BOLIN CREEK WATERSHED RESTORATION INITIATIVE

FINAL REPORT

Fiscal Year 2008 Section 319 Nonpoint Source Water Quality Improvement Grant

of $369,792 in Federal Funding

NC-DENR Project Contract # 1666

Contract Period October 1, 2008 through September 30, 2012

Town of Chapel Hill, NC, Sponsor

Trish D'Arconte, Project Coordinator and Author

November 15, 2012

ACKNOWLEDGMENTS

This project was funded by a US Environmental Protection Agency Section 319 Grant. Project partners formally included the Town of Chapel Hill, the Town of Carrboro, NC State University's Water Quality Group, the NC Division of Water Quality, and the Ecosystem Enhancement Program.

We would like to thank Dave Almond and Randy Dodd for contributing to writing this report, and to Sue Burke and Wendy Smith for review.

In the following report, "project members", "team members", and "we" generally refers to the Chapel Hill, Carrboro, and NC State University staff that were involved most frequently in implementation. This includes Randy Dodd of Carrboro; Trish D'Arconte, Wendy Smith, and Dave Almond of Chapel Hill; Paul Clark of NC DWQ; and Greg Jennings and Zan Price of NCSU.

However, many others contributed to implementing and completing this complex set of restoration activities. We would like to thank:

From Chapel Hill: Sue Burke, Ernest Odei-Larbi, Chris Jensen, Robert Sykes, Traval Watkins, Joe Farrington, Mike Riggsbee, Cary Degraffenreidt, Philander Logan, and Santiago Hernandez

From Carrboro: Trish McGuire, Ruth Heaton, and Will Autry

From NCSU's Water Quality Group, NC Cooperative Extension, and Watershed Education for Communities and Officials (WECO): Bill Hunt, Mike Shaffer, Karen Hall, Erica Tillinghast, Andrew Anderson, Ryan Winston, Dave Penrose, Christy Perrin, Patrick Beggs, and Carolyn Buckner

And: Kim Nimmer and Robin Markham of NC DWQ; Tony Able of US EPA; Dave Lenat of Lenat Consulting; and Mike Herrmann and Anjie Ackerman of NC EEP

We would also like to thank North State Environmental and Wright Contracting for their excellent construction work on the Trinity Court stream restoration, Baldwin Park stream restoration and bioretention, and Dickerson Court bioretention.

TABLE OF CONTENTS

Acknowledgments ii

Table of Contents iii

Appendices v

List of Figures vi

List of Tables vi

List of Abbreviations vii

Executive Summary viii

1. Introduction and Background 1

  1.1 Bolin Creek Watershed 1

  1.2 Watershed Restoration Background 1

  1.3 Project Objectives and Grant Specifics 3

    Estimates of load reductions 4

  1.4 Detailed Project Proposals 4

    Baldwin Park Stream Restoration and Stormwater Retrofit 4

    Mill Race Tributary Stream Erosion Control and Gully Repair 4

    Analysis of Stormwater Management Alternatives for Tanyard Branch 5

    Develop a Watershed Restoration Plan 5

  1.5 Proposed Monitoring 6

    Monitoring Goals and Approach 6

    Complimentary Monitoring 6

  1.6 Proposed Public Involvement 7

  1.7 Project Measures of Success 8

2. Methods and Execution 9

  2.1 Brief Review of Deliverables 9

  2.2 Implementation of Selected Deliverables 12

Development of the Watershed Restoration Plan 12

Development of the Problems and Projects Geodatabase 16

Tanyard Branch Stormwater Alternatives Analysis 20

Baldwin Park 22

Mill Race Tributary 25

Monitoring 30

3. Results and Conclusions 32

3.1 Monitoring Results and Discussion 32

Water Level and Discharge Monitoring 32

Water Chemistry Monitoring 34

Temperature Monitoring 36

Rain Gauge Data 38

Benthic Macroinvertebrate Monitoring 39

3.2 Project Evaluation 43

Evaluation Against Measures of Success 43

Grant Budget Summary 45

Match Amounts and Discrepancies 45

3.3 Lessons Learned 47

Monitoring 47

Education and Outreach 47

Planning and Preparation 48

Other issues 49

APPENDICES

Appendix 1: Baldwin Park Project Materials

Appendix 2: Mill Race Tributary Project Materials

Appendix 3: Stormwater Alternatives Analysis for Tanyard Branch

Appendix 4: Trinity Court Stream Restoration Project Materials

Appendix 5: Mitchell Lane Bioretention Project Materials

Appendix 6: Dickerson Court Bioretention Project Materials

Appendix 7: Hargraves Fire Lane Project Materials

Appendix 8: Carrboro Rain Gardens Project Materials

Appendix 9: Geodatabase of Restoration Projects Feature Class Attributes

Appendix 10: Bolin Creek Watershed Situation Assessment

Appendix 11: "Can We Heal Our Waterways?" Symposium Presentation

Appendix 12: Approved Monitoring Quality Assurance Program Plan

Appendix 13: Budgeted and Actual Expenditures

LIST OF FIGURES

Figure 1: Location of Bolin Creek Watershed 1

Figure 2: Example of an Earth Tech Geomorphic Study Field Form 17

Figure 3: Revised Chapel Hill Stream Walk Field Form 18

Figure 4: Baldwin Park Water Level Data 33

Figure 5: Mill Race Tributary Stage-Discharge 34

Figure 6: Baldwin Park Stage-Discharge 34

Figure 7: Baldwin Park Temperature (F) Before Construction 37

Figure 8: Baldwin Park Temperature (F) After Construction 37

Figure 9: Mill Race Trib Temperature (F) Before Construction 38

Figure 10: Mill Race Trib Temperature (F) After Planned Construction Period 38

Figure 11: Chapel Hill Town Hall Rain Gauge Data 39

LIST OF TABLES

Table 1: Description of 9 Scenarios Modeled in PCSWMM

Table 2: Baldwin Park Water Chemistry Pre- and Post-Construction

Table 3: Mill Race Tributary Water Chemistry Pre-Construction

Table 4: Abundance of Benthic Insects Collected from Baldwin Park and Mill Race Tributary

Table 5: Diversity and Bioclassifications of Baldwin Park and Mill Race tributary

Table 6: Actual and Budgeted Cash and In-Kind Match Amounts

LIST OF ABBREVIATIONS

ASSHTO	American Association of State Highway and Transportation Officials
BMP	Best Management Practice (in this report, those used for stormwater)
CIP	Capital Improvements Project
EPA	Environmental Protection Agency
GIS	Geographic Information System
LID	Low Impact Development
MS4	Municipal Separate Storm Sewer System
NC DENR	North Carolina Department of Environment and Natural Resources
NC DOT	North Carolina Department of Transportation
NC DWQ	North Carolina Division of Water Quality
NC EEP	North Carolina Ecosystem Enhancement Program
NCSU	North Carolina State University
NPDES	National Pollutant Discharge Elimination System
NWIS	National Water Information System
OWASA	Orange Water and Sewer Authority
QAPP	Quality Assurance Program Plan
SCM	Stormwater Control Measure
SVAP	Stream Visual Assessment Protocol
TJCOG	Triangle J Council of Governments
TMDL	Total Maximum Daily Load
UNC	University of North Carolina
URL	Uniform Resource Locator (i.e. web address)
USGS	United States Geological Survey
WECO	Watershed Education for Communities and Officials

EXECUTIVE SUMMARY

Bolin Creek is a fourth order stream flowing through the Towns of Carrboro and Chapel Hill, NC. It is impaired for biological integrity along approximately half its length. Causes of impairment include flashy storm flows, low base flows, stormwater runoff, stream channel scour and erosion, poor habitat quality, and sedimentation. The project team anticipates that through improving physical and chemical stream conditions in Bolin Creek and its tributaries, this will encourage the recolonization and diversification of the stream macroinvertebrate community in Bolin Creek, and thence restore full uses to this impaired stream.

This 319-funded project is expected to be the first of several projects aimed at addressing the complex set of urban stressors impacting Bolin Creek, with the ultimate goal of improving Bolin Creek's biological health. To work towards this goal, the objectives of this project were to:

1. Develop a nine-element Watershed Restoration Plan with significant stakeholder input.
2. Analyze multiple alternative stormwater management methods and costs for a piped urban stream in Chapel Hill (Tanyard Branch), to determine which methods are sufficient to protect the channel downstream from erosion.
3. Install stormwater and erosion control for a tributary to Mill Race in Chapel Hill, repair of two severe gullies, and stream stabilization along an adjacent sanitary sewer line.
4. Restoration of a pair of small streams along a park in Carrboro (Baldwin Park), including energy-dissipating BMPs and riparian enhancement.

Project success was based on reducing effects of stormwater runoff at the implementation sites, determination of feasible alternatives and costs for stormwater retrofit in a dense urban area, and public education about Bolin Creek, its sources of impairment, and methods for its restoration.

The Watershed Restoration Plan was completed after considerable interaction with stakeholders, including a detailed survey of public attitudes towards Bolin Creek. In addition to this public input, the process of implementing the other elements of this project has significantly informed and improved the development of the Plan. This was further supported by the completion of the Tanyard Branch Stormwater Alternatives Analysis, which helped us better understand the comparative benefits and subwatershed needs of distributed versus regional stormwater management approaches in a densely urban area. The analysis has formed the basis of Chapel Hill's implementation steps for restoration of the Bolin Creek Watershed.

Our original restoration and retrofit plans and designs changed in response to landowner cooperation and detailed information about conditions at Baldwin Park and Mill Race tributary. Two streams bracketing Carrboro's Baldwin Park underwent restoration and riparian enhancement, and a bioretention basin was installed to divert street runoff from entering the stream directly. Severe channel erosion has been successfully repaired and riparian forest is now regenerating at this location. This project is very visible to the public and has served very well for public education and outreach. Difficulties with implementing the project elements for the Mill Race tributary meant finding alternative locations that would meet the same water quality benefits. Four alternative project elements were installed on Chapel Hill properties near areas of public foot traffic: restoration of a steep, badly eroded stream (Trinity Court); installation of two bioretention basins (Mitchell Lane and Dickerson Court) treating parking lot and street runoff; and installation of permeable grass pavers to replace a compacted gravel fire lane (Hargraves Community Center). These alternative locations provide much better public education opportunities than the original Mill Race tributary project elements, and provided outreach to staff in other Town Departments.

1. INTRODUCTION AND BACKGROUND

1.1 BOLIN CREEK WATERSHED

Bolin Creek is a fourth order stream draining an area of about 7800 acres, or about 12 square miles. It starts in unincorporated parts of Orange County, NC and flows mostly southeast into first the Town of Carrboro and then into the Town of Chapel Hill. It is one of the major streams draining southern Orange County, as it drains 12 square miles in carving a path through the heart of Carrboro and Chapel Hill (Figure 1). Moving downstream, the watershed transitions from rural to suburban to urban.

When it reaches the confluence with Booker Creek in Chapel Hill the combined streams become known as Little Creek. Little Creek is one of the many streams included in the drainage area known as the "Upper New Hope Arm" of Jordan Lake, which also includes Morgan Creek, New Hope Creek, Northeast Creek, and Third Fork Creek. The Bolin Creek Watershed is shown in Figure X in relation to the drainage area for the Upper New Hope Arm of Jordan Lake, and the combined drainage areas for Little Creek and Morgan Creek.

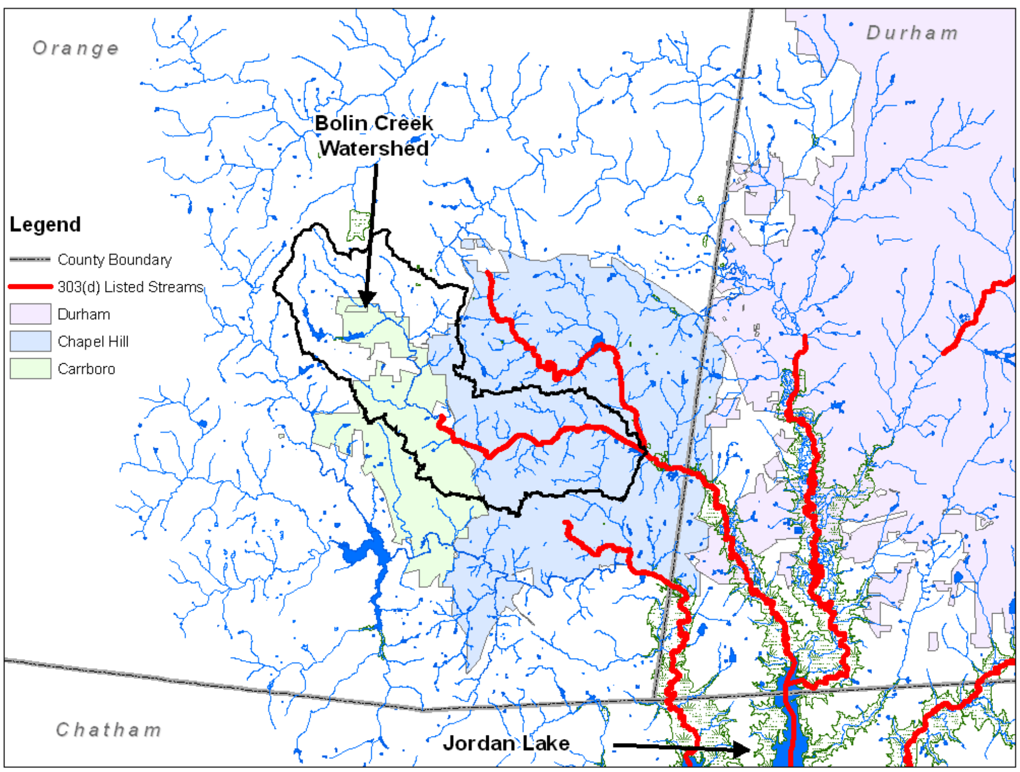


Figure 1: Location of Bolin Creek Watershed

1.2 WATERSHED RESTORATION BACKGROUND

The Division of Water Quality has conducted several rounds of targeted macroinvertebrate collection to better track changing ecological conditions in Bolin Creek. Bolin Creek was found to be meeting its intended uses in 1986, but became impaired by the next round of monitoring in 1993. The length of impaired stream has only increased since then. As of 2012, Bolin Creek continues to be impaired for biological integrity, the impairment starting about halfway through Carrboro and extending through Chapel Hill. It exhibits a progressive decline in watershed functional health from upstream to downstream, mirroring the increases in land use intensity as you move downstream.

The local community has a fond relationship with the creek, and at the same time, a growing body of evidence over the past several decades has documented that the aquatic life of Bolin Creek and its tributaries is threatened and impaired from the human activity occurring within its watershed. The causes of the impairment are both simple—land disturbance and development—and complex: alterations in hydrology, erosion and sedimentation, introduction of toxic contaminants and other pollutants, and habitat disruption. The bottom line is that the concern is also an opportunity for restoring the creek to a healthier status.

To investigate potential stressors and causes of impairment in the Creek, assessments of the watershed were conducted in 2002 and 2003 by the Watershed Assessment Restoration Program. The study indicated that several effects of urbanization, including habitat degradation, riparian degradation, channel incision, high embeddedness, low base flow, and toxicity, are believed to be the primary factors stressing this watershed. Most of these problems were more prominent as one moves downstream in the watershed. Other potential stressors included temperature (ranges and extremes), high biochemical oxygen demand, nutrients, and cross-connections or leaks from sanitary sewer lines. No streamflow data were taken as part of this study, but scour and related morphological and hydrological modifications were considered a primary contributor to the aforementioned stressors. The study recommended that feasible and cost-effective stormwater retrofit projects be implemented to mitigate the hydrologic and potential toxic effects of existing development.

In 2003 through 2004, the NC Ecosystem Enhancement Program (then Wetlands Restoration Program) undertook a Local Watershed Planning Initiative for the Morgan and Little Creek watersheds. Although the resulting NC EEP report made some recommendations for preservation opportunities, stream restoration projects, and potential stormwater management measure retrofit sites, these were selected based on the particular requirements of the EEP. These requirements are based on the use of the NC EEP as a mitigation bank for the state's Department of Transportation, and selected projects did not target specific identified problem areas or stressors.

Staff from the Carrboro Planning Department, Chapel Hill Stormwater Management Division, the North Carolina Department of Environment and Natural Resources (NC DENR), and the US Environmental Protection Agency (EPA) began meeting in April 2006. Together these organizations formed the Bolin Creek Watershed Restoration Team (BCWRT) to participate in EPA's Watershed Restoration Program in restoring and enhancing Bolin Creek and its tributaries. The Bolin Creek Watershed Restoration Initiative was started to provide organization and support for the Towns of Chapel Hill and Carrboro to participate in EPA's Watershed Restoration Program.

The primary goal of the Initiative is to restore the biological health of the Bolin Creek Watershed. The Initiative focuses on hydrologic modification and habitat degradation by addressing some of the primary causes of these stressors including streambank and streambed erosion, disconnection from stream floodplains, sedimentation, scour, thin or absent forested riparian buffers, the "flashy" nature of urban stream hydrographs, very low base flow, the effects of stream crossings, and purposeful modifications such as channelization and desnagging. Water quality issues related to toxins are expected to be addressed separately by the Towns' respective Illicit Discharge Detection and Elimination programs as part of their Nonpoint Source Discharge Elimination System (NPDES) Municipal Separate Storm Sewer System (MS4) permits.

In 2007, the Bolin Creek Watershed Restoration Team decided a geomorphological analysis of the watershed with would identify projects more likely to have measurable results and directly address the Team's goal. The Team applied for and was awarded a Clean Water Management Trust Fund (CWMTF) stormwater mini-grant. These funds were used to contract with EarthTech to conduct a geomorphological analysis including surveying the entire watershed and walking the majority of the intermittent and perennial streams in the watershed. During this survey, potential stormwater management measures and stream restoration sites targeted to the worst problems were identified, with a greater focus on the former. This report can be viewed online:

> Carrboro webpage URL for Earth Tech report:
> http://www.ci.carrboro.nc.us/pzi/Env/PDFs/BolinCreek_Report_final_11-6-07.pdf
> Chapel webpage URL for Earth Tech report and related information:
> http://www.townofchapelhill.org/index.aspx?page=1942

EarthTech's report served as an initial guide in the selection of projects for future 319 grant applications. The restoration team has focused its efforts within individual subwatersheds of Bolin Creek in order to concentrate hydrological, morphological, and biological improvements that can be most readily detected as measurable results. The projects funded by this 319 grant are based on this concentrated approach.

1.3 PROJECT OBJECTIVES AND GRANT SPECIFICS

The overarching goal of all Bolin Creek Watershed Restoration Team projects is to restore the aquatic health and water resource quality of Bolin Creek and its tributaries. The Team anticipates that through improving physical and chemical stream conditions in Bolin Creek and its tributaries, this will encourage the recolonization and diversification of the stream macroinvertebrate community in Bolin Creek, and thence restore full uses to this impaired stream. To work towards this goal, the objectives of the 319-funded project described and reviewed in this report were to:

1. Address stream erosion, invasive species, missing riparian forest, and uncontrolled stormwater along a pair of small streams at the mutual boundary of Carrboro and Chapel Hill (known as the "Baldwin Park project").
2. Address stream erosion, invasive species, missing riparian forest, and repair two large gullies in a steep valley in Chapel Hill (known as the "Mill Race tributary project").
3. Conduct an analysis of stormwater management methods for a heavily-urbanized stream suffering severe erosion, to determine whether there are alternatives to installing a wet retention pond in-line on a perennial stream, in support of future downstream restoration.
4. Create an EPA 9-element Watershed Restoration Plan to guide future planning of stream restoration and stormwater retrofit projects across the Bolin Creek Watershed and support future grant applications to fund these projects.

Non-point pollution sources to be addressed included urban runoff/stormwater, habitat modification, hydrologic modification, excess nitrogen excess phosphorus, sedimentation, low dissolved oxygen, and temperature.

Of critical importance was the selection of project areas and restoration methods that were likely to demonstrate improvement within the grant period. Achieving measurable results within the grant period was an objective that was very strongly impressed upon project staff as important to all 319 projects. This is a challenge, given the time required for streams to demonstrate geomorphic stability after restoration construction, and the more extensive time required for stream biological communities to respond to favorable conditions. This is in comparison to the short, three-year grant period for 319 grants, which includes the time set aside for construction when no improvement would be expected.

Project objectives for the Mill Race tributary changed when project staff failed to secure permission from property owners adjacent to the project areas for access. In this very steep terrain access for heavy equipment was severely limited. Project staff identified other areas where projects would meet similar objectives of erosion control and stormwater management at four sites in Chapel Hill: Trinity Court, two locations at Hargraves Community Center, and Dickerson Court. These replacement projects are described in detail under the Mill Race Tributary sections of this report.

ESTIMATES OF LOAD REDUCTIONS

Based on the estimates of the Earth Tech study from which the restoration activities were selected, Baldwin Park stream restoration was proposed to reduce soil erosion by 2400 tons per year, equivalent to reducing export of nitrogen by 4800 pounds per year and phosphorus by 2400 pounds per year (for a 1000 foot segment – extrapolated from a smaller segment calculation). Repair of the two severe gullies at the Mill Race tributary stream was proposed to reduce soil erosion by 1400 tons per year, equivalent to reducing export of nitrogen by 2800 pounds per year and phosphorus by 1400 pounds per year. The load reduction was calculated using the BANCS model (Bank Height Erosion Index combined with Near-Bank Stress).

Because stormwater BMPs for Baldwin Park and stabilization of Mill Race tributary's streambanks were recommended by NCSU after projects were selected from the Earth Tech report, the Team did not have the expertise to calculate the expected load reductions for sediment (eroded soil), nitrogen, or phosphorus.

1.4 DETAILED PROJECT PROPOSALS

BALDWIN PARK STREAM RESTORATION AND STORMWATER RETROFIT

Baldwin Park is a small urban "pocket park" on the boundary between Carrboro and Chapel Hill. A small stream traversing the park, flowing into Tanyard Branch (one of the major, highly-urbanized tributaries of Bolin Creek), it was highlighted as one of the 32 high priority projects in the Earth Tech report. The upper portion of the stream has been put into a pipe, and street runoff drains directly to the stream from a curb inlet. Site reconnaissance identified a tributary to this stream to the east that had scour at the upper end where runoff drains from another street. Both tributaries had instream scour and erosion, poor instream habitat and morphology, minimal to no vegetation on the banks except close-cut grass (Carrboro side) and a few trees (Chapel Hill side) with the exception of the confluence area that was almost entirely Chinese privet.

The conceptual plan for this project was a combination of the Earth Tech recommendations and further additions recommended by NCSU's Water Quality Group. Stream restoration, including changes in channel cross-section, reducing bank slopes, creating a bankfull bench, and improving riffle and pool habitats were proposed for about 300 feet of each of the tributaries. Stream enhancement (vegetating the banks) was proposed for an additional 400 feet of the Chapel Hill tributary. 3 BMPs for handling street runoff would be placed at the upper ends of the streams to prevent degradation of the restored channels. See Appendix 1 for the concept drawings for work proposed at Baldwin Park.

MILL RACE TRIBUTARY STREAM EROSION CONTROL AND GULLY REPAIR

Mill Race is a major tributary of Bolin Creek draining a portion of the Historic District of Chapel Hill. This area is densely urban and largely built-out, rugged with a shallow depth to bedrock, has piped springs and convoluted storm drainage networks, and sanitary sewer lines running down most stream valleys, with streams pushed against the valley walls. A large tributary to Mill Race was found to have two (later found to be three) severely-eroded gullies, one of which was highlighted as one of the 32 high priority projects in the Earth Tech report.

Further site reconnaissance found the following: a) streambed scour/incision and deposition of the pea-gravel/sand mix (used for sidewalks in the Historic District) below a stormwater outfall at the top of the stream, b) a sanitary sewer line crossing the stream near the bottom of the subwatershed which is being undermined, and c) along the length of the stream a lack of bank vegetation, bank collapse, and heavy instream deposition of "Chapel Hill gravel" (the aforementioned pea-gravel/sand mix) due to the proximity of a sanitary sewer line to the stream and the apparent use of Chapel Hill gravel as fill material to flatten out the easement for vehicle access. (The native soil in this area is a very fine silt-clay, the apparent native stream bed material is boulders and bedrock. This is typical for this area of Town.) Kudzu had also infested the middle portions of the stream valley and was pulling down the tree canopy.

The conceptual plan for this project called for repair of the gullies by adding pipe to the existing stormwater outfalls and bringing the runoff to the bottom of hill and using a BMP to dissipate energy and allow infiltration. The outfall at the top of the subwatershed was to be retrofitted to reduce scour, permeable pavers (and other methods) used to replace the gravel sidewalks in that block to reduce the deposition of sand and gravel in the stream, correcting the undermining of the sanitary sewer crossing (possibly by installation of step-pools), and treatment of the parallel-running sanitary sewer easement to stabilize the streambanks and reduce erosion. See Appendix 2 for the concept drawings for work proposed on the tributary to Mill Race.

ANALYSIS OF STORMWATER MANAGEMENT ALTERNATIVES FOR TANYARD BRANCH

One of the high-priority projects identified by Earth Tech was the bank reshaping, stabilization, and riparian reforesting of an upper segment of Tanyard Branch. By Earth Tech's estimates this deeply incised and severely eroding stream segment contributes over 1900 tons of sediment per year to the Bolin stream system. Further site reconnaissance found potential conflicts with a nearby sanitary sewer line and an existing greenway trail. In addition, Chapel Hill staff were aware of significant erosion occurring upstream of this site just below a large stormwater outfall. The area draining to this outfall is approximately 98% impervious surface (all downtown Chapel Hill), and includes a historically-known spring that has since been piped. Staff concluded (and have observed) that the energy from this drainage could be sufficient to severely degrade any stream restoration or bank stabilization that may be undertaken downstream.

In order to address this in advance of future downstream restoration, Chapel Hill staff inquired with EPA about the use of an in-line BMP to control the flow and volume from this combined spring-stormwater system. Because it would be placed along a perennial stream it would need to meet requirements for 401/404 certification. The primary requirement for such certification would be an analysis of alternatives for the management of runoff flow and volume in this subwatershed, using such methods as cisterns, green roofs, underground storage, etc. that would be appropriate for high-density urban situations, and comparing the costs for implementation of the needed amount of each BMP type to the cost of an in-line BMP at the stormwater outfall.

DEVELOP A WATERSHED RESTORATION PLAN

A comprehensive, coherent watershed restoration plan was suggested as important for successfully winning grant applications for future restoration projects. The Team agreed to develop a nine-element EPA watershed restoration plan including:

1. An information/education component to enhance public understanding of the project and increase public participation.
2. A monitoring component to evaluate the effectiveness of the implementation efforts over time measured against the criteria.
3. An identification of the causes (stressors) and sources or groups of similar sources that need to be controlled to achieve pollutant load reductions estimated in the watershed.
4. An estimate of the improvements associated with the chosen management measures.
5. A description of the measures that will need to be implemented to achieve load reductions as well as to achieve other watershed goals identified in the watershed based plan.
6. A set of criteria that can be used to determine whether loading reductions are being achieved over time and substantial progress is being made towards attaining water quality standards.
7. An estimate of the amount of technical and financial assistance needed, associated costs and or sources, and authorities that will be relied upon, to implement the plan.
8. A schedule for implementing the NPS management measures identified in this plan that is reasonably expeditious.
9. A description of interim, measurable milestones to track progress in achieving restoration goals.

The aforementioned NC EEP, NC DWQ, and Earth Tech watershed studies already contain a considerable amount of information that could be compiled to meet the nine required elements of a watershed restoration plan. The Bolin Creek Watershed Restoration Plan was proposed to focus on the hydrologically-related stressors identified in these studies, but would also address other water quality issues and develop appropriate solutions and project locations for those solutions.

In addition to the 9 elements, it was proposed to include an analysis of development scenarios, a geodatabase of identified problems and solutions, evaluate local ordinances and capabilities with regard to supporting or inhibiting restoration and preservation efforts, examine future development scenarios and determine Town ordinance and planning needs for protection and preservation of Bolin Creek and its tributaries, catalog other activities in the basin, and ultimately be coordinated with the Towns' Comprehensive Plans and other specific plans such as the Greenways Plan. It was anticipated that detailed studies of individual subwatersheds may be needed to refine the plan where there are complex conditions identified.

1.5 PROPOSED MONITORING

MONITORING GOALS AND APPROACH

In order to demonstrate measurable improvement in these subwatersheds, monitoring of individual project locations around the Baldwin Park stream restoration/BMP sites and sites on the tributary to Mill Race was proposed. Sediment mobilization, water quality and field parameters, stability/quality of stream banks and instream features and habitats, water temperature, dissolved oxygen, and survivorship of desired riparian vegetation were identified as indicators of success. Monitoring was to commence when a Quality Assurance Program Plan had been developed, with the assistance of the NCSU Water Quality Group, at the beginning of the contract period to obtain sufficient data to properly compare pre- and post- conditions at these sites.

COMPLIMENTARY MONITORING

The Towns of Carrboro and Chapel Hill continued ongoing monitoring activities in other parts of the Bolin Creek watershed that are supportive of documentation of measurable improvement, can be used for documenting improvement at future project sites, and provide valuable diagnostic information for addressing impairments in other tributaries of Bolin Creek. Chapel Hill collected base flow water chemistry samples at three points along the mainstem of Bolin Creek from1994 to 2009. Parameters included suspended sediment, turbidity, nitrogen series, phosphorus, fecal coliform, metals, and field parameters. Discharge measurement is not conducted yet but is planned in the near future. Carrboro has conducted, and Chapel Hill proposed to start, annual macroinvertebrate collection at four points along the mainstem of Bolin Creek.

Complimentary to and independent of the Bolin Creek watershed restoration efforts, the Towns had begun conducting stream walks and monitoring activities as part of their NPDES Phase 2 permits to address illicit discharges and connections. The areas that Bolin Creek flows through are both the oldest and most dense parts of both Chapel Hill and Carrboro, and thus are likely to have much higher priority in their respective IDDE programs. It was expected that these activities would address the issue of toxins as contributing stressors as identified in the 2003 Biological Assessment report.

1.6 PROPOSED PUBLIC INVOLVEMENT

The project proposed several ways that project staff would interact with and involve the public in implementation:

- Direct consultation with the Historic District Commission to address the use of highly erodible pea-gravel/sand for sidewalks, and come up with acceptable alternatives or treatments.
- Direct consultation with the Orange Water and Sewer Authority regarding erosion treatments of their streamside sanitary sewer lines.
- Direct consultation with local residents and property owners (and/or their landscapers) to vegetate the projects in a way that is aesthetically pleasing, sufficiently easy to maintain, and meets concerns regarding neighborhood crime (i.e. hiding places), in addition to the usual enhancement goals of bank stability, shade, and native species.
- Following construction we would offer Riparian Plant Maintenance Workshops – intended to allow property owners to learn how to care for the riparian plants they have selected (plant selection by owners helps guarantee care and acceptance) and would serve as prototype for a Stream Steward Program involving riparian planting and maintenance. This may extend to possible targeted eradication of invasive species and subsequent monitoring will also likely involve local garden clubs, the North Carolina Botanical Garden, and Orange County’s Master Gardeners.
- Involvement of neighborhood associations local to the projects.
- Construction of two rain gardens in public spaces (in Carrboro) with educational signage.
- “Ribbon cutting” ceremonies involving local officials and the media to publicly present completed projects.
- Educational signage for Baldwin Park.
- Creating a Bolin Creek Watershed Restoration Initiative webpage and email list server to keep interested citizens informed of project status, and offer a venue for continued conversation with Chapel Hill and Carrboro staff.
- Involvement of Friends of Bolin Creek volunteers in collecting water quality samples, annual stream morphology and vegetation monitoring and replenishment.

- Development of the Watershed Restoration Plan was expected to involve a considerable number and variety of stakeholder groups, from Town Departments, UNC-Chapel Hill, Orange Water and Sewer Authority (OWASA), the Federal Railroad Administration, property-owner and neighborhood associations, among others.
- One or two "kickoff" public informational meetings at the beginning of the contract period to update citizens on status of Bolin Creek Watershed effort as well as to gain valuable insight when developing the nine-element watershed restoration plan.

1.7 PROJECT MEASURES OF SUCCESS

Some of the management measures planned for this project were designed to reduce hydrologic impacts of existing developed areas in the watershed. These practices were expected to reduce stormwater volumes and peaks, thus reducing streambank erosion, streambed aggregation and degradation, etc. Other management measures planned for this project were related to improving water quality, particularly in stormwater flows. These water quality management measures were expected to generate some improvements specifically addressing the hydromodification, sediment transport, temperature, and dissolved oxygen stressors.

It was expected that significant improvement in benthic communities is likely to take longer than the three-year duration of this project. The very small size of the project streams also limits the probable maximum diversity that can be expected. However, reducing the impact of these stressors was expected to lead to recovery of benthic communities in the watershed.

Specific improvements expected from this multi-year set of projects include:

- Reduced export of sediment from both Baldwin Park and Mill Race tributary watersheds
- Improved instream habitat for macroinvertebrates
- Reduced levels of nitrogen and phosphorus
- Reduced maximum temperatures in stormwater
- Increased environmental interest and involvement in a lower-income population
- General education of the Towns' populations regarding stream functions, health, protection, restoration
- Demonstration to the local environmentally-oriented population of the Towns' commitment to environmental protection and sustainability
- An alternatives analysis that enables watershed restoration projects with a higher probability of success in a high-density urban area

Possible side effects:

- Increased rainfall infiltration to groundwater throughout the watershed, with the aim to increase the extremely low base flows identified as a potential stressor
- Provide an example of successful watershed restoration to be applied to other officially impaired (and unclassified but imperiled) waterbodies and their watersheds in the Chapel Hill – Carrboro area
- Broader use of Low Impact Development (LID), redevelopment that reduces urban hydrologic effects, and increased environmental sustainability of public and private landowner (and resident) activities

2. METHODS AND EXECUTION

2.1 BRIEF REVIEW OF DELIVERABLES

1. Nine-element Watershed Restoration Plan, integrated with other Town Plans.

The Watershed Restoration Plan has recently been completed. However, integration with other Chapel Hill plans has proven challenging because of the large number of plans, active revisions going on, and competition between plans for the attention of Senior Management for review and implementation. Nevertheless, the Watershed Restoration plan has been integrated with the Chapel Hill Stormwater Management Division's draft Stormwater Master Plan. Watershed restoration activities are part of Chapel Hill's larger Capital Improvements Projects (CIP), and a CIP prioritization scheme is currently in review. This part of the project is addressed in further detail in the following section.

2. Alternatives analysis for inline and/or watershed-wide runoff management in upper Tanyard Branch.

This project was an excellent success, very useful for education of other Town staff and for planning future stormwater retrofitting and stream restoration in the most heavily-developed parts of Chapel Hill. This part of the project is addressed in detail in the following section, and the study is attached as Appendix 3.

3. Quarterly reports and final report.

Quarterly reports were prepared for 15 quarters, plus the final report. Chapel Hill, Carrboro, and NCSU staff all contributed to each report.

4. Construction of three BMPs and stream restoration/enhancement (approximately 1000 feet) in Baldwin Park with signage.

Stream restoration and riparian enhancement were completed along two forks of a stream that bracket Baldwin Park in Carrboro, and on the border with Chapel Hill. A bioretention and an experimental sanitary sewer stream ford crossing were installed at Baldwin Park. This part of the project is addressed in further detail in the following section. Photos and plans are presented in Appendix 1.

5. Repair of two severe gullies, installation of associated BMPs, a BMP reducing sidewalk erosion in Historic District, and treatment reducing streambank erosion along sanitary sewer easement and crossing.

After extensive outreach to property owners through mailings, phone calls, guided stream walks, and invitations to meetings to present engineering design and specifics, all Mill Race project elements had to be dropped due to the lack of cooperation of three property owners (out of 50+) whose properties were situated at critical access locations, which prevented crossing the properties to access other areas in this very steep-sided valley. Photos and plans are presented in Appendix 2.

Mill Race project elements were replaced by a stream restoration at Trinity Court, installation of a bioretention basin at Hargraves Community Center (Mitchell Lane), installation of a bioretention basin at Dickerson Court, and installation of permeable grass-pavers on a fire lane at Hargraves. This part of the project is addressed in further detail in the following section. Project information and photos are presented in Appendices 4, 5, 6, and 7, respectively.

6. Two Riparian Plant Maintenance workshops.

Carrboro staff coordinated a workshop attended by about a dozen volunteers on riparian plants at Baldwin Park. A similar workshop organized by Chapel Hill for Chapel Hill residents was not well-attended.

A guided project walkthrough and review were held for one of the projects used to replace the Mill Race tributary work (Trinity Court), and was attended by staff from both Towns and OWASA. Carrboro and NCSU staff held training for Carrboro employees to learn how to care for newly-planted riparian zones and for the rain gardens installed in Carrboro.

7. Two "ribbon-cutting" ceremonies with local government officials.

A very-well-attended dedication ceremony was held at Baldwin Park, where the mayors of the two Towns planted a tree in the bioretention area and read a joint proclamation. Pictures and other information related to the event can be found in Appendix 1.

At the request of the Friends of Bolin Creek, the Towns participated in organization of, and presentation at, a half-day Symposium "Can We Heal Our Waterways?" along with presenters from NC DWQ and other organizations. This symposium complemented the Situation Assessment of public attitudes conducted by NCSU's Watershed Education for Communities and Officials (WECO) to address stakeholder vision and collaboration, as described below in the section on development of the Watershed Restoration Plan.

8. Installation of two Carrboro rain gardens (bioretention basins) with signage.

Carrboro staff installed a demonstration bioretention basin by an entrance to Carrboro's Town Hall, and included a brochure box for rain garden handouts. Carrboro staff also contracted the installation of a bioretention basin in a residential subdivision (Tramore West), and provided outreach to the Homeowner's Association. Photos, brochures, and plans can be found in Appendix 8.

9. Creation of a geodatabase containing locations and information on identified stream water quality, morphology, or other problems, and locations and information on proposed stream restoration and stormwater BMP projects.

While systematically storing stream "problem" information in a geodatabase proved to be challenging (problems come in all shapes and sizes and were difficult to represent in anything other than geographic information system (GIS) annotation and stream segment assessment forms), systematically collecting and storing "project" information in a geodatabase has proven very helpful. This part of the project is addressed in further detail in the following section. The list of the project GIS feature class attributes can be found in Appendix 9.

10. Regular updates from staff to public email listserver and webpage.

Public updates throughout the grant period were done through Bolin Creek webpages, each Town hosting its own version for local control. These webpages are still active and not restricted to grant-specific activities; new links and information are posted as we find new studies (local universities are quite active in our area!), present results of new data collection, and conduct other activities in the watershed.

Carrboro's Bolin Creek webpage URL: http://www.ci.carrboro.nc.us/pzi/Env/Water/bcwrt.htm

Chapel Hill's Bolin Creek webpage URL: http://www.townofchapelhill.org/index.aspx?page=1757

Public email listserve updates from Chapel Hill were done the first year and a half as project steps were completed. These were advertised at local events, and we handed out postcards with subscription information. Subsequently the Town's Public Information approach was changed to compile projects and activities of the Stormwater Management Division into a single listserve. We felt it inappropriate to automatically subscribe previous listserve members to this new, much more broadly-themed listserve. In the last year, Chapel Hill staff created an informal, targeted email list of stakeholders (mostly Town staff) for biweekly updates of project details and steps.

In addition to updating their Bolin Creek project webpage, Carrboro activities included posting information on the Town's electronic message board about the project and providing public updates through Board of Aldermen agenda items.

11. Installation of two pressure transducers to measure stream stage and establishment of rating curves for each site.

Pressure transducers for measuring water level were installed as part of the ISCO stormwater sample collecting equipment. Implementation of monitoring is described below, and results of monitoring at Baldwin Park and Mill Race tributary are reviewed in full in the Results and Conclusions Chapter.

12. Installation of two automated storm samplers to collect "first flush" and composite storm samples.

ISCO stormwater sample collectors were installed at Baldwin Park at Mill Race tributary, collecting monthly samples and composite storm samples. After investigation of nitrogen transport in stormflow, it was determined "first flush" was inappropriate for evaluation. Implementation of monitoring is described below, and results of monitoring at Baldwin Park and Mill Race tributary are reviewed in full in the Results and Conclusions Chapter.

13. Pre- and post-construction morphological, erosion, and vegetation survivorship monitoring data for the two subwatersheds.

"As-built" drawings and plant lists were not created by the contractors for any of the riparian enhancements and bioretention plantings, making formal monitoring of vegetation survival difficult. Instead, survival has been monitored informally, with replanting or filling-in occurring as needed. Morphological and erosion monitoring turned out to be inappropriate given the construction techniques used. Changes to this monitoring and reasoning are described below.

14. 72 (36 for each site) monthly base flow and 240 (120 for each site) storm flow samples (approximately 20 storms per year, 2 samples per storm) analyzed for suspended sediment, nitrogen series, and phosphorus.

ISCO stormwater sample collectors were installed at Baldwin Park at Mill Race tributary to collect these samples. Implementation of monitoring is described below, and results of monitoring at Baldwin Park and Mill Race tributary are reviewed in full in the Results and Conclusions Chapter.

15. Continuous temperature and dissolved oxygen measurements for storms before and after project installation.

HOBO temperature probes were installed to measure temperature every 15 minutes. It was determined continuous monitoring of dissolved oxygen would be not provide useful information for the amount of effort required and amount of error likely to affect measurements, and was replaced with benthic macroinvertebrate monitoring. Implementation of monitoring is described below, and results of monitoring at Baldwin Park and Mill Race tributary are reviewed in full in the Results and Conclusions Chapter.

2.2 IMPLEMENTATION OF SELECTED DELIVERABLES

Some project deliverables had much greater complexity and much more convoluted paths to completion than others and warrant a detailed and comprehensive description. Implementation of the following deliverables will be discussed in detail:

Development of the Watershed Restoration Plan
Development of the Problems and Projects Geodatabase
Tanyard Branch Stormwater Alternatives Analysis
Baldwin Park
Mill Race Tributary
Monitoring

DEVELOPMENT OF THE WATERSHED RESTORATION PLAN

Development of the Watershed Restoration Plan started with guidance from Paul Clark of NC DWQ (our advisor and guide throughout the process) early in the grant period. The project team members primarily involved in writing the Plan include Trish D'Arconte and Wendy Smith of Chapel Hill and Randy Dodd of Carrboro. Initially we held a thorough discussion of the nine elements of an EPA watershed restoration plan, how this may be able to replace the need for development of a Total Maximum Daily Load (TMDL) for Bolin Creek, and how this fit into NC DWQ's Use Restoration Watershed Program. We had several other watershed restoration plans to look at in creating our own, although we learned that every plan is quite unique and really only demonstrates the breadth of watershed restoration planning approaches. A general outline, a schedule for getting sections completed, and who would write which sections were drawn up.

Our initial outline, proposed writing schedule, and writing assignments, while seemingly a good idea, did not make the writing process easier or clearer. Team members had different ideas of what belonged in the plan, how to organize it, the amount to pull from pre-existing plans, and what an implementation section would look like. Thus, multiple versions of plan sections and parts of sections came into being. We expected we would have time to sort out these differences before taking the draft plan to various advisory boards, holding several public hearings, and eventually taking the plan to our governing bodies for adoption in the last year of the grant period.

We were fortunate that several studies and one significant plan had already been done for the larger area. In particular, NC EEP's Local Watershed Plan had extensive data collection, analysis, modeling, risk assessment, and project identification and ranking. A very thorough assessment of current conditions and watershed characterization was incredibly useful, but it became confusing as to how to refer back to this wonderful amount of information, yet still have our own plan that was a complete document in itself. Why rewrite a thorough watershed characterization? Why rerun a thorough analysis of stressors and sources? This uncertainty and indecision diffused writing focus and energy, and contributed to team members' different writing paths and approaches.

Early on, it was recognized that certain entities that controlled significant amounts of land or were responsible for extensive infrastructure would have a disproportionate effect on streams through current activities, which projects could be implemented and how because of how much area they "controlled," or they were likely to undertake or fund restoration projects themselves. In the Summer of 2010 and 2011 we met with staff from the University of North Carolina (UNC), OWASA, Orange County, NC EEP, NC Division of Transportation (NC DOT), NC Cooperative Extension, and Orange County Soil and Water Conservation District, known as the Bolin Creek Technical Coordinating Committee, to update them on our progress and find out what activities they might have going on in the watershed.

The planning process became complicated in 2009 as Carrboro was creating its Greenways Plan. Generally, the two Towns have taken an approach that uses stream corridors as alternative transportation corridors in addition to being attractive for recreation. The Towns have installed several paved bicycle-pedestrian greenways and generally planned to join them together to improve transportation options for residents. These are designed to AASHTO/NC DOT specifications, being at least ten feet wide with four feet cleared on either side, on a compacted base like a small road. However, many of these are within stream riparian zones. One of the proposed Carrboro greenways was in Bolin Creek's riparian zone as it traversed UNC's Carolina North property, an area treasured by many amateur naturalists, nature-lovers, and others enjoying a walk in the woods.

Residents in the two Towns divided into two very vocal and completely opposed camps, one opposing any greenway paving along Bolin Creek because of the potential negative effects, the other insisting on a paved greenway to encourage more bicycle transportation over car travel and better access for less mobile residents. Websites were created, many letters to the editor were written, every meeting of Carrboro's Environmental Advisory Board (charged with making a greenways recommendation) had large guest attendance and some discussions became very fractious. Carrboro staff were thoroughly consumed with the advisory board meetings and trying to forge some tentative plan.

Early in 2010 this division was so severe that it actually split our local citizens' watershed group, the Friends of Bolin Creek. Their Board of Directors was dissolved and many members left, putting Friends of Bolin Creek (Friends) unofficially in the "anti-paving" camp. Remaining members reorganized and formed a Bolin Creek Watershed Plan Committee to create their own watershed planning document. The purpose as explained to project members was to make a definitive case against greenway paving along Bolin Creek. In Spring 2010 the Friends started holding many discussion and planning meetings regarding creating a watershed plan, and invited staff from the two Towns to present about our 319 projects and development of the Towns' Watershed Restoration Plan.

Our interaction with the Friends regarding its proposed watershed plan diverted Town staff from the process of developing a plan for this 319 grant. Considerable time was spent interacting with Friends of Bolin Creek members to discuss what we were preparing, who it was for, what was its purpose or use, whose goals and views were represented, who had what information for analysis, which one would take precedence (or which one would the Towns follow or implement), and who had the responsibility to create or implement it. Trying to answer the last two questions created considerable disagreement, confusion, distrust, and unwillingness to cooperate between the Towns and Friends of Bolin Creek. There was the fact that the Town of Chapel Hill was obliged to create a plan to meet the requirements of the grant contract. Members of Friends of Bolin Creek felt their organization represented the needs of the watershed and the attitudes of the general public better than local government did.

It became apparent between the earlier strong feelings of many residents regarding the Carrboro greenway, and later distrust between the Towns and Friends of Bolin Creek regarding creation of the Watershed Restoration Plan, that we no longer had a good, working relationship with the citizen watershed organization for Bolin Creek. Nor did we have a good understanding of how citizens viewed natural resources, what they considered important, and what their environmental goals might be. We became uncertain whether we could develop a Watershed Restoration Plan that would reflect the public's values and priorities and be viewed as legitimate.

In discussing this problem with Paul Clark, we were introduced to NCSU's Watershed Education for Communities and Officials (WECO), an NC Cooperative Extension program that had helped other communities navigate differing values and ideas of their citizens regarding environmental resources. They recommended a Situation Assessment. A situation assessment is built upon a series of interviews and focus group meetings representing residents, businesses, non-profits, local and state government staff, and recreationists from a cross section of interests in a watershed or area of interest. The purpose would be to better understand the interests of watershed stakeholders and organizations, to identify opportunities to engage stakeholders in watershed restoration while meeting multiple interests, and to determine how stakeholders would like to participate in restoration efforts.

Project members considered the lack of communication so severe that a modification of the contract with NCSU to put some of the Mill Race project budget towards a Situation Assessment seemed the best way through conflict and miscommunication, to engage watershed stakeholders, and gain support creation and implementation of a Watershed Restoration Plan. The earlier plan for an extensive, yet measured public outreach process for the watershed plan was no longer workable. Attitudes and opinions had become so polarized that we feared a typical public review process for a local plan (which already can extend well over a year when there is very little that is controversial) could occupy all of the project members' time to the exclusion of completing any other elements of the project.

Stakeholders were identified, interviews were conducted, and the Situation Assessment was produced in February 2011. See Appendix 10 for the full Bolin Creek Watershed Situation Assessment, which includes methods used, stakeholders interviewed, a summary of how respondents viewed Bolin Creek and solutions to water quality problems, and specific recommendations to help the diverse stakeholders in the watershed come together to address watershed restoration.

The Situation Assessment recommendations include:

- Create a multi-organizational, collaborative watershed initiative to serve as the nexus for the watershed.
- Engage an entity with no vested interest in the watershed to coordinate and facilitate the Group (WECO, TJCOG, Dispute Settlement Center of Orange County are organizations who regularly do this work).
- Enlist a neutral party to develop and actively manage an interactive online hub for the watershed community.
- Examine how to more holistically plan and manage water resources across departments and jurisdictions.
- Increase community outreach and engagement on the Carolina North Forest Stewardship Plan.
- Investigate how to raise revenue dedicated to water quality protection and restoration, such as a stormwater utility or other mechanism.
- Continue to work together to address the landfill and groundwater contamination issues in the Rogers Road - Eubanks community.
- Convene a facilitated search for common understanding about ways to connect pedestrian and cyclist routes while also protecting and improving Bolin Creek's riparian corridor.

These results and recommendations contributed to the development of our Watershed Restoration Plan and were referenced therein.

WECO's observations of citizen attitudes did support our understanding that protecting environmental resources was important to the public, and that people perceived that Bolin Creek was impaired ecologically. Interviewees had a wide variety of views on how to address Bolin Creek's impairments. They perceived a need for education and outreach to develop greater community awareness and clearly expressed a strong desire for more active involvement in watershed planning and management. There was agreement that the proposed Carrboro greenway has divided the community, and that there is a need to develop common natural resource goals and objectives among the many stakeholders beyond simply protecting and restoring Bolin Creek.

In preparing the Plan, we have taken these perceptions and values into consideration. We recognize the need for a neutral party to help the community navigate the many differing uses and visions, and understand that the Towns cannot act in this role. We have thus put much greater emphasis on public education and outreach (presented as "watershed stewardship"), and proposed concrete restoration implementation steps with the understanding that greater public support will be required.

Through the process of the Situation Assessment stakeholder interviews, our relationship with Friends of Bolin Creek was mended such that we were asked to help organize and were invited to speak at their half-day symposium on "Can We Heal Our Waterways?" held in February 2011. Both Carrboro and Chapel Hill staff presented at this symposium, along with presenters from DWQ and other organizations. We laid out the challenges of trying to address multiple stressors in an urban landscape, the need for broad citizen participation to effect changes in watershed conditions, and presented the recommendations of the Situation Assessment. We highlighted the recommendation for the creation of a Watershed Coordinator role as a neutral, stakeholder-supported position to help implement the other recommendations. Our slide presentations are printed in a slide-notes layout in Appendix 11.

Starting in Spring 2011 project members contacted NC EEP staff to confirm the status of their pledged $20,000 grant match activities. NC EEP had no promising projects in the watershed on the horizon, and that information contributed to our request for a contract extension. Later in the summer, when holding a meeting of the Bolin Creek Technical Coordinating Committee, we learned NC EEP was in the process of reorganization and was facing a significant change in how stream mitigation projects were implemented. They were also inquiring with the Army Corps of Engineers whether stormwater BMPs could be counted towards stream mitigation credits. Given that there were very few stream restoration opportunities in the Bolin Creek watershed in general, the potential to install BMPs as a match was something worth investigating. Through 2011 we waited to hear whether NC EEP could find a project to implement, and discussed with them the possibility of installation of a United State Geological Survey (USGS) gage as a replacement for the NC EEP match.

As 2011 progressed Chapel Hill staff became wrapped up in the challenges of implementing the Mill Race tributary projects (described below), and couldn't focus any more attention on plan development until Spring 2012. By this time we had resolved to restate some of what was in NC EEP's Local Watershed Plan in order to have a more complete narrative in the Bolin Creek Watershed Restoration Plan, rather than simply referring the reader to the Local Watershed Plan. Some Team members had already started writing a new, detailed watershed characterization and others had newer and higher resolution data to do a watershed analysis. We decided against throwing away all of this work, and instead focused on blending it together. This may have been a very good decision, simply because this more thoroughly familiarized Team members with watershed conditions, stressors, limitations, and opportunities. Combined with local knowledge of financial, technical, and social realities we were able to propose restoration steps and a timeline that were more realistic for the Towns to implement and more reflective of the fine level of understanding of stressors and sources that could be more readily targeted. The draft was reviewed by Carrboro and Chapel Hill staff and the final version sent on to Paul Clark at NC DWQ.

Between the Situation Assessment and uncertainty over the legitimacy of this planning approach (being led by the Towns, rather than another entity) in the public's eyes, we did not feel we could pursue the same broad, extensive public review that we had originally envisioned. Furthermore, Chapel Hill was still in the process of drafting its own Stormwater Master Plan for its Stormwater Management Program. It was likely that Chapel Hill advisory boards or the Town Council would want the Master Plan completed first, before accepting what would be viewed as an adjunct to the Master Plan. Project members focused simply on completing the document, completing the Plan shortly before final reporting. Integration with other Chapel Hill plans has proved challenging because of the large number of plans, active revisions going on, and competition between plans for the attention of Senior Management for review and implementation. Nevertheless, the Watershed Restoration plan has been written to be integrated with the Stormwater Management Division's draft Stormwater Master Plan. Watershed Restoration activities are part of the larger Capital Improvements Projects, and a CIP project prioritization scheme is currently in review. This part of the project is addressed in further detail in the following section.

The final Bolin Creek Watershed Restoration Plan can be found online at the following webpage URL: http://www.townofchapelhill.org/index.aspx?page=1757

We were very pleased to learn in June 2012 that NC EEP had decided to fund the installation of a USGS gage on Bolin Creek to cover their pledged match. The real-time stream discharge gage on Bolin Creek at Village Drive (Station ID 0209734440) has been installed and is in the process of calibration. Preliminary stage data are online at USGS's NWIS web interface, at URL: http://waterdata.usgs.gov/usa/nwis/uv?0209734440.

DEVELOPMENT OF THE PROBLEMS AND PROJECTS GEODATABASE

The grant application included a proposal for the development of a "problems and projects geodatabase", that is, a geographically referenced database of water quality impairments, stressors, and other problems, potential water quality improvement projects, and information about these "problems" and "projects" that could be used to rank or otherwise evaluate the priority or feasibility of them. The database started with the problems and reparative projects identified by Earth Tech in their study. Earth Tech had created streamwalk field forms for systematic data collection (see Figure 2) and had stored other, less systematic information as a GIS annotation layer that was provided to the staff of the two Towns. This information formed the base of the "problems" part of the problems and projects geodatabase.

From before the beginning of the project, Chapel Hill staff had been developing a Stormwater Master Plan to guide the activity and budgeting of the Stormwater Management Division. As the Bolin Creek project started up, early in 2009, the same town staff involved in that project were also starting detailed assessments of two other subwatersheds in Chapel Hill – Upper Booker Creek and Tracy Branch (aka Ephesus) in preparation of development of subwatershed modeling and detailed plans to be prepared by a contractor. These assessments involved stream walks and measures of channel shape and cross-section, with data collection based on the stream walks conducted as part of the Earth Tech study. Data collection methods were designed to collect stream condition information across Town that was comparable and ultimately could be stored in the same database, saving staff effort in the future. Figure 3 shows the revised stream walk data collection form that was used. These data structures have not yet been systematized in such as way to enable easy summarization in GIS attribute tables for the "problems" part of the geodatabase. This has been partly because of a need to adjust some data collection methods, but largely because of the difficulty of storing water quality problems that have a broad array of geographic presentations. Problems may present as points where pollutants enter or distinct problems are observed, sections of stream bank, stream segments, stream and bank segments, floodplain or riparian areas, and combinations of these. This makes it difficult to determine how to store all this information in a GIS layer, explaining why Earth

Tech wound up storing much of the stream walk notes as an annotation layer, which could accommodate notes and diagrams of all kinds, not dependent on a particular type of feature class. Thus, problems of all sorts are stored in a variety of GIS feature classes. In spite of this, such collection of stressors and problems all into a group of datasets was very useful to stressor analysis in the development of the Watershed Restoration Plan. So while the "problems" part of the geodatabase did not turn out as originally envisioned, the underlying goal of collecting information about stressors and sources in a group of datasets is working out well for Chapel Hill use.

STREAM NAME: UT	**DATE: 5/7/07**	**MAP SHEET #: 1**
PHOTO NUMBERS:	**LANDMARK: W. OF TALBRYN**	**SKETCH ON BACK**
GPS ID START: **DESCRIPTION:**	**GPS ID END:** **DESCRIPTION:**	
RAIN IN LAST 24 HOURS ☐ Heavy rain ☐ Steady rain X None ☐ Intermittent ☐ Trace	**PRESENT CONDITIONS** ☐ Heavy rain ☐ Steady rain ☐ Intermittent X Clear ☐ Trace ☐ Overcast ☐ Partly cloudy	
SURROUNDING LAND USE: ☐ Industrial ☐ Commercial ☐ Urban/Residential X Suburban/Res X Forested ☐ Institutional ☐ Golf course ☐ Park ☐ Crop ☐ Pasture ☐ Other:		
BASE FLOW WIDTH AS % CHANNEL WIDTH ☐ 0-25% ☐ 25-50 % ☐ 50%-75% X 75-100%	**WATER CLARITY** ☐ Clear X Turbid *(suspended matter)* ☐ Stained *(clear, naturally colored)* ☐ Opaque *(milky)* ☐ Other (chemicals, dyes)	
DOMINANT SUBSTRATE ☐ Silt/clay (fine or slick) ☐ Sand (gritty) X Gravel (0.1-2.5") ☐ Cobble (2.5 –10") ☐ Boulder (>10") ☐ Bed rock	**CHANNEL DIMENSIONS AT RIFFLE** **Height**: Low bank ___1_____(ft) **Width**: Bottom ___2_____(ft) Top ___3_____(ft) Water Surface ___2_____(ft) **Depth:** Max BKF _________(ft) **B:H Ratio:** Low bank/Max BKF=________	**OBSERVED IMPACTS** ☐ Outfall ☐ Confluence ☐ Impacted buffer ☒ Stream crossing- 36" CMP, paved road downstream ☐ Channel mod ☐ Utility impacts ☐ Beaver ☒ Other- Beaver
CHANNEL DYNAMICS ☐ Downcutting ☒ Widening ☒ Headcutting ☐ Aggrading	☐ Bed scour ☐ Bank failure ☒ Bank scour ☐ Sed. deposition ☐ Slope failure ☐ Channelized ☐ Unknown	**NOTES** **WIDENING IS REMNANT** **SHALLOW ROADSIDE DITCH AT CULVERT**
QUALITATIVE IMPAIRMENT RATING: ☐ Low X Moderate ☐ Severe		**CHANNEL EVOLUTIUON STAGE:** ☐ I ☐ II ☐ III ☐ IV ☐ V ☐ VI (*Simon et. al., 2003*)

Figure 2: Example of an Earth Tech Geomorphic Study Field Form

As the modeling of the non-Bolin Creek subwatersheds was progressing, the contractor was also developing a prioritization scheme for Capital Improvements Projects. It had been identified in discussions with staff that Capital Improvements fell into two categories worthy of separate prioritization schemes: Water Quantity CIP (i.e. Flooding and Infrastructure CIP), and Water Quality CIP. Town staff worked with the contractor to come up with a set of information to collect about citizen calls for assistance that led to staff drainage repair recommendations or Capital Improvements Projects. This included a combination of information about problems and recommended solutions (projects). Staff and the contractor teased apart these elements in order to use them more effectively for comparison, splitting problem information from project information, and then again splitting based on its application towards relieving flooding vs. addressing a water quality issue. Information for flooding problems was used as a primary ranking method for flooding Capital Improvements Projects themselves. Ranking for water quality problems or projects was set aside, but the information comparing project information (both types) formed the basis of Chapel Hill's projects portion of the geodatabase. Chapel Hill staff shared this preliminary list of project information with Carrboro staff for comment.

Reach Data:	Reach ID		Climatic condition		Reach Length	
Observers:	Date		Recent Precip		Stream Order	
	GPS Top		Geologic Region		Position in Landscape	
Units: Feet Meters	GPS Bot.		Flow Regime		Slope from Topo	

Riparian Data:	*None, weak, moderate, strong*	**Channel Data:**	*None, weak, moderate, strong*	**Cover Habitats:**	*Number*
Overstory Density		Sinuosity		Large Woody Debris	
Understory Density		Pool/Riffle Development		Aquatic Plants	
Groundcover Density		Embeddedness		Aquatic Moss	
Organic/Mulch Layer		Entrenchment		Undercut Banks	
Invasive Dominance		Algae		Overhanging Vegetation	
Floodplain Erosion		Flow		Leaf Packs / Small Debris	
FP Encroachment		Midchannel Bars		Root Mats	
Predom. Land Use		Bank Erosion		Protected Slackwater Areas	
Plant Comm. Type		Channel Modification		Manmade Habitats	
Floodplain Encroachment Types	Trails Roads OWASA Other Utility Fill Structures Other	Modification Type	Riprap Straightened Rerouted Dredged Gabions Concrete Other	Riffle Dominant Substrate	
				Flow Habitats :	*Percent of reach*
				Riffles (fast-shallow flow)	
Invasive Species Present:		Channel Dynamics: Downcutting Widening Sed Deposition Aggrading Headcuts Bank Failure Bank Scour Bed Scour		Runs (fast-deep flow)	
				Pools (slow-deep flow)	
				Glides (slow-shallow flow)	

Channel Measurements	1	2	3	Average
Top of Bank Height				
Top of Bank Width				
Bankfull Height				
Bankfull Width				
Bed Width				
Wetted Width (% of bed width)				
Riffle Water Depth				
Pool Water Depth				

Figure 3: Revised Chapel Hill Stream Walk Field Form

Up to this point, Carrboro had been developing its own structure for the projects portion of the geodatabase. This was based on the project information put together by Earth Tech, and additional projects collected by Carrboro. Chapel Hill started with this spreadsheet and data, and added fields for comparing feasibility in different ways, numbers and types of property owners involved, area covered, potential water quality benefits (calculated using models in some cases, not able to be modeled in others such as biology), and several other ways to compare the difficulty of implementing projects.

As Chapel Hill staff searched for and implemented projects to replace the elements of Mill Race tributary gully repair and erosion control, more information about projects presented itself as very useful to record for posterity. Some potentially good projects turned out to be infeasible for reasons that required a good deal of information to discover. Rather than let this valuable information about the Infeasibility of a project be forgotten or leave with the staff member that found it, it was recorded in the ever-expanding list of attributes of potential projects.

At this point (early 2012), Chapel Hill staff folded in basic information about projects recommended in the EEP Local Watershed Plan, and a preliminary assessment done for NC EEP's predecessor (Wetlands Restoration Program) by KCI. Many of these projects had been investigated for feasibility multiple times, but by different people, each time finding they were infeasible or inappropriate for different reasons. A method of recording these investigations made itself clear in the attributes for Bolin Creek projects. Projects from across both Towns were included, not just in the Bolin Creek Watershed, because it was easier to pull them all in together. However, because of the disparate sources, filling in attributes is a slow, ongoing process, with the highest-priority and most recently investigated having more details entered than other projects. NC EEP helpfully had developed GIS layers for project boundaries, project watershed boundaries, and BMP shapes that formed the basis of the GIS portion of the projects geodatabase (up until that point, everything was all in a spreadsheet). After researching many plans and studies to find any wayward restoration project recommendations, Chapel Hill presented this final list to Carrboro for comment.

As noted above, the problems information proved very useful in the preparation of the Watershed Restoration Plan, especially in the Watershed Analysis of Stressors and Sources. However, the collection of projects and their attributes proved less useful to the development of the Plan's implementation steps and milestones. Both Towns are committed to ongoing geodatabase updates as new projects or project information come to light. For future data collection, during implementation of Chapel Hill's portion of the Bolin Creek Watershed Restoration Plan, this structure may be modified very slightly to accommodate Stream Visual Assessment Protocol (SVAP) measurements with additional NC DWQ habitat measurements in order to be comparable to those methods (as these are commonly used biological assessment methods), but also collect information on other characteristics of interest to Town staff that have shown to be specifically useful for identifying problem areas or problem sources.

For Chapel Hill's part, the small, isolated nature of most of the projects in the dataset did not lend itself to addressing the two biggest (Bolin Creek watershed) problem areas observed: the Tanyard Branch and Mill Race (entire, not tributary) subwatersheds. These areas demonstrated through their poor macroinvertebrate communities that they were in very bad shape ecologically, and staff experience with areas of these subwatersheds made it clear that a subwatershed-wide, systematic approach would be necessary to keep these tributaries from "exporting their problems" to Bolin Creek any further, and possibly beginning to heal.

In comparison, the projects dataset was excellent for comparing individual stream restoration or stormwater retrofit projects, but not adequate for a full subwatershed overhaul, as is needed for Tanyard Branch and Mill Race. The projects dataset will be very useful in the many smaller retrofit opportunities that other organizations may want to cooperate with either Town on. Friends of Bolin Creek, the Orange County Soil and Water Conservation District, and the Carrboro-Chapel Hill City Schools system are looking to be enthusiastic cooperators on isolated stormwater retrofit projects. This comparison of projects allows us to pull out some of the most promising projects when potential cooperators or funding sources make themselves apparent.

The list of the Projects Geodatabase feature class attributes can be found in Appendix 9.

TANYARD BRANCH STORMWATER ALTERNATIVES ANALYSIS

(Tanyard Branch project elements were implemented by Chapel Hill Stormwater Management staff and NCSU engineers. In this section "we" refers strictly to Chapel Hill Town staff.)

As noted in the Introduction, an analysis of stormwater alternatives for Tanyard Branch was proposed as part of the funded project. The uppermost parts of Tanyard Branch once flowed through downtown Chapel Hill, but those segments have been put underground in a pipe over the two centuries of development of the oldest parts of Town. Subsequently the entire drainage network of the area was routed to this piped stream as well, leading to one very large stormwater network that drains an area that is largely covered with impervious surface. The stream and connected drainage open to the surface through two 48 inch pipes north of downtown Chapel Hill in the Northside neighborhood. High amounts of impervious surface and intense networking of stormwater results in very high energy flow that is eroding away a huge area below the outfall.

After crossing Caldwell Street, the stream plunges into a steep, narrow valley that has a small "shelf" on one side where the local OWASA sewer line is run. That stream segment has four to five foot vertical banks, and has cut down to a cobble-bedrock substrate. The bank is composed of a layer of cobble and gravel at the very bottom, with the majority above made of layers of fine silt and clay interspersed with bottles and other trash. We suspect, though have not been able to find proof, that this material is the remnant bottom sediment of a farm pond. We were aware that properties in this neighborhood had been progressively carved out of pasture and farmland over the years. In any case, the severe and continuing erosion demonstrates that the stream channel is out of equilibrium with its flow, a situation which may be exacerbated by deposits of fine sediment. So, while we would like to restore this segment of stream, even if we were able to create a bankfull bench as part of restoration (only if we can move the OWASA line), what remained would still be prone to erosion.

This stream drains a concentrated commercial zone (with associated illicit discharge issues), with occasional storm drainage-sanitary sewer cross-connections (unsurprising because of the amount of abandoned infrastructure below the oldest properties), some of the oldest sanitary sewer lines in Town, and the extensive impervious area, we suspect this stream is considerably more polluted than others. Between the need to reduce the energy and erosivity of storm drainage to allow future downstream restoration, and the need to trap and treat the pollutants, the most logical choice is a stormwater treatment method like a wet retention pond. Since Tanyard Branch is a perennial stream, this requires an analysis of alternative stormwater management methods to determine whether there are methods besides a wet pond that will adequately control stormwater to protect the downstream segment from erosion.

For this analysis, we contracted with Dr. Bill Hunt, of NCSU's Department of Biological and Agricultural Engineering. The grant funded tuition and a stipend for one of his graduate students for two years, and in return the student (Erica Tillinghast) would collect needed data, run models, estimate costs, and produce a report that we could use as an Alternatives Analysis in the future, should we seek permits for installing a stormwater management structure on the uppermost part of Tanyard Branch.

Preparation for analysis included extensive, highly detailed mapping of the entire stormdrainage network leading to the outfall above Caldwell Street. Town staff designed a GIS data structure that would capture details such as pipe sizes, materials, lengths, slopes, and connections; inlet types, "mouth"/grate dimensions, and box dimensions; and information on their condition. Erica then used this detailed information to create a PCSWMM model of the stormdrain network. Erica also collected information on the downstream streambed and bank material sizes, stream cross-sections, and set up a pressure transducer to measure flow in response to rain events.

The analysis modeled nine different stormwater management alternatives, shown in Table 1 (excerpt pulled directly from the report):

Table 1: Description of 9 Scenarios Modeled in PCSWMM		
Scenario	**Areas Treated**	**Description**
1	None	Existing condition
2	Entire watershed (68 ha) with additional 1.2 ha[1]	Undersized wet pond at outlet
3	Entire watershed (68 ha) with additional 2.4 ha[1] (Figure 6)	Full-size wet pond at outlet
4	Residential area only (24 ha)	41 cisterns and 56 rain gardens
5	Residential area + under-sized wet pond (25.2 ha)	48 cisterns, 63 rain gardens, under-sized wet pond from scenario 2
6	Residential + UNC campus (36 ha)	41 cisterns, 56 rain gardens, 4 green roofs (0.49 ha), and 7 permeable pavements (2.45 ha)
7	Residential + UNC campus + under-sized wet pond (37.2 ha)	48 cisterns, 63 rain gardens, 4 green roofs (0.49 ha), 7 permeable pavements (2.45 ha), and under-sized wet pond from scenario 2
8	Residential + UNC campus + downtown (68 ha)	41 cisterns, 56 rain gardens, 10 green roofs (1.01 ha), and 13 permeable pavements (6.5 ha)
9	Residential + UNC campus + downtown + under-sized wet pond (69.2 ha)	48 cisterns, 63 rain gardens, 10 green roofs (1.01 ha), 13 permeable pavements (6.5 ha), and under-sized wet pond from scenario 2

The concluding section of her cost-benefit analysis very neatly sums up the results:

> *Per this cost-benefit analysis, as higher geomorphic stability within a stream is achieved, so, too, do the costs of the project increase. Of 9 retrofit scenarios, scenario 9 (residential + UNC + downtown + under-sized wet pond) would mitigate the disturbances from the heavily impervious watershed the best at an estimated cost of $14 million ($200,000/ha), while scenario 7 (residential + UNC + under-sized wet pond) provided comparable stream stability at 29% of the cost.*
>
> *Both the wet ponds, under-sized and full sized, decreased volume of eroded bedload; however, increased erosional hours from the existing scenario. When used solely, the under-sized wet pond provided minimal mitigation for 1) eroded sediment and 2) nitrogen and phosphorous reduction, negatively impacting ecological services when compared to the other scenarios. While the full sized wet pond had the highest reduction of estimated nitrogen and phosphorous, it also had the highest number of erosional hours, about 2.3 times larger than the existing condition. However, being such a large (68 ha) impervious (60%) watershed, LID practices alone did not provide sufficient benefits (4% and 5% reduction of nitrogen and phosphorous, respectively, and minimal ecological services) for their total appropriate capital costs. To obtain the most benefits in terms of the cost of the project, LID practices are needed with detention SCMs; however alternative methods to reduce nitrogen would be needed regardless of scenario chosen (unless full sized wet pond) to meet current Jordan Lake introduction and phosphorous reduction goals.*

Erica's analysis is presented in two excerpted chapters from her Master's Thesis (the geomorphic analysis and cost-benefit analysis), and an accompanying Appendix, here reproduced together in Appendix 3. A summary of the project, project excerpts, and a link to her entire thesis is available through the Town's webpage at URL: http://www.townofchapelhill.org/index.aspx?page=1889

In the wake of two years of macroinvertebrate monitoring in the area (results described in the Results and Conclusions chapter), Tanyard Branch and Mill Race Branch have been determined to be far and away the most degraded tributaries of Bolin Creek in Chapel Hill. With such poor conditions on these two streams, and being significant sources of pollutants and hydrologic modification, we concluded that a subwatershed-wide restoration of these two had the greatest potential to improve Bolin Creek's condition. This alternatives analysis has been invaluable for identifying and examining our options and what costs we may face, and what benefits we could potentially gain. Thus it has formed the germ of a multi-year implementation plan to install sufficient stormwater management in the Tanyard Branch subwatershed and subsequent stream restoration. This plan is described in detail, with steps and milestones laid out, in the Bolin Creek Watershed Restoration Plan.

BALDWIN PARK

The original Baldwin Park proposal called for stabilization/restoration of about 600 feet of stream bracketing the Park, planting trees along another 400 feet or so, installation of an energy dissipation basin where an ephemeral stream emerged from a stormdrain pipe at the end of Starlite Drive, rerouting street drainage piped along Broad Street to a bioretention above where the stream issued from being piped itself, and stabilization of an eroding path leading from Chapel Hill to Carrboro, crossing the ephemeral stream.

In November 2008, very shortly after the grant contract period started, we organized a stream walk for the neighbors to meet them, introduce them to the project and its goals, and answer any questions they may have. In Summer 2009 the ISCO stormwater sampler was sited on Town property, below the confluence of the two project streams, and installed with little difficulty. After a contract was set up for laboratory analysis, monitoring started to get necessary flow information for engineering design. As with Mill Race tributary, we had calibration problems on the low flow end that we believe have contributed to water level data that has been difficult to interpret.

Through 2009 and 2010, Carrboro staff worked with Carrboro landowners and stakeholders to gain necessary approvals and coordinate with an upcoming community garden project also being sited in Baldwin Park. Carrboro staff coordinated with NCSU on permitting, invasive plant removal, and engineering design of the bioretention basin and the stream segment on the western side of the park.

However, there was significant miscommunication between the Towns regarding roles and responsibilities for the Baldwin Park project elements. Chapel Hill staff included Baldwin Park in the grant application because team members were advised their application would be more favorable if more entities were involved, including projects occurring in both Towns. This seemed reasonable to Chapel Hill staff if Carrboro took the lead on implementing the project. In return, Chapel Hill staff would take care of monitoring for both locations. Carrboro's choice was on the border with Chapel Hill, and some of the problems were on the Chapel Hill side of the park. However, Chapel Hill staff were working under the assumption that Carrboro staff would be doing all the property owner contacting, including for those on the Chapel Hill side (the park did back up to Chapel Hill, and the eastern stream flowed on the border). This was not how Carrboro staff understood the arrangement, and by this time a separate 319 grant project applied for by Carrboro was underway, dividing Carrboro staff time.

As a result, in early 2010 Chapel Hill staff had to scramble to do the necessary outreach for private properties on the eastern side of Baldwin Park, well after concept plans were drawn up and NCSU was ready to get property owner permission for the 401/404 permit. We received passive resistance from some property owners. They would not return messages, would not talk with staff on the phone, or respond to letters. Our attempts to contact property owners through Empowerment (as the closest thing to a homeowners association in Northside that existed), but were informed that the property owners were not interested in talking to us. Finally, after persistently leaving messages begging for an audience, the owners agreed to meet with us. We provided plan information, maps, and other materials to explain the project, which were ignored. We were told point blank that the owners did not trust the Town because "the Town let Greenbridge go through," meaning the Town let developers continue to convert Northside from a historic black neighborhood to a neighborhood comprised of student rentals. As Town employees, we represented those other actions of the Town, and were denied even an opportunity to revise the project details to meet any concerns they might have. The only concern they would share is their fear the Town would keep them from using their property as a result of the project, a somewhat reasonable concern, given that we would request that the owners not disturb the dissipation basin we proposed to install or the streamside trees we planted. This led to dropping the path stabilization across the stream, the upper energy dissipation basin, and rerouting of the ephemeral channel away from the OWASA easement from the project entirely.

One of the proposed elements of erosion control at the Baldwin Park site was the stabilization of a dirt path that ran down from Craig Street, crossing the stream, and linking up with a cement sidewalk on the Carrboro side. NCSU had recommended that mulch should be sufficient to prevent the path's erosion. As this path runs beside the property of the owners who did not want us to install the upper dissipation basin, we decided we should not aggravate the situation by doing work of any sort in that area, even though it wasn't on the property in question. As it turns out, once the downstream step-pools were installed we saw much less erosion at this site. In the interim, we have discussed the installation of a bridge over the creek and sidewalk from Craig Street with a Boy Scout troop and with Chapel Hill Parks & Recreation staff. This would be a fairly large bridge for an Eagle Scout project, so at this time no scouts have chosen to install a bridge at this crossing.

Fortunately, properties along the stream abutting Chapel Hill, further downstream where the erosion was significant, were primarily rentals and we received little resistance (but little interest) to our proposal for stabilizing the severe erosion there. However, the one owner at the very end, Marva Burnett, was quite interested and cooperative, seeing as how we would move the stream away from her eroding garden area where a fence was being undermined. We are very grateful to her for working with us and keeping in touch with us regularly.

Chapel Hill staff worked through 2010 to keep willing property owners informed of progress, requested NCSU to revise plans as necessary, and get permission forms for 401/404 permit application and construction easement access signed by property owners. In the fall of 2010 Invasive Plant Control treated the extensive amounts of Chinese privet and other invasive plants choking out the understory of the remaining forest area. We received very positive feedback from property owners on removing this scrubby understory.

Construction finally started in late 2010, overseen by NCSU staff with input from project members. The western stream fork was routed away from a very steep bank, where a bend in the stream had been carving progressively deeper into the bank. The eastern stream fork was routed away from a garden and its fence where it had been similarly eroding the streambank, introducing a good meander bend in the process. Along both forks several step-pool structures were installed to absorb and dissipate the energy of flowing water and prevent the stream from eroding down through its bed again. These step-pool structures consisted of two rows of very large rocks (eight feet long, four feet wide) laid perpendicularly to the flow, with rock filled in behind to effectively step the stream down. To reduce the amount of street runoff directly going into the stream, and treat it for pollutants, water from a stormdrain inlet along Broad Street was rerouted to what would become a bioretention basin beside Broad Street. Engineering plans, before and after photos, and other details can be found in Appendix 1. Chapel Hill staff recorded an informational video that was posted to the Town's Vimeo website and advertised with the other video shorts that the Town's Public Affairs office was producing at the time. The URL for the video is: http://vimeo.com/21352340

As construction proceeded, Chapel Hill staff worked with property owners on an acceptable list of trees to plant in the riparian zone on the Chapel Hill side. Most property owners had no concerns, but one did not want us to put trees along the stream, keeping just grass in place. We eventually got agreement to fairly low-density planting of small, attractive trees about ten feet from each bank. In late March of 2011, project members and many volunteers planted a few hundred bare-root trees along both of the restoration segments. On the Carrboro side, trees and shrubs were planted much more densely, and native grass and wildflower seed was sown in the planting area. Meanwhile, project members organized the first tree planting and dedication ceremony of the project (the "ribbon-cutting" referred to in the deliverable language), to be held in early April 2011.

When construction was underway, a contractor for OWASA was constructing an extension of a sanitary sewer main that extended across the larger of the two stream forks, between the restoration area and our monitoring site. We have observed that many OWASA fords are built like small dams, raised up areas of large rock that interrupt the normal flow and transport of water, bed sediment, and woody debris. Depending on the construction, the stream may wind up cutting around the riprap if it obstructs flow too much. Other OWASA crossings have unstable or eroded banks due to equipment traffic and the way the ford was designed. Where small culverts are used for OWASA crossings, we've invariably observed culvert obstruction, either through crushing the pipe or clogging with debris, and rerouting of the stream around the clogged culvert, eroding sediment in the process.

Since we were unable to get the dissipation basin installed above the construction zone, we needed to install a different BMP that would meet similar water quality improvements. For a few years before this, we had wanted to test out alternative methods of constructing OWASA crossings to reduce their effects on stream channels. Both stream forks of the Baldwin Park project site were crossed by OWASA easements, and the smaller stream's OWASA crossing suffered from the kinds of effects we were hoping to avoid with a different ford design. We decided to test a geogrid material that could accommodate cobble-sized rocks in a new OWASA ford so we could see how this would perform compared to the regular riprap ford. While this BMP was not used for dissipation, we believed maintaining stream channel stability and function while allowing a stable crossing for heavy equipment, especially in cases where other crossings have been a problem, was an equitable replacement. In particular, we believed this would mitigate the negative effects that the sewer main construction would have that would be picked up at our monitoring site, confounding our monitoring of the stream restoration.

At the tail end of the small stream's rerouting and stabilization work we observed that the stream was beginning to cut around the riprap and gravel placed on the channel at the OWASA easement. We consulted with NCSU, OWASA, and the construction company putting in the nearby new sewer main and sewer laterals to design a simpler but still less-obstructive ford that would not encourage the stream to cut around the riprap. Being a much smaller stream, we also wanted to test out methods that could be used on the tiniest of streams, where culverts are commonly placed. This required some channel reshaping and extension of rock from where NCSU's work ended at the last-step pool to maintain a bed elevation that would not encourage pooling of water in front of the ford material, and reshaping of the ford material to create a contiguous small channel. As we were unable to do stabilization of the pathway (the third BMP in the deliverable), we felt restructuring the OWASA crossing met or exceeded the water quality benefits the pathway mulching would have provided.

A very-well-attended dedication ceremony was held at Baldwin Park, where the mayors of the two Towns planted a tree in the bioretention basin and read a joint proclamation. This was one of several stops that day on a tour of water quality projects in the two Towns organized by project members, NCSU, and Friends of Bolin Creek. NCSU and Carrboro staff conducted a workshop for Carrboro landscaping employees to properly care for the plants in the riparian zone and bioretention basin. Carrboro staff have since installed signs providing information on the restoration and the bioretention basin. Pictures and other information related to the event can be found in Appendix 1.

In the year after construction, Carrboro staff have conducted several tours of the project area. Carrboro maintenance staff refrained from mowing along the newly-restored stream segments, and continue maintenance of the bioretention basin. That was a fairly dry summer, and Carrboro staff provided some watering during the worst parts. A lot of the small trees and shrubs along the streams and in the bioretention basin were grazed to nubs by deer. However, when visiting in spring 2012, the riparian zone and bioretention basin were remarkably verdant. We had been advised that many of the native grasses and wildflowers would not germinate until the next spring, which is what appears to have happened. The step-pools and other channel reshaping was completely unchanged and appeared to be stable.

MILL RACE TRIBUTARY

(Mill Race project elements were implemented by Chapel Hill Stormwater Management staff and NCSU engineers. In this section "we" refers strictly to Chapel Hill Town staff.)

In November 2008, very shortly after the grant contract period started, we organized a stream walk for the neighbors to meet them, introduce them to the project and its goals, and answer any questions they had. We requested a response to our mailing, but got interest from only two property owners out of more than 50 who received invitations. Again in March of 2009 we attempted some outreach to property owners with an information brochure, but received response from only one property owner (one of the ones who had responded to us before). Facing difficulty with getting our ISCO samplers up and running at both sites, project staff focused their attention on getting the monitoring underway. During this first year we had difficulties in coordinating all the team members and getting needed steps accomplished in a timely fashion. We started using weekly emailed task lists to team members to get us back on track. Emails had lists of current tasks, due dates, and who was assigned; lists of past tasks and when completed; and a list of upcoming tasks and assignments so team members could plan accordingly.

Installation of monitoring equipment started in Summer 2009. Implementation challenges at Mill Race started with simply trying to site the ISCO sampler inside its metal "bear box" and a pole for its solar cell. The best place for the sampler was downstream of all the construction work, at a culvert that formed a "control point" for setting up discharge measurements. This property was owned by the homeowners association. The nearby property owner was president of the homeowners association, and objected to the placement of the sampler in this location, finding it aesthetically unpleasing. Because of the lack of reliable solar recharging, the sampler's battery ran down on a regular basis, requiring equipment setup and recalibration each time. We believe this contributed to water level data that has been difficult to interpret.

By late 2009/early 2010, we were anticipating getting back to Mill Race outreach. However, as described in the Baldwin Park section, communication problems and changing stakeholder relationships meant Chapel Hill staff could not return attention to Mill Race preparation or property owner outreach and communication until mid-2011. By this point we had requested a one-year extension, figuring that with Baldwin Park experience we should be able to move along faster at Mill Race. But since it was a more complicated project, with extensive invasive plant control, long areas of stream stabilization including incipient gullies on both forks, repair of three huge gullies, replace a blocked stream culvert for an OWASA line with a stabilized ford, LID treatment of the eroding gravel sidewalks that drained to this stream, and stabilization of the stream channel above an encased OWASA line, we planned many more, and more convenient, opportunities for property owners to talk with us about the proposed project. Given that we still heard from occasional property owners who had some interest in seeing the erosion being corrected, we did not expect the very active resistance that we received.

We announced several meetings and got very little response except those who had already contacted us before. We started to set up a comprehensive invasive management plan while NCSU finalized engineering plans. As these were completed, we sent out much more detailed information with permission forms for the 401/404 permit, treating the invasive species, and conducting the construction on each property (or merely crossing, as was appropriate). In the midst of all this we were attempting to set up an invasive species management contract so that the kudzu could be treated at the most effective time – August and September. We met with several property owners who were uncomfortable with the use of pesticides in order to allay their fears, as we also required permission to control the kudzu.

By mid-August, we were contacting property owners directly by phone in an effort to get permission to go forward with the project. We readily received permission from about 30 properties. Several property owners directed a large amount of abuse at staff on these phone calls. The general tone of these conversations was that all government was incompetent, corrupt, getting in business where it did not belong, including not trying to repair an eroding stream and gullies. The Town was lumped in with all other levels of government in some of these extensive rants. People were very angry at government in general (or maybe at state and federal levels), and we were the only contact they had, their only route to diffuse their anger. For many of these calls, we did not explicitly require access permission because the property only touched the larger project area, and we figured we could just avoid those properties. However, there were three critical properties where the owners refused that forced us to abandon the whole set of Mill Race tributary project elements. One of these properties had the large kudzu field, one of the huge gullies, and one of the two OWASA easements we could use for access for large construction equipment. One of these properties had one of the incipient gullies forming, and the other OWASA access point that would accommodate the large equipment. The third was at the junction of the two stream forks leading to the lower stream segment, along which the OWASA easements followed, through which we would need to travel to get to the other two gullies and the majority of the stream stabilization area. This property also had the crushed culvert that we hoped to replace with a stream ford. We were not merely denied permission to do the project elements on their property, we were denied permission even to cross in order to access other parts of the project. One property owner confused us with OWASA, and was unhappy that we “kept making ruts in her backyard” and she was going to forbid us from entering so there’d be no more ruts. We told her we were offering to repair and stabilize the ruts, and that she could not keep OWASA contractors from entering her property, so there would be more if we did not fix the situation. But she denied us access anyway.

By October 2011, it appeared clear we would not be able to secure the necessary permission from these three property owners, nor would upper levels of Town management agree to contact property owners on our behalf. We regretfully informed property owners of cancellation of the project elements, and set about trying to find replacement projects to cover the many elements of the Mill Race tributary erosion control. Materials related to the Mill Race tributary erosion control project elements can be found in Appendix 2.

Of the many elements we had put together for our final engineering plans, most were add-ons to improve the subwatershed-repair approach and not formally part of the contract. So we looked for replacement projects that could meet the underlying water quality improvement needs that the contracted elements were designed to address. These elements were the LID treatment of the gravel sidewalks to prevent erosion, stabilization of eroding stream segments including an OWASA crossing, and repair of two gullies with associated BMPs. We reviewed over 18 individual project sites in the course of two months to find projects that were feasible, could be completed within the budget, were on Town property (thus removing the need for property owner permission, and the risk of it being denied), and looked to address the same kind of water quality problem of approximately the same severity. Site investigation involved extensive local storm drainage mapping, identification of construction access, and multiple site visits to each location. It also required extensive meetings with Parks and Recreation staff, as most available sites were managed by this department and would need to meet their needs, or at least not interfere with their activities.

By December we had identified five very promising locations – two potential bioretention areas at Hargraves Community Center, an eroding pea-gravel fire lane suffering lots of flooding and erosion at Hargraves, a bioretention at the end of Dickerson Court, and a stream stabilization at Trinity Court. Given how far in the project timeline we were, we received permission from NC DWQ to proceed with the replacement projects without a contract revision, with the requirement that we explain thoroughly how these projects could match or exceed the water quality benefits of the project elements we could not complete at Mill Race tributary. As these would be installed less than a year before the grant period ended we would be unable to do post-construction morphological monitoring or vegetation monitoring.

Because these sites were managed by the Town's Parks & Recreation department, or adjacent to their facilities, Parks & Recreation staff were very concerned about how our construction would affect their operations and community programming. We consulted and communicated with their staff frequently, sometimes onsite, including sending out weekly stakeholder update emails to keep them apprised of all decisions, activities, and plans.

To replace the stream stabilization and OWASA stream crossing, we found a similarly very steep, badly eroded stream on Town property north of Trinity Court. This intermittent stream connects directly to Bolin Creek opposite the Town's Umstead Park. The pre-construction condition of the stream included steep, very high banks that were eroding, and an otherwise fairly smooth channel that accelerated stormwater down the hillside. Stormwater could not access the floodplain, and the channel contained the most erosive, intensive flows, causing more bank erosion. Erosion was cutting into both sides, but very close along one side ran an OWASA sanitary sewer line, which was threatened by the erosion.

NCSU engineers proposed a similar set of step-pools and OWASA easement stabilization that was proposed for the Mill Race tributary. This would build the streambed up to allow flood flows to get over the banks, and thereby reduce velocity and take advantage of natural floodplain processes of water storage and nutrient processing. Plants were selected for the streambank that would improve stability yet be acceptable to OWASA, since they were right next to the sewer line. This included small shrubs such as yellow buckeye and spicebush, and perennial ferns that create a shallow, yet very fibrous network of roots.

This project got underway fairly quickly early in 2012, with construction completed in 3 days in April, and streamside plantings done shortly afterwards. Construction consisted of installation of several sets of very large rocks to create step-pools. Behind these step-pools was layered erosion control fabric, a sand-wood chip mixture, topped by heavier gravel. This is used to encourage hyporheic (below streambed) flow and the associated nutrient processing and cycling that occurs in the hyporheos, and is called a "regenerative stormwater conveyance." See Appendix 4 for Trinity Court stream restoration engineering plans and before and after photos.

After construction and planting was completed, we held a streamwalk guided by NCSU engineers and invited staff from Chapel Hill (other than Stormwater staff), Carrboro, OWASA, and UNC. Because this project was adjacent to Town public housing, we invited the Housing Director and community advocates from the housing project. We had moderate turnout, but great interest by those who did participate. This area had a significant trash problem that Town staff and community advocates were made aware of, and this led to the organization of a community-wide cleanup day.

We were unable to find severe gullies similar to the ones at the Mill Race tributary in other locations where we could get permission for projects. We found a potential bioretention site at Hargraves Community Center and another at Dickerson Court. We found a good replacement for the sidewalk LID treatment also at Hargraves. The Dickerson Court area lies directly next to Bolin Creek in the Triassic Basin. The Hargraves projects are in the Upper Tanyard Branch watershed. Among the stormwater management recommendations from the Tanyard Branch Alternatives Analysis, were the subwatershed-wide installation of BMPs which detain/retain runoff to lengthen the hydrologic response time and reduce shear stress on eroding streambanks. While the substitute recommendations from the study projects we wanted to implement did not all address the same suite of pollutants or water quality impact as the projects to be replaced, we believed the projects as a group would result in improvements to water quality equal to or greater than the set of projects we had to replace because they would retain and treat runoff where the original projects do not.

To replace one of the two severe gully repair efforts at Mill Race we looked at several areas we could potentially install bioretention basins at Hargraves Community Center. We looked at trying to capture roof drainage from the buildings, but after extensive investigation found all the drains were deeply buried under walkways and connected directly to the extensive stormdrainage network in the area. We then looked at capturing flow from one or more of the four parking lots on the property. Two very promising bioretention sites were located, and NCSU did surveying and design for both of them. One of the two Hargraves bioretention sites was not feasible because of utility lines under the proposed location that were found after engineering designs were drawn up.

The other site, which would become known as the “Mitchell Lane bioretention basin” had a good, open spot downhill from a parking lot. However, its drainage was linked directly to the extensive network that went through the entire site. We considered whether we could reroute that whole network to this location for treatment, but determined the runoff volume would vastly overfill any bioretention basin we could put in that area. Instead, we decided to try to split the parking lot runoff from the larger stormdrain network.

An NCSU engineer designed a bioretention basin that would treat flow from approximately 50,000 square feet of area in total, approximately 14,000 square feet of untreated impervious surface, mostly parking lot. This setup would divert direct stormwater inputs to the stormdrain system leading to Tanyard Branch into treatment instead. Prior to installing the bioretention basin, we had to capture the parking lot flow. Chapel Hill Stormwater Engineers designed a new stormwater inlet box that would drain the lot, and the old inlet would be closed off. Getting this new box and a pipe to the treatment area was tricky, as we had very limited time before the summertime pool season when we could not have the lot blocked off. Chapel Hill’s Stormwater Maintenance Crew installed the box and pipe very quickly in May in time for the pool opening. See Appendix 5 for the Mitchell Lane bioretention basin engineering plans and before and after photos.

Even this location had utilities that challenged our design – an electric guy pole and line used to keep tension on the power lines and poles across the street. This wound up not being moveable, so the bioretention basin was designed around it. A forebay was designed to allow a place for fine material from the lot to settle to avoid clogging the soil media. Construction of the bioretention basin took place in Summer 2012. While it was directed by an NCSU engineer and installed by an NCSU contractor, both required considerable oversight by Chapel Hill Stormwater Engineers because of apparent lack of experience with bioretention design and installation. Construction took a few weeks and required several field revisions.

This location was also beset by many invasive species, including kudzu, English ivy, and wisteria. Town staff had attempted to get professional removal done before construction, but could not get quotes in time nor arrange for Town Landscaping staff to do the work. As a result, Town staff designed a planting plan for the bioretention basin and adjacent steep slope with native species that were fairly aggressive and had a chance of outcompeting the invasive species. Further, being in a fairly urban and well-traveled area, and after consultation with the Town's Landscaping Division, we selected more showy, tidy, low-growing herbaceous species rather than the standard native shrubs and trees commonly planted in bioretention basins. Herbaceous species also ensured we could try to manage the invasive species by annual mowing, which we would not be able to do with shrubs or trees. Because the plantings were almost all herbaceous, a high planting density was selected to ensure good ground cover quickly to fend off colonization by invasive species. To assist the NCSU engineer, commercial sources for these plant species were researched by Town staff and provided with the planting plan.

However, NCSU ordered plants through a different plant vendor that did not carry most of the desired species, and new ones were selected. Town staff learned of this substitution on the planting day. Some of the selected species were acceptable, but others were lacking in either aggressive growth, short stature, showiness, tidy habit, partial shade tolerance, perennial growth, or a multiple of those. The planting density used was appropriate for trees and shrubs, at 400 stems/acre, but inappropriate for herbs and grasses that have a mature maximum spread of 3 feet. With the exception of the three specified small trees used as centerpieces, the layout of the planting plan also was not followed. The stabilizing grass species for the steep hillside had not been ordered nor seed laid down.

Town staff conveyed their specific concerns that inappropriate species had been installed. Since planting at Mitchell had occurred while the other bioretention basin at Dickerson Court was being constructed, an agreement was made that a similar set of species and planting density to that specified in the original Mitchell planting plan would be ordered for Dickerson.

To replace the other Mill Race tributary gully repair, the proposed bioretention basin at the end of Dickerson Court would treat flow from approximately 22,000 square feet of area total, 13,000 square feet of untreated impervious surface, mostly public street. The storm drainage from this street was routed directly to Bolin Creek. This bioretention site would reduce contaminants and flows that would have otherwise gone directly to the creek by intercepting a stormdrain and rerouting it to treatment. While this and the Mitchell Lane bioretention basins were likely not halting the contribution of as much sediment as the Mill Race gullies were, instead we were removing multiple pollutants from inflow, rather than just reducing the erosiveness and sediment load of the inflow.

The NCSU engineer designed this bioretention basin as well, with guidance from Chapel Hill Stormwater Engineers. Rather than constructing a new stormwater collection system, or unearthing the existing one to modify it, the engineers used the existing lay of the street and position of a driveway apron to direct street runoff to the bioretention basin. To convert the existing stormdrain inlet to an overflow device, the engineers designed very careful repaving of the street to make a small rise in front of the inlet that would only overflow at a set amount of water. In late summer 2012 a different and experienced NCSU contractor constructed the bioretention basin fairly quickly and with few problems. The Town hired a contractor to cut down the driveway apron so water would flow directly from the street, and hired the asphalt paving contractor. See Appendix 6 for the Dickerson Court bioretention basin engineering plans and before and after photos.

As noted above, the Dickerson planting plans resembled the original Mitchell plan, and Town staff drew up the planting layout, staked out the site in advance, rounded up volunteers for planting, and directed (and participated in) the planting. Some of the large plants installed at Mitchell were transplanted to Dickerson, and the design used those plants as centerpieces. Planting was completed over two days, and then moved back over to Mitchell to increase the planting density and get showy grass plugs installed on the hillside. Town Landscaping staff provided planting equipment and additional assistance, and provided watering the first day to get the plants established. After that the Stormwater Maintenance Crew did almost-daily watering to help get the sod and plants established. A comparatively wet summer and fall greatly assisted us in this regard. Lastly, Town staff designed and NCSU ordered educational signage for both bioretention sites that explained how bioretention works, why we use it, and about the plants used.

To replace the LID treatment of the grit sidewalks in the Historic District, draining (and eroding to) the Mill Race tributary, we found a fire lane and hillslope on Town property (Hargraves Community Center) composed of the same “Chapel Hill grit” which is used on the Historic District sidewalks on North Street. Between the action of heavy equipment and informal construction of two bike paths on the slope, the area was beginning to form channels as the ground was compacted and material carried away to nearby stormwater inlets. We found a considerable amount of grit deposited several hundred feet away at the stormwater outfall. We proposed the installation of an LID grass-grid-paver system in the fire lane and fencing to direct traffic to less erodible pathways and away from the eroding hill. We estimated this project area to be very close in size to the LID treatment area on North Street.

The fire lane sits between the gym and ball field, and is on a hill above the Mitchell Lane bioretention site described above. It was composed of fairly compacted “Chapel Hill grit,” which is a pea gravel-sand mixture with a considerable amount of finer material. It is both easily compacted and yet easily eroded. This area never drained properly and runoff would pool up along the gym. Addressing this problem was of particular interest to the Town’s Parks & Recreation Department, and our installation schedule was designed around the center’s programming and activities to inconvenience patrons as little as possible.

This entire area around the gym seems to be made of or covered with Chapel Hill grit, including the hillside above the Mitchell bioretention area. Trees behind the gym had poor soil with no leaf mulch because of a practice of removing fallen leaves. Visitors had been cutting paths directly down the face of the hill, creating a channel which was starting to erode, and we found a considerable amount of this material in the stormwater inlet boxes downhill. Part of the Mitchell Lane project involved placing large boulders excavated from the bioretention site to block travel directly down the hill, and direct it to a more stable, lower sloped path on the hill.

The installation was designed by Chapel Hill Stormwater Engineers, and construction took place in Summer of 2012, conducted by Chapel Hill’s Stormwater Maintenance Crew. We considered this a valuable experience to learn to work with this material, as we wanted a demonstration area to present to other Town staff to show how well grass-paver systems could work. See Appendix 7 for the Hargraves fire lane grass-paver engineering plans and before and after photos.

MONITORING

Water level and discharge measurement, water chemistry sample collection, continuous water temperature measurement, rainfall gauging, and care of the ISCO stormwater samplers were carried by Chapel Hill Stormwater Management staff with advice and assistance from Michael Shaffer of NCSU. Biological monitoring was contracted separately through Dave Lenat and Dave Penrose, with assistance from Carrboro and Chapel Hill staff.

A Quality Assurance Program Plan was required to be submitted after the grant was awarded (see Appendix 12 for the approved QAPP). A QAPP helps the monitoring entity organize and plan monitoring in such a way that attention can be paid to monitoring environmental conditions that will measure what you are actually interested in, making sure that monitoring is done at a sufficient frequency and with an adequate level of quality to detect information of interest.

Water chemistry, stage (water level), discharge, and temperature monitoring were carried out, albeit with challenges. ISCO stormwater samplers are difficult to set up and get running, and a good deal of construction knowledge is required (Mike Shaffer of NCSU was invaluable for this). We had persistent problems with power loss at Mill Race tributary because we were not permitted to put up a solar panel. Thus we had to frequently reset and recalibrate this site. Rating curves for determining loads from water concentration data are easy at moderate flows, but error-prone at low flows and increasingly difficult (and unsafe) at flows at and beyond bankfull. Flows of this amount are also very brief and difficult to “catch in the act” in these flashy, urban drainages. Because of the error we were getting at low flows, we inquired with NCSU as to whether we could install a weir to help us more accurately measure low flows. We were advised that even our smaller watershed, Mill Race Tributary, was much too large for installation of a weir. Thus our rating curves are more limited than we would prefer, and don’t work well at either the high or the low end of flow. We must have also had some calibration (or measurement) problem that we still have not determined the cause of, leading to low stage readings that when converted to discharge give a negative number.

In the course of writing the QAPP, it was determined that some information that was proposed to be collected in the grant contract was not appropriate or infeasible. For example, in-situ dissolved oxygen meters can get fouled easily and require servicing every few days to few weeks, making continuous monitoring difficult. The likelihood of detecting significant changes in dissolved oxygen after construction was also doubted because we would not be treating stormwater at either project location in a way that would change effects on dissolved oxygen. We determined that measuring nitrogen in “first-flush” was inappropriate given the solubility and transport characteristics of nitrogen compounds. Further, we were interested in loads as a whole, which could be better calculated with flow-weighted storm composite samples rather than first flush. Fortunately, ISCO samplers could be programmed to collect such samples.

Some changes to monitoring occurred even after the QAPP was submitted upon finding in the field that we would not be able to collect data the way we wanted to. Installation of bank pins was inappropriate given the intensive earth-moving and installation of large rocks done at the stream restoration sites. Before and after construction comparison of bank erosion using bank pins is meaningless if you cannot compare the same section of bank or cannot leave the pins in place. The same goes for habitat conditions in the area of the restoration, when the methods used were installation of step-pools. More general geomorphic data comparison (such as Rosgen channel characteristics) before and after construction was constrained by the fact that we were relying on the contractor (NCSU) to collect preconstruction geomorphic data, but were unspecific on what needed to be collected. Similarly, planting plans were drawn up for planting the Baldwin Park bioretention, and plants selected for riparian planting, but the lack of an accounting of what was actually planted and where plants were placed made evaluation of survival and plant success impossible.

This misunderstanding of roles affected other parts of this project, and points to the importance of having crystal-clear monitoring goals, methods, and roles – ALL of the details – laid out prior to even applying for the grant. Pressure to get “measureable improvements,” and therefore to measure everything possible to detect even the smallest improvement may have contributed to an overly-ambitious monitoring plan, which could have been questioned if detailed pre-project scoping of monitoring needs had occurred, including staff time and what are the best, yet simplest methods to detect changes. Such planning would have also prevented the problems in contracting for laboratory analysis (no lab had been selected prior to project commencement; no estimates of lab analysis costs had been included in the budget). Such planning may have also helped Chapel Hill staff avoid being overwhelmed in trying to get the QAPP written and approved, acquiring necessary equipment (which was complicated separately by miscommunication on budget amendments with Chapel Hill's Finance Department), get necessary monitoring started up, troubleshooting of difficult and testy equipment, setting up a lab analysis contract, etc. This prevented Chapel Hill staff from paying sufficient attention in Year 1 to other aspects of project implementation, such as extensive outreach to property owners in both project areas.

Even for the monitoring we did carry out effectively, the baseflow and stormflow water chemistry samples, it may have been unreasonable to expect changes in anything but sediment loading. As more recent studies are discovering, a restored section of stream may not recover its nutrient cycling and retention capabilities in a short amount of time, if ever. This is because most nutrient retention in eastern streams comes from retention and extensive microbial colonization of leaf litter, rather than capturing nutrients dissolved in the water column. Where leaves are not being retained and allowed time to decompose and their nutrients absorbed into the food chain because of scour or other removal, those nutrients are flushed downstream. Where nutrients are dissolved in the water column, rather than being supplied through leaf litter, only algae (and to a small degree terrestrial plants that can tolerate root saturation) can retain and slow the export of nutrients. This requires a lot of sunlight for algal photosynthesis, and completely changes the stream food web, temperature, dissolved oxygen and pH diurnal patterns, and other physico-chemical characteristics that macroinvertebrates are sensitive to. Essentially, relying on algae to remove nutrients means changing the ecological community type of the stream.

Much of the nutrient reduction was expected through reduction of soil, streambank, and stream channel erosion. This could have been detected strictly through total suspended solids, and measuring nutrients was completely unnecessary for this.

It must be noted that Mill Race tributary sampling was concluded in late 2011 when it became apparent that we could not complete the project in that area due to property owner resistance and technical challenges. Therefore we have fewer than anticipated samples for Mill Race tributary, and none of them are post-construction.

Macroinvertebrate monitoring using NC DWQ methods was added fairly easily since Carrboro was already conducting annual monitoring at several locations as part of its grant match, and Chapel Hill was setting up a contract to do so as well. As it turns out, monitoring benthic macroinvertebrates may have been the most useful method, best able to detect changes and requiring the least amount of project staff time because it was largely contracted out. This is in spite of the fact that macroinvertebrate communities are slow to show improvement after restoration activities, but that may be dependent on where sampling takes place. We sampled below the construction area at Baldwin Park, and at the construction area at Mill Race tributary. To see what benthic macroinvertebrate monitoring told us, see the Monitoring Results section of the Results and Conclusions chapter. The temperature, flow/discharge, and water chemistry information can also be found there.

3. RESULTS AND CONCLUSIONS

3.1 MONITORING RESULTS AND DISCUSSION

WATER LEVEL AND DISCHARGE MONITORING

While we have over 2 years of water level data for Baldwin Park, we had extensive difficulties with the Mill Race sampler and data. At best we were able to get some two- to four-week contiguous periods for Mill Race, and in joining these we found we had much more time where no readings were taken or they were zero than we had data. This was not caught because we did not have time to thoroughly check every downloaded dataset, but most that we looked at appeared alright. In the future we hope to get much better guidance on using this equipment and how to troubleshoot data problems.

The entirety of Baldwin Park water level data is presented in Figure 4.

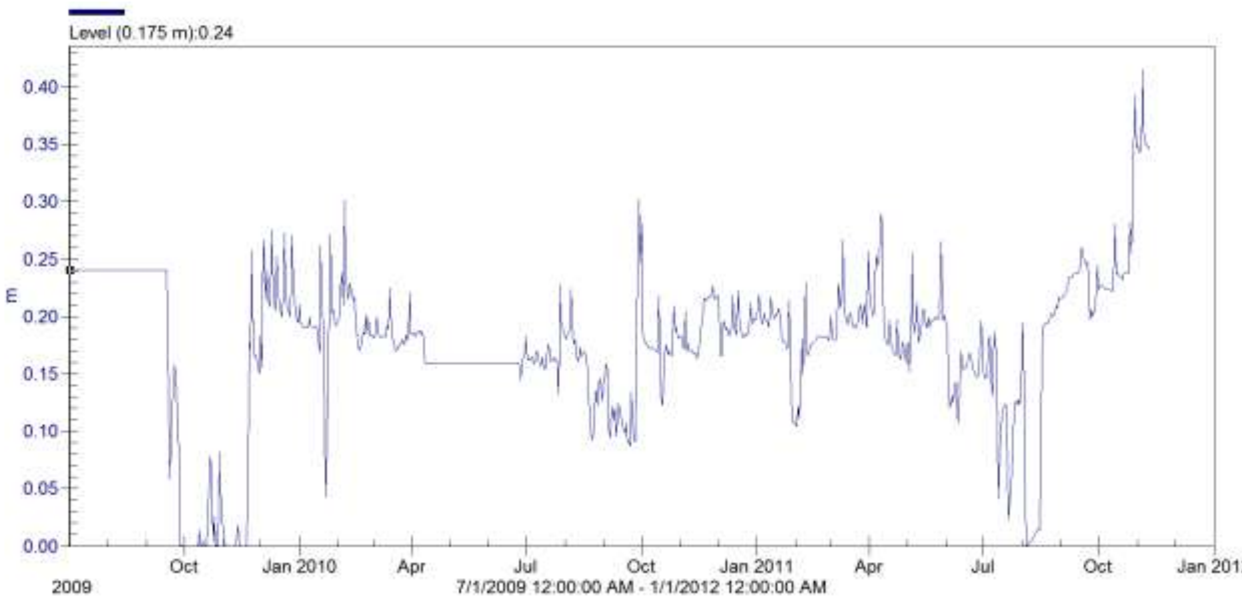


Figure 4: Baldwin Park Water Level Data

As noted in the Methods and Execution Chapter, we had difficulty setting up rating curves for both sites. In particular, when regression equations were applied, the lower ends resulted in negative discharges, which is not what we observed. We believe these were the result of calibration problems. Figures 5 and 6 show the stage-discharge rating curves for the two sites, with 3 different regression equations shown. Each equation had similar problems with generating negative discharges at low flows. We will be consulting with NCSU more extensively to try to diagnose what went wrong with our data collection.

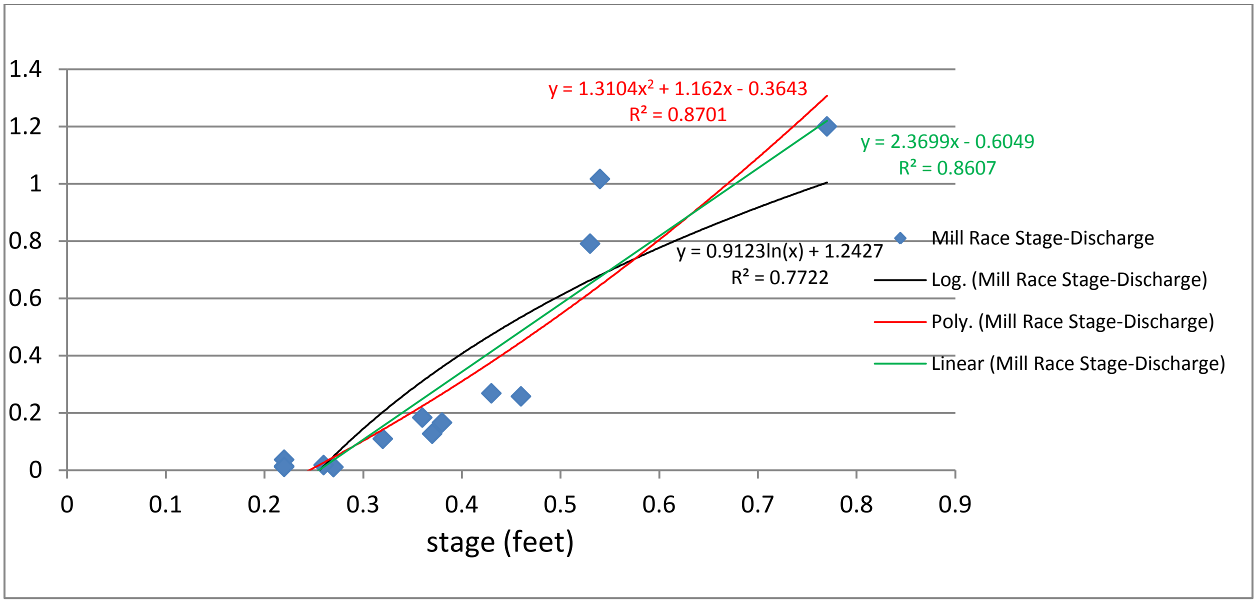


Figure 5: Mill Race Tributary Stage-Discharge

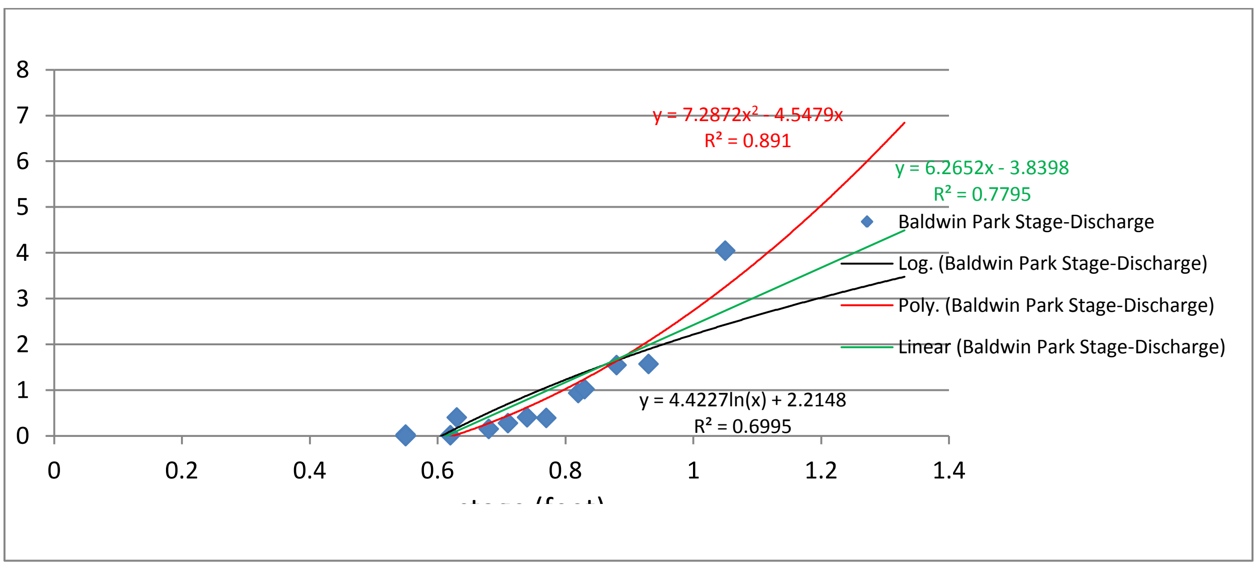


Figure 6: Baldwin Park Stage-Discharge

WATER CHEMISTRY MONITORING

We had much greater success with water chemistry monitoring at Baldwin Park than at Mill Race tributary, not to mention the fact that we could divide Baldwin Park samples into pre- and post-construction samples as proposed, and could not do that for Mill Race tributary. The greater problems with equipment calibration and functioning at Mill Race tributary also limited our sample collection. The data for Baldwin Park are presented in Table 2, and the data for Mill Race tributary are presented in Table 3. Stormwater flow composite samples are shaded to differentiate them from the base flow grab samples.

Table 2: Baldwin Park Water Chemistry Pre- and Post-Construction

TYPE	DATE	total Kjeldahl nitrogen mg/L	ammonia mg/L	nitrate + nitrite mg/L	total phosphate mg/L	ortho-phosphate mg/L	suspended solids mg/L	conductivity µs/cm	Diss. Oxygen mg/L	pH
Pre-Construction										
Baseflow	1/15/2010	0.68	0	1.06	0.24	0.15	21	369	11.63	6.65
Baseflow	2/19/2010	1.03	0.04	1.38	0.22	0.18	27	451	10.76	6.54
Baseflow	2/19/2010	0.43	0.42	0.54	0.79	0.73	1			
Baseflow	3/19/2010	0.37	0.03	0.79	0.19	0.18	11	390	10.23	6.51
Stormflow	3/29/2010	1.54	0.19	0.63	0.23	0.19	189			
Baseflow	4/16/2010	1	0.07	1.03	0.21	0.19	47	430	7.88	6.08
Stormflow	4/26/2010	2.86	0.04	1.04	0.5	0.25	228			
Baseflow	5/21/2010	0.8	0.03	0.92	0.29	0.26	98	438	7.07	7.59
Stormflow	5/22/2010	3.09	0.06	0.45	0.71	0.19	578			
Baseflow	6/11/2010	0.36	0.03	1.39	0.15	0.14	15	420	6.57	7.62
Baseflow	7/16/2010	0.47	0.07	0.58	0.34	0.34	7	383	4.77	7.57
Baseflow	8/27/2010	0.25	0.01	0.64	0.4	0.35	40	393	5.31	7.58
Stormflow	9/28/2010	6.21	0.05	1.29	0.66	0.4	323	458	6.65	7.4
Baseflow	10/18/2010	0.32	0	0.83	0.37	0.16	14	441	7.77	7.43
Stormflow	10/27/2010	2.22	0.07	0.26	0.93	0.34	409	491	6.38	7.27
Baseflow	1/19/2011	0.94	0.02	1.36	0.27	0.16	39			
Baseflow	2/11/2011	0.83	0	1.12	0.21	0.21	4	479	11.52	7.4
Stormflow	3/1/2011	1.77	0.31	0.63	0.63	0.26	974	415	11.56	7.71
Post-Construction										
Baseflow	7/19/2011	0.4	0.03	0.45	0.21	0.13	31		6.19	7.25
Stormflow	9/22/2011	1.98	0.03	1.2	0.31	0.17	76	517	7.43	7.15
Baseflow	11/10/2011	0.23	0.03	1.01	0.19	0.17	6			7.12
Stormflow	11/29/2011	0.58	0.04	1.09	0.15	0.11	2	268	9.21	6.99
Stormflow	12/8/2011	1.89	0.03	0.5	0.24	0.02	218	431	9.66	7.11
Stormflow	1/27/2012	1.58	0.25	0.56	0.21	0.02	41			
Stormflow	3/6/2012	0.35	0	0.6	0.04	0.03	684			
Stormflow	3/24/2012	4.47	0.03	0.29	1.53	0.04	641			

Table 3: Mill Race Tributary Water Chemistry Pre-Construction

TYPE	DATE	total Kjeldahl nitrogen mg/L	ammonia mg/L	nitrate + nitrite mg/L	total phosphate mg/L	ortho-phosphate mg/L	suspended solids mg/L	conductivity µs/cm	Diss. Oxygen mg/L	pH
Pre-Construction										
Baseflow	1/15/2010	0.49	0	2.59	0.28	0.18	2	205.2	11.66	6.59
Baseflow	2/19/2010	0.09	0.01	2.56	0.2	0.16	16	279	10.61	6.72

Baseflow	2/19/2010	0.55	0.48	0.54	0.78	0.74	0.3			
Baseflow	3/19/2010	0.32	0.03	1.61	0.16	0.16	16	231	10.03	6.41
Baseflow	4/16/2010	0.68	0.03	1.68	0.2	0.19	16	236	6.74	6.13
Stormflow	4/26/2010	0.15	0.01	0.01	0.09	0.03	0	239	4.88	6.81
Baseflow	5/21/2010	0.11	0.01	1.4	0.23	0.22	17	220	7.75	7.08
Baseflow	6/11/2010	0.65	0.01	2.06	0.11	0.06	4	228	6.8	7.3
Baseflow	7/16/2010	0.32	0.03	1.54	0.27	0.26	4	224	0.18	7.19
Stormflow	8/27/2010	6.69	2.17	1.42	0.52	0.48	134	232	6.38	7.2
Baseflow	10/18/2010	0.4	0.01	1.55	0.48	0.16	21	220	8.33	7.15
Baseflow	1/19/2011	1.54	0	1.97	0.18	0.17	13			
Stormflow	2/7/2011	3.26	0.1	1.04	0.19	0.18	576	336	10.35	7.17
Baseflow	2/11/2011	0.22	0	1.99	0.24	0.23	13	359	10.73	6.99
Stormflow	4/9/2011	4.02	0.19	0.35	0.66	0.17	491			
Stormflow	4/27/2011	1.04	0.34	1.36	0.2	0.19	61	104.3	6.74	7
Baseflow	7/19/2011	0.76	0.02	1.35	0.19	0.1	19		5.46	6.8
Stormflow	9/22/2011	3.46	0.33	1.56	0.53	0.15	255	202.4	6.09	9.93

Given these limitations, upon examining the results we do not see significant differences in water chemistry at Baldwin Park between the pre- and post-construction periods. The one exception is orthophosphate – dissolved phosphate that is available to plants and algae for uptake (in contrast to other forms of phosphate which are not). This is surprising, as we expected total phosphate to be reduced by adding stormwater BMPs and reducing erosion, not just orthophosphate (which is clearly not the majority of the total much of the time). We don't see a difference in total phosphate or suspended solids, either.

From the high conductivity readings we have reason to believe that Baldwin Park is impacted by illicit discharges or sewer cross-connections, which we do not expect stream restoration or stormwater retrofits to address. Monitoring shows a great deal of suspended solids transport during stormwater flows at both sites. With the very small amount of stormwater treatment that our BMP at Baldwin Park provides to the stream there in comparison to other untreated sources, we might conclude that this one BMP is simply not enough to address systemic watershed erosion problems. Alternatively, the site simply may not have "settled" after the considerable amount of instream construction for the restoration itself, as well as the installation of the stabilized OWASA stream ford in between the restoration area and the monitoring site. It is possible that suspended sediment is not the best constituent to monitor for issues of aquatic health or stream stability. Spot turbidity readings, rather than stormwater composites of sediment, may tell us more about conditions relevant to organisms. Stream stability may be better monitored through cross-section surveys or bank pins and scour chains.

TEMPERATURE MONITORING

Temperature monitoring started in Fall 2009 and went into Summer 2010. Temperature probes were removed for a period to download data, and then to allow construction to proceed. As it appeared construction would not happen at Mill Race tributary, we put the probe back in for a time. Before and after temperature at both Baldwin Park and Mill Race tributary are shown in Figures 7 through 10.

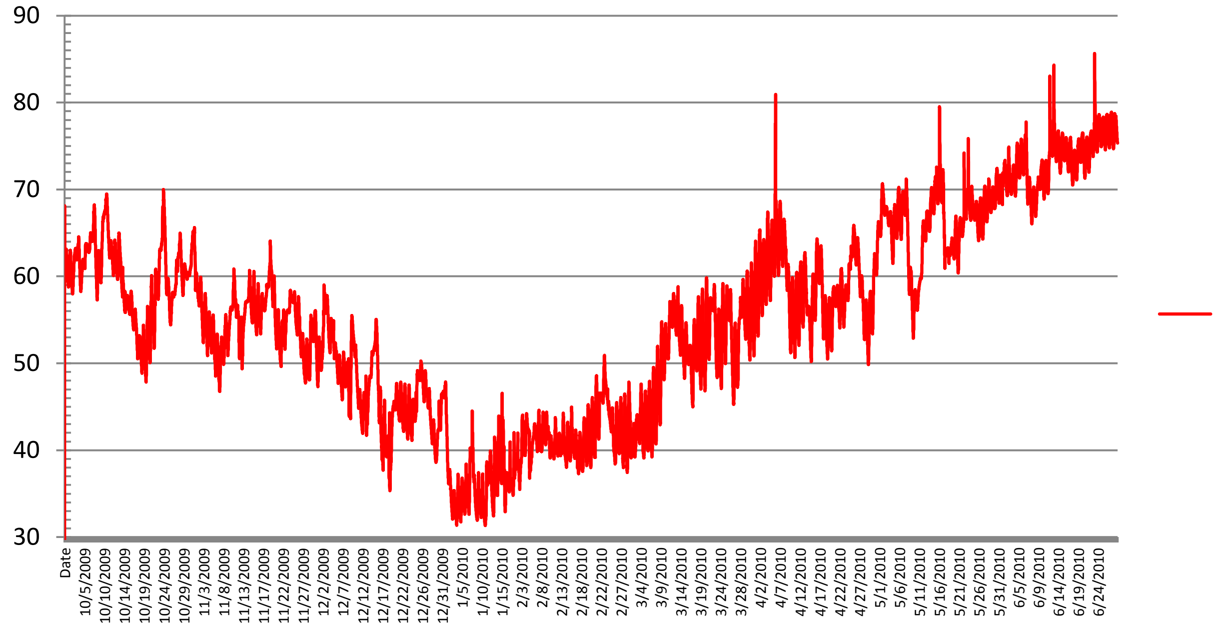


Figure 7: Baldwin Park Temperature (F) Before Construction

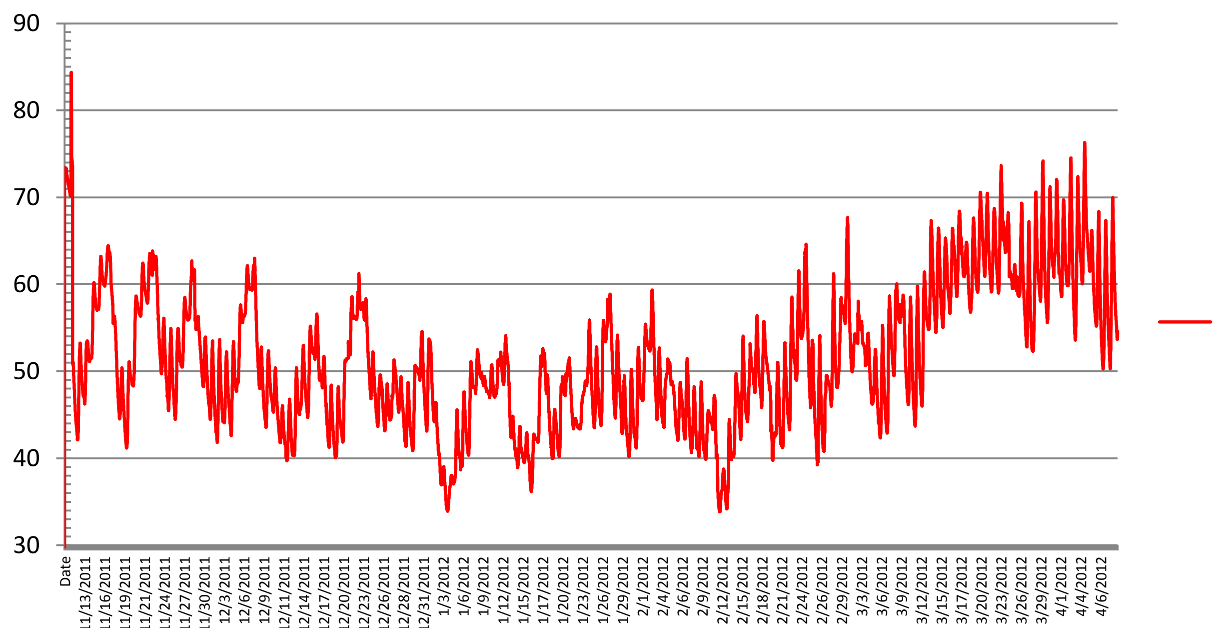


Figure 8: Baldwin Park Temperature (F) After Construction

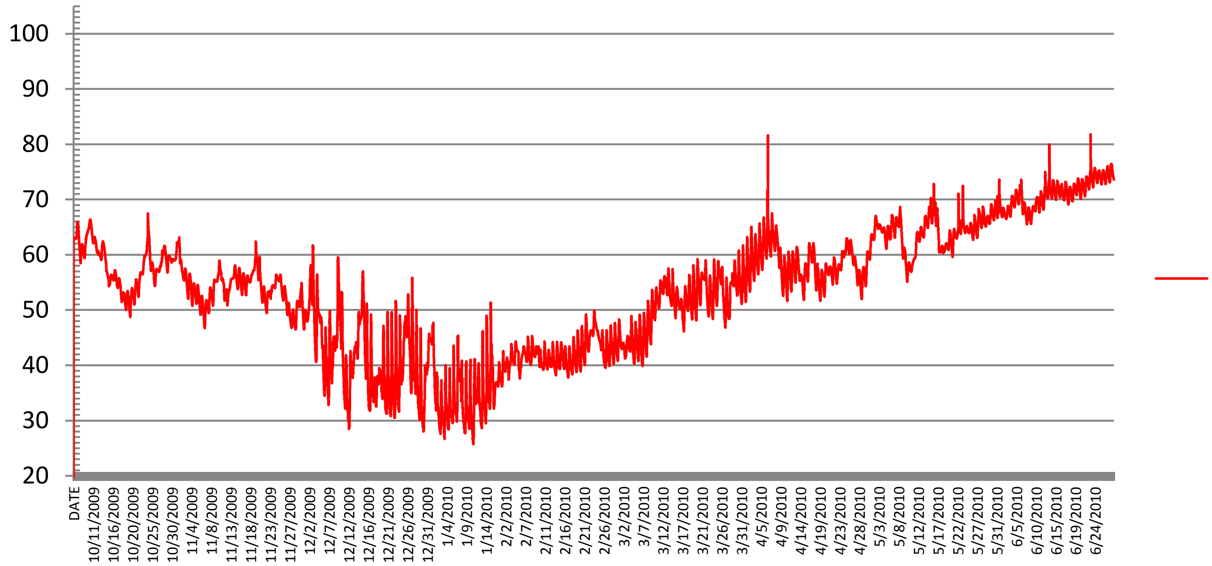


Figure 9: Mill Race Trib Temperature (F) Before Construction

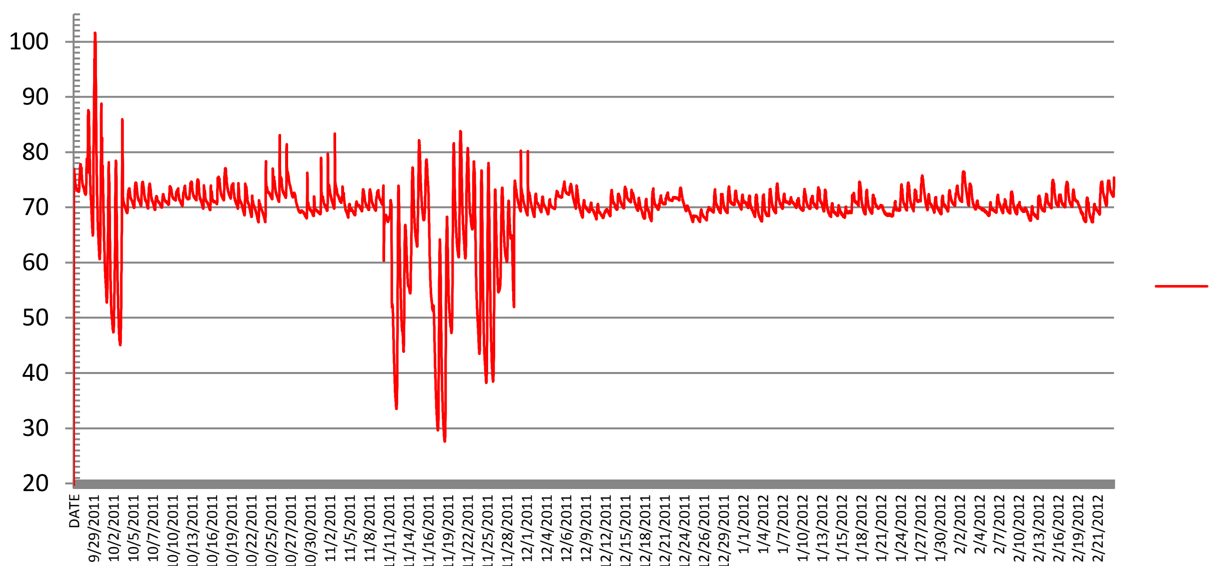


Figure 10: Mill Race Trib Temperature (F) After Planned Construction Period

RAIN GAUGE DATA

Rainfall was monitored from the beginning of the project to assist with modeling of the project subwatersheds and engineering design of the stormwater management structures (BMPs). In the following rainfall hyetograph (Figure

11, we have aggregated rainfall to total daily values. We have a brief period in late 2010 that appears to be very dry. This is when the gauge sensor's battery had run out, and reflects the time it took us to get a new one in.

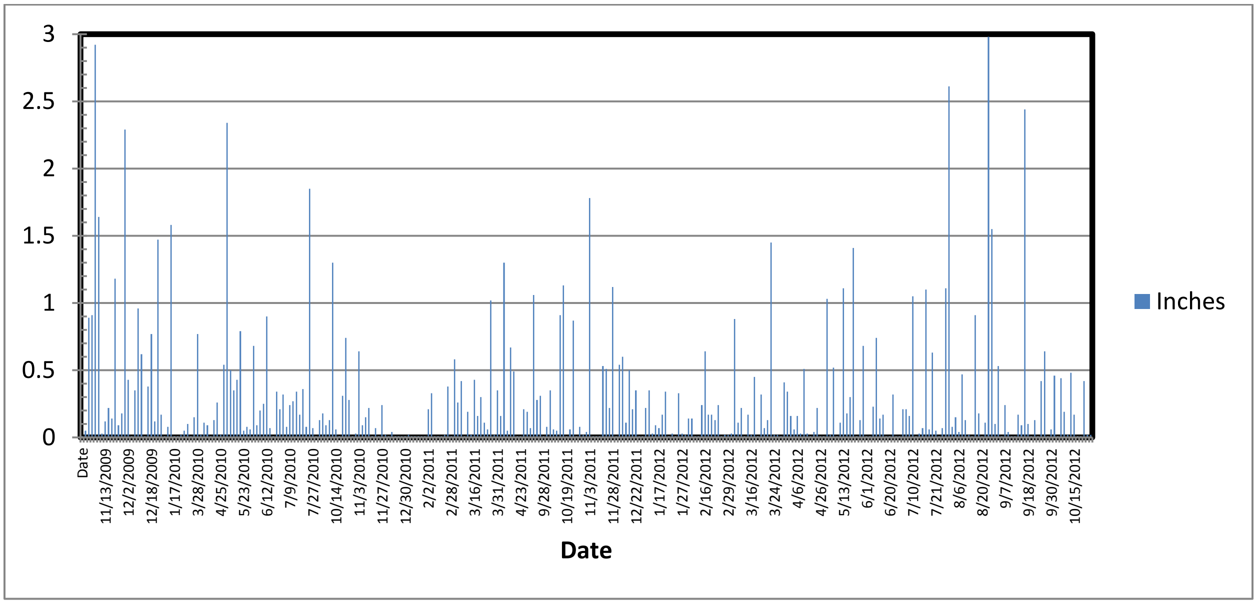


Figure 11: Chapel Hill Town Hall Rain Gauge Data

BENTHIC MACROINVERTEBRATE MONITORING

Benthic macroinvertebrates collected at the two sites are presented in Table 4. Organisms are picked out from a sample roughly in proportion to their abundance, but no attempt is made to remove all organisms. If an organism can be reliably identified as a single taxon in the field, then no more than 10 individuals need to be collected. Some organisms are not picked, even if found in the samples, because abundance is difficult to quantify or because they are most often found on the water surface or on the banks and are not truly benthic. Organisms are classified as Abundant if 10 or more specimens are collected, Common if 3-9 specimens are collected, and Rare if 1-2 specimens are collected.

Table 4: Abundance of Benthic Insects Collected from Baldwin Park and Mill Race Tributary	**Baldwin Park 2009**	**Baldwin Park 2012**	**Mill Race trib 2010**
Taxon	*Abundance*		
Ephemeroptera			
Family Baetidae			
Baetis flavistriga		**A**	
Trichoptera			
Family Hydropsychidae			
Diplectrona modesta			**R**
Cheumatopsyche spp	**A**	**A**	
Hydropsyche betteni	**A**	**R**	
Family Philopotamidae			
Chimarra sp		**R**	

Diptera			
Family Tipulidae			
Tipula spp		**R**	**R**
Family Chironomidae			
Conchapelopia group		**R**	**R**
Natarsia spp			**C**
Paratendipes spp			**C**
Cricotopus annulator group	**C**	**A**	
Cricotopus fugax		**R**	
Cricotopus triannulatus gr		**A**	
Eukiefferiella claripennis group	**A**	**C**	
Orthocladius obumbratus	**R**		
Zavrelimyia spp		**R**	
Corynoneura spp		**R**	
Coleoptera			
Family Dryopidae			
Helichus spp			**R**
Family Dytiscidae			
Hydroporus spp		**R**	**R**
Family Elmidae			
Stenelmis spp			**A**
Family Psephenidae			
Ectopria nervosa			**A**
Odonata			
Family Cordulegasteridae			
Cordulegaster spp			**R**
Family Coenagrionidae			
Argia spp		**C**	**R**
Oligochaeta			
Family Enchytraeidae	**C**	**R**	
Family Lumbricidae			
Lumbriculus spp	**C**		
Family Lumbriculidae			**R**
Family Tubificidae			
Limnodrilus spp (hofmeisteri)	**C**	**C**	
Ilyodrilus templetoni	**R**		
Family Naidiae			
Nais spp	**A**	**C**	
Slavina appendiculata		**C**	
Crustacea			
Family Gammaridae			
Crangonxy spp			**C**
Family Asellidae			

Caecidotea sp (forbesi)	**R**		
Family Cambaridae			
Procambarus acutus	**R**		
Mollusca			
Family Physidae			
Physella sp		**A**	
Abundance codes: A = Abundant, C = Common, R = Rare			

Table 5 presents the tabulated measures of biotic diversity (richness), NC biotic index score, and bioclassification based on NC DWQ's Small Streams Biocriteria:

Table 5: Diversity and Bioclassifications of Baldwin Park and Mill Race tributary

	Baldwin Park 2009	**Baldwin Park 2012**	**Mill Race trib 2010**
TOTAL TAXA RICHNESS	12	21	13
TOTAL EPT RICHNESS	2	4	1
BIOTIC INDEX	7.5	7.8	5.8
BIOCLASSIFICATION	Poor	Poor	Good/Fair

Regarding the benthic monitoring results, Dave Lenat, who did the collections at Baldwin Park noted in 2009:

> *The stream fauna indicated that this stream usually has flowing water, with hydropsychid caddisflies abundant in riffle areas. There was good rocky habitat, although there were few leaves and few good bank areas. Low taxa richness (12), low EPT taxa richness (2) and a high biotic index (7.5) all indicated Poor water quality. Only tolerant species were abundant: Cheumatopsyche, Hydropsyche betteni, Eukiefferiella claripennis group and Nais. Poor water quality is often associated with urban runoff, so this pattern is not unexpected. Restoration efforts should target improvements in water quality, as there is no evidence of existing sedimentation problems in this stream.*

Since considerable sediment was being eroded from segments upstream, we suspect that it is either being carried through or deposited upstream.

And in 2012:

> *This stream drains both residential and commercial areas, with most of the catchment in Carrboro. This site was not sampled during the regular tributary collections in the spring of 2011, but a special collection had been made in March 2009. The latter collection was to establish baseline conditions, prior to mitigation efforts near the park. Although both collections produced a Poor rating, total taxa richness increased from only 12 in 2009 to 21 in 2012; EPT taxa richness increased from 2 to 4 over the same period. The mayfly Baetis flavistriga was especially abundant in this stream segment. Although this small stream has good habitat after the mitigation project, conductivity remains very high (500+ µmohs/cm in 2012).*

We note that the specific conductivity measured at the time of sample collection was 510 µS, nearly twice as high as any of the other 20 sites sampled that year. This indicates considerable dissolved materials in the water, and is a strong indicator of illicit discharges or sewer cross-connections. However, it appears there is some marginal improvement at Baldwin Park, even though it is not enough to change the Bioclassification. On the other hand, this may be merely because 2012 was a wetter year than 2009.

Habitat was characterized using NC DWQ's methods in 2012, but not in any year prior, so we are unable to compare habitat scores over time or between these sites.

Dave Penrose, who did the collection at Mill Race tributary notes in his report:

> *The fauna was dominated by two species of beetles (Ectopria and Stenelmis) both of which are relatively tolerant. Interestingly the only EPT taxa collected from this site is an intolerant hydropsychidae (Diplectrona modesta). No mayflies or stoneflies were collected at this location. The NC Division of Water Quality (DWQ 2008) has recently developed bioclassification for small streams which is based on the biotic index values of representative taxa – UT of Bolin Creek at this location received a Good/Fair bioclassification based on these criteria.*

A site on the mainstem of Mill Race below the confluence with this tributary has consistently scored a bioclassification of Poor in both 2011 and 2012 sampling. Mill Race's tributary is clearly in much better shape and is mainly exporting a considerable amount of coarse sediment (the pea gravel and sand that is eroding in the valley). It does not appear to be exporting much fine sediment, and so may not be contributing much to the poor water quality conditions at the mainstem Mill Race site. The leads us to reconsider whether the severe erosion noted in the Mill Race tributary valley needs to be addressed in order to restore Mill Race's or Bolin Creek's water quality.

3.2 PROJECT EVALUATION

EVALUATION AGAINST MEASURES OF SUCCESS

Compared to the measures of success proposed in the grant application, how does the project measure up? Did the project elements get implemented as planned? Monitoring? Public outreach?

These were the proposed measures of success:

- Reduced export of sediment from both Baldwin Park and Mill Race tributary watersheds
- Improved instream habitat for macroinvertebrates
- Reduced levels of nitrogen and phosphorus
- Reduced maximum temperatures in stormwater
- Increased environmental interest and involvement in a lower-income population
- General education of the Towns' populations regarding stream functions, health, protection, restoration
- Demonstration to the local environmentally-oriented population of the Towns' commitment to environmental protection and sustainability
- An alternatives analysis that enables watershed restoration projects with a higher probability of success in a high-density urban area

Some of the project elements, public involvement, and monitoring did not get implemented as planned, although we did strive to implement on-the-ground projects that would have equivalent water quality benefits. In retrospect, we have learned that our project vision was simultaneously too vague in some ways and overly specific in others. This contributed to unrealistic expectations, insufficient planning, and lack of coordination. Implementing this project taught all of the project team members, even our NC DWQ team member, some very valuable lessons. These lessons are presented in a set of "Lessons Learned" in the next section, presented in a way that would have been very useful for our team to have seen prior to starting out.

There were indications of improved biological conditions at Baldwin Park, but our original monitoring methods did not pick up significant improvements. However, we have not observed any further erosion going on at Baldwin Park, and recognize that the biological community can take longer than a year to show significant improvement. As with the other project elements, implementation itself presented many opportunities for public interaction and education, and gave project members a better understanding of property owner concerns in this historically African-American neighborhood. Installation of a modified OWASA stream ford crossing was educational for both Chapel Hill staff and OWASA staff, and has opened up discussion on how to minimize geomorphic effects of stream crossing fords.

Since we did not carry out the projects at Mill Race tributary, we did not meet the measures of success for that site in particular. And because we only did pre- and post-construction monitoring for Baldwin Park, we are not able to evaluate whether the replacement projects for Mill Race tributary (Trinity Court Stream Restoration, Hargraves Fire Lane, Dickerson Court Bioretention, or Mitchell Lane Bioretention) resulted in any physical, chemical, or biological changes in receiving waters downstream. However, two of these replacement projects drain directly to Tanyard Branch. The installation of new stormwater management in this built-out area is supported by the results of the Tanyard Branch Alternatives Analysis, which encourages both the use of distributed and regional stormwater retrofits in the subwatershed to address downstream erosion.

These replacement projects were excellent opportunities for outreach to other Chapel Hill Departments and Divisions who are unfamiliar with or skeptical of stormwater retrofit and stream restoration projects. We believe this has opened up a positive and productive dialogue between Departments and Divisions and forms a good base for setting up more retrofit and restoration projects on Town property. Being on Town property in fairly public areas, where there is a lot of foot traffic, these sites offer a better opportunity for public outreach and education than the Mill Race tributary project elements would have. The Mill Race project elements were all situated in property owners' back yards in a deep valley, affording no opportunities for public education beyond the property owners themselves. Our replacement sites are getting signs installed (still in design to make sure they meet the needs of the affected departments), which allows us to share our message passively, rather than requiring tours and other direct staff involvement.

For the Watershed Restoration Plan, we did not have any measures of success other than those related to public education. While the process of writing the Watershed Restoration Plan was difficult due to distraction and division, we now have a very thorough and directed Watershed Restoration Plan for the watershed. Our interactions with the public and environmental organizations have taught us we must place greater emphasis and effort on public outreach and involvement. Our completely unplanned but necessary Situation Assessment told us much more about public attitudes than we could have learned even through direct interaction with the interviewed stakeholders. A third party provided neutrality that we could not. We definitely increased environmental interest and involvement as measured by the amount of interaction we had with Friends of Bolin Creek, the Situation Assessment itself, and the events that had increasing attendance as the project progressed. We have definitely demonstrated to local environmental organizations and environmentally-minded citizens that the town has a commitment to environmental protection and sustainability. We have begun the process of educating the general public on water resources in general, only touching on stream health and functions. In this regard we have a lot more work to do, as this project only interacted with a comparatively small portion of the general public.

We have an excellent alternatives analysis for Tanyard Branch that is serving as the foundation for watershed restoration implementation steps for Chapel Hill that are described in the Watershed Restoration Plan. This study, and the benthic macroinvertebrate monitoring done over the past few years, has crystallized our focus. It suggests that tackling the most degraded streams for comprehensive subwatershed-scale restoration is probably the most effective way to improve Bolin Creek's overall biological health, even though with such high land use intensities such projects will be extraordinarily challenging.

Overall, we do consider the project a success, even if it did not turn out as planned. We have learned a great deal about stream restoration and stormwater retrofit project planning, siting, design, and implementation; things even our professional staff engineers were unfamiliar with. Interaction with different stakeholders and parts of the public has shown us new dimensions on public attitudes that we would not have known about otherwise, including strongly negative feelings and attitudes unrelated to environmental issues that the Towns should pay better attention to. We now have a much better understanding of the kinds and depth of public resistance and support we can anticipate for future projects. We have learned the limitations and boundaries of our own organizations, but also developed deeper cooperation and communication. Environmental organizations that would partner with us now have a better understanding of what they are asking of us, and what environmental objectives are more realistic than others. These experiences will serve us very well as we start down the path of implementing our Watershed Restoration Plan.

GRANT BUDGET SUMMARY

The total proposed project cost was $632,320. The amount of 319 Funds requested was $369,792. The proposed match amount was $185,200 in-kind and $77,328 cash, for a total of $246,528, provided by the Towns of Chapel Hill and Carrboro, NCSU's Water Quality Group, the Friends of Bolin Creek, and the NC Ecosystem Enhancement Program. Match consisted of staff time, installation of demonstration projects, monitoring, website and outreach, reports, project administration, and NC EEP preservation/restoration activities.

Actual total expenditures were a total of $737,826.89, including additional local match activities as described below, including the installation of a USGS real-time stream gage on Bolin Creek. The cost split was 48.65% federal funds, 51.35% non-federal.

Table6 summarizes the actual and budgeted amounts of cash and in-kind match funds.

Table 6: Actual and Budgeted Cash and In-Kind Match Amounts		
	Actual	**Budgeted**
Total	*$378,863.89*	*$262,528.00*
Cash	*$87,049.37*	*$77,328.00*
In-kind	*$291,814.52*	*$185,200.00*

Appendix 13 presents final federal and non-federal expenditures broken out by quarter, expenditure type, and the total amount.

MATCH AMOUNTS AND DISCREPANCIES

In preparing our grant application, we were encouraged to include all water quality activities in Bolin Creek watershed as match amounts. On the other hand, we were not advised well on how much staff time implementation would consume or how to budget cash versus in-kind match amounts. Thus, our original match amounts were weighted heavily towards tasks other than project implementation, and our actual match expenditures were weighted much more towards salary and benefits for staff. This also meant that if we spent more in match during the project period that the total project cost would go up. This is an unfortunate side-effect of using activities not part of project implementation as match in this way.

At the time, Chapel Hill staff were doing water chemistry monitoring, and had originally planned on three years of water chemistry monitoring match, $7200 total. In actuality, $10,082.95 was spent for two years of macroinvertebrate monitoring in the watershed, and $2691.50 was spent for water chemistry monitoring.

Similarly, Carrboro's initial match estimate for water chemistry was $5700, and $18,000 for macroinvertebrate monitoring. Their actual match amounts for benthic monitoring were $21,900 and $1350 for water chemistry.

NCSU had originally pledged $45,000 as an in-kind match. In initial cost calculations, project staff mistakenly subtracted this from NCSU's estimate of project engineering and construction costs. NCSU had given us the engineering and construction estimate with the match amount already subtracted, meaning our budgeted amounts in our initial contract were incorrect. As it turns out, NCSU contributed $60,000 as an in-kind match.

NC EEP had originally pledged $20,000 in Bolin Creek preservation work. However, by Summer 2011 we were uncertain NC EEP would be able to cover their match, as they were having great difficulty finding project sites. This need to cover their match amount figured into Chapel Hill's decision to use our own crew for some of the Mill Race tributary replacement projects.

In the process of developing our budget, our original subproject budget breakdown (including monitoring, supplies, educational labor and materials, gas, etc.) was approximately:

Administration and contingency:	$42,550
Watershed Plan:	$50,400
Alternatives Analysis:	$50,000
Baldwin Park:	$229,160
Mill Race tributary:	$198.260
Carrboro rain gardens:	$11,050

Calculating actual costs for each part is somewhat more complicated. We did not have a budget item for Town staff labor devoted to implementing Baldwin Park or Mill Race tributary elements. Hence, these wound up being recorded as "Administration." When more Chapel Hill staff were brought in to implement the replacement projects for Mill Race tributary, it did not make sense to mark these as "administration," so these were logged in the same cost category that NCSU match amounts were.

NCSU's match amounts as well as the invoiced contract amounts were also confused by not being clearly tied to particular project elements. Hence, NCSU match amounts were divided evenly between Baldwin Park and Mill Race tributary until 2012, when all NCSU activity at Baldwin Park was truly complete. Furthermore, with $15,000 more contributed in match, it is difficult to know which project element this was spent on. The invoiced contract work suffered the same problem.

There were some specific issues with 319 budgeting and expenditures tracking that tripped us up. The contracting arrangement with NC DWQ required that the Town spend no less than 10% of the 319 funds in the very last quarter of the project, rather than spend it earlier and wait to be reimbursed the last 10% until after the final report was submitted. Attempts to clarify indicated the issue was when 319 funds were *spent*, not when they were *reimbursed*. This was very confusing, as we were using 319 funds for engineering and construction services provided by NCSU. If our project was being executed on time, this meant our design and construction would be completed well before the last quarter. To meet this unexpected spending standard, we set up a payment schedule with NCSU that broke out spending approximately matching when they would be conducting which activities, but drew out payments through the last quarter, including no less than 10% of the 319 funds to be billed by NCSU in the last quarter. This greatly constrained our ability to tie specific work to specific amounts spent in a quarter, and confused just about everyone.

The grant application had estimates of 319 funds spent in each quarter to the closest 5%. We were not instructed by our NC DWQ advisor or NCSU staff on how to come up with milestones for activities or how to estimate amounts to be spent in each quarter, but it did not seem to be a problem for our application. However, when it came time to sign the contract we had to go through extensive and highly detailed revision of the milestone and planned expenditure table, estimate spending to the closest dollar (not closest 10 dollars or 100 dollars) each quarter, and calculate the quarter and cumulative expenditures to hundredths of a percent. These revised numbers were initially pulled from our fixed payment schedule with NCSU (noted above, which went to the closest $1000), but meeting the exact dollar amount took guesswork.

3.3 LESSONS LEARNED

MONITORING

- Create your QAPP prior to applying for grants to get the most out of writing it, including tight estimates of costs, equipment needs, labor needs, quality assurance sample needs, scheduling, identification of the most sensitive parameters, and exclusion of those that will not give you much information. (Treat monitoring as its own project for best results.)
- If you are monitoring a small stream, first-order perennial, intermittent, or ephemeral, consider the installation of a weir to help you measure the smallest flows and provide a pool for your pressure transducer. This has the benefit of giving you a verifiable level that is truly zero flow. This will also allow you to calculate discharge much more reliably for such small streams than trying to measure using a flow meter. The flow meter approach works better on second- to third-order streams where you can find a good control point.
- Select the simplest monitoring approach you can that focuses tightly on the most important, and encompassing, characteristics that are likely to detect what you are most interested in. (Or, contract out for monitoring work to minimize time requirements for project staff.)
- In a three-year grant period you are unlikely to get sufficient pre-construction and post-construction monitoring data where statistical significance or high variability is an issue, such as for water chemistry or flow/discharge.
- In a three-year grant period it is unlikely (but possible, as we learned in our case) that the macroinvertebrate community will have recovered from construction stressors enough to detect improvement. Sample downstream of the project area rather than at the project area.
- Use simpler, more approximate, methods to calculate discharge at very high flows rather than trying to measure discharge directly, unless high data quality is required to detect statistically significant changes. Contract out if higher data quality is required.
- Bank pins are good to use ahead of project proposal and design to get a quantitative measurement of bank erosion, especially in places where you have considerably instability. They are not so useful for monitoring bank erosion after construction if bank or channel reshaping is part of the project. In that case, it is better to get several as-built cross-sections surveyed and resurvey them once a year.
- Ideally, conduct monitoring on tributaries or below areas most likely to receive a stormwater retrofit or stream restoration for a few years prior to applying for a grant to install those projects. This information will get you started faster on engineering design and give you more information to compare post-construction conditions to. A Watershed Restoration Plan can help you identify those tributaries and areas so you can set up a targeted long-term monitoring program. It can also help you better quantify present stressors and their severity, and better quantify expected water quality improvements from a project.

EDUCATION AND OUTREACH

- Set up a list of people who should be privy to the excruciating details of implementation. This should include your potential utility contacts, property owners, contractors, anyone directly affected by the activity, and anyone else who might have advice for or be critical of implementation details. When in doubt add people, noting that you thought they might want to be informed of these details, and instruct them to ask you to remove them if it is too much information. Set up a simple email template to help you remember what you need to cover in each email and help readers quickly scan it for essential information such as contract number, site, project name, stage in implementation, specific questions for specific recipients, action items for recipients and when due, review of past requested/completed action items, upcoming milestones or steps, critical dates, etc. This is especially important if you are trying to coordinate the activities of many people, or there are certain people who can be a bottleneck in the process if they do not act at the right time. Optimally, set up an actual subscriber-style listserver (rather than email list) to allow participants to control how much they hear from you.

- Plan on a secondary, less information-dense, general public interest listserver or other method to less regularly (perhaps monthly) distribute updates (compared to the higher-frequency stakeholder list). At the start of the project, directly invite journalists/bloggers to subscribe and indicate the volume of email they should expect. Mirror your message across your webpage, Facebook, Twitter, and whatever other hot new social networking tool is in fashion, even phone texts. Each person has a different preferred method of receiving information. Print up business cards with an inviting description of what you are doing for all the different contact methods, then hand them out everywhere.

PLANNING AND PREPARATION

- Have tight, detailed concept plans prior to grant application. Have a clear vision of what you are proposing to construct, and what the interim steps might look like to better describe the final project and project steps to property owners. Review of a site with a fine-toothed comb may be necessary to identify potential pitfalls and problems. Get a utility locate service done when doing the concept plan. Get a professional survey done of the proposed site. Opportunities not perceived from GIS or drive-by surveys may be found when closely observing the site. Review of conditions with the property owners to identify not-easily-viewable or uncommon conditions is essential.
- Have signed construction access agreements prior to applying for a grant. Because properties can be sold in the time it takes to secure a grant for a project, research whether you can get a five-year construction access agreement that is registered with the Register of Deeds, and travels along with the property if it is sold.
- Identify whether some perpetual protection in the form of an easement is required or might be a good idea for a project. Where there is a hazard of a property owner not maintaining a BMP determine whether your organization can take on maintenance, and the property owner may grant a public stormwater easement for that purpose. Alternatively, select designs that require less maintenance or are less likely to fail. Make sure such agreements of maintenance are spelled out clearly in a binding agreement with the property owner.
- Make sure you know ALL of the project implementation steps – every detail, even if not explicitly required in the grant application. This is where a highly detailed concept plan is necessary. When you are contracting work out, review these steps with the contractor to make sure there are no unspoken or assumed steps that need to be scheduled and assigned.
- With a detailed list of implementation steps, review costs thoroughly. What is included in contract work? What outreach activities might you do? Developing a QAPP before grant application will help you in this step immeasurably.
- Contingency planning. Identify possibly pitfalls. Identify points where you have little control over what happens and have alternative plans. Property owner cooperation, weather, proper equipment functioning, cooperation of other departments or agencies, construction challenges, timing and scheduling – all can go in a way not planned on that you have little influence on. Set up an alternative

path for accomplishing deliverables to cover these cases where possible. Do include a contingency amount in your budget, but first discuss what is acceptable with the granting agency.

- Understand your contracting and procurement steps, and do the preliminary setup work for them as soon as you are notified of the grant award. This includes getting quotes, vendor tax information, contractor insurance information, contract details, prepare to setup Purchase Orders, etc.
- Identify needs and requirements of utilities in the area of your project. Find out if they have any plans in the works for that area, or even existing but unused easements. Ask their organization to assign a primary contact for you regarding your project and any activities they may have in the area. Put this person on your regular stakeholder update list.

OTHER ISSUES

- Take lots of photos, ideally, weekly (less frequently before a grant is awarded). Take them from the same locations every time to make comparison over time easier. Make it a habit to download photos immediately upon returning, and write down a short dated note of what is going on to leave in the same directory as the photos. Schedule taking photos (and a general quick site visit) into your calendar. This is especially important if you have considerable administrative or writing duties, or other ongoing projects that may distract you from the passage of time.
- Enlist someone else to take lots of photos at events so you can be open to interacting with the public, and not look busy with other things.
- Identify all steps, roles, and responsibilities of partners. Be very specific. Set out in draft Memoranda of Agreement prior to grant application, and finalized and signed before the grant period starts.
- Consider whether there are stakeholders or partners that you are leaving out, or that would feel insulted if not involved directly in the project. Ask them how they would want to be involved. Make sure their involvement is formalized in a draft Memorandum of Agreement that is signed before the grant period starts.

APPENDIX 1: BALDWIN PARK PROJECT MATERIALS

Background

Baldwin Park is a neighborhood park off Broad Street near the boundary between the Town of Carrboro and the Town of Chapel Hill. The park consists of a children's play set, picnic areas, a basketball court (scheduled for expansion), and open fields. A stream, Tanbark Branch, flows along the northern portion of the park. An unnamed ephemeral tributary of Tanbark Branch exists along the eastern boundary of the park. (Note: the NC Division of Water Quality shall determine whether the tributary is ephemeral or intermittent prior to NC and Army Corps permit submittals)

The Department of Biological and Agricultural Engineering of North Carolina State University (NCSU) is working with the Town of Chapel Hill and the Town of Carrboro to implement watershed restoration practices as a component of an EPA 319 grant project in the Bolin Creek Watershed. The purpose is to improve ecosystem health and water quality by restoring natural stream functions and managing stormwater runoff in degraded areas in the watershed.

This report outlines the conceptual stream enhancement and stormwater best management practices (BMP) design for Baldwin Park. The site has been divided into eight areas (see Figure 1). The purpose of this report is make sure town staff and local property owners are agreeable to the proposed project before the design is finalized.

Recommendations

Area 1. Two Tier Bioretention Area

A bioretention area is proposed to treat stormwater runoff generated along Broad Street. Currently, this runoff is directly discharged to Tanbark Branch through a storm sewer pipe. A bioretention area captures runoff from an impervious surface and allows that water to infiltrate through the soil media. As the water infiltrates, pollutants are removed from the stormwater runoff through a variety of mechanisms including adsorption, microbial activity, plant uptake, sedimentation, and filtration. Some of the incoming runoff is temporarily held by the soil of the bioretention area and later "leaves" the system by way of evapotranspiration, exfiltration to the ground water, or discharge from the underdrains. The construction of a bioretention system in clay type soils involves importing a sand/compost mixture (1 – 2 in/hr infiltration rate) and installing perforated underdrains within a gravel layer.

The proposed bioretention area is located in the grassy area between the basketball court and the sidewalk along Broad Street. See photograph below.

Proposed Bioretention Site

The two trees in the above photograph will have to be removed. Stormwater will be intercepted from the existing 15-inch storm sewer along Broad Street. The approximate drainage area to the storm sewer at this location is 1.2-acres (80% impervious, 20% open grassed area). There is not sufficient space in the proposed bioretention area to treat the entire first flush volume from the drainage area due to existing constraints (e.g., basketball pad and sidewalk). Therefore, an adjustable weir shall be installed in the diversion structure such that the initial portion of runoff (typically the dirtiest portion) will be diverted to the bioretention area and excess runoff can pass over the weir and remain in the existing storm sewer that discharges to the creek.

A two-tiered bioretention area will be required due to the steeper topography of the proposed location. Diverted stormwater will discharge to the upper bioretention cell. A grass spillway lined with turf reinforced matting will be designed to convey excess runoff from the upper bioretention cell to the lower cell. An overflow outlet structure will be designed to convey excess runoff from the lower cell to Tanbark Branch. Furthermore, the bioretention underdrains will tie into the overflow structure. See Figure 2 for the proposed bioretention footprint.

Area 2. Tanbark Branch – Park Property

Area 2 is located at the outfall of the main storm sewer pipe by the intersection of Broad Street and Hill Street. The property is owned by the Town of Carrboro (PIN 9778977937). The stream is labeled Tanbark Branch on the USGS map.

There is limited pool habitat in this area, very limited riparian vegetation, and the streambanks are starting to erode.

The following measures are proposed in this area. See attached Figure 3:

- Boulder plunge pool at storm sewer outfall to dissipate energy and reduce erosion downstream
- Invasive plant removal
- Native riparian planting
- Create boulder step pools to improve pool habitat
- Create a bankfull bench and reduce bank slope to stabilize the streambanks

Storm Sewer Outfall

Area 2 Facing Downstream

Area 3. Tanbark Branch - Atwaters

Area 3 is located on the property owned by the Atwaters (PIN 9778987131). The stream is currently eroding the left bank in close proximity to their house. There are two options for this area depending on what the property owner will allow.

Option 1: Leave the stream where it is, reduce the bank slope, remove invasive vegetation, and stabilize the area with coir matting and native riparian vegetation. The property owner will lose a portion of their yard to reduce the bank slope.

Option 2: Relocate the stream away from the eroding bank. Create a new and stable bankfull channel in the floodplain adjacent to the existing channel. Stabilize the area with coir matting and native riparian vegetation. Fill the abandoned channel with material generated onsite. See attached Figure 4.

Area 3 Eroding Streambank

Area 4. Tanbark Branch - Safavis

Area 4 is located on the property owned by the Safavis (PIN 9778987139) and extends to the confluence with the unnamed tributary. The stream is fairly stable in this area. Only invasive vegetation management and native riparian planting are proposed for this area. See attached Figure 4.

Area 4 View Facing Downstream

Area 5. Tributary – Masons & Burnetts

Area 5 is located on the properties owned by the Masons (PIN 9778988271) and the Burnetts (PIN 9778989009) and extends up the unnamed ephemeral tributary approximately 90 feet from the confluence with Tanbark Branch to an existing sewer crossing. The existing channel has been filled with debris and needs to be reshaped to a stable bankfull channel. Invasive vegetation management and native riparian planting are also proposed for this area. See attached Figure 5.

Nothing is proposed for the existing rip rap sewer crossing as OWASA requires this area to remain open and passable for their service vehicles.

Area 5 View Facing Downstream

Area 6. Tributary –Burnetts

Area 6 is located on the properties owned by the Burnetts (PIN 9778989009). The stream is currently eroding the right bank in close proximity to a garden. There are two options for this area depending on what the property owner will allow.

Option 1: Leave the stream where it is, reduce the bank slope, and stabilize the area with coir matting and native riparian vegetation. The property owner will lose a portion of their garden to reduce the bank slope and for riparian plants.

Option 2: Relocate the stream away from the eroding bank. Create a new and stable bankfull channel in the floodplain adjacent to the existing channel. Stabilize the area with coir matting and native riparian vegetation. Fill the abandoned channel with material generated onsite. This option will require relocating the existing footbridge. See attached Figure 6.

Area 6 View Facing Downstream

Area 7. Tributary - Head Cut

Area 7 is located upstream of Area 6. The stream is located close to the property line of the Town of Carrboro park parcels and five Chapel Hill residential properties off Bynum Street. A small head cut is located in this portion of the stream. The area downstream of the head cut is slightly incised. The area upstream of the head cut is currently stable and will not be modified, except for invasive plant removal and riparian planting. See attached Figure 7.

The following measures are proposed in this area:

- Add some fill below the head cut to bring up the downstream portion of the channel and create a stable slope. Create boulder step pool system to stabilize the channel in the head cut area.
- Create a bankful bench where the channel is incised
- Invasive plant removal
- Native riparian planting

Additionally, a footpath leading to the stream in this area will be hardened with a combination of gravel and filter fabric to reduce trail erosion and sedimentation downstream. A small footbridge is proposed where the path crosses the stream.

Area 7 View of Head Cut Facing Upstream

Area 7 Trail Crossing

Area 8. Energy Dissipation Basin

Area 8 is located in the most upstream portion of the tributary within the Baldwin (PIN 9788070468) and St. Joseph Christian (PIN 9778979579) properties. The stream is daylighted from a 30-inch culvert at this point and takes a 90-degree turn. There are also two sewer crossing in this area.

The proposed enhancement for this area is to relocate the existing stream to a rock lined energy dissipation basin. The basin would be planted with a native juncus for stabilization and stormwater treatment. The purpose of the basin is to slow down stormwater flow, dissipate energy, and remove sediment to prevent degradation of the downstream restored sections. The new alignment would also avoid the two sewer crossings. Additionally, a swale will be designed to transport runoff to the basin from an existing 15-inch stormwater pipe outfall at the turn on Starlite Drive. See attached Figure 8.

Area 8 View from 30-inch Culvert Outfall

Figures

DRAWING NO.
SHEET NO.
FILENAME
PROJECT NO.
DATE 09/14/09

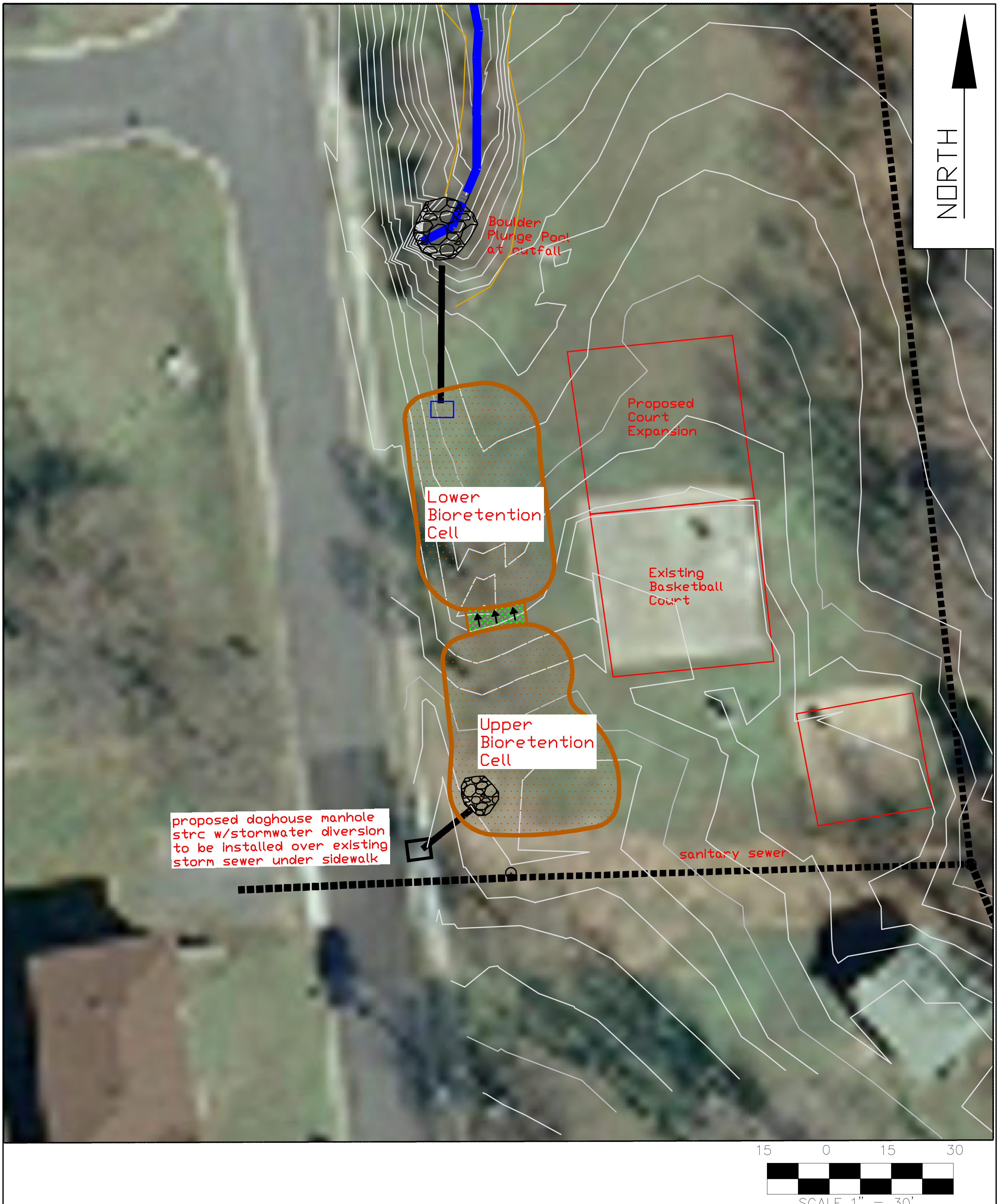
Conceptual Design
Baldwin Park
Carrboro, N.C.

FIGURE 1
SITE LOCATION MAP

NC STATE UNIVERSITY

BIOLOGICAL & AGRICULTURAL ENGINEERING
Weaver Labs Campus Box 7625
North Carolina State University
Raleigh, NC 27695

NO	REVISIONS	DRN	CHK	DATE



DRAWING NO.	SHEET NO.	FILENAME	PROJECT NO.	DATE 09/14/09

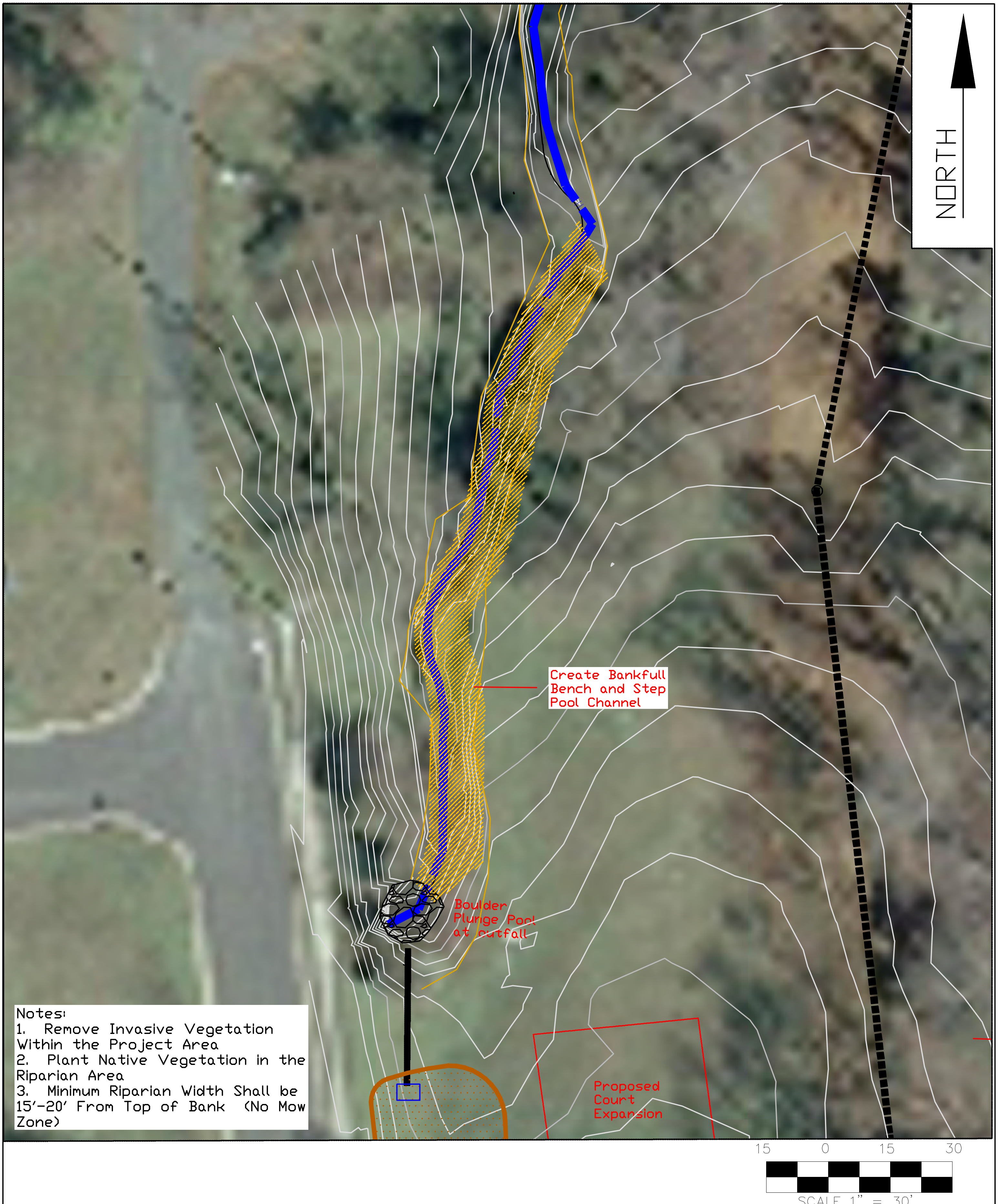
Conceptual Design
Baldwin Park
Carrboro, N.C.

FIGURE 2
AREA 1

NC STATE UNIVERSITY

BIOLOGICAL & AGRICULTURAL ENGINEERING
Weaver Labs Campus Box 7625
North Carolina State University
Raleigh, NC 27695

NO	REVISIONS	DRN	CHK	DATE



Notes:
1. Remove Invasive Vegetation Within the Project Area
2. Plant Native Vegetation in the Riparian Area
3. Minimum Riparian Width Shall be 15'-20' From Top of Bank (No Mow Zone)

DRAWING NO.	SHEET NO.	FILENAME	PROJECT NO.	DATE
				09/14/09

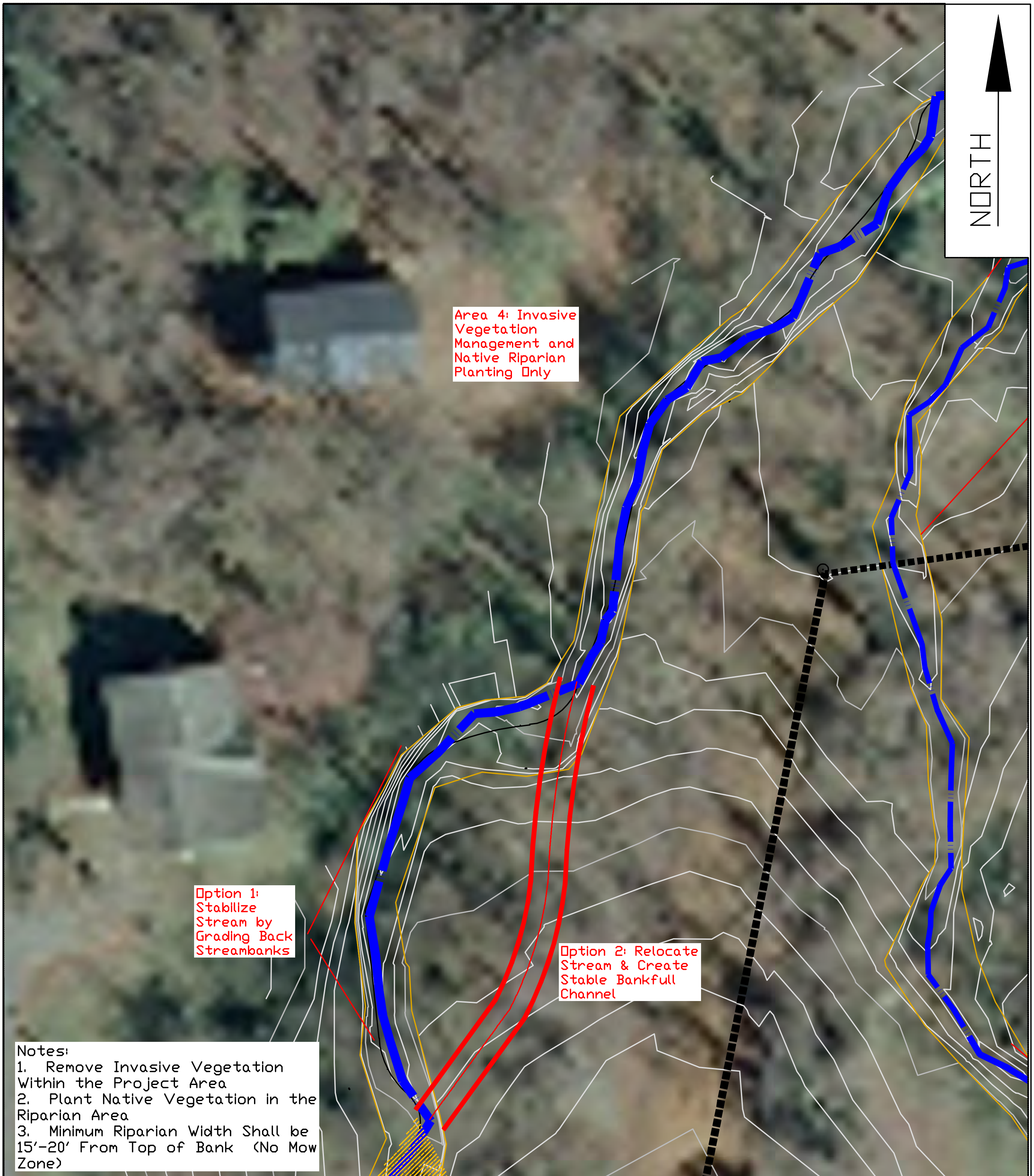
Conceptual Design
Baldwin Park
Carrboro, N.C.

FIGURE 3
AREA 2

NC STATE UNIVERSITY

BIOLOGICAL & AGRICULTURAL ENGINEERING
Weaver Labs Campus Box 7625
North Carolina State University
Raleigh, NC 27695

NO	REVISIONS	DRN	CHK	DATE



15 0 15 30

SCALE 1" = 30'

DRAWING NO.	SHEET NO.	FILENAME	PROJECT NO.	DATE
				09/14/09

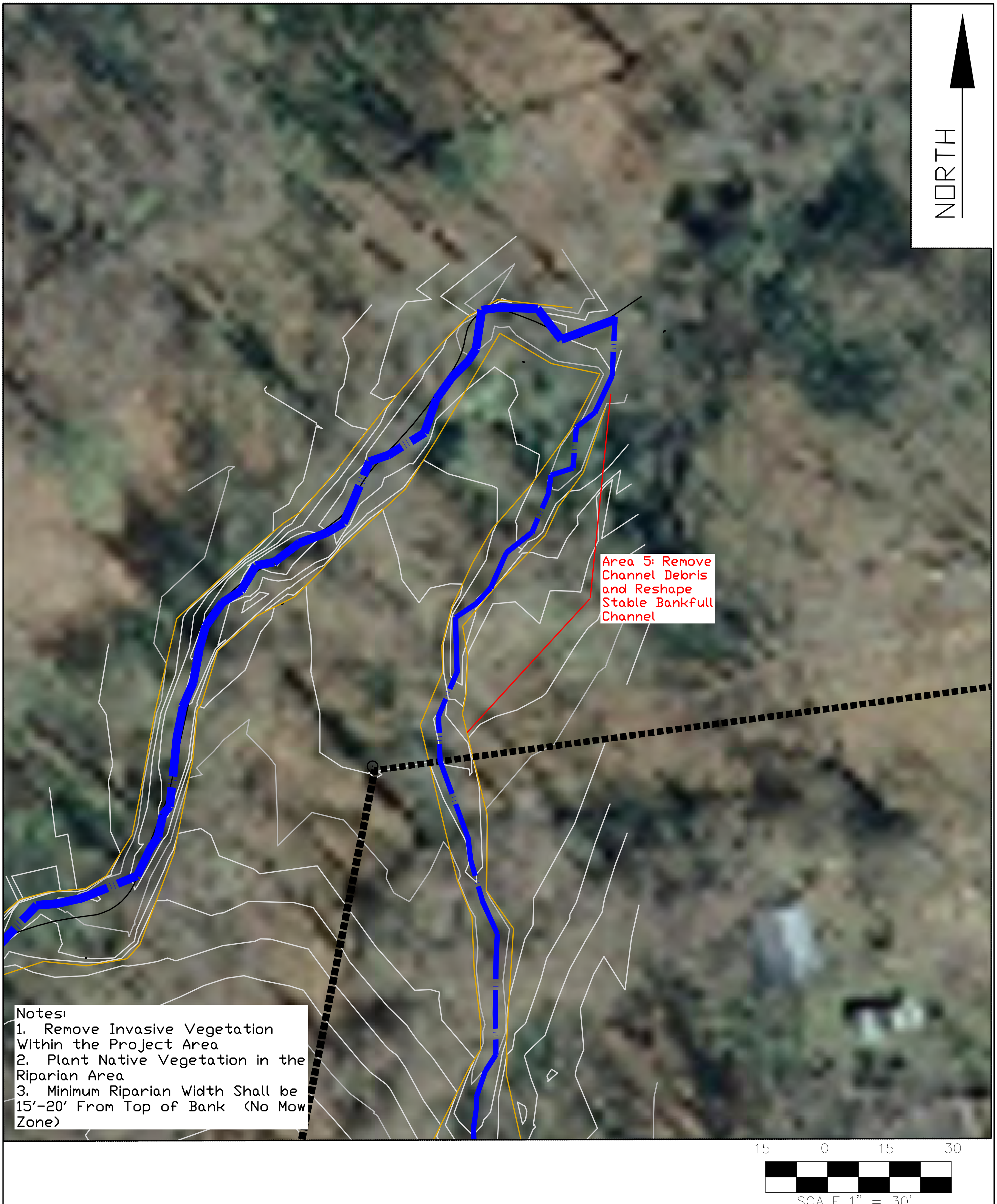
Conceptual Design
Baldwin Park
Carrboro, N.C.

FIGURE 4
AREA 3 & 4

NC STATE UNIVERSITY

BIOLOGICAL & AGRICULTURAL ENGINEERING
Weaver Labs Campus Box 7625
North Carolina State University
Raleigh, NC 27695

NO	REVISIONS	DRN	CHK	DATE



DRAWING NO.
SHEET NO.
FILENAME
PROJECT NO.
DATE 09/14/09

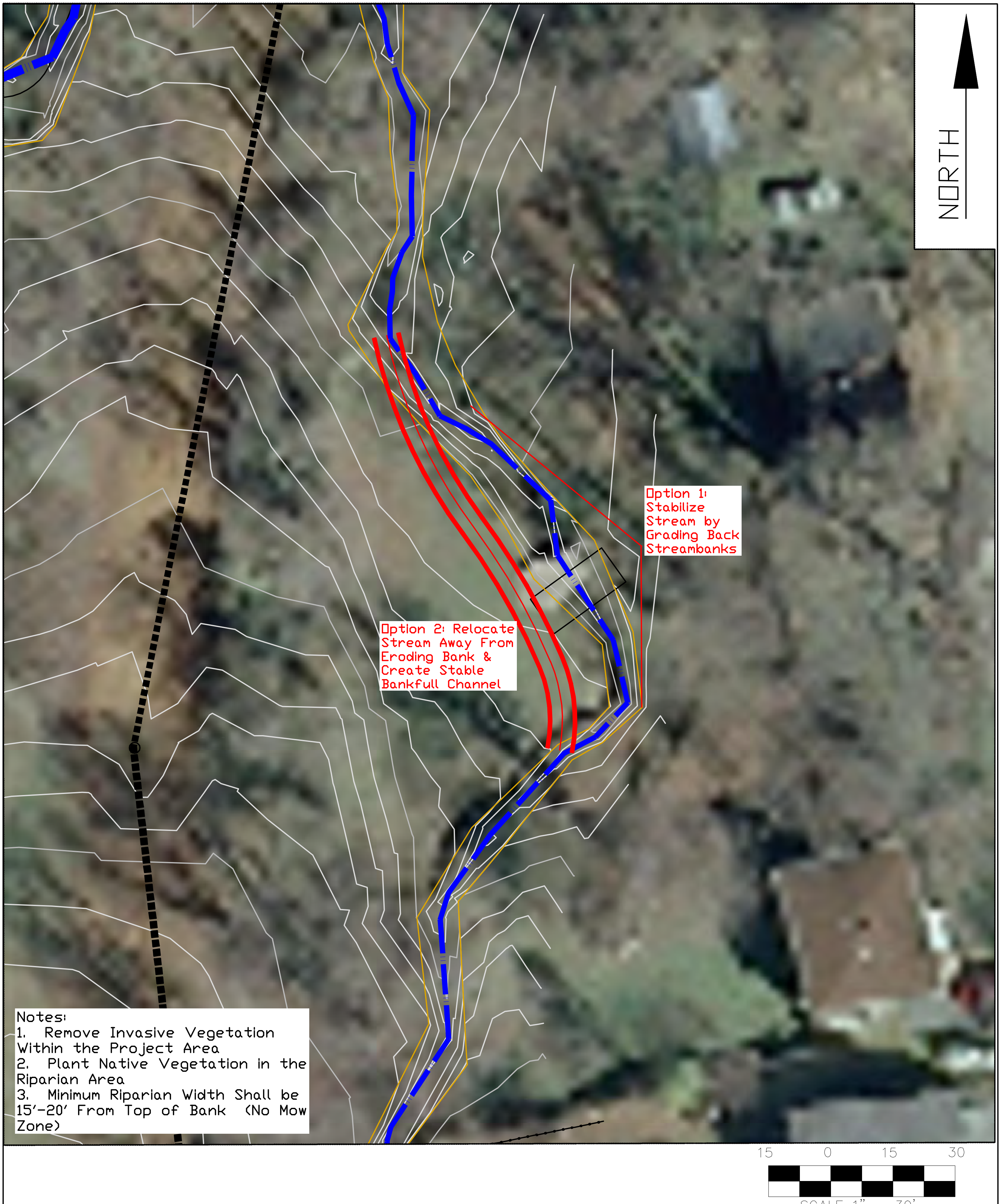
Conceptual Design
Baldwin Park
Carrboro, N.C.

FIGURE 5
AREA 5

NC STATE UNIVERSITY

BIOLOGICAL & AGRICULTURAL ENGINEERING
Weaver Labs Campus Box 7625
North Carolina State University
Raleigh, NC 27695

NO	REVISIONS	DRN	CHK	DATE



DRAWING NO.	SHEET NO.	FILENAME	PROJECT NO.	DATE 09/14/09

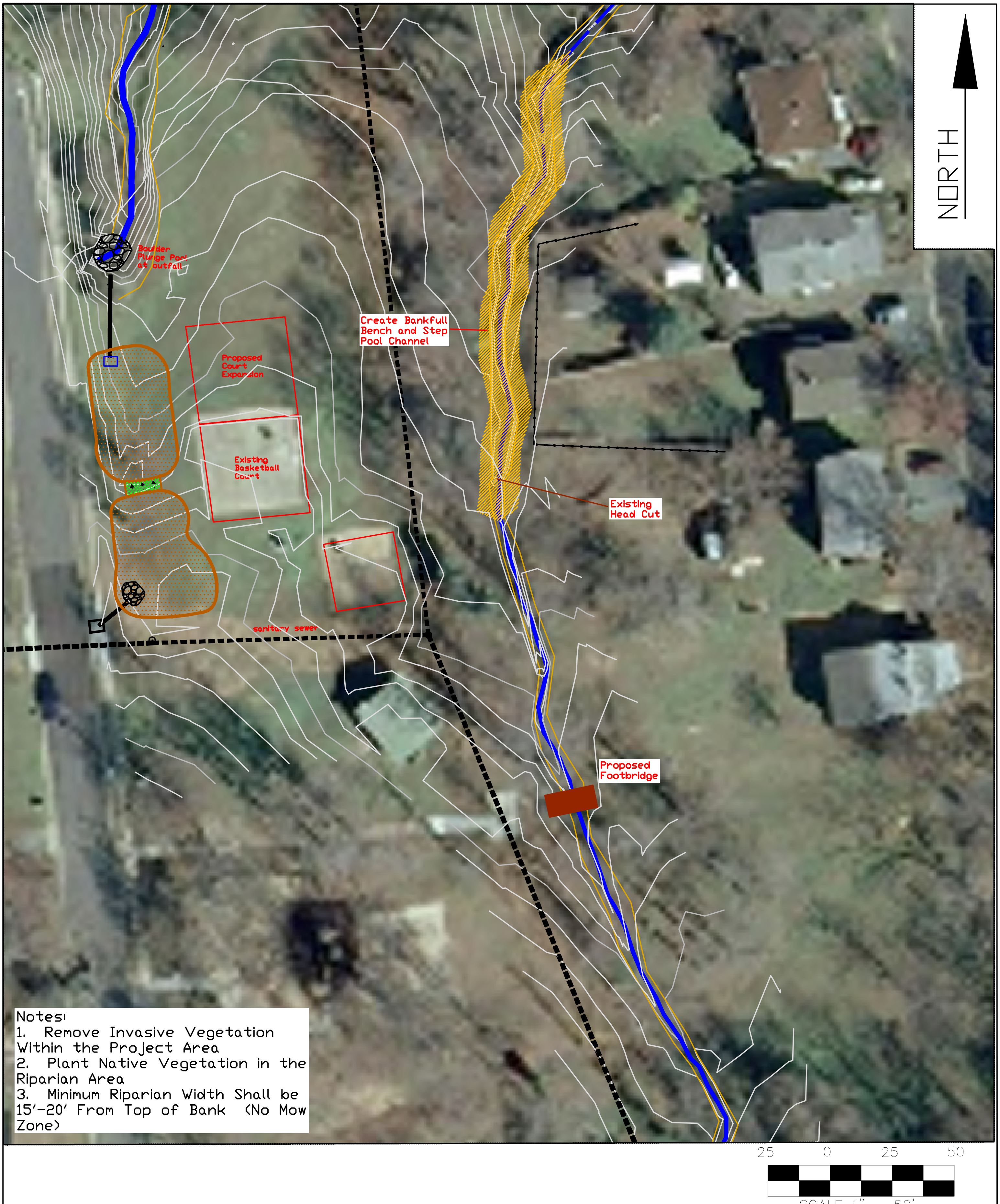
Conceptual Design
Baldwin Park
Carrboro, N.C.

FIGURE 6
AREA 6

NC STATE UNIVERSITY

BIOLOGICAL & AGRICULTURAL ENGINEERING
Weaver Labs Campus Box 7625
North Carolina State University
Raleigh, NC 27695

NO	REVISIONS	DRN	CHK	DATE



DRAWING NO.	SHEET NO.	FILENAME	PROJECT NO.	DATE 09/14/09

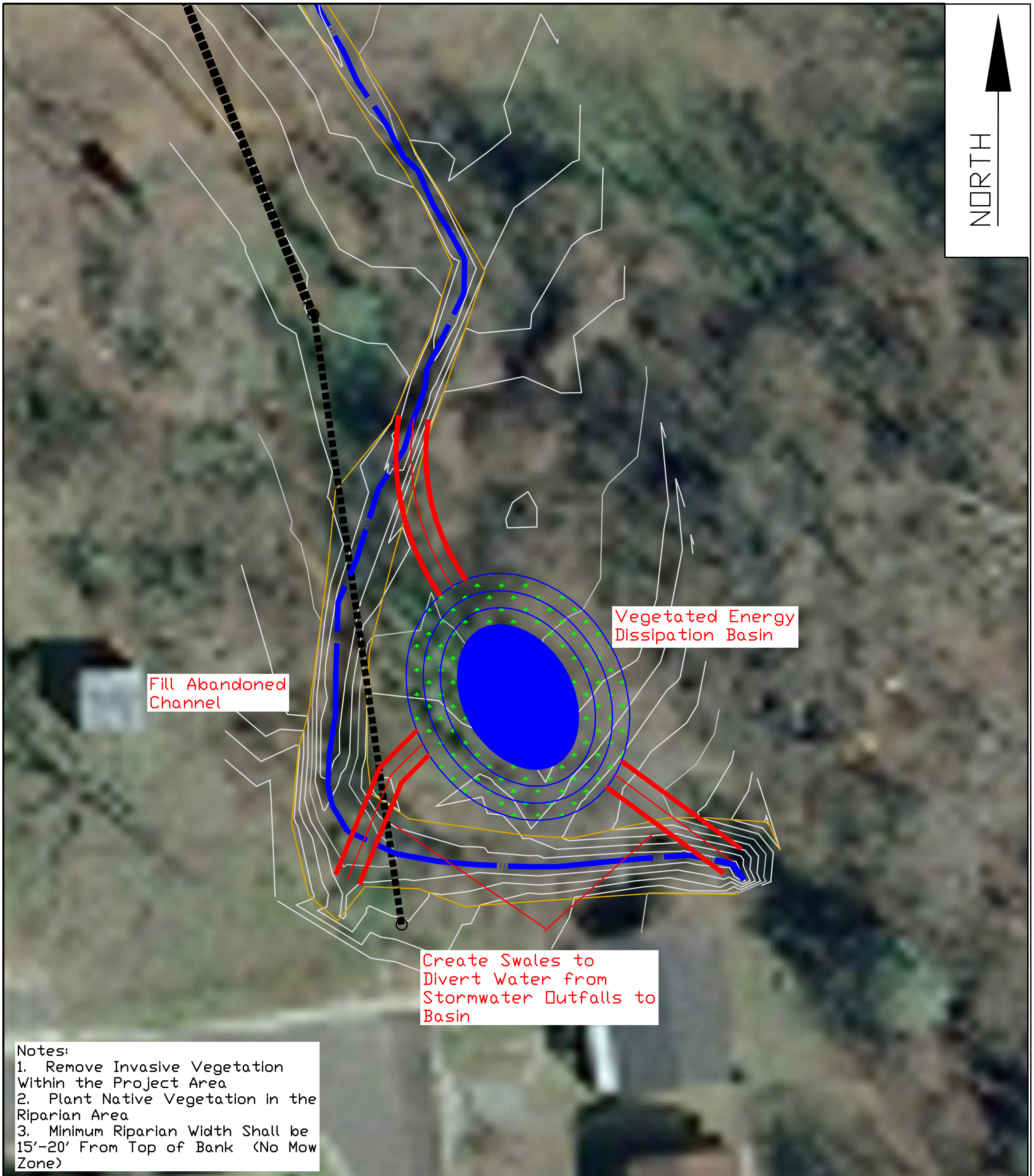
Conceptual Design
Baldwin Park
Carrboro, N.C.

FIGURE 7
AREA 7

NC STATE UNIVERSITY

BIOLOGICAL & AGRICULTURAL ENGINEERING
Weaver Labs Campus Box 7625
North Carolina State University
Raleigh, NC 27695

NO	REVISIONS	DRN	CHK	DATE



15 0 15 30

SCALE 1" = 30'

DRAWING NO. | SHEET NO. | FILENAME | PROJECT NO. | DATE 09/14/09

Conceptual Design
Baldwin Park
Carrboro, N.C.

FIGURE 8
AREA 8

NC STATE UNIVERSITY

BIOLOGICAL & AGRICULTURAL ENGINEERING
Weaver Labs Campus Box 7625
North Carolina State University
Raleigh, NC 27695

NO	REVISIONS	DRN	CHK	DATE

Baldwin Park Rain Garden Design
Carrboro and Chapel Hill, NC
Designer, Zan Price, PE, Extension Associate, NCSU

Site Suitability

Overall, the site appears to be conducive for rain garden placement.

Terrain: Carrboro staff identified a potential rain garden site on the western portion of the property between an existing basketball court and Broad Street. The terrain in this area is gently sloped toward the creek (Tanbark Branch). The site is confined by the basketball court and proposed court expansion to the east, sanitary sewer to the south, sidewalk to the west, and creek to the north.

Existing Vegetation: The proposed area is grassed and two medium sized trees are located within the proposed footprint of the garden. These trees will have to be removed and can potentially be used in the stream enhancement portion of the project.

Education Opportunities: Since the proposed site is a public park, there are lots of opportunities to educate the public on stormwater. An interpretive sign shall be placed adjacent to the garden to inform the public about raingardens.

Water Table: Based on baseflow water levels in the adjacent stream, it appears the seasonally high water table is approximately eight feet below the proposed top of the rain garden. It is recommended that the water table not be within two feet of the bottom of the constructed rain garden. This will allow for at least a three foot rain garden depth plus a gravel underdrain layer.

Runoff Availability: Currently, the proposed area does not receive much stormwater runoff. However, a buried 15-inch stormwater pipe is located under the sidewalk adjacent to the proposed rain garden. This stormwater pipe drains Broad Street through a series of curb inlets. To get runoff to the garden, a diversion structure will be installed over the existing stormwater pipe to divert runoff to the garden. Since the area available for the garden is likely not large enough to treat the entire drainage area, an overflow weir shall be installed in the structure to allow larger runoff events to bypass the area.

Maintenance/Access: Maintenance will be a crucial part of the overall effectiveness of the rain garden. As part of a park system, site maintenance should be available. Access for construction equipment also appears to be acceptable.

Design Summary

The design of the rain garden area (bioretention) at the site consists of the following general steps, which are detailed in the subsequent section.

1. Determine watershed size and characteristic
2. Determine volume of runoff to catch
3. Determine size of bioretention area
4. Set bio-retention area depth and soil type
5. Size underdrain and gravel envelope
6. Assign an overflow device
7. Choose vegetation and a planting plan
8. Construction Sequence
9. Maintenance Schedule

Baldwin Park Rain Garden Design
Carrboro and Chapel Hill, NC
Designer, Zan Price, PE, Extension Associate, NCSU

Design Procedure and Results

Determine watershed size and characteristic: Based on the site map and aerial photography, the watershed draining to the proposed bio-retention area is approximately 50,283 square feet (1.2 acres). The drainage area consists of approximately 53% impervious (i.e. road and sidewalk) and 47% residential (average lot ¼-acre). Based on information obtained from an area soil map, the majority of the drainage area consists of an Iredell soil type, which is a SCS hydrologic soil group D.

A curve number of 98 is appropriate for the impervious portion of the watershed and a curve number of 87 is appropriate for the residential portion of the watershed (residential ¼ acre lots, soil group D).

Determine volume of runoff to catch: Given the goal of improving water quality, the first flush rainfall depth, or one inch, is chosen as the design storm. Using a curve number of 98 and a precipitation depth (P) of 1.0 inches, the runoff can be calculated as $(P – 0.2 S)^2 \div (P + 0.8 S)$, where $S=(1000\div CN) – 10$. The resulting runoff depth is 0.79 inches.

Using a curve number of 87 and a P of 1.0 inches, the resulting runoff depth is 0.22 inches.

The total volume of runoff is equal to [(0.79 inches) * (50,283 square feet) * 53%] + [(0.22 inches) * (50,283 square feet) * 47%], or 26,253 square foot inches. Thus, the total volume of runoff to treat is equivalent to 2,188 cubic feet.

Determine size of bioretention area: The storage volume of the bioretention area shall be 2,188 cubic feet to capture runoff from 1-inch of rain. An initial ponding depth of 9 to 10 inches is typical of those assigned to bioretention areas. A 10-inch ponding depth will be used here. Thus, the required surface area is (26,253 square feet inches) / (10 inches), or 2,625 square feet. A review of the site plan indicates that the maximum rain garden area available is approximately 1,830 square feet. This is due to the existing site constraints listed above and the existing terrain to obtain 3:1 or flatter side slopes.

The available area is 70 percent of the area needed to store the design storm. However, the method used to determine the bioretention area is a conservative approach as it assumes no infiltration at the beginning of the storm. Therefore, the available area should be able to treat greater than 70 percent of the 1-inch rain runoff. The diversion structure shall be equipped with an adjustable weir so excess runoff can remain in the existing storm sewer and bypass the rain garden. Additionally, the rain garden will be equipped with an overflow structure and emergency spillway.

Set bio-retention area depth and soil type: The onsite soil consists mostly of clay, which should not be used in the rain garden. Thus, soil will be excavated from the site to the design depth and subsequently backfilled (after the placement of underdrain and gravel envelope) with the recommended mix of 85-88% sand, 8-12% silt and clay, and 3-5% organic matter. This soil mix should not be imported from an agricultural site, and should be tested for nutrient concentrations prior to use. Specifically, the P-index for the imported soil should be between 10 and 25. Imported soil should have a permeability of 1-2 inches per hour.

The design depth is based on the project goals and on the type of vegetation required. With the exception of nitrogen removal, water quality benefits generally occur in the top 18 inches of the rain garden. However, aesthetics are important to the park, so plantings of shrubs will be recommended. Shrubs require at least 30-36 inches of rain garden depth. Thus, media depth of the rain garden is set to 36 inches, which will also help with nitrogen removal. This depth is greater than two feet above the maximum water table depth.

The water drawdown rate can be calculated using Darcy's equation, $Q = (2.3 * 10^{-5}) * K * A * \Delta H/\Delta L$, where K is the hydraulic conductivity of the soil, A is the surface area, ΔH represents the driving head of the water, and ΔL represents the fill media depth. K is assumed to be 1 inch per hour, which represents the minimum allowed hydraulic conductivity of the soil; A is 3952 square feet, and ΔH/ΔL is set to equal 1 for simplicity. Assuming an initial 10 inch ponded depth of water, the time required to draw water down to two feet below the surface is found in the following manner:

- Find drawdown rate using Darcy's equation: $Q = (2.3*10^{-5})*1*1830*1 = 0.04$ cfs
- Determine ponded volume to drawdown: V = 1830 sq ft * 0.83 ft = 1525 cubic feet
- Find time required to drawdown ponded volume: T = 1525 cubic feet / 0.04 cfs = 36,300 sec = 10 hours
- Find volume of water in top two feet of soil (assume soil porosity, n, = 0.45): V = 0.45* 2 feet * 1830 square feet = 1647 cubic feet
- Find time required to drawdown saturated volume: T = 1647 cubic feet / 0.04 cfs = 41175 sec = 11.5 hours
- Find total time for drawdown of ponded water to 2 feet below surface: T = 10 hrs + 11.5 hrs = 21.5 hrs (***Note:*** This assumes that the surface drawdown and subsurface drawdown occur in discrete time steps. In reality, both will take place simultaneously, resulting in a drawdown time less than 21.5 hours.)

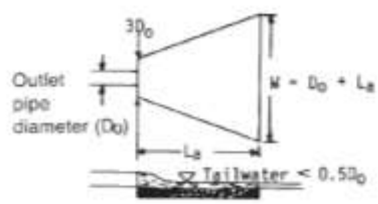
Size underdrain and gravel envelope: A rearranged version of Manning's equation, $N*D = 16 *(Q*n/s^{0.5})^{3/8}$, can be used to determine the required size of the underdrain piping (N = number of pipes and D = diameter of pipe). A safety factor of 10 is applied to the known flow rate. Thus, Q=0.4 cfs for use in underdrain sizing. Let Manning's n=0.015, a representative value for corrugated plastic pipes. Assume an internal slope of 0.5%. Therefore, $N*D = 16*(0.4*0.015/0.005^{0.5})^{3/8}$, or N*D = 6.3. Therefore, one 6 inch pipe would be marginally acceptable. However, given the potential for pipe clogging, two 4 inch corrugated plastic pipes should be installed. A cleanout should be installed for each pipe. Additionally, a 6 inch gravel envelope (2 inches above the pipes) should be used.

Recent research has shown the presence of an internal water storage zone can help with pollutant removal efficiencies and increase infiltration. An internal water storage zone can be achieved by upturning the underdrain outlets. For this project, the underdrains will be connected to the overflow structure and the discharge point of the underdrains will be set at an elevation to achieve a 1-foot internal water storage zone in the lower portion of the bioretention mix.

Assign an overflow device: While bioretention areas are generally not designed to mitigate the peak flow of larger rainfall events, the runoff will need to be routed through the bioretention area. In this case, a diversion structure will be used to keep some excess runoff in the existing storm sewer to avoid the bioretention area. To be conservative, the overflow device will be designed as if there was no diversion structure routing runoff away from the bioretention area. A round overflow structure and emergency spillway, modeled as a weir, are recommended to carry flows up to the 10-year, 24-hour design storm peak flow. Due to safety and stability concerns, it is desired that the water not exceed an elevation of 2 inches above the crest of the emergency spillway. Given this, the overflow device is sized in the following manner:

Baldwin Park Rain Garden Design
Carrboro and Chapel Hill, NC
Designer, Zan Price, PE, Extension Associate, NCSU

- Find peak flow using Rational Equation, Q=CIA: C is set at 0.74, composite C assuming the impervious area (53%) is 0.95 and the residential area (47%) is 0.50 (Rooney Malcom); I is set to the 10-year, 24-hour rainfall intensity for Chapel Hill, or 7.3 inches per hour (***Note:*** obtained from the NOAA Precipitation Frequency Estimate for Chapel Hill assuming a 5 minute time of concentration.); A is equal to 1.2 acres. Thus, Q=6.5 cfs.
- Find weir length using weir equation, $Q= C_W*L*H^{1.5}$: The weir coefficient is set at 3.0; H is set to 2 inches, or 0.17 feet. Thus, L can be calculated to be 31 feet.
- Choose overflow device: A PVC bullhead riser tee shall be located on the north end of the bioretention area. The crest of the inlet should be set at a height of 10 inches above the surface of the bioretention area. In addition to the primary outlet, an emergency spillway (length = 30 - 35 feet) lined with turf reinforced matting shall be cut into the surrounding raingarden berm. The crest of the spillway shall be set at a height of 11 inches above the surface of the bioretention area.
- Size riprap outlet protection for 15" RCP discharging to bioretention area. Assume minimum tailwater conditions since the flow will be able to spread out in the area.



	Minimum TW
	Figure 8.06a
Riprap d_{50}, (ft.)	0.4
Minimum apron length, L_a (ft.)	8
Apron width at pipe outlet (ft.)	3.75
Apron width at outlet end (ft.)	9.25
Max Stone Diameter, dmax (ft.)	0.6
Apron Thickness(ft.)	0.9

Choose vegetation and a planting plan: The rain garden has been designed to accommodate plants sized up to shrubs. Vegetation should be able to tolerate short periods of inundation, as well as periods of drought. Potential rain garden plants are listed below. A mix of 8 – 10 different plants from this list will be chosen for the garden based on availability from local nurseries.

Baldwin Park Rain Garden Design
Carrboro and Chapel Hill, NC
Designer, Zan Price, PE, Extension Associate, NCSU

Shrubs

Deciduous

Chokeberry (1,3) – *Aronia arbutifolia*
Beautyberry (2) – *Callicarpa americana*
Sweet Shrub (2) – *Calycanthus floridus*
Buttonbush (3) – *Cephalanthus occidentalis*
Pepperbush (2) – *Clethra alnifolia*
Strawberry Bush (2) – *Euonymous americanus*
Winterberry (3) – *Ilex verticillata*
Virginia Willow (3) – *Itea virginica*
Spicebush (2) – *Lindera benzion*
Possumhaw (3) – *Viburnum nudum*

Evergreen

Inkberry (2) – *Ilex glabra*
Wax Myrtle (1,2) – *Myrica cerifera*

Perennials

Blue Star (3) – *Amsonia tabernaemontana*
Lady Fern (2) – *Athyrium felix-femina*
Butterflyweed (1) – *Asclepias tuberosa*
Swamp Milkweed (3) – *Asclepias incarnata*
Climbing Aster (3) – *Aster carolinianus*
False Indigo (1,2) – *Baptisia species*
Boltonia (3) – *Boltonia asteriodes*
Turtlehead (3) – *Chelone glabra*
Green and Gold (2) – *Chrysogonum virginianum*
Mouse Ear Coreopsis (2) – *Coreopsis auriculata*
Tickseed (1,2) – *Coreopsis lanceolata*
Swamp Coreopsis (2) – *Coreopsis rosea*
Joe Pye Weed (3) – *Eupatorium dubium*
Swamp Sunflower (3) – *Helianthus angustifolius*
Swamp Mallow (3) – *Hibiscus moscheutos*
Texas Star (3) – *Hibiscus coccineus*
Blue Flag Iris (3) – *Iris virginica*
Cardinal Flower (3) – *Lobelia cardinalis*
Cinnamon Fern (3) – *Osmunda cinnamomea*
Royal Fern (3) – *Osmunda regalis*
Garden Phlox (2) – *Phlox paniculata*
Moss Pinks (1,2) – *Phlox subulata*
Rudbeckia (1,2) – *Rudbeckia fulgida*
Green Headed Coneflower (3) – *Rudbeckia laciniata*
Goldenrod (3) – *Solidago rugosa*
Ironweed (3) – *Vernonia novaboracensis*

Ornamental Grasses

River Oats (1,3) – *Chasmanthium latifolium*
Muhly Grass (1,2) – *Muhlenbergia capillaris*
Panic Grass (1,3) – *Panicum virgatum*
Indiangrass (1,2) – *Sorghastrum nutans*

Baldwin Park Rain Garden Design
Carrboro and Chapel Hill, NC
Designer, Zan Price, PE, Extension Associate, NCSU

<u>Sedges and Rushes</u>

Lurid Sedge (3) – *Carex lurida*
Fringed Sedge (3) – *Carex crinita*
White-topped Sedge (3) – *Rhynchospora latifolia*
Woolgrass (3) - *Scirpus cyperinus*

1. **Plants that, once established*, can withstand considerable drought (3-4 weeks without rainfall)**
2. **Plants that grow best in moist to average soils and will only tolerate short periods (1-2 days) of flooding.**
3. **Plants that will tolerate longer periods of flooding (3-5 days), but will also grow in moist to average soils.**

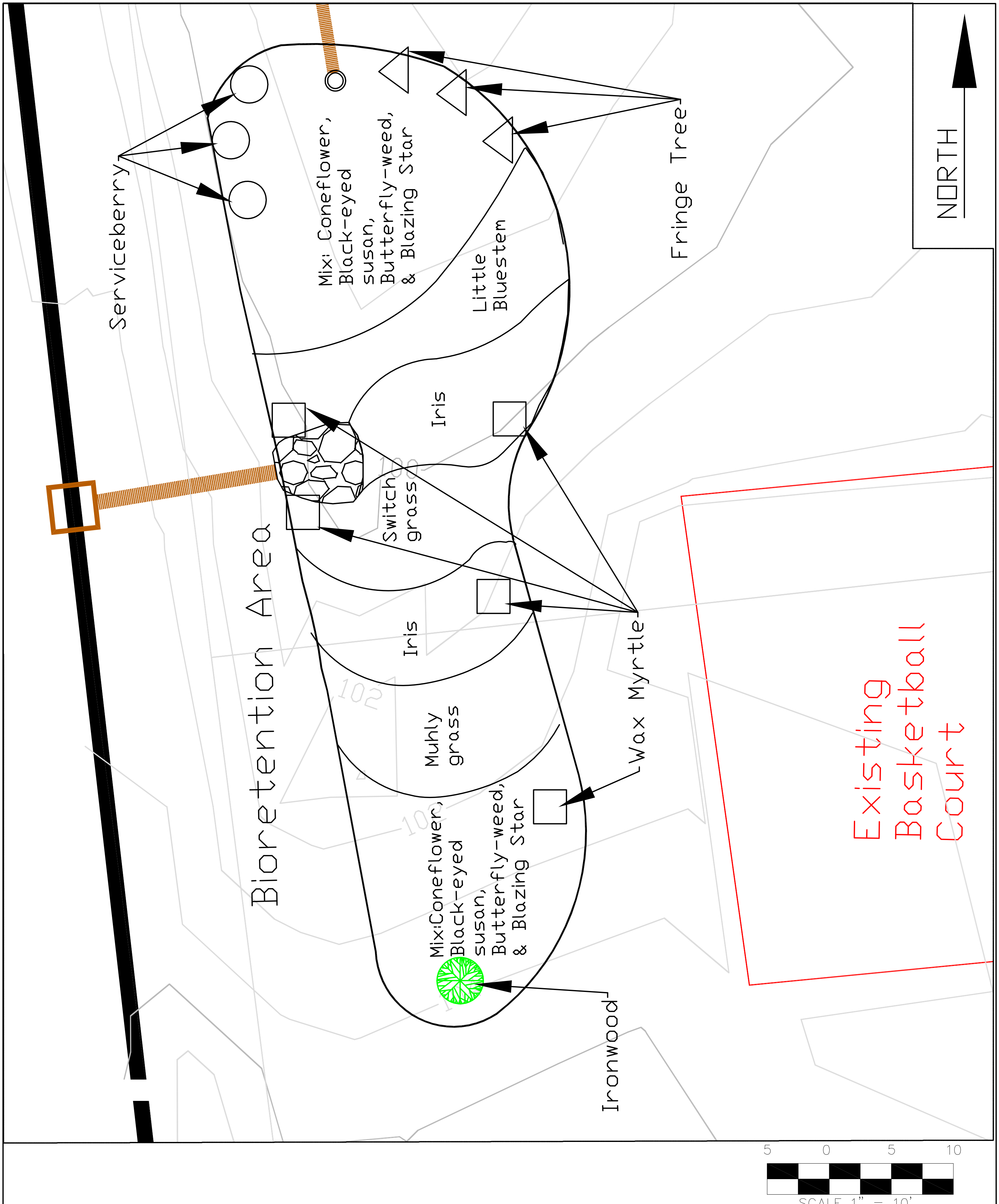
Construction Sequence:

- Pre-construction meeting on site with NCSU, Carrboro and Chapel Hill representatives, and Contractor
- Locate and mark all underground utilities for the project area.
- Install silt fence per the site plan
- Onsite construction supervision provided by NCSU engineer.
- Since exact invert elevations of the existing buried 15” storm sewer is not known, excavate area for proposed doghouse diversion structure to confirm pipe elevations. Final location of proposed doghouse structure shall be approved by the onsite NCSU engineer.
- Install diversion structure per the plan sheet and associated details. Do not install diversion weir until the bioretention area is completed and stabilized.
- Excavate the bioretention area per the plans.
- Provide orange safety fence for all open excavations.
- Install the primary overflow outlet structure in the bioretention area.
- Line the excavated bioretention area with a permeable geotextile fabric.
- Install gravel layer (washed #57 stone) and underdrains per the plans
- Install 2” choking stone layer and 2” pure sand layer above the #57 stone.
- Place approved bioretention media above the sand layer in 12-18 inch lifts without compaction.
- Install 15” reinforced concrete pipe with flared end section from diversion structure to bioretention area. Plug pipe in diversion structure until area is stabilized.
- Install rip-rap apron at pipe outlet.
- Install sod filter strip on 3:1 side slopes surrounding the bioretention area.
- Install turf reinforced matting along the emergency spillway.
- Install bioretention vegetation per a planting plan provided by the engineer. This will depend on plant availability from the vegetation list above. A mix of 8 – 10 different species will be planted.
- Install 3” double or triple shredded hardwood mulch in the bioretention area.
- Irrigate the area per the maintenance plan below.
- Install diversion weir in the diversion structure per the detail sheets.

Baldwin Park Rain Garden Design
Carrboro and Chapel Hill, NC
Designer, Zan Price, PE, Extension Associate, NCSU

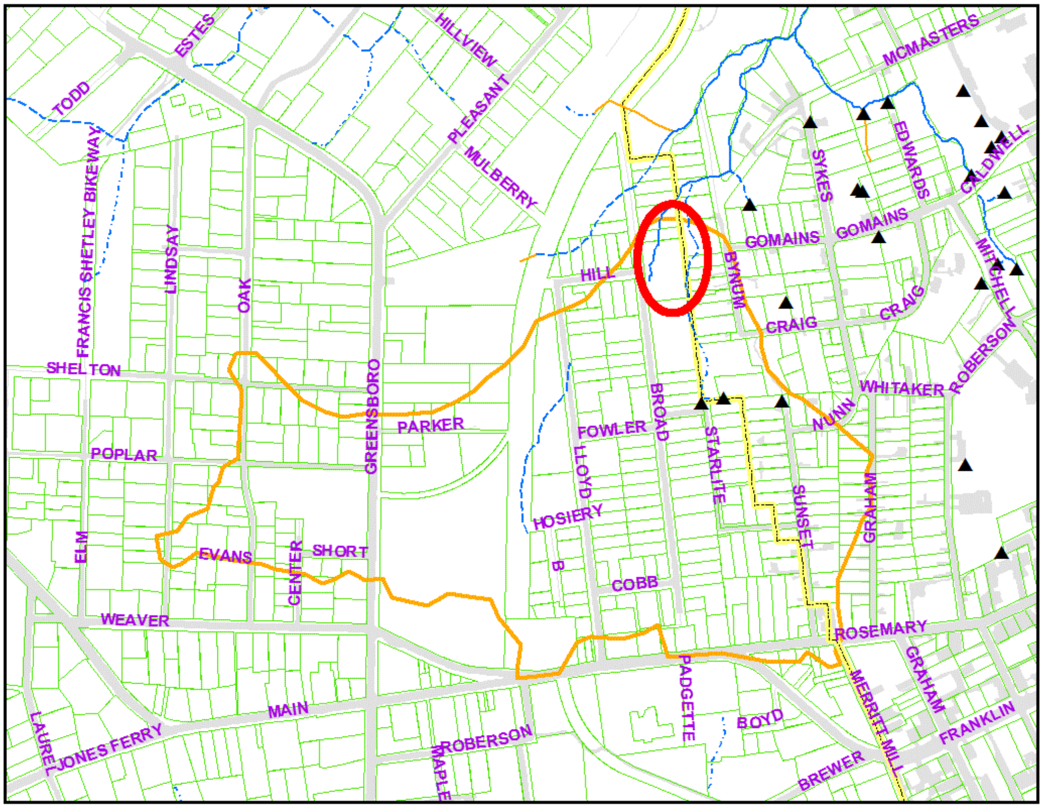
Bioretention Maintenance Schedule:

Task	Frequency	Maintenance Notes
Pruning	1 - 2 times / year	Nutrients in runoff often cause vegetation to flourish
Mulching	1 time/ year	Use shreaded hardwood mulch
Mulch removal	1 time / 3 years	Mulch accumulation reduces available water storage volume. Removal of mulch also increases surface infiltration rate of fill soil.
Watering	1 time / 2 - 3 days for first 1 - 2 months. Sporadically after establishment	If droughty, watering after the initial year may be required.
Fertilization	1 time initially	One time spot fertilization for "first year" vegetation
Remove and replace dead plants	1 time / year	Within the first year, 10 percent of plants may die. Survival rates increase with time.
Miscellaneous upkeep	12 times / year	Tasks include trash collection, spot weeding, and removing mulch from overflow device.



DATE 4/4/11	Baldwin Park Carrboro, N.C.	NC STATE UNIVERSITY
PROJECT NO.		
FILENAME	Bioretention Area Planting Plan	BIOLOGICAL & AGRICULTURAL ENGINEERING Weaver Labs Campus Box 7625 North Carolina State University Raleigh, NC 27695
SHEET NO.		
DRAWING NO.		

NO	REVISIONS	DRN	CHK	DATE



The project location


Erosion on the east side of the park, before construction

Erosion on private property to the north – pre-construction


Erosion on the west channel in Baldwin Park – pre-construction

Erosion on the east channel – pre-construction


The stream gage below the project area

The autosampler below the project area

The giant(8’x4’x4’) rocks used to create the step-pools

Placement of the giant rocks perpendicular to the channel to create the step-pools

Creating the new channel on the east side

Creating the new channel on the west side

Installing more giant rocks to create step-pools

Laying the filter fabric and hooking up the pipes in the bioretention

Installing the bioretention basin

More work on the bioretention basin


Construction of the eastern channel is complete

Upper part of the eastern channel with higher gradient

Laying coir matting on the western channel after construction

The western channel after grass has started to grow

Close-up of a step-pool – there is a giant rock under there, but you can see only about 3 feet

Step-pool close-up on the eastern side

The OWASA crossing done incorrectly

View of the tree-planting ceremony and bioretention planting from Broad Street

Donna Bell (CH Councilwoman) introduces a special speaker – Howard Baldwin

Project team members

Carrboro and Chapel Hill VIPs planting the tree

The western stream a year later

Most of the plants in the bioretention basin have survived the winter and grazing by deer

Western stream one year later


The OWASA crossing redone – this time correctly

The upper part of the eastern channel one year later

Town of Chapel Hill

Proclamation

Whereas, the Towns of Chapel Hill and Carrboro are active participants in the Bolin Creek Watershed Restoration Initiative, and the Towns are committed to pursuing watershed restoration opportunities; and

Whereas, the Towns have worked on restoration activities with State and Federal Agencies including the US Environmental Protection Agency, the North Carolina Division of Water Quality, the Ecosystem Enhancement Program, the Clean Water Management Trust Fund, and community groups and members, and understand that restoration efforts require broad collaboration and will take many years; and

Whereas, the Towns have been specifically working together and with North Carolina State University and contractors on a grant received in 2008 under Section 319 of the Clean Water Act to pursue Bolin Creek watershed restoration projects; and

Whereas, one of the projects under the 319 grant has involved restoration efforts on two streams flowing through Baldwin Park, including stream stabilization and enhancement, invasive plant management, native plant establishment, and stormwater management; and

Whereas, these efforts will also result in the establishment of a more beautiful and enjoyable park; and

Whereas, volunteers and residents are supporting these efforts by helping to establish native vegetation;

Now Therefore I, Mark Kleinschmidt, Mayor of the Town of Chapel Hill, in honor of Earth Action Day, do hereby additionally proclaim April 9, 2011 as

"Bolin Creek Action and Appreciation Day"

in the Town of Chapel Hill and offer sincere appreciation to EPA, the North Carolina Division of Water Quality, North Carolina State University staff, contractors, and to the community members who are supporting the restoration and enhancement of Baldwin Park and its streams.

Given under my hand and the seal of the Town of Chapel Hill on this the 9th day of April in the year 2011.

MARK KLEINSCHMIDT, MAYOR

RAIN GARDENS

Treating Stormwater Runoff

In conventional ***Stormwater Management***, runoff from impervious surfaces, such as paved areas, travels through storm drains and is not treated before it is discharged into streams and rivers. Stormwater runoff often has elevated concentrations of pollutants and sediment, an increased temperature, and can scour streambanks, which degrades water quality.

Stormwater treatment practices such as **Rain Gardens** are a more sustainable way to treat runoff before it is discharged to streams and rivers. As water infiltrates through the rain garden, large pollutants such as sediment and trash are filtered, and metals and excess nutrients are reduced by the soil layers. The best plants to use in rain gardens are native grasses, flowers, and shrubs that can withstand both extended wet and dry conditions. For more information on rain gardens, contact the Town of Chapel Hill Stormwater Management Division, or Carrboro Planning Department or visit:
http://townofchapelhill.org/Modules/ShowDocument.aspx?documentid=9320

Rough grading: excavated the existing low infiltration soil

During construction: lined with geotextile fabric, added a gravel layer with underdrains, and several feet of high infiltration soil

Post construction: elected officials, volunteers, and residents installed native plants

The ***Baldwin Park rain garden*** receives stormwater runoff from a portion of Broad Street. Before the rain garden installation, untreated runoff rapidly discharged directly to the stream. Currently, runoff is diverted from the road storm sewer to the rain garden. The water infiltrates down through the soil layers of the rain garden where it is slowed, cooled, and treated prior to discharging to the adjacent stream.

Can I build my own rain garden?
Yes! Rain gardens are a fun and inexpensive way for you to improve water quality and beautify your yard. To find out more about installing your own rain garden, contact the Carrboro Planning Department

What are other ways to treat stormwater naturally?
Other stormwater treatment practices include stormwater wetlands, bioswales, green roofs, and permeable paving. These are designed to treat stormwater near the source.

NC STATE UNIVERSITY

Originally 3' by 4'

Bolin Creek Watershed Restoration Project
Baldwin Park ♦ Carrboro/Chapel Hill, NC

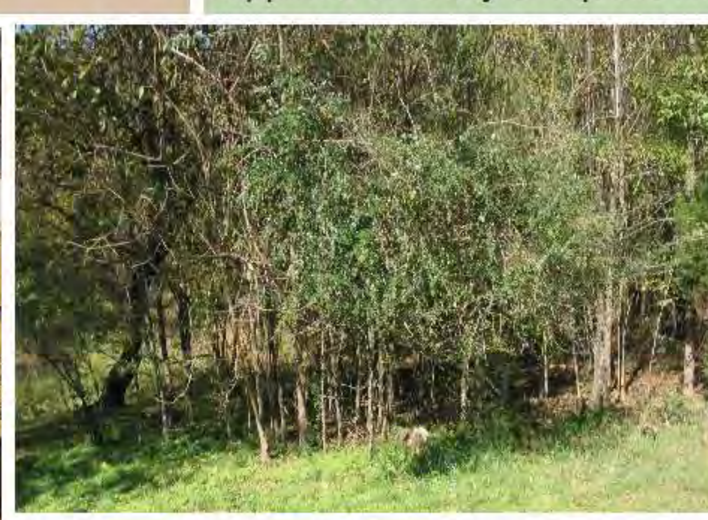
Project Description: Funding from EPA 319 grant to the Town of Chapel Hill in partnership with the Town of Carrboro and the NC State University Stream Restoration Program for design, construction, materials, and plants to repair stream erosion, enhance in-stream habitat and dissolved oxygen levels, improve overall water quality in Bolin Creek, and eliminate invasive plant species in the stream buffer. This project is one of three restorations in Carrboro and Chapel Hill to improve water quality in the Jordan Lake Watershed.

Before the project, **EROSION** created large cuts in the streambed and bank, destroying property and sending tons of sediment into Bolin Creek. Sediment harms stream habitat, carries pollutants, clogs gills of aquatic life and can increase water temperatures.

A series of in-stream "step-pools" were constructed with large granite blocks to reduce erosion on the banks and to improve in-stream habitat by providing riffles and pools to support a diversity of aquatic life.

BANK RESHAPING angles the banks back to reduce the energy of water during high flows, and prevents further erosion of the banks. After reshaping, stream banks were covered with natural fiber matting to prevent erosion, then planted with native trees and bushes.

Stormwater from the street's drains will flow into a **BIORETENTION CELL**, or engineered rain garden, instead of directly into the creek. This will reduce erosion, slow water, recharge groundwater, and allow pollutants to be filtered through soil and plants. ►



▲**INVASIVE PLANTS** outcompete native trees and vegetation so were removed from the restored area. Native species were planted to stabilize banks, provide shade to reduce water temperature, and offer specific food sources for aquatic life. Native plants will also provide privacy for homeowners while requiring little maintenance.

NC STATE UNIVERSITY Bio&Ag ENGINEERING Stream Restoration Program

Originally 2' by 3'