Water Resources Research Institute of the University of North Carolina Annual Technical Report FY 2013

Introduction

During 2013-2014 (Fiscal Year 2013), the Water Resources Research Institute (WRRI) of The University of North Carolina System was 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.

Research priorities continue to be identified by the WRRI Advisory Committee, composed of representatives of several federal and state agencies, local governments, industries, and non-governmental environmental organizations (NGOs), as well as by other water resource experts in the state with whom WRRI has close relationships. A technical review committee is also convened on an annual basis to advise WRRI staff on the scientific merit of research proposals submitted for funding. Full-time faculty members from all North Carolina institutions of higher education are eligible to receive grants from WRRI.

The information transfer program continued to focus on disseminating results of sponsored research and providing information on emerging water issues, solutions, and regulations. Results of research are disseminated by publication of technical completion reports, summaries in the WRRI newsletter, publication of summaries on the WRRI website, and presentations by investigators at the WRRI Annual Conference and individual group meetings where appropriate. WRRI continues to be a sponsor of continuing education credits by the NC Board of Examiners of Engineers and Surveyors and the NC Board of Landscape Architects. This allows WRRI to offer Professional Development Hours (PDHs) and contact hours for attendance at the WRRI Annual Conference and other workshops and seminars that WRRI sponsors.

WRRI continues to adapt to changes in the landscape of its home institution, NC State University, by consolidating its operations and maximizing staff efficiencies and outputs. They continue to leverage funds from a variety of sources to expand the reach and impact of research and outreach activities, and grow their involvement in and support of water-related research and outreach across the state.

Research Program Introduction

During 2013-2014 (Fiscal Year 2013), WRRI continued its regular program of fostering research, training, and information transfer responsive to water issues of the state and region. Results from Institute-supported research efforts are expected to assist local, municipal, state, regional and federal agencies improve their decision-making in the management and stewardship of their water resources.

NC WRRI was affected by the national budget cuts known as the sequester, and our federal dollars to support funding into FY 13 (from the call for proposals sent out in FY 12) were reduced by $36,810. WRRI was able to make up that difference with supplemental research dollars from a consortium of water utilities in order to fully fund our desired research portfolio of 6 projects from the FY 12 call. WRRI's ability to maintain this level of funding into the future should budget cuts continue is unsure.

To help it chart and sponsor a research program responsive to the water resource issues and opportunities in North Carolina, WRRI interacts closely with the N.C. Department of Environment and Natural Resources, other agencies, water and power utilities, and an array of research and outreach programs within the UNC system and at private higher educational institutions across North Carolina. A research advisory committee provides input, guidance, and review of the Institute's research priorities on an annual basis. This committee is composed of representatives of several federal and state agencies, local governments, industries, and non-governmental environmental organizations (NGOs). In 2013, the committee consolidated some positions and appointed many new members to replace those whose terms had expired, to reflect changes in state agency organization, and to ensure more comprehensive geographic representation and topical expertise on the committee.

The results of this process are shared with prospective investigators as part of WRRI's annual call-for-proposals. Proposals that address the annual priorities and meet peer review and other criteria receive preferential consideration for funding. Research priorities, as determined via the above process, are incorporated into our Section 104 Objectives on an annual basis. The proposal solicitation, as in the past, is sent to relevant contacts at colleges and universities across North Carolina to apprise them of the opportunity to submit proposals. The call for proposals is also sent to an email distribution list of approximately 180 university faculty across North Carolina. Full-time faculty members from all North Carolina institutions of higher education are eligible to receive grants from WRRI.

The proposals received are sent to a Technical Committee and to external peer reviewers to determine the relevancy, need for the proposed research and relative strength and weaknesses. The Technical Committee convenes on an annual basis to review all comments made by reviewers, advise WRRI staff on the scientific merit of research proposals, and make recommendations regarding proposal funding.

Efforts were made to maintain a consolidated, refined, and focused list of FY13-14 research priorities based on in-depth discussions of the most significant water research needs and priorities for the state of North Carolina. These priorities were included in the annual call for FY 2013-2014, and the projects resulting from this annual call will be funded from March 1, 2014 to February 28, 2015 and will be reported in the next USGS Annual Report.

The FY 2013-2014 research priorities were:

•quantifying the economic value of water quality •quantifying sources, transport, and fate of nutrients and sediments in surface waters, and water quality changes in NC watersheds in which TMDLs and nutrient management plans have been implemented •defining and evaluating in-stream flow needs and aquatic ecosystem function •human impacts on groundwater availability and quality, interaction of surface water and groundwater resources, and fundamental hydrogeological understanding needed to support sustainable use of groundwater resources •development and evaluation of methods for quantifying pollutant removal from stream restoration practices and projects •defining and evaluating different stormwater control and nutrient reduction measures, their relative pros and cons, their cost-effectiveness, and appropriate pollutant removal credits for these measures as they relate to sediment, nitrogen, phosphorous, pathogens/bacteria, and other stormwater contaminants in urban stormwater systems •defining and evaluating realistic management measures that can quantifiably mitigate the effects of impervious cover on aquatic life, in different urban settings and stormwater systems •understanding, quantifying, and managing risks and uncertainties in public water supplies, in the face of changing population, land use, climate, and regulations •setting rates and financing capital improvements for water and/or sewer utilities, in the face of changing population, land use, climate, and regulations •applying social science and economic valuation methodologies to help utilities better understand customers' level-of-service expectations, their motivations, and willingness to pay for services, as well as understand customer perceptions, attitudes, opinions and beliefs related to water, wastewater, and reclaimed water •identifying, understanding, and applying innovative processes and technologies for water and wastewater treatment, plant operation, distribution systems, and potable and reclaimed water supply and waste discharge management •evaluation of alternative water sources (e.g., graywater or harvested rainwater) for differing consumptive uses (e.g., home irrigation), health risks of alternative sources, and potential impacts of alternative water use on overall water supply and demand

In FY13, WRRI also assisted the NC Urban Water Consortium-Stormwater Group (SWG) with issuing a separate request for proposals for a literature and data review of benthic macroinvertebrate studies and stream ratings. This addresses a long-standing topic of concern for the stormwater utilities of the SWG who are under continuing pressure from state and federal regulators to manage water quality and biological integrity in urban streams. WRRI assisted with crafting the RFP and collecting and reviewing submitted proposals. The work is expected to occur in FY 14.

A mesocosm study to determine nitrogen assimilation capacity of a restored wetland slated to receive pumped drainage water - a critical component to maximize improvement to the Pamlico Sound

Basic Information

Title:	A mesocosm study to determine nitrogen assimilation capacity of a restored wetland slated to receive pumped drainage water - a critical component to maximize improvement to the Pamlico Sound
Project Number:	2013NC181B
Start Date:	3/1/2013
End Date:	2/28/2014
Funding Source:	104B
Congressional District:	NC-02
Research Category:	Water Quality
Focus Category:	Wetlands, Treatment, Nutrients
Descriptors:	None
Principal Investigators:	Michael Burchell, Stephen W. Broome Broome

Publications

There are no publications.

Interim report: Project 13-03-W

A mesocosm study to determine nitrogen assimilation capacity of a restored wetland slated to receive pumped drainage water - a critical component to maximize improvement to the Pamlico Sound.

Submitted to:
NCSU Water Resources Research Institute

Submitted by:
NCSU Biological and Agricultural Engineering Department

Date submitted:
February 2014

Project budget period:
March 2013 – February 2014

Principle Investigators
Michael R. Burchell, Ph.D. - Associate Professor & Extension Specialist
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Stephen Broome, Ph.D. – Professor

Tiffany Messer - Ph.D. Graduate Student

Introduction

Restored wetlands in eastern North Carolina that receive agricultural drainage water have been shown to reduce the amount of nitrogen that could ultimately enter adjacent estuaries. These wetland restorations, strategically designed and positioned to divert water away from estuaries, should do so without negatively affecting other downstream ecosystems (i.e. contribute to eutrophication). This project seeks to provide guidance for an innovative full-scale wetland restoration design plan on approximately 1,500 ha of less productive farmland in Hyde County, NC that is enrolled in the Natural Resource Conservation Service's Wetlands Reserve Program (NRCS-WRP). Project partners need to know the restoration will not impose negative ecological impacts downstream in the Alligator River National Wildlife Refuge (ARNWR).

Whole system estimates of nitrogen transformations have been difficult to identify and quantify at this scale. Therefore, the primary goals of this study are to utilize wetland mesocosms with two distinct soils to 1.) Determine the amount of pumped agriculture drainage water and associated nitrogen loads that could be diverted from the estuary into the proposed wetland restoration areas without significant negative impacts to other downstream nitrogen limited receiving waters and 2.) Improve our understanding of the fate of nitrogen in these two distinct restored wetland systems with advanced analytical techniques to enable wetland designers to enhance nitrate removal through mechanisms such as denitrification.

Mesocosm Experimental Setup (Completed)

Six large wetland mesocosms (3.5 m long X 0.9 m wide X 0.75 m deep) were constructed in a greenhouse near North Carolina State University (Figure 1). The mesocosms were loaded with three randomized replicates of Scuppernong soil (a poorly drained, organic soil typically associated with pocosins) and Deloss soil (a poorly drained, mineral soil typically associated with marine terraces) that were excavated directly from two future restoration sites. Total carbon content was 75% in the Scuppernong soil and 16% in the Deloss soil. Soft-stemmed bulrush (*Schoenoplectus tabernaemontani*) was planted in the mesocosms in May 2011 to allow for wetland establishment prior to experimentation that began in September 2012. Three smaller mesocosms served as controls for the experiment.

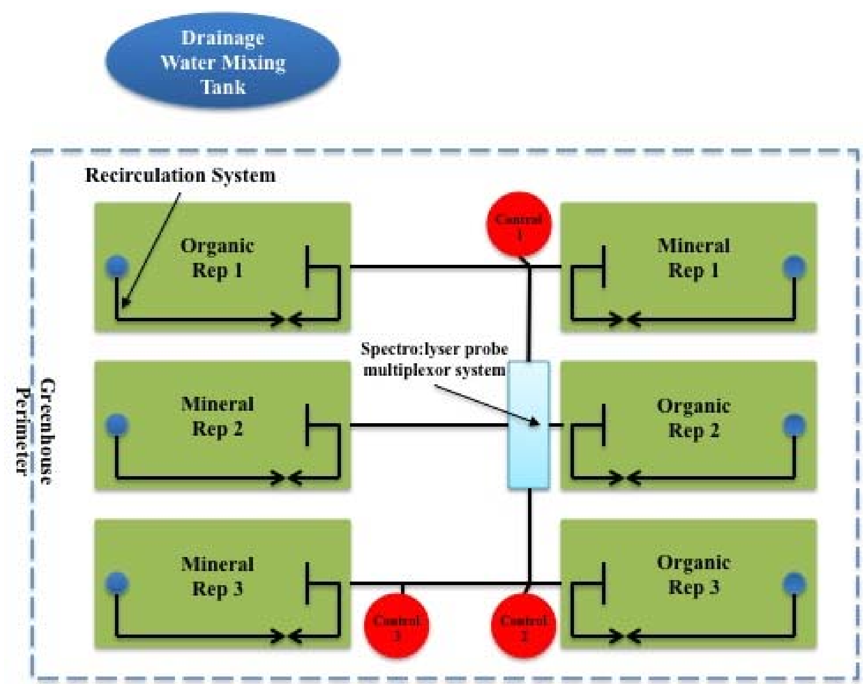

Figure 1. Wetland mesocosm experimental setup. Wetlands labeled with organic and mineral represent the wetlands constructed with Scuppernong and Deloss soils, respectively.

Wetland Mesocosm Experimental Design (Completed)

The experiments were conducted as batch studies that evaluated nutrient removal in each wetland mesocosm at various hydraulic and nutrient loading rates. Eleven batch studies were completed between September 2012 and October 2013 to capture differences in nitrogen removal rates in these wetlands throughout the year. Nitrate-N (NO_3-N) concentrations were varied throughout the batch studies with concentrations commonly found in agricultural drainage water (2.5-15 mg L^{-1}). Simulated drainage water with 2.5 mgL^{-1} of NO_3-N at a depth of 18 cm was determined to be the base load (1X) for these experiments, because water sampling at the restoration site and literature suggest that the restored wetland loadings will be frequently near this level. Each batch study lasted 7-10 days with water depths varying between 18 and 30 cm. Control tanks, with no soil or plants, were loaded with the same depth of water as the mesocosms during each batch study.

Sampling Plan and Analysis (In Progress)

Water quality grab samples were collected from the recirculation system on days 0, 1, 2, 3, 5, 7, and 10. Samples were analyzed for nitrogen species (NO_3-N, ammonium-N (NH_4-N), and Total Kjeldahl Nitrogen (TKN)) and dissolved organic carbon (DOC). Organic-N (ON) was determined as the difference in measured TKN and NH_4-N values. Chloride (Cl^-) was measured to serve as a biologically conservative ion to assess changes in concentrations due to water loss or gain in the mesocosms. Soil redox was measured at 5 and 15 cm depths with platinum tipped electrodes connected to a pH/mV meter. Dissolved oxygen and pH in the water column were measured daily with an YSI® Professional Plus Multiparameter Instrument (Aquatic Habitats, Apopka, FL) and pH meter (HM Digital, Culver City, CA), respectively. Water temperature was monitored hourly using 8k HOBO pendant temperature sensors (Onset Computer Corporation, Bourne, MA). Evapotranspiration was determined based on the changes in the water table depth measured on a stage gage in each mesocosm over the course of each batch study.

Soil samples were taken at the beginning and end of each growing season to determine total nitrogen and carbon contents in these pools for 2011- 2013. Soil cores were also analyzed at the beginning of the growing season each year for humic matter, bulk density, and other critical nutrients. Additionally, above and below ground biomass samples were taken at the end of the growing seasons of 2011- 2013 to assess the total nitrogen and carbon contents in the biomass pools.

A Spectro::Lyzer automatic field spectrophotometer probe (S::CAN company-Vienna, Austria) allowed for the collection of over 1000 more NO_3-N and DOC readings for each experimental run than would have been possible if only laboratory analysis was used. The Spectro::Lyzer was connected to a specially designed multiplexor and pumping system that was controlled with a programmable logic controller (PLC). This allowed for hourly measurements of NO_3-N and DOC concentrations in each mesocosm (Figure 4). NO_3-N and DOC concentrations from grab samples were used to calibrate the probe.

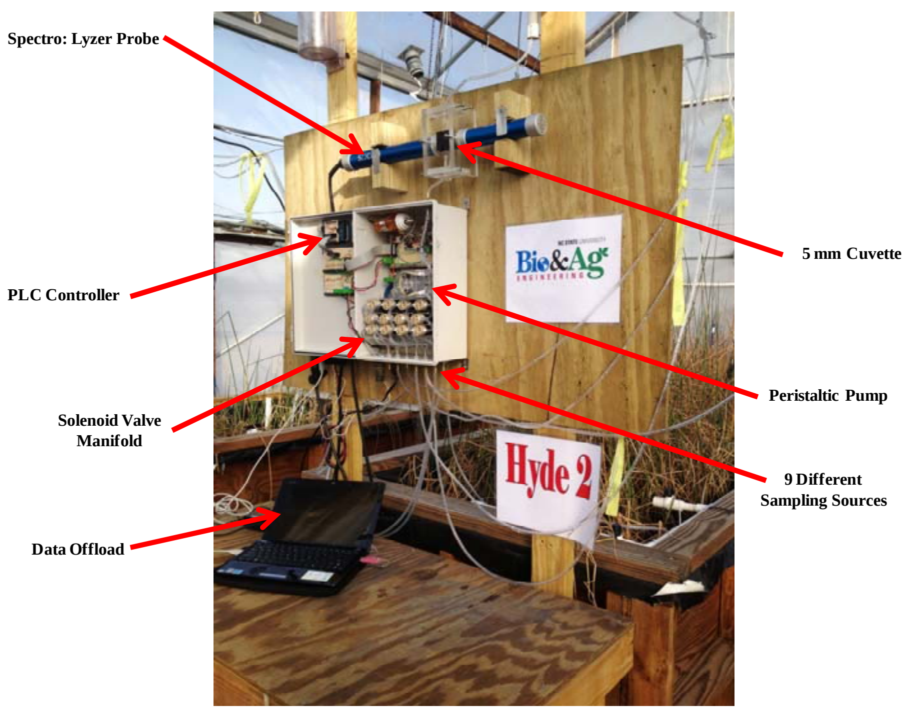

Figure 2. Spectro::Lyzer probe and a multiplexer pumping system that allowed for hourly water quality sampling from the mesocosms.

Statistical Analysis of Batch Studies (In Progress)

Multivariate statistical analyses will be used to determine differences in NO_3-N concentrations between the two wetland soil treatments and the controls over time using a linear mixed effects model in SAS glimmix® (SAS Institute, Cary, NC). Additionally, the effects of treatment, season, and N loading, will be assessed with SAS glimmix® utilizing the Tukey honest significance tests. All statistical tests will be considered significant at $\alpha=0.05$.

Wetland Mesocosm ^{15}N Tracer Study (In Progress)

We consulted with Dr. John Bohlke at the U.S. Geological Survey site in Reston, GA and Dr. Craig Tobias at the University of Connecticut in Groton, CT prior to beginning the ^{15}N studies. Both individuals have successfully completed several ^{15}N studies in stream and wetland systems and provided guidance for our setup, monitoring, and analysis for the completed experiment.

A coupled Ar gas tracer and Br^- solute tracer study was completed in July 2013 to determine the Gas Transfer Velocity (GTV) of N_2 within one mineral and one organic wetland system during a batch study. The GTV will aid in determining the mass of N_2 lost from the wetland mesocosm most likely due to denitrification. Duplicate water samples were collected to assess Ar concentrations at 0 min, 30, min, 1 hr, 2 hr, 4 hr, 8 hr, 12 hr, 16 hr, 20 hr, 24 hr, and 48 hr following the introduction of the slug. Samples were analyzed at the MCTC Analytical Instrumentation Laboratory at the University of Connecticut. Duplicate Br^- samples were collected at the same time of each Ar sampling event and evaluated at the Environmental and Agriculture Testing Laboratory at NCSU.

The wetland mesocosm-scale ^{15}N tracer study was completed in August 2013 in one organic and one mineral soil mesocosm rather than all six mesocosms to avoid residual tracer in all of the mesocosms, and allow for more intensive sample collection that would fit within the project budget. The batch study was 7 days long with water depths of 30 cm. After estimating N pools in the soil, plants, and water, drainage water was enriched with 10% $^{15}NO_3$-N for the study to ensure there would be detectable amounts in the system.

The N pool sizes for the water, sediment, and biomass were calculated directly from dry mass of samples (g), concentrations of each pool (g N/ g substrate), and estimated coverage for the substrate sampled (m^2) in each mesocosm. Duplicate NO_3-^{15}N and N_2-^{15}N samples were collected on days 1, 2, 3, 5, and 7 of the batch run and were analyzed for $^{15}N/^{14}N$ at the USGS Stable Isotope Laboratory in Reston, Virginia. N_2O samples were collected from the water column on days 0, 1, 2, 3, 5, and 7 of the batch run and analyzed in the Environmental Analytical Testing Service Laboratory at NCSU on a GC-MS. Sediment and biomass samples were taken in triplicate before the experiment to determine baseline levels of ^{15}N, and following the experiment. Sediment and biomass samples were analyzed at the Duke Environmental Stable Isotope Laboratory (DEVIL) for $^{15}N/^{14}N$ to determine ^{15}N in these pools.

N transformations (i.e., denitrification, plant uptake) will be quantified utilizing the percent recovery of the ^{15}N tracer from the water, biomass, and sediment samples. Multivariate statistical analyses will be utilized to determine differences between nitrogen fates in the two wetland soil treatments. Variables will include carbon availability, pH, and dissolved oxygen.

Preliminary Results

Eleven batch studies and one ^{15}N tracer study have been completed. Preliminary results show significant NO_3-N reduction in wetland mesocosms compared to the control mesocosms (α=0.05), presumably due to denitrification. Differences in NO_3-N removal between soils, season, and N load also appear significant (α=0.05). A summary of all completed batch runs is shown in Table 1. Preliminary results indicate NO_3-N concentration reductions were higher during warmer temperatures, and 90% reduction during some runs was achieved in as few as 5-7 days. NO_3-N concentrations reduced at slightly faster rates within the Deloss ($Wetland_{Min}$) wetland mesocosms than the Scuppernong ($Wetland_{Org}$) wetland mesocosms (α=0.05). Preliminary mass balance estimates indicate denitrification accounted for 44-65% and 60-80% of NO_3-N removal in $Wetland_{Org}$ and $Wetland_{Min}$ systems, respectively.

Table 1. Summary of completed batch run conditions and results. Note: C_i indicates initial NO_3-N concentrations, and 1X Loads are the base load (2.5 mgL^{-1}, 18 cm depth).

Run	Season (Date)	Avg. Water Temp (°C)	Monitoring Time (day)	Water Depth (cm)	Target C_i ($mg\ L^{-1}$)	Actual Mean C_i ($mg\ L^{-1}$)	Load	Mean NO_3-N % Removal $Wetland_{Org}$	Mean NO_3-N % Removal $Wetland_{Min}$
1	Fall (9/15-10/4)	21.7	9	30	2.5	2.07	2X	65%	93%
2	Fall (10/16-10/26)	17.2	10	18	5	5.25	2X	81%	81%
3	Fall (11/5-11/15)	10.6	10	30	10	6.55	4X	51%	47%
10	Fall (9/24-10/4)	20.6	10	30	10	12.52	8X	56%	70%
11	Fall (10/15-10/25)	16.7	10	18	2.5	2.76	1X	95%	97%
4	Winter (1/22-2/1)	8.9	10	18	2.5	2.11	1X	48%	55%
5	Winter (2/11-2/21)	10.6	10	18	5	4.80	2X	41%	43%
6	Spring (5/28-6/7)	25.0	10	18	2.5	2.42	1X	100%	100%
7	Summer (7/2-7/12)	27.2	10	30	2.5	2.43	2X	97%	99%
8	Summer (8/6-8/16)	26.7	10	30	5	5.36	4X	96%	99%
9	Summer (8/20-8/27)	25.6	7	30	2.5	2.97	2X	90%	89%

Figure 3 displays the change in NO_3-N over time for three batch runs completed in fall, winter, and spring with the base load (2.5 mg NO_3-N L^{-1}, 18 cm water depth). The results clearly show the expected positive effect warmer temperatures and growing season had on NO_3-N removal rates. Further analysis of these removal curves will allow us to determine NO_3-N removal rate constants in each wetland type that can be adjusted for temperature.

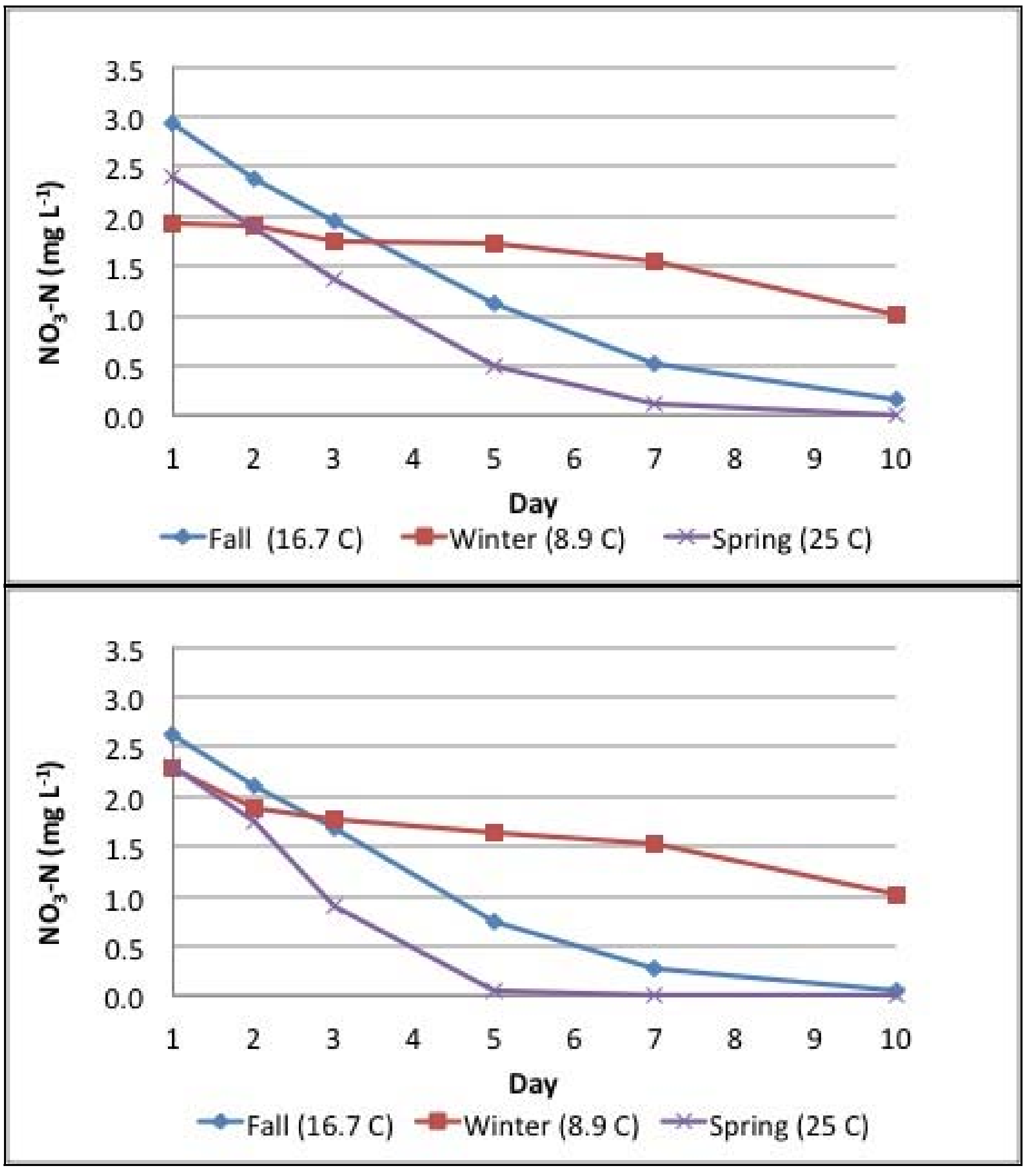

Figure 3. NO_3-N concentrations for $Wetland_{Org}$ (top graph) and $Wetland_{Min}$ (bottom graph) 1X Load (2.5 mgL^{-1} at 18 cm water depth).

Figure 4 shows calibrated NO_3-N concentrations measured with the automatic Spectro::Lyzer probe during a wetland batch study in September 2013. Of note, the hourly data collected from the batch run indicates diurnal changes, which are rarely observed in experiments of this nature that rely solely on water quality grab sampling and laboratory analysis. However, with the use of the Spectro:Lyzer probe and the closed system mesocosm setup, we can investigate hourly NO_3-N transformations occurring internally within these systems, which are likely linked to plant and microbial metabolic processes that vary over the course of a day.

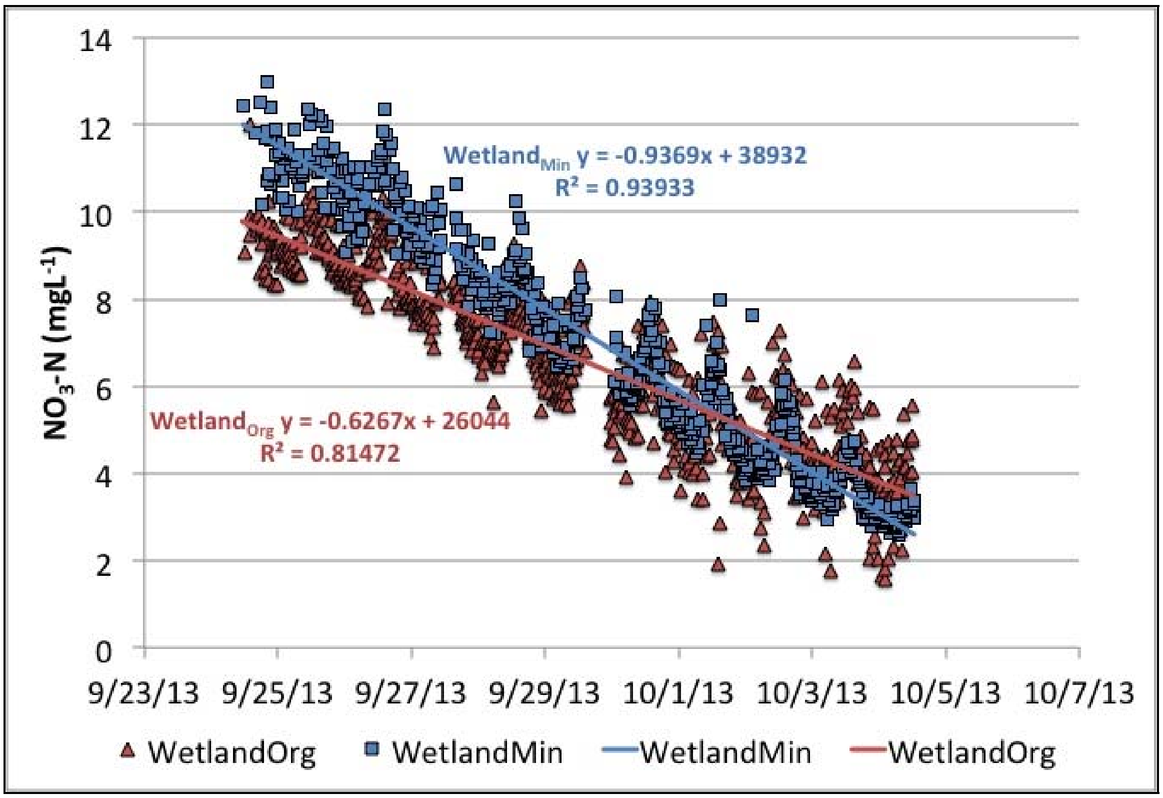

Figure 4. Hourly NO_3-N concentrations from the Spectro:Lyzer for Batch Run 10 (September 2013, 15 mgL^{-1}, 30 cm water depth).

Preliminary Conclusions and Proposed Future Evaluations

As expected, significant NO_3-N removal was obseved within the wetland mesocosms. This data will be used to develop NO_3-N removal rate constants within these systems. Assimilation constants will be calculated utilizing a widely used first order process equation (Burchell *et al.*, 2007; Reed *et al.,* 2005; Kadlec and Knight, 1995). Rate constants will then be used to determine maximum NO_3-N loads that can be pumped into the full-scale wetland under various conditions.

The ^{15}N tracer study that was completed will be used to evaluate the NO_3-N mass balance and fate at the end of the growing season. However, to provide a more complete assessment of the effects of season, N load, and antecedent moisture conditions on the NO_3-N transformations, more batch runs and a spring ^{15}N tracer study are planned. Over the next 11 months we hope to complete additional batch runs to add to seasonal observations especially for the spring and summer. Therefore, batch runs are planned to restart in spring 2014 and continue into the fall 2014. An additional ^{15}N tracer study is planned for the beginning of the 2014 growing season to provide a better understanding of N transformations at the beginning and end of the growing season.

With the completion of this last set of experiments, a comprehensive assessment of the wetland conditions that significantly affect the NO_3-N removal and the maximum assimilation potentials for these systems will be determined. The combination of the two tracer studies will provide a better understanding of which mechanisms are removing NO_3-N in these systems.

References:

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Surface and Subsurface Properties Regulating Manganese Contamination of Groundwater in the North Carolina Piedmont

Basic Information

Title:	Surface and Subsurface Properties Regulating Manganese Contamination of Groundwater in the North Carolina Piedmont
Project Number:	2013NC182B
Start Date:	3/1/2013
End Date:	2/28/2014
Funding Source:	104B
Congressional District:	NC-02
Research Category:	Water Quality
Focus Category:	Water Quality, Hydrology, Groundwater
Descriptors:	None
Principal Investigators:	Matthew Polizzotto, Aziz Ammozegar, Robert E Austin, Rick Bolich, Phil Bradley, Owen Duckworth, Dean Hesterberg

Publications

There are no publications.

PROGRESS REPORT

to the
Water Resources Research Institute
of
The University of North Carolina

For Research entitled

Surface and Subsurface Properties Regulating Manganese Contamination of Groundwater in the North Carolina Piedmont

WRRI Project 13-05-W

March 7, 2014

Submitted by

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1. INTRODUCTION

Manganese (Mn) is a naturally occurring contaminant of increasing concern for North Carolina's water supplies. In particular, it is a widespread problem in groundwater of the Piedmont physiographic region, where roughly 40-50% of wells have Mn concentrations exceeding North Carolina's drinking water standard of 0.05 mg/L (Smith, 2006; NC DENR 2010). High concentrations of Mn in North Carolina well water are correlated with increased infant and cancer-induced mortality rates (Spangler and Spangler, 2009; Spangler and Reid, 2010). High Mn concentrations also impair effective water treatment and impact water aesthetics. The underlying causes for elevated Mn in Piedmont groundwater are not well defined, and existing hydrogeochemical datasets are insufficient to predict groundwater Mn concentrations. Our WRRI project seeks to fill in existing knowledge gaps, better understand the controls on Mn distributions in well water, and develop decision-making tools that may be used to help reduce Mn exposure to people across the North Carolina Piedmont.

2. PROJECT ACTIVITIES AND FINDINGS TO DATE

Our project activities are centered on three research objectives that link geospatial, field, laboratory, and spectroscopic analyses. To date, we have collected all of the proposed data for the project and are now completing analyses and interpretations. Highlights of our activities and findings to date are outlined below, and they are organized according to the original proposed project objectives. Each section also describes ongoing work that is being conducted.

2.1. Objective 1: Relate the spatial variability of groundwater Mn concentrations to surface and subsurface properties that have been mapped across the North Carolina Piedmont.

2.1.1. Activities

We have assembled and linked existing statewide well-water quality data [from the USGS National Uranium Resource Evaluation (Smith, 2006) and the NC Department of Public Health private well testing database (NC DENR, 2011)], soil map data [Natural Resources Conservation Service Soil Survey Geographic database (SSURGO, 2014)], and geology map data [NC Geologic Survey maps (NCGS, 1985)]. The data sources have been integrated, analyzed, and visualized using a Geographical Information System (GIS) and the statistic software R.

2.1.2. Key Findings

2.1.2.1. Manganese distributions in well water

Manganese concentrations in well water are spatially variable across the Piedmont physiographic region, and concentrations range from the below 1 μg/L to greater than 1000 μg/L (**Figure 1**). For reference, the North Carolina Mn recommended drinking water guideline is 50 μg/L.

The majority of wells with Mn > 50 μg/L are shallower than 50 m deep, and the highest Mn concentrations (> 500 μg/L) are generally found in wells shallower than ~30 m deep (**Figure 2**).

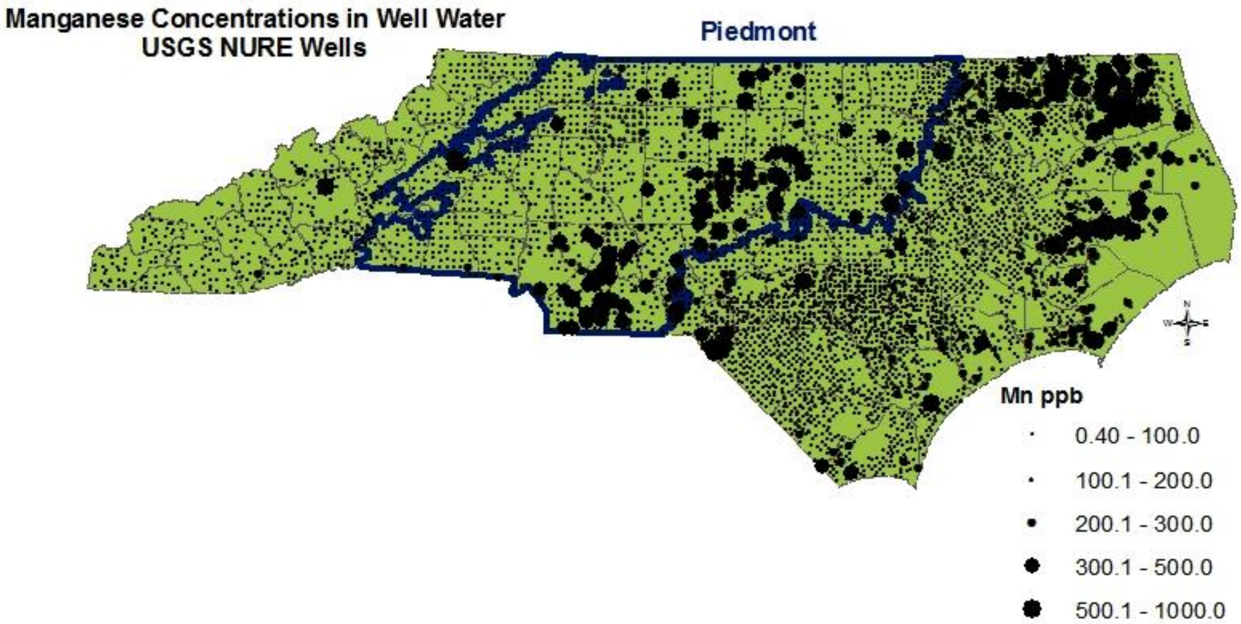

Figure 1. Manganese concentrations in well water across North Carolina. The Piedmont region is outlined in blue. Concentrations are depicted by black filled circles, with values proportional to symbol size. Data are from the USGS National Uranium Resource Evaluation well database (Smith, 2006). 1 ppb = 1 μg/L.

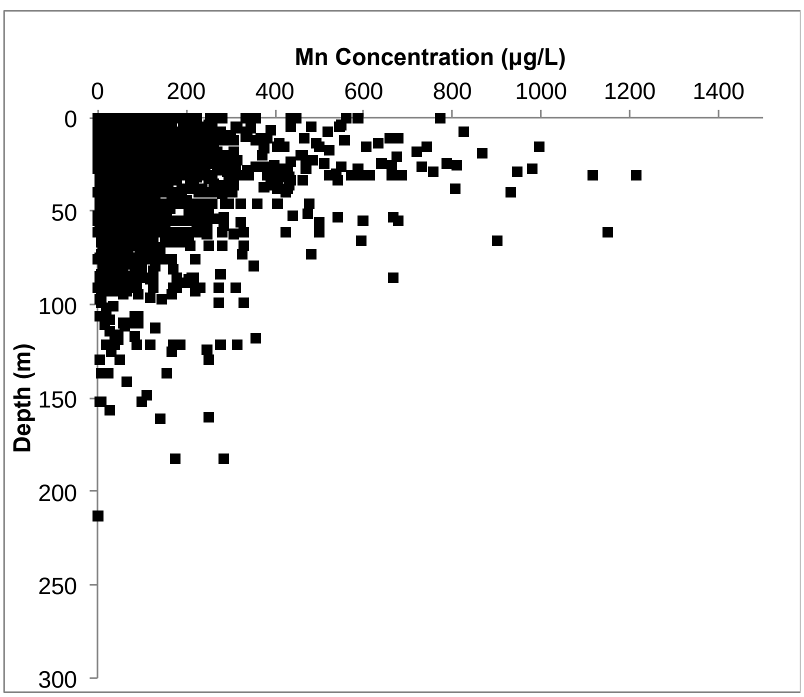

Figure 2. Depth distribution of Mn concentrations in well water within the NC Piedmont region. Depths reflect the bottoms of drilled wells. Data are from the USGS National Uranium Resource Evaluation well water database (Smith, 2006). 1 ppb = 1 μg/L.

2.1.2.2. Manganese concentrations, soil, and geologic properties

Manganese concentrations cluster by soil system in the Piedmont, with the Carolina Slate Belt and Triassic Basin systems being particularly affected (**Figures 3 and 4**). The highest Mn concentrations are found in wells located in the Carolina Slate Belt system, with a mean concentration of 108 μg/L and a maximum concentration of 2420 μg/L, compared to the NC drinking water guideline of 50 μg/L. However, within other systems, elevated Mn concentrations may also exist in well water. For instance, the lowest average Mn concentrations are found in wells located in the Felsic Crystalline system, but even there, >17% of wells have measured concentrations greater than the NC drinking water guideline of 50 μg/L.

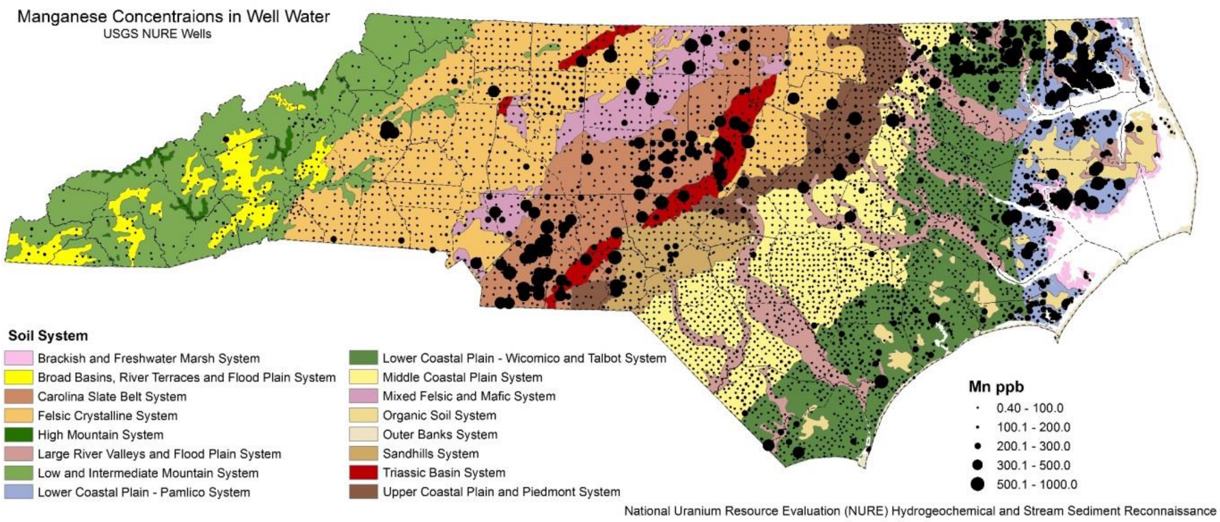

Figure 3. Manganese concentrations in well water [USGS National Uranium Resource Evaluation well water database (Smith, 2006)] mapped over NC soil systems [Natural Resources Conservation Service Soil Survey Geographic database (SSURGO, 2014)]. Concentrations are depicted by black filled circles, with values proportional to symbol size. 1 ppb = 1 μg/L.

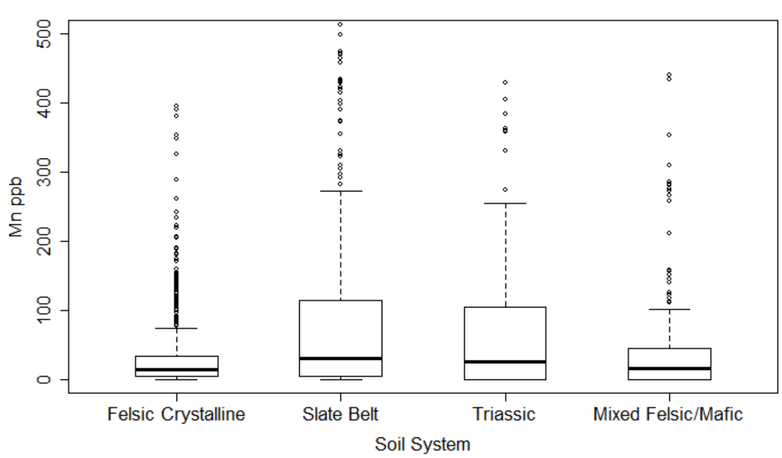

Figure 4. Manganese well water concentration data (Smith, 2006) and soil system (SSURGO, 2014). The highest maximum, mean, and median Mn concentrations are found in the Carolina Slate Belt, followed by the Triassic Basin and then the Mixed Felsic/Mafic system. 1 ppb = 1 μg/L.

Using data across the Piedmont, we are examining associations between Mn concentrations and soil properties hypothesized to influence Mn release and transport (**Table 1**). Well-water Mn concentrations are negatively correlated with the sand fraction and hydraulic conductivity of soils, but positively correlated with the silt fraction of soils. Across the Piedmont, these correlations are weak, and we are currently examining such relationships in isolated areas of interest. However, the textural relationships may suggest that Mn in well water may be associated with finer particles, such as those Mn oxides; such hypotheses are supported by geological data and chemical analyses described below.

Table 1. Correlation matrix of Mn concentration in well water (USGS National Uranium Resource Evaluation well water database) and soil properties (Soil Survey Geographic database) In the table, mn_ppb = Mn concentration in well water; sandtotal_r = % sand fraction of soil texture; silttotal_r = % silt; claytotal_r = % clay; om_r = organic matter content; ksat_r = hydraulic conductivity; ecec_r = cation exchange capacity of soil.

	mn_ppb	sandtotal_r	silttotal_r	claytotal_r	om_r	ksat_r	ecec_r
mn_ppb	1.00	-0.15	0.18	0.00	0.01	-0.05	0.05
sandtotal_r	-0.15	1.00	-0.94	-0.63	-0.12	0.73	-0.35
silttotal_r	0.18	-0.94	1.00	0.33	0.16	-0.58	0.30
claytotal_r	0.00	-0.63	0.33	1.00	-0.05	-0.72	0.30
om_r	0.01	-0.12	0.16	-0.05	1.00	-0.04	0.90
ksat_r	-0.05	0.73	-0.58	-0.72	-0.04	1.00	-0.23
ecec_r	0.05	-0.35	0.30	0.30	0.90	-0.23	1.00

By assessing well water concentrations in terms of mapped geologic/aquifer properties, we have found that the highest Mn concentrations are associated with sedimentary and unconsolidated rock classes, with igneous rocks being the least likely to host wells with high Mn concentrations (**Figure 5**). High Mn concentrations are associated with more weathered rocks and finer-grained rocks, which may indicate sources of Mn to groundwater such as secondary minerals like Mn oxides.

Spatial analyses also indicate a weak association between Mn concentrations in well water and the distance of wells to mapped faults and dykes (**Figure 6**). Faults and dikes are common within the Carolina Slate Belt and Triassic Basin, where well-water Mn concentrations are highest, potentially enabling transport of dissolved Mn from the near-surface to aquifers. Many faults and dykes within the Piedmont have yet to be mapped by geologists, complicating this analysis. Accordingly, our ongoing analyses are targeting smaller areas where the best mapping coverage of these geologic features exists.

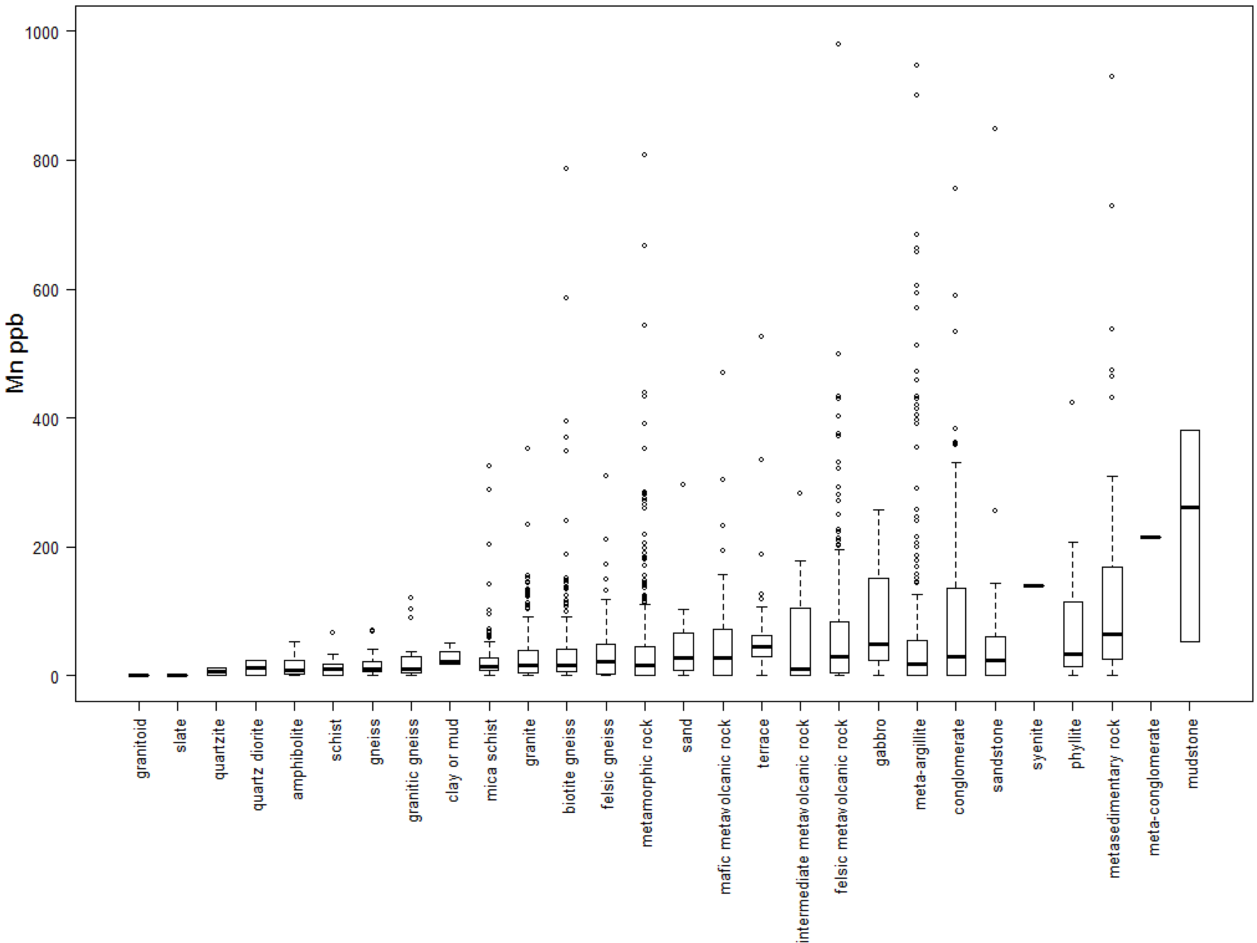

Figure 5. Manganese well water concentration data (Smith, 2006) and rock type from mapped geologic rock type (NCGS, 1985). 1 ppb = 1 μg/L.

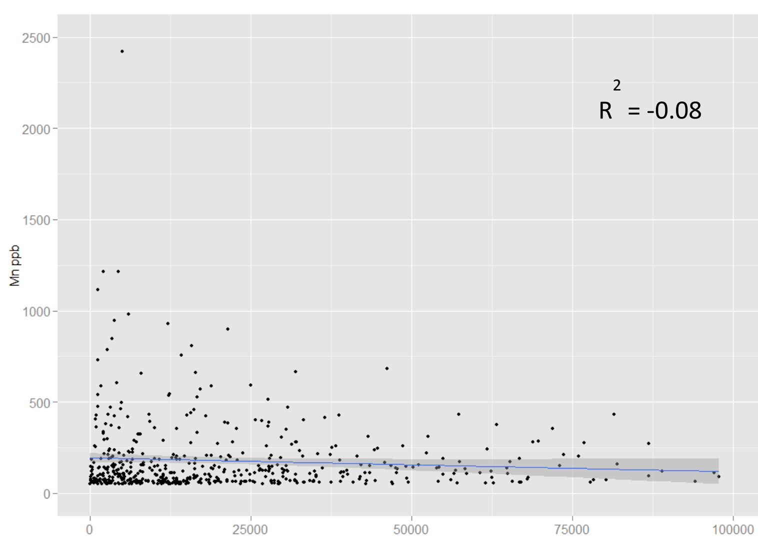

Figure 6. Mn well water concentration (Smith, 2006) and distance to mapped fault or dyke. A weak association exists between Mn concentration and distance of the well from faults/dykes. 1 ppb = 1 μg/L.

2.1.3. Ongoing Work

We are continuing are geospatial analyses to better define linkages between well-water Mn concentrations and mapped surface and subsurface properties. Our preliminary findings have indicated Mn associations with fine-grained soils and rocks and more weathered systems. Additionally, high Mn concentrations may also be found in wells that are near mapped faults and dykes. However, due to the substantial spatial variability in well water concentrations, as well as uncertainties with mapped features, our observed Piedmont-wide associations are weak. Accordingly, using hypotheses generated from the first suite of geospatial analyses and newly collected hydrogeochemical data (Objective 2, below), we are refining our analyses by targeting specific regions within the Piedmont where surface and subsurface features are more completely mapped, and where we can quantify spatial relationships on smaller scales.

2.2. Objective 2: Characterize the hydrogeochemical conditions of Mn-contaminated aquifers, potential sources of Mn, and Mn retention capacities of soil, saprolite and aquifer solids.

2.2.1. Activities

We have collected well-water and solid-phase samples from 10 NC Division of Water Resources Resource Evaluation Program Groundwater Monitoring and Research Stations across the Piedmont (**Figures 7 and 8**). Station locations are representative of NC's hydrogeologic regions and are designed to provide groundwater quality information that is useful to regulators and the public. At each site, multiple wells are screened at varying depth intervals to capture soil/saprolite, transition-zone, and bedrock-aquifer groundwater; libraries of rock cores are also available for each site, allowing for geochemical analysis of soil, saprolite, and bedrock solids.

We have sampled well water at >50 wells in the summer and winter. Samples have been analyzed to obtain depth profiles for Mn concentrations, bulk anions and cations, redox-sensitive parameters, nutrients, and organic and inorganic carbon. Solid phases from all sites have been analyzed for total Mn concentrations by total digestion. Manganese speciation in solids has been defined by sequential extractions and X-ray absorption near-edge structure (XANES) spectroscopy. We have also conducted Mn adsorption isotherm experiments to quantify retention capacities and partitioning coefficients for Mn at different locations and depths.

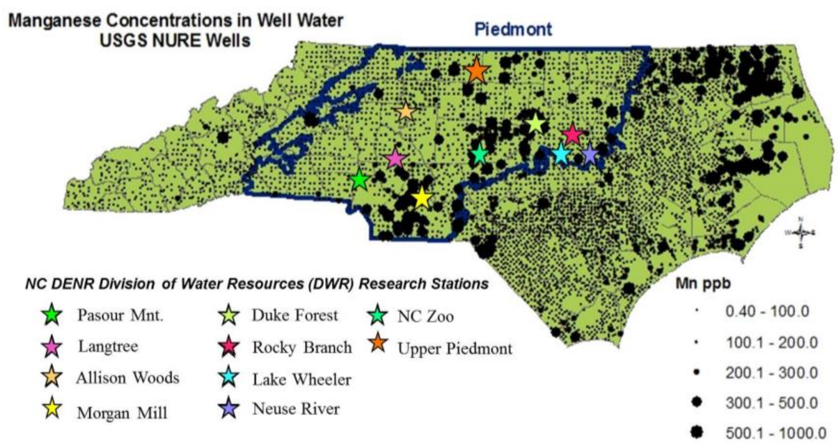

Figure 7. Locations of NC Division of Water Resources groundwater monitoring research stations superimposed on map of Mn concentrations in well water (Smith, 2006). 1 ppb = 1 μg/L.

Figure 8. Representative pictures of soil (left panel) and bedrock (right panel) cores, collected from DWR research stations.

2.2.2. Key Findings

2.2.2.1. Hydrogeochemical characterization

Trends in measured well-water Mn concentrations from the > 50 wells at NC DWR research station sites are aligned with those observed from the broader USGS National Uranium Resource Evaluation water-quality data set. Depth profiles of Mn in the DWR site wells show generally higher concentrations in shallower wells, and data indicate that the depth trends for the Piedmont are also reflected in profiles at individual sites (**Figure 9**).

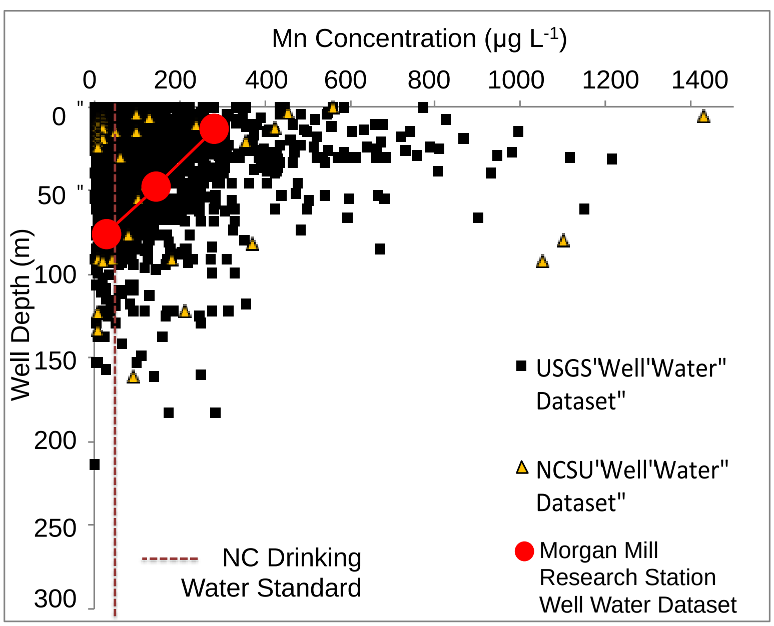

Figure 9. Depth distribution of Mn concentrations in well water from USGS National Uranium Resource Evaluation well water database (black squares), our collected samples from >50 wells at 9 NC DWR groundwater research stations (yellow triangles), and our analyses from samples collected at the Morgan Mill DWR research station (red circles).

Groundwater chemical parameters from the DWR research sites also allow us to determine broader influences on Mn concentrations in well water than we were able to from the existing Piedmont-wide datasets. Based on pH and Eh measurements, Mn^{2+} is the most stable Mn phase within the groundwater from wells across the Piedmont DWR sites (**Figure 10**). Because Mn^{2+} is relatively mobile and there is little oxygen (or other oxidants) to oxidize it, once Mn^{2+} gets into solution, it may remain there and contaminate groundwater.

Geochemical modeling (via MINTEQ) has shown that most of the water from bedrock wells is under-saturated with respect to common primary and secondary Mn-bearing minerals. Dissolved organic carbon profiles decrease with depth, with the lowest concentrations in the bedrock wells. Collectively, these data indicate that Mn is not being actively released to solution from bedrock solids via equilibrium or reductive dissolution.

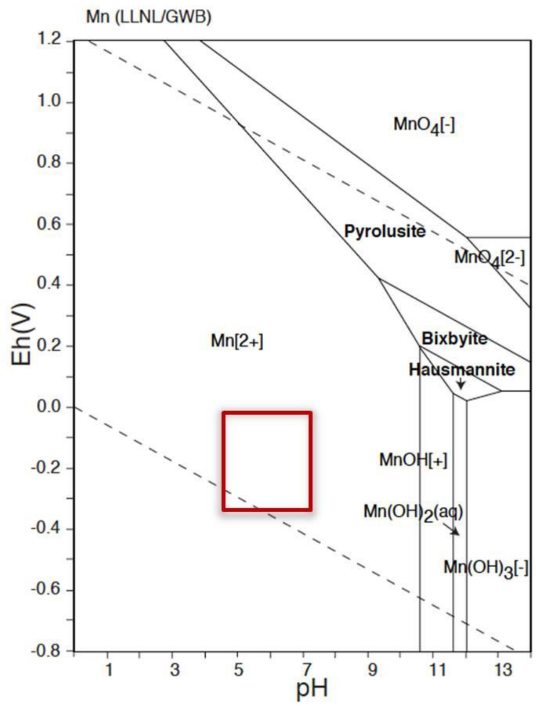

Figure 10. Manganese pH-Eh stability diagram, modified from Morgan (2000), The red box outlines the span of measured pH and Eh values from > 50 wells across our field area, indicating that Mn^{2+} is the stable form of Mn in aquifers.

2.2.2.2. Manganese source characterization

We have used digestion procedures (McDaniel and Buol, 1991) to quantify Mn concentration depth profiles in soil, saprolite, and bedrock at each of the DWR research sites. Across all sites, similar-trending profiles are observed, with a maximum Mn concentration ~15-25 feet in depth; however, the magnitudes of concentrations vary from site to site (**Figure 11**). The peak in Mn concentrations typically corresponds to depths within the saprolite just above the water table. We interpret this profile as a consequence of 1) near-surface weathering and Mn repartitioning from bedrock source rocks, 2) Mn mobilization and accumulation above the water table, and then 3) reduction, release and downward transport of Mn upon saturation (below the Mn peak). Ongoing studies seek to verify this model.

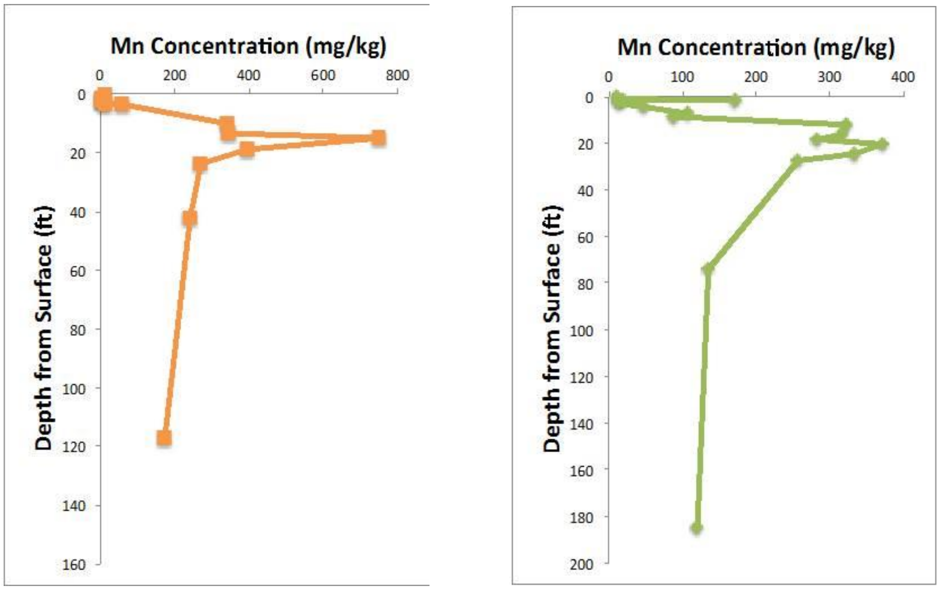

Figure 11. Representative concentration profiles of solid-phase Mn in soil, saprolite, and bedrock. Data are shown for cores collected at the Morgan Mill (left panel) and NC Zoo (right panel) DWR research stations.

Sequential extraction (**Figure 12**) and X-ray absorption near-edge structure (XANES) spectroscopy (**Figure 13**) are being used to define Mn species (and hence reactivity) within solid phases. In general, the majority of Mn is found in residual, non-dissolvable phases (purple bars, Figure 12), with Mn oxides dominating non-residual forms of solid-phase Mn (green bars, Figure 12). Manganese-oxide concentrations are highest at or above the water table (i.e. the peak of total Mn concentrations) and then decrease below the water table, a likely consequence of reductive dissolution of Mn oxides under saturated conditions. XANES data confirm that Mn(IV) species (e.g. Mn oxides) are most prevalent where total Mn concentrations are highest. Ongoing analyses seek to quantify species distributions from XANES data.

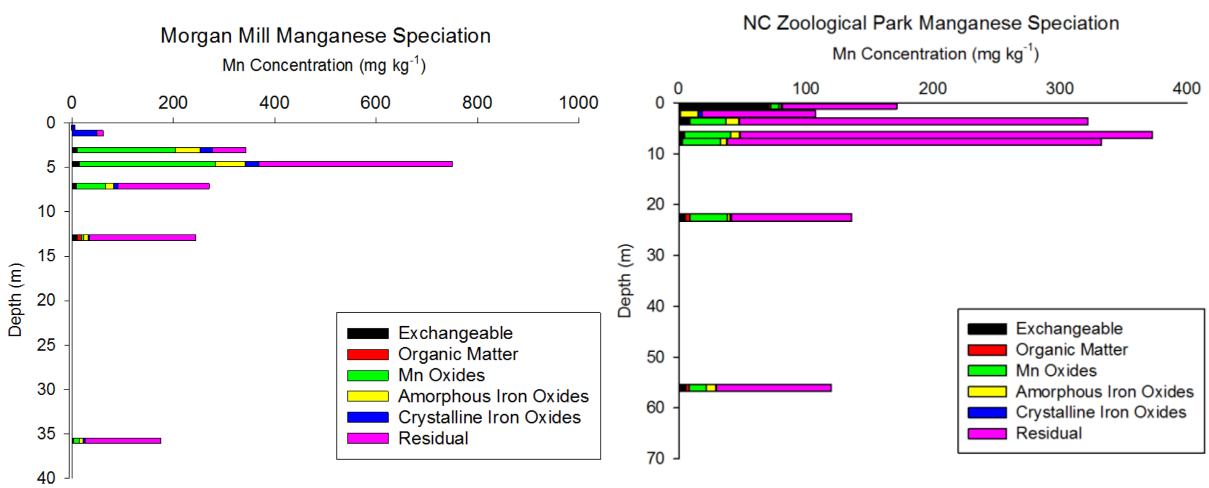

Figure 12. Representative Mn sequential extraction data from soil, saprolite, and bedrock samples. Data are shown for cores collected at the Morgan Mill (left panel) and NC Zoo (right panel) research stations.

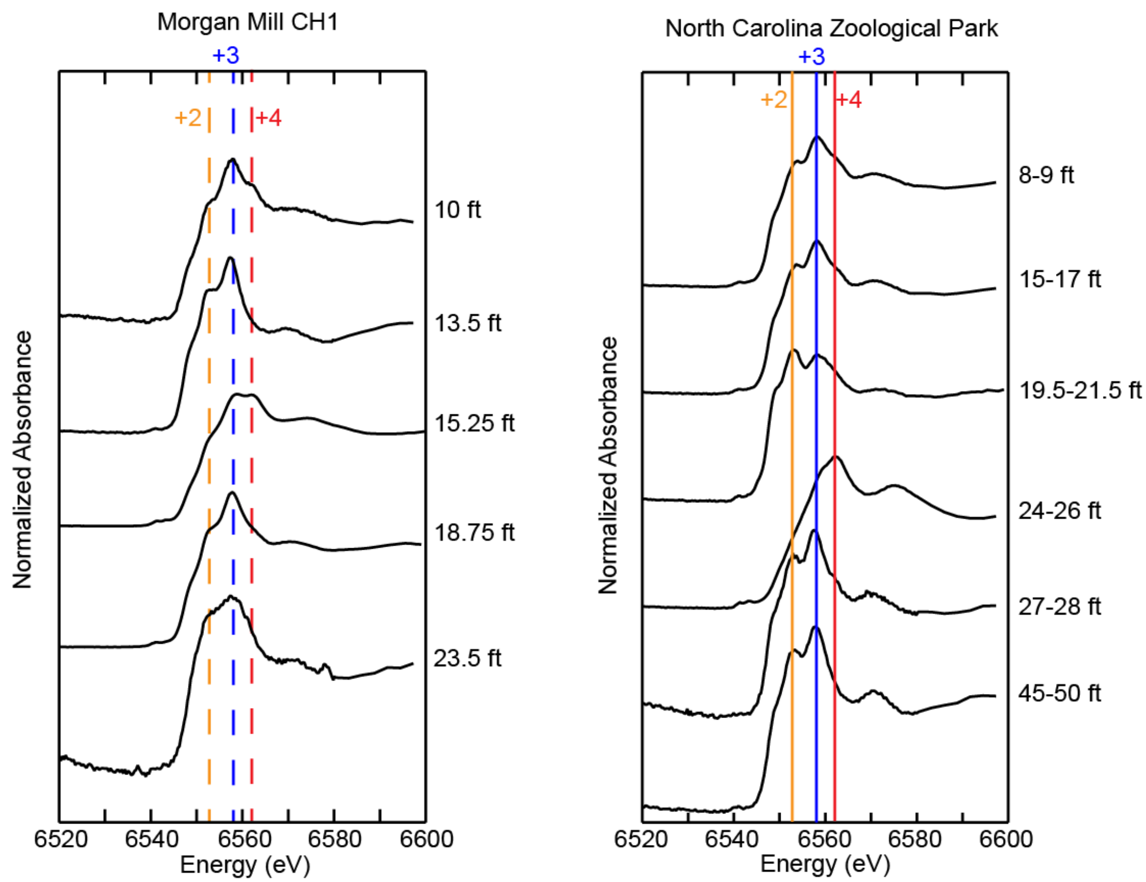

Figure 13. Representative Mn X-ray absorption near-edge structure (XANES) spectra of solid-phase core samples collected at the Morgan Mill (left panel) and NC Zoo (right panel) DWR research stations. XANES data provide oxidation and speciation information. When potentially reactive Mn oxides are abundant in the solids, spectra peaks exist at the energy associated with Mn^{4+} (red lines in plots).

2.2.2.3. Manganese retention quantification

We are comparatively quantifying Mn^{2+} adsorption onto soil, saprolite and bedrock solids by conducting adsorption isotherm experiments (**Figure 14**). Based on an initial test-trial, we have found greater partitioning of added Mn^{2+} to the solid-phases within saprolite as compared to bedrock samples. These results indicate that once in solution, Mn is more mobile within the bedrock aquifers than in the upper portions of the soil-saprolite-bedrock system. A full set of isotherm experiments have been run for a broader range of initial dissolved Mn concentrations and solid-phase samples, and results are pending analysis of water samples.

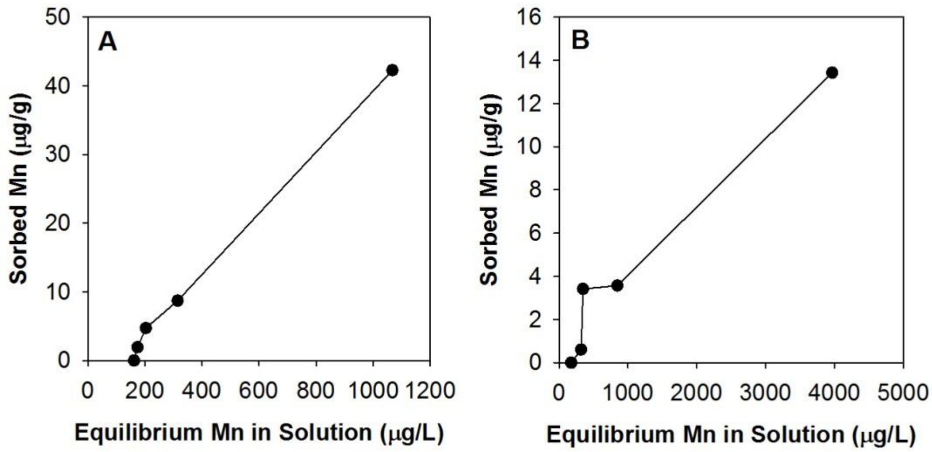

Figure 14. Test-trial adsorption isotherms for Mn^{2+} sorbed to **A.** Morgan Mill saprolite (7 m depth) and **B.** Langtree bedrock (16 m depth). Results show greater retention of dissolved Mn within the saprolite than the bedrock (i.e. greater partitioning of Mn to the solid-phase than the aqueous phase in the saprolite as compared to the bedrock).

2.2.3. Ongoing Work

To date, we have collected all field and experimental samples associated with this objective, and only some isotherm experiment concentration measurements are outstanding for required data collection. Upcoming work is aimed at analyzing the existing aqueous and solid-phase chemical data and synthesizing findings. Particular work will include 1) analysis of chemical profiles for all aqueous species measured in well water, 2) linear combination fitting of XANES unknown spectra with reference standard spectra to quantify Mn speciation in solids, 3) modeling and quantification of Mn retention distribution coefficients, and 4) statistical integration of data.

2.3. Objective 3: Develop regional-scale maps that classify the vulnerability of aquifers to elevated groundwater Mn concentrations.

2.3.1. Activities and Ongoing Work

We are currently integrating our results from Objectives 1 and 2 to develop maps that classify aquifers at risk for elevated Mn concentrations in well water. We are using geospatial analyses to statistically quantify vertical and lateral variability in Mn concentrations and translate these results into user-friendly maps that display the likelihood of exceeding key Mn concentration thresholds (e.g. 50 μg/L, the NC standard).

Key findings to date suggest that deeper wells generally provide more protection from elevated Mn concentrations, suggesting a key management step is to adequately case wells into the bedrock during well construction. We have worked to communicate this finding with certified well drilling professionals. Ongoing work will result in maps and summary brochures that will be provided to well drillers, environmental health specialists, and colleagues at the NC Division of Water Resources.

3. STUDENT INVOLVEMENT

One M.S. student (Elizabeth Gillispie), four undergraduates (Allison Sams, Cory Connell, Christine Knight, and Matthew Church), and two post-docs (Nelson Rivera and Megan Andrews) have participated in this project.

Research in the project has comprised Elizabeth Gillispies's graduate thesis. She has led the field work and laboratory experiments, and she has also contributed to the geospatial analyses presented here. Elizabeth has gained experience in interdisciplinary and multi-scale research approaches, and research efforts have been coupled with professional development opportunities. She has delivered 5 presentations at academic and professional meetings, and three additional presentations are planned prior to her graduation (expected August 2014). For her work on this project, Elizabeth was awarded the Hugh Hammond Bennett Scholarship from the Hugh Hammond Bennett Chapter of the Soil and Water Conservation Society, in recognition of advanced study that will contribute to sound use of soil and water resources.

Four undergraduates have participated in the project by assisting with field work and laboratory experiments. The students have collected and analyzed data, performed experiments, and presented results in lab group meetings. One of the students has developed an Honors undergraduate thesis as part of the project, and another student has used the project as a springboard for graduate school (Christine Knight: University of Michigan, beginning Fall 2014). A third student secured a consulting job through his activities with the project, and the final undergraduate still works in the lab of the PI. Three of the undergraduates are majoring in Environmental Science, and the fourth is majoring in Environmental Technology at NC State University.

The two post-docs have collected and analyzed spectroscopic data in order to define the speciation of Mn in solid phases.

4. PRELIMINARY EXPLANATION OF SIGNIFICANCE OF FINDINGS TO DATE

Based on our findings to date, we propose a conceptual model for the main processes driving Mn contamination of well water in the NC Piedmont (**Figure 15**). Following years of bedrock weathering at the near-surface, Mn has repartitioned from primary minerals to secondary, Mn-oxide minerals. Manganese oxides accumulate above the water table, where redox conditions allow, but once saturated, reductively dissolve. Manganese that enters the aqueous phase can migrate downward, due to natural flow processes of the region (Heath, 1994). Manganese downward transport may be partially facilitated by surficial faults and dykes, as well as bedrock fractures. Bedrock solids, which are dominated by primary mineral phases, have little capacity to retain dissolved Mn, and as a result, Mn that enters aquifers stays partitioned in the aqueous phase and is able to contaminate well water.

This new model for Mn cycling and transport in the Piedmont will allow for better selection of well drilling locations and depths. Ongoing work seeks to further evaluate this overall model and quantify Mn delivery rates between surface and subsurface zones. We also intend to conduct additional geospatial analyses to better understand causes for spatial variability in well water concentrations. By linking these ongoing findings together, we will develop first-order vulnerability maps that would be useful for determining suitable well locations and provide readily accessible tools for decision-makers interested in reducing exposure to manganese.

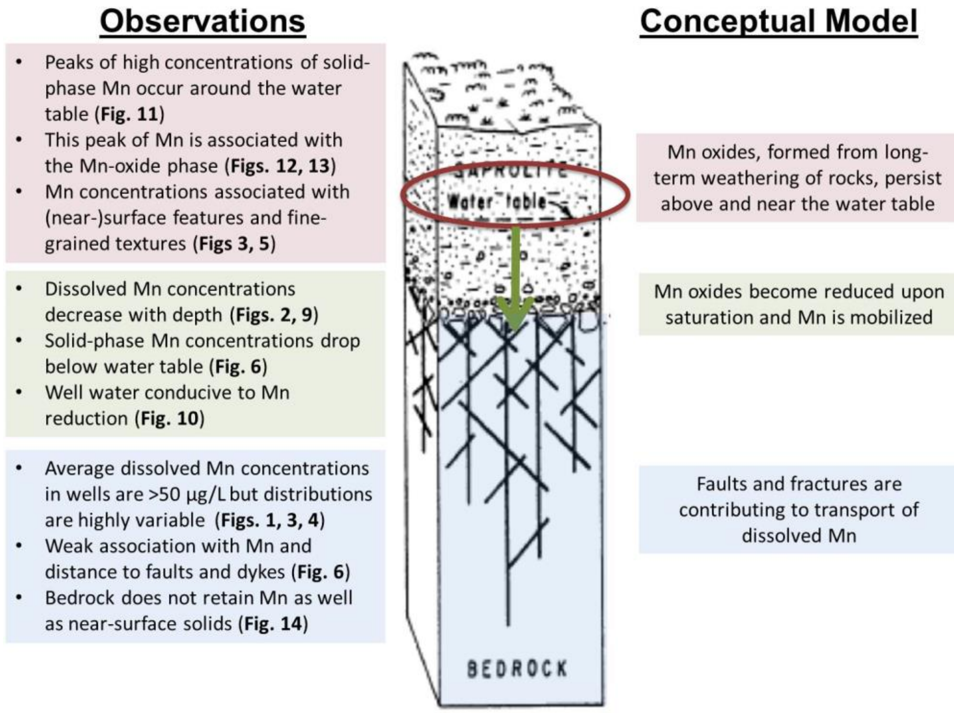

Figure 15. Conceptual model of processes influencing Mn contamination of well water in the Piedmont. Observations and figures listed refer to those in this Progress Report. Cross-section from Heath (1994).

5. DEVIATIONS FROM ORIGINAL PROJECT PLAN

There have been no significant deviations from the original project plan.

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APPENDIX 1: List of Abbreviations and Symbols

DWR	Division of Water Resources
Mn	Manganese
NC	North Carolina
USGS	United States Geologic Survey

APPENDIX 2: List of Project Outputs To Date

Delivered Presentations:

Gillispie, EC., Austin, R., Abraham, J., Wang, S., Bolich, R., Bradley, P., Amoozegar, A., Duckworth, O., Hesterberg, D., and Polizzotto, ML. *Sources and variability of manganese in well water of the North Carolina Piedmont.* Guilford County Well Contractors Day, Greensboro, NC, February, 2014. Invited Presentation.

Gillispie, EC., Austin, R., Abraham, J., Wang, S., Bolich, R., Bradley, P., Amoozegar, A., Duckworth, O., Hesterberg, D., and Polizzotto, ML. *Sources and variability of manganese in well water of the North Carolina Piedmont.* Soil Science Society of North Carolina Annual Meeting, Raleigh, NC, January 2014. Poster presentation.

Gillispie, EC., Austin, R., Abraham, J., Wang, S., Bolich, R., Bradley, P., Amoozegar, A., Duckworth, O., Hesterberg, D., and Polizzotto, ML. *Sources and variability of manganese in well water of the North Carolina Piedmont.* Soil Science Society of America Annual Meeting, Tampa, FL, November 2013. Poster presentation.

Gillispie, E., Polizzotto, M., and Bolich, R. *Sources and variability of manganese concentrations in well water of the NC Piedmont*. 29th Annual Onsite Water Protection Conference, Raleigh, NC, October 2013. Invited presentation.

Gillispie, EC., Austin, R., Bolich, R., Bradley, P., Amoozegar, A., Duckworth, O., Hesterberg, D., and Polizzotto, ML. *Characterizing the sources and variability of manganese in well water of the North Carolina Piedmont.* 12th International Conference on the Biogeochemistry of Trace Elements, Athens, Georgia, June 2013. Poster presentation.

Planned Presentations:

Gillispie, EC., Austin, R., Abraham, J., Wang, S., Bolich, R., Bradley, P., Amoozegar, A., Duckworth, O., Hesterberg, D., and Polizzotto, ML. *Sources and variability of manganese in well water of the North Carolina Piedmont.* Water Resources Research Institute of the University of North Carolina System Annual 2014 Conference, Raleigh, NC, March 2014. Poster Presentation.

Gillispie, EC., Austin, R., Abraham, J., Wang, S., Bolich, R., Bradley, P., Amoozegar, A., Duckworth, O., Hesterberg, D., and Polizzotto, ML. *Sources and variability of manganese in well water of the North Carolina Piedmont.* 2014 N.C. State University Graduate Research Symposium, Raleigh, NC, March 2014. Poster Presentation.

Gillispie, EC., Austin, R., Abraham, J., Wang, S., Bolich, R., Bradley, P., Amoozegar, A., Duckworth, O., Hesterberg, D., and Polizzotto, ML. *Sources and variability of manganese in well water of the North Carolina Piedmont.* Advanced Well Workshop, Asheville, NC, May 2014. Invited Presentation.

Polizzotto, ML., Gillispie, EC., Austin, R., Rivera, NA., Abraham, J., Wang, S., Bolich, R., Bradley, P., Duckworth, O.W., Amoozegar, A., and Hesterberg, D. Manganese near-surface repartitioning and delivery to groundwater in North Carolina. Goldschmidt Geochemistry Conference, Sacramento, CA, June 2014. Oral Presentation.

Efforts at technology transfer or communication of results to end users, policy makers, or others

To date, we have communicated results to end users and policymakers through formal presentations and discussions. Well drillers and environmental health officials have been targeted at presentations at the Guilford County Well Contractors Day (February 2014) and the NC Onsite Water Protection Conference (October 2013); additionally, a presentation is confirmed for the Advanced Well Workshop in Asheville, NC (May 2014).

Information Transfer Program Introduction

The Water Resources Research Institute (WRRI) is heavily geared to providing water resources information to the water professional. WRRI maintains a strong information transfer program by cooperating with various state agencies, municipalities, and professional organizations to sponsor workshops and other events and by seeking grants for relevant activities.

The professionals targeted by this program include private entrepreneurs, federal, state and local government staff and officials, and representatives of industry, agriculture, consulting, and environmental groups. The main forms of information transfer are through an Institute internet site, quarterly newsletter, conferences, seminars, forums, workshops, luncheons, and research publications.

The workshops conduced through WRRI's partnership with the Department of Environment and Natural Resources Division of Energy, Mineral and Land Resources constitute the primary means by which the Division meets its educational obligations on sediment control under the state's Sediment Control Act.

WRRI continues to be a sponsor of continuing education credits by the NC Board of Examiners of Engineers and Surveyors as an Approved Sponsor of Continuing Professional Competency activity for Professional Engineers and Surveyors licensed by the State of North Carolina. In addition, WRRI also submits information for approval to the N.C. Board of Landscape Architects to offer contact hours to landscape architects. This allows WRRI to offer Professional Development Hours (PDHs) to engineers and surveyors, and Continuing Education Units (CEUs) to landscape architects for attendance at the WRRI Annual Conference and other workshops, seminars and forums that WRRI sponsors.

During this reporting year, WRRI provided 67.75 PDHs and 50.5 CEUs to 1237 people at 12 workshops, seminars, and other events described in the following pages.

WRRI Information Transfer Program

Basic Information

Title:	WRRI Information Transfer Program
Project Number:	2013NC183B
Start Date:	3/1/2013
End Date:	2/28/2014
Funding Source:	104B
Congressional District:	NC-04
Research Category:	Not Applicable
Focus Category:	None, None, None
Descriptors:	None
Principal Investigators:	Nicole Wilkinson

Publications

There are no publications.

FY 2013 Information Transfer Progress & Achievements

WRRI SPONSORED WORKSHOPS, FORUMS AND SEMINARS

Below is a list of the educational and training events WRRI sponsored during the project year, along with a description of each and the number of attendees. In total, WRRI provided 67.75 PDHs and 50.5 CEUs to 1237 people at 12 workshops.

March 6, 2013 Erosion and Sedimentation Control Planning and Design Workshop

Description: These workshops are structured to educate and familiarize design professionals with the NC Sedimentation Pollution Control Act (SPCA), the rules implementing the Act, design standards for erosion and sedimentation control BMPs, and elements that are necessary to submit an erosion control plan. This comes directly from the source—the NC Division of Energy, Mineral and Land Resources Land Quality Section – and its partners to provide professionals with the information they need to submit an erosion control plan and prevent pollution by sedimentation.

Attendance: 59

March 20-21, 2013 WRRI Annual Conference and NCWRA Symposium

Description: The WRRI annual conference is the premier research conference focusing on North Carolina's water resource issues, solutions, and opportunities. The NC Water Resources Association was again a key partner, with the NCWRA Annual Symposium "Nutrient Credit Trading and Markets in North Carolina: Implications for Water Quality Management" being an integral element of the conference program. This session explored barriers and opportunities for creating nutrient credit trading in North Carolina, and presented diverse perspectives on the pros and cons of trading programs. The conference offered 11.75 PDHs, 10.5 CEUs, and had 209 attendees. Over a 2-day period, the conference featured 110 presentations – 61 oral presentations over 16 concurrent sessions, 7 invited speakers in special sessions, and 27 poster presentations.

Attendance: 209

March 21, 2013 Progress Energy Seminar "Water, Energy and Security: Colliding Imperatives"

Description: There is widespread awareness that both energy and water are vital for human security. Water is essential for survival and energy is involved in almost every facet of our life from the provision of medical services to our economic production. What is less well appreciated is the symbiotic relationship between water and energy – the distribution and purification of water often depends on energy, while energy production often requires the diversion and/or causes the contamination of water. Also less well understood is the crucial role played by energy and water in ensuring, not just human security, but also national and international security. Finding a way to promote our best interests in all three areas simultaneously creates some subtle challenges. These are best met by collaborative efforts across disciplines. This seminar engaged an expert panel to address these topics on state, national, and international scales and resulted in a lively discussion with the audience.

Attendance: 150

April 5, 2013 Erosion and Sedimentation Control Planning and Design Workshop

Description: These workshops are structured to educate and familiarize design professionals with the NC Sedimentation Pollution Control Act (SPCA), the rules implementing the Act, design

standards for erosion and sedimentation control BMPs, and elements that are necessary to submit an erosion control plan. This comes directly from the source—the NC Division of Energy, Mineral and Land Resources Land Quality Section – and its partners to provide professionals with the information they need to submit an erosion control plan and prevent pollution by sedimentation.
Attendance: 83

May 29, 2013 Capacity and Resource Needs of North Carolina Watershed Programs: Working Towards a Collaborative Statewide Watershed Network
Description: WRRI and partners completed an extensive statewide study on existing watershed stewardship resources, organizational capacities, and local needs. The research team hosted this workshop to share the outcomes and results with watershed professionals and volunteers from across the state, and that participation was used in crafting a strategic path toward a collaborative statewide watershed network that will provide access to a network of watershed experts, peer support, and technical and programmatic resources for more successful watershed management efforts. Leaders representing government, non-profit, and private organizations with an interest in watershed protection, restoration and stewardship across North Carolina participated.
Attendance: 51

September 9, 2013 NCWRA Seminar "The New Division of Water Resources"
Description: The 2013 NC Legislature consolidated the state's water quantity and water quality programs into one division within the Department of Environment and Natural Resources as of August 1, 2013. This presentation reviewed the rationale behind the consolidation, implications for program realignment and impacts to the Division's customers. The event also included a webinar session that allowed participation statewide.
Attendance: 177

November 6, 2013 Erosion and Sedimentation Control Planning and Design Workshop
Description: These workshops are structured to educate and familiarize design professionals with the NC Sedimentation Pollution Control Act (SPCA), the rules implementing the Act, design standards for erosion and sedimentation control BMPs and elements that are necessary to submit an erosion control plan. This comes directly from the source – the NC Division of Energy, Mineral and Land Resources Land Quality Section – and its partners to provide design professionals with the information they need to submit a plan and prevent pollution by sedimentation. The workshop focused on considerations for land planning and enhancement of developing watersheds. Techniques will be discussed for channel design, conveyance of runoff, and surface dewatering. Design criteria for erosion control materials will be demonstrated through use of online tools.
Attendance: 108

December 9, 2013 NCWRA Seminar "Managing Nutrients in the Linear Environment – NCDOT's New Guided Reduction of Excess Environmental Nutrients (GREEN) Program"
Description: Nutrients and eutrophication are important and high profile issues in North Carolina. In response to these growing concerns, NCDOT is leveraging a variety of its programs into a focused effort to reduce nutrient loading from its road and non-road facilities. Known as the Guided Reduction of Excess Environmental Nutrients, the GREEN Program uses university conducted research to guide the application of stormwater BMP retrofits and other nutrient

load reduction measures. This presentation provided an overview of NCDOT's new GREEN program.
Attendance: 66

December 12, 2013 Erosion and Sedimentation Control Planning and Design Workshop
Description: These workshops are structured to educate and familiarize design professionals with the NC Sedimentation Pollution Control Act (SPCA), the rules implementing the Act, design standards for erosion and sedimentation control BMPs and elements that are necessary to submit an erosion control plan. This comes directly from the source – the NC Division of Energy, Mineral and Land Resources Land Quality Section – and its partners to provide design professionals with the information they need to submit a plan and prevent pollution by sedimentation. The workshop focused on considerations for land planning and enhancement of developing watersheds. Techniques will be discussed for channel design, conveyance of runoff, and surface dewatering. Design criteria for erosion control materials will be demonstrated through use of online tools.
Attendance: 104

January 14, 2014 Improving Water Efficiency, Loss Control and Your Bottom Line with AWWA M36 Methodology
Description: Best-practices for Water Auditing and Loss Control, as developed by the American Water Works Association, are beginning to take hold among water systems in the Southeast and across the nation. Water Auditing and Loss Control programs are the most effective ways for a utility to conserve water, save operating expenses, and increase revenues. To this end, the AWWA Water Loss Control Committee has made available a free software application as a useful and easy way for utilities to compile a basic, preliminary audit of water supply and billing operations, and begin to measure key performance indicators for water system efficiency. This workshop helped participants learn how to use the software, gain a thorough understanding of the data inputs and data validity, and understand software outputs and how to apply them to their utility. Participants benefitted from team work, paper exercises, computer work, and a small amount of lecture, and learned using real data from their own utilities. The small number of participants allowed for a 1:4 ratio of trainers to participants and enabled effective small group work with generous time for in-depth discussions and problem solving.
Attendance: 15

February 4-5, 2014 Local Programs Erosion and Sediment Control Workshop
Description: The Local Programs Workshop provides training for local governments that have ordinance delegation and enforces the North Carolina Sedimentation Pollution Control Act. The training provides local programs an opportunity to be updated on the most current erosion and sedimentation control research and to get together with other local programs and exchange sedimentation and erosion control ideas and practices utilized at the local level. This training is helpful for landscape architects that may work for a local government that has an erosion and sedimentation control program.
Attendance: 106

February 10, 2014 NCWRA Seminar "Recent NCSU Stormwater Research and Corresponding Changes to NCDENR's BMP Manual"
Description: Technical stormwater engineering expert, William Hunt, presented on applied research conducted by the Stormwater Engineering Group at NCSU's Department of Biological

and Agricultural Engineering, and how that research is reflected in the newest installments of the state's Stormwater BMP Manual. He addressed such practices as rainwater harvesting, downspout disconnection, and bioretention, and reflected on statewide efforts to update and apply low impact development tools in North Carolina.
Attendance: 109

CENTER OF EXCELLENCE FOR WATERSHED MANAGEMENT
There are more than 1,700 watersheds in North Carolina, and hundreds of organizations, agencies and individuals dedicated to protecting these watersheds. But until recently, there was no avenue for professionals and volunteers from these different groups to effectively communicate, collaborate or cross-train.

In 2012, WRRI and partners from the University of North Carolina – Chapel Hill, NC Department of Environment and Natural Resources, NC State University's Watershed Education for Community Officials program, and the Triangle J Council Of Governments joined forces to better understand the state's diverse watershed programs. The project team surveyed both watershed professionals and volunteers and issued a detailed assessment of statewide capacity and resource needs. WRRI's motivation for pursuing these efforts stems from its designation by EPA in 2010 as a Center of Excellence for Watershed Management.

In May 2013, sixty participants representing local, state and federal government agencies and private and nonprofit organizations met to review the needs assessment data and begin to flesh out plans for the North Carolina Watershed Stewardship Network (WSN). From this meeting, a steering committee formed to develop a strategic plan for WSN to engage a wide variety of stakeholders, create online and face-to-face opportunities for networking and training, and foster public education about water quality impacts and watershed protection.

WRRI has played a lead role in the development of the steering committee and moving strategic planning efforts forward. There is a clear need for a statewide coordinator to help manage the efforts of the steering committee, and WRRI is currently assessing options to support a part-time staff member to serve this role.

The WSN in its current form is a collaborative effort of diverse organizations. The mission is to empower more effective watershed stewardship because water is critical to economic, environmental, and community health. The WSN's approach to fulfilling this mission is to *identify, include, link* and *serve* watershed stakeholders in North Carolina. WRRI will continue to work with the rest of the committee and network to develop a strategic plan and explore options for tangible services that the WSN can and should provide to watershed stakeholders across the state, and further develop WRRI's role and offerings as a Center of Excellence for Watershed Management.

NEWSLETTER
Published the *WRRI News* three times during the reporting period (April-June 2013 Issue #382, July-Sept 2013 Issue #383 and Oct 2013-Jan 2014 Issue #384). The WRRI News is an 8-12 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 now sent electronically to 1012 federal and state agencies, university personnel, multi-county planning

regions, city and local officials, environmental groups, consultants, businesses and individuals. It is also posted on the WRRI website http://ncsu.edu/wrri/code/publications/currentpublications.htm

INTERNET SERVICES

WRRI continues to maintain a website, www.ncsu.edu/wrri. Overall, the goals of our website are:

- to provide access to information on upcoming events (seminars, workshops, etc) that are hosted by WRRI and other events in the state related to water resources, as well as access to materials and resources from past events;
- to provide information to the research community about funding opportunities and state research priorities;
- to increase dissemination of information by providing access to research reports, the WRRI newsletter, and other relevant publications;
- to provide information on key organizations with which WRRI has strong partnerships and which play a key role in water resource research and management in the state;
- to provide background information about WRRI at the state and federal levels, our roles, and what we can offer to different audiences throughout the state.

A related component of the website involves working with NC State University's DH Hill Library to increase and enhance WRRI's use of their technical reports repository for all WRRI publications. Through this collaboration, we are now able to direct people to this well organized, easily searchable site where they can access research reports from all WRRI-funded projects as far back as the 1960s.

WRRI ELECTRONIC LISTS

WRRI maintains the following electronic mail lists (listservs) for information transfer purposes:

- **Water-Research list** - 209 subscribers – inform water researchers from NC universities about calls for papers, grants, upcoming conferences, student internships, etc.;
- **WRRI-News list** - 1012 subscribers - informs researchers, local governments, municipalities, interest groups etc. about calls for papers, grants, upcoming conferences and events, etc.;
- **NCWRA-info list** - 339 subscribers - provides information of the North Carolina Water Resources Association sponsored events;
- **Sediments list** – 485 subscribers- used to disseminate erosion and sedimentation control information in North Carolina.
- **Urban Water Consortium (UWC) list** for Urban Water Consortium member communications;
- and **UWC-Stormwater Group list** for the UWC Stormwater Group member communications.

NC URBAN WATER CONSORTIUM

WRRI administers the NC Urban Water Consortium (UWC) and meets with the members quarterly. The consortium was established in 1985 by the Institute, in cooperation with several of North Carolina's larger cities to provide a program of research and development, and technology transfer on water problems that urban areas share. Through this partnership, WRRI and the State of North Carolina help individual facilities and regions solve problems related to local environmental or regulatory circumstances. Participants support the program through annual dues and enhancement funds and guide the program through representation on an advisory board, selection of research topics, participation in design of requests for proposals, and review of proposals. There are 12 member cities/special districts in North Carolina, and several members hosted quarterly meetings on the following dates: March 8, 2013 in Charlotte; June 21, 2013 in Wilmington; October 11, 2013 in Greensboro; and December 6, 2013 in Durham.

The UWC also provided financial support to two research projects, which increased WRRI's ability to fund other high quality research with 104(b) funds. The two projects funded by the UWC were:

- "Bromide occurrence in North Carolina drinking water sources effect on disinfection by-product formations" by PI Detlef Knappe of NC State University
- "Expanding and Enhancing Customer-Level Billing Analysis: Non-Residential Customer Sales Profiles and Resilient Pricing Structures Modeled (and Vetted)" by PI Jeffrey Hughes of UNC-Chapel Hill

NC URBAN WATER CONSORTIUM - STORMWATER GROUP

In 1998, several members of the NC UWC partnership formed a special group to sponsor research and technology transfer on issues related to urban stormwater and management. The Urban Water Consortium (UWC) Stormwater Group is administered by WRRI. Participants support the program through annual dues and enhancement funds. They guide the program through selective representation on the WRRI advisory board, determining stormwater-related research priorities, participation in the design of requests for proposals and review of proposals submitted to WRRI directly or to the SWG. During this reporting year, the SWG added their ninth member, the City of Burlington, to their membership. Quarterly meetings were held on the following dates: March 7, 2013 in Durham; June 20, 2013 in Fayetteville; September 18, 2013 in Wilmington; and December 17, 2013 in Burlington.

Individual members of the UWC-SWG provided funding for two research projects as enhancement projects through WRRI entitled:

- "Person Street Low Impact Development Design Project" by PI William Hunt of NC State University
- "City of Durham Water Quality Web Portal" by PI Jennifer Dorton of UNC-Wilmington

The SWG also provided financial support to two other research projects (one from the WRRI annual call), which increased WRRI's ability to fund other high quality research with 104(b) funds. These projects funded by the SWG were:

- "Environmental approaches to understanding temperature and flow responses of select North Carolina macroinvertebrates" by PI David Buchwalter of NC State University
- "Nutrient and Carbon Loading in Gross Solids in Urban Catch Basins: A Nutrient Accounting Opportunity?" by PI William Hunt of NC State University

USGS Summer Intern Program

None.

Student Support					
Category	Section 104 Base Grant	Section 104 NCGP Award	NIWR-USGS Internship	Supplemental Awards	Total
Undergraduate	6	0	0	0	6
Masters	1	0	0	0	1
Ph.D.	1	0	0	0	1
Post-Doc.	2	0	0	0	2
Total	10	0	0	0	10

Notable Awards and Achievements

1. Dr. John Fear Named New Deputy Director of NC WRRI and NC Sea Grant

John Fear is now deputy director the Water Resources Research Institute of the University of North Carolina and of North Carolina Sea Grant. "John's experience in relevant Sea Grant and WRRI research areas, as well as his successes in building long-term, positive partnerships across North Carolina and the region, will help us address current efforts and our strategic planning," notes Susan White, executive director for WRRI and Sea Grant. "We are pleased to have him join our team."

Fear's focus will be developing and executing research portfolios for the two interinstitutional programs that work with academic, agency, business and community partners across the state. Both programs are headquartered at North Carolina State University.

For nine years, Fear worked as research coordinator for the N.C. Coastal Reserve program within the N.C. Division of Coastal Management. The Coastal Reserve includes the N.C. National Estuarine Research Reserve, a state-federal partnership. From 2006 to 2007, he led a water quality-monitoring project in Currituck Sound in collaboration with the USGS and USACE.

"I look forward to joining the outstanding team at Sea Grant and WRRI. I have admired their great body of work for years and am excited about the opportunity to contribute toward the continued growth and success of both programs," Fear adds.

He holds a doctorate in environmental sciences and engineering from the University of North Carolina at Chapel Hill's School of Public Health. A North Carolina native, he also has a bachelor's degree in biology and chemistry from UNC-CH and served as a postdoctoral fellow at its Institute for Marine Sciences.

He has served on the North Carolina Sea Grant Advisory Board and was a member of the steering committees for ocean policy and inner coast studies led by Sea Grant and the N.C. Coastal Resources Law, Planning and Policy Center. Fear currently is on the core management team for the N.C. Sentinel Site Cooperative, a multiagency partnership established as part of a National Oceanic and Atmospheric Administration effort to provide coastal communities and resource managers with information on potential impacts of sea-level rise on coastal habitats.

2. Development of Watershed Stewardship Network

There are more than 1,700 watersheds in North Carolina, and hundreds of organizations, agencies and individuals dedicated to protecting these watersheds. But until recently, there was no avenue for professionals and volunteers from these different groups to effectively communicate, collaborate or cross-train.

In 2012, WRRI, in partnership with UNC-Chapel Hill's Institute for the Environment, the NC Department of Environment and Natural Resources, NC State University's Watershed Education for Community Officials program, and the Triangle J Council Of Governments joined forces to gain a better understanding of the state's diverse watershed programs. The project team surveyed both watershed professionals and volunteers and issued a detailed assessment of statewide capacity and resource needs.

In May 2013, sixty participants representing local, state and federal government agencies and private and nonprofit organizations met to review the needs assessment data and begin to flesh out plans for the North Carolina Watershed Stewardship Network (WSN). From this meeting, a steering committee formed to develop a strategic plan for the WSN to engage a wide variety of stakeholders, create online and face-to-face opportunities for networking and training, and foster public education about water quality impacts and watershed protection. One of the WSN's first tasks is to design an interactive website tool that helps watershed stewards gather information about their watersheds, share information about their efforts, identify or publicize volunteer opportunities and seek partnerships.

The WSN is a collaborative effort of diverse organizations. The mission is to empower more effective watershed stewardship because water is critical to economic, environmental, and community health. Our approach to fulfilling this mission is to identify, include, link and serve watershed stakeholders in North Carolina. Efforts are underway for WRRI to help fund a WSN coordinator position to help further the strategic planning efforts and to implement that plan through on-the-ground offerings of the network.

3. NC WRRI Participates in National Committee to Enhance USGS/NIWR Partnerships

In response to ongoing pressure on the Water Resource Research Institutes at the federal level, particularly regarding funding resources, a committee was formed to explore options for enhanced collaboration between the USGS and NIWR that can help to ensure that financial resources and research efforts of the Institutes are compatible with and support USGS missions and priorities. During FY13, the committee met many times by conference call and collected a wealth of information from Institutes around the country about projects that directly support USGS' water goals as part of the USGS science strategy plan. A total of 28 projects were submitted by Institutes, and there were projects for each of the five goals. This information was compiled into a publication that was made available at the 2014 Annual NIWR Meeting that highlighted the model partnership that exists between NIWR and USGS. The NC WRRI was an active participant in this committee and will continue to be involved in these efforts in the future.

Publications from Prior Years

1. 2011NC160B ("Identification of membrane foulants and optimum cleaning strategies for nanofiltration and reverse osmosis membranes treating groundwaters from the Castle Hayne and Peedee aquifers") - Water Resources Research Institute Reports - Coronell, Orlando and Gorzalski, Alexander, 2013, Identification of Membrane Foulants and Optimum Cleaning Strategies for Nanofiltration and Reverse Osmosis Membranes Treating Groundwaters from the Castle Hayne and Peedee Aquifers, UNC-WRRI-417, NC WRRI, NC State University, Raleigh, NC, 128 pp.
2. 2011NC158B ("Uncertainty in Surface Water Availability over North Carolina due to climate and land use changes") - Water Resources Research Institute Reports - Arumugam, Sankar, Sinha, T., and Singh, H. August 2013, Uncertainty in Surface Water Availability Over NC Due to Climate and Land Use Changes, UNC-WRRI-435, NC WRRI, NC State University, Raleigh, NC, 33 pp.