LYLE CREEK STREAM RESTORATION SITE
AS-BUILT CONSTRUCTION REPORT
CATAWBA COUNTY, NORTH CAROLINA

(SCO ID# 00-05378-01)

Prepared for:

North Carolina Wetlands Restoration Program
Raleigh, North Carolina

Prepared by:

EcoScience

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August 2002

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AS-BUILT CONSTRUCTION REPORT
CATAWBA COUNTY, NORTH CAROLINA

I.0 INTRODUCTION

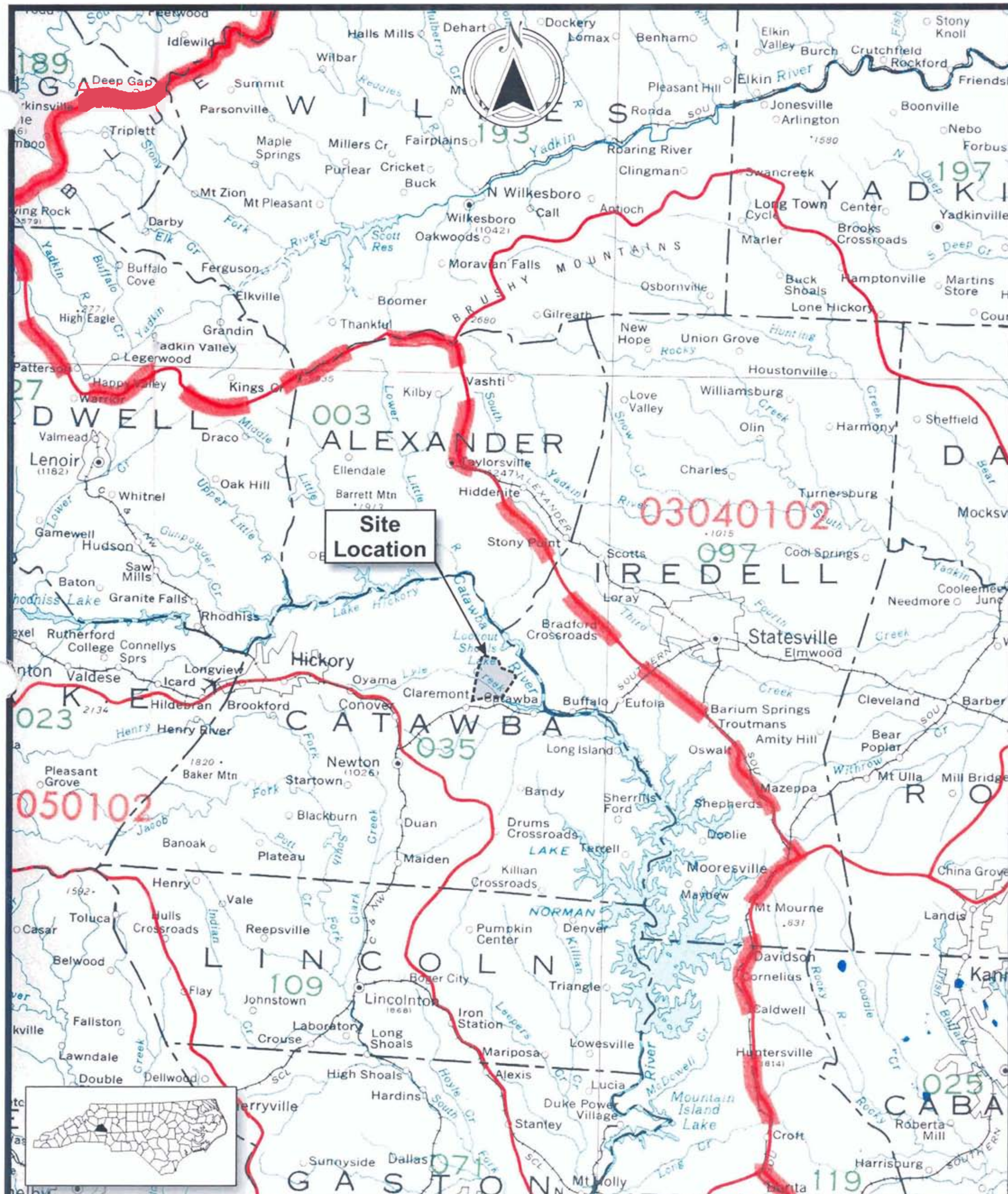
The N.C. Wetlands Restoration Program (WRP) has developed a stream mitigation site within the northeastern Piedmont region of the Catawba River basin. As part of this effort, WRP has implemented detailed mitigation plans for the Lyle Creek Mitigation Site (hereafter referred to as the "Site"), an approximately 12.4-acre tract located along an unnamed tributary to Lyle Creek, approximately three miles west of the Catawba River. This region of the state is located within U.S. Geological Survey subbasin 03050101 (USGS 1974) (Figure 1). The Site is situated between U.S. Interstate Route 40 (I-40) and U.S. Route 70, approximately three miles west of the Catawba and Iredell County line (Figure 2).

The Site historically was utilized for agricultural hay production and livestock grazing. On-site streams are characterized as first- to second-order streams which have been degraded by past land uses, including vegetative clearing, dredging and straightening activities, and livestock trampling. Dredging and straightening appears to have been conducted to facilitate agricultural production and to expedite drainage from the Site. Straightening of the channel and channel instability from livestock trampling appears to have resulted in an entrenched stream channel with headcut migration occurring through the Site.

Stream mitigation activities have been designed to restore stream features and functions similar to those exhibited by reference streams in the region. Site alterations designed to restore characteristic stream channel dimension, pattern, and profile include 1) installation of grade control/bank stabilization structures (cross vane weirs, J-hook vanes, and log vanes), excavation of bankfull benches, channel backfilling to design depth, bank stabilization through installation of root wad structures and erosion control matting, and the excavation of channel on new location. Tree and shrub planting is expected to be conducted in the fall of 2002 to facilitate establishment of diagnostic natural communities. Vegetative planting has not been documented as part of this as-built report.

After implementation, the Site is expected to support 12.4 acres of riverine and adjacent slope forest encompassing 2400 linear feet of restored stream channel (1345 linear feet restored on new location and 1055 linear feet restored in place). Stream enhancement/preservation activities will also be undertaken along approximately 800 linear feet of a secondary, unnamed tributary through bare root plantings and livestock exclusion.

Experience shows that restoring streams requires specialized knowledge both from a design and construction perspective. As a relatively new science, the task of designing and implementing these systems necessitates field evaluations and on-the-spot alterations during the course of construction. Piedmont streams similar to the Site are no exception. Several minor changes were made with respect to the original design in order to facilitate the process and ultimately increase the Site's chances for success. Minor changes include the location and addition of several structures, channel stabilization methods, the addition of two borrow pits, and radius of curvature modifications.



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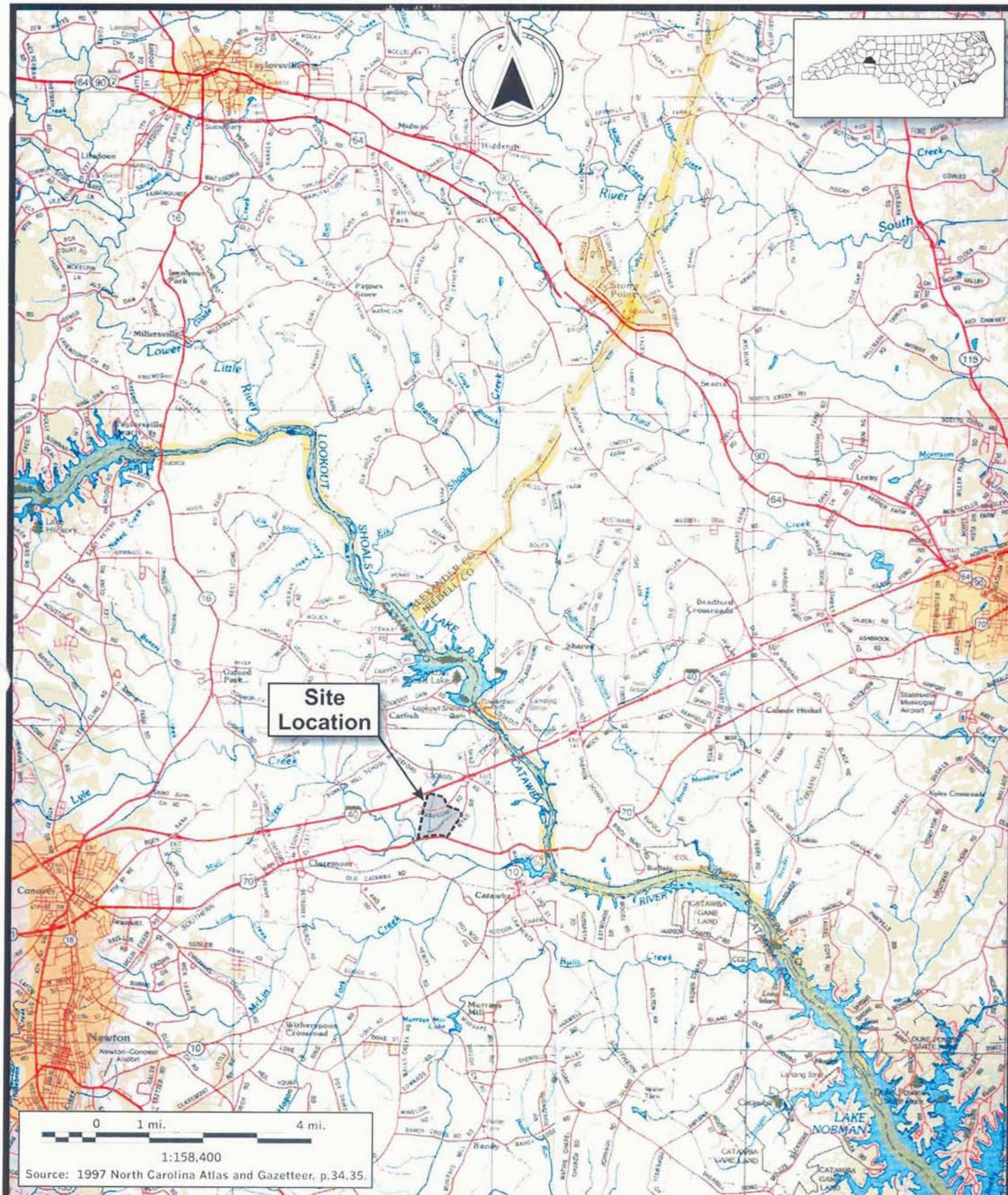
SERVICE AREA - LYLE CREEK
AS-BUILT CONSTRUCTION REPORT
Catawba County, North Carolina

Dwn. by:	MAF
Ckd by:	WGL
Date:	AUG 2002
Project:	98-047.16
FIGURE	1



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SITE LOCATION - LYLE CREEK
AS-BUILT CONSTRUCTION REPORT
Catawba County, North Carolina

Dwn. By:	MAF	FIGURE
Ckd By:	WGL	
Date:	AUG 2002	2
Project:	98-047.16	

The purpose of this project is to construct a stable, riffle pool stream channel that will enhance water quality functions in the vicinity of the Site and provide habitat for area wildlife. This document summarizes the step-wise implementation procedure used to restore the Lyle Creek Stream Restoration Site. Restoration construction activities were initiated on May 20, 2002 and completed on July 12, 2002.

2.0 SUMMARY

2.1 Pre-Construction Conditions

Prior to mitigation activities, the Site was characterized by pastureland actively grazed by livestock and disturbed hardwood forest. The stream had incised and downcut below the effective rooting depth of existing on-site vegetation. Both the mainstem channel and secondary tributary supported a transitional channel characterized by a G-type (gully) and F-type (widened gully) stream (Rosgen 1996). G-type streams are characterized as highly entrenched streams with a low width/depth ratio (<12). Typically, G-type streams downcut and widen by eroding laterally into channel banks during peak flows. Over time, the widened gully develops into an F-type channel that supports a relatively high width/depth ratio (>12) (Rosgen 1996a).

Photo 1

Pre-Construction Conditions (Pastureland)

The mainstem channel, the primary on-site restoration feature, supported a flood-prone area ranging from 11 feet to 34 feet in width with an entrenchment ratio in degraded reaches ranging from 1.1 to 1.3. Without bank vegetation to reduce erosion, the banks would have continued to erode into a broad, widened gully with intermittent point and mid-channel bars (F-type stream). The amount of eroded material required to re-establish a stable floodplain and meandering stream has been estimated at approximately 14,500 cubic yards.

Photo 2

Pre-construction Conditions (Bank Erosion)

Photo 3

Pre-construction Conditions (Stream Downcutting and Widening)

2.2 Project History

In the spring of 2001, WRP contacted EcoScience Corporation (ESC) to prepare a detailed mitigation plan at the Site. Detailed mitigation studies were completed in the fall of 2001. Upon completion of the detailed mitigation plan and issuance of permits, construction plans and bid documents were developed and the project was bid on March 27, 2002. North State Environmental was awarded the construction contract and work was initiated on May 20, 2002. The project was monitored by the State Construction Office, Charlotte District. Information on project managers and contractors follows.

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2.3 Sequencing

This restoration effort is designed to restore a stable, meandering stream that approximates hydrodynamics, stream geometry, and local microtopography characteristic of reference conditions. Site alterations designed to restore characteristic stream functions include 1) restoration of channel on new location and 2) restoration of channel in-place. An as-built stream restoration plan, including the locations of each reach, is depicted in Figure 3. Although work was conducted simultaneously on both reaches, each reach will be discussed separately for organizational purposes.

<u>Major Equipment Used in Stream Construction Activities</u>

Two major types of heavy equipment were used during construction of the Site: Track Hoe and Front End Loader. Task descriptions are listed below.

<u>Front End Loader</u>

- Materials Hauling
- Large-scale Excavation
- Ditch Backfill and Compaction

<u>Track Hoe</u>

- Floodplain Grading
- New Channel Excavation
- Structure Installation
- Ditch Plug Installation

2.3.1 Reconstruction on New Location

The reach of stream proposed for reconstruction on new location includes the downsteam portion of the mainstem channel where dredging and straightening of the channel has occurred. This portion of the Site is characterized by an adjacent floodplain which is suitable for design channel excavation. Primary activities designed to restore the channel on new location include 1) beltwidth preparation and grading, 2) channel excavation, 3) installation of in-stream structures, 4) channel ford construction, 5) installation of channel plugs, and 6) abandoned channel backfilling.

<u>1) Beltwidth Preparation and Grading</u>

The stream beltwidth corridor was cleared to allow survey equipment and machinery access. Care was taken to avoid the removal of existing deeply rooted vegetation within the beltwidth corridor, which may provide design channel stability. Floodplain grading occurred at the convergence of the design channel with the existing channel near the downstream end of the Site (Figure 4). Material excavated during floodplain grading were stockpiled immediately adjacent to the channel segments to be abandoned and backfilled. These segments were backfilled after stream diversion was complete.

After preparation of the beltwidth corridor and floodplain grading the design channel was staked and painted based on design parameters (Table 1). Design parameters painted included pool-to-pool spacing, radius of curvature, meander wavelength, and channel width. Stakes were placed on the design channel at the top of riffle, bottom of riffle, and pool locations. Stakes were labeled with riffle elevations, pool elevations, and other pertinent data. Once the channel was painted, detailed measurements were taken at each pool, including radius of curvature, arc length, and points of tangent.

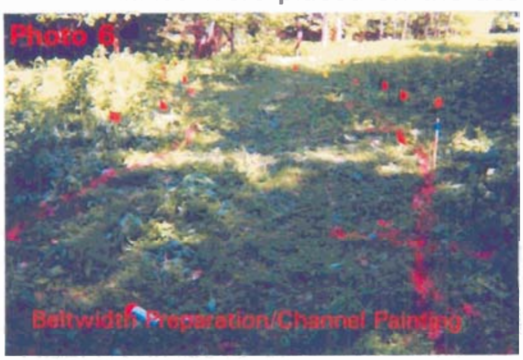


Table 1 Design Channel Pattern Variables (in feet)

Variable	Average	Range
Bankfull Width	11.2	9.9–13.3
Width (pool)	14.6	11 – 17
Beltwidth	88	33 - 141
Meander Length	71.9	41 - 163
Pool Length	20.2	15 - 43
Radius of Curvature	23.5	11 – 38
Pool-to Pool-Spacing	49	17 – 131
Sinuosity	1.5	

2) New Location Channel Excavation

Once beltwidth preparation was complete and the new location channel was painted, the channel was excavated utilizing a Track Hoe. The channel was excavated to grade based on design channel elevations. The top and bottom of each riffle were measured regularly with a laser level during excavation to ensure the desired grade was achieved. The channel was excavated to the range of dimension values presented in Table 2. The cross-sectional area, upon excavation, measured approximately 16 square feet, with a bankfull width ranging between 10 and 14 feet, and an average bankfull depth ranging between 1 and 2 feet.

Photo 8 New Channel Excavation

Photo 9 Maintaining Grade on New Channel Excavation

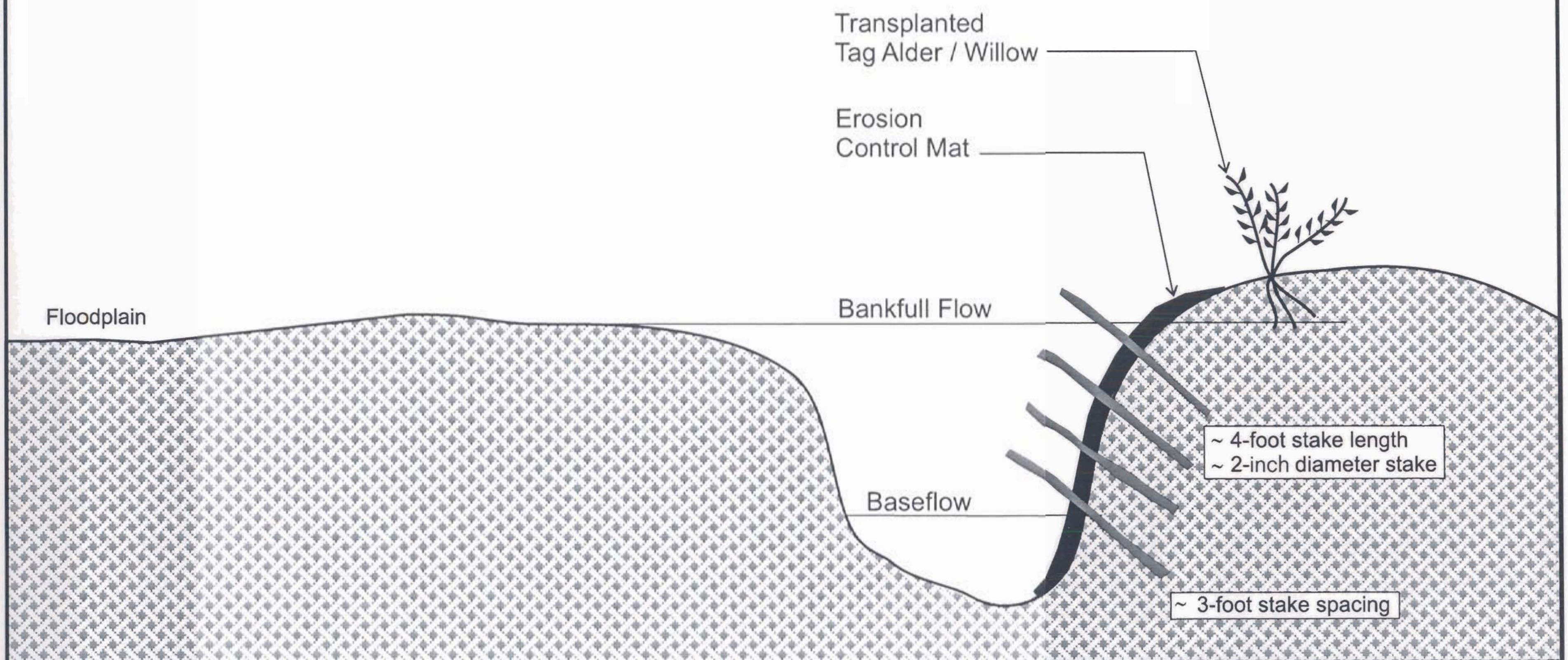
Table 2 Design Channel Dimension Variables (in feet)

Variable	Average	Range
Bankfull X-Sec Area	16.8	
Bankfull Width (riffle)	11.2	9.9–13.3
Depth Ave. (riffle)	1.5	1.0 – 2.0
Max Depth (riffle)	2.0	1.5 – 2.3
Width (pool)	14.6	11 - 17
Max Depth (pool)	3.0	2.6 – 3.5
Width/Depth Ave.	8	5 - 12
Bank Height Ratio	1.0	

Particular attention was directed toward providing stable vegetative cover and root growth along the outer bends of each stream meander. Live willow stake revetments were constructed as conceptually depicted in Figure 5. Available root mats or biodegradable, erosion control matting were embedded into the break-in-slope to promote channel stability. Willow stakes were harvested the night before installation and inserted through erosion control matting into the underlying soil.

3) Installation of In-stream Structures

In-stream structures were installed at locations depicted in Figure 3. Structures installed in the new location reach include cross vane weirs and log vane weirs. The purpose of these structures is to 1) direct high velocity flows during bankfull events toward the center of the channel, 2) increase the average pool depth throughout the reach, and 3) modify energy distributions through increases in channel roughness and local energy slopes during peak flows.



Not To Scale

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Live Willow Stake Embankment with Erosion Control Matting
LYLE CREEK AS-BUILT CONSTRUCTION REPORT
Catawba County, North Carolina

Figure: 5
Project: 98-047.16
Date: AUG 2002

a) Cross Vane – Cross vane weirs were constructed of boulders approximately 18 inches in minimum width. A typical cross-vane structure is depicted in Figure 6. Cross vane construction was initiated by imbedding footer rocks into the stream bed for stability and to prevent undercutting of the structure. Header rocks were subsequently placed atop the footer rocks at the design elevation. Footer and header rocks create an arm that slopes from the center of the channel upward at approximately 10 to 15 degrees, tying in at the bankfull floodplain elevation. The cross vane arms at both banks were tied into the bank with a sill to eliminate the possibility of water diverting around the structure (Figure 6).

Once the header and footer stones were in place, filter fabric was buried into a trench excavated around the upstream side of the vane arms. The filter fabric was draped over the header rocks to force water over the vane. The upstream side of the structure was then backfilled with suitable material to the elevation of the header stones.


Photo 10
Cross Vane Weirs (Installation of Footer Stones)


Photo 11
Cross Vane Weirs (Installation of Filter Fabric)


Photo 12
Cross Vane Weirs (Installation of Filter Fabric)

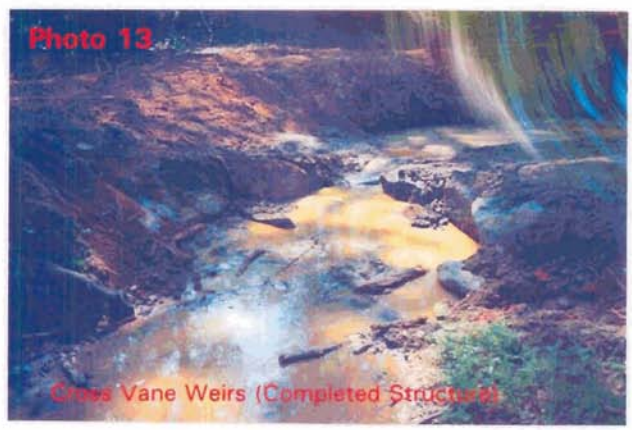
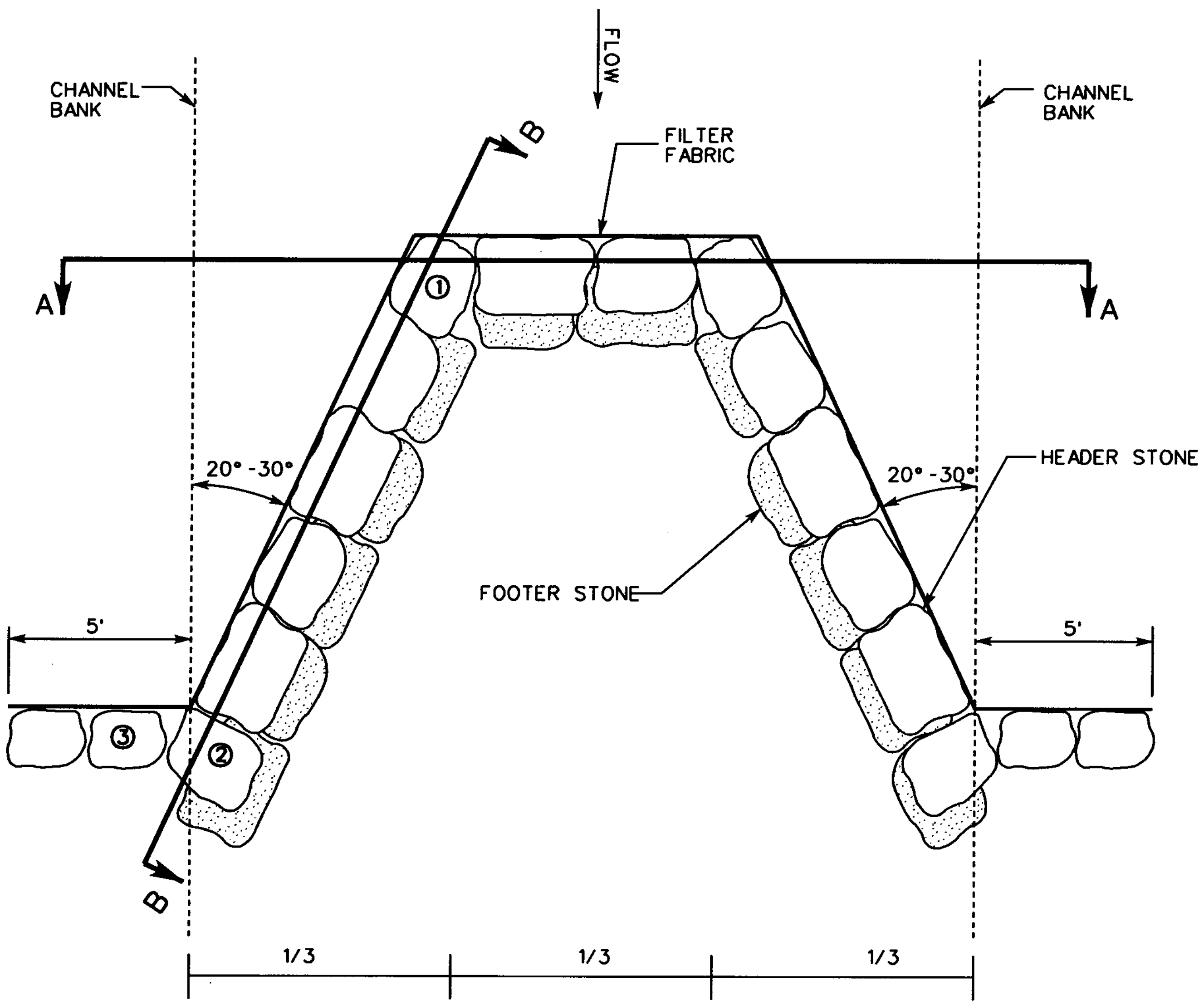


Photo 13
Cross Vane Weirs (Completed Structure)

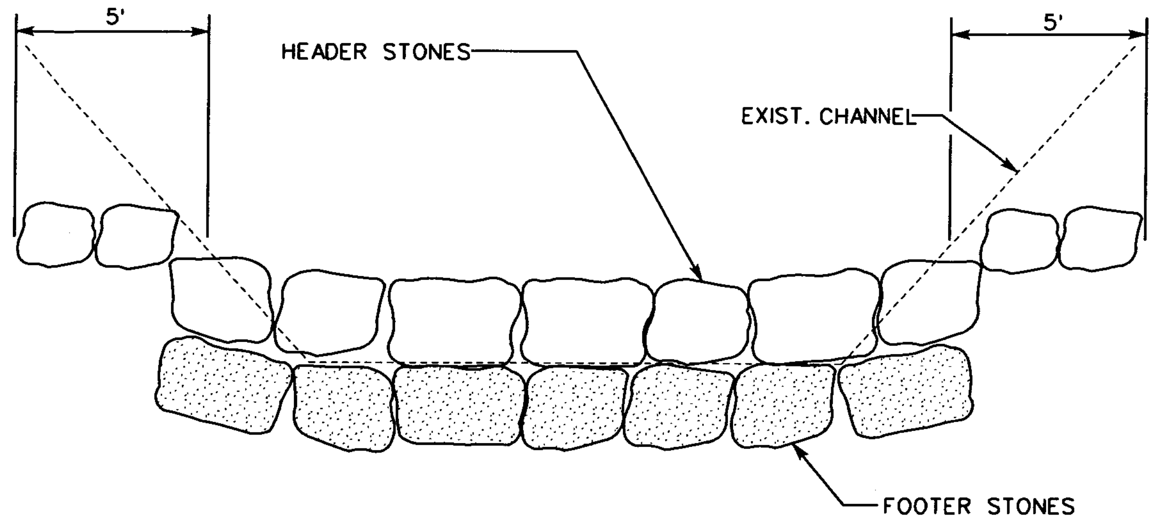
b) Log Vane – Log vane weirs were constructed utilizing large tree trunks harvested from the Site. A typical log vane structure is depicted in Figure 7. The tree stem harvested for a log vane arm must be long enough to be imbedded into the stream channel and extend several feet into the floodplain.



PLAN VIEW

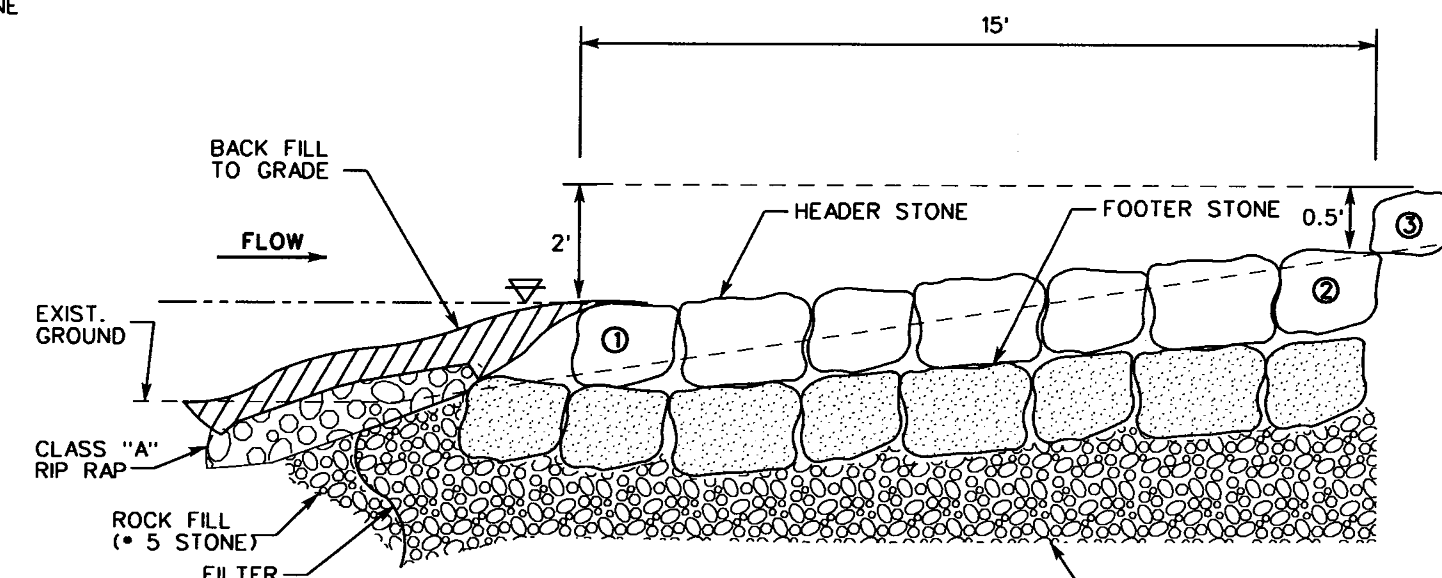
SCALE: N.T.S.

NOTE: HEADER AND FOOTER STONES ARE LARGE BOULDERS APPROXIMATELY 36" IN DIAMETER



SECTION A-A

SCALE: N.T.S.



SECTION B-B

SCALE: N.T.S.

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REVISIONS

Client:
NC WETLAND RESTORATION PROGRAM

Project:
LYLE CREEK AS-BUILT CONSTRUCTION REPORT

CATAWBA COUNTY, NORTH CAROLINA

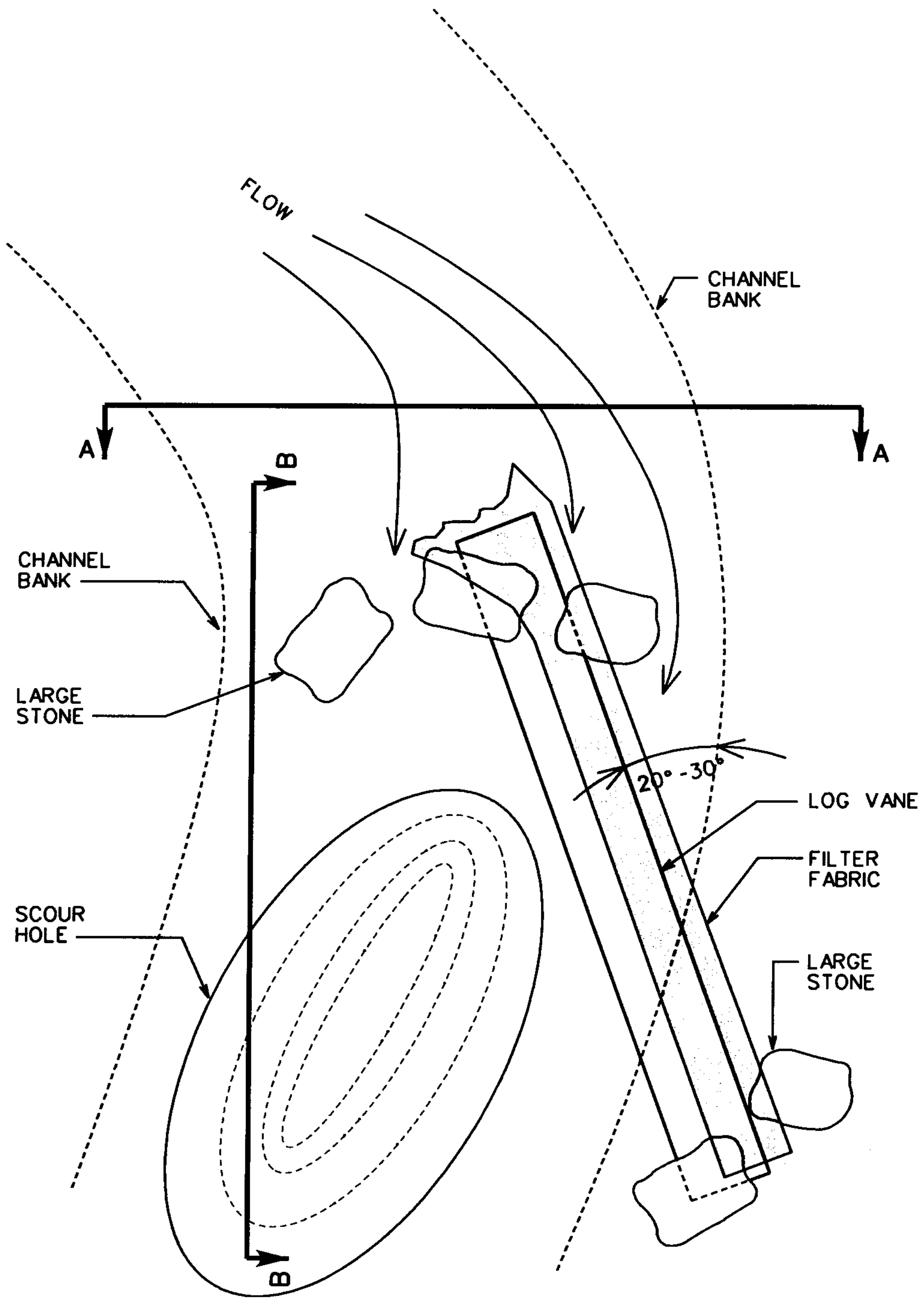
Title:
CROSS-VANE WEIR

Dwn By: MAF	Date: AUG 2002
Ckd By: JG	Scale: As Shown

ESC Project No.: 98-047.16

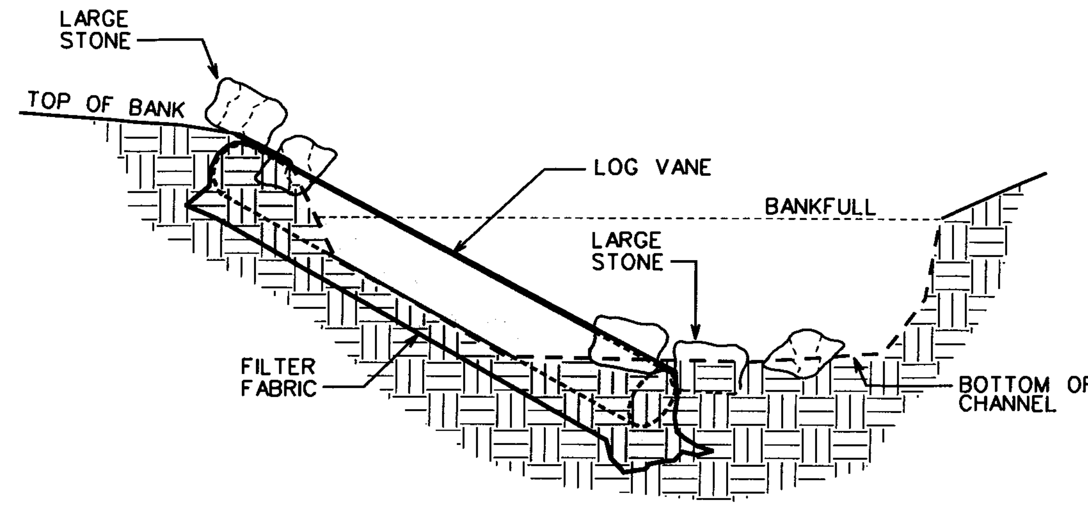
FIGURE

6

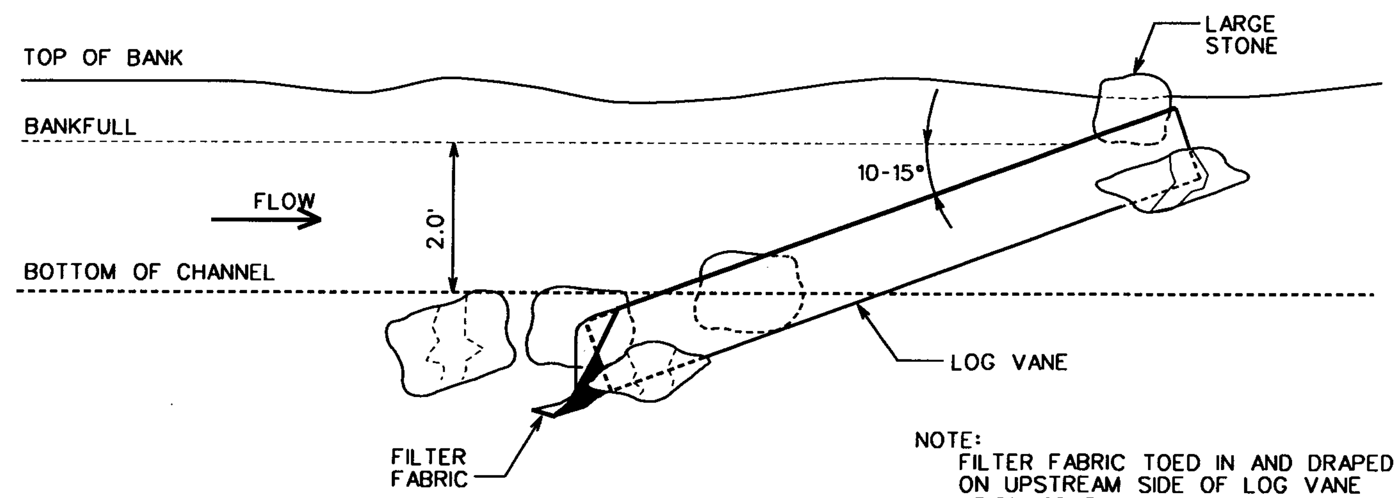


PLAN VIEW
SCALE: N.T.S.

NOTE:
FILTER FABRIC TOED IN AND DRAPED ON UPSTREAM SIDE OF LOG VANE PRIOR TO BACKFILL.



CROSS-SECTION A-A
SCALE: N.T.S.



PROFILE B-B
SCALE: N.T.S.

NOTE:
FILTER FABRIC TOED IN AND DRAPED ON UPSTREAM SIDE OF LOG VANE PRIOR TO BACKFILL.

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REVISIONS

Client:
NC WETLAND RESTORATION PROGRAM

Project:
LYLE CREEK AS-BUILT CONSTRUCTION REPORT

CATAWBA COUNTY, NORTH CAROLINA

Title:
LOG VANE WEIR

Dwn By: MAF	Date: AUG 2002
Ckd By: JG	Scale: As Shown

ESC Project No.: 98-047.16

FIGURE
7

A trench is dug into the stream channel that is deep enough for the head of the log to be at or below the channel invert. The trench is extended into the floodplain and the log is set into the trench such that the log arm is below the floodplain elevation. If the log is not of sufficient size to completely block stream flow (gaps occur between the log and channel bed) then a footer log or stone footers was installed beneath the header log. Boulders are then situated at the base of the log and at the head of the log to hold the log in place.


Photo 14 Log Vane Weirs (Excavating Channel Bed)

Similar to a cross vane, the log forms an arm that must slope from the center of the channel upward at approximately 10 to 15 degrees, tying in at the bankfull floodplain elevation. Once the log vane is in place, filter fabric is toed into a trench on the upstream side of the vane and draped over the log to force water over the structure. The upstream side of the log vane is then backfilled with suitable material.


Photo 15


Photo 16 Log Vane Weirs (Backfilling Behind Vane)


Photo 17 Log Vane Weirs (Final Structure)

4) Channel Ford Construction

A channel ford was constructed at the downstream reach of the Site in order to allow access to the northern portion of the property. The ford consists of a shallow depression in the stream banks where vehicular crossings can be made. The ford location is depicted in Figure 3 and a typical ford design is depicted in Figure 8.

Ford construction was initiated by excavating the approach grades on each side of the stream channel. The ford approaches are approximately 30 feet in length and are graded at an approximately 10:1 slope. Once the approaches were excavated, the ford was covered in filter fabric that was toed into a trench on the upstream edge. Boulders were then placed on the filter fabric and keyed into the stream bed. Boulders covered the channel bed and approach arms to reduce the risk of channel meander around the ford. The ford bed elevation was constructed to the slope and bed elevation of the design stream channel above and below the ford to reduce the risk of headcutting. After the boulders were in place, rip-rap and small boulders were placed along the ford and compacted into small holes and soil surfaces adjacent to the boulders.


Photo 18
Channel Ford Construction (Installation of Filter Fabric)

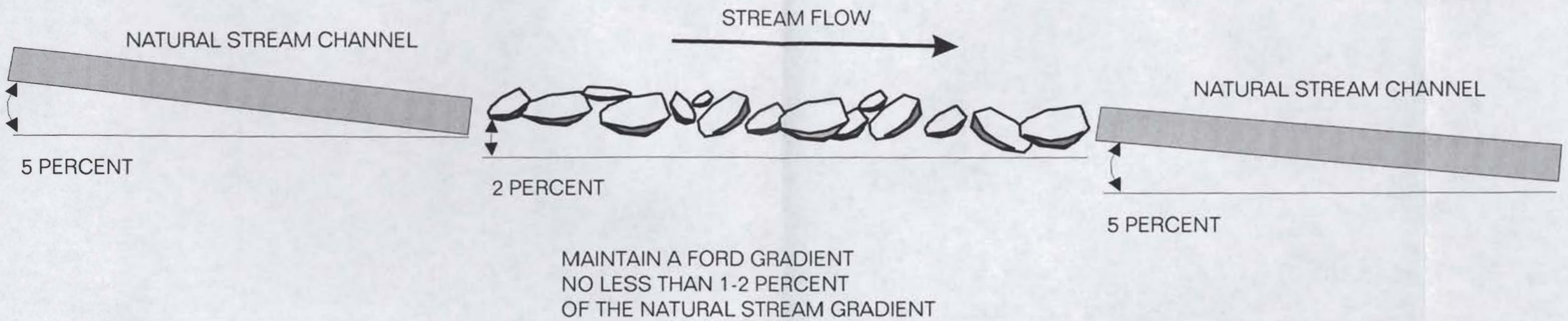

Photo 19
Channel Ford Construction (Boulder Installation)


Photo 20
Channel Ford Construction (Rip-Rap Approach Arms and Gaps)

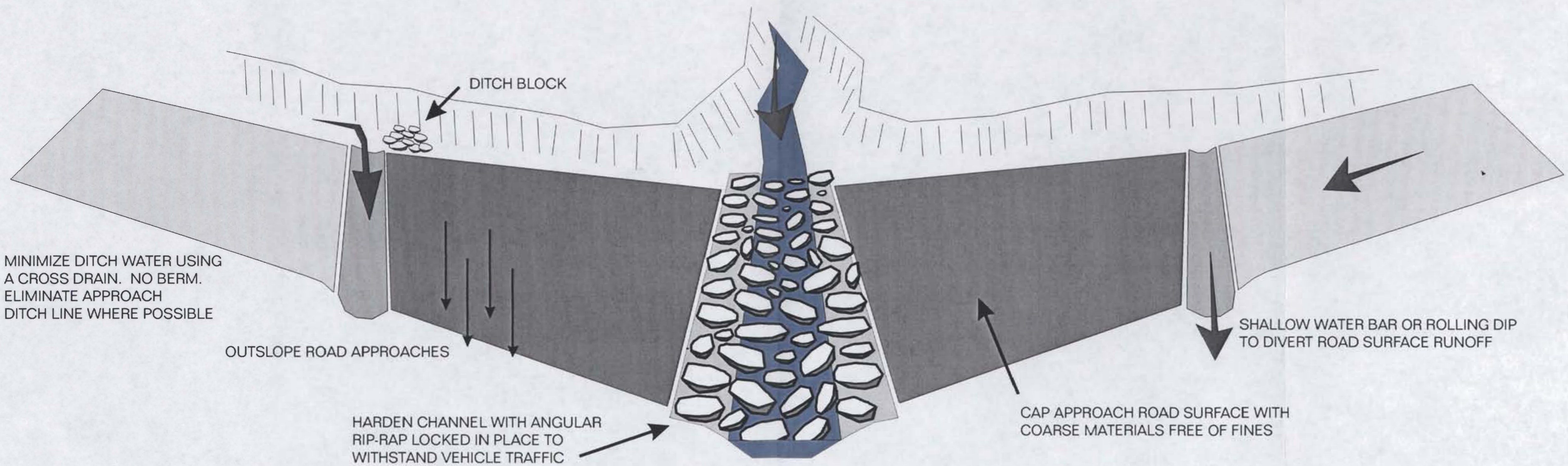
5) Installation of Channel Plugs

Impermeable plugs were installed along abandoned channel segments at locations identified in Figure 3. The plugs consist of low-permeability materials designed to be of sufficient strength to withstand erosive surface flows across the site. Dense clays excavated from borrow areas on-site were compacted within the channel and the channel was backfilled behind the channel plugs with stockpile material. The plugs were sufficiently wide and deep to form an imbedded overlap in the existing banks and channel bed.

Adapted from Stream Crossing Guidebook for Fish Streams. A Working Draft 1997/1998 Forest Practice Code Guide Books. B.C Canada



CROSS-SECTIONAL VIEW



PLAN VIEW

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TYPICAL FORD CONSTRUCTION
LYLE CREEK AS-BUILT CONSTRUCTION REPORT
Catawba County, North Carolina

Figure:	8
Project:	98-047.16
Date:	JUL 2002

6) Channel Backfilling

After impermeable plugs were installed, the abandoned channel was back-filled. Backfilling was performed primarily by pushing stockpiled materials into the channel. The channel was filled and compacted to maximize microtopographic variability, including ruts, ephemeral pools, and hummocks.

A deficit of fill material for channel back-fill occurred; therefore, additional fill material was obtained from two borrow areas located on the northern floodplain edge (Figure 3). In addition, a series of closed linear depressions were left along confined segments of the abandoned channel. These pools are expected to stabilize and fill with organic material over time. Vegetation debris (root mats, root wads, top soils, shrubs, woody debris, *etc.*) was be redistributed across the backfill area upon completion.

2.3.2 Reconstruction In-Place

The reach of stream proposed for reconstruction in-place includes the upstream portion of the mainstem channel where livestock have degraded the existing stream. This portion of the Site is characterized by a sinuous stream pattern, which is laterally confined by narrow and steep valley walls. The narrow valley precludes the development of a channel on new location. Primary activities designed to restore the channel in-place include 1) installation of in-stream structures, 2) bankfull bench excavation, and 3) installation of root wad structures.

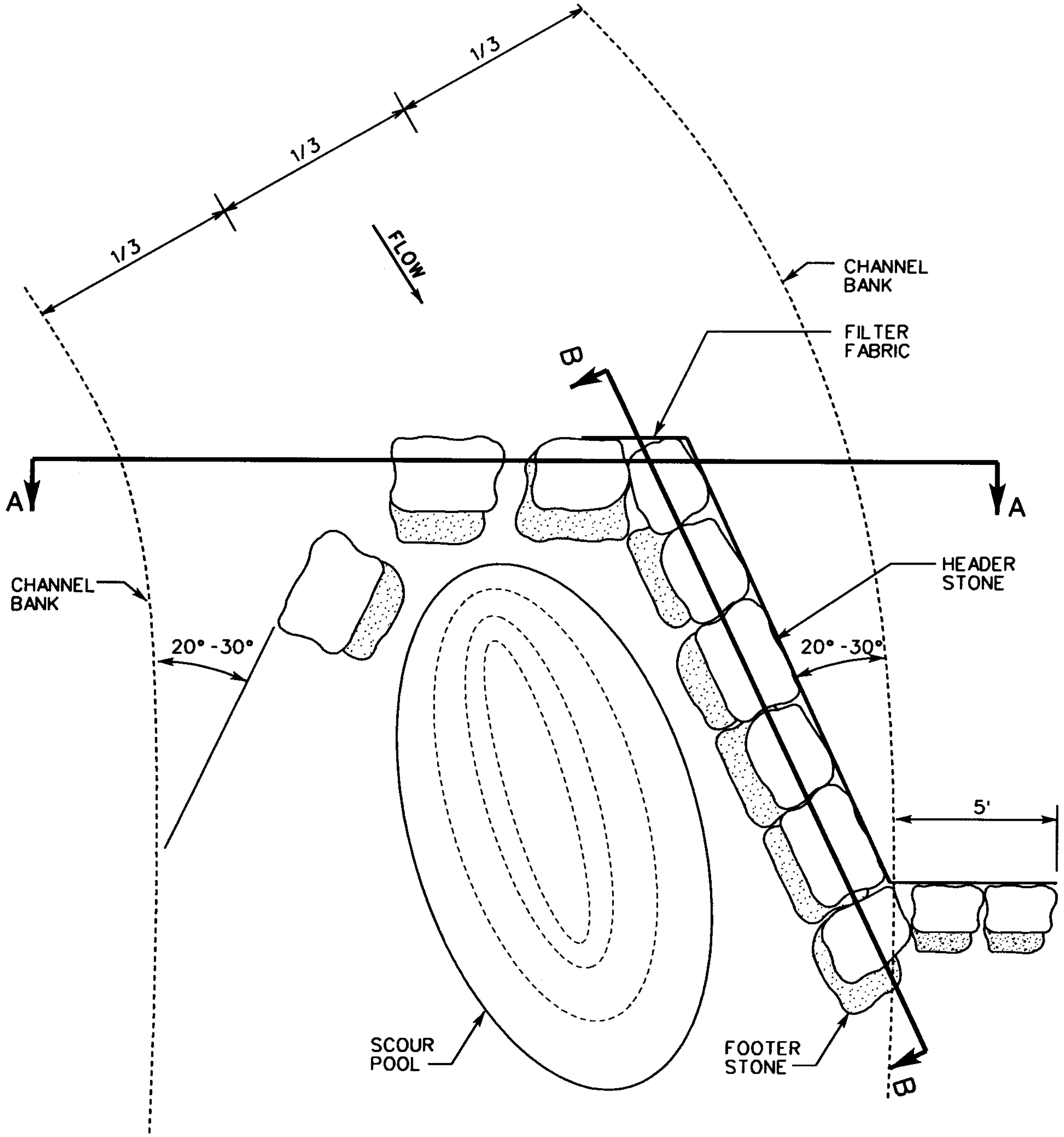
1) Installation of In-Stream Structures

In-stream structures were installed at locations depicted in Figure 3. Structures installed include 1) cross vane weirs, 2) log vanes, and 3) a J-hook vane. The purpose of these structures is to 1) increase the water surface elevations and reconnect the adjacent floodplain to flooding dynamics from the stream, 2) direct high velocity flows during bankfull events toward the center of the channel, and 3) modify energy distributions through increases in channel roughness and local energy slopes during peak flows.

Cross vane weir and log vane construction were described in detail in Section 2.3.1 (Reconstruction on New Location) of this report and therefore will not be discussed in detail in this section. One J-hook vane was installed at the upper extent of the Site, even though the original construction plans indicated a cross vane weir was to be utilized at this location. No grade control was required for the first structure at the upstream project terminus; therefore, a J-hook vane was installed to reduce the amount of stone in this structure. J-hook vanes are constructed similar to cross-vane weirs; however, one arm (inner bend of the stream) is eliminated from the structure and the structure functions to reduce stress on the outer bank. A typical J-hook vane is depicted in Figure 9.

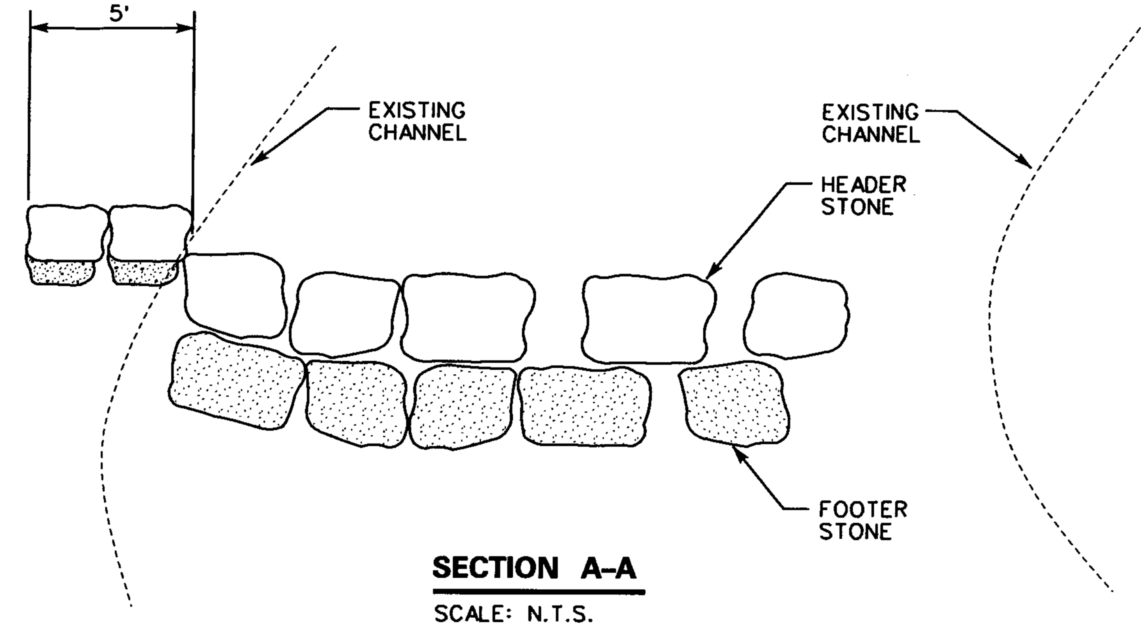
2) Bankfull Bench Excavation

The creation of a bankfull floodplain bench is expected to 1) remove eroding material and collapsing banks, 2) promote over bank flooding during bankfull flood events, 3) reduce the bank height ratio to 1.0, and 4) increase the width of the active floodplain. The location of bankfull benches in the upstream reach are depicted in Figure 3.



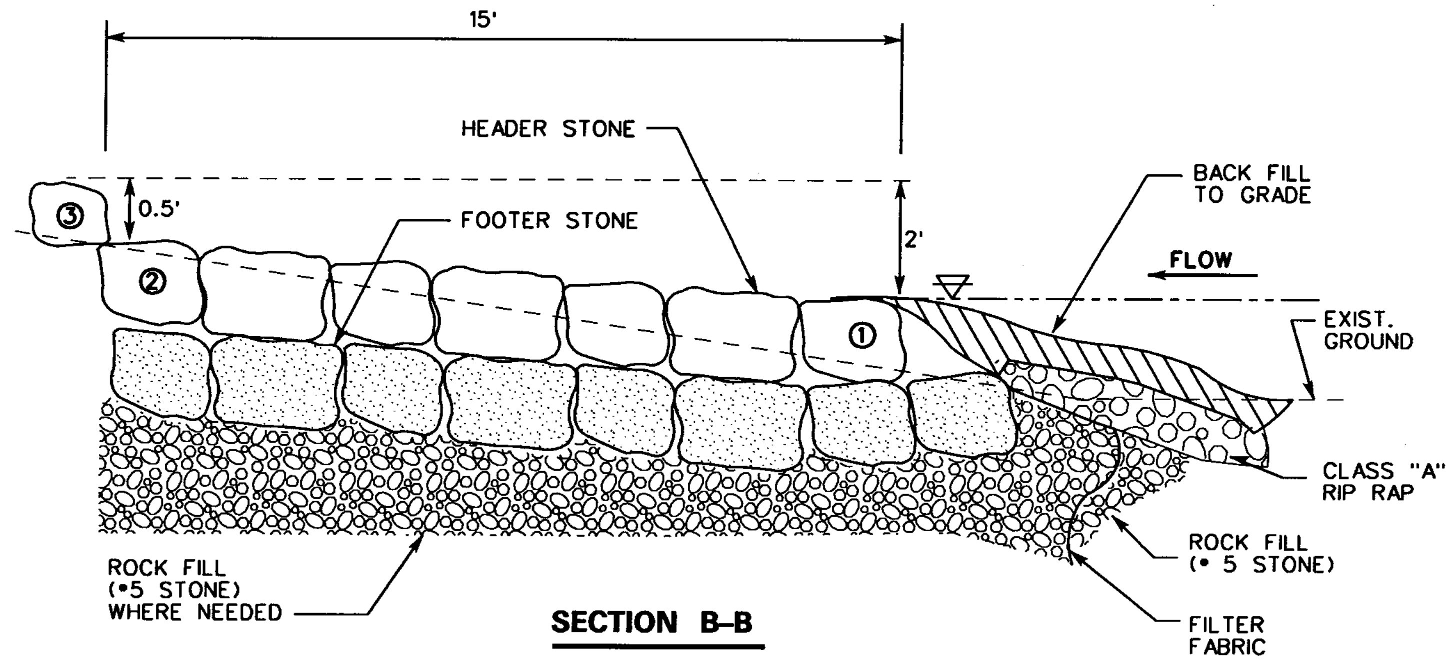
PLAN VIEW

SCALE: N.T.S.



SECTION A–A

SCALE: N.T.S.



SECTION B–B

SCALE: N.T.S.

NOTE: HEADER AND FOOTER STONES ARE LARGE BOULDERS APPROXIMATELY 36" IN DIAMETER

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Raleigh, North Carolina

REVISIONS

Client:

NC WETLAND RESTORATION PROGRAM

Project:

LYLE CREEK AS–BUILT CONSTRUCTION REPORT

CATAWBA COUNTY, NORTH CAROLINA

Title:

TYPICAL J–HOOK VANE

Dwn By: MAF	Date: AUG 2002
Ckd By: JG	Scale: As Shown
ESC Project No.: 98-047.16	

FIGURE

9

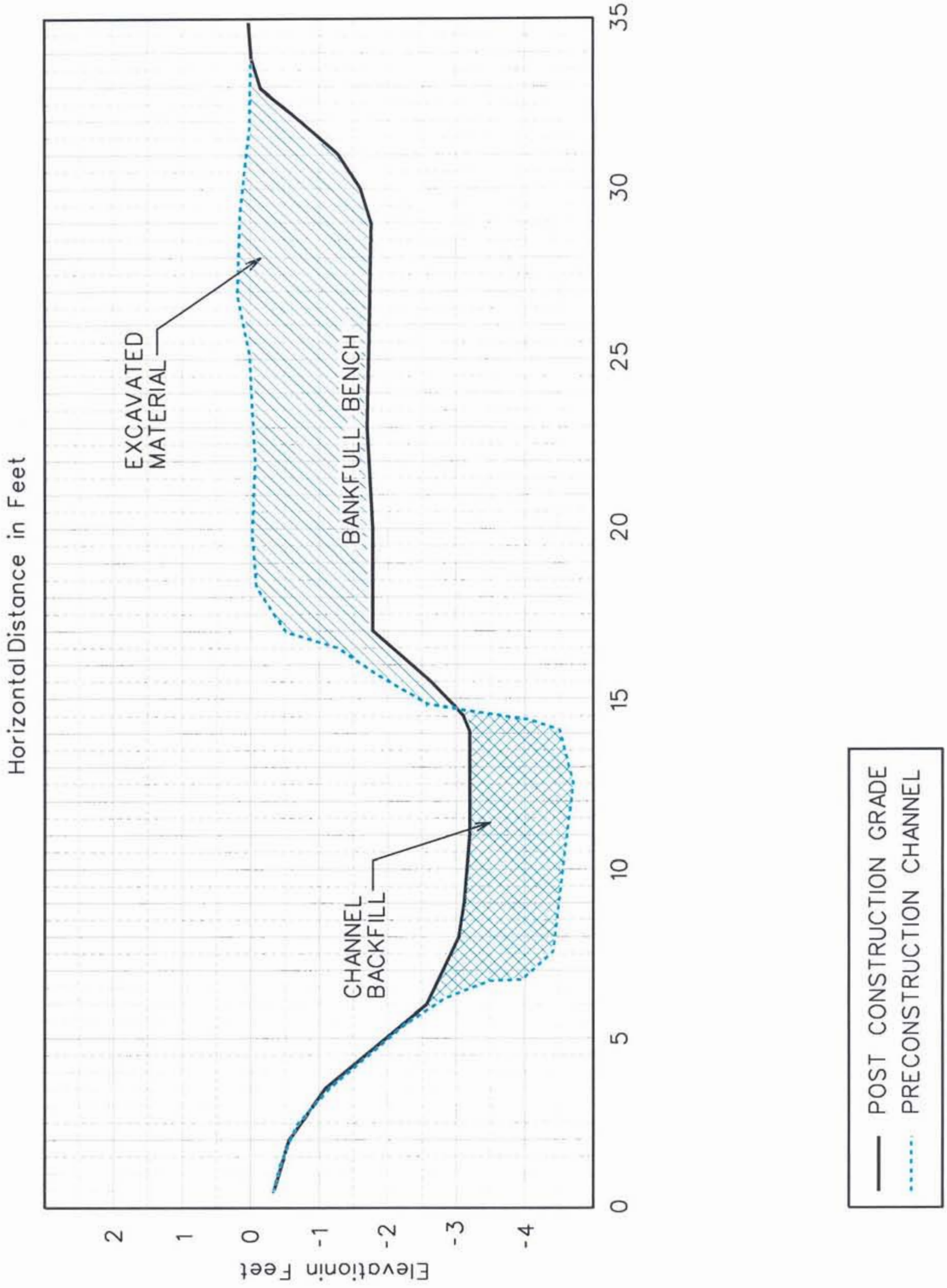
Bankfull benches were created by excavating the adjacent floodplain to bankfull elevations or filling eroded/abandoned channel areas with suitable material. The proposed floodplain bench extends for approximately 15 feet from the stream bank. A 2:1 slope rises from the floodplain bench to the existing floodplain grade (Figure 10). Approximately 300 cubic feet of material was removed during bench excavation. The proposed floodplain bench increases the floodprone area in the upstream reach from 25 feet to 42 feet (G-type stream to an E-type stream) and reduces the bank height ratio from 1.5 to 1.0 (low bank height/maximum bankfull depth).

After excavation, or filling of the bench, a relatively level floodplain surface was stabilized with suitable erosion-control measures. Planting of the bench with permanent seeding and erosion-control matting is expected to reduce erosion of bench sediments, reduce flow velocities in flood waters, filter pollutants, and provide wildlife habitat.

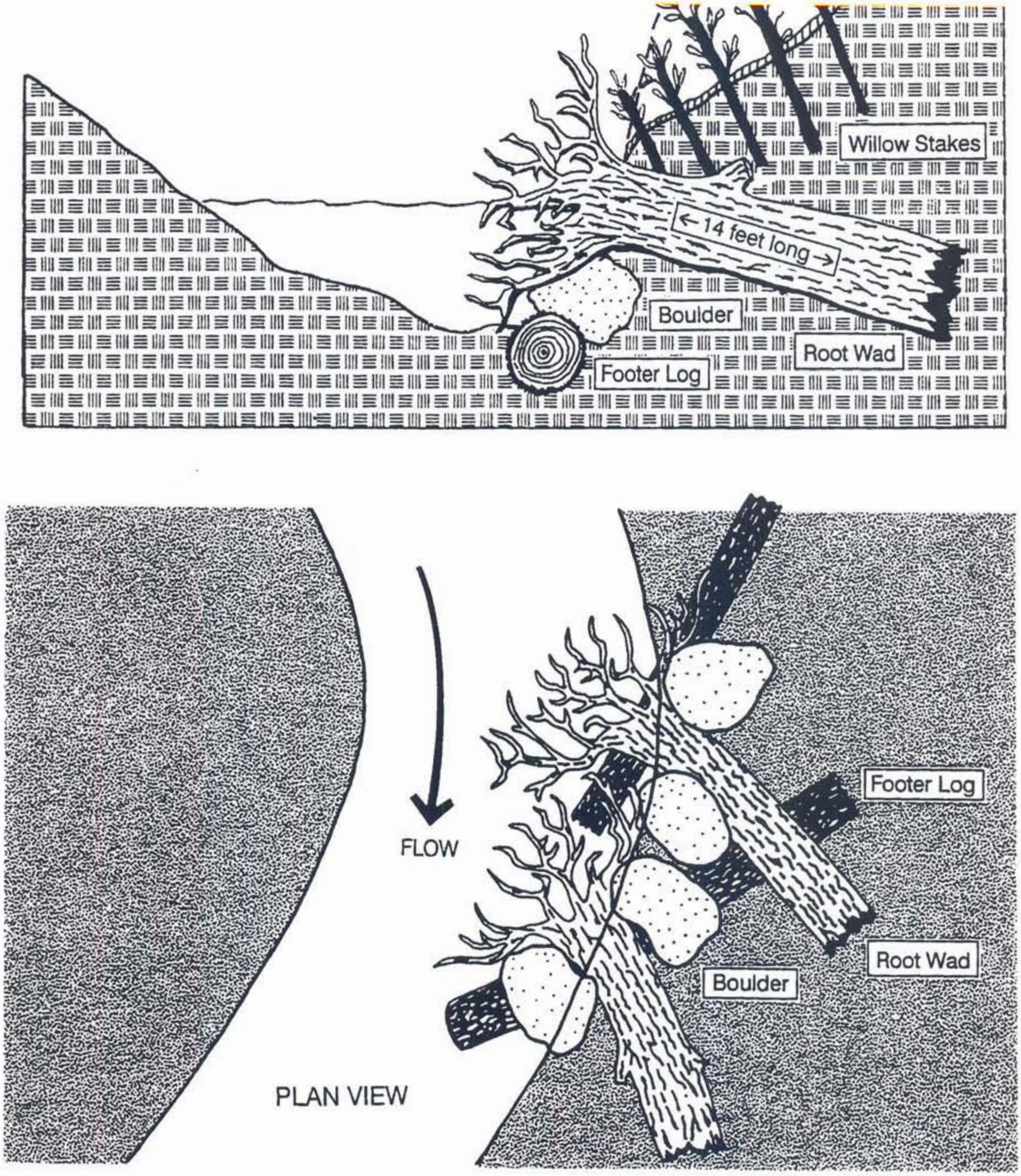
<u>3) Root Wad Installation</u>

Root wads were installed in high-energy areas or in reaches of the channel characterized by excessive bank collapse. Root-wad structures were installed at locations depicted in Figure 3. The purpose of the root wads are to 1) stabilized stream banks and reduce erosion/sedimentation of the stream, 2) reduce shear stress in the near bank region, 3) reduce stream width to design parameters, and 4) provide diverse in-stream habitat including shade, detritus, and bank overhang.

A typical root-wad structure is depicted in Figure 11. Root wads were harvested on-site from trees that had to be removed for machinery access. Upon uprooting of a tree, approximately 10 to 15 feet of trunk was left intact. This 10- to 15-foot section of trunk was used to anchor the root wad in the bank. Prior to the installation of each root wad, a trench was excavated along the toe of the bank. Toe protection, consisting of a footer log or boulder, was placed within the excavated trench. Individual root wads were subsequently placed on top of the footer log with the root mass oriented such that the velocity vectors flow across the structure (Figure 11). Once the root wads were in place, large boulders were placed on top of the root-wad trunks and the trench excavation area was backfilled and compacted.



EcoScience Corporation Raleigh, North Carolina	Client: **NC WETLAND RESTORATION PROGRAM**	Project: **BANKFULL BENCH EXCAVATION** **LYLE CREEK AS–BUILT CONSTRUCTION REPORT** **Catawba County, North Carolina**	Dwn By: MAF Ckd By: WGL Date: AUG 2002 Scale: NO SCALE ESC Project No.: 98-047.16	FIGURE **10**



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ROOT WAD REVETMENT
(Modified from Rosgen 1996)
LYLE CREEK AS-BUILT CONSTRUCTION REPORT
Catawba County, North Carolina

Dwn. by:	MAF
Ckd by:	WGL
Date:	AUG 2002
Project:	98-047.16

FIGURE 11

2.3.3 Secondary Tributary Enhancement

Enhancement of approximately 800 linear feet of secondary tributary is expected to occur through the removal of livestock from the channel and supplemental planting. No proactive restoration activities were conducted in the secondary tributary during this phase of construction. However, supplemental plantings are scheduled for the fall of 2002. Livestock were removed from the Site prior to initiation of construction on the mainstem channel.

2.4 As-Built Physical Stream Attributes

This stream restoration effort includes approximately 2400 linear feet of constructed stream, including approximately 1345 linear feet restored on new location and 1055 linear feet restored in place. A current plan view of the constructed stream is depicted in Figure 12. Table 3A depicts a summary of stream pattern, dimension, profile, and substrate attributes measured before construction and after construction, as well as proposed stream attributes. Table 3B depicts stream attribute ratios for analysis.

Channel Dimension Attributes

Channel dimension attributes were obtained from cross-sections depicted in Figure 12. Seven cross-sections were established along the constructed channel, four in the new location reach and three in the in-place reach. The constructed channel currently exhibits a bankfull median width of 11.2 feet, a bankfull median depth of 1.4 feet, and a bankfull median width/depth ratio of 8. The cross-sectional area averages 16.5 feet and ranges from 15.2 to 17.5 square feet (Tables 3A and 3B). Riffle and pool maximum depths were 2.5 and 2.9 feet, respectively. Channel dimensions do not vary significantly from the proposed variables.

Channel Pattern Attributes

Channel pattern attributes measured in the field are depicted in Figure 12. The belt width ranges from 33 feet to 141 feet and meander wavelengths range from 32.7 feet to 114 feet (Tables 3A and 3B). Sinuosity measures approximately 1.6 throughout the on-site reach. The floodprone area width varies between 132 feet to 175 feet, including entrenchment ratios range from 12 to 16 (floodprone area/bankfull width). Channel pattern attributes do not vary significantly from the proposed variables.

Channel Slope and Substrate Attributes

Channel slope and substrate attributes were obtained from constructed bed slope calculations and profile measurements (Figure 13). The water surface slope averaged 0.0076 (rise/run) relative to a valley slope of approximately 0.012 (rise/run). The median riffle and pool slopes were 0.0141 and 0.0022, respectively. Compared to proposed conditions, the range of riffle and pool slopes were slightly extended. Several conditions may explain this discrepancy including drought conditions (no water in the channel during as-built surveying) and variations in survey techniques during as-built measurements.

Channel materials were quantified by a representative, stratified pebble count (Appendix A). The D50 for the composite total (used for classification purposes) measured 0.2 millimeter (fine sand). The segmented particle size for the D50 in the riffle sections also

Table 3A
Stream Geometry and Classification
Lyle Creek Stream Restoration Site
(Area of Watershed 0.5 square miles)

Dimension

Attribute	Pre-construction Median	Pre-construction Range	Proposed Conditions Median	Proposed Conditions Range	Post Construction Median	Post Construction Range
A_{bkf}	16.8	NA	16.8	NA	16.5	15.2 – 17.5
W_{bkfl} (riffle)	9.9	8.5 - 13.3	11.2	9.9 - 13.3	11.2	10.7 – 13.2
D_{bkf} (riffle)	1.4	1.2 - 2.2	1.5	1.0 - 2.0	1.4	1.2 - 1.6
D_{max} (riffle)	2.2	1.7 - 2.7	2.0	1.5 - 2.3	2.5	2.2 – 2.7
FPA (riffle)	15.2	11 - 34.3	150	108 - 209	152	132 – 175
W_{pool}	11.7	9.4 - 14	14.6	11 - 17	14.6	12.8 – 16.4
D_{max} (pool)	3.1	2.7 - 3.4	3.0	2.6 - 3.5	2.9	2.7 – 3.1
L_{pool}	97.3	41 - 163	20.2	15 - 43	27	14 – 64
LBH	4.7	2.2 - 6.2	2.0	1.5 - 2.3	2.4	2.2 – 2.8

Pattern

Attribute	Pre-construction Median	Pre-construction Range	Proposed Conditions Median	Proposed Conditions Range	Post Construction Median	Post Construction Range
W_{belt}	No distinct repetitive pattern of riffles and pools within the degraded channel		88	33 - 141	88	33 – 141
L_m			72	41 - 163	63	32.7 – 114
R_c			23.5	11 - 38	22.4	14.9 – 37.5
$L_{p\text{-}p}$			49	17 - 131	54	22 – 161
Sin	1.3	1.1 - 1.7	1.5	NA	1.6	NA

Profile

Attribute	Pre-construction Median	Pre-construction Range	Proposed Conditions Median	Proposed Conditions Range	Post Construction Median	Post Construction Range
S_{sw}	.0093	NA	.008	NA	.0076	NA
S_{valley}	.012	NA	.012	NA	.012	NA
S_{riffle}	No distinct repetitive patter of riffles and pools		.010	.004 - .015	.0141	0 - .0364
S_{pool}			.0049	.0042 - .0056	.0022	0 - .0066

Stream Type	G 4/5	E 4/5	E 5

A_{bkf} Bankfull cross-sectional area (riffle) (ft^2)
W_{bkf} Bankfull width (ft)
D_{bkf} Average bankfull depth (ft)
D_{max} Maximum depth (ft)
FPA Floodprone Area (ft)
W_{pool} Channel width at a pool (ft)
L_{pool} Individual pool length (ft)
LBH Low bank height (distance from thalweg to the top of low bank) (ft)

W_{belt} Belt width (ft)
L_m Meander wavelength (ft)
R_c Radius of Curvature (ft)
$L_{p\text{-}p}$ Length from pool to pool (ft)
Sin Sinuosity (thalweg dist/straight-line dist.)
S_{ws} Slope of the water surface (rise/run)
S_{valley} Slope of the valley (rise/run)
S_{riffle} Slope of the riffle (rise/run)
S_{pool} Slope of the pool (rise/run)

Table 3B
Stream Geometry and Classification Ratios
Lyle Creek Stream Restoration Site
(Area of Watershed 0.5 square miles)

Dimension Ratios

Attribute	Pre-construction		Proposed Conditions		Post Construction	
	Median	Range	Median	Range	Median	Range
ENT	1.3	1.1 - 3.5	13	10 - 19	12	12 – 16
W_{bkf}/D_{bkf}	8	4 – 10	10	6 - 14	8	7 – 11
BHR	2	1 - 2.8	1.0	1.0 - 1.2	1.0	1.0 – 1.1
D_{max} (riffle) / D_{ave} (riffle)	1.3	1.2 - 1.8	1.3	1.0 - 1.5	1.6	1.6 – 1.8
D_{max} (pool) / D_{ave} (riffle)	2.2	1.9 - 2.4	2.0	1.7 - 2.3	2.0	1.9 – 2.2
W_{pool} / W_{bkf} (riffle)	1.2	0.9 - 1.4	1.3	1.0 - 1.5	1.3	1.1 – 1.4

Pattern Ratios

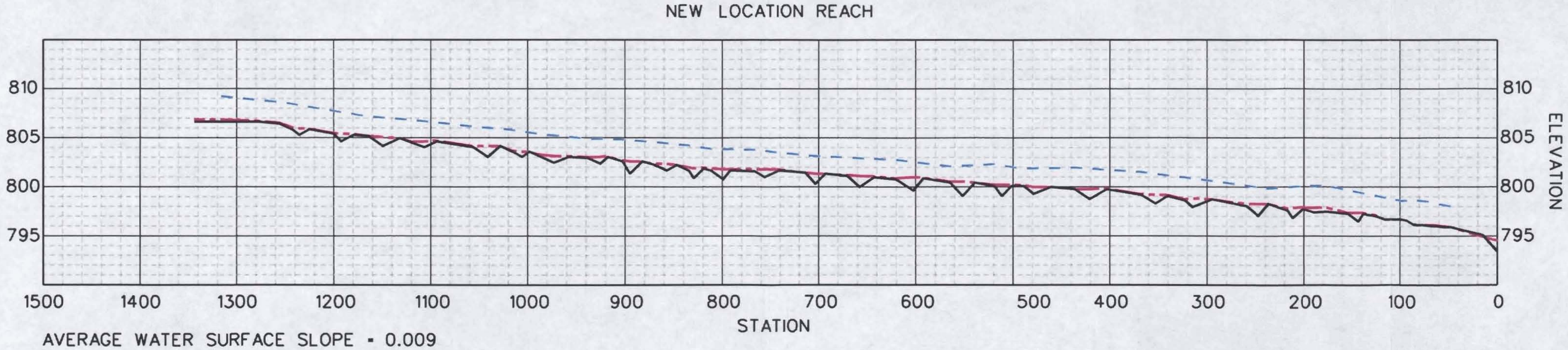
Attribute	Pre-construction		Proposed Conditions		Post Construction	
	Median	Range	Median	Range	Median	Range
W_{belt}/W_{bkf}	No distinct repetitive pattern of riffles and pools within the degraded channel		7.8	2.9 – 12.5	7.9	2.9 – 12.6
L_m/W_{bkf}			6.4	3.5 – 14	5.6	2.9 – 10.2
R_c/W_{bkf}			2.1	1.0 – 3.4	2	1.3 – 3.3
L_{p-p}/W_{bkf}			4.3	1.5 – 11.6	4.8	2.0 – 14.4

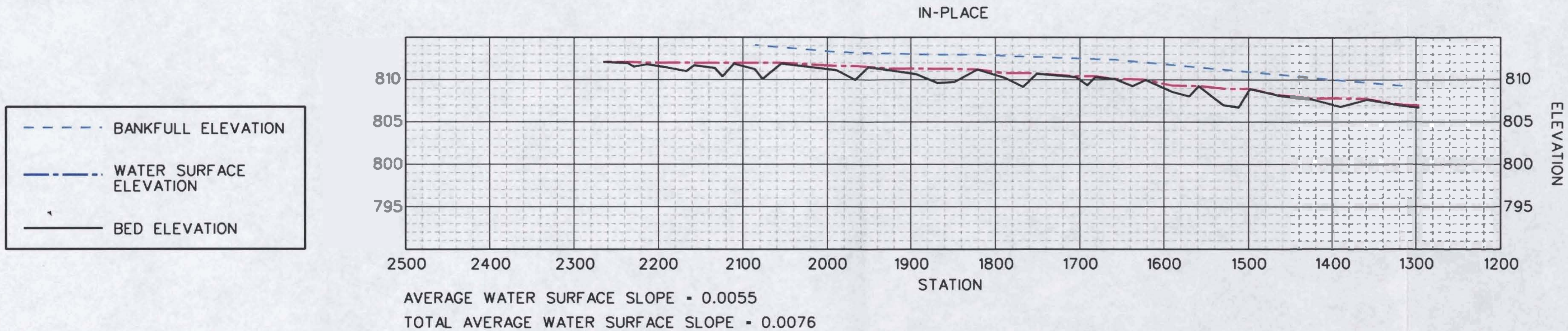
Profile Ratios

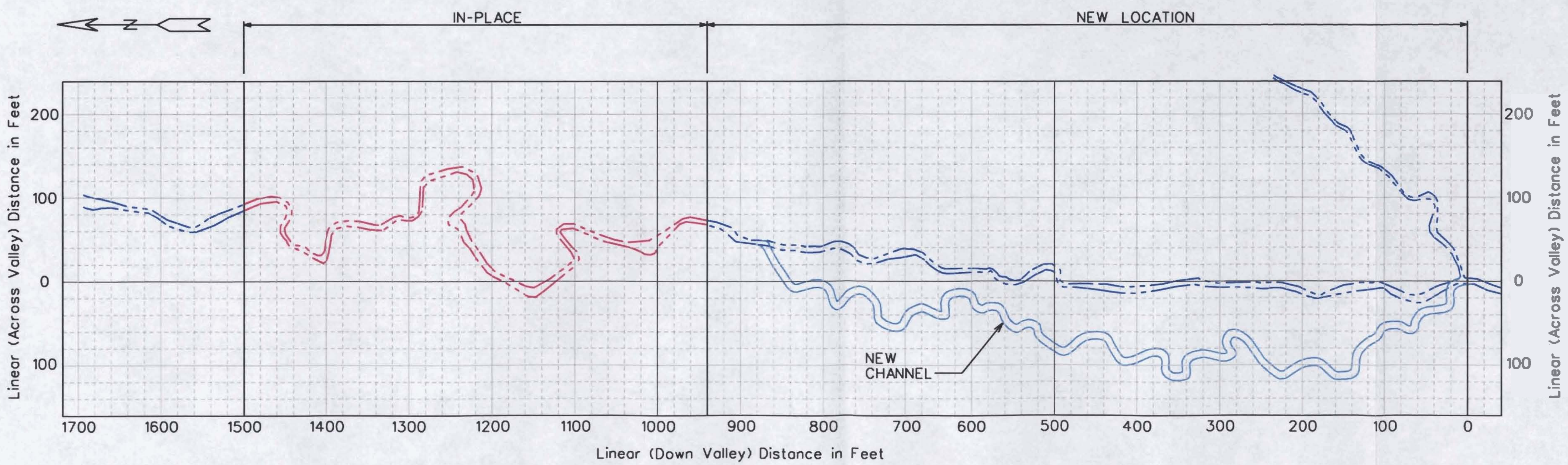
Attribute	Pre-construction		Proposed Conditions		Post Construction	
	Median	Range	Median	Range	Median	Range
S_{valley}/S_{ws}	1.3	NA	1.5	NA	1.6	NA
S_{riffle}/S_{ws}	No distinct repetitive pattern of riffles and pools		1.4	0.6 – 2.1	1.9	0 – 4.8
S_{pool}/S_{ws}			0.7	0.6 – 0.8	0.3	0 – 0.9

ENT Entrenchment ratio (FPA/W_{bkf})
W_{bkf} Bankfull width (ft)
D_{bkf} Average bankfull depth (ft)
BHR Bank height ratio [low bank height/D_{max} (riffle)]
D_{max} Maximum depth (ft)
FPA Floodprone area (ft)
W_{pool} Channel width at a pool (ft)
L_{pool} Individual pool length (ft)
LBH Low bank height (distance from thalweg to the top of low bank) (ft)

W_{belt} Belt width (ft)
L_m Meander wavelength (ft)
R_c Radius of Curvature (ft)
L_{p-p} Length from pool to pool (ft)
Sin Sinuosity (thalweg dist/straight-line dist.)
S_{ws} Slope of the water surface (rise/run)
S_{valley} Slope of the valley (rise/run)
S_{riffle} Slope of the riffle (rise/run)
S_{pool} Slope of the pool (rise/run)







EcoScience Corporation
Raleigh, North Carolina

REVISIONS

Client:
NC WETLAND RESTORATION PROGRAM

Project:
LYLE CREEK AS–BUILT CONSTRUCTION REPORT

CATAWBA COUNTY, NORTH CAROLINA

Title:
CHANNEL SLOPE ATTRIBUTES

Dwn By: MAF	Date: AUG 2002
Ckd By: WGL	Scale: AS SHOWN
ESC Project No.: 98-047.16	

FIGURE
13

measured 0.2 millimeter (fine sand). Typically, the riffle D50 would be characterized by coarser material than the composite D50. However, stream restoration occurred by excavating a channel in a silt/clay substrate and/or backfilling the channel with a silt/clay substrate. The resultant D50 is characterized by a higher percentage (32 percent) of fine particles. It would be expected that establishment of coarse material on the riffles will occur through time as sediment is transported within the newly constructed channel. The proposed D50 composite total is approximately 2.0 millimeters (coarse sand/very fine gravel).

3.0 MONITORING PLAN

Monitoring of Site restoration efforts will be performed for a five-year period or until success criteria are fulfilled. The monitoring effort will involve 1) two surveyed stream reaches extending for a minimum of 300 feet along the restored channel, 2) annually monitored vegetation plots, and 3) annual photographic plots. A monitoring plan, including monitoring reaches, proposed vegetative plots, and photographic plot locations is provided in Figure 14. Pre-construction photographs and post construction photographs at each photographic plot are included in Appendix B.

Monitoring of the Site is expected annually for a period of 5 years. Annual monitoring is expected to occur in the fall of each year, after the growing season. Three copies of the annual monitoring reports will be sent the WRP for submission to U.S. Army Corps of Engineers and N.C. Division of Water Quality. The reports should be three ring bound for inclusion into this as-built report.

3.1 STREAM MONITORING

Two stream reaches of channel will be monitored for geometric attributes as depicted in Figure 14. Annual fall monitoring will include development of a channel plan view, channel cross-sections on riffles and pools, pebble counts, and a water surface profile of the channel. The data will be presented in graphic and tabular format. Data to be presented will include 1) cross-sectional area, 2) bankfull width, 3) average depth, 4) maximum depth, 5) width/depth ratio, 6) meander wavelength, 7) belt width, 8) water surface slope, 9) sinuosity, and 10) stream substrate composition. The stream will subsequently be classified based on geomorphic principles outlined in *Applied River Morphology* (Rosgen 1996). Significant changes in channel morphology will be tracked and reported by comparing data in each successive monitoring year.

3.2 STREAM SUCCESS CRITERIA

Success criteria for stream restoration will include 1) successful classification of the reach as a functioning stream system (Rosgen 1996) and 2) channel stability indicative of a stable stream system.

The channel configuration will be compared on an annual basis to track changes in channel geometry, profile, or substrate. These data will be utilized to assist in determining the success of restoring stream channel stability. Specifically, the channel will be successfully classified as an E-type or borderline C-type/E-type stream including an entrenchment ratio greater than 2.2 with a bankfull width/depth ratio that does not vary significantly for the previous monitoring year. The field indicator of bankfull will be described in each monitoring year and indicated on representative channel cross-section that mimic those depicted in Figure 12.

Channel stability will be assessed based on dimension, pattern and profile variables. Bank erosion and headcut migration through the Site will be assessed visually and through cross-sectional data and profile data. Specifically, bank height ratios must remain less than 1.4 and changes in cross-sectional area and channel width must indicate less than 0.5 fOOt of bed and/or bank erosion per year along the monitoring reach. In addition, abandoned channel reaches or shoot cutoffs must not occur and sinuosity values must remain greater than 1.5 (thalweg distance/straight-line distance).

The stream must maintain shear stress values to adequately transport sediment through the Site. Pebble counts will be conducted annually to determine D50 and D84 values within the restored stream. Pebble counts would be expected to indicate a general coarsening of materials on the riffles throughout the monitoring period. Substrate will be considered successful if the channel is by a substrate consisting of coarse sand/fine gravel (D50 greater than 2 millimeters).

Visual assessment of in-stream, cross-vane weirs will be conducted to determine if failure has occurred. Failure of a structure may be indicated by collapse of the structure, undermining of the structure, abandonment of the channel around the structure, and/or stream flow beneath the structure.

3.3 STREAM CONTINGENCY

In the event that stream success criteria are not fulfilled, a mechanism for contingency will be implemented. Stream contingency may include, but may not be limited to, 1) structure repair and/or installation; 2) repair of dimension, pattern, and/or profile variables; and 3) bank stabilization. The method of contingency is expected to be dependent upon stream variables not in compliance with success criteria. Primary concerns which may jeopardize stream success include 1) structure failure, 2) headcut migration through the site, and/or 3) bank erosion.

Structure Failure – In the event that on-site structures are compromised (as described in Section 3.2 Stream Success Criteria), the affected structure may be repaired, maintained, or replaced. Once the structure is repaired or replaced, it must function to stabilize adjacent stream banks and/or maintain grade control within the channel. Structures which remain intact, but exhibit flow around, beneath, or through the header/footer stones may be repaired by excavating a trench on the upstream side of the structure and re-installing filter fabric in front of the header and footer stones. Structures which have been compromised, resulting in shifting, or collapse of, header/footer stones should be removed and replaced with a structure suitable for on-site flows.

Headcut Migration Through the Site – In the event that a headcut occurs within the Site (identified visually or through on-site measurements [i.e. bank height ratios exceeding 1.4]), provisions for impeding headcut migration and repairing damage caused by the headcut may be implemented. Headcut migration may be impeded through the installation of in-stream grade control structures (rip rap sill and/or cross vane weir) and/or restoring stream geometry variables until channel stability is achieved. Channel repairs to stream geometry may include channel backfill with course material and stabilizing the material with erosion control matting, vegetative transplants, and/or willow stakes.

Bank Erosion – In the event that severe bank erosion occurs at the Site, resulting in width/depth ratios significantly higher than the previous monitoring year, contingency measures to reduce bank erosion and width/depth ratios may occur. Bank erosion contingency may include the installation of cross vane weirs and/or bank stabilization measures. If the resultant bank erosion induces shoot cutoffs or channel abandonment, a channel may be excavated which will reduce shear stress to stable values.

3.4 VEGETATION MONITORING

Restoration monitoring procedures for vegetation are designed in accordance with EPA guidelines enumerated in MiST documentation (EPA 1990) and COE Compensatory Hardwood Mitigation Guidelines (DOA 1994). A general discussion of the restoration monitoring program is provided.

After planting has been completed in winter or early spring, an initial evaluation will be performed to verify planting methods and to determine initial species composition and density. Supplemental planting and additional site modifications will be implemented, if necessary.

During the first year, vegetation will receive cursory, visual evaluation on a periodic basis to ascertain the degree of overtopping of planted elements by nuisance species. A photographic record of plant growth should be included in each annual monitoring report. Photographic plot locations are depicted in Figure 14. A photographic record including pre-construction and post construction pictures has been initiated and is included in Appendix B.

Subsequently, quantitative sampling of vegetation will be performed in the fall or early winter after each growing season until the vegetation success criterion is achieved. During quantitative vegetation sampling in early fall of the first year, approximately seven sample plots will be randomly placed within the Site. Sample-plot distributions are expected to resemble locations depicted in Figure 14; however, best professional judgment may be necessary to establish vegetative monitoring plots upon completion of construction activities. In each sample plot, vegetation parameters to be monitored include species composition and species density. Visual observations of the percent cover of shrub and herbaceous species will also be recorded.

3.5 VEGETATIVE SUCCESS CRITERIA

Success criteria have been established to verify that the vegetation component supports community elements necessary for floodplain forest development. Success criteria are dependent upon the density and growth of characteristic forest species. Additional success criteria are dependent upon density and growth of "Character Tree Species." Character Tree Species include planted species along with species identified through visual inventory of an approved reference (relatively undisturbed) bottomland forest community used to orient the project design. All canopy tree species planted and identified in the reference forest will be utilized to define "Character Tree Species" as termed in the success criteria. Tree species identified in reference forest measurements are included in Appendix C.

An average density of 320 stems per acre of Character Tree Species must be surviving in the first three monitoring years. Subsequently, 290 character tree species per acre must be surviving in year 4, and 260 character tree species per acre in year 5. Planted species must represent a minimum of 30 percent of the required stem per acre total (96 stems/acre). Each naturally recruited character species may represent up to 10 percent of the required stem per acre total. In essence, seven naturally recruited character species may represent a maximum of 70 percent of the required stem/acre total. Additional stems of naturally recruited species above the 10 percent - 70 percent thresholds are discarded from the statistical analysis. The remaining 30 percent is reserved for planted character species (oaks, *etc.*) as a seed source for species maintenance during mid-successional phases of forest development.

3.6 VEGETATION CONTINGENCY

If vegetation success criteria are not achieved based on average density calculations from combined plots over the entire restoration area, supplemental planting will be performed with tree species approved by regulatory agencies. Supplemental planting will be performed as needed until achievement of vegetation success criteria.

No quantitative sampling requirements are proposed for herb assemblages as part of the vegetation success criteria. Development of floodplain forests over several decades will dictate the success in migration and establishment of desired understory and groundcover populations. Visual estimates of the percent cover of herbaceous species and photographic evidence will be reported for information purposes.

4.0 SUMMARY

The N.C. Wetlands Restoration Program (WRP) has developed an approximately 12.4-acre stream restoration site in eastern Catawba County. The Site encompasses approximately 2150 linear feet of second-order stream and 800 linear feet of first-order stream which converge at the downstream Site terminus. On-site streams drain to Lyle Creek, a tributary to the Catawba River. The Site watersheds encompass approximately 0.5 square mile and 0.2 square mile respectively and support a mixture of pastoral and residential land use. Topsoils in the Piedmont have eroded over the last century, exposing clay subsurface layers that are susceptible to severe erosion where disturbed. In addition, entrenched streams and rivers contribute to further erosion and sedimentation within the area.

Land use within the Site included historic conversion of the floodplain for agriculture and pastoral use. During landuse conversion, the primary channel was dredged and straightened. Forest vegetation was cleared and cattle were introduced into the flooplain. The on-site streams began to erode due to hoof shear and a lack of deeprooted riparian vegetation, resulting in channel entrenchment and over-widening. The channel effectively abandoned its floodplain and terrace formation commenced.

Stream mitigation activities have been designed to restore stream features and functions similar to those exhibited by reference streams in the region. Site alterations designed to restore characteristic stream channel dimension, pattern, and profile include 1) installation of grade control/bank stabilization structures (cross vane weirs, J-hook vanes, and log vanes), excavation of bankfull benches, channel backfilling to design depth, bank stabilization through installation of root wad structures and erosion control matting, and the excavation of channel on new location. Tree and shrub planting is expected to be conducted in the fall of 2002 to facilitate establishment of diagnostic natural communities.

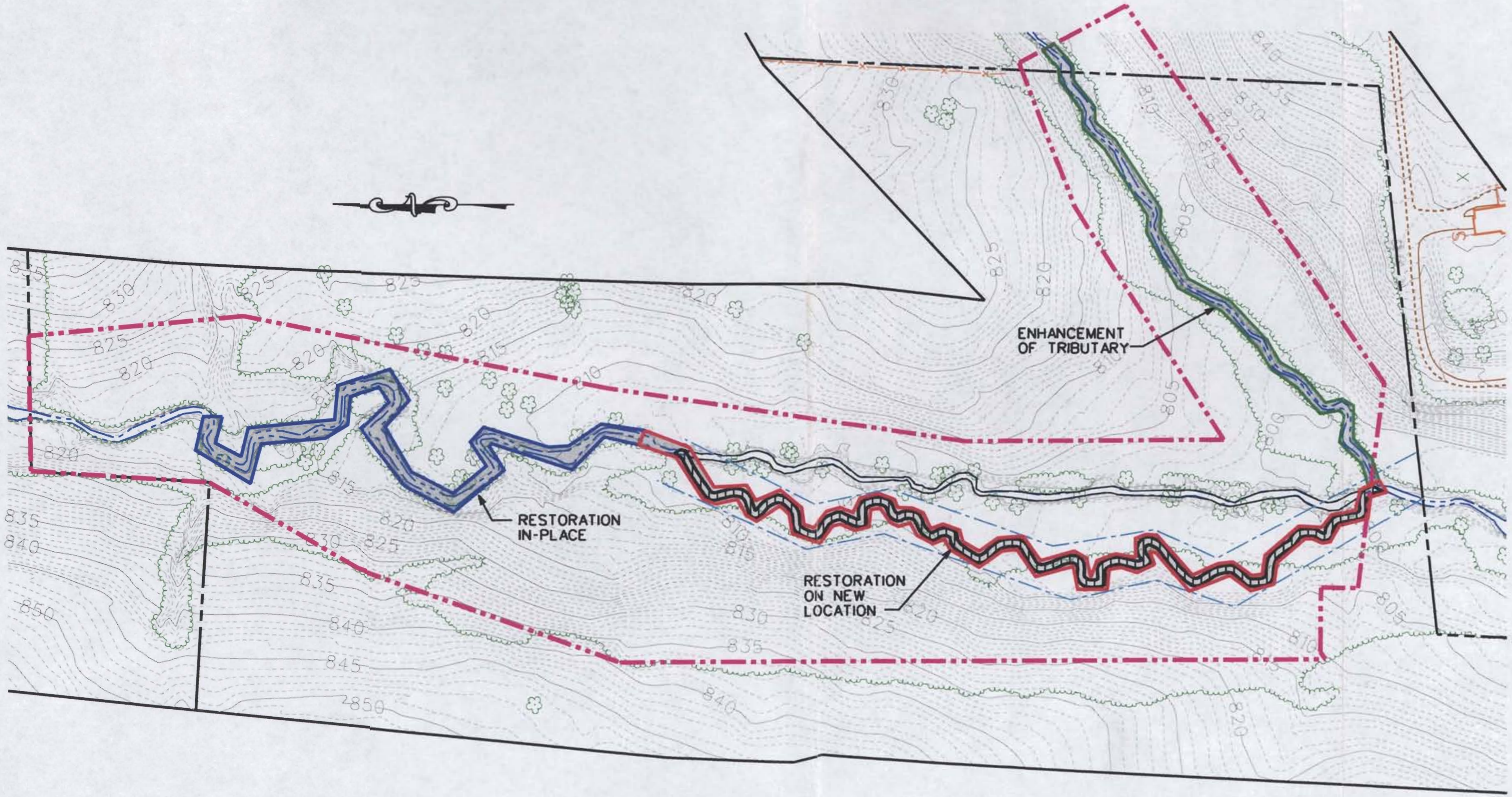
After implementation, the Site is expected to support 12.4 acres of riverine and adjacent slope forest encompassing 2400 linear feet of restored stream channel (1345 linear feet restored on new location and 1055 linear feet restored in place). Stream enhancement/preservation activities will also be undertaken along approximately 800 linear feet of a secondary, unnamed tributary through bare root plantings and livestock exclusion. Figure 15 depicts the restoration reaches and enhancement reaches at the Site.

LEGEND

			linear feet
STREAM RESTORATION EASEMENT		RESTORATION IN-PLACE	1055
APPROXIMATE PROPERTY BOUNDARY		RESTORATION ON NEW LOCATION	1345
BELT WIDTH CORRIDOR		ENHANCEMENT OF TRIBUTARY	800
EXISTING TREE LINE			
EXISTING STREAM			
850 MAJOR CONTOURS			

DISTANCE IN FEET

200 100 0 100 200



PLAN VIEW

SCALE: 1"=150'

EcoScience Corporation

Raleigh, North Carolina

REVISIONS

Client:

NC WETLAND RESTORATION PROGRAM

Project:

LYLE CREEK AS-BUILT CONSTRUCTION REPORT

CATAWBA COUNTY, NORTH CAROLINA

Title:

MITIGATION LOCATION AND CLASSIFICATION

Dwn By: MAF	Date: AUG 2002
Ckd By: WGL	Scale: 1"= 150'

ESC Project No.: 98-047.16

FIGURE

15

5.0 REFERENCES

Department of the Army (DOA). 1994. Corps of Engineers Wilmington District Compensatory Hardwood Mitigation Guidelines (12/8/93).

Environmental Protection Agency (EPA). 1990. Mitigation Site Type Classification (MiST). EPA Workshop, August 13-15, 1989. EPA Region IV and Hardwood Research Cooperative, NCSU, Raleigh, North Carolina.

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United States Geological Survey (USGS). 1974. Hydrologic Unit Map - 1974. State of North Carolina.

6.0 APPENDICES

Appendix A: Pebble Count Data
Appendix B: Photographic Plot Data
Appendix C: Reference Tree Species and Data

Appendix A

Pebble Count Data

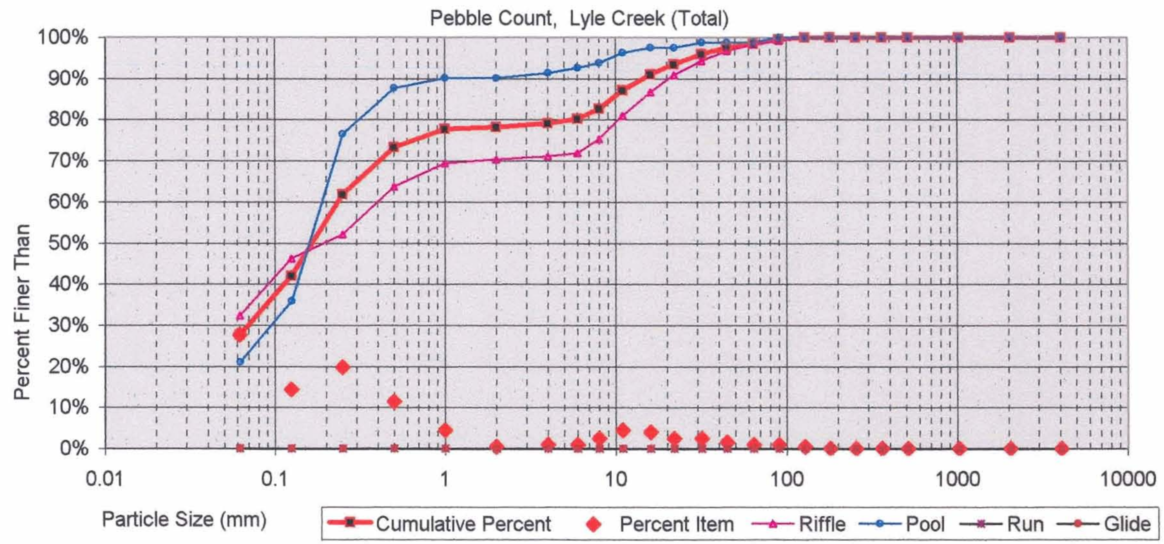
Weighted Pebble Count

Percent Riffle:	60	Percent Run:	0
Percent Pool:	40	Percent Glide:	0

Pebble Count,
Lyle Creek (Total)

Note: **Both New Location and In-Place Composite**

Material	Size Range (mm)		Total #	
silt/clay	0	0.062	27.7	# #
very fine sand	0.062	0.13	14.4	# #
fine sand	0.13	0.25	19.8	# #
medium sand	0.25	0.5	11.4	# #
coarse sand	0.5	1	4.5	# #
very coarse sand	1	2	0.5	# #
very fine gravel	2	4	1.0	# #
fine gravel	4	6	1.0	# #
fine gravel	6	8	2.5	# #
medium gravel	8	11	4.5	# #
medium gravel	11	16	4.0	# #
coarse gravel	16	22	2.5	# #
coarse gravel	22	32	2.5	# #
very coarse gravel	32	45	1.5	# #
very coarse gravel	45	64	1.0	# #
small cobble	64	90	1.0	# #
medium cobble	90	128	0.5	# #
large cobble	128	180	0.0	# #
very large cobble	180	256	0.0	# #
small boulder	256	362	0.0	# #
small boulder	362	512	0.0	# #
medium boulder	512	1024	0.0	# #
large boulder	1024	2048	0.0	# #
very large boulder	2048	4096	0.0	# #
bedrock			0.0	#
Weighted Count:			100	
True Total Particle Count:			202	



Size percent less than (mm)				
D16	D35	D50	D84	D95
#N/A	0.09	0.2	9	27

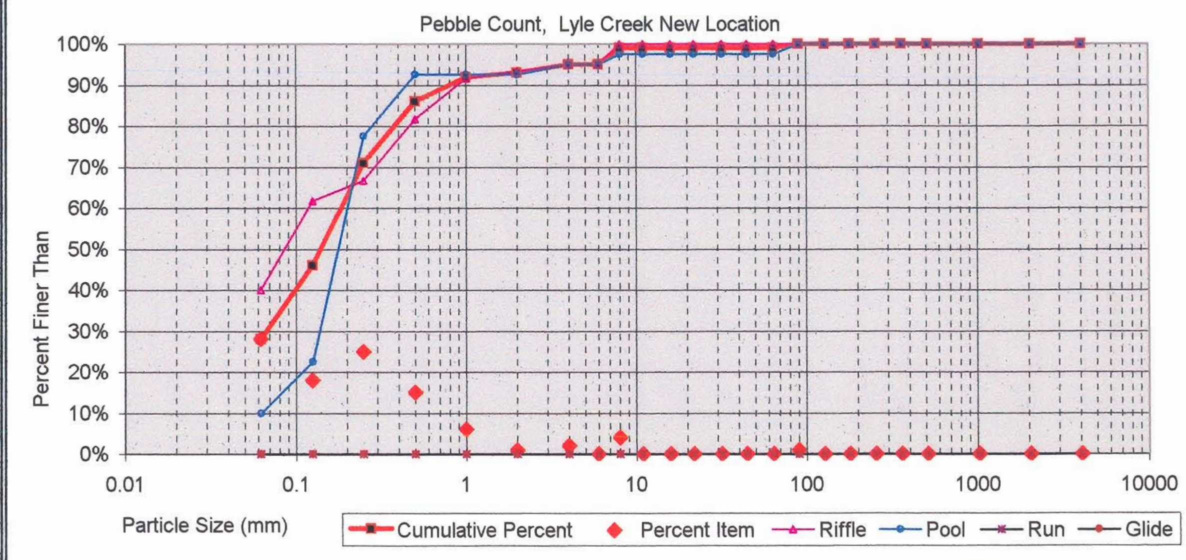
Percent by substrate type					
silt/clay	sand	gravel	cobble	boulder	bedrock
28%	50%	20%	1%	0%	0%

Weighted Pebble Count

Percent Riffle:	**60**	Percent Run:	**0**	
Percent Pool:	**40**	Percent Glide:	**0**	Pebble Count,
				Lyle Creek New Location

			Note:	**New Location Reach Composite**

Material	Size Range (mm)		Total #	
silt/clay	0	0.062	28.0	# #
very fine sand	0.062	0.13	18.0	# #
fine sand	0.13	0.25	25.0	# #
medium sand	0.25	0.5	15.0	# #
coarse sand	0.5	1	6.0	# #
very coarse sand	1	2	1.0	# #
very fine gravel	2	4	2.0	# #
fine gravel	4	6	0.0	# #
fine gravel	6	8	4.0	# #
medium gravel	8	11	0.0	# #
medium gravel	11	16	0.0	# #
coarse gravel	16	22	0.0	# #
coarse gravel	22	32	0.0	# #
very coarse gravel	32	45	0.0	# #
very coarse gravel	45	64	0.0	# #
small cobble	64	90	1.0	# #
medium cobble	90	128	0.0	# #
large cobble	128	180	0.0	# #
very large cobble	180	256	0.0	# #
small boulder	256	362	0.0	# #
small boulder	362	512	0.0	# #
medium boulder	512	1024	0.0	# #
large boulder	1024	2048	0.0	# #
very large boulder	2048	4096	0.0	# #
bedrock			0.0	#
Weighted Count:			100	
True Total Particle Count:			100	



Size percent less than (mm)				
D16	D35	D50	D84	D95
#N/A	0.08	0.1	0	6

Percent by substrate type					
silt/clay	sand	gravel	cobble	boulder	bedrock
28%	65%	6%	1%	0%	0%

Weighted Pebble Count

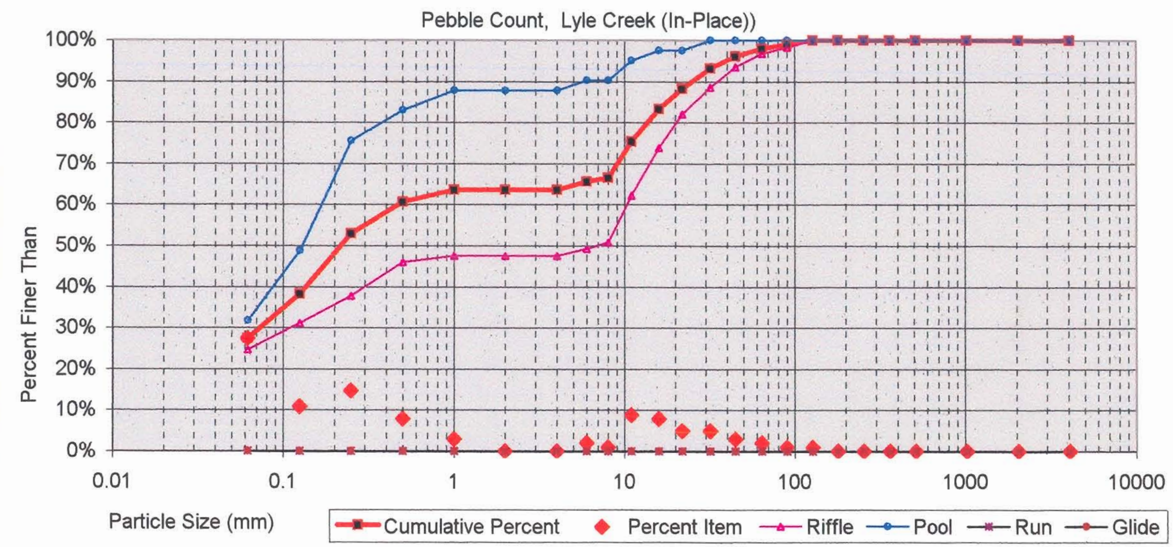
Percent Riffle:	60	Percent Run:	0
Percent Pool:	40	Percent Glide:	0

Pebble Count,

Lyle Creek (In-Place))

Note: **In-Place Reach Composite**

Material	Size Range (mm)		Total #	
silt/clay	0	0.062	27.4	# #
very fine sand	0.062	0.13	10.8	# #
fine sand	0.13	0.25	14.7	# #
medium sand	0.25	0.5	7.8	# #
coarse sand	0.5	1	2.9	# #
very coarse sand	1	2	0.0	# #
very fine gravel	2	4	0.0	# #
fine gravel	4	6	2.0	# #
fine gravel	6	8	1.0	# #
medium gravel	8	11	8.8	# #
medium gravel	11	16	7.9	# #
coarse gravel	16	22	4.9	# #
coarse gravel	22	32	4.9	# #
very coarse gravel	32	45	3.0	# #
very coarse gravel	45	64	2.0	# #
small cobble	64	90	1.0	# #
medium cobble	90	128	1.0	# #
large cobble	128	180	0.0	# #
very large cobble	180	256	0.0	# #
small boulder	256	362	0.0	# #
small boulder	362	512	0.0	# #
medium boulder	512	1024	0.0	# #
large boulder	1024	2048	0.0	# #
very large boulder	2048	4096	0.0	# #
bedrock			0.0	#
		Weighted Count:	100	
		True Total Particle Count:	102	



Size percent less than (mm)				
D16	D35	D50	D84	D95
#N/A	0.10	0.2	17	40

Percent by substrate type					
silt/clay	sand	gravel	cobble	boulder	bedrock
27%	36%	34%	2%	0%	0%

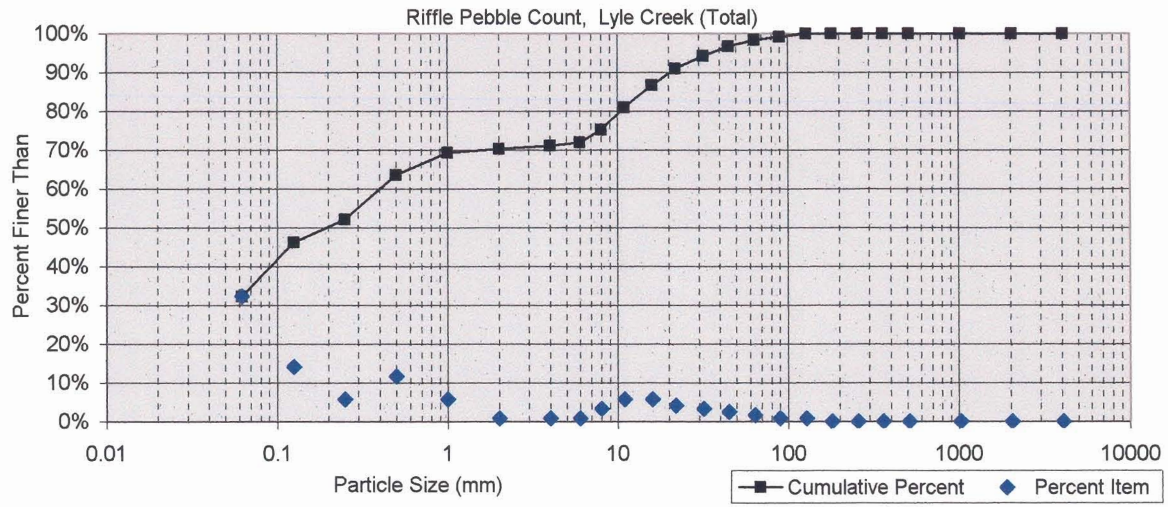
Riffle Pebble Count

Riffle Pebble Count,

Lyle Creek (Total)

Note: **New Location Reach (Riffles)**

Material	Size Range (mm)		Count	
silt/clay	0	0.062	**39**	# #
very fine sand	0.062	0.13	**17**	# #
fine sand	0.13	0.25	**7**	# #
medium sand	0.25	0.5	**14**	# #
coarse sand	0.5	1	**7**	# #
very coarse sand	1	2	**1**	# #
very fine gravel	2	4	**1**	# #
fine gravel	4	6	**1**	# #
fine gravel	6	8	**4**	# #
medium gravel	8	11	**7**	# #
medium gravel	11	16	**7**	# #
coarse gravel	16	22	**5**	# #
coarse gravel	22	32	**4**	# #
very coarse gravel	32	45	**3**	# #
very coarse gravel	45	64	**2**	# #
small cobble	64	90	**1**	# #
medium cobble	90	128	**1**	# #
large cobble	128	180		# #
very large cobble	180	256		# #
small boulder	256	362		# #
small boulder	362	512		# #
medium boulder	512	1024		# #
large boulder	1024	2048		# #
very large boulder	2048	4096		# #
bedrock				#
		Total Particle Count:	121	



Size percent less than (mm)				
D16	D35	D50	D84	D95
#N/A	0.07	0.2	13	36

Percent by substrate type					
silt/clay	sand	gravel	cobble	boulder	bedrock
32%	38%	28%	2%	0%	0%

Appendix B

Photographic Plot Data

PHOTO PLOT 1

Pre-construction
Looking Downstream

Post Construction
Looking Downstream

PHOTO PLOT 2

Post Construction
Looking Upstream

Post Construction
Looking Downstream

PHOTO PLOT 3

Pre-construction
Looking Up-Valley

Post Construction
Looking Up-Valley

Pre-construction
Looking Upstream

Post Construction
Looking Upstream

Pre-construction
Looking Downstream

Post Construction
Looking Downstream

PHOTO PLOT 4

Post Construction
Looking Upstream

Post Construction
Looking Downstream

PHOTO PLOT 5

Post Construction
Looking Upstream

Post Construction
Looking Downstream

PHOTO PLOT 6

Pre-construction
Looking Upstream

Post Construction
Looking Upstream

Pre-construction
Looking Downstream

Post Construction
Looking Downstream

PHOTO PLOT 7

Pre-construction
Looking Upstream

Post Construction
Looking Upstream

Pre-construction
Looking Down-valley

Post Construction
Looking Down-valley

PHOTO PLOT 8

Pre-construction
Looking Upstream

Post Construction
Looking Upstream

PHOTO PLOT 9

Pre-construction
Looking Upstream

Post Construction
Looking Upstream

PHOTO PLOT 10

Pre-construction
Looking Downstream

Post Construction
Looking Downstream

Post Construction
Looking Upstream

PHOTO PLOT 11

Pre-construction
Looking Downstream

Post Construction
Looking Downstream

Post Construction
Looking Upstream

PHOTO PLOT 12

Pre-construction
Looking Upstream

Post Construction
Looking Upstream

Reference Forest Ecosystem Plot Summary
Bottomland Hardwood Forest (Canopy Species)
Turkey Cock Creek

Tree Species	Number of Individuals[1]	Relative Density (%)	Frequency[1] (%)	Relative Frequency (%)	Basal Area ft^2/ acre	Relative Basal Area (%)	Importance Value (%)
Carpinus caroliniana	19	23.7	100	14.8	8.4	6.3	14.9
Fraxinus pennsylvanica	15	18.8	75	11.1	27.5	20.4	16.8
Liriodendron tulipifera	15	18.8	100	14.8	33.9	25.2	19.6
Acer rubrum	11	13.8	75	11.1	24.2	17.9	14.3
Quercus rubra	5	6.3	75	11.1	5.8	4.3	7.2
Juglans nigra	3	3.8	25	3.7	11.2	8.3	5.3
Platanus occidentalis	2	2.5	25	3.7	12.7	9.5	5.2
Cercis canadensis	2	2.5	25	3.7	0.5	0.4	2.2
Diospyros virginiana	2	2.5	25	3.7	2.6	2.0	2.7
Nyssa sylvatica	1	1.3	25	3.7	0.7	0.5	1.8
Carya tomentosa	1	1.3	25	3.7	1.7	1.3	2.1
Carya ovata	1	1.3	25	3.7	1.4	1.1	2.0
Viburnum prunifolium	1	1.3	25	3.7	0.2	0.2	1.7
Oxydendrum arboreum	1	1.3	25	3.7	2.0	1.5	2.1
Prunus serotina	1	1.3	25	3.7	1.9	1.4	2.1
TOTALS	80	100	676	100	135	100	100

[1]Summary of four - 0.1-acre plots

Appendix C

Reference Tree Species

Reference Forest Ecosystem Plot Summary
Bottomland Hardwood Forest (Canopy Species)
Rocky River

Tree Species	Number of Individuals[1]	Relative Density (%)	Frequency[1]	Relative Frequency (%)	Basal Area ft²/ acre	Relative Basal Area (%)	Importance Value (%)
Fraxinus pennsylvanica	62	42	10	26	57.8	51	39
Acer negundo	41	28	9	23	17.0	15	22
Ulmus americana	15	10	7	18	10.7	9	12
Quercus michauxii	6	4	1	3	11.8	10	6
Carpinus caroliniana	8	5	3	8	1.1	1	5
Quercus lyrata	4	3	3	8	5.1	4	5
Celtis laevigata	6	4	2	5	7.0	6	5
Platanus occidentalis	1	1	1	3	1.8	2	2
Ulmus alata	3	1	1	3	0.1	0	2
Fraxinus caroliniana	2	1	1	3	0.3	0	1
Ligustrum sinense	1	1	1	3	0.1	0	1
TOTALS	149	100	39	103	113	98	100

* Summary of ten - 0.1-acre plots

Appendix D

(2002 Mitigation Monitoring)

STREAM MONITORING

The monitoring program calls for measurement of approximately 2400 linear feet of restored channel at the Lyle Creek stream restoration site. Annual fall monitoring protocol includes development of channel cross-sections on riffles and pools, water surface profile, and pebble counts. Specific stream data to be presented include 1) cross-sectional area, 2) bankfull width, 3) average depth, 4) maximum depth, 5) width/depth ratio, 6) water surface slope, 7) sinuosity, and 8) stream substrate composition. The stream is subsequently classified based on geomorphic principles outlined in *Applied River Morphology* (Rosgen 1996). Significant changes in channel morphology will be tracked and reported by comparing data in each successive monitoring year. First year monitoring photographs are included in the attached Photographic Plot Data, found at the end of this monitoring report.

MONITORING RESULTS

First year monitoring results indicate stream restoration efforts totaling approximately 2400 linear feet, including approximately 1345 linear feet restored on new location and 1055 linear feet restored in place. A plan view and typical cross-sections of the restored stream are depicted in Figure 1. Table 1 contains a summary of stream dimension, pattern, and profile attributes measured during first year monitoring, as well as proposed attributes and as-built attributes.

Channel Dimension Attributes

Channel dimension attributes were obtained from cross-section locations depicted in Figure 1. Seven cross-sections were established during as-built measurements, four in the new location reach and three in the in-place reach. The restored channel currently exhibits a bankfull median width of 11.8, a bankfull median depth of 1.4, and a bankfull median width/depth ratio of 9. The cross-sectional area averages 16.6 square feet and ranges from 15.4 to 17.4 square feet (Table 1). Riffle and pool maximum depths were 2.5 and 2.9 respectively. Channel dimension attributes do not vary significantly from the proposed or as-built variables.

Channel Pattern Attributes

Survey of stream pattern variables was not scoped for this monitoring report. However, visual observations during first year measurements did not indicate abandoned reaches or shoot cutoffs. Dimensional data do not indicate significant bank or bed erosion at monumented cross-sections. In addition, the channel is not characterized by collapsing banks or significant band erosion that would indicate a change in pattern variables. The channel is characterized by similar sinuosities as

Table 1
Stream Geometry and Classification
Lyle Creek Stream Restoration Site
(Area of Watershed 0.5 square miles)

Attribute	Proposed Conditions Median	Proposed Conditions Range	As-Built Conditions Median	As-Built Conditions Range	First Year Conditions Median	First Year Conditions Range
A_{bkf}	16.8	NA	16.5	15.2 – 17.5	16.6	15.4 – 17.4
W_{bkf} (riffle)	11.2	9.9 - 13.3	11.2	10.7 – 13.2	11.7	10.7 – 12.4
D_{bkf} (riffle)	1.5	1.0 - 2.0	1.4	1.2 - 1.6	1.4	1.3 – 1.6
D_{max} (riffle)	2.0	1.5 - 2.3	2.5	2.2 – 2.7	2.5	2.3 – 2.9
FPA (riffle)	150	108 - 209	152	132 – 175	152	132 – 175
W_{pool}	14.6	11 - 17	14.6	12.8 – 16.4	15.7	12.7 – 18.6
D_{max} (pool)	3.0	2.6 - 3.5	2.9	2.7 – 3.1	2.9	2.8 – 2.9
L_{pool}	20.2	15 - 43	27	14 – 64	24	9 – 87
LBH	2.0	1.5 - 2.3	2.4	2.2 – 2.8	2.5	2.4 – 3.0
ENT	13	10 - 19	12	12 – 16	12	11 – 15
W_{bkf}/D_{bkf}	10	6 - 14	8	7 – 11	9	7 – 10
BHR	1.0	1.0 - 1.2	1.0	1.0 – 1.1	1.0	1.0 – 1.1
D_{max} (riffle) / D_{ave} (riffle)	1.3	1.0 - 1.5	1.6	1.6 – 1.8	1.8	1.7 – 1.8
D_{max} (pool) / D_{ave} (riffle)	2.0	1.7 - 2.3	2.0	1.9 – 2.2	2.1	1.9 – 2.2
W_{pool} / W_{bkf} (riffle)	1.3	1.0 - 1.5	1.3	1.1 – 1.4	1.3	1.1 – 1.4
Sin	1.5	NA	1.6	NA	1.6	NA
S_{sw}	.008	NA	.0076	NA	.0075	NA
S_{valley}	.012	NA	.012	NA	.012	NA
S_{riffle}	.010	.004 - .015	.0141	0 - .0364	.0147	0 – .07*
S_{pool}	.0049	.0042 -.0056	.0022	0 - .0066	.0024	0 - .0114
S_{valley}/S_{ws}	1.5	NA	1.6	NA	1.6	NA
S_{riffle}/S_{ws}	1.4	0.6 – 2.1	1.9	0 – 4.8	2.0	0 – 9.3
S_{pool}/S_{ws}	0.7	0.6 – 0.8	0.3	0 – 0.9	0.3	0 – 1.5

Stream Type	Proposed Conditions	As-Built Conditions	First Year Conditions
Stream Type	E 4/5	E 5	E 5

A_{bkf} Bankfull cross-sectional area (riffle) (ft^2)
W_{bkf} Bankfull width (ft)
D_{bkf} Average bankfull depth (ft)
D_{max} Maximum depth (ft)
FPA Floodprone Area (ft)
W_{pool} Channel width at a pool (ft)
L_{pool} Individual pool length (ft)
LBH Low bank height (distance from thalweg to the top of low bank) (ft)
W_{belt} Belt width (ft)
L_m Meander wavelength (ft)
R_c Radius of Curvature (ft)
$L_{p\text{-}p}$ Length from pool to pool (ft)
Sin Sinuosity (thalweg dist/straight-line dist.)
S_{ws} Slope of the water surface (rise/run)
S_{valley} Slope of the valley (rise/run)
S_{riffle} Slope of the riffle (rise/run)
S_{pool} Slope of the pool (rise/run)

* High range of riffle slopes occur in riffles containing cross-vane weirs.

as-built conditions (1.6). Pattern variables appear stable after the year one monitoring period.

Channel Slope and Substrate Attributes

Channel slope and substrate attributes were obtained from profile measurements and pebble count data (Figure 2). The water surface slope averaged 0.0075 (rise/run) relative to a valley slope of approximately 0.012 (rise/run). The median riffle and pool slopes were 0.0147 and 0.0024, respectively. Compared to proposed conditions, the ranges of riffle and pool slopes were slightly extended. Several conditions may explain this discrepancy including the formation of small drops and scour holes immediately downstream of cross-vane weirs resulting in shortened riffles with steep individual facet slopes.

Channel material was quantified by a representative, stratified pebble count (Graphs A, B, and C). The D50 for the composite total (used for classification purposes) measured 0.2 millimeter (fine sand). The segmented particle size for the D50 in the riffle sections measured 0.3 millimeter (medium sand). As expected, establishment of course material on riffles has begun as sediment is transported through the recently constructed channel. As sediment conveyance continues through the restored channel, it is expected that D50 values will increase. The proposed D50 composite total is approximately 2.0 millimeters (course sand/very course sand).

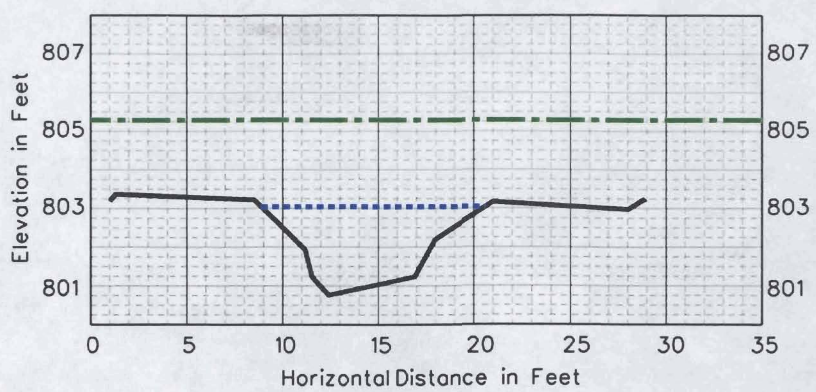
EVALUATION OF SUCCESS CRITERIA

Success criteria for stream restoration has been subdivided into two components; 1) successful classification of the reach as a functioning stream system (Rosgen 1996) and 2) channel stability indicative of a stable stream system.

For classification purposes, the stream supports a median entrenchment ratio of 12 and a median width/depth ratio of 9. The channel exhibits high sinuosity (approximately 1.6), a water surface slope of 0.0075 (rise/run), and a substrate dominated by fine sand (D50 of 0.2). Therefore, stream geometry and substrate measurements under current conditions indicate a stable E 5 stream type. Achievement of the proposed E 4/5 stream type (substrate of gravel/sand) is anticipated as sediment transportation throughout the reach continues through time.

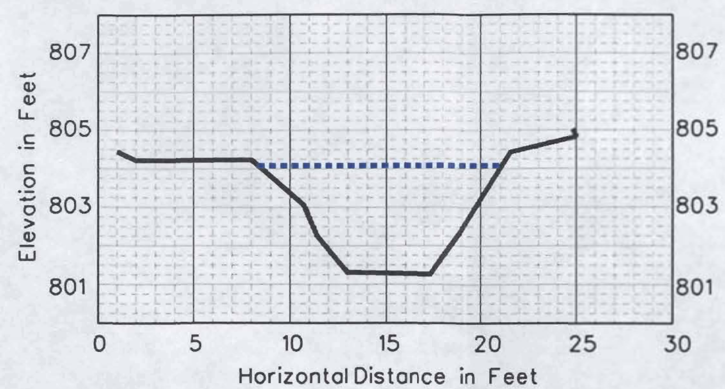
Channel stability has been assessed based on dimension, pattern and profile variables. Specifically, bank height ratios exhibit a value of 1.02 while cross-sectional area and channel width indicate less that 0.5 foot of bed and/or bank erosion. Field investigations did not reveal any abandoned channel reaches or shoot

CROSS-SECTION 1
Riffle 16



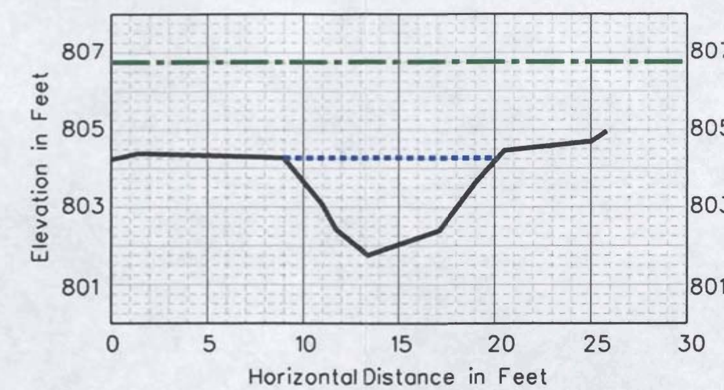
Bankfull Width: 11.8'
Bankfull Maximum Depth: 2.3'
Bankfull Average Depth: 1.3
Bankfull Cross-sectional Area: 15.4 sq. ft..
Width of Flood Prone Area: 175.0'

CROSS-SECTION 2
Pool 20



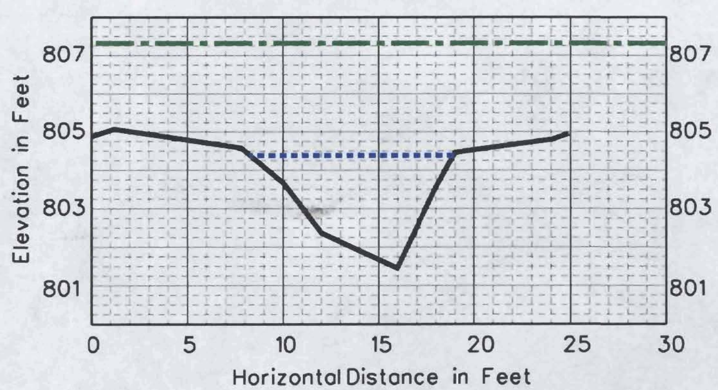
Bankfull Width: 12.7'
Bankfull Maximum Depth: 2.8'
Bankfull Average Depth: 1.8
Bankfull Cross-sectional Area: 23.4 sq. ft.

CROSS-SECTION 3
Riffle 20



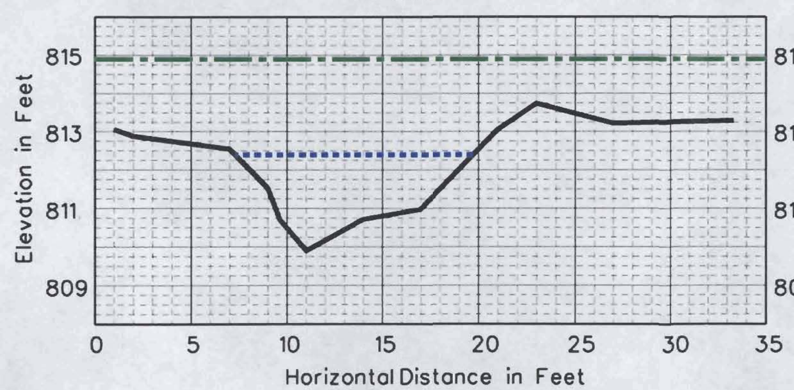
Bankfull Width: 11.1'
Bankfull Maximum Depth: 2.5'
Bankfull Average Depth: 1.5
Bankfull Cross-sectional Area: 16.7 sq. ft..
Width of Flood Prone Area: 132.0'

CROSS-SECTION 4
Riffle 21



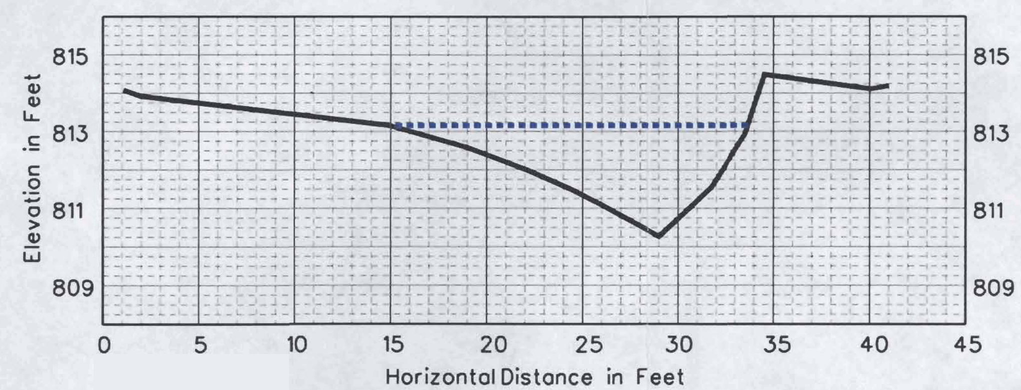
Bankfull Width: 10.7'
Bankfull Maximum Depth: 2.9'
Bankfull Average Depth: 1.6
Bankfull Cross-sectional Area: 17.4 sq. ft..
Width of Flood Prone Area: 152.0'

CROSS-SECTION 6
Riffle 39



Bankfull Width: 12.4'
Bankfull Maximum Depth: 2.
Bankfull Average Depth: 1.4
Bankfull Cross-sectional Area: 17.1 sq. ft..
Width of Flood Prone Area: 142.0'

CROSS-SECTION 7
Pool 41

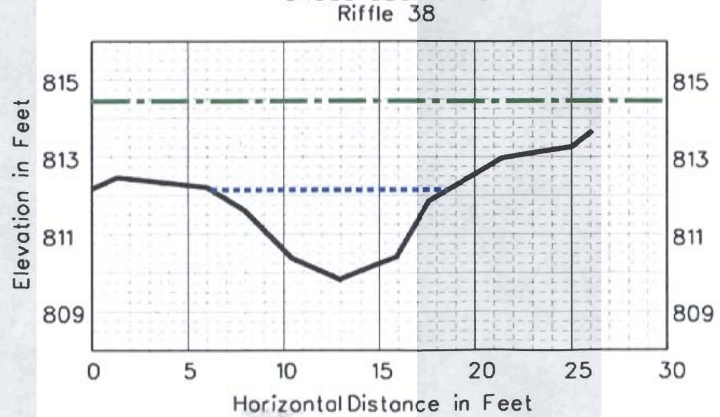


Bankfull Width: 18.6'
Bankfull Maximum Depth: 2.9'
Bankfull Average Depth: 1.4
Bankfull Cross-sectional Area: 25.3 sq. ft..

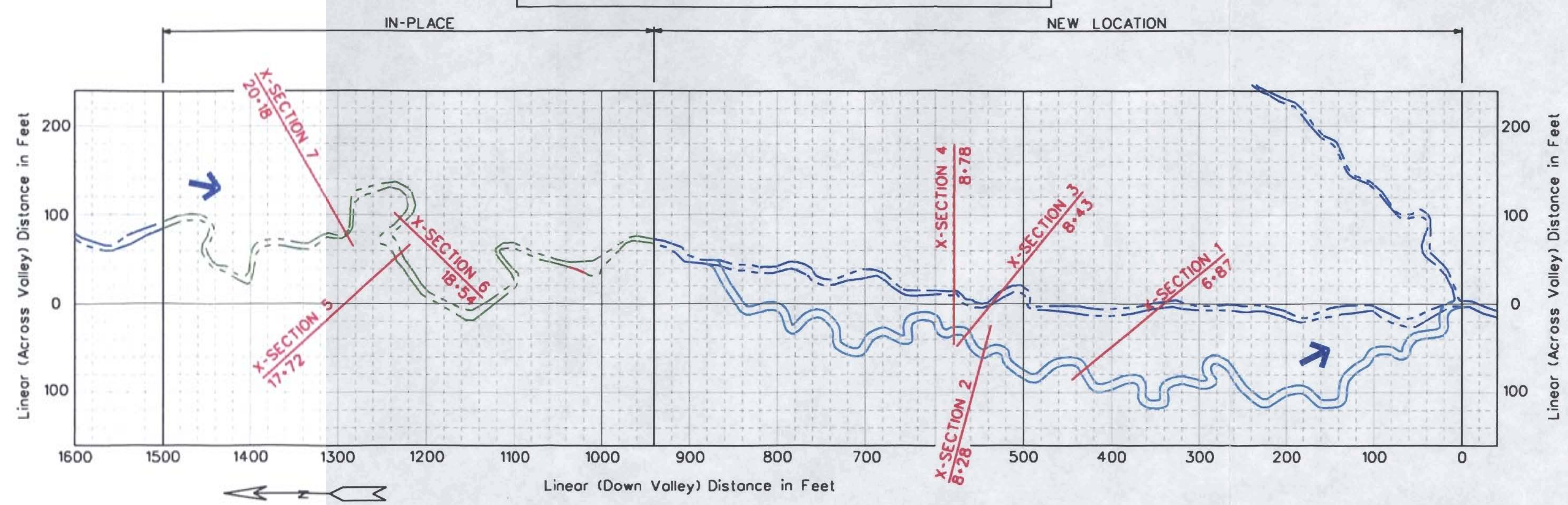
BANKFULL
EXISTING GRADE
FLOOD PRONE AREA

NOTE:
All Cross-sections Facing the Down ream Direction

CROSS-SECTION 5
Riffle 38



Bankfull Width: 12.4'
Bankfull Maximum Depth: 2.3'
Bankfull Average Depth: 1.3
Bankfull Cross-sectional Area: 16.2 sq. ft..
Width of Flood Prone Area: 154.0'



EcoScience Corporation
Raleigh, North Carolina

REVISIONS

Client:
NC WETLAND RESTORATION PROGRAM

Project:
LYLE CREEK FIRST YEAR MONITORING REPORT

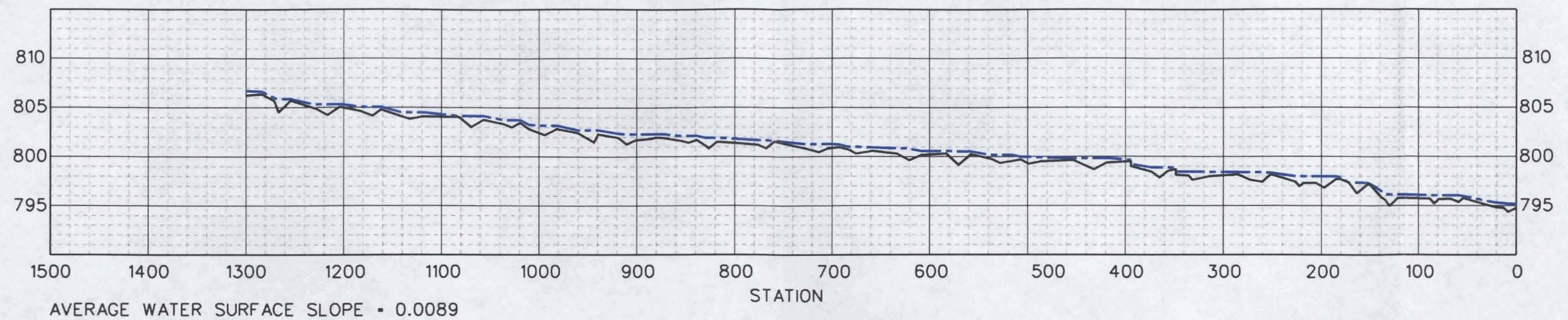
CATAWBA COUNTY, NORTH CAROLINA

Title:
PLAN VIEW AND CROSS-SECTIONS

Dwn By: MAF	Date: DEC 2002
Ckd By: WGL	Scale: AS SHOWN
ESC Project No.: 98-047.17	

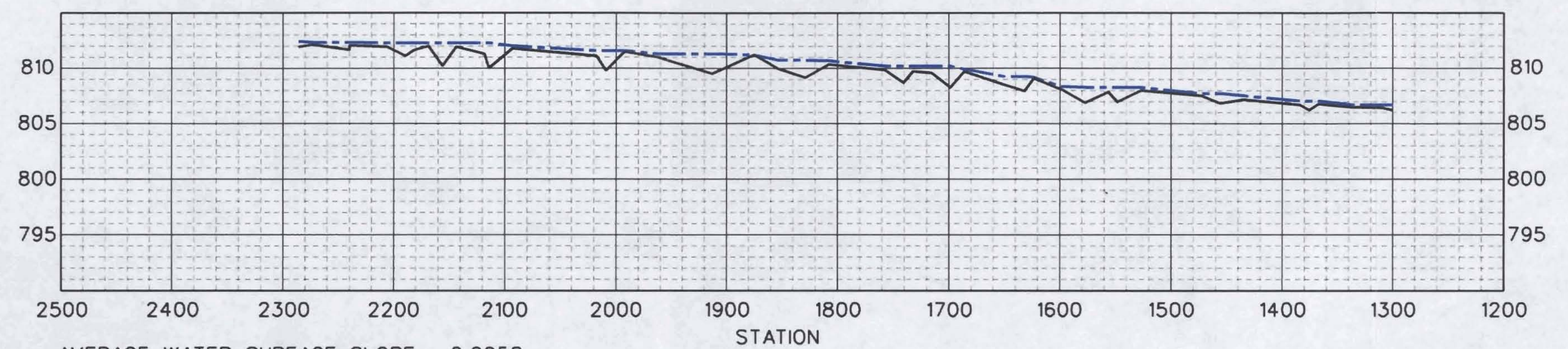
FIGURE
1

NEW LOCATION REACH



AVERAGE WATER SURFACE SLOPE - 0.0089

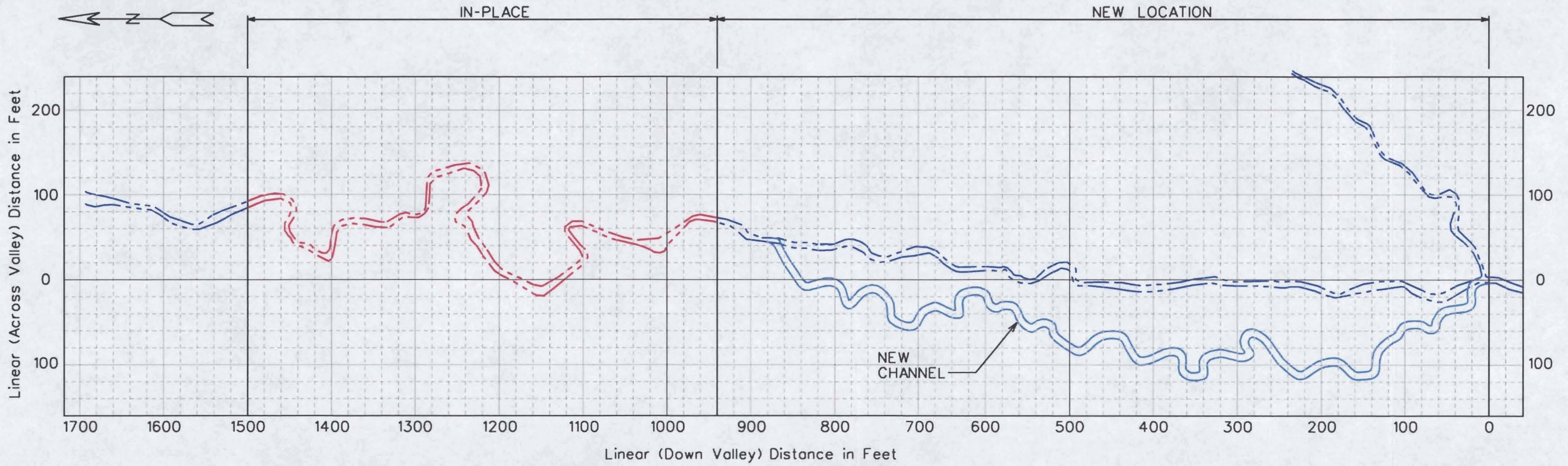
IN-PLACE



AVERAGE WATER SURFACE SLOPE - 0.0058

TOTAL AVERAGE WATER SURFACE SLOPE - 0.0075

- - - - BANKFULL ELEVATION
—·—·— WATER SURFACE ELEVATION
——— BED ELEVATION



EcoScience Corporation
Raleigh, North Carolina

REVISIONS

Client:
NC WETLAND RESTORATION PROGRAM

Project:
LYLE CREEK FIRST YEAR MONITORING REPORT

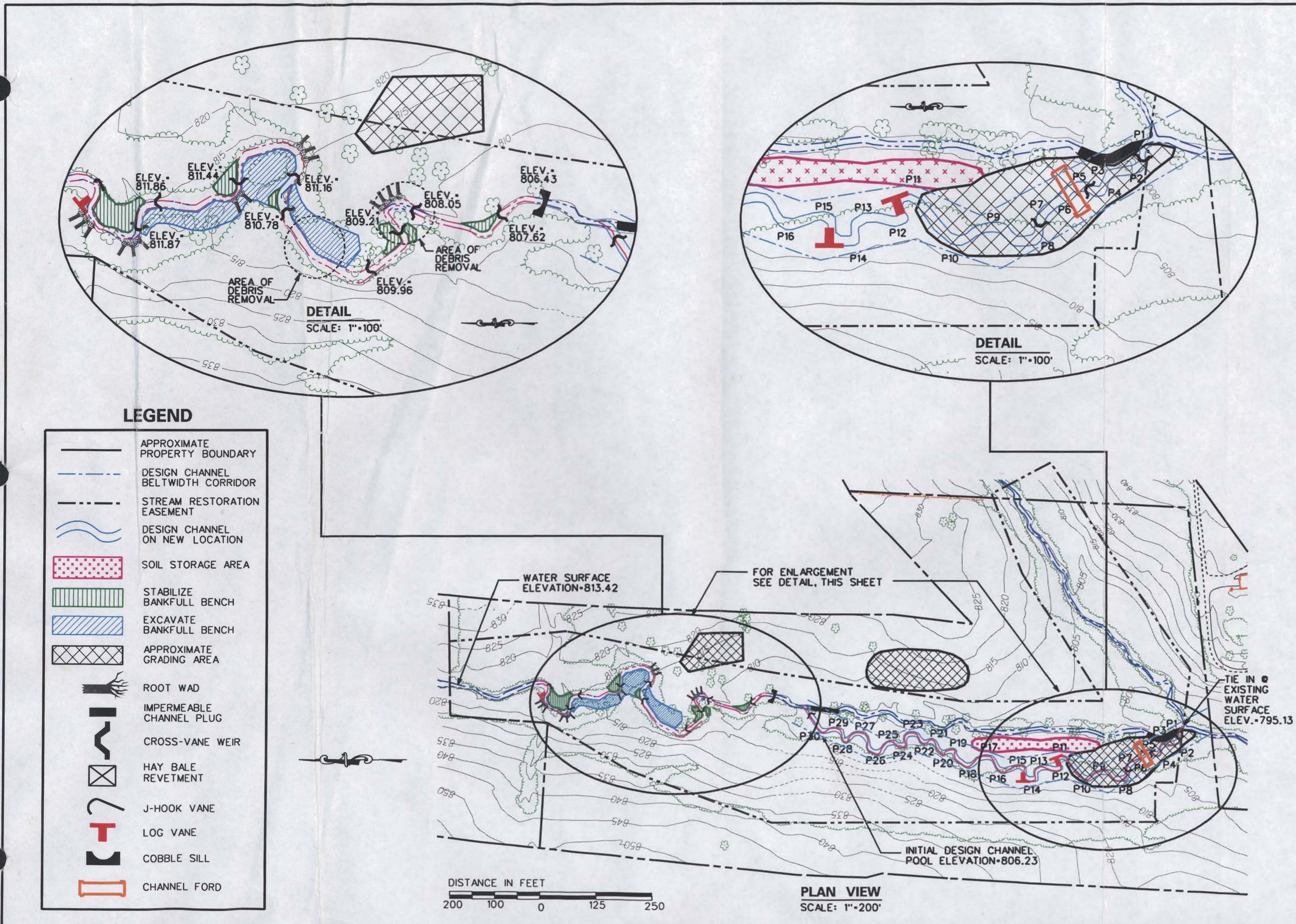
CATAWBA COUNTY, NORTH CAROLINA

Title:
CHANNEL SLOPE ATTRIBUTES

Dwn By: MAF	Date: DEC 2002
Ckd By: WGL	Scale: AS SHOWN
ESC Project No.: 98-047.17	

FIGURE

2



EcoScience Corporation
Raleigh, North Carolina

REVISIONS

Client:
NC WETLAND RESTORATION PROGRAM

Project:
LYLE CREEK AS-BUILT CONSTRUCTION REPORT

CATAWBA COUNTY, NORTH CAROLINA

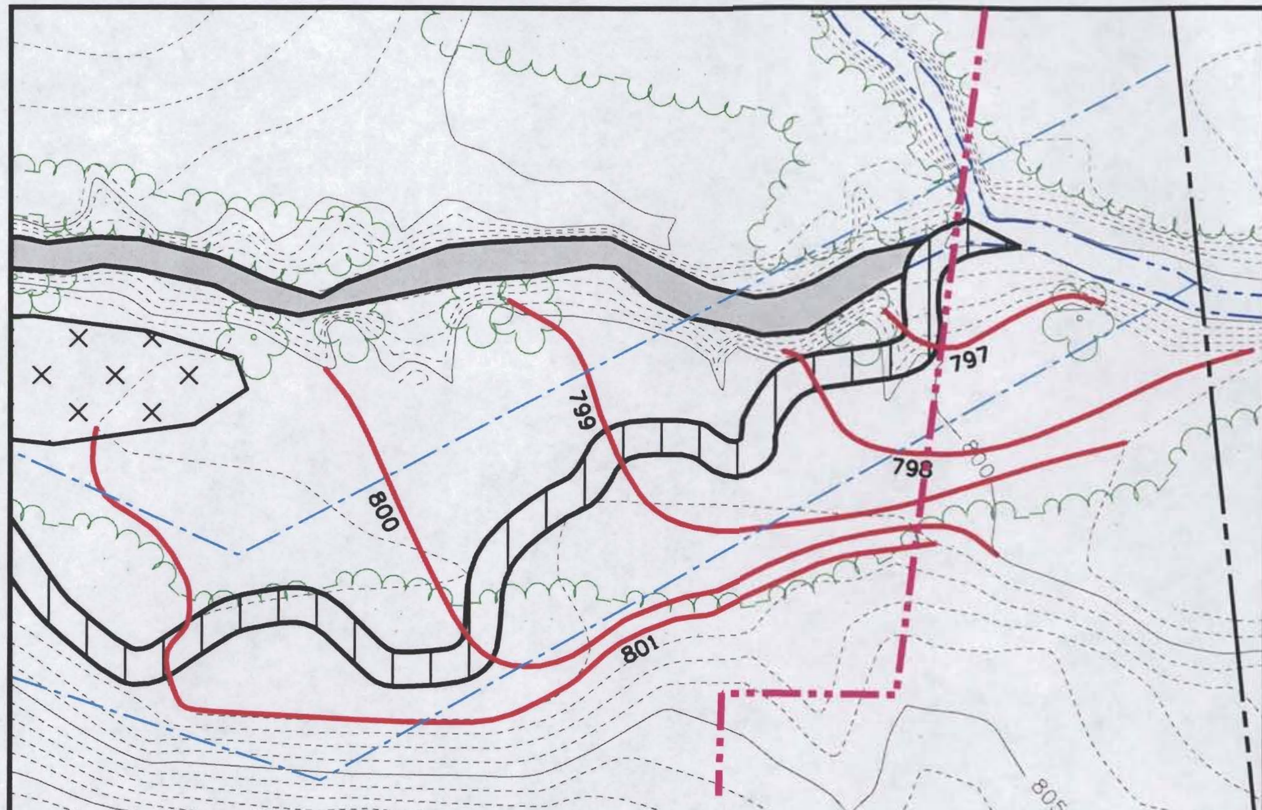
Title:
AS-BUILT CONSTRUCTION PLAN

Dwn By:	Date:
MAF	AUG 2002
Ckd By: WGL	Scale: 1"= 200'

ESC Project No.: 98-047.16

FIGURE

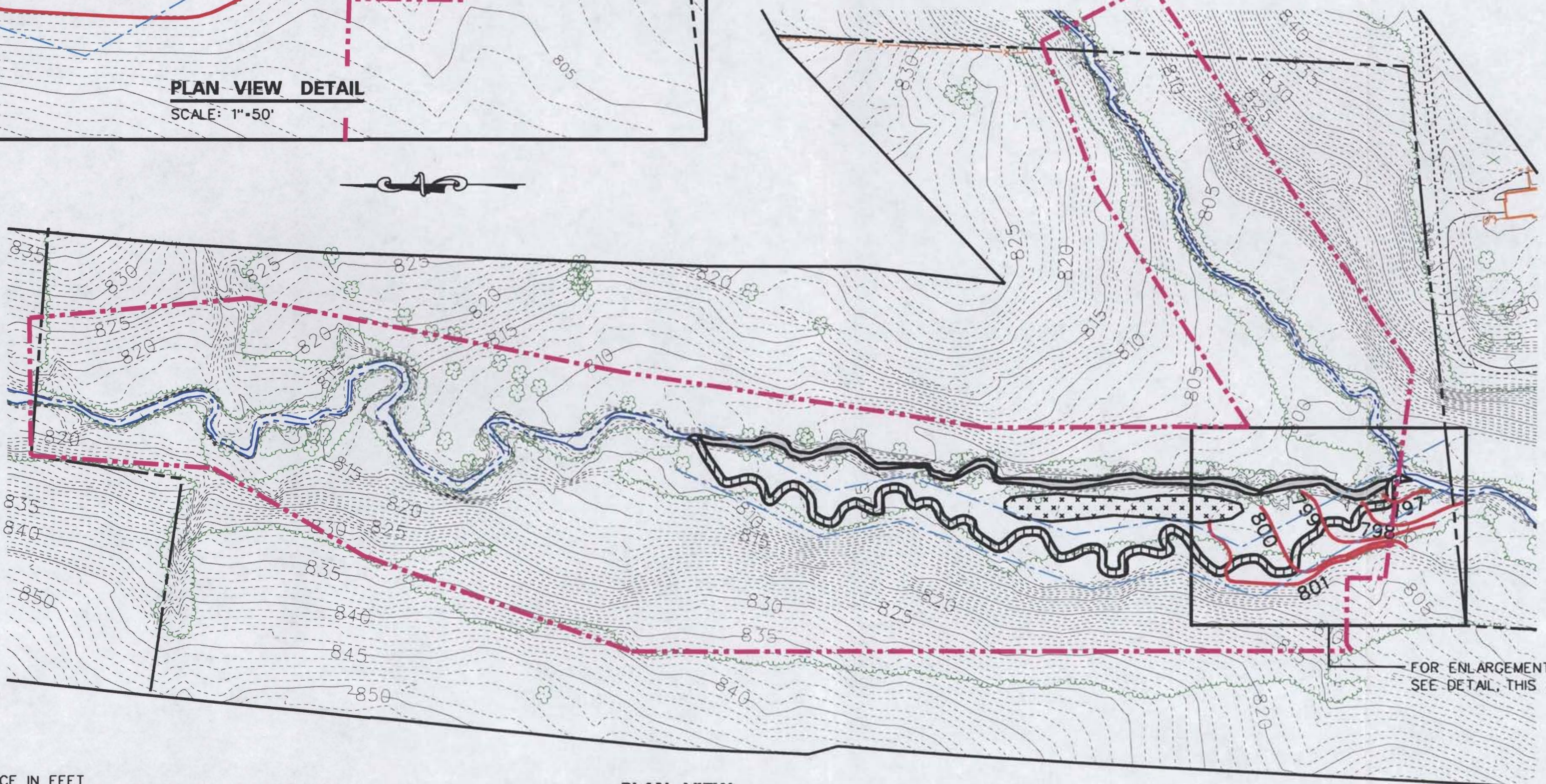
3



PLAN VIEW DETAIL
SCALE: 1"=50'

LEGEND

STREAM RESTORATION EASEMENT	
APPROXIMATE PROPERTY BOUNDARY	
BELT WIDTH CORRIDOR	
EXISTING TREE LINE	
EXISTING STREAM	
850	MAJOR CONTOURS
800	PROPOSED CONTOURS
DESIGN CHANNEL EXCAVATION AREA	
SOIL STOCKPILE AREA	
CHANNEL BACKFILL AREA	



DISTANCE IN FEET
200 100 0 100 200

PLAN VIEW
SCALE: 1"=150'

EcoScience Corporation
Raleigh, North Carolina

REVISIONS

Client:
NC WETLAND RESTORATION PROGRAM

Project:
LYLE CREEK AS-BUILT CONSTRUCTION REPORT

CATAWBA COUNTY, NORTH CAROLINA

Title:
NEW LOCATION REACH FLOOD PLAIN GRADING PLAN

Dwn By: MAF	Date: AUG 2002
Ckd By: WGL	Scale: 1"= 150'
ESC Project No.: 98-047.16	

FIGURE
4

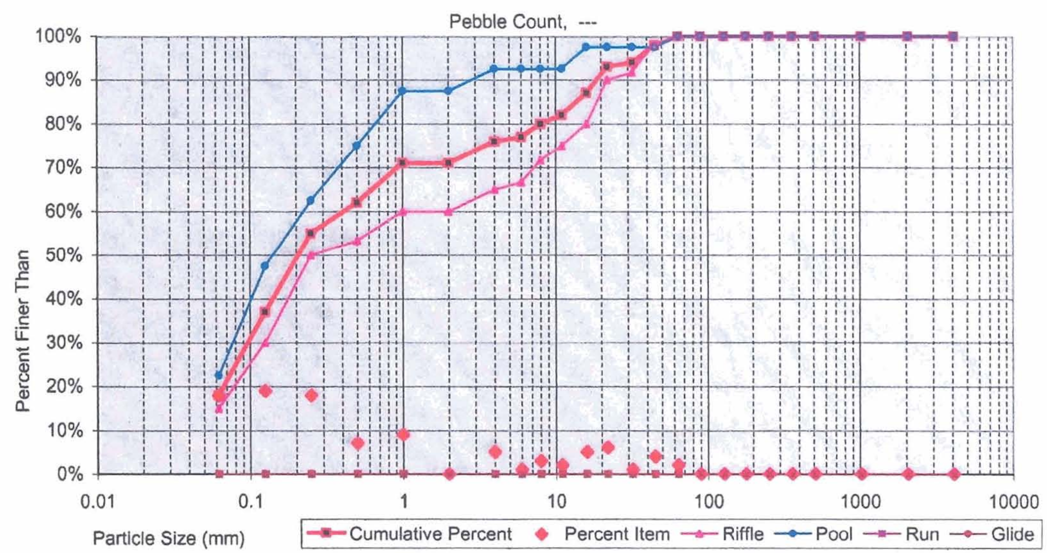
Graph A

Weighted Pebble Count

Percent Riffle:	**60**
Percent Pool:	**40**

Note:	**Lyle Creek First Year Monitoring**

Material	Size Range (mm)		Total #
silt/clay	0	0.062	18.0
very fine sand	0.062	0.13	19.0
fine sand	0.13	0.25	18.0
medium sand	0.25	0.5	7.0
coarse sand	0.5	1	9.0
very coarse sand	1	2	0.0
very fine gravel	2	4	5.0
fine gravel	4	6	1.0
fine gravel	6	8	3.0
medium gravel	8	11	2.0
medium gravel	11	16	5.0
coarse gravel	16	22	6.0
coarse gravel	22	32	1.0
very coarse gravel	32	45	4.0
very coarse gravel	45	64	2.0
small cobble	64	90	0.0
medium cobble	90	128	0.0
large cobble	128	180	0.0
very large cobble	180	256	0.0
small boulder	256	362	0.0
small boulder	362	512	0.0
medium boulder	512	1024	0.0
large boulder	1024	2048	0.0
very large boulder	2048	4096	0.0
bedrock			0.0
Weighted Count:			100
True Total Particle Count:			100



Size percent less than (mm)				
D16	D35	D50	D84	D95
#N/A	0.12	0.2	13	35

Percent by substrate type					
silt/clay	sand	gravel	cobble	boulder	bedrock
18%	53%	29%	0%	0%	0%

cutoffs. Profile comparisons of as-built versus year one water surface slopes (average water surface slope [0.0076 vs. 0.0075], riffle slopes [0.0141 vs. 0.0147], and pool slopes [0.0022 vs. 0.0024]) do not indicate significant changes. Based on dimension, pattern, and profile measurements, current monitoring indicates that the restored channel appears stable upon completion of year one monitoring.

CONTINGENCY

In the event that stream success criteria are not fulfilled, a mechanism for contingency will be implemented. Stream contingency may include, but may not be limited to, 1) repair of dimension, pattern, and/or profile variables and 2) bank stabilization. The method of contingency is expected to be dependent upon stream variables not in compliance with success criteria. Primary concerns which may jeopardize stream success include 1) headcut migration through the site and/or 2) bank erosion.

<u>Headcut Migration Through the Site</u> – In the event that a headcut occurs within the Site (identified visually or through on-site measurements [i.e. bank height ratios exceeding 1.4]), provisions for impeding headcut migration and repairing damage caused by the headcut may be implemented. Headcut migration may be impeded through the installation of in-stream grade control structures (rip rap sill and/or cross vane weir) and/or restoring stream geometry variables until channel stability is achieved. Channel repairs to stream geometry may include channel backfill with course material and stabilizing the material with erosion control matting, vegetative transplants, and/or willow stakes.

<u>Bank Erosion</u> – In the event that severe bank erosion occurs at the Site, resulting in width/depth ratios significantly higher than the previous monitoring year, contingency measures to reduce bank erosion and width/depth ratios may occur. Bank erosion contingency may include the installation of cross vane weirs and/or bank stabilization measures. If the resultant bank erosion induces shoot cutoffs or channel abandonment, a channel may be excavated which will reduce shear stress to stable values.

VEGETATION MONITORING

MONITORING PROGRAM

Restoration monitoring procedures for vegetation are designed in accordance with EPA guidelines enumerated in MiST documentation (EPA 1990) and COE Compensatory Hardwood Mitigation Guidelines (DOA 1994). A general discussion of the restoration monitoring program is provided.

Vegetative planting has not occurred; however, it is expected to take place in the winter of 2003. After planting has been completed, an initial evaluation will be performed to verify planting methods and to determine initial species composition and density. Supplemental planting and additional Site modifications will be implemented, if necessary.

Upon planting completion, four sample plots will be randomly placed within the Site. In each sample plot, vegetation parameters to be monitored include species composition and species density.

MONITORING RESULTS

Planting is expected to occur in the winter of 2003. Vegetation monitoring will commence immediately following the initial planting. Results will be provided upon completion of vegetative monitoring.

EVALUATION OF SUCCESS CRITERIA

Success criteria have been established to verify that the vegetation component supports community elements necessary for floodplain forest development. Success criteria are dependent upon the density and growth of characteristic forest species. Additional success criteria are dependent upon density and growth of "Character Tree Species." Character Tree Species include planted species along with species identified through visual inventory of an approved reference (relatively undisturbed) bottomland forest community used to orient the project design. All canopy tree species planted and identified in the reference forest will be utilized to define "Character Tree Species" as termed in the success criteria. Tree species identified in reference forest measurements are included in the As-Built Construction Report, Appendix C.

An average density of 320 stems per acre of Character Tree Species must be surviving in the first three monitoring years. Subsequently, 290 character tree species per acre must be surviving in year 4, and 260 character tree species per acre in year 5. Planted species must represent a minimum of 30 percent of the required stem per acre total (96 stems/acre). Each naturally recruited character species may represent up to 10 percent of the required stem per acre total. In essence, seven naturally recruited character species may represent a maximum of 70 percent of the required stem/acre total. Additional stems of naturally recruited species above the 10 percent - 70 percent thresholds are discarded from the statistical analysis. The remaining 30 percent is reserved for planted character species (oaks, *etc.*) as a seed source for species maintenance during mid-successional phases of forest development.

Evaluation of success criteria will be provided upon completion of vegetation monitoring.

CONTINGENCY

If vegetation success criteria are not achieved based on average density calculations from combined plots over the entire restoration area, supplemental planting will be performed with tree species approved by regulatory agencies. Supplemental planting will be performed as needed until achievement of vegetation success criteria.

No quantitative sampling requirements are proposed for herb assemblages as part of the vegetation success criteria. Development of floodplain forests over several decades will dictate the success in migration and establishment of desired understory and groundcover populations. Visual estimates of the percent cover of herbaceous species and photographic evidence will be reported for information purposes.

REFERENCES

Department of the Army (DOA). 1994. Corps of Engineers Wilmington District Compensatory Hardwood Mitigation Guidelines (12/8/93).

Environmental Protection Agency (EPA). 1990. Mitigation Site Type Classification (MiST). EPA Workshop, August 13-15, 1989. EPA Region IV and Hardwood Research Cooperative, NCSU, Raleigh, North Carolina.

Rosgen D. 1996. Applied River Morphology. Wildland Hydrology. Pagosa Springs, Colorado.

Photographic Plot Data

(Plot Locations can be found in Figure 14 of the As-Built Document)

PHOTO PLOT 1

J-Hook

Looking Downstream

PHOTO PLOT 2

Looking Upstream

Looking Downstream

PHOTO PLOT 3

Looking Upstream

Looking Downstream

PHOTO PLOT 4

Looking Upstream

Looking Downstream

PHOTO PLOT 5

Cross-Vane Weir

Looking Downstream

PHOTO PLOT 6

Looking Upstream

Looking Downstream

PHOTO PLOT 7

Looking Upstream

Looking Down-valley

PHOTO PLOT 8

(tree branches in foreground of pictures are the result of an ice-storm)

Looking Upstream

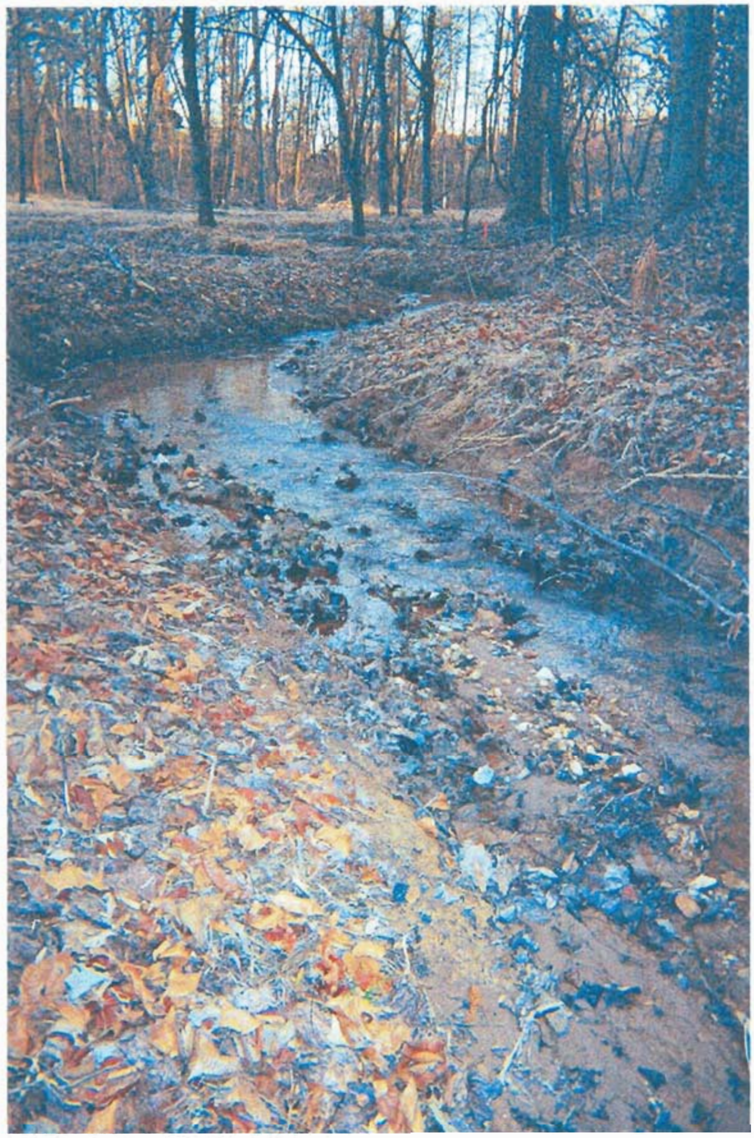
Looking Downstream

PHOTO PLOT 9

Looking Upstream

Looking Downstream

PHOTO PLOT 10



Looking Downstream

PHOTO PLOT 11

Looking Upstream

Looking Downstream

PHOTO PLOT 12

Looking Upstream

Looking Downstream

ATTACHMENT TO APPENDIX D (AS-BUILT MITIGATION REPORT)
2002 Mitigation Monitoring
Vegetative Sampling Results

2002 Vegetative Sampling

Quantitative sampling of vegetation at Lyle Creek was carried out in February 2002, approximately six months after construction and one month after planting of the site. Four sampling plots were established, being located to equally sample the floodplain bottomland hardwood community and the stream-side forest and shrub community (Supplement Figure 1).

Each sample plot is a continuous 600-foot transect, except for Plot #3, which is divided into two separate 300-foot transects. Plot width along each transect extends 4 feet on each side of the central line, providing a 0.11 acre sample (600 feet x 8 feet). The total area sampled thus comprises 0.44 acre, approximately 10 percent of the total planted area. The center and end points of each plot are permanently established with labeled, white polyvinyl chloride (PVC) pipes. All woody species rooted within the plot boundary were tallied by species and recorded regardless of height or diameter breast height (dbh). In order to compare sampling results to success criteria, collected data were analyzed to determine species composition, abundance, density, and relative density.

Year One Monitoring Results and Discussion

Results of vegetative sampling are presented in Supplement Table 1. A total of 18 tree and 5 shrub species were recorded within the four sample plots to provide an overall estimated density of 780 stems/acre. All of the shrub species encountered were planted (buttonbush, elderberry, tag alder, viburnums, and bankers dwarf willow) and accounted for a combined density of 108 stems/acre (14 percent). The three planted *Viburnum* species were lumped into one species category because of difficulty in identification to the species level. Planted tree species were estimated to account for a density of 630 stems/acre (81 percent) and recruit (volunteer) tree species accounted for a density of 42 stems/acre (5 percent), for a combined tree stem density of 672 stems/acre. Black willow was the most abundant planted tree species, accounting for 161 stems/acre, followed by American sycamore (95 stems/acre), ironwood (82 stems/acre), American elm (66 stems/acre), and green ash (57 stems/acre). The least represented planted tree species were black cherry (27 stems/acre) and blackgum (25 stems/acre). Recruit saplings and preexisting trees were dominated by persimmon (14 stems/acre) and black walnut (7 stems/acre). As expected, measured densities are somewhat correlated with planted densities of each species within the bottomland hardwood component (see As-Built Construction Report).

Considering that no Characteristic Tree Species may account for more than 20 percent (64 stems/acre) of the minimum required density (320 stems/acre), the maximum sampled density that may be applied toward success criteria is 483 stems/acre. This estimate includes volunteer tree species that were present in the reference plots. In addition, 83 percent of tree species sampled are Characteristic Tree Species, and the planted tree density represents 93 percent of the allowed tree density of 483 stems/acre. Therefore, characteristic tree density and species composition currently meet the minimum requirements for the proposed success criteria.

CITY OF RALEIGH
WAKE COUNTY, N.C.

WATERSHED AREA 0.53 SQMI
USGS TOPO MAP

NC STATE UNIVERSITY

BIOLOGICAL & AGRICULTURAL ENGINEERING
Weaver Labs Campus Box 7625
North Carolina State University
Raleigh, NC 27695

NO	REVISIONS	DRN	CHK	DATE
1	WATERSHED AREA			

Main = 0.53
≈ 14 sq ft
≈ 40 sq ft

Main Above trib = 0.3
≈ 11 sq ft
≈ 30 sq ft

Trib = .12
≈ 5 sq ft
≈ 15 sq ft