STREAM RESTORATION CASE STUDIES IN NORTH CAROLINA

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Abstract. Natural stream functions in many areas of North Carolina are threatened by changes in watershed hydrology and land use, often resulting in unstable streams with poor habitat and water quality. Impacts include eroding streambanks, unsafe water supplies, impaired habitat, fish kills, flooding, loss of floodplain function, and reservoir siltation. Causes of stream impairment include channelization, increased stormwater runoff, road crossings, increased sediment loads, and loss of riparian vegetation.

Over the past decade, natural resource agencies in North Carolina have adopted a natural channel design approach for restoring and enhancing unstable streams. This approach is based on the use of reference stream morphology and biology information. Permitting agencies evaluating the hydrologic, water quality, and wildlife impacts of stream restoration and mitigation projects require that designers use natural channel design approaches. These requirements have facilitated interest among many government and private organizations in learning what restoration techniques are most appropriate for local watershed conditions. Numerous stream restoration projects have been implemented recently by agencies, consultants, Universities, and citizen groups (Doll et al, 2001; Jennings et al, 2001). The purpose of this paper is to describe several stream restoration project case studies and lessons learned in North Carolina.

INTRODUCTION

Stream restoration is a priority focus for many government agencies and watershed organizations in North Carolina. Restoration professionals work to restore stability to disturbed streams by using a natural channel design approach. Stability is achieved when the stream has developed a stable dimension, pattern, and profile such that, over time, channel features are maintained and the stream system neither aggrades nor degrades (Rosgen, 1996). Natural channel design involves rebuilding natural stream characteristics, including a properly sized bankfull channel, adequate floodplain width, meanders, riffles, and pools. The area and discharge of the bankfull channel are based on the existing condition survey and validated using regional curves (Doll et al, 2000). The width and depth of the bankfull channel, floodplain width, meander pattern, and the riffle and pool spacing and slope are based on dimensionless ratios taken from a stable reference reach (Rosgen, 1998).

Rosgen developed a natural channel design priority-based approach for repairing incised stream channels (Rosgen, 1997). Four priorities are considered based on available land, flooding, cost, and project objectives. The four priorities, in order of preference, include: 1) re-establish the channel on its previous floodplain, 2) re-establish the channel and floodplain at the stream's existing elevation, 3) convert stream types without creating an active floodplain, and 4) stabilize the channel in place. Various land use constraints and flooding restrictions dictate which priority option is used in the restoration design. Rosgen's geomorphic approach to restoring incised rivers was tested on the stream restoration projects described in this paper.

PINE VALLEY GOLF COURSE TRIBUTARY

The Pine Valley Golf Course Tributary project is located in a 130-ha urban watershed in Wilmington, NC. The existing perennial stream was incised due to historic ditching for construction of the golf course and surrounding residential community. The City of Wilmington, along with the New Hanover County Tidal Creeks Program, Cape Fear Resource Conservation and Development Council, NC Sea Grant, NC Cooperative Extension Service, NC State University, and Pine Valley Country Club, coordinated a comprehensive restoration design and construction project beginning in 1998 and built in 2001. This stream restoration project serves as a pilot for a larger restoration project on the golf course scheduled to be implemented by the NC Wetlands Restoration Program in 2003.

This coastal stream, a tributary to Hewlett's Creek, drains an urban watershed comprised of the golf course and single-family residential development. Historically, the stream was channelized through the golf course and more recently piped through the residential area upstream of the golf course. The resulting narrow, deep trench flows significantly faster than a stream spread out across a wide flood plain, causing erosion through lateral migration. The removal of woody vegetation from the streamside accelerated erosion on this stream. The sandy soils found at Pine Valley have low cohesion and are comprised of particles small enough to be moved by relatively low flows and velocities.

The goal was to demonstrate the application of natural channel design techniques to restore a degraded coastal stream. The objectives were to reduce the rate of erosion by restoring the stream to a natural balance or dynamic equilibrium, and to improve the aquatic and streamside habitats. A Rosgen Priority 2 approach was selected for the restoration design, as the historic floodplain area needed for a Priority 1 approach was not available to construct a new channel. Also, the culvert at the beginning of the project requires that the stream be maintained at its existing elevation. The natural channel design process included identification of bankfull channel dimension and discharge and the identification and analyses of a stable reference reach to be used as a "blueprint" in the restoration design.

The stream restoration included the construction of a narrow and deep bankfull channel to improve stream efficiency and aquatic habitat. The floodplain was widened to slow the water and reduce erosive forces at high flow. The stream was re-meandered through the new floodplain to dissipate energy, restore natural bed features, and improve the aesthetics of the stream. To prevent future erosion, improve streamside habitat, and provide shade, the floodplain and banks were planted with a mix of native wetland plants, grasses, low growing shrubs, and trees that can survive periodic inundation. The vegetation was located keeping the golf course in mind with taller trees being placed on the edge of fairways. Log cross vanes and root wads were installed for grade control, to help prevent future erosion in meander bends, improve aquatic habitat, and protect two concrete cart bridges. Log sills were installed in tight radius meander bends to prevent short-circuiting of flow during flooding events.

Project constraints included a sewer line along the left streambank, two permanent golf cart bridges, several irrigation line crossings, and vegetation concerns for three golf holes crossing the stream reach. The project design called for constructing a new stable E5 stream and floodplain at the elevation of the existing channel. The existing channel with a top width of 6-8 m was widened to create a floodplain ranging from 12 to 25 m wide with a meandering 3-m wide bankfull channel in the bottom. The bankfull channel was meandered through the new floodplain increasing stream length from 270 to 310 m. Streamflow was diverted through a pump during construction.

COVE CREEK

The Cove Creek restoration project is located in the small community of Cove Creek in Watauga County, NC. The existing perennial stream was incised due to a headcut advancing upstream from a downstream mill dam removed in 1989. The NC Cooperative Extension Service, along with USDA-NRCS, NC State University, and the Watauga Basin Nonpoint Source Team, coordinated a comprehensive restoration design and construction project beginning in 1998 and built in 1999. This project is part of a large effort to improve stream stability and habitat throughout the Watauga River Basin. Cove Creek drains an urbanizing mountain watershed comprised of residential areas located in the valleys near streams. Historically, the stream was channelized through the valley to facilitate agriculture. The removal of woody vegetation along the stream contributed to the streambank instability and habitat degradation.

The goal was to demonstrate natural channel design techniques to restore a degraded mountain stream. The objectives were to reduce erosion by restoring the stream to a natural balance, and to improve the aquatic and streamside habitats. The upstream end of the reach was a bridge which prevented consideration of a Rosgen Priority 1 restoration approach. Adjacent landowners were not able to provide sufficient property to construct a new meandering stream, thereby eliminating a Rosgen Priority 2 approach. The resulting Priority 3 project called for changing stream types from F4 to B4c by excavating floodplain benches and enhancing habitat using in-stream structures.

The stream restoration included the construction of a 3-5 m floodplain bench on the left bank and grading of both banks to allow vegetation to become established. The floodplain bench and banks were planted with a mix of native wetland plants, grasses, low growing shrubs, and trees that can survive periodic inundation. Boulder cross vanes and root wads were installed to provide grade control, prevent future erosion in meander bends, and improve aquatic habitat. Project constraints included the upstream bridge, adjacent buildings along the streambank, and a steep hillside along most of the right bank. The project design called for constructing a new stable B4c stream and floodplain at the elevation of the existing channel. The existing confined channel with a top width of 15-18 m was widened to create a floodplain ranging from 25 to 28 m wide with a 14-m wide bankfull channel in the bottom. Immediately following construction, transplants, seeding, and erosion mats were used to maintain bank stability.

SHAWNEEHAW CREEK

The Shawneehaw Creek project is located in a trout stream in the Town of Banner Elk in Avery County, NC. The perennial stream is located in a park and has been altered to accommodate utilities and bridges. Most natural riparian vegetation has been removed and replaced with mowed grass. The resulting stream was unstable with eroding streambanks and poor habitat. The Watauga Basin Nonpoint Source Team coordinated a comprehensive restoration design and construction project beginning in 1999 and built in 2000-2001. Shawneehaw Creek drains an urbanizing mountain watershed comprised of residential areas typically located in the valleys near stream channels. Historically, the stream was channelized through the valley to facilitate agricultural land uses. The removal of woody vegetation along the stream contributed to the streambank instability and habitat degradation.

The project applied a Priority 1 approach with the goals of stabilizing streambanks, providing grade control to prevent channel degradation, enhancing habitat using in-stream structures, and adding riparian vegetation to improve riparian corridor function. The restoration included construction of a new meandering channel replacing straightened reaches and excavation of pools in meander bends. The floodplain and banks were planted with native wetland plants, grasses, low growing shrubs, and trees that can survive periodic inundation. Boulder cross vanes and root wads were installed to provide grade control, prevent erosion in meander bends, and improve habitat. Project constraints included several foot bridges, stormwater pipes, sewer lines, and adjacent buildings along the streambank. The project design called for constructing a stable E4 stream with floodplain at the top of bank. Construction was completed during low flow conditions. Immediately following construction, transplants, seeding, and erosion mats were used to maintain bank stability.

ROCKY BRANCH

Rocky Branch is a severely degraded creek that cuts through the NC State University campus in Raleigh, NC. Campus development over the last 100 years has encroached upon the 1800 m of creek on University property. Floodplains have been filled and large sections of the creek have been channelized and culverted to accommodate the construction of athletic fields, parking lots and buildings. The stream has a 260-ha watershed at the point at which it exits University property. The campus constitutes a large portion of the watershed and includes curb and gutter streets, asphalt parking lots, buildings, and athletic facilities. These features of the urban environment have tremendously increased the impervious surface area, thus increasing stormwater runoff, stormwater velocity and nonpoint source pollution.

The creek is severely incised as a result of the increased stormwater runoff, floodplain filling, channel armoring and alterations in the stream's dimension, pattern and profile. Streambanks are undercut, trees have toppled into the creek and algal blooms occur seasonally. Streambank erosion from Rocky Branch contributes large volumes of sediment to downstream waterways each year.

NC State University is currently implementing a multi-phase stream restoration plan designed to improve Rocky Branch. Phase I began in 2000, with construction completed in 2002. Phase I restored 900 m of stream channel. The design applied Rosgen Priorities 1 through 3. Numerous lateral restrictions were encountered in the design of Phase I, including underground utilities, overhead power lines, parking lots, and tennis courts. In addition, three road crossing culverts and 16 stormwater outfalls were addressed in the design.

In order to achieve the design goals for stream sinuosity, bankfull channel width, floodplain width and embankment stability, it was necessary to relocate 330 m of sewer line, remove 660 square meters of parking lot and replace two culverts. The culverts were replaced in order to raise the bed elevation of the stream by several feet and were configured to allow for both bankfull channel and floodplain flow. Rock vanes and log vanes were installed to provide grade control and take pressure off streambanks during storm events, thus reducing bank erosion. After the stable morphologic pattern was reconstructed, bioengineering was used to stabilize streambanks. Natural materials including rootwads, logs and willow branches were installed for streambank stabilization rather than riprap and other traditionally used man-made materials. Stormwater outfalls have been equipped with several different energy dissipaters that reduce the erosiveness of storm flows entering the stream.

SUMMARY AND CONCLUSIONS

Stream restoration using a natural channel design approach is being applied throughout North Carolina to improve water quality and aquatic habitat. Projects are implemented with multi-agency teams of hydrologists, engineers, and biologists with objectives of improving water quality and aquatic habitat, demonstrating effective stream protection measures, and evaluating the effectiveness of implemented measures.

Projects are initiated by landowners and watershed stakeholders who identify unstable stream reaches with potential for restoration. Project teams work with landowners and local resource agencies to select the preferred restoration option and develop a construction plan. Components of successful projects include constructed channels and floodplains, instream structures, stabilized banks using vegetation and rootwad revetments, and protected stream corridors with riparian plantings. The effectiveness of these projects is evaluated using sediment sampling, stream channel measurements, water chemistry, and biological assessment. Educational programs are used to share experiences in order to improve future projects.

Monitoring to date indicates that natural channel design techniques can be effective in improving channel stability and water quality. Minor bank erosion and structure stability problems have been repaired on each project. It is important to note that restored stream channels are highly vulnerable during the first few years following construction while vegetation is being established. It is common for these projects to require maintenance on 5-10% of the streambank length and structures during the first year or two. Limited biological monitoring indicates that at least 2-5 years may be necessary for aquatic habitat to be fully restored following construction of a new stream channel.

The stream restoration projects described in this paper represent geographic diversity and include a variety of constraints and challenges. These projects demonstrate that natural channel design techniques can be applied in urban and rural watersheds to create stable streams with improved water quality and habitat. They also demonstrate the increased effort and cost of working in an urban environment, including landowner issues, flooding, utilities, crossings, and aesthetics.

Lessons learned from these projects include:

- Teams of hydrologists, engineers, planners, landscape architects, and biologists must work together to develop and implement achievable restoration objectives throughout the project.
- Landowner cooperation is essential to implement natural channel design approaches that will achieve long-term stability.
- Stable reference reaches must be used to determine appropriate natural channel design parameters.
- Natural channel design must address both hydraulic capacity and sediment transport such that stability is maintained.
- Stream restoration designs must include systems of measures to prevent pollution, establish riparian vegetation, and address channel stability.
- On-site construction management by designers is essential to ensure that earth-moving contractors follow design specifications.
- Monitoring is essential to develop designs, measure success, and determine if follow-up work is needed following initial construction.

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