

Internal Technical Guide for Stream Work in North Carolina

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Version 3.0

1. Regulatory Guidelines
2. Technical Guidelines
3. Stream Compensatory Mitigation Guidelines

The Division of Land Resources (DLR)
The Division of Water Quality (DWQ)



Purpose:

This document is the product of a workgroup of representatives of the Division of Land Resources (DLR), the Division of Water Quality (DWQ), and the US Army Corps of Engineers (USACE). Its purpose is to provide internal guidance for DENR staff regarding work that directly impacts streams in North Carolina. The information will guide the user to resources that provide information about stream restoration (or natural channel) design, relocation, enhancement, stabilization and fill (culverting, for instance) projects. Also provided is general information about the regulatory processes of the above agencies, including compensatory mitigation requirements. This document will be modified in the future to include more specific information and additional resources as they become available.

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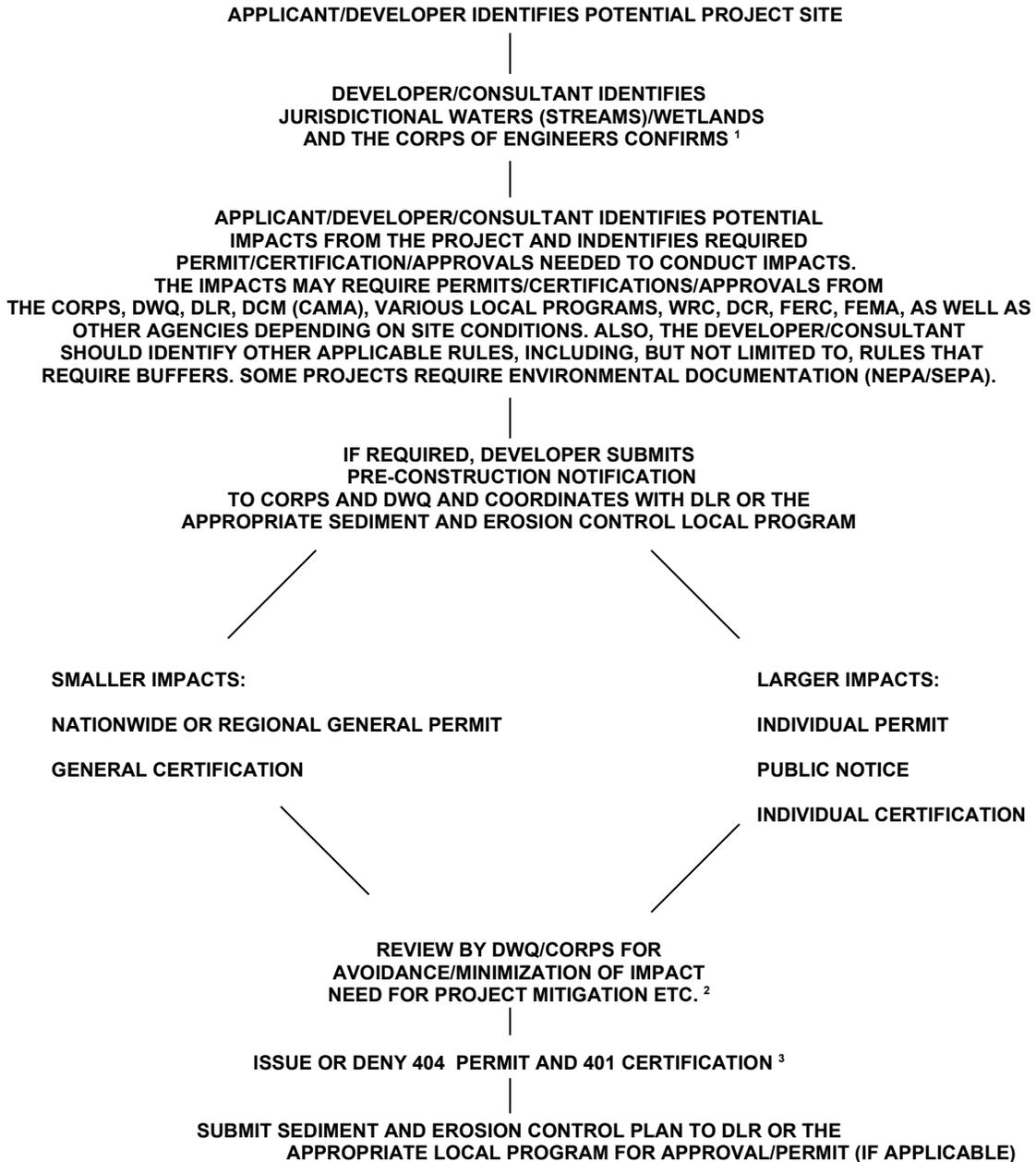
1. Regulatory Guidelines for Stream Work

1.1 List of Stream Work Activities that Require Regulatory Review

- Stream Relocation
- Stream Stabilization
- Stream Culverting/Filling
- Stream Restoration
- Buffer Impacts (such as impacts to buffers in the Neuse Basin or Water Supply Watersheds)

It is important to note that there are various thresholds above which application for use of a USACE permit and DWQ General Water Quality Certification are required depending on the type of work being conducted and the nature of the stream being impacted. In some cases, Individual USACE Permits and Water Quality Certifications are necessary. Please contact the USACE or DWQ for more information regarding application thresholds for individual projects.

1.2. Chart of the Basic Approval Process for Stream Work in North Carolina



1 NOTE: DWQ CONFIRMS THE EXISTENCE OF STREAMS AND EXTENT OF BUFFERS IN THE NEUSE AND TAR-PAMLICO BASINS IN REGARDS TO NEUSE AND THE TAR-PAMLICO BUFFER RULE REQUIREMENTS (THIS MAY EXPAND TO OTHER BASINS IN THE NEAR FUTURE)

2 NOTE: APPROPRIATE DOCUMENTATION FOR DLR/LOCAL PROGRAM APPROVAL IS NEEDED

3 NOTE: BOTH INDIVIDUAL AND GENERAL PERMITS AND CERTIFICATIONS MAY HAVE CONDITIONS THAT MUST BE MET PRIOR TO IMPACTS

1.3. Division of Land Resources Basic Stream Work Requirements

If an acre or more of land is to be cleared for commercial, residential, industrial or road construction purposes, a state or local government approved erosion control plan is required (local government programs may have more stringent requirements). The property owner or financially responsible party must submit and receive approval of an erosion and sedimentation control plan before beginning the land disturbing activity. The plan must be followed until the land disturbing activity is complete and a permanent groundcover is established. The law also requires the use of erosion and sediment control measures to keep sedimentation out of streams and lakes and from washing onto adjacent property. Streams will be protected by buffers on a site by site basis. Land disturbing activities within the Neuse River and Tar-Pamlico drainage basins are subject to a minimum buffer width of 50'. This requirement may expand to other basins in the near future. Trout streams also require riparian buffer protection. Stream and stream bank stabilization, when required, must utilize erosion and sedimentation control devices that will withstand velocities and shear stresses generated by the design storm as set forth in 15A NCAC 4B Sedimentation Control.

Failure to have an approved plan before the land disturbing activity begins may result in a temporary restraining order (TRO), injunctive relief, restoration of waters damaged by sediment generated by the land disturbing activities, stop work orders, and/or a civil penalty assessment (CPA) of up to \$5,000 per day, and possible criminal charges.

1.4. Division of Water Quality Basic Stream Work Requirements

Section 401 of the Clean Water Act delegates authority to the states to issue a 401 Water Quality Certification, which is essentially a verification by the state that a given project will not degrade Waters of the State or otherwise violate water quality standards. When the U.S. Army Corps of Engineers determines that a 404 Permit is required for work in wetlands or waters, then a 401 Water Quality Certification is also required. Many projects qualify for a Nationwide, Regional or General Permit; however, some projects require an Individual Permit. For each of these Permits, there must be a corresponding Water Quality Certification (General or Individual) in order for the Permit to be valid. Some General Certifications do not require written notification or application to DWQ as long as all of the conditions are met. Please contact DWQ's Wetlands Unit at (919) 733-1786 or visit the Wetlands Unit website at <http://h2o.enr.state.nc.us/ncwetlands> to obtain more information on how to apply for a 401 Water Quality Certification.

Also, please be aware that there are other DWQ rules and regulations that may affect stream work. These include rules that have buffer requirements such as the Neuse and Tar-Pamlico Buffer Rules and Water Supply Rules, for instance. There are other rules that apply to waters such as those classified as Trout Waters, High Quality Waters, or Outstanding Resource Waters. Please be aware that these rules and classifications change often. Also, many local programs are adopting ordinances that have additional buffering and other water quality related requirements. Violations of Water Quality Standards can result in civil penalty assessments up to \$25,000 per day per violation.

1.5. US Army Corps of Engineers Basic Stream Work Requirements

Pursuant to Section 10 of the Rivers and Harbors Act of 1899, a Department of the Army (DA) permit is required for any structure or work in or affecting navigable waters of the United States. Navigable waters are those waters that are subject to the ebb and flow of the tide and/or are presently used, or have been used in the past, or may be susceptible for use to transport interstate or foreign commerce.

A DA permit is also required pursuant to Section 404 of the Clean Water Act for any discharge of excavated or fill material into waters of the United States. Site visits are often required by Corps personnel to confirm the need for a DA permit. Waters of the United States include:

- All waters which are currently used, or were used in the past, or may be susceptible for use to transport interstate or foreign commerce;
- All interstate waters including interstate wetlands
- All other waters such as intrastate lakes, rivers, stream (including intermittent streams), mudflats, sandflats, wetlands...the use, degradation or destruction of which could affect interstate or foreign commerce
- All impoundments of waters otherwise defined as waters of the United States
- Tributaries of waters as described above
- The territorial seas
- Wetlands adjacent to waters as described above

With respect to stream restoration, a DA permit is required for any discharge of excavated or fill material below the ordinary high water mark of a stream (including intermittent stream) or river, and/or any discharge of excavated or fill material into adjacent wetlands. This includes earthen material as well as rock, concrete, or other similar materials utilized as fill. Ordinary high water is defined as “the line on the shore established by the fluctuations of water and indicated by physical characteristics such as clear, natural lines impressed on the bank, shelving, changes in the character of soil, destruction of terrestrial vegetation, the presence of litter and debris, or other appropriate means that consider the characteristics of the surrounding areas.” In Wilmington District, the two-year storm elevation is considered to be a reasonable approximation of ordinary high water for permitting purposes, although best professional judgement is utilized when appropriate.

For information regarding DA permit applications and processing, Wilmington District Corps regulatory field office personnel and areas of responsibility, and other general regulatory information, please visit the Regulatory Homepage Website at <http://www.saw.usace.army.mil/wetlands/regtour.htm>.

2. Technical Guidelines

2.1. Background

This section is intended to provide clarification and technical recommendations for the design requirements and acceptable practices regarding stream work in the State of North Carolina in order to meet permit requirements for the USACE, DLR, and DWQ.

2.2. Division of Land Resources Requirements

2.2.1 Storm Water Outlet Protection

The Division of Water Quality, Corps of Engineers, and Division of Land Resources recognize the erosive nature of water as it enters and exits pipes, culverts and other man made structures where the velocity of the water can be higher than those velocities which would occur in the natural stream channel. The need to minimize the erosion and subsequent loss of soil at such areas is also recognized. There are many strategies which can be utilized to minimize the accelerated loss of soil at these discharge points. The purpose of these guidelines is to discuss these methods and note that there are available alternatives which would allow a developer and his designer to minimize possible impacts to segments of streams. Such alternatives may still require permitting under DWQ or Corps rules, but should adequately meet the requirements of the Division of Land Resources.

Applicable Regulations

In rules promulgated under the North Carolina Sedimentation Pollution Control Act of 1973, any person conducting a land disturbing activity must conduct the activity so that the post construction velocity of the ten year storm does not exceed certain criteria as outlined NCAC 15A Chapter 4.0009. One of the most common management measures utilized is to provide energy dissipaters at the discharge point. Of the methodologies available for use as an energy dissipater, placement of rip rap is probably the most common.

Riprap Dissipaters

In the design of rip rap dissipaters to meet these regulations, two methods are outlined in the Erosion and Sediment Control Planning and Design Manual (ESC Manual). The first method (outlined on page 8.06.01) requires the designer to determine if the outlet is in a minimum or maximum tailwater condition. Once this is determined, the applicant can use the appropriate table provided to determine the diameter of the median size stone (d_{50}) in a well graded rip rap apron and the minimum length of the apron. The maximum size of stone (d_{max}) can then be determined as $1.5 \times d_{50}$. The thickness of the apron is $1.5 \times d_{max}$. The apron is fitted to the site by making it level for the minimum length. Often the size of the rip rap may need to be increased where protection of the channel side slopes are necessary. This method, can use smaller stone (because of the level apron) but requires a longer length of apron.

An alternative method of designing rip rap aprons outlined the ESC Manual (on page 8.06.5) is the New York Dissipater Method which was developed by the New York Department of Transportation. For similar pipe exit velocities this method will likely require larger stone but a shorter length than the previous method. It also allows the apron to be placed on the natural slope of the channel which could make design or installation easier.

Other Dissipater types

In steeper terrain or where an overfall exists at pipe outlets, or where flows are excessive, a lined stilling basin (armored scour hole) should be considered.

There are also alternative designs for dissipaters that *might* allow a shorter length of dissipater. Such methods include the impact basin outlet structure and the PWD Outlet structure.

In many situations, designers have had success in providing stream bank stability and grade control at inlet and outlet structures as well as meander bends using boulder cross-vanes, rootwads, plunge pools and other similar structures. It is important that these types of stream bank stabilization practices be carefully designed to accepted specifications and carefully constructed to ensure proper function (see Section 2.3.2, 4, and Appendix G).

Additional Measures

Additionally, other measures may be needed to ensure long term upstream and downstream stability. Also, archway or “bottomless” culverts and bridges should be considered whenever possible.

Finally, designers should provide information in all submittals for the 2-year and 10-year frequency peak discharges as well as the bankfull condition for the main channel. Careful determination of the appropriate Manning’s roughness coefficients consistent with accepted engineering practice and specific site conditions is critical.

2.3. Division of Water Quality Requirements

2.3.1 Stream Stabilization and Enhancement

Stream enhancement is the process of implementing certain stream rehabilitation practices in order to improve water quality and/or ecological function. These practices are typically conducted on the stream bank or in the flood prone area. For example, an enhancement procedure may be fencing out a stream from cattle and re-establishing vegetation in order to provide stream bank stability. However, these types of practices should only be attempted on a stream reach that is not experiencing severe aggradation or erosion. Enhancement activities may also include the placement of instream habitat structures. However, care must be taken to ensure that the placement of the instream structures will not affect the overall dimension, pattern, or profile of a stable stream.

Stream stabilization is the in-place stabilization of a severely eroding streambank. Please note that stabilization techniques which include “soft” methods or natural materials (such as root wads, rock vanes (see Appendix G), vegetated crib walls) may be considered as part of a restoration design. However, stream stabilization techniques that consist primarily of “hard” engineering, such as concrete lined channels, rip rap, or gabions, while providing bank stabilization, will not be considered restoration or enhancement in most cases.

Stabilization and Enhancement

Some techniques provide both stabilization and enhancement. These include the placement of appropriate instream grade control structures and the establishment appropriate stream bank vegetation.

2.3.2 Stream Stabilization and Enhancement Techniques

The techniques listed below have been used for enhancement or stabilization, and are not listed in any order of preference. Also, the use of these techniques should be evaluated on a case by case basis because none of the practices below work in every situation. In general, “soft” techniques such as vegetation are preferred over hard techniques such as rip rap wherever applicable. Careful consideration should be given to the applicability of a given technique in each situation.

Techniques that make use of channel and flood plain geometry to control velocity and shear stress are preferred to techniques that only involve stream channel widening and/or hardening. Many enhancement techniques are not strictly for stabilization, but can also create aquatic life habitat.

It is recommended that the various references that describe the techniques below be consulted in order to help establish which techniques should be used in each situation, as well as to review the design requirements. Additionally, there are techniques other than the ones listed below which must be evaluated on a case by case basis. References for the techniques are listed in the References and Recommended Reading Section (4).

- Boulder Clusters
- Weirs, Sills
- Fish Passages
- Tree Revetments
- Wing Deflectors
- Vanes (including J-Hook Vanes, W Weirs, Cross-Vanes - See Appendix G)
- Fiber Rolls
- Fiber Erosion Control Matting
- Live Staking
- Bank Reshaping
- Root Wads Revetments
- Step Pools/Check Dams
- Floating Log/Tree Covers

2.3.3 Stream Restoration/Relocation

Definition

On March 23, 1999, a multi-agency team met in Raleigh to discuss and explore various issues about the components of stream restoration. Federal and state agencies participating in this meeting included: the US Army Corps of Engineers, Natural Resource Conservation Service, US Fish and Wildlife Service, the Environmental Protection Agency and North Carolina State University, from DENR: Divisions of Water Resources, Coastal Management, Soil and Water, Land Resources, Water Quality, and the Wildlife Resources Commission. The goals of the meeting were to define stream restoration, in the context of the expected end result and in its relation to stream mitigation. The multi-agency team agreed to define stream restoration as follows:

“Stream restoration is defined as the process of converting an unstable, altered or degraded stream corridor, including adjacent riparian zone and flood-prone areas to its natural or referenced, stable conditions considering recent and future watershed conditions. This

process also includes restoring the geomorphic dimension, pattern, and profile as well as biological and chemical integrity, including transport of water and sediment produced by the stream's watershed in order to achieve dynamic equilibrium."

Introduction

The guidance in this section is intended to assist designers in providing the kinds of information that may be required for stream restoration plan approval. True stream restoration (see Section 3.1 for definition) involves returning a stream, its floodplain, and riparian area to a stable (natural or naturalized) dimension pattern and profile as well as re-establishing proper biological habitat and function. As such, conducting a successful stream restoration requires a large amount of background knowledge and research. This section outlines the types of information needed by DWQ to help ensure that a proposed stream restoration has been designed adequately. This information is required by DWQ for all projects being conducted as compensatory stream mitigation including stream relocations. However, not all of the information is required for every project. The designer must judge which information is relevant in each situation. Please remember, though, that DWQ must be satisfied that the definition of stream restoration is being met in order for the project to be approved. Stream restoration plans that are being submitted to DWQ but are not for compensatory stream mitigation may not need to provide all of the information. However, it is suggested that these items be examined for non-compensatory stream restoration projects since these measures will likely increase the chances for a successful project.

Streams are not simply stormwater conveyances. Streams have complex ecosystems with morphological characteristics that are dependant on appropriate geomorphic dimension, pattern and profile as well as biological and chemical integrity. Proper stream function also includes the transport of water and sediment produced by the stream's watershed in dynamic equilibrium.

Traditional methods of stream engineering mostly address flooding issues and stormwater channel design. However, progressive stream design practices attempt to address the entire stream system through design work that includes providing an appropriate, stable geomorphic dimension, pattern and profile as well as biological and chemical integrity. This includes addressing transport of water and sediment produced by the stream's watershed when it is dynamic equilibrium. A good engineering analogy to compare stormwater channel design to more progressive stream design would be to compare the design of a municipal wastewater collection system to the design of the collection system and the wastewater treatment plant. Although many similar hydraulic calculations are used, the design of the wastewater treatment plant often requires knowledge of complex biological, chemical, and physical systems not considered in the design of the collection system. Similarly, stream restoration design work requires extensive knowledge of hydrology, geomorphology, sediment transport, and biological principles that go beyond traditional storm channel design.

It must be remembered that stream restoration or relocation projects conducted for mitigation will have monitoring requirements. If the project fails, it will have to be corrected. As such, it is important that the restoration be properly designed to better ensure success.

II Goals and Objectives of a Stream Restoration Plan

The goals and objectives of a proposed stream restoration project should be clearly and succinctly stated. Stream restoration includes converting an unstable, altered or degraded stream corridor, including adjacent riparian zone and flood-prone areas to its natural or referenced, stable condition (considering recent and future watershed conditions). This process also includes restoring the geomorphic dimension, pattern, and profile as well as biological and chemical integrity. The transport of water and sediment produced by the stream's watershed in dynamic equilibrium must also be addressed. The plan must also match the stream type, based on the stream potential, to the valley morphology.

Project Description

Detailed specifications of the stream restoration project should be provided. This information should be provided for the reference reach(es) as well as the design channel when appropriate. The specifications should include detailed plans showing the plan-view, longitudinal profile and a number of cross section views to adequately describe the project. Also, the assumptions used and the calculations or discussions necessary to support the assumptions must be included. A checklist of design considerations is provided in Appendix F to help guide the designer in addressing various components of a proper stream restoration. The components of stream restoration specifications are listed below (Some of the components are discussed in more detail below.):

- site maps
- detailed site plans
- details regarding existing and proposed biological community types
- biological and physical monitoring plan for the restored stream
- soil and geological survey of site as appropriate
- morphological stream classifications and table of morphological characteristics
- sediment transport evaluations including appropriate pebble counts and/or other stream bed material transport evaluations

Site Maps

Site maps should be included as part of any restoration or relocation project submittal. A USGS 7.5 minute topographic quad or an orthophotograph are preferable for larger projects. GIS or CAD maps are acceptable if proper details are shown. The maps and supporting documentation should include the following information:

- The precise location of the project,
- The proximity of the project to roads, cities, and other municipalities,
- The drainage area impacting the project,
- The specific land use conditions in each part of the watershed, including historical, current and predicted conditions as appropriate,
- The location of relevant water-control structures, such as dams, levees, weirs, risers and culverts

- Stream reach morphological classification delineation (The length of a reach is typically at least two meander wave lengths or approximately 20 channel widths.)
- Relevant soil type and geological information
- The location of stream gauging stations
- Stream Hydrologic Order based on a 1:24,000 USGS map
- Water Quality stream classifications (e.g. trout waters, water supply watershed, etc. and water quality information as determined from the NC Division of Water Quality Basinwide Water Quality Management Plans)
- Vegetation
- Topography
- Utility and other ROWs including infrastructures, e.g. power lines, sewer lines or water lines as well as the presence of roads and bridges
- Potential hazardous waste sites, i.e. trash, chemical dump sites or UST's
- Presence of threatened, rare and/or endangered species and any listings of rare or unique plant community types within the project area
- Presence of known cultural resources
- Impact on neighboring communities (including flood studies)
- Wetland impacts

Detailed Site Plans

The channel design should include detailed plans for the entire stream reach and floodway, including detailed plan-view drawings and an adequate number of cross sections to show details for:

- Vegetation,
- In stream structures,
- Bank stabilization, grade control and/or thalweg management structures,
- Pool and Riffle cross sections
- Longitudinal Profile(s)
- Tie-ins to the existing channel, culverts or other structures.

If any structures are proposed for in-channel work, such as rock vanes or weirs, schematics should be included which reference elevations, orientation on the stream, and proper angle of installation (See Appendix G).

Details Regarding Biological Community Types

An assessment of the vegetative community types for the riparian area and floodplain surrounding the project stream reach should be provided for the existing conditions, the reference reach, and riparian zone design plans. The target community types should be based on the reference riparian zone. A planting plan listing sizes, densities, and planting schedule should be included as part of the plan. Also, see Biological and Physical Monitoring Plan for the Restored Stream below.

Morphological Stream Classification

While there are several stream classification methods available, this guide recommends using the Rosgen Stream Classification system. The reference, existing, and proposed stream reach(s) should be morphologically classified. (The length of a reach is typically at least two meander wave lengths or approximately 20 channel widths.) It is important to remember that streams may have several classifications along a channel length. As such, each classification, existing or proposed, should be delineated along each reach (Rosgen, 1996) (Rosgen, 1994).

Table of Morphological Characteristics

Morphological characteristics, critical to design, must be measured and recorded from the existing channel and floodway, a reference or gage station channel and floodway, as well as the design channel and floodway. A sample table is provided in Appendix B.

Biological and Physical Monitoring Plan for the Restored Stream

A proper biological monitoring program includes procedures to monitor benthic macroinvertebrates using **Internal Technical Guide: Benthic Macroinvertebrate Monitoring Protocols for Stream Restoration Projects** (DWQ, 2001). A summary of the above guidance is provided in Appendix D. Monitoring should be conducted for one year before the stream is disturbed (**or for one year at a reference stream**) followed by at least three years of biological monitoring starting one year after the stream is restored. Plant survival should also be assessed and plants replaced as necessary.

Physical monitoring should monitor stream bank stability as well stream morphology. The geomorphology of the stream should be assessed using the Rosgen or similar stream morphological classification system. The report should include permanent cross sections of riffles and pools, longitudinal profiles, and pebble counts. All of the above monitoring should be recorded in an annual report. The monitoring period should be at least five years.

2.3.4 Buffer and Planting Requirements

Restored streams should have a buffer. Typically this buffer should be 50 feet from each bank of the stream. The buffer should be planted with 400 trees per acre (native species). The survival rate after 5 years is assumed to be (and should be) 320 trees per acre.

2.3.5 Potential Problem Areas

Urban and suburban areas can present challenges for stream restoration, enhancement and stabilization designs. The following is a list of list of challenges or "hurdles", often encountered in urban and suburban areas, that require innovative design considerations. In the case of stream restoration proposals in urban areas, it may not be possible to overcome these challenges in many cases. In these cases, stream enhancement may be the only option:

- a) Changing hydrology
- b) Stormwater pollutants
- c) Restricted land/flood plain availability
- d) Flashy Hydrology
- e) Conflicting vegetation requirements (for safety issues, for instance)
- f) Identifying the "bankfull" stage and/or channel forming discharge

Tying a stream into restored/relocated streams and culverts can present a challenge to designers. Stability needs to be achieved and documented, while minimizing the use of hard

structures and amount of impact from the tie-in. Also tie-ins should not impede the migration of aquatic life (Appendix G and Poulin et. al 1997/1998).

3. Stream Compensatory Mitigation Guidelines

3.1. Background and Definition

DWQ has recently developed stream mitigation options in addition to stream restoration as defined in Section 2.3.3 of this document. These options are provided in the latest version of the document **Interim Internal DWQ Policy on Stream Mitigation Options and Associated Macrobenthos Monitoring (DWQ 2000)**. This policy was developed with the cooperation of the North Carolina Department of Transportation, the City of Charlotte, the North Carolina Wildlife Resources Commission, DWQ's Wetlands Restoration Program, and DWQ's Wetlands Unit. This policy currently only applies to State stream mitigation requirements.

3.2. Compensatory Mitigation Requirements

Stream mitigation requirements can be conditions of 404 Permits issued by the U.S. Army Corps of Engineers and 401 Certifications issued by DWQ. The current policy (September 1999) of DWQ requires compensatory mitigation for impacts greater than 150 linear feet to perennial streams. USACE mitigation requirements are based on USACE policy and may differ from DWQ requirements. The Corps may require mitigation in some instances that DWQ may not and vice versa, for instance. In any event, DWQ requires 1:1 stream restoration as defined above. Revisions to this policy will be sent to DWQ's 401 Certification mailing list, posted on DWQ's Wetlands Unit web site at <http://h2o.enr.state.nc.us/ncwetlands> and by other means of public notice. Representatives of both agencies should be contacted in order to determine compensatory mitigation requirements for a project.

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Appendix A Abbreviations

USACE - U.S. Army Corps of Engineers
CAD - Computer Aided Design
CPA - Civil Penalty Assessment
DA - Department of the Army
DENR - North Carolina Department of Environment and Natural Resources
DLR - North Carolina Division of Land Resources
DWQ - North Carolina Division of Water Quality
GIS - Geographical Information System
NHP - National Heritage Program
USDA - United States Department of Agriculture
USF&W - United State Fish and Wildlife Service
UST - Underground Storage Tank
FEMA - Federal Emergency Management Agency
CAMA - Coastal Area Management Act
FERC - Federal Energy Regulatory Commission
DCR - Division of Cultural Resources
DCM - Division of Coastal Management
NEPA/SEPA - National Environmental Policy Act/State Environmental Policy Act

Appendix B Morphological Measurement Table

Variables	Existing Channel	Proposed Reach	USGS Station	Reference Reach
1. stream type				
2. drainage area				
3. bankfull width				
4. bankfull mean depth				
5. width/depth ratio				
6. bankfull cross-sectional area				
7. bankfull mean velocity				
8. bankfull discharge, cfs				
9. bankfull max depth				
10. width of floodprone area				
11. entrenchment ratio				
12. meander length				
13. ratio of meander length to bankfull width				
14. Radius of curvature				
15. Ratio of radius of curvature to bankfull width				
16. Belt width				
17. Meander width ratio				
18. Sinuosity (stream length/valley length)				
19. Valley Slope				
20. Average slope				
21. Pool slope				
22. Ratio of pool slope to average slope				
23. Maximum pool depth				
24. Ratio of pool depth to average bankfull depth				
25. Pool width				
26. Ratio of pool width to bankfull width				
27. Pool to pool spacing				
28. Ratio of pool to pool spacing to bankfull width				
29. Ratio of lowest bank height to bankfull height (or max bankfull depth)				

Appendix C Sources

1) Sources for general information on Stream Restoration.

Rosgen, 1996; USDA, 1999; North Carolina Wildlife Resources Commission, 1999.

2) Sources of Regional Curve Information.

Wilkerson et al, 1998; Harman et al *In Press*.

3) Sources for stabilization and enhancement techniques.

Rosgen, 1996; USDA, 1999; Allen, 1997; North Carolina Wildlife Resources Commission, 1999.

4) Sources for tie-in techniques

V.A. Poulin, and Associates Ltd. 1997/1998;

5) Web Sources

➤ Wetlands Unit – <http://h2o.enr.state.nc.us/ncwetlands>

➤ USDA, Stream Corridor Restoration Principles, Processes, and Practices - http://www.usda.gov/stream_restoration

➤ USACE - <http://www.usace.army.mil/>

➤ USACE Coastal and Hydraulics Laboratory - <http://chl.wes.army.mil/>

➤ Sediment Transport and Geomorphology - <http://www.sedlab.olemiss.edu/>

➤ Water Related Best Management Practices (BMP's) in the Landscape - <http://abe.msstate.edu/csd/NRCS-BMPs/index.html>

➤ Related projects at - <http://abe.msstate.edu/csd/index.html>

➤ Stream Restoration Institute - <http://www5.bae.ncsu.edu/programs/extension/wqg/sri/>

➤ Web Site with Links to Various Resources - <http://www.stream.fs.fed.us/pointers.html>

➤ Water Road Interaction - <Http://www.stream.fs.fed.us/water-road/index.html>

Appendix D - Biological Monitoring Guidelines

Please note that the following is considered a summary document for Technical Guide: Benthic Macroinvertebrate Monitoring Protocols for Stream Restoration Projects (DWQ, 2001). Also, smaller stream restoration projects may not require biological monitoring, while larger projects may require biological monitoring. Please see Technical Guide: Benthic Macroinvertebrate Monitoring Protocols for Stream Restoration Projects for details.

Habitat Descriptions. A description of the instream and riparian habitats must be conducted at each monitoring location. The North Carolina Division of Water Quality has tested and promotes the use of a habitat classification system where appropriate (NCDENR 1997). This habitat classification system is specific for mountain/piedmont streams and for coastal plain streams and contains nine assessment categories (riffle habitat quality is not included in the coastal plain form). Each category is given a subjective score and then all scores are totaled. One hundred (100) is the maximum score for each of the forms. These forms are included in this document as Appendix F.

Collection Methods for Benthic Macroinvertebrates.

- a. *Mountain and Piedmont Streams.* Benthic macroinvertebrate samples must be collected from sites above and within the restoration reach. In addition, reference data may, optionally, be collected from a minimally stressed neighboring stream or below the restoration reach (see conditions of reference reach). A qual-4 collection method is recommended for small streams with a watershed of less than one square mile (orders 1 and 2) and full scale semiquantitative collection methods are recommended for larger wadable stream systems (3rd order or larger). These collection methods are described in the NCDENR Standard Operating Procedures: Biological Monitoring, 1997 (SOP) document. The qual-4 collection method is similar to the standard EPT method except that all organisms are collected, not just EPT (Ephemeroptera, Plecoptera and Trichoptera). EPT taxa are not generally considered primary stream colonizers and would, therefore, not typically be well represented in newly established stream reaches. If a tributary interrupts the mitigation reach, thus making it a third order system in part, full scale collection methods should be used at all monitoring locations. It should be noted that surveys need to be conducted during similar seasons (months) and if possible during similar flow patterns. Samples should not be collected immediately following extremely high flows.
- b. *Coastal Plain Streams.* At the current time DWQ has only one collection method for coastal plain or swamp stream systems. This method is described in the above mentioned SOP document. DWQ investigations have illustrated that winter surveys (Dec-Feb) are the best time to collect samples from swamp streams to assess the effects of perturbations and land use. Samples should be collected during similar seasons (months) and flow patterns.

Taxonomic Considerations. All taxonomic identifications should be done to the lowest practical level. However, genus/species identifications are preferred. Numerous investigations have shown that more interpretive ability is obtained from surveys in which genus/species identifications are done versus family level identifications.

Data Analyses and Report Requirements. Reports summarizing results of biological investigations shall be submitted to the DWQ/Wetlands Unit no later than 6 months from completion of the investigation. Each summary report must summarize data from all previous investigations. Each summary report also shall contain a list of all taxa collected during each investigation and pertinent summary statistics. Examples of summary statistics include biotic indices for each sample, EPT abundance calculations, and percent feeding type for major taxonomic groups. Biotic Index values are calculated using values listed in the above mentioned SOP document.

Appendix E DWQ Stream Habitat Evaluation Form

5/99 Revision 4

Habitat Assessment Field Data Sheet Mountain/ Piedmont Streams

Directions for use of this Assessment: The observer is to survey a minimum of 100 meters of stream, preferably in an upstream direction starting above the bridge pool and the road right-of-way. The stream segment which is assessed should represent average stream conditions. In order to perform a proper habitat evaluation the observer needs to get into the stream. All meter readings need to be performed prior to walking the stream. When working the habitat index, select the description which best fits the observed habitats and then circle the score. If the observed habitat falls in between two descriptions, select an intermediate score. There are eight different metrics in this index and a final habitat score is determined by adding the results from the different metrics.

Stream _____ Location/Road _____ County _____

Date _____ CC# _____ Basin _____ Subbasin _____

Observer(s) _____ Office Location _____ Agency _____

Type of Study: Fish Benthos Basinwide Special Study (Describe) _____

Latitude _____ Longitude _____ Ecoregion (circle one) MT P Distance Surveyed _____ meters

Physical Characterization: Land use refers to immediate area that you can see from sampling location - include what you see driving thru the watershed in the remarks section. Also use the remarks section for such descriptions as "deeply incised" or "exposed bedrock" or other unusual conditions.

Land use: Forest _____% Active Pasture _____% Active Crops _____% Fallow Fields _____% Commercial _____%
Industrial _____% Residential _____% Other _____%-Describe: _____

Width: (meters) Stream _____ Channel _____ Average Stream Depth: (m) _____ Velocity _____ m/sec

Flow conditions (circle one): High Normal Low

Manmade Stabilization: Y[] N[] Describe: _____

Water Quality: Temperature _____°C Dissolved Oxygen _____ mg/l Conductivity _____ μmhos/cm pH _____

Turbidity: (circle) Clear Slightly Turbid Turbid Tannic

Weather Conditions: _____ **Photo #** _____

Remarks: _____

I. Channel Modification (Use topo map as an additional aid for this parameter)	<u>Score</u>
A. channel natural, frequent bends (good diversity of bends or falls).....	5
B. channel natural, infrequent bends.....	4
C. some channelization present.....	3
D. more extensive channelization, >40% of stream disrupted.....	2
E. no bends, completely channelized or rip rapped or gabioned, etc.....	0

Remarks _____ Subtotal _____

II. Instream Habitat: Consider the percentage of the reach that is favorable for benthos colonization or fish cover. Circle the habitats which occur- (Rocks) (Macrophytes) (sticks and leaf packs) (snags and logs) (undercut banks or root mats) Definition: leafpacks consist of older leaves that are packed together and have begun to decay. Piles of leaves in pool areas are not considered leaf packs. EXAMPLE: If >70% of the reach is rocks, 1 type is present, circle the score of 17.

AMOUNT OF REACH FAVORABLE FOR COLONIZATION OR COVER

	>70%	40-70%	20-40%	<20%
	Score	Score	Score	Score
4 or 5 types present.....	20	16	12	8
3 types present.....	19	15	11	7
2 types present.....	18	14	10	6
1 type present.....	17	13	9	5
No types present.....	0			

Remarks _____ Subtotal _____

III. Bottom Substrate (silt, sand, detritus, gravel, cobble, boulder) look at entire reach for substrate scoring, but only look at riffle for embeddedness.

	Score
A. substrate with good mix of gravel cobble and boulders	
1. embeddedness <20% (very little sand, usually only behind large boulders).....	15
2. embeddedness 20-40%.....	12
3. embeddedness 40-80%.....	8
4. embeddedness >80%.....	3
B. substrate gravel and cobble	
1. embeddedness <20%.....	14
2. embeddedness 20-40%.....	11
3. embeddedness 40-80%.....	6
4. embeddedness >80%.....	2
C. substrate mostly gravel	
1. embeddedness <50%.....	8
2. embeddedness >50%.....	2
D. substrate homogeneous	
1. substrate nearly all bedrock.....	3
2. substrate nearly all sand.....	3
3. substrate nearly all detritus.....	2
4. substrate nearly all silt/ clay.....	1

Remarks _____ Subtotal _____

IV. Pool Variety Pools are areas of deeper than average maximum depths with little or no surface turbulence. Water velocities associated with pools are always slow. Pools may take the form of "pocket water", small pools behind boulders or obstructions, in large high gradient streams.

	Score
A. Pools present	
1. Pools Frequent (>30% of 100m area surveyed)	
a. variety of pool sizes.....	10
b. pools same size.....	8
2. Pools Infrequent (<30% of the 100m area surveyed)	
a. variety of pool sizes.....	6
b. pools same size.....	4
B. Pools absent	
1. Runs present.....	3
2. Runs absent.....	0

Remarks _____ Page Total _____

V. Riffle Habitats

Riffles **Frequent** Riffles **Infrequent**
Score Score

A. well defined riffle and run, riffle as wide as stream and extends 2X width of stream.... 16 12

B. riffle as wide as stream but riffle length is not 2X stream width	14	7
C. riffle not as wide as stream and riffle length is not 2X stream width	10	3
D. riffles absent.....	0	
		Subtotal_____

VI. Bank Stability and Vegetation

	Left Bank <u>Score</u>	Rt. Bank <u>Score</u>
A. Banks stable		
1. no evidence of erosion or bank failure, little potential for erosion	7	7
B. Erosion areas present		
1. diverse trees, shrubs, grass; plants healthy with good root systems.....	6	6
2. few trees or small trees and shrubs; vegetation appears generally healthy.....	5	5
3. sparse vegetation; plant types and conditions suggest poorer soil binding.....	3	3
4. mostly grasses, few if any trees and shrubs, high erosion and failure potential at high flow	2	2
5. no bank vegetation, mass erosion and bank failure evident.....	0	0
		Total_____

Remarks_____

VII. Light Penetration (Canopy is defined as tree or vegetative cover directly above the stream's surface. Canopy would block out sunlight when the sun is directly overhead).

	<u>Score</u>
A. Stream with good shading with some breaks for light penetration	10
B. Stream with full canopy - breaks for light penetration absent.....	8
C. Stream with partial shading - sunlight and shading are essentially equal.....	7
D. Stream with minimal shading - full sun in all but a few areas.....	2
E. No shading	0

Remarks_____ Subtotal_____

VIII. Riparian Vegetative Zone Width

Definition: A break in the riparian zone is any area which allows sediment to enter the stream. Breaks refer to the near-stream portion of the riparian zone (banks); places where pollutants can directly enter the stream.

	Lft. Bank Score	Rt. Bank Score
A. Riparian zone intact (no breaks)		
1. zone width > 18 meters.....	5	5
2. zone width 12-18 meters.....	4	4
3. zone width 6-12 meters.....	3	3
4. zone width < 6 meters.....	2	2
B. Riparian zone not intact (breaks)		
1. breaks rare		
a. zone width > 18 meters.....	4	4
b. zone width 12-18 meters.....	3	3
c. zone width 6-12 meters.....	2	2
d. zone width < 6 meters.....	1	1
2. breaks common		
a. zone width > 18 meters.....	3	3
b. zone width 12-18 meters.....	2	2
c. zone width 6-12 meters.....	1	1
d. zone width < 6 meters.....	0	0

Remarks _____

Total _____

TOTAL SCORE _____

5/99 Revision 4

Habitat Assessment Field Data Sheet
Coastal Plain Streams

Directions for use of this Assessment: The observer is to survey a minimum of 100 meters of stream, preferably in an upstream direction starting above the bridge pool and the road right-of-way. The stream segment which is assessed should represent average stream conditions. In order to perform a proper habitat evaluation the observer needs to get into the stream. All meter readings need to be performed prior to walking the stream. When working the habitat index, select the description which best fits the observed habitats and then circle the score. If the observed habitat falls in between two descriptions, select an intermediate score. There are seven different metrics in this index and a final habitat score is determined by adding the results from the different metrics.

Stream _____ Location/Road _____ County _____

Date _____ CC# _____ Subbasin _____ Basin _____

Observer(s): _____ Office Location _____ Agency _____

Type of Study: Fish Benthos Basinwide Special Study (Describe) _____

Latitude _____ Longitude _____ Ecoregion (circle one) CA CB Swamp Distance Surveyed _____ meters

Physical Characterization: Land use refers to immediate area that you can see from sampling location - include what you see driving thru the watershed in the remarks section.

Land use: Forest _____% Active Pasture _____% Active Crops _____% Fallow Fields _____% Commercial _____%
Industrial _____% Residential _____% Other _____%. Describe: _____

Width: (meters) Stream _____ Channel _____ Average Stream Depth: (m) _____ Velocity _____ m/sec

Flow conditions (circle one): High Normal Low

Manmade Stabilization: Y[] N[] Describe: _____

Water Quality: Temperature _____ °C Dissolved Oxygen _____ mg/l Conductivity _____ μmhos/cm pH _____

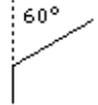
Turbidity: (circle) Clear Slightly Turbid Turbid Tannic

Weather Conditions: _____ **Photo #** _____

Remarks: _____

I. Channel Modification (Use topo map as an additional aid for this parameter)

	Natural Channel	Modified Channel
(channelized)		
A. Frequent bends	<u>Score</u>	<u>Score</u>
1. bends > 60°.....	15.....	12
2. bends < 60°.....	13.....	10
B. Infrequent bends		
1. bends > 60°.....	11.....	7
2. bends < 60°.....	8.....	5
Remarks _____		Subtotal _____



II. Instream Habitat: Consider the percentage of the reach that is favorable for benthos colonization or fish cover. Circle the habitats which occur- (Rocks) (Macrophytes) (sticks and leaf packs) (snags and logs) (undercut banks or root mats) Definition: leafpacks consist of older leaves that are packed together and have begun to decay. Piles of leaves in pool areas are not considered leaf packs. EXAMPLE: If >70% of the reach is rocks, 1 type is present, circle the score of 17.

AMOUNT OF REACH FAVORABLE FOR COLONIZATION OR COVER

	>50%	30-50%	10-30%	<10%
	<u>Score</u>	<u>Score</u>	<u>Score</u>	<u>Score</u>
4 or 5 types present.....	20	16	12	8
3 types present.....	19	15	11	7
2 types present.....	18	14	10	6
1 type present.....	17	13	9	5
No types present.....	0			

Remarks _____ Subtotal _____

III. Bottom Substrate (silt, sand, detritus, gravel, cobble, boulder) look at entire reach for substrate scoring, but only look at riffle for embeddedness.

A. substrate types mixes	<u>Score</u>
1. gravel/rocks dominant.....	15
2. sand dominant.....	13
3. detritus dominant.....	7
4. silt/clay dominant.....	4
B. substrate homogeneous	
1. substrate nearly all gravel.....	12
2. substrate nearly all sand.....	7
3. substrate nearly all detritus.....	4
4. substrate nearly all silt/ clay.....	1

Remarks _____ Subtotal _____

IV. Pool Variety Pools are areas of deeper than average maximum depths with little or no surface turbulence. Water velocities associated with pools are always slow. Pools may take the form of "pocket water", small pools behind boulders or obstructions, in large high gradient streams.

A. Pools present	<u>Score</u>
1. Pools Frequent (>30% of 100m area surveyed)	
a. variety of pool sizes.....	10
b. pools same size.....	8
2. Pools Infrequent (<30% of the 100m area surveyed)	
a. variety of pool sizes.....	6
b. pools same size.....	4
B. Pools absent	
1. Runs present.....	3
2. Runs absent.....	0

Remarks _____ Page Total _____

V. Bank Stability and Vegetation

	Lft. Bank Score	Rt. Bank Score
A. Banks stable		
1. no evidence of erosion or bank failure, little potential for erosion	10	10
B. Erosion areas present		
1. diverse trees, shrubs, grass; plants healthy with good root systems.....	9	9
2. few trees or small trees and shrubs; vegetation appears generally healthy.....	7	7
3. sparse vegetation; plant types and conditions suggest poorer soil binding.....	4	4
4. mostly grasses, few if any trees and shrubs, high erosion and failure potential at high flow	2	2
5. no bank vegetation, mass erosion and bank failure evident.....	0	0
		Total _____

Remarks _____

VI. Light Penetration (Canopy is defined as tree or vegetative cover directly above the stream's surface. Canopy would block out sunlight when the sun is directly overhead).

	Score
A. Stream with good shading with some breaks for light penetration	10
B. Stream with full canopy - breaks for light penetration absent.....	8
C. Stream with partial shading - sunlight and shading are essentially equal.....	7
D. Stream with minimal shading - full sun in all but a few areas.....	2
E. No shading	0

Remarks _____

VII. Riparian Vegetative Zone Width

Definition: A break in the riparian zone is any area which allows sediment to enter the stream. Breaks refer to the near-stream portion of the riparian zone (banks); places where pollutants can directly enter the stream.

	Lft. Bank Score	Rt. Bank Score
A. Riparian zone intact (no breaks)		
1. zone width > 18 meters.....	5	5
2. zone width 12-18 meters.....	4	4
3. zone width 6-12 meters.....	3	3
4. zone width < 6 meters.....	2	2
B. Riparian zone not intact (breaks)		
1. breaks rare		
a. zone width > 18 meters.....	4	4
b. zone width 12-18 meters.....	3	3
c. zone width 6-12 meters.....	2	2
d. zone width < 6 meters.....	1	1
2. breaks common		
a. zone width > 18 meters.....	3	3
b. zone width 12-18 meters.....	2	2
c. zone width 6-12 meters.....	1	1
d. zone width < 6 meters.....	0	0
		Total _____

Remarks _____

TOTAL SCORE _____

Appendix F Stream Work Checklist

The purpose of this checklist is to provide the stream project designer with a basic guide for the types of information considered when DWQ, DLR, and the USACE review a stream work plan. There are many approaches to stream stabilization, enhancement, and restoration in current literature; however, some key concepts are pervasive in the most common and accepted methods. Understanding and addressing these items should increase the chances of success for a restoration project. It is important to document in any submittal how each of the applicable items was considered. All calculations and supporting information should be included along with detailed justifications for methods used. (☞ = restoration, ← = enhancement, ☛ = stabilization)

- ❑ Determination of the Dominant Channel Forming Discharge – This is often referred to as the bankfull bench (in natural, stable streams), effective discharge, or the channel forming flow. This discharge is usually the result of a 1 to 2 year storm on most streams. In the North Carolina Piedmont this has been demonstrated to occur from a 1.1 to 1.8 year discharge. (☞) (USDA, 1999; Rosgen, 1996; Harman et. al., in press; Wilkerson et. al., 1998)
- ❑ Determination of proper bed, bank, and flood plain cross-section geometry – This is an important determination for the normal flow, the channel forming flow, and extreme high flow conditions. These dimensions can be determined from by comparison to proper reference reaches and confirmed by the use of regional curves. This usually requires several cross-sections showing the position of gravel bars, thalwegs, pools, riffles, etc.(☞ ← ☛) (USDA, 1999; Rosgen, 1996; Harman et. al., in press; Wilkerson et. al., 1998)
- ❑ Determination of Morphological Stream Classification – This is a description of how a stream should or does behave in its natural condition.(☞) (USDA, 1999; Rosgen, 1996)
- ❑ Determination of Sediment Transport, Yield, and Delivery Budgets – No natural stream is absolutely stable; however, most natural streams exist in a state of relative equilibrium. As such, it is essential to determine and understand proper or expected sediment movement in a stream system. Maintaining or re-establishing sediment transport equilibrium in a stream is essential to achieving natural stream stability. All assumptions should be documented with calculations or discussions. (☞ ← ☛) (USDA, 1999; Rosgen, 1996)
- ❑ Determination of proper bed, bank, slope, and flood plain planform geometry – This includes proper determination of meander geometry, riffle-pool or gravel bar-pool sequencing. (☞) (USDA, 1999; Rosgen, 1996)
- ❑ Establishment of Riparian Buffer Zones – Buffers are needed to protect the stream and enhance aquatic habitat.(☞ ←)(Section 2.3.3)
- ❑ Aquatic Biological Considerations - One of the main goals of stream restoration and or enhancement projects is to provide better habitat for aquatic organisms. Assumptions and techniques used to provide for improved aquatic habitat should be provided. (☞ ← ☛) (USDA, 1999; Rosgen, 1996; Allen et. al., 1997; NC Wildlife Resources Commission, 1999)
- ❑ Proper selection, density, and placement of vegetation - The vegetation that will be planted or encouraged along the banks and in the riparian zone must be properly addressed. Assumptions used should be documented. The use of turf grasses should be limited to temporary stabilization practices. (☞ ← ☛)(Section 2.3.3)
- ❑ Discussion of Soil Properties - The surrounding soil types and properties should be considered, and all assumptions explained any stream work project. (☞ ← ☛) (USDA, 1999; Rosgen, 1996)
- ❑ Selection of proper in stream structures and substrate - If in-stream structures, habitat, and/or substrate are to be provided, then documentation should be provided to validate the assumptions used in choosing the above. (☞ ←) (USDA, 1999; Rosgen, 1996; Allen et. al., 1997; NC Wildlife Resources Commission, 1999)
- ❑ Monitoring Plan - Physical monitoring should monitor stream bank stability as well stream morphology. A proper biological monitoring program includes procedures to monitor macrobenthos

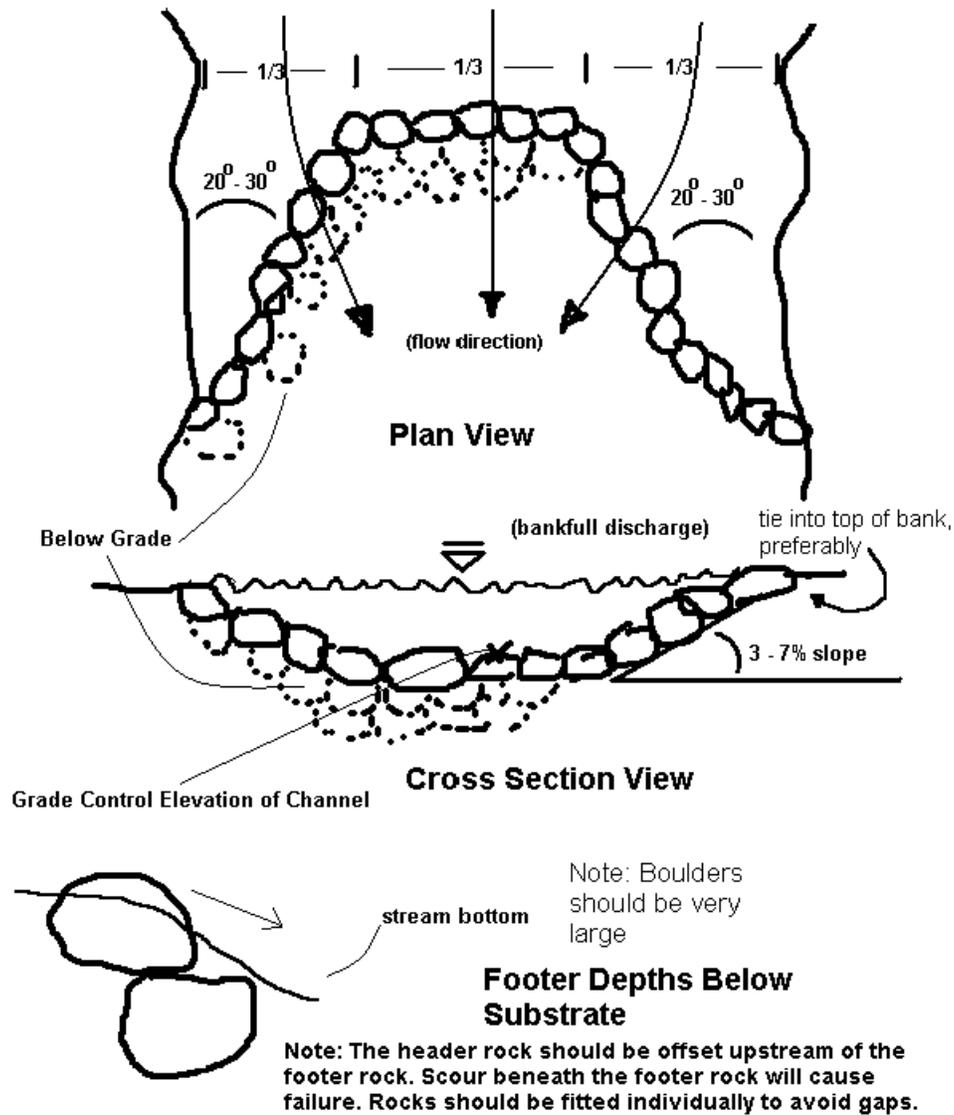
(Section 2.3.3 Biological and Physical Monitoring Plan for the Restored Stream; Appendix E). Plant survival and stream bank stability should be monitored as well (Section 2.3.4). (🌳)

- Evaluation of Stability – The success of any stream relocation or restoration project is largely dependent on the designer’s ability to use sound professional judgement in the application of a comprehensive methodology embracing the biological and engineering aspects of stream systems. Maximum expected velocity and shear stress along the boundary of the channel surface and overbanks are critical objective data necessary for the design and evaluation of stream stability. Designers are critical objective data necessary for the design and evaluation of stream stability. Designers should provide this information in all submittals for the 2-year and 10-year frequency peak discharges as well as the bankfull condition for the main channel. Careful determination of the appropriate Manning’s roughness coefficients consistent with accepted engineering practice and specific site conditions is critical. Designers should compare these predicted velocity and shear stress values with the manufacturer’s data for proposed stabilization enhancement products, where applicable. The predicted values should also be compared with those estimated for the stable reference reach considered in the design process. The designer is encouraged to consider use of allowable velocity and stress checks detailed in the references listed with this guidance document (Chapter 8, Stream Corridor Restoration Principles, Processes, and Practices, USDA, for example). Please keep in mind that a stream is a dynamic system, as such, hard structures should only be used where absolutely necessary. As such the need for hard structures will need to be convincingly demonstrated. There should be no accelerated erosion (see Sediment Transport, Yield, and Delivery Budgets, above). (🌳 → 🌳) (Section 2.2.)

Appendix G

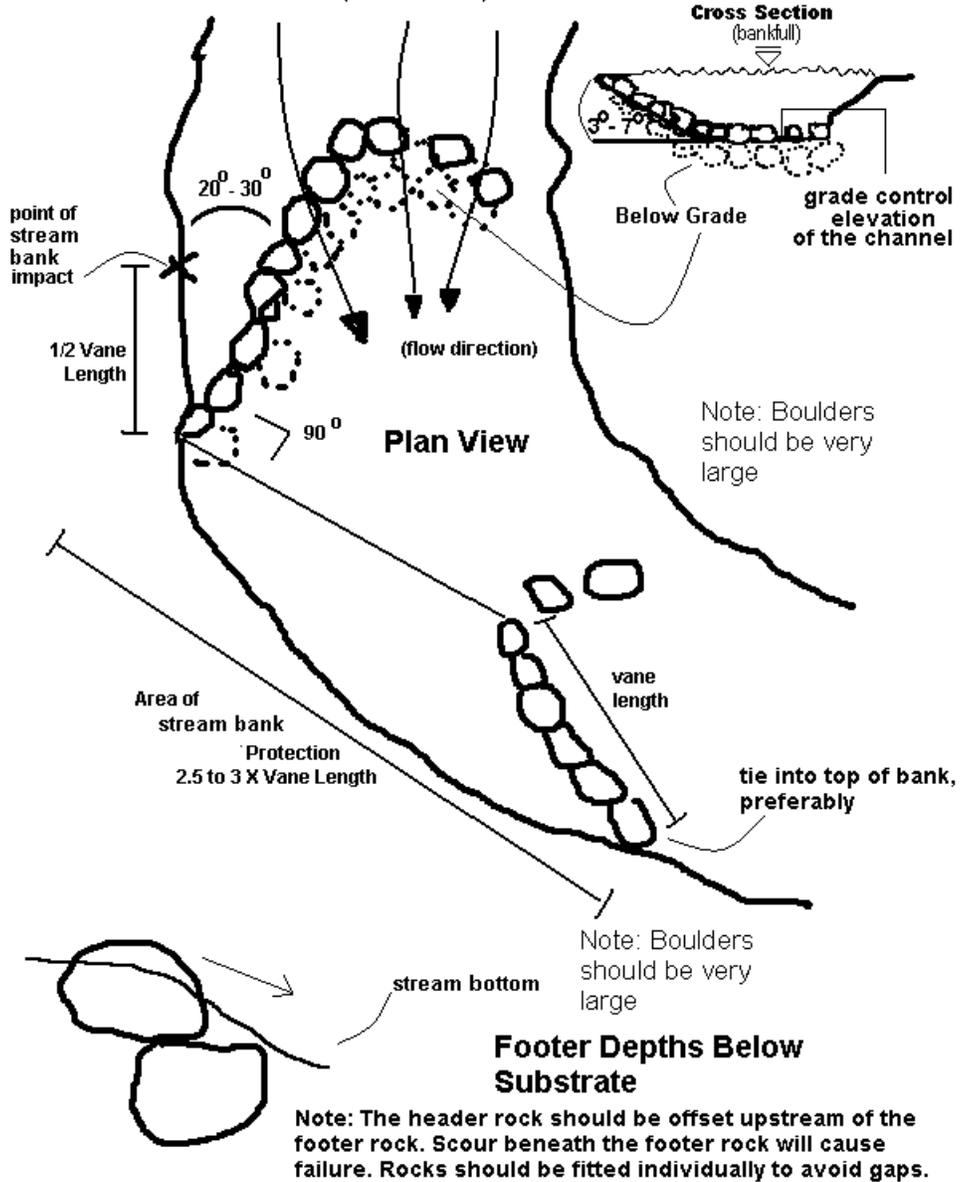
Cross-Vane (Conceptual Design)

(adapted from Rosgen, *Fluvial Geomorphology for Engineers Course Manual*, p. D-143)
(not to scale)



"J - Hook" Vane (Conceptual Design)

(adapted from Rosgen, Fluvial Geomorphology for Engineers Course Manual and notes p. D-170)
(not to scale)



**Hypothetical Use of Instream
Structures for Stream Bank Protection
and Grade Control:**

