have found it better explains water quality variations than does total impervious surface area (Hatt et al. 2004). For future advances in our understanding of urban land-use effects on streams, hydrologic metrics will need to be developed that quantify how connected impervious area is to the stream network (Booth et al. 2004). In our proposed research we will aim to evaluate the use of stable isotope metrics to help quantify cumulative effects of upstream effective impervious area in the Coastal Plain of North Carolina.

Past research has shown that increased imperviousness in various North Carolina settings has resulted in increased peak stormflows (Mason, Jr. et al. 2001) and increased variability of streamflow and stage (McMahon et al. 2003). A growing body of work shows that physical, chemical, and biological degradation of water quality and stream channel alteration has occurred throughout North Carolina as a result of increased impervious area and stormwater stresses (Lenat and Crawford 1994, Line et al. 1997, Mallin et al. 2001, Borden et al. 2002, Line et al. 2002, Gage et al. 2004, Carle et al. 2005, Ulseth and Hershey 2005). However, there have been few documented studies on the effects of urban land-use and impervious area on baseflow contributions to streams in any of the physiographic regions of North Carolina.

Streams in the Coastal Plain physiographic province are important because they nourish bottomland hardwood forest systems, provide habitat for fish and wildlife, feed coastal and estuarine systems, provide water for domestic and industrial uses, and provide sites for wastewater disposal. Low-order Coastal Plain streams are typically blackwater streams because of their gentle gradients, long residence times, and associated dissolution of abundant organic matter within and adjacent to these rivers (Hupp 2000). Coastal Plain watersheds in North Carolina typically lose large amounts of water to evapotranspiration, particularly during summer months. This results in an extreme decrease in baseflows during the summer and the potential for the cessation of flows. A comparison of Coastal Plain and

mountain hydrology in North Carolina revealed that annual evapotranspiration in a Coastal Plain watershed in Carteret County was 70% of the precipitation input, whereas the mountain site at Coweeta returned 47% of its precipitation by evapotranspiration (Sun et al. 2002). These differences are due to warmer climate in the Coastal Plain and gentler topography. Flooding recurrence of Coastal Plain streams differs markedly from other physiographic regions. Bankfull recurrence intervals in North Carolina Coastal Plain streams have been found to be much shorter than in other settings, a recent study indicates that bankfull recurrence for Coastal Plain streams may be on the order of 0.19 years (Sweet and Geratz 2003). In other settings bankfull recurrence interval is typically estimated at 1.5 years (Brooks et al 2003). This indicates that Coastal Plain streams are much more likely to overtop their banks in a given year than streams in other topographic settings.

River-ground water interactions in the Coastal Plain are controlled by the near-channel stratigraphic framework and the surficial aquifer. The surficial aquifer that extends across the Coastal Plain of North Carolina ranges from 4-224 feet thick (Lautier 2001). It consists of fine grained sand, silt, clay, and shell materials typically of Holocene to Pleistocene in age. The surficial aquifer is the likely source of a significant portion of annual stream flow in Coastal Plain rivers. The complex stratigraphy of floodplain settings, active channel sediments, and the surficial aquifer influence the direction and magnitude of ground water flows to rivers within the Coastal Plain. Age dates are rare for ground water within the surficial aquifer but recent work at the Lizzie site (Greene County, NC) showed ground waters in the surficial aquifer were less than 50 years old (n=10) and within the alluvial aquifer adjacent to tributary streams the ground waters were typically less than 10 years old (n=4) (Spruill et al. 2005). Residence times for three tributary streams at the research site were all found to be less than 30 years old. This work indicates that ground water feeding Coastal Plain streams from the surficial aquifer has a high likelihood of being affected by land-use changes that have occurred over the past 50 years. Alterations to the land cover within the Coastal Plain are likely to affect recharge to the surficial aquifer and aquifer-fed streams over relatively short timeframes; alterations in recharge may result in measurable baseflow reductions in Coastal Plain streams.

Several methods exist to evaluate baseflow contributions to streams. These include seepage runs (Zelwegger et al. 1989), physical hydrograph separation (Lim et al. 2005), stable isotope and radioactive tracing (Clark and Fritz 1997), geochemical tracers (Katz et al. 1997), piezometry (Lee and Cherry 1978), thermal monitoring (Silliman et al. 1995, O'Driscoll 2006), etc. Stable isotope tracers have not been documented to evaluate baseflow contributions to streams in the Coastal Plain of North Carolina. Precipitation isotopic data collected at Wilmington, North Carolina indicate that there is significant seasonal and storm variability in ^{18}O composition of rainfall in the region (Willey et al. 2000). Ground water isotopic composition data collected in the Coastal Plain of North Carolina is quite different from that of rainfall, therefore stable isotopes may be useful tracers of surface water-ground water interactions in this setting (Hedges 2002).

In the past stable isotope tracers have been effectively used to provide insight into hydrological processes and runoff generation from forested catchments (Buttle 1994, Kendall and McDonnell 1998). Recently stable isotope techniques have been used to quantify differences in hydrology across different physiographic settings (O'Driscoll et al. 2005) and to evaluate urban land-use alterations to hydrological processes (Sidle and Lee 1999, Burns et al. 2005). There is great potential to advance the understanding of land-use effects on hydrology through the application of stable isotope techniques (Burns 2002). In this study we aim to document the applicability of stable isotope techniques to reflect land-use alterations to hydrology in the Coastal Plain. There is promise that this approach can be used to evaluate watershed-scale stormwater runoff effects in this and other physiographic settings.

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- McMahon, G., Bales, J.D., Coles, J.F., Giddings, E.M., and Zappia, H. 2003. Use of stage data to characterize hydrologic conditions in an urbanizing environment. *JAWRA* 39(6): 1529-1546.
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Willey, J.D., Kieber, R.J., Eyman, M.S., and Avery, G.B.Jr. 2000. Rainwater dissolved organic carbon: Concentrations and global flux. *Global Biogeochemical Cycles* 14 (1):139-148.

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(7) Training Potential

Students	Field of specialty	Degrees expected
(1) Graduate	Geology	M.S.
(1) Undergraduate	Geology	B.S.

One graduate student and one undergraduate student in the field of geology will participate in field data collection, data compilation and analyses, and data interpretation as a result of this proposed project. One M.S. thesis is expected to document this study. The urban streams within the monitoring network are typically located less than 5-miles from ECU campus; these sites will also be used for numerous class field trips for hydrology-related courses.

(8) Investigators' Qualifications: (next four pages)

Michael A. O'Driscoll

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Professional Preparation

University of Connecticut	Geology	B.S. (Cum Laude), Dec. 1996
The Pennsylvania State University	Environmental Pollution Control	Masters, May 1999
The Pennsylvania State University	Geosciences	M.S., May 2000
The Pennsylvania State University	Forest Hydrology	Ph.D., Dec. 2004

Appointments

East Carolina University	Assistant Professor-Geology Department	Spring 2005
East Carolina University	Instructor-Geology Department	Fall 2004
The Pennsylvania State University	Adjunct Faculty-Geology (Harrisburg)	Fall 2003
The Pennsylvania State University	Research Assistant	Jan. 1999-Aug. 2003
The Pennsylvania State University	Teaching Assistant-Hydrogeology	Fall 1998
The Pennsylvania State University	Lab Instructor-Physical Geology	Fall 1997- Spring 1998
Hygenix, Inc. - Stamford, CT	Environmental Consultant	Dec. 1996 – Aug. 1997
United States Navy - Norfolk, VA	Aviation Mechanic, Petty Officer 3 rd Class	1990–1994

Publications

O'Driscoll, M.A. and DeWalle, D.R. Stream-air temperature relations to classify stream-ground water interactions in a karst setting, central Pennsylvania , USA . 2006. *Journal of Hydrology* 329:140-153.

O'Driscoll, M.A., S.R. Riggs, D.V. Ames, M. M. Brinson, D.R. Corbett, and D. J. Mallinson. 2006. Geomorphic, Ecologic, and Hydrologic Dynamics of Merchants Millpond, North Carolina . In "Hydrology and Management of Forested Wetlands." Proceedings of The ASABE International Conference on Hydrology and Management of Forested Wetlands. New Bern , North Carolina, USA. Pp. 423-431.

DeWalle, D.R., Buda, A.R., Eismeier, J.A., Sharpe, W.E., Swistock, B.R., Craig, P.L., and O'Driscoll, M.A. 2005. Nitrogen cycling on five headwater forested catchments in mid-Appalachians of Pennsylvania. In: *Dynamics and Biogeochemistry of River Corridors and Wetlands (IAHS-294)*. Eds: Heathwaite,L., Webb,B., Rosenberry,D., Weaver, D., and Hayashi, M. International Association of Hydrological Sciences, Oxfordshire, UK. Pp. 29-36.

O'Driscoll, M.A., DeWalle, D.R., McGuire, K.J. and Gburek, W.J. 2005. Seasonal ¹⁸O variations and ground water recharge for three landscape types in central Pennsylvania,USA. *Journal of Hydrology* 303: (1-4):108-124.

O'Driscoll, M.A., and DeWalle, D.R. 2004. Stream-air temperature relationships as indicators of ground water inputs. *Watershed Update* 2 (6). An online publication of the American Water Resources Association. (<http://www.awra.org/committees/techcom/watershed/watershed.html>).

O'Driscoll, M.A. and Parizek, R.R.. 2003. The hydrological catchment area of a chain of karst wetlands in central Pennsylvania. *Wetlands* 23 (1): 171-179.

O'Driscoll, M.A. and DeWalle, D.R. 2002. Episodic stream/aquifer interactions in a Pennsylvania urban/agricultural watershed. In: Ground Water/Surface Water Interactions. Kenny, J.F. (ed.) AWRA 2002 Summer Specialty Conference Proceedings, American Water Resources Association, Middleburg, Virginia. pp. 535-540.

Professional Activities

- **American Water Resources Association** - Hydrology and Watershed Management Committee. Journal of the American Water Resources Association - Manuscript Reviewer.
- **Geological Society of America (GSA)** - South East Section GSA Grant Reviewer.
- **National Science Foundation** - Grant reviewer for Hydrological Sciences Section.
- **Otter Creek Natural Area Committee** (2004-present).
- **American Geophysical Union, North Carolina Water Resources Association, National Ground Water Association, International Association of Hydrological Sciences**

Funded Grants

Zarate, M., O'Driscoll, M., and Humphrey, C. 2006. The Effects of On-Site Wastewater Systems on Shallow Ground-Water Quality in Coastal North Carolina. ECU Division of Research and Graduate Studies 2006 Research Development Grant Program. \$25,000.

O'Driscoll, M. A. 2006-2007. The Influence of Streamflow and Storm Runoff on Nutrient Transport to an Estuary. ECU, Thomas Harriot College of Arts and Sciences Research Award. \$4,500.

Brinson, M.M., Rheinhardt, R.D., Christian, R.R., and O'Driscoll, M.A. 2006-2008. Development and Training for Reach and Watershed Assessment Protocols in Coastal Plain North Carolina. North Carolina Department of Environment and Natural Resources, Ecosystem Enhancement Program. \$218, 555.

O'Driscoll, M.A. and Mallinson, D.J. 2006. Characterization of surface water/ground water interactions along the Tar River using ground penetrating radar. North Carolina Water Resources Research Institute 2005-2006 Program. \$45,129.

O'Driscoll, M.A. 2006. Land-use effects on river-ground water interactions in the Coastal Plain of North Carolina. East Carolina University Research/Creative Activity Grants 2005-2006. \$18,331.

O'Driscoll, M.A. 2005. An outdoor field laboratory for hydrology at Otter Creek Natural Area and the Voice of America site. East Carolina University Student Computer and Technology Fee Innovative Project Proposal, 2004-2005. \$13,973.

O'Driscoll, M.A. and DeWalle, D.R. 2003. Stream-ground water interactions in a carbonate watershed. College of Agricultural Science Competitive Grant Program for Graduate Students, Penn State University. \$2,000.

O'Driscoll, M.A., DeWalle, D.R., and Parizek, R.R. 2001. Tracers of surface water-ground water interactions in an urban, karst watershed. Center for Environmental Chemistry and Geochemistry Research Initiation Grant, Penn State University. \$10,000.

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Education

B.S. 1965, Heidelberg College, Tiffin, Ohio; M.S. 1967, University of Michigan, Ann Arbor, Michigan; Ph.D. 1973, University of Florida, Gainesville, Florida

National Committees

Testimony before Subcommittee on Environmental Protection of the Committee on Environment and Public Works, U.S. Senate, April 9, 1991. (S. Hrg. 102-69); Testimony before Committee on Interior and Insular Affairs, U.S. House of Representatives, February 26, 1992; Panel of USDA Competitive Grants Program (July 1991); Site reviews of 2 NSF-LTER projects (1991); Committee on Wetlands Characterization, National Research Council, National Academy of Sciences (1993-1995); Member of Commission on Ecosystem Management, IUCN (The World Conservation Union) 1998-2000; American Institute of Biological Science, Board of Directors, Chair of Public Policy Review Committee (1998-2000); Chair of Committee on Riparian Areas: Functions and Strategies for Management, National Research Council, National Academy of Sciences (2000-2002).

Professional Experience

Department of Biology, East Carolina University, Assistant Professor, 1973-77; Associate Professor, 1977-81; Professor, 1981-present; Director of Graduate Studies in Biology, 1981-86. Ecologist, Office of Biological Services, U.S. Fish and Wildlife Service, 1979-80. Visiting Assistant Professor of Botany, University of North Carolina at Chapel Hill, Summer 1976. Research Associate, Center for Aquatic Sciences, University of Florida, Summer 1971. Fisheries Biologist, Peace Corps, Turrialba, Costa Rica, 1967-69.

Honors

Foreign Area Fellowship Program (Ford Foundation) for research in Latin America (1971-73); Award for Excellence for Graduate Research, Ph.D.--Institute of Food and Agricultural Sciences, University of Florida (1974); Helms Faculty Research Award from Sigma Xi, East Carolina University (1978 and 1988) American Men and Women of Science (1976); National Wetlands Award for Science Research cosponsored by the Environmental Law Institute and the Environmental Protection Agency (1995); East Carolina University, College of Arts and Sciences, Distinguished Professor Award (1997); East Carolina University, Board of Trustees, Lifetime Achievement Award (1997); East Carolina University, Distinguished Research Professor Award (1997); Merit Award, Society of Wetland Scientists (1998).

Selected Refereed Journal Publications (since 1993)

- Brinson, M.M. 1993. Gradients in the functioning of wetlands along environmental gradients. Wetlands 13:65-74.
- Moorhead, K.K. and M.M. Brinson. 1995. Response of wetlands to rising sea level in the lower Coastal Plain of North Carolina. Ecological Applications 5:261-271.
- Young, D.R., G. Shao, and M.M. Brinson. 1995. The impact of the October 1991 northeaster storm on barrier island shrub thickets (*Myrica cerifera*). Journal of Coastal Research 11:1322-1328.
- Brinson, M.M., R.R. Christian, and L.K. Blum. 1995. Multiple states in the sea-level induced transition from terrestrial forest to estuary. Estuaries 18:648-659.
- Brinson, M. M. and R. Rheinhardt. 1996. The role of reference wetlands in functional assessment and mitigation. Ecological Applications 6:69-76.
- Rheinhardt, R.D., M.M. Brinson, and P.M. Farley. 1997. Applying wetland reference data to functional assessment, mitigation, and restoration. Wetlands 17:195-215.

- Michener, W.K., E.R. Blood, K. L. Bildstein, Mark M. Brinson, and L.R. Gardner. 1997. Climate change, hurricanes and tropical storms, and rising sea level in coastal wetlands. Ecological Applications 7(3):770-801.
- Brinson, M.M. and R.R. Christian. 1999. Stability of *Juncus roemerianus* patches in a salt marsh. Wetlands 1:171-191.
- Rheinhardt, R.D., M.C. Rheinhardt, M.M. Brinson, and K. Faser. 1998. Forested wetlands of low order streams in the inner Coastal Plain of North Carolina, USA. Wetlands 18(3): 365-378.
- Brinson, M.M. and R.R. Christian. 1999. Stability of *Juncus roemerianus* patches in a salt marsh. Wetlands 1:171-191.
- Rheinhardt, R.R., M.C. Rheinhardt, M.M. Brinson, and K.E. Faser, Jr. 1999. Application of reference data for assessing and restoring headwater ecosystems. Ecological Restoration 7(3):241-251
- Whigham, D.F., L.C. Lee, M. M. Brinson, R. D. Rheinhardt, M.C. Rains, J.A. Mason, H. Kahn, M.B. Ruhlman, and W.L. Nutter. 1999. Hydrogeomorphic (HGM) assessment – a test of user consistency. Wetlands 19:560-569.
- Rheinhardt, R., D.F. Whigham, H. Kahn, and M. Brinson. 2000. Vegetation of headwater wetlands in the inner Coastal Plain of Virginia and Maryland. Castanea 65(1):21-35.
- Brinson, M.M. and A.I. Malvárez. 2002. Temperate freshwater wetlands: types, status, and threats. Environmental Conservation 29(2):115-133. Abstract at: <http://www.icef.eawag.ch/abstracts/temperateswamp.pdf>
- Kroes, D. and M. M. Brinson. 2004. Occurrence of riverine wetlands on floodplains along a climatic gradient. Wetlands 24:167-177.
- Refereed and Invited Chapters (since 1998)***
- Brinson, M.M. and R. D. Rheinhardt. 1998. Wetland functions and relations to societal values. Chapter 2 (pp. 29-48) In M. Messina and W. Conner (editors). Southern Forested Wetlands: Ecology and Management, Lewis Publishers, Ann Arbor, Michigan.
- Brinson, M.M., R.D. Smith, D.F. Whigham, L.C. Lee, R.D. Rheinhardt, and W.L. Nutter. 1998. Progress in development of the hydrogeomorphic approach for assessing the functioning of wetlands. Pages 393-406, In A. J. McComb and J. A. Davis, editors. Wetlands for the Future. Gleneagles Publishing, Adelaide, Australia.
- Brinson, M.M. and J. Verhoeven 1999. Chapter 8. Riparian Forests. Pages 265-299 in M.L. Hunter (editor). Maintaining Biodiversity in Forested Ecosystems. Cambridge University Press, Cambridge, England.
- Richardson, J.L. and M.M. Brinson. 2000. Chapter 9. Wetland soils and the hydrogeomorphic classification of wetlands. Pages 209-227 in J.L. Richardson and M.J. Vepraskas (editors). Wetland Soils: Genesis, Hydrology, Landscapes, and Classification. Lewis Publishers, Boca Raton, Florida, USA.
- Christian, R.R., L.E. Stasavich, C.R. Thomas, and M.M. Brinson. 2000. Reference is a moving target in sea-level controlled wetlands. Pages 805-825. In M.P. Weinstein and D.A. Kreeger (editors). Concepts and Controversies in Tidal Marsh Ecology. Kluwer Press, The Netherlands.
- Poff, N.L., M.M. Brinson, and J.W. Day, Jr. 2002. Potential Impacts on Inland Freshwater and Coastal Wetland Ecosystems in the United States. Pew Center on Global Climate Change, Arlington, VA. 45 pp. (special report)
- Lugo, A.E., M.M. Brinson, and S. Brown (eds.). 1989. Forested Wetlands. Vol. 15 of Ecosystems of the World Series. Elsevier Scientific Publishers, Amsterdam. 527 pp.