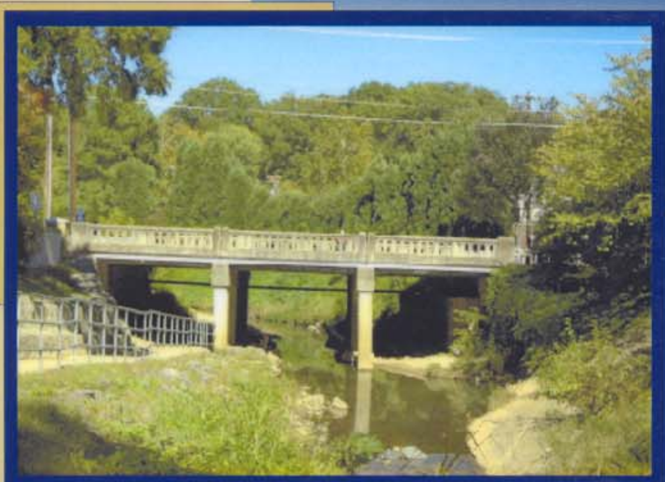
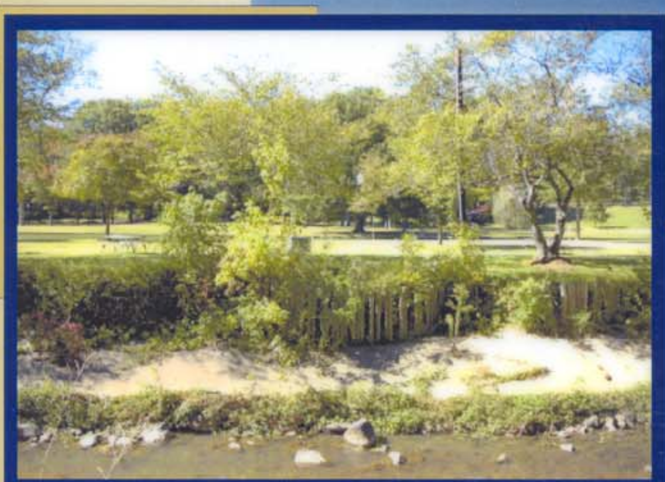
FINAL REPORT

Little Sugar Creek at Freedom Park Stream Restoration Plan

Mecklenburg County, North Carolina





HDR

HDR Engineering, Inc. of the Carolinas

in association with

HARP, Inc.

Habitat Assessment and Restoration Program

October 2002

TABLE OF CONTENTS

SECTION | **PAGE**

1.0 INTRODUCTION **1**

2.0 GOALS AND OBJECTIVES **1**

3.0 LOCATION INFORMATION **2**

4.0 GENERAL WATERSHED DESCRIPTION **2**

4.1 Current Land Use 2
4.2 Future Land Use 3

5.0 EXISTING STREAM CONDITIONS **3**

5.1 Hydrological Features 3
5.2 Soils 3
5.3 Plant Communities 4
5.4 Protected Species 4
5.5 Stream Geometry 4
5.6 Stream Substrate 4
5.7 Constraints 5
5.8 Storm Water 5

6.0 REFERENCE STREAM INFORMATION **5**

6.1 Briar Creek Reference Reach 5
6.1.1 Stream Classification 6
6.1.2 Dimension 6
6.1.3 Pattern 6
6.1.4 Profile 7
6.1.5 Plant Community 7

6.2 Long Creek Reference Reach 7
6.2.1 Stream Classification 8
6.2.2 Dimension 8
6.2.3 Pattern 8
6.2.4 Profile 8
6.2.5 Plant Community 9
6.3 USGS Gauging Data 9

6.4 Regime Data Analysis 9

7.0 STREAM RESTORATION PLAN 10

7.1 Restored Stream Classification 11
7.2 Restored Stream Morphology 11
7.3 Sediment Transport Analysis 11
7.4 Stability Analysis 15
7.4.1 Velocity and Stability Analysis 15
7.4.2 Traction Force Criteria and Shield Curve Analysis 16
7.4.3 Bed and Bank Stability Structures 17
7.5 Vegetation 19
7.6 Storm Water 19

8.0 STREAM PERFORMANCE CRITERIA AND MONITORING PLAN 19

8.1 Substrate Monitoring 20
8.2 Vegetation 20
8.3 Monitoring Schedule 20
8.4 Monitoring Methods 20

9.0 STREAM RESTORATION BENEFITS 20

10.0 REFERENCES 22

FIGURES

Figure 1 – Little Sugar Creek Watershed at Freedom Park ..... Appendix A
Figure 2 – Aerial Overview, Little Sugar Creek at Freedom Park ..... Appendix A
Figure 3 – Freedom Park Soils ..... Appendix A
Figure 4 – Little Sugar Creek Longitudinal Profile ..... Appendix A
Figure 5 – Approximate Bedrock Locations ..... Appendix A
Figure 6 – Storm Water Outfall Locations ..... Appendix B
Figure 7 – Briar Creek Watershed ..... Appendix A
Figure 8 – Diameters and Radii of Stream for Briar Creek ..... Appendix A
Figure 9 – Briar Creek Reference Reach Longitudinal Profile ..... Appendix A
Figure 10 – Long Creek Watershed ..... Appendix A
Figure 11 – Long Creek Cross Sections ..... Appendix A
Figure 12 – Long Creek Pattern Map Near Primm Road ..... Appendix A
Figure 13 – Long Creek Topographic Map Near Primm Road ..... Appendix A
Figure 14 – Long Creek Reference Reach, Longitudinal Profile ..... Appendix A
Figure 15 – Discharge Rating Curve for Little Sugar Creek ..... Appendix A

Figure 16 – Discharge Rating Curve for Little Sugar Creek .... Appendix A
Figure 17 – Discharge Rating Curve for Briar Creek .... Appendix A
Figure 18 – Discharge Rating Curve for Long Creek .... Appendix A
Figure 19 – 1996-2001 Annual Peak Flow for Little Sugar Creek .... Appendix A
Figure 20 – 1997-2001 Annual Peak Flow for Briar Creek .... Appendix A
Figure 21 – 1966-2000 Annual Peak Flow for Long Creek .... Appendix A
Figure 22 – Regime Curve Data .... Appendix A
Figure 23 – Bankfull Cross Sections .... Appendix A
Figure 24 – Overall Site Plan .... Appendix A
Figure 25 – Planform of Little Sugar Creek .... Appendix A
Figure 26 – Riffle Type .... Appendix A
Figure 27 – Inner Berm and Point Bar Channel Constrictor Schematic .... Appendix A
Figure 28 – Little Sugar Creek Proposed Longitudinal Profile .... Appendix A
Figure 29 – Interpolation Curves for Freedom Park .... Appendix A
Figure 30 – Sediment Transport .... following p. 18
Figure 31 – Estimated Velocities and Bed Material Sizing .... following Figure 30
Figure 32 – Bank Stability Analysis .... following Figure 31
Figure 33 – Shield Curve Analysis .... following Figure 32

TABLES

Table 1 – Preliminary Estimates of Fluvial Morphologic Parameters .... Appendix A
Table 2 – Briar Creek Vegetation .... Appendix A
Table 3 – Long Creek Vegetation .... Appendix A
Table 4 – Bed Shear Stress Estimates .... Appendix A
Table 5 – Estimated Bed Traction Force and Minimum D50 for Stability .... Appendix A
Table 6 – Freedom Park Potential Planting List .... Appendix A

APPENDICES

A Figures and Tables
B Survey of Storm Water Outfalls

Little Sugar Creek at Freedom Park
Stream Restoration Plan
Mecklenburg County, North Carolina

1.0 INTRODUCTION

HDR Engineering, Inc. of the Carolinas (HDR) and Habitat Assessment and Restoration Program (HARP) have prepared this stream restoration plan (Plan) of Little Sugar Creek at Freedom Park, Charlotte, for the intended use of the North Carolina Department of Environment and Natural Resources (NCDENR) Wetland Restoration Program (WRP).

The development of a restoration design for the approximately 4,200 linear feet (LF) of Little Sugar Creek in Freedom Park entailed a multifaceted study of the historical and current stream conditions within both the Little Sugar Creek watershed and two local reference reach watersheds. Historical human activities, including development within the watershed and physical alteration of the stream channel, have led to the current desire to restore the stream to more of a natural state. However, the urban environment of the Little Sugar Creek watershed prohibits any restoration to completely natural conditions. Constraints including development, infill in the floodplain, and large volumes of storm water runoff from impervious surfaces restrict the number of applicable restoration options.

In most urban streams and creeks, restoration to pristine conditions is an unrealistic goal due to the extent of prior watershed alteration. It has been documented that degradation of stream quality occurs at relatively low levels (10 to 20 percent) of imperviousness; and at watershed imperviousness levels above 30 percent, predevelopment channel stability and biodiversity cannot be fully maintained, even when Best Management Practices (BMPs) or retrofits are fully applied. The restoration objectives in urban streams should then be set to target realistically attainable conditions. For the reach of interest along Little Sugar Creek, this translates to reduction of bank erosion and partial restoration of aquatic and riparian habitat.

This report documents the attainable goals and objectives of restoring Little Sugar Creek within the Project Area and presents an implementation strategy. Plans are based on Rosgen stream restoration principles and reference reach analysis. In addition, a monitoring plan and schedule ensure the long-term stability and success of this restoration effort.

2.0 GOALS AND OBJECTIVES

The goal of the Plan is to restore the stream ecosystem within the boundaries of Freedom Park. Restoration to pristine conditions is an unrealistic goal due to the extent of prior watershed alteration; therefore, restoration plans are based on the best available options to restore the natural functions of Little Sugar Creek. Specific objectives of the Plan include the following: (1) water quality improvement, (2) restoration of aquatic habitat, (3) re-establishment of native vegetation, (4) flood volume storage, (5) reduction of bank erosion, and (6) improvement of stream corridor aesthetics. Discussion of the plans to accomplish these objectives is included in Section 7.0. After project completion, monitoring will be conducted to ensure the objectives of the Plan are met and the project is successful.

Actions by other local agencies will also contribute to the overall goal of restoring natural stream functions to Little Sugar Creek. The Mecklenburg County Parks and Recreation Department is concurrently planning the establishment of a greenway along the length of Little Sugar Creek. Construction is slated for completion in 2003. Coordination with this and other local agencies during the planning and construction of this project will accomplish the overall goal of providing the community with open space and natural recreation areas. Additionally, efforts by Mecklenburg County (County) and the City of Charlotte (City) to implement storm water improvement strategies in the upper Little Sugar Creek watershed will improve water quality.

3.0 LOCATION INFORMATION

The Project Area is located on Little Sugar Creek in the Catawba River Basin (HU No. 03050103) in Mecklenburg County, North Carolina (Figure 1). The Project Area for this site is the stream reach bounded by East Boulevard and Princeton Avenue (Figure 2) and lies entirely within Freedom Park and the City of Charlotte. Freedom Park is a part of the Mecklenburg County Park and Recreation Department public park system.

The North Carolina Division of Water Quality (NCDWQ) lists Little Sugar Creek in Subbasin No. 03-08-34 and classifies the best usage of this 303(d)-listed stream as Class C. Class C waters are those protected for secondary recreation, fishing, wildlife, fish and aquatic life propagation and survival, agriculture, and other uses suitable for Class C. Secondary recreation includes wading, boating, and other uses involving human body contact with water where such activities take place in an infrequent, unorganized or incidental manner. There are no restrictions on watershed development activities. Wastewater discharge and storm water management requirements are applicable (NCDWQ, 1999). The factors of water quality concern are fecal coliform, biological impairment, and sediment pollution.

4.0 GENERAL WATERSHED DESCRIPTION

The drainage area for Little Sugar Creek at Freedom Park is approximately 12 to 14 square miles (Figure 1). This figure (a mosaic of the Charlotte East and Derita USGS Quadrangles) also illustrates the predominant urban character of the watershed. The range in drainage area is due to the additional drainage represented largely by Dairy Branch, a tributary that enters Little Sugar Creek within Freedom Park. The headwaters of Little Sugar Creek begin near the interchange of Interstate I-85 and Highway 29/49 and flow south-southwest through a highly urbanized portion of the City, including the uptown business district, to Freedom Park.

4.1 Current Land Use

While the Plan will be constructed within Freedom Park, the land use throughout the watershed is highly urbanized and considered built-out. The watershed includes a portion of the urbanized City within the I-277 beltway. Commercial and dense residential areas surround the uptown area of the City. Currently, less than 15 percent of the area within the watershed is classified as vacant. This small percentage of infill parcels is mostly located in the uppermost portions of the watershed near Derita. Development includes floodplain encroachment by structures, which is most noticeable in aerial photographs from the 1960s and 1970s.

Urban development correlates to a high percentage of impervious area. Land use/land cover in the upper Little Sugar Creek watershed is approximately 15 to 20 percent high-density commercial and industrial (75 percent impervious cover), 40 to 45 percent low-density residential (15 to 20 percent impervious), and 30 percent forested land (0 percent impervious), with minor water and other land use types (Vempaty, 1997). Using land cover to impervious cover relationships developed by the United States Soil Conservation Service (USSCS, 1986), the overall impervious cover is estimated at 38 percent (Wilkerson, et. al., 1998). The same authors estimate the watershed runoff curve number as 78. The estimated percent impervious cover and runoff curve numbers for the upper Little Sugar Creek watershed are the highest values for watersheds of comparable size in the County. Because of this high degree of imperviousness, the watershed experiences quick response to storm runoff, which translates to rapid increases in stream flows.

4.2 Future Land Use

Future development will be minimized because the watershed is considered built-out. Infill development can occur on the remaining vacant parcels. As this infill development continues, a small increase in watershed imperviousness is likely. Redevelopment of currently developed parcels is also likely in this urbanized watershed.

5.0 EXISTING STREAM CONDITIONS

5.1 Hydrological Features

Past records indicate that multiple entities have dredged and/or channelized Little Sugar Creek, including the 4,200 LF of stream within Freedom Park (Figure 2). Around 1917, an article entitled "Drainage Work in Mecklenburg County," prepared by Heriot Clarkson, then chair of the Mecklenburg County Drainage Commission, makes it clear that most, if not all, of the larger tributaries of the Catawba River that drain the County were part of a County-wide dredging program that occurred between 1911 and 1930. The dredging of Little Sugar Creek was completed by 1917 to a minimum channel width of approximately 20 feet and depth of 8 feet.

Review of historical aerial photographs reveal Little Sugar Creek has had an established alignment for at least the last 60 to 80 years. Overall, the current alignment has existed since early part of the 1900s. In the 1920s, the main trunk sewer line along Little Sugar Creek was put in place (per. comm. Andrew Burg), and this essentially corrected the alignment for the areas above Tyvola Road. The aerial photographs also indicate that the creek was periodically cleared of vegetation.

In the mid-1960s and early 1970s, the City initiated on erosion control system along the banks of Little Sugar Creek, as it flows through Freedom Park, using a combination of grouted riprap and concrete bank covering. The bottom of the channel was left in its "natural" condition. During July 2002, the County removed the grouted riprap and concrete banking and temporarily stabilized the banks with erosion control matting. Additionally, the large flood control weir structure located approximately 450 feet upstream of Princeton Avenue was removed.

These impacts to Little Sugar Creek and its watershed influence the hydrology of the stream. During a bankfull event, stream discharge ranges from 1,600 cubic feet per second (CFS) to an estimate of 2,300 CFS at watershed build-out conditions. According to the nearest stream gage maintained by the United States Geological Survey (USGS), bankfull discharge is 1,900 CFS (Table 1). These storm events carry water at an estimated velocity of 6.3 feet per second.

5.2 Soils

According to the Mecklenburg County Soil Survey, soils within the Project Area include Monacan and Pacolet (Figure 3). Monacan soils are deep, moderately well and somewhat poorly drained with moderate permeability. They formed in recent alluvial sediments of the Piedmont and Coastal Plain. Slopes are commonly less than two percent. Pacolet soils consists of very deep, well drained, moderately permeable soils that formed in material weathered mostly from acid crystalline rocks of the Piedmont uplands. Within the Project Area, these soils occur on slopes ranging from 15 to 25 percent (USDA, 1979).

5.3 Plant Communities

The composition and distribution of plant communities are reflective of topography, soils, hydrology, and past and present land usage. In this case, the vegetation of the Project Area is primarily determined by land use. The vegetation on the west side of the stream within Freedom Park is urban with no natural community cover and is currently maintained by the County. On the east side of Little Sugar Creek, a mature canopy of pine, ash, sweetgum, box elder and mixed oaks (white and red) exists. Near the Nature Museum at the southern end of the Project Area, vegetation includes an understory of dogwood and privet with a ground cover of honeysuckle, English, and poison ivy.

5.4 Protected Species

A review of the North Carolina Natural Heritage Program database of rare species and unique habitats (as of March 23, 2002) shows no occurrence of Federally protected species within one mile (1.6 km) of the Project Area.

5.5 Stream Geometry

Little Sugar Creek within Freedom Park can be classified as a Rosgen Class C3 to C5 stream. Class C streams are typically slightly entrenched with a moderate to high width to depth ratio (Rosgen, 1996). Little Sugar Creek exhibits an entrenchment ratio of greater than 5 and a high width to depth ratio of 12.5 (Table 1). More specifically, Class C3 to C5 streams exhibit a slope ranging from 0.001 to 0.02 (Rosgen, 1996). Little Sugar Creek at Freedom Park exhibits a slope of 0.0029, which is within this range (Figure 4). Bedrock outcroppings also influence the channel slope and sinuosity by creating nick points (Figure 5).

However, this stream segment does not exhibit all the parameters for a Class C channel. Little Sugar Creek at Freedom Park has been channelized and dredged; therefore, it does not have the high sinuosity typical of Class C streams (Table 1). Additionally, the relationship between the stream channel and floodplain has been altered by these activities. Flash flooding occurs in this urban area. Dredging has also altered typical riffle and pool sequences.

5.6 Stream Substrate

The stream travels over several zones of bedrock and, in at least six locations within the stream course, large outcrops of the native bedrock material can be seen in the stream channel and along the banks. The channel bottom is comprised primarily of sand and pebbles, with several areas of cobble riffles, a few large boulders, and native rock outcrop zones (Figure 5).

Riffle, pool, and point bar pebble counts present a quantitative characterization of streambed material, sediment transport, and hydraulic stress. Surface particles, or pavement material, are typically coarser than subpavement particles. These later particles are likely to be mobilized by stream flows and velocities associated with near bankfull storm events. The riffle substrate D50 particle size is 4.8 mm, while the pool D50 is a larger 6.6 mm. The point bar D50, expected to be the smallest of the three measurements, is 2.6 mm. The larger D84 sizes range from 6.4 mm in riffles to 25.1 mm in pools (Table 1). Further substrate analysis is presented in Section 7.3.

5.7 Constraints

The stream restoration design of Little Sugar Creek has four sources of constraints that are outside the realm of fluvial geomorphology and hydrology. These constraints are cost, a sewer line, riparian land use, and adverse flooding impacts. The latter two impose severe limits on the degree to which a design can strictly achieve a full restoration of Little Sugar Creek back to its original floodplain setting.

A fifth constraint, not directly affecting the restoration design, is water quality. Little Sugar Creek, from its source tributaries to the South Carolina state line, is an Environmental Protection Agency (EPA) 303(d) listed Class C stream with fecal coliform, biological impairment, and sediment pollution being the factors of concern. The restoration of aquatic habitat will be impeded, regardless of the design, by the existing water quality problems, a solution for which lies outside the scope of this specific effort. These degraded conditions will likely improve as additional restoration efforts are implemented in the upper watershed and as the County and the City move to implement additional storm water improvement strategies.

In addition, three bridges cross Little Sugar Creek within Freedom Park (Figure 2). These structures must be protected to ensure their continued safety for pedestrians. The restoration design considerations of dimension, pattern, and profile are limited by the location of these structures.

5.8 Storm Water

Little Sugar Creek receives storm water from 21 locations along the stream reach within Freedom Park (Figure 6). These outfalls play a part in both flow volume and water quality in Little Sugar Creek. A comprehensive discussion, including recommendations and proposed actions, is provided in Appendix B.

6.0 REFERENCE STREAM INFORMATION

Seven sites were investigated for their feasibility as possible reference reaches. Of these seven areas, only two were found to have appropriate characteristics to merit the collection of reference reach data. These are Long Creek, located in the northwest portions of the County, and Briar Creek, located just to the east of Little Sugar Creek at Freedom Park.

6.1 Briar Creek Reference Reach

The reference reach on Briar Creek was chosen based on recommendations from City/County Storm Water staff regarding the stability of the reach in the vicinity of Myers Park High School (Figure 7). Dames and Moore (2001), on behalf of the United States Army Corps of Engineers (USACE), previously studied the Briar Creek reference reach in order to provide a foundation for an initial design framework for USACE restoration work along Little Sugar Creek from East Boulevard to Tyvola Road.

This reference reach has approximately 19 square miles of drainage from lands predominant of residential use and is directly adjacent to the upper Little Sugar Creek drainage basin (Figure 5). Therefore, the sites have similar topography, soils, and land use characteristics. The two primary differences between these sites are: 1) the Little Sugar Creek basin is more heavily developed by commercial and industrial land use with more impervious cover and piped storm drains, and 2) the Briar Creek reach behind Myers Park High School is, for most of its length, running in bedrock with an overall valley grade that is 0.0048 as opposed to the 0.0029 valley grade of Little Sugar Creek in Freedom Park.

Briar Creek, near Myers Park High School, has substantial portions of both bed and banks composed of bedrock. The rock has essentially stabilized the channel regardless of watershed land cover changes. However, the channel is wide enough to pass the dredges used in early 1900s, so channel alteration cannot be assumed. The Clarkson drainage report specifically mentions that Briar Creek was dredged, but did not discuss in any detail the limits of dredging along the creek. Additionally, the reach has a sewer line that was blasted into the bedrock along the east side of Briar Creek. This created a bench composed of rock aggregate along the east bank and modified the cross-section of the stream. Despite these detractors, Briar Creek has the most similar land use/land cover and drainage area to Little Sugar Creek. As a part of design research, additional data was collected to augment and confirm the data collected in the Dames and Moore USACE study.

In summary, there are three detractors from using Briar Creek as a reference reach. First, historical documents indicate that the creek was part of the dredging program implemented between 1913 and 1930. Second, when the sewer line was installed on the east bank, the rock banks were broken up and a bench or berm was constructed along the east bank modifying its cross-section, particularly below the bankfull stage. Third, the reach behind Myers Park High School is largely a bedrock-founded reach, which would not easily adjust to any urbanization flow regime, thus appearing stable despite changing hydrology. However, as previously mentioned, Little Sugar Creek is unlikely to have any directly comparable reference reach in the region; thus this data, combined with other reference reach information, needs to be collectively considered in the development of a stable restoration design.

6.1.1 Stream Classification

Briar Creek, near Myers Park High School, exhibits similar characteristics of Little Sugar Creek at Freedom Park, and therefore is classified similarly as a Class C/E3 to C/E5 stream. Class E streams have a higher width-to-depth ratio and sinuosity than Class C streams. Class E3 to E5 streams have similar slope ranges as Class C3 to C5 streams (Rosgen, 1996).

6.1.2 Dimension

The USACE reported cross-section area and bankfull stage information are included in Table 1 for the purpose of completing the Rosgen-type morphologic analysis. It must be viewed with some caution due to the disturbed nature of the east bank and the likelihood that bedrock reaches are not likely to respond rapidly to changing watershed conditions.

6.1.3 Pattern

Table 1 reports both the prior USACE data, as well as the additional data collected for this study. Additional pattern information was gathered from the low elevation infrared (IR) aerial photograph acquired at the onset of this project. Figures 8a and 8b show the pattern of Briar Creek behind Myers Park High School, as well as below Runnymede Lane where a set of more regular meanders are preserved. A series of 12 well-defined meanders can be mapped from these photographs and used to calculate an average meander radius of curvature of 186 feet. The meander belt width is dependent on whether one includes, or excludes, large bends produced by bedrock ledges. Excluding the large bend behind Myers Park High School yields a meander belt width that ranges from 80 to 200 feet. Including this bend takes the belt width to 520 feet. Bedrock control on the variability of stream pattern in the North Carolina Piedmont makes statistical averaging of this type of data of marginal usefulness. A typical value for areas without strong bedrock control would be approximately 150 feet (e.g., below Runnymede Lane).

6.1.4 Profile

The prior USACE study on Briar Creek stated the valley grade as .0086; however a new longitudinal profile (1,040 feet in length) yielded only .0044 for an average stream slope (Table 1, Figure 9). From what can be gathered from the location figure in the USACE report, the new profile is close to the reference reach cross-section area indicated in that report. However, the new longitudinal profile (conducted by using an instream level transit, survey tape, and stadia rod) indicates an average stream slope of 0.0044, with riffle slopes ranging from 0.007 to 0.072. The profile included eight riffle sections, on average 32 feet in length, with an average spacing of 98 feet. Stream sinuosity is only 1.1 along the 1,040-foot section, yielding .0048 as the valley slope (Table 1).

6.1.5 Plant Community

The plant community surrounding Briar Creek at Myers Park High School can be best classified as Piedmont Levee Forest (Schafale and Weakley, 1990). Briar Creek has very little active floodplain area or floodplain shelf in the channel. The stream channel is deep enough that the terrace is not impacted as frequently by flooding. Hence, the forest stops at the top of bank. Those species growing along the toe of slope of Briar Creek include Yellow poplar (*Liriodendron tulipifera*), Red maple (*Acer rubrum*), and Sweetgum (*Liquidambar styraciflua*) (Table 2). Because the forest has been protected in the past, the sizes of the trees are greater than those at Long Creek.

Due to the urban location of Briar Creek, the number of exotic tree species, such as Mimosa (*Albizia julibrissin*), and invasive species is high (Table 2). Invasive species include Privet (*Lonicera sinense*), Amur honeysuckle (*Lonicera mackii*), and English ivy (*Hedera helix*). Additionally, a sewer line on Briar Creek has been maintained as a cross country/nature trial.

6.2 Long Creek Reference Reach

A second reference reach was established in the northwest portions of the County along Long Creek. The stable and accessible segment of Long Creek used for a reference reach had a slightly smaller drainage area than the Freedom Park reach of Little Sugar Creek, but is closer to the drainage area of Little Sugar Creek at East Boulevard than the Briar Creek reference reach (Figure 10). The Long Creek reference reach has dimensions smaller than 18 feet and would not have passed the dredges used in the early 1900's dredging program. The Long Creek reach also has a bedrock based riffle section with v-shaped valley profile that is inconsistent with the rock removal and downcutting practices used in conjunction with the earlier dredging program.

The Long Creek watershed drains to the Catawba River in the northernmost part of Lake Wylie, just below the dam, to Mt. Island Lake. The reference reach on Long Creek is just 1/4 mile southeast of Gar Creek Cove on Mt. Island Lake. It can be accessed off Primm Road, along the County or North Carolina Department of Transportation (NCDOT) access into the future I-485 corridor. The reach will eventually be partially impacted by the new outer belt. The watershed that drains to the reference has approximately 10 and 1/2 square miles of drainage from predominant residential lands, but with subordinate forested and commercial/industrial tracts (Figure 10). Approximately 1,200 feet of the reach were surveyed to define the pattern, dimension, profile, and bed characteristics of the reach. Conventional stream assessment survey techniques were used (Rosgen 1994) to acquire this information.

In lieu of field pebble counts, meander, point bar, and riffle substrate samples were collected for laboratory grain size analysis, and independent armor studies were made in riffle and meander pool areas to more accurately assess grade and cross-section influences on bed transport characteristics in this reach. Additionally, the County 1:200 topographic maps augmented and provided an independent verification on stream pattern and longitudinal profile.

6.2.1 Stream Classification

Long Creek can also be classified as a Rosgen Class C3 to C5 stream. Class C streams are typically slightly entrenched with a moderate to high width-to-depth ratio (Rosgen, 1996). Long Creek is more entrenched than the other two streams, with an entrenchment ratio of 1.2 and a high width-to-depth ratio of 13.2 (Table 1). More specifically, Class C3 to C5 streams exhibit a slope ranging from 0.001 to 0.02 (Rosgen, 1996). Long Creek exhibits a slope of 0.0033, which is within this range.

6.2.2 Dimension

The average bankfull depth of Long Creek is 2.8 feet, while the bankfull width is 37 feet. This correlated to a width to depth ratio of 13.2. Long Creek exhibits an entrenchment ratio of 1.9. This data and other morphological characteristics are presented in Table 1. Typical stream cross sections are presented in Figure 11.

6.2.3 Pattern

The stream pattern of this reference reach is portrayed in Figure 12, from field surveys, as well as in Figure 13 from the 1:200 topographic maps. The field surveys reveal some small variation in bank structure not seen in the topographic maps, but which are otherwise reasonably consistent. On Figure 12, the location and length of riffle zones are shown. The average radius of curvature for meander bends is 76 feet, which is 2.05 times the bankfull width. The meander belt width is less than 70 feet if one focuses only on the downstream lower gradient portions of the reference reach, but if one includes the larger bend through the bedrock ridge, the belt width is closer to 420 feet (Table 1). The meander wavelength on average is 362. The sinuosity for this reach is 1.39.

6.2.4 Profile

One attribute of this reference reach that made it appealing for design purposes for the Freedom Park project is that the reach includes two gradient regimes. A bedrock-founded riffle zone, some 160 feet in length, where the stream cuts through a bedrock ledge is located at the upper end of this reference reach (Figure 14). Downstream from this area, the gradient is lower and broken up into smaller riffle and meander areas. In Freedom Park, the lower portions of the reach also have a steeper bedrock based zone, and thus have some parallels to the variations seen in this 1,200-foot reference reach.

Long Creek riffles varied from 22 to 162 feet in length, with a riffle-to-pool ratio of 0.58, and an average riffle spacing of 104 feet (pool length). Long Creek exhibits a valley grade of 0.0045 (ft/ft) and an average stream grade of 0.0033 (Figure 12). Riffle grades are approximately 0.012. Other morphologic data for this reference reach appears in Table 1.

6.2.5 Plant Community

The plant community surrounding Long Creek can best be classified as Piedmont Levee Forest (Schafale and Weakley, 1990). Typical tree canopy species include Sycamore (*Platanus occidentalis*) and Sweetgum (*Liquidambar styraciflua*). Typical subcanopy species include Alder (*Alnus serrulata*), Redbud (*Cercis canadensis*), and Red cedar (*Juniperus virginiana*) (Table 3).

Additionally, Long Creek has a shallow cross-section and there is an active floodplain bench in places, particularly on the south side of Long Creek. This bench provides habitat for shrubby species such as Alder (*Alnus serrulata*), Silky dogwood (*Cornus amomum*), Silky willow (*Salix sericea*), Giant cane (*Arundinaria gigantea*), and Spicebush (*Lindera benzoin*). Those species growing on the toe of the slope above the floodplain include Yellow poplar (*Liriodendron tulipifera*), Black walnut (*Juglans nigra*), and Red cedar (*Juniperus virginiana*) (Table 3). These species are most prevalent on the north side of Long Creek.

However, past management has impacted the site, so that the forest is of lower quality than Briar Creek, both in diversity and size of tree specimens. In comparison, there are less exotic tree species, but not less exotic herbaceous species (Table 3).

6.3 USGS Gauging Data

There are four gaging stations near the three creeks involved in this study: 1) a station above Freedom Park in the Medical Center, 2) a station below Freedom Park at Archdale Drive, 3) a station above the reference reach on Briar Creek at Colony Road; and 4) a Long Creek gauging station downstream from the reference reach off of Primm Road. The period of record for each of these stations is relatively short, but each can be used to determine a rating curve for confirmation of a discharge for a given cross-section area or stage, and thus used to verify bankfull discharge values. Each has sufficient annual peak flows to determine an estimate of what the 1.5- and 2-year storm discharges would be (Figure 15-18). These values can then be inverted with the rating curves to determine the bankfull stage height for the stream at the gaging sections. In the case of the Medical Center and the Colony Road stations, the watershed has a very similar drainage area and can provide a good estimate of the bankfull cross-section and stage heights for verification and design purposes.

The USGS data can be used to derive rating and annual peak flow probability curves (Figures 19-21). The data on bankfull discharge is carried over into Table 1, on morphologic parameters.

6.4 Regime Data Analysis

The data included in Table 1 from Little Sugar Creek, Long Creek, and Briar Creek can be compared to other data collected in rural and urban areas of the Piedmont of North Carolina to determine whether or not they are internally consistent and appropriate for providing a reference for the restoration design. As previously mentioned, a strict reference reach approach for Little

Sugar Creek would be problematic due to project constraints and the uniqueness of its watershed characteristics. Therefore, restoration goals for the pattern, dimension, and profile of the restoration design are developed using this data taken in combination with empirical (USGS gaging data) and hydrologic modeling data.

Figure 22 shows the Little Sugar Creek, Briar Creek, and Long Creek bankfull parameters on North Carolina Piedmont Regime Data curves. Data collected by various engineers and scientists over the last decade has been incorporated into these curves. The rural curves originate from a diversity of areas in the North Carolina Piedmont (Harmon et. al., 1997), but the urban curves are largely derived from data collected in the City by Wilkerson and others, 1997; or Keaton, 1999; but integrated into a report by Doll et. al., 2000. Both the Charlotte projects were completed by the first authors as part of Master Thesis requirements in the Department of Civil Engineering at UNC-Charlotte. The larger urban streams in the Wilkerson et. al. study have channel dimensions consistent with the operation of the dredging program in the early 1900s. The use of these urban regime curves should be taken with great caution, not only because we cannot be confident they were not dredged, but also because, bedrock-founded sections (like the Briar Creek at Myers Park reference reach) cannot easily adjust to urban conditions on short time cycles. The reference reach data collected from Long Creek is very consistent with the rural regime curves. The data from the urban streams is also consistent with the urban regime data, though as stated above this data may be biased.

7.0 STREAM RESTORATION PLAN

Fluvial geomorphic and hydrologic reference reach data are presented and discussed in light of the proposed design. The design follows the basic procedures laid out in the Technical Guidelines for Stream Restoration in North Carolina (2001) in that a reference reach approach is initially used to define the basic fluvial geomorphic elements of pattern, dimension, and profile. This data is summarized in Table 1. There are two factors that make a strict reference reach approach to the restoration problematic. First, storm flow from piped storm drains in the older and more urbanized parts of the City has produced a flashy storm surge in Little Sugar Creek which is unparalleled in any of the surrounding watersheds that might be viewed as a comparable watershed for reference reach purposes. USGS data (Medical Center) indicates that Little Sugar Creek rises faster and higher for a given storm than the adjacent Briar Creek watershed (gage at Colony Road) with a larger drainage area. Secondly, the majority of Little Sugar Creek was enlarged and entrenched by dredging prior to 1917, lowering the creek with respect to the surrounding landscape. Unfortunately, these activities were followed by over 80 years of fill and construction within the Little Sugar Creek floodway. Restoration to original conditions is currently not reasonable, as it would require elevating the streambed by approximately 5 feet, with associated substantial losses in conveyance and an attendant increase in flood damages within the FEMA designated floodway.

The restoration design attached, in section, planform, and longitudinal view, can be characterized by the morphologic parameters indicated in Table 1 (Figures 23-28). These parameters vary slightly from the upper to lower ends of Freedom Park due to the drainage added by Dairy Branch. The primary difference in the two areas of the design is that additional width has been added below Dairy Branch to compensate for the increase in drainage area. In the design, it is not possible to elevate Little Sugar Creek 4 to 5 feet to bring the bankfull stage to the current top of bank. The dredging completed in early the 1900s lowered this reach by an estimated 4 to 6 feet. This entrenchment cannot be recovered due to encroachment within the floodway. However, the entrenchment can be accommodated by the construction of an inner floodplain bench at the 6- to 8-foot stage, coupled with the use of lower inner berms to constrict the lower portions of the channel and add low flow sinuosity. This tiered channel system allows the design to yield Rosgen or fluvial geomorphology parameters comparable to the reference reach and regime data sets.

Thus, in this perspective, while the design does not recover exactly back to original conditions, it recovers a natural balance of stream morphologic characteristics.

7.1 Restored Stream Classification

Little Sugar Creek's existing classification of a Class C3 to C5 stream will not change with the restoration efforts. This classification is similar to both reference reaches. Although specific characteristics of the stream will be improved, such as increasing meander belt width, improving riffle and pool sequences, and reducing bankfull estimated mean velocities, these improvements will not change the Rosgen stream classification significantly. Constraints, including the urban nature of the watershed, limit the amount of sinuosity that can be restored to Little Sugar Creek.

7.2 Restored Stream Morphology

The morphology for the restored stream reach of Little Sugar Creek at Freedom Park is based on the level II Rosgen analysis presented in Table 1. This table presents the existing stream conditions, reference reach analysis, and the proposed stream characteristics. Little Sugar Creek is divided into upper and lower segments to compensate for the added water volume from Dairy Branch.

Typical cross section dimensions are presented for both the upper and lower segments of Little Sugar Creek. Downstream of Dairy Branch, the cross sectional area of the stream channel and floodplain area is larger to compensate for the added flow. These cross sections include planned side slope ranges (Figure 23). Sinuosity and riffle-to-pool sequences will be added to Little Sugar Creek as part of the Plan (Figures 24 and 25a-e). The sinuosity is designed based on the constraints of Freedom Park and floodplain conditions. Typical riffle cross-section schematics are presented in Figures 26a-c.

The presented Plan view also includes planned instream actions (Figures 23a-e). Side slopes range from 1.5:1 to 3:1. Planted toe revetment using boulders is necessary in the indicated areas to prevent scour and erosion. Other details include bankfull benches created, where possible, along inner meander bends for floodplain storage and vegetated inner berms. An inner berm and point bar channel constrictor schematic showcases a built-in wing deflector and downstream drop weir of cobble material sized for immobility, seeded soil sock placement, and vegetation (Figure 27). At the southern end of the Project Area, root wads and rock vanes will be used to stabilize the meander and stream banks.

Additionally, the longitudinal profile of the stream will be altered to include riffles, pools, and existing bedrock formations (Figure 28). These restoration plans also include interpolation analysis of the bankfull stages of Little Sugar Creek and the reference reaches (Figure 29).

7.3 Sediment Transport Analysis

One goal in stream restoration work is to design a channel that is capable of maintaining its dimension, pattern and profile over time. To that end, the channel should neither aggrade nor degrade over time; rather it should be capable of migrating slowly across the landscape while maintaining form and function. In other words, the channel should have attained a state of dynamic equilibrium (or grade) where given its discharge and sediment load, the channel maintains form and slope over time. A useful way of thinking about the concept of grade is illustrated in Figure 30. For example, as either stream discharge or stream slope increases, the stream tends to erode. Alternatively, if sediment size or sediment load increases, other parameters being held constant, the stream tends to accumulate sediment.

In stream restoration work, it is vital to design the stream slope and sediment size so that the stream will maintain an equilibrium state given expected discharges and sediment load. By using sediment size data from reference reach studies, it should be possible to predict the sediment size distribution required to maintain a channel at grade. Of first importance in such studies of sediment size distributions is the size distribution of the armor layer. This layer protects the underlying material from erosion and transport. Thus, the critical bed shear stresses required to move the armored layer would control the initiation of movement and transport of the bulk of the sediment comprising the channel floor. Once the armor layer is set in motion, the maximum bedload transport rate for the given discharge for the stretch of channel likely will be achieved.

In order to understand the transport of sediment in streams a short discussion of water motion is in order. When observing water flow, various types of flow behavior can be observed. The first is steady flow where, at the point of observation, flow parameters such as mean velocity, pressure, density and temperature of the fluid remain the same and do not change with time. If the flow conditions change with time, then the flow is unsteady. Such behavior is exhibited during flood events where first the stage (and mean velocity) rises and then the stage falls. Uniform flows are those where the velocity is constant in the direction of the flow whereas non-uniform flows exhibit a variation of velocity in the direction of the flow. Non-uniform flow can be observed where a flow exits a pool and enters a riffle of smaller cross-sectional area.

In flowing water there are two main regimes exhibited by the flow, laminar flow and turbulent flow. Laminar flow can be visualized by injecting a stream of dye into a slow-moving fluid. In such slow-moving fluids one molecule of the fluid will travel behind the molecule immediately downstream of it. In laminar flow, the viscosity of the fluid supplies the main resistance to motion and the viscous force is transmitted from the non-moving fluid at the bed upward through the flow. Thus, a velocity gradient occurs where velocity at the bed is zero and velocity increases progressively above the bed.

With increased velocities of the fluid, dye tracer experiments document the transition from laminar to turbulent flow. In turbulent flow, water molecules move in discrete packets in a wide range of directions known as eddies. The mutual interference of the packets of water molecules causes an increased resistance to motion known as the eddy viscosity. These eddies can originate as slow-moving packets of water that rise from the bed in events known as bursts. As the packets of slow-moving water rise above the bed into progressively faster-moving portions of the flow, they interfere with the motion of water higher in the flow. The interference generates more turbulent eddies, some of which descend toward the bed as fast-moving packets known as sweeps. The sweep events can generate short-lived but intense bed shear stresses capable of initiating grain motion. As flow velocities increase, the number and strength of the sweep events increase as well. It is because of these eddy effects, that many stabilization efforts fail that use only average velocity determinations derived from discharge – area relationships. For these reasons, an adjustment safety factor of 1.5 is commonly employed in estimating the expected traction forces that may operate on bank and bed materials.

Sediment is transported in streams in three ways: as dissolved load, as suspended load and as bedload. The dissolved load has little effect on alluvial channel form that instead is more strongly influenced by the transport and deposition of the solid sediment. The dissolved load will not be discussed here. Suspended load comprises those sediments that are kept in motion above the bed. They are held aloft by the turbulent eddies within the flow or by collisions with other upward-moving grains. In order to remain suspended, the upward directed eddies must exceed the settling velocities of the grains in suspension. The settling velocities are governed by the size, density, shape and concentration of the grains. Once in motion, suspended load can be kept in motion by relatively slow-moving flows.

Bedload comprises those solid sediments that move in contact with the bed. The contact can be both continuous in nature as is the case in rolling or sliding, or intermittent as is the case in saltation. In order to initiate grain motion as bedload, a critical bed shear stress needs to be exceeded. The critical shear stress has two main components: the drag component and the lift component. The drag component acts tangentially on the grain and it increases as the flow velocity increases. The lift component, similar to the lift acting on an airplane wing, is also a function of the increased velocity. As streamlines of the flow are compressed around a protruding grain, the velocity along a streamline increases. This results in a drop in the pressure force along that streamline as predicted by Bernoulli's equation. The resulting drop in pressure is expressed as a lift force that aids in the initiation of motion. Once the grain rises into the flow, the moving fluid can pass both below and above the grain, thereby diminishing the lift force. Hence, with increased height above the bed, the lift force diminishes and the drag force becomes more important. This helps explain the trajectory of saltating grains that typically rise steeply from the bed and then exhibit a pathway of gradual descent downstream. The impact of the saltating grain may dislodge additional grains that then rise upward into the flow.

In order for grain motion to initiate, the critical bed shear stress has to overcome the force of gravity that keeps the grains on the bed. Bed shear stress calculations for Little Sugar Creek are presented in Table 4. In addition, natural streambed material consists of particles of a wide range of sizes and shapes that are commonly interlocked. Also, the top surface of the sediment on the floor of a stream is commonly covered by an armor of material whose mean grain size is coarser than the material immediately below the surface. Thus, the critical shear stress required to move the armor has to overcome the weight force and the friction associated with the interlocking grains. Once grain motion of the armor is initiated, the material beneath the armor (which is typically finer grain sizes) is also subject to initiation of motion.

In natural streams, a maximum bedload transport rate can be defined for a given discharge and sediment size distribution, and bedload transport often occurs at this full capacity (Richards, 1982). This occurs for a variety of reasons. First, the source of the bedload is restricted to the channel bed and walls, so sediment transport is directly controlled by conditions within the channel. Second, the movement of bedload is brief and discontinuous, in part due to the frequency of those sweep events that exceed the critical bed shear stress, and in part because bedload particles move at velocities that are less than 15 percent of the flow velocities. This results in the floodwater that initiates bedload transport quickly outpacing the moving particles of bedload resulting in the redeposition of the bedload. Third, bedload is normally less than 10% of the total solids in transport and exhausting the supply of bedload material is not likely to occur. And fourth, bedload transport utilizes much of the available stream energy and it is unlikely that all of the available bedload material will be moved in a single flood event. So, once the armor layer begins to move, and then the material beneath the armor layer is subject to moving downstream. The distance the sediment moves downstream is governed by the size of the flood event.

The transport rate of bedload increases with discharge until the supply of appropriate sediment is exhausted. Extremely large discharges that occur rarely can have an important impact on channel form. However, in the intervening period between extreme events, the channel form may be modified by more common but less powerful discharges. According to Richards (1982, p.122-

123) "Bankfull discharge, which fills the channel without overtopping the banks, is an intermediate discharge often considered a critical or dominant channel-forming event in natural rivers", where a dominant channel-forming discharge is a single discharge which represents the range of flows experienced by a channel and is thought to be responsible for the channel morphology. Bankfull discharges recur every one to two years according to Wolman and Leopold (1957). Thus, the size and amount of sediment being transported by a stream in dynamic equilibrium is likely to be governed by the bankfull discharge.

These principles of sediment transport were included in the stream restoration design. Grain size data is presented in Table 1 for both reference reaches and Little Sugar Creek. The samples were collected in three discrete flow/depositional environments, so as to have an appropriate foundation for the estimation of design parameters, and a means to verify 'in regime' and hydrologic assumptions of sediment transport. Thus, riffles, pools, and point bars environments were each carefully sampled and analyzed for their grain distributions. In addition, armor material was separated from substrate material to more accurately determine the maximum bed traction forces acting in riffle and pool environments. In both reference reaches as well as Little Sugar Creek, many riffle zones are positioned, and controlled by, bedrock ledges that impede the vertical or lateral migration of the stream. This is a common, if not ubiquitous, feature of North Carolina's Piedmont streams. In these areas a very coarse armor is commonly found which exceeds the maximum sizes of grains expected to be mobilized by bankfull bed traction forces. These armors are distinct from riffles within alluvial channels that commonly have armor that is episodically involved in bedload transport. Underlying, and amongst, the armor paving the bedrock ledge are finer grained pockets of sand and gravel, which as mentioned above, become mobilized during events which destabilize the interlocking framework within the riffle zone.

The Plan uses the bedrock ledge model for riffle zones. In the design of these bedrock-analog riffles, a separation of armor and substrate sizes is needed to carefully balance that portion of the stream bed which is intended to mimic the bedrock (and its armor of large lag stones) and that which represents components in bedload transport. The sizing for the lag stones is extrapolated from both reference reach data sets as well as verified by calculations of maximum channel bed traction forces (discussed further below). As mentioned above, a stream that is in morphologic equilibrium typically achieves its maximum bedload transport rate during a bankfull event. Since the riffle areas of Freedom Park represent less than 30 percent of the channel bed, having substrates that can mobilize, and are features that mimic conditions found in the reference reach, no significant impacts are expected on the channel's ability to transport sediment or dissipate stream energy in the restoration reach. The remainder of the channel bed is to be lined with gravel that most appropriately matches existing materials in bedload transport within the Little Sugar Creek watershed.

Because of the highly urbanized nature of Little Sugar Creek watershed, the upper source tributaries of Little Sugar Creek may be undergoing adjustments. These adjustments may cause future bedload transport of materials into the restoration reach to temporarily exceed the transport out of the reach (or vice-versa). This is in part due to the fact that bedload moves much slower than the peak storm surge and large accumulations of sediment derived from instabilities in the upper watershed can only move so far in a given storm. The Plan must anticipate periods when the reach will store variable amounts of bedload sediment. These periods may be easily misinterpreted as indications of channel instability due to observations in the short term of aggrading (or degrading) channel conditions, whereas, in actuality, they represent snapshots of a moving wave of sediment in the stream system, much like a sand dune moving across the Sahara Desert. Long term monitoring (over several bankfull events) is needed to distinguish evolutionary from episodic trends in channel sedimentation and erosion, particularly in reaches that may be undergoing some adjustments to changing watershed conditions. One attribute of the urban runoff from the upstream city center area of Charlotte is that much of the runoff is piped directly from building roof tops and asphalt parking lots, and as such, is relative poor in bed load sediment (not including suspended load components). This runoff reaches the main stem of Little Sugar Creek with very little in the way of 'bedload' material. This runoff then has a large potential to entrain bedload and move it down stream. For these reasons, the restoration reach may experience a pattern of decline in bed materials as it reaches equilibrium with the low volumes of input bed loads, which could then lead to potential down cutting along the restoration reach. The existence of bedrock along the reach, and the use of artificial bedrock riffle zones (which are sized for immobility) will thus provide important protection of the channel bed.

7.4 Stability Analysis

There are five approaches to the analysis of stability for this restoration. First, the reference reach is the foundation for the design's pattern, dimension, and profile. This paradigm assumes that nature finds a stable design for any given watershed setting, provided there is sufficient time for adaptation and evolution. This design model assumes that nature will find comparable fluvial morphologies for comparable sets of watershed characteristics (topography, climate, soils, bedrock, land use, etc.). Thus, one check on the stability of a design is that it has similar characteristics to those observed in the selected reference reach areas.

A corollary to this reference reach model is the regime approach. The regime approach states that, at a regional level, there are some central tendencies in streams of similar morphologic class (e.g., Rosgen E or C-type streams) to have comparable morphologic parameters for similar drainage areas. The regime approach has the benefit of averaging out a lot of 'noise' that occurs in individual watersheds (e.g., disruption of normal tendency by odd events or features; e.g. hurricane, downed tree, small pond, etc.). However, neither the reference reach nor regime approach is necessarily sufficient to achieve a stable design. Both sets of data are susceptible to yielding guidelines that may be erroneous for a given circumstance. Thus, independent of the reference reach or regime data, a separate effort must be made to check or verify the stability of the restoration design.

The second and third methods used here for stability analysis are the determinations of transport thresholds for bank and in-stream materials. These checks on transport, or erosion potential, for bed and bank materials are either a minimum velocity analysis or critical traction force analysis. There are two approaches for checking velocity thresholds for the design at Freedom Park, and two approaches for the critical traction force analysis.

Lastly, stability can be looked at from a structural viewpoint. Structures can be placed or found (e.g., the stream can be located over or within bedrock) to provide added stability. These structural approaches are usually folded into a given project as a design unfolds and areas of greater risk, or opportunity, are discovered.

7.4.1 Velocity and Stability Analysis

In 1994 the USACE published a graph of allowable velocity-depth data for granular materials ranging in size from 0.1 to 500 mm. Velocity estimates for eight cross-sections in the design for Freedom Park, and for 1.5-, 2-, 10-, and 100-year storms are shown in Figure 31. The range of expected velocities extends from 3.5 to 8.2 fps, with water depths ranging from 7 to 18 feet. For any given cross-section, there is a positive correlation of velocity with depth. The expected ranges in velocities are plotted in Figure

31 to determine the range of sizes of granular materials that would be unstable as exposed non-cohesive materials along the channel (this is the shaded area shown in Figure 31). From this analysis, it is clear that materials with D50s less than 70 to 100 mm will be unstable. In the restoration plan there are limited zones where incohesive geomaterials will be installed with the expectation that they will not be displaced by expected storm flows. There are five bridges along the restoration reach, and a sewer line runs the entirety of the reach along the west side. This infrastructure constrains the design to a non-deformable restoration pattern, dimension, and profile and requires that the banks be engineered for little if any adjustments to flows over time. Secondly, velocity estimates can be expected to exceed 12-14 fps when eddy effects are included in the calculations of expected velocities (average velocities from HEC-RAS). These velocities are over or very close to the threshold velocities for many bioengineered bank treatments (Chen and Cotton, 1988, Parsons, D. A., 1963, Theisen, 1992, Fischenich, 2001). For these reasons, a limited amount of boulder toe material has been used along the toe of the slope in conjunction with the coir fiber logs to further inhibit bank failure. This zone of boulder toe revetment is also needed to provide adequate footing for the coir fiber logs, as gravel substrate in the channel is to be sized for mobility, and could mobilize before plant roots have had a chance to tie coir fiber logs into banks and bed.

There is one zone above the confluence with Dairy Branch that has FEMA impacts that cannot be readily resolved with a full bioengineered bank slope. Manning coefficients less than 0.045 are needed in this zone to eliminate adverse flooding impacts. The only vegetated treatments with appropriate Manning coefficients would be grass or very sparse (light) low lying woodly vegetation. The former cannot be expected to withstand velocity or bed traction forces, and the latter, has insufficient density to provide bank support without additional hard materials. For this zone (which is approximated at 300 feet in length), planted boulder armor on the banks may be necessary to provide both protection and the required flow conveyance.

In 1977 the USDA published guidelines for basic velocities for erosion and mobilization of non-cohesive bank materials along drainage channels as a function of grain size for both sediment-laden water and sediment-free water. Figure 32 shows the graph (as reprinted in USACE, 1994) that is commonly used in the stability analysis. In this figure, the expected ranges in velocity for Little Sugar Creek for the 1.5-, 2-, 10-, and 100-year storms are shown. The minimum (3.5 fps) and maximum (8.2 fps) flows, together with the curves for sediment-free and sediment-laden water, limit the field of potential threshold velocities for grains of differing sizes. From this analysis, it can be concluded that cobbles up to 4 inches in diameter are unstable as non-cohesive bank materials. Also, in Figure 32, Table 5-1 from the USACE manual on Channel Stabilization (1994) is shown with the 8.2 fps limit overlaid to illustrate that even soft rock formations are transitionally unstable at the expected upper velocities. From this table, the only truly stable banks of earth materials would be igneous or hard metamorphic rocks.

7.4.2 Traction Force Criteria and Shield Curve Analysis

Newbury and Gabory's (1993) Traction Force Criteria and Shield Curve Analysis shows that, for streams with non-cohesive bed materials greater than 1 cm in diameter (fine gravel), a general rule of thumb for stability may be approximated as:

Tractive Force (kg/m^2) = incipient diameter (cm);

This indicates that there is an empirical relationship arising from a compilation of in transport streambed materials and tractive force observations for a wide range of channels worldwide. The Newbury and Gaboury criteria are derived from compilations presented by Lane (1955) and Magalhaes and Chau, (1983). These critical traction forces versus grain size analyses and curves are sometimes referred to as Shield Curves. Table 2 includes calculations of the bed traction force derived using the formula:

Tau (kg/m^2) = 1000 x (depth (m)) x (slope (ft/ft))

This relationship is roughly equivalent to the Tau = RS formulation used by Rosgen (1994) but can yield more accurate estimations of the maximum traction forces needed for stability analysis, as a maximum depth can be used in lieu of the hydraulic radius. We are more concerned with the maximum conditions that may exceed thresholds and trigger failure in the channel system, just as a mechanical engineer would be interested in the maximum shear stress conditions for mechanical failure. Thus, the DS rather than RS method is used here to calculate critical traction forces.

Figure 33 shows a variation of a "Shield Curve" with data from Leopold (1964) upon which the minimum and maximum traction forces for eight cross-sections at Freedom Park are shown. These were calculated from the maximum depth and velocity estimates made by the hydraulic modeling for the 1.5-, 2-, 10-, and 100-year storms.

These critical traction force calculations indicate that the bed will need to have an armored with material with D50s ranging from 10 to 70 cm in riffle areas to ensure stability. The lower range is sufficient for meander areas with lower stream gradients, but the higher estimates are needed for riffle areas with gradients upwards of 0.014.

7.4.3 Bed and Bank Stability Structures

The attached plans, cross-sections, and longitudinal profiles show the location of structures present in the design to assist in the stabilization of the restored channel (Figures 23-28).

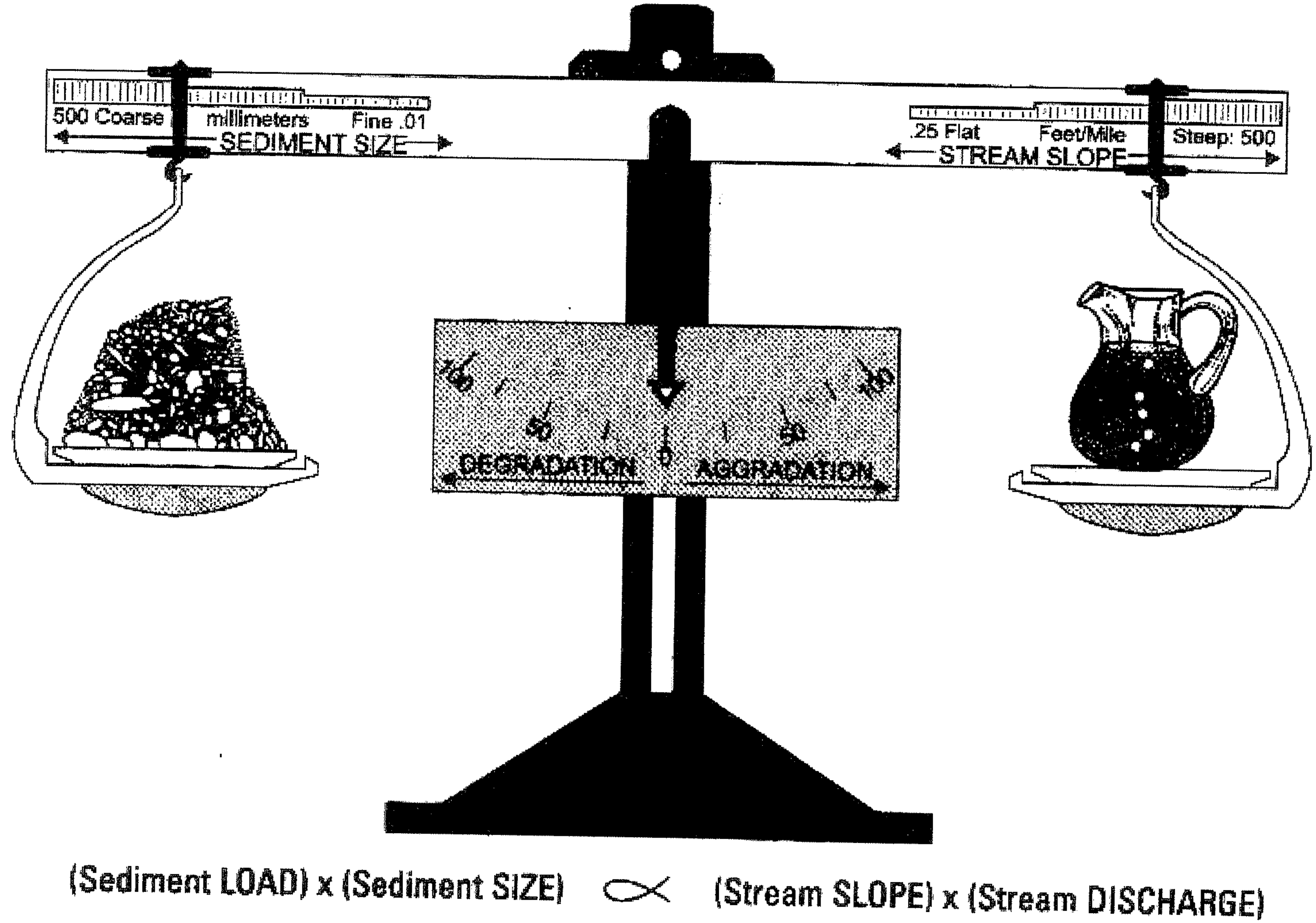
With respect to bed stability, the Little Sugar Creek reach at Freedom Park contains numerous bedrock nick points that have been carefully considered in the preparation of the new channel's alignment (Figure 5). The new alignment intersects in a sufficient number of the riffle sections to provide distributed grade control along the 4,000+ feet of this restoration. Thus, no artificial grade control is needed in this design.

Secondly, hydrologic analysis indicates that only light shrubbery can be used along the banks for approximately 300 feet upstream from the confluence with Dairy Branch so that the Manning Coefficient can be kept close to 0.0045. If heavy shrubbery is used, there will be unacceptable negative impacts on flooding due to the higher roughness. Since light shrubbery would result in some exposure of the underlying non-cohesive bank materials along this reach (alluvial soils were discovered in the excavation below the Nature Museum), the light shrubbery must be mixed with materials that can resist erosion and transport. Thus, the design here will be to use appropriately sized boulders along the banks (probably large rounded cobbles and boulders along the toe, for aesthetic purposes, and angular riprap higher for greater stability on slopes with a higher angle of repose).

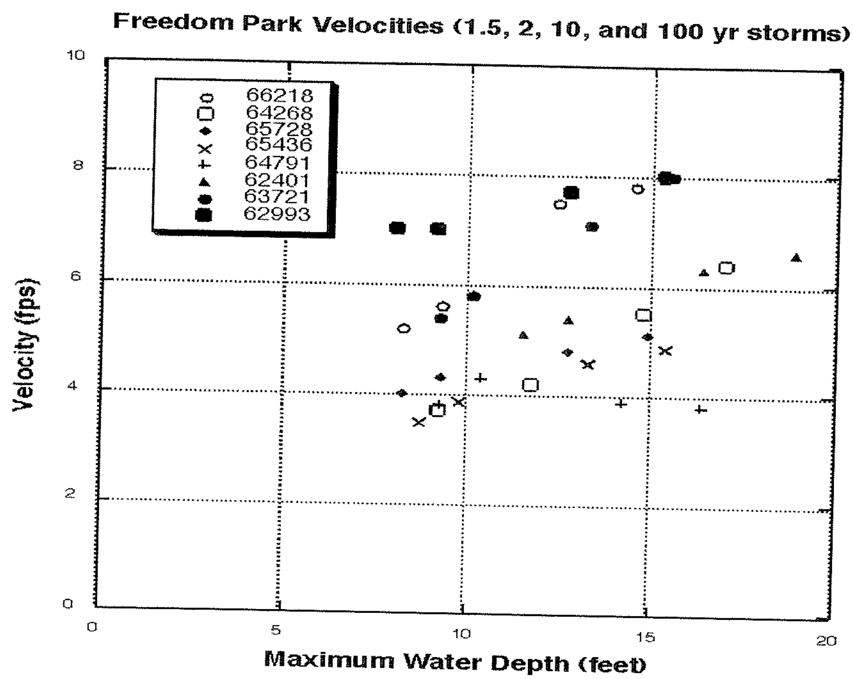
Stream banks up- and downstream of the three bridge crossings will require stabilization to limit erosive forces on the bridge supports and ensure safety. Recommendations include placing armor along 50 feet of the stream banks above and below each bridge. This armor will be planted, and should offer similar ecological function to the other bank areas. Protection is not necessary in those areas with exposed bedrock.

Riffles and pools will also need to be sized using the above critical traction force estimates (Table 5). The estimates for D50 and D84 for riffle and pool armor are noted in Table 1. Riffles are designed to create shallow areas with aquatic habitat as well as back up water to form pools. Detail riffle cross sections are presented in Figures 23a-b. In addition, inner berms will be designed to allow sediment deposition and transport while maintaining their stability in terms of dimension, pattern, and profile (Figure 27). The inner berms constrict that portion of the channel below the bankfull stage to appropriate dimensions for an 'in regime' channel, yet permit higher storm flows to pass along the reach without impacting negatively the expected flood stage heights. The leading edges of the berms act as hard structural flow deflectors, and are sized for immobility for these reasons. The down stream tail of the inner berms are also armored due to the expected high hydraulic shear stresses as flow is forced to drop back down and converge at the down stream end of each inner berm (as outlined by Haltiner, Kondolf, and Williams, 1996).

Riffles in this design act also as bedrock ledges, thus can be viewed as multipurpose structures that provide habitat, water quality benefits, and grade control. The riffle crest is to be slightly 'v' shaped in cross section to inhibit "outflanking" and sized to resist bed traction forces expected from a top-of-bank flow event. The sizes of riffle armor decrease down stream. Schematics of the riffles are shown in Figure 26a-c.

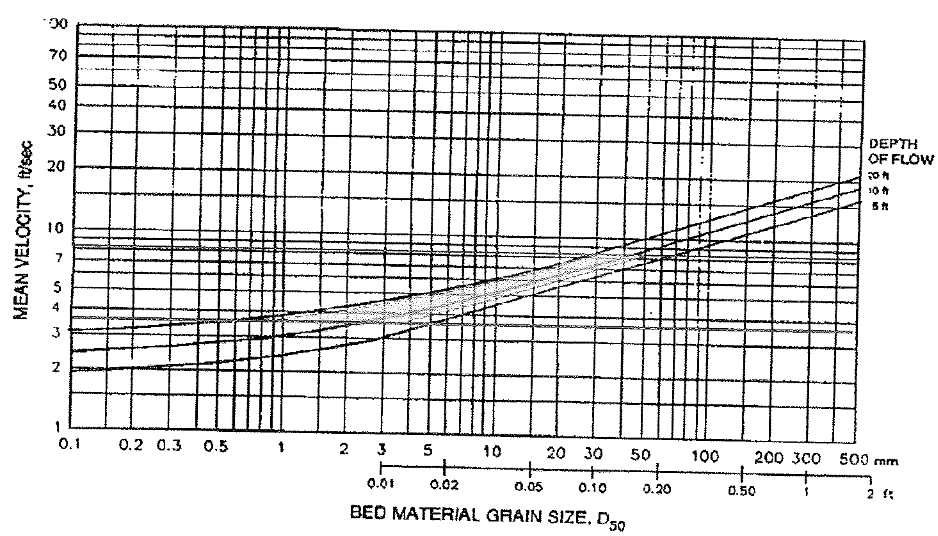


HDR Engineering, Inc. of the Carolinas Habitat Assessment and Restoration Program	**Figure 30: Sediment Transport** Stream Restoration Plan Little Sugar Creek at Freedom Park	August 2002 Project: 09177-017-018



Velocity Maximum Depth Estimates from HEC-RAS based flow calculations for 1.5, 2, 10 and 100 Year Storms at 8 sections using the proposed general riffle and meander cross sections.

EM 1110-2-1418
31 Oct 94



Example of allowable velocity-depth data for granular materials.
From USACOE 1994 Appendix A and B.

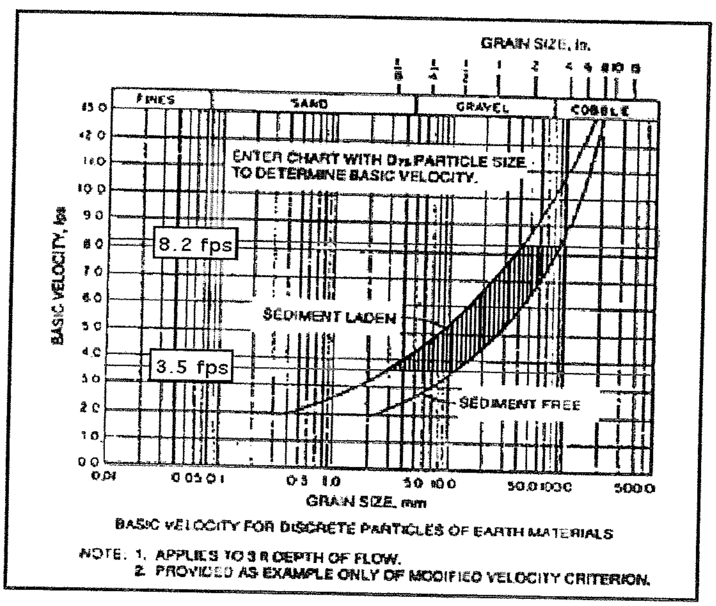
Range of estimated velocities for the 1.5, 2, 10 and 100 year storms plotted on the Mean Velocity vs Bed Material Size (D 50) chart from the USACOE 1994 guide to stream stabilization.

HDR HDR Engineering, Inc. of the Carolinas Habitat Assessment and Restoration Program	**Figure 31: Estimated Velocities and Bed Material Sizing** Stream Restoration Plan Little Sugar Creek at Freedom Park	August 2002 Project: 09177-017-018

Table 5-1
Example of Simple Allowable Velocity Data
(From EM 1110-2-1601)

Channel Material	Mean Channel Velocity, fps
Fine Sand	2.0
Coarse Sand	4.0
Fine Gravel	6.0
Earth	
Sandy Silt	2.0
Silt Clay	3.5
Clay	6.0
Grass-lined Earth (slopes less than 5%)	
Bermuda Grass	
Sandy Silt	6.0
Silt Clay	8.0
Kentucky Blue Grass	
Sandy Silt	5.0
Silt Clay	7.0
Poor Rock (usually sedimentary)	10.0
Soft Sandstone	8.0
Soft Shale	3.5
Good Rock (usually igneous or hard metamorphic)	20.0

Unstable ↑ — 8.2 fps — ↓ Stable



BASIC VELOCITY FOR DISCRETE PARTICLES OF EARTH MATERIALS

NOTE: 1. APPLIES TO 3 ft DEPTH OF FLOW.
2. PROVIDED AS EXAMPLE ONLY OF MODIFIED VELOCITY CRITERION.

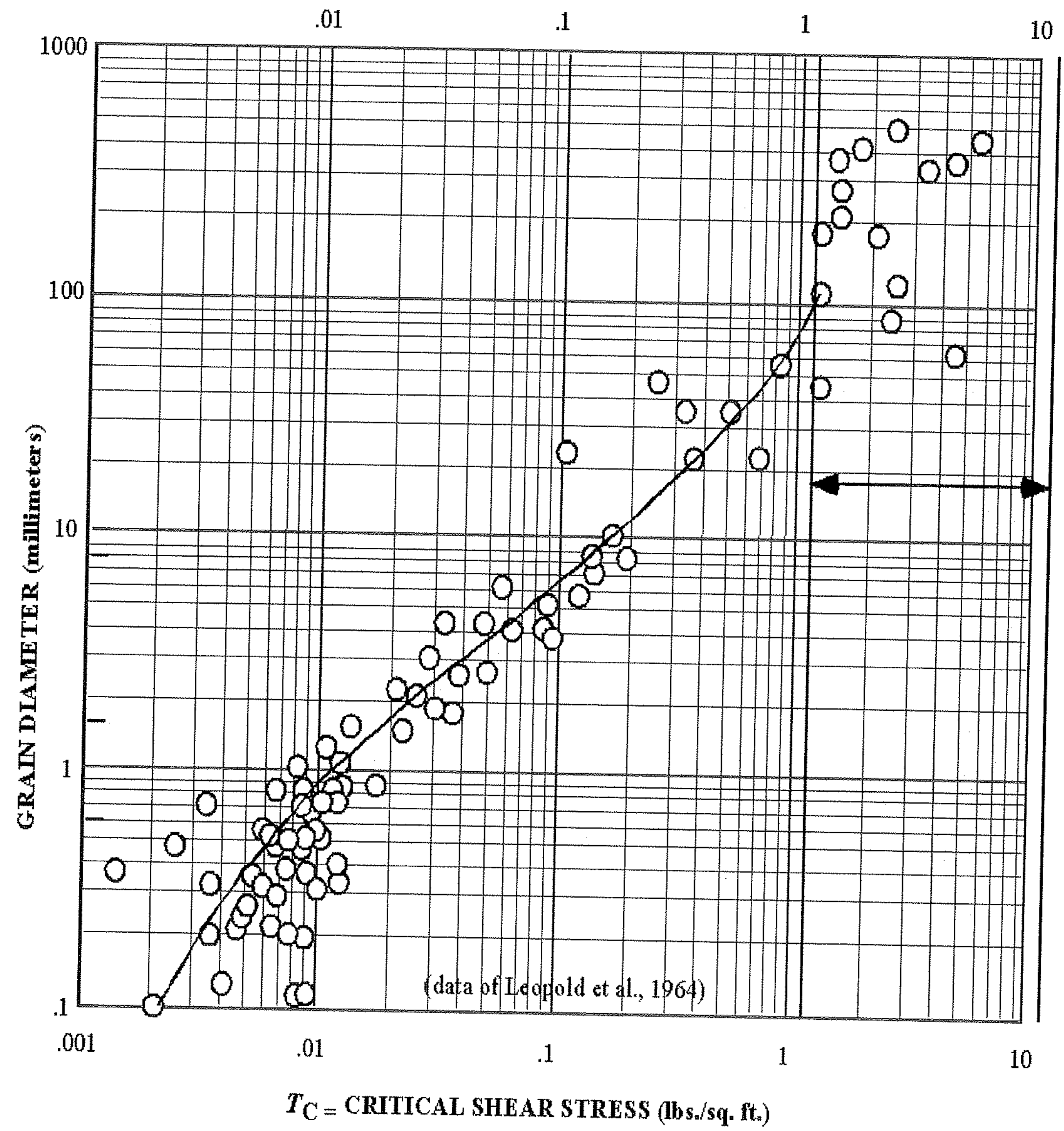
Figure showing the estimated velocities for the Freedom Park reach of Little Sugar Creek for the 1.5, 2, 10, and 100 year storms. The base table and graph are originally from USDA 1977, but reprinted in USACOE, 1994 manual on Stream Stabilization.

HDR Engineering, Inc.
of the Carolinas
Habitat Assessment and Restoration Program

Figure 32: Bank Stability Analysis
Stream Restoration Plan
Little Sugar Creek at Freedom Park

August 2002

Project: 09177-017-018



HDR Engineering, Inc. of the Carolinas

Habitat Assessment and Restoration Program

Figure 33: Shield Curve Analysis

Stream Restoration Plan

Little Sugar Creek at Freedom Park

August 2002

Project: 09177-017-018

7.5 Vegetation

Following construction, vegetation will be planted along the banks of Little Sugar Creek. Plants were chosen based on five factors: exposure, position on the slope, root structure, size, and native species versus introduced species. These species will be planted along three areas of the stream bank: the toe, midslope, and top of slope. The estimated number of plants is over 40,000. This number, as well as the mix of species planted, will be refined as construction plans continue.

In preparation for the planting effort, native plant material has already been collected, rooted and stored. Approximately 30,000 specimens have been treated in this manner. The major benefit to having plants in this form will be that the root system is already well established which will lead to quicker stabilization and better shade growth. The remainder of the plantings will occur as traditional live staking or some other industry standard bioengineering planting techniques.

Typical native species chosen for Freedom Park include Blueberry (*Vaccinium* spp.), Button bush (*Cephalanthus occidentalis*), Elderberry (*Sambucus canadensis*), Silky dogwood (*Cornus amomum*), and Smooth hydrangea (*Hydrangea arborescens*). In addition, some exotic species are also planned including Glossy Abelia (*Abelia grandiflora*) and Shrubby St Johnswort (*Hypericum prolificum*) (Table 6).

Vegetation choices are limited by the site conditions. As previously mentioned in Section 7.4.3, plants must be able to withstand the high velocity flows and water forces in Little Sugar Creek as well as not reduce the conveyance abilities of the stream during storm events. In addition, soil conditions and bedrock outcroppings shape planting plans.

7.6 Storm Water

Stream restoration of Little Sugar Creek within Freedom Park will restore pattern, dimension, and profile to the stream. These alterations from existing conditions necessitate the relocation of storm water drainage outfalls within the Project Area. A comprehensive discussion of recommendations and proposed actions for those storm water outfalls is presented in Appendix B. Eleven storm water drainage areas are impacted by the Plan. Where feasible, recommended improvements promote infiltration of storm water and reduce pollutant loading to Little Sugar Creek. In addition, these outfalls must be protected from erosive forces. These recommended actions consider budget and Project Area constraints.

8.0 STREAM PERFORMANCE CRITERIA AND MONITORING PLAN

Restoration of Little Sugar Creek in Freedom Park will be determined a success after the monitoring period is complete. The stream channels should maintain their dimension, pattern, and profile over time. Additionally, instream structures should remain secure and stable during the monitoring period.

It is expected that there will be some minimal changes in the cross-sections, profile, and/or substrate composition. Changes that may occur during the monitoring period will be evaluated to determine if they represent a movement toward a more unstable condition (e.g., downcutting, deposition, and/or erosion) or if they are minor changes that represent an increase in stability (e.g., settling, vegetative changes, and/or decrease in width-to-depth ratio). Unstable conditions that require remediation will indicate failure of restoration activities.

8.1 Substrate Monitoring

A Modified Wolman Pebble Count (Rosgen, 1996) provides a quantitative characterization of streambed material. This composition information is used as an indicator of changes in stream character, channel form, hydraulics, erosion rates, and sediment supply. Pebble count data can be used to interpret the movement of materials in the stream channels. Established D50 and D84 sizes should increase in coarseness in riffles and increase in fineness in pools. Data collected over the monitoring period should be plotted over that of the previous year(s) for comparison. Over time, established D50 and D84 should be compared.

8.2 Vegetation

Native vegetation, as determined by reference reach vegetation inventories, will be planted. Survival of vegetation within the riparian buffer will be evaluated using survival plots. Survival of live stakes will be evaluated along the stream corridor of the restoration site. Vegetation survival of target dominant species will be confirmed. Woody vegetation will be monitored for five years, or for two bankfull events. Plants should be replaced per the contract documents.

8.3 Monitoring Schedule

Annual monitoring is required for a five-year period beginning in 2003 and ending in 2007. Reports will be submitted in 2003, 2005, and 2007 to the USACE and the NCDWQ Wetland Restoration Program.

8.4 Monitoring Methods

Monitoring at established locations will ensure consistency and allow comparison of data over time. Permanent cross-sections will be established in Little Sugar Creek. Cross-section changes can indicate changes in the width-to-depth ratio of the stream. Bank slopes should remain stable. Comparison of longitudinal profiles during the monitoring period will indicate excessive changes over time. Monitoring at these locations, as well as established vegetation plots and pebble count locations, will ensure consistency and allow comparison of data over time.

9.0 STREAM RESTORATION BENEFITS

As previously discussed, Little Sugar Creek is an EPA 303(d) listed stream with fecal coliform contamination, biological impairment, and sediment pollution being the factors of concern. Water quality within Freedom Park is influenced by upstream land use activities, lack of habitat, poor mature tree cover and stream bank erosion. While this plan does not address stream conditions outside of Freedom Park, there are significant benefits that will occur due to the project.

Improvements will occur with the addition of a vegetated stream buffer zone. These buffers provide three main benefits. The buffers will filter runoff before it enters the stream, which will remove pollutants and promote infiltration. The buffers will also shade the stream, lowering stream water temperatures, and reducing the algae blooms that occur during the summer months. These buffers also provide terrestrial habitat for small mammals and birds. As additional restoration efforts are implemented in the upper watershed, including storm water improvements, the degraded water quality conditions will continue to improve.

Aquatic habitat improvements for this project include the creation of riffle and pool sequences within the channel, as well as rock and log structures. These variations in habitat will provide shelter and feeding opportunities for aquatic organisms and provide for a wider array of habitat locations, thus increasing aquatic community diversity.

The Plan will restore sinuosity to Little Sugar Creek within Freedom Park. This improvement in pattern will reduce erosive stream velocities. Dissipated stream energy will also have positive effects downstream by the reduction of velocity and ultimately sediment inputs. Added sinuosity will also increase the amount of aquatic habitat available since the stream will be longer as compared to the pre-project length.

Opportunities for storm water improvements will also improve water quality and reduce volume contributions to the stream. Improving storm water outfall structures and their locations, thermal spikes can be avoided or minimized, pollution can be filtered out of storm water and infiltration can be encouraged. The Freedom Park pond also has an overflow structure that currently discharges directly into Little Sugar Creek. This outfall is a heavy source of fecal coliform contamination and the Restoration Plan will help to begin addressing this water quality concern.

Additionally, there is an excellent opportunity for environmental education associated with this restoration effort. The Charlotte Nature Museum is located near the east bank of Little Sugar Creek within the Freedom Park property. This environmental education center conducts workshops and camps for children and is open to visitors. Educational efforts will include the need for water quality and aquatic habitat improvements in Little Sugar Creek and urban streams in general. The riparian area adjacent to the Nature Center and the restored stream provides the opportunity to address the functions and benefits of native vegetation and riparian areas.

10.0 REFERENCES

CH2MHill, 2002, Charlotte Area Local Watershed Plan Task 1: Data Collection, Subwatershed Delineation, Historical Context Review and Indicators Establishment for the NC WRP.

Charlotte-Mecklenburg SWIM Stream Buffers. Accessed October 25, 2001. http://www.charmeck.nc.us/ciengr/land/text.htm#SurfaceWaterImprovementand Management.

Clarkson, Hariot, 1917(?) *Drainage in Mecklenburg County.* Source unidentified, appended to CH2Mhill (2002) report above.

Dames and Moore-NC, 2001, Final Little Sugar Creek Geomorphic Analysis, USACE, Wilmington Office, North Carolina.

Doll, Barbara, Wise-Frederick, D.E., Buckner, C.M., Wilkerson, S.D., Harmon, W.A., Smith, R.E. 2000. Hydraulic Geometry Relationships for Urban Streams throughout the Piedmont of North Carolina, in NCSU Course Notes: N. C. Stream Restoration Institute, River Course, Raleigh, NC.

Harmon, et al. 1999. Bankfull Hydraulic Geometry Relationships for North Carolina Streams. In: AWRA Wildland Hydrology Proceedings. D.S. Olsen and J. P. Potyondy eds., AWRA Summer Symposium, Bozeman, Mt, pp. 401-408.

Keaton, Jeffrey. 1998. Development and Analysis of Hydraulic Geometry Relationships for the Urban Piedmont of North Carolina, Final Rpt., Year 1, Charlotte Storm Water Services.

Lane, E.W., 1955. *Design of Stable Channels*, American Society of Civil Engineers Trans., v. 120 p. 1234-1279.

Leopold, L.B., Wohman, M.G., and Miller, J.P. 1964. *Fluvial Processes in Geomorphology*, W.H. Freeman and Sons, San Francisco, CA.

Magalhaes, L. and Chau, T.S., 1983. Initiation of motion conditions for shale sediments, Canadian Journal of Civil Engineering, v. 10, p. 549-554.

Mecklenburg County Park and Recreation Department. 1999. *Mecklenburg County Greenway Master Plan*, Charlotte, NC.

Newbury, R. W., and Garoury, M. N., 1993. *Stream Analysis and Fish Habitat Design, A field Manual*, Newbury Hydraulics, Gibsons, British Columbia, Canada, 262 p.

North Carolina Department of Environment and Natural Resources. 1999. *Catawba River Basinwide Water Quality Plan.* Division of Water Quality. Raleigh, NC.

_____. 2000. *2000 303(d) List (Final Draft).* http://h2o.enr.state.nc.us/mtu/download.html.

_____. 2001. *2001 Draft Internal Technical Guide for Stream Work in North Carolina, ver. 2.* Division of Water Quality, Raleigh, NC.

_____. 2002. *Natural Heritage Element Occurrences.* Division of Parks and Recreation, Natural Heritage Program, Raleigh, NC.

North Carolina Division of Land Resources and North Carolina Division of Water Quality. 2000. "Draft Internal Technical Guide for Stream Work in North Carolina."

Radford, A.E., H.E. Ahles, and C.R. Bell. 1968. *Manual of the Vascular Flora of the Carolinas*. University of North Carolina Press, Chapel Hill, NC.

Richards, Keith. 1982. *Rivers, Form and Process in Alluvial Channels*. Methuen, London and New York, 358 p.

Rosgen, D.L. 1994. A Classification of Natural Rivers, Catena 22 (1994): 169-199.

Rosgen, D.L.1997. A Geomorphological Approach to Restoration of Incised Rivers, Proceedings of the Conference on Management of Landscapes Disturbed by Channel Incision.

Rosgen, D.L. 1996. *Applied River Morphology*. Wildland Hydrology Books, Pagosa Springs, CO.

Schafale, Michael P. and Alan S. Weakley. 1990. *Classification of the Natural Communities of North Carolina – Third Approximation*. North Carolina Natural Heritage Program. Raleigh, NC.

United States Army Corps of Engineers. 1994. *Channel Stability Assessment for Flood Control Projects*, EM 1110-2-1418.

United States Department of Agriculture. 1977. *Design of Open Channels*, Tech. Release No. 25, Soil Conservation Service, Washington, D.C.

_____, 1980. *Soil Survey of Mecklenburg County, North Carolina*. Natural Resource Conservation Service.

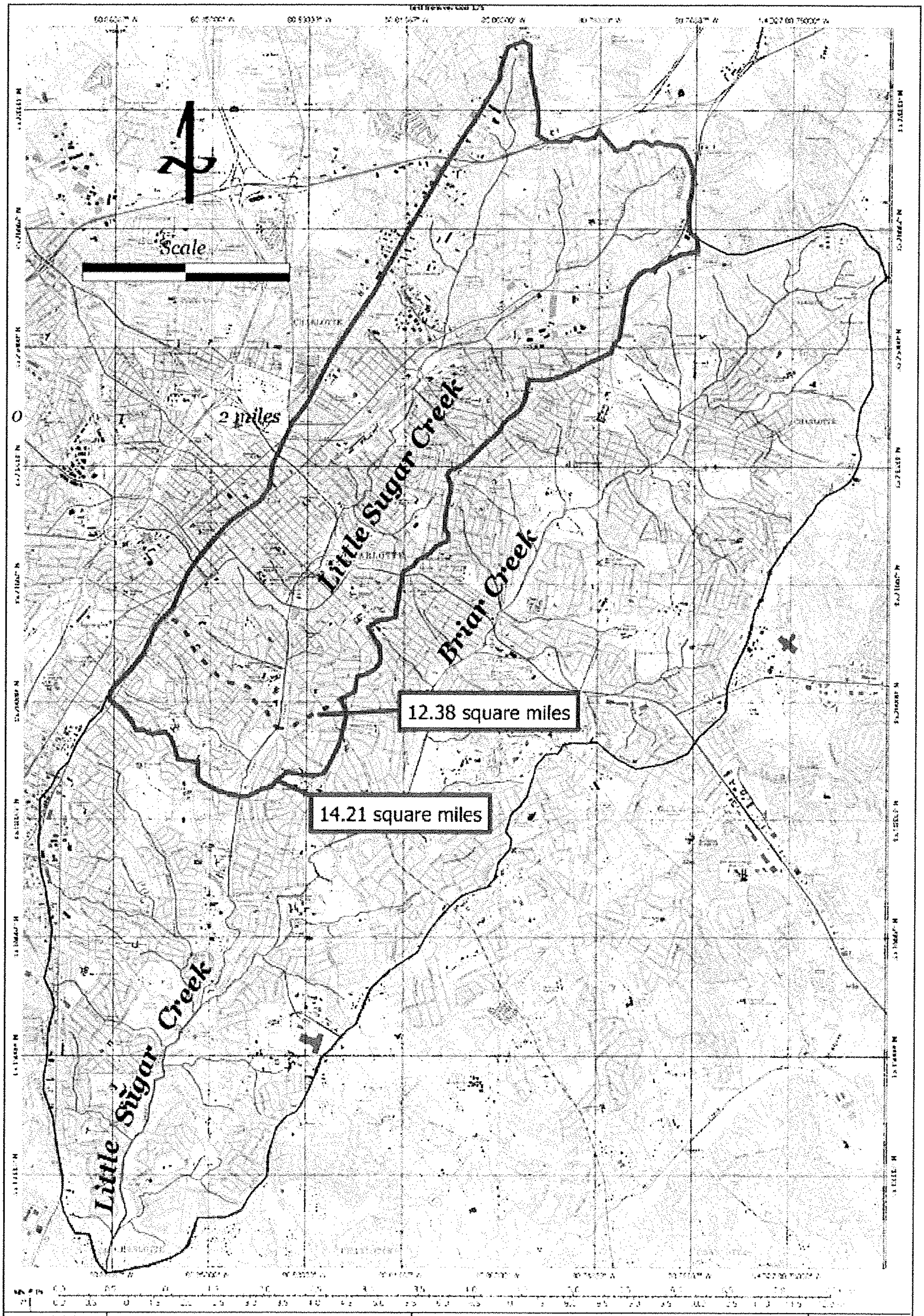
United States Soil Conservation Service. 1986. Urban Hydrology for Small Watersheds, Tech. Rel. 55 (2nd ed.).

Vempaty, Ganesh. 1997. Relationship between water quality and Landuse in the Sugar Creek Watershed, N.C. Master Thesis Dissertation, Department of Civil Engineering, University of North Carolina-Charlotte.

Wilkerson, Shawn, Karl Lindin, James Brown, and Craig Allan. 1998. Development and Analysis of Hydraulic Geometry Relationships for the Urban Piedmont of North Carolina, Technical Report To Charlotte Stormwater Services.

Wolman, M.G., and Leopold, L.B. 1957. River flood plains: some observations on their formation, Professional Paper, United States Geological Survey, 282C, pp. 87-107.

FIGURES



HDR HDR Engineering, Inc. of the Carolinas	**Figure 1: Little Sugar Creek Watershed at Freedom Park** Stream Restoration Plan Little Sugar Creek at Freedom Park	August 2002 Project: 09177-017-018

Figure 2: Aerial Overview Little Sugar Creek at Freedom Park

200 0 200 400 Feet

N

Legend

- Exisiting 100-Year Floodplain
- Structures
- Streets
- Stream
- Project Limits

HDR

HDR Engineering, Inc. of the Carolinas

Habitat Assessment and Restoration Program

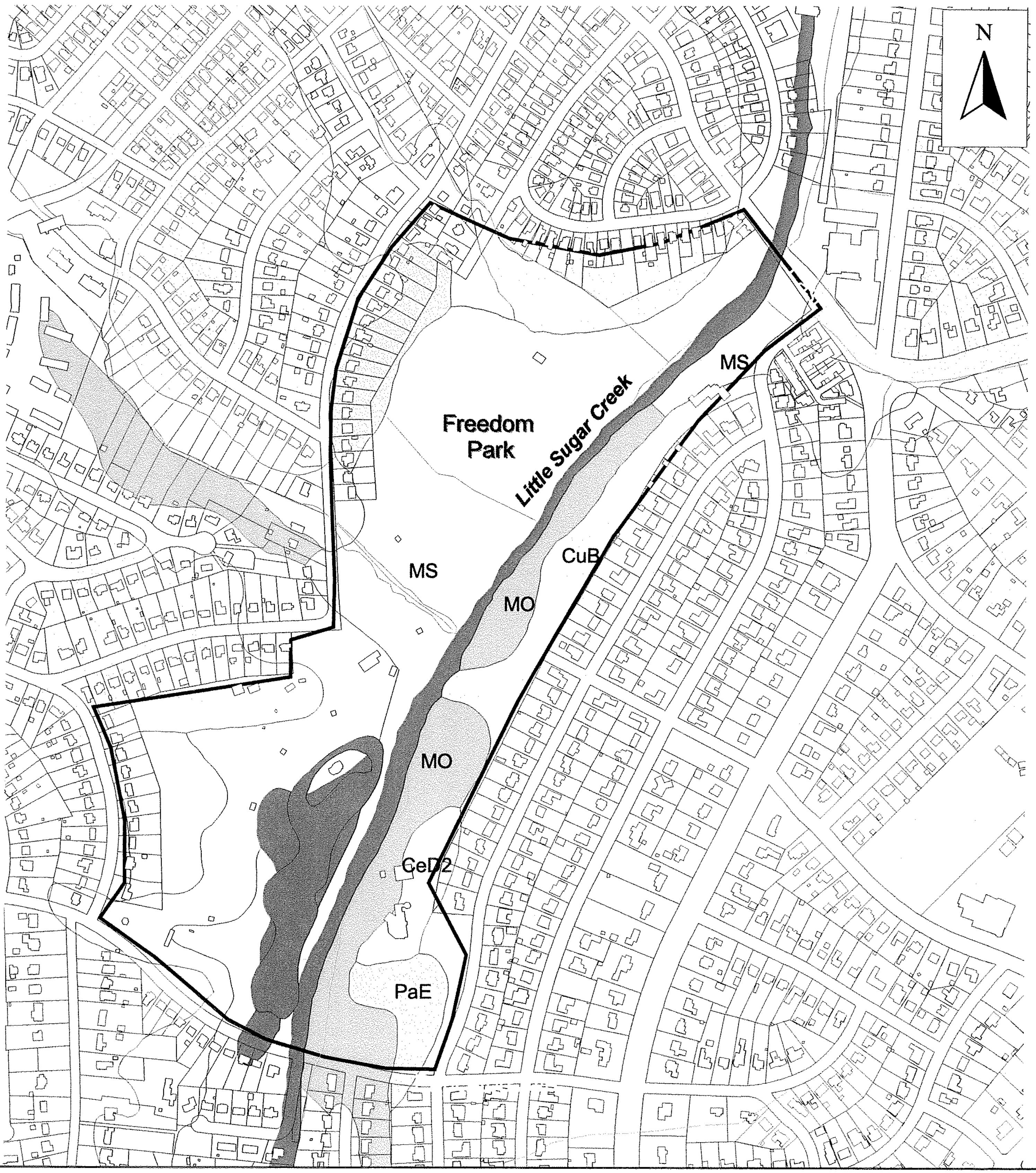


Figure 3: Freedom Park Soils
Stream Restoration Plan
Little Sugar Creek at Freedom Park

Legend

Streams

Parcels

Soils

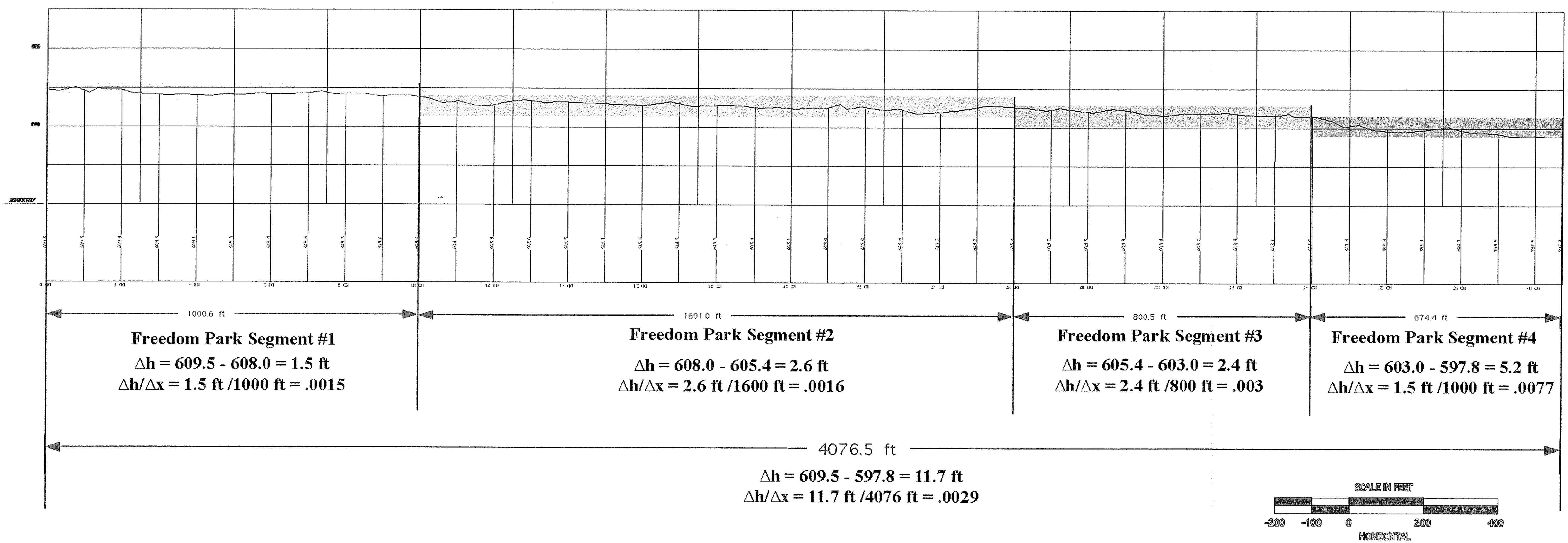
Cecil

Monacan

Monacan loam

Pacolet

500 0 500 1000 Feet

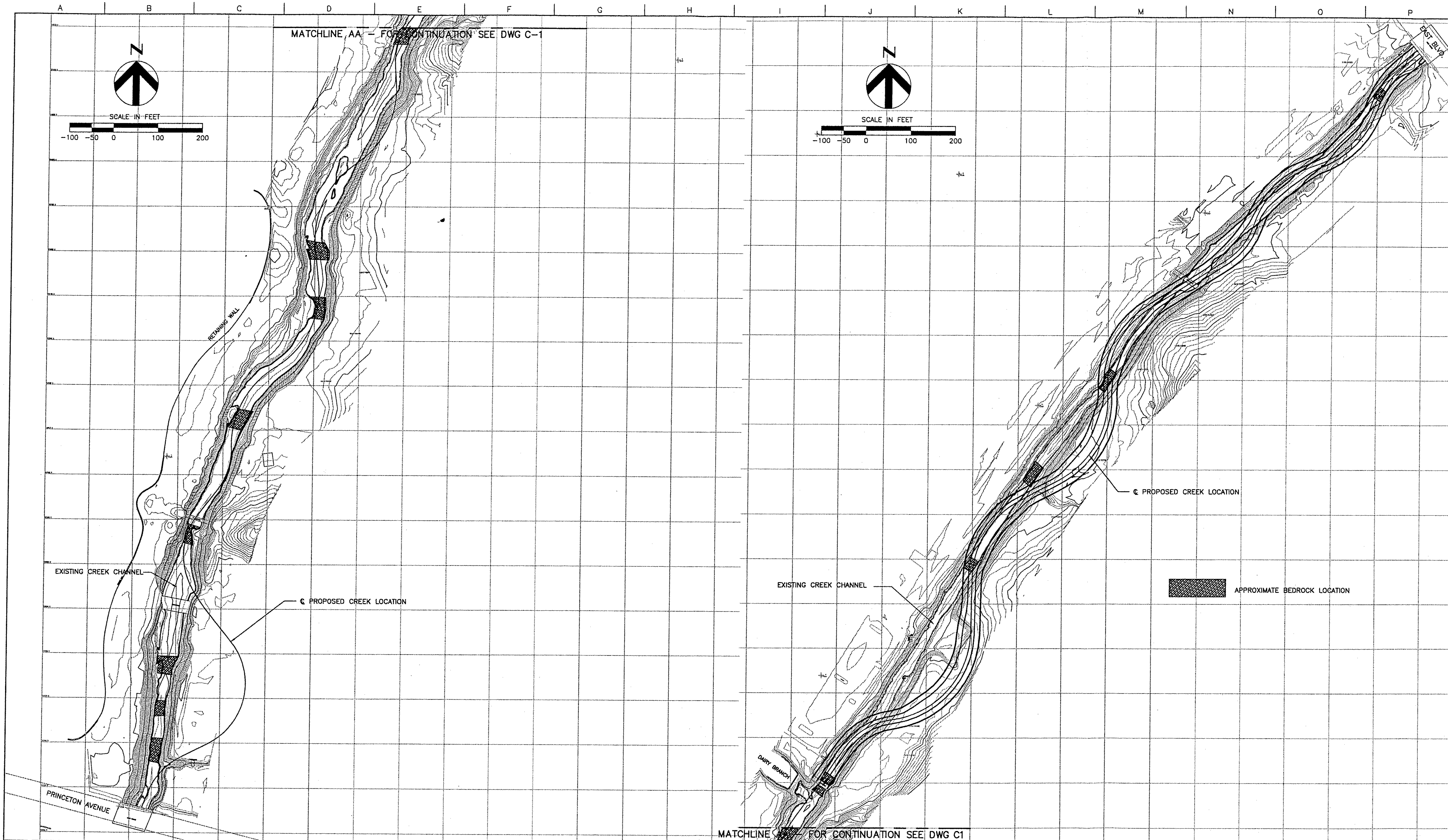


HDR Engineering, Inc.
of the Carolinas

Figure 4: Little Sugar Creek Longitudinal Profile
Stream Restoration Plan
Little Sugar Creek

August 2002

Project: 09177-017-018



Issue No.	Description	Date	Drwn.	Chkd.	Resp. Engr.	Proj. Mgr.

HDR

HDR Engineering, Inc.

BAR LENGTH ON ORIGINAL DRAWING EQUALS ONE INCH. ADJUST SCALE ACCORDINGLY.

Project Manager

Designed

Designed

Checked

Drawn G. Huneycutt

N C Wetlands Restoration Program
Freedom Park - Little Sugar Creek
Channel Restoration

Charlotte North Carolina

Approximate Bedrock Locations

Date: Aug. 2002

Scale: AS NOTED

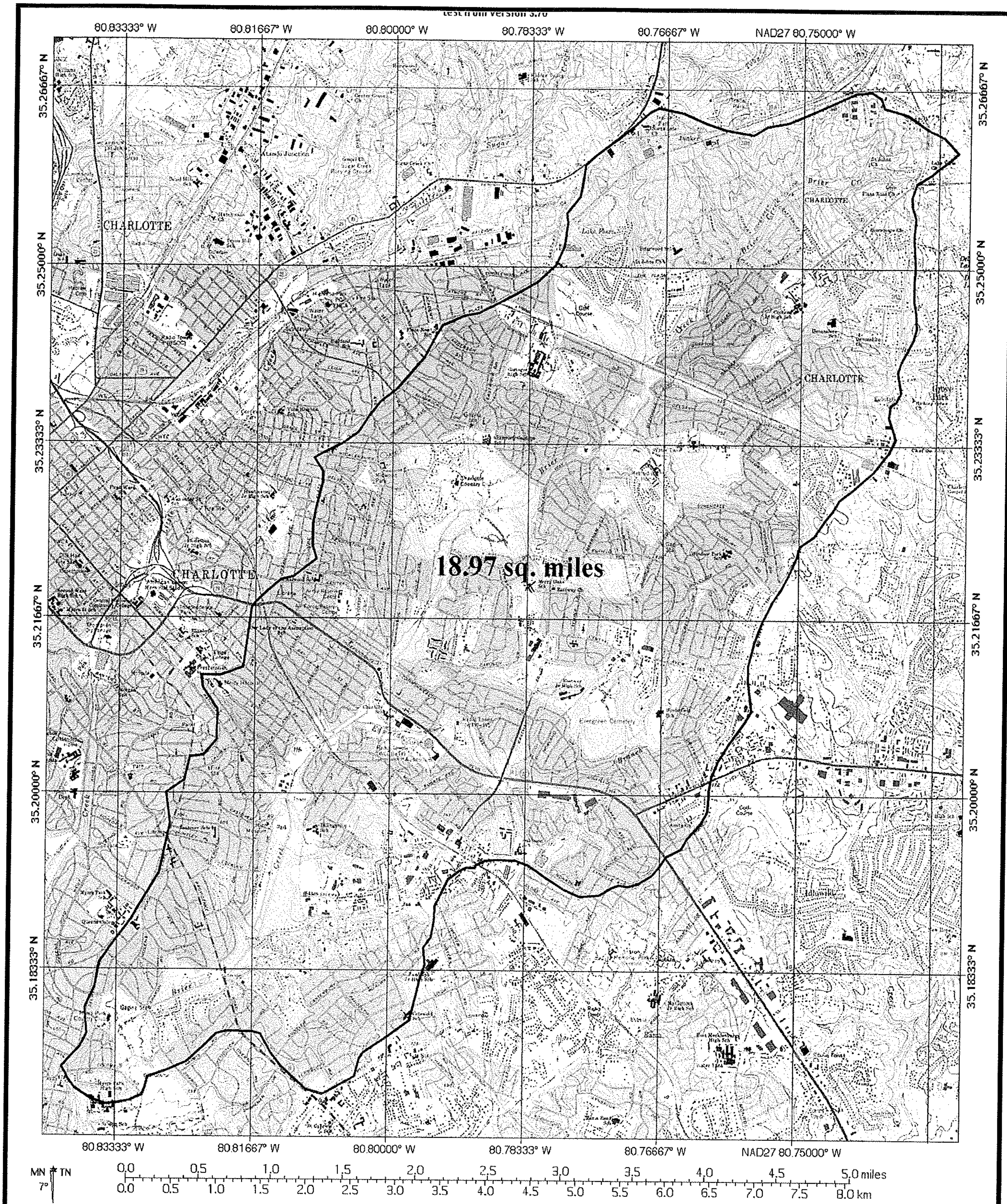
Project No.: 09177-017-018-05

File Name: XXXXX.DWG

Drawing No.: **Fig. 5**

Issue: **A**

C:/WINDH/09177017.018/FIG-5.DWG 08-28-02 GHUNEYCU 15:51:49



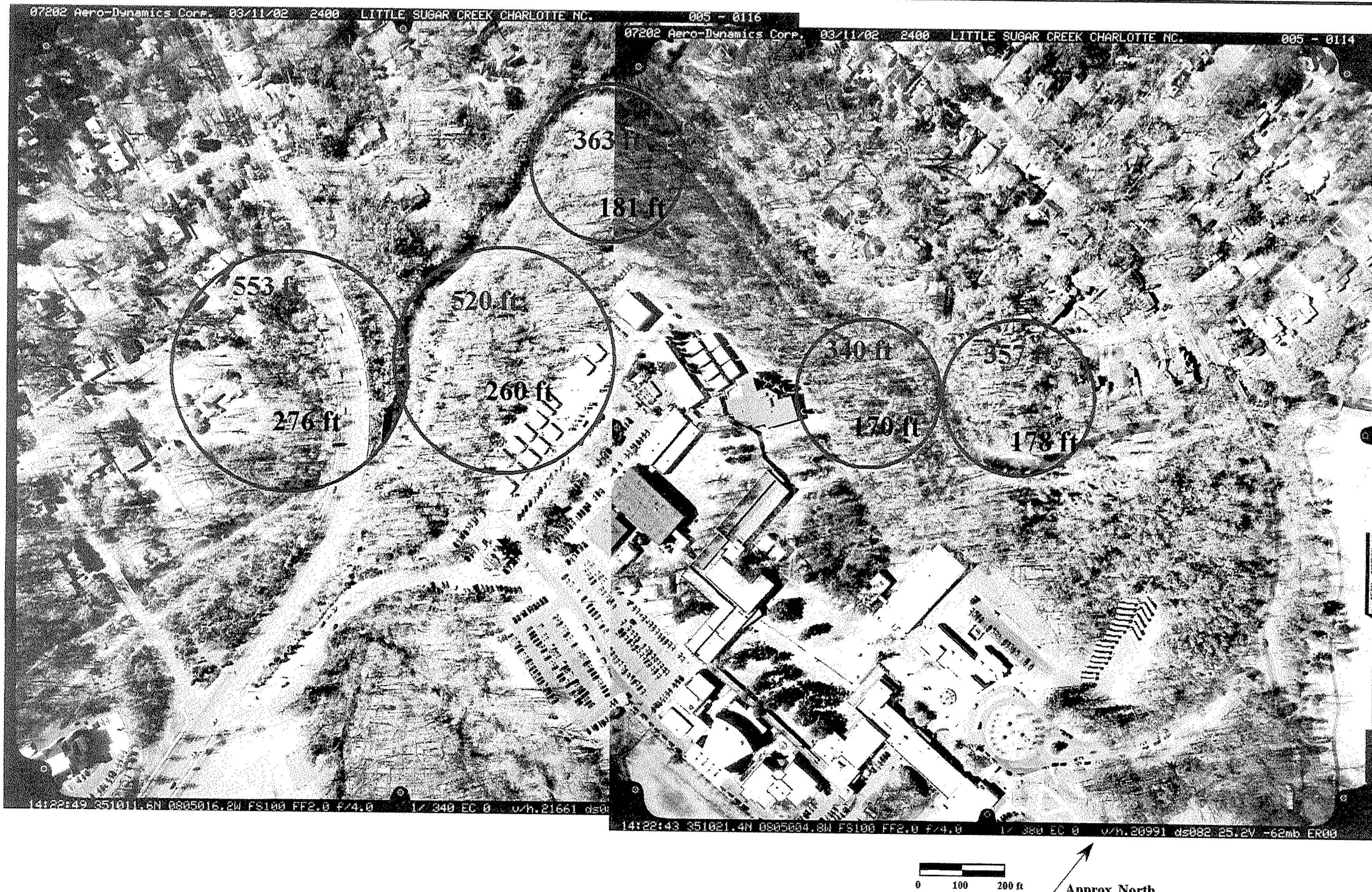
HDR

HDR Engineering, Inc.
of the Carolinas
Habitat Assessment and Restoration Program

Figure 7: Briar Creek Watershed
Stream Restoration Plan
Little Sugar Creek at Freedom Park

August 2002

Project: 09177-017-018



HDR Engineering, Inc. of the Carolinas
Habitat Assessment and Restoration Program Inc.

Figure 8a : Diameters and Radii of Stream for Briar Creek Behind Myers Park High School

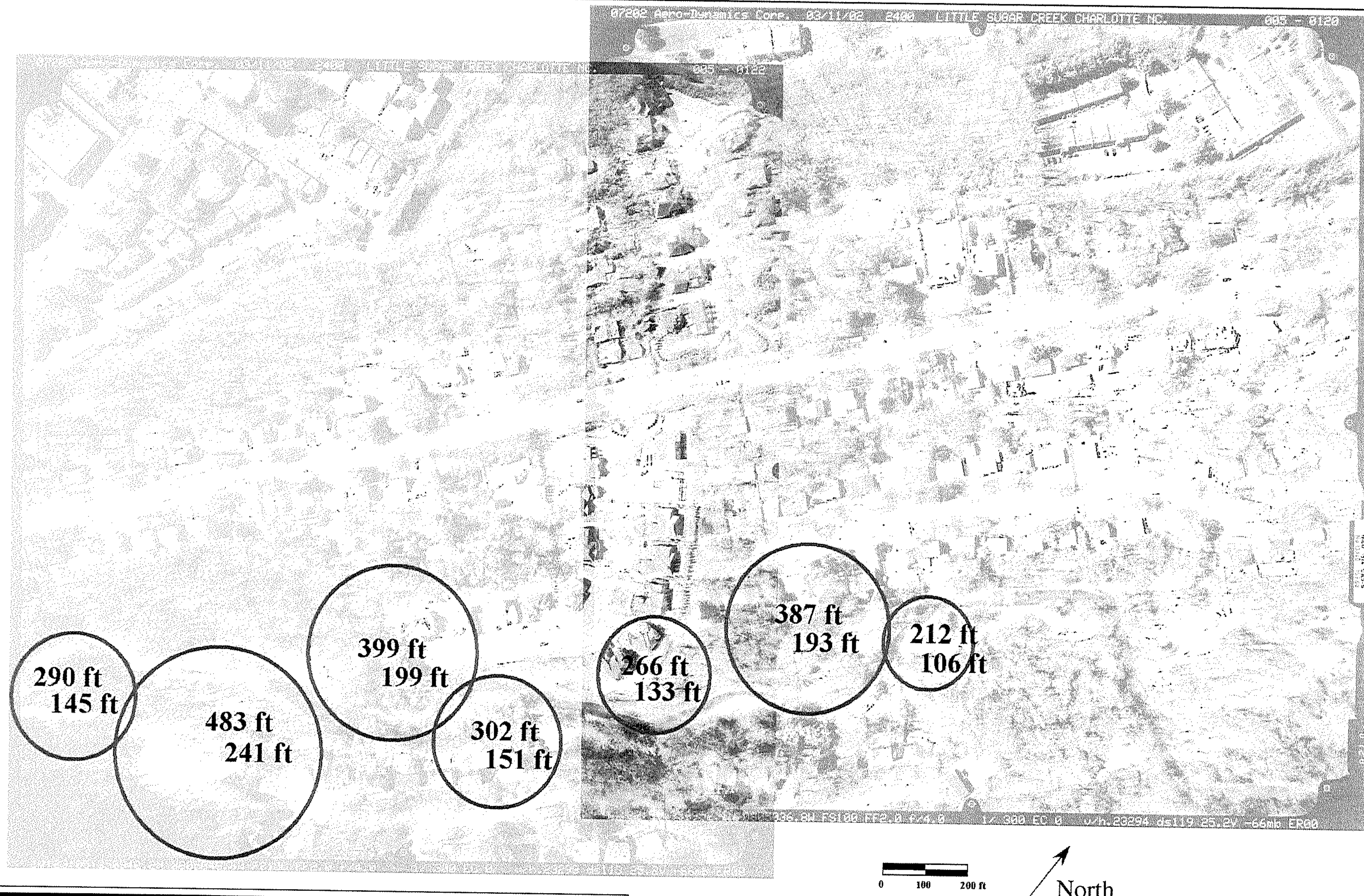
Stream Restoration Plan

Little Sugar Creek at Freedom Park

Photography March 2002

August 2002

Project: 09177-017-018



HDR Engineering, Inc.
of the Carolinas
Habitat Assessment and Restoration Program Inc.

Figure 8b : Diameters and Radii of Stream for Briar Creek between Runnymede Ln and Park Rd

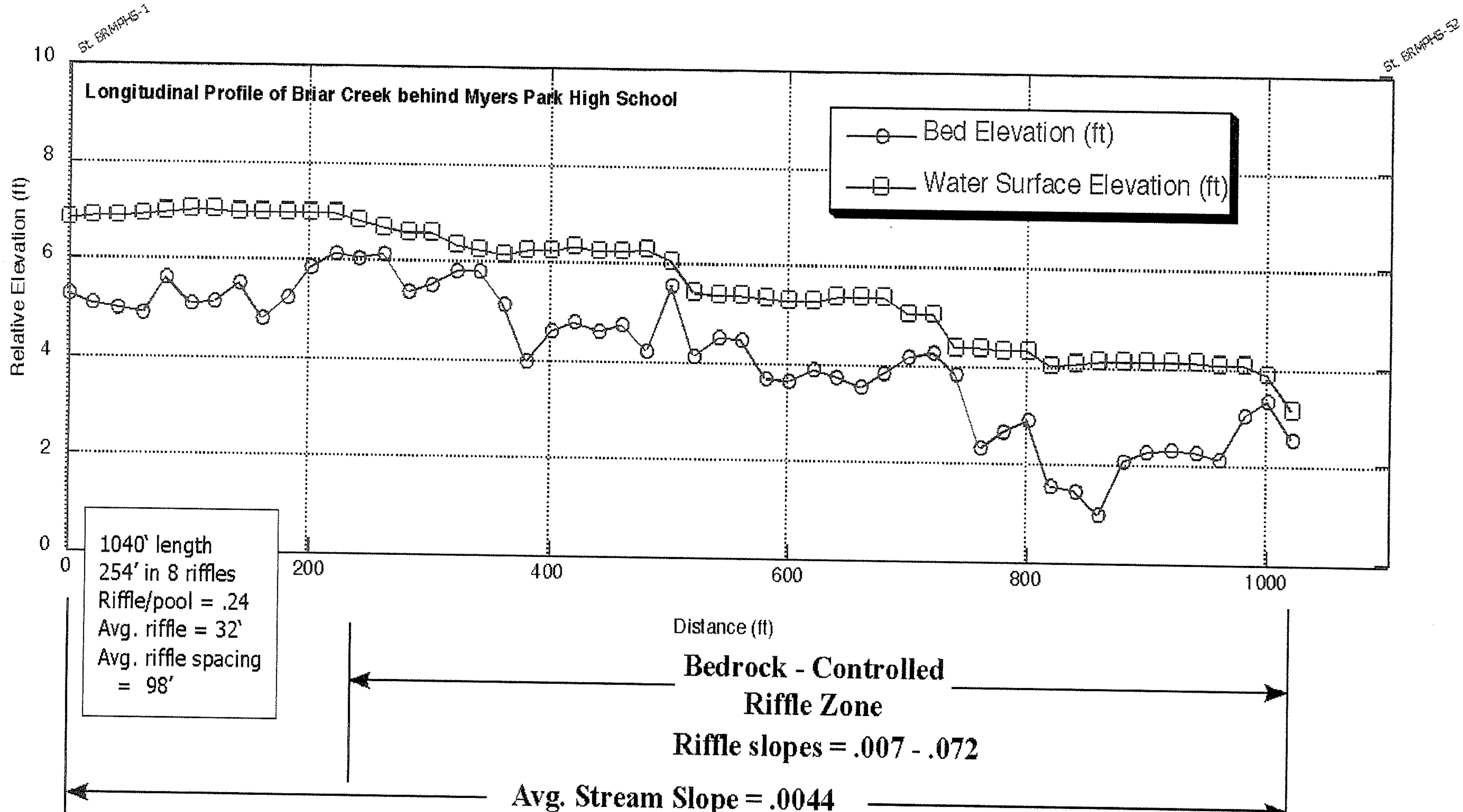
Stream Restoration Plan

Little Sugar Creek at Freedom Park

Photography March 2002

August 2002

Project: 09177-017-018



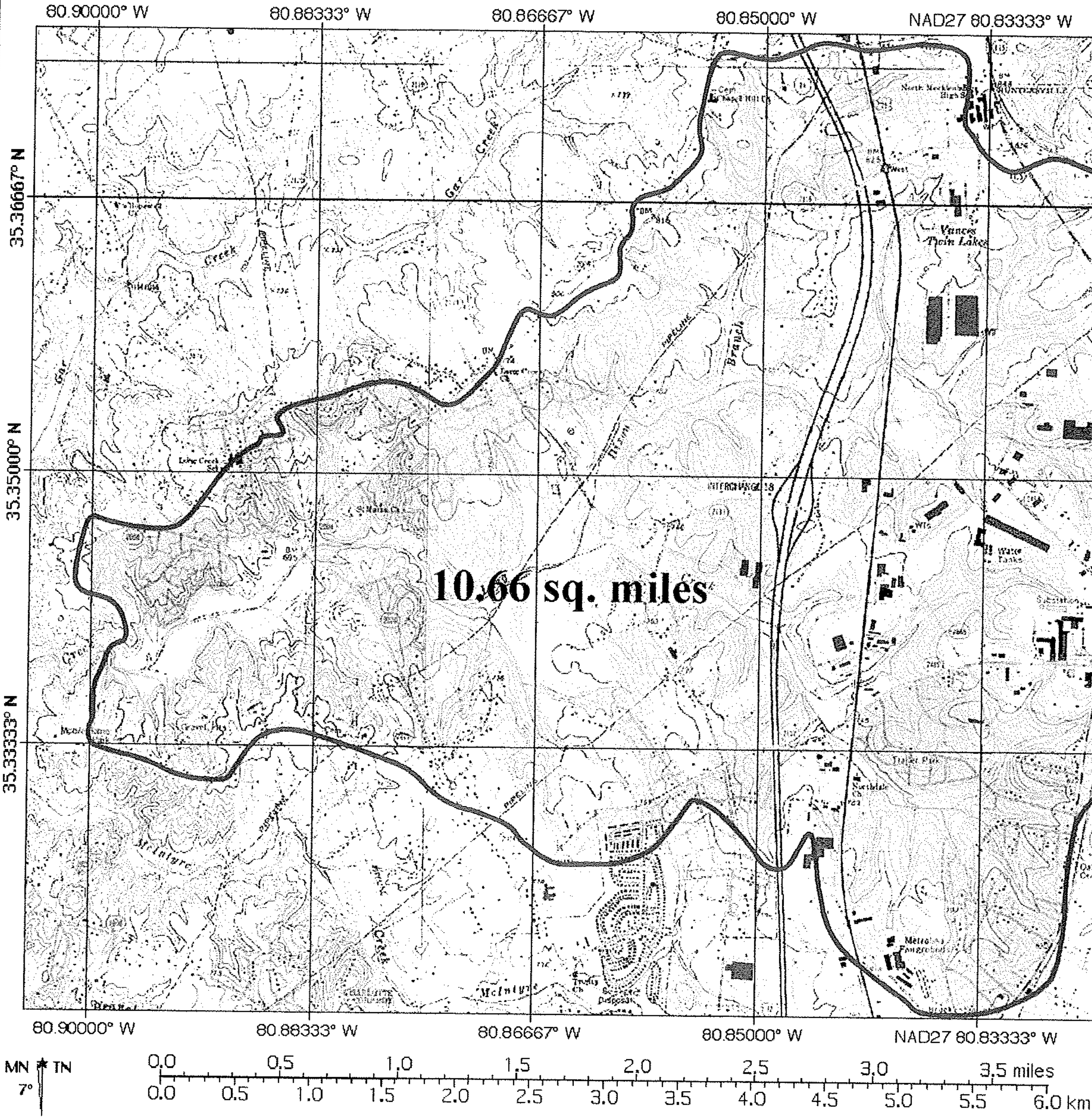
HDR Engineering Inc.
of the Carolinas

Habitat Assessment and Restoration Program Inc.

Figure 9 : Briar Creek Reference Reach Longitudinal Profile
Stream Restoration Plan
Little Sugar Creek at Freedom Park

August 2002

Project: 09177-017-018



HDR

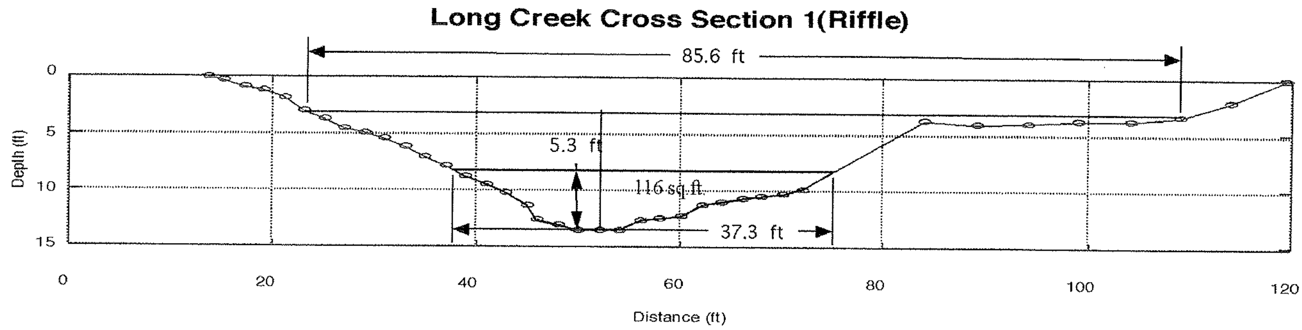
HDR Engineering, Inc.
of the Carolinas

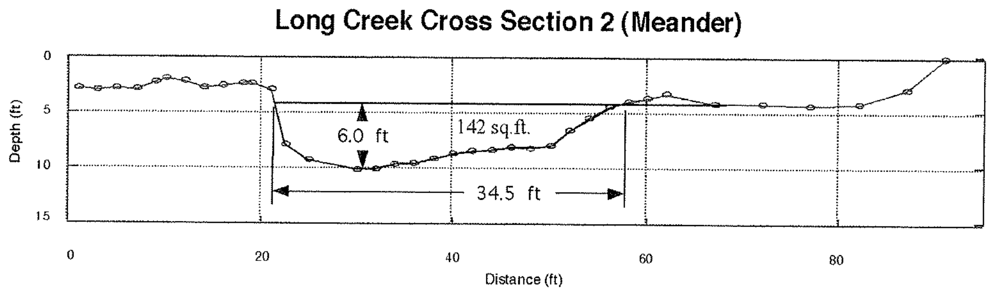
Habitat
Assessment and
Restoration
Program

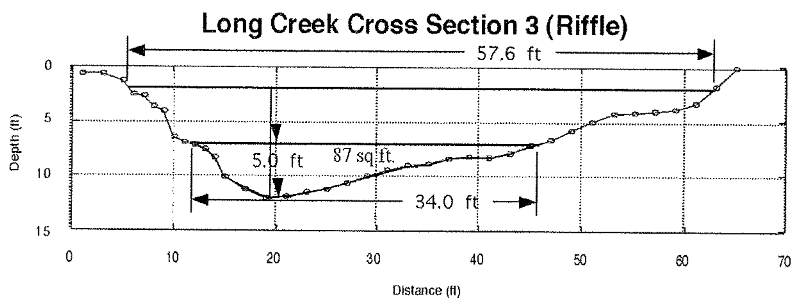
Figure 10: Long Creek Watershed
Stream Restoration Plan
Little Sugar Creek at Freedom Park

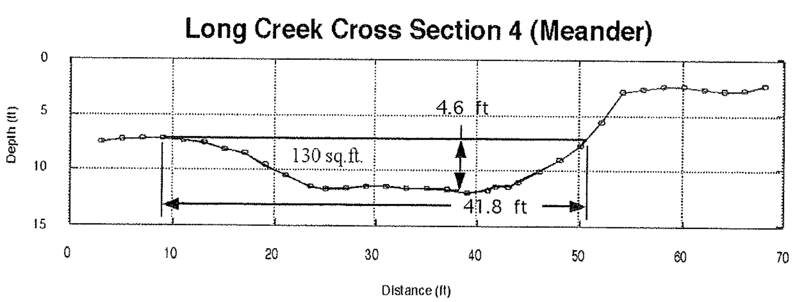
August 2002

Project: 09177-017-018









Avg. Bankfull Area
= 119 sq. ft
= 101 sq.ft. (Riffles)
Avg. Bankfull Width
= 37 ft
= 37 ft (Riffles)
Avg. Bankfull Depth
= 3.2 ft
= 2.8 ft (Riffles)
Avg. Bankfull Max. Depth
= 5.2 ft
= 5.12 ft (Riffles)
Avg. Floodprone Width
= 71.6 ft (Riffles)
Width/Depth Ratio
= 13.2 (Riffle)
Entrenchment Ratio
= 1.9

HDR

HDR Engineering, Inc. of the Carolinas

Habitat Assessment and Restoration Program

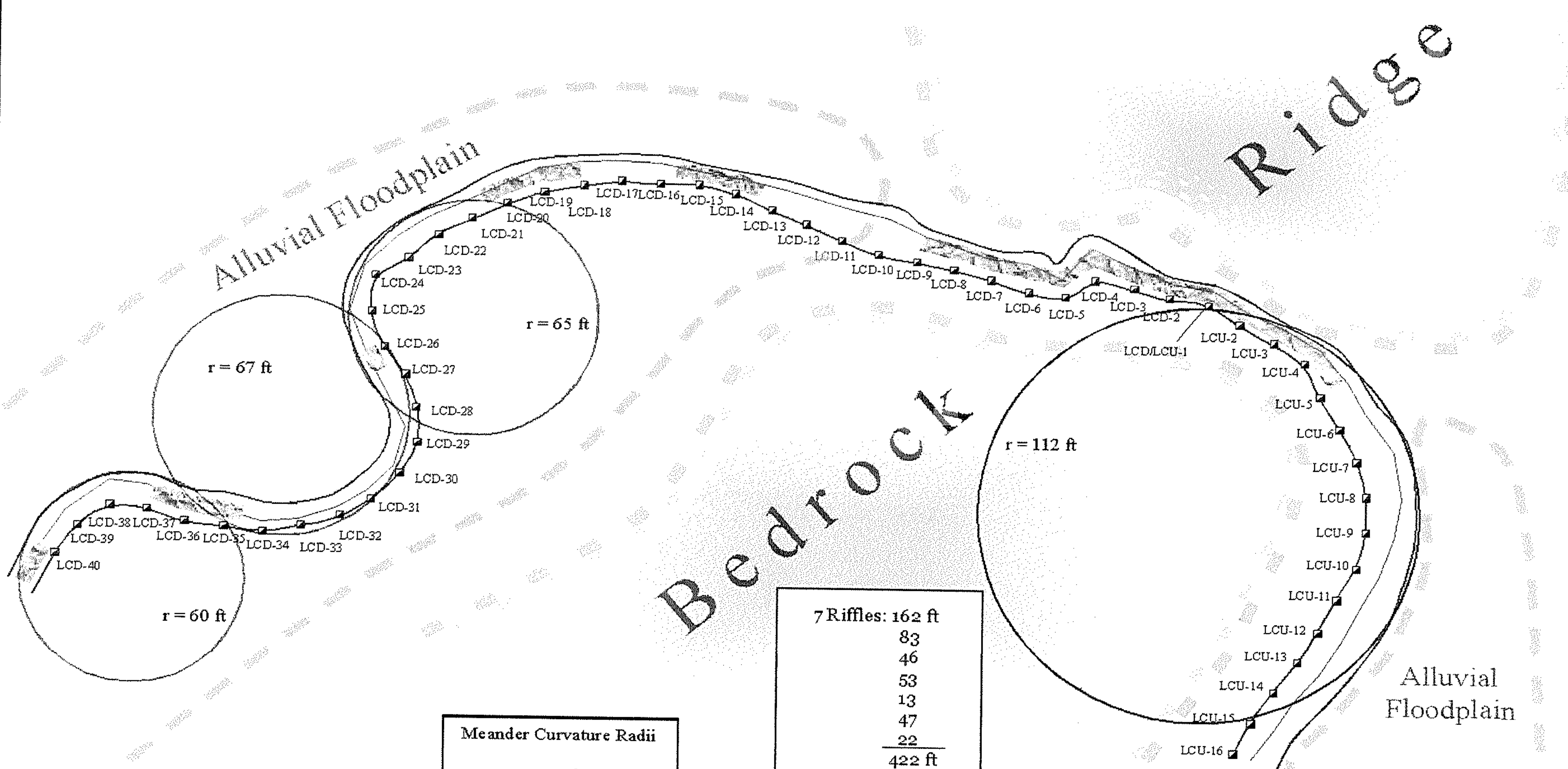
Figure 11: Long Creek Cross Sections

Stream Restoration Plan

Little Sugar Creek at Freedom Park

August 2002

Project: 09177-017-018



Meander Curvature Radii

60 ft
67 ft
65 ft
112 ft

Avg. 76 ft

7 Riffles:	162 ft
	83
	46
	53
	13
	47
	22
	422 ft
7 Pools:	732 ft
Total:	1158 ft

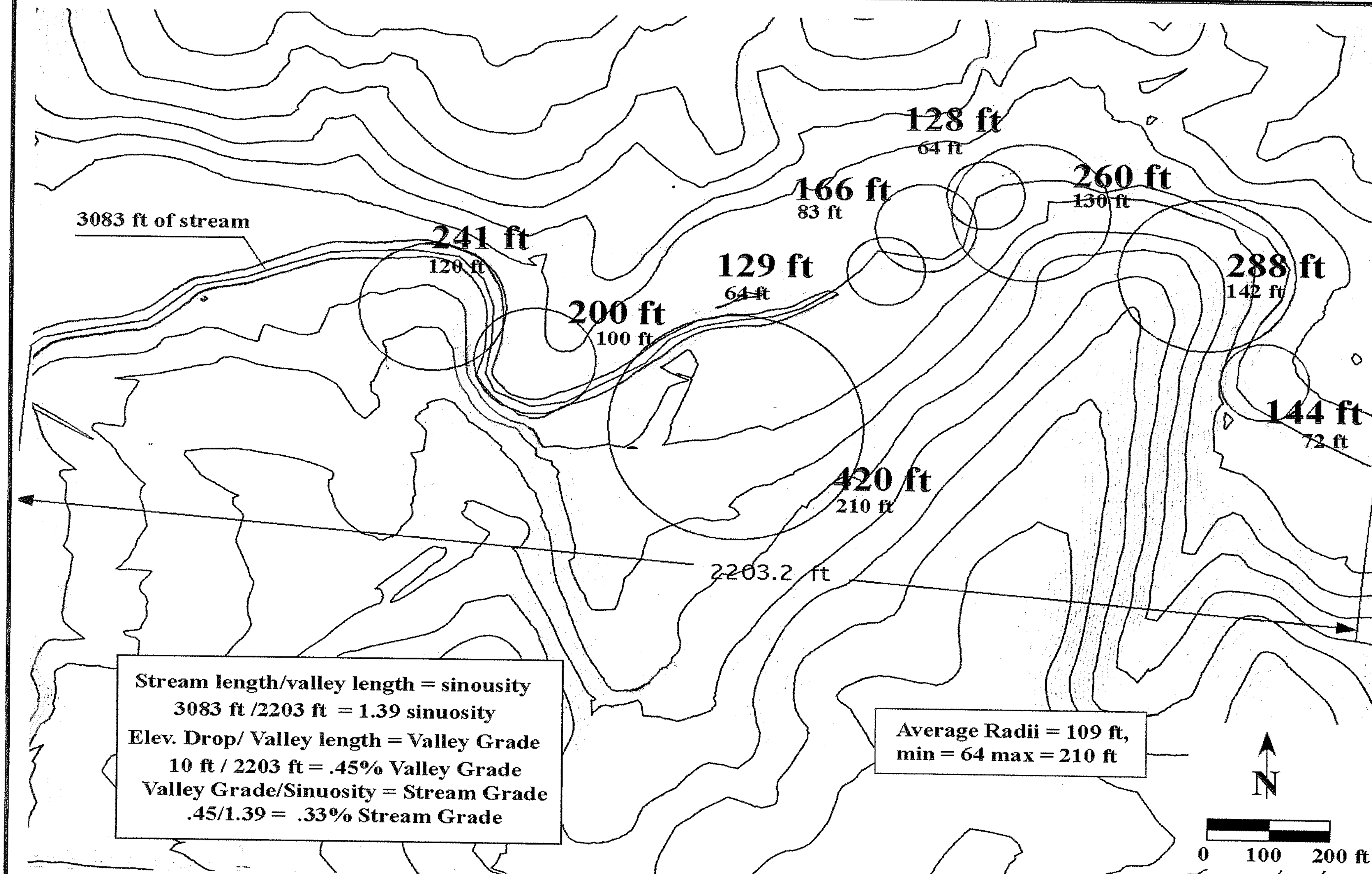
Riffle/Pool = .58
Avg. Riffle = 61 ft
Avg. Pool = 104 ft

HDR
HDR Engineering, Inc. of the Carolinas
Habitat Assessment and Restoration Program Inc.

Figure 12 : Long Creek Pattern Map Near Primm Road
Stream Restoration Plan
Little Sugar Creek at Freedom Park

August 2002

Project: 09177-017-018



HDR

HDR Engineering, Inc.
of the Carolinas

Habitat Assessment and Restoration Program

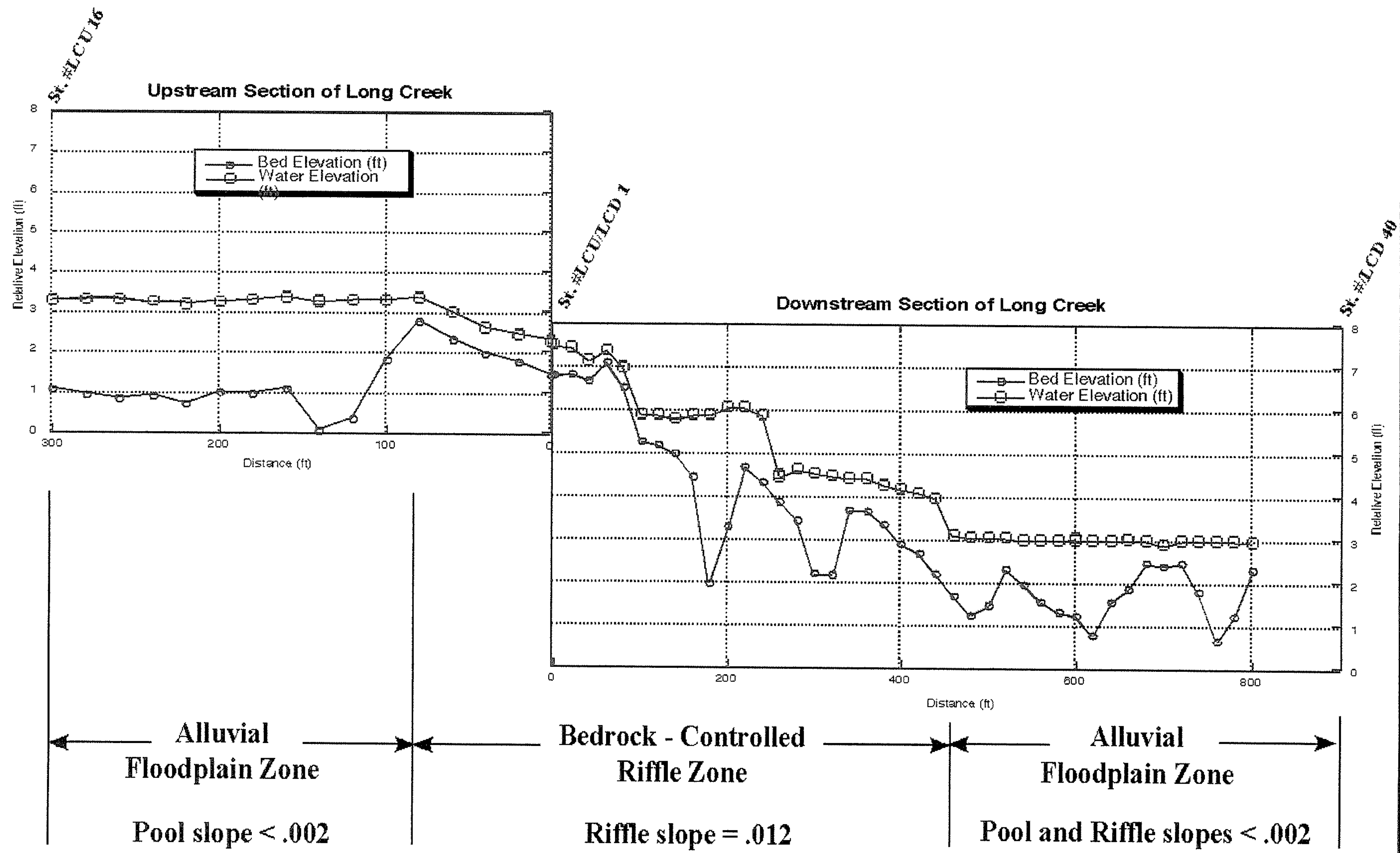
Figure 13 : Long Creek Topographic Map Near Primm Road

Stream Restoration Plan

Little Sugar Creek at Freedom Park

August 2002

Project: 09177-017-018

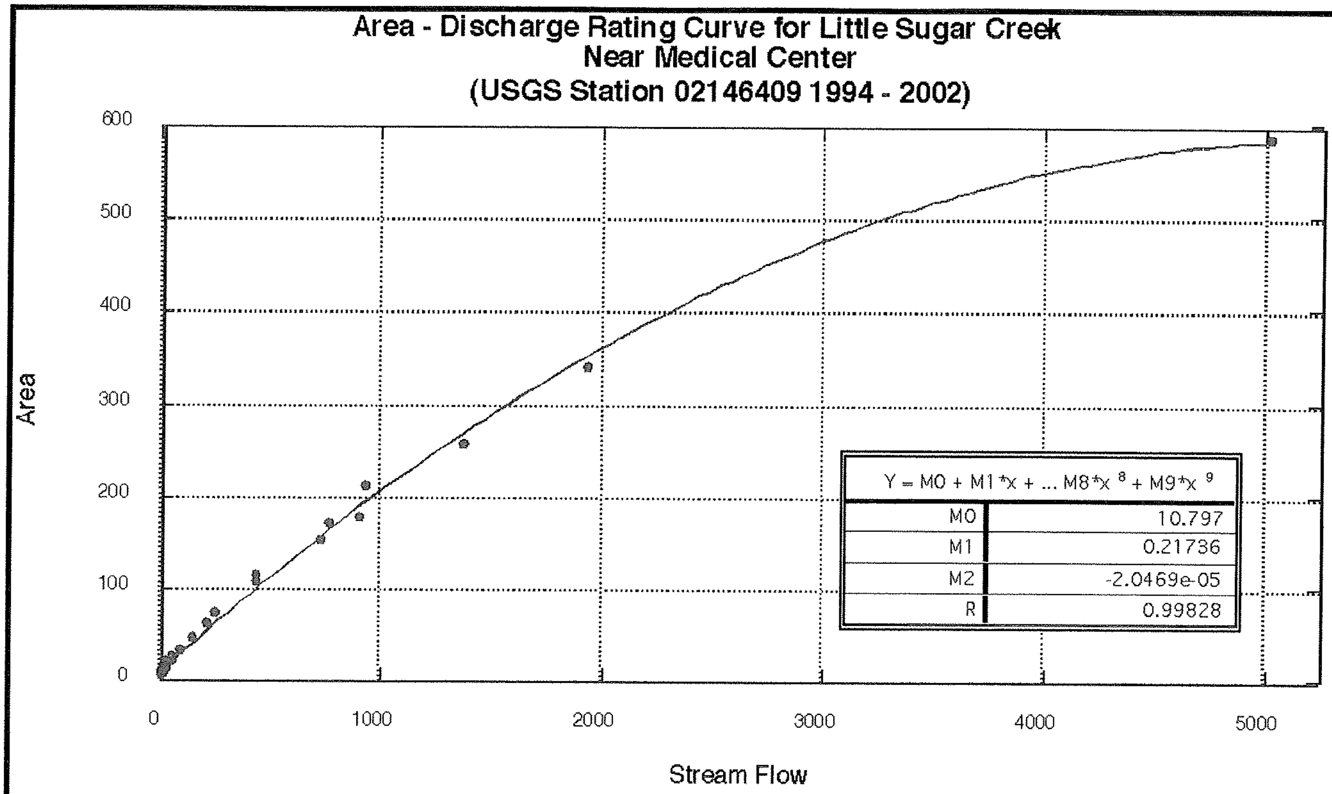


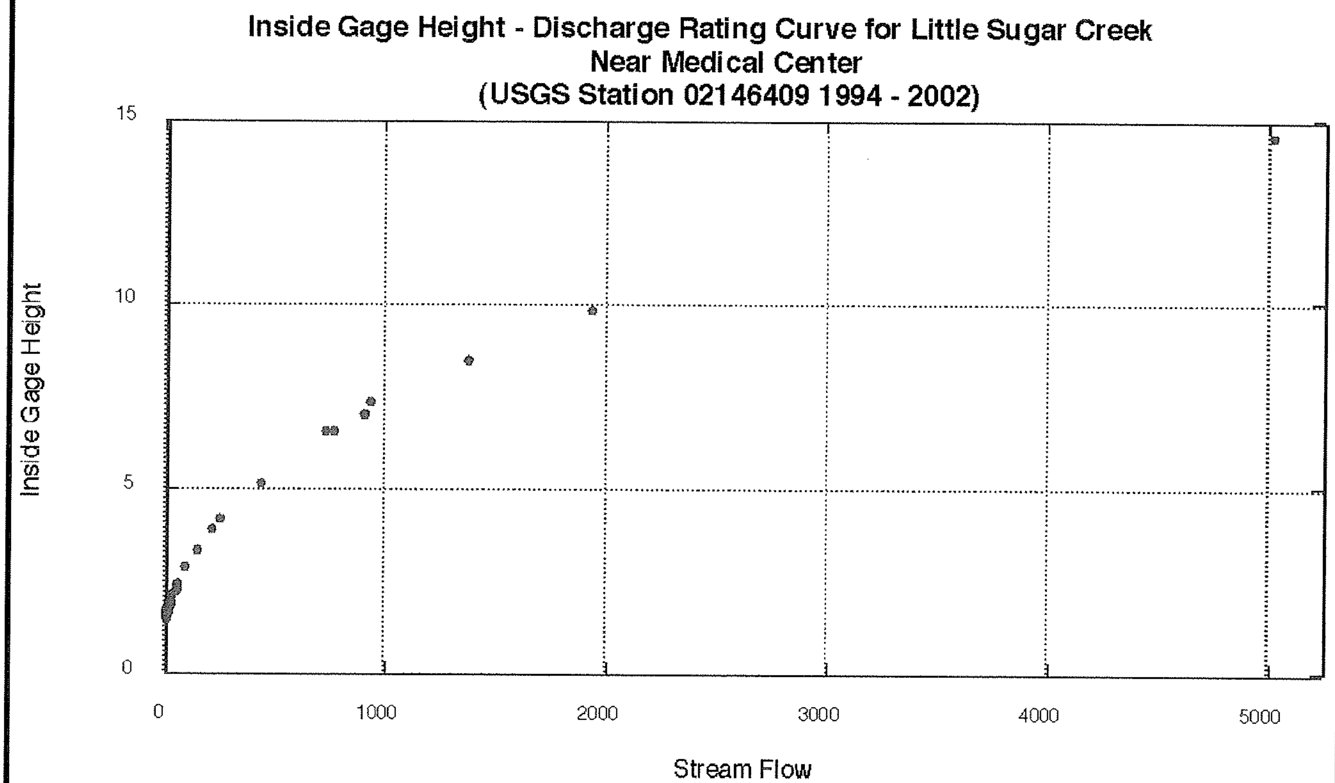
HDR Engineering, Inc. of the Carolinas
Habitat Assessment and Restoration Program

Figure 14 : Long Creek Reference Reach, Longitudinal Profile
Stream Restoration Plan
Little Sugar Creek at Freedom Park

August 2002

Project: 09177-017-018





HDR Engineering, Inc.
of the Carolinas

Habitat Assessment and Restoration Program

Figure 15: Discharge Rating Curve for Little Sugar Creek Near Medical Center

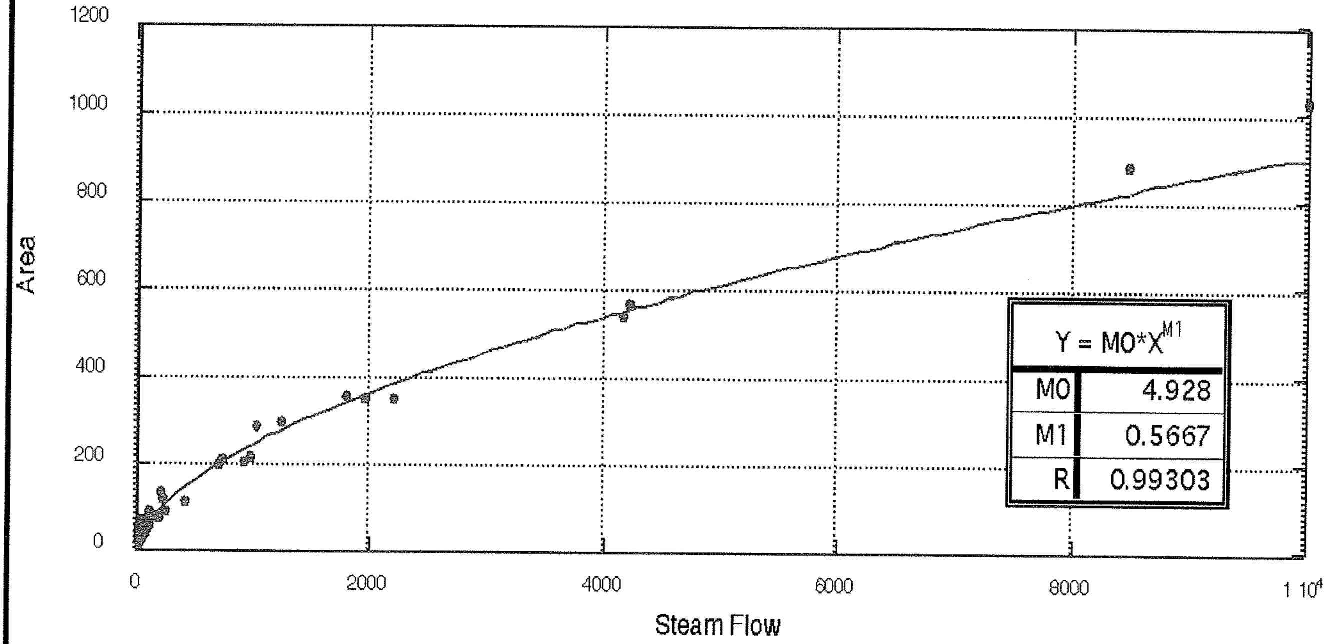
Stream Restoration Plan

Little Sugar Creek at Freedom Park

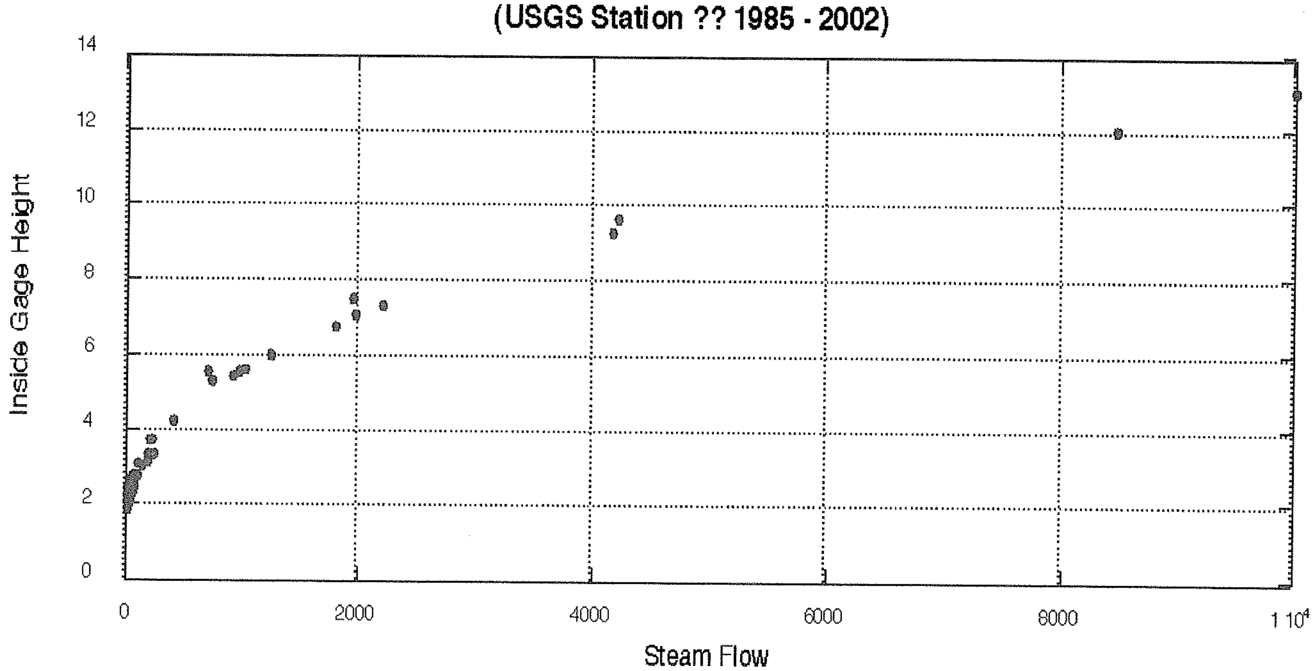
August 2002

Project: 09177-017-018

Area - Discharge Rating Curve for Little Sugar Creek Near Archdale Drive (USGS Station ?? 1985 - 2002)



Inside Gage Height - Discharge Rating Curve for Little Sugar Creek Near Archdale Drive (USGS Station ?? 1985 - 2002)



HDR Engineering, Inc. of the Carolinas

Habitat Assessment and Restoration Program Inc

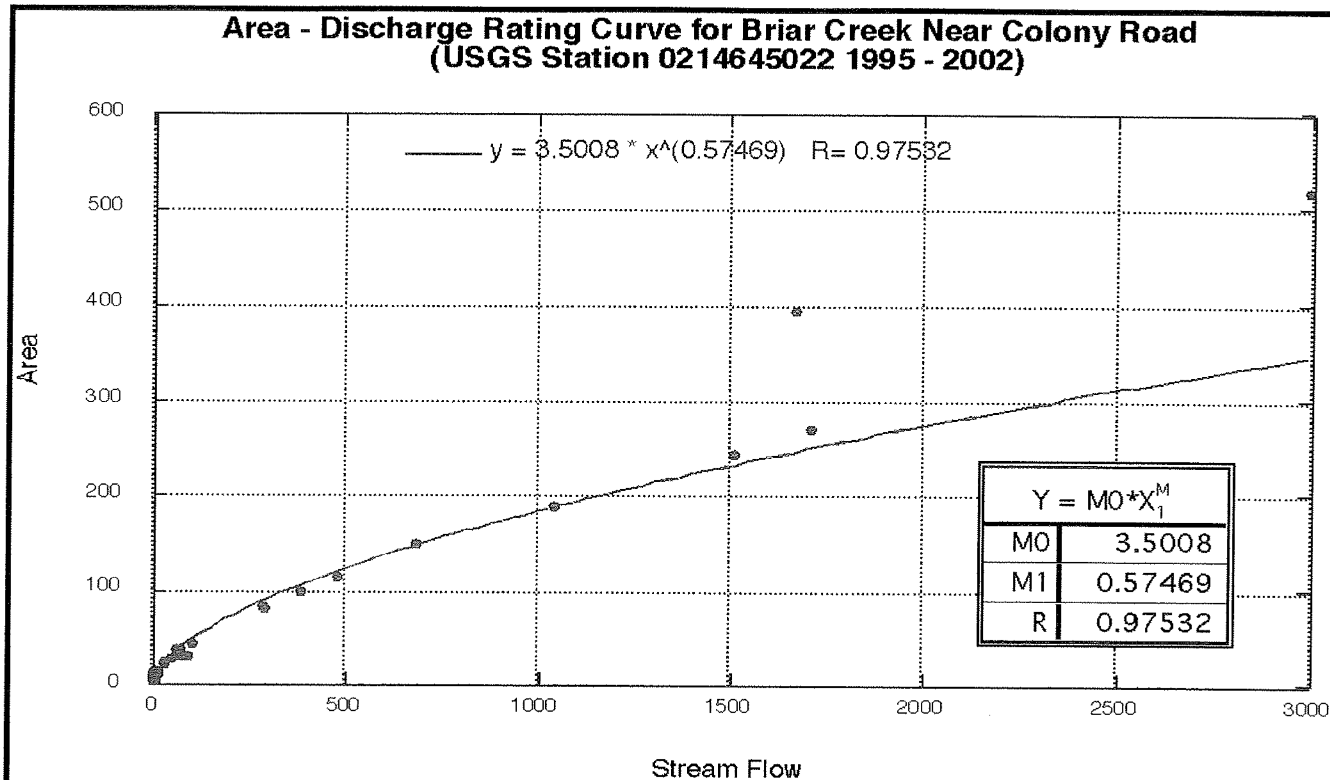
Figure 16: Discharge Rating Curve for Little Sugar Creek Near Archdale Drive

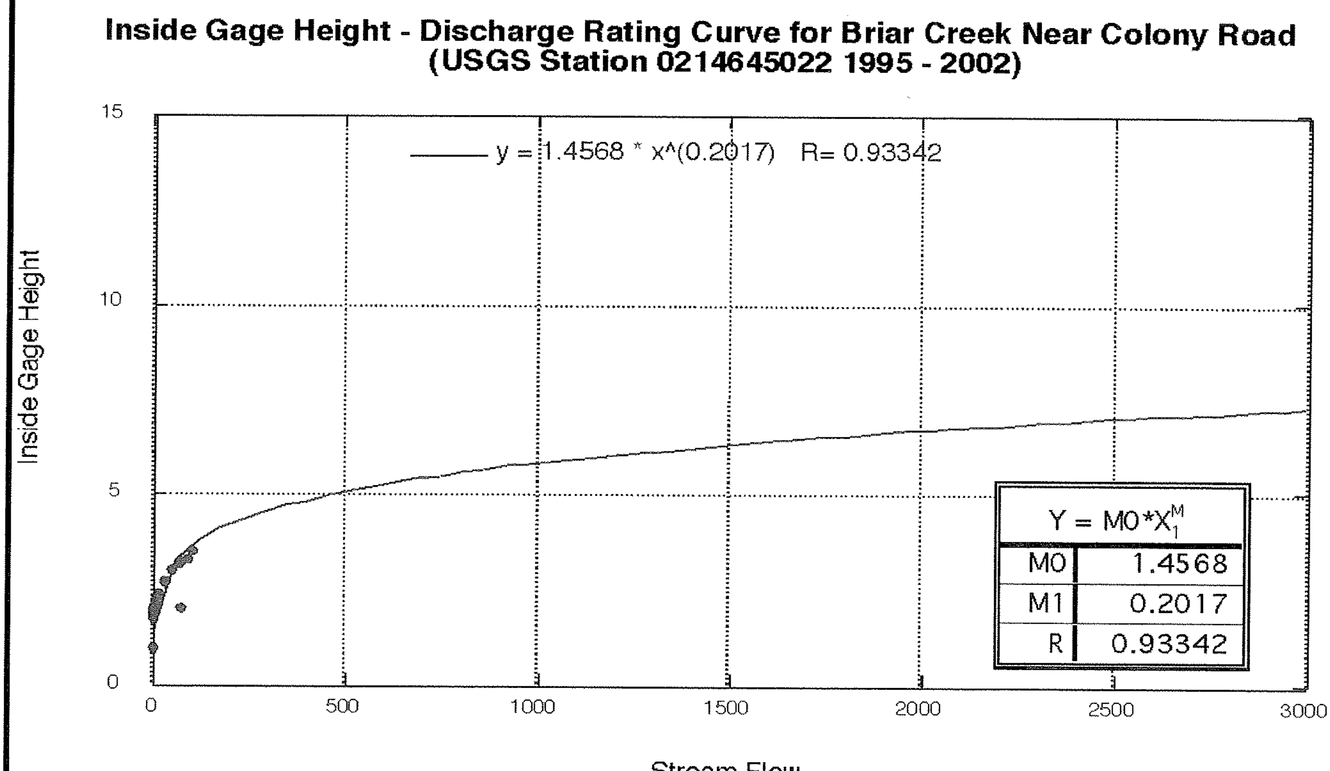
Stream Restoration Plan

Little Sugar Creek at Freedom Park

August 2002

Project: 09177-017-018





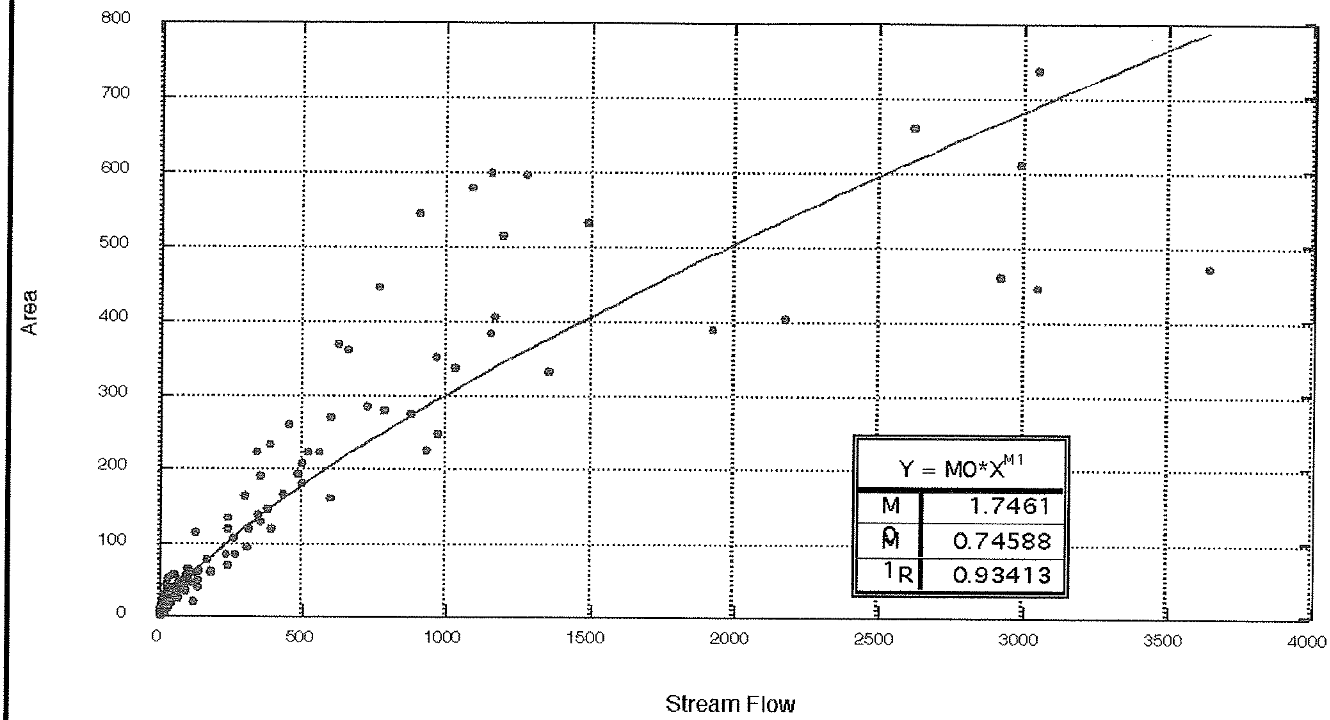
HDR
HDR Engineering, Inc. of the Carolinas
Habitat Assessment and Restoration Program

Figure 17: Discharge Rating Curve for Briar Creek Near Colony Road
Stream Restoration Plan
Little Sugar Creek at Freedom Park

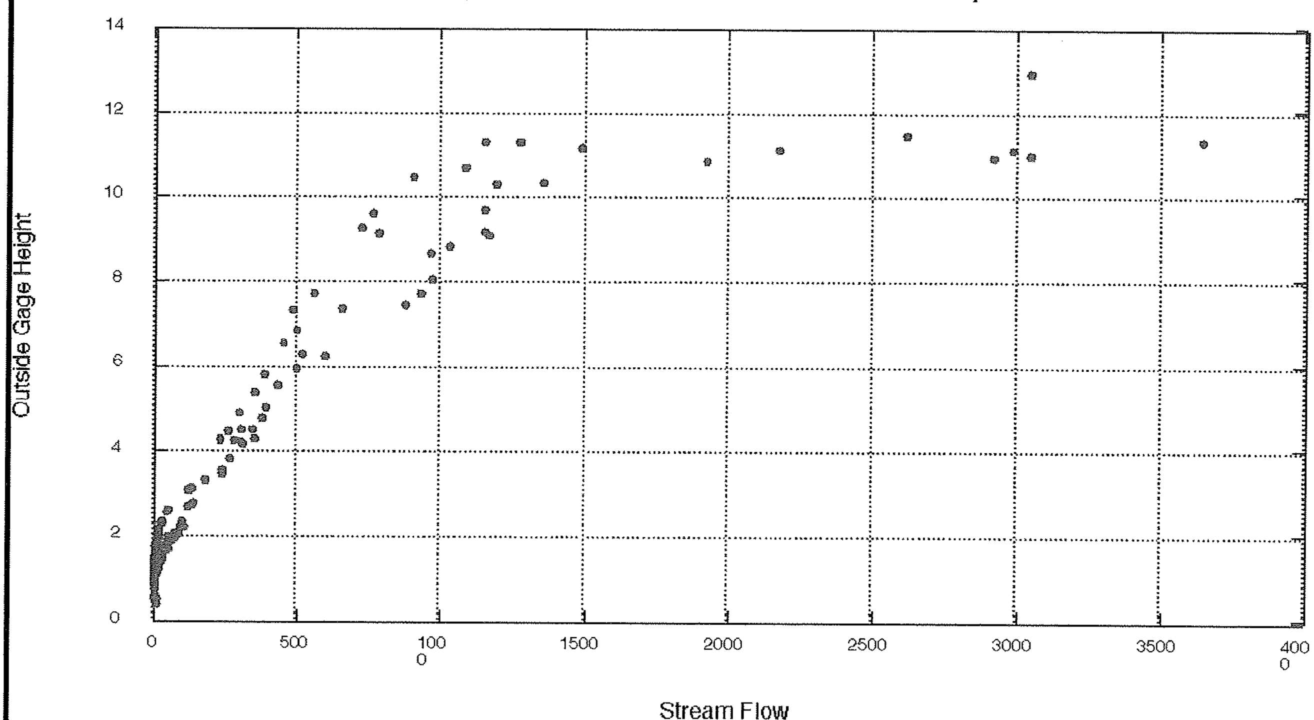
August 2002

Project: 09177-017-018

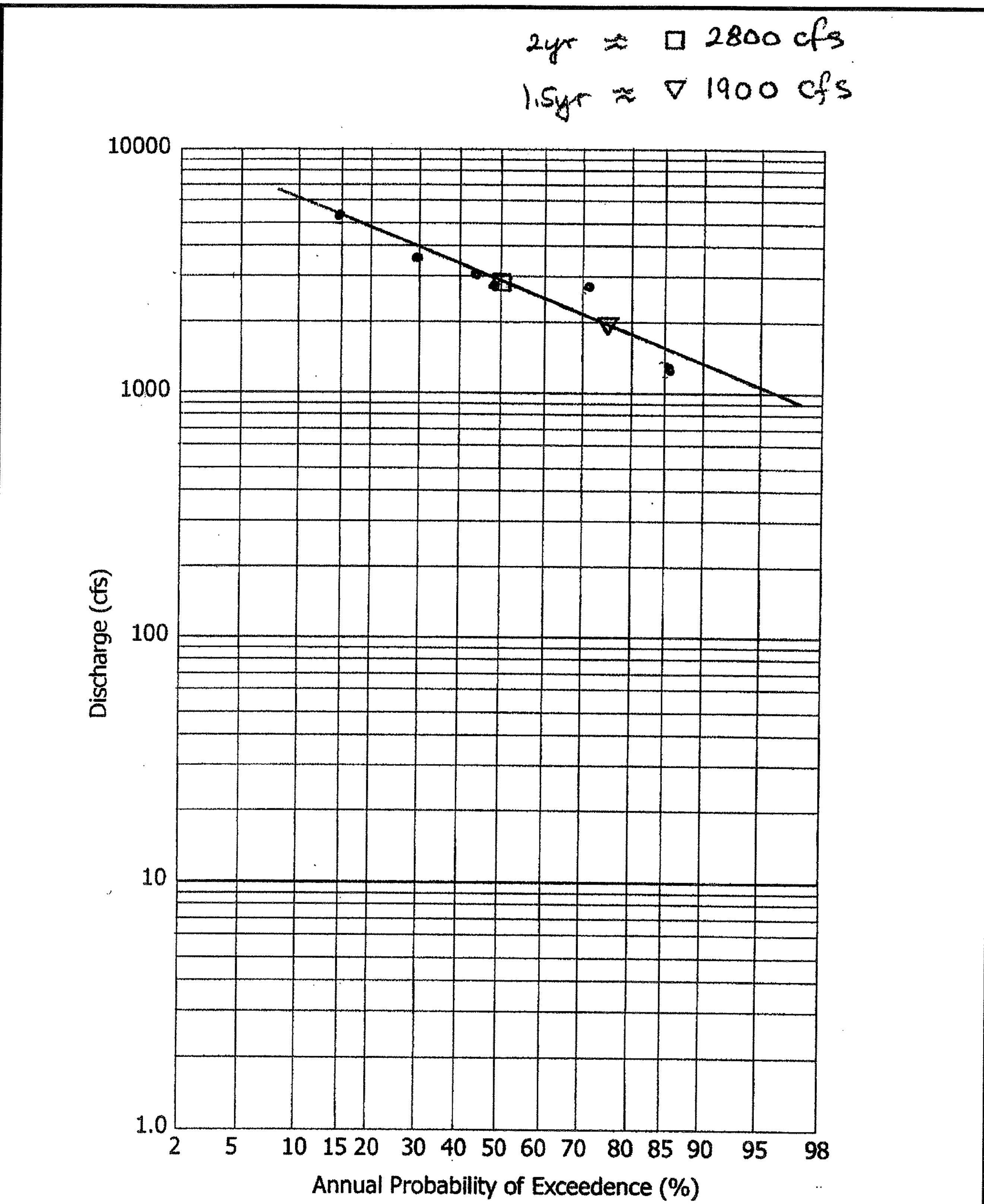
Area - Discharge Rating Curve for Long Creek
(USGS Station No. 02142900 1965 - 2002)



Outside Gage Height - Discharge Rating Curve for Long Creek
(USGS Station No. 02142900 1965 - 2002)



HDR Engineering, Inc. of the Carolinas	**Figure 18: Discharge Rating Curve for Long Creek** Stream Restoration Plan Little Sugar Creek at Freedom Park	August 2002 Project: 09177-017-018

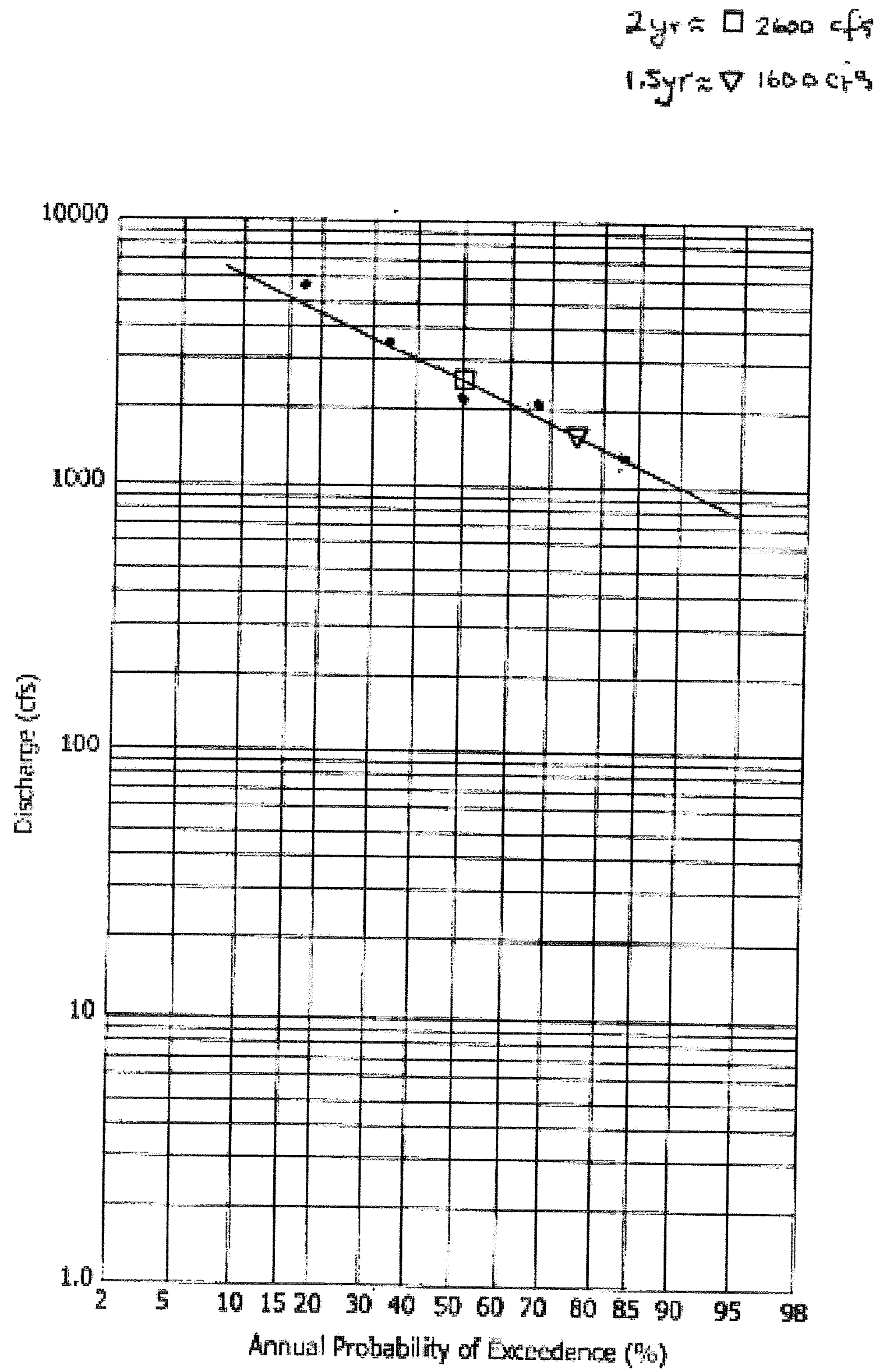


HDR Engineering, Inc. of the Carolinas
Habitat Assessment and Restoration Program

Figure 19: 1996-2001 Annual Peak Flow for Little Sugar Creek Near Medical Drive
Stream Restoration Plan
Little Sugar Creek at Freedom Park

August 2002

Project: 09177-017-018

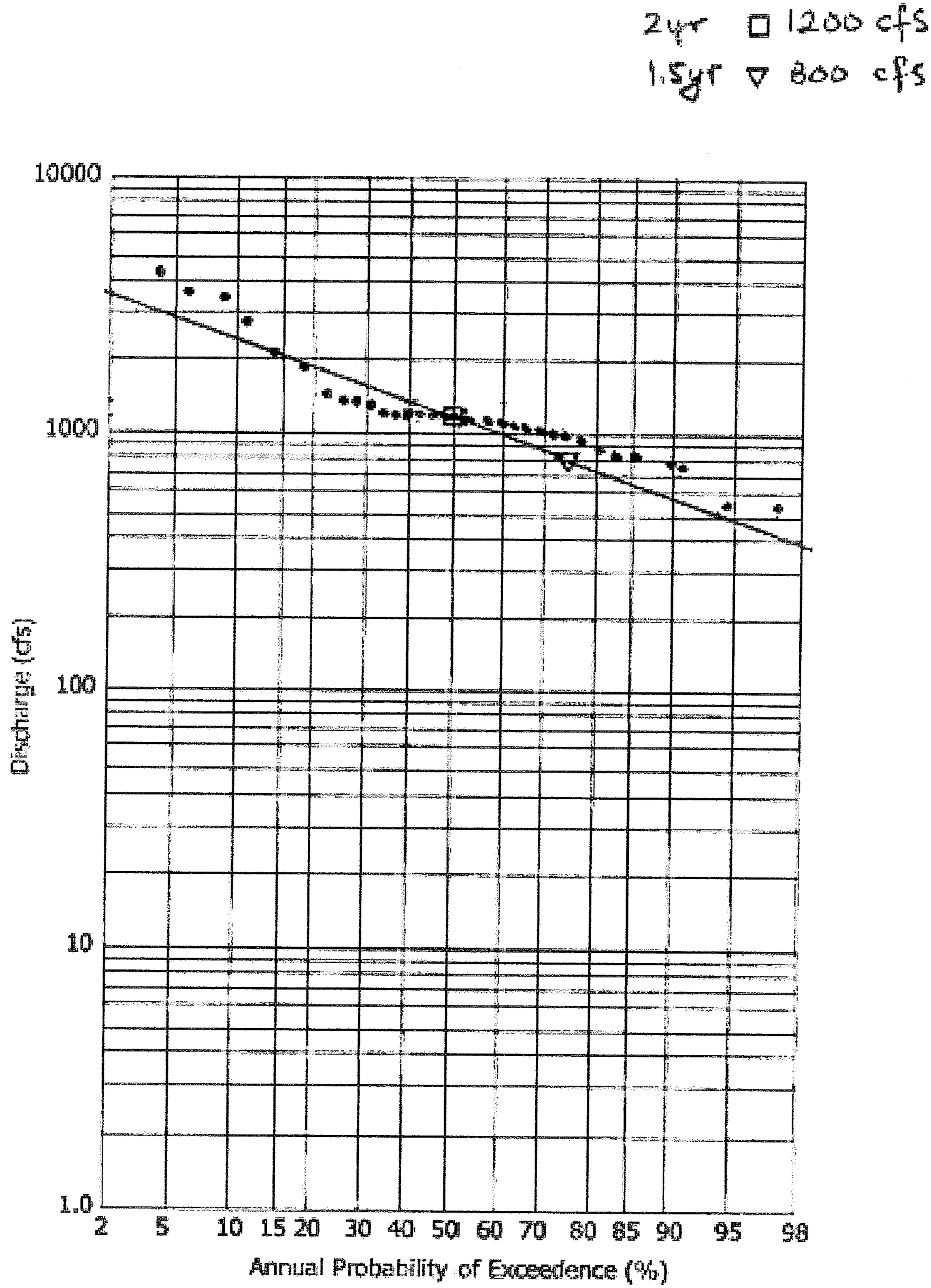


HDR Engineering, Inc. of the Carolinas
Habitat Assessment and Restoration Program

Figure 20: 1997-2001 Annual Peak Flow for Briar Creek North of Colony Road
Stream Restoration Plan
Little Sugar Creek at Freedom Park

August 2002

Project: 09177-017-018



HDR Engineering, Inc. of the Carolinas

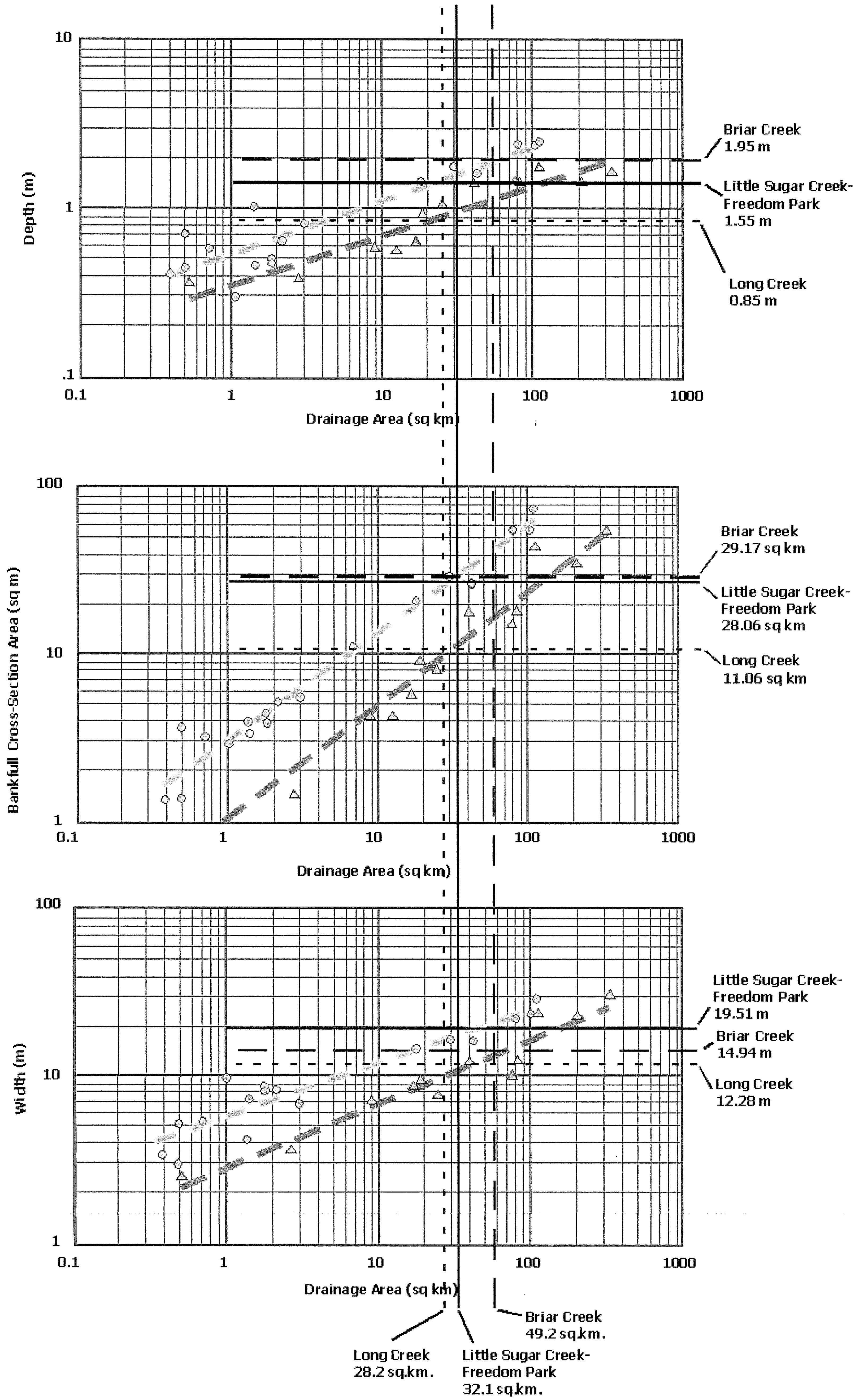
Figure 21: 1966-2000 Annual Peak Flow for Long Creek Near Paw Creek

Stream Restoration Plan

Little Sugar Creek at Freedom Park

August 2002

Project: 09177-017-018



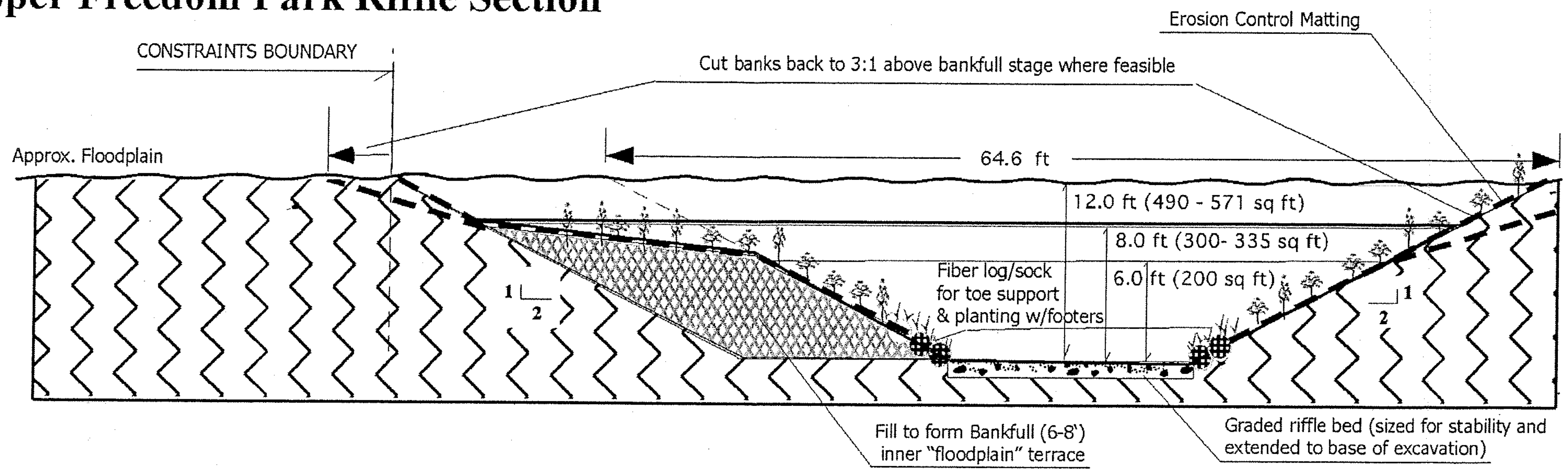
HDR Engineering, Inc.
of the Carolinas
Habitat Assessment and Restoration Program

Figure 22: Regime Curve Data
Stream Restoration Plan
Little Sugar Creek

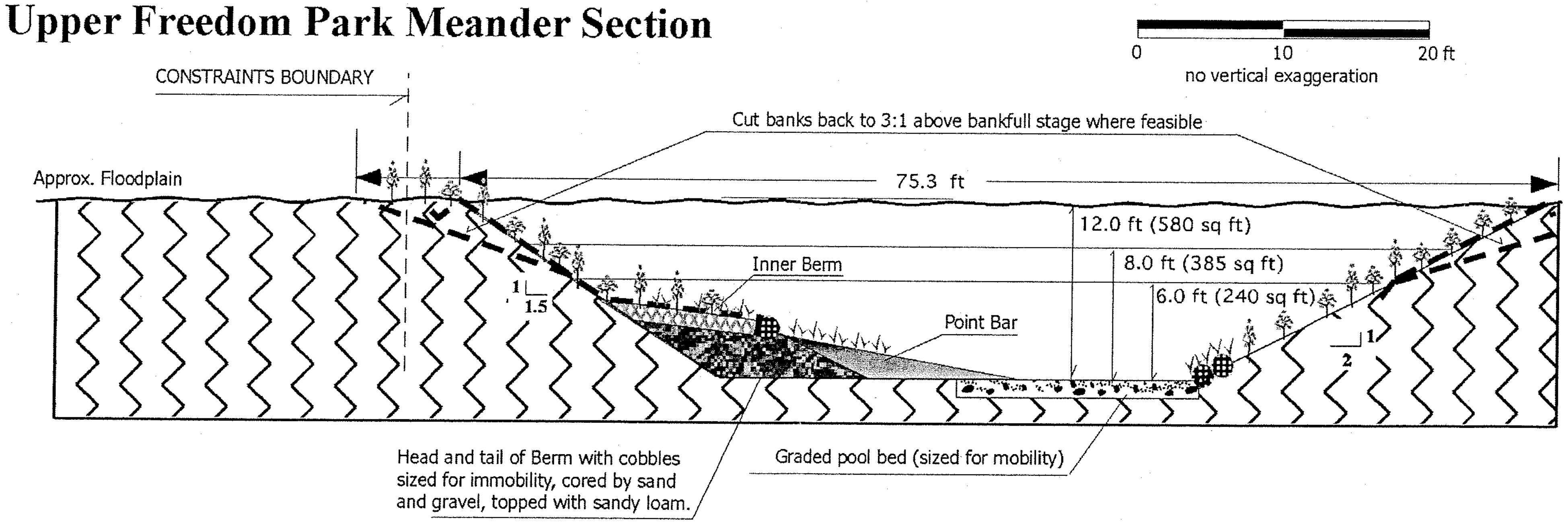
August 2002

Project: 09177-017-018

Upper Freedom Park Riffle Section



Upper Freedom Park Meander Section



HARP /HDR

Freedom Park Restoration Project, Proposed Bankfull Cross Sections - East Blvd to Dairy Branch

Revised 9/30/02

HDR Engineering, Inc.

G. Huneycutt

N C Wetlands Restoration Program
Freedom Park - Little Sugar Creek
Channel Restoration

Charlotte North Carolina

Bankfull Cross Sections

East Blvd. to Dairy Branch

Aug. 2002

AS NOTED

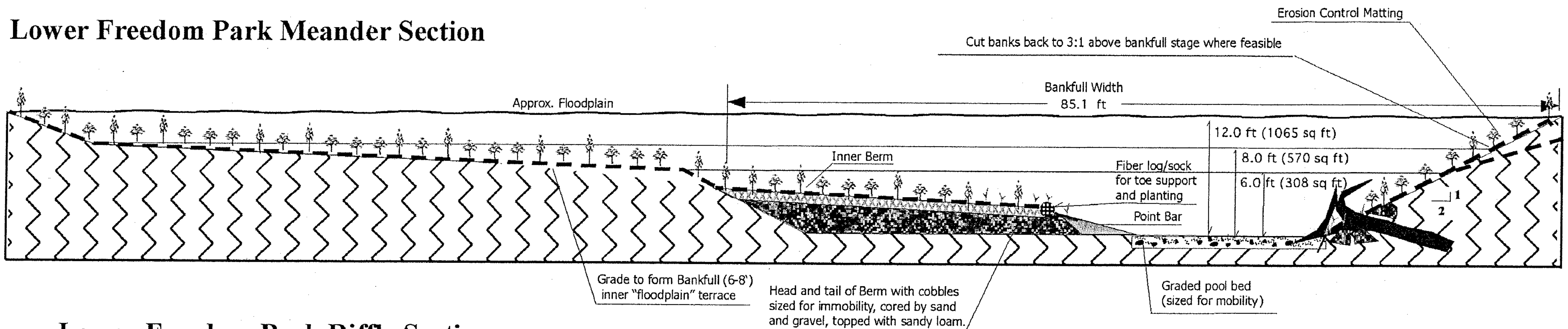
09177-017-018-05

XXXXX.DWG

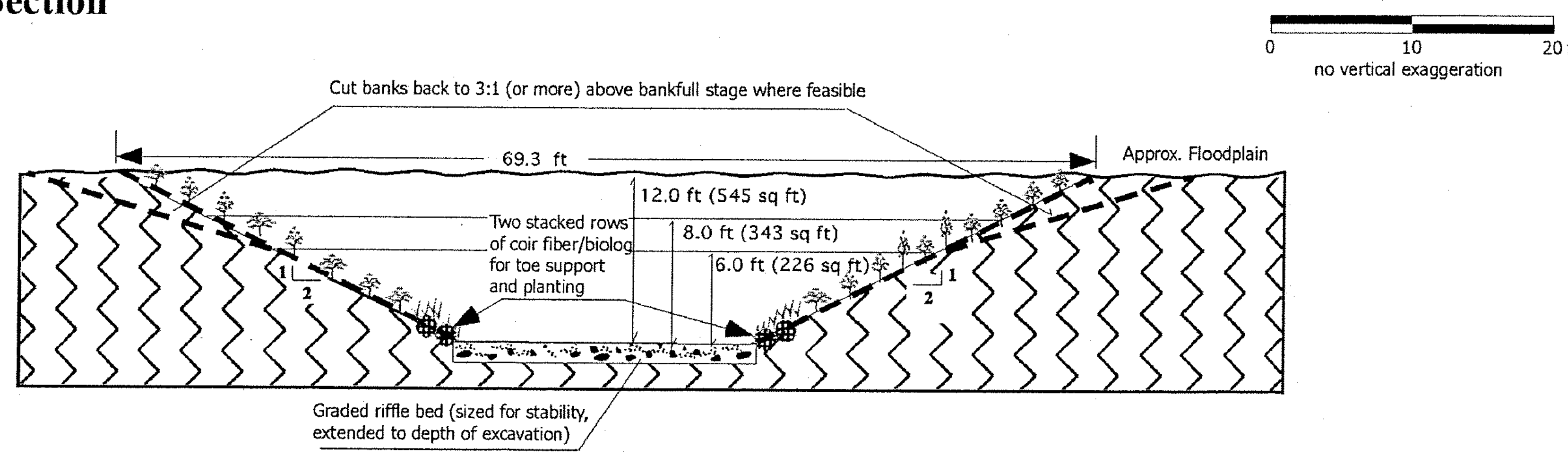
Fig. 23A

A

Lower Freedom Park Meander Section



Lower Freedom Park Riffle Section



HARP /HDR	Freedom Park Restoration Project, Proposed Bankfull Cross Sections - Dairy Branch to Princeton Ave.	Revised 9/30/02

HDR Engineering, Inc.

Project Manager | Designed | Designed | Checked | Drawn: G. Huneycutt

N C Wetland Restoration Program
Freedom Park - Little Sugar Creek
Channel Restoration

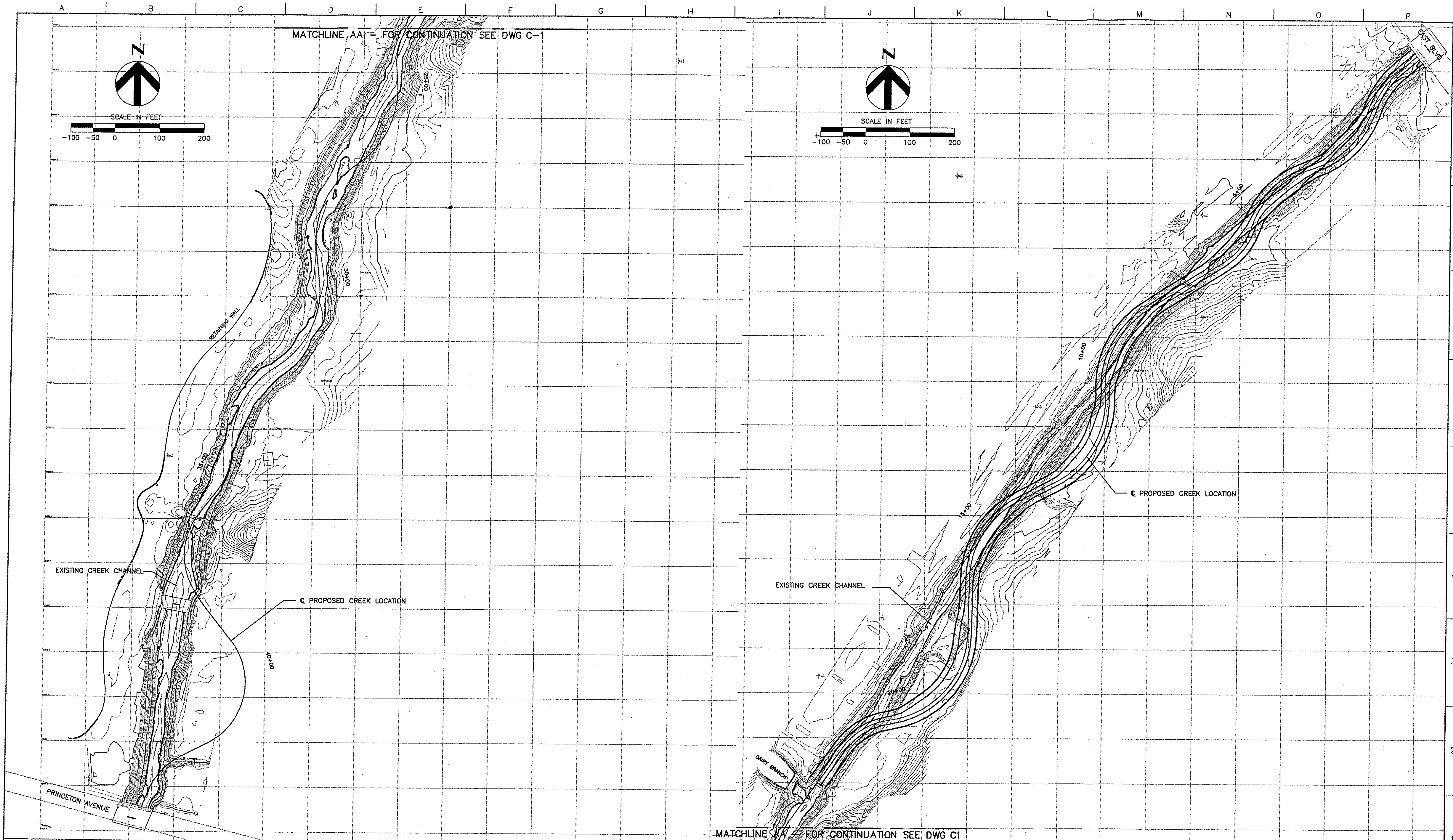
Charlotte — North Carolina

Bankfull Cross Sections

Dairy Branch to Princeton Ave.

Date	Project No.	Drawing No.	Issue
Aug. 2002	09177-017-018-05	Fig. 23B	A
Scale: AS NOTED	File Name: XXXXX.DWG		

Issue No. | Description | Date | Drwn. | Chkd. | Resp. Engr. | Proj. Mgr.



C:/WINDM/09177017.018/FP-OVERALL.DWG 07-30-02 GHUNEYCU 14:10:51

Issue No.	Description	Date	Drwn.	Chkd.	Resp. Engr.	Proj. Mgr.

HDR Engineering, Inc.

BAR LENGTH ON ORIGINAL DRAWING EQUALS ONE INCH. ADJUST SCALE ACCORDINGLY.

Project Manager

Designed

Designed

Checked

Drawn G. Huneycutt

N C Wetlands Restoration Program
Freedom Park - Little Sugar Creek
Channel Restoration

Charlotte North Carolina

Overall Site Plan

Date Aug. 2002

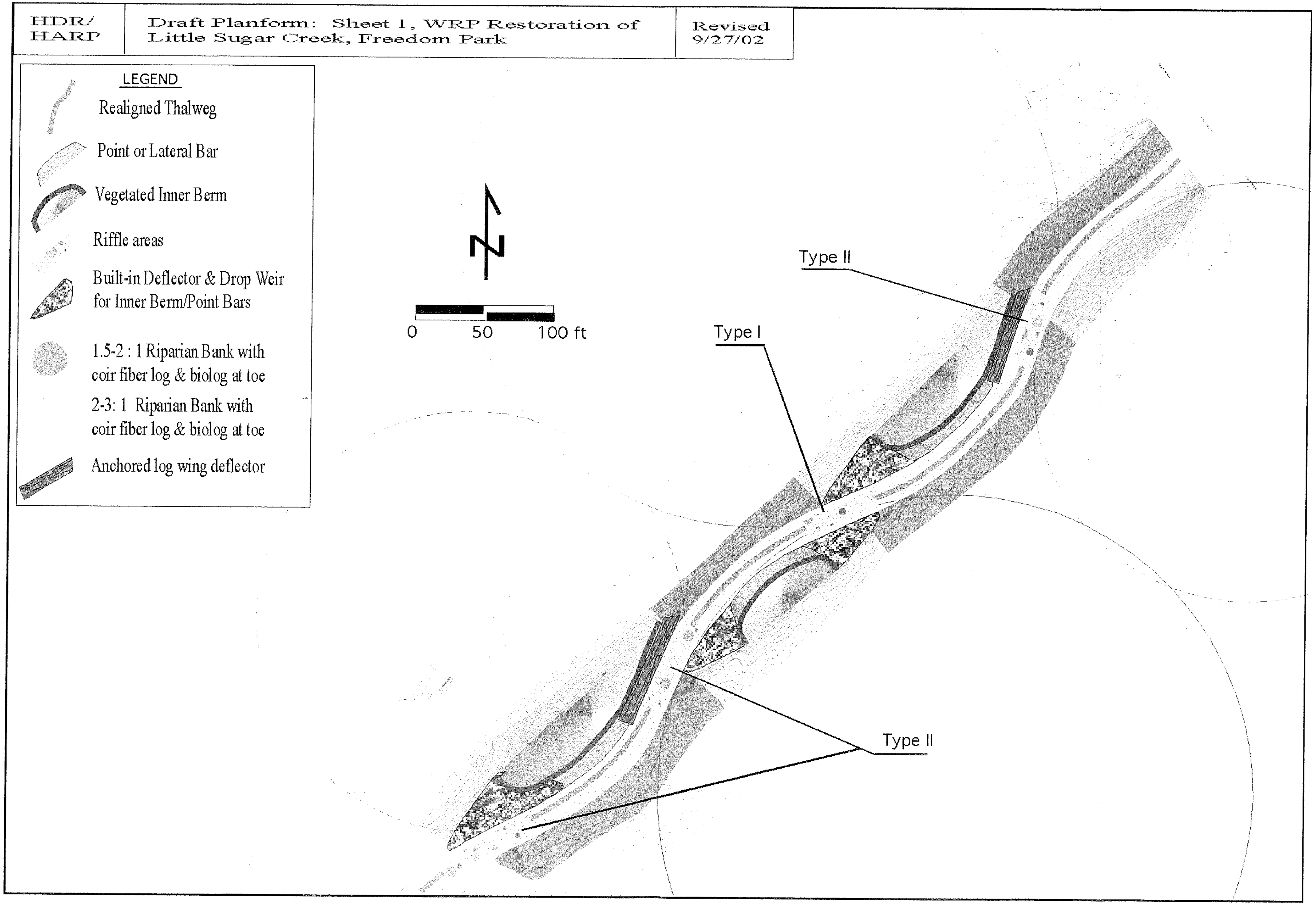
Project No. 09177-017-018-05

Scale NOT TO SCALE

File Name XXXXX.DWG

Drawing No. **Fig. 24**

Issue **A**

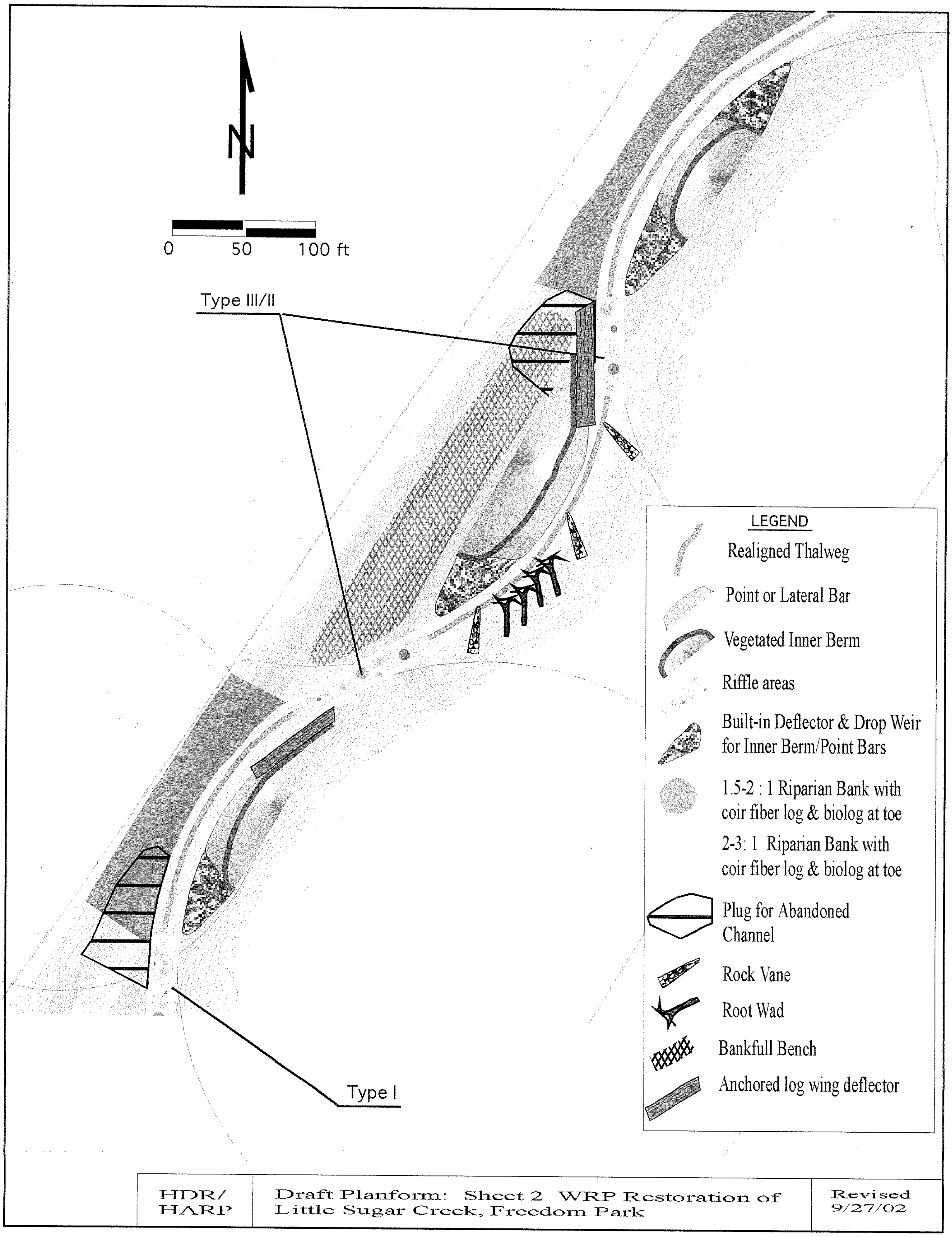


HDR
HDR Engineering, Inc. of the Carolinas
Habitat Assessment and Restoration Program

Figure 25a: Planform of Little Sugar Creek at Freedom Park
Stream Restoration Plan
Little Sugar Creek

September 2002

Project: 09177-017-018



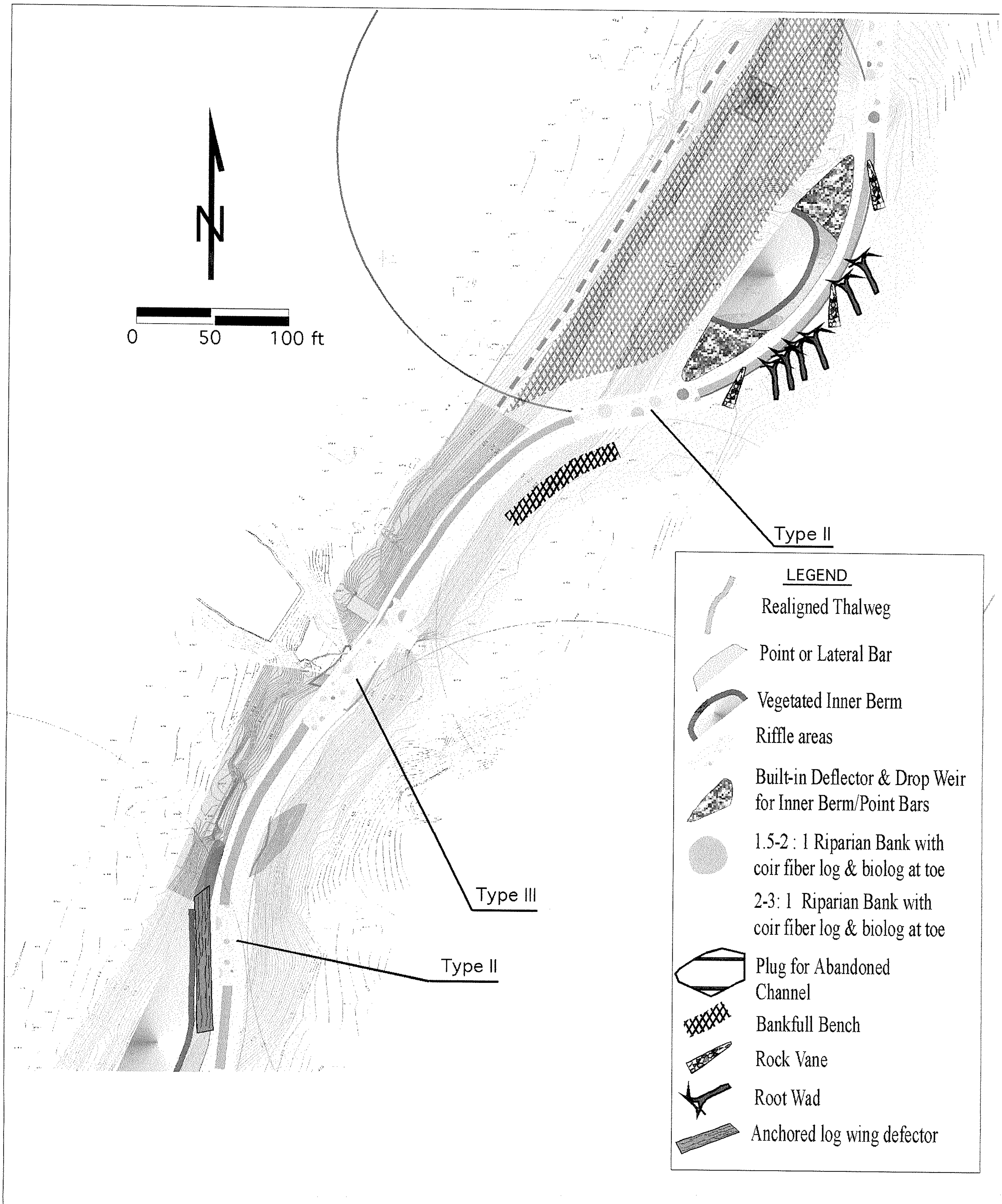
HDR Engineering, Inc. of the Carolinas
Habitat Assessment and Restoration Program Inc.

Figure 25b: Planform of Little Sugar Creek at Freedom Park

Stream Restoration Plan
Little Sugar Creek

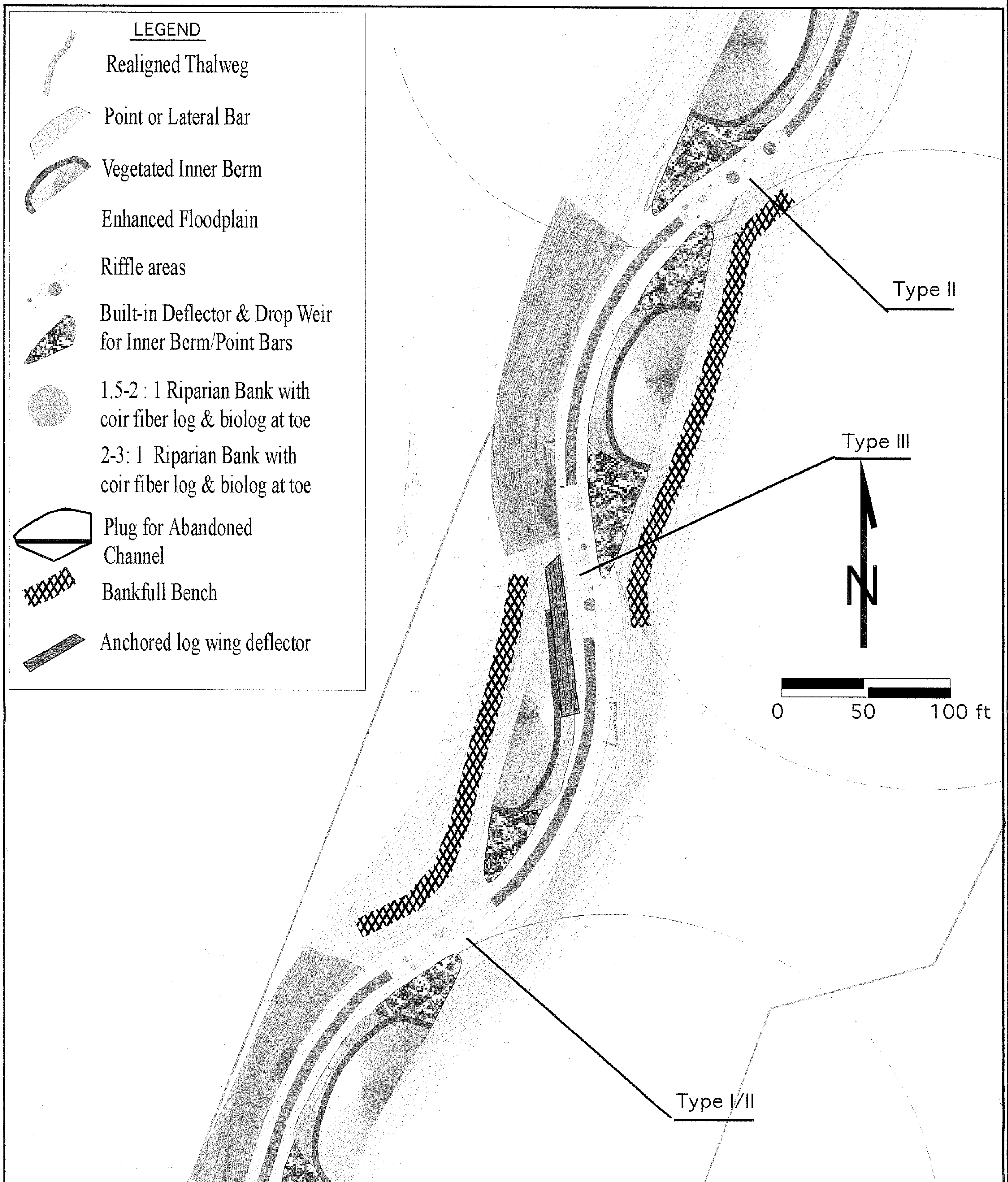
September 2002

Project: 09177-017-018



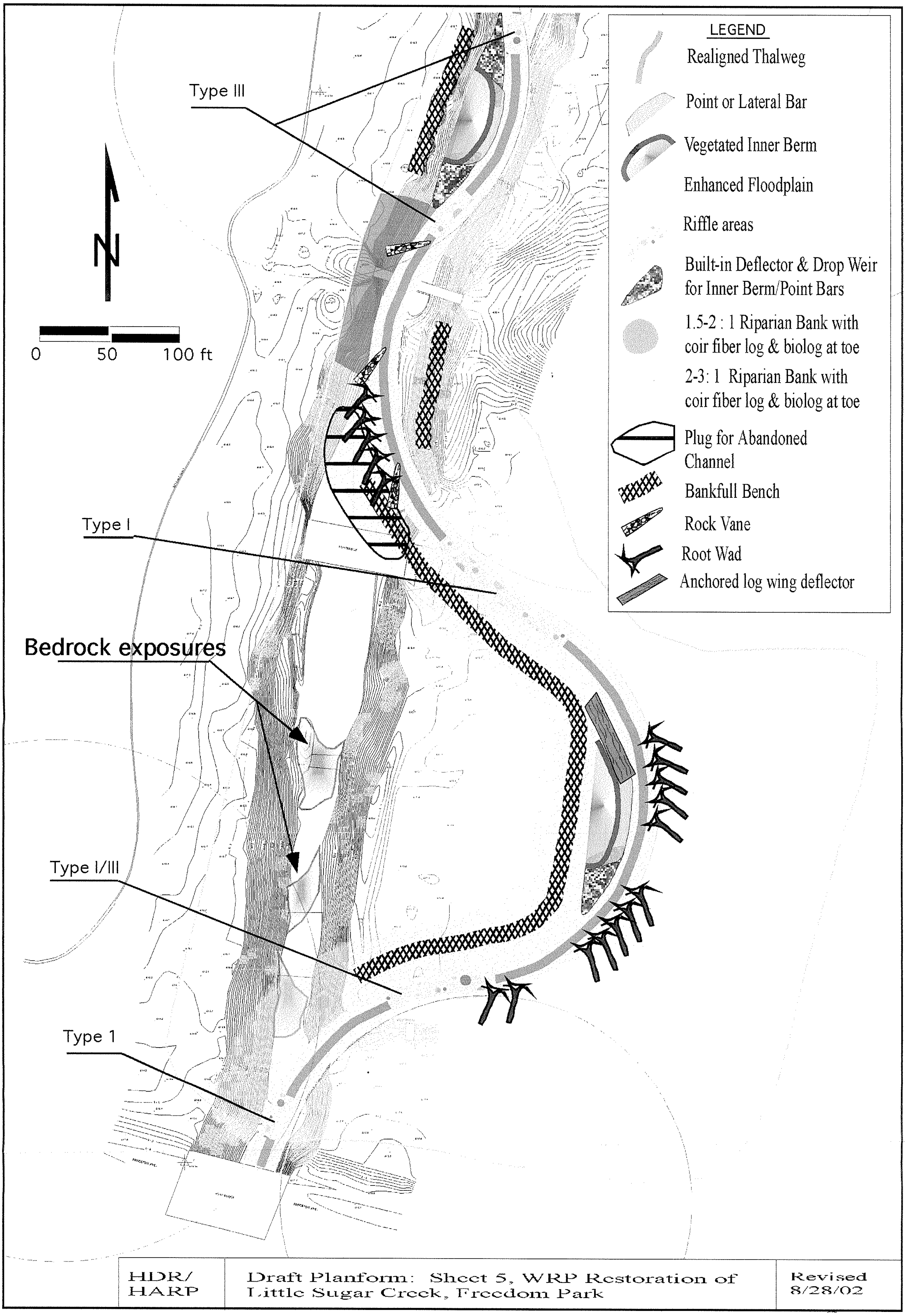
HDR/ HARP	Draft Planform: Sheet 3, WRP Restoration of Little Sugar Creek, Freedom Park	Revised 9/27/02

HDR Engineering, Inc. of the Carolinas Habitat Assessment and Restoration Program Inc.	**Figure 25c: Planform of Little Sugar Creek at Freedom Park** Stream Restoration Plan Little Sugar Creek	September 2002 Project: 09177-017-018



HDR/ HARP	Draft Planform: Sheet 4, WRP Restoration of Little Sugar Creek, Freedom Park	Revised 9/27/02

HDR Engineering, Inc. of the Carolinas; Habitat Assessment and Restoration Program Inc.	**Figure 25d: Planform of Little Sugar Creek at Freedom Park** Stream Restoration Plan Little Sugar Creek	September 2002; Project: 09177-017-018



HDR Engineering, Inc. of the Carolinas
Habitat Assessment and Restoration Program

Figure 25e: Planform of Little Sugar Creek at Freedom Park

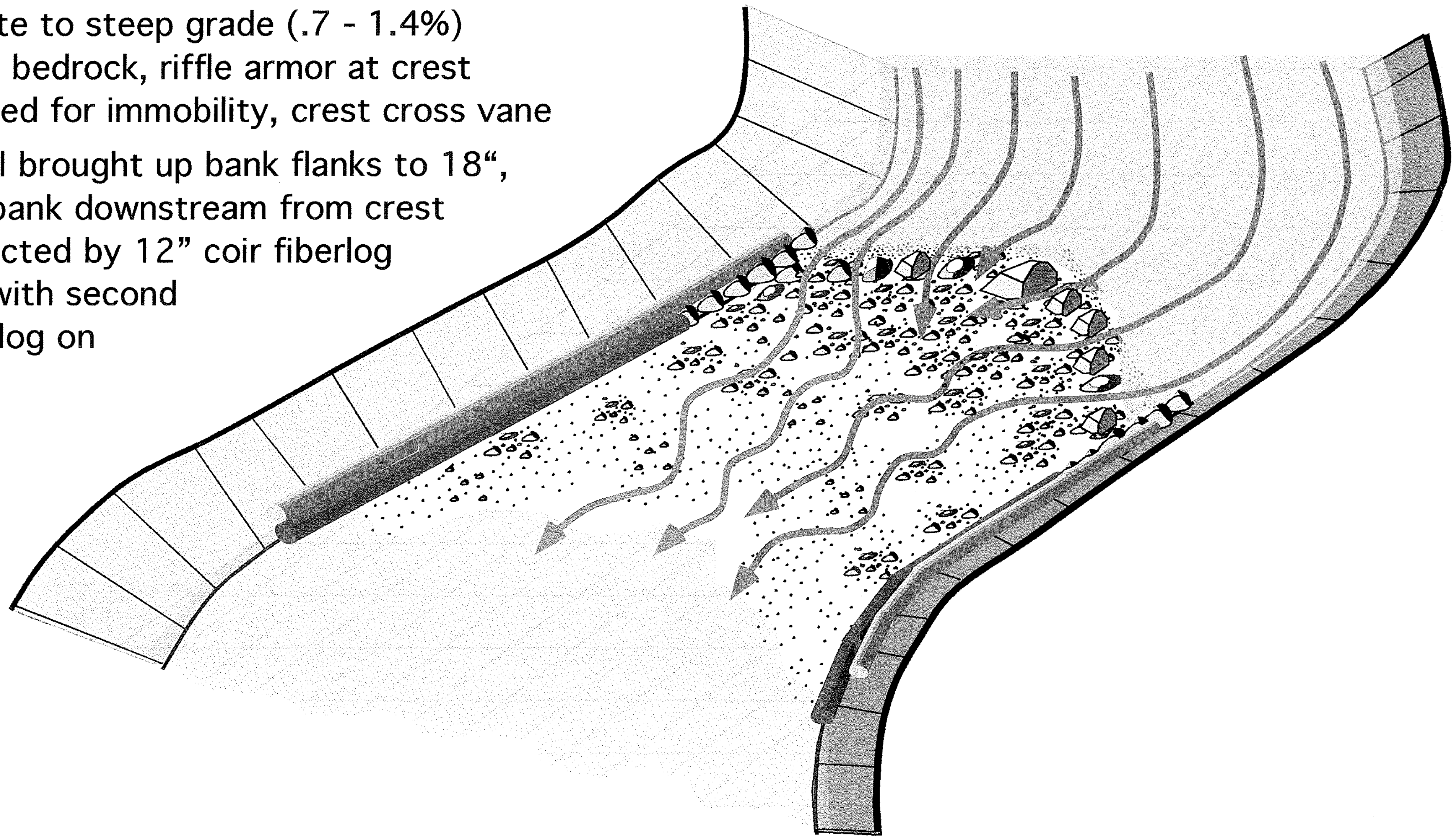
Stream Restoration Plan

Little Sugar Creek

September 2002

Project: 09177-017-018

Riffle Type 1. (cross vane riffle crest)
Moderate to steep grade (.7 - 1.4%)
without bedrock, riffle armor at crest
D_{50} sized for immobility, crest cross vane
material brought up bank flanks to 18“,
toe of bank downstream from crest
is protected by 12” coir fiberlog
at toe with second
12“ biolog on
top.



HDR HARP	NC WETLANDS RESTORATION PROGRAM	Freedom Park Restoration Reach Little Sugar Creek	Riffle Type I. Built-in cross vane at riffle crest,immobile armor	SEPT 27, 2002

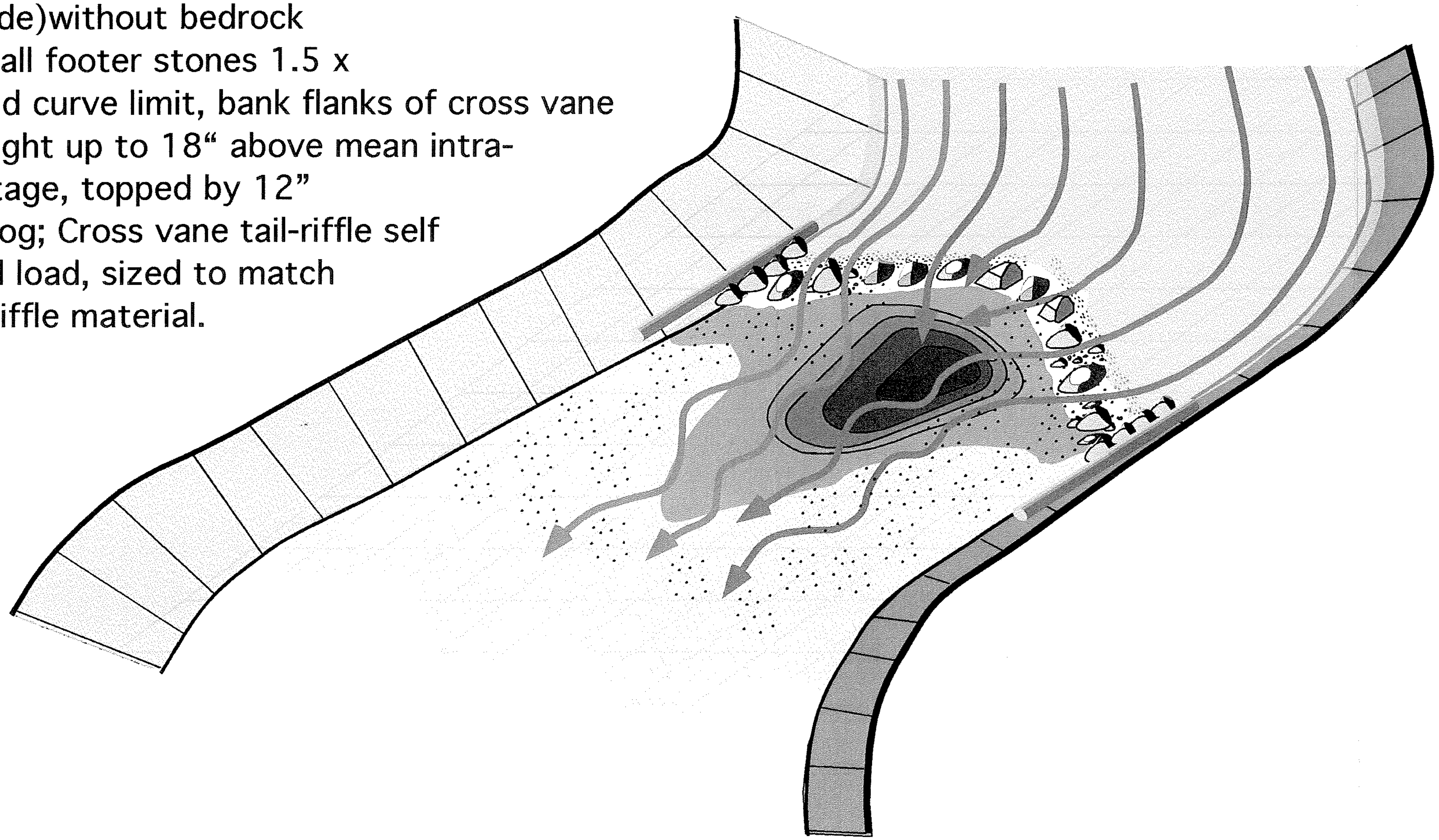
HDR Engineering, Inc. of the Carolinas
Habitat Assessment and Restoration Program

Figure 26a: Riffle Type I
Stream Restoration Plan
Little Sugar Creek

September 2002

Project: 09177-017-018

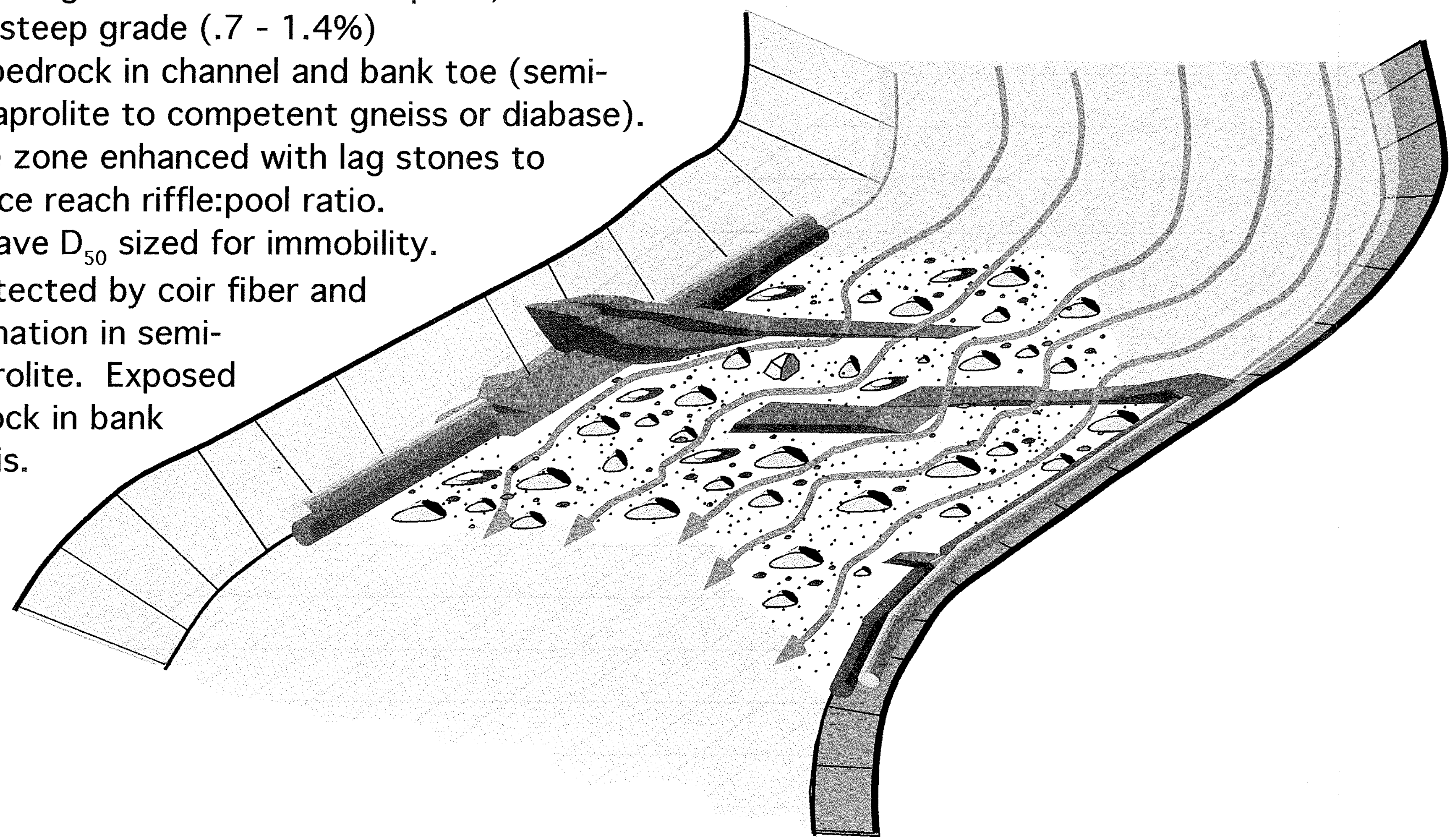
Riffle Type II. Cross vane-riffle front with intra-riffle pool, used for low grade inflection areas (.3 - .7% grade)without bedrock (Cross vane: all footer stones 1.5 x mobility Shield curve limit, bank flanks of cross vane material brought up to 18“ above mean intra-storm flow stage, topped by 12” diameter biolog; Cross vane tail-riffle self adjusting bed load, sized to match existing D_{50} riffle material.



HDR HARP	NC WETLANDS RESTORATION PROGRAM	Freedom Park Restoration Reach Little Sugar Creek	Riffle Type II, Cross vane w/self-adjusting low grade tail riffle and pool	SEPT 27, 2002

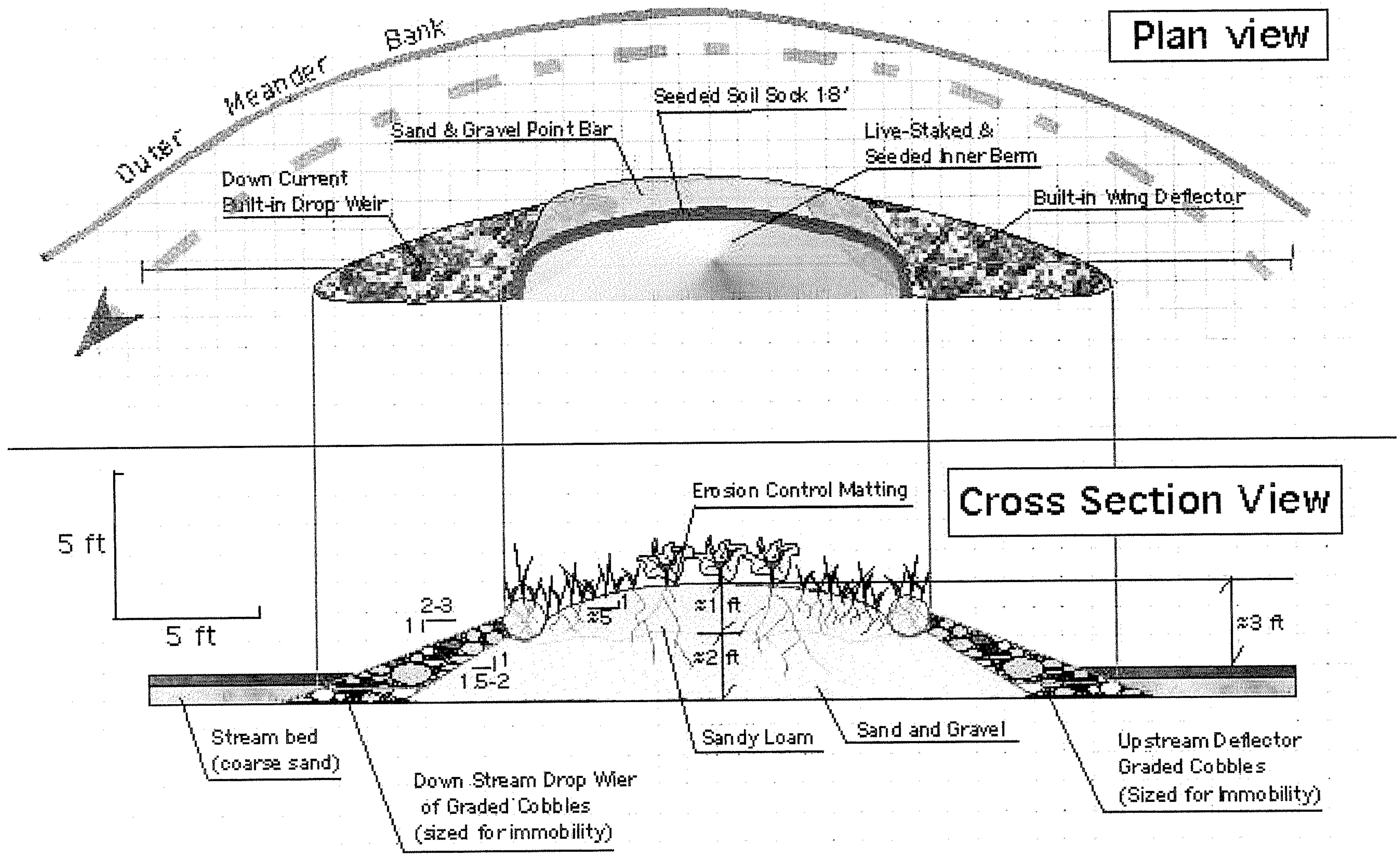
HDR Engineering, Inc. of the Carolinas Habitat Assessment and Restoration Program	**Figure 26b: Riffle Type II** Stream Restoration Plan Little Sugar Creek	September 2002 Project: 09177-017-018

Riffle Type III. Augmented bedrock nickpoint, moderate to steep grade (.7 - 1.4%) with limited bedrock in channel and bank toe (semi-competent saprolite to competent gneiss or diabase). Bedrock riffle zone enhanced with lag stones to meet reference reach riffle:pool ratio. Lag stones have D_{50} sized for immobility. Bank toe protected by coir fiber and biolog combination in semi-cohesive saprolite. Exposed competent rock in bank to be left as is.



HDR HARP	NC WETLANDS RESTORATION PROGRAM	Freedom Park Restoration Reach Little Sugar Creek	Riffle Type III. Enhanced Bedrock Nickpoint Zone.	SEPT 27, 2002

HDR HDR Engineering, Inc. of the Carolinas Habitat Assessment and Restoration Program	**Figure 26c: Riffle Type III** Stream Restoration Plan Little Sugar Creek	September 2002 Project: 09177-017-018

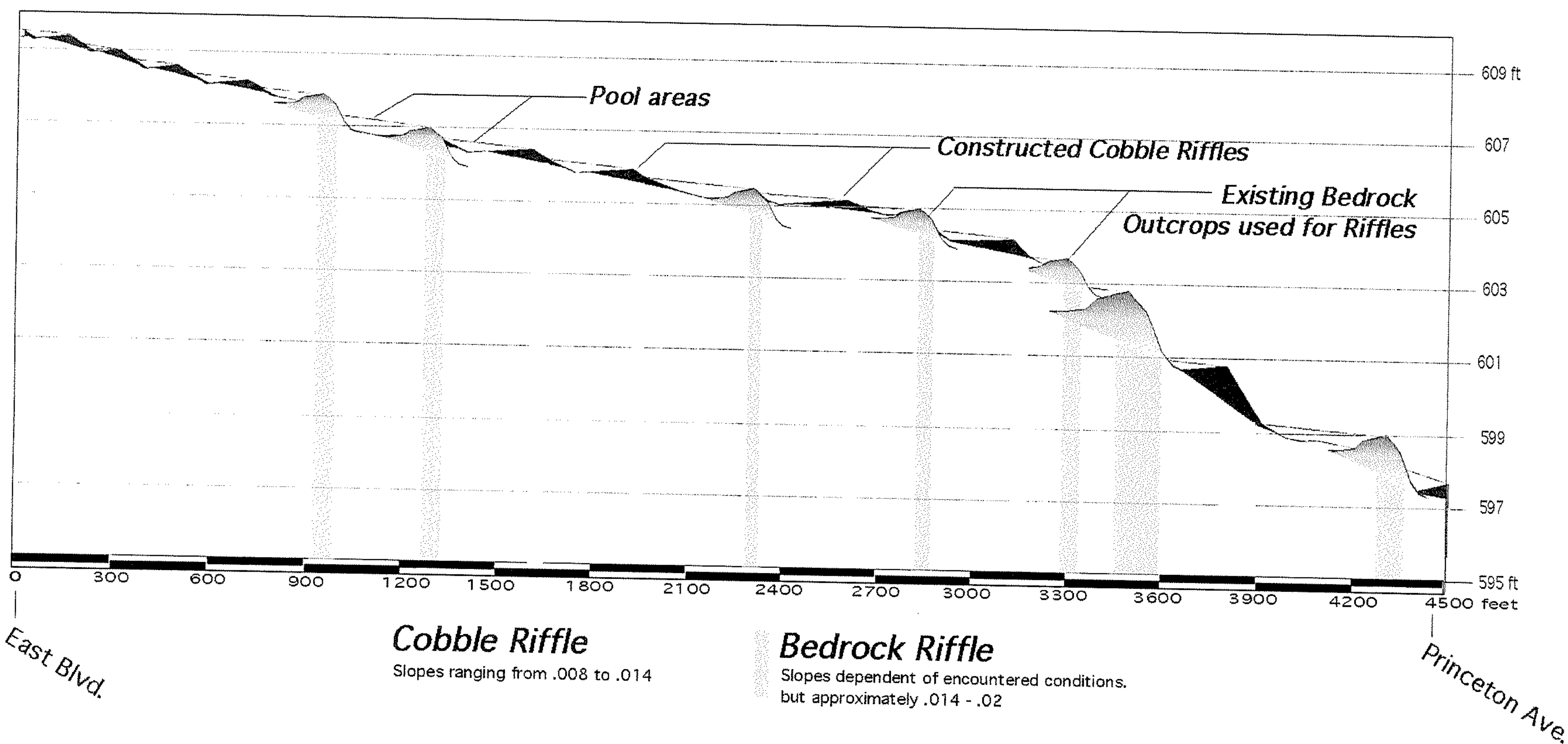


HDR Engineering, Inc. of the Carolinas
Habitat Assessment and Restoration Program

Figure 27: Inner Berm and Point Bar Channel Constrictor Schematic
Stream Restoration Plan
Little Sugar Creek at Freedom Park

August 2002

Project: 09177-017-018



HDR Engineering, Inc.
of the Carolinas

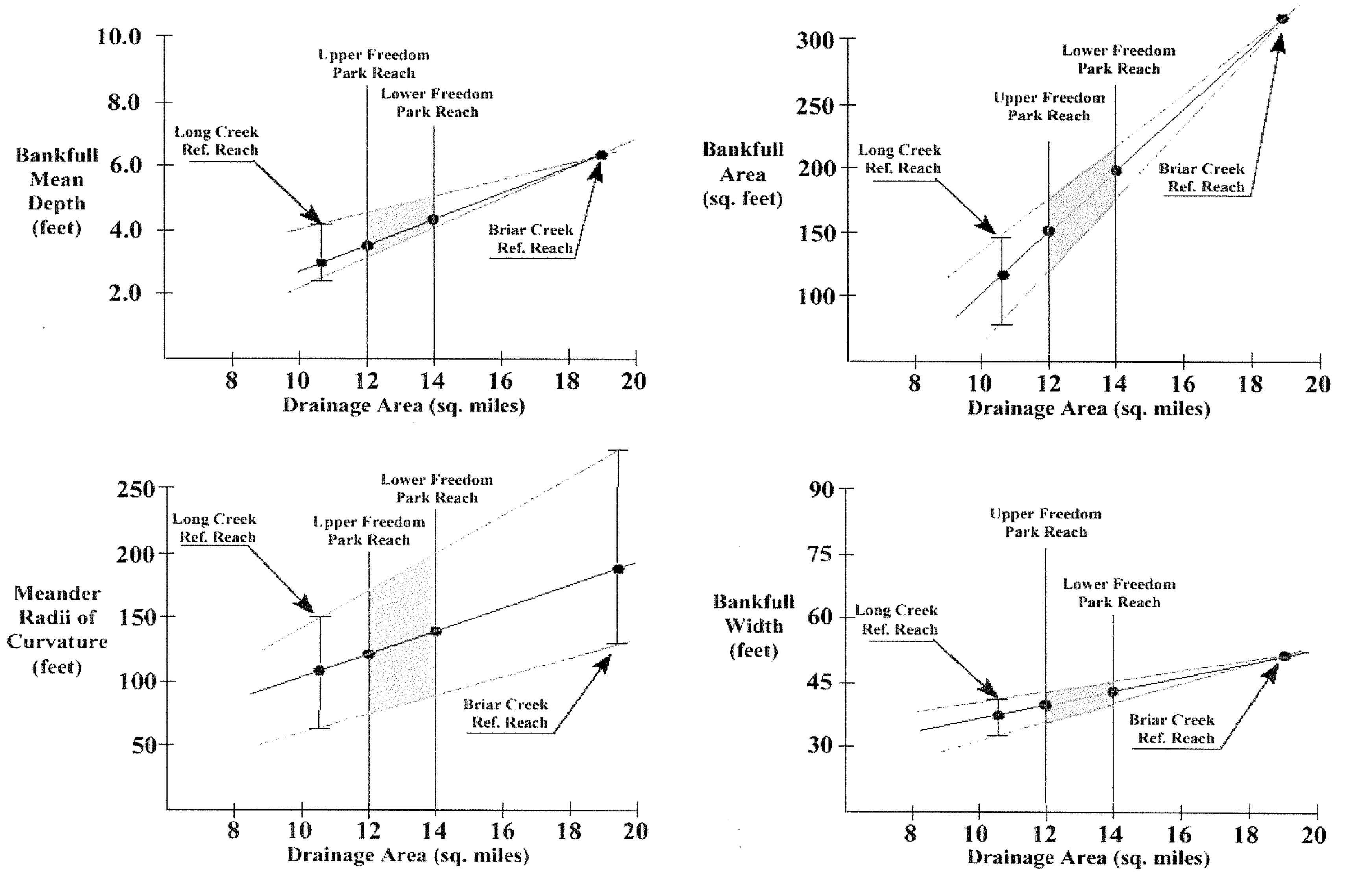
Habitat Assessment and Restoration Program Inc.

Figure 28: Little Sugar Creek Proposed Longitudinal Profile
Stream Restoration Plan
Little Sugar Creek at Freedom Park

August 2002

Project: 09177-017-018

Interpolation Curves for Freedom Park Restoration - Little Sugar Creek



HDR Engineering, Inc. of the Carolinas

Habitat Assessment and Restoration Program Inc.

Figure 29: Interpolation Curves for Freedom Park
Stream Restoration Plan
Little Sugar Creek at Freedom Park

August 2002

Project: 09177-017-018

TABLES

Table 1
Preliminary Estimates of Fluvial Morphologic Parameters

Parameters	Little Sugar Creek Freedom Park Reach	Briar Creek Reference Reach (**)	Briar Creek Reference Reach (^^)	Long Creek Prim Road Reach	Little Sugar Creek Freedom Park Design Upper End	Little Sugar Creek Freedom Park Design Lower End
Watershed Area (sq. miles)	12.38 - 14.21	19	19	10.9	12.38 - 14.21	12.38 - 14.21
Bankfull Width (ft)	64	49		37	51	57
Bankfull Area (sq. feet)	302	314		119	335	343
Ave. Bankfull Depth (feet)	5.1	6.41		2.8	6.5	6
Max. Depth (feet)	9	11.09		5.2	8	8
Flood Prone Width (feet)	300	>150		71.6	>300	>300
Entrenchment Ratio	>>5	>>2.2		1.9	>>5	>>5
Width/Depth Ratio	12.5	7.64		13.2	7.8	9.5
Valley Slope (feet/feet)	0.0029	0.0086	0.0048	0.0045	0.0029	0.0029
Average Water Slope (feet/feet)	0.0028	0.0078	0.0044	0.0033	0.0026	0.0029
Sinuosity	1.04	1.1	1.1	1.39	1.11	1.11
Riffle/Pool Ratio		0.86	0.24	0.58	0.3	0.3
Riffle Slope		.006-.074 (avg, .033)	.007 - .072 (avg. .018)	0.012	.01 - .014	.01 - .014
Pool Slope		0 -.0027 (.0009)	<<.002	0 - .002	<.0003	<.0003
Ave. Riffle Spacing (feet)		98	98	104	141	141
Riffle Armor D50		45 mm	165 mm	84 mm	440 mm	440 mm
Riffle Armor D84(low)			95 mm	48 mm	220 mm	220 mm
Riffle Armor D84 (high)			295 mm	150 mm	700 mm	700 mm
Riffle Substrate D50	4.8 mm		1.9 mm	1.1 mm	4.8 mm	4.8 mm
Riffle Substrate D84	6.4 mm		3.0 mm	2.6 mm	6.4 mm	6.4 mm
Pool Armor (D50)				44 mm	40 mm	40 mm
Pool Armor (D84 low)				25 mm	24 mm	24 mm
Pool Armor (D84 high)				82 mm	56 mm	56 mm
Pool D50	6.63 mm		1.9 mm	.4 mm	6.63 mm	6.63 mm
Pool D84	25.1 mm		3.0 mm	.8 mm	25.1 mm	25.1 mm
Point/Medial Bar D50	2.6 mm		1.1 mm	.7 mm	2.6 mm	2.6 mm
Point/Medial Bar D84	9.8 mm		2.1 mm	1.1 mm	9.8 mm	9.8 mm
Meander Radius of Curvature (ft)		94 - 200 (avg.155)	186	64 - 210 (avg. 109)	160-220 ft	160-220
Meander Wave Length (ft)	433 - 532	456 -552 (avg. 515)	550	362	395 ft	395 ft
Meander Belt Width (ft)	0 - 125	92 - 150 (115)	150	200	200 ft	467 ft
Bankfull Discharge (cfs) via * or **	1600 - 2300 (*)	2100 (**)			1600 - 2300 (*)	1600 - 2300 (*)
Bankfull Discharge (cfs) via ^ or ^^	1900 (^)		1600 (^)	495 (^^^)	1900 (^)	1900 (^)
Bankfull Est. Mean Velocity (ft/sec)	6.29	6.68		4.16	5.67	5.53
Rosgen Class (***)	C3-C5	C/E (3-5)		C3-C5	C3-C5	C3-C5

(*) HDR estimate at watershed buildout
(**) Army Corp. Eng. 2001 Study Estimate
(***)Rosgen & Silvey, 1998, however none of the above fit all parameters for C or E channels
(^) estimates from recorded annual peak flows at USGS gage stations near reference reach
(^^) supplemental data collected for this study
(^^^) estimated using Manning Eq. Assuming Manning Coef. .03

Table 2 Briar Creek Vegetation	
Canopy	
River birch	*Betula nigra*
Sycamore	*Platanus occidentalis*
Yellow poplar	*Liriodendron tulipifera*
White oak	*Quercus alba*
Sweetgum	*Liquidambar styraciflua*
Green ash	*Fraxinus pennsylvanica*
Willow oak	*Quercus phellos*
Black walnut	*Juglans nigra*
Southern sugar maple	*Acer sacchaurm ssp. floridanum*
Box elder	*Acer negundo*
Pignut hickory	*Carya glabra*
Black willow	*Salix nigra*
Subcanopy	
Transgressives of the Canopy Species	
Black gum	*Nyssa sylvatica*
Ironwood	*Carpinus caroliniana*
Dogwood	*Cornus florida*
Pawpaw	*Asimina triloba*
Redbud	*Cercis canadensis*
Exotic Invasives	
Mimosa	*Albizia julibrissin*
Tree of heaven	*Ailanthis altissima*
Privet	*Lonicera sinense*
Amur honeysuckle	*Lonicera mackii*
Wisteria	*Wisteria sinensis*
Porcelain berry	*Ampelopsis brevipedunculata*
English ivy	*Hedera helix*
Japanese or Wax-leaf ligustrum	*Ligustrum japonicum*
Toe of Slope	
Southern red oak	*Quercus falcata*
Yellow poplar	*Liriodendron tulipifera*
White oak	*Quercus alba*
White ash	*Fraxnius americana*
Sourwood	*Oxydendrum arboretum*
Red maple	*Acer rubrum*
Catalpa	*Catalpa speciosa*
Sweetgum	*Liquidambar styraciflua*

Table 3
Long Creek Vegetation

Canopy	
Sycamore	*Platanus occidentalis*
Beech	*Fagus grandifolia*
River birch	*Betula nigra*
Water oak	*Quercus phellos*
Cottonwood	*Populus deltoides*
Sweetgum	*Liquidambar styraciflua*
Black willow	*Salix nigra*
Box elder	*Acer negundo*
American elm	*Ulmus americana*
Red maple	*Acer rubrum*
Loblolly pine	*Pinus taeda*
Subcanopy	
Alder	*Alnus serrulata*
Redbud	*Cercis canadensis*
Red cedar	*Juniperus virginiana*
Winged elm	*Ulmus alata*
Pawpaw	*Asimina triloba*
Floodplain Shelf	
Silky dogwood	*Cornus amomum*
Silky willow	*Salix sericea*
Alder	*Alnus serrulata*
Spicebush	*Lindera benzoin*
Toe of Slope above Floodplain	
White oak	*Quercus alba*
Sweetgum	*Liquidambar styraciflua*
Black walnut	*Juglans nigra*
Yellow poplar	*Liriodendron tulipifera*
Shortleaf pine	*Pinus echinata*
Mockernut hickory	*Carya tomentosa*
Pignut hickory	*Carya glabra*
Red cedar	*Juniperus virginiana*

Table 4

Bed Shear Stress Estimates

	Maximum Slope	Density of Water (lb/cu.ft)	1.5 year		2 year		10 year		100 year	
			Max. Depth	Bed Shear Stress	Max. Depth	Bed Shear Stress	Max. Depth	Bed Shear Stress	Max. Depth	Bed Shear Stress
Pool	0.0003	62.460	11.6	0.2174	11.6	0.2174	16.7	0.3129	19.2	0.3598
Riffle	0.0140	62.460	11.6	10.1435	11.6	10.1435	16.7	14.6031	19.2	16.7892

Tau (lb/sq.ft) = Water density (lb/cu.ft) x Depth (ft) x slope (ft/ft)

Table 5

Estimated Bed Traction Force And Minimum D50 for Stability, Freedom Park Reach of Little Sugar Creek

Section No.	Reach Type	Max. Depth (ft)	Max. Depth (m)	Slope min.	Slope max.	Velocity (fps)	Velocity (mps)	Tractive Force min. (kg/m^2)	Tractive Force max.* (kg/m^2)	Tractive Force min. (lb/ft^2)	Tractive Force max. (lb/ft^2)	Grain size (cm)* incipient movement	Grain size (cm) incipient movement
66218	Riffle	12.4	3.78	0.01	0.014	7.5	2.29	37.80	52.91	7.74	10.84	37.80	52.91
64268	Riffle	14.8	4.51	0.01	0.014	5.5	1.68	45.11	63.15	9.24	12.93	45.11	63.15
65728	Meander	12.7	3.87	0.001	0.0014	4.8	1.46	3.87	5.42	0.79	1.11	3.87	5.42
65436	Meander	13.3	4.05	0.001	0.0014	4.6	1.40	4.05	5.68	0.83	1.16	4.05	5.68
64791	Meander	14.2	4.33	0.001	0.0014	3.9	1.19	4.33	6.06	0.89	1.24	4.33	6.06
62401	Riffle	16.4	5.00	0.01	0.014	6.3	1.92	49.99	69.98	10.24	14.33	49.99	69.98
63721	Meander	13.3	4.05	0.001	0.0014	7.1	2.16	4.05	5.68	0.83	1.16	4.05	5.68
62993	Meander	12.7	3.87	0.001	0.0014	7.7	2.35	3.87	5.42	0.79	1.11	3.87	5.42

* For non-cohesive bed materials greater than 1 cm in diameter the relationship of tractive force to stable grain diameter is approximated as:
**Tractive Force (kg/m^2) = incipient movement diameter (cm); e.g. 52 kg/m^2 = 53 cm diameter cobbles at incipient movement

Table 6
Freedom Park Potential Planting List

Botanical Name	Common Name	Size	Slope Placement	Root Structure	Exposure	Comments
Abelia grandiflora *	Glossy Abelia	3-5'	Mid/Top	fibrous	Sun/Part Shade	Exotic; a number of cultivars available
Aesculus parviflora	Bottlebrush Buckeye	8-12'	Mid	taproot	Sun/Shade	Native
Aralia spinosa	Devils Walking Stick	10-20'	Mid	colonial/fibrous	Sun/Part Shade	Native; thorny stems
Aronia arbutifolia *	Chokecherry	8-10'	Toe/Mid	fibrous	Sun	Native
Asimina triloba	Pawpaw	15-20'	Toe	colonial/fibrous	Part shade/Shade	Native
Buddleia davidii	Butterflybush	5-10'	Mid	fibrous	Sun	Exotic; a number of cultivars available
Callicarpa americana *	American Beautyberry	6'	Toe	fibrous	Sun	Native
Calycanthus floridus *	Sweet Shrub	8-10'	Mid	colonial/fibrous	Part shade/Shade	Native
Ceonothus americanus	New Jersey Tea	3'	Top	fibrous	Sun/Part Shade	Native
Cephalanthus occidentalis *	Button Bush	6-10'	Toe	fibrous	Sun/Part Shade	Native
Clethra alnifolia *	Sweetpepper Bush	3-10'	Toe/Mid/Top	colonial/fibrous	Sun	Native; a number of cultivars available
Cornus amomum *	Silky Dogwood	10'	Toe/Mid	colonial/fibrous	Sun/Part Shade	native
Cornus sericea *	Red Twig Dogwood	6-8'	Toe/Mid	colonial/fibrous	Sun	Native ;a number of cultivars available
Cotoneaster divaricatus	Spreading Cotoneaster	3-5'	Top	fibrous	Sun	Exotic; a number of cultivars available
Cytisus scoparius	Scotch Broom	5'	Mid/Top	taproot/fibrous	Sun	Exotic
Diervilla sessilifolia	Southern Bush-Honeysuckle	3-5'	Top	fibrous	Sun/Part Shade	Native
Fothergilla gardenii *	Dwarf Fothergilla	3-5'	Top	fibrous	Sun/Part Shade	Native; a few cultivars available
Hydrangea arborescens *	Smooth Hydrangea	3-5'	Top	fibrous	Part shade/Shade	Native
Hydrangea macroplylla	Big-leaf Hydrangea	3-6'	Mid/Top	fibrous	Part shade/Shade	Exotic; a number of cultivars available
Hypericum frondosum 'Sunburst' *	Sunburst St Johnswort	3'	Top	fibrous	Sun/Part Shade	Native
Hypericum 'Hidcote'	St Johnswort	3'	Top	fibrous	Part shade/Shade	Exotic
Hypericum prolificum *	Shrubby St Johnswort	5'	Top	fibrous	Sun/Part Shade	Native
Ilex glabra	Inkberry Holly	3-6'	Top	fibrous	Sun	Native; a number of cultivars available
Ilex verticillata *	Winterberry Holly	3-10'	Toe/Mid	fibrous	Sun/Part Shade	Native; a number of cultivars available
Illicium parviflorum	Anise	6-10'	Mid	fibrous	Sun/Shade	
Itea virginica *	Virginia Sweetspire	3-5'	Toe/Mid/Top	fibrous	Sun/Part Shade	Native; a few of cultivars available
Juniperus sp.	Juniper Species	1-5'	Toe/Mid/Top	fibrous	Sun	Exotic; a number of cultivars available
Leucothoe axillaris	Dog Hobble	3-5'	Top	fibrous	Part shade/Shade	Native
Physocarpus opulifolius	Ninebark	5-10'	Toe/Mid	fibrous	Sun/Part Shade	Native
Pseudocydonia sinensis	Flowering Quince	5-10'	Mid/Top	taproot/fibrous	Sun/Part Shade	Exotic
Rhododendron sp.	Rhododendron species	4-12'	Toe/Mid/Top	fibrous	Part shade/Shade	Native; many species available
Rhus sp. *	Sumac species	5-12'	Mid	taproot	Sun	Native
Salix seresia	Silky willow	10-20'	Toe	colonial/fibrous	Sun/Part Shade	Native
Sambucus canadensis *	Elderberry	10'	Toe	colonial/fibrous	Sun	Native
Spiraea sp.	Spirea species and cultivars	3-5'	Mid/Top	fibrous	Sun/Part Shade	Exotic; a number of cultivars available
Staphylea trifolia	Bladdernut	6-10'	Toe/Mid	colonial/fibrous	Part shade/Shade	Native
Symphoricarpos orbiculatus *	Coralberry	2-4'	Toe/Mid/Top	colonial/fibrous	Sun/Shade	Native
Vaccinium sp. *	Blueberries species and cultivars	3-10'	Mid/Top	colonial/fibrous	Sun	Native; many species available
Viburnum sp. *	Viburnum species	6-12'	Toe/Mid	colonial/fibrous	Sun/Shade	Native
Xanthorhiza simplicissima *	Yellowroot	3'	Toe/Mid/Top	colonial/fibrous	Part shade/Shade	Native
Zenobia pulverulenta	Dusty Zenobia	3-5'	Top	colonial/fibrous	Sun/Part Shade	Native

Note: Asterisked plants would be top choices subject to availability

Survey of Storm Water Outfalls
Little Sugar Creek at Freedom Park

A field inventory of storm water discharges into Little Sugar Creek (Creek) at Freedom Park was completed on June 20, 2002. Locations are presented in Figure 6. Below is a comprehensive discussion of each location, its type, and recommended actions. For each location, Alternative A presents the best management practice (BMP) recommended to treat storm water under the conditions of an unlimited budget and scope. The proposed action at this time, within the Scope of Work, budget, and Project Area constraints, is presented in Alternative B. In those cases where Alternative A is considered feasible and is the recommended action, Alternative B is not mentioned.

Typical renderings of example storm water BMPs applicable to Freedom Park are also included, courtesy of the Center for Watershed Protection. The bioretention/rain garden rendering exhibits landscaping features as well as storm water treatment. Both the dry or grassed swale and infiltration trench/gallery renderings feature designs to encourage storm water infiltration.

1. A 7′ x 5′ concrete box culvert.

   The culvert outlet is at Creek level. This inflow drains East Boulevard and an unknown area upslope. The culvert was supplying some base flow seepage to the Creek on June 20, 2002, the day the survey was performed. The drainage area and land-use for this inflow are unknown.

   Alternative A: The size and location of this drain generate storm water treatment problematic and is beyond the scope of the current stream restoration project. Storm water treatment would have to begin well outside the Freedom Park boundaries to be effective. However, given the large storm water volume contributed by this outlet, the greatest improvement in the Creeks water quality would involve a water quality BMP retrofit of this inflow.

   Alternative B: No action. This structure is not impacted by the proposed stream alignment or construction activities.

2. An 18″ diameter concrete culvert.

   The culvert outlet daylights approximately 3 feet above Creek level and spills onto the concrete creek lining before draining into the Creek. This culvert was dry on the day of the survey. The culvert drains the tennis courts entrance road and parking lot on the east side of the Creek. The drainage area for this culvert is 1.72 acres (1.21 acres impervious, 0.51 acres grass and shrub).

   Alternative A: There is considerable potential to treat storm water runoff at this site by enlarging the grassed swale on the north side of the tennis courts. Construction would involve daylighting the storm drain upslope of the swale, and slightly enlarging and deepening the swale. Overflow from the swale would need to be stepped down to Creek level.

   Alternative B: No action at this time. This structure is not impacted by the proposed stream alignment or construction activities.

3. Turbid water entering the Creek along east bank from under concrete lining.

   Alternative A: Check the Creek for sanitary sewer leak by notifying Mecklenburg County (County) Department of Environmental Protection (DEP).

4. Flared 5′ steel culvert entering at Creek level.

   The culvert was dry on the survey day. The culvert drains a concrete lined swale that runs from a straightened stream channel behind private housing. This channel collects runoff from three road crossings and the neighborhood on the west side of the park. The culvert also collects runoff from the playing field area just south of the main drainage. The drainage area for this culvert is 53.53 acres (46.70 acres single-family residential, 6.83 acres grassed playing field). It is unclear if this culvert runs above or below the sanitary sewer crossing at this site.

   Alternative A: There is considerable potential to treat storm water runoff at this site by removing the concrete lining and constructing a larger grassed swale along the current drainage course within the park boundaries. Construction would involve removing the existing concrete lining, and enlarging and deepening the swale. Overflow from the swale would need to be stepped down to Creek level.

   Alternative B: The culvert outlet will be located on the inner berm area of a proposed stream meander. Sheet flow will then be encouraged to infiltrate. It will be necessary to stabilize the stream bank with hard substrate immediately adjacent to and below the outfall to prevent erosion. Removing the concrete lining was not considered as part of this Alternative because its location is outside the Project Area.

5. Channelized surface inflow has scoured 4′ to 5′ into the stream bank.

   The channel was covered with kudzu and dry on the survey day. The channel becomes a rock-lined 3′ x 1′ channel upslope of the walking trail that parallels the east stream bank and collects some local runoff. The channel drains a culvert running under a private garage and lot (1438 Sterling Avenue). The origin of the drain is two road culverts on Sterling Avenue in front of this property. The total drainage area for this inflow is 5.85 acres (5.66 acres single-family residential, 0.31 acres forested local drainage associated with the lower channel).

   Alternative A: Proposed channel restoration plans do not allow for a floodplain level infiltration gallery at the outlet of this channel. There is an opportunity to create a significant rain garden running from the break-in slope to the stream bank. Outflow from the rain garden would need to be stepped down to stream level. A second possibility would be to create a lateral infiltration swale with an overflow outlet that could be stepped down to stream level. The swale would parallel the current walking trail along the east stream bank.

   Alternative B: This area will become part of a stream channel meander with appropriate action occurring during construction.

6. A 2″ diameter half-filled concrete culvert that drains extensive storm drain network underlying parking lots and playing fields on west bank of the Creek.

   The channel was dry on the survey day. The drainage area for this culvert is 19.51 acres (2.20 acres single-family residential, 10.86 acres grassed playing field, 6.45 acres impervious road and parking areas).

   Alternative A: Given the proximity of the culvert outlet to the stream and the proposed alteration to the Creek's current course, at this point there is the potential to construct an infiltration gallery within the newly constructed floodplain of the restored channel. Construction would involve excavating the current storm drain outlet and raising it to the level of the new floodplain. Water from the culvert outlet would be allowed to infiltrate into a perforated pipe network underlying the floodplain.

Alternative B: The culvert outlet will be located on the inner berm area of a proposed stream meander. Sheet flow will then be encouraged to infiltrate on the inner berm and vegetated bench area. It will be necessary to stabilize the stream bank with hard substrate immediately adjacent to and below the outfall to prevent erosion.

7. Large excavated low bank area covered with kudzu. No obvious drainage channel into the stream is visible. There is a concrete/cobble ramp that leads down to a concrete apron on the east bank. There is no obvious collection area upslope of this feature and it likely only contributes local drainage to the Creek.

   Alternative A: This area will become part of a stream channel meander with appropriate action occurring during construction.

8. A 3′ trapezoidal flume draining a small portion of the west bank parking area.

   The flume drains under a sidewalk, past a garbage collection container, and flows as surface flow over some riprap from the top of the bank. Approximate drainage area is 0.5 acres (100 percent impervious roadway and parking surfaces).

   Alternative A: Given the close proximity of this outlet to the stream and the proposed alteration to the Creek's current course at this point, there is the potential to either tie this drain into the infiltration gallery proposed for inflow No. 6 or construct a separate infiltration gallery within the newly constructed floodplain of the restored channel. Construction would involve the routing of runoff from the top of the bank to the level of the new floodplain. Water from the culvert outlet would be allowed to infiltrate into a perforated pipe network underlying the floodplain. An alternative consideration would involve the use of permeable pavement or curbing to allow infiltration of runoff from this relatively small impervious area.

   Alternative B: The culvert outlet will be located on the inner berm area of a proposed stream meander. Sheet flow will then be encouraged to infiltrate on the inner berm and vegetated bench area. It will be necessary to stabilize the stream bank with hard substrate immediately adjacent to and below the outfall to prevent erosion.

9. A 3′ trapezoidal flume draining the southeast portion of the west bank parking area.

   This flume drains under a sidewalk and flows as surface flow over some riprap from the top of the bank. Approximate drainage area is 0.5 acres (100 percent impervious roadway and parking surfaces).

   Alternative A: Unlike Inflows 6 and 8, this storm water input would fall downstream of the proposed enhanced floodplain of the channel restoration. Given the close proximity of this outlet to the stream, there is little opportunity to construct an infiltration gallery at this point unless it is tied into the infiltration gallery serving Inflows 6 and 8. An alternative consideration would involve the use of permeable pavement or curbing to allow infiltration of runoff from this relatively small impervious area.

   Alternative B: No action at this time. This structure is not impacted by the proposed stream alignment or construction activities.

10. A 16″ concrete culvert with welded steel grate.

This pipe appears decommissioned although there appeared to be some base flow seepage draining from the pipe. The pipe outlet is approximately 2 feet above the creek base flow level.

Alternative A: Remove or seal off pipe during construction if decommission can be verified.

11. Inflow from dammed Dairy Branch tributary.

The right side of the dam, facing downstream, appears to allow surface flow over the dam. One storm water drain from the west bank parking lot (approximately 1/4 acre, 100 percent impervious) discharges into an impounded pool upstream of the dam. Some diffuse seepage through the riprap below the dam was evident on the survey day.

Alternative A: Dam integrity should be determined on right side of channel, facing downstream. The riprap apron below the dam appears stable and should be left as is during construction and monitored after stream restoration.

12. Small top of bank surface inflow (likely a pedestrian trail) allows local inflow directly into the Creek.

Alternative A: Bank landscaping to discourage overbank drainage.

13. Approximately 20 linear feet of bank, 1′ to 2′ in height, is eroding as flow is directed towards the west bank by a medial bar and bedrock dyke. There is a top of bank headcut where local surface flow drains directly into the Creek from the top of the bank.

Alternative A: If improvement is necessary, this area will become part of a stream channel meander with appropriate action taking place during construction.

14. A 20″ concrete culvert entering stream at Creek level.

The pipe is halfway full of sediment. This culvert collects an extensive storm drain system under the seating facing the stage on the pond island. The drainage wraps around the north end of the pond and extends to the top of slope above the seating area. Some seepage was evident on the day of the survey. The drainage area for this culvert is 9.77 acres (1.96 acres single-family residential, 7.81 acres grassed playing field). The culvert inlet is approximately 10′ below ground level.

Alternative A: Given the proximity of the culvert outlet to the stream and the proposed alteration to Little Sugar Creek's current course, at this point there is the potential to construct an infiltration gallery within the newly constructed riparian bank of the restored channel. Construction would involve excavating the current storm drain outlet and raising the outlet to the level of the new floodplain. Water from the culvert outlet would be allowed to infiltrate into a perforated pipe network underlying the riparian zone. It should be noted that this drain collects runoff from a large grassed area with minimal impervious surface.

Alternative B: No action at this time. This structure is not impacted by the proposed stream alignment or construction activities.

15. A 26″ concrete culvert drains from the top of the bank over a concrete apron into stream.

    The culvert runs from two street drains on Sterling Avenue, then under 1628 Sterling Avenue and through a forested area. The culvert was dry on the day of the survey. The drainage area for this culvert is 8.83 acres of single-family residential housing.

    Alternative A: Proposed channel restoration plans do not allow for a floodplain level infiltration gallery at the outlet of this channel. There is an opportunity to create a significant rain garden running from the break in slope to the stream bank. Outflow from the rain garden would need to be stepped down to stream level. A second possibility would be to create a lateral infiltration swale with an overflow outlet that could be stepped down to stream level. The swale would parallel the current walking trail along the east stream bank.

    Alternative B: No action at this time. This structure is not impacted by the proposed stream alignment or construction activities.

16. A 26″ cemented steel culvert at top of bank.

    This likely served as an outlet drain for the Freedom Park pond and is decommissioned. The culvert was dry on the survey day.

    Alternative A: Remove or seal off pipe during construction.

17. A 26″ mid-bank concrete flume that drains mid bank into the Creek.

    This culvert drains a storm grate located in the nature museum parking lot. Runoff occurs from the parking lots and entrance road to the museum. The culvert was dry on the survey day. The drainage area for this culvert is 1.16 acres, 0.96 acres of which is impervious asphalt. The remainder consists of a pervious landscaped traffic island.

    Alternative A: There is a scope for the construction of a small rain garden to treat the parking lot runoff at this site. The existing culvert intake would need to be sealed and runoff routed into an excavated area where a rain garden could be sited. Considerable room exists for such a structure as two buildings have recently been demolished near the culvert intake.

    Alternative B: Outfall improvement using hard substrate will be made during construction in an effort to prevent erosion.

18. A 24″ concrete culvert serving as a drainage outlet for the vertical riser in Royce Pond.

    The surface area of the pond is approximately 6.12 acres, including a 0.68-acre island. Some seepage was noted on the day of the survey.

    Alternative A: Given the close proximity of this outlet to the stream and the proposed alteration to the Creek's current course at this point, there is considerable potential to tie this drain into an infiltration gallery within the newly constructed floodplain of the restored channel. Construction would involve the routing of runoff from the outlet culvert to the level of the new floodplain. Water from the culvert outlet would be allowed to infiltrate into a perforated pipe network underlying the floodplain. Given the considerable waterfowl population that utilizes Royce Pond year round, treatment of pond overflow would certainly enhance downstream water quality.

Alternative B:

19. A 6′ concrete culvert entering the Creek from the east bank.

    This serves as storm drain conveyance from Princeton Avenue. The culvert is slightly below Creek level and it is not clear if seepage was occurring on the day of the survey.

    Alternative A: The size and location of this drain generate storm water problematic and beyond the scope of the current project. Storm water treatment would have to begin well outside the Freedom Park boundaries to be effective. However, given the large storm water volume contributed by this outlet the greatest improvement in the Creek's water quality would involve a water quality BMP retrofit of this and site one inflows.

    Alternative B: No action at this time. This structure is not impacted by the proposed stream alignment or construction activities.

20. An 18″ concrete culvert entering Creek from the west bank.

    This culvert travels from a structure draining a 0.29-acre grassed depression near the south entrance to Freedom Park. The culvert was dry on the day of the survey.

    Alternative A: Seal storm drain. This storm drain seems like overkill. It drains a small, grassed depression on the east side of the Princeton Avenue Freedom Park entrance. Water in this depression should simply be allowed to infiltrate in place rather than be piped to the stream channel.

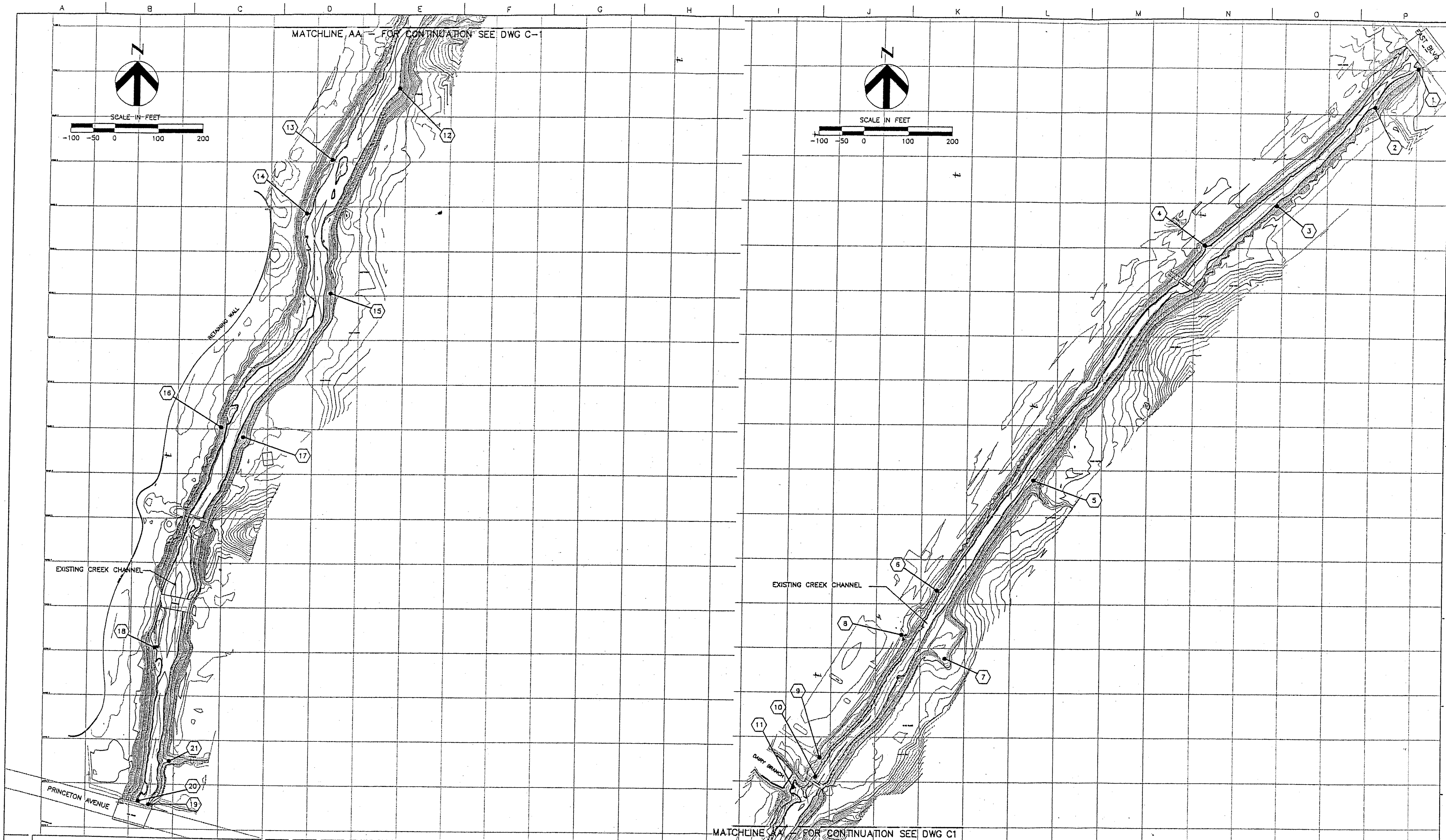
    Alternative B: No action at this time. This structure is not impacted by the proposed stream alignment or construction activities.

21. A 2′ x 4′ open channel that enters the Creek from the top of the east bank.

    The channel drains 4.60 acres of a forested area downslope of the Nature Museum.

    Alternative A: Runoff from this channel would likely have good water quality and a low delivery rate to the Creek given the complete forest cover of the drainage area. Present stream restoration plans call for a significant relocation of the channel through this site that may completely remove this as a storm water input to the Creek. If the channel retains its present position, the recommendation is to simply step this channel down to Creek level.

    Alternative B: Meander construction will address the location of this channel. Channel drainage into the Creek will be protected with a hardened substrate to prevent erosion.



C:/WINDM/09177017.018/FIG-6.dwg
08-28-02 GHUNEYCU 09:55:28

Issue No.	Description	Date	Drwn.	Chkd.	Resp. Engr.	Proj. Mgr.

HDR

HDR Engineering, Inc.

BAR LENGTH ON ORIGINAL DRAWING EQUALS ONE INCH. ADJUST SCALE ACCORDINGLY.

Project Manager

Designed

Designed

Checked

Drawn

N C Wetlands Restoration Program
Freedom Park - Little Sugar Creek
Channel Restoration

Charlotte North Carolina

Storm Water Outfall

Locations

Date

Scale

Project No.

File Name

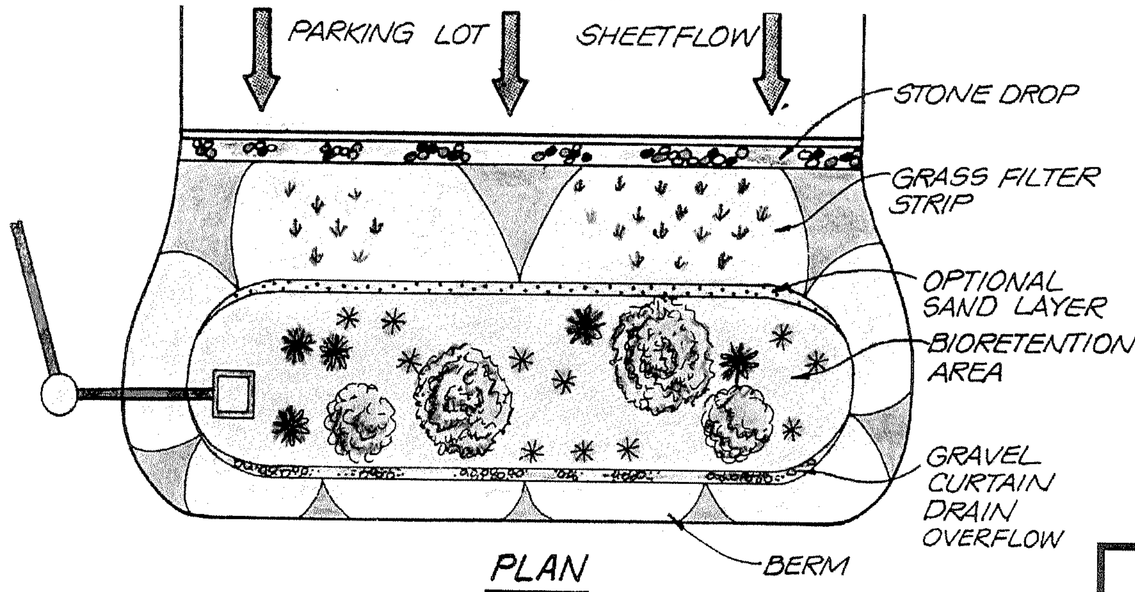
Drawing No.

Fig. 6

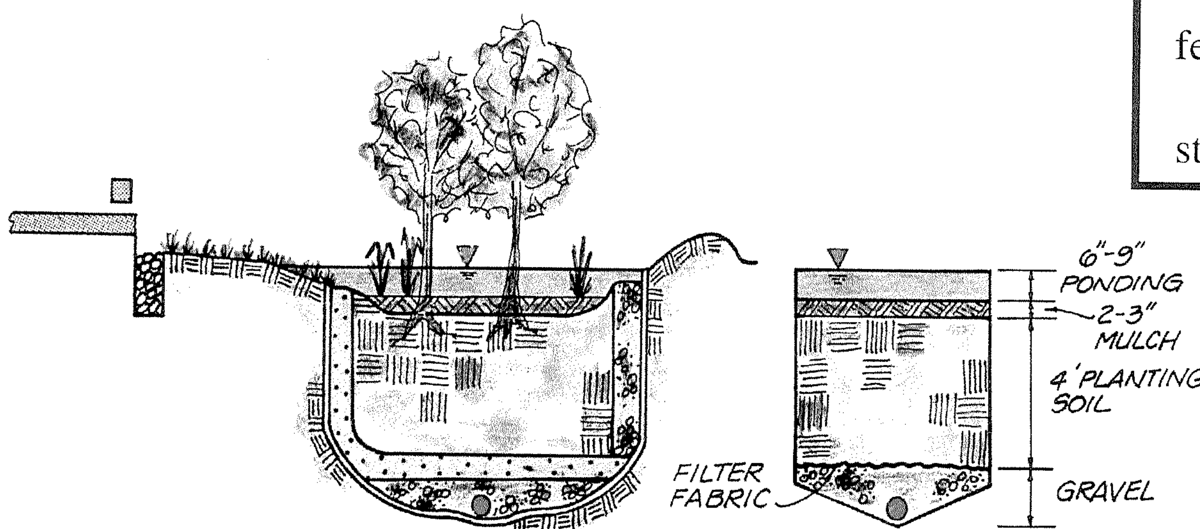
Issue

A

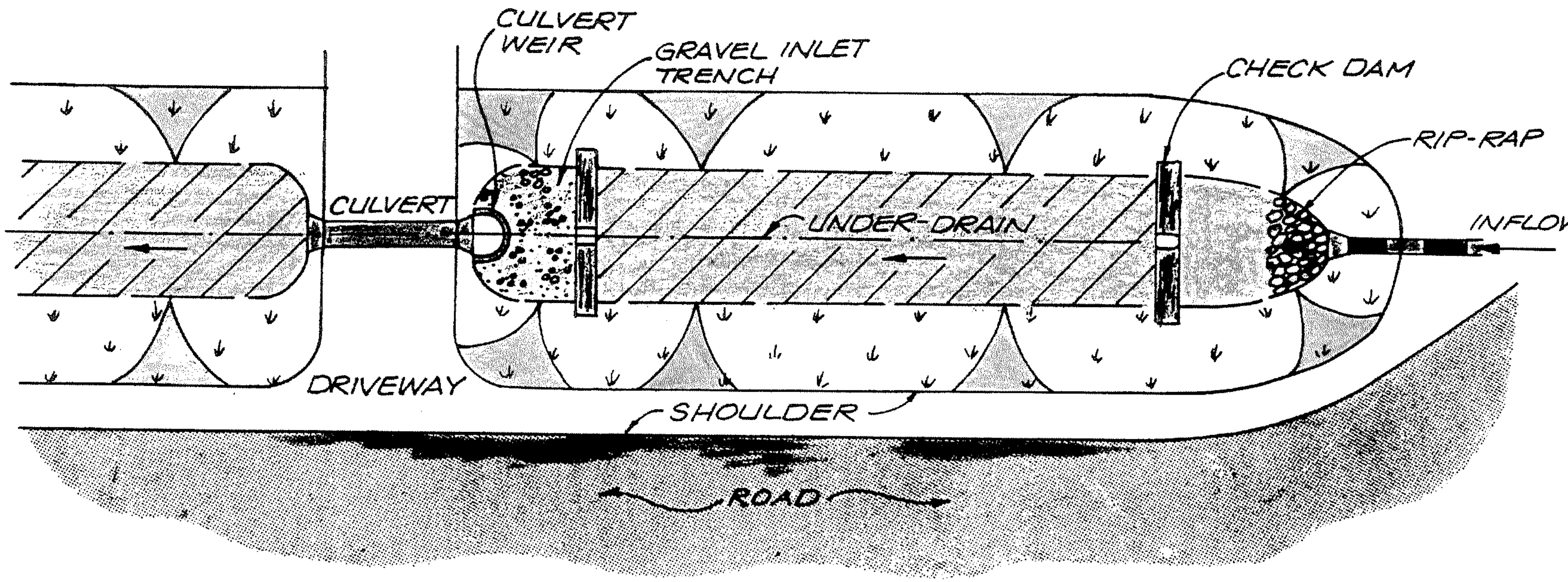
Bioretention/Rain Garden



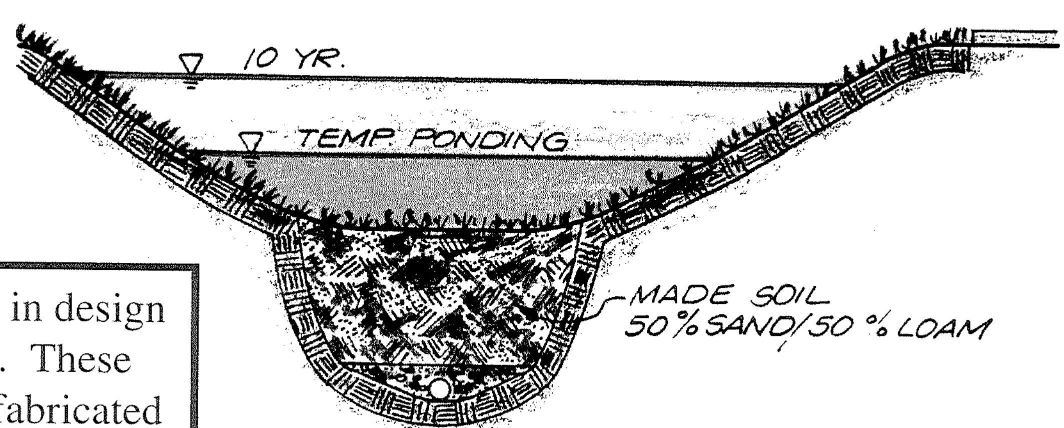
Bioretention areas are landscaping features adapted to treat on-site stormwater runoff.



Dry or Grassed Swale



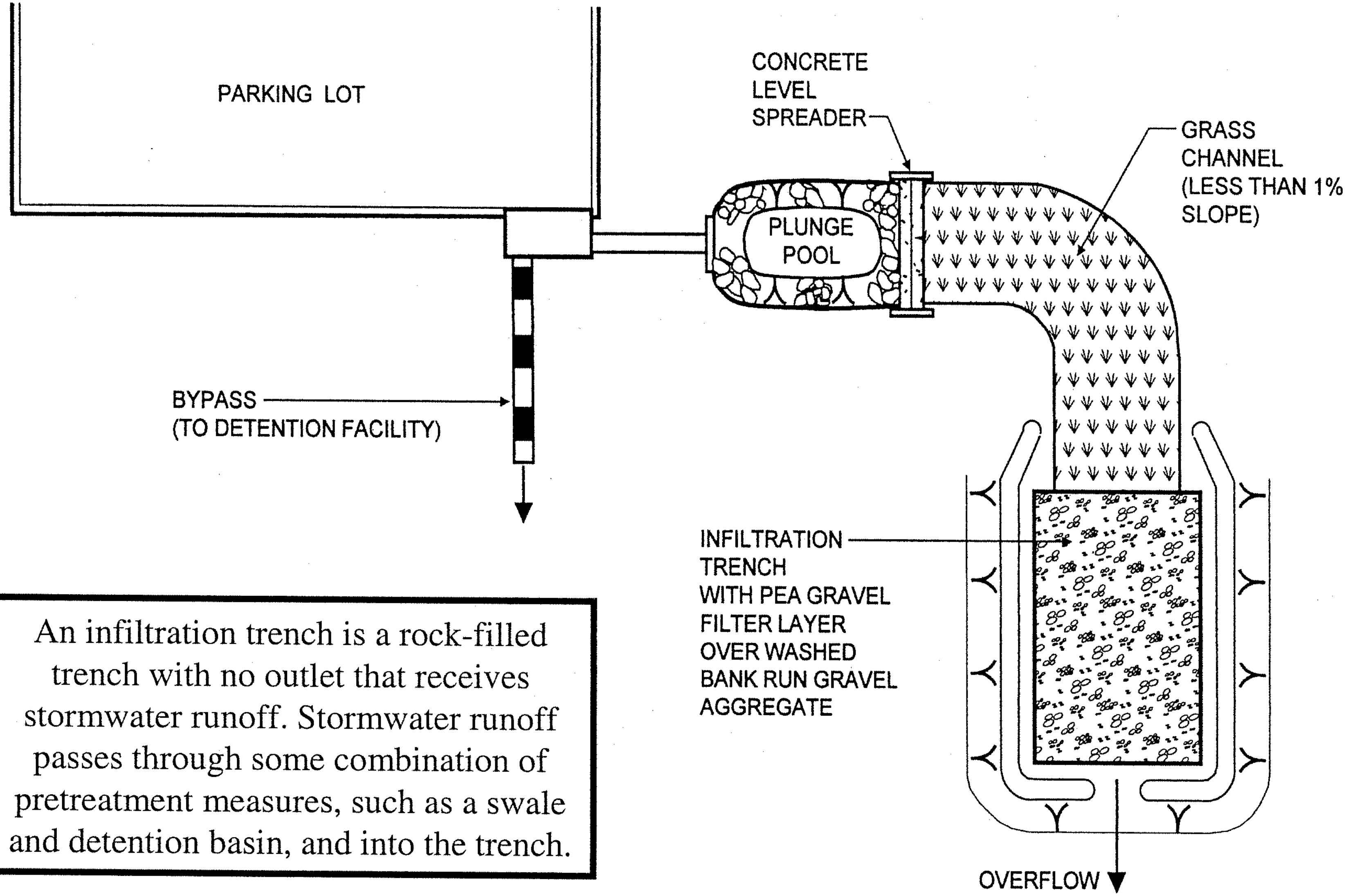
PLAN



PROFILE

Dry swales are similar in design to bioretention areas. These designs incorporate a fabricated soil bed into their design.

Infiltration Trench/Gallery



An infiltration trench is a rock-filled trench with no outlet that receives stormwater runoff. Stormwater runoff passes through some combination of pretreatment measures, such as a swale and detention basin, and into the trench.

PLAN VIEW