STREAM AND RIPARIAN RESTORATION PLAN

PLEMMONS/KIRKPATRICK MITIGATION SITE
SPRING CREEK, MADISON COUNTY

Prepared in partnership with the
North Carolina Ecosystem Enhancement Program

North Carolina Wildlife Resources Commission
Division of Inland Fisheries
Watershed Enhancement Group

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Introduction

In 1996, the North Carolina Wildlife Resources Commission (WRC), United States Army Corps of Engineers (USACE), and the North Carolina Division of Water Quality (DWQ) raised concerns over the significant environmental impacts that the North Carolina Department of Transportation (DOT) would have in constructing Transportation Improvement Project No. A-10, the Interstate 26 extension through Madison County, North Carolina. Because of these concerns, permit conditions required that DOT mitigate for project impacts by restoring degraded stream habitat in Madison County. Under the original agreement, the DOT requested that the WRC assume responsibility for providing the mitigation required in permits issued by the regulatory agencies. Mitigation requirements are now overseen by the North Carolina Ecosystem Enhancement Program (EEP). The WRC's interest in conducting the stream restoration in Madison County was based on the prevalence of coldwater stream suffering from degraded habitat conditions that limit trout population success.

The WRC will be providing needed stream mitigation credits to the EEP by implementing broad based mitigation projects that address channel morphology, riparian function, water quality, and agricultural best management practices (BMPs). By working with the Natural Resources Conservation Service (NRCS), Soil and Water Conservation District (SWCD), and private landowners in Madison County the WRC is actively pursuing mitigation opportunities. This mitigation document details plans prepared for the Von Plemmons and John Kirkpatrick properties. This plan documents existing stream channel conditions and the proposed design plans to enhance and restore channel function, stability, and habitat quality along 680 linear feet of Spring Creek (HUC 06010105120010) and referred to as the Plemmons/Kirkpatrick mitigation site, Madison County (Figure 1).

Methods

Existing conditions at the Plemmons/Kirkpatrick site were determined through field investigations conducted during July 2005. Representative cross-sectional dimensions and longitudinal profile data were collected using standard stream channel survey techniques (Harrelson et al. 1994; Doll et al. 2003). The geomorphology of the stream was classified using the Rosgen (1996) stream classification system. Site and reference conditions were analyzed, and the project design developed using RIVERMorph stream assessment and restoration software, Version 3.1 (RSARS 2003). Topographical maps were used to determine stream drainage area. Mountain and piedmont regional curve data were used to evaluate field conditions and in the development of the final restoration design (Harman et al. 1999, 2000; Doll et al. 2002). Bed material composition and mobility was assessed by doing reach-wide and riffle cross section pebble counts, and by taking a pavement and sub-pavement sample from a riffle (Rosgen 1996; NCSRI 2003).

Existing Conditions

Channel Morphology

Spring Creek, at this location, has a drainage area of approximately 29.3 mi^2 (Figure 2). Land use along the creek consists of agriculture, grazing, and timber production. Very little of the land use has resulted in the creation of impermeable surfaces within the watershed. Those that do exist are primarily from low density residential development and roads. The percentage of the watershed impacted by this type of development is probably too low to significantly alter watershed hydrology. The valley at this location is classified as a type VIII with wide, gentle slopes and a well-developed floodplain adjacent to river terraces. The existing reach is 680 linear feet, beginning at the Madison County Secondary Road 1151 bridge and continuing downstream to the boundary of the Plemmons and Kirkpatrick properties.

The Spring Creek reach being proposed for mitigation has a valley slope of 0.0115 (ft/ft). The project reach is only slightly meandering, having a sinuosity of 1.22, indicating past channel straightening. The entrenchment ratio measured at a riffle is 13.3. An earthen berm is present along the top of the left bank for the entire reach. This berm restricts flood waters from reaching the floodplain during flows up to 1.5 times the bankfull stage. The width/depth ratio measured at the riffle cross section is 15.9. These values indicate that this is a C stream type and, based on measurements of the substrate, it is a C4.

Four cross-sections were surveyed to evaluate existing channel dimensions (Figure 3; Appendix 1). Bankfull was determined using field indicators that included a scour line along the bank, terraces, and the existing floodplain. The bankfull stage obtained from these measurements was evaluated using regional curve information (Harman et al. 1999; Doll et al. 2002). The cross-section at station 6+73 (cross section 4) was used as a representative of this reach. Bankfull width at this cross-section was 52.6 ft, bankfull depth was 3.3 ft, and cross-sectional area was 173.2 ft^2. The measured cross-sectional area for this reach was slightly lower than that predicted by the mountain regional curve. This is fairly typical for streams in Madison County as they generally fall below the mountain regional curve (M. Clemmons, Buck Engineering, personal communication).

The longitudinal profile of the reach was surveyed from a point approximately 300 ft upstream of the SR 1151 bridge and continuing to a point approximately 100 ft downstream of the property line (Figure 4). The location and length of riffles, runs, pools, and glides were measured along the profile. The project reach does not consist of a full meander wavelength. The upstream meander is constricted laterally and, therefore, not well developed. Channel straightening, dredging, and the placement of the SR 1151 bridge have likely altered the natural pattern. The upper half of the project reach is dominated by riffles and runs. A single over-sized pool exists between stations 4+00 and 4+70. The size of the pool has been exaggerated by the presence of several large boulders, automobile bodies, and a school bus. These structures form a "pinch" or choke point in the channel that causes instability of the right stream bank just downstream of the bus. Downstream of the bus for approximately 100 linear feet the outside (right) bank is vertical and sloughing. Down valley channel meander migration appears to be occurring at the downstream end of the pool. The channel is attempting to re-establish a

meander radius by migrating to the right of the second choke point created by the presence of 6+ automobile bodies.

The typical pattern of occurrence of the existing features (riffles, runs, glides, pools) is disturbed by the straightness of the channel, significant berming of the left bank, and presence of automobile bodies and other foreign debris within the channel and riparian area (Figure 5). The modifying influence of the berming and straightening has created long sections of riffle and run features. Relatively long reaches of riffle and run type habitat are interrupted by a single pool over the entire 680 linear feet. The substrate of riffles is composed of gravel or cobble with little accumulation of fines and sand. Some reaches designated as riffles could have been designated as shallow runs with gravel and cobble substrate. A single pool was found in association with the only meander in the project reach.

Bed Material

Pebble count data indicate that 50 percent (D_{50}) of the particles observed in the riffle were small cobble (104 mm) or finer, as measured on the intermediate axis (Table 1). However, the D_{50} particle size observed in the reach-wide and pavement/sub-pavement surveys indicate that the mean particle size was within the gravel category, 43 mm and 20 mm. This is likely due to a higher percentage of smaller particles found in the pool counts used for the reach wide survey as well as in the pavement and sub-pavement collections. The percent of particles by substrate class indicates again that cobble is the dominant component (56%) in the riffle sample, with gravel the primary component in the reach-wide (31%) and pavement/sub-pavement (57%) samples. There are no outcroppings of bedrock at this site; although several large boulders are present. The cumulative percent of particles finer than a specific particle size and the number of individual particles by sizes are summarized in Appendix 2.

Reference Reach

Reference reach data was not available on Spring Creek. Morphological data from a stable reference reach channel within a particular valley type was desired (Rosgen 1998). Surveys of Basin Creek (Wilkes County) and Long Hope Creek (Watauga County) were used because they are the same stream types (C4), and situated in the same type valley (VIII) as the Spring Creek project reach (Table 2). The same methods as previously referenced were utilized at these sites to characterize the cross-sectional dimensions, pattern, profile, and substrate of these reference reaches (Rosgen 1996). Dimensionless ratios derived from the reference reach data were used with the mountain regional curve data to calculate design values for the Plemmons/Kirkpatrick mitigation site.

Riparian Buffer

At the Plemmons/Kirkpatrick mitigation site, Spring Creek flows through a moderately wide, flat valley. The valley at the upstream end of the project reach is narrowed by intruding ridge lines. These features narrow the valley on the left and right bank upstream of the project site. The valley is similar in width (≈500 ft) on the left and right bank within the project area and maintains this width some distance below the project reach.

The riparian area on the left bank has been bermed; the bank itself is very steep from the waters edge up approximately 8 vertical feet to the toe of the 3 foot high berm. The toe of the berm is at the top of the stream bank. This area is well vegetated with mature trees, under-brush and herbaceous plants; many of which are invasive exotic species. Several automobile bodies, a barn, abandoned machinery, and scrap metal products are incorporated into the left bank and berm. Outside the berm is an infrequently maintained fescue pasture, and nearest to the downstream end is a small Fraser fir *Abies fraseri* Christmas tree plantation.

The riparian area on the right bank consists of heavily grazed pasture, a feed lot, and corral. The feed lot and corral area are within the proposed conservation easement and will be relocated as part of the restoration plan. At the top of the bank is the existing livestock fence. Although livestock do not have access to the creek, the width of the buffer between the creek and fence, adjacent to the feed lot and corral, is reduced to approximately 20 feet. The buffer is absent below the school bus, on the outside of the eroding meander, and cattle actively graze up to the existing fence line. In addition to the school bus, scrap metal, and old machinery; six or more automobile bodies are incorporated into the streambank and channel bed downstream of the pool, close to the project boundary. The right bank has not been bermed and an inner berm feature has formed in places. Vegetation consists of mature trees, under-brush, and herbaceous plants.

Within the riparian area on both sides of the creek, native trees are present including; tag alder *Alnus serrulata*, sycamore *Platanus occidentalis*, black walnut *Juglans nigra*, black cherry *Prunus serotina*, black locust *Robinia pseudo-acacia*, and river birch *Betula nigra*. Invasive exotic species are present at this site including privet *Ligustrum spp.*, multiflora rose *Rosa multiflora*, and Japanese honeysuckle *Lonicera japonica*, which individually or in combination dominate portions of the riparian area and impede colonization by beneficial native vegetation. This area supports populations of wildlife including various songbirds, rabbits *Sylvilagus sp*., quail *Colinus virginianus*, wild turkey *Meleagris gallopavo*, and whitetail deer *Odocoileus virginianus.*

Conservation Easement

Prior to any ground disturbing activity a conservation easement was established to protect the restored stream channel from future impacts. An easement corridor was surveyed and permanently marked. The easement width is approximately 75 ft from the centerline of the stream on both sides; or, approximately 50 ft from the top of the bank, to the easement boundary line. Overall, an easement corridor of 150 ft, including the stream channel, was established. A conservation easement document was developed that stipulates the rights and responsibilities of the landowner, as well as those of the WRC. The contents of the easement have already been agreed to and the document signed by the landowners, WRC, and DOT. The conservation easement agreement will be recorded with the deed and held in perpetuity by the WRC. This will insure protection of the site into the future.

Restoration Plan

Objectives

The objective of this project is to restore stable function to this reach of Spring Creek and improve in-stream and riparian habitats for aquatic and terrestrial species. To achieve these objectives the WRC proposes to: 1) establish a conservation easement on both stream banks for the entire length of the restoration project; 2) remove the existing invasive exotic vegetation; 3) remove the abandoned barn, automobile bodies, school bus, and other foreign materials from the stream banks and riparian area; 4) remove the berm from the top of the left bank; 5) remove the two choke points at station 3+50 and 4+75; 6) reduce stream bank erosion on the right bank of the meander bend by establishing a stable radius of curvature and by installing in-stream structures and bank protection; 7) install two additional in-stream structures to enhance aquatic habitat features; 8) shape banks to a stable slope, create a bankfull bench and inner berm features; 9) re-establish native vegetation within the riparian zone; and 10) design and construct a livestock corral and feed/waste structure, watering system, and install fencing to exclude livestock from the conservation easement and stream.

The project reach of Spring Creek connects to the floodplain at or above 2 times the bankfull depth. The existing berm along the left bank was evidently established to reduce the frequency of flooding for those residences that exist within the floodplain on the left side of Spring Creek. It may be necessary to reconstruct this berm along the conservation easement boundary line on the left side to maintain the same level of flood protection that currently exists for these residences. By moving the berm back, the area between the new berm and the top of the left bank will provide an increased floodplain area for bankfull events.

Channel Morphology

The proper channel dimensions will be re-established for the entire project reach (Figure 6). All depths are relative to the bankfull elevation. Constructed riffles associated with the J-hooks will have a design mean depth of 3.6 ft, maximum depth of 5.4 ft, width of 54.0 ft, and width/depth ratio of 14.3 (Table 2). The invert depth of all J-hook structures will be 4.75 ft (0.9 times the maximum depth). Pools will have a mean depth of 4.1 ft and a maximum depth of 7.2 ft. Runs and glides will be transitional features between riffles and pools.

The stream profile will be adjusted in accordance to the design values and based on the location of proposed in-stream structures (Figure 7). In-stream structures will consist of rock J-hooks. J-hook structures #1 and #4 at stations 0+86 and 6+73 will be installed to improve aquatic habitat. J-hook structures #2 and #3 will be installed at the point of curvature and point of tangency of the constructed meander bend. Placement of structures at these points in the meander bend will reduce near bank stress and result in the creation of a compound pool through the bend. Root-wad structures will be placed in the outside of the meander bend for additional bank protection. All structures will be constructed according to standard guidelines (Appendix 3).

Channel morphology will be repaired to a stable form by implementing enhancement Level II and restoration mitigation types (USACE 2003). Enhancement Level II (500 lf) activities will involve lowering the existing stream banks and creating a bench so that bankfull or greater flows can access the floodplain. Topsoil from cut slopes will be stockpiled and spread on the final floodplain surface. Excess excavated material will be spread outside of the conservation easement boundary line, but within the project limits. Large boulders (≈5'x3'x18") will be used for constructing J-hook structures. Two J-hook structures will be constructed as part of the Enhancement Level II construction. Restoration (180 lf) activities will involve constructing a meander bend to the desired channel dimension, pattern, and profile. Two J-hook structures will be installed at the point-of-curvature and point-of-tangency at the constructed meander. Root-wad structures will be placed in the outside bend of the restored meander for added bank protection and habitat diversity. Large rock will be used in conjunction with root-wads to provide additional stability (Figure 8). Construction of the four J-hook structures may vary from design specification based on site specific conditions and at the discretion of the project engineer.

Reference information was taken from Basin Creek (HUC 03040101060010) and Long Hope Creek (HUC 05050001010020) survey data (both C4 streams in western North Carolina) and the North Carolina mountain regional curves. Each reference reach is similar in stream type, substrate, and valley type to the project reach. Reference information was used to develop the final design values for the project reach of Spring Creek (Table 2). The final design was based on dimensionless ratios of the reference morphological measurements and compared to the mountain regional curve information to develop bankfull width, mean depth, and cross sectional area for the Spring Creek site.

Minimal work will be done to the existing channel pattern except to improve the radius of curvature at the meander bend between stations 3+00 and 5+00. The channel between stations 3+00 and 5+00 will be restored to a meandering pattern that is typical of a C4 type stream. The proposed meander pattern will fit within the easement area that is established. This is the only meander bend within the project reach. The belt-width, or width over which the stream meanders, is 231 ft and the constructed meander will have a radius of curvature of 192 ft. Channel length will not change from the pre-construction length of 680 linear feet (Figure 8).

Bed Transport

In general, conditions associated with this mitigation site are not a result of bed transport problems. However, two choke points have contributed to upstream aggradation and downstream degradation by creating excessive slope and velocity conditions. Choke point areas will be modified as part of the overall adjustments to the project's pattern and profile. Additionally, past mechanical modifications of dredging, straightening, armoring, and berming the stream channel have created a conduit for mobilizing bed material.

The competency of the proposed channel, based on design parameters, was evaluated to guard against aggradation or degradation. Sediment transport was validated using RIVERMorph Sediment Transport Competency module (RSARS 2003). This module calculates the minimum depth required to maintain channel competency without aggradation or degradation. The

channel competency depth is predicted using a critical dimensionless shear stress formula that is based on the largest particle observed in mobilized material, which is the largest particle from the bar sample (Andrews and Erman 1986). This method is based on the ratio of D_i to the D_{50}, 141.0 mm ÷ 104.0 mm = 1.4. This results in a critical dimensionless shear stress of 0.028 and a required minimum mean depth of 2.26 ft. The design bankfull mean depth of 3.6 ft exceeds the minimum required mean depth. This design depth should not promote aggradation. Sediment transport conditions were validated by comparing calculated bankfull shear stress values to predicted values from a Shields Diagram (RSARS 2003).

Construction sequence

The construction sequence will be planned so that as much work as possible will be done in the dry or out of the stream flow. Construction will be sequenced from upstream to downstream so that as the abandoned barn, berms, automobile bodies, other foreign material, and undesirable vegetation are removed the banks will be shaped, seeded, and covered with biodegradable matting or straw the same day as the ground disturbance (see Riparian Zone and Erosion Control sections for details). At stations where structures are to be installed, construction will be tied to the bankfull elevation before continuing with downstream clearing and shaping. Channel bed material will be excavated, as necessary, to configure pool and riffle features and to shape bed features according to design values. The bank will be shaped to the desirable slope and a bankfull bench created for only the distance that can be disturbed, shaped, and covered in a single work day. Foreign materials will be sorted and temporarily stockpiled to be hauled to a landfill or scrap metal facility. It is anticipated that work can be completed within 20 days.

Riparian Zone

One of the most important components of this plan is to restore the riparian zone and make it accessible to stream flows at or above bankfull stage throughout the length of the conservation easement. This will require removal of the left bank berm and bank shaping. Similarly, the right bank will be shaped and a bankfull bench created. Where practical, bank shaping will tie into existing bank elevations, also incorporating existing inner berm features. During construction, small trees and shrubs will be salvaged and heeled into a soil bank for later replanting on the floodplain and along the restored streambank. Where possible, existing sod composed of herbaceous plants will be salvaged and replanted along the stream banks. Larger native trees growing at or near the bankfull stage will be left and incorporated into the riparian design. Larger trees that must be removed will be used to create root-wad structures. Along the margins of the constructed floodplain, where it will slope up to the existing ground elevation, slopes will not exceed 1:1, and will be less where possible. Topsoil excavated from the floodplain area will be stockpiled and re-applied to the floodplain after excavation.

After stream banks have been sloped they will be seeded with brown top millet (1 lb/1,000 ft^2) and with a WRC all-purpose native seed mix at the rate of 10 lb/acre (Table 3). Soil amendments will be added according to soil test recommendations made by the North Carolina Department of Agriculture. After seeding, banks will be stabilized using coir or jute ground matting anchored with wooden landscape pegs. Installation of erosion control materials and seeding will be done daily, as stream segments are complete. Woody vegetation, including live

stakes, bare-rooted trees, and container grown specimens will be planted along all disturbed areas during the dormant season (Table 4). Native understory shrub species such as elderberry *Sambucus canadensis*, silky dogwood *Cornus amomum*, silky willow *Salix sericea*, and tag alder *Alnus serrulata* will be planted along stream banks. Silky dogwood and silky willow specimens will be planted as live stakes. Native trees that provide shade, cover, and food for wildlife will be planted as bare-root or container grown specimens at the top of the banks and extending to the conservation easement boundary line. The 2.1 acre conservation easement will be planted with 1,300 trees and shrubs including most or all of the 28 species in Table 4. Trees will be planted every 10-20 ft and shrubs every 5-10 ft. Live stakes will be planted every 2 ft. All species will be evenly dispersed along the restored reach. Survival of woody vegetation will monitored to insure the minimum rate of 320 stems per acre through year three, as specified in the USACE stream mitigation guidelines manual (USACE 2003). Exotic invasive species of privet *Ligustrum sp.*, multiflora rose *Rosa multiflora*, and Japanese honeysuckle *Lonicera japonica*, will be removed during excavation and burned. Cut stumps will be treated with the herbicide solution glyphosate.

Agricultural Best Management Practices (BMPs)

In cooperation with the Madison County NRCS and SWCD, a covered winter feed/waste structure with a year-round water supply was engineered and constructed on high ground outside the conservation easement. In addition, a new corral with a chute and head gate for working livestock was designed and constructed adjacent to the feed/waste structure. Permanent fencing will be installed on the right bank along the conservation easement boundary to prevent cattle access to the stream and newly constructed riparian area. Livestock husbandry is not desired by the owner on the left bank; therefore, fencing is not proposed as part of the BMPs.

Erosion Control

Erosion control is an important and required element of this plan (Appendix 4). We will be diligent to insure that the project does not generate erosion and sedimentation problems. We plan to accomplish this by staging the work so that as the banks are cleared and shaped, only the amount of ground that can be seeded and stabilized with coir and jute matting in a day will be disturbed. Secondarily, we will accomplish additional erosion control measures through the use of erosion control materials and practices in accordance with the Erosion and Sediment Control Planning and Design Manual (NCSCC 1988).

Slopes from the wetted perimeter to the new bankfull elevation will be planted with a seed mixture containing annual and perennial plant species. Planted areas will then be covered with a biodegradable erosion control blanket, coir or jute matting (Appendix 5). Disturbed ground above bankfull will also be seeded with annual and perennial plant species and covered with straw. Jute matting will be used to cover strips of bare ground that are narrow or need less protection than that provided by the coir matting. Done in this sequence, this project should not require having more than one acre of riparian ground exposed during construction at any one time. Total ground disturbance for the project is 3.97 acres (Appendix 4).

Soil excavated from the new floodplain will be stockpiled on high ground and protected from erosion by having a silt fence installed between the spoil and down slope areas. Upon project completion this soil will be graded into the landscape and seeded. The silt fence will remain in place until the spoil area is completely vegetated. A temporary gravel construction entrance/exit consisting of 50 ft of 2-3 in coarse aggregate will be constructed on both sides of the project reach. Ballast stone (3 in) will also be placed on soft areas of the construction access roads as needed.

Graded or impacted areas outside of the conservation easement will be permanently seeded with timothy *Phluem pretense* or tall fescue *Festuca spp.* and mulched with straw. All erosion control practices will be inspected at irregular intervals until the site stabilizes. Spoil areas will be checked regularly to insure proper function. If additional measures are needed, they will be carried out within 5 days.

General Work Sequence for the Plemmons/Kirkpatrick Stream Mitigation Project

1) Stockpile erosion control materials on site.
2) Move equipment on site and walk through the entire project with the contractor.
3) Delineate, clear, and haul stone to prepare construction access roads on site.
4) Establish high ground spoil areas on each side of the creek. Left bank spoil to be located between garden area and Christmas tree plot. Right bank spoil area to be located adjacent to old feed lot.
5) Haul boulders to the site for building stream structures.
6) Remove non-native vegetation within the conservation easement area. Salvage and heel-in native trees and shrubs that can be re-planted. Salvage and stockpile larger trees for root-wad structures when available.
7) Remove existing barn, berms, automobile bodies, machinery, and other foreign material from within the conservation easement proceeding from upstream to downstream. Separate metals and foreign materials from soil and stockpile.
8) Excavate and shape stream banks to design elevations and construct bankfull benches. Slope from the back of the bankfull benches to existing ground elevation not to exceed 1:1.
9) Cover disturbed ground with seed mixes, fertilizer, coir matting, jute matting or straw by the end of each work day.
10) Complete left bank by re-constructing 2.5 ft high x 7.0 ft wide berm along conservation easement boundary line. Top of new berm to be approximately 2.5 ft above bankfull elevation.
11) Construct J-hook structures at locations shown on the design drawing when these stations are reached in the clearing and shaping process.
12) Excavate bed features according to design values.
13) Install root-wads at locations shown on design drawing to provide added bank protection and enhance aquatic habitat.
14) Complete any final floodplain sloping, replant salvaged trees and shrubs, install bare-root, container grown and live stake plant material, seed any remaining disturbed areas with temporary and permanent seed mix. Inspect and add any needed erosion control practices.

15) All stockpiled materials will be hauled off-site to an approved landfill or scrap metal facility. All woody waste material will be burned on-site in accordance with local regulations.
16) Remove all equipment and unused construction materials, including any trash or waste, from project site.
17) Install permanent fencing the length of the conservation easement boundary on the left bank.
18) Erosion control structures will be checked weekly and after every significant rainfall event while the project proceeds to insure that all structures are functioning. Regular inspections will continue and modifications made after project completion, until permanent vegetation is established. Any needed maintenance or repair will be made by the WRC immediately after the inspection and no later than 5 days after determination is made.

Conclusion

Restoration of this C4 stream type by removing automobile bodies, stream choke points, left bank berm, sloping vertical banks, and constructing a wider cross-sectional area with a bankfull bench will allow this reach of stream to access its floodplain. Installation of J-hooks and root-wads will provide stability in areas of near bank stress and increase in-stream aquatic habitat diversity. Water quality will be improved through removal of the livestock feed lot and corral from the riparian area. This will reduce animal waste and sedimentation from entering the stream. Native vegetation enhancement within the conservation easement will benefit wildlife species by providing a riparian corridor. Aquatic fauna will benefit from stable stream banks and a functioning stream channel with improved habitat.

References

Andrews, E. D. and D. C. Erman. 1986. Persistence in the size distribution of surficial bed material during an extreme snowmelt flood. Water Resources Research. 22(2):191-197.

Doll, B. A., D. E. Wise, C. M. Buckner, S. D. Wilkerson, W. A. Harman, R. E. Smith, and J. Spooner. 2002. Hydraulic geometry relationships for urban streams throughout the piedmont of North Carolina. Journal of American Water Resources Association, 38(3):641-651.

Doll, B. A., G. L. Grabow, K. R. Hall, J. Jalley, W. A. Harman, G. D. Jennings, and D. E. Wise. 2003. Stream restoration: a natural channel design handbook. North Carolina Stream Restoration Institute and North Carolina Sea Grant. Raleigh.

Harman, W. A., G. D. Jennings, J. M. Patterson, D. R. Clinton, L. O. Slate, A G. Jessup, J. R. Everhart, and R. E. Smith. 1999. Bankfull hydraulic geometry relationships for North Carolina streams. Pages 401-408 *in* D.S. Olsen and J.P. Potyondy, editors. American Water Resources Association, Wildland Hydrology Symposium Proceedings. American Water Resources Association, Middleburg, Virginia.

Harman, W. A, D. E. Wise, M. A. Walker, R. Morris, M. A. Cantrell, M. Clemmons, G. D. Jennings, D. Clinton, and J. Patterson. 2000. Bankfull regional curves for North Carolina

mountain streams. Pages 185-190 *in* D.L. Kane, editor. Proceedings of the American Water Resources Association Conference: Water Resources in Extreme Environments. American Water Resources Association, Middleburg, Virginia.

Harrelson, C. C., J. P. Potyondy, and C. L. Rawlins. 1994. Stream channel reference sites: an illustrated guide to field technique. General Technical Report RM-245, U.S. Department of Agriculture, Forest Service, Fort Collins, Colorado.

NCSCC (North Carolina Sedimentation Control Commission). 1988. Erosion and Sediment Control Planning and Design Manual. Raleigh.

NCSRI (North Carolina Stream Restoration Institute). 2003. Stream restoration: a natural channel design handbook. North Carolina Stream Restoration Institute, North Carolina State University, Raleigh. Available: www.bae.ncsu.edu/programs/extension/wqg/sri/. (September 2005).

Rosgen, D. L. 1996. Applied river morphology. Printed Media Companies, Minneapolis, Minnesota.

Rosgen, D. L. 1998. The reference reach – a blueprint for natural channel design. American Society of Civil Engineers River Restoration Conference. American Society of Civil Engineers, Reston, Virginia.

RSARS (RIVERMorph Stream Assessment and Restoration Software). 2003. Version 3.1. Professional edition. Copyright 2002-2005, RIVERMorph LLC, Louisville, Kentucky. Available: www.rivermorph.com. (September 2005).

USACE (U.S. Army Corps of Engineers, U.S. Environmental Protection Agency, North Carolina Wildlife Resources Commission, North Carolina Division of Water Quality). 2003. Stream mitigation guidelines. U.S. Army Corps of Engineers, Wilmington District, NC. Available: www.saw.usace.army.mil/wetlands/Mitigation/ stream_mitigation.html. (September 2005).

TABLE 1.—Bed material values from a riffle; reach wide, pavement and sub-pavement sample, Plemmons/Kirkpatrick mitigation site, Spring Creek, French Broad River drainage, Madison County. Bed material values presented by size (mm) and by class (%) for each feature. Ranges in size of bed material for each class also provided.

	Channel feature sampled		
Bed material	Riffle	Reach	Sub-pavement & pavement
By size (mm)			
D_{16}	34.17	0.19	0.00
D_{35}	71.09	19.30	7.69
D_{50}	104.00	43.38	19.73
D_{84}	234.29	128.00	78.97
D_{95}	412.00	180.00	121.62
D_{100}	1023.95	1023.95	141.00
By class (%)			
Silt/Clay (>0.062)	1.00	4.00	0.00
Sand (0.062-2.0)	6.00	24.00	23.55
Gravel (2.0-64.0)	25.00	31.00	56.72
Cobble (64.0-256.0)	56.00	29.00	19.73
Boulder (256.0-2048.0)	12.00	2.00	0.00
Bedrock	0.00	0.00	0.00

TABLE 2.—Stream reference reach existing and proposed restoration design values for the Plemmons/Kirkpatrick stream mitigation site, Spring Creek, French Broad River drainage, Madison County. (Basin Creek reference data, D. Clinton et al. 1998; Long Hope Creek reference data, A. Jessup et al. 2005).

	Reference reach		Existing	Proposed
Data type	Basin Creek	Long Hope Creek	Spring Creek	Spring Creek
General characteristics				
Drainage area	7.6	2.2	29.3	29.3
State	NC	NC	NC	NC
County	Wilkes	Watauga	Madison	Madison
Hydrologic unit code	03040101060010	05050001010020	06010105120010	
Ecoregion	Blue Ridge Mtn Southern Crystalline Ridges and Mtn	Blue Ridge Mtn Amphibolite Mtn	Blue Ridge Mtn Southern Crystalline Ridges and Mtn	
Latitude			035°47' 29.35"	
Longitude			082°51' 48.80"	
Survey date	Oct.1998		July 2005	
Classification data				
Valley type	VIII	VIII	VIII	VIII
Valley slope			0.0115	0.0115
Number of channels	1	1	1	1
Width (Wbkf)	33.2	16.3	52.6	54.0
Mean depth (Dbkf)	2.1	1.5	3.3	3.6
Flood prone width (ft)	329	202	700	700
D_{50} (mm)	58.0	26.0	43.4	43.4
Water surface slope (ft/ft)	0.0144	0.0090	0.0094	0.0094
Sinuosity	1.22	1.70	1.22	1.22
Cross. sect. area (Abkf)	68.4	24.8	173.2	197.8
Entrenchment ratio	11.3	12.4	13.3	13.0
Width/depth ratio	15.8	10.9	15.9	14.3
Stream classification	C4	C4	C4	C4
Dimension data				
Riffle area (ft^2)	68.4	24.8	173.2	197.8
Max. riffle depth (ft)	3.1	2.2	5.4	5.4
Mean riffle depth (ft)	2.1	1.5	3.3	3.6
Min. req. mean depth			2.3	2.3
Riffle width (ft)	33.2	16.3	52.6	54.0
Pool area (ft^2)	109.6	36.2	198.2	254.8
Max. pool depth (ft)	4.8	2.4	6.4	7.2
Mean pool depth (ft)	2.7	2.0	4.5	4.1
Pool width (ft)	50.3	17.9	44.4	56.7
Run area (ft^2)	97.7	29.8	179.6	190.4
Max. run depth (ft)	3.8	2.0	6.1	5.9
Mean run depth (ft)	2.2	1.4	3.7	3.6
Run width (ft)	44.8	21.3	48.3	52.8
Glide area (Sq ft)	98.7	41.8		197.5
Max. glide depth (ft)	3.7	2.3		5.0
Mean glide depth (ft)	2.7	1.6		3.7
Glide width (ft)	38.3	26.1		54.0

TABLE 2.—Continued.

Pattern data	Reference reach		Existing	Proposed
	Basin Creek	Long Hope Creek	Spring Creek	Spring Creek
Meander wavelength (ft)	350.0	196.0	1187.9	1187.9
Radius of curvature (ft)	51.2	64.9	155.7	192
Belt width (ft)	64.7	57.7	229.9	231.0
Channel length (ft)	427.0	333.0	1449.2	1449.2
Profile Data				
Slope riffle (ft/ft)	0.0208	0.0126	0.0147	0.0202
Slope pool (ft/ft)	0.0019	0.0037	0.0009	0.0021
Slope run (ft/ft)	0.0031	0.0146	0.0023	0.0186
Slope glide (ft/ft)	0.0065	0.0054	0.0074	0.0057
Pool to pool length (ft)	305.0	97.5	326.0	249.5
Pool length (ft)	37.5	17.4	76.4	88.5
Low bank Ht. (ft)	3.1	2.2	5.3	5.4
Bankfull slope (ft/ft)	0.0144	0.0090	0.0094	0.0094

TABLE 3.—North Carolina Wildlife Resources Commission's native seed mix used for stream restoration and mitigation projects.

Common name	Scientific name	Percent
Rice cut grass	*Leersia oryzoides*	10.0
Virginia wild rye	*Elymus virginicus*	10.0
Woolgrass	*Scirpus cypemus*	10.0
Sensetive fern	*Onoclea sensibillis*	5.0
Green bulrush	*Scirpus atrovirens*	5.0
Hop sedge	*Carex lupilina*	5.0
Soft rush	*Juncus effusus*	5.0
Softstem bulrush	*Scirpus validus*	5.0
Deer tongue	*Panicum clandestinum*	5.0
Lesser bur-reed	*Sparganium americanum*	5.0
Eastern gamagrass	*Tripascum dactyloides*	5.0
Elderberry	*Sambucus canadensis*	5.0
Many leaved bulrush	*Scirpus polyphyllus*	2.5
Nodding bur-marigold	*Bidens cernua*	2.5
Squarestem monkey flower	*Mimulus ringens*	2.5
Joe pye weed	*Eupatorium fistulosa*	2.5
Swamp milkweed	*Asclepias incarnata*	2.5
Red chokeberry	*Aronia arbutifolia*	2.5
Silky dogwood	*Cornus amomuin*	2.5
Winterberry	*Ilex verticillata*	2.5
Spicebush	*Lindera benzoin*	2.5
Maple-leaved viburnum	*Viburnum acerifolium*	2.5
Total	10 lb/acre	100.0

TABLE 4.—Species composition of live stake, bare-root, and container-grown trees and shrubs proposed to be planted inside the conservation easement at the Plemmons/Kirkpatrick stream mitigation site, Spring Creek, French Broad River drainage, Madison County.

Type	Common name	Scientific name	Proposed Number
Trees	Beech	*Fagus grandifolia*	10
	Black cherry	*Prunus serotina*	10
	Black walnut	*Juglans nigra*	10
	Black willow [a]	*Salix nigra*	100
	Box elder	*Acer negundo*	10
	Green ash	*Fraxinus pennsylvanica*	10
	Northern red oak	*Quercus rubra*	10
	Persimmon	*Diospyrus virginiana*	20
	Red maple	*Acer rubrum*	5
	River birch	*Betula nigra*	20
	Service berry	*Amelanchier arborea*	10
	Shagbark hickory	*Carya ovata*	20
	Sycamore	*Platanus occidentalis*	10
	Sugarberry	*Celtis occidentalis*	20
	White oak	*Quercus alba*	10
	Wild plum	*Prunus americana*	20
	Yellow poplar	*Liriodendron tulipifera*	5
Shrubs	Button bush	*Cephalanthus occidentalis*	20
	Elderberry	*Sambucus canadensis*	20
	Hazel nut	*Corylus americana*	20
	Maple leaf viburnum	*Viburnum acerfolium*	20
	Pawpaw	*Asimina triloba*	20
	Red choke berry	*Aronia arbutifolia*	20
	Spicebush	*Lindera benzoin*	20
	Silky dogwood [a]	*Cornus amomum*	400
	Silky willow [a]	*Salix sericea*	400
	Tag alder	*Alnus serrulata*	40
	Winterberry	*Ilex verticillata*	20
		Total	1,300

[a]Species will be planted as live stakes.

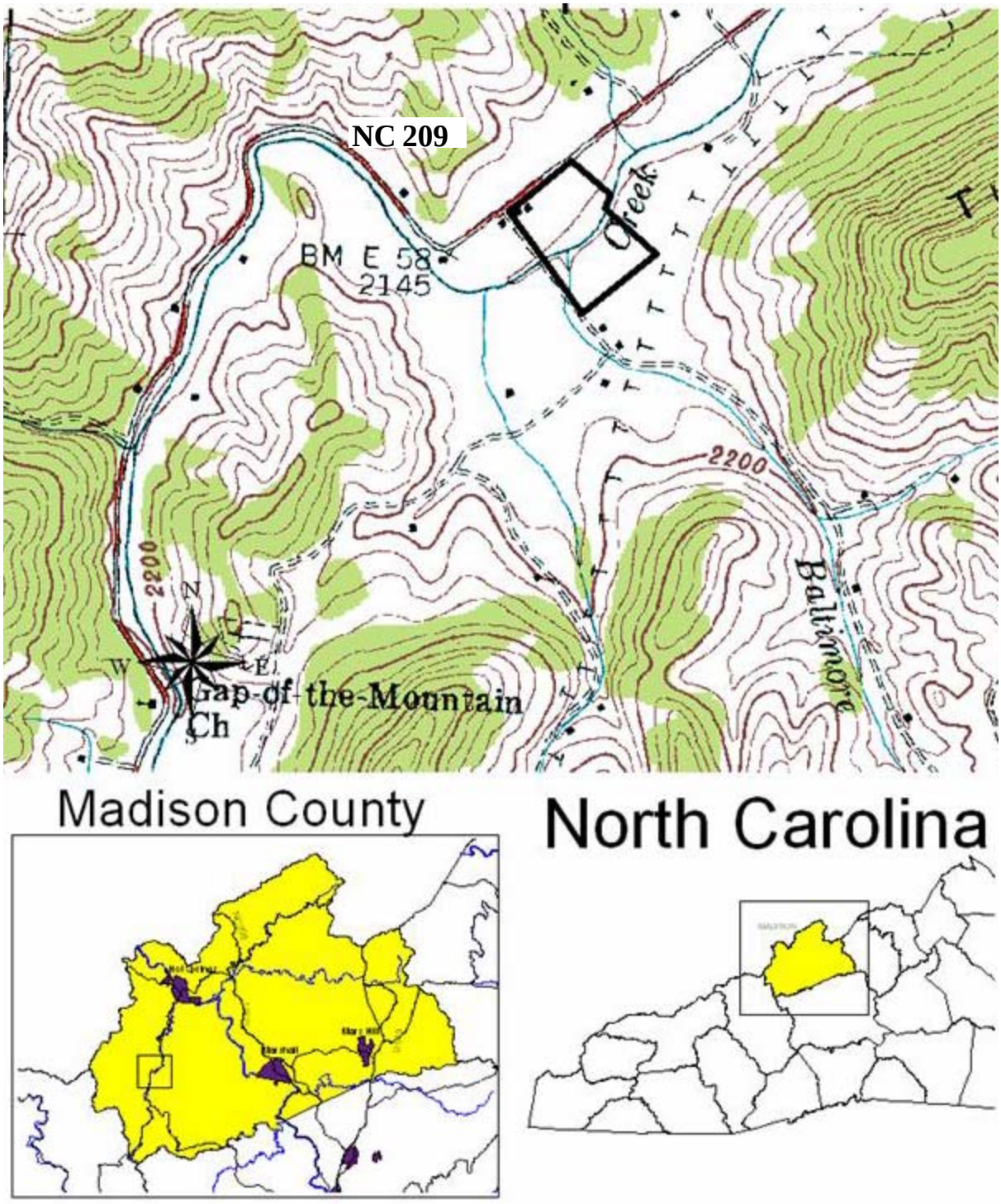


FIGURE 1.—Location of the Plemmons/Kirkpatrick mitigation site, Spring Creek, French Broad River drainage, Madison County (HUC 06010105120010).

PLEMMONS/KIRKPATRICK MITIGATION SITE

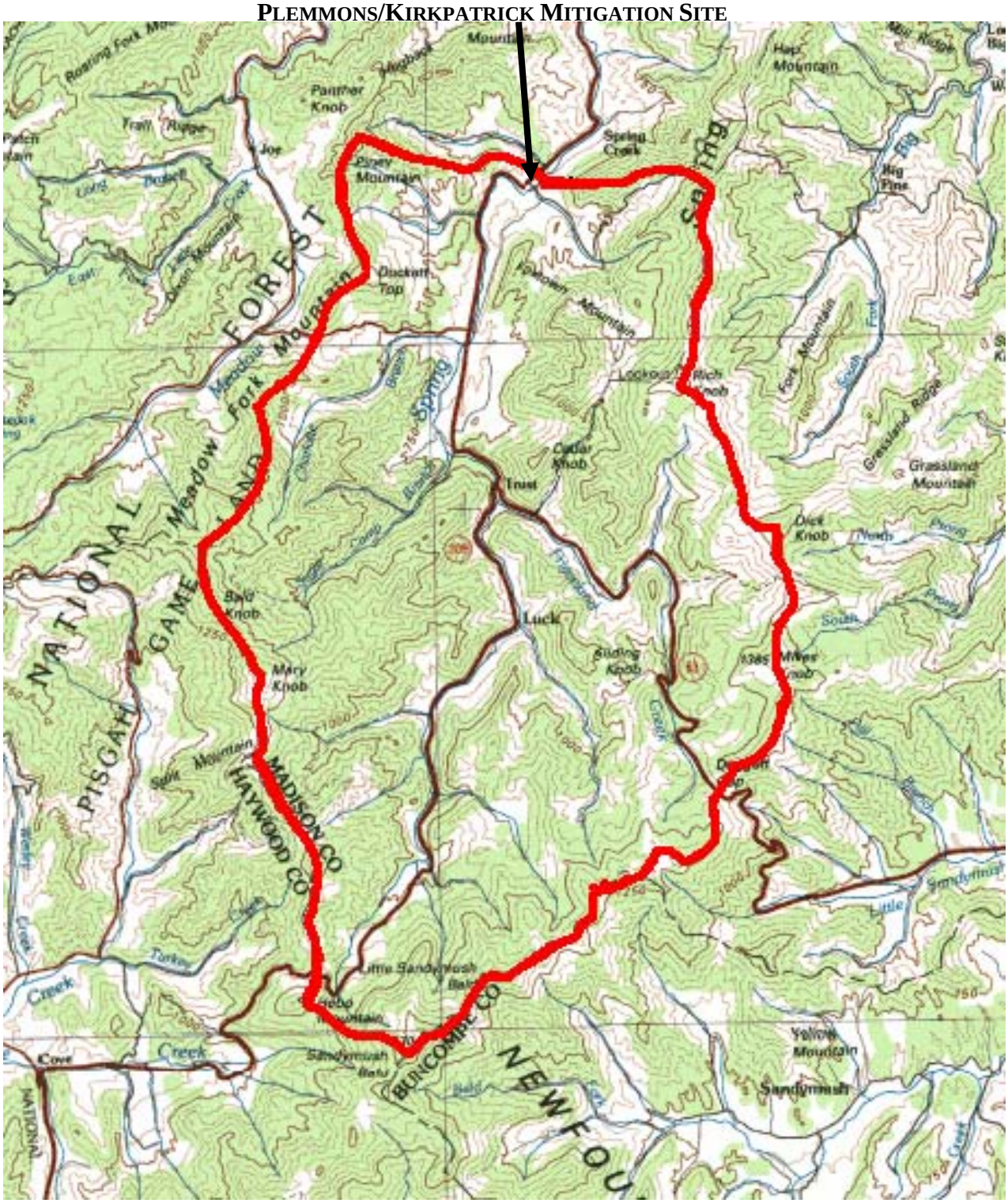


FIGURE 2.—Outlined in red is the 29.3 mi^2 drainage area of the Plemmons/Kirkpatrick mitigation site, Spring Creek, French Broad River drainage, Madison County.

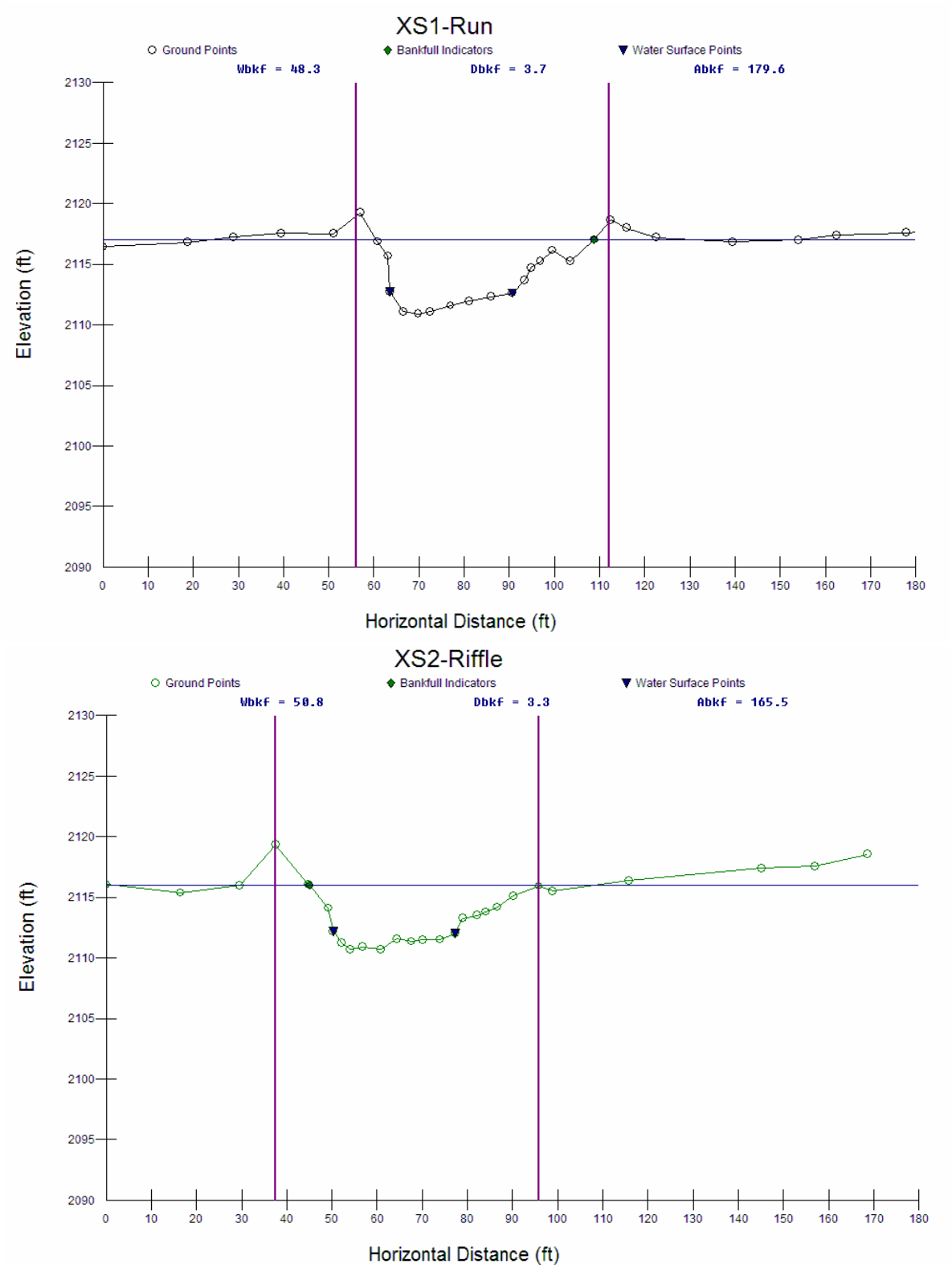
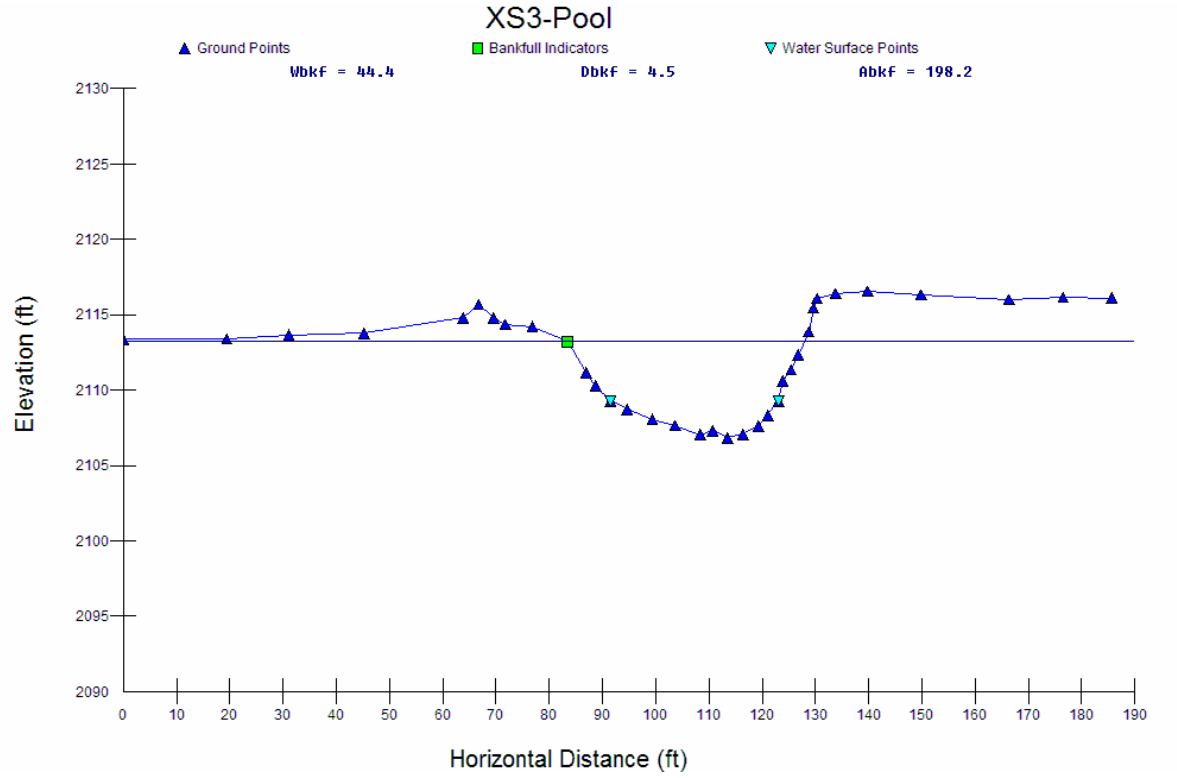


FIGURE 3.—Existing channel dimensions of four cross sections within the project reach of the Plemmons/Kirkpatrick mitigation site, Spring Creek, French Broad River drainage, Madison County. Vertical lines define the horizontal extent of the bankfull calculations. The horizontal line is the bankfull elevation.



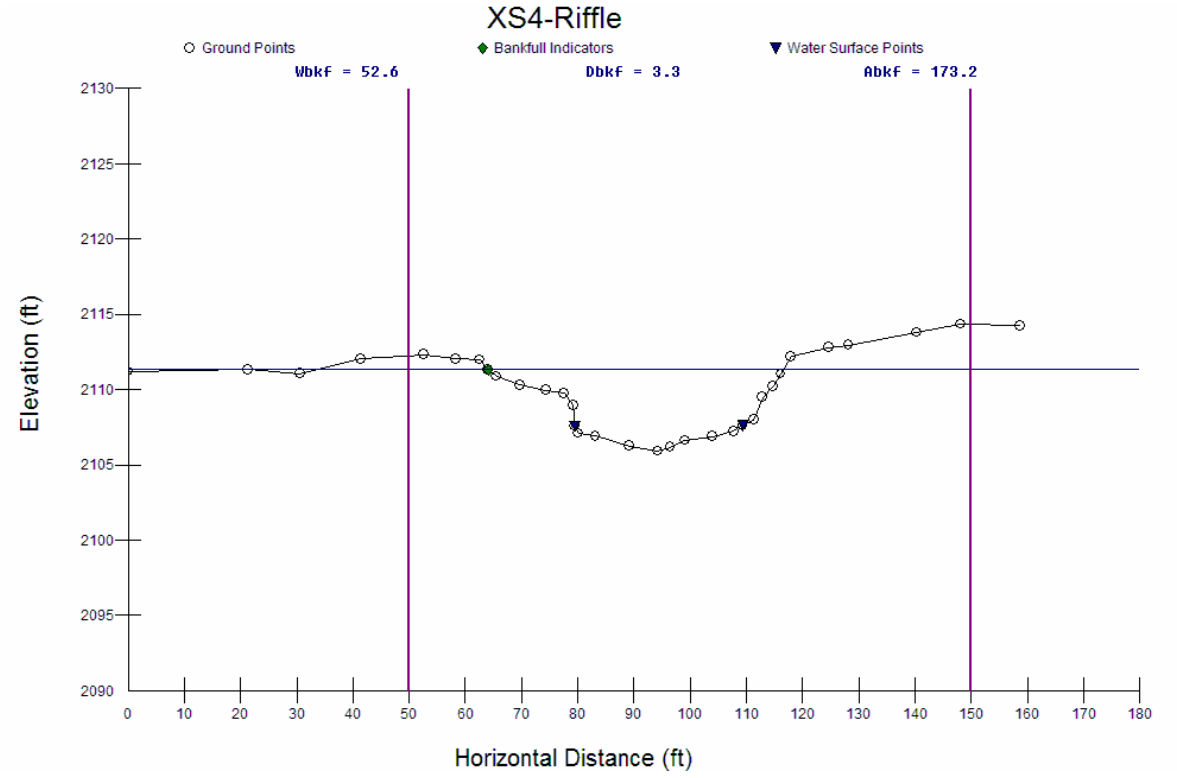


FIGURE 3.—Continued.

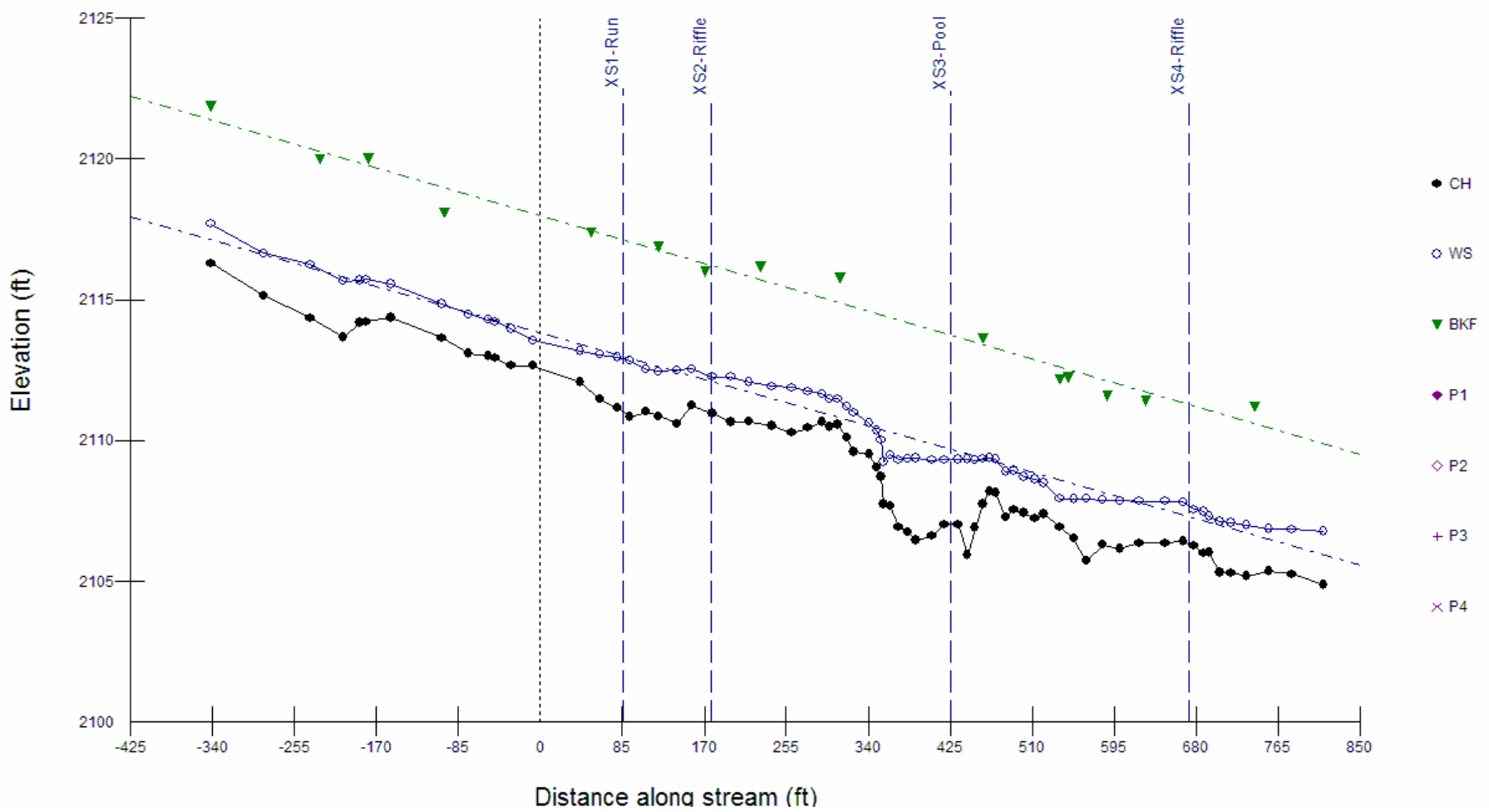


FIGURE 4.—Existing longitudinal profile at the Plemmons/Kirkpatrick mitigation site, Spring Creek, French Broad River drainage, Madison County. The locations of cross-sections relative to their station along the longitudinal profile are shown. Dashed line at station 0+00 represents upper project boundary.

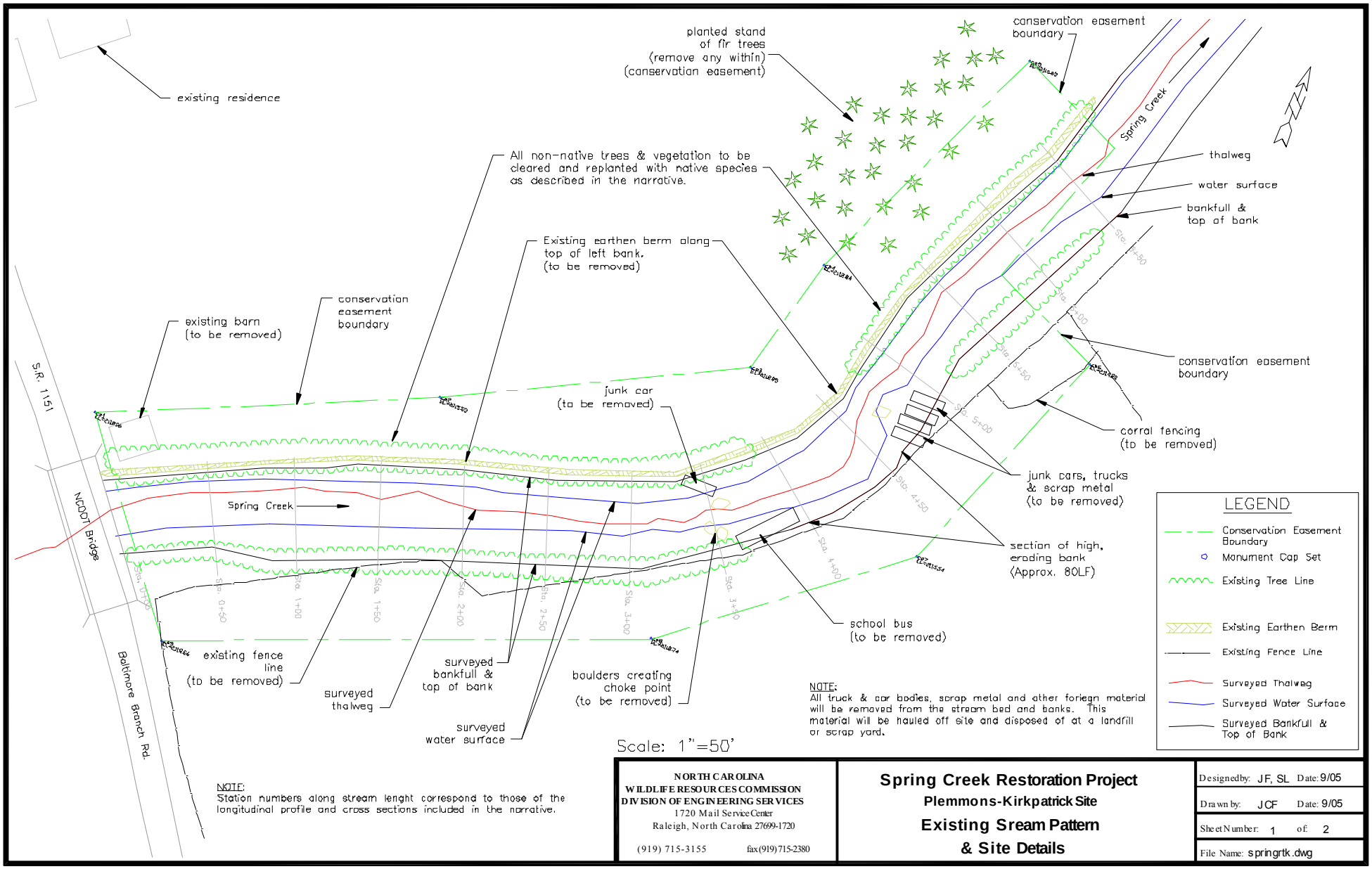
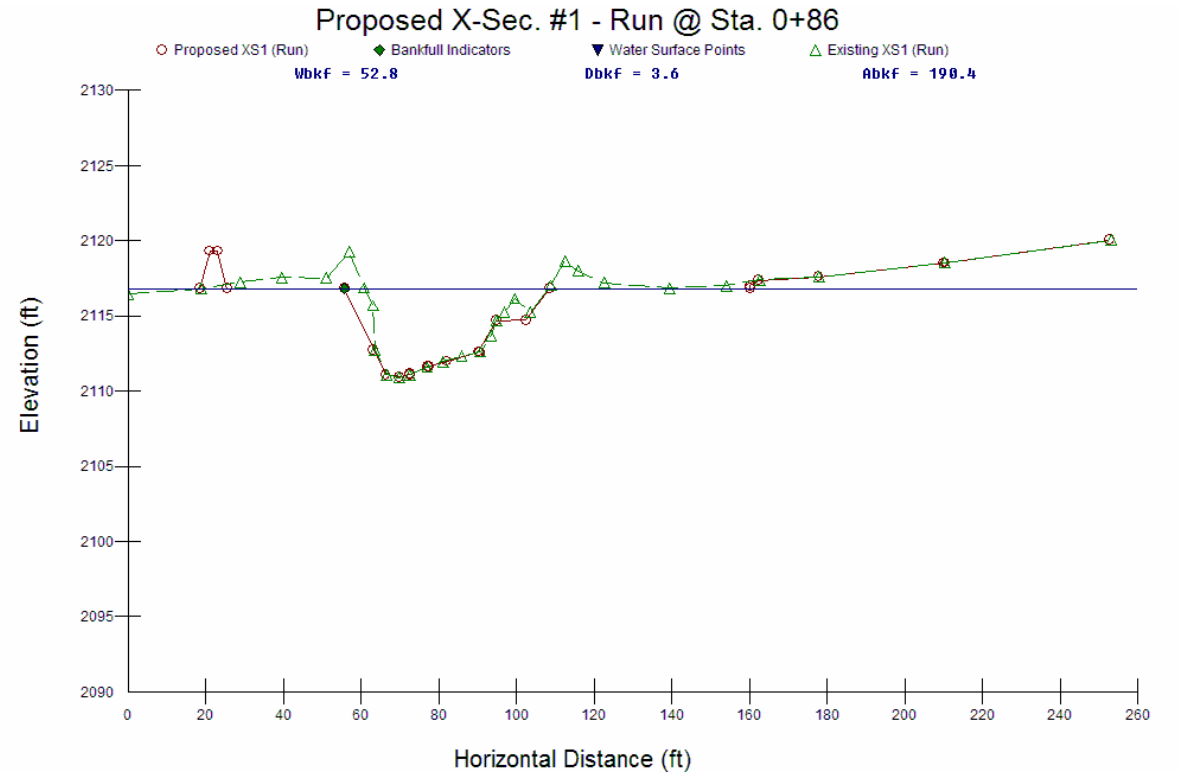


FIGURE 5.—Existing conditions of the Plemmons/Kirkpatrick mitigation site, Spring Creek, French Broad River drainage, Madison County.



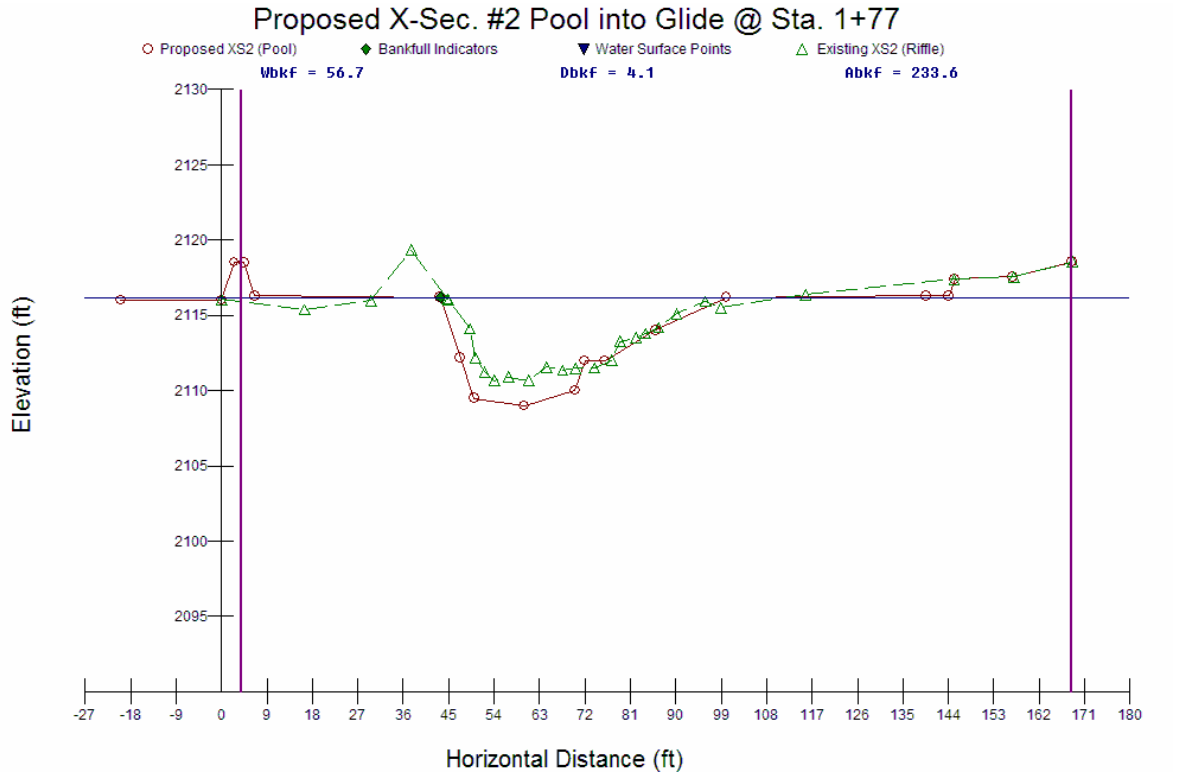
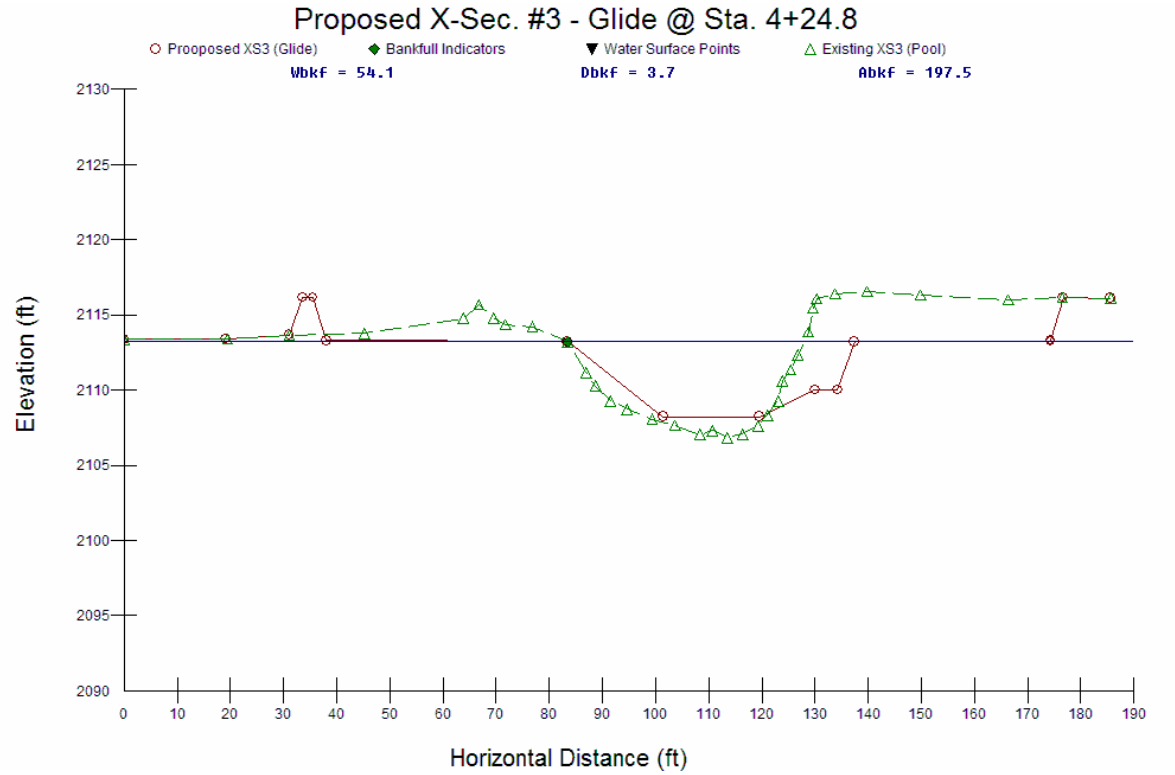


FIGURE 6.—Proposed channel dimensions at the four cross sections within the project reach, Plemmons/Kirkpatrick mitigation site, Spring Creek, French Broad River drainage, Madison County. Vertical lines (X-sec 2, only) define the horizontal extent of the bankfull calculations. The horizontal line is the bankfull elevation.



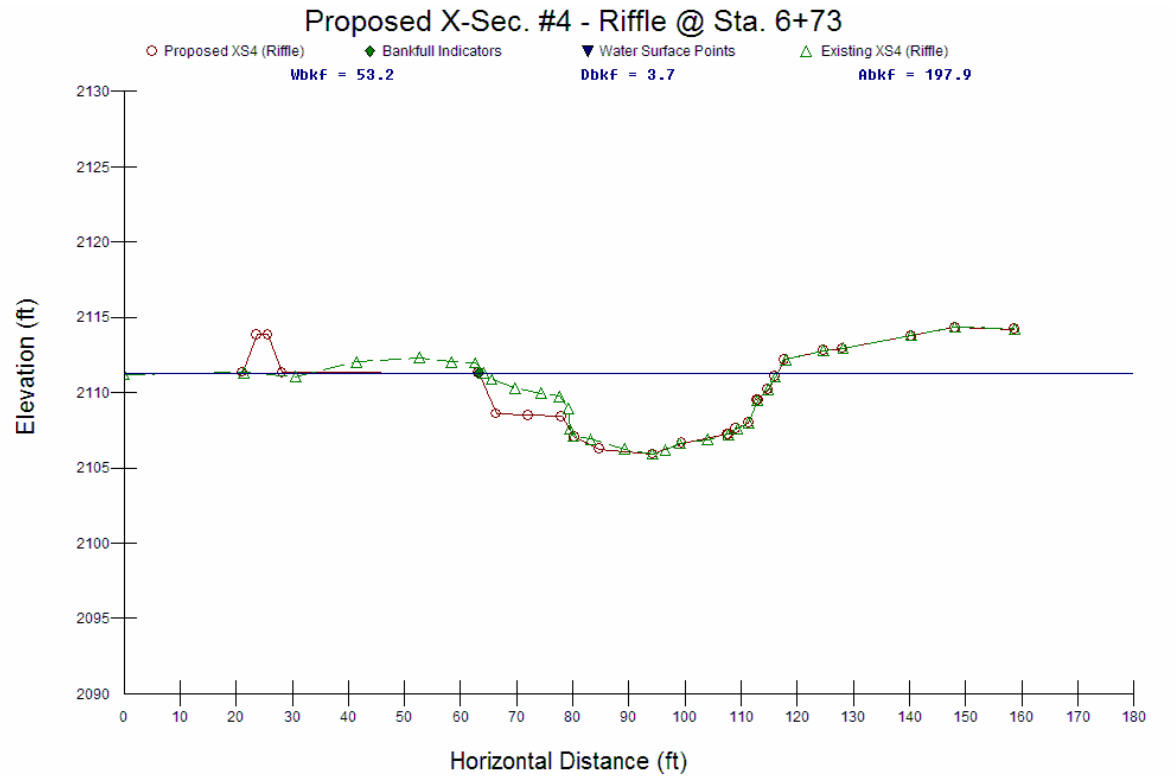


FIGURE 6.—Continued

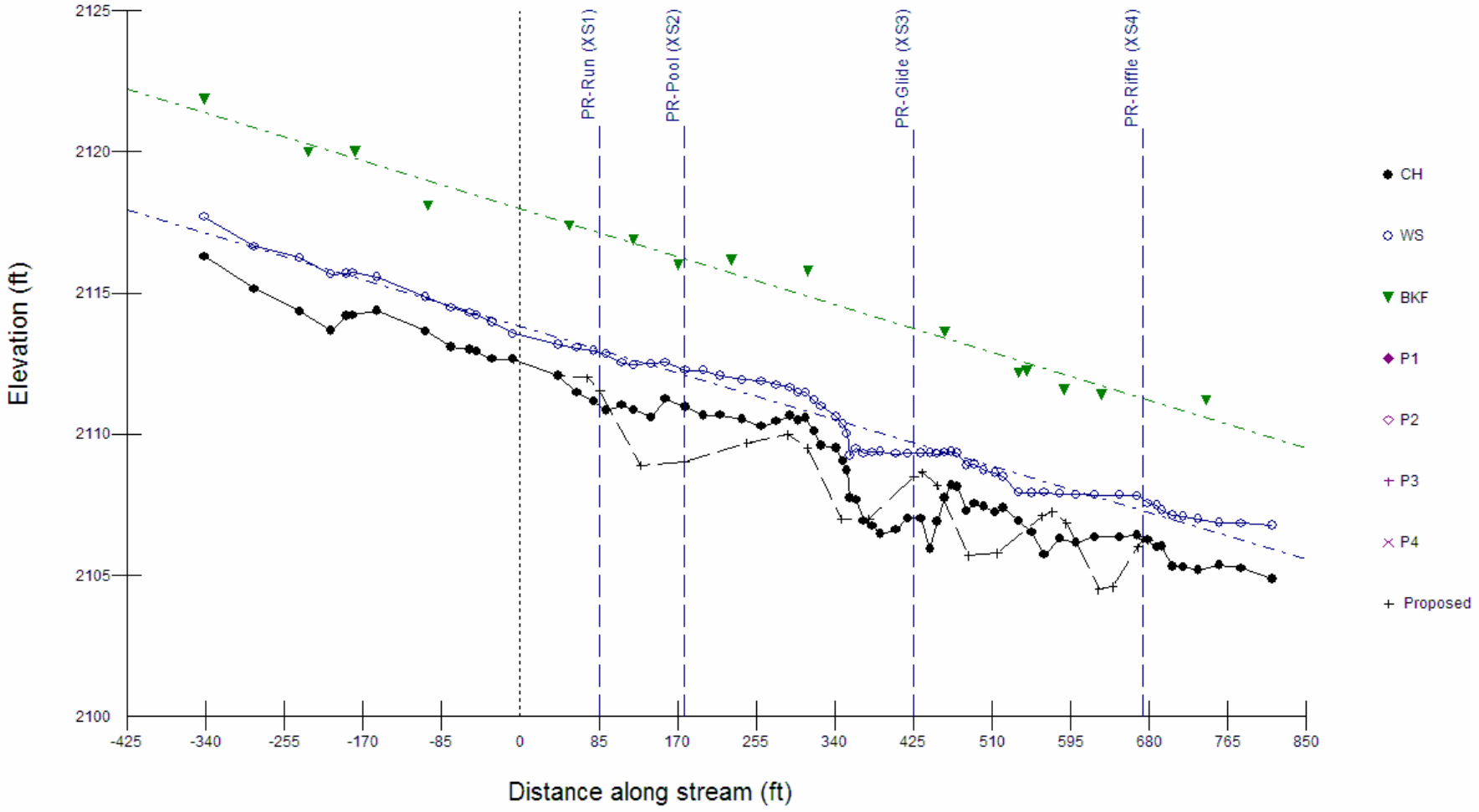


FIGURE 7.—Proposed longitudinal profile at the Plemmons/Kirkpatrick mitigation site, Spring Creek, French Broad River drainage, Madison County. The locations of cross-sections relative to their station along the longitudinal profile are shown. Dashed line at station 0+00 represents upper project boundary.

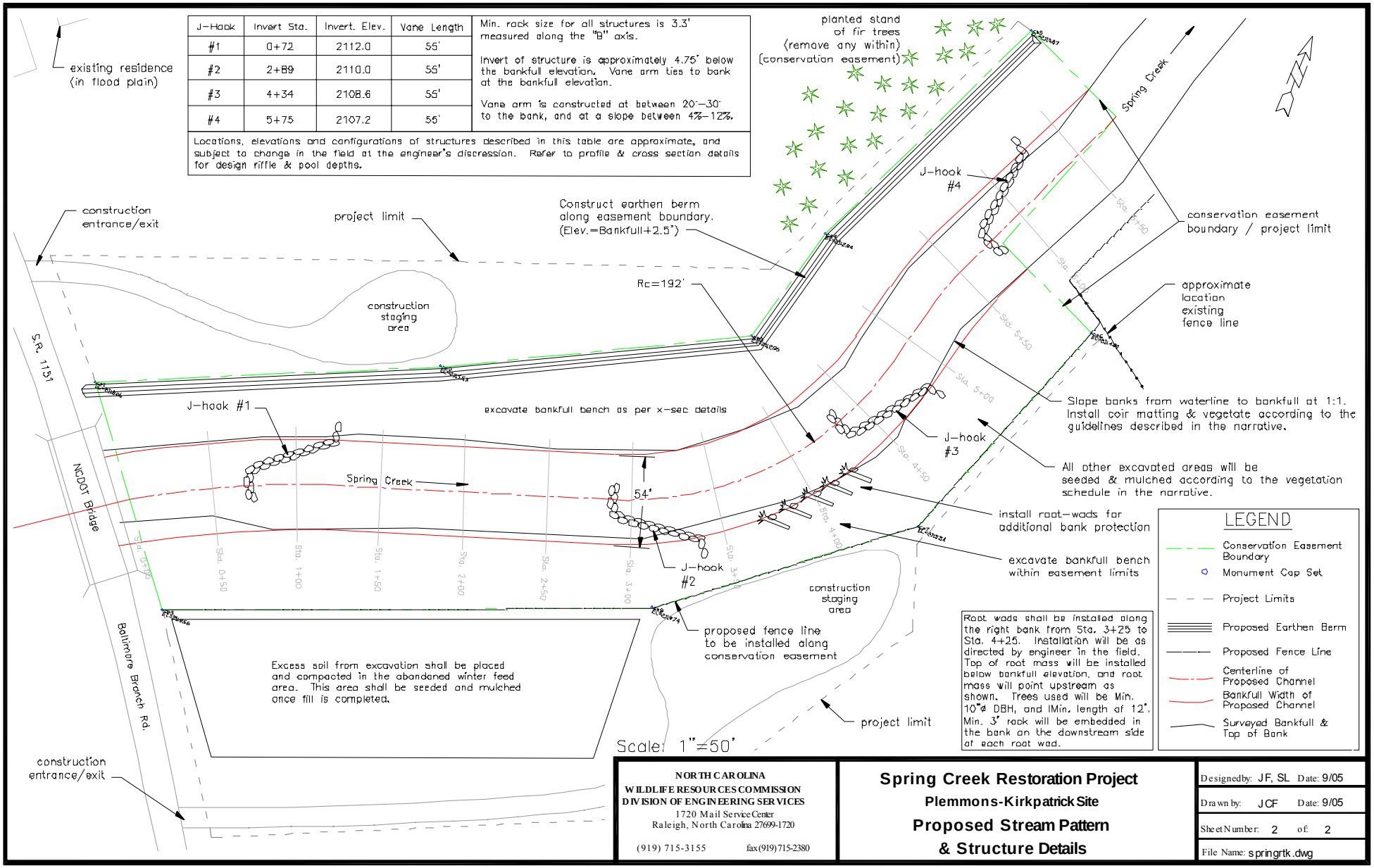


FIGURE 8.—Proposed restoration plan for the Plemmons/Kirkpatrick mitigation site, Spring Creek, French Broad River drainage, Madison County.

APPENDIX 1: Plemmons/Kirkpatrick mitigation site photos, Spring Creek, French Broad River drainage, Madison County, July 2005. Horizontal red line indicates location of cross-sectional survey.

A1.1.—Cross-section 1, sta. 0+86, run, looking downstream.

A1.2.—Cross-section 1, sta. 0+86, run, looking upstream.

A1.3.—Cross-section 2, sta. 1+77, riffle, looking downstream.

A1.4.—Cross-section 2, sta. 1+77, run, looking upstream.

A1.5.—Cross-section 3, sta. 4+24.8, pool, looking downstream.

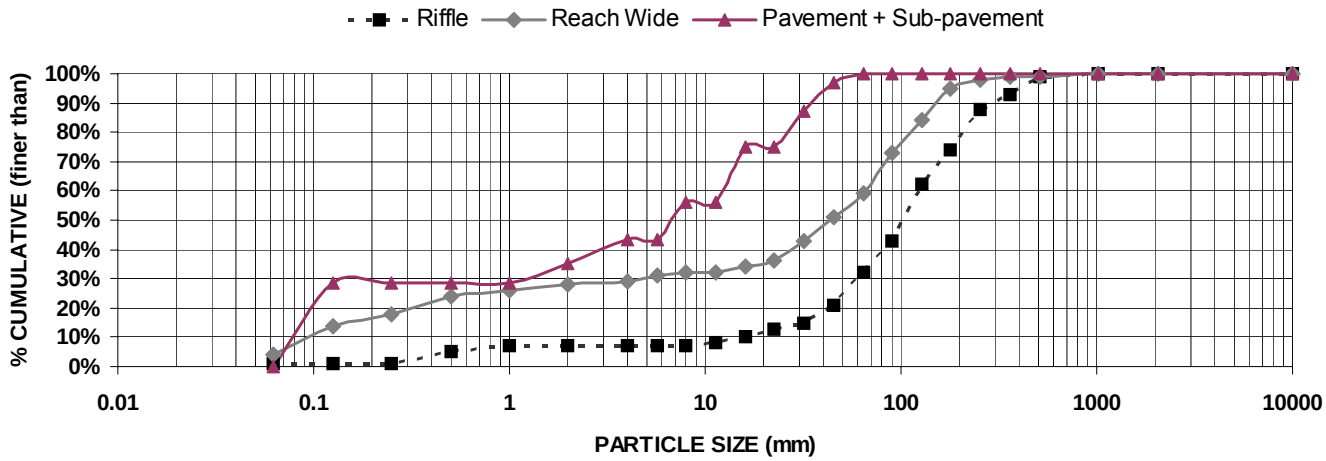
A1.6.—Cross-section 3, sta. 4+24.8, pool, looking upstream.

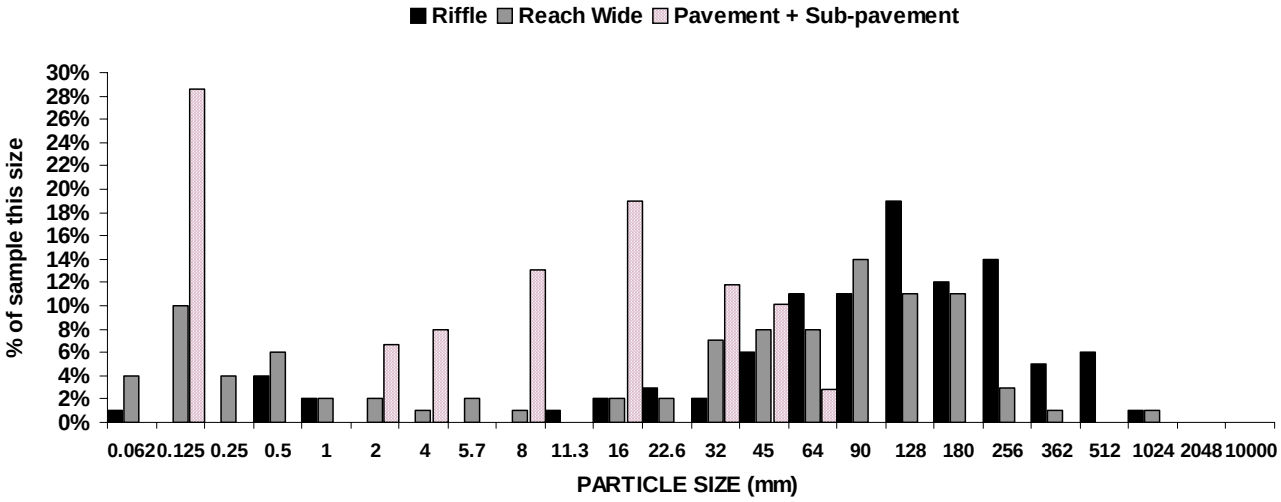
A1.7.—Cross-section 4, sta. 6+73, riffle, looking downstream.

A1.8.—Cross-section 4, sta. 6+73, riffle, looking upstream.

Appendix 2: Pebble count and bed material (pavement and sub-pavement) particle size data from the Plemmons/Kirkpatrick mitigation site, Spring Creek, French Broad River drainage, Madison County.

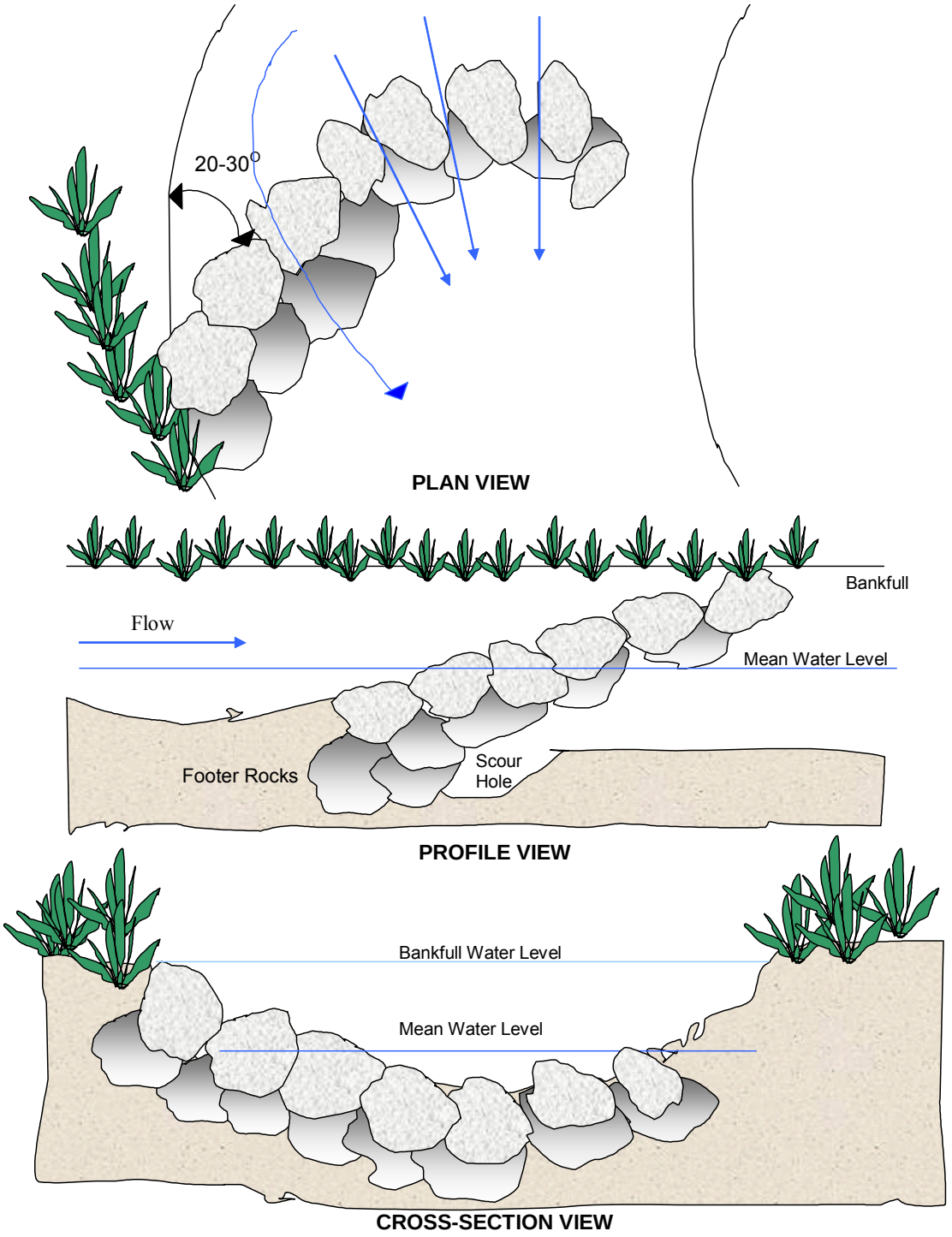
A1.—The top graph shows the cumulative percent finer than a specific particle size. The bottom graph shows the percent of the sample within a specific particle size range.





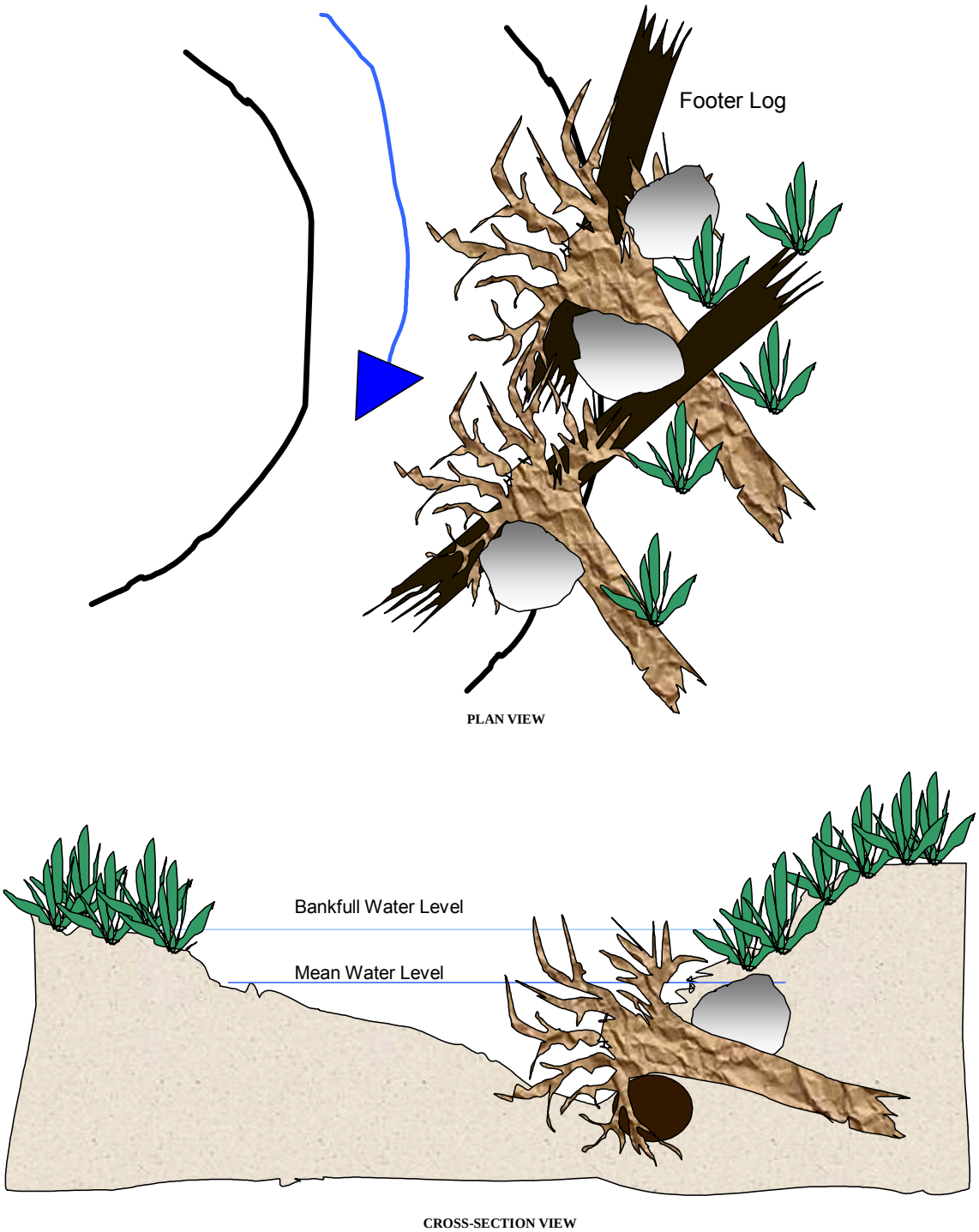
Appendix 3.—Drawings of typical in-stream structures that will be constructed at the Plemmons/Kirkpatrick stream mitigation site, Spring Creek, French Broad River drainage, Madison County.

A.3.1.—Typical design for J-hook structure showing plan and profile views.

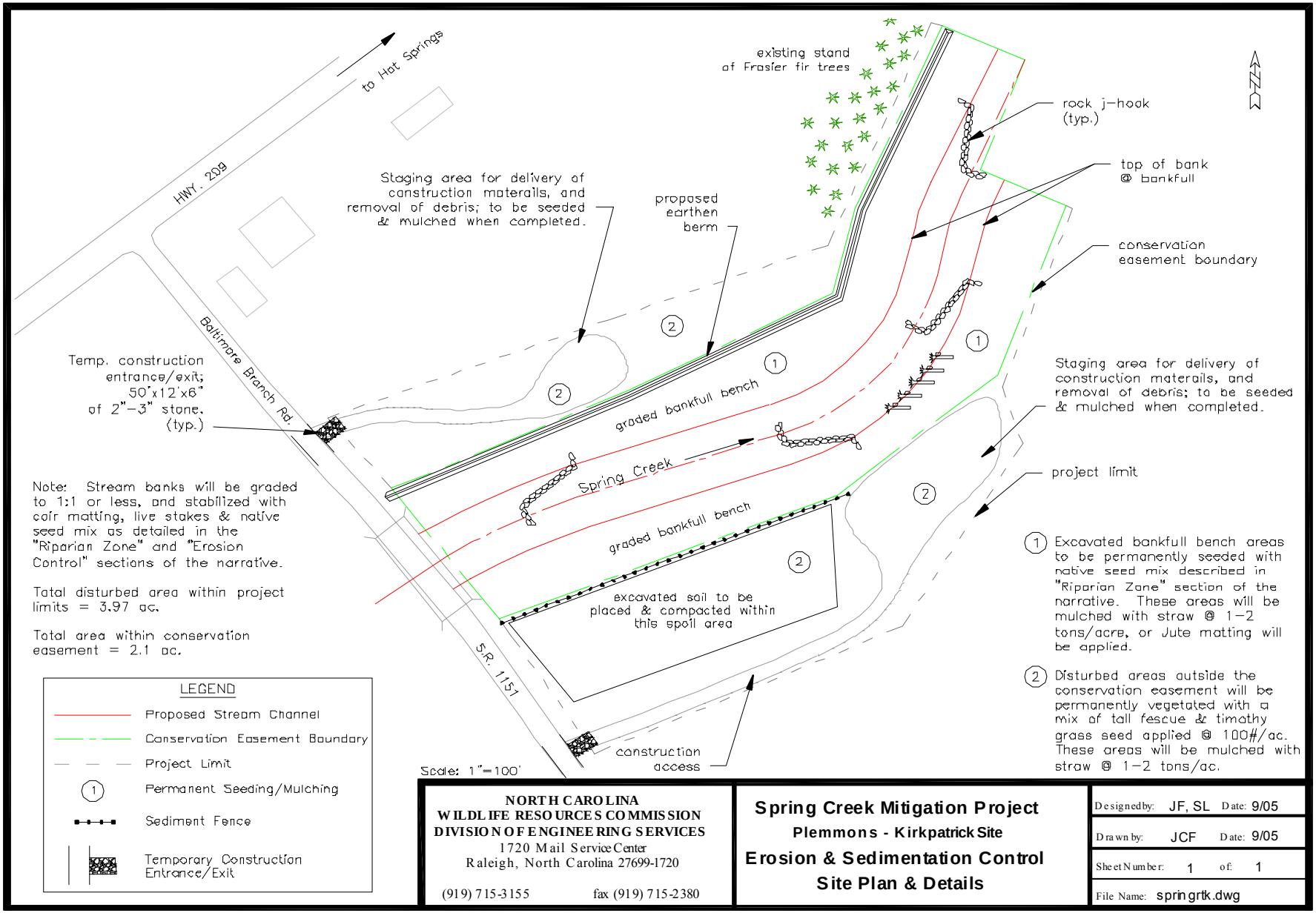


APPENDIX 3.—Continued.

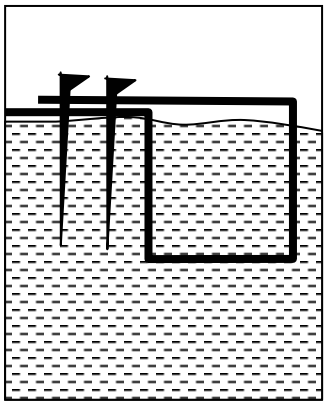
A3.2.—Typical root-wad structure showing plan and cross section views.



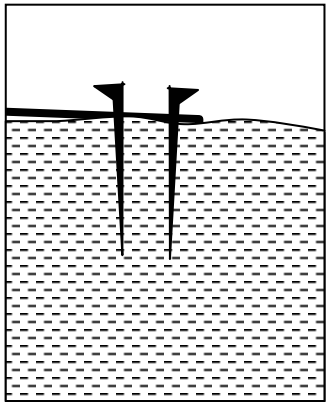
Appendix 4: Erosion and sedimentation control site plan details for the Plemmons/Kirkpatrick stream mitigation site, Spring Creek, French Broad River drainage, Madison County.



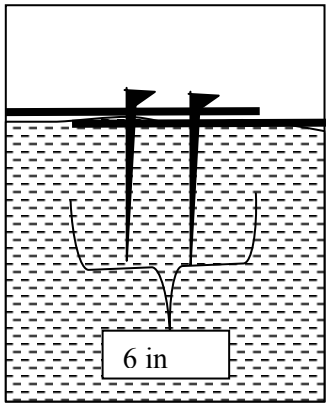
Appendix 5: Typical erosion control methods and guidelines for coir and jute matting installation.



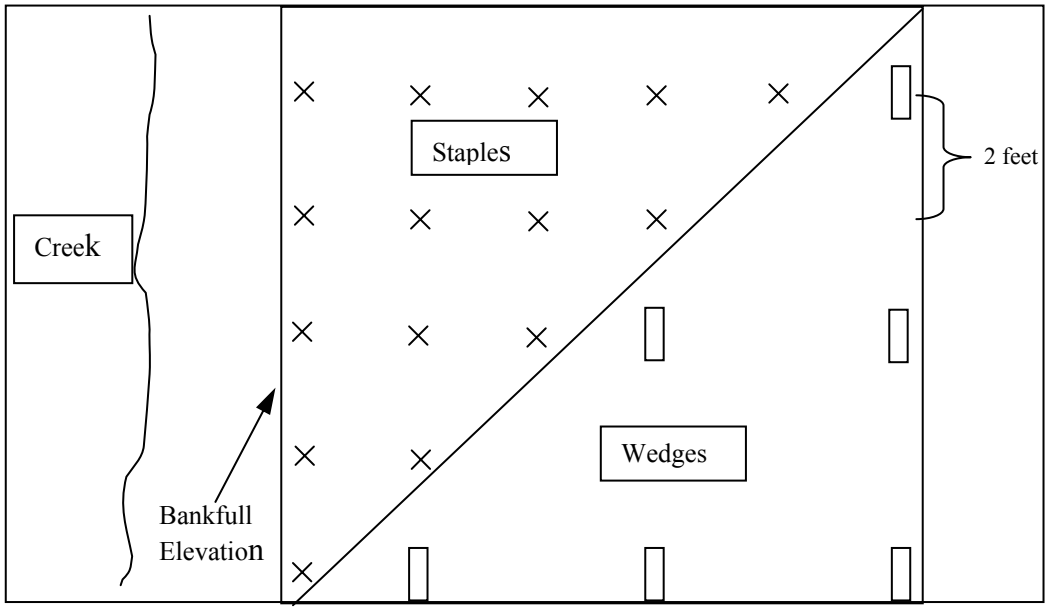
Beginning and end of mat anchored in trench.



Sides of the mat anchored.



6 in Overlap anchored through both mats and at regular INTERVALS.



Erosion Control Mat Installation

1. Prepare soil before installing blankets, including application of fertilizer, lime and seed.
2. Stream edge of mat located at bankfull elevation or lower and tucked behind coir roll (when used).
3. Begin at the top of the channel by anchoring the blanket with soil and double stapling.
4. Roll center of mat in direction of water flow. Staple every 2 ft across and down or every 4 ft with wooden staples.
5. Place blankets end over end (shingle style) with a 6 in overlap. Use a double row of staggered staples or wooden wedges to secure blankets.
6. Full length edge of blankets at top of slopes must be anchored.
7. Adjoining blankets on side slopes must be overlapped 6 in and stapled every 2 ft or every 4 ft with wooden staples.
8. The terminal end of the mat must be anchored in a soil trench. Backfill and compact the trench.
9. Anchoring of blankets will be done with either 6" staples or 12" wooden "Eco-stakes".