Snow Creek
Stream Restoration Design Report

Stokes County, North Carolina

Produced for

North Carolina Wetland Restoration Program

By

EcoLogic Associates, PC

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Snow Creek Restoration Design Report

1. Introduction

The North Carolina Wetland Restoration Program seeks to restore approximately 3300 linear feet of Snow Creek and 500 feet of an unnamed tributary to Snow Creek, located in Stokes County, North Carolina. A Priority 2 stream restoration is proposed. Snow Creek is located in the Upper Dan River Watershed of the Roanoke River Basin. This document summarizes the project's purpose, existing site conditions, assessment methodologies, and proposed restoration design. Supporting information is included in the attached appendices.

a. Project Justification

Both the main stem and tributary of Snow Creek are prior straightened channels located in an agricultural valley where cattle have until recently had access to the creek. The riparian buffers have been cut to increase agricultural production and browsed by cattle. As a result, the main and tributary channels suffer from exposed, vertical failing banks, planform and cross-sectional geometry instabilities, poor development and distribution of bed features, and heavy siltation. Taken together, these features result in significant sediment contributions to the Dan River watershed, which can be greatly reduced through restoration and stabilization. In addition, the in-stream habitat for aquatic species is poor. Habitat for small-anthered bittercress (*Cardamine micranthera*), a federal and state endangered plant species that lives in the active channel, is also limited. These poor habitat conditions will also be addressed and improved as a result of the restoration.

2. Goals and Objectives

The design goals of the Snow Creek restoration project are as follows:

1. Improve water quality by reducing the sediment load generated by eroding banks and by restoring a riparian buffer;
2. Reestablish stable channel dimension, pattern, and profile;
3. Restore a functioning floodplain;
4. Enhance aquatic and terrestrial habitat in the stream corridor;
5. Provide a stable ford across the main channel for tractor access;
6. Provide two pedestrian bridges across the main channel for access to the temple property and agricultural fields;
7. Enhance habitat in the main channel and tributary for small-anthered bittercress (*Cardamine micranthera*), a federally endangered plant that currently occurs in the Snow Creek channel.

3. Location Information

a. River Basin

Snow Creek drains to the Upper Dan River in the Roanoke River basin.

b. USGS Catalog Number

The USGS 8-digit Catalog number of the watershed that includes the restoration reach is 03040102- Snow Creek, NC. The EHNR classification of the watershed is .0313 Roanoke River Basin, Snow Creek sections 22-20-(0.5) and 22-20-(5.5).

c. County

The site is in north central Stokes County.

d. Site Map (See Appendix 1, Vicinity Map)

e. Location

Access can be obtained from Moir Farm Road (SR1652), northwest of its intersection with Sheppard Mill Road (SR 1674). The project starts in the stream reach behind the large white barn on Moir Farm Road. The project reach trends south and then east from that point. The lower limit of the project is below a bedrock outcrop above a pool used as a swimming hole with a rope swing. It is best accessed from the end of Prabhupada Road. The east side of the creek can be accessed from Krishna Road.

4. General Watershed Information

a. Drainage Area

The Snow Creek watershed above the restoration reach drains about 22 square miles. In addition, two significant tributaries flow into Snow Creek within the restoration reach. Mill Creek contributes a drainage area of 4.5 square miles, and the unnamed tributary, also part of this restoration plan, adds an additional 0.83 square miles. For simplicity, a drainage area of 27 square miles was used for the Snow Creek restoration design. The headwaters originate east of the town of Lawsonville, NC, just south of the Virginia-North Carolina border. (See Appendix 1, Watershed Map)

b. Dominant Land Use

The watershed consists primarily of woodland and agriculture. The upper watershed contains intensively cultivated tobacco fields. Some of the largest and oldest farms in Stokes County occur in this area.

c. Distribution of Land Use

Cultivated land is a significant portion of the watershed, although it has been declining in the last two decades. Peak agricultural land use occurred in the late 1950's, with as much as 30-35 percent of the upper watershed under agricultural (mostly tobacco) cultivation. Currently the percentage of agricultural lands has dropped to about 25 percent with just over half of that being cultivated land and the rest grazing and hay fields (personal communication from Tom Smith, Stokes County SWCD).

The remainder of the watershed is woodlands, which often are extensively and routinely logged. There are scattered residential lots throughout the watershed, with a few clusters of residential areas along the highway (NC 704) that follows the eastern and northern ridgeline. There are no urban, commercial or industrial land uses in the watershed.

The Stokes County Natural Heritage Inventory identified only three significant sites in the Snow Creek watershed. Two of these were occurrences of a federally endangered plant, the Small-Anthered Bittercress (*Cardamine micranthera*), which occurs in two headwater creeks of the Snow Creek watershed. These locations are about 12 miles upstream of the restoration reach. The third natural heritage site in the Snow Creek watershed is Prabhupada Wetland that contains an exceptional population of amphibians. This wetland is in the floodplain adjacent to the confluence of the main channel and the unnamed tributary also undergoing restoration. (See Appendix 1, Rare Species List)

d. Estimation of Future Land Use Change

Residential development has increased over the last several years. Increased residential development will likely lead to increases in the volume of stormwater discharging into Snow Creek. Residential and small commercial development is expected to continue in the watershed in the future. (See Appendix 1, Tax Map)

5. Description of Existing Conditions

The current owners have been on the property for about 10 years. Current land use in the valley includes animal pastures and hayfields and a large cultivated field on the inside bend of the main channel. Cattle and horse pasture comprise most of the land use adjacent to the restoration reaches. The community has a significant agricultural focus and has been expanding their agricultural fields in recent years. Prior to that the site was a horse farm with some bottomland agricultural fields.

There are six agricultural landowners cooperating to restore this section of Snow Creek. They are all part of a religious commune that is donating a conservation easement along the creek and tributary in exchange for the restoration work. The designers' believe this community will be good stewards of the conservation site.

An old quarry is located on the east side of the creek. A former road crossing at the upper end of the restoration reach accessed it. Some large rocks and culvert sections still remain, although the river has cut through the old road. This crossing appears to have been destroyed by high water flows prior to new ownership. No quarry activity has occurred recently.

a. Existing Hydrological Features

The Snow Creek restoration site is located in a relatively low-slope Piedmont valley in Stokes County, NC. It is a fourth-order tributary to the Dan River. The restoration reach runs through a hay field between the east side of Moir Farm Road and an agricultural field on the east side of the creek. The upstream limit is the fence line of the adjacent farm, currently producing tobacco. The downstream limit occurs at a large rock outcrop at a point where the valley type becomes steeper, more confined, and has more bedrock control. The watershed of this section of Snow Creek has a drainage area of approximately 27.4 square miles.

Snow Creek is listed as Class C waters, protected for secondary recreation, fishing, wildlife, fish and aquatic life propagation and survival, and agriculture. There are no restrictions on watershed development activities.

b. Geology and Soils

The Snow Creek watershed is in the northern Inner Piedmont ecoregion of North Carolina (Glenn Griffith, USDA-NRCS). The geology of most of the watershed is included in the Bassett Formation of the Smith River allocthon, resulting from the movement of rock over a low angle thrust fault.

The geology of the region strongly influences the morphology of the stream and the distribution of the bed material. The valley of Snow Creek is on the edge of the Sauratown Anticlinorium, a geological feature responsible for the uplift of the Sauratown Mountains. As a result of this uplifting of rock, there are exposed bedrock outcrops found occasionally throughout the channel. The restoration reach ends at a large rock outcropping at a point where the valley becomes confined by steep rock banks and has lost most of its floodplain.

Soils around Snow Creek are primarily Riverview and Tocca, both well drained, moderately permeable soils on floodplains. Slopes range from 0 to 4 percent. These soils are good agricultural soils comprised of recent alluvium. The alluvium originated from weathered igneous and metamorphic rocks, including gneiss, schist, and granite. Surface runoff is very low and internal drainage is moderate. Because of the low-lying position near streams, they are subject to overflow about once every 10 years. Most of this soil series has been cleared of forest throughout the basin. (See Appendix 1, Soils Map)

Since the stream is incised, several sections of bare, vertical bank are exposed. Materials eroded from these areas are transported downstream to the Dan River.

c. Existing Plant Communities

The natural historical vegetation throughout the valley was likely mixed hardwoods with thick undergrowth of riparian shrubs and herbs. There are several natural plant communities listed in the Third Approximation of Natural Communities of North Carolina, which would be found in this area depending on the local conditions and amount of disturbance.

The current vegetation is a mixture of remnant natural alluvial community and introduced agricultural weedy and pasture species. The riparian vegetation corridor varies in width from essentially zero to several hundred feet of successional forest. On average, the buffer width is probably less than 35 feet. In places, agricultural fences are placed right at the top of the bank.

On the east side of Snow Creek, below the confluence with Mill Creek and extending around the major bend in the creek, is an area of vegetable production with cultivated soil extending to within 15 feet of the top of the bank.

The banks are vegetated with some large trees including Sycamores, Walnuts, Boxelders, Green Ash, Tulip Trees, Black Willows and Cherries. The understory species include Spicebush, Tag Alders, Cane, Multiflora Rose and young of the above tree species. There are also several areas with thick growths of Japanese Honeysuckle, Greenbrier, Poison Ivy and Blackberry Brambles. There are herbs in the areas that have few trees including mixtures of native and introduced grasses such as Blue Grass, Orchard Grass, Timothy, Fescue, bromes, vetches, clover, Wingstem, Japanese Grass, several sedges, Soft rush, Christmas Fern, Grape Ferns, False Nettle, Virginia Cup-plant, Asters, native Sunflower species and Goldenrods.

Cattle pasture makes up much of the land use on adjacent uplands above the floodplain containing the restoration reach. The cattle currently have access to the main channel and the tributary at the upper end of the restoration reach floodplain and access the creek at many locations. At low-water times of the year, they walk along the bed, damaging and grazing much of the in-stream and bank vegetation.

d. Stream Geometry and Substrate

1. Level II Classification

An existing condition survey of Snow Creek was conducted in June 2002. The pre-restoration surveyed stream length is 3310 linear feet in the main channel and about 700 feet of the unnamed tributary. Based on the Rosgen stream classification system, the main Snow Creek channel is an incised C4/1, while the tributary is an F4 stream type (*Applied River Morphology,* D. Rosgen, 1996.) See Appendix 2, Stream Classification and Assessment.

The cross-section dimensions, such as bankfull depth, width, and area, are within the expected range for these stream types and drainage areas (See Appendix 5, Morphology Summary Table). The main channel has a sinuosity of 1.4, a width-to-depth ratio of 15.9 and an entrenchment ratio of 7.8. The tributary has a sinuosity of 1.75, a width-to-depth ratio of 14.9 and an entrenchment ratio of 1.2. It is this low entrenchment ratio that makes this reach an F-type stream.

The bank height ratios (low bank height/max. bankfull depth) of 1.4 for the main channel of Snow Creek and 1.8 for the tributary indicate unstable to highly unstable banks. Ideally, when the stream has full access to its floodplain, this ratio equals 1. The ratios of 1.4 to 1.8 indicate that the channels have incised and carry more than bankfull flow before accessing the floodplains. This increases shear stress on the banks and accelerates bank erosion.

Sinuosity of the main channel of Snow Creek, at 1.4, is in the accepted range for a C4/1 stream type. Generally, a C stream channel has a sinuosity of 1.2 or greater. The upper sections are lower in sinuosity as the result of two long straight sections with very poorly developed bed features. In places where the woody vegetation has been removed or undermined by the stream, the lateral movement of the banks has increased. There is at least one location where the landowner believes the bank has moved more than 20 feet in the ten years he has lived on that property. There are several areas where the channel is over-wide and mid-channel bars and islands have formed.

At the head of the restoration reach near the property line, a stream crossing once existed to access the former quarry on the east side of the creek. It is likely that this former culverted crossing contributed to local scour and instability in the upper portion of the restoration reach.

The former stream crossing occurred in an area of bedrock outcrops. A few other bedrock outcrops are located within the limits of the project. These rock layers serve as natural grade controls along this reach.

The bankfull width measured for the main channel of Snow Creek was 68.4 feet, resulting in a cross-sectional area of 294 square feet. The unnamed tributary that is part of the restoration project has a bankfull width of 14.5 feet and a calculated cross-sectional area of 14.1 square feet. The North Carolina Rural Piedmont Regional Curve and a gage analysis of the South Mayo River near Nettleridge in neighboring Patrick County, VA were used to verify the bankfull stage identified in the field.

The tributary to be restored has a length of about 500 feet. The start of the reach is just below a section with a good bank height ratio and good woody vegetation. The proposed beginning of the restoration occurs at a point in the channel where the woody vegetation has been removed and the bank height starts to increase dramatically. The sinuosity of this reach is very high at 1.7. This results from the reach having several very sharp bends, with failing banks along the lower end of the channel.

Additional information not included in the Geomorphology Table includes the Bank Erodibility Hazard Rating of the main channel of Snow Creek and the tributary both of which rated very high. These ratings correlate to 7.4 cubic feet of soil loss per foot of bank in the tributary and 8.0 cubic feet of soil loss per foot of bank on the main channel.

2. Pavement / Subpavement Analysis

The pavement and subpavement of the most diagnostic portions of the stream were sampled at one location each for the main channel and the tributary. The typical pavement D_{50} for Snow Creek was 19.5 mm, with the D_{84} being 53 mm. The subpavement D_{50} was 5.7 mm, with a D_{84} of 36 mm. The typical pavement D_{50} for the tributary was 127 mm, with a D_{84} of 161 mm. The subpavement D_{50} is 32.7 mm and the D_{84} is 56 mm. EcoLogic believes the smaller particle sizes found in the main channel reflect an excessive number of fines in the system.

Given the following values, a sub-pavement D_{50} of 5.7 mm and the largest particles in the pavement and sub-pavement 55 mm to 73 mm and 130 mm to 138 mm respectively, the entrainment calculation results in a depth of 5.12 feet required to move the largest particle. The updated Shields curve (see Appendix 3) increases the size of the particles that will move at critical shear stresses above 0.01 pounds per square foot (psf). As a result, we believe that a lower depth will move the largest particles. The calculated slope is 0.0022 ft/ft, which combined with the depth gives a bankfull shear stress of 0.59 psf. The entrainment calculation indicates that the existing channel is slightly aggrading and is not competent to move its entire sediment load.

The tributary has a sub-pavement D_{50} of 32.7 mm with the largest particles in the sub-pavement being 90 mm to 128 mm. The entrainment calculation results in a depth of 0.98 feet required to move the largest particle in the bar sample. The calculated slope is 0.0075 ft/ft, which combined with the depth gives a bankfull shear stress of 0.47 psf. The entrainment calculation indicates that the channel is stable and is competent to move its sediment load.

The velocity comparison for the main channel of Snow Creek gives a velocity range of 3.3 to 6.6 feet per second (fps), with the 3.3 fps value calculated from the continuity equation. The velocity comparison for the unnamed tributary gives a range of velocities from 2.6 to 5.4 fps. Refer to Appendix 3 for Existing Entrainment and Velocity Forms and Pavement and Sub-pavement Sample Data.

6. Reference Reach Data

a. Classification of Reference Stream

The reference reach believed most useful for this project is Long Branch in Patrick County, Virginia. (See Appendix 4, Reference Reach Data) Angela Jessup, the NC Stream Restoration Coordinator for the Natural Resource Conservation Service, identified this reference reach for use in a Level 3 Stream Assessment course taught by Dave Rosgen in April 2002. The reach was used in the field exercises of the course and was surveyed and analyzed extensively by teams of course participants.

The site is known to be home to three federally endangered species, two fish species and a plant, small-anthered bittercress (*Cardamine micranthera*) that lives in the wetted portion of the channel. Before the landowners, the Virginia Natural Heritage Program, and the US Fish and Wildlife Service would grant permission for Rosgen to use the reach, they required that the plants be flagged to limit disturbance to the plant population. Dr. Ken Bridle, Principal Biologist of EcoLogic Associates, was contacted to identify and flag the plants in the field and teach the team leaders how to identify the plant. Additionally, he was on hand during the first class outing to ensure the students did not harm or harass this rare species.

Due to their concern for this plant species, the landowners will allow only the Rosgen group to access their property, but will not grant permission for others to survey independently. The data used for reference at Snow Creek was gathered by the Level 3 course participants and evaluated by Dave Rosgen and Angela Jessup. In exchange for this data, EcoLogic committed to assist in the monitoring of the rare plant population and flagging the plants as needed for future study. Jennifer Frye of the Winston-Salem DWQ Office has approved use of this site as a reference reach based on her review of the data provided to us by Angela Jessup.

Reference reaches in the Piedmont and Mountains are difficult to find in low-slope valleys with broad floodplains. These valleys have a long and continuing history of agricultural disturbance and few make suitable reference reaches. We, and other investigators in the region, have had more success finding reference reaches that are in slightly steeper and narrower valleys found in wooded areas often associated with parklands.

b. Reference Dimension, Pattern and Profile

Long Branch flows through a wooded valley and is a second order stream at the location of the reference survey. The drainage area is 1.7 square miles. It has a bankfull width of 14.4 feet, a cross-sectional area of 17.6 square feet, a sinuosity of 1.2 and an entrenchment ratio of 6.6. The Rosgen classification is a C4 stream type. The dimension and profile data show good distribution of pools and riffles, with lengths, widths and depths appropriate for a stream of this size. The estimated discharge correlates well with the NC Rural Piedmont Regional Curve.

Additional information not included in the Geomorphology Table includes a width depth ratio stability rating of 1.12, which denotes a stable channel. Likewise, the Pfankuch channel stability evaluation arrived at a score of 57, which for a C4 stream is an Excellent condition rating. The bank height ratio of 1.2 denotes a moderately stable bank condition throughout the reach. The Bank Erosion Hazard Index (BEHI) indicates low to moderate erosion potential of the banks throughout the reach. The sediment supply rating is low.

c. Reference Stream Morphology Table

The relevant design data has been assembled for review in the Morphology Summary Table, Appendix 5.

d. Reference Stream Vegetative Community

The reference reach is found in a valley that has its headwaters in the low hills at the foot of the Blue Ridge escarpment. The peak at the head of the valley is Pikes Mountain. The majority of the topography is steep and has been forested, never farmed or converted to pasture. The forests in the upper watershed have been logged recently, and a few dirt roads contribute some sediment to one of the tributaries of Long Branch. Two major tributaries combine at a culvert that passes under SR 103. From this point it is approximately two miles to the confluence with Peters Creek. The reference section is approximately one-half mile north of this confluence, just above the road crossing of SR 661. Below the road crossing, the land has been converted to pasture and the stream is confined to a narrow wooded strip.

The existence of old fence lines indicates that the site had been grazed at one time, so there are some weedy species along the road edge at the southern end of the reference reach. The native vegetation along the reference section of Long Branch is a diverse mixture that includes a canopy of Red Oaks, Red

Maple, Tulip Trees, Hickories, Sycamore, Pines, Boxelder and Green Ash. The sub canopy includes juveniles of these species plus Ironwood, Dogwood and Redbud. The shrub layer includes thick stands of Tag Alder, Silky Dogwood, several Vaccinium species, Clethera and some plants typical of old farm sites like Multiflora Rose and Japanese Honeysuckle. The streamside vegetation is thick along the banks with abundant Lady Fern, New York Fern and Christmas Fern. Additional plants along the riparian edge include Greenbrier, Evergreen Gingers, Blackberry, Foamflower, Falsenettle, Lamp Rush, and several grasses and sedges.

The stream bank and many of the rocks and logs in the channel are colonized by several species of mosses and other bryophytes. Most significantly, there are large colonies of small-anthered bittercress (*Cardamine micranthera*) and a related species known as round-leafed bittercress, the former listed as federally endangered species.

7. Stream Restoration Plan

a. Stream Classification of Restored Site

The natural channel design procedure relies on the interpretation of all available information about the site and its watershed. Aerial photographs from 1978 and 1993 are of extremely low quality and are not available in forms that copy well. The 1996 and 2001 aerial photographs show enough detail to provide insight into recent trends but no historical information on channel stability, modifications, and adjustment.

Based on the current stream condition, valley type and slope, as well as the existing dimension, pattern and profile of the channel, the proposed Snow Creek design will restore the channel to a stable C4/1; the tributary to a stable C4.

b. Morphological Table

1. Existing Conditions
(See Appendix 5)

2. Proposed Conditions
(See Appendix 5)

3. Reference Conditions
(See Appendix 5)

c. Plan View of Existing Conditions
(See Appendix 7)

d. Proposed Channel With Structures

Cross vanes and existing bedrock will be used to control grade at the tops of riffles. Root wads will be used to protect the outside of meander bends. J-hook vanes will be used to protect banks and provide habitat for Small-anthered bittercress and fish. In the interest of reducing the bank height ratio, vertical banks will be laid back to create a bankfull bench and to establish a stable growing surface. Stream plugs constructed of clay and reinforced with boulders and root wads will be installed in the old channels at the point of separation to prevent seepage and rechannelization. Structural details and specifications will be provided in the final design package. (See Appendix 9, Detail of Structures)

The tie-in to natural grade at the upstream end of the Snow Creek restoration will be made using a cross vane located at the bedrock outcrop near the upstream property line. The downstream tie-in will be at a bedrock outcrop just upstream of the big rock above the pool with a rope swing in the main channel. The tributaries along the restoration will tie in to the restored channel in pools below rock weirs. The upstream limit of the restoration of the tributary will be fixed with a cross vane at the end of the pool by the old fence line crossing the creek. The lower end of the reach will be the confluence with Snow Creek. The natural substrate of the streams will not be altered.

e. Proposed Longitudinal Profile

(See Appendix 8)

f. Sediment Transport Analysis

The critical shear stress calculated for any proposed channel must be able to move the largest particle on the point bar or from the subpavement sample. Entrainment calculations based on the riffle pebble count and sieved pavement/subpavement samples for both proposed channels are included in Appendix 6.

Based on the calculations, the critical dimensionless shear stress calculated for Snow Creek is 0.0272. This value corresponds to a required mean bankfull depth of 5.4 feet to move the design particle size. Measured mean depth is 4.3 feet. The bankfull water surface slope required is 0.0022 ft/ft, which is close to the current average slope of 0.0020 ft/ft.

The calculated bankfull shear stress for the proposed Snow Creek channel is 0.58 pounds per square foot (psf). Based on the Shields diagram, bankfull flow can move a particle greater than 37 mm in diameter. However, using a revised curve generated by Dave Rosgen based on competence of natural rivers to move particles, a shear stress of 0.59 psf corresponds to moving a particle closer to 130 mm in diameter. This is consistent with the 90-mm and 128-mm particles found in the pavement and subpavement samples.

Estimated channel velocities for Snow Creek, based on four calculation methods for the proposed conditions, range from 3.4 to 8.6 feet per second (fps). The estimated velocity selected is 5.8 fps for proposed conditions. This velocity was then compared with velocities predicted by Figure 8.31 on page 8-49 of *Stream Corridor Restoration Principals, Processes, and Practices* (1998, Federal Interagency Stream Restoration Working Group). The chart predicted velocities ranging from 5.7 to 8.0 fps depending on sediment load. This range supports the selected velocity estimate for the proposed bankfull flow event.

The critical dimensionless shear stress calculated for the tributary is 0.0153. This value corresponds to a required mean bankfull depth of 0.75 feet to move the design particle size. Design mean depth is 0.8 feet. The bankfull water surface slope required is 0.0093 ft/ft, which is slightly lower than the proposed bankfull slope of 0.010 ft/ft. Mean depth calculations indicate a stable stream.

The calculated bankfull shear stress for the proposed tributary channel is 0.49 psf. Based on the Shields diagram, bankfull flow can move a particle 30 mm in diameter. However, using a revised curve generated by Dave Rosgen based on competence of natural rivers to move particles, a shear stress of 0.59 psf corresponds to moving a particle closer to 110 mm in diameter. This is consistent with a 73-mm to 138-mm particles found in the pavement and subpavement samples. Since the subpavement particles were larger than the particles in the pavement, the largest particles found in the pavement were used in the entrainment calculations.

Estimated channel velocities for the tributary, based on four calculation methods for proposed conditions, range from 2.4 to 7.9 fps. The estimated velocity selected is 6.0 fps for proposed conditions. This velocity was then compared with velocities predicted by Figure 8.31 on page 8-49 of *Stream Corridor Restoration Principals, Processes, and Practices*. The chart predicted basic velocities ranging from 5.7 to 8.1 fps depending on sediment load. This range supports the selected velocity estimate for the proposed bankfull flow event. (See Appendix 6, Proposed Entrainment and Velocity Calculations)

8. Summary

The stability inventory for the Level 3 assessment indicates that Snow Creek is a laterally unstable, bedrock controlled, C4/1 stream type, which can be restored to a stable C4/1. Problems are indicated by a high bank height ratio and high sediment supply from failing, vertical banks, loss of woody bank vegetation, overly sharp bends combined with long, straight reaches, and poorly distributed and defined riffles and pools. Therefore, the restoration design will focus on restoring stable meander geometry and establishing a bank height ratio of one (1) by creating bankfull benches and laying back banks so that woody vegetation can be established. These measures will restore stability and diminish sediment loads delivered into the creek.

Similarly the Level 3 analysis of the unnamed tributary indicates that it is an unstable F4 stream type that can be restored to a stable C4.

The restoration of Snow Creek will improve habitat, create stable bed features, and reduce sediment supply. The revegetated riparian zone will improve habitat for aquatic and terrestrial species, which is important to the landowners and the NCWRP. In addition, this project provides the first protected population of the federally endangered small-anthered bittercress (*Cardamine micranthera*), and will produce valuable management information and experience for this species.

9. Stream Performance Criteria and Monitoring Plan

The purpose of post-construction monitoring is to assess 1) the stability of the restored channel (physical monitoring of stream geomorphology) and 2) the survival rate of the vegetation planted during the restoration. EcoLogic will provide as-built plans following construction and prior to the first annual monitoring. The restoration of Snow Creek and its tributary involves changes to each channel's dimension, pattern and profile. Benchmarks for permanent monitoring cross-sections, reference photo points, and at other locations along the restoration reach profile will be installed during construction. These benchmarks will be referenced during all subsequent monitoring visits to allow for comparable monitoring data.

The monitoring period will be five (5) years from the end of construction. The monitoring shall be done annually during fall and winter, preferably following a bankfull event. EcoLogic staff will conduct the first year of monitoring. NC WRP staff or their designated contractor will conduct subsequent monitoring. Reports from each monitoring year will be sent to the NC WRP.

The minimum requirement for dimension monitoring of one cross-section per 20 bankfull widths can be met with six (6) cross-sections. The cross-sections will be located in such a way as to capture the range of cross-sectional geometry installed at the site. One cross-section will be located in a riffle section in the middle of the project that will also be the site of monitoring pebble counts and channel geometry diagnostics such as width/depth ratio, entrenchment ratio, bank height ratio and bankfull depth. The other cross-sections will be spread throughout the remainder of the channel to monitor other geomorphic features and locations.

The pattern of the restored stream will be documented with measurements of sinuosity, meander width ratio, and radius of curvature on the newly constructed meanders (first year only).

The longitudinal profile will be monitored throughout the length of the restoration reach. The profile will measure the bed, water surface, and bankfull indicator elevations, with careful documentation of bed features. The resultant data will provide facet slopes of the riffles and pools, average slope, and the spacing and length of the features documented (e.g., pool-to-pool spacing).

The bed materials will be documented by conducting a pebble count at each reference location. The D50 and D84 of the riffles and pools will be calculated and reported. A classification pebble count based on the percentage of riffles and pools will also be conducted and reported.

Photographs showing the banks and the channel, with a scale included, will document each permanent (reference) cross-section. Photographs will also be taken of in-stream structures, the riparian vegetation, and one or more longitudinal views of the restoration reach.

Transects or sample blocks will be established for monitoring riparian vegetation. Seeded areas, transplants, and/or new seedlings will be assessed for establishment, survival rate and durability. Woody transplants and/or planted woody stems will be counted and assessed for species survival. Monitoring of woody vegetation will document attainment of the success criteria of 320 stems per acre after five years (5) and species diversity.

The monitoring plan should include stream channel evaluation of the colonization by small-anthered bittercress.

10. Sediment and Erosion Control Plan
(To be completed as part of the final design)

a. Narrative

b. Supporting Calculations

c. Schematics of Structures

Snow Creek Stream Restoration

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Appendix 1

Vicinity Map of Snow Creek

Watersheds of Restoration Reaches

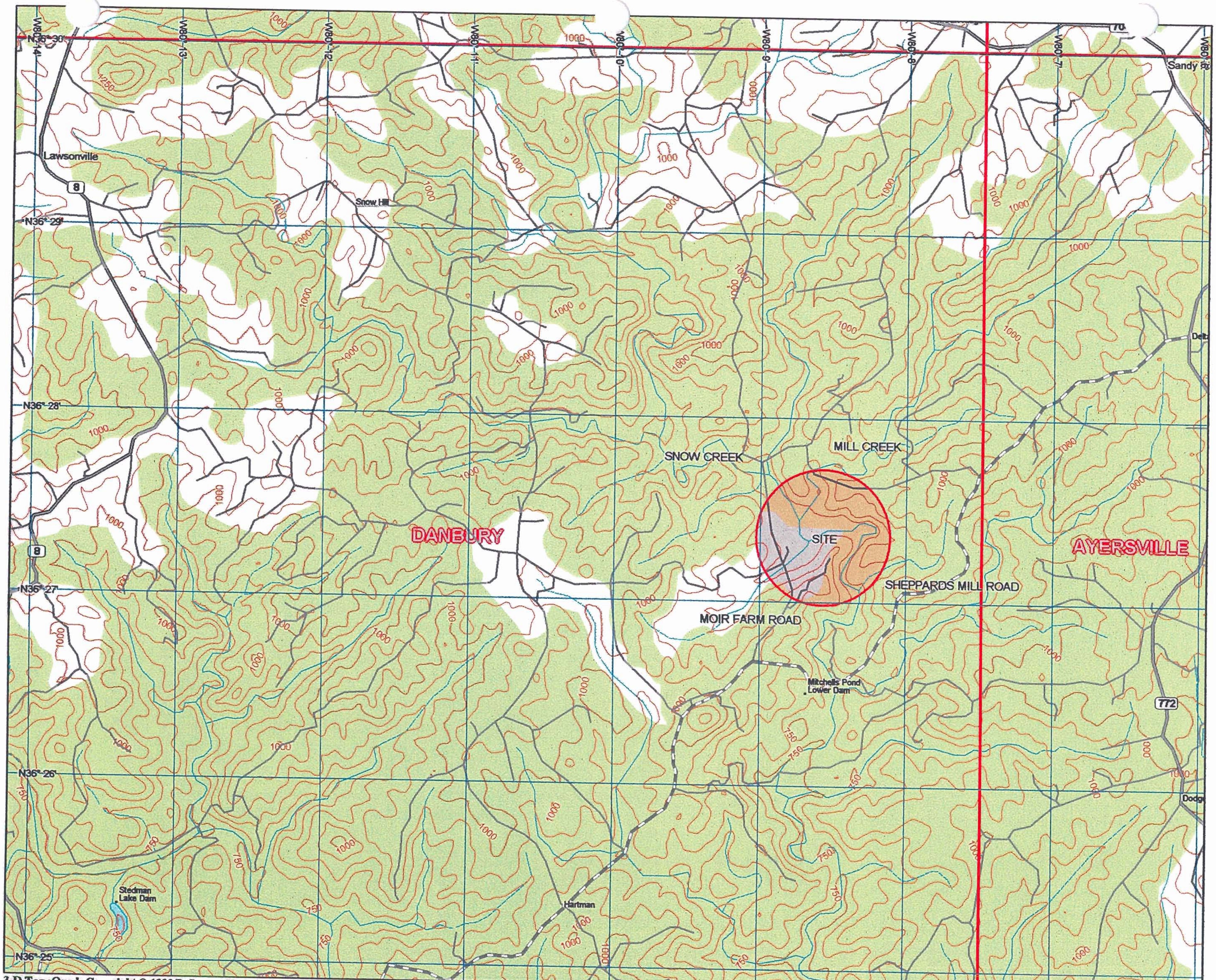
Soil Map

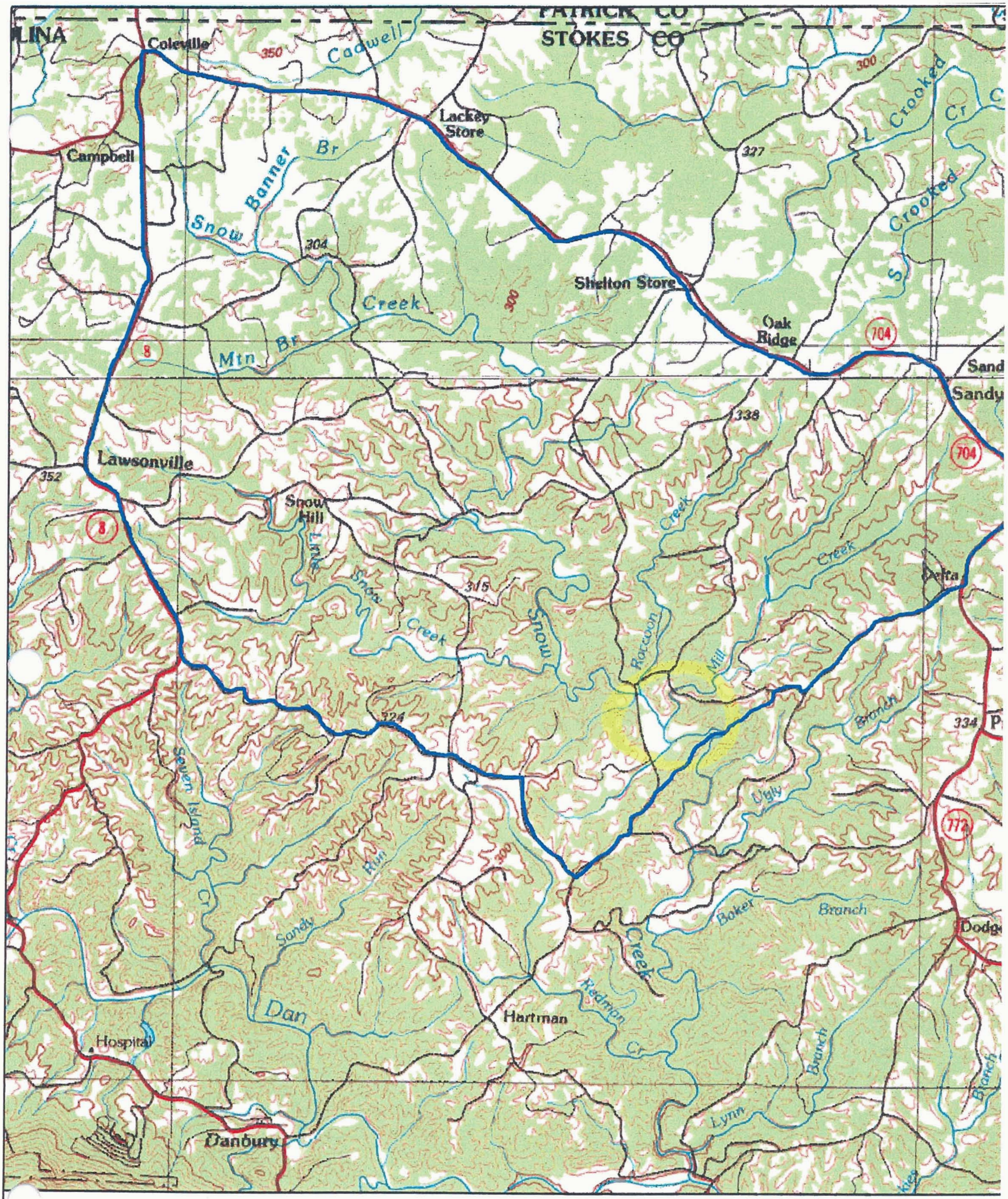
Tax Map

Site Photographs

Rare Species List for Danbury Quadrangle

Water Classification from BIMS website

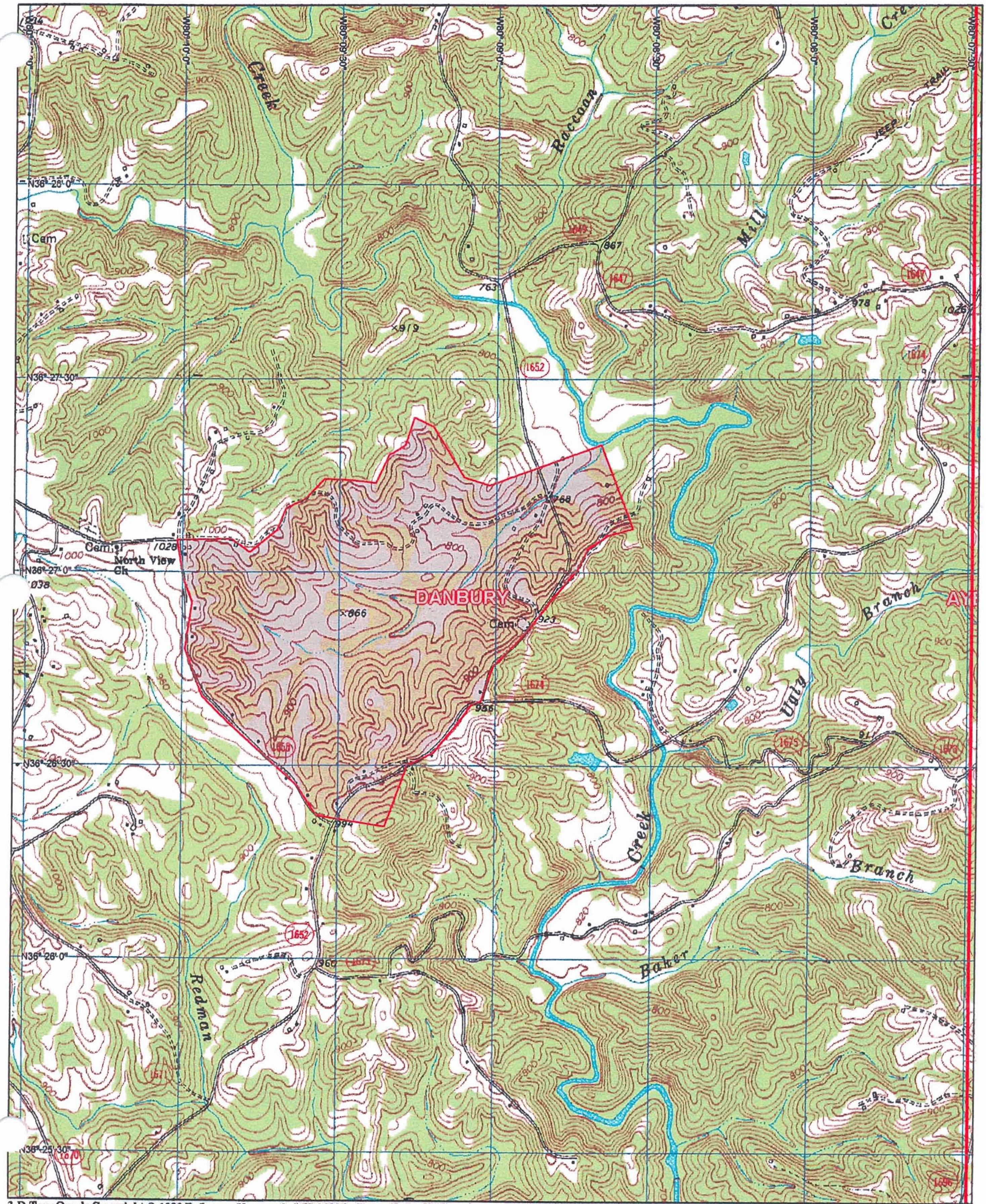

AYERSVILLE
DANBURY
SITE
MILL CREEK
SNOW CREEK
SHEPPARDS MILL ROAD
MOIR FARM ROAD
Mitchells Pond Lower Dam
Lawsonville
Snow Hill
Hartman
Stedman Lake Dam
Sandy
772
8



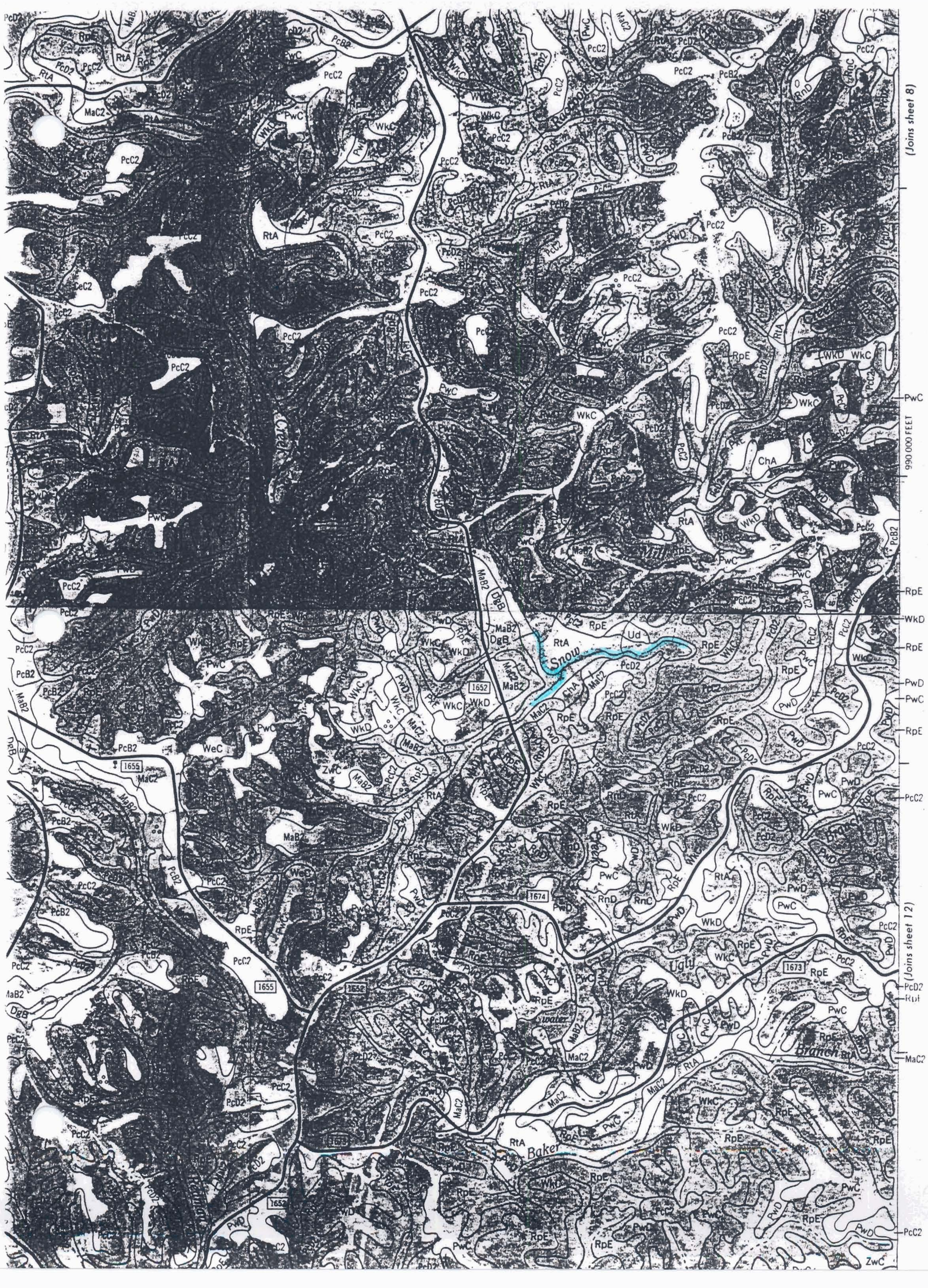
Name: WINSTON-SALEM
Date: 9/19/2002
Scale: 1 inch equals 1.052 miles

Location: 036° 28' 21.8" N 080° 10' 08.3" W
Caption: Snow Creek Watershed
28 Square Miles

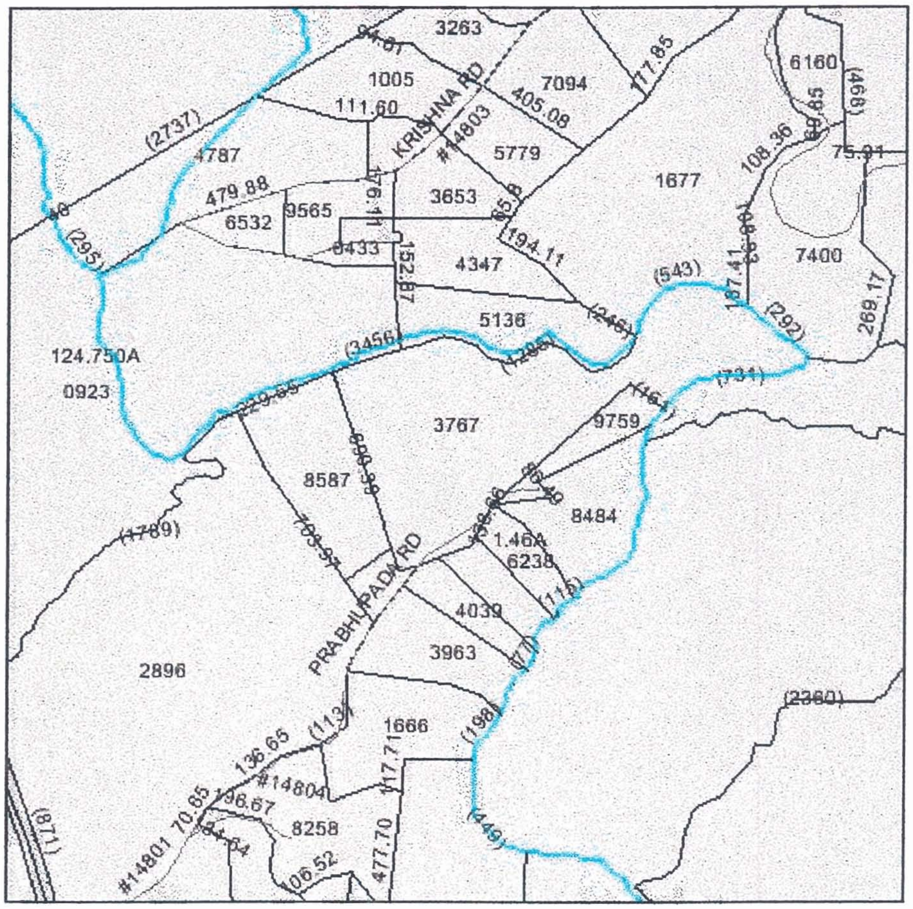
UT to Snow Creek DA = 0.87 mi^2



3-D TopoQuads Copyright © 1999 DeLorme Yarmouth, ME 04096 Source Data: USGS 950 ft Scale: 1 : 24,000 Detail: 13-1 Datum: WGS84


(Joins sheet 8)
(Joins sheet 12)
990 000 FEET
Snow
Ugly
Baker
Branch
1652
1655
1674
1673
PwC
WkD
RpE
PwD
PcC2
PcD2
PcB2
MaB2
MaC2
DgB
RtA
ChA
Ud
WkC
RnD
WeC
ZwC

Stokes Co., NC



DISCLAIMER: This map was prepared from information furnished by government and private industry sources. This map is not a "survey" and may not be used to prepare "legal descriptions". The County of Stokes specifically disclaims any and all responsibility for errors which may be disclosed by a survey of the property shown herein. In no event shall the County of Stokes be liable for any damages, direct or consequential, from the use of this map or the information contained therein. Any errors should be reported to the Stokes County Mapping/GIS Department.

Anderson & Associates, Inc. http://www.andassoc.com

Appendix 3

Existing Channel Velocity and Entrainment Calculations

Pavement and Sub-pavement Sample Data

Shields Curve

Velocity Comparison Form			
Existing Condition			
Date	9/4/2002	Team	Louise, Ken, Kyle, Don
Stream	Snow Creek	Location	Stokes County, NC
Input Variables		Output Variables	
Bankfull Cross Sectional Area (A_{BKF})	294	Bankfull Mean Depth $D_{BKF} = (A_{BKF}/W_{BKF})$	4.3
Bankfull Width (W_{BKF})	68.4	Wetted Perimeter (WP) $(\sim(2*D_{BKF})+W_{BKF})$	77.0
D84 (Riffle) (mm)	73	D84 (ft) (mm/304.8)	0.24
Bankfull Slope (S) (ft/ft)	0.0021	Hydraulic Radius (A_{BKF}/WP)	3.8
Gravitational Acceleration (g)	32.2	R/D84 (use D84 in FEET)	15.95

R/D84, u/u*, Mannings n	
u/u* (using R/D84: see Reference Reach Field Book: p188, River Field Book: p233)	9.69
Mannings n: (Reference Reach Field Book: p189, River Field Book: p236)	0.028
Velocity: (from Manning's equation: $u=1.49R^{2/3}S^{1/2}/n$)	6.0

u/u*=2.83+5.7logR/D84	
u*: $u^*=(gRS)^{0.5}$	0.51
Velocity: u=u*(2.83+5.7logR/D84)	4.9

Mannings n by Stream Type	
Stream Type	F4
Mannings n: (Reference Reach Field Book: p187, River Field Book: p237)	0.033
Velocity: (from Manning's equation: $u=1.49R^{2/3}S^{1/2}/n$)	5.1

Continuity Equation	
Q_{BKF} (cfs) from regional curve or stream gage calibration	980
Velocity: (u=Q/A or from stream gage hydraulic geometry)	3.3

After Wildland Hydrology 2001

ENTRAINMENT CALCULATION FORM

Stream:	Snow Creek, existing	Reach:	Prabhupada Village
Team:	Ken, Louise, Kyle	Date:	9/12/2002

Information Input Area

20.6	D_{50}	Riffle bed material D50 (mm)			
5.7	$D^{\wedge}_{50}$	Bar sample D50 (mm)			
73.02	D_i	Largest particle from bar sample (mm)	0.24	(feet)	304.8 mm/foot
0.002	S_e	Existing bankfull water surface slope (ft/ft)			
4.3	d_e	Existing bankfull mean depth (ft)			
4.2	R	Hydraulic Radius of Riffle Cross Section (ft)			
1.65	γ_s	Submerged specific weight of sediment			

Calculation of Critical Dimensionless Shear Stress

3.61	$D_{50}/D^{\wedge}_{50}$	If value is between 3-7	**Equation 1** will be used: $\tau^*_{ci} = 0.0834(D_{50}/D^{\wedge}_{50})^{-0.872}$
3.54	D_i/D_{50}	If value is between 1.3-3.0	**Equation 2** will be used: $\tau^*_{ci} = 0.0384(D_i/D_{50})^{-0.887}$
0.0272	τ^*_{ci}	Critical Dimensionless Shear Stress	**Equation used:** 1

Calculation of Bankfull Mean Depth Required for Entrainment of Largest Particle in Bar Sample

5.12	d_r	Required bankfull mean depth (ft)	$d_r = \frac{\tau^*_{ci}\gamma_s D_i}{S_e}$		
0.84	d_e/d_r	Existing mean bankfull depth / Required mean bankfull depth	Stable ($d_e/d_r = 1$)	Aggrading ($d_e/d_r<1$)	Degrading ($d_e/d_r>1$)
aggrading	Vertical Stability of Stream				

Calculation of BKF Water Surface Slope Required for Entrainment of Largest Particle in Bar Sample

0.0025	S_r	Required bankfull water surface slope (ft)	$S_r = \frac{\tau^*_{ci}\gamma_s D_i}{d_e}$		
0.84	S_e/S_r	Existing water surface slope / Required water surface slope	Stable ($S_e/S_r = 1$)	Aggrading ($S_e/S_r < 1$)	Degrading ($S_e/S_r > 1$)
aggrading	Vertical Stability of Stream				

Sediment Transport Validation

0.55	Bankfull Shear Stress $\tau_c = \gamma RS$ (lb/ft2) γ = Density of water = 62.4 lbs/ft^3
35-180	Moveable particle size (mm) at bankfull shear stress (predicted by the Shields Diagram: Blue field book:p238, Red field book:p190)
0.55-1.3	Predicted shear stress required to initate movement of D_i (mm) (see Shields Diagram: Blue field book:p238, Red field book:p190)

Velocity Comparison Form			
Existing Condition			
Date	9/12/2002	Team	Louise, Ken, Kyle, Don
Stream	UT to Snow Creek	Location	Stokes County, NC
Input Variables		Output Variables	
Bankfull Cross Sectional Area (A_{BKF})	14.1	Bankfull Mean Depth $D_{BKF} = (A_{BKF}/W_{BKF})$	1.0
Bankfull Width (W_{BKF})	14.5	Wetted Perimeter (WP) $(\sim(2*D_{BKF})+W_{BKF})$	16.4
D84 (Riffle) (mm)	88	D84 (ft) (mm/304.8)	0.29
Bankfull Slope (S) (ft/ft)	0.008	Hydraulic Radius (A_{BKF}/WP)	0.9
Gravitational Acceleration (g)	32.2	R/D84 (use D84 in FEET)	2.97

R/D84, u/u*, Mannings n	
u/u* (using R/D84: see Reference Reach Field Book: p188, River Field Book: p233)	5.52
Mannings n: (Reference Reach Field Book: p189, River Field Book: p236)	0.043
Velocity: (from Manning's equation: $u=1.49R^{2/3}S^{1/2}/n$)	2.8

u/u*=2.83+5.7logR/D84	
u*: $u^*=(gRS)^{0.5}$	0.47
Velocity: u=u*(2.83+5.7logR/D84)	2.6

Mannings n by Stream Type	
Stream Type	F4
Mannings n: (Reference Reach Field Book: p187, River Field Book: p237)	0.033
Velocity: (from Manning's equation: $u=1.49R^{2/3}S^{1/2}/n$)	3.6

Continuity Equation	
Q_{BKF} (cfs) from regional curve or stream gage calibration	76
Velocity: (u=Q/A or from stream gage hydraulic geometry)	5.4

After Wildland Hydrology 2001

ENTRAINMENT CALCULATION FORM

Stream:	UT to Snow Creek existing	Reach:	Prabhupada Village
Team:	Ken, Louise, Kyle	Date:	9/12/2002

Information Input Area

32	D_{50}	Riffle bed material D50 (mm)			
32.7	$D^{\wedge}_{50}$	Bar sample D50 (mm)			
90.6	D_i	Largest particle from bar sample (mm)	0.30	(feet)	304.8 mm/foot
0.005	S_e	Existing bankfull water surface slope (ft/ft)			
1	d_e	Existing bankfull mean depth (ft)			
0.9	R	Hydraulic Radius of Riffle Cross Section (ft)			
1.65	γ_s	Submerged specific weight of sediment			

Calculation of Critical Dimensionless Shear Stress

0.98	$D_{50}/D^{\wedge}_{50}$	If value is between 3-7	**Equation 1** will be used: $\tau^*_{ci} = 0.0834(D_{50}/D^{\wedge}_{50})^{-0.872}$	
2.81	D_i/D_{50}	If value is between 1.3-3.0	**Equation 2** will be used: $\tau^*_{ci} = 0.0384(D_i/D_{50})^{-0.887}$	
0.0153	τ^*_{ci}	Critical Dimensionless Shear Stress	**Equation used:**	2

Calculation of Bankfull Mean Depth Required for Entrainment of Largest Particle in Bar Sample

0.93	d_r	Required bankfull mean depth (ft)	$d_r = \frac{\tau^*_{ci}\gamma_s D_i}{S_e}$		
1.07	d_e/d_r	Existing mean bankfull depth / Required mean bankfull depth	Stable ($d_e/d_r = 1$)	Aggrading ($d_e/d_r<1$)	Degrading ($d_e/d_r>1$)
stable	Vertical Stability of Stream				

Calculation of BKF Water Surface Slope Required for Entrainment of Largest Particle in Bar Sample

0.0075	S_r	Required bankfull water surface slope (ft)	$S_r = \frac{\tau^*_{ci}\gamma_s D_i}{d_e}$		
1.07	S_e/S_r	Existing water surface slope / Required water surface slope	Stable ($S_e/S_r = 1$)	Aggrading ($S_e/S_r < 1$)	Degrading ($S_e/S_r > 1$)
stable	Vertical Stability of Stream				

Sediment Transport Validation

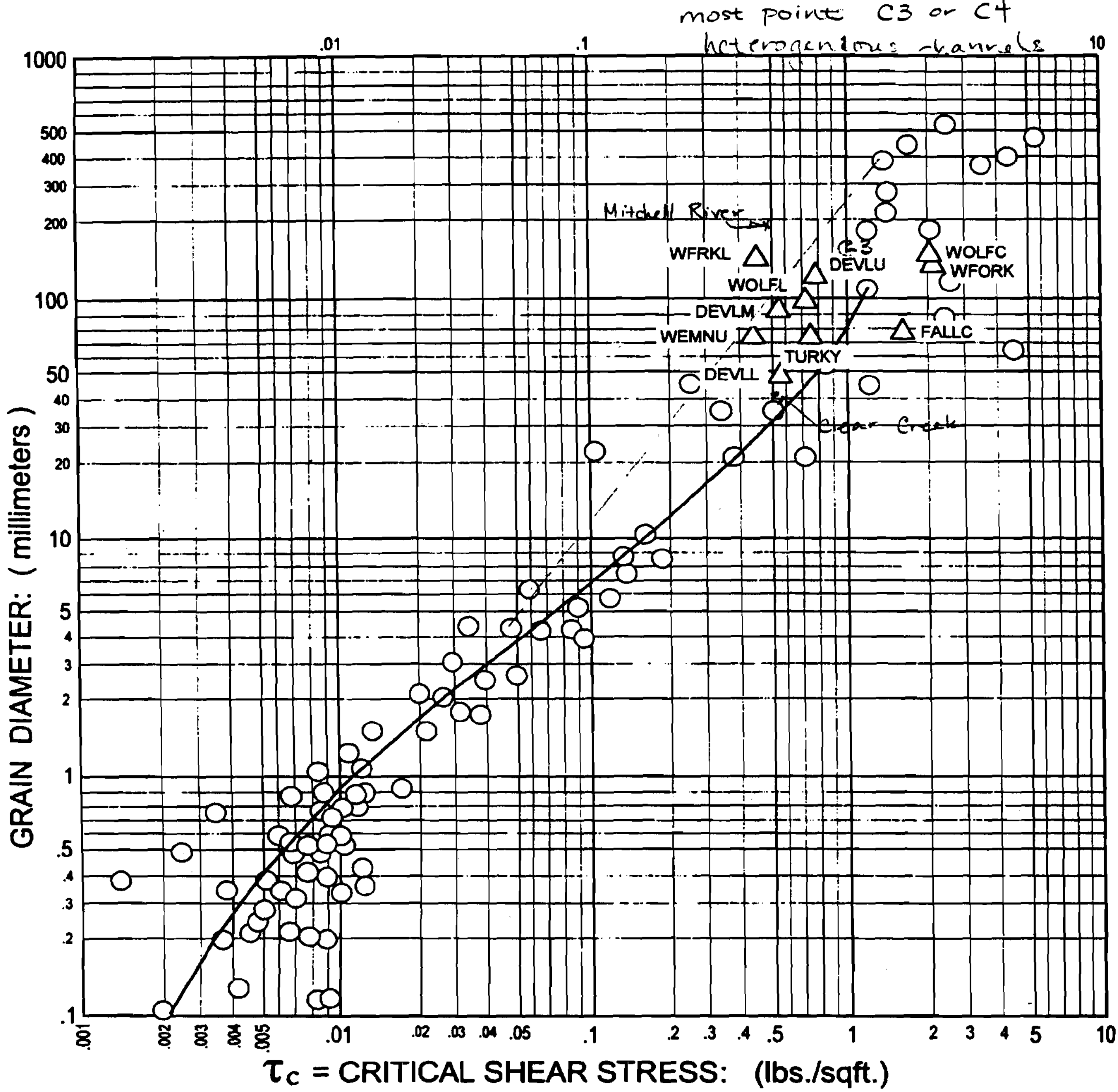
0.45	Bankfull Shear Stress $\tau_c = \gamma RS$ (lb/ft2) γ = Density of water = 62.4 lbs/ft^3
27-100	Moveable particle size (mm) at bankfull shear stress (predicted by the Shields Diagram: Blue field book:p238, Red field book:p190)
0.4-1.1	Predicted shear stress required to initate movement of D_i (mm) (see Shields Diagram: Blue field book:p238, Red field book:p190)

Snow Creek Stream Restoration
Prabhupada Village, Stokes County
NC Wetlands Restoration Program

	Snow Creek Pavement			Snow Creek Subpavement		
Particle sizes (mm)	weight (oz)	%	% cum.	weight (lb)	%	% cum.
< 2 mm	13	0.17	0.17	3.75	0.12	0.12
2 mm - 4 mm	7	0.09	0.27	1.75	0.06	0.17
4 mm - 8 mm	6	0.08	0.35	1.75	0.06	0.23
8 mm - 16 mm	8	0.11	0.45	3.25	0.10	0.33
16 mm - 32 mm	12	0.16	0.61	5	0.16	0.49
32 mm - 64 mm	20	0.27	0.88	2.5	0.08	0.57
> 64 mm	9	0.12	1.00	13.5	0.43	1.00
TOTAL	75			31.5		
largest particles	73 mm			lgst part.	130 mm	
	55 mm				138 mm	
d50=	19.5	mm		d50=	5.7	mm
d84=	53.0	mm		d84=	36.0	mm

	UT to Snow Creek Pavement			UT to Snow Creek Subpavement		
Particle sizes (mm)	weight (oz)	%	% cum.	weight (lb)	%	% cum.
< 2 mm	2	0.01	0.01	3.75	0.12	0.12
2 mm - 4 mm	1	0.00	0.01	1.75	0.06	0.17
4 mm - 8 mm	3	0.01	0.03	1.75	0.06	0.23
8 mm - 16 mm	7	0.03	0.06	3.25	0.10	0.33
16 mm - 32 mm	14	0.07	0.13	5	0.16	0.49
32 mm - 64 mm	21	0.10	0.23	2.5	0.08	0.57
> 64 mm	160	0.77	1.00	13.5	0.43	1.00
TOTAL	208			31.5		
largest particles	160 mm			lgst part.	170 mm	
	90 mm				128 mm	
					126 mm	
d50=	127	mm		d50=	32.7	mm
d84=	150	mm		d84=	56.0	mm

Figure 6. Critical Dimensionless Shear Stress Required to Initiate Movement of Grains



Laboratory and field data on critical shear stress required to initiate movement of grains (Leopold, Wolman, & Miller 1964). The solid line is the Shields curve of the *threshold of motion*; transposed from the θ versus R_g form into the present form, in which critical shear stress is plotted as a function of grain diameter.

△ EPA TMDL Study Sites (1997-1999)

Snow Creek
Prabhupada Village, Stokes County

Riparian zone lacking woody vegetation

Endangered plant, small-anthered bittercress (*Cardamine micranthera)*

Snow Creek
Prabhupada Village, Stokes County

Old pasture fence at top of 8'-10' vertical bank

Mid-channel bar

Unnamed tributary to Snow Creek
Prabhupada Village, Stokes County

BEHI cross section measured in this area

Tight radius of curvature with lots of woody debris

Search Criteria: =Danbury

Quads: 24

Major Group	Scientific Name (Habitat link)	Common Name	State Status	Federal Status	State Rank	Global Rank	Quad Status
Reptile	Crotalus horridus	Timber Rattlesnake	SC	-	S3	G4	Historic - DANBURY
Amphibian	Plethodon wehrlei	Wehrle's Salamander	T	-	S1	G5	Historic - DANBURY
Fish	Etheostoma podostemone	Riverweed Darter	SC	-	S2	G4	Current - DANBURY
Fish	Hypentelium roanokense	Roanoke Hog Sucker	SR	-	S3	G4	Current - DANBURY
Fish	Noturus gilberti	Orangefin Madtom	E	FSC	S1	G2	Historic - DANBURY
Fish	Scartomyzon ariommus	Bigeye Jumprock	T	-	S2	G4	Current - DANBURY
Mollusk	Pleurobema collina	James Spinymussel	SR	E	S1	G1	Current - DANBURY
Vascular Plant	Baptisia albescens	Thin-pod White Wild Indigo	SR-P	-	S2	G4	Historic - DANBURY
Vascular Plant	Cardamine micranthera	Small-anthered Bittercress	E	E	S1	G1	Current - DANBURY
Vascular Plant	Fothergilla major	Large Witch-alder	SR-T	-	S2	G3	Current - DANBURY
Vascular Plant	Minuartia groenlandica	Greenland Sandwort	SR-D	-	S2	G5	Current - DANBURY
Vascular Plant	Quercus ilicifolia	Bear Oak	SR-P	-	S1	G5	Current - DANBURY
Vascular Plant	Sedum glaucophyllum	Cliff Stonecrop	SR-P	-	S2	G4	Current - DANBURY
Vascular Plant	Silphium connatum	Virginia Cup-plant	SR-T	-	S1	G3?Q	Current - DANBURY
Vascular Plant	Thermopsis mollis sensu stricto	Appalachian Golden-banner	SR-P	-	S2	G3G4Q	Historic - DANBURY
Natural Community	Canada Hemlock Forest	-	-	-	S5	G5	Current - DANBURY
Natural Community	Chestnut Oak Forest	-	-	-	S5	G5	Current - DANBURY
Natural Community	Dry Oak--Hickory Forest	-	-	-	S4	G5	Current - DANBURY
Natural Community	Dry-Mesic Oak--Hickory Forest	-	-	-	S5	G5	Current - DANBURY
Natural Community	Low Elevation Rocky Summit	-	-	-	S2	G2	Current - DANBURY
Natural Community	Piedmont Calcareous Cliff	-	-	-	S1	G1	Current - DANBURY
Natural Community	Piedmont/Coastal Plain Heath Bluff	-	-	-	S3	G4?	Current - DANBURY
Natural Community	Pine--Oak/Heath	-	-	-	S4	G5	Current - DANBURY
Natural Community	Rich Cove Forest	-	-	-	S4	G4	Current - DANBURY

NC NHP database updated: July, 2002. Search performed on Tuesday, November 12, 2002 at 14:54:36 Eastern Standard Time.
Total number of searches since 01/01/02: 1966
Explanation of Codes
Do NOT bookmark this search results page, instead bookmark: www.ncsparks.net/nhp/quad.html

Name of Stream	Description	Curr. Class	Date	Prop. Class	Basin	Stream Index #
Scott Creek (Steadmans Creek)	From source to Dan River	C	09/01/74		Roanoke	22-17
Mill Creek	From source to Dan River	C	08/03/92		Roanoke	22-18
Flat Shoals Creek	From source to Dan River	C	07/01/73		Roanoke	22-19
Snow Creek	From source to Dan River	C	08/01/98		Roanoke	22-20
Banner Branch	From source to Snow Creek	C	09/01/74		Roanoke	22-20-1
Mountain Branch	From source to Snow Creek	C	09/01/74		Roanoke	22-20-2
Little Snow Creek	From source to Snow Creek	C	09/01/74		Roanoke	22-20-3
Raccoon Creek	From source to Snow Creek	C	09/01/74		Roanoke	22-20-4
Mill Creek (Hawkins Mill Creek)	From source to Snow Creek	C	09/01/74		Roanoke	22-20-5
Ugly Branch	From source to Snow Creek	C	08/01/98		Roanoke	22-20-6
Baker Branch	From source to Snow Creek	C	08/01/98		Roanoke	22-20-7
Redman Creek	From source to Snow Creek	C	08/01/98		Roanoke	22-20-8
Lynn Branch (Lynn Creek)	From source to Snow Creek	C	08/01/98		Roanoke	22-20-9
Wood Benton Branch	From source to Dan River	C	08/01/98		Roanoke	22-21
Blackies Branch	From source to Dan River	C	08/01/98		Roanoke	22-22
Zilphy Creek	From source to Dan River	C	08/01/98		Roanoke	22-23
Fulk Creek	From source to Dan River	C	08/01/98		Roanoke	22-24
Town Fork Creek	From source to Dan River	C	08/01/98		Roanoke	22-25
Brushy Fork Creek	From source to Town Fork Creek	C	09/01/74		Roanoke	22-25-1
Straight Fork Creek	From source to Brushy Fork Creek	C	09/01/74		Roanoke	22-25-1-1
Timmons Creek	From source to Town Fork Creek	C	09/01/57		Roanoke	22-25-2

Appendix 2

Stream Classification and Assessment

Existing Cross Sections

Existing Longitudinal Profile

Pebble Count Data

Pfankuch Stability Rating

BEHI Rating

Bank Erosion Prediction

Summary of Stability Condition Categories for the Level III Inventory

Stream: SNOW CREEK		**Location:** PRABHUPADA VILLAGE, STOKES CO.			**Date:** 5-14-02	**Observers:** LS, DS	
Level III Variables	Stream Type: C4/1	Flow Regime: P2 P8	Stream Size: S6	Stream Order:	Meander Pattern: M3	Depositional Pattern: B1, B2	Debris/Channel Blockage: D3, D10
	Riparian Vegetation: RV10b RV11	Current Compo/density:	Potential Comp/density:		Altered Channel State: Prior straightened; Riparian zone reduced for ag. production		
Channel Dimension	Mean Bankfull Depth (ft): 4.3	Mean Bankfull Width (ft): 68.4	Width/Depth Ratio (ft): 15.9				
Channel Dimension Relationships	Existing Width/Depth Ratio(W/D_{ex}): 15.9	Reference Condition Width/Depth Ratio (W/D_{ref}): 11.8 - 19.7	$(W/D_{ex})/(W/D_{ref})$: 1.34 0.81	Circle: Excellent (Good) Fair Poor — Moderately Unstable			
Channel Pattern		MWR	Lm/W_{bkf}	Rc/W_{bkf}	Arc Length/W_{bkf}	Arc Angle	Sinuosity
	Mean (Range)	1.75	5.3	1.5			
River Profile and Bed Features	Circle: (Riffle/Pool) Step/Pool Convergence/Divergence Dunes/antidunes/smooth bed						
	Max Bankfull Depth (ft): Riffle 6.2	Pool 5.6	Depth Ratio (Max/Mean): Riffle 1.4	Pool 1.4	Pool to Pool Spacing: 397 (210 - 630)	Slope — Valley: 0.0029	Average Bankfull: 0.0026
Channel Stability Rating	Pfankuch Rating: 99			Pfankuch Adjusted by Stream Type: FAIR			
Stream Channel Scour/Deposition Potential	Largest Particle - Bar Sample (mm): 73	τc_i: 0.0272	Existing $Depth_{BKF}$: 4.3	Required $Depth_{BKF}$: 5.1	Existing $Slope_{BKF}$: 0.002	Required $Slope_{BKF}$: 0.0025	
	Circle: Stable (Aggrading) Degrading						
Vertical Stability	Bank Height Ratio: 1.4	Stable	Moderately unstable	(Unstable)	Highly Unstable	Width of Flood Prone Area (ft): 535	Entrenchment Ratio: 7.8
Bank Erosion Summary	Length of Bank Studied (ft): 300	Annual Streambank Erosion Rate (tons/yr): 133	Curve Used: Colorado	Dominant BEHI: VERY HIGH	Dominant NBS: VERY HIGH		
Stream Evolution Scenario	C4 → G4 → F4 → C4 → →			Existing Stream State (type): C4/1	Potential Stream State (type): C4/1		
Sediment Supply	Circle: Extreme Very High (High) Moderate Low						
Dimensionless Sediment Rating Curve:	Normal (Above Normal) Excessive						

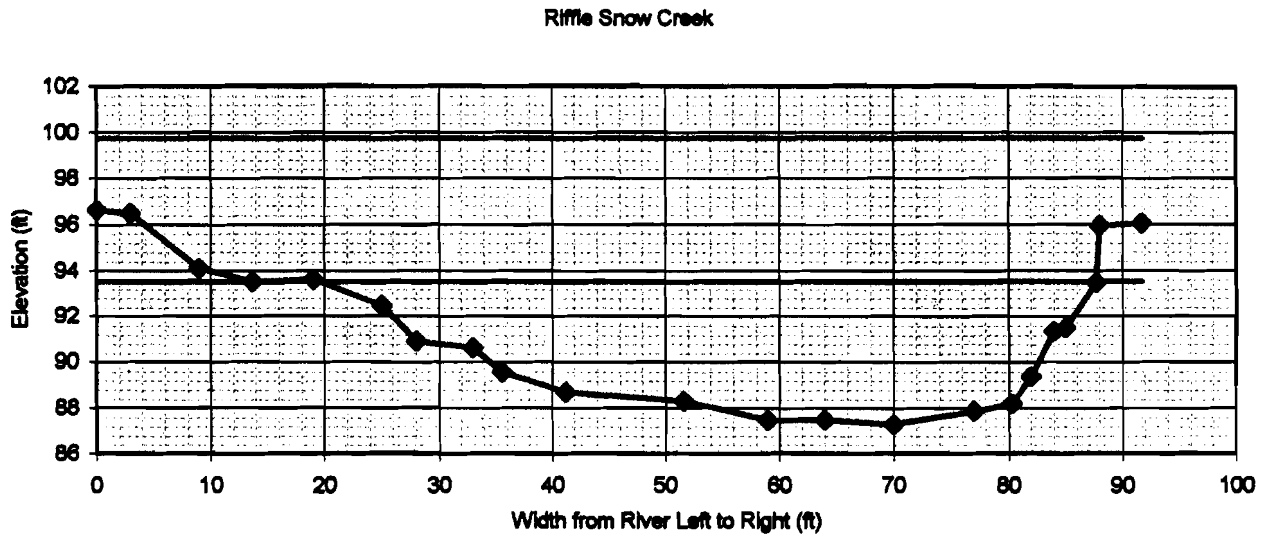
Summary of Stability Condition Categories for the Level III Inventory

Stream: UT to Snow Creek		**Location:** Stokes County Hare Krishna Village			**Date:** 5/16/02	**Observers:** Louise + Kyle
Level III Variables	Stream Type:	Flow Regime: P2/P8	Stream Size: S-3	Stream Order: 2	Meander Pattern: M2/M7/M8	Depositional Pattern: B1/B2/B4
						Debris/Channel Blockage: D4/
	Riparian Vegetation: Current Compo/density: RV10b	Potential Comp/density:		Altered Channel State: straightened. loss of riparian veg.		
Channel Dimension	Mean Bankfull Depth (ft): 1.0	Mean Bankfull Width (ft): 14.5	Width/Depth Ratio (ft): 14.9			
Channel Dimension Relationships	Existing Width/Depth Ratio(W/D_{ex}): 14.9	Reference Condition Width/Depth Ratio (W/D_{ref}): 11.8 19.7	$(W/D_{ex})/(W/D_{ref})$: 1.26 0.75	Circle: Excellent (Good) Fair Poor Moderately Unstable		

Channel Pattern		MWR	Lm/W_{bkf}	Rc/W_{bkf}	Arc Length/W_{bkf}	Arc Angle	Sinuosity
	Mean (Range)	4.1	4.6	1.2 1.1 - 1.3			1.7

River Profile and Bed Features	Circle: (Riffle/Pool) Step/Pool Convergence/Divergence Dunes/antidunes/smooth bed						
	Max Bankfull Depth (ft): Riffle 1.8	Pool 3.0	Depth Ratio (Max/Mean): Riffle 1.8	Pool 3.3	Pool to Pool Spacing: 76 (52-157)	Slope Valley: 0.0108	Average Bankfull: 0.008
Channel Stability Rating	Pfankuch Rating: 106			Pfankuch Adjusted by Stream Type: GOOD FOR F; FAIR FOR C			
Stream Channel Scour/Deposition Potential	Largest Particle - Bar Sample (mm): 90	τ_{ci}: 0.0153	Existing $Depth_{BKF}$: 1.0	Required $Depth_{BKF}$: 0.93	Existing $Slope_{BKF}$: 0.008	Required $Slope_{BKF}$: 0.0075	
	Circle: Stable Aggrading (Degrading)						
Vertical Stability	Bank Height Ratio: 1.8-4.1	Stable Moderately unstable Unstable (Highly Unstable)			Width of Flood Prone Area (ft): 17	Entrenchment Ratio: 1.2	
Bank Erosion Summary	Length of Bank Studied (ft): 150	Annual Streambank Erosion Rate (tons/yr): 62	Curve Used: Colorado		Dominant BEHI: VERY HIGH	Dominant NBS: EXTREME	
Stream Evolution Scenario	C → G → F → C → →				Existing Stream State (type): F4	Potential Stream State (type): C4.	
Sediment Supply	Circle: Extreme Very High (High) Moderate Low						
Dimensionless Sediment Rating Curve:	Normal (Above Normal) Excessive						

Cross Section



section:	Riffle Snow Creek Dan River in Roanoke River Basin
description:	Riffle above big Sycamore
height of instrument (ft):	100.00

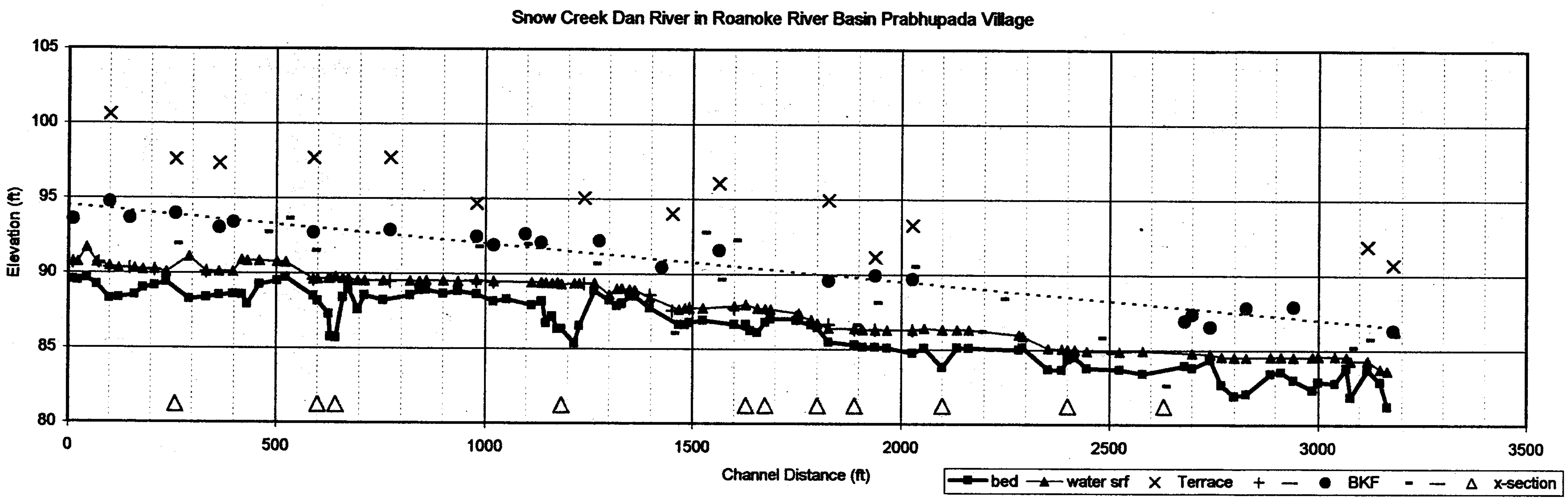
notes	omit pt.	distance (ft)	FS (ft)	elevation
left pin		0	3.35	96.65
LTOB		3	3.49	96.51
		9	5.87	94.13
		13.7	6.44	93.56
LBKF		19	6.38	93.62
		25	7.5	92.5
		28	9.05	90.95
		33	9.36	90.64
sand bar		35.6	10.4	89.6
LEW		41.2	11.29	88.71
D=0.1		51.6	11.68	88.32
D=0.7		59	12.5	87.5
D=0.7		64	12.48	87.52
D=0.7		70	12.67	87.33
D=0.4		77	12.1	87.9
REW		80.3	11.79	88.21
		82	10.6	89.4
RBKF		84	8.63	91.37
		85	8.48	91.52
		87.7	6.52	93.48
RTOB		88	4.05	95.95
right pin		91.7	3.94	96.06

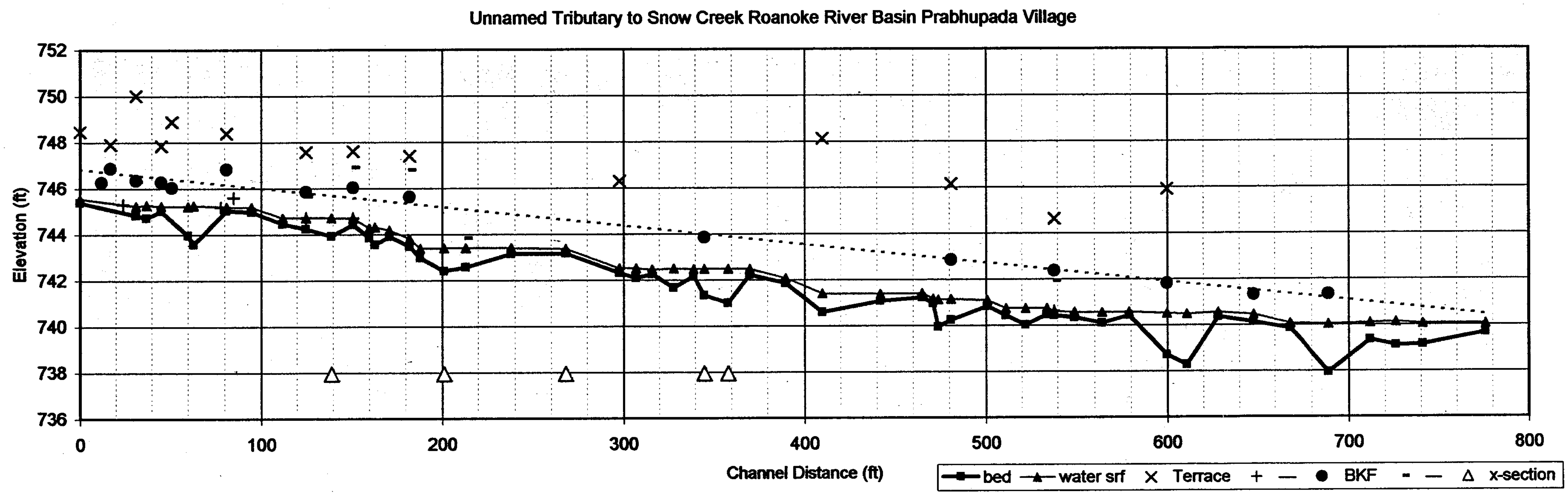
FS bankfull	FS top of bank	W fpa (ft)	channel slope (%)	Manning's "n"
6.44	4.05	80.0	0.0026	
93.56	95.95			

dimensions			
296.5	x-section area	4.3	d mean
68.4	width	71.1	wet P
6.2	d max	4.2	hyd radi
8.6	bank ht	15.8	w/d ratio
80.0	W flood prone area	1.2	ent ratio

hydraulics	
0.0	velocity (ft/sec)
0.0	discharge rate, Q (cfs)
0.01	shear stress ((lbs/ft sq)
0.06	shear velocity (ft/sec)
0.000	unit stream power (lbs/ft/sec)
0.00	Froude number
0.0	friction factor u/u*
0.6	threshold grain size (mm)

check from channel material			
54	measured D84 (mm)		
24.6	relative roughness	10.8	fric. factor
0.031	Manning's n from channel material		

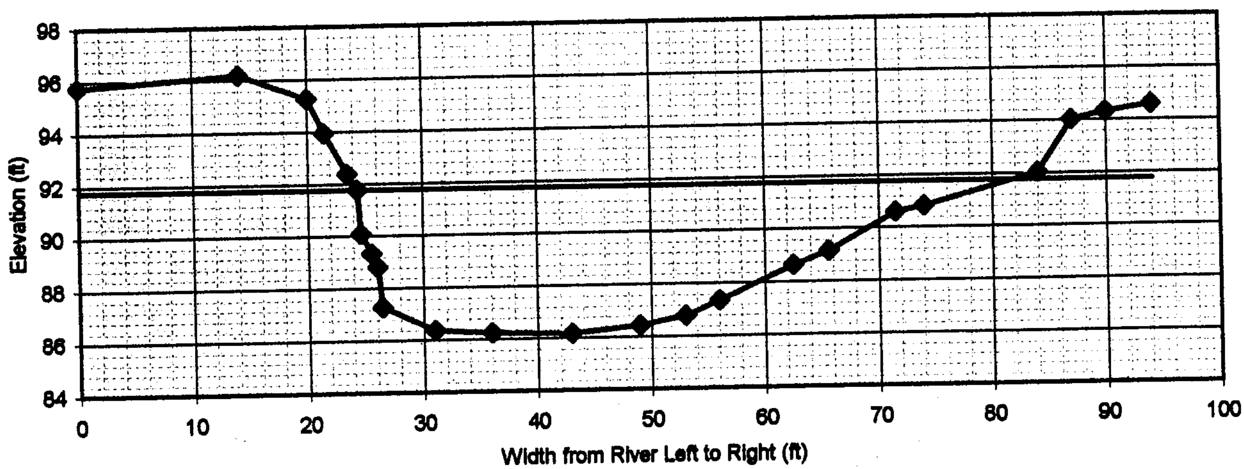

Snow Creek Dan River in Roanoke River Basin Prabhupada Village
Elevation (ft)
105
100
95
90
85
80
0
500
1000
1500
2000
2500
3000
3500
Channel Distance (ft)
bed
water srf
Terrace
BKF
x-section



5/6/2002

EcoLogic Associates

Cross Section



section:

Pool
Snow Creek
Dan River in Roanoke River Basin

description:

height of instrument (ft): 100.00

notes	omit pt.	distance (ft)	FS (ft)	elevation
left pin	☐	0	4.23	95.77
	☐	14	3.79	96.21
LTOB	☐	20	4.71	95.29
	☐	21.5	6.04	93.96
	☐	23.5	7.6	92.4
LBKF	☐	24.3	8.2	91.8
	☐	24.6	9.89	90.11
	☐	25.5	10.64	89.36
sand bar	☐	26	11.17	88.83
LEW	☐	26.4	12.7	87.3
0.9	☐	31	13.6	86.4
1.02	☐	36	13.72	86.28
1.1	☐	43	13.8	86.2
0.83	☐	49	13.53	86.47
	☑	52.5		
0.5	☐	53	13.2	86.8
REW	☐	56	12.64	87.36
	☐	62.5	11.33	88.67
	☐	65.6	10.83	89.17
	☐	71.5	9.38	90.62
RBKF (?)	☐	74	9.15	90.85
	☑	80.3		
	☐	84	7.93	92.07
RTOB	☐	87	5.95	94.05
	☐	90	5.67	94.33
right pin	☐	94	5.4	94.6

FS bankfull	FS top of bank		channel slope (%)
8.2	5.95		0.0026
91.8	94.05		

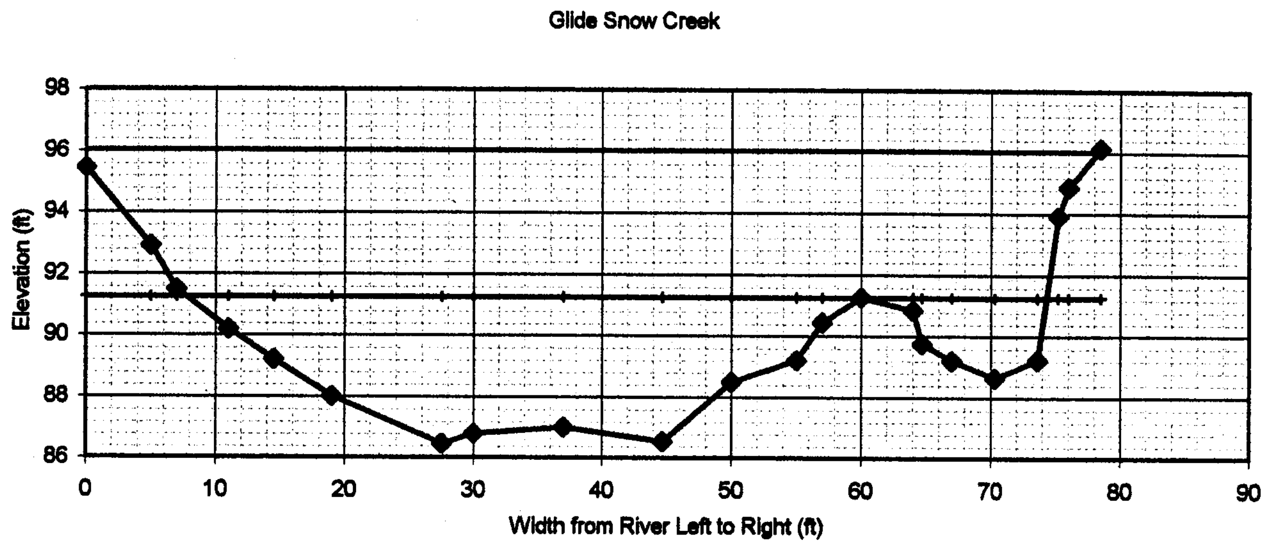
dimensions

188.3	x-section area	4.1	d mean
45.7	width	49.3	wet P
5.6	d max	3.8	hyd radi
7.9	bank ht		

hydraulics

0.01	shear stress ((lbs/ft sq)
0.06	shear velocity (ft/sec)
0.5	threshold grain size (mm)

Cross Section



section:

Glide
Snow Creek
Dan River in Roanoke River Basin

description:

height of instrument (ft): 100.00

notes	omit pt.	distance (ft)	FS (ft)	elevation
left pin and	■	0	4.53	95.47
	■	5	7.06	92.94
	■	7	8.5	91.5
	■	11	9.79	90.21
LEW	■	14.5	10.78	89.22
1.1	■	19	11.96	88.04
2.65	■	27.5	13.51	86.49
2.5	■	30	13.18	86.82
2.23	■	37	12.97	87.03
2.7	■	44.7	13.44	86.56
0.7	■	50	11.48	88.52
REW	■	55	10.77	89.23
	■	57	9.54	90.46
top of bar	■	60	8.73	91.27
	■	64	9.14	90.86
	■	64.7	10.22	89.78
LEW trib	■	67	10.77	89.23
0.6	■	70.3	11.35	88.65
REW	■	73.6	10.75	89.25
	■	75.2	6.07	93.93
	■	76	5.12	94.88
right pin	■	78.5	3.85	96.15
	■			
	■			
	□			

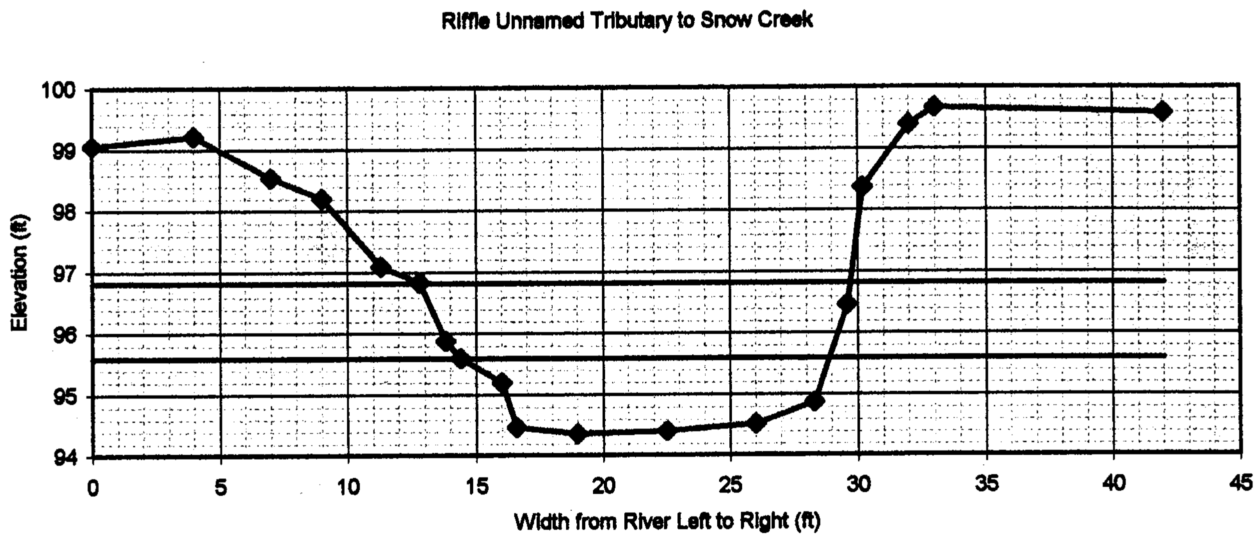
FS bankfull	FS top of bank		channel slope (%)	
8.73	4.53		0.0026	
91.27	95.47			

dimensions			
186.9	x-section area	2.8	d mean
66.6	width	70.3	wet P
4.8	d max	2.7	hyd radi
9.0	bank ht		w/d ratio
			ent ratio

hydraulics	
	[illegible]
	[illegible]
0.00	shear stress ((lbs/ft sq)
0.05	shear velocity (ft/sec)
	[illegible]
	[illegible]
	[illegible]
0.3	threshold grain size (mm)

	[illegible]		
	[illegible]		
	[illegible]		

Cross Section



section:

Riffle
Unnamed Tributary to Snow Creek
Roanoke River Basin

description: Station 268 of Long Pro

height of instrument (ft): 103.98

notes	omit pt.	distance (ft)	FS (ft)	elevation
L pin	■	0	4.91	99.07
LTOB	■	4	4.76	99.22
	■	7	5.44	98.54
	■	9	5.77	98.21
	■	11.3	6.88	97.1
	■	12.8	7.14	96.84
	■	13.8	8.1	95.88
BKF	■	14.4	8.38	95.6
	■	16	8.78	95.2
LEW	■	16.6	9.51	94.47
d=0.16	■	19	9.61	94.37
d=0.12	■	22.5	9.57	94.41
REW	■	26	9.46	94.52
	■	28.3	9.1	94.88
	■	29.6	7.51	96.47
	■	30.2	5.6	98.38
	■	32	4.58	99.4
	■	33	4.3	99.68
R pin	■	42	4.39	99.59
	■			
	■			
	■			
	■			
	■			
	□			

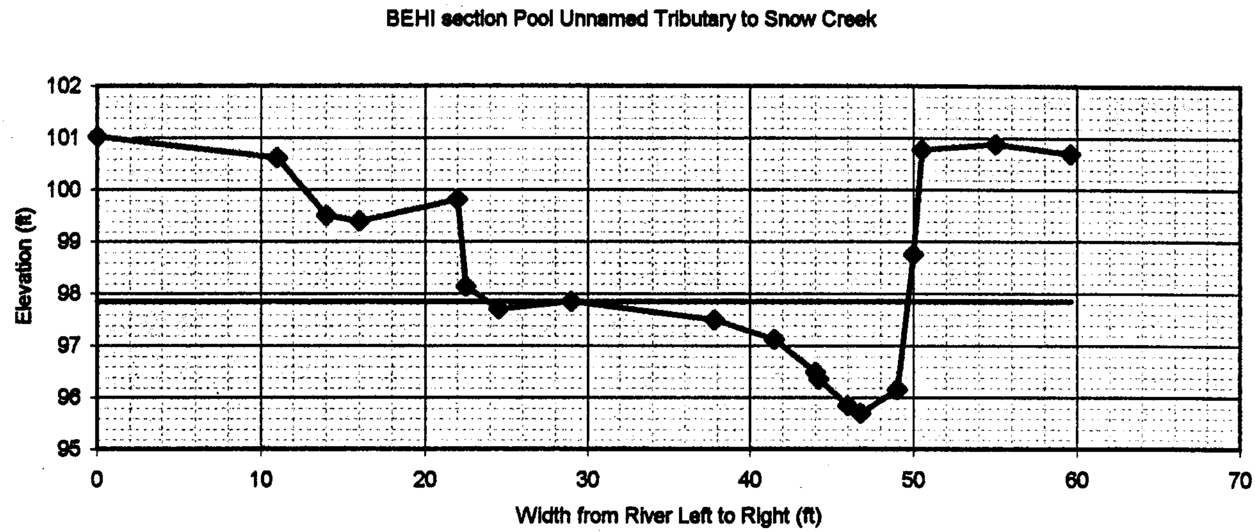
FS bankfull	FS top of bank	W fpa (ft)	channel slope (%)	Manning's "n"
8.38	4.76	17.0	0.0087	
95.6	99.22			

dimensions			
14.1	x-section area	1.0	d mean
14.5	width	15.3	wet P
1.2	d max	0.9	hyd radi
4.9	bank ht	14.9	w/d ratio
17.0	W flood prone area	1.2	ent ratio

hydraulics	
0.0	velocity (ft/sec)
0.0	discharge rate, Q (cfs)
0.01	shear stress ((lbs/ft sq)
0.05	shear velocity (ft/sec)
0.000	unit stream power (lbs/ft/sec)
0.00	Froude number
0.0	friction factor u/u*
0.4	threshold grain size (mm)

check from channel material			
68	measured D84 (mm)		
4.4	relative roughness	6.5	fric. factor
0.040	Manning's n from channel material		

Cross Section



section:	BEHI section
	Pool Unnamed Tributary to Snow Creek Roanoke River Basin
description:	Station 350.5 on Long Pro
height of instrument (ft):	104.63

notes	omit pt.	distance (ft)	FS (ft)	elevation
L pin	■	0	3.59	101.04
	■	11	4	100.63
	■	14	5.11	99.52
	■	16	5.22	99.41
	■	22	4.8	99.83
	■	22.5	6.48	98.15
	■	24.5	6.92	97.71
	■	29	6.76	97.87
	■	37.8	7.12	97.51
	■	41.5	7.49	97.14
	■	44	8.12	96.51
LEW	■	44.2	8.26	96.37
d=0.5	■	46	8.77	95.86
TW d=0.6	■	46.8	8.91	95.72
REW d=.1	■	49	8.46	96.17
	■	50	5.86	98.77
R TOB	■	50.5	3.84	100.79
	■	55	3.73	100.9
R pin	■	59.6	3.92	100.71
	■			
	■			
	■			
	■			
	■			
	□			

FS bankfull	FS top of bank		channel slope (%)	
6.76	3.84		0.0087	
97.87	100.79			

dimensions			
16.5	x-section area	0.6	d mean
25.9	width	27.3	wet P
2.1	d max	0.6	hyd radi
5.1	bank ht	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]

hydraulics	
[illegible]	[illegible]
[illegible]	[illegible]
0.00	shear stress ((lbs/ft sq)
0.04	shear velocity (ft/sec)
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
0.2	threshold grain size (mm)

[illegible]			
[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		

Weighted Pebble Count

Percent Riffle:	50	Percent Run:	
Percent Pool:	50	Percent Glide:	

Pebble Count,

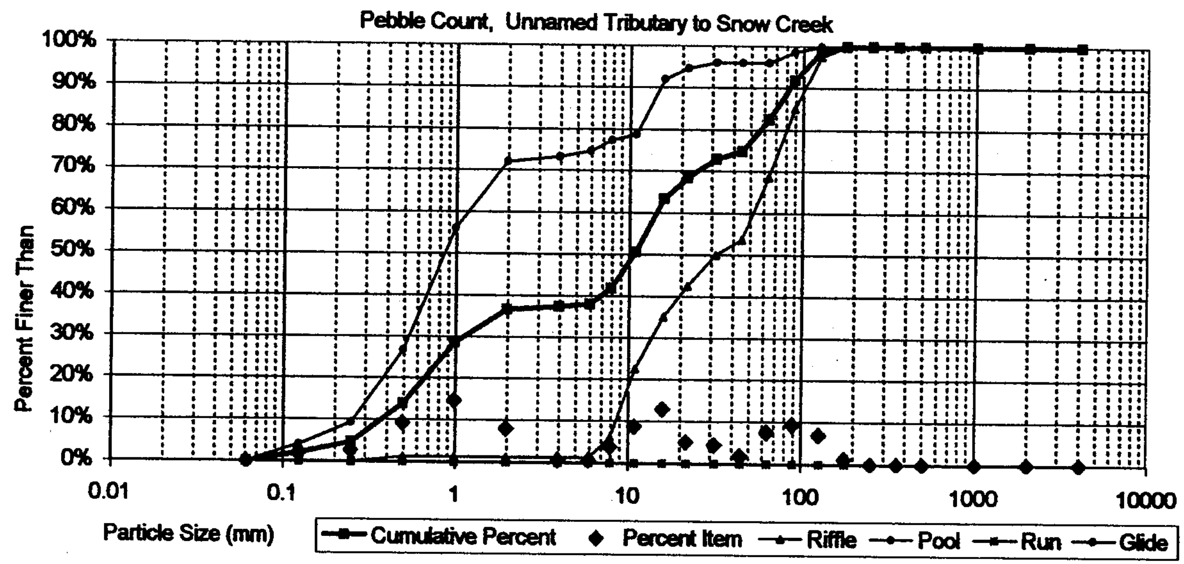
Unnamed Tributary to Snow Creek

Roanoke River Basin

Prabhupada Village

Note:

Material	Size Range (mm)		Total #
silt/clay	0	0.062	0.0
very fine sand	0.062	0.13	2.0
fine sand	0.13	0.25	2.7
medium sand	0.25	0.5	9.3
coarse sand	0.5	1	14.7
very coarse sand	1	2	8.0
very fine gravel	2	4	0.7
fine gravel	4	6	0.7
fine gravel	6	8	3.8
medium gravel	8	11	8.8
medium gravel	11	16	12.9
coarse gravel	16	22	5.1
coarse gravel	22	32	4.4
very coarse gravel	32	45	1.9
very coarse gravel	45	64	7.5
small cobble	64	90	9.5
medium cobble	90	128	6.9
large cobble	128	180	1.3
very large cobble	180	256	0.0
small boulder	256	362	0.0
small boulder	362	512	0.0
medium boulder	512	1024	0.0
large boulder	1024	2048	0.0
very large boulder	2048	4096	0.0
bedrock			0.0
Weighted Count:			100
True Total Particle Count:			155



Size percent less than (mm)				
D16	D35	D50	D84	D95
0.551	1.74	10.8	68	106

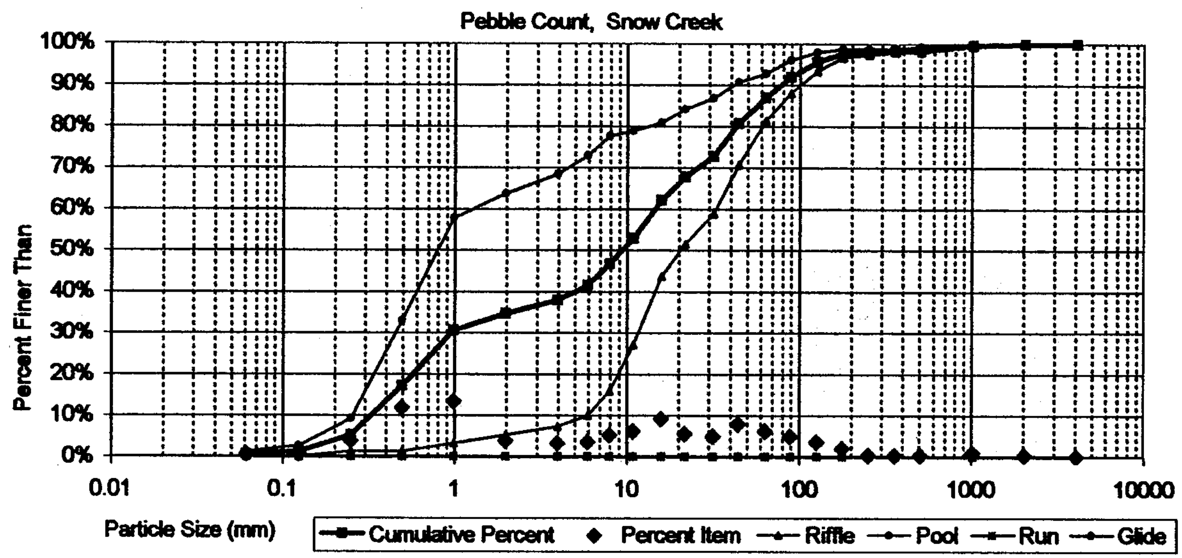
Percent by substrate type					
silt/clay	sand	gravel	cobble	boulder	bedrock
0%	37%	46%	18%	0%	0%

Weighted Pebble Count

Percent Riffle:	50	Percent Run:	
Percent Pool:	50	Percent Glide:	

Pebble Count,
Snow Creek
Dan River in Roanoke River Basin
Prabhupada Village
Note:

Material	Size Range (mm)		Total #	
silt/clay	0	0.062	0.7	# #
very fine sand	0.062	0.13	0.7	# #
fine sand	0.13	0.25	3.9	# #
medium sand	0.25	0.5	11.8	# #
coarse sand	0.5	1	13.4	# #
very coarse sand	1	2	3.9	# #
very fine gravel	2	4	3.3	# #
fine gravel	4	6	3.6	# #
fine gravel	6	8	5.2	# #
medium gravel	8	11	6.2	# #
medium gravel	11	16	9.2	# #
coarse gravel	16	22	5.6	# #
coarse gravel	22	32	4.9	# #
very coarse gravel	32	45	7.9	# #
very coarse gravel	45	64	6.2	# #
small cobble	64	90	4.9	# #
medium cobble	90	128	3.6	# #
large cobble	128	180	2.0	# #
very large cobble	180	256	0.3	# #
small boulder	256	362	0.3	# #
small boulder	362	512	0.3	# #
medium boulder	512	1024	1.0	# #
large boulder	1024	2048	0.3	# #
very large boulder	2048	4096	0.0	# #
bedrock			0.7	#
Weighted Count:			100	
True Total Particle Count:			305	



Size percent less than (mm)				
D16	D35	D50	D84	D95
0.469	2.20	9.4	54	120

Percent by substrate type					
silt/clay	sand	gravel	cobble	boulder	bedrock
1%	34%	52%	11%	2%	1%

PFANKUCH CHANNEL STABILITY EVALUATION

Reach Location: SNOW CREEK Date: 5-15-02 Observers: LOUISE DON STREAM TYPE: C4

		catagory	EXCELLENT		GOOD		FAIR		POOR	
UPPER BANKS	1	Landform Slope	Bank Slope Gradient <30%	2	Bank slope gradient 30–40%.	4	Bank slope gradient 40-60%.	6	Bank slope gradient 60% +.	(8)
	2	Mass Wasting	No evidence of past or future mass wasting.	3	Infrequent. Mostly healed over. Low future potential.	6	Frequent or large, causing sediment nearly year long.	(9)	Frequent or large causing sediment nearly year long or imminent danger of same.	12
	3	Debris Jam Potential	Essentially absent from immediate channel area.	2	Present, but mostly small twigs and limbs.	4	Moderate to heavy amounts, mostly larger sizes.	(6)	Moder. to heavy amounts, predom. larger sizes.	8
	4	Vegetative Bank Protection	90%+ plant density. Vigor and variety suggest a deep dense soil binding root mass.	3	70-90% density. Fewer species or less vigor suggest less dense or deep root mass.	6	<50-70% density. Lower vigor and fewer species form a shallow, discontinuous root mass.	(9)	<50% density, fewer species and less vigor indicate poor, discontinuous and shallow root mass.	12
LOWER BANKS	5	Channel Capacity	Ample for present plus some increases. Peak flows contained. W/D ratio <7	1	Adequate. Bank overflows rare. W/D ratio 8-15.	2	Barely contains present peaks. Occasional overbank floods. W/D ratio 15 to 25.	3	Inadequate. Overbank flows common. W/D ratio >25	4
	6	Bank Rock Content	65%+ with large angular boulders. 12"+ common	2	40-65%. Mostly small boulders to cobbles 6-12".	4	20-40% with most in the 3-6" diameter class.	(6)	<20% rock fragments of gravel sizes, 1-3" or less.	8
	7	Obstructions to Flow	Rocks and logs firmly imbedded. Flow pattern without cutting or deposition. Stable bed.	2	Some present causing erosive cross currents and minor pool filling. Obstructions newer and less firm.	4	Moder. frequent, unstable obstructions move with high flows causing bank cutting and pool filling.	(6)	Frequent obstructions cause erosion year-long. Sediment traps full, channel migration occurring.	8
	8	Cutting	Little or none. Infreq. raw banks less than 6".	4	Some, intermittently at outcurves and constrictions. Raw banks may be up to 12".	(6)	Significant. Cuts 12-24" high. Root mat overhangs and sloughing evident.	12	Almost continuous cuts, some over 24" high. Failure of overhangs frequent.	16
	9	Deposition	Little or no enlargement of channel or pt. bars	4	Some new bar increase, mostly from coarse gravel.	8	Moder. deposition of new gravel and course sand on old and some new bars.	(12)	Extensive deposits of predominately fine particles. Accelerated bar development.	16
BOTTOM	10	Rock Angularity	Sharp edges and corners. Plane surfaces rough.	1	Rounded corners and edges, surfaces smooth, flat.	2	Corners and edges well rounded in two dimensions.	(3)	Well rounded in all dimensions, surfaces smooth.	4
	11	Brightness	Surfaces dull, dark or stained. Gen. not bright.	1	Mostly dull, but may have <35% bright surfaces.	(2)	Mixture dull and bright. ie 35-65% mixture range.	3	Predom. bright, 65%+ exposed or scoured surfaces.	4
	12	Consolidation of Particles	Assorted sizes tightly packed or overlapping.	2	Moderately packed with some overlapping.	(4)	Mostly loose assortment with no apparent overlap.	6	No packing evident. Loose assortment easily moved.	8
	13	Bottom Size Distribution	No size change evident. Stable mater. 80-100%.	4	Distribution shift light. Stable material 50-80%.	(8)	Moder. change in sizes. Stable materials 20-50%.	12	Marked distribution change. Stable materials 0-20%.	16
	14	Scouring and Deposition	<5% of bottom affected by scour or deposition.	6	5-30% affected. Scour at constrictions and where grades steepen. Some deposition in pools.	12	30-50% affected. Deposits & scour at obstructions, constrictions, and bends. Some filling of pools.	(18)	More than 50% of the bottom in a state of flux or change nearly year-long.	24
	15	Aquatic Vegetation	Abundant. Growth moss-like, dark green, perennial. In swift water too.	1	Common. Algal forms in low velocity and pool areas. Moss here too.	(2)	Present but spotty, mostly in backwater. Seasonal algal growth makes rocks slick.	3	Perennial types scarce or absent. Yellow-green, short term bloom may be present.	4
			totals			22		69		8

Stream Width .... x avg. depth .... x mean velocity .... =Q .... cfs

Gauge Ht .... Reach Gradient .... Stream Order .... Sinuosity Ratio ....

Width Bf .... Depth Bf .... W/D Ratio .... Bf Dischrge (Q Bf) ....

Drainage Area .... Valley Gradient .... Stream Length .... Valley Length ....

Sinuosity .... Entrenchment Ratio .... Length Meander (Lm) .... Belt Width ....

Sediment Supply
Extreme ....
Very High ....
High ....
Moderate ....
Low ....

Stream Bed Stability
Aggrading ....
Degrading ....
Stable ....

Width/Depth Ratio Condition
Normal ....
High ....
Very High ....

TOTAL SCORE for Reach E........+ G........+ F........+ P........=

Remarks ....

Stream Type: C4
Pfankuch Rating: 99
Reach Condition (from table): FAIR

Stream Type	A1	A2	A3	A4	A5	A6	B1	B2	B3	B4	B5	B6	C1	C2	C3	C4	C5	C6	D3	D4	D5	D6
GOOD	38-43	38-43	54-90	60-95	60-95	50-80	38-45	38-45	40-60	40-64	48-68	40-60	38-50	38-50	60-85	70-90	70-90	60-85	85-107	85-107	85-107	67-98
FAIR	44-47	44-47	91-129	96-132	96-142	81-110	46-58	46-58	61-78	65-84	69-88	61-78	51-61	51-61	86-105	91-110	91-110	86-105	108-132	108-132	108-132	99-125
POOR	48+	48+	130+	133+	143+	111+	59+	59+	79+	85+	89+	79+	62+	62+	106+	111+	111+	106+	133+	133+	133+	126+

Stream Type	DA3	DA4	DA5	DA6	E3	E4	E5	E6	F1	F2	F3	F4	F5	F6	G1	G2	G3	G4	G5	G6
GOOD	40-63	40-63	40-63	40-63	40-63	50-75	50-75	40-63	60-85	60-85	85-110	85-110	90-115	80-95	40-60	40-60	85-107	85-107	90-112	85-107
FAIR	64-86	64-86	64-86	64-86	64-86	76-96	76-96	64-86	86-105	86-105	111-125	111-125	116-130	96-110	61-78	61-78	108-120	108-120	113-125	108-120
POOR	87+	87+	87+	87+	87+	97+	97+	87+	106+	106+	126+	126+	131+	111+	79+	79+	121+	121+	126+	121+

PFANKUCH CHANNEL STABILITY EVALUATION

Reach Location: UT to Snow Creek Date: 2/16/02 Observers: Louise & Kyle STREAM TYPE: F4

		catagory	EXCELLENT		GOOD		FAIR		POOR	
UPPER BANKS	1	Landform Slope	Bank Slope Gradient <30%	2	Bank slope gradient 30-40%.	4	Bank slope gradient 40-60%.	6	Bank slope gradient 60% +.	(8)
	2	Mass Wasting	No evidence of past or future mass wasting.	3	Infrequent. Mostly healed over. Low future potential.	6	Frequent or large, causing sediment nearly year long.	(9)	Frequent or large causing sediment nearly year long or imminent danger of same.	12
	3	Debris Jam Potential	Essentially absent from immediate channel area.	2	Present, but mostly small twigs and limbs.	4	Moderate to heavy amounts, mostly larger sizes.	(6)	Moder. to heavy amounts, predom. larger sizes.	8
	4	Vegetative Bank Protection	90%+ plant density. Vigor and variety suggest a deep dense soil binding root mass.	3	70-90% density. Fewer species or less vigor suggest less dense or deep root mass.	6	<50-70% density. Lower vigor and fewer species form a shallow, discontinuous root mass.	(9)	<50% density, fewer species and less vigor indicate poor, discontinuous and shallow root mass.	12
LOWER BANKS	5	Channel Capacity	Ample for present plus some increases. Peak flows contained. W/D ratio <7	1	Adequate. Bank overflows rare. W/D ratio 8-15.	2	Barely contains present peaks. Occasional overbank floods. W/D ratio 15 to 25.	(3)	Inadequate. Overbank flows common. W/D ratio >25	4
	6	Bank Rock Content	65%+ with large angular boulders. 12"+ common	2	40-65%. Mostly small boulders to cobbles 6-12".	4	20-40% with most in the 3-6" diameter class.	6	<20% rock fragments of gravel sizes, 1-3" or less.	(8)
	7	Obstructions to Flow	Rocks and logs firmly imbedded. Flow pattern without cutting or deposition. Stable bed.	2	Some present causing erosive cross currents and minor pool filling. Obstructions newer and less firm.	4	Moder. frequent, unstable obstructions move with high flows causing bank cutting and pool filling.	(8)	Frequent obstructions cause erosion year-long. Sediment traps full, channel migration occurring.	8
	8	Cutting	Little or none. Infreq. raw banks less than 6".	4	Some, intermittently at outcurves and constrictions. Raw banks may be up to 12".	6	Significant. Cuts 12-24" high. Root mat overhangs and sloughing evident.	(12)	Almost continuous cuts, some over 24" high. Failure of overhangs frequent.	16
	9	Deposition	Little or no enlargement of channel or pt. bars	4	Some new bar increase, mostly from coarse gravel.	8	Moder. deposition of new gravel and course sand on old and some new bars.	(12)	Extensive deposits of predominately fine particles. Accelerated bar development.	16
BOTTOM	10	Rock Angularity	Sharp edges and corners. Plane surfaces rough.	1	Rounded corners and edges, surfaces smooth, flat.	2	Corners and edges well rounded in two dimensions.	(3)	Well rounded in all dimensions, surfaces smooth.	4
	11	Brightness	Surfaces dull, dark or stained. Gen. not bright.	1	Mostly dull, but may have <35% bright surfaces.	(2)	Mixture dull and bright. ie 35-65% mixture range.	3	Predom. bright, 65%+ exposed or scoured surfaces.	4
	12	Consolidation of Particles	Assorted sizes tightly packed or overlapping.	2	Moderately packed with some overlapping.	(4)	Mostly loose assortment with no apparent overlap.	6	No packing evident. Loose assortment easily moved.	8
	13	Bottom Size Distribution	No size change evident. Stable mater. 80-100%.	4	Distribution shift light. Stable material 50-80%.	(8)	Moder. change in sizes. Stable materials 20-50%.	12	Marked distribution change. Stable materials 0-20%.	16
	14	Scouring and Deposition	<5% of bottom affected by scour or deposition.	6	5-30% affected. Scour at constrictions and where grades steepen. Some deposition in pools.	(12)	30-50% affected. Deposits & scour at obstructions, constrictions, and bends. Some filling of pools.	18	More than 50% of the bottom in a state of flux or change nearly year-long.	24
	15	Aquatic Vegetation	Abundant. Growth moss-like, dark green, perennial. In swift water too.	1	Common. Algal forms in low velocity and pool areas. Moss here too.	2	Present but spotty, mostly in backwater. Seasonal algal growth makes rocks slick.	3	Perennial types scarce or absent. Yellow-green, short term bloom may be present.	(4)
			totals			26		60		20

Stream Width.......x avg. depth.......x mean velocity.......=Q ....cfs

Gauge Ht.......Reach Gradient.......Stream Order.......Sinuosity Ratio.......

Width Bf.......Depth Bf.......W/D Ratio.......Bf Dischrge (Q Bf).......

Drainage Area.......Valley Gradient.......Stream Length.......Valley Length.......

Sinuosity.......Entrenchment Ratio.......Length Meander (Lm).......Belt Width.......

Sediment Supply	Stream Bed Stability	Width/Depth Ratio Condition
Extreme.......	Aggrading.......	Normal.......
Very High.......	Degrading.......	High.......
High.......	Stable.......	Very High.......
Moderate.......		
Low.......		

TOTAL SCORE for Reach E.......+ G.......+ F.......+ P.......=

Stream Type: [ ]

Pfankuch Rating: 106

from table — Reach Condition: [ ]

Remarks: Stream historically a C or E, currently an F. Could be a C.

Stream Type	A1	A2	A3	A4	A5	A6	B1	B2	B3	B4	B5	B6	C1	C2	C3	C4	C5	C6	D3	D4	D5	D6
GOOD	38-43	38-43	54-90	60-95	60-95	50-80	38-45	38-45	40-60	40-64	48-68	40-60	38-50	38-50	60-85	70-90	70-90	60-85	85-107	85-107	85-107	67-98
FAIR	44-47	44-47	91-129	96-132	96-142	81-110	46-58	46-58	61-78	65-84	69-88	61-78	51-61	51-61	86-105	91-110	91-110	86-105	108-132	108-132	108-132	99-125
POOR	48+	48+	130+	133+	143+	111+	59+	59+	79+	85+	89+	79+	62+	62+	106+	111+	111+	106+	133+	133+	133+	126+

Stream Type	DA3	DA4	DA5	DA6	E3	E4	E5	E6	F1	F2	F3	F4	F5	F6	G1	G2	G3	G4	G5	G6
GOOD	40-63	40-63	40-63	40-63	40-63	50-75	50-75	40-63	60-85	60-85	85-110	85-110	90-115	80-95	40-60	40-60	85-107	85-107	90-112	85-107
FAIR	64-86	64-86	64-86	64-86	64-86	76-96	76-96	64-86	86-105	86-105	111-125	111-125	116-130	96-110	61-78	61-78	108-120	108-120	113-125	108-120
POOR	87+	87+	87+	87+	87+	97+	97+	87+	106+	106+	126+	126+	131+	111+	79+	79+	121+	121+	126+	121+

Bank Erodibility Hazard Rating Guide

Stream Snow Creek Reach Prabhupada Village Date 5-16-02 Crew Ken, Louise, Kyle

Bank Height (ft): Bankfull Height (ft):		Bank Height/ Bankfull Ht	Root Depth/ Bank Height	Root Density %	Bank Angle (Degrees)	Surface Protection%
VERY LOW	Value	1.0-1.1	1.0-0.9	100-80	0-20	100-80
	Index	1.0-1.9	1.0-1.9	1.0-1.9	1.0-1.9	1.0-1.9
	Choice	V: I:	V: I:	V: I:	V: I:	V: I:
LOW	Value	1.11-1.19	0.89-0.5	79-55	21-60	79-55
	Index	2.0-3.9	2.0-3.9	2.0-3.9	2.0-3.9	2.0-3.9
	Choice	V: I:	V: I:	V: I:	V: I:	V: I:
MODERATE	Value	1.2-1.5	0.49-0.3	54-30	61-80	54-30
	Index	4.0-5.9	4.0-5.9	4.0-5.9	4.0-5.9	4.0-5.9
	Choice	V: I:	V: 0.40 I: 4.9	V: I:	V: I:	V: 45 I: 4.7
HIGH	Value	1.6-2.0	0.29-0.15	29-15	81-90	29-15
	Index	6.0-7.9	6.0-7.9	6.0-7.9	6.0-7.9	6.0-7.9
	Choice	V: I:	V: I:	V: I:	V: 90 I: 7.9	V: I:
VERY HIGH	Value	2.1-2.8	0.14-0.05	14-5.0	91-119	14-10
	Index	8.0-9.0	8.0-9.0	8.0-9.0	8.0-9.0	8.0-9.0
	Choice	V: I:	V: I:	V: I:	V: I:	V: I:
EXTREME	Value	>2.8	<0.05	<5	>119	<10
	Index	10	10	10	10	10
	Choice	V: 2.94 I: 10	V: I:	V: 2 I: 10	V: I:	V: I:
V = value, I = index					SUB-TOTAL (Sum one index from each column)	37.5

Bank Erosion Potential

Bank Material Description:

Bank Materials

- Bedrock (Bedrock banks have very low bank erosion potential)
- Boulders (Banks composed of boulders have low bank erosion potential)
- Cobble (Subtract 10 points. If sand/gravel matrix greater than 50% of bank material, then do not adjust)
- Gravel (Add 5-10 points depending percentage of bank material that is composed of sand)
- Sand (Add 10 points)
- Silt Clay (+ 0: no adjustment)

BANK MATERIAL ADJUSTMENT +5

Stratification Comments:

Stratification

Add 5-10 points depending on position of unstable layers in relation to bankfull stage

STRATIFICATION ADJUSTMENT 0

VERY LOW	LOW	MODERATE	HIGH	VERY HIGH	EXTREME
5-9.5	10-19.5	20-29.5	30-39.5	40-45	46-50

Bank location description (circle one)

Straight Reach Outside of Bend

GRAND TOTAL BEHI RATING 42.5

Bank Erosion Prediction

Stream	Cross Section	Date
Snow Creek	STA 26+31	5-16-02

Near Bank Stress Rating

Mean Shear Stress	
Bankfull Hydraulic Radius (ft) R	3.8
Water Surface Facet Slope (ft/ft) S	0.0004
Shear Stress (lb/ft^2) $\tau = \gamma RS$ (γ=62.4lb/ft^3)	0.0015

Near Bank Shear Stress	
Bankfull Hydraulic Radius (ft) R (near bank 1/3)	4.8
Near Bank Water Surface Slope (ft/ft) S	0.0004
Shear Stress (lb/ft^2) τ near bank= γRS	0.0019

Near Bank Stress/ Mean Shear Stress (τ near bank/τ)	1.27

Conversion of Numerical Indices to Adjective Ratings

Near Bank Stress Rating	Near Bank Stress/Mean Shear Stress
Very Low	<0.8
Low	0.8 - 1.05
Moderate	1.06 - 1.14
High	1.15 - 1.19
Very High	1.2 - 1.6
Extreme	>1.6
Near Bank Stress Rating	VERY HIGH

Stream Bank Erodibility Rating

BEHI Rating	VERY HIGH

Bank Erosion Prediction at Cross Section

A	B	C	D
Lateral Erosion at Cross Section (feet/year)	Bank Height (feet)	Length of Bank (feet)	Predicted Erosion feet^3
0.8	10	1	8.0 CF/FT

Circle graph used: (Colorado) Yellowstone

Column A:	Use Stream Bank Erodibility Rating and Near Bank Stress Rating in conjunction with Figure 6-27 in Rosgen, 1996.
Column B:	Study Bank Height (Use Cross Section Plot: top of bank - toe of bank)
Column C:	Input 1 foot for point erosion @ cross section
Column D:	Columns A*B*C

Bank Erodibility Hazard Rating Guide

Stream UT to Snow Creek Reach Prabhupada Village Date 5-15-02 Crew Kyle, Louise

Bank Erosion Potential

Bank Height (ft): / Bankfull Height (ft):		Bank Height/ Bankfull Ht	Root Depth/ Bank Height	Root Density %	Bank Angle (Degrees)	Surface Protection%
VERY LOW	Value	1.0-1.1	1.0-0.9	100-80	0-20	100-80
	Index	1.0-1.9	1.0-1.9	1.0-1.9	1.0-1.9	1.0-1.9
	Choice	V: I:	V: I:	V: I:	V: I:	V: I:
LOW	Value	1.11-1.19	0.89-0.5	79-55	21-60	79-55
	Index	2.0-3.9	2.0-3.9	2.0-3.9	2.0-3.9	2.0-3.9
	Choice	V: I:	V: I:	V: I:	V: I:	V: I:
MODERATE	Value	1.2-1.5	0.49-0.3	54-30	61-80	54-30
	Index	4.0-5.9	4.0-5.9	4.0-5.9	4.0-5.9	4.0-5.9
	Choice	V: I:	V: 0.4 I: 4.9	V: I:	V: I:	V: 45 I: 4.7
HIGH	Value	1.6-2.0	0.29-0.15	29-15	81-90	29-15
	Index	6.0-7.9	6.0-7.9	6.0-7.9	6.0-7.9	6.0-7.9
	Choice	V: I:	V: I:	V: I:	V: 85 I: 6.8	V: I:
VERY HIGH	Value	2.1-2.8	0.14-0.05	14-5.0	91-119	14-10
	Index	8.0-9.0	8.0-9.0	8.0-9.0	8.0-9.0	8.0-9.0
	Choice	V: I:	V: I:	V: I:	V: I:	V: I:
EXTREME	Value	>2.8	<0.05	<5	>119	<10
	Index	10	10	10	10	10
	Choice	V: 2.94 I: 10	V: I:	V: 2 I: 10	V: I:	V: I:
V = value, I = index					SUB-TOTAL (Sum one index from each column)	36.4

Bank Material Description:

Bank Materials

- Bedrock (Bedrock banks have very low bank erosion potential)
- Boulders (Banks composed of boulders have low bank erosion potential)
- Cobble (Subtract 10 points. If sand/gravel matrix greater than 50% of bank material, then do not adjust)
- Gravel (Add 5-10 points depending percentage of bank material that is composed of sand)
- Sand (Add 10 points)
- Silt Clay (+ 0: no adjustment)

BANK MATERIAL ADJUSTMENT: +5

Stratification Comments:

Stratification

Add 5-10 points depending on position of unstable layers in relation to bankfull stage

STRATIFICATION ADJUSTMENT: 0

VERY LOW	LOW	MODERATE	HIGH	VERY HIGH	EXTREME
5-9.5	10-19.5	20-29.5	30-39.5	40-45	46-50

Bank location description (circle one)

Straight Reach Outside of Bend

GRAND TOTAL BEHI RATING: 41.4

Bank Erosion Prediction

Stream	Cross Section	Date
UT to Snow Creek	STA 350.5	5-15-02

Near Bank Stress Rating

Mean Shear Stress	
Bankfull Hydraulic Radius (ft) R	0.6
Water Surface Facet Slope (ft/ft) S	0.0006
Shear Stress (lb/ft²) $\tau = \gamma RS$ (γ=62.4lb/ft³)	0.024

Near Bank Shear Stress	
Bankfull Hydraulic Radius (ft) R (near bank 1/3)	1.1
Near Bank Water Surface Slope (ft/ft) S	0.0006
Shear Stress (lb/ft²) τ near bank= γRS	0.041
Near Bank Stress/ Mean Shear Stress (τ near bank/τ)	1.72

Conversion of Numerical Indices to Adjective Ratings

Near Bank Stress Rating	Near Bank Stress/Mean Shear Stress
Very Low	<0.8
Low	0.8 - 1.05
Moderate	1.06 - 1.14
High	1.15 - 1.19
Very High	1.2 - 1.6
Extreme	>1.6
Near Bank Stress Rating	EXTREME

Stream Bank Erodibility Rating

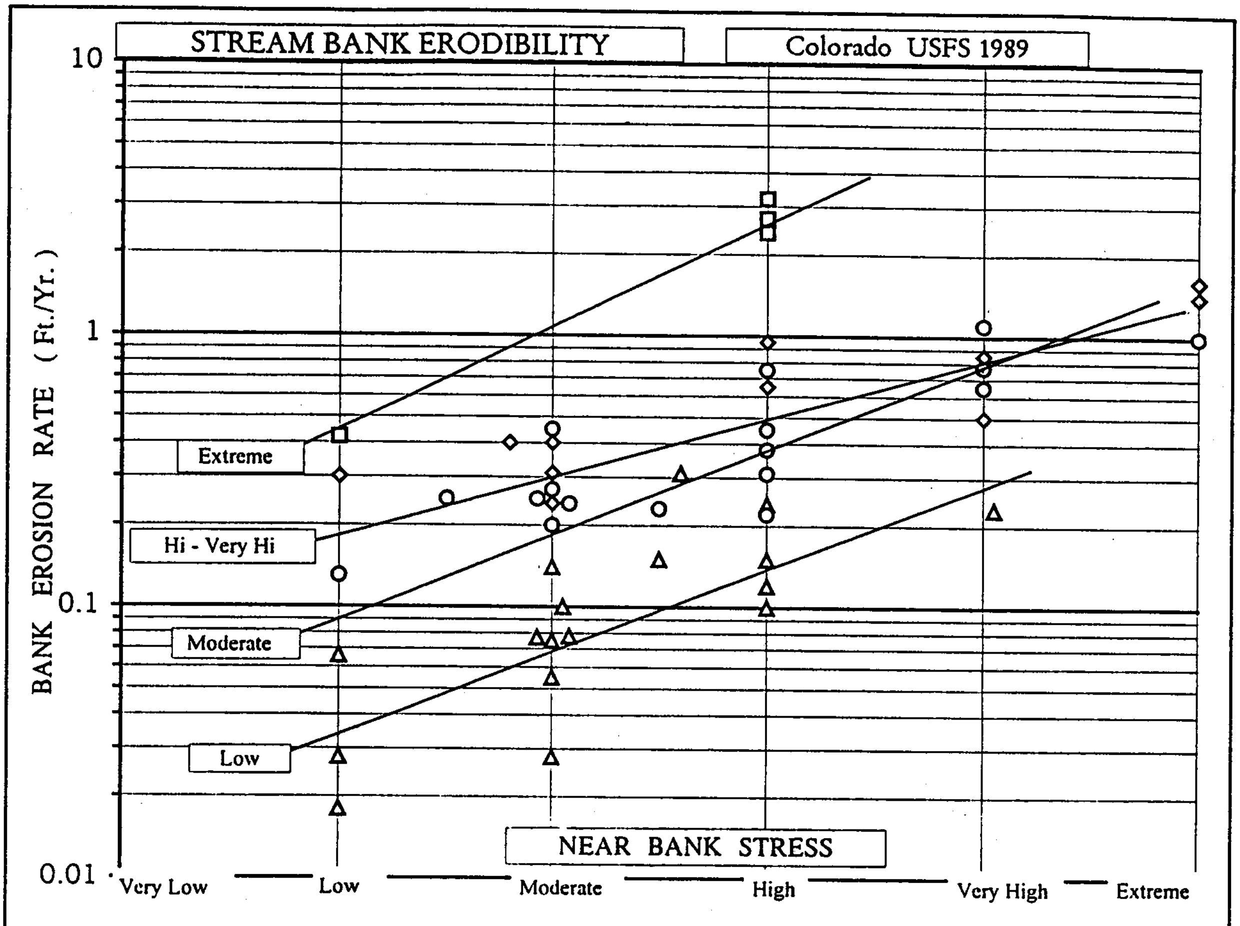
BEHI Rating	VERY HIGH

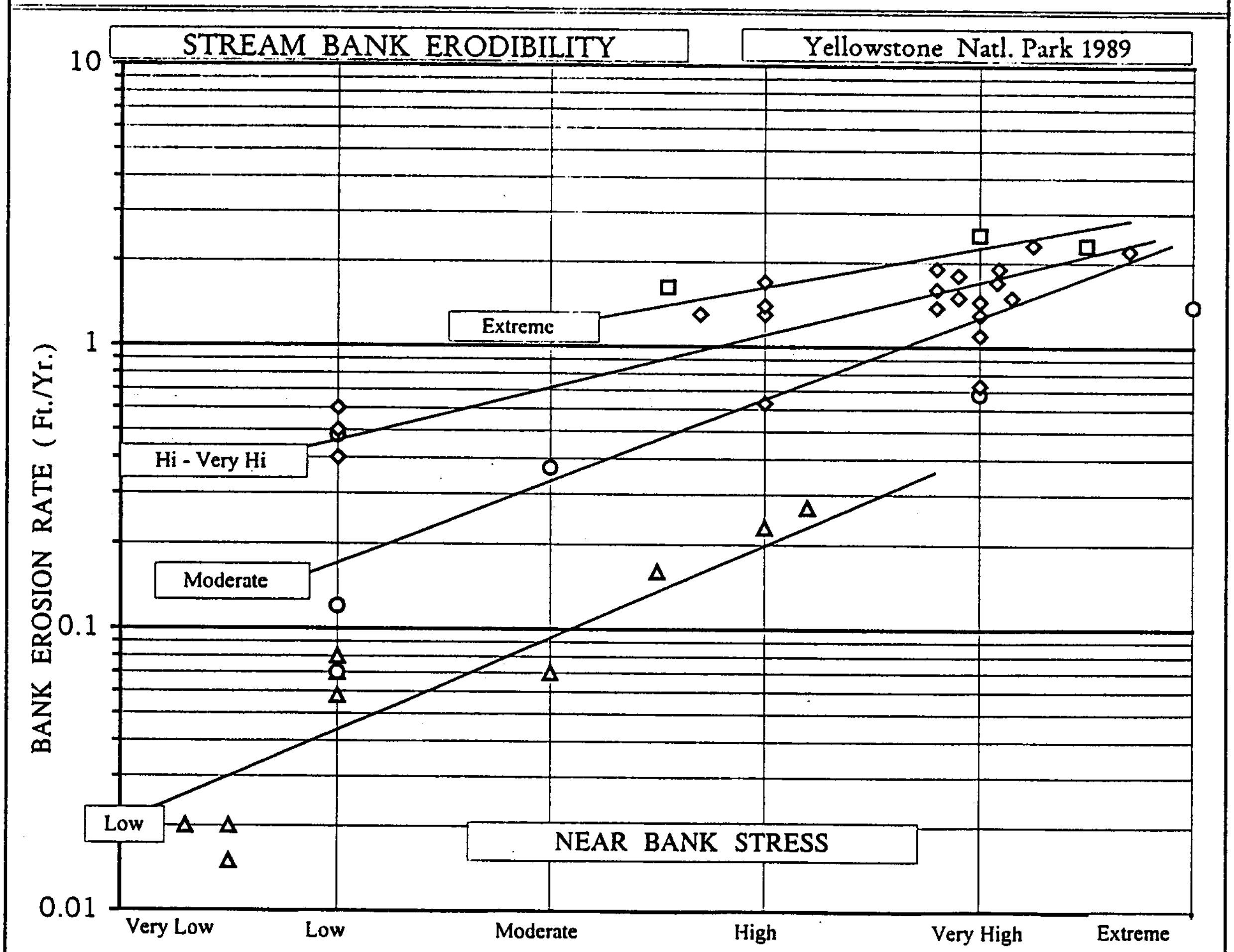
Bank Erosion Prediction at Cross Section

A	B	C	D
Lateral Erosion at Cross Section (feet/year)	Bank Height (feet)	Length of Bank (feet)	Predicted Erosion feet³
1.4	5.3	1	7.42 CF/FT

Circle graph used: (Colorado) Yellowstone

Column A:	Use Stream Bank Erodibility Rating and Near Bank Stress Rating in conjunction with Figure 6-27 in Rosgen, 1996.
Column B:	Study Bank Height (Use Cross Section Plot: top of bank - toe of bank)
Column C:	Input 1 foot for point erosion @ cross section
Column D:	Columns A*B*C


STREAM BANK ERODIBILITY
Colorado USFS 1989
BANK EROSION RATE (Ft./Yr.)
10
1
0.1
0.01
Extreme
Hi - Very Hi
Moderate
Low
NEAR BANK STRESS
Very Low
Low
Moderate
High
Very High
Extreme


STREAM BANK ERODIBILITY
Yellowstone Natl. Park 1989
BANK EROSION RATE (Ft./Yr.)
10
1
0.1
0.01
Extreme
Hi - Very Hi
Moderate
Low
NEAR BANK STRESS
Very Low
Low
Moderate
High
Very High
Extreme

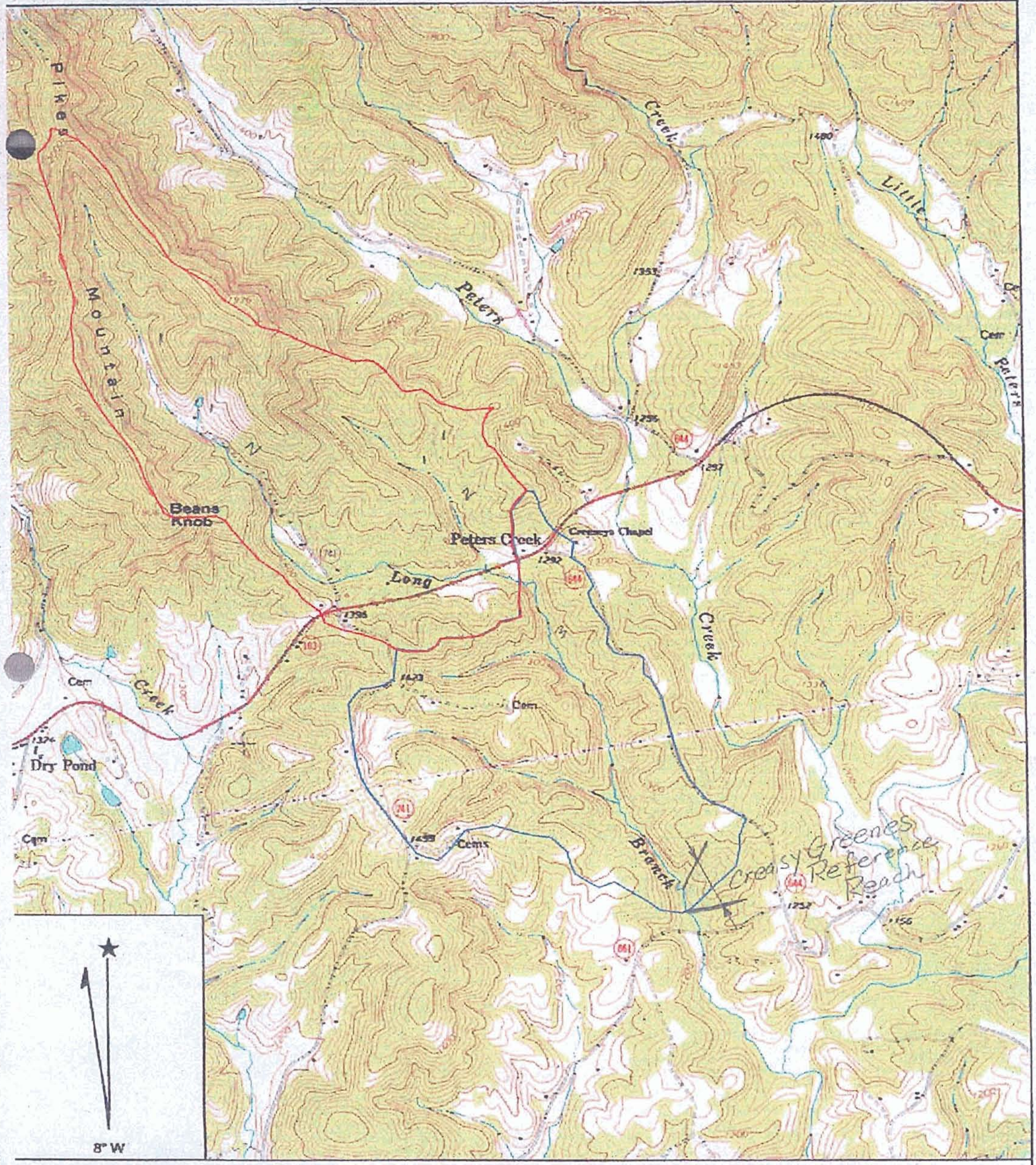
Appendix 4

Reference Reach Data

North Carolina Rural Piedmont Regional Curve


LONG BRANCH 1"=660'
PATRICK COUNTY, VA
FIELD DAY 1
TEAM # 2, 3 AND 4
Creasy Greenes Reach
1663
1641
NHEL

4-3-02



Name: STUART SE
Date: 3/19/2002
Scale: 1 inch equals 2000 feet

TEAMS #3 & #4
WILLIAMS PROPERTY

Location: 036° 35' 26.2" N 080° 19' 07.6" W
Caption: Long Branch just North of Hwy 661
Drainage Area = 1.7 sq. mi.

CREASY GREENES,
4-3-02 LONG BRANCH

MORPHOLOGICAL CHARACTERISTICS OF THE EXISTING AND PROPOSED CHANNEL WITH GAGE STATION AND REFERENCE REACH DATA

(After Rosgen, 1996)

Reference Reach (Name of stream & location): Long Branch, Williams Property, on upstream side of VA Hwy 661 near Stuart, VA in Patrick County.

VARIABLES	REFERENCE REACH
1. Stream type	C4
2. Drainage area (sq. mi.)	1.7
3. Bankfull width (w_{bkf}) – ft.	Mean: 14.4 Range: 13.5-15.2
4. Bankfull mean depth (d_{bkf}) – ft.	Mean: 1.2 Range: 1.1-1.4
5. Width/depth ratio (w_{bkf}/d_{bkf})	Mean: 11.8 Range: 9.6-13.2
6. Bankfull cross-sectional area (A_{bkf}) – sq. ft.	Mean: 17.5 Range: 15.9-18.9
7. Bankfull mean velocity (v_{bkf}) – f/s	Mean: 3.5 Range: 3.2-3.8
8. Bankfull discharge, cfs (Q_{bkf})	60.4
9. Bankfull Maximum depth (d_{max}) – ft.	Mean: 1.7 Range: 1.5-1.9
10. Max d_{riff}/d_{bkf} ratio	Mean: 1.4 Range: 1.25-1.6
11. Riffle length (ft)	Mean: 53.3 Range: 20-109
12. Riffle length to bkf width ratio	Mean: 3.7 Mean: 1.4-7.6
13. Low bank height to max. d_{bkf} ratio	Mean: 1.18 Range: 1.0-1.5
14. Width of flood prone area (w_{fpa}) – ft.	Mean: 94.5 Range:
15. Entrenchment ratio (w_{fpa}/w_{bkf})	Mean: 6.6 Range: 6.6-7.0
16. Meander length (L_m) – ft.	Mean: 97.5 Range:

VARIABLES	EXISTING CHANNEL
17. Ratio of meander length to bankfull width (L_m/w_{bkf})	Mean: 6.8 Range:
18. Radius of curvature (ft)	25.25 ft.
19. Ratio of radius of curvature to bankfull width (R_c/w_{bkf})	Mean: 1.8 Range:
20. Belt width (w_{blt}) - ft.	Mean: 41.7 Range: 30-54
21. Meander width ratio (w_{blt}/w_{bkf})	Mean: 2.9 Range: 2.1-3.8
22. Sinuosity = k (Stream Length$_{thalweg}$/ valley distance)	$\frac{314}{262}$ = 1.198=1.2
23. Valley slope (ft/ft)	0.016
24. Average water surface slope-ft/ft (s_{avg}) = (s_{valley}/k)	0.0118
25. Pool slope (s_{pool}) – ft/ft	Mean: 0.00532 Range:0.00207-0.001
26. Ratio of pool slope to average slope (s_{pool}/s_{bkf})	Mean: 0.5 Range: 0.2-0.8
27. Maximum pool depth ($d_{max\ pool}$) – ft.	Mean: 2.6 Range:
28. Ratio of pool depth to average bankfull depth ($d_{max\ pool}/d_{bkf}$)	Mean: 2.1 Range:
29. Pool width (w_{pool}) – ft.	Mean: 14.5 Range:
30. Ratio of pool width to bankfull width (w_{pool}/w_{bkf})	Mean: 1.0 Range:
31. Pool Area – sq ft (A_{pool})	Mean: 18.0 Range:
32. Ratio of Pool Area to Bankfull Area (A_{pool}/A_{bkf})	Mean: 1.0 Range:
33. Pool to pool spacing (p-p) – ft.	Mean: 69.25 Range: 17.5-159

VARIABLES	EXISTING CHANNEL
34. Ratio of p-p spacing to bankfull width ($p\text{-}p/w_{bkf}$)	Mean: 4.8 Range: 1.2-11.0
35. Pool length (L_{pool}) – ft.	Mean: 18.7 Range: 11-26
36. Ratio of Pool length to bankfull width (L_{pool}/w_{bkf})	Mean: 1.3 Range: 0.8-1.8
37. Avg. riffle slope (s_{riff}) - ft./ft.	Mean: 0.0169 Range:0.0103-0.0235
38. Ratio of riffle slope to avg. slope (s_{riff}/s_{avg})	Mean: 1.4 Range:0.9-2.0
39. Avg. run slope ft/ft	Mean: 0.0358 Range:0.0167-0.0556
40. Ratio of run slope to avg slope (s_{run}/s_{avg})	Mean: 3.0 Range: 1.4-4.7
41. Avg. glide slope ft/ft	Mean: 0.0029 Range:0.0025-0.0033
42. Ratio of glide slope to avg slope (s_{glide}/s_{avg})	Mean: 0.2 Range: 0.2-0.3
43. Max run depth ($d_{max\ run}$) – ft.	Mean: 2.1 Range:
44. Ratio of max. run depth to mean bkf depth ($d_{max\ run}/d_{bkf}$)	Mean: 1.7 Range:
45. Run width (w_{run}) – ft.	Mean: 15.9 Range:
46. Run width to bankfull width ratio (w_{run}/w_{bkf})	Mean: 1.1 Range:
47. Mean run depth (d_{run}) ft.	Mean: 1.0 Range:
48. Run w/d ratio (w_{run}/d_{run})	Mean: 15.7 Range:
49. Ratio of run w/d to riffle w/d	Mean: 1.3 Range:
50. Run length (L_{run}) – ft.	Mean: 10.1 Range: 5.5-20
51. Ratio of run length to bankfull width (L_{run}/w_{bkf})	Mean: 0.7 Range: 0.4-1.4
52. Max. glide depth ($d_{max\ glide}$) – ft.	Mean: 1.8 Range:

VARIABLES	EXISTING CHANNEL
53. Ratio of max. glide depth to mean bkf depth ($d_{max\ glide}/d_{bkf}$)	Mean: 1.7 Range:
54. Glide width (w_{glide}) – ft.	Mean: 14.1 Range:
55. Ratio of glide width to bankfull width (w_{glide}/w_{bkf})	Mean: 1.0 Range:
56. Glide mean depth (d_{glide}) – ft.	Mean: 1.3 Range:
57. Glide w/d ratio (w_{glide}/d_{glide})	Mean: 8.1 Range:
58. Ratio of glide w/d to riffle w/d	Mean: 0.7 Range:
59. Glide length (L_{glide}) – ft.	Mean: 6.7 Range: 4-10
60. Ratio of glide length to bankfull width (L_{glide}/w_{bkf})	Mean: 0.5 Range: 0.3-0.7
61. Riffle thalweg slope ($s_{riff\ TW}$) – ft/ft	Mean: 0.017 Range: 0.0117-0.027
62. Run thalweg slope ($s_{run\ TW}$) – ft/ft [Note: Run reach that goes into pool]	Mean: 0.0447 Range: 0.0182-0.088
63. Glide thalweg slope ($s_{glide\ TW}$) – ft/ft	Mean: -0.032 Range: -0.023 to –0.0375
64. Pool entrance thalweg slope ($s_{pool\ TW\ entrance}$) – ft/ft	Mean: 0.0386 Range: 0.00375 to 0.059
65. Pool exit thalweg slope ($s_{pool\ TW\ exit}$) – ft/ft	Mean: -0.0225 Range: -0.019 to -0.0471

*** Data in Item Nos. 59 through 63 are for use with a CAD system.**

Remarks: Surveyed by Team #4 in Rosgen 2002 RAM Course @ Primland.

VARIABLES	EXISTING CHANNEL

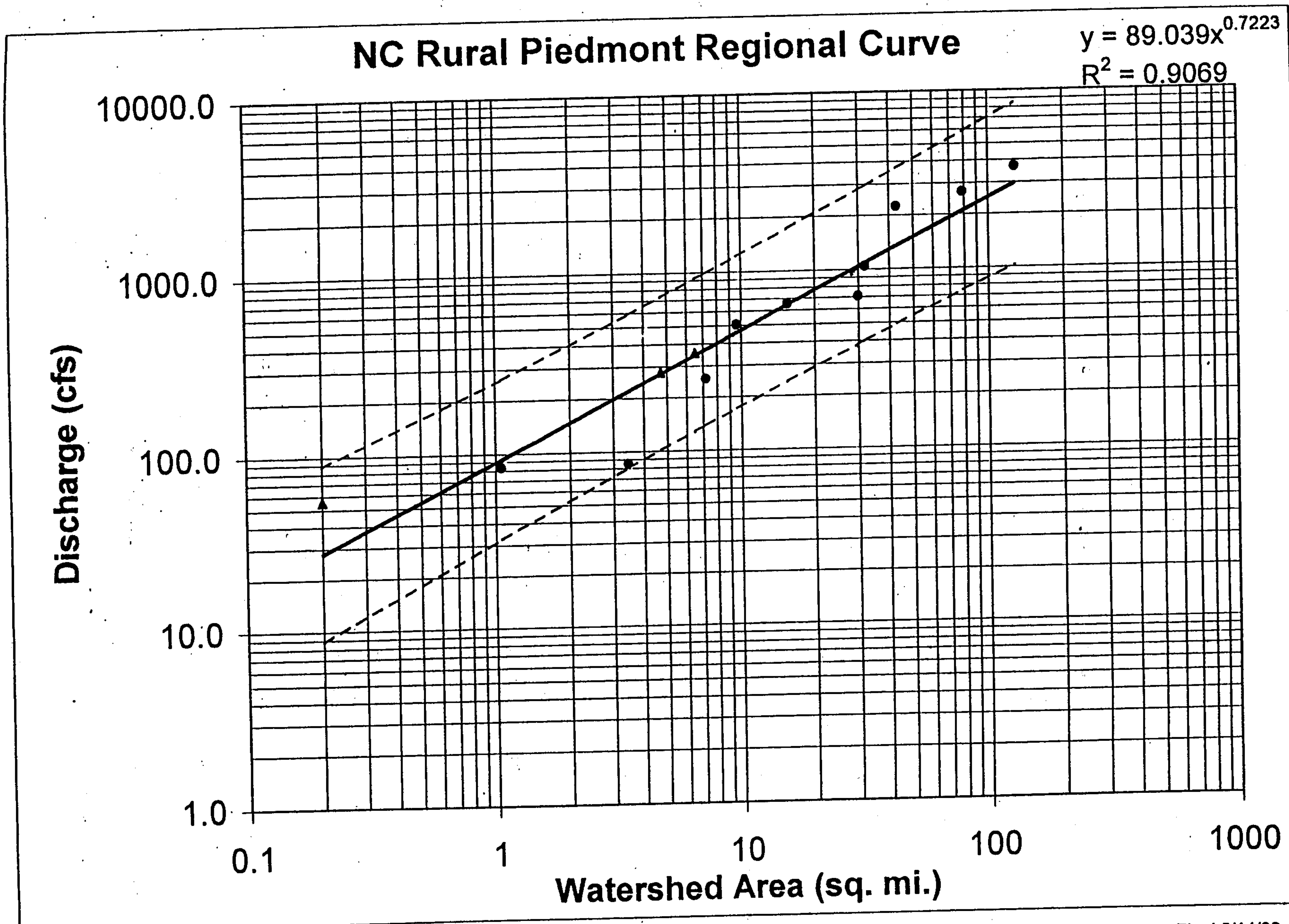
MATERIALS:			
1. Particle Size Distribution of Channel Material	Classification Pebble Count (mm)	100 count in riffle bed (mm)	
D_{16}	N/A	8.0	
D_{35}	0.12	11.8	
D_{50}	3.4	18.4	
D_{84}	34	73	D_{84} from 100 count used in velocity calcs
D_{95}	64	100	
2. Particle Size Distribution of Bar Material	Pavement Sample (mm)	Subpavement Sample (mm)	
D_{16}	39	N/A	
D_{35}	48	5	D_{50} from pavement sample used in entrainment calcs for riffle bed material D_{50}
D_{50}	50	13	$D^{\wedge}_{50}$ from subpavement sample used in entrainment calcs
D_{84}	79	43	
D_{95}	100	55	
Largest size particle from sample layer	109.22	69.85	D_i from subpavement sample used in entrainment calcs

SEDIMENT TRANSPORT VALIDATION (BASED ON BANKFULL SHEAR STRESS)	Existing Condition
Bankfull shear stress - Calculated value (lb/ft^2)	0.74
Moveable particle size (mm) at bankfull shear stress – Value from Rosgen Curve on Shields Diagram	175
Predicted shear stress required to initiate movement of D_i (mm) - Value from Rosgen Curve on Shields Diagram (lb/ft^2)	0.30
Critical dimensionless shear stress	0.026
Minimum mean d_{bkf} calculated using critical dimensionless shear stress equations	0.83
Manning's "n"	0.042

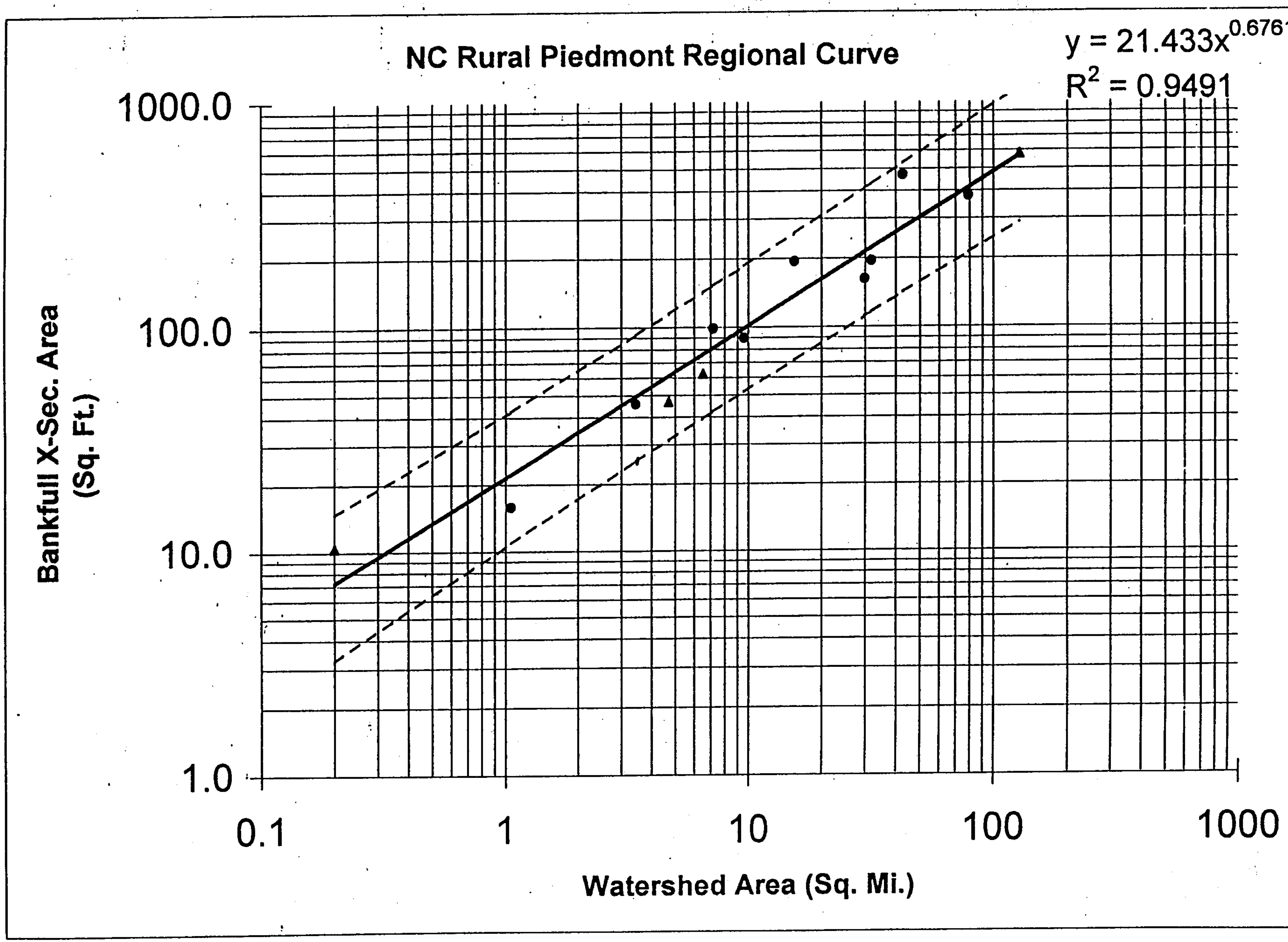
These values and ratios were calculated and proposed by:

Name: Angela G. Jessup **Location: Yadkinville, NC**

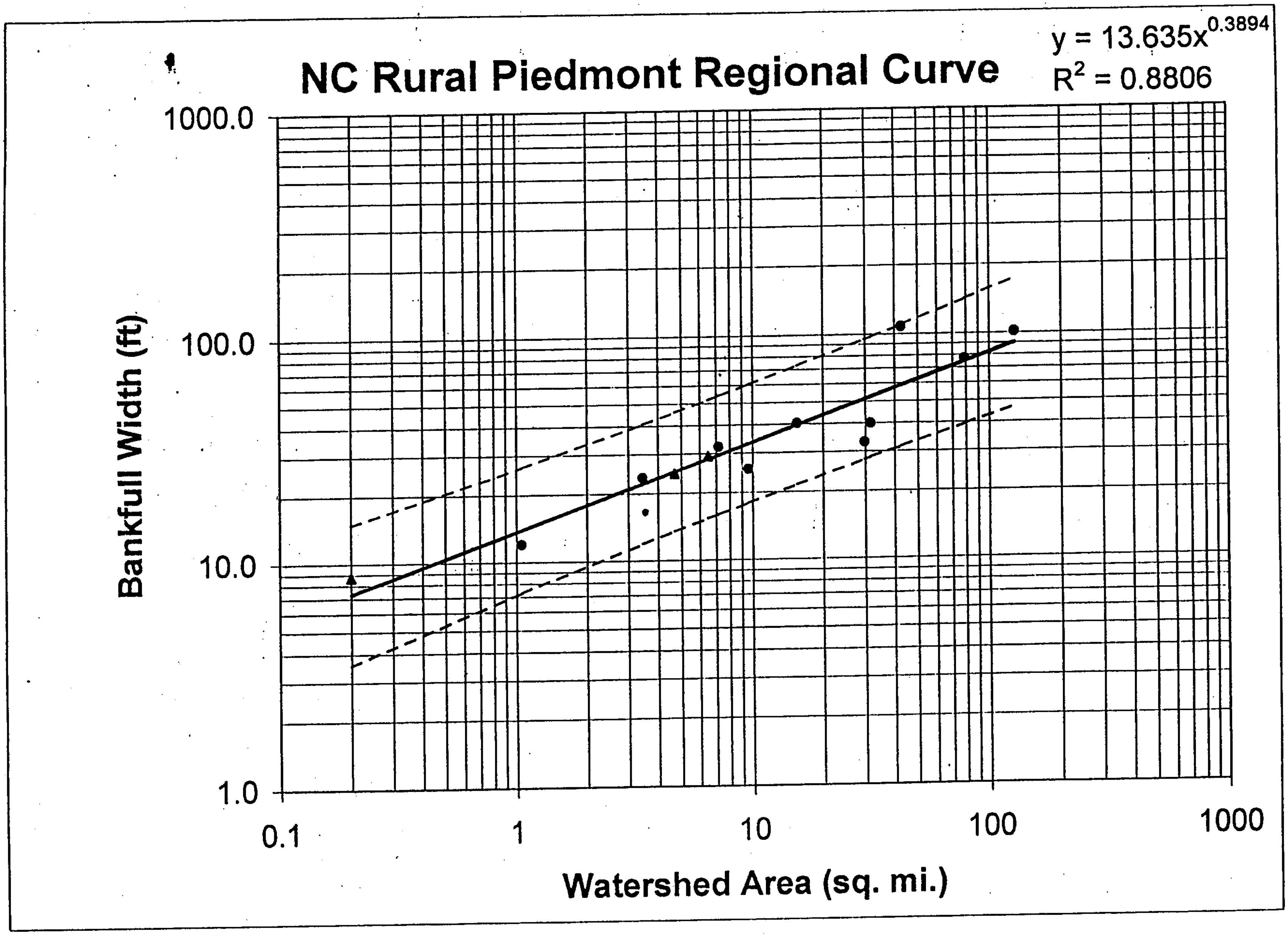
Title: Civil Engineer **Date: 6-27-02**


NC Rural Piedmont Regional Curve
y = 89.039x0.7223
R2 = 0.9069
Discharge (cfs)
10000.0
1000.0
100.0
10.0
1.0
0.1
1
10
100
1000
Watershed Area (sq. mi.)

Final 5/14/99

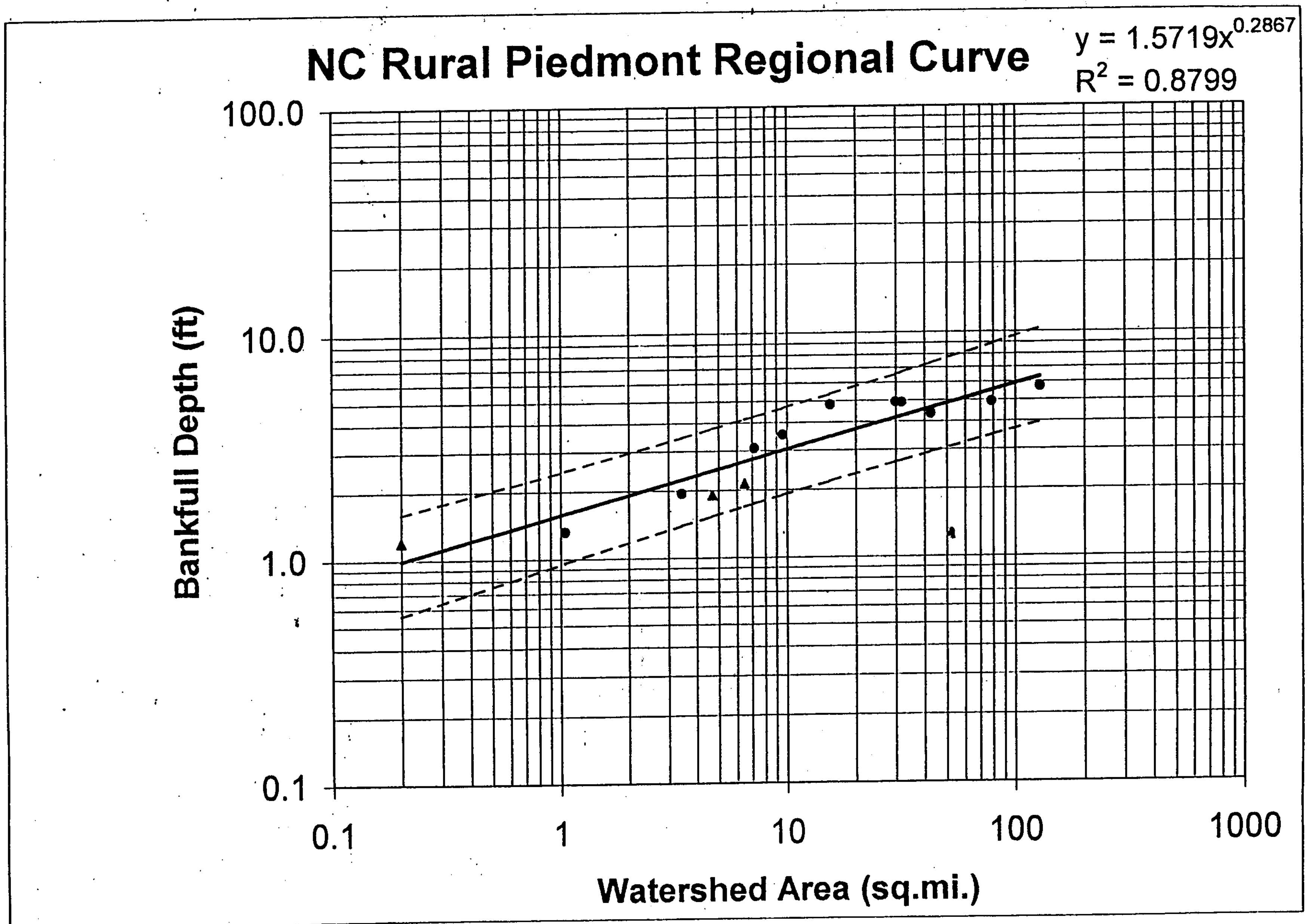

NC Rural Piedmont Regional Curve
y = 21.433x^0.6761
R^2 = 0.9491
1000.0
100.0
10.0
1.0
Bankfull X-Sec. Area
(Sq. Ft.)
0.1
1
10
100
1000
Watershed Area (Sq. Mi.)

Final 5/14/99



NC Rural Piedmont Regional Curve
y = 13.635x^0.3894
R^2 = 0.8806
1000.0
100.0
10.0
1.0
Bankfull Width (ft)
0.1
1
10
100
1000
Watershed Area (sq. mi.)

Final 5/14/99



NC Rural Piedmont Regional Curve
y = 1.5719x^0.2867
R^2 = 0.8799
100.0
10.0
1.0
0.1
Bankfull Depth (ft)
0.1
1
10
100
1000
Watershed Area (sq.mi.)

Final 5/14/99

Stream Name	Gage Station ID	Drainage Area (mi2)	Stream Type (Rosgen)	Bankfull Discharge (cfs)	Bankfull Xsec Area (ft2)	Bankfull Width (ft)	Bankfull Mean Depth (ft)	Water Surface Slope (ft/ft)	Return Interval (Years)	Exceedence Probability (%)
Sal's Branch	Reference Reach	0.2	E4	55.4	10.4	8.7	1.2	0.0109	n/a	n/a
Humpy Creek	02117030	1.05	E5	83	15.8	12.0	1.3	0.0060	1.7	59
Dutchmans	02123567	3.44	C5	85.1	45.6	23.5	1.9	0.0170	1	100
Mill Creek	Reference Reach	4.7	E4	277	46.7	24.5	1.9	0.0080	n/a	n/a
Upper Mitchell River	Reference Reach	6.5	B4c	356	62.5	29.2	2.1	0.0095	n/a	n/a
Norwood Creek	0214253830	7.18	E5	253.7	98.8	32.0	3.1	0.0008	1.1	91
North Pott's Creek	02121180	9.6	E5	507.2	89.6	25.4	3.5	0.0012	1.7	59
Tick Creek	02101800	15.5	E	655.3	194	40.5	4.8	0.0005	1.3	77
Moon Creek	02075160	29.9	E5	708.8	162	33.0	4.9	0.0015	1.8	56
Long Creek	02144000	31.8	E5	1041	195	40.0	4.9	0.0010	1.4	71
Little Yadkin River	02114450	42.8	G5	2236	469	77.5	6.0	0.0018	1.4	71
Mitchell River	02112360	78.8	C	2681	377	77.0	4.9	0.0030	1.6	63
Fisher River	02113000	128	C3	3687	578	101	5.7	0.0023	1.4	71

Table 1: Hydraulic geometry, survey summary, and flood frequency analyses for gaged and ungaged stream reaches.

Bankfull width and mean depth corrected for Little Yadkin River

Appendix 5

Morphology Summary Table

Snow Creek Morphological Data

CLASSIFICATION DATA	Snow Creek Existing	Trib to Snow Creek Existing	Reference Long Branch (VA)	Reference Barnes Creek	Gage South Mayo River (VA)	Proposed Channel (Main stem)	Proposed Channel (Tributary)
Rosgen Stream Type	C4/1	F4	C4	C4	B4	C4/1	C4
Drainage Area (sq mi)	27.3	0.83	1.7	23	84.6	27.3	0.83
Bankfull Width (W_{bkf}) (ft)	68	14.5	14.4	64.9	66.5	60	12.0
Bankfull Mean Depth (d_{bkf}) (ft)	4.3	1.0	1.2	3.3	5.4	4.8	0.8
Bankfull Cross Sectional Area (A_{bkf}) (sf)	294	14.1	17.6	214	357.8	286	9.6
Width/Depth ratio (W_{bkf}/d_{bkf})	15.9	14.9	11.8	19.7	12.4	12.4	15.0
Maximum depth (d_{mbkf}) (ft)	6.2	1.2	1.7	4.6	6.4	7.0	1.2
Width of flood prone area (W_{fpa}) (ft)	535	17	94.5		126	535	30
Entrenchment ratio (ER)	7.8	1.2	6.6	0.0	1.9	9.0	2.50
Water surface slope (S) (ft/ft)	0.0021	0.008	0.012	0.003	0.003	0.002	0.010
Sinuosity (stream length/valley length)	1.4	1.75	1.2		1.3	1.6	1.4
DIMENSION DATA							
Pool Depth (ft)	4.1	0.9	2.6	2.7	5.7	5.3	1.0
Max Pool Depth (ft)	5.6	3.0	2.6	6.8	9.5	9.6	1.6
Riffle Depth (ft)	4.3	1.0	1.2	3.3	5.4	4.8	0.8
Pool Width (ft)	46	15.8	14.5	48.5	77.2	65	14.4
Riffle Width (ft)	68	14.5	14.4	64.9	66.5	60	12.0
Pool XS Area (sf)	187	14.8	18	133.1	439.7	346	11.5
Riffle XS area (sf)	294	14.1	14.4	214	357.8	286	9.6
Pool depth/mean riffle depth	1.0	0.9	2.1	0.8	1.1	1.1	1.2
Pool width/riffle width	0.7	1.1	1.0	0.7	1.2	1.1	1.2
Pool area/riffle area	0.6	1.0	1.0	0.6	1.2	1.2	1.2
Max pool depth/d_{bkf}	1.3	3.0	2.1	2.1	1.8	2.0	2.0
Low bankheight/max bankfull depth	1.4	2.2 (1.8-4.1)	1.18	1	1.4	1	1
Mean bankfull velocity (V) (fps)	4.9	5.4	3.5		3.9	5.8	6.0
Bankfull discharge (Q) (cfs)	980	76	110		1390	980	76
PATTERN DATA							
Meander length (L_m) (ft)	360	67	97.5			417	84
Radius of curvature (Rc) (ft)	75-125	17	25.25			137	28
Belt width (W_{blt}) (ft)	120	59	41.7			175	40
Meander width ratio (W_{blt}/W_{bkf})	1.75	4.07	2.9	0.0	0.0	2.9	3.3
Radius of curvature/bankfull width	1.46	1.17	1.8	0.0	0.0	2.3	2.3
Meander length/bankfull width	5.3	4.6	6.8	0.0	0.0	7.0	7.0
PROFILE DATA							
Valley slope	0.0029	0.014	0.016	0.0026	0.004	0.0029	0.014
Average water surface slope	0.0021	0.008	0.012	0.003	0.003	0.0018	0.01
Riffle slope	0.02	0.02	0.017	0.024	0.004	0.005	0.030
Pool slope	0.0011	0.0009	0.005	0.000	0.0007	0.001	0.005
Pool to pool spacing	397 (210-630)	76	69.25	410	444	226	52
Pool length	93	16	18.7	155.8	200	77	16
Riffle slope/avg water surface slope	9.5	2.5	1.4	8.7	1.28	3	3
Pool slope/avg water surface slope	0.5	0.1	0.50	0.0	0.20	0.5	0.5
Run slope/avg water surface slope	4.8	1.1	3.0	0.4	1.5	1.4	1.4
Run depth/d_{bkf}	0.77	1.20	1.7		1.12	1.05	1.10
Pool length/bankfull width	1.4	1.1	1.30	2.4	3.01	1.30	1.30
Pool to pool spacing/bankfull width	5.8 (3.1-9.2)	5.2	4.8 (1.2-11)	6.3 (3.8-9.7)	6.7	3.8	4.3
CHANNEL MATERIALS							
D16	0.47	0.55	8		0.5	0.47	0.55
D35	2.2	1.7	11.8		1.2	2.2	1.7
D50	9.4	10.8	18.4		13.3	9.4	10.8
D84	54	67.9	73		272	54	67.9
D95	120	106	100		883	120	106
PAVEMENT MATERIALS							
D16	2	35	21.4		18.6	2	35
D35	9	96	35.8		35.4	9	96
D50	19.5	127	49.7		39.5	19.5	127
D84	53	150	88.3		69	53	150
D95	69	157	102.5		83	69	157
SUBPAVEMENT MATERIALS							
D16	1.6	3.3	<2		1.3	1.6	3.3
D35	3.2	16.5	5.1		1.8	3.2	16.5
D50	5.7	32.7	13.3		3.8	5.7	32.7
D84	36	56	43		71	36	56
D95	42	61	55		83	42	61

Appendix 6

Proposed Channel Velocity and Entrainment

Velocity Comparison Form			
Proposed Condition			
Date	9/4/2002	Team	Louise, Ken, Kyle, Don
Stream	Snow Creek	Location	Stokes County, NC
Input Variables		Output Variables	
Bankfull Cross Sectional Area (A_{BKF})	285.7	Bankfull Mean Depth $D_{BKF} = (A_{BKF}/W_{BKF})$	4.8
Bankfull Width (W_{BKF})	59.5	Wetted Perimeter (WP) $(\sim(2*D_{BKF})+W_{BKF})$	69.1
D84 (Riffle) (mm)	73	D84 (ft) (mm/304.8)	0.24
Bankfull Slope (S) (ft/ft)	0.002	Hydraulic Radius (A_{BKF}/WP)	4.1
Gravitational Acceleration (g)	32.2	R/D84 (use D84 in FEET)	17.26

R/D84, u/u*, Mannings n	
u/u* (using R/D84: see Reference Reach Field Book: p188, River Field Book: p233)	9.88
Mannings n: (Reference Reach Field Book: p189, River Field Book: p236)	0.028
Velocity: (from Manning's equation: $u=1.49R^{2/3}S^{1/2}/n$)	5.8

u/u*=2.83+5.7logR/D84	
u*: $u^*=(gRS)^{0.5}$	0.49
Velocity: u=u*(2.83+5.7logR/D84)	4.8

Mannings n by Stream Type	
Stream Type	C4
Mannings n: (Reference Reach Field Book: p187, River Field Book: p237)	0.019
Velocity: (from Manning's equation: $u=1.49R^{2/3}S^{1/2}/n$)	8.6

Continuity Equation	
Q_{BKF} (cfs) from regional curve or stream gage calibration	980
Velocity: (u=Q/A or from stream gage hydraulic geometry)	3.4

After Wildland Hydrology 2001

ENTRAINMENT CALCULATION FORM

Stream:	Snow Creek, proposed	Reach:	Prabhupada Village
Team:	Ken, Louise, Kyle	Date:	9/12/2002

Information Input Area

20.6	D_{50}	Riffle bed material D50 (mm)			
5.7	$D^{\wedge}_{50}$	Bar sample D50 (mm)			
73.0	D_l	Largest particle from bar sample (mm)	0.24	(feet)	304.8 mm/foot
0.002	S_e	Existing bankfull water surface slope (ft/ft)			
4.8	d_e	Existing bankfull mean depth (ft)			
4.6	R	Hydraulic Radius of Riffle Cross Section (ft)			
1.65	γ_s	Submerged specific weight of sediment			

Calculation of Critical Dimensionless Shear Stress

3.61	$D_{50}/D^{\wedge}_{50}$	If value is between 3-7	**Equation 1** will be used: $\tau^*_{ci} = 0.0834(D_{50}/D^{\wedge}_{50})^{-0.872}$
3.54	D_l/D_{50}	If value is between 1.3-3.0	**Equation 2** will be used: $\tau^*_{ci} = 0.0384(D_l/D_{50})^{-0.887}$
0.0272	τ^*_{ci}	Critical Dimensionless Shear Stress	**Equation used:** 1

Calculation of Bankfull Mean Depth Required for Entrainment of Largest Particle in Bar Sample

5.37	d_r	Required bankfull mean depth (ft)	$d_r = \frac{\tau^*_{ci}\gamma_s D_l}{S_e}$		
0.89	d_e/d_r	Existing mean bankfull depth / Required mean bankfull depth	Stable ($d_e/d_r = 1$)	Aggrading ($d_e/d_r<1$)	Degrading ($d_e/d_r>1$)
aggrading	Vertical Stability of Stream				

Calculation of BKF Water Surface Slope Required for Entrainment of Largest Particle in Bar Sample

0.0022	S_r	Required bankfull water surface slope (ft)	$S_r = \frac{\tau^*_{ci}\gamma_s D_l}{d_e}$		
0.89	S_e/S_r	Existing water surface slope / Required water surface slope	Stable ($S_e/S_r = 1$)	Aggrading ($S_e/S_r < 1$)	Degrading ($S_e/S_r > 1$)
aggrading	Vertical Stability of Stream				

Sediment Transport Validation

0.58	Bankfull Shear Stress $\tau_c = \gamma RS$ (lb/ft2) γ = Density of water = 62.4 lbs/ft^3
37-130	Moveable particle size (mm) at bankfull shear stress (predicted by the Shields Diagram: Blue field book:p238, Red field book:p190)
0.37-0.95	Predicted shear stress required to initate movement of D_l (mm) (see Shields Diagram: Blue field book:p238, Red field book:p190)

Velocity Comparison Form			
Proposed Condition			
Date	9/12/2002	Team	Louise, Ken, Kyle, Don
Stream	UT to Snow Creek	Location	Stokes County, NC
Input Variables		Output Variables	
Bankfull Cross Sectional Area (A_{BKF})	9.6	Bankfull Mean Depth $D_{BKF} = (A_{BKF}/W_{BKF})$	0.8
Bankfull Width (W_{BKF})	12	Wetted Perimeter (WP) $(\sim(2*D_{BKF})+W_{BKF})$	13.6
D84 (Riffle) (mm)	88	D84 (ft) (mm/304.8)	0.29
Bankfull Slope (S) (ft/ft)	0.01	Hydraulic Radius (A_{BKF}/WP)	0.7
Gravitational Acceleration (g)	32.2	R/D84 (use D84 in FEET)	2.44

R/D84, u/u*, Mannings n	
u/u* (using R/D84: see Reference Reach Field Book: p188, River Field Book: p233)	5.04
Mannings n: (Reference Reach Field Book: p189, River Field Book: p236)	0.046
Velocity: (from Manning's equation: $u=1.49R^{2/3}S^{1/2}/n$)	2.6

u/u*=2.83+5.7logR/D84	
u*: $u^*=(gRS)^{0.5}$	0.48
Velocity: u=u*(2.83+5.7logR/D84)	2.4

Mannings n by Stream Type	
Stream Type	C4
Mannings n: (Reference Reach Field Book: p187, River Field Book: p237)	0.019
Velocity: (from Manning's equation: $u=1.49R^{2/3}S^{1/2}/n$)	6.2

Continuity Equation	
Q_{BKF} (cfs) from regional curve or stream gage calibration	76
Velocity: (u=Q/A or from stream gage hydraulic geometry)	7.9

After Wildland Hydrology 2001

ENTRAINMENT CALCULATION FORM

Stream:	UT to Snow Creek, proposed	Reach:	Prabhupada Village
Team:	Ken, Louise, Kyle	Date:	9/12/2002

Information Input Area

32	D_{50}	Riffle bed material D50 (mm)			
32.7	$D^{\wedge}_{50}$	Bar sample D50 (mm)			
90.0	D_i	Largest particle from bar sample (mm)	0.30	(feet)	304.8 mm/foot
0.010	S_e	Existing bankfull water surface slope (ft/ft)			
0.8	d_e	Existing bankfull mean depth (ft)			
0.78	R	Hydraulic Radius of Riffle Cross Section (ft)			
1.65	γ_s	Submerged specific weight of sediment			

Calculation of Critical Dimensionless Shear Stress

0.98	$D_{50}/D^{\wedge}_{50}$	If value is between 3-7 **Equation 1** will be used:	$\tau^*_{ci} = 0.0834(D_{50}/D^{\wedge}_{50})^{-0.872}$
2.81	D_i/D_{50}	If value is between 1.3-3.0 **Equation 2** will be used:	$\tau^*_{ci} = 0.0384(D_i/D_{50})^{-0.887}$
0.0153	τ^*_{ci}	Critical Dimensionless Shear Stress	**Equation used:** 2

Calculation of Bankfull Mean Depth Required for Entrainment of Largest Particle in Bar Sample

0.75	d_r	Required bankfull mean depth (ft)	$d_r = \frac{\tau^*_{ci}\gamma_s D_i}{S_e}$		
1.07	d_e/d_r	$\frac{\text{Existing mean bankfull depth}}{\text{Required mean bankfull depth}}$	Stable ($d_e/d_r = 1$)	Aggrading ($d_e/d_r<1$)	Degrading ($d_e/d_r>1$)
stable	Vertical Stability of Stream				

Calculation of BKF Water Surface Slope Required for Entrainment of Largest Particle in Bar Sample

0.0093	S_r	Required bankfull water surface slope (ft)	$S_r = \frac{\tau^*_{ci}\gamma_s D_i}{d_e}$		
1.07	S_e/S_r	$\frac{\text{Existing water surface slope}}{\text{Required water surface slope}}$	Stable ($S_e/S_r = 1$)	Aggrading ($S_e/S_r < 1$)	Degrading ($S_e/S_r > 1$)
stable	Vertical Stability of Stream				

Sediment Transport Validation

0.49	Bankfull Shear Stress $\tau_c = \gamma RS$ (lb/ft2) γ = Density of water = 62.4 lbs/ft^3
30-110	Moveable particle size (mm) at bankfull shear stress (predicted by the Shields Diagram: Blue field book:p238, Red field book:p190)
0.4-1.1	Predicted shear stress required to initate movement of D_i (mm) (see Shields Diagram: Blue field book:p238, Red field book:p190)

Appendix 7

Plan View of Existing Conditions

Appendix 8

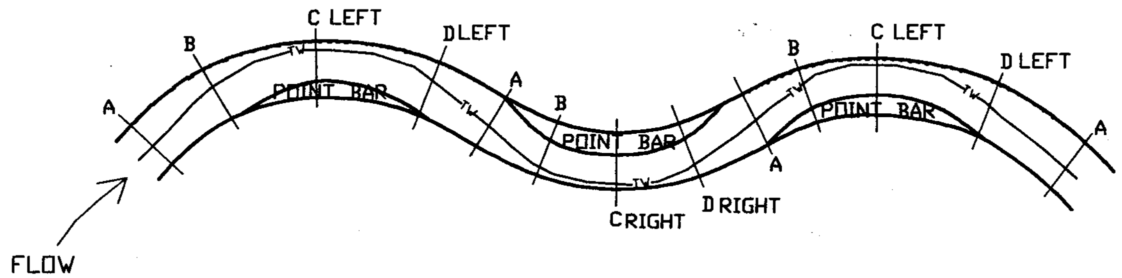
Plan View of Proposed Channel with Structures

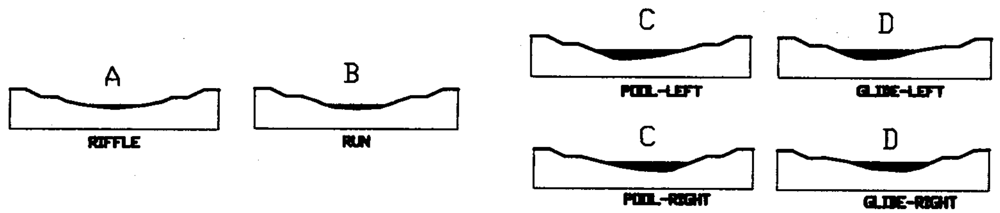
Appendix 9

Typical Cross Sections

Details of Structures

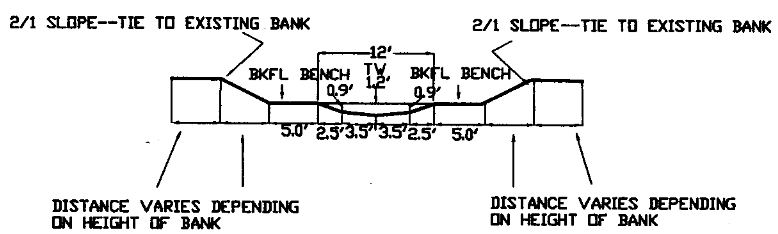
UNNAMED TRIBUTARY SNOW CREEK TYPICAL CROSS SECTIONS





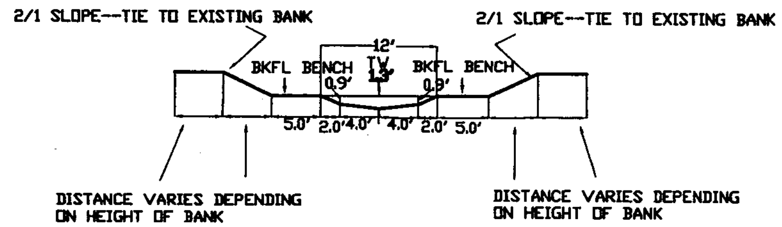
BED FEATURE SEQUENCE AND CROSS SECTIONS

SEE TYPICAL CROSS SECTIONS AND STATIONING FOR MORE DETAILS.



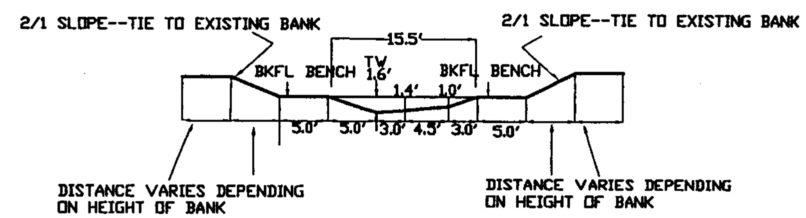
TYPICAL SECTION-RIFFLE

DETAIL 2



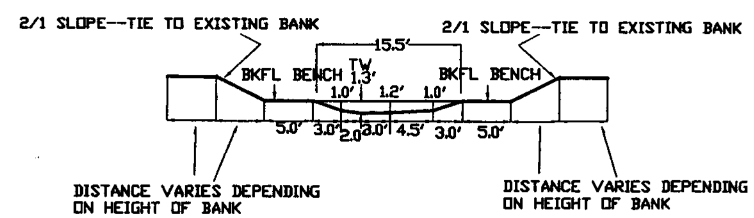
TYPICAL SECTION-RUN

DETAIL 3



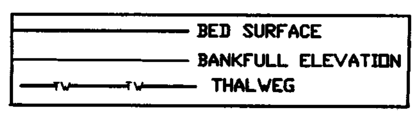
TYPICAL SECTION-POOL

DETAIL 4



TYPICAL SECTION-GLIDE

DETAIL 5



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PROJECT: CLEAR CREEK STREAM RESTORATION

PREPARED FOR: NORTH CAROLINA WETLANDS RESTORATION PROGRAM

NO.	DESCRIPTION	DATE

REVISIONS

UNNAMED TRIBUTARY TYPICAL CROSS SECTIONS

SCALE: NO SCALE
DATE: 1/22/02
DRN. BY: KDH
CHECKED BY:

PROJECT NO: –

SHEET 10 OF 12

DRAWING

10