Linville River Restoration Master Plan

Gill State Forest
Avery County, North Carolina

Prepared for:

North Carolina Forest Service

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March 19, 2014

EXECUTIVE SUMMARY

The North Carolina Forest Service (NCFS) requested a Master Plan be developed to identify potential stream restoration projects with the goals of improving water quality and ecological functions of the Linville River and tributaries on the Gill State Forest in Avery County, North Carolina. The NCFS contracted with Stantec to prepare this report, which documents existing conditions, summarizes stakeholder input, and presents conceptual design information for potential river restoration projects within the State Forest.

For the purposes of this study, the Linville River within the property has been separated into three reaches:

- Reach 1: Sloop Dam to approximately 100 feet upstream of new bridge (4,400 feet)
- Reach 2: 100 feet upstream of new bridge to private property boundary (2,900 feet)
- Reach 3: Private property boundary to Greene Road bridge (1,400 feet)

Two perennial tributaries enter the Linville River within these extents. The project for Reach 2 of the Linville River also includes improvements to Tributary 1, while the project for Reach 3 includes improvements to Tributary 2.

Primary goals of potential river restoration include: enhancement of trout fisheries, improved flood protection for facilities, and increased opportunities for education, public visibility, and utilization of the Mountain Training Facility.

The river corridor does include active fields, a gun range, two bridges, and multiple utilities. Multiple parcels of private property are located along portions of the Linville River. In addition to these physical constraints, any restoration project needs to include consideration of public access, maintenance, and the potential for disruption of nursery or training center operations.

Restoration components, benefits, and constraints for potential projects are summarized in the following table.

Reach	Project Elements	Primary Benefits	Constraints
1	- Bankfull bench creation (600 ft) - Increased floodplain access - In-stream structures (3) - Changes to cross-section dimension - Streambank stabilization - Vegetation enhancement	- Habitat improvement - Bank protection	- Private property - Existing fields - Bedrock
2	- Channel realignment (2,450 ft) - Floodplain creation - In-stream structures (10) - Infrastructure protection - Remove low water bridge - Vegetation enhancement - Wetland enhancement - Tributary 1 improvements	- Habitat improvement - Bank protection - Infrastructure protection - Flood mitigation - Improved public access	- Existing fields - Bridges - Utilities - Bedrock - Gun range - Gravel road - Intake structures
3	- Channel realignment (1,400 ft) - Floodplain creation - In-stream structures (5) - Vegetation enhancement - Tributary 2 improvements	- Habitat improvement - Bank protection - Flood mitigation	- Private property - Bridge - Bedrock

Estimated design and construction costs based on the above project elements and attached conceptual designs are $240,000 (Reach 1), $540,000 (Reach 2), and $310,000 (Reach 3). Qualitative evaluations of potential benefits and constraints for the projects are below.

Potential Benefits

	Reach 1	Reach 2	Reach 3
Reduction of bank erosion	Moderate	High	High
Floodplain creation/enhancement	Moderate	High	High
Wetland creation/enhancement	Low	Moderate	Low
Creation/enhancement of in-stream habitat	Moderate	High	High
Infrastructure protection	Low	Moderate	Low
Flood mitigation	Low	Moderate	Moderate
Tributary enhancement	Low	High	High
Visibility and education potential	Low	High	Moderate
Overall Potential Benefit	**Low-Moderate**	**Moderate-High**	**Moderate**

Constraints

	Reach 1	**Reach 2**	**Reach 3**
Impact to existing fields	Moderate	Low	Low
Impact to existing utilities and infrastructure	Low	Moderate	Low
Private property	Moderate	Low	High
Vertical limitations due to bedrock	Moderate	Moderate	Moderate
Difficulty of equipment access	Moderate	Low	Low
Overall Constraints	**Low-Moderate**	**Low-Moderate**	**Moderate**

Of the three potential projects, Reach 2 provides the highest overall benefit toward achievement of project goals, followed by Reach 3, then Reach 1. Constraints for Reach 1 and 2 are fairly low; Reaches 1 and 3 may have limitations due to multiple private landowners on one side of the Linville River. This validates the decision by the NCFS to pursue grant funding for restoration of Reach 2 as the initial restoration effort to demonstrate successful river improvement as a model for future projects.

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I. INTRODUCTION

The North Carolina Forest Service (NCFS) requested a Master Plan be developed to identify potential stream restoration projects with the goals of improving water quality and ecological functions of the Linville River and tributaries on the Gill State Forest in Avery County, North Carolina. The Linville River comprises the upper reaches of the Catawba River Basin; upstream of Linville Gorge. The Gorge is part of 13 river miles designated as a State Natural & Scenic River. The Linville River Nursery is located on both sides of the river within Gill State Forest. The NCFS Mountain Training Facility, which serves numerous state agencies and affiliates, is located on the left bank of the river within the State Forest.

Once completed, river restoration projects within Gill State Forest could serve as a catalyst to encourage other property owners to participate in similar restoration work. Projects would provide the potential to increase visibility of the partnering agencies and their commitment to restoring and enhancing the water resources of the state. The proximity of the targeted river reaches to the NCFS Mountain Training Facility also represents an ideal classroom and outdoor laboratory opportunity for state agency training events pertaining to water quality, river ecology and restoration practices.

The NCFS has contracted with Stantec to complete the following Scope of Services:

TASK 1: Existing Conditions Data Collection

- Assemble any readily available existing data (aerial imagery, 2-5 foot contour topography, soils, land use/cover, and other relevant GIS files) related to watershed and stream conditions within the Gill State Forest property and contributing watersheds.
- Perform geomorphic assessments of streams and floodplains to evaluate existing fluvial conditions and restoration potential. Also, obtain supplemental detailed stream crossing data (inverts, pipe size, edge of road/crown, upstream/downstream sections).
- Assess and document existing riparian conditions, including: 1) stream morphology, 2) streambed substrate, 3) streambank erodibility (BEHI), 4) floodplain land uses, 5) vegetation composition, and 5) equipment accessibility for treatment.

TASK 2: Stakeholder Engagement

- Meet with NCFS personnel (and any other stakeholders as identified and invited by NCFS) to identify specific objectives and constraints for future stream restoration efforts.
- Maintain ongoing communication regarding project progress, matters of concern and path forward.
- Identify and analyze limiting factors for stream restoration project efforts based on stakeholder input.
- Present the plan completed in Task 3 to revisit objectives and elaborate on how specific concerns were addressed and incorporated.

TASK 3: Restoration Project Elements

- Using existing topographic data and supplemental detailed stream crossing data (from Task 1), Stantec will develop and produce conceptual sketch plan figures for feasible restoration project elements, including plan view, longitudinal profile, typical cross-sections, and planting zones.
- Based on the above evaluation and a single design concept, Stantec will assemble a preliminary engineering opinion of cost to include approximation of design fees, construction cost plus contingency.
- Additionally, Stantec will develop a prioritization matrix of feasible restoration project elements using qualifiers for project feasibility, conceptual opinion of quantities and cost, and benefit qualifications as basis of comparison.

TASK 4: Final Report

- Assemble an electronic Final Report consisting of all deliverables from Tasks 1, 2, and 3 to be delivered to NCFS.
- Meet with Project Managers to present findings included in Final Report.

II. EXISTING CONDITIONS

Sheets A1 through A5 in Appendix A provide overall site information, including locations, soils, topography, and historical aerial photography. For the purposes of this study, the Linville River within the property has been separated into three reaches:

- Reach 1: Sloop Dam to approximately 100 feet upstream of new bridge (4,400 feet)
- Reach 2: 100 feet upstream of new bridge to private property boundary (2,900 feet)
- Reach 3: Private property boundary to Greene Road bridge (1,400 feet)

Existing conditions within these reaches of the Linville River are detailed below. Potential restoration options for these areas are described in Section IV.

Reach 1

Most of Reach 1 flows through well-vegetated areas, and is laterally and vertically stable. An exception to this is 600 feet of the left bank which is steep, highly erodible, and adjacent to a field with minimal buffer (Photo 1). Additionally, minor bank erosion exists on the right bank at the outside of the large meander bend (Photo 2).

Generally, the left bank is well-vegetated with a mix of river birch (*Betula nigra*), white pine (*Pinus strobus)*, yellow poplar (*Liriodendron tulipifera)*, and an understory of rhododendron (*Rhododendron* sp.) and mountain laurel (*Kalmia latifolia*.). However, an historic levee does exist along much of the left bank, limiting floodplain access.

Vegetation on the right bank is composed of mixed hardwoods with some white pine (*Pinus strobus*) and rhododendron (*Rhododendron* sp.). Very good herbaceous cover exists at the toe of the slope, along the right edge of the channel.

Reach 1 has multiple property owners on the right bank of the Linville River near the upstream end of the NCFS property. The right bank along private property is stable and is not recommended as a site for structural or vegetation work at this time.

Photo 1: Reach 1, downstream view from adjacent field

Photo 2: Reach 1, right bank erosion

The streambed throughout this reach is dominated by shallow water features, such as riffles, runs, and glides. Some pools do exist, though bedform diversity could be increased through deepening existing pools and/or creating new pools. Cross-section dimensions are generally

uniform in the reach, with exceptions occurring in two locations: the channel is over-wide at the confluence with Mill Timber Creek, and again approximately 1,000 feet upstream of the bridge. In these locations, the wide channel has become braided, through the deposition of sand, gravel, and cobble.

Reach 2

Reach 2 contains two bridges: one recently constructed and one several decades old. At the upstream bridge, riprap exists on the streambanks, though the bridge piers remain susceptible to scour at high flows. The downstream bridge was designed for use during times of low flow, and is currently not used at all, due to damage to the bridge deck. A nursery-related irrigation line is affixed to this low water bridge. Between the two bridges, streambanks are covered with mowed grass, and lack deep-rooted vegetation (Photo 3).

Photo 3: Reach 2, upstream view from low-water bridge

A large mid-channel bar (approximately 440 feet long and 28,000 square feet in area) exists downstream of the low-water bridge (Photo 4). The bar is primarily vegetated with tag alder (*Alnus serrulata*), with some areas covered by willow (*Salix* sp.) and sedges (*Carex* sp.).

Photo 4: Reach 2, downstream view from low-water bridge, mid-channel bar on right

The right bank through much of Reach 2 is steep and very high (up to 14 feet). This steep slope provides a very narrow stream buffer (approximately 20 feet wide) dominated by American beech (*Fagus grandifolia*) trees and a rhododendron (*Rhododendron* sp.) understory.

The left bank, from the mid-channel bar to the end of Reach 2, contains a mixed hardwood forest, with yellow poplar (*Liriodendron tulipifera*), red maple (*Acer rubrum*), sycamore (*Platanus occidentalis*), green ash (*Fraxinus pennsylvanica*), American beech (*Fagus grandifolia*), river birch (*Betula nigra*), and northern red oak (*Quercus rubra*). The understory contains rhododendron (*Rhododendron* sp.), and doghobble (*Leucothoe* sp.). Between the low water bridge and the confluence with Tributary 1, the vegetated buffer is narrow (generally 20-30 feet wide), and is topped by a levee protecting wastewater infrastructure. Further downstream, the buffer widens and the levee disappears. Within the widened buffer are a small wetland and tributary (Tributary 1).

The existing longitudinal profile of Reach 2 is included as Sheet A6 in Appendix A. The vertical change in the water surface along Reach 2 is 10.4 feet, resulting in an average water surface slope of 0.0036 feet/foot, or 0.36%. The bedform is dominated by shallow water features, such as riffles, runs, and glides. Two notable pools do occur in Reach 2: one in the vicinity

of the new bridge, and one downstream of a prominent bedrock ledge (Photo 5). This bedrock provides a vertical drop of 1.4 feet in the water surface, followed by 500 feet of flat water. A water intake for irrigation is located on the right bank upstream of the bedrock.

Photo 5: Reach 2, bedrock step with water intake just upstream

Cross-section data from Reach 2 is presented in Sheet A7. Measured cross-section dimensions indicate the river channel is over-wide (existing bankfull width is 80-140 feet, compared to reference width of approximately 70 feet). Downstream of the low-water bridge, the channel is also incised, with reduced floodplain access. This is confirmed by measured existing bank height ratios, which range from over 2.0 (due to left bank levee) to near 1.2 (near downstream end of reach).

The streambed substrate was quantified with a pebble count, with results in Sheet A8. The median particle size on the streambed was 90 millimeters, or a small cobble. However, only 26% of measured particles were cobbles; the remainder included sand (17%), gravel (26%), and boulders (14%). Bedrock does exist in multiple locations, though only at the aforementioned ledge is it prominent across the entire width of the stream.

Bank erodibility was approximated using the Bank Erosion Hazard Index (BEHI). This index was used for both the left and right streambanks in Reach 2 (Sheet A9). All BEHI classifications in Reach 2 were moderate, low, or very low. However, observed near bank stress (NBS) was often high, particularly in the vicinity of the mid-channel bar, indicating high erodibility. The combinations of BEHI and NBS were used to approximate streambank erosion rates, resulting in an estimated 68 cubic yards (102 tons) of sediment lost annually due to bank erosion.

Reach 3

Most of Reach 3 is a multi-thread channel, with flow split around two large mid-channel bars. The upstream mid-channel bar begins near the upstream extent of Reach 3, with the lower bar ending at the Greene Road bridge, at the bottom of Reach 3 (Photo 6). Vegetation on the upstream bar is dominated by tag alder (*Alnus serrulata*), with the lower bar containing mixed hardwood trees.

Reach 3 has multiple property owners on the left bank of the Linville River. The NCFS owns land to the right of the river throughout the reach; however, three private landowners own the entirety of the left bank. The left bank in the vicinity of the houses is characterized by eroding streambanks and a mowed grass buffer. The adjacent mid-channel bar and confluence with a tributary (Tributary 2) exacerbate the bank erosion. Near the Greene Road bridge, the left bank is better vegetated, with some alder and mixed hardwoods. Throughout Reach 3, the right bank is well-vegetated. Red maple (*Acer rubrum*) is dominant, with some hickory (*Carya* Sp.), green ash (*Fraxinus pennsylvanica*), sycamore (*Platanus occidentalis*), and northern red oak (*Quercus rubra*).

Photo 6: Reach 3, upstream view of mid-channel bar from Greene Road bridge

Like Reach 2, Reach 3 suffers from lack of bedform diversity and an over-wide channel. However, Reach 3 is less incised, with generally good floodplain access, particularly on the right bank. However, an historic levee does exist along portions of the right bank, restricting the available floodplain width.

Forest Access Road Crossings

The Forest Access Road crosses tributaries flowing through culverts at five locations. Maintenance needs and retrofit possibilities were identified at each of these crossings to improve stream and road stability and to reduce downstream sedimentation. Common issues to be addressed at these culvert crossings include the following:

- Upstream clogging with sediment and plant debris following heavy runoff events. Culverts should be regularly inspected for clogging and cleaned out manually or mechanically to ensure full access during high flow events, minimizing the amount of flow across the road surface. Additionally, each culvert should be evaluated to ensure that it is the proper diameter and length.
- Downstream head-cutting of the channel undermining the culvert and road. This has resulted in the downstream ends of all five culverts perched above the streambed, impairing fish passage and exacerbating erosion. Rock steps should be installed from the culvert outlet down to the stable streambed to carry flows without causing additional scouring of the bed and banks.
- Rills and gullies on the road surface resulting from runoff along and across the road. Water bars, broad-based dips, or other suitable diversions should be installed along the roads sloping down toward culvert crossings to reduce concentrated flow and sediment load at the culvert crossings. In some locations, the roadbed in the vicinity of the culvert should be re-graded with an inslope to promote flow toward the upstream end of the culvert.

Due to changing conditions at the road culverts following runoff events and heavy road use by logging trucks, it is recommended that site-specific engineering solutions be developed for each crossing at the time of maintenance to address existing conditions appropriately. Followup maintenance to remove future clogging and rills is essential for long-term stream and road protection.

III. STAKEHOLDER INPUT

Stantec personnel have attended multiple meetings and site visits with the NCFS, in order to fully understand the priorities and constraints for potential restoration projects on the Linville River. A formal meeting with the NCFS was held in Morganton, North Carolina on March 26, 2013. Notes from that meeting, as summarized by the NCFS, are included as Appendix B. A summary of goals and limiting factors identified over the course of the master planning process is below.

Goals of potential river restoration include:

- Improve flood protection for NCFS facilities
- Maintain traditional river uses
- Enhance trout fisheries on the Linville River
- Increase utilization of the Mountain Training Facility
- Create opportunities for state agency training events pertaining to hydrology, river ecology and restoration practices
- Increase the visibility of the partnering agencies and their commitment to restoring and enhancing the water resources of the state
- Remove non-functioning low water bridge for increased public safety and river function

Limiting factors to river restoration include:

- Ensuring no disruption of nursery and training center operations
- Maintaining public exclusion from the area surrounding the gun range
- Private property owners upstream of Greene Road and downstream of Sloop Dam
- Recently constructed bridge will remain in current location
- Water intake from river exists on right bank
- Six-inch irrigation line currently under low water bridge
- Existing fields adjoin some portions of the river
- Maintain public access at designated parking area
- Points for public access to the river need to be considered
- Ongoing maintenance and site management should be minimized

IV. RESTORATION PROJECT ELEMENTS

Appendix C contains information related to conceptual designs for the potential projects. Sheet C2 provides an overview of the projects, with plans for the individual reaches on Sheets C3 through C5. Sheets C6 through C10 show typical riffle and pool cross-sections, structure details, and planting information appropriate for these projects.

Potential Project 1: Linville River, Reach 1

Overall, the restoration approach for Reach 1 maintains the channel along the existing planform position, and focuses on improvements to the streambanks and the streambed. The following elements are included in the restoration project on Reach 1:

Bankfull bench creation: Along the 600 feet of sparsely vegetated left bank, a 10 foot wide floodplain bench will be created, then graded into the existing field at a stable slope. A wood toe will be incorporated into the bench to enhance in-stream habitat.

Increased floodplain access: Where a levee exists along the left bank, a 20 foot long breach will be created every 100 feet.

In-stream structures: Three in-stream structures will be installed (2 boulder cross vanes, 1 log/boulder j-hook). One of these will be located to protect the eroding right bank in the meander bend. Additional structures will be located in areas of channel over-widening. All structures will include pool creation, and when practical, woody debris incorporated within or nearby the proposed structures.

Changes to cross-section dimension: At the two over-widened areas, streambank creation and minor channel realignment will take place to establish an appropriate cross-section.

Streambank stabilization: After final grading, eroding streambanks in the upper field (left bank) and meander bend (right bank) will be stabilized with coir matting and vegetation.

Vegetation enhancement: Native vegetation will be planted in any disturbed areas, on streambanks, and in the upper field to create a 50 foot wide vegetated buffer on the left bank. This includes a riparian grass seed mix, live stakes, and container plants.

Potential Project 2: Linville River, Reach 2

The restoration approach for Reach 2 is multi-faceted, and include considerations of existing infrastructure in addition to improvements to the Linville River, Tributary 1, and an existing wetland. The following elements are included in a restoration project on Reach 2:

Channel realignment: Approximately 2,450 feet of the river (between low-water bridge and end of Reach 2) will be realigned into a new channel with appropriate cross-section dimensions, bedform, and pattern. Based on reference reach data, experience with similar projects, and observations/measurements taken along Reach 2, morphological design parameters were established and applied in generating the provided conceptual design. Table 1 summarizes these morphological design parameters for the new channel. Generally, the new channel overlaps parts of the existing channel, yet changes in horizontal and vertical alignment through narrowing the channel or shifting to the left. Mid-channel bars will be removed, with the material used to build new floodplain adjacent to the new channel.

Floodplain creation: The areas adjacent to the new channel will be graded to provide floodplain access during bankfull flow. To the right of the channel, this involves creating new floodplain adjacent to the steep right bank. To the left of the channel, the existing floodplain will be graded to the appropriate elevations.

In-stream structures: Ten in-stream structures will be installed (4 boulder cross vanes, 6 log/boulder j-hooks). The most upstream boulder cross vane will be located immediately upstream of the new bridge to provide protection of the bridge piers and enhance access adjacent to the public parking lot. The second boulder vane will be located immediately downstream of the existing low water bridge, in order to provide stability and grade control for a constructed cobble riffle bed that may be used as a stream crossing. Additional structures will be constructed with the goals of bank protection, pool creation, and habitat creation. When practical, woody debris, including wood toes, will be incorporated within or nearby the proposed structures.

Infrastructure protection: As described above, boulder cross vanes will be used to protect the bridge and future cobble-bed river crossing. If the irrigation line, currently at the low water bridge, needs to remain, it will be routed under the streambed immediately upstream of the cross vane. No changes will be made to the existing left bank levee protecting buildings and sewer infrastructure. A pool will be maintained at the existing water intake on the right bank.

During the design process, modeling (HEC-RAS) will be used to provide for "no-impact" in the 100-year flood elevations as a result of the project.

Remove low-water bridge: The existing deck and any loose material (concrete and rock) will be removed from the low-water bridge. Large concrete material below the streambed may remain in place to serve as the base for a new stream crossing. Atop the buried concrete, a low slope riffle of large cobble will be installed to serve as a low water crossing, with grade control and stabilization provided by the boulder cross vane immediately downstream.

Vegetation enhancement: Native vegetation will be planted on the new streambanks and floodplain. This includes a riparian grass seed mix, live stakes, and container plants. Additionally, tag alder (*Alnus serrulata*) will be transplanted from the existing mid-channel bar to the new streambanks and floodplain. Sod mats, consisting of sedges (*Carex* sp.) will be harvested from the mid-channel bar and used to protect new streambanks.

Wetland enhancement: The existing wetland (between Linville River and Tributary 1) will be enhanced to provide additional flood storage and improve ecological function. Grading will occur to hydraulically connect the existing wetland to the river at flood flows. Existing peak (2-year and higher) flow diversions in the vicinity of the wetland and Tributary 1 will be graded to promote uninterrupted flow in Tributary 1 and set the design storage volume in the wetland. The outlet of the wetland should be further designed to maintain discharge control and stability into Tributary 1. Coir matting and native plants will be used to stabilize these areas after construction.

Tributary 1 improvements: In-stream boulder structures will be installed in the vicinity of the road culvert to provide stability and promote sediment transport. The riparian buffer will be enhanced with native species, particularly in areas where only mowed grass is between the stream and the road. Where planting occurs near the road, low-growing species (e.g., rhododendron) should be chosen for aesthetics and low maintenance. Downstream of the gun range, beaver removal and sporadic in-channel work (repair of beaver impacts and minor bank erosion) will occur. Near the existing wetland and confluence with the Linville River, removal of flow diversions and minor channel realignment will occur, in order to promote a stable channel and confluence with Reach 2, as described above.

Table 1. Linville River Morphological Design Parameters
(Note: When multiple values exist, median is reported with range in parentheses.)

Cross-section dimension (riffle)

Area	235	square feet
Width	68.6	feet
Mean depth	3.4	feet
Maximum depth	5.1	feet
Maximum depth ratio	1.5	
Width/depth ratio	20.0	
Bank height ratio	1.0	

Cross-section dimension (pool)

Area	358	square feet
Width	82.3	feet
Mean depth	4.4	feet
Maximum depth	8.2 (7.5 - 8.9)	feet
Maximum depth ratio	2.4 (2.2 - 2.6)	

Longitudinal profile

Stream length	2894	feet
Stream elevation change	10.4	feet
Average slope	0.0036	feet/foot
Riffle length	126 (64-170)	feet
Riffle length ratio	1.8 (0.9 - 2.5)	
Riffle slope	0.0056 (0.0040 - 0.0070)	feet/foot
Riffle slope ratio	1.6 (1.1 - 1.9)	
Pool length	131 (108 - 263)	feet
Pool length ratio	1.9 (1.6 - 3.8)	
Pool slope	0.0000	feet/foot
Pool spacing	278 (183 - 370)	feet
Pool spacing ratio	4.1 (2.7 - 5.4)	
Step height	0.35 (0.20 - 0.40)	feet

Potential Project 3: Linville River, Reach 3

The restoration approach for Reach 3 includes narrowing of the channel by removing both mid-channel bars. Both the Linville River and Tributary 2 will be shifted away from private property on the left bank to eliminate erosion and provide a stable confluence. Specific restoration elements for Reach 3 include:

Channel realignment: The entire 1,400 feet of the Linville River in Reach 3 will be realigned into a new channel with appropriate cross-section dimensions, profile, and pattern. Generally, the new channel overlaps parts of the existing channel, yet changes in alignment through narrowing the channel or shifting to the right. Mid-channel bars will be removed, with the material used to build new floodplain adjacent to the new channel. A stable confluence for Tributary 2 will be created.

Floodplain creation: The areas adjacent to the new channel will be graded to provide floodplain access during bankfull flow. To the left of the channel, this involves creating new floodplain adjacent to private property. To the right of the channel, the existing floodplain will be graded to the appropriate elevations, and a small levee will be breached.

In-stream structures: Five 5 in-stream structures will be installed (1 boulder cross vane, 4 log/boulder j-hooks). The most downstream structure will be a boulder cross vane, in order to center flow under the Greene Road bridge. The j-hook structures will be constructed with the goals of bank protection, pool creation, and habitat creation. When practical, woody debris, including wood toes, should be incorporated in or near the structures.

Vegetation enhancement: Native vegetation will be planted on the new streambanks and floodplain. This includes a riparian grass seed mix, live stakes, and container plants. Additionally, tag alder (*Alnus serrulata*) will be transplanted from the existing mid-channel bars to the new streambanks and floodplain.

Tributary 2 improvements: A stable confluence between Tributary 2 and the Linville River will be created. The tributary will enter the river at an appropriate angle, and in a location that does not promote bank erosion and endanger private property. This includes the realignment of approximately 250 feet of the stream, with appropriate cross-section dimensions and bedform. In-stream structures will be installed within these 250 feet to provide stability to the

new channel. Upstream of the realignment, proposed work is minimal, and only includes beaver population management and buffer enhancement as needed.

Comparison of Potential Restoration Projects

A summary of the aforementioned project elements in presented in Table 2, along with project benefits and major constraints.

Table 2. Summary of Potential Projects

Reach	Project Elements	Primary Benefits	Constraints
1	- Bankfull bench creation (600 ft) - Increased floodplain access - In-stream structures (3) - Changes to cross-section dimension - Streambank stabilization - Vegetation enhancement	- Habitat improvement - Bank protection	- Private property - Existing fields - Bedrock
2	- Channel realignment (2,450 ft) - Floodplain creation - In-stream structures (10) - Infrastructure protection - Remove low water bridge - Vegetation enhancement - Wetland enhancement - Tributary 1 improvements	- Habitat improvement - Bank protection - Infrastructure protection - Flood mitigation - Improved public access	- Existing fields - Bridges - Utilities - Bedrock - Gun range - Gravel road - Intake structures
3	- Channel realignment (1,400 ft) - Floodplain creation - In-stream structures (5) - Vegetation enhancement - Tributary 2 improvements	- Habitat improvement - Bank protection - Flood mitigation	- Private property - Bridge - Bedrock

Table 3 summarizes estimated costs for these potential projects. The costs for improvements to Tributaries 1 and 2 are included in costs for Reach 2 and 3, respectively. These costs are based on quantities estimated from the conceptual plans, and informed by professional judgment based on experience with other river restoration projects. Costs per linear foot of river vary due to level of construction effort needed for grading and in-stream structures. While detailed morphology survey data have been collected for Reach 2, similar data collection has not been performed on Reaches 1 and 3. Additional refinement to these numbers should be expected as the design process progresses.

Table 3. Estimated Project Costs

	Reach 1	Reach 2	Reach 3
Mobilization	$20,000	$20,000	$20,000
Grading	$30,000	$90,000	$60,000
Materials	$40,000	$85,000	$40,000
Channel work	$30,000	$90,000	$50,000
Structures	$25,000	$60,000	$30,000
Supplies	$10,000	$20,000	$10,000
Vegetation	$5,000	$15,000	$10,000
Bridge and utility work	$0	$50,000	$0
Total construction cost	**$160,000**	**$425,000**	**$220,000**
Design and permitting	$50,000	$75,000	$60,000
Construction administration and observation	$30,000	$40,000	$30,000
Total project cost	**$240,000**	**$540,000**	**$310,000**

Note: Total project cost does not include project administration or monitoring.

Table 4 contains an opinion of the relative potential benefit (low, moderate, high) provided by some aspects of the project, as well as the relative impact of the primary constraints.

Table 4. Project Prioritization

Potential Benefits

	Reach 1	Reach 2	Reach 3
Reduction of bank erosion	Moderate	High	High
Floodplain creation/enhancement	Moderate	High	High
Wetland creation/enhancement	Low	Moderate	Low
Creation/enhancement of in-stream habitat	Moderate	High	High
Infrastructure protection	Low	Moderate	Low
Flood mitigation	Low	Moderate	Moderate
Tributary enhancement	Low	High	High
Visibility and education potential	Low	High	Moderate
Overall Potential Benefit	**Low-Moderate**	**Moderate-High**	**Moderate**

Constraints

	Reach 1	**Reach 2**	**Reach 3**
Impact to existing fields	Moderate	Low	Low
Impact to existing utilities and infrastructure	Low	Moderate	Low
Private property	Moderate	Low	High
Vertical limitations due to bedrock	Moderate	Moderate	Moderate
Difficulty of equipment access	Moderate	Low	Low
Overall Constraints	**Low-Moderate**	**Low-Moderate**	**Moderate**

Of the three potential projects, Reach 2 provides the highest overall benefit toward achievement of project goals, followed by Reach 3, then Reach 1. Constraints for Reach 1 and 2 are low to moderate; Reach 3 likely has more limitations due to multiple private landowners. This validates the decision by the NCFS to pursue grant funding for construction of Reach 2 as a model for potential future river restoration projects.

APPENDIX A

EXISTING CONDITIONS

A1. Site Location
A2. Site Overview
A3. Site Topography
A4. Soils
A5. Historical Aerial Imagery
A6. Existing Longitudinal Profile
A7. Existing Cross-sections
A8. Pebble Count Data
A9. Bank Erodibility Assessment

Legend

Gill State Forest Boundary — Streams — Roads

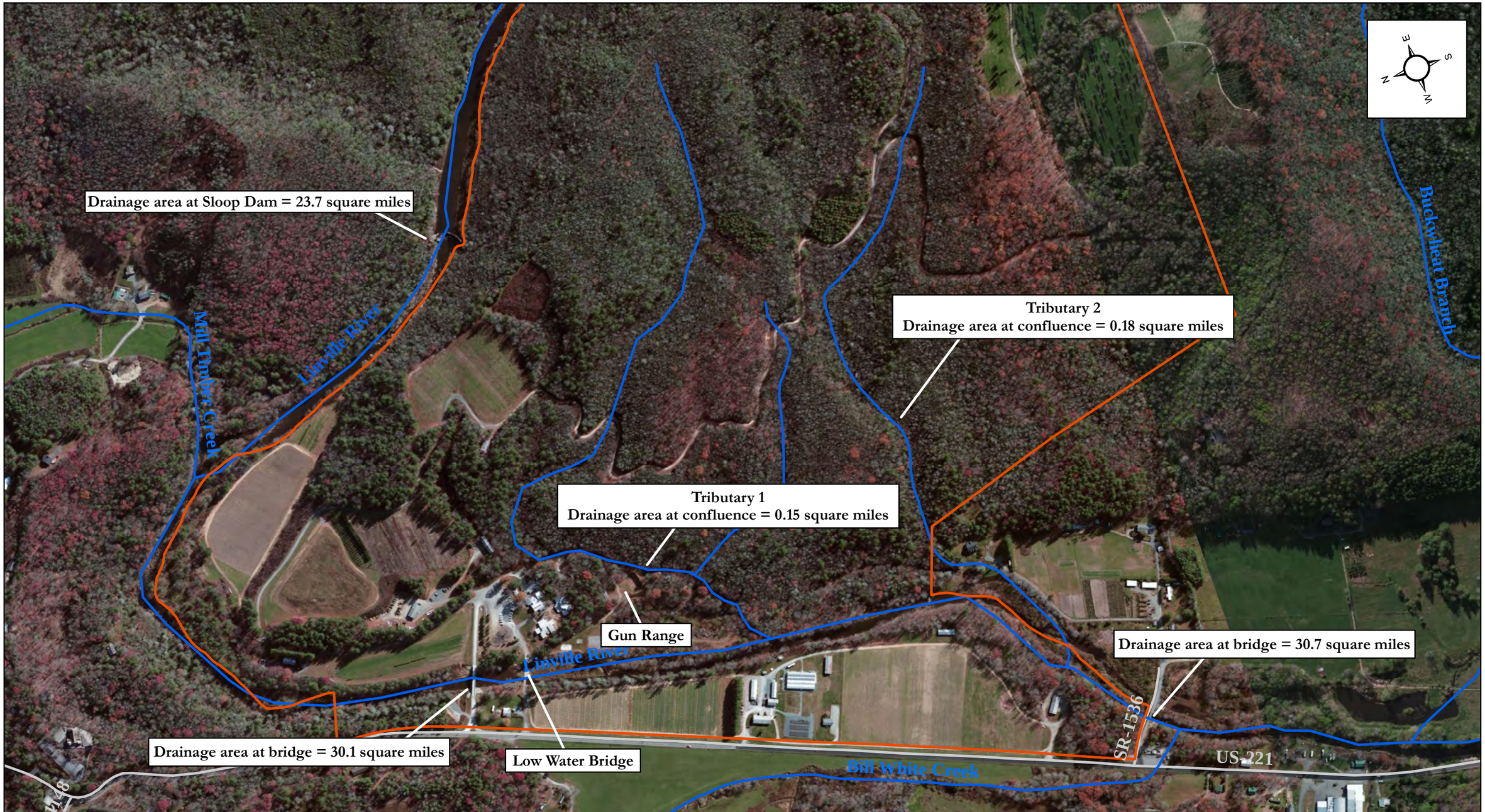
Aerial imagery from Bing Maps, (c) 2010 Microsoft Corporation and its data suppliers

Site Location

0 500 1,000 2,000 Feet

Linville River Restoration Project
Gill State Forest
Avery County, North Carolina

Sheet A1



Legend

Gill State Forest Boundary — Streams — Roads

Aerial imagery from Bing Maps, (c) 2010 Microsoft Corporation and its data suppliers

Site Overview

0 250 500 1,000 Feet

Linville River Restoration Project
Gill State Forest
Avery County, North Carolina

Sheet A2

Legend

Gill State Forest Boundary

Streams

Contour, interval 20 feet

Contour, interval 100 feet

Aerial imagery from Bing Maps, (c) 2010 Microsoft Corporation and its data suppliers

Site Topography

0 250 500 1,000 Feet

Linville River Restoration Project
Gill State Forest
Avery County, North Carolina

Sheet A3

CrE	Crossnore-Jeffrey complex
CrF	Crossnore-Jeffrey complex
CuA	Cullowhee loam
EpD	Edneytown-Pigeonroost complex
EtE	Edneyville-Chestnut complex
EtF	Edneyville-Chestnut complex
NkA	Nikwasi loam
OsB	Ostin cobbly fine sandy loam
RoA	Rosman loam
RsB	Rosman sandy loam
SaC	Saunook loam
SbD	Saunook loam
SoD	Soco-Ditney complex
SoE	Soco-Ditney complex
SoF	Soco-Ditney complex
SpD	Spivey cobbly loam
Ssb	Statler loam
StD	Stecoah-Soco complex
W	Water
WhB	Whiteoak fine sandy loam
WkC	Whiteoak fine sandy loam
WtD	Whiteoak fine sandy loam

CrE
SoF
OsB
CrF
So
SoD
WkC
SoE
SoF
SpD
SoD
Buckwheat Branch
SoD
SoD
SoE
Linville River
OsB
SoE
EtE
SoF
SaC
SsB
WhB
WtD
RoA
RsB
W
OsB
CuA
OsB
OsB
Linville River
EpD
EtF
NkA
W
NkA
W
RoA
SR-1536
US-221
SbD
NkA
CuA
Bill White Creek
SaC
NkA
EtE
1148

Legend

Gill State Forest Boundary — Streams — Roads

Soil data from NRCS Web Soil Survey

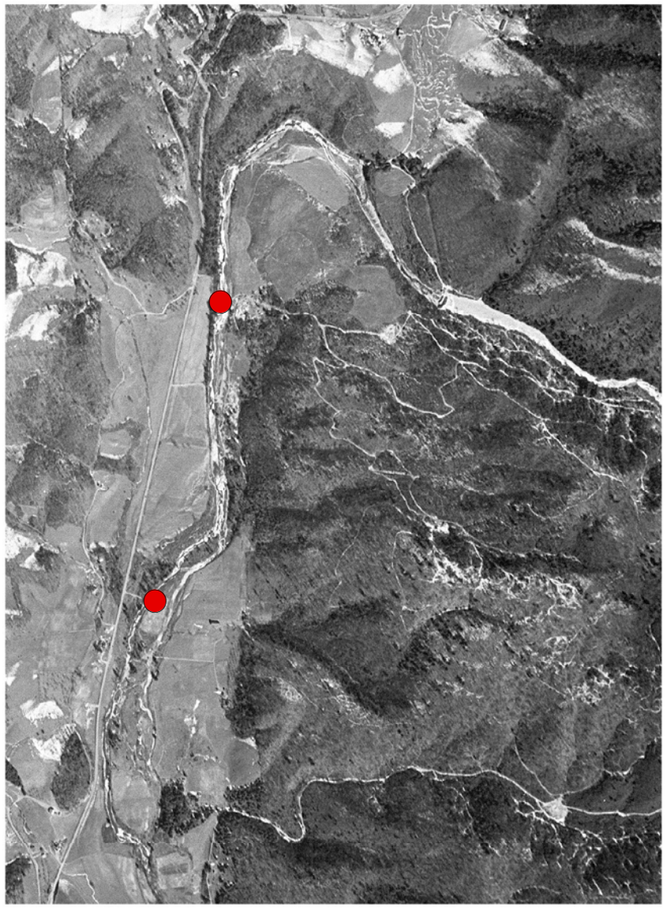
Soils

0 250 500 1,000 Feet

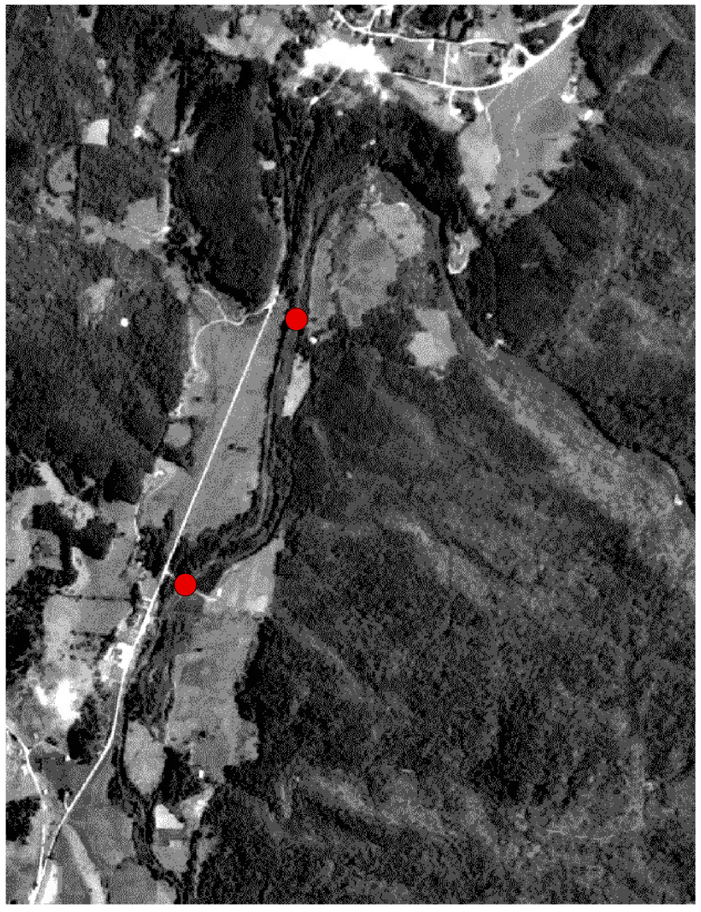
Linville River Restoration Project
Gill State Forest
Avery County, North Carolina

Sheet A4

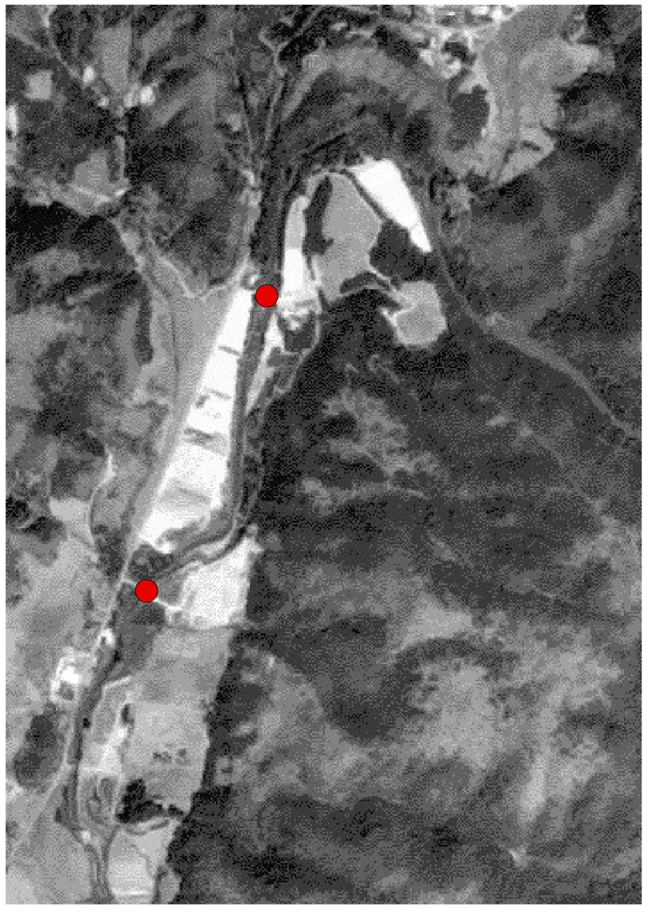
February 11, 1947



June 30, 1961



April 5, 1976



Legend

Approximate positions of low-water and Greene Road bridges

Historical aerial imagery from USGS Earth Explorer

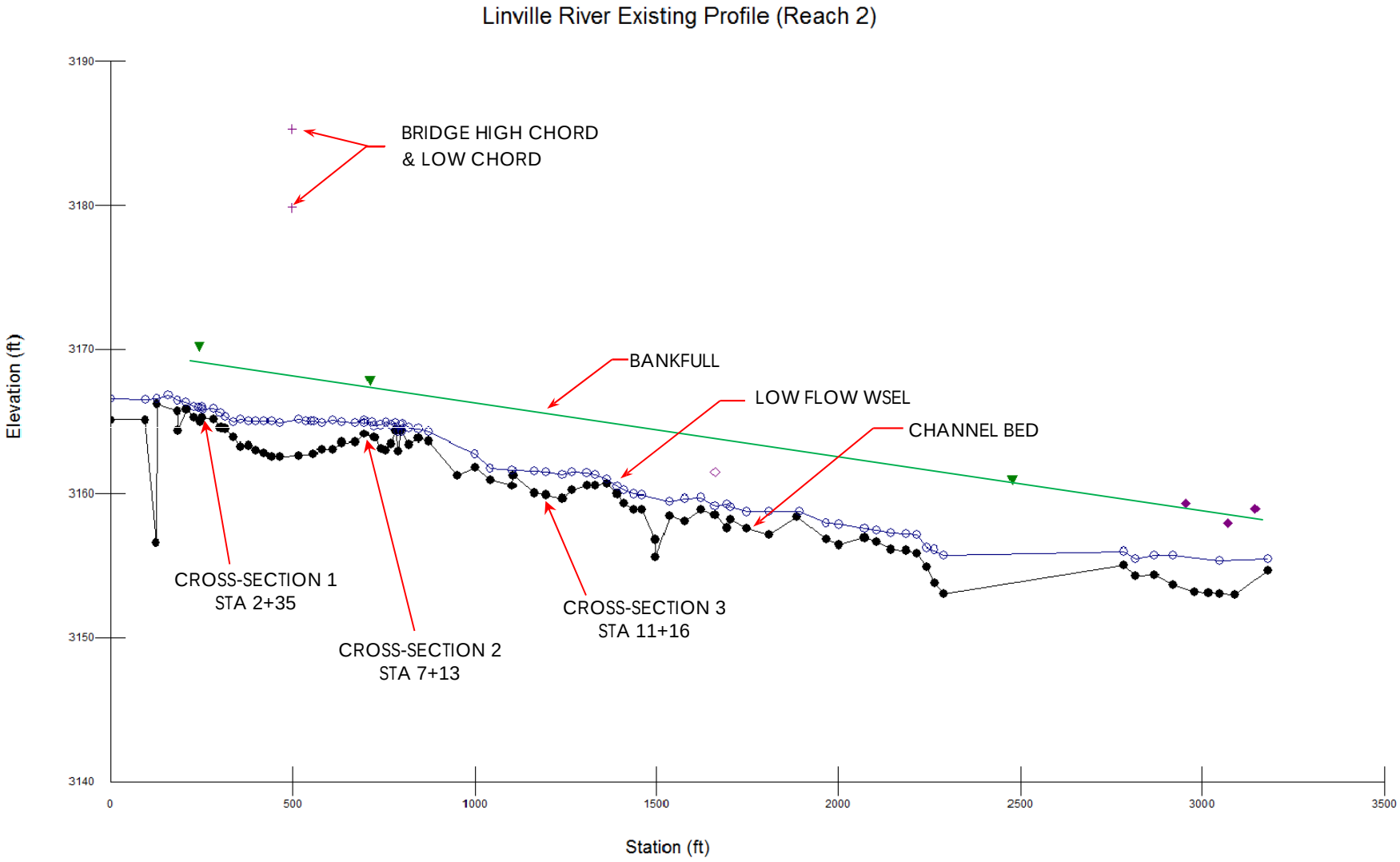
Historical Aerial Imagery

Minor variations in scale and orientation among photos

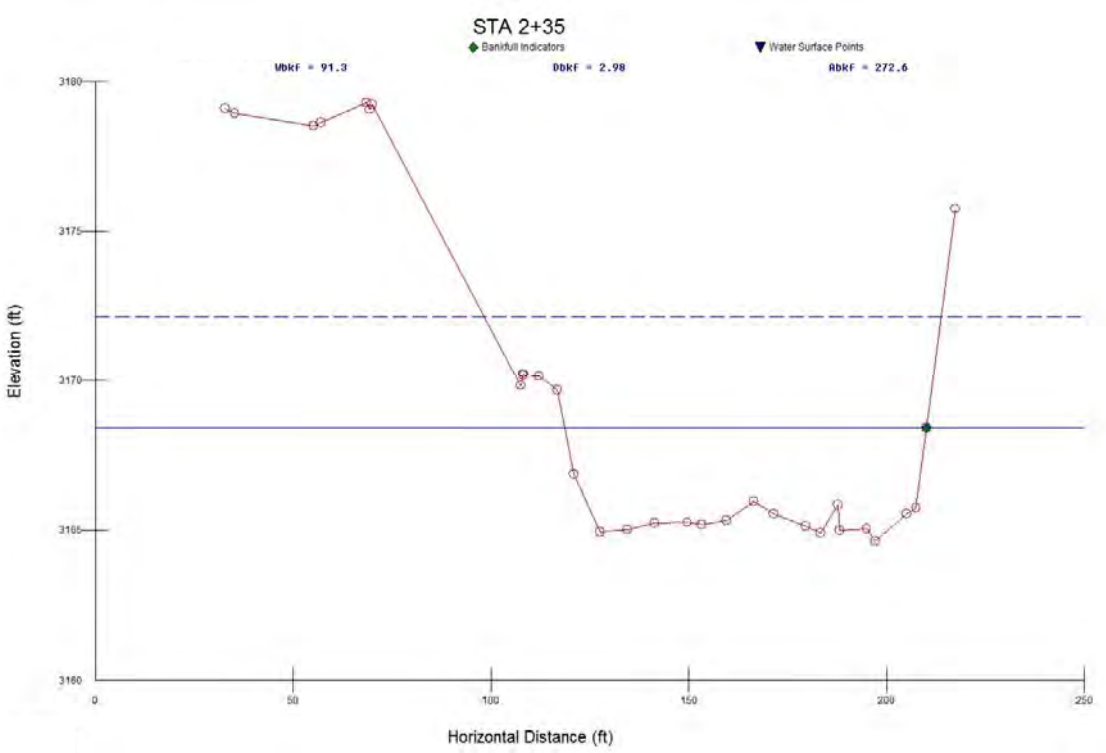
Linville River Restoration Project
Gill State Forest
Avery County, North Carolina

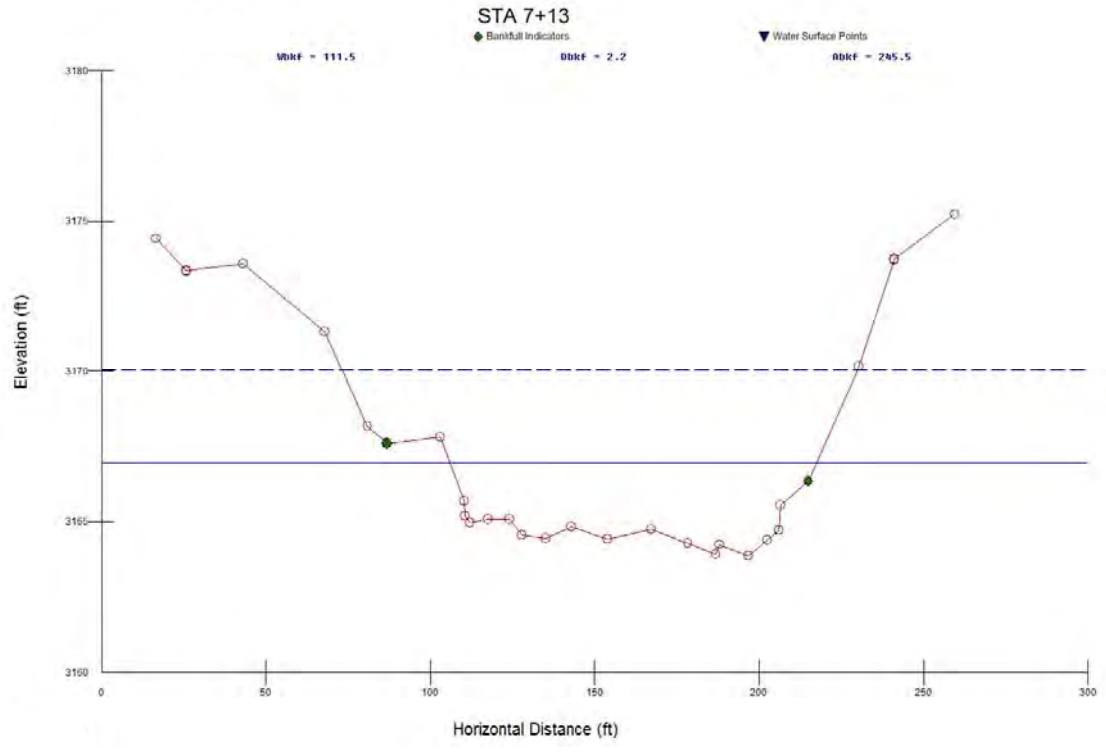
Sheet A5

A6. Existing Longitudinal Profile

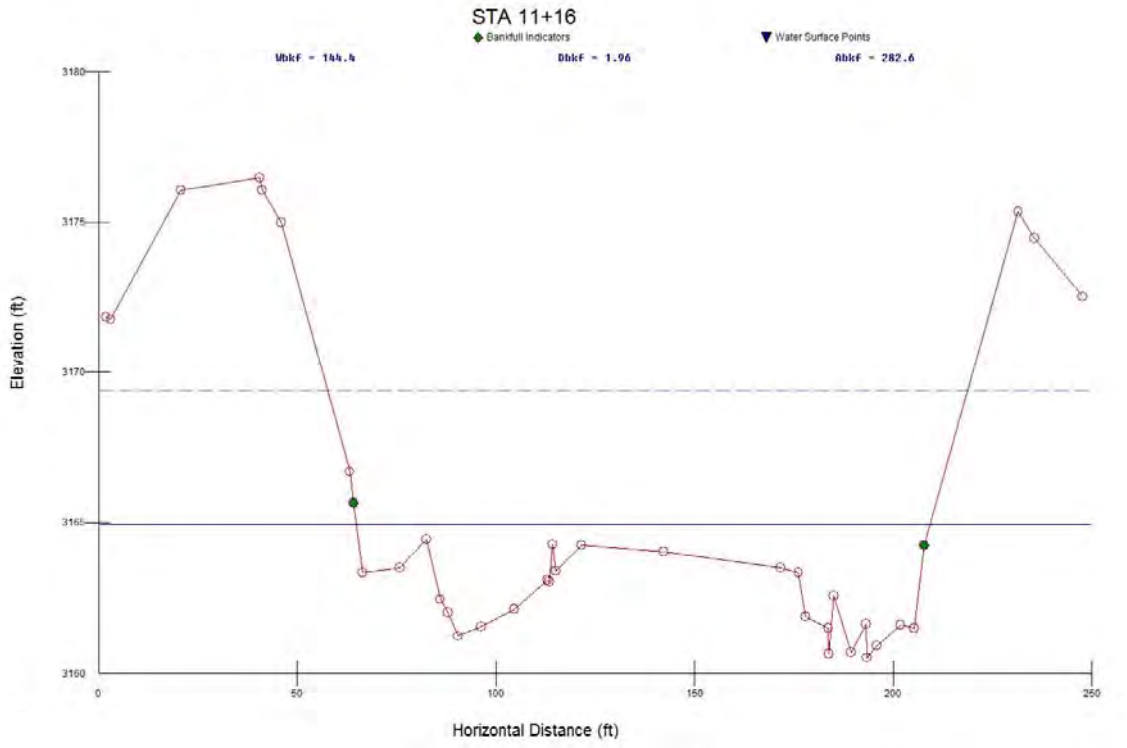


A7. Existing Cross-sections



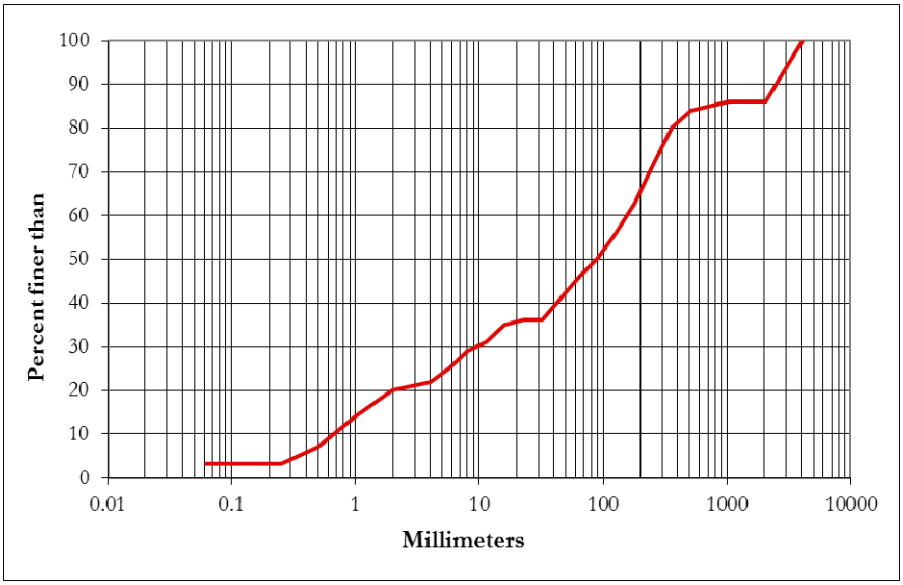


A7. Existing Cross-sections (continued)



A8. Pebble Count Data

d_{16} (mm)	1.3
d_{35} (mm)	16
d_{50} (mm)	90
d_{84} (mm)	512
d_{95} (mm)	bedrock
d_{100} (mm)	bedrock



Class Name	Particle Size Class (mm)	Total	Cumulative %
Silt/Clay	<0.062	3	3
Very Fine Sand	0.062 - 0.125	0	3
Fine Sand	0.125 - 0.25	0	3
Medium Sand	0.25 - 0.5	4	7
Coarse Sand	0.5 - 1.0	7	14
Very Coarse Sand	1.0 - 2.0	6	20
Very Fine Gravel	2.0 - 4.0	2	22
Fine Gravel	4.0 - 5.7	3	25
Fine Gravel	5.7 - 8.0	4	29
Medium Gravel	8.0 - 11.3	2	31
Medium Gravel	11.3 - 16.0	4	35
Coarse Gravel	16.0 - 22.6	1	36
Coarse Gravel	22.6 - 32	0	36
Very Coarse Gravel	32 - 45	5	41
Very Coarse Gravel	45 - 64	5	46
Small Cobble	64 - 90	4	50
Small Cobble	90 - 128	6	56
Large Cobble	128 - 180	7	63
Large Cobble	180 - 256	9	72
Small Boulder	256 - 362	8	80
Small Boulder	362 - 512	4	84
Medium Boulder	512 - 1024	2	86
Large Boulder	1024 - 2048	0	86
Bedrock	>2048	14	100

A9. Bank Erodibility Assessment

Description	Begin Station (feet)	End Station (feet)	Bank	BEHI	NBS	Erosion Rate (feet/year)	Erosion Volume (tons/year)
Upstream of new bridge	0	70	L	very low	low	0.02	0.3
	0	70	R	low	low	0.02	0.3
Under new bridge	70	110	L	low	low	0.02	0.2
	70	110	R	low	low	0.02	0.2
Between new bridge and low-water bridge	110	440	L	moderate	low	0.02	1.5
	110	440	R	moderate	low	0.02	1.5
Through first mid-channel bar	440	800	L	moderate	high	0.12	9.6
	440	800	R	moderate	very high	0.28	22.4
Through second mid-channel bar	800	1300	L	low	high	0.12	13.3
	800	1300	R	moderate	very high	0.28	31.1
To confluence with Tributary 1	1300	1780	L	low	low	0.02	2.1
	1300	1780	R	moderate	low	0.02	2.1
Through large pool	1780	2450	L	low	low	0.02	3.0
	1780	2450	R	moderate	low	0.02	3.0
To end of reach (beginning of mid-channel bar)	2450	2810	L	moderate	high	0.12	9.6
	2450	2810	R	low	low	0.02	1.6

APPENDIX B

STAKEHOLDER INPUT

March 26, 2013 Meeting Notes (prepared by NCFS)

Linville River/Gill State Forest Water Resource Master Plan
March 26, 2013 Stakeholder Meeting Notes: Morganton NC

Attendees:
Hunter Birckhead: NCFS Lenoir District Forester-D2.
Michael Cheek: NCFS Asst. Regional Forester-R3.
Tom Gerow, Jr.: NCFS Staff Forester.
Ron Hollifield: NCFS Regional Ranger-R3.
Clyde Leggins: NCFS Tree Improvement Supv.-West
Ken Roeder: NCFS Forest Geneticist.
Bill Swartley: NCFS Forest Hydrologist.
Greg Yates: NCFS Regional Forester-R3.
Greg Jennings, PE: Stantec.
Jason Zink, PE: Zink Environmental, PLLC.

Chasity Carnett: NCFS Admin. Assistant-Crossnore

Swartley explained intent and purpose: NCFS is hiring Jennings Environmental to assess current conditions, evaluate options, and prepare a master plan related to water resources on entire Gill State Forest (GSF) property, including potential restoration in the Linville River. Cost of plan will be paid from a grant awarded by NC Division of Water Resources to NCFS last year. We are working through NCDACS and State Construction Office to hire Jennings Environmental. Not all stream restoration projects are the same: Some projects are done for compensatory mitigation and monies are exchanged between parties for the right to do restoration. Some projects are done solely to improve the natural resources. Some projects are done to fix/repair/remediate degradation problems which impact human activities (flooding, bank erosion, stream crossings, etc.)

Roeder: Any work done at GSF should not increase potential for contamination of nursery stock from root-rot fungus or other pathogens which could jeopardize the nursery's operations. If there is increased public access to the GSF, this would increase potential for contamination.

Hollifield: NCFS does not have staffing to make GSF an open, public facility. Only have 2 FTE's (and 1 is now vacant). The main purpose of the property is to host training events and support nursery. Also, before work is done on-the-ground, the adjoining (downstream) private property owners should be informed and made aware of potential work. The NCFS local/regional staff should be the main point-of-contact with any landowners, not contractors.

Several commented that current traditional users of Linville River (fishermen) usually park in areas on the west side of the River off the highway, either in designated areas or anywhere they can park. NCFS needs to keep public fishermen parking on the west side of river, we cannot support public/fishing parking on the east side "at the Facility" itself.

Several stated there is no desire to create a trail network. There are current footpaths leading to the river from Linville Falls highway, those paths are fine. Some are contributing sedimentation or bank erosion and may need work. Yates said that NCFS would support an educational/training trail coming directly from the Training Facility, down to the River, for instruction of students, etc.

Jennings: There are no options "on" or "off" the table: this plan is being prepared for the NCFS with no pre-conceived notions of what should be done or should not be done. Now is the time to get all of our

wants, needs, concerns, limitations, goals on the table so that the plan accurately reflects NCFS long term management mission for this property (as it relates to water resources).

Much discussion was had on irrigation needs for nursery beds. Currently there is 1 pump house feeding into a 6-inch line. That line crosses the river on the low-water bridge, then goes north to the fields on east side of River. There was no consensus on what the ideal solution would be if the irrigation system was modified in the future, but generally the group recognized that if the low-water bridge is removed, the irrigation system could be altered to maintain irrigation. Some options included: burying the 6-inch line below the river; installing dry-hydrants in the river down south and up north, then using a portable pump as needed, or multiple portable pumps. Or installing a new permanent intake and pump up north to use it for irrigating the east-side fields, and leaving the existing pump & intake to irrigate the west-side fields. Also possibly hanging a new irrigation line off the high-water bridge to cross the river. There may be other options. Jennings noted that if restoration was done on the Linville River, there may be opportunities to create small pools in the river which could be tapped by the irrigation intake(s), thus assuring water availability even during droughts or low-flow conditions in the river.

Much discussion was had about the low-water bridge. Currently the east-side section has settled and heavy equipment is restricted from driving across. The gates are kept locked until access is needed. A tractor-pulled mower may be too wide to fit through the high-water bridge, but general consensus was that all other NCFS heavy equipment would fit through the high-water bridge "if you're careful, not much room for error". Group agreed that the old low-water bridge needs to be addressed, either removed completely or repaired. Group generally understood the benefits of removing the structure and supported a replacement large stone-cobble-aggregate ford crossing at the same location that could be included if the Linville River was restored. A low-water ford crossing would satisfy NCFS needs for large equipment crossing on a limited basis while eliminating the low bridge structure. Jennings and Swartley noted that most likely, a grant fund or permitting agency would almost certainly require that the low bridge (and the gravel island "bar" in the middle of the river) to be removed as a condition of funding or allowing a restoration project to proceed in the Linville River, in an effort to functionally "restore" and improve the river conditions and remove obstacles.

Jennings asked about potential to improve or expand existing riparian buffers, mainly along the Linville River. Yates noted that some of the grassy mowed areas could be naturalized, but that we should maintain some readily-accessible areas for users of the Training Facility: the river naturally draws attention from visitors and we do not want to prohibit or restrict all access. Roeder and Leggins stated that further discussions with supervisor (James West) would be needed to determine how much, if any, of current nursery fields could be sacrificed to create or expand riparian buffers. There may be some places where mowing along or within a buffer can stop and not interfere with nursery beds, thus allowing natural vegetation re-growth, but in other places we would likely have to give up production area to add to buffer zones. Issue needs to be investigated further.

Hollifield, Yates and others agreed that work is needed to better control stormwater runoff from the parking lots and driveways and shops situated on the adjoining hillslope. Some work has been done to control runoff, but more work would be welcomed to keep sediment out of the river and prevent erosion wash-outs of the driveways and parking lot.

Linville River/Gill State Forest Water Resource Master Plan
March 26, 2013 Stakeholder Meeting Notes: Morganton NC

Needs

- Irrigation capabilities from the Linville River for nursery bed fields on each side of the River
- Ability to drive wide, large, oversized equipment across the River on a limited basis; at another location besides the high-water bridge

Concerns

- Side-effects of restoration work that would attract more public visitation/use of river corridor; we need to keep public use confined within the corridor. No additional parking expansion for fishermen.

Limitations

- Minimize impact to nursery operations/infrastructure
- Minimize impact to Mountain Training Facility operations/infrastructure
- Retain gun firing range operations in place: recognize the need to expand or install new barriers within the shooting gallery area if current terrain is altered (to maintain safety certification)
- No negative impact to adjoining private property owners downstream (hydro-trespass)

Goals

- Improve flood protection for Mountain Training Facility and Linville River Nursery infrastructure
- Improve stormwater runoff management from adjoining hillslopes, roads, parking lots
- Improve sediment control, aquatic habitat, and environmental conditions of Linville River
- Resolve failed old low-water bridge: either need to fix it or remove it
- Improve footer protection of new high-water bridge from being undermined during floods
- Protect (improve?) existing high quality headwater streams up on Gill State Forest
- Resolve sedimentation/road erosion problems up on Gill State Forest

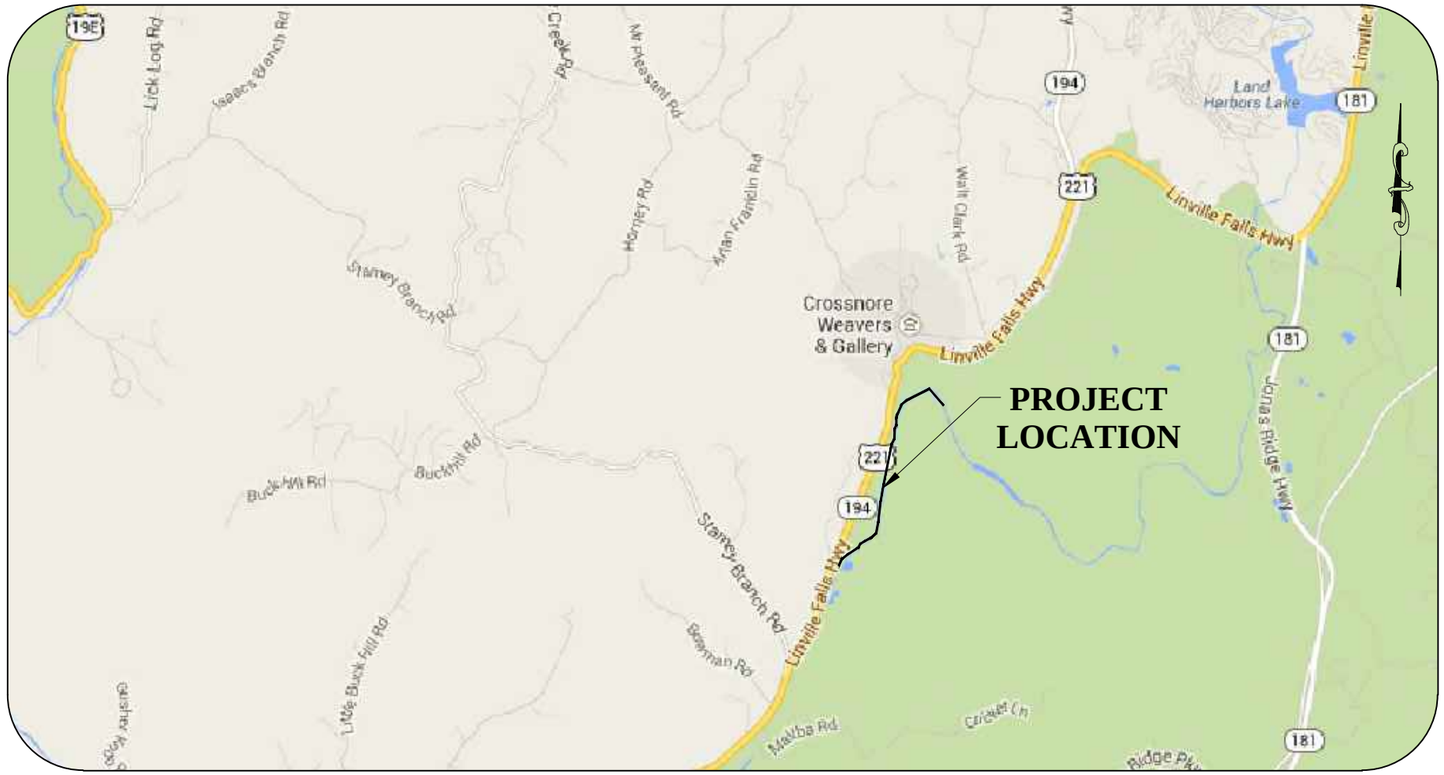
APPENDIX C

CONCEPTUAL DESIGN DRAWINGS

C1. Cover Sheet
C2. Plan View, Overview
C3. Plan View, Reach 1
C4. Plan View and Profile, Reach 2
C5. Plan View and Profile, Reach 2
C6. Plan View, Reach 3
C7. Typical Cross-sections and Hydraulic Geometry
C8. Typical Details (1 of 2)
C9. Typical Details (2 of 2)
C10. Planting Zones

Appendix C:
Conceptual Design Drawings
Linville River Stream Restoration
For North Carolina Forest Service
(Not For Construction)

INDEX OF SHEETS



VICINITY MAP

NTS

PROJECT LOCATION:
GILL STATE FOREST
NEWLAND, NC

2127 Ayrsley Town Boulevard, Suite 300
Charlotte, North Carolina 28273
www.stantec.com

C1
FEBRUARY 5, 2014
175613047

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FEBRUARY 5TH, 2014
175613047

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Legend

- INNER BERM
- BANKFULL
- NATIVE MATERIAL RIFFLE
- CHANNEL PLUG
- ROCK CROSS VANE
- WOOD TOE HABITAT REVETMENT
- LOG VANE WITH J-HOOK

Note:
PROPERTY BOUNDAIRES APPROXIMATE ONLY.

Client/Project
NCFS
LINVILLE RIVER RESTORATION
C2

Drawing No.
2 OF 10

Title
OVERALL PLAN

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Legend

- INNER BERM
- BANKFULL
- NATIVE MATERIAL RIFFLE
- IMPERVIOUS CHANNEL PLUG
- ROCK CROSS VANE
- WOOD TOE HABITAT REVETMENT
- LOG VANE WITH J-HOOK

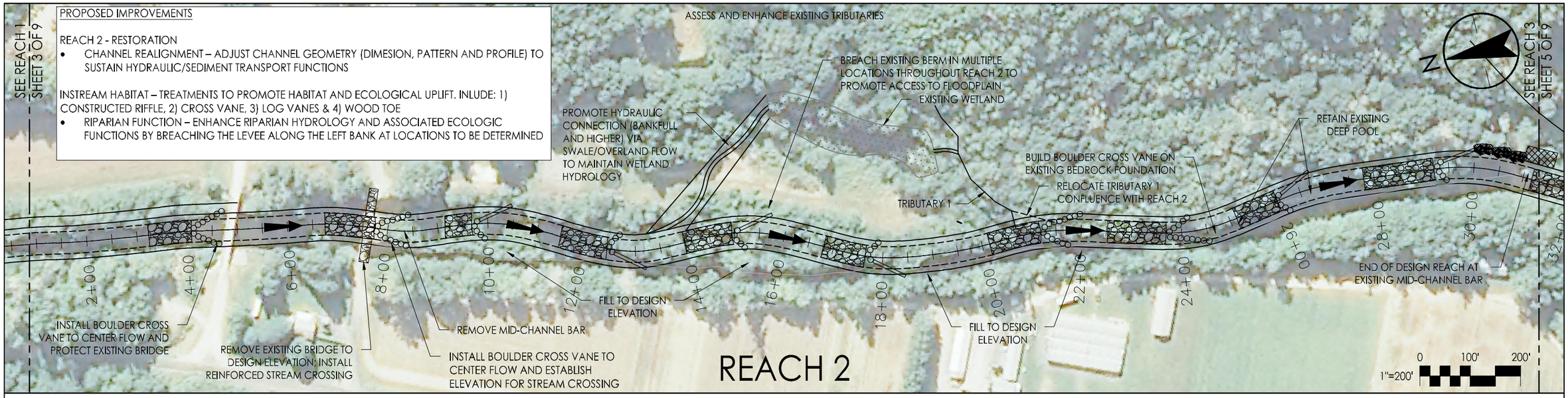
Notes

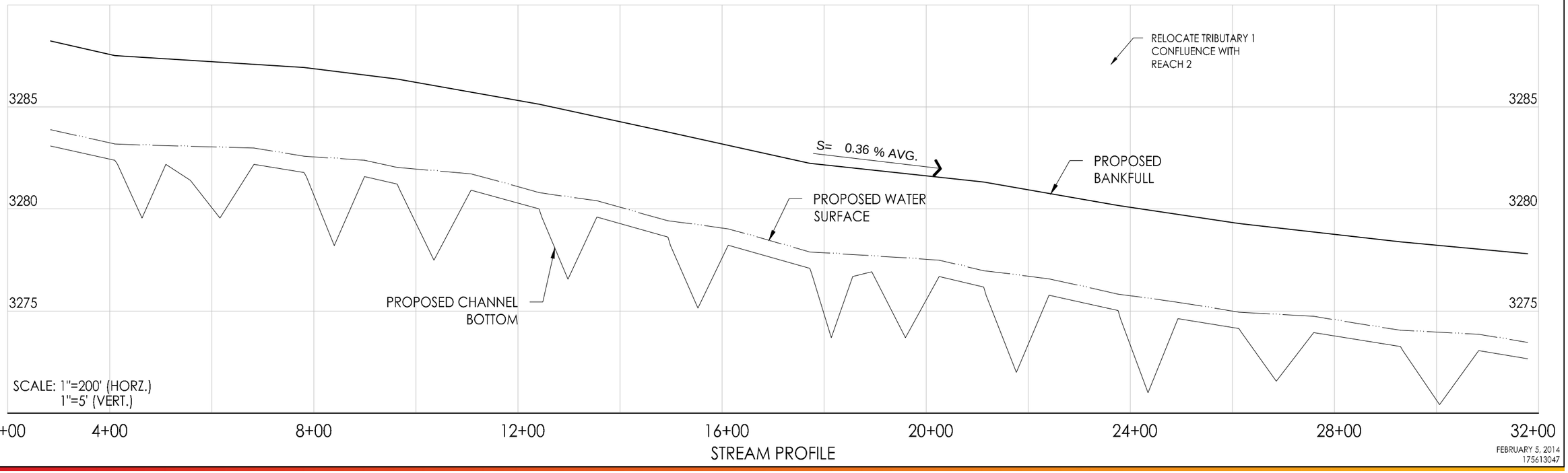
DETAILED ASSESSMENT AND DESIGN HAVE NOT BEEN PERFORMED FOR REACHES 1 AND 3. SPECIFIC TREATMENTS AND LOCATIONS OF TREATMENTS ARE SUBJECT TO CHANGE.

Client/Project
NCFS
LINVILLE RIVER RESTORATION
C3

Drawing No.
3 OF 10

Title
CONCEPTUAL PLAN
REACH 1





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Legend

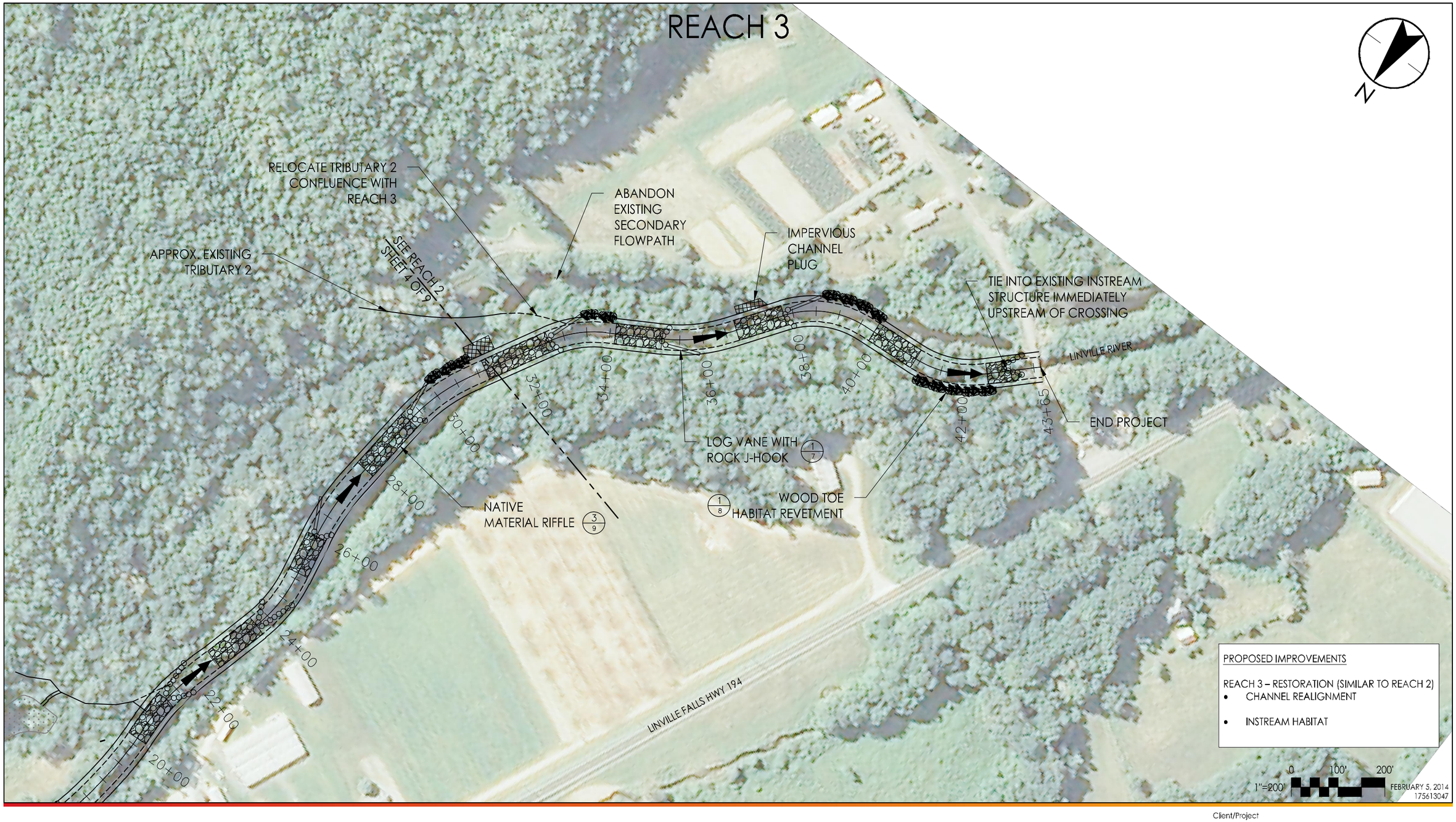
- INNER BERM
- BANKFULL
- NATIVE MATERIAL RIFFLE
- IMPERVIOUS CHANNEL PLUG
- ROCK CROSS VANE
- WOOD TOE HABITAT REVETMENT
- LOG VANE WITH J-HOOK

Notes

DETAILED ASSESSMENT AND PRELIMINARY DESIGN ANALYSIS HAVE BEEN PERFORMED FOR REACH 2.

Client/Project
NCFS
LINVILLE RIVER RESTORATION
C4
Drawing No.
4 OF 10
Title
CONCEPTUAL PLAN AND PROFILE REACH 2

FEBRUARY 5, 2014
175613047



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Legend

- INNER BERM
- BANKFULL
- NATIVE MATERIAL RIFFLE
- IMPERVIOUS CHANNEL PLUG
- ROCK CROSS VANE
- WOOD TOE HABITAT REVETMENT
- LOG VANE WITH J-HOOK

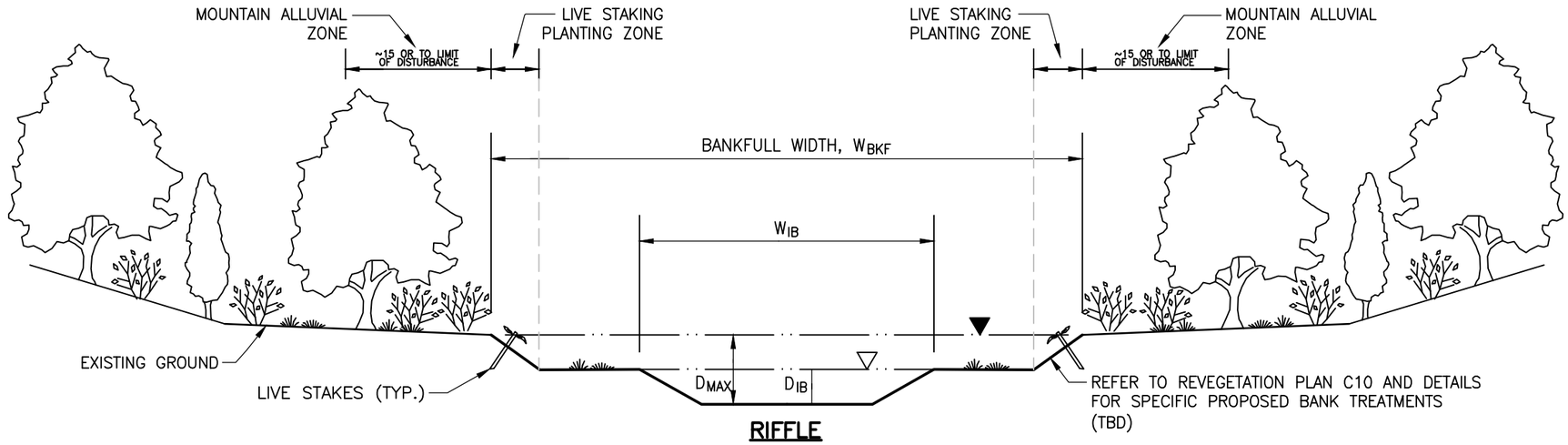
Notes

DETAILED ASSESSMENT AND DESIGN HAVE NOT BEEN PERFORMED FOR REACHES 1 AND 3. SPECIFIC TREATMENTS AND LOCATIONS OF TREATMENTS ARE SUBJECT TO CHANGE.

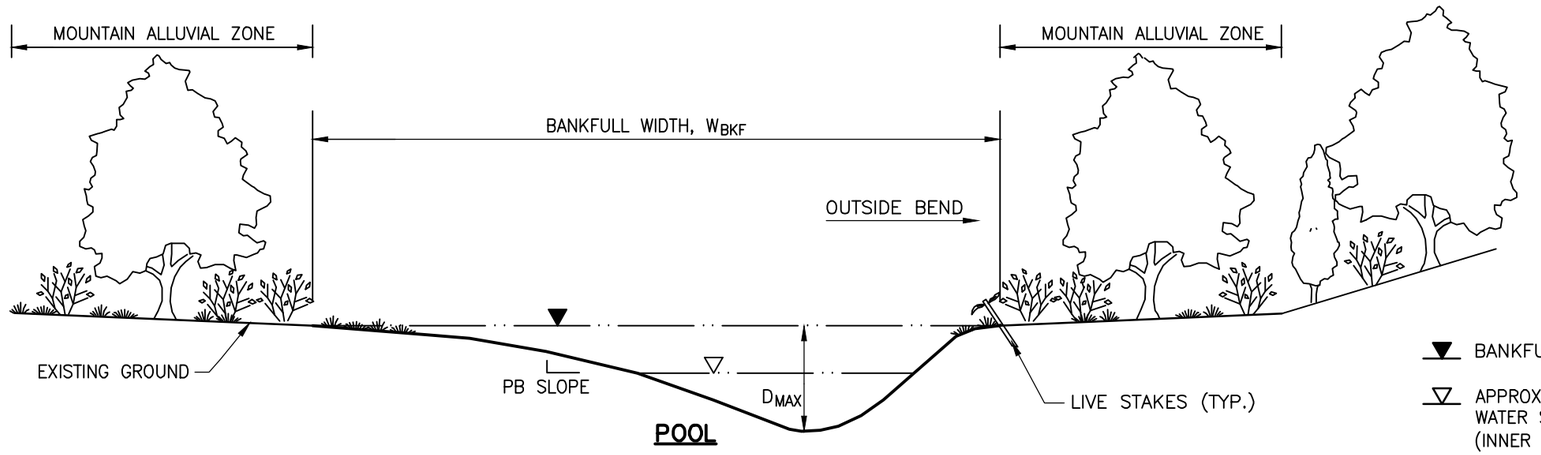
Client/Project
NCFS
LINVILLE RIVER RESTORATION
C5

Drawing No.
5 OF 10

Title
CONCEPTUAL PLAN
REACH 3



RIFFLE



POOL

DIMENSIONAL HYDRAULIC GEOMETRY

REACH	RIFFLE							POOL			
	A_{BKF} (ft2)	W_{BKF} (ft)	W_{IB} (ft)	D_{AVG} (ft)	D_{MAX} (ft)	D_{IB} (ft)	W/D	A_{BKF} (ft2)	W_{BKF} (ft)	D_{MAX} (ft)	PB SLOPE
1	-	-	-	-	-	-	-	-	-	-	-
2	235	68.6	34.3	3.4	5.1	1.7	20.0	358	82.3	8.2	
3	-	-	-	-	-	-	-	-	-	-	-

LONGITUDINAL HYDRAULIC GEOMETRY

REACH	AVERAGE SLOPE(ft)	RIFFLE LENGTH(ft)	RIFFLE LENGTH RATIO	RIFFLE SLOPE (ft)	RIFFLE SLOPE RATIO	POOL LENGTH(ft)	POOL LENGTH RATIO	POOL SLOPE (ft)	POOL SPACING(ft)	POOL SPACING RATIO	STEP HEIGHT(ft)
1	-	-	-	-	-	-	-	-	-	-	-
2	0.0036	126	1.8	0.0056	1.6	131	1.9	0.0000	278	1.9	0.35
3	-	-	-	-	-	-	-	-	-	-	-

NOTES:
1. THESE ARE TYPICAL DIMENSIONS. CONTRACTOR SHOULD REVIEW PROPOSED CONTOURS AND PROPOSED CROSS SECTIONS FOR ACTUAL DIMENSIONS.
2. GEOMETRY FOR REACHES 1 AND 3 TO BE DETERMINED FOLLOWING ADDITIONAL DATA COLLECTION.

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175613047

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Legend

Notes

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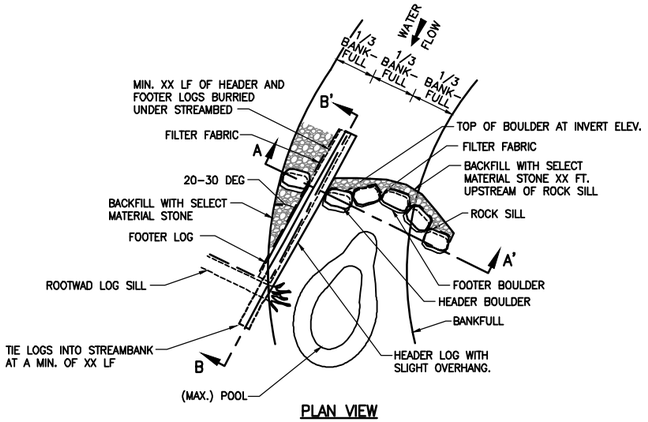
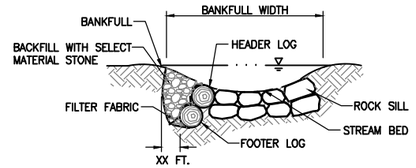
Charlotte, North Carolina 28273
www.stantec.com

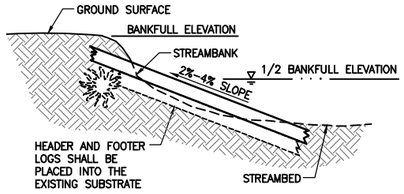
Client/Project
NCFS
LINVILLE RIVER RESTORATION
C6
Drawing No.
6 OF 10
Title
TYPICAL SECTION



PLAN VIEW

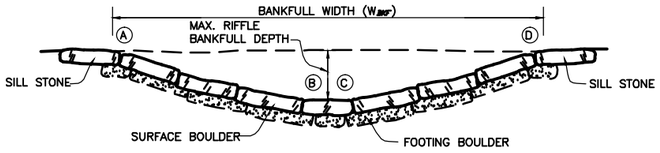


SECTION A–A

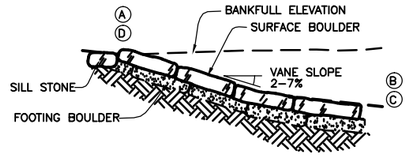


SECTION B–B

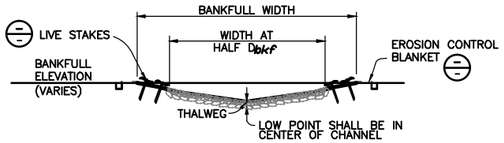
1/7 DETAIL – LOG VANE WITH ROCK J-HOOK
NOT TO SCALE



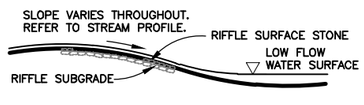
CROSS VANE TYPICAL CROSS–SECTION



CROSS VANE LONGITUDINAL PROFILE



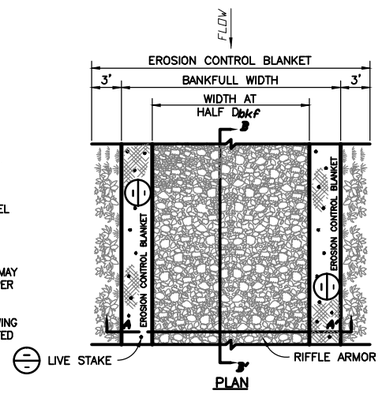
CROSS–SECTION A–A'



PROFILE B–B'

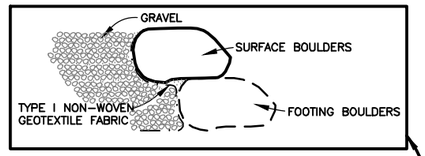
NOTES:

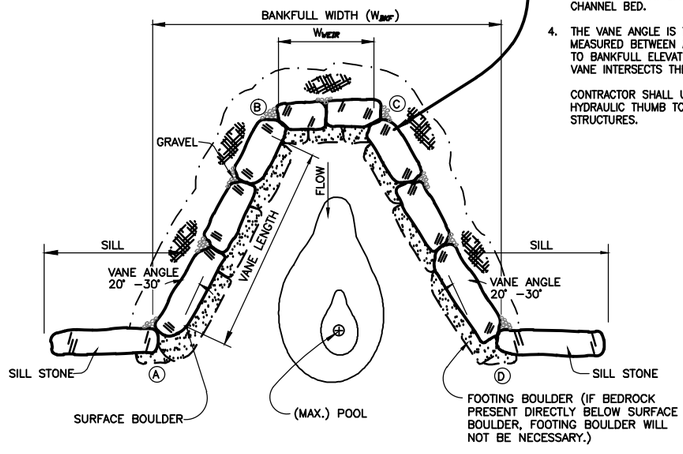
1. RIFFLE ARMOR DEPTH SHALL AVERAGE ___ FEET.
2. EXTEND RIFFLE ARMOR UP TO HALF BANKFULL DEPTH.
3. LOW POINT (THALWEG) SHALL BE IN THE CENTER OF CHANNEL.
4. RIFFLE SUBGRADE SHALL CONSIST OF A LAYER OF CLASS ___ CHANNEL LINING.
5. RIFFLE SURFACE STONE SHALL CONSIST OF A MIXTURE OF _____ ___ STONE.
6. GRAVEL SUBSTRATE FROM THE EXISTING CHANNEL SHALL BE STOCKPILED AND REUSED AS SURFACE STONE IN THE NEW CHANNEL WHERE FEASIBLE. GRAVEL SHALL BE PLACED AT EACH RIFFLE LOCATION IN ACCORDANCE WITH THE GRADATION SHOWN ON THESE PLANS.
7. SOME EXCAVATION OR UNDERCUTTING OF CHANNEL BED MATERIAL MAY BE NECESSARY PRIOR TO PLACEMENT OF RIFFLE TO ENSURE PROPER CROSS–SECTIONAL DIMENSIONS ONCE RIFFLE IS CONSTRUCTED.
8. RE–DRESSING OF CHANNEL AND BANKS MAY BE REQUIRED FOLLOWING CONSTRUCTION OF RIFFLES AND CHANNEL AND SHALL BE ACCOUNTED FOR IN CONTRACTOR'S BID ITEM.



PLAN

2/7 DETAIL – RIFFLE ARMOR
NOT TO SCALE





CROSS–VANE PLAN VIEW

NOTES FOR CROSS VANE INSTALLATION:

1. FOOTING BOULDERS ARE BOULDERS PLACED TO PROVIDE A FOUNDATION FOR THE SURFACE BOULDERS IN EACH STEP CROSS VANE. FOOTING BOULDERS SHALL BE DURABLE WITH A MINIMUM DIAMETER OF ___ FT.
2. SURFACE BOULDERS ARE THE TOP MOST COURSE OF BOULDERS USED IN EACH STEP CROSS VANE. SURFACE BOULDERS SHALL BE DURABLE WITH A MINIMUM INTERMEDIATE DIAMETER OF ___ FT.
3. THE VANE LENGTH IS THE STRAIGHT LINE PORTION OF CROSS VANE STRUCTURES MEASURED FROM THE STREAM BANK AT BANKFULL ELEVATION TO THE CHANNEL BED.
4. THE VANE ANGLE IS THE SMALLEST ANGLE MEASURED BETWEEN A VANE AND A LINE TANGENT TO BANKFULL ELEVATION AT THE POINT WHERE THE VANE INTERSECTS THE BANK.

CONTRACTOR SHALL USE AN EXCAVATOR WITH A HYDRAULIC THUMB TO CONSTRUCT IN–STREAM STRUCTURES.

3/7 DETAIL – CROSS VANE
NOT TO SCALE

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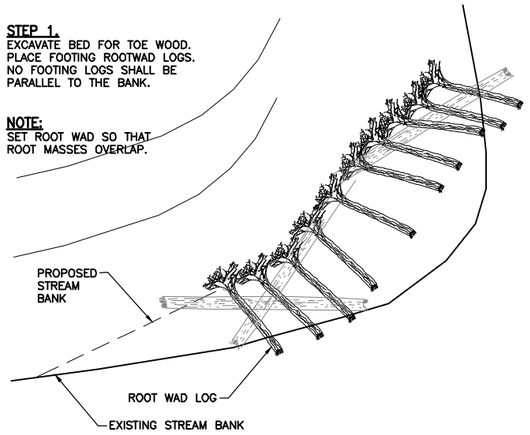
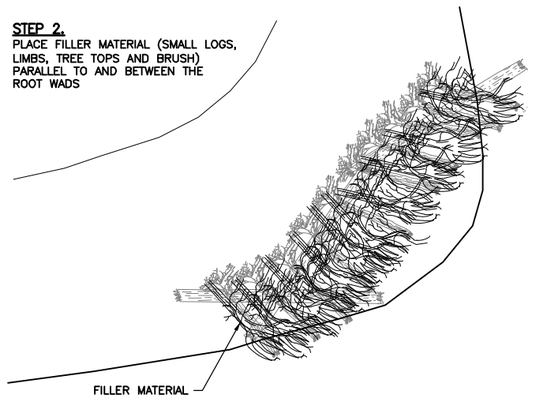
STEP 1.
EXCAVATE BED FOR TOE WOOD. PLACE FOOTING ROOTWAD LOGS. NO FOOTING LOGS SHALL BE PARALLEL TO THE BANK.

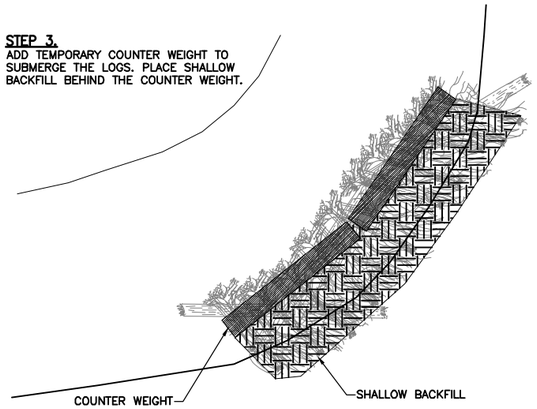
NOTE:
SET ROOT WAD SO THAT ROOT MASSES OVERLAP.



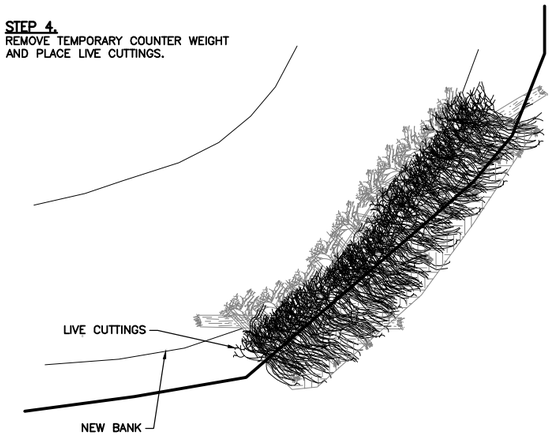
STEP 2.
PLACE FILLER MATERIAL (SMALL LOGS, LIMBS, TREE TOPS AND BRUSH) PARALLEL TO AND BETWEEN THE ROOT WADS



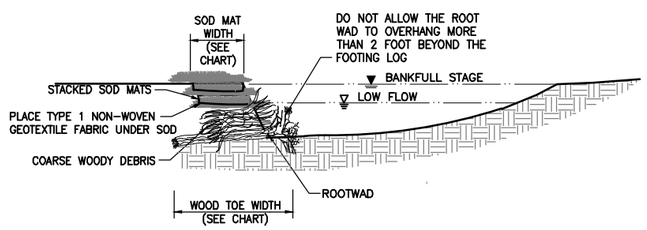
STEP 3.
ADD TEMPORARY COUNTER WEIGHT TO SUBMERGE THE LOGS. PLACE SHALLOW BACKFILL BEHIND THE COUNTER WEIGHT.



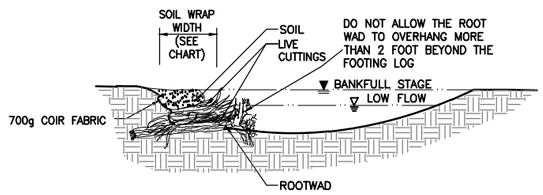
STEP 4.
REMOVE TEMPORARY COUNTER WEIGHT AND PLACE LIVE CUTTINGS.



STEP 5.
INSTALL STACKED SOD MATS OR WRAPPED SOIL LIFTS AND LAYERS OF CUTTINGS BETWEEN SOIL LIFTS UP TO BANKFULL STAGE.

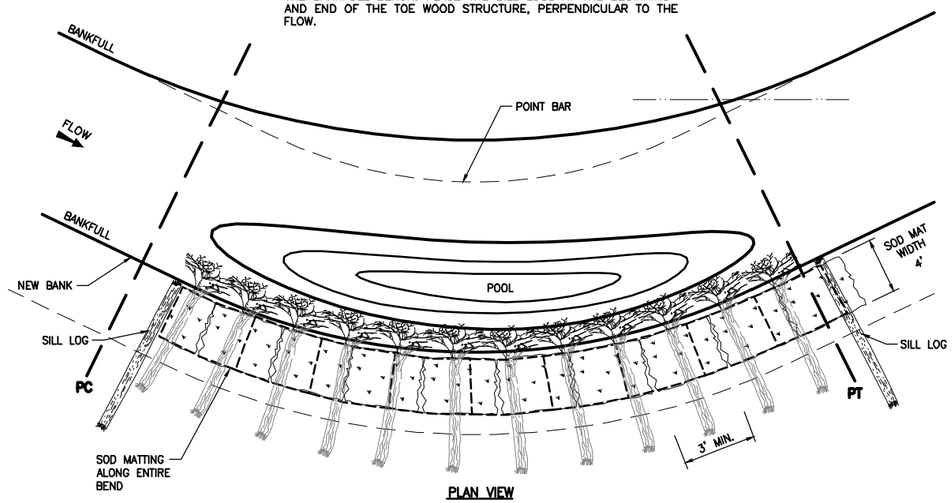


SOD MAT WITH WOOD TOE SECTION VIEW



LIVE BRUSH LAYER WITH WOOD TOE SECTION VIEW

STEP 6.
SILL LOGS ARE BURIED FLUSH OR 6 INCHES BELOW THE TOP OF THE BANKFULL BENCH. PLACE THE SILL LOGS AT THE BEGINNING AND END OF THE TOE WOOD STRUCTURE, PERPENDICULAR TO THE FLOW.



PLAN VIEW

1/8 DETAIL – WOOD TOE HABITAT REVETMENT
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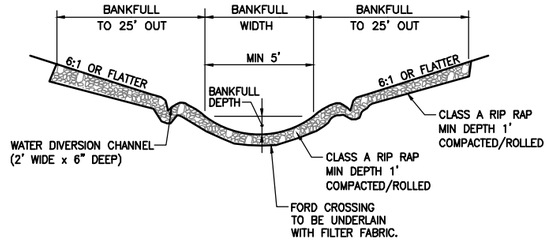
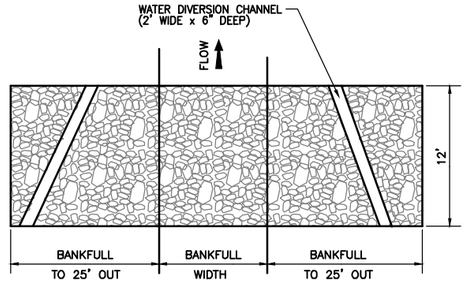


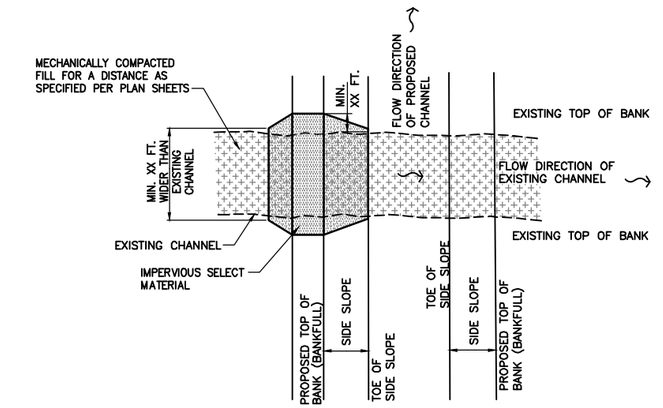
CROSS-SECTION



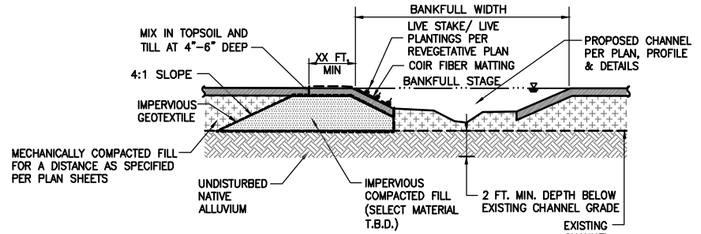
PLAN VIEW

NOTE:
ALL MATERIALS ARE TO BE APPROVED BY ENGINEER OR ENGINEER'S ONSITE CONSTRUCTION MANAGER.

1/9 DETAIL – PERMANENT FORD CROSSING
NOT TO SCALE

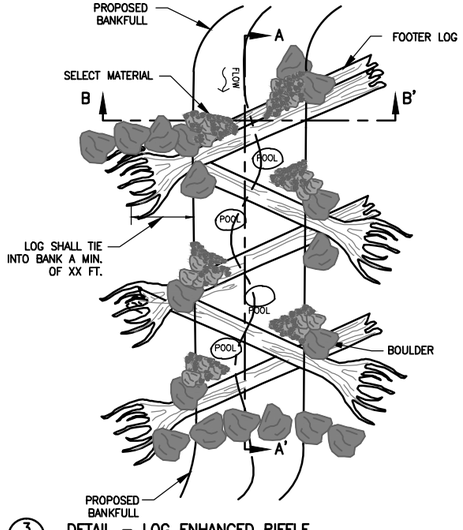


PLAN VIEW

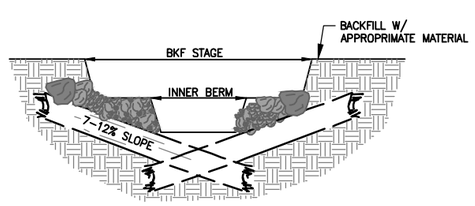


CROSS-SECTION

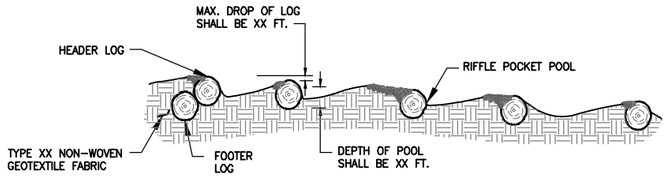
2/9 DETAIL – IMPERVIOUS STREAM CHANNEL PLUG
NOT TO SCALE



3/9 DETAIL – LOG ENHANCED RIFFLE
NOT TO SCALE



LOG ENHANCED RIFFLE – SECTION B–B'



LOG ENHANCED RIFFLE – PROFILE A–A'

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Zone	Common Name	Scientific Name
1 - Live Stakes	Silky willow	*Salix sericea*
	Buttonbush	*Cephalanthus occidentalis*
	Elderberry	*Sambucus nigra* ssp. *canadensis*
	Tag Alder	*Alnus serrulata*
2 - Bottomland Hardwood	River Birch	*Betula nigra*
	Sycamore	*Platanus occidentalis*
	Tulip poplar	*Liriodendron tulipifera*
	Green ash	*Fraxinus pennsylvanica*
	Ironwood	*Carpinus caroliniana*
	Eastern cottonwood	*Populus deltoides*

Notes

1. LIVESTAKE PLANTING ZONE FROM INNER BERM TO 1 ROW BEYOND BANKFULL
2. MOUNTAIN ALLUVIAL FOREST PLANTING ZONE MIN 15' OS TOP OF BANKFULL TO MAX LIMIT OF DISTURBANCE

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- INNER BERM
- BANKFULL
- NATIVE MATERIAL RIFFLE
- IMPERVIOUS CHANNEL PLUG
- ROCK CROSS VANE
- WOOD TOE HABITAT REVETMENT
- LOG VANE WITH J-HOOK

Notes

DETAILED ASSESSMENT AND PRELIMINARY DESIGN ANALYSIS HAVE BEEN PERFORMED FOR REACH 2.

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REACH 2