The Duke Forest Stormwater Improvement and Wetlands Restoration Project

Final Report to
The North Carolina Clean Water Management Trust Fund
and
The North Carolina Ecosystem Enhancement Program

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19 December 2005
EXECUTIVE SUMMARY

In an effort to address the degraded state of Sandy Creek, the Duke University Wetland Center (DUWC), in conjunction with personnel from the Duke Forest and the Pratt School of Engineering, restored 2000 feet (600 m) of stream and approximately five acres of bottomland hardwood wetlands in the downstream portion of the watershed. In addition a 1.6 ha stormwater reservoir was constructed on the Duke Forest. The Duke Forest Stormwater Improvement and Wetlands Restoration Project aims to improve the hydrology, habitat, and water quality of Sandy Creek before its confluence with New Hope Creek. This final report summarizes the status of the stormwater reservoir construction, current status of the 5 acre (2 ha) restored wetland area within the Duke Forest Sandy Creek Wetland Restoration site as well as the restoration of over 2000 feet of stream. In addition an earthen dam was completed to retain, control and treat stormwater runoff from the Duke Campus and the City of Durham before it enters New Hope Creek and eventually the Jordan Reservoir.

A three-phase restoration of Upper Sandy Creek and it’s adjacent floodplain was developed in conjunction with the Duke University Wetland Center, Duke Forest and the Dept. of Civil and Environmental Engineering. Funding was provided by the Clean Water Management Trust, Ecosystem Enhancement Program, Duke University Facilities and the Duke Wetland Center Endowment for completion of phases I and II. The Projects completed are outlined below.

1. **Phase I: Re-contour and Restore** more than 600 meters (2000 ft) of degraded stream to hydrologically reconnect the stream with the adjacent floodplain to improve biogeochemical transformations and stream water quality (Stream restoration was completed in July 2004).

2. **Phase II: Build an earthen dam and 1.6-hectare stormwater reservoir** to regulate stormwater delivery to downstream water bodies, to replace a deteriorating dam farther downstream, and allow for additional retention and removal of excess nutrients and sediments from the stream (Dam construction was completed in November of 2005).

3. **Phase III: Build a 0.5-hectare treatment wetland** to intercept and improve the water quality of a tributary stream impacted by high concentrations of N and P (UNDER DESIGN).
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ACKNOWLEDGMENTS

We would like to thank the following cooperating and granting agencies for their contributions to the overall Duke Forest Stormwater Improvement and Wetlands Restoration Project.

- City of Durham
- Duke University Facilities Management Department
- Durham Soil and Water Conservation District
- National Science Foundation
- New Hope Creek Corridor Committee
- North Carolina Clean Water Management Trust Fund (CWMTF)
- North Carolina Department of Environment and Natural Resources (EEP)
- North Carolina Ecosystem Enhancement Program
- US Department of Agriculture – Natural Resources Conservation Service
- US Environmental Protection Agency

Major funding for phase I and Phase II of the project was provided by the NC Clean Water Management Trust Fund. Supplemental support was also given by the NC EEP Program. Duke University provided the land on Duke Forest and additional funding for dam construction.

The authors would also like to thank the following individuals for their assistance on this project:

- Dr. Emily Bernhardt
- Erin Brosnan
- Dr. Gregory Bruland
- Richard Broadwell
- Julie DeMeester
- Judson Edeburn
- Ryan Elting
- Amy Hammontree
- Wyatt Hartman
- Paul Heine
- Dr. Mengchi Ho
- Dr. Ryan King
- Lauren Kinsman
- Margaret Athey Lawrence
- Dr. Miguel Medina
- Jennifer Morse
- Michael Osland
- Julie Rice
- Brian Roberts
- Ariana Sutton-Grier
- Evie Turley
- Sarah Watts
- Wes Willis
- Dr. Justin Wright
PROJECT BACKGROUND

Introduction

The pre-European piedmont of North Carolina was a mosaic of prairie, savannah and forest communities (Lawson, 1714; Schafale and Weakley, 1990; Luczkovich, 2001), partially situated on the Piedmont’s Triassic Basin. The bedrock of this basin is highly impermeable and exhibits extremely low base flows to central North Carolina watersheds. Upon weathering the Triassic Basin bedrock forms clays below the soil horizons that are additionally impermeable to water (Buol, 1999). As a result, watersheds in the region, such as the Sandy Creek and New Hope Creek watersheds in the Cape Fear River Basin, demonstrate naturally high surface runoff to sub-surface flow ratios. With minimal potential groundwater infiltration, non-point surface runoff into floodplains and stream courses is therefore the dominant fate of precipitation in this part of central North Carolina.

Land-use practices since European settlement of the region have intensified non-point source discharge patterns. Intensive agriculture in central North Carolina during the late 19th and early 20th centuries resulted in excessive erosion of as much as 17 cm of upland topsoil (Forest History Society, 2000) into floodplain streambeds and wetlands (Trimble, 1974). As agriculture declined in the early 20th century, the sediments deposited in the stream channels began to erode. Down-cutting of the stream into the bed sediments and increased shear stress on bank sediments resulted in deepened and straightened drainages with increased flow velocities (Figure 1). Undercutting of bank vegetation and bank collapse also resulted, and the streams themselves have become a source of suspended sediments. While this process of channelization “is an efficient method for moving water quickly out of an area, this is a poor configuration for maintaining habitat integrity, leading to sandy-bottomed channels unsuitable for most aquatic organisms,” (Elting, 2003).

Modern conversion of agricultural and forested lands to residential and commercial purposes exacerbates floodplain erosion. The watershed of the eastern branch of upper Sandy Creek drains 1228 acres of southwestern Durham County and the City of Durham. Within the Sandy Creek watershed, approximately 30% of the soils in the watershed are classified as either Urban soils or urban soil complexes, which are essentially impervious surfaces following compaction and removal of topsoil (Elting, 2003). Pulse flows aggravate the erosion occurring within the streambed, with impacts related to the extent of impervious cover in the watershed (CWP, 2003). Sandy Creek receives nonpoint surface runoff from a variety of landscape features such as a botanical garden, a cemetery, a golf course, parking lots and suburban residential areas, and the Duke Campus, as well as from undeveloped forest. The watershed has a mean impervious area of 20.6%, with individual subwatersheds ranging from 12.6-29.0%, much of which has drainage directly funneled into Sandy Creek watershed stream courses. The Sandy Creek streambed has widened and become severely incised (> 2.5 meters in many places; see Figure 2) into the floodplain, with a rectangular cross-channel profile (Elting, 2003). These changes in stream morphology, coupled with the spread of impervious surfaces in the watershed, allow for the rapid transport of nutrient- and contaminant-laden surface water into and through the floodplain stream system. Impairments in water quality within Sandy Creek and in its downstream receiving bodies should therefore not be surprising.
Figure 1. Original state of Sandy Creek, shown in a 1998 FCIR image in relation to Duke University West Campus. The green box indicates the general location of the DUWC Southern Wetland Assessment and Management Park (SWAMP). The two linear sections of Sandy Creek just south of Cameron Boulevard were the result of flashy, rapid stormwater deliveries as described in the text. Note the proximity of the Duke Forest jogging trail (yellow) and the City of Durham municipal sewer (pink, with manholes as pink circles).

Improvement of water quality can be segregated into three sub-categories: sediments, nutrients, and fecal coliforms. Sediment reduction will occur both in the restored stream and floodplain, and within the treatment wetland. The physical stream reconstruction will reduce sediment load by promoting overbank flooding and also by creating riffle-pool architecture within the main stem of the stream. Overbank flooding during storm events slows the velocity of floodwaters laden with sediments when those waters flood into the floodplain back swamp. The drop in velocity promotes precipitation of the sediments from the water column and deposition in the floodplain. Riffle-pool architecture accomplishes the same goal within the main stem, by slowing flow in the pools and providing a site for sedimentation.

Nitrogen and phosphorus reductions will occur in the soils of the restored floodplain via nitrification/denitrification of N and sedimentation and soil sorption of P. Both herbaceous wetlands and riparian and bottomland swamps have been used extensively for water quality improvement (see citations in Mitsch and Gosselink, 2000). The use of floodplain and bottomland communities in particular has proven to be highly effective in nutrient reduction. Floodplain and bottomland communities offer a greater opportunity for P retention than herbaceous dominated marshes, due to an abundant sediment load in overbank floodwaters. By providing a constant supply of sediments onto the newly restored floodplain, P adsorbs onto
these sediments, and is then subsequently buried when those sediments precipitate during low-flow conditions. While the herbaceous vegetation in both the wetland cells and the riparian communities in the floodplain will remove P and N from the water, there will be some re-release of those nutrients into the lotic waters following end-of-season vegetation senescence and decay. However, the value of this uptake by herbaceous vegetation is two-fold. First, it serves as a temporary nutrient sink to ameliorate eutrophic waters both in-system and downstream. Second, it serves as a mechanism of nutrient transformation of both N and P from inorganic to organic forms that will be available to heterotrophic consumers downstream from the project site following decay and export from the system.

The purpose of the Duke Forest Stormwater Improvement and Wetlands Restoration Project (hereafter, the Duke Forest Project) is to restore the Sandy Creek stream course and channel morphology, improve water quality (i.e. reduced sediments, N and P, and coliform bacteria), and provide targeted replanting of riparian buffers in the floodplain. High nutrient loads in Sandy Creek, New Hope Creek, and Jordan Reservoir have led to their classification as Nutrient Sensitive Waters (NSW) by the NC Division of Water Quality. Such a classification
mandates an improvement strategy and is partially responsible for Duke’s recent grant to improve water quality in Sandy Creek. The North Carolina Ecosystem Enhancement Program considers headwater wetlands a high priority for restoration and water quality improvement, but very few projects with the capability of quantifying water quality improvements from peak storm events exist in the Piedmont today. Such quantification is a major goal of the Duke Forest project.

Site Description

The proposed constructed wetland site is located in Durham, North Carolina, within a portion of the Upper Sandy Creek Watershed in the Duke Forest. About 14 acres of land is found south of NC 751 (Cameron Blvd.). This area contains the main stem of Sandy Creek and several small tributary streams (Figure 1) in a former riparian bottomland hardwood forest that had in time developed an increasingly mesic (upland) character due to the hydrologic isolation of the floodplain from Sandy Creek following progressive incising and straightening of the stream channel. Sandy Creek feeds into New Hope Creek, a tributary to the Jordan Reservoir and a drinking source for many Durham and Chapel Hill residents. Sandy Creek, New Hope Creek, and Jordan Reservoir are all smaller components of the Cape Fear Watershed in North Carolina (Figure 3).

Project Rationale

The Sandy Creek floodplain has been impacted by deposition of eroded upland sediments and the altered hydrologic patterns of a developed watershed. The floodplain is no longer capable of improving water quality for stream-borne nutrients, sediments and contaminants under these conditions, and thus at present Sandy Creek is delivering impaired waters into New Hope Creek and the Jordan Lake watershed.

Sandy Creek feeds into New Hope Creek between Chapel Hill and Durham 0.5 miles north of SR 2220. New Hope Creek in turn feeds the Jordan Lake drinking water reservoir, and the watershed is part of the Haw River hydrologic unit, one of six within the Cape Fear River basin. The Haw River hydrologic unit was listed as United Watershed Assessment Category I – Needing Restoration - High Priority (NCDENR, 2001). All but 0.5 miles of upper New Hope Creek are listed by the NCDENR (2003) as “fully supporting.” NCDENR (2001) delineates upper New Hope Creek from lower New Hope Creek at NC SR2220, which is 0.5 miles downstream of the confluence of Sandy Creek with New Hope Creek. This short reach and the subsequent 24.5 miles of lower New Hope Creek are listed as “partially supporting,” strongly suggesting that Sandy Creek is a major source of this impairment. NCDENR (2003) lists 24.5 miles of lower New Hope Creek as impaired by fecal coliforms, 1377 acres impaired by excess chlorophyll a (i.e. eutrophication), and 25 miles of the creek showing habitat degradation. NCDENR (2001) suggests that the possible causes of the observed water quality impairment are excess fecal coliforms, sediments, and manganese, leading to habitat impairment due to urban runoff and point source discharges from wastewater treatment plants.

Suspended sediment loads in Sandy Creek ranged from 2-654 mg/L during a storm event on 15 October 2002, with a measured rainfall at Raleigh-Durham airport of 0.84 inches (Town of
Figure 3. Map of the northern headwaters of the Cape Fear River Basin, showing the location of the Sandy Creek watershed (red circle), a tributary watershed of New Hope Creek and the Jordan Lake Reservoir.

Cary, 2002). While there is no state standard for TSS, as well as no EPA guidelines directly comparable to TSS data (EPA, 2002), values in excess of 100 mg/L are considered high (LJEA, 2000). Preliminary watershed monitoring related to the Duke Forest Stormwater Improvement and Wetlands Restoration Project has indicated fecal coliforms in the main stem Sandy Creek in excess of published state water quality guidelines (Pahl, unpublished data compared to NCDENR/DWQ, 2003).

Two separate projects were conducted prior to stream restoration to document water quality in Sandy Creek. From March-November 2000, Turley (2001) monitored 19 stations on both the main stem of Sandy Creek and several tributary streams. Elting (2003) monitored three sites along the main stem of Sandy Creek during a two-month period from August-October 2002 as part of an effort to model hydrology and nutrient discharge. Both studies monitored total-N and both total- and ortho-P. Compared to the EPA’s (2000) recommended surface water criteria for Ecoregion IX (Southeastern Temperate Forested Plains and Hills) for both total nitrogen (N) and phosphorus (P), Turley (2001) calculated a compliance frequency of only 38% for total-P,
and a 44% compliance frequency for total-N. Direct measurements from Elting (2003) demonstrated total-P in excess of 1 mg/L for almost three hours during a storm event at the downstream discharge point of the targeted watershed, as well as measured values approaching 2 mg/L in watershed discharge waters during storm events during the monitored two-month period. His model predicted potential mainstream P concentrations in excess of 4 mg/L during storm events. EPA-recommended TP criteria (2002) for rivers and streams is 0.037 mg/L. Thus both Turley’s (2001) and Elting’s (2003) studies demonstrated that stormwaters in the Sandy Creek watershed are out of compliance with EPA-recommended criteria both for N and P.

The forests in the Sandy Creek watershed are primarily second-growth following abandonment of agriculture in the early 20th century (Elting, 2003). Watts (2000) identified portions of the floodplain community as qualifying as wetland vegetation. However, most of the hydrophytic vegetation seen was in the canopy tree layer, which was dominated by sweet gum (Liquidambar styraciflua L.: FAC+), with sycamore (Platanus occidentalis L.: FACW-), red maple (Acer rubrum L.: FAC), tulip poplar (Liriodendron tulipifera L.: FAC) and American elm (Ulmus americana L.: FACW) as subdominants. Note that all taxonomy is according to USDA (2005). Watts (2002) found evidence that the site was transitioning to a more xerophytic character, particularly from the shrub and herbaceous communities. The shrub/sapling stratum was overwhelmingly dominated by Chinese privet (Ligustrum sinense Lour.: FAC), with pecan (Carya illinoensis (Wangenh.) K. Koch: FAC) and mockernut hickory (Carya alba (L.) Nutt. ex Ell.– indicator status not available) identified as subdominants, and the herbaceous layer was dominated by Japanese stilt grass (Microstegium vimineum (Trin.) A. Camus: FAC+). Watts (2000) attributed this transition to the lack of overbank flooding into the floodplain from the stream channel during storm events. Due to the downward excision of the streambed through the aforementioned alluvial deposits now present in the riparian areas, the floodplain has become hydrologically isolated from the stream (Elting 2003).

The classification of the Lower New Hope Creek as an impaired water body (NCDENR/DWQ, 2003) between Sandy Creek and Jordan Lake suggest that this watershed is a source of fecal coliform into the Jordan Lake watershed, which we can confirm from pre-construction sampling of our main stem stations. Data indicate fecal coliforms in excess of the published state water quality criteria of 200 colonies per 100 mL both within both Sandy Creek and New Hope Creek (Pahl, unpublished data compared to NCDENR/DWQ, 2003). Coliform concentrations are highest within the main stem of Sandy Creek, with little contribution from the tributary streams, suggesting that the source of the pollution is in the upper reaches of the watershed.

**Project Objectives**

In response to the recognition of impaired floodplain functioning and water quality, a three-phase restoration of Upper Sandy Creek and its adjacent floodplain was developed in conjunction with the Duke University Wetland Center, Duke Forest and the Dept. of Civil and Environmental Engineering (Figure 4). Phases I and II were funded by CWMTF, EEP and Duke University.
Figure 4. Restored state of Sandy Creek, shown in relation to the SWAMP research plots (biodiversity experiment in orange and invasive experiment in red), the Phase Two dam impoundment (dark blue) and the Phase Three treatment wetland (green). The Phase Two impoundment is approximately overlaid on the 294’ contour line, while the Phase Three treatment wetland is an intended location relative to a new tributary stream alignment.

- **Phase I: Re-contour** more than 600 meters of degraded stream. Completion of this phase was done in July 2004. It is intended to promote overbank flooding during storm events, thereby re-establishing the hydrologic link between the stream and floodplain and fostering biogeochemical transformations of stormwater.

- **Phase II:** An earthen dam and 1.6-hectare stormwater reservoir was completed in November 2005 to regulate stormwater delivery to downstream water bodies and to replace a deteriorating dam farther downstream. Completion of this phase is intended to further promote reductions in nutrients via biogeochemical processing in and on the fringes of the impoundment, and also reduce fecal coliform and sediment content by promoting sedimentation.

- **Phase III:** Currently in the design phase is a 0.5-hectare treatment wetland to intercept and improve the quality of stormwater associated with Duke University West Campus.
entering the main stem of Sandy Creek via a tributary stream impacted by high concentrations of N and P. Funding for this project is from the NC Division of Water Resources and Duke University Wetland Center.

This project was undertaken with the primary objective of improving water quality in Upper Sandy Creek and in the larger New Hope Creek and Cape Fear River Watersheds. The proposed wetlands restoration aims to cut total nitrogen and total phosphorus levels by 50%. Additionally, we sought to provide stormwater runoff protection for Duke Campus, and create a variety of habitats for wetland plants and animals and increase biodiversity. We also were proceeding towards the specific goal of providing educational and research opportunities by creating an outdoor laboratory the Southern Wetlands Assessment Management Park, or SWAMP, that would be available to the surrounding community for education and research purposes. This final report focuses on activities that were undertaken during the first two phases, namely the stream and floodplain restoration and creation of a new dam and upstream impoundment.

PROJECT SUMMARY

Task Overview

This final report summarizes the progress made at the Duke Forest Project restoration site through 2005, as originally described in our agreement work plan. During our Watershed Management Plan Phase in the two summers (2002-2003) prior to the onset of construction activities, we completed work on background vegetation, soils (see Figure 5 for an example of background soil conditions) and basic hydrology surveys for the site. Complete reports are available on each phase of the background work. A topographic map (one foot contours) of the 5.9-hectare portion of the Sandy Creek watershed that is within Duke Forest was completed in 2001 to facilitate design of low profile earthen control structure, stream and wetlands restoration sites. Documentation of existing stream bank and riparian area conditions in the project area were done as well as an assessment of the reference reach conditions for the stream restoration phase of the project. A water quality monitoring plan has been in place since July 2003 and data has been collected on a monthly basis from 11 locations (see Figure 6 for exemplary nitrate concentration data). We therefore will be able to identify incremental changes in water quality associated with the component Phases of the restoration project. Detailed site plans have been developed and GIS maps produced for the site.

In the Design and Permitting phase of the project we contracted worked primarily with Engineering Consulting Services and ATC Associates of Raleigh NC to oversee the engineering designs for the dam site and Buck Engineering was hired to design and construct the stream restoration through their affiliate Riverworks, Inc. All the design plans for the dam site as well as for the stream restoration were completed by January 2004. We submitted our plans for our 404/401 permits and received approval for our proposed plans. After field tests and a detailed assessment of the site we met with staff from the Corps of Engineers, WRP and NCDENR to develop a final plan for the site. A revised plan for the site was developed in January and February of 2002 and a final plan was submitted to both the Corps and NCDENR in March of 2002. We received a nationwide permit (27) from the Corps on 2 April 2002 (Action ID
The Construction Phase of the stream and floodplain restoration and the new dam and impoundment are now completed. Construction of a new main stem stream channel began in May 2004 and concluded in August 2004, with final streamside vegetation planting of floodplain trees and shrubs occurring in January 2005. The cover photo of this report shows a section of the newly constructed stream channel (compare that to the photo of the stream pre-construction in Figure 1.2). Construction of the new dam began in December 2004 with the logging of trees from the construction zone and the area that will be impounded when the dam is fully operational. Construction of the dam itself began in June 2005 and, with the exception of the installation of the electronically-controlled weir on the dam sluice, was completed in late November 2005 (Figure 7). We anticipate installation of the weir in January 2006. The slopes of the dam and margins of the impoundment were hydroseeded on 6 December 2005 to stabilize the site against potential erosion. In spring 2006 the margins and interior shallow benches of the impoundment will be planted with a mixture of herbaceous and woody wetland plant species, to be determined by DUWC personnel. Figure 2.2 above shows the completed dam and the upstream impoundment in November 2005.

The Monitoring Phase of the study began in July 2003 following our application for EPA Clean Water Act Section 319(h) Nonpoint Source Management Program funds, administered by the NC DENR Water Quality Division (DWQ). Although the contract with DWQ was not delivered until June 2005, we felt it necessary to begin regular monthly monitoring as early as possible to provide as a pre-construction “background” survey of Sandy Creek water quality. Measurements of ambient or base flow have been collected on a monthly basis, and we have also
recently begun 48-72 hour sampling of storm events in conjunction with Dr. Emily Bernhardt of the Duke University Biology Department. Water quality collections from twenty locations have shown that values for TP exceeded 100 µg/L for 6 of the 9 months in year one monitoring (thus meeting an EPA compliance frequency of only 38%). Median values for TN were greater than 500 µg/L for the entire sampling period (an EPA compliance frequency of only 44%). Thus, water quality for the two major nutrients responsible for downstream eutrophication were very poor prior to construction of the stream and stormwater holding area. Additional work is underway to complete a nutrient budget for the site prior to and after the construction of the wetland. Ten water level monitoring stations are installed to measure groundwater levels. A complete vegetation analysis for the area was completed in the summer of 2001 and these data gave us a basis for our planting regime to restore the wetlands of the site. A full soils analysis was done at the site and existing hydric soils were identified.
Figure 7. Photo of the newly constructed dam (top) and upstream impoundment (bottom) taken on 15 November 2005, prior installation of the weir with which we will vary impoundment volume and depth. The partially filled lake in the bottom picture where water depths will vary from 0.9-2.4 meters (3-8 feet) when the maximum water depth is set on the dam weir. The dry margins visible in the bottom photo will be inundated to a depth of 0.3 meters (1 foot) when maximum water depth is attained.
The Public Outreach and Education phase of our project has focused on the preparation of educational materials as well as media releases concerning various phases of the project. We have just completed our first brochure for the public and have presented this information as well as prepared a poster for display at the recent Triangle (RTP) Earth Day celebration. We have prepared signage for the Duke wetland construction site as well as preparing for a general kickoff announcement with local press and members of the Clean Water Management Trust, Wetlands Restoration Program as well as the Duke Administration, County officials and Wetland Center Staff.

Once Phases 1-3 are complete, we will construct a series of trails and boardwalks with informational placards designed by Lawrence (2003) specifically about the restoration as well as generally regarding Piedmont riparian ecology. The site will be accessible as an educational resource by a wide array of public users from local K-12 students to the professional environmental restoration community.

Confining the restoration project to Duke University property allowed for the development of a research and teaching field laboratory wetland, which we have termed the Southern Wetland Assessment and Management Park (SWAMP). The 3.2-ha SWAMP ecosystem will serve as an outdoor classroom and field laboratory for students and researchers and provide a site for research on biological diversity, hydrology, mosquito control, invasive plant species and other environmental concerns. Historic and ongoing research projects relative to the Duke Forest Project and SWAMP are listed below.

The following grants and research projects are currently in progress to aid in the educational and research components of SWAMP.

- Quantification of Water Quality Improvement in Sandy Creek, a Tributary Watershed of Jordan Lake in the Cape Fear River Basin, After Stream and Riparian Restoration and Wetland Treatment Cell Creation (Pahl and Richardson, EPA 319(h) Grant, 2005-2007)
- Water Resources Stream Restoration Development Project for Durham County (Richardson, Durham Soil and Water Conservation District Grant, 2005)
- Trajectory of Ecosystem Recovery in Restored Riparian Zones in Urban Settings (Morse, 2005 EPA STAR Grant)
- The Role of Plant Functional Diversity in Regulating Nitrogen Removal in a Restored Riparian Wetland (Sutton-Grier, NSF Doctoral Dissertation Improvement Grant, 2005-2007)
- Do Restoration Activities Foster the Spread of Invasive Plant Species (*Microstegium vimineum* (Trin.) A. Camus and *Ligustrum sinense* Lour.) In the Sandy Creek Floodplain (DeMeester and Osland ongoing doctoral research)
- An Assessment of Mosquito Population Dynamics at the Duke Forest Stream and Wetland Restoration Site (McHugh, ongoing doctoral research)

The following grants and projects have been completed. Much of the site characterization data presented earlier in this report are from these research efforts.

- A Wetland Model Incorporating Overland and Channel Flow, Solute Transport and
Surface/Ground Water Interactions (Kazezyilmaz-Alhan, 2005 Dissertation)

- A Macroinvertebrate Survey of Sandy Creek in Durham County and Comparison to Other Triassic Basin Watersheds in North Carolina (Roberts, 2005 Master’s Project and continuing efforts)
- A Pre-Restoration Hydrologic Assessment and Nutrient Budget for Sandy Creek, Durham, NC (Elting, 2003 Master’s Project)
- Integrating the Sandy Creek Restoration Project with Environmental Education (Lawrence, 2003 Master’s Project)
- The Effects of a Wetland Restoration on Water Quality: A Baseline Assessment of Water Quality Indices in the Sandy Creek Project Area, Durham, North Carolina (Turley, 2001 Master’s Project)
- The Effects of Reduced Flooding Frequency on Species Composition in a Bottomland Hardwood Stand in the Piedmont of North Carolina (Watts, 2000 Master’s Project)
- Duke Forest Stormwater Improvement and Wetlands Restoration Project (Richardson, Edeburn and Medina; Cleanwater Management Trust Fund Grant, 2000-2005)

A brief project overview of the engineering work done to-date is included in the next section.

**Engineering Overview**

Engineering Consulting Services, Ltd. completed an engineering investigation and hydraulic and hydrologic analysis for the proposed earth fill dam located at the site. The dam has a maximum structural height of 18.0 feet and an impoundment capacity of approximately 20.7 acre-feet at normal pool. The spillway for the dam was designed so the principal and emergency spillways would pass the 1/3 pmp design storm. The center of the dam is located at approximately 35° 59.3’ north, latitude and 78° 56.7’ west longitude. The dam will impound water from an unnamed Branch of Sandy Creek in the Cape Fear River Basin. The primary purpose of impoundment for the dam is to provide stormwater retention as well as being a water source for restored and experimental wetlands to be created in conjunction with Duke’s Nicholas School of the Environment and Earth Sciences.

**Field Observations**

The site of the dam, lake area and surrounding area is currently undeveloped and wooded and has an unnamed branch of Sandy Creek that flows generally northeast to southwest across the site. The soils observed in the vicinity of the site include alluvium in the bottomlands consisting of silty sands and clayey sands. The uplands consist of Triassic clays and silts (White Store) and were well suitable for dam construction. A diabase rock outcrop was noted on the south end of the site.

**Site Geology**

The site is located in the Triassic Basin. The bedrock in this area is primarily sedimentary, formed approximately 200-190 million years before present during the separation of the North American and African plates. The residual soils are clayey and are highly
impermeable, resulting in extremely low base flows (Giese and Mason, 1993).

**Borrow Material**

Borrow material used for the dam construction consisted of clayey silts and silts. These materials typically have a maximum dry density, which varies from 104 pounds per cubic foot to 107 pounds per cubic foot. Triaxial tests in the Durham area indicate an effective cohesion, which ranges from 100 to 400 psf, and an effective angle of internal friction of 22 to 26 degrees.

**Slope Stability Analysis**

Experience with slope stability analysis with these type of soils using the simplified Janbu Method of slices and the modified Bishop Method using circular failure surfaces indicated a minimum safety factor of 1.5 for the proposed 2.5H:1V slopes for the dam under steady state conditions. A minimum factor of safety of 1.3 is expected for rapid drawdown conditions.

**Hydraulic And Hydrologic Analysis And Results**

**General Information on Dam**

The Estimated Design Life is 50 years assuming proper maintenance. This design may be extended at the discretion of the design engineer, based on the maintenance level, operational use, and hydrologic factors.

The proposed filling schedule for the dam is that the dam will be closed in January of 2006 and the lake area filled to capacity during the winter of 2006 once the permit for filling the reservoir is received from the Dam Safety Office. Duke will develop and maintain an operation and maintenance plan for the site that corresponds to state guidelines.

**Observed Changes in Site Hydrology**

Twenty monitoring wells were installed in September 2000 to track changes in groundwater elevation throughout the Duke Forest Project site over time (Figure 8). The 5-cm diameter PVC well screens, 0.25 mm (0.010”) slot size, were installed to a depth of 120 cm using a 15-cm auger, with the drill hole backfilled with medium-grain sand and sealed from the surface with a bentonite-mortar cap as per WRAP (2000).

We have measured the elevation of the groundwater in the wells continually on a bi-weekly basis since 29 September 2000. The onset of construction activities associated with the Phase 1 stream channel reconfiguration resulted in the destruction of eight wells, so that since August 2004 only twelve wells have been available for measurement since construction started. To further develop a full hydrologic model of the site 72 additional wells and piezometers were installed in the summer of 2005 to establish groundwater flow patterns and determine water table changes since the stream restoration. Precipitation data corresponding to the two-week period prior to groundwater elevation observations was collected from online sources (http://www.wunderground.com/), for comparison with groundwater data. Preliminary results
are as follows.

When the aggregate dataset between October 2000 and June 2005 was analyzed, groundwater elevations in all wells studied were significantly cross-correlated at $P = 0.10$, and were also significantly correlated to rainfall. However, the pattern of response was different when the data were segregated between time periods prior to and after the completion of Phase 1 construction activities and the capture of the Sandy Creek main stem flow by the newly reconfigured channel. Both time periods retained significant and total correlation in groundwater elevations between all wells. In contrast to the overall dataset, though, while rainfall was significantly correlated to groundwater elevation in all wells for the four-year period prior to reconfiguration, after main stem flow capture by the new stream channel there were no significant correlations between rainfall and groundwater elevation in any of the wells. The water levels in the groundwater now are more closely connected to the elevated stream water levels as a result of the restoration. Thus, the floodplain now seems to be connected to stream hydrologic conditions as demonstrated by the rise of water tables in wells A and B even during a drought period (Figure 8)

Future Research and Monitoring Plans

- Phase III construction of an off-line treatment wetland that will intercept tributary storm event flows will further reduce nitrogen and phosphorus inputs into the main stem of Sandy Creek.

- Continued monitoring of all groundwater elevation wells and the installation of continuous-reading gauges (RDS Inc.) should document the continued re-establishment of wetland hydrology throughout the riparian floodplain of the project area following stream channel reconstruction and in response to the completion of Phase II dam construction.

- A complete water and nutrient budget will be developed for the site to determine the effectiveness of the stream and stormwater restoration efforts to improve water quality and reduce sediment loads to the Jordan Reservoir.

- We are exchanging technical expertise with the North Carolina Ecosystem Enhancement Program (NC EEP) regarding the design and functional response of this project.

- Educational programs are being developed with local schools and the Durham Life and Science Museum. In addition stream and wetland training programs are to be conducted at the site for state and local officials.
Figure 8. Preliminary data suggest increases in groundwater elevations within the floodplain following stream channel reconstruction. The top figure shows the location of groundwater monitoring wells (red diamonds) within the Duke Forest Project area. Wells are shown in relationship to the restored Sandy Creek stream channel (blue), the Al Buehler jogging trail (yellow) and the City of Durham sanitary sewer (magenta). Bi-weekly groundwater elevations in the bottom two graphs are shown in relation to monthly precipitation totals recorded at Raleigh-Durham International Airport. The pink line indicates the 30-cm groundwater depth criteria for defining wetland hydrology. The grey background is the period prior to stream reconstruction, and the white background is after reconstruction.
REFERENCES


