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.