Caldwell Station Creek and Associated Floodplain Wetlands Restoration Plan

60% RESTORATION PLAN

MECKLENBURG COUNTY
NORTH CAROLINA

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PREPARED BY:

HDR Engineering, Inc.
of the Carolinas

Habitat
Assessment and
Restoration
Program

CALDWELL STATION CREEK AND ASSOCIATED FLOODPLAIN
WETLANDS RESTORATION PLAN

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CALDWELL STATION CREEK AND ASSOCIATED FLOODPLAIN WETLANDS RESTORATION PLAN

60% Draft 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 and wetlands restoration plan (Plan) for Caldwell Station Creek, un-named tributaries to Caldwell Station Creek, and their associated floodplain riparian areas, for the intended use of the North Carolina Department of Environment and Natural Resources (NCDENR) Ecosystem Enhancement Program (EEP).

The project is located in the Town of Huntersville, Mecklenburg County, at Exit 25 on I-77. The watershed is rapidly becoming developed due to single-family housing and retail/business infrastructure. The project location was selected due to the ownership of the land (Town of Cornelius), the undevelopable nature of the land surrounding the stream, and the instability of the restoration reach.

This report documents the attainable goals and objectives of restoring both stream and wetland components within the Project Area and presents an implementation strategy. Plans for stream restoration are based on Rosgen stream restoration principles and reference reach analysis. Wetland restoration follows guidance criteria for restoration projects as laid out in the USACOE RGL#02-2 (12/2002). In addition, a monitoring plan and schedule ensure the long-term stability and success of this restoration effort.

2.0 GOALS AND OBJECTIVES

Restoration projects for aquatic resource impacts need to be founded in a watershed approach that recognizes the systemic interactions among its hydrologic, biologic, geologic, and anthropogenic settings that, in turn, determine its "functional" resource attributes, levels of impairment, and practical strategies for restoration. The watershed restoration goals in this project include both stream and wetland components within the same riparian corridor and necessitate careful consideration of the interactions of stream and bottomland wetland components. The benefits from the proposed stream and wetland restorations include water quality improvement, habitat enhancement/restoration, stream stability, increase in land value, and opportunity for education. These benefits are individually discussed below, followed by a description of the specific site attributes and the recommendations for restoration activities.

Water Quality

The areas being proposed for stream and riparian wetland restoration are part of the McDowell Creek WS-IV watershed that drains to Mountain Island Lake, the primary source for potable water for the City of Charlotte. McDowell Creek is currently 303(d) listed as impaired due to biological data with unknown cause(s) (NCDENR, 2003); with a C classification upstream of Statesville Road (SR 21) and WS-IV classification downstream of SR 21. The class C segments rank low priority, and the WS-IV portions high priority. Historically the waters were listed as impaired due to sediment pollution; but at this time additional data collection and analysis must be performed before a definitive cause can be assigned and the waters move to other rankings for remedial action. The analysis of existing conditions along the reaches proposed for restoration show unnatural channel geometry (e.g. dimension and profile) that can be a causative factor in channel instability and sediment erosion, but also result in substantially lower aquatic habitat. Downstream on McDowell Creek, the USGS has been monitoring sediment loads for many years and during large storm flows, such as the May 22, 2003, event, records excessive sediments loads up to 3,000 tons/day. The primary water quality improvement goal of this restoration effort will be to restore stream morphologies promoting stability and thus potentially improve downstream water quality and biological conditions. Secondly, a restoration plan is proposed to protect, enhance, and restore wetlands to the bottomland areas adjacent to the streams. These wetlands will promote water quality goals by three means: a) they enhance groundwater storage that augments baseflow and interstorm stream water quality; b) they intercept and treat overland stormflow from the adjacent developed residential and commercial properties; and c) they receive overbank stormflow from the existing stream channels, which provides additional treatment of stormwater (for discharges exceeding the channel capacity).

Aquatic and Wetland Habitat

The proposed restoration plan will potentially restore and enhance up to 11 acres of bottomland hardwood wetland, and approximately 3,980 linear feet of 1^{st} to 3^{rd} order streams. The combined stream and wetland restoration will provide an integrated multifunctional stream corridor that supports a robust matrix of natural habitats. Structures used to provide for long-term stability in the restored reach will also enhance the aquatic habitat by reducing homogeneity and providing for an abundance of niche habitats.

Stream Stability

Approximately 3,560 linear feet of previously channelized streams will be restored to a natural state promoting long-term channel stability, which may be a primary factor in biological impairment of the downstream reaches of McDowell Creek. An additional 420 linear feet of stream will be enhanced to improve channel stability, water quality and habitat. Increased stream stability will reduce excess sediment loads and extend the life of the downstream Mountain Island Lake reservoir.

Land Values

The restoration of stream and wetland functions along the streams within the McDowell Creek watershed represents intangible community benefits which promote quality of life indices that in turn underpin and improve land values of the surrounding communities.

Education [Cornelius Eco-park]

The landowner (Town of Cornelius) has proposed to develop an environmental education facility at this restoration location, preliminarily called an Eco-park. The details on this endeavor are still being developed and will be discussed in the future as the process becomes more defined.

3.0 LOCATION INFORMATION

The restoration tracts are located to the east of SR 21 approximately 2,000 feet north of the intersection of SR 21 and Sam Furr Road in northern Mecklenburg County, North Carolina, south of the township of Cornelius. The Mecklenburg County Tax parcel IDs are 00504219A & B, and 00503219A & B, with 9 and 12 acres, respectively. All tracts are owned by the Township of Cornelius, which has the intent of using the tracts for an Eco-park. Most of the area lies within the 100-year floodplain for Caldwell Station Creek. The site can be reached by taking Exit 25 off of I-77 and heading east on Sam Furr Road for approximately 1,000 feet to the intersection with SR 21, then north for approximately 2,000 feet on SR 21, where SR 21 crosses the culvert for Caldwell Station Creek.

4.0 GENERAL WATERSHED DESCRIPTION

Caldwell Station Creek and its tributaries lie within the McDowell Creek basin in Catawba River Subbasin 03-08-33/USGS CU 03050101. The site receives drainage from the upper 2.4 square miles of headwaters for Caldwell Station Creek. The eastern boundary of the watershed lies along Old Statesville Road (SR 115), and separates the Upper Catawba River and Yadkin-Pee Dee basins. The location and topographic settings for these headwaters are detailed in Figure 1. This watershed is located within the North Carolina Piedmont physiographic province. The province is characterized by rolling hills of moderate to low relief and is underlain by deeply weathered rocks of variable igneous, metamorphic, and indurated sedimentary rock types. Drainage is relatively mature with a well-developed dendritic network of predominantly C and E Rosgen Class streams. The upper watershed to Caldwell Station Creek has approximately 100 feet of fall from the hilltop divide, along Old Statesville Road (at an elevation of 800 feet above MSL) down to 700 feet above MSL just below SR 21 (a horizontal distance of approximately 1.5 miles). The landcover, soils, and geology of the watershed are described below and illustrated in Figures 2, 3, 4, and 5.

4.1 Land Use/Landcover

A review of the available historical aerial photography dating back to 1938 indicates that the lands adjacent to, and upstream from, the restoration tracts, along SR 21, have been predominantly rural in nature. However, during the last two decades there has been a dramatic increase in both residential and commercial development. The construction of Interstate 77 (I-77) to the west, and the nearby intersections of Sam Furr Road with SR 21 and I-77 provide the foundation for a regional commercial/industrial/ municipal hub around which has developed a large number of residential communities. Color aerial photography (2002) of the three watersheds (Figure 2) was digitally classified into landcover types in order to understand the hydrologic and stream morphologic impacts of land use and landcover changes. The results from the landcover analysis are shown in Figure 3 and tabulated in Table 1. It is estimated that approximately 70 percent of the watershed east of SR 21 is covered by vegetation, with about 42 percent under tree canopy, 24 percent by grass or pasture, and 3 percent by brush. Thirty percent of the watershed is estimated to be surfaced by either building roofing materials or pavement. The transition from a rural landscape, with an approximately equal mix of forested and open agricultural lands, to suburban lands is still ongoing and will continue to change the runoff characteristics within the watershed for many years to come. As demonstrated in this report, estimates of the bankfull discharge are greater than those expected for rural streams with similar watershed areas, yet significantly lower than that seen in watersheds that are fully developed. Understanding the future hydrologic characteristics of the watershed depends on what stormwater and land-use controls are instituted to meet existing and future stormwater management concerns.

4.2 Soils

Soil information for the watershed comes from the Mecklenburg County (County) Soil Survey (USDA, 1980). Figure 4 shows the soils within the contributing drainage basin to the study site. The majority of the lands in upland areas in this study area are underlain by Cecil CeB2 soils, which then transition through hill slope and lowland Cecil CeD2 and Helena HeB soils with subordinate Pacolet PaE, Vance VaB and VaD, Mecklenburg MeB and MeD, Wilkes WkB and WkD, Enon EnB and EnD soils to the bottomland floodplains exclusively covered by Monacan MO soils. The descriptions of soil types in the watershed are summarized below (as described in the Soil Survey of Mecklenburg County (USDA, 1980).

None of the soils in the contributing drainage basin is among the soils on the North Carolina list of Hydric Soils. (Source: USDA NRCS Soils.)

Cecil Series: Consist of well drained, moderately permeable soils found on broad ridges and side slopes with grades ranging from 2 to 15 percent. Hydrologic Group B.

CeB2: Cecil sandy clay loam, 2 to 8 percent slopes, eroded.
This well drained soil is on broad smooth ridges on the uplands. Typically, the surface layer is yellowish red sandy clay loam about 6 inches thick. The subsoil is 47 inches thick. The upper part is red clay, and the lower part is red clay loam. The underlying material to a depth of 65 inches is red and yellow loam. The organic matter content is low in the surface layer. Permeability is moderate, the available water capacity is medium, the shrink-swell potential is moderate, and surface runoff is medium. Depth to bedrock is more than 60 inches. The water table is below 6 feet.

CeD2: Cecil sandy clay loam, 8 to 15 percent slopes, eroded.
This well drained soil is on side slopes on the uplands. Typically, the surface layer is yellowish red sandy clay loam about 6 inches thick. The subsoil is 47 inches thick. The upper part is red clay, and the lower part is red clay loam. The underlying material to a depth of 65 inches is red and yellow loam. The organic matter content is low in the surface layer. Permeability is moderate, the available water capacity is medium, the shrink-swell potential is moderate, and surface runoff is medium. Depth to bedrock is more than 60 inches. The water table is below 6 feet.

Enon Series: Consists of well drained, slowly permeable soils found on broad and narrow ridges and side slopes with grades ranging 2 to 15 percent. Hydrologic Group C.

EnB: Enon sandy loam, 2 to 8 percent slopes.
This well drained soil is on broad ridges on the uplands. Typically, the surface layer is brown sandy loam about 7 inches thick. The subsoil is 29 inches thick. The upper part is yellowish brown sandy clay loam, the middle part is yellowish brown clay, and the lower part is yellowish brown clay loam. The underlying material to a depth of 60 inches is light olive brown clay loam and sandy loam. The organic matter content is low in the surface layer. Permeability is slow, the available water capacity is medium, the shrink-swell potential is high, and surface runoff is medium. Depth to bedrock is below 60 inches. The water table is below 6 feet.

EnD: Enon sandy loam, 8 to 15 percent slopes.
This well drained soil is on side slopes on the uplands. Typically, the surface layer is brown sandy loam about 7 inches thick. The subsoil is 29 inches thick. The upper part is yellowish brown sandy clay loam, the middle part is yellowish brown clay, and the lower part is yellowish brown clay loam. The underlying material to a depth of 60 inches is light olive brown clay loam and sandy loam. The organic matter content is low in the surface layer. Permeability is slow, the available water capacity is medium, the shrink-swell potential is high, and surface runoff is rapid. Depth to bedrock is below 60 inches. The water table is below 6 feet.

Helena Series: Consists of moderately well drained, slowly permeable soils found on broad ridges and foot slopes on the uplands. Slopes range from 2 to 8 percent. Hydrologic Group C.

HeB: Helena sandy loam, 2 to 8 percent slopes.
This moderately well drained soil is on broad ridges and in slightly concave areas around the heads of intermittent streams. Typically, the surface layer is light olive brown sandy loam about 8 inches thick. The subsoil is 32 inches thick. The upper part is brownish yellow sandy clay loam, the middle part is brownish yellow and yellowish brown clay, and the lower part is mottled yellowish brown, light gray, and reddish brown clay loam. The underlying material to a depth of 50 inches is light gray sandy clay. Below, this is light gray sandy clay loam. The organic matter content is low in the surface layer. Permeability is slow, the available water capacity is low, the shrink-swell potential is high, and surface runoff is medium. Depth to rippable bedrock is 40 to 60 inches. Seasonally, the perched water table is only 1 to 2.5 feet below the surface.

Mecklenburg Series: Consists of well drained, slowly permeable soils found on broad ridges and side slopes with grades ranging 2 to 15 percent. Hydrologic Group C.

MeB: Mecklenburg fine sandy loam, 2 to 8 percent slopes.
This well drained soil is on broad ridges on the uplands. Typically, the surface layer is dark reddish brown fine sandy loam about 7 inches thick. The subsoil is yellowish red clay 27 inches thick. The underlying material to a depth of 45 inches is mottled strong brown and yellowish red clay loam. Below this to a depth of 65 inches it is very dark grayish brown and light olive brown loam. The organic matter content is low in the surface layer. Permeability is slow, the available water capacity is medium, the shrink-swell potential is moderate, and surface runoff is medium. Depth to bedrock ranges from 48 to 60 inches. The water table is below 6 feet.

MeD: Mecklenburg fine sandy loam, 8 to 15 percent slopes.
This well drained soil is on side slopes on the uplands. Typically, the surface layer is dark reddish brown fine sandy loam about 7 inches thick. The subsoil is yellowish red clay 27 inches thick. The underlying material to a depth of 45 inches is mottled strong brown and yellowish red clay loam. Below this to a depth of 65 inches it is very dark grayish brown and light olive brown loam. The organic matter content is low in the surface layer. Permeability is slow, the available water capacity is medium, the shrink-swell potential is moderate, and surface runoff is rapid. Depth to bedrock ranges from 48 to 60 inches. The water table is below 6 feet.

Monacan Series: Consists of somewhat poorly drained, moderately permeable soils found on floodplains adjacent to streams. Hydrologic Group C.

MO: Monacan soils.
These somewhat poorly drained, nearly level soils are on floodplains along streams and drainageways. The surface layer of these soils is brownish loam, fine sandy loam, or sandy loam. The subsoil is reddish loam in the upper part and brownish or grayish silty clay loam, fine sandy loam, sandy clay loam, and sandy clay in the lower part. The organic matter content is low in the surface layer. Permeability is moderate, the available water capacity is high, the shrink-swell potential is low, and surface runoff is slow. Depth to bedrock is more than 60 inches. Depth to the seasonal high water table is only 0.5 to 2 feet in winter and early spring. Flooding is for brief periods late in winter and early in spring.

Pacolet Series: Consists of well-drained, moderately permeable soils with slopes ranging from 15 to 45 percent. Hydrologic Group B.

PaE: Pacolet sandy loam, 15 to 25 percent slopes.
This well drained soil is on side slopes adjacent to drainageways. Typically, the surface layer is very dark grayish brown sandy loam about 3 inches thick. The subsoil is 28 inches thick. The upper part is red clay, and the lower part is red clay loam. The underlying material to a depth of 65 inches is mottled red, yellowish red, yellow, and reddish yellow sandy loam. The organic matter content is low in the surface layer. Permeability is moderate, the available water capacity is low, the shrink-swell potential is low, and surface runoff is rapid. Bedrock is below 60 inches. The water table is below 6 feet.

Vance Series: Consists of well drained, slowly permeable soils found on broad ridges and side slopes with grades ranging 2 to 15 percent. Hydrologic Group C.

VaB: Vance sandy loam, 2 to 8 percent slopes.
This well drained soil is on broad ridges and side slopes on the uplands. Typically, the surface layer is yellowish brown sandy loam about 8 inches thick. The subsoil is strong brown clay 25 inches thick. The underlying material to a depth of 50 inches is mottled strong brown, yellow, and red clay loam and loam. The organic matter content is low in the surface layer. Permeability is slow, the available water capacity is medium, the shrink-swell potential is moderate, and surface runoff is medium. Depth to bedrock range is below 60 inches. The water table is below 6 feet.

VaD: Vance sandy loam, 8 to 15 percent slopes.
This well drained soil is on side slopes on the uplands. Typically, the surface layer is yellowish brown sandy loam about 8 inches thick. The subsoil is strong brown clay 25 inches thick. The underlying material to a depth of 50 inches is mottled strong brown, yellow, and red clay loam and loam. The organic matter content is low in the surface layer. Permeability is slow, the available water capacity is medium, the shrink-swell potential is moderate, and surface runoff is rapid. Depth to bedrock range is below 60 inches. The water table is below 6 feet.

Wilkes Series: Consists of well drained, moderately slowly permeable soils found on ridges and narrow side slopes with grades ranging from 4 to 45 percent. Hydrologic Group C.

WkB: Wilkes loam, 4 to 8 percent slopes.
This well drained soil is on upland ridges. Typically, the surface layer is dark grayish brown loam about 4 inches thick. The subsurface layer is brown loam 3 inches thick. The subsoil is 8 inches thick. The upper part is strong brown clay, and the lower part is strong brown clay loam. The underlying material to a depth of 48 inches is olive brown, green, and black sandy loam. Below this is dark colored hard rock. The organic matter content is low in the surface layer. Permeability is moderately slow, the available water capacity is very low, the shrink-swell potential is moderate, and surface runoff is medium. Depth to hard bedrock ranges from 40 to 80 inches. The water table is below 6 feet.

WkD: Wilkes loam, 8 to 15 percent slopes.
This well drained soil is on narrow ridges and side slopes of the uplands. Typically, the surface layer is dark grayish brown loam about 4 inches thick. The subsurface layer is brown loam 3 inches thick. The subsoil is 8 inches thick. The upper part is strong brown clay, and the lower part is strong brown clay loam. The underlying material to a depth of 48 inches is olive brown, green, and black sandy loam. Below this is dark colored hard rock. The organic matter content is low in the surface layer. Permeability is moderately slow, the available water capacity is very low, the shrink-swell potential is moderate, and

surface runoff is rapid. Depth to hard bedrock ranges from 40 to 80 inches. The water table is below 6 feet.

Urban Land (Ur): Consists of areas where more than 85 percent of the surface area is covered with asphalt, concrete, buildings, or other impervious cover. Most of the soil material has been cut, filled, and graded, and the natural characteristics altered or destroyed. The rest is small lawns or shrub gardens near buildings, sidewalks, and in parking lots.

4.3 Geology

The site lies within the Charlotte belt of the North Carolina Piedmont, which is a geologic province dominated by large areas of variably metamorphosed plutonic and volcanic rocks. The dominant plutonic rocks are generally characterized as being pre-, syn-, or post-tectonic with respect to the early and middle Paleozoic phases of deformation that imparted new textures and secondary minerals into existing units. The resulting oriented fabrics or foliations represent weaknesses within these rocks that have been worked on by the forces of weathering and erosion, and are often followed by today's surface streams imparting to them a lower than expected sinuosity for the low grades and giving them mixed C and E stream class traits. The Caldwell Creek watershed drains two map units within the Charlotte belt, the *mqdf* and *mqd* units (Goldsmith et al., 1988). Of these two, the *mqd* unit is predominant with only a small southern fringe of the watershed underlain by the *mqdf* unit. *Mqd* is a unit of grey metamorphosed quartz diorite and tonalite that is largely composed of the minerals: plagioclase, quartz, biotite, hornblende, and epidote. The *mqdf* unit is a metamorphosed finer grained biotite tonalite that is more strongly foliated with the conspicuous absence of hornblende. The latter yields more clayey soil horizons due to the lower abundance of quartz. Stream channel density is markedly higher with greater hillslope incision in the latter of the two units. No exposures of these units appear within the restoration site, and it is presumed that the reaches in consideration are resting on a thin veneer of aggradational floodplain deposits, themselves resting on weathered biotite tonalite (saprolite).

4.4 Water Quality

Caldwell Station Creek and its tributaries lie within the approximate 26-square mile McDowell basin, which has a North Carolina WS-IV classification within the upper Catawba River basin of North Carolina south of SR 21 to the Mountain Island Lake reservoir, and a C classification from source to SR 21. The Mountain Island Lake reservoir supplies drinking water to the City of Charlotte. McDowell Creek is currently CWA 303(d) listed as impaired for biological data of unknown cause(s). The USGS has instrumented McDowell Creek for water quality investigations, and has reported elevated sediment loads during storms. A maximum sediment load of 3,000 tons/day (USGS) was recorded on May 22, 2003. Additional water quality information for the McDowell Creek watershed can be found in the preliminary engineering watershed assessment report for McDowell Creek watershed completed in 2003 by Watershed Concepts, Inc; which is presented in Appendix C.

5.0 HISTORIC AND EXISTING CONDITIONS

5.1 History of the Proposed Restoration Site

The historical changes that have occurred along the reaches of interest for this restoration effort within the upper Caldwell Station Creek watershed have been investigated by an analysis of aerial photography dating back to 1938. The series of seven time increments of aerial photographs (1938, 1951, 1956, 1968, 1975, 1980, and 1983) are shown in Figures 6 and 7 for the restoration site. These photographs track the evolution of the channels and riparian land uses since 1938.

The earliest photography indicates that the two primary streams, Caldwell Station Creek and the un-named tributary that drains the northern portion of the watershed (Tributary #1 of Figure 1), were channelized along the upper and lower edges of the Caldwell Station watershed floodplain, and had their intervening floodplain cleared for agricultural uses. The floodplain in between the two channels had at least one distributary bifurcation from Caldwell Station Creek which transferred waters into the other tributary. The interstream distributary branch was located approximately along the current alignment of SR 21. The channel pattern and riparian land use did not change significantly till the early 1950s, when Statesville Road was constructed. The first available images after the construction of SR 21 were taken in 1956. The 1956 photography shows the truncation of the lower approximately 3,000 linear feet of Tributary #1 and the diversion of the stream flow along the eastern embankment of SR 21 to a new confluence with Caldwell Station Creek just east of the SR 21 culvert. This diversion then resulted in the approximate doubling of stream flow within the reach of Caldwell Station Creek between SR 21 and the older, original, confluence (some 3,000 linear feet to the southwest; see middle diagram of Figure 7).

The next significant alteration of the channels in this portion of the watershed came with the construction of I-77. This occurred between 1968 and 1975 based on the aerial photography. The 1975 aerial photography shows that the construction of I-77 truncated the remaining elements of the previously impacted Tributary #1 by diverting the stream along the eastern embankment of I-77 to a new confluence with Caldwell Station Creek just east of the I-77 culvert. This then further increased the stream flow in Caldwell Station Creek down to the older, now abandoned, confluence with Tributary #1.

Lastly, in looking at the 1983 aerial photography, Tributary #1 has lines of bare dirt lining both banks indicating that this reach was redredged in the period leading up to the acquisition of the aerial photography.

In summary, the reaches of concern were channelized prior to the earliest available photography and likely realigned along opposing fringes of the floodplain to allow better agricultural use of the bottomlands. The channels were not totally isolated from each other in these earlier times, as at least one channel is mapped between Caldwell Station Creek and Tributary #1. The construction of SR 21 resulted in the abandonment of approximately 3,000 linear feet of the Tributary #1 south of SR 21 downstream to its earlier confluence with Caldwell Station Creek, and the overloading of Caldwell Station Creek for an equivalent 3,000 linear feet. As both watersheds have similar drainage areas, this resulted in an approximate doubling of flow in this reach. Finally, the construction of I-77 further truncated the lower remaining portion of the Tributary #1 from its original confluence up to the east side of I-77. The flow was again redirected into Caldwell Station Creek along the eastern edge of I-77, further overloading the Caldwell Station Creek. It should be noted that Caldwell Station Creek has a culvert under SR 21 that is insufficient in capacity to convey the 100-year flood (see Appendix C).

5.2 Hydrology

5.2.1 USGS Gaging Data and Recurrence-Discharge Analysis

The USGS gage station 02146470 on Little Hope Creek [within Hydrologic Unit 03050103] at Seneca Place in Charlotte [Latitude 35°09'52", Longitude 80°51'11" NAD83] provides the most appropriate set of flow information with a sufficient period of record to determine both an estimate of bankfull discharge and a recurrence interval. The drainage area for this station is 2.63 square miles, which is very close to the 2.39 square miles of combined drainage from the two principal watersheds that converge on the project site at the confluence just above the SR 21 culvert (see Figure 13). The two watersheds that converge at the restoration site have similar drainage areas, land use, as well as other physical attributes (e.g., geology, soils, topography), thus would have comparable rainfall-runoff relationships. This similarity allows an estimate of their independent contributions to the combined flow to be approximated by proportioning the combined flow by their relative drainage basin areas. The gaging station at Seneca Place has collected peak stream flow data since 1967, and daily stream flow since 1982. The annual peak data is shown in Table 2. A convention for analyzing the frequency or return interval for floods of a given magnitude for streams of mid-latitudes has been adopted, which uses a historical set of annual peak flow data. This method has been referred to as the Weibull method (Dalrymple, 1967; Chow, 1964), and requires that peak discharges for the period of record be ranked from highest to lowest discharge, and assigned a probability of "exceedance," P which is calculated by:

$$P = [m / (n + 1)] \times 100 \text{ percent, where:}$$

n = number of years of record, and
m = rank or magnitude (1 for the largest, etc.)

The recurrence interval, T, can then be expressed as:

$$T = (n + 1) / m$$

The discharge and return interval plot for this station is shown in Figure 8. From this plot, estimates of the discharge for the 1- and 1.5-year storms can be obtained. These return intervals are thought to be close to the dominant or "channel-forming" storm within the North Carolina Piedmont (Harmon et. al., 1999, Doll, et. al., 2000). These estimates are 539 cubic feet per second (cfs) for the1-year return storm, and 727 cfs for the 1.5-year return storm. In order to make an estimate of the independent contributions arising from the two sub-watersheds converging at the project site, these values are proportioned on a watershed area basis and yield 307 cfs (1-year return) and 414 cfs (1.5-year return) for Caldwell Station Creek, and 232 cfs (1-year return) and 313 cfs (1.5-year return) for Tributary #1. The landcover analysis results for Little Hope Creek are presented in Figure 9 and values are listed in Table 1. The results indicate that this watershed, which is built-out to full extent, has approximately 50 percent non-vegetated surfaces, which is significantly higher than the 30 percent estimated for the upper Caldwell Station Creek watersheds. Thus, the discharge values calculated by this method are considered to be valid projections for the future flow conditions, should the Caldwell Station Creek watershed be built out in a similar manner.

5.2.2 North Carolina Piedmont Regime Analysis

A second method of determining the likely dominant (channel forming) discharges in a given setting of the North Carolina Piedmont is to use "regime" relationships worked out by analysis of streams that have good bankfull morphologic indicators as well as USGS gaging. This analysis has been performed for both rural and urban streams in the North Carolina Piedmont (Harmon et. al., 1999, Doll, et. al., 2000) and generated the following sets of relationships:

Urban Streams (this set is in meters and km^2):

$$A_{bkf} = 3.11\ A_w^{0.64}$$
$$Q_{bkf} = 5.44\ A_w^{0.57}$$
$$W_{bkf} = 5.79\ A_w^{0.32}$$
$$D_{bkf} = 0.54\ A_w^{0.32}$$

Rural Streams (this set is in feet and mi^2):

$$A_{bkf} = 66.57\ A_w^{0.89}$$
$$Q_{bkf} = 18.31\ A_w^{0.75}$$
$$W_{bkf} = 11.89\ A_w^{0.43}$$
$$D_{bkf} = 1.50\ A_w^{0.32}$$

In these equations,

A_w = the drainage basin contributing area
A_{bkf} = cross section area of flow at the bankfull stage

Q_{bkf} = discharge at the bankfull stage
W_{bkf} = width of the water surface at the bankfull stage
D_{bkf} = mean depth of flow at the bankfull stage

In a followup study to the urban stream analysis of Harmon et. al., 1999, Forsythe et al., 2004 reanalyzed the urban bankfull relationships to watershed area for stream located in the Charlotte metropolitan area. This latter study recorded stage and discharges directly at sections with bankfull indicators rather than by extrapolation from USGS gaging station cross sections. It also verified scaling laws within individual urban watersheds. The second study verifies the earlier conclusion that urban watersheds have adjusted (enlarged) geometries in the Piedmont of North Carolina, but indicates the earlier study over extimated the adjustments. The modified set of urban relationships (in feet and mi^2) is :

$$A_{bkf} = 45.57\ A_w^{\ 0.64}$$
$$Q_{bkf} = 169.55\ A_w^{\ 0.70}$$
$$W_{bkf} = 21.53\ A_w^{\ 0.29}$$
$$D_{bkf} = 2.11\ A_w^{\ 0.35}$$

The stream drainage areas pertaining to this project are shown in Table 3. Both the rural and urban estimates for A_{bkf}, Q_{bkf}, W_{bkf}, and D_{bkf} generated from the above equations are listed in this table. It should be noted that a preponderance of the data used to generate the urban curves was obtained from urban streams in Mecklenburg County. The values for bankfull discharges under rural and urban conditions are dramatically different, begging an implied history of instability as the creeks transition from rural to urban conditions within their watersheds. The ratios of urban (using the Mecklenburg Co. data, Forsythe et al., 2004) to rural values for discharge and bankfull area, respectively, range from 2 to 3.2 and 2.4 to 3.0 for the watersheds listed in Table 3. The differences in channel dimensions that are required to carry the increased stormflow resulting from urbanization of the watershed create challenges in restoration efforts. Stability under current conditions and stability under future conditions potentially dictate different channel pattern and dimensional attributes. Measures are adopted in the restoration design to limit instability as the watershed undergoes future development.

5.2.3 Manning's Equation based Estimation of Bankfull Discharge

The observations of bankfull indicators within the three reaches of the restoration site have been annotated on the plots of the survey cross sections shown in Figures 10 and 12. The estimated cross-sectional areas, wetted perimeters, and channel slope, combined with estimated Manning's roughness coefficients, provide input parameters for discharge calculation at each cross section using the Manning's equation. The input parameters and calculated results are presented in Table 4. The estimate of Manning's roughness coefficient is subjective and brings some ambiguity into these calculations. A roughness coefficient value of .026 is adopted for the tributaries based on the depth of bankfull flow with respect to diameter of channel bed materials, the stable bed framework, and bed material sizes following concepts summarized in Arcement and Schneider, 1984. This base value is then modified for other resistance factors such as sinuosity, bank vegetation, and obstructions. To reflect reasonable variation of these parameters within the studied stream reaches, two values of roughness coefficient (.03 and .04) were used to calculate a range of discharge values. The resulting range of discharges for each stream is shown in Table 4 wherein values determined using the urban and rural regime relationships are also shown for comparison. Estimated flows for the Caldwell Station Creek reach upstream SR 21 are 114 cfs (n=.04) or 152 cfs (n=.03), and are higher than estimates generated from the rural regime curves, but still lower than that for the urban watersheds of similar drainage area. Flows for Tributaries #1 and #2 were calculated using Manning's equation and are significantly lower than the rural regime estimates. This is most likely due to the fact that these streams are E (low gradient-floodplain) reaches that have been altered, both by human agrarian practices, as well as more recently by beaver activity. E class channels, however, can have stable morphologic attributes with bankfull return intervals much shorter than other stream classes due to the abrupt decay of bed shear stresses at or above the bankfull stage. Providing the restoration designs keep bankfull stage at the level of the adjacent flood plain or floodplain bench (in the case of the restoration design for UT#2) higher frequencies of bankfull events should not, in and of itself, lead to instability in the channel.

5.3 Plant Communities

The restoration site has been largely under agricultural land use since the turn of the century. However, as the historical aerial photographs illustrate, the distribution of open fields has shifted from time to time within the floodplain and adjacent hillslope areas, and since the 1980s has shifted to scrub/shrub, pine and a variety of immature tree species. A detailed map that breaks down the riparian areas within the restoration tract into ten vegetation communities is shown in Figure 14 and in Appendix A, Figure A1. These are briefly described below, and are illustrated by photos located in Appendix A. Figure A1 also illustrates the locations and direction in which the photos were taken.

Area 1 is **Mixed Hardwoods Upland** with an average diameter breast height (dbh) of 10". The canopy contains Sweetgum (*Liquidambar styraciflua*) to 14" dbh, Green ash (*Fraxinus pennsylvanica*) to 14" dbh, American elm (*Ulmus americana*) to 18" dbh, Persimmon (*Diospyros virginiana*) to 12" dbh, Red maple (*Acer rubrum*) to 18" dbh, Sycamore (*Platanus occidentalis*) to 14" dbh, White oak (*Quercus alba*) to 14" dbh, Southern red oak (*Q. falcata*) to 30" dbh, Swamp red oak (*Q. shumardii*) to 40" dbh, and Hackberry (*Celtis laevigata*) to 12" dbh. The subcanopy and shrub layers are poorly developed, but do contain Cane (*Arundinaria gigantea*) and Autumn Olive (*Elaeagnus umbellata*). The largest trees are situated in the western corner of this area. See Figure A2.

Area 2 is **Pine and Mixed Hardwoods Upland** with an average dbh of 8". The canopy is dominated by Loblolly pine (*Pinus taeda*) to 12" dbh, with Sweet gum to 8" dbh, Sycamore to 10" dbh, and Red maple to 10" dbh. The subcanopy contains Red cedar (*Juniperus virginiana*) to 8" dbh, Tag alder (*Alnus serrulata*) and Pawpaw (*Asimina triloba*). The shrub layer is open and contains Cane and Autumn Olive. Vines are Catbrier (*Smilax* spp.). See Figure A3.

Area 3 is mixed **Bottomland Hardwoods with Pine Floodplain** and has an average dbh of 8". The canopy is fairly open and contains Sweet gum to 16" dbh, Yellow poplar (*Liriodendron tulipifera*) to 10" dbh, Black walnut (*Juglands nigra*) to 10" dbh, Wild cherry (*Prunus serotina*) to 8" dbh, and Loblolly pine to 16" dbh. The subcanopy contains Red cedar. The shrub layer is open to dense with Privet (*Ligustrum sinense*), Cane, and Tag alder. See Figure A4.

Area 4 is a relatively young **Loblolly Pine Planting Floodplain** with an average dbh of 6". The stand is Loblolly pine to 8" with a subcanopy of young hardwoods. See Figure A5.

Area 5 is a relatively young, even aged, mixed **Bottomland Hardwoods Floodplain with potential wetland inclusions**, with an average dbh of 6". The canopy is dominated by Sweet gum to 14" dbh, and Yellow poplar to 10" dbh, with Sycamore to

8" dbh, Willow oak (*Q. phellos*) to 6" dbh, Red maple to 12" dbh, American elm to 8" dbh, and Black willow (*Salix nigra*) to 12" dbh. A few Loblolly pines to 12" dbh are scattered within the canopy. The subcanopy and shrub layers are absent. Standing water and a de-watering ditch are also in this area. See Figure A6.

Area 6 in an old **Former Beaver pond with potential wetland inclusions**, which was drained a year or more ago. It is dominated by grasses and sedges with a fringe of small caliper trees and shrubs around the perimeter. These are dominated by Black willow with Silky dogwood (*Cornus amomum*), Arrow wood (*Viburnum dentatum*), Tag alder, Red maple, Green ash, and Elderberry (*Sambucus canadensis*). See Figure A7.

Area 7 is **Mixed Bottomland Hardwoods Floodplain with wetlands**, with an average dbh of 8". It is dominated by Red maple to 10" dbh, with Black willow and Green ash also present in the canopy. The shrub layer consists of Tag alder, Arrow wood and Silky dogwood. See Figure A8.

Area 8 is **Mixed Bottomland Hardwoods Floodplain with potential wetland inclusions,** a swale-like area below the Beaver dam. It is comprised of even aged small caliper trees with an average dbh of 4". The canopy contains Black willow to 10", Green ash to 4" dbh, Red maple to 3" dbh, Sycamore to 4" dbh, and a few scattered Loblolly pines to 10" dbh. The shrub layer contains Tag alder and Button bush (*Cephalanthus occidentalis*). See Figure A9.

Area 9 is **Mixed Bottomland Hardwoods Floodplain**, has a fairly open canopy dominated by Green ash with an average dbh of 8". The canopy contains Green ash to 8" dbh, Sycamore to 12" dbh, Red maple to 24" dbh, and Yellow poplar to 10" dbh. The subcanopy consists of Red maple to 8" dbh. The shrub layer contains Black berry (*Rubus* spp.), Cane and Arrow wood. See Figure A10.

Area 10 is **Mixed Bottomland Hardwoods Floodplain with potential wetland inclusions,** similar to Area 8. It is comprised of even aged small caliper trees with an average dbh of 4". The canopy contains Black willow to 6", Green ash to 4" dbh, Red maple to 3" dbh, and Sycamore to 4" dbh. The shrub layer contains Tag alder and Silky dogwood. See Figure A11.

The sewer line that parallels Caldwell Station Creek is overgrown with small caliper trees, Black berry, and Japanese honeysuckle (*Lonicera japonica*).

The power line right-of-way is overgrown with a number of small caliper weedy species such as Sweet gum and Black locust (*Robinia pseudo-acacia*).

The undisturbed creek bank is lined with trees that range in size from small shrubs to 30" dbh, with an average dbh of 12 to 14".

5.4 Aquatic Habitat

Within the three individual stream reaches at the restoration site, riffle and pool habitats are very poor. This is due to a combination of factors, the most significant being the lack of appropriate pattern (e.g., sinuosity of the channels). The channel beds are dominated by sand and finer materials with no indications of bedrock. Current beaver activity was observed in these streams, and represents an unpredictable factor influencing aquatic habitat. Beaver dams located just downstream of the SR 21 culvert and upstream of the I-77 culvert have created large sections of upstream pooling water. An older, now breached, beaver dam was developed on Tributary #1, approximately 800 feet upstream from the confluence with Caldwell Station Creek sometime after the 1983 aerial photography was taken. This had allowed substantial upstream channel areas to fill in with sediment. The aggradational areas above the old beaver dam are now mapped as wetlands. Given both, the historical and current indications of beaver activity, it is reasonable to expect this activity to continue, regardless of the restoration. Surveys of the existing creek profiles have been made to define existing grade and bed conditions. The longitudinal profiles of the streams are shown in Figure 11. The locations of debris- and riprap-controlled abrupt drops in grade are shown on these profiles. The drops in grade form the only riffle areas in the stream, and from this data a riffle-to-pool ratio of .05 to .2 was found among the three reaches with riffle spaces ranging from 52 to 185 feet. This indicates very poor conditions in comparison to the reference reach (see Table 5) but is typical of channelized and dredged steams that are situated in aggradational floodplain settings. Since the stream was channelized, it is difficult to obtain a true or accurate Rosgen Classification. The closest approximation that can be derived yields a stream classification of C2 with virtually no sinuosity.

5.5 Protected Species

A review of the North Carolina Natural Heritage Program database (October 2003) of rare species and unique habitats for the Cornelius and Lake Norman South USGS quads shows no element occurrence records for protected species within one mile (1.6 km) of the Project Area. In addition, field investigations of the terrestrial and aquatic habitats on-site yielded no indication of protected species listed for the two quads. The table below indicates the listed species, communities and habitats for the project location.

Scientific Name	Common Name	State Status	Federal Status	Quad Status
Condylura cristata	Star-nosed mole	SC	-	Historic
Etheostoma collis	Carolina darter	SC	FSC	Current
Villosa vaughaniana	Carolina creekshell	E	FSC	Current
Aster georgianus	Georgia aster	T	C	Historic
Helianthus schweinitzii	Schweinitz's sunflower	E	E	Current
Lotus helleri	Carolina birdfoot trefoil	SR-T	FSC	Current
Thermopsis mollis	Appalachian golden banner	SR-P	-	Historic
Glyptemys muhlenbergii	Bog turtle	T	T(S/A)	Potential
Cyprinella zanema	Santee chub	SR	-	Obscure
Silphium perfoliatum	Northern cup plant	SR-P	-	Current
Basic Mesic Forest		-	-	Current
Basic Oak - Hickory Forest		-	-	Current
Wading Bird Rookery		-	-	Current

SC = Special Concern, SR = Significantly Rare, C = Candidate, FSC = Federal Species of Concern, T = Threatened, E = Endangered

5.6 Stream Geometry

The pattern, dimensions, and profile characteristics of three jurisdictional perennial stream reaches on the tracts available for restoration above SR 21 were surveyed and the survey results are shown in Figures 10, 11, 12, and 13. The morphologic parameters of three streams are listed in Tables 5a and 5b.

Pattern

All three reaches lie in bottomland settings within floodplain deposits (i.e., Monacan Series soils). Within the restoration parcels there are approximately 2,100 linear feet of Caldwell Station Creek (from the culvert up to the eastern boundary of the property). There are approximately 1,600 linear feet along Tributary #1 between the confluence with Caldwell Station Creek and the northern property boundary, and approximately 500 linear feet along Tributary #2. The lengths that were surveyed to verify the map pattern of these reaches are depicted on Figure 13, and were 2,100 feet for Caldwell Station Creek, 1,500 feet for Tributary #1, and 460 feet for Tributary #2.

Caldwell Station Creek, with the exception of one bend located approximately 900 feet upstream from the SR 21 culvert, is a straight channel that had been realigned to the southern perimeter of the floodplain prior to the earliest available aerial photography in 1938. The one bend makes the stream length slightly longer than the valley length, yielding a sinuosity of 1.14. Tributary #1 has a sinuosity of 1.1, again resulting largely from the artificial diversion of the tributary along the embankment of SR 21 to join Caldwell Station Creek upstream of the SR 21 culvert. The 1983 aerial photography shows bare dirt dredge spoils lining both banks and indicates that the channel was recently dredged. Like Caldwell Station Creek, it was straightened along the perimeter of the floodplain prior to the 1938 aerial photography. Tributary #2 has a sinuosity of 1.1. This tributary has not been clearly identified in the historic aerial photographs, but is believed to be straightened, given its morphologic attributes.

Dimensions

Cross sections were surveyed for all three tributaries to determine the existing cross section areas for flow and to provide information to estimate existing bankfull parameters and bankfull discharges using the Manning's Equation (discussed in Section 5.2.3). The cross sections are shown in Figures 10 and 12, along with summaries of the dimensional parameters of bankfull width, cross section area, mean and maximum bankfull depth, and the width/depth (W/D) ratios. In all cases, the flood prone stage (2 x the maximum bankfull depth) was well above the existing elevation of the floodplain, such that entrenchment ratios, while in all cases greater than 5, could not be determined from the cross section information. The estimates of bankfull stage were determined by bank erosional features developed in the upper bank profiles, but were found to be inconsistent from one cross section to the next. This could be due to channel obstructions, or other factors, that have locally influenced bank erosion or channel hydrology. The average bankfull cross-sectional area for Caldwell Station Creek is 29.9 square feet, is slightly higher than predicted from the rural Piedmont regime equations. Also, the area is only 50 percent of the area seen in the reference reach (discussed further), and only 40 percent of the area predicted using the urban regime curves. The changes seen from one cross section to the next along this reach, despite its straight alignment, argue that reach is out-of-regime, with some segments undergoing bank failure, bed aggradation, and commensurate increases in W/D ratios (cross sections #4 and #6). Other cross sections remained largely unchanged (cross sections #1, #2, #3, and #5). Two cross sections surveyed for Tributary #1 (cross sections #7 and #8), presented in Figure 12, show dramatically different cross-sectional areas, and both are smaller than required bankfull-event area of rural Piedmont streams with similar watershed size. The dimensions here have been impacted by at least two periods of channelization and dredging, as well as the aforementioned beaver activity. One cross section was surveyed for Tributary #2 (cross section #9). This cross section shows bankfull values similar in proportion to the rural curves as Caldwell Station Creek, with values slightly higher than those for rural conditions, but less than half that seen for urban settings.

Longitudinal Profile

Longitudinal profiles were surveyed along all three reaches and are shown in Figure 11. In each profile the riffle areas are broken out so that a riffle/pool ratio, average riffle spacing, and grades can be accurately determined for each bed zone. All three reaches are characterized by short or abrupt changes in grade, and in almost all cases these were produced by debris blocking the low flow channel bottom. Despite the floodplain setting, the grades in Caldwell Station Creek upstream of SR 21 culvert and Tributary #1 are almost twice the grades seen in the reference reach (discussed below) or in the Caldwell Station reach below the SR 21 culvert. The average water surface slope for Tributary #1 is artificially too steep due to the channel diversion that was made when SR 21 was constructed. The profile shows an abrupt steepening of the grade as the channel enters the diversion zone along the base of the road embankment. The grade for Caldwell Station Creek is steeper than expected due to the low sinuosity of the creek. Tributary #2 has the steepest grade of the three streams (.012), and is likely also impacted by channelization. Tributary #2 is a lower order stream than the other two, and thus a slightly higher grade would be expected.

5.7 Stream Substrate

The channel beds of all three reaches were surveyed for riffle and pool areas, as well as bedrock. The riffle areas exist due to either riprap infill (laid in Caldwell Station Creek upper sewer line crossing near the SR 21 culvert) or woody debris deposition. No bedrock has been encountered in any of the surveyed reaches. All reaches are characterized by sandy material with very limited zones of fine gravel and pebbles. Samples of bed materials for grain size analysis were collected from typical lateral and medial bars within the channelized reach of Caldwell Station Creek above SR21. The results are shown in Figure 20a, and indicate a low range in grain sizes with a mean of .08 mm (coarse sand).

5.8 Constraints

5.8.1 Utilities

The stream restoration design has several sources of constraints that are outside the realm of fluvial morphology and hydrology. First, two existing wastewater mains run in parallel direction with Caldwell Station Creek and Tributary #1 and are in close proximity. The mains cross these streams in several places in the project area. Second, the high probability of increase in impervious area due to watershed build-out, leading to increased peak flow runoff rates, is a real concern.

5.8.2 FEMA Issues

The preliminary engineering report prepared for Mecklenburg County by Watershed Concepts in 2003 (see Appendix C) indicates that under current conditions the SR 21 culvert does not pass the 100-year flood, and will result in overtopping SR 21. No structures in this part of the watershed lie within the 100-year floodplain.

The FEMA Flood Insurance Rate Map (FIRM) panel number 0046 for Mecklenburg County and incorporated areas, which includes the project area, was updated in February 2004. Since the majority of the project area lies within the FEMA detailed study limits, the proposed wetland and stream restoration project will be located inside the Caldwell Station Creek floodway boundary. Therefore, due to possible changes in 100-year WSE, the hydraulic analysis of this development is required.

The available HEC-RAS model (Model) of this FEMA study shows four model cross sections upstream of SR 21 culvert and their WSE during the 100-year storm event. The terrain changes resulting from the project will need to be reflected in the Model and a "No-Impact" on the 100-year WSE must be documented and certified.

The modeling process requires the following steps:

- Development of the correction to the existing model by updating the existing FEMA Model with recent surveyed terrain topographic data.
- Adding more modeling cross sections in the area of proposed changes into the corrected existing model – creating an effective existing model.
- Implementing the proposed changes into the cross sections – creating an effective proposed model.
- Comparing the effective existing and effective proposed model for any changes.

5.8.3 Protected Species and Cultural Recourses

Protected species and cultural resources will not be impacted by the proposed restoration plan and therefore they do not present any design constraints.

6.0 STREAM AND WETLAND RESTORATION PLAN

6.1 Wetlands Restoration Plan

There are four general approaches to wetland restoration: creation, restoration, enhancement, and protection. The bottomland settings of the restoration tracts are natural environments for bottomland hardwood wetlands.

Of the 21 acres of available land in the restoration parcels, there are approximately 7.3 acres of wetlands that are likely to meet jurisdictional wetland criteria based on existing hydrology, plant communities, and soils (see Figure A12 in Appendix A). These existing areas are considered threatened due to precarious hydrologic conditions and are likely candidates for enhancement and preservation. There are 1.2 acres of transitional wetlands, wherein one can find mixed wetland and non-wetland plant and soil conditions. The upper 12 inches of soil in the transitional zone are currently saturated, but this may not persist significantly into the growing season. The area of mixed conditions would likely be available for either restoration or enhancement, depending on verification of the current jurisdictional status. Lastly, there are approximately 2.5 to 3 acres of riparian bottomlands, where wetlands may be restorable if stream restoration can be performed in a manner that enhances wetland hydrology. The three classes of potential wetland restoration are shown on Figure 15, and conceptual design plans for all three classes of restoration are discussed below.

6.2 Enhancement and Preservation Zone

Water level recorders have been installed to monitor soil hydrology in the upper 18 inches over the next few months. Soils in this zone are largely Monacan Series floodplain silts and sands with an upper hydric soil horizon. Hydric conditions are not as uniform as wetland hydrology and vegetation would indicate, and believed to be due to the unstable, aggradational nature of the floodplain. Newly laid floodplain deposits are oxidized sediments derived from upland soils, and will only become reduced as organic matter accumulates and decays over time within a seasonally saturated soil environment. Thus, in some zones, such as the old beaver pond area, some borings have yielded hydric soils, while others show upper oxidized layers overlying reduced organic-rich horizons.

In order to enhance the existing wetlands area, the following four strategies are proposed. First, existing overland drainage shall be intercepted upslope of wetland areas and redirected into wetland areas by appropriate grading without the use of hard structures. Second, existing drainage ditches within the bottomlands (old field drainage ditches) should be blocked and existing wetland areas strategically bermed along downslope fringes to restrict overland outflow. Third, to the feasible extent, stream restoration will be performed in a manner that allows seasonal/spring overflow of the storms approaching the bankfull discharge recurrence. The implied shorter bankfull recurrence interval is justified for E class Rosgen channels. Finally, planting will occur to enhance wetland ecology that will increase organic soil contents; a necessary precursor to hydric soil development.

6.3 Enhancement/Restoration Zone

The 1 to 2 acres of land with some indications of wetland conditions are to be enhanced or restored to bottomland wetlands by the same mix of strategies described in Section 6.2. In this area, where existing vegetation is not of significant value, an additional strategy will initiate a more aggressive program of regrading within the floodplain to promote wetland hydrology. The existing topography is currently being mapped at the 6-inch contour level to facilitate detail planning for restoration in this zone. Once the mapping is completed, the data can be combined with the vegetation data to determine which soil areas could be regraded to promote wetland hydrology and hydric soil development. Depending on the soil characteristics, some soil amendments may also be exploited. Otherwise, the same strategies as described in Section 6.2 for the area enhancement and preservation shall be used.

6.4 Restoration/Creation Zone

There are an additional 3 acres of land distributed along the central corridor and southern fringe of the property that represent opportunities for additional wetland restoration. There are basically three environments, which could be transformed into bottomland hardwood wetlands. Two of these environments constitute restoration and one creation.

The first restoration area lies along the southern edge of the enhancement/restoration zone, and represents the potential expansion of this wetland area if the strategies used to enhance the transitional wetland areas are successful. The expanded areas abut the proposed realigned and restored Caldwell Station Creek, which would have a margin of elevated relief to retain overbank flow within the floodplain fringe in the periods following overbank flow storm events. Surface drainage would be terminated from all wetland areas, such that interflow or groundwater flow would be the only output, other than evapotranspiration. Where feasible, low permeability soils will be used for surface regrading in wetland areas, as the maintenance of perched water table conditions will be essential to meet hydrologic wetland criteria in proximity to the restored Tributary #1 or Caldwell Station Creek.

The second restoration wetland area is located along the southernmost edge of the property, where it may be feasible to restore hillslope wetlands when the existing Caldwell Station Creek is moved over to the central corridor of the restoration tract. The proposed new alignment for Tributary #2 will use the old Caldwell Station Creek alignment, but will have a higher elevation through the zone with E-class channel dimensions that promote seasonal overbank flows and increase the local water table in this zone. As the zone lies along the north facing toe of the hillslope, low solar radiation and enhanced seasonal overbank flows have a reasonable chance of creating the hillslope wetlands in this area.

The one area of wetland creation lies in a proposed linear hollow that would be left along the abandoned channel alignment of Caldwell Station Creek. The natural reference model for wetlands of this nature is an abandoned "ox-bow." As meander bends grow and eventually cut off on E-type channels in floodplain settings, they fill and eventually create bottomland hardwood wetlands. The bottom of the abandoned channel will lie near, or above, the regional water table. In the case of the proposed abandoned alignment for Caldwell Station Creek, it should be possible to infill and broaden the old channel bottom to create a broader hollow of bottomland hardwood wetlands. A detailed grading plan for this area will be created after the detailed topographic maps of the site are available.

6.5 Stream Restoration Plans

All three perennial stream channels on the property were previously modified and have altered pattern, dimensions, and profile characteristics. In order to develop an appropriate design framework for these channels, it was essential to find and document a stable, natural, E-type Rosgen channel for a watershed of similar size, land use, physiographic, and geologic setting. Over 20 potential reference reaches located nearby were investigated over the course of two months, and finally a stable E-reach was found located north of the project site in the Mooresville, NC, area along the lower portions of West Fork Reeds Creek. The documentation of the reference reach is enclosed in Appendix D, and the reference reach morphologic parameters are summarized in Tables 5a and 5b along with the parameters for existing conditions of the degraded reaches. The reference reach data is directly applicable to design parameters for Caldwell Station Creek and Tributary #1 under current watershed land use conditions. Additional reference reach data collected from smaller tributaries in the Charlotte area are shown in Table 5b for the restoration design for Tributary #2. The reference reach information in conjunction with NC Piedmont regime data and site constraints are all used in combination to formulate the best possible design constraints to achieve habitat, water quality, and channel stability goals. As such, the restoration parameters listed in Tables 5a and 5b represent a balanced consideration of all governing factors.

The preliminary restoration design established new alignments for 1,861 linear feet of Caldwell Station Creek, 160 linear feet of Tributary #1, and 1,539 linear feet of Tributary #2 (Figure 15). Approximately 420 additional linear feet of Tributary #2 is proposed for enhancement (Figure 15a). This brings the potential total stream restoration and enhancement to 3,980 linear feet. All three of the reaches proposed for restoration involve adding new significant elements to the pattern, dimension, and profile. The proposed alignments shown in Figure 15 have been selected to be appropriate to current land use and hydrologic attributes, as well as to protect and enhance riparian wetlands. Meander belt widths, radii of curvature, and sinuosities are all based on consideration of reference reach conditions as well as site-specific constraints.

The stream restoration plan is shown in more detail in Figures 15b and 15c. Figure 15b shows the proposed new alignments overlain on the more detailed topography of the site that was collected in order to formulate the hydrologic improvements for wetland habitat. The plan shows how the new alignments in combination with strategically placed bank and floodplain low head (< 1 ft) levees and small berms will augment both the frequency of flooding and duration of saturation with the various components of the wetland areas. Bank side levees mimic those found in natural E-type channels of the North Carolina Piedmont, and are thus consistent with a design-to-nature approach. A number of smaller old drainage gullies will be blocked.

Figure 15c shows the locations of the instream bank stability and habitat features. The design uses bio-engineering approach that integrates habitat and stability measures on a feature-by-feature basis. The instream structures are discussed further in the next section. The riffle zones shown in the inflection areas of the stream are diagrammatic in their length on this plan. The average riffle length and spacing are shown in Tables 5a and 5b.

The restoration of dimensional attributes for the restoration reaches is illustrated in Figures 16a and 16b. Figure 16a shows cross sections from which one can determine the inter-relationship of the channel restoration measures to the surrounding floodplain. Figure 16b illustrates the consistency of the proposed restoration channel dimensions to the specific design dimensional parameters of Tables 5a and 5b. The detail cross sections located at Figure 16b also illustrate the designed stabilization measures and the proposed vegetated zones. The planting design detail is presented in the Section 6.7.

The restoration longitudinal profiles for UT#2 and Caldwell Station Creek are shown in Figure 17. The length of the riffle zones, their spacing, and riffle/pool ratios are based on the reference reach conditions. Riffle and pool slopes have been adjusted to match overall E-type channel valley slope constraints. The slope of the riffle zones has been checked for continuity with transportable dominant (D_{50}) grain sizes, and therefore, over time with bankfull events, should not aggrade under nominal environmental conditions. The emplacement of meander bends within the restored reaches will result in the excavation of 4- to 18-inch pools along the reaches within each pool area. These pools are not shown on Figure 17 as they will naturally develop hydraulically in a short period (generally 1 to 3 years) after the restoration is completed. The armoring of the inflection zone riffle areas with rounded natural river cobble with a D_{84} sized for immobility will promote and enhance long term riffle habitat. Thus the restoration will produce a dramatic improvement in aquatic habitat in the reach with both the restored pool and riffle areas. Over 90 percent of the existing stream channels consist of sand runs with very low habitat.

6.6 Stability and Sediment Transport Analysis

There are four approaches to the analysis of stability for this restoration project. First is the reference reach 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, such as disruption of normal tendency by odd events or features (e.g. hurricane, downed tree, small pond, etc.). Neither the reference reach nor the 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 Caldwell Station and two approaches for the critical traction force analysis.

Finally, stability can be examined from a structural viewpoint. Structures can be emplaced 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.

6.6.1 Reference Reach and Regime Analysis

Tables 5a and 5b show reference reach information gathered from various sources. None of the reference reaches are sufficiently comparable in stream or watershed attributes to use a direct design template and assurance for stability. The restoration morphologic parameters need to reflect the anticipated future changes in the contributing catchment, as well as the wetland restoration goals within the adjacent floodplain. Increasing overbank flooding to improve wetland hydrology means increasing the frequency of the bankfull event. This is accomplished in two different approaches for UT#2 and Caldwell Station. UT#2, which is fed by in part by large commercial parcels with requirements for storm water BMP's, needed to have slight dimensional adjustments in the restoration plan, as there is less expectations for increased storm flow with mitigating BMP's in place. For the larger Caldwell Station Creek, however, the build out landuse will be primarily residential with no anticipated requirements for storm water BMP's. For this restoration, dimensions slightly over the rural dimensions, but significantly under the dimensions for urban conditions have been selected to meet project goals.

The regime equations developed for the rural and urban Piedmont were shown in section 5.2.2. The regime values for the restoration reaches are shown in Table 3. As previously discussed, the reference reach data are reasonably consistent with the regime curves, and therefore, provide a reasonable basis for the extrapolation and selection of restoration parameters.

The restoration design attached in planform, section, and longitudinal views of Figures 15, 15a, 15b, 16a, 16b, and 17 can be characterized by the morphologic parameters indicated in Tables 5a and 5b. Meander bend radii of curvature, wavelength, meander belt width, riffle/pool ratios, sinuosity, bankfull widths, depths and cross section areas have all been selected to be consistent with the range of conditions seen in the reference reach data, and the North Carolina regime data. While the primary concern is the impact of future urbanization on the restoration morphology, this concern is largely mitigated by the construction of E channels with aggressive grade control. All morphologic elements have been selected to be hydraulically in equilibrium with a morphologically-defined bankfull flow event. As E channels have abrupt attenuations of bed traction forces and mean velocities with flood stages over the bankfull elevation, the frequency of bankfull events cannot be considered a determinant morphologic attribute of the reach. For these reasons, a fixed bankfull discharge design approach is not required to assure stability.

6.6.2 USDA and USACE Velocity Analysis

The USACE (1994) published a graph of allowable velocity-depth data for granular materials ranging in size from 0.1 to 500 millimeters (mm). The range of expected bankfull mean velocities is listed in Tables 5a and 5c, and extends from approximately 2.5 to 4.5 feet per second (fps). The expected range in velocities are plotted in Figure 19 on a stability chart from the USACE (1994) that can be used determine the range of sizes of granular materials that would be unstable as exposed incohesive materials along the channel. This is the shaded area shown in the figure. From this analysis, it is clear those materials with $D_{50's}$ less than 1 centimeter (cm) will be unstable with Caldwell Station Creek, and .1 cm for UT#2. For these reasons all banks areas with fine soils will need to be matted to protect banks until vegetation is established with good root density and depth.

6.6.3 Newbury and Gabory's (1993) Traction Force Criteria and Shield Curve Analysis

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

This 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 force versus grain size analyses and curves are sometimes referred to as Shield Curves. Tables 5a and 5b include calculations of the bed traction force derived using the following equation:

Tau (kg/m^2) = 1,000 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. For a successful restoration, one is more concerned with the maximum conditions that may exceed thresholds and trigger failure in the channel system. Thus, the DS rather than RS method is used here to calculate critical traction forces. The values in the tables are estimated for the floodprone stage. The corresponding threshold diameters for particle stability (using the first equation) are then multiplied by a 1.5 safety factor, and used to determine the D_{84} for the inflection zone grade control cobble and cross vane material.

Figure 18 shows a variation of a “Shield Curve” with data from Leopold (1964). On this figure the expected conditions for events with floodprone stages (2 x maximum Bankfull depth) are plotted to show the corresponding stable threshold particle sizes for both Caldwell Station Creek and UT#2. These values are lower than the design diameters for riffle armor and cross vanes and thus indicate the design should be adequate to stabilize the bed.

6.6.4 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.

First, with respect to bed or grade stability, at the upper and lower tie-in points on affected reaches cross vanes will be installed with rock sized for immobility. Second, cross vanes are to be installed approximately every 4th inflection zone in conjunction with the cobble material to augment riffle habitat. Again cross vane and riffle materials are sized to promote long term bed stability. The estimates for D_{50} and D_{84} for riffle armor are noted in Tables 5a and 5b.

Where the proposed new channels leave the old alignments, channel plugs will be installed up to the surrounding floodplain elevation for a minimum distance of 20 feet.

Inner meander bends are graded to a lower slope (≈4:1; run/rise) to allow attenuation of flood velocities at or near the bankfull stage. The outer banks of meanders are treated either with a series of 2 to 3 rock vanes or with the layered footer - coir fiber log - brush mattress - soil lift system shown in Figure 16b. The footers buried below the low flow water line with allow meander pool development without bank toe failure and coir fiber roll subsidence. The brush mattress will leaf out and provide pool shade, bank resistance to sloughing and rotational failure, and displace the thalweg high velocity line away from the bank, lowering bank shear stresses. The overlying soil-lift will distribute bank load over the brush mattress and prevent soil loss and bank sloughing.

Typical installation schematics will be included in the final construction documents for all features.

6.7 Planting Plan

The vegetation installed as part of the Caldwell Station stream restoration project is an integral component that provides stability, habitat enhancement and long-term project viability. As such, the HDR/HARP team has provided a master list of commercially available species that can be used for the planting of the proposed wetland restoration and enhancement zones and the new stream corridors.

Initially the Caldwell Station Creek site was segregated into ten zones of vegetation communities, based on the existing plants, topography, and hydrology. However these 10 components can be grouped into three existing and one potential zone, for enhancement. Figure 21 shows the regrouping of the ten zones in four zones, A, B, C and D. The planting plan is therefore based on the four zone arrangement.

A Master List for shrubs and trees (Table 6a) and Zone specific planting lists (Table 6b) have been developed as the basis of the plan. Since quantities and types of commercially available material changes due to environmental conditions, nursery availability and active project requirements, not all of the species listed will be used in the final planting effort. However, the list is broad enough such that ample species and quantities should be available at the time of planting.

6.7.1 Legend for the Proposed Planting Zones

The enclosed planting lists for the proposed planting plan have been developed primarily for enhancement of the existing flora. As such, the species recommended for the A, B, and C Planting Zones are those selected from the Master Lists of Trees and Shrubs that do not occur (or are not abundant) on this site. Selecting these species provides for a greater diversity in the final product. It is assumed that the existing flora will provide the propagules for volunteer fill-in of the site.

No attempt has been made to recreate a "typical" natural N.C. Plant Community, as described by Schafale and Weakley, but rather an enhancement of a diverse habitat in the Piedmont, using species native to this physiographic province.

6.7.2 Zone Descriptions

Zone A - This zone is a relatively dry bottomland hardwood forest. There may be seasonal flooding, but standing water is not a long-term condition.

Zone B – This zone is a wet bottomland hardwood forest. Seasonal flooding occurs with extended periods of standing water. Jurisdictional wetlands are a component of this zone.

Zone C – This is the vegetation of the restored streambank. The shrub species selected are those that will provide maximum bank stability and potential shade for the aquatic habitat.

Zone D – This zone includes easements and potentially disturbed areas that require planting following construction. Areas in this zone have not been determined as yet. They may fall into Zones A-C, or as a result of construction, could constitute a new zone.

7.0 STREAM AND WETLAND PERFORMANCE CRITERIA AND MONITORING PLAN

Restoration of Caldwell Station Creek and Tributaries #1 and #2 will be deemed a success after the monitoring period is complete. The stream channel should maintain its dimension, pattern, and profile over time. Additionally, instream structures should remain secure and stable during the monitoring period. The wetlands should maintain a steady vegetative growth of diverse, non-invasive and native plant species. The plant species should appear healthy. Organic matter is expected to accumulate.

It is also 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., down cutting, deposition, and/or erosion) or if they are minor changes that represent an increase in stability (e.g., settling, changes in vegetation, and/or decrease in width-to-depth ratio). Unstable conditions that require remediation will indicate failure of restoration activities.

7.1 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.

7.2 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 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. Permanent sampling quadrats will be established at random locations within the restoration site. Expected desired species will be monitored and records of sampling locations will be maintained. Non-native, exotic, and undesirable species will be noted during the sample collection.

7.3 Monitoring Schedule

Annual monitoring is required for a minimum five-year period beginning in 2006, until success criteria are met. Reports will be submitted annually to the USACE and the NCDWQ Ecosystem Enhancement Program.

7.4 Monitoring Methods

Monitoring at established locations will ensure consistency and allow comparison of data over time. Permanent cross-sections will be established in Caldwell Station Creek and Tributaries #1 and #2. Cross-section changes can indicate changes in the width-to-depth ratio of the stream. Bank slopes and the flood plain bench 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.

Wetlands will be monitored at sufficient number of established quadrats. The records of a specie density, growth of cross-sectional area, height, and coverage will be maintained and compared to reference community. The shifts in the plant community detected from year to year provide a basis for management decisions. Wetland hydrology will be monitored to demonstrate improvements in the number of days of saturated soil conditions in the upper 12 inches during the March 15th to November 15th growing season and/or the frequency of overbank flooding. In addition anaerobic wetland soil conditions shall be demonstrated by monitoring soil redux values within the wetand restoration areas. These shall be determined using standard field techniques for saturated soils (i.e. using calibrated platinum-tipped and reference-bridge soil Eh probes).

8.0 STREAM AND WETLAND RESTORATION BENEFITS

The primary goal of stream restoration is to promote long-term channel stability. Channel stability implies sediment transport continuity, aquatic habitat stability, and improvement of water quality, for all of the reasons described in Section 2.0. Most elements affecting channel flow regime can also influence channel stability. Thus, all aspects of the proposed work must be evaluated using a number of analytical; means (mostly by comparison to known stable reference streams or published hydraulic relationships).

The secondary goal of stream restoration is to enhance and stabilize aquatic habitat within the low flow channel. Currently, the channel has a scarcity of both pools and riffles.

The primary goals of wetland restoration are to improve the overall water quality and provide for water storage, flood conveyance, aquatic habitat, enhanced stability, and aesthetic improvement to the watershed.

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TABLES

Table 1. Landcover Analysis - Caldwell Station Creek, Unnamed Tributaries #1 and #2, and Little Hope Creek

	UT #2 to Caldwell Station Creek		*UT #1 to Caldwell Station Creek*		*Caldwell Station Creek*		*West Fork Reeds Creek*		*Little Hope Creek*	
Class	**Samples**	***Percent***	**Samples**	***Percent***	**Samples**	***Percent***	**Samples**	***Percent***	**Samples**	***Percent***
decid_trees	14629	*42.2*	29914	*35.1*	30615	*34.5*			935817	*21.5*
conif_trees	1820	*5.2*	4354	*5.1*	7030	*7.9*			0	*0.0*
Subtotal trees	16449	*47.4*	34268	*40.2*	37645	*42.4*			935817	*21.5*
grass1	1405	*4.0*	10441	*12.2*	10517	*11.9*			343842	*7.9*
grass2	5219	*15.0*	15331	*18.0*	11159	*12.6*			594072	*13.7*
Subtotal grass	6624	*19.1*	25772	*30.2*	21676	*24.4*			937914	*21.6*
scrub-shrub	1526	*4.4*	2696	*3.2*	2912	*3.3*			0	*0.0*
Total Pervious	**24599**	***70.9***	**62736**	***73.5***	**62233**	***70.1***			**1873731**	***43.1***
Com/ind-bldg	1301	*3.7*	4470	*5.2*	2854	*3.2*			328196	*7.5*
asphalt	2301	*6.6*	5688	*6.7*	5120	*5.8*			485470	*11.2*
asphalt2	3310	*9.5*	6523	*7.6*	11911	*13.4*			277678	*6.4*
shingled_bldg	946	*2.7*	3399	*4.0*	4788	*5.4*			470646	*10.8*
shingled_bldg2	217	*0.6*	446	*0.5*	190	*0.2*			697324	*16.0*
shingled_bldg3	2031	*5.9*	2076	*2.4*	1629	*1.8*			214335	*4.9*
Total Impervious	**10106**	***29.1***	**22602**	***26.5***	**26492**	***29.9***			**2473649**	***56.9***
Total	34705	*100.0*	85338	*100.0*	88725	*100.0*			4347380	*100.0*

Table 2. Annual Peak Flows (Little Hope Creek)

(USGS Gage St. 02146470)

Year	Date	Stage (ft)	Discharge (cfs)
1967	8/22/1963	8.12	1110
1968	6/8/1964	7.91	1020
1969	7/23/1965	6.39	487
1971	5/12/1967	7.32	788
1972	7/25/1968	8.39	1240
1983	12/5/1979	7.02	1170
1985	6/6/1981	8.47	1680
1988	8/27/1984	6.36	684
1989	5/8/1985	7.09	988
1990	5/26/1986	6.49	736
1995	8/26/1991	7.77	1280
1996	8/10/1992	6.64	766
1997	7/22/1993	8.50	1700
1998	4/8/1994	7.91	1350
1999	1/22/1995	6.70	791
2000	7/11/1996	5.81	454
2001	6/27/1997	5.68	412
2002	5/29/1998	6.60	749

BEST FIT discharge (cfs) = 539.15 + 1067.8 x log (Return Interval (year))

Return Interval (year)	Discharge (cfs)
0.5	218
0.75	406
1	539
1.25	643
1.5	727
2	861

Table 3. North Carolina Rural and Urban Piedmont Regime Calculations

Site	Drainage Area A_w	Drainage Area A_w	**Urban** (Doll et al., 2000) X-Section Area A_{bkf}	Flow Q_{bkf}	X-Section Area A_{bkf}	Flow Q_{bkf}	Bankfull Width W_{bkf}		Bankfull Depth D_{bkf}		**Rural** (Harmon et al., 1999) Flow Q_{bkf}	X-Section Area A_{bkf}	Flow Q_{bkf}	X-Section Area A_{bkf}	Bankfull W_{bkf}	Width Depth D_{bkf}
	(sq.miles)	(sq.km)	(sq.m.)	(cms)	(sq.ft.)	(cfs)	(m)	(ft)	(m)	(ft)	(cfs)	(sq.ft.)	(cms)	(sq.m.)	(ft)	(ft)
Caldwell St. Creek	1.36	3.52	6.96	11.15	74.94	393.73	8.66	28.42	0.81	2.65	87.52	23.06	2.48	2.14	13.57	1.66
Caldwell St. Creek Trib.1	1.02	2.64	5.79	9.46	62.34	334.19	7.90	25.92	0.74	2.42	67.75	18.58	1.92	1.73	11.99	1.51
UT#2 To Caldwell St. Ck.	0.40	1.04	3.18	5.55	34.24	196.00	5.86	19.21	0.55	1.79	29.45	9.21	0.83	0.86	8.02	1.12
Caldwell St. Creek -below confluence with Trib.#1	2.39	6.19	9.99	15.38	107.51	542.97	10.38	34.04	0.97	3.17	144.56	35.20	4.09	3.27	17.29	1.98
West Fork Reeds Creek	1.49	3.86	7.38	11.75	79.45	414.76	8.92	29.26	0.83	2.73	94.93	24.69	2.69	2.29	14.11	1.70
Little Hope Creek, Seneca Place	2.49	6.45	10.25	15.74	110.36	555.80	10.51	34.49	0.98	3.22	149.93	36.29	4.25	3.37	17.60	2.01

Site	Drainage Area A_w	Drainage Area A_w	**Urban** (Mecklenburg County; Forsythe et al., 2004) Flow Q_{bkf}	X-Section Area A_{bkf}	Flow Q_{bkf}	X-Section Area A_{bkf}	Bankfull W_{bkf}	Width Depth D_{bkf}
	(sq.miles)	(sq.km)	(cfs)	(sq.ft.)	(cms)	(sq.m.)	(ft)	(ft)
Caldwell St. Creek	1.36	3.52	206.43	55.48	5.85	5.15	23.54	2.35
Caldwell St. Creek Trib.1	1.02	2.64	171.71	46.15	4.86	4.29	21.65	2.12
UT#2 To Caldwell St. Ck.	0.40	1.04	94.32	25.35	2.67	2.36	16.51	1.53
Caldwell St. Creek -below confluence with Trib.#1	2.39	6.19	296.12	79.59	8.39	7.39	27.72	2.86
West Fork Reeds Creek	1.49	3.86	218.85	58.82	6.20	5.46	24.17	2.43
Little Hope Creek, Seneca Place	2.49	6.45	303.99	81.70	8.61	7.59	28.05	2.90

Table 4. Manning's Equation Based Discharge Calculations at the Morphologic Bankfull Channel Dimensions

Stream	Bankfull X-section Area (sq ft)	Bankfull Width (ft)	Bankfull Mean Depth (ft)	W/D Ratio (ft/ft)	Hydraulic Radius (ft)	Wetted Perimeter (ft)	Manning's Coefficient n1	Manning's Coefficient n2	Slope (ft/ft)	Discharge: Manning's Equation ^Q_1 (cfs)	Discharge: Manning's Equation ^^Q_2 (cfs)	Discharge: Regime Equation Q_r (cfs)	Discharge: Regime Equation Q_u (cfs)
Caldwell Station Creek	29.9	13.0	2.3	5.9	1.699	17.6	0.04	0.03	0.0052	**114.0**	**152.1**	**87.5**	**206.4**
Caldwell Station Creek Restored	52.0	20.0	3.8	5.3	1.884	27.6	0.04	0.03	0.004	**186.4**	**248.5**	**87.5**	**206.4**
Unnamed Tributary #1	10.4	9.0	1.2	8.1	0.912	11.4	0.04	0.03	0.0058	**27.7**	**36.9**	**67.8**	**171.7**
Unnamed Tributary #2	13.2	7.3	1.8	4.0	1.211	10.9	0.04	0.03	0.0012	**19.3**	**25.7**	**29.5**	**94.3**
Unnamed Tributary #2 Restored	9.0	9.0	1.0	9.0	0.818	11.0	0.04	0.03	0.004	**18.5**	**24.7**	**29.5**	**94.3**
West Fork Reeds Creek	61.9	20.3	3.1	6.7	2.336	26.5	0.04	0.03	0.0017	**166.9**	**222.6**	**94.9**	**218.8**

^ Discharge based on a Manning roughness of .04

^^ Discharge based on a Manning roughness of .03

Q_r Rural regime discharge estimate

Q_u Urban regime discharge estimate

Table 5a. Estimates of Fluvial Morphologic Parameters – Caldwell Station Creek

Parameters	Caldwell Station Existing Conditions	Reeds Creek West Fork Reference Reach	Caldwell Station Restoration Parameters
Watershed Area (sq. miles)	1.36	1.49	1.36
Bankfull Width (ft)	13	20.3	20
Bankfull Area (sq. feet)	29.9	61.9	50
Ave. Bankfull Depth (feet)	2.3	3.1	3 to 3.8
Max. Depth (feet)	3.2	4.9	4 to 5
Flood Prone Width (feet)	>100	>100	>100
Entrenchment Ratio	>7.6	>5.1	>5
Width/Depth Ratio	5.9	6.7	5 - 6.5
Valley Slope (feet/feet)	0.0046	0.0020	0.0052
Average Water Slope (feet/feet)	0.0046	0.0017	0.004
Sinuosity	1	1.2	1.2
Riffle/Pool Ratio	0.077	0.51	0.5
Riffle Slope	0.08	0.0028	0.01
Pool Slope	0.0018	0.0013	0.0012
Ave. Riffle Spacing (feet)	185.4	28.1	63
Riffle Substrate D50 (mm)	NA	3.2	3.2
Riffle Substrate D84 (high) (mm)	NA	6.8	6.8
Riffle Armour D50 (mm)	NA	17.0	200.0
Riffle Armour D84 (high) (mm)	NA	28.0	400.0
Bulk Stream Bed D50 (mm)	0.8	4.5	0.8 to 3.2
Bulk Stream Bed D84 (high) (mm)	1.5	7.3	1.5 to 7
Meander Radius of Curvature (ft)	29.6	41.2	41.2
Meander Wave Length (ft)	N/A	111.2	111.2
Meander Belt Width (ft)	N/A	76.2	76.2
Bankfull Discharge (cfs) *	114 to 152, avg.: 133	167 to 223, avg.: 195	186 to 249, avg.: 217
Bankfull Est. Mean Velocity (ft/sec)	4.5	3.15	4.34
Floodprone (2x Bankfull stage) Bed Shear Stress (Newtons/sq m)	1541.41	82.61	270.95
Maximum Diameter for Bankfull Sediment Movement (cm)	157.29	8.43	27.65
Floodprone (2x Bankfull stage) Bed Tractive Force (lb/sq ft)	33.55	1.80	5.90
Rosgen Class **	Channelized Ditch	E3	E3

* Estimated using Manning Eq. Assuming Manning Coef. .03 min, .04 max, .035 avg.
** Rosgen & Silvey, 1998

Table 5b. Estimates of Fluvial Morphologic Parameters – UT#2

Parameter	UT to Mill Ck. Lewisville, NC, Forsyth Co.	UT to Yadkin River Yadkin Co.	Flat Branch, Six Mile Ck. Mecklenburg Co.	UT#2 to Caldwell Station Ck. Existing Conditions	UT#2 o Caldwell Station Ck. Restored Conditions
Watershed Area (sq. miles)	0.29	0.38	0.30	0.4	**0.4**
Bankfull Width (ft)	6.7	7.5	10.0	7.3	**9**
Bankfull Area (sq. feet)	6.6	9.8	9.1	13.2	**9**
Ave. Bankfull Depth (feet)	1.0	1.3	0.9	1.8	**1**
Max. Depth (feet)	1.4	1.5	1.8	2.5	**1.8**
Flood Prone Width (feet)	25.0	9.8	24.5	NA	**45**
Entrenchment Ratio	3.73	1.31	2.45	NA	**5**
Width/Depth Ratio	6.7	5.8	11.0	4	**9**
Valley Slope (feet/feet)	0.012	0.016	0.010	0.013	**0.005**
Average Water Slope (feet/feet)	0.009	0.014	0.009	0.012	**0.004**
Sinuosity	1.30	1.11	1.10	1.11	**1.27**
Riffle/Pool Ratio	0.62	0.65	2.29	0.11	**0.6**
Riffle Slope	0.018	0.030	0.021	0.17	**0.008**
Pool Slope	0.003	0.003	0.003	0	**0.003**
Ave. Riffle Spacing (feet)	15.38	41.00	39.00	52.8	**31**
Riffle Substrate D50 (mm)	NA	1.00	8.50	<1.00	**8 to 20**
Riffle Armour D50 (mm)	NA	NA	NA	NA	**66.3**
Riffle Armour D84 (mm)	NA	NA	NA	NA	**132.7**
Bulk Stream Bed D50 (mm)	NA	0.58	2.80	<1.00	**<1.00**
Meander Radius of Curvature (ft)	15.2	19.0	25.0	22.4	**24**
Meander Wave Length (ft)	56	93	44	128.3	**90 - 100**
Meander Belt Width (ft)	33	50	35	N/A	**35**
Bankfull Discharge (cfs) *	22.21	47.97	30.18	69.94	**21.20**
Bankfull Est. Mean Velocity (ft/sec)	3.38	4.92	3.32	5.30	**2.36**
Bankfull Bed Shear Stress (Newtons/sq m)	155.45	270.95	231.39	2558.98	**86.70**
Maximum Diameter for Bankfull Sediment Movement (cm)	15.86	27.65	23.61	261.12	**8.85**
Bankfull Bed Tractive Force (lb/sq ft)	3.38	5.90	5.04	55.69	**1.89**
Rosgen Class **	E	E/C	C	Eroding C Channel / May have been channelized in the past	**E**

* Estimated using Manning Eq. Assuming Manning Coef. .035

** Rosgen & Silvey, 1998

Table 6a. Master Planting List

Shrubs									
	Common Name	**Scientific Name**	**Size**	**Root Structure**	**Position**	**Exposure**	**Indicator**	**Zone**	**Province**
1	Red buckeye	*Aesculus pavia*	8'-12'	taproot	Mid	Shade	FAC	A-D	C
2	Piedmont buckeye	*Aesculus sylvatica*	3'-10'	taproot	Toe-Mid	Shade	FAC	A-D	P
3	Tag alder	*Alnus serrulata*	16'	fibrous		Shade/Sun	FACW	B-C-D	M-P-C
4	Devils walking stick	*Aralia spinosa*	10'-20'	colonial/fibrous	Mid	Shade	FAC	A-D	M-P-C
5	Chokecherry	*Aronia arbutifolia*	8'-10'	fibrous	Toe		FACW	B-C-D	M-P-C
6	Beautyberry	*Callicarpa americana*	6'	fibrous	Toe		FACU-	A-B-C-D	P-C
7	Sweet shrub	*Calycanthus floridus*	8'-10'	colonial/fibrous	Mid	Shade	FACU+	A-D	M-P
8	New Jersey tea	*Ceanothus americanus*	3'	fibrous	Top		UPL	*	M-P-C
9	Button bush	*Cephalanthus occidentalis*	6'-10	fibrous	Toe		OBL	B-C-D	M-P-C
10	Sweet pepper bush	*Clethra alnifolia*	3'-10'	colonial/fibrous	Mid-Top		FACW	B-C-D	LP-C
11	Silky dogwood	*Cornus amomum*	10'	colonial/fibrous	Toe-Mid		FACW+	B-C-D	M-P
12	American hazelnut	*Corylus americanus*		fibrous			FACU	A-D	M-P
13	Strawberry bush	*Euonymus americanus*	3'-6'	fibrous	Top	Shade	FAC-	B-C-D	M-P-C
14	Dwarf fothergilla	*Fothergilla gardenii*	3'-5'	fibrous	Top	Partial shade	FACW	B-C-D	C
15	Smooth hydrangea	*Hydrangea arborescens*	3'-5'	fibrous	Top	Shade	FACU	A-D	M-P
16	Carolina holly	*Ilex ambigua* var. *montana*		fibrous	Mid-Top		UPL	*	M-P-C
17	Inkberry holly	*Ilex glabra*	3'-6'	fibrous	Top		FACW	B-C-D	C
18	Winterberry holly	Ilex verticillata	3'-10'	fibrous	Toe-Mid		FACW	B-C-D	M-P-C
19	Virginia willow	*Itea virginica*	3'-5'	fibrous	All	Partial shade	FACW+	B-C-D	M-P-C
20	Dog hobble	*Leucothoe axillaris* var. *editorum*	3'-5'	colonial/fibrous	Toe-Mid	Shade	FACW	B-C-D	C
21	Spice bush	*Lindera benzoin*	3'-10'	fibrous	Top	Shade	FACW	A-D	M-P-C
22	Male-berry	*Lyonia ligustrina*	10'	fibrous			FACW	B-C-D	M-P-C
23	Ninebark	*Physocarpus opulifolius*	5'-10'	fibrous	Toe-Mid		FAC-	A-D	M-P
24	Rhododendron	*Rhododendron* spp.	4'-12'	fibrous	Toe-Mid	Shade	FAC	A-D	M-P-C
25	Winged sumac	*Rhus* copallina	5'-12'	taproot	Mid		UPL	*	M-P-C
26	Elderberry	*Sambucus canadensis*	10'	colonial/fibrous	Toe		FACW-	A-B-C-D	M-P-C
27	Bladdernut	*Staphylea trifolia*	10'	colonial/fibrous	Toe-Mid	Shade	FAC	A-D	P
28	Coralberry	*Symphoricarpos orbiculatus*	2'-4'	colonial/fibrous	Top	Shade	FAC-	A-C-D	M-P
29	Blueberries	*Vacccinium* spp.	3'-10'	colonial/fibrous	Mid-Top	Partial shade	FACU	A-D	M-P-C
30	Arrowood	*Viburnum dentatum var. lucidum*	6'-12'	colonial/fibrous	Toe-Mid		FACW	B-C-D	P-C
31	Possum haw	*Viburnum nudum*		fibrous			FACW+	B-D	LM-P-C
32	Dusty Zenobia	*Zenobia pulverulenta*	3'-5'	colonial/fibrous	Top		OBL	B-D	C

Trees					
	Common Name	**Scientific Name**	**Size**	**Indicator**	**Zone**
1	Red maple	*Acer rubrum*	Canopy	FAC	A-B-D
2	Serviceberry	*Amelanchier arborea*	Sub-canopy	FACU	A-D
3	Pawpaw	*Asimina triloba*	Sub-canopy	FAC	A-D
4	River birch	*Betula nigra*	Canopy	FACW	A-B-D
5	Ironwood	*Carpinus caroliniana*	Sub-canopy	FAC	A-D
6	Bitternut hickory	*Carya cordiformis*	Canopy	FAC	A-D
7	Hackberry	*Celtis laevigata*	Canopy	FACW	A-B-D
8	Redbud	*Cercis canadensis*	Sub-canopy	FACU	A-D
9	Fringe tree	*Chionanthus virginicus*	Sub-canopy	FACU	A-D
10	Flowering dogwood	*Cornus florida*	Sub-canopy	FACU	A-D
11	Persimmon	*Diospyros virginiana*	Sub-canopy	FAC	A-B-D
12	Green ash	*Fraxinus pennsylvanica*	Canopy	FACW	A-B-D
13	Silverbell	*Halesia carolina*	Sub-canopy	FAC-	A-D
14	Witch hazel	*Hamamelis virginiana*	Sub-canopy	FACU	A-D
15	Deciduous holly	*Ilex decidua*	Sub-canopy	FACW	A-B-D
16	American holly	*Ilex opaca*	Sub-canopy	FAC-	A-D
17	Black walnut	*Juglans nigra*	Canopy	FACU	A-D
18	Yellow poplar	*Liriodendron tulipifera*	Canopy	FACU	A-B-D
19	Black gum	*Nyssa sylvatica*	Canopy	FAC	A-B-D
20	Sycamore	*Platanus occidentalis*	Canopy	FACW	A-B-D
21	Cottonwood	*Populus deltoides*	Canopy	FAC+	A-B-D
22	White oak	*Quercus alba*	Canopy	FACU	A-D
23	Overcup oak	*Quercus lyrata*	Canopy	OBL	B-D
24	Swamp chestnut oak	*Quercus michauxii*	Canopy	FACW	A-D
25	Water oak	*Quercus nigra*	Canopy	FAC	A-D
26	Cherrybark oak	*Quercus pagoda*	Canopy	FAC+	A-D
27	Pin oak	*Quercus palustris*	Canopy	FACW	A-B-D
28	Willow oak	*Quercus phellos*	Canopy	FACW-	A-B-D
29	Red oak	*Quercus rubra*	Canopy	FACU	A-D
30	Shumard oak	*Quercus shumardii*	Canopy	FACW	A-B-D
31	Black willow	*Salix nigra*	Canopy	OBL	B-D
32	Silky willow	*Salix sericea*	Sub-canopy	OBL	B-D
33	American elm	*Ulmus americana*	Canopy	FACW	A-B-D

Table 6b. Proposed Planting List

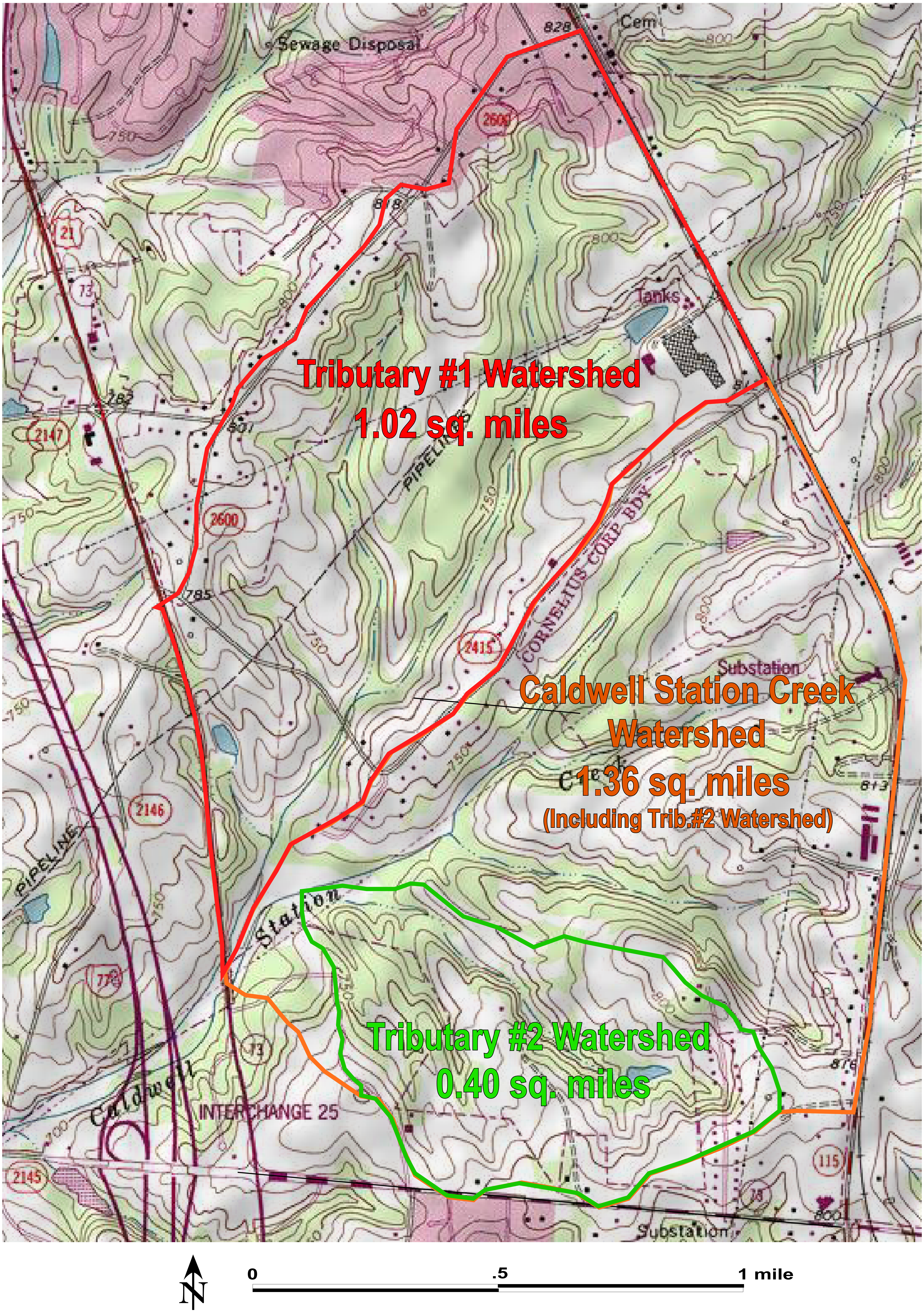
Zone A					
Trees					
Common name	**Scientific name**	**Stratum**	**Indicator**	**Zone**	**Province**
River birch	*Betula nigra*	Canopy	FACW	A-B-D	
Bitternut hickory	*Carya cordiformis*	Canopy	FAC	A-D	
Black gum	*Nyssa sylvatica*	Canopy	FAC	A-B-D	
Cherrybark oak	*Quercus pagoda*	Canopy	FAC+	A-D	
Swamp chestnut oak	*Quercus michauxii*	Canopy	FACW	A-D	
Deciduous holly	*Ilex decidua*	Sub-canopy	FACW	A-B-D	
Ironwood	*Carpinus caroliniana*	Sub-canopy	FAC	A-D	
Shrubs					
Piedmont buckeye	*Aesculus sylvatica*	3'-10'	FAC	A-D	P
American hazelnut	*Corylus americanus*	3'-10'	FACU	A-D	M-P
Smooth hydrangea	*Hydrangea arborescens*	3'-5'	FACU	A-D	M-P
Spice bush	*Lindera benzoin*	3'-10'	FACW	A-D	M-P-C
Bladdernut	*Staphylea trifolia*	10'	FAC	A-D	P

Zone B					
Trees					
Common name	**Scientific name**	**Stratum**	**Indicator**	**Zone**	**Province**
Overcup oak	*Quercus lyrata*	Canopy	OBL	B-D	
Pin oak	*Quercus palustris*	Canopy	FACW	A-B-D	
River birch	*Betula nigra*	Canopy	FACW	A-B-D	
Cottonwood	*Populus deltoides*	Canopy	FAC+	A-B-D	
Silky willow	*Salix sericea*	Sub-canopy	OBL	B-D	
Shrubs					
Chokecherry	*Aronia arbutifolia*	8'-10'	FACW	B-C-D	M-P-C
Beautyberry	*Callicarpa americana*	6'	FACU-	A-B-C-D	P-C
Strawberry bush	*Euonymus americanus*	3'-6'	FAC-	B-C-D	M-P-C
Winterberry holly	*Ilex verticillata*	3'-10'	FACW	B-C-D	M-P-C
Virginia willow	*Itea virginica*	3'-5'	FACW+	B-C-D	M-P-C

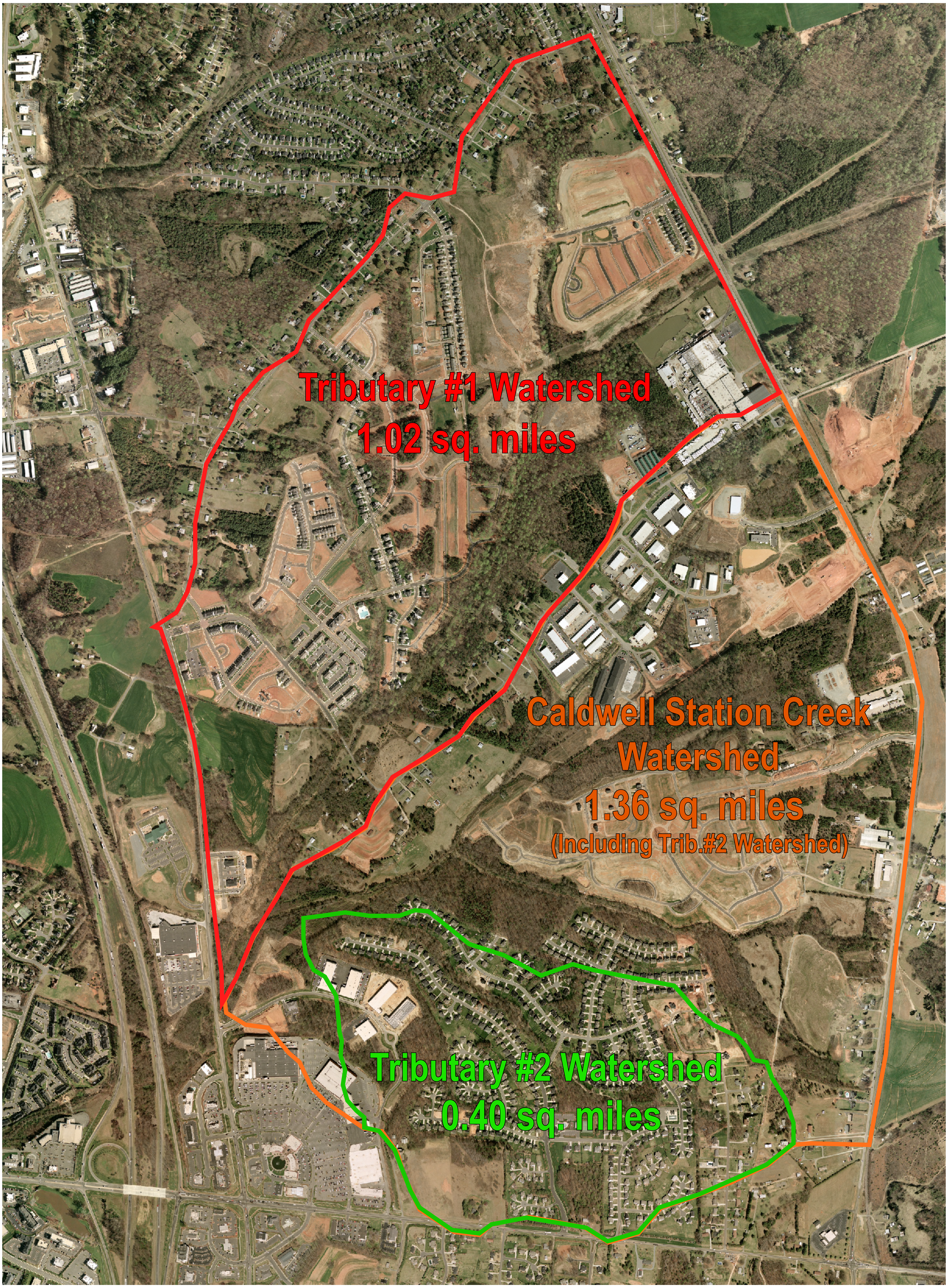
Zone C					
Shrubs					
Common name	**Scientific name**	**Stratum**	**Indicator**	**Zone**	**Province**
Tag alder	*Alnus serrulata*	16'	FACW	B-C-D	M-P-C
Dog hobble	*Leucothoe axillaris* var. *editorum*	3'-5'	FACW	B-C-D	M-P
Virginia willow	*Itea virginica*	3'-5'	FACW+	B-C-D	M-P-C
Sweet pepper bush	*Clethra alnifolia*	3'-10'	FACW	B-C-D	LP-C
Silky dogwood	*Cornus amomum*	10'	FACW+	B-C-D	M-P
Elderberry	*Sambucus canadensis*	10'	FACW-	A-B-C-D	M-P-C
Coralberry	*Symphoricarpos orbiculatus*	2'-4'	FAC-	A-C-D	M-P
Male-berry	*Lyonia ligustrina*	10'	FACW	B-C-D	M-P-C

M-Mountians Province
P-Piednont Province
C-Coastal Plain Province

FIGURES



HDR and Habitat Assessment and Restoration Program Inc.	NCEEP Caldwell St. Creek Restoration Site Mecklenburg Co., NC	Figure 1. Watershed Topography and USGS Hydrology (1:24,000)	1/29/04

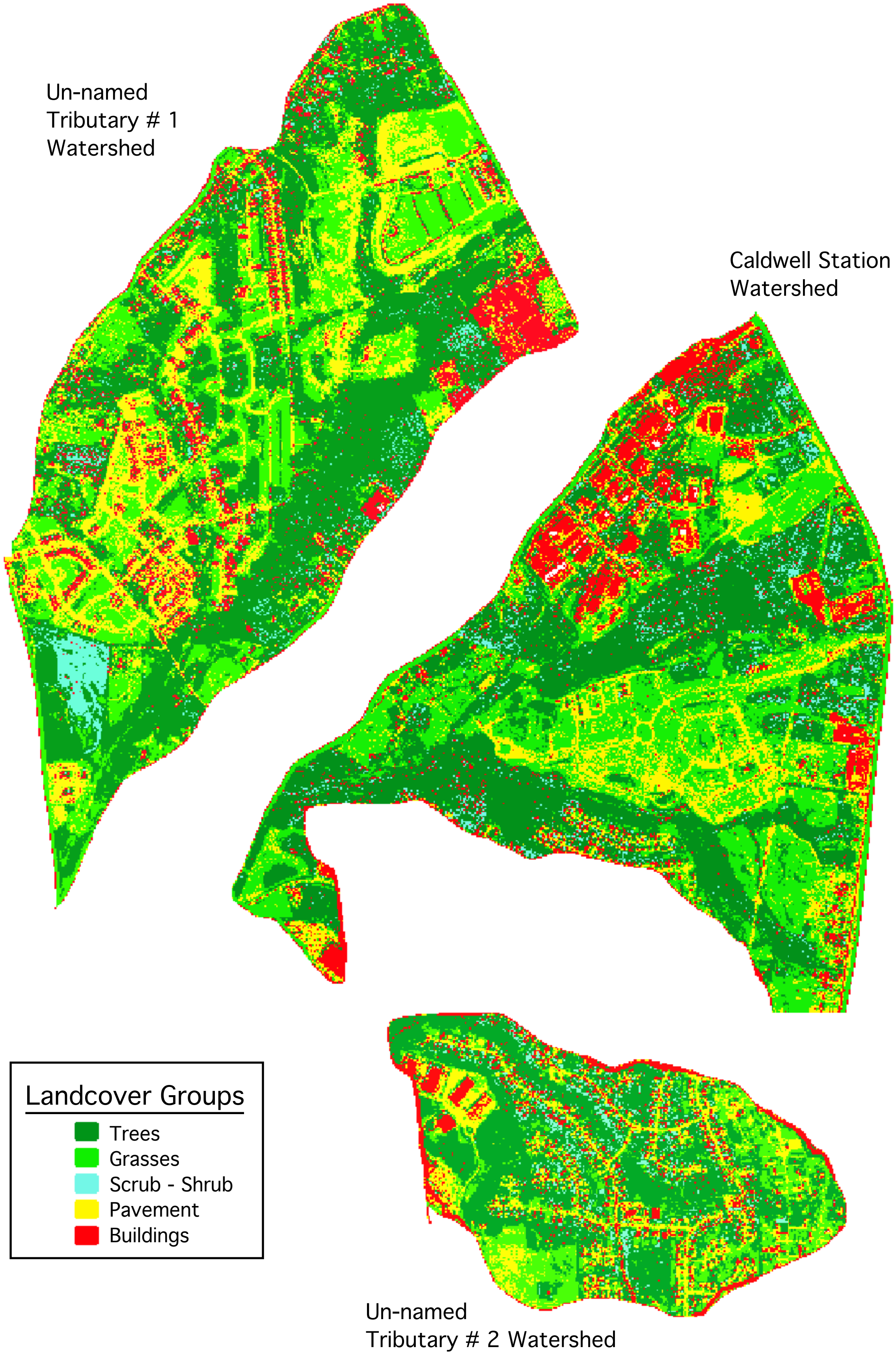


HDR ONE COMPANY Many Solutions and Habitat Assessment and Restoration Program Inc.

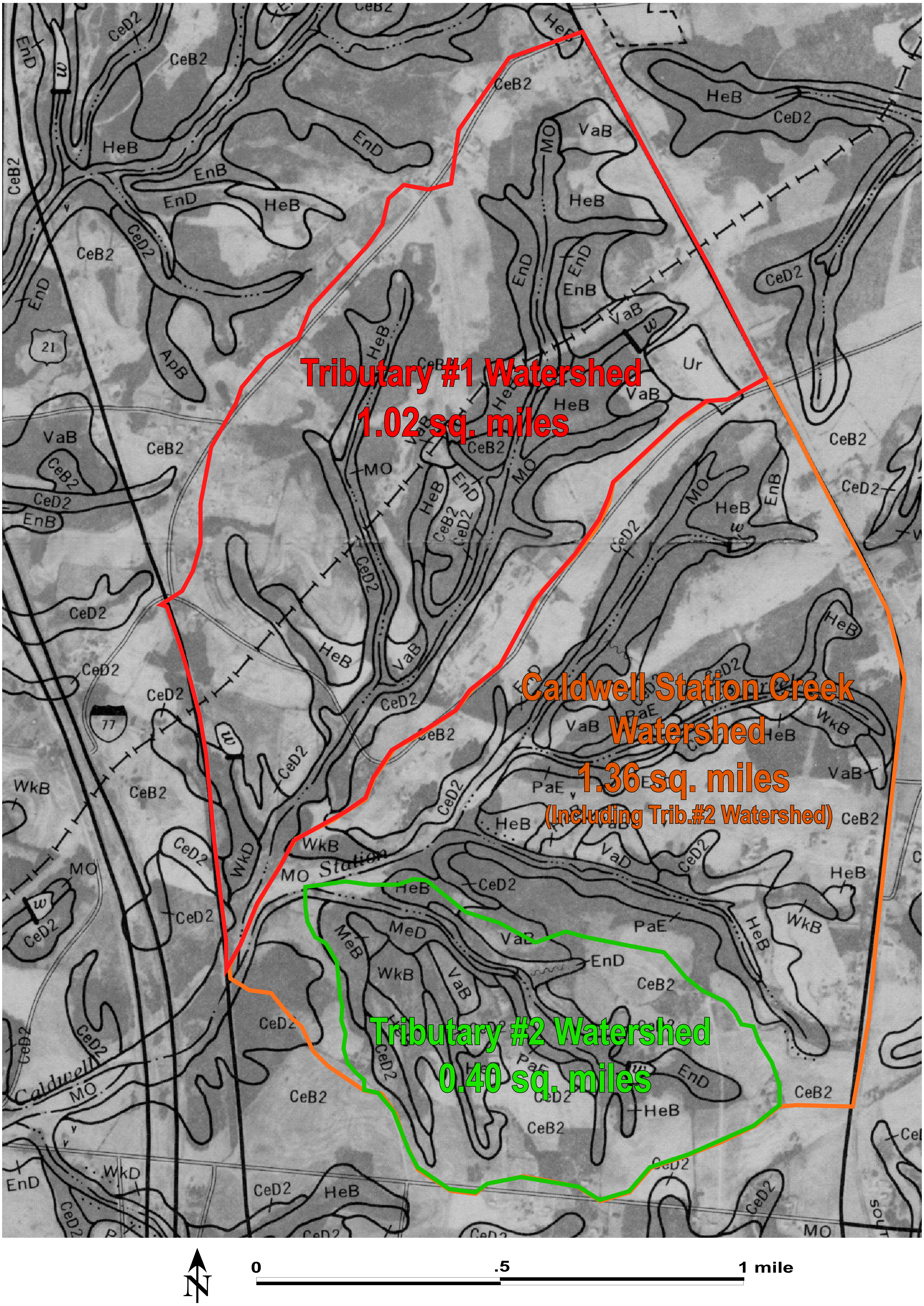
NCEEP Caldwell St. Creek Restoration Site Mecklenburg Co., NC

Figure 2. 2002 Color Orthophoto Mosaic of Watershed

1/29/04



HDR and Habitat Assessment and Restoration Program Inc.	NCEEP Caldwell Station Creek Site Mecklenburg County, NC	Figure 3. Landcover in the Caldwell Station Watersheds - "Supervised" Spectral Maximum Likelihood Classification Algorithm	4/04

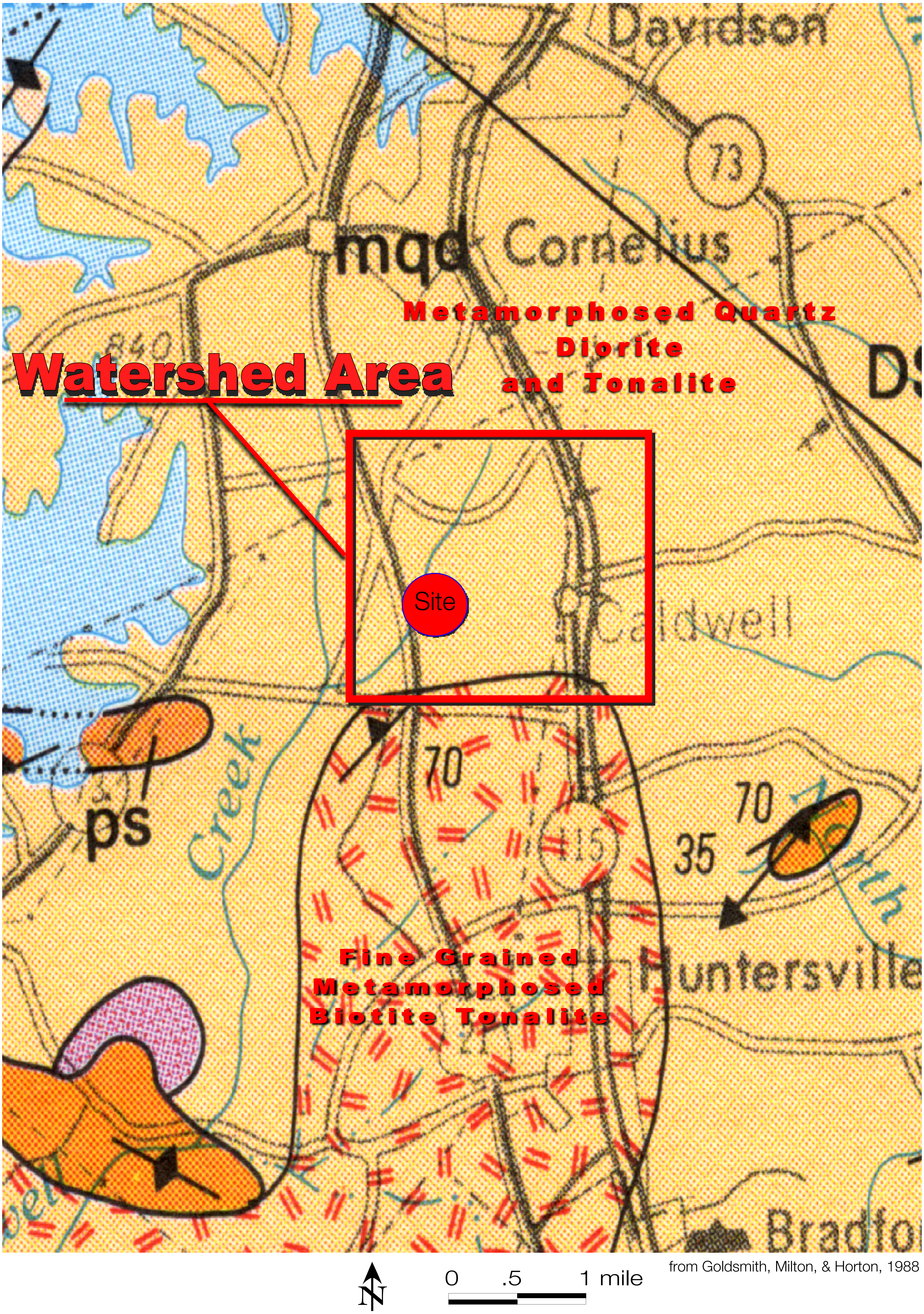


HDR ONE COMPANY Many Solutions and Habitat Assessment and Restoration Program Inc.

NCEEP Caldwell St. Creek Restoration Site
Mecklenburg Co., NC

Figure 4. Soil Types of the Watershed

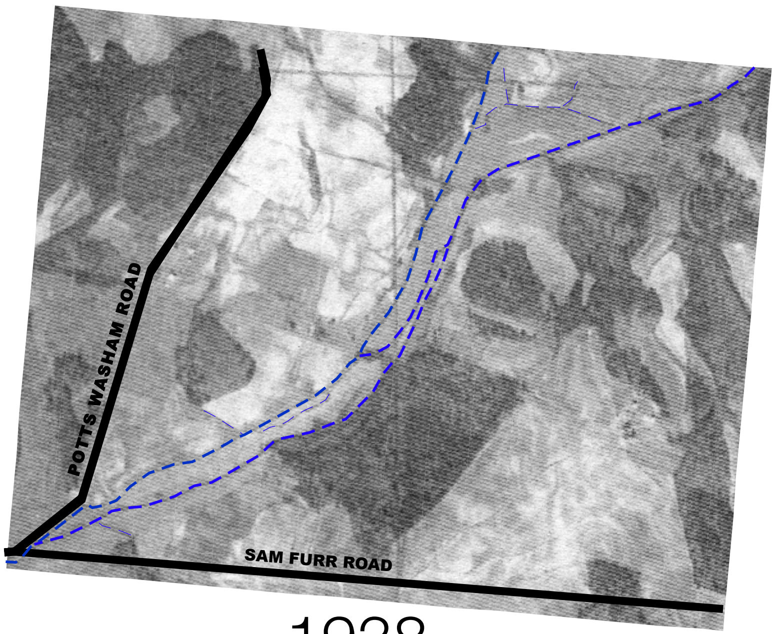
1/29/04



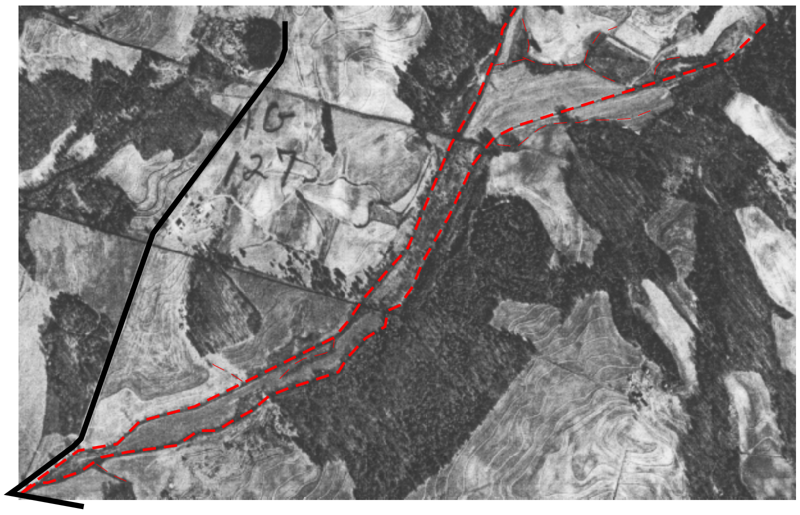
from Goldsmith, Milton, & Horton, 1988

HDR ONE COMPANY Many Solutions and Habitat Assessment and Restoration Program Inc.

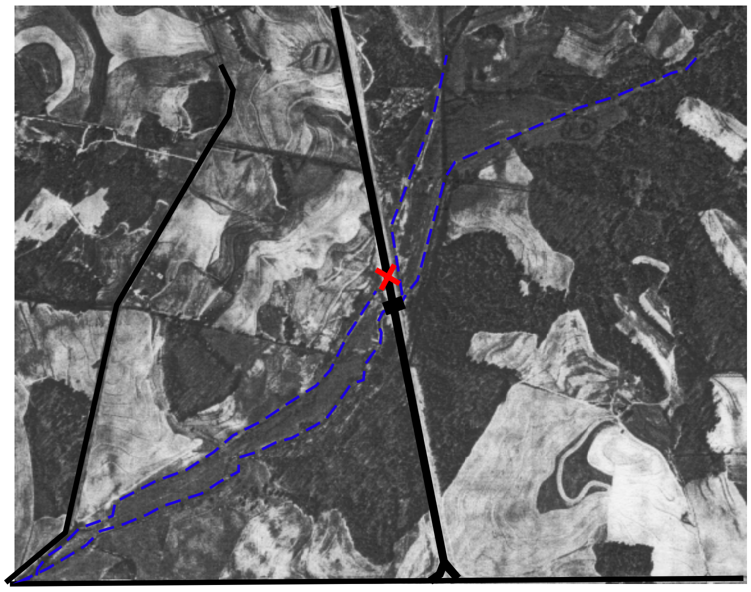
NCEEP Caldwell St. Creek Restoration Site Mecklenburg Co., NC	**Figure 5. Geologic Map of the Watershed Area**	1/29/04



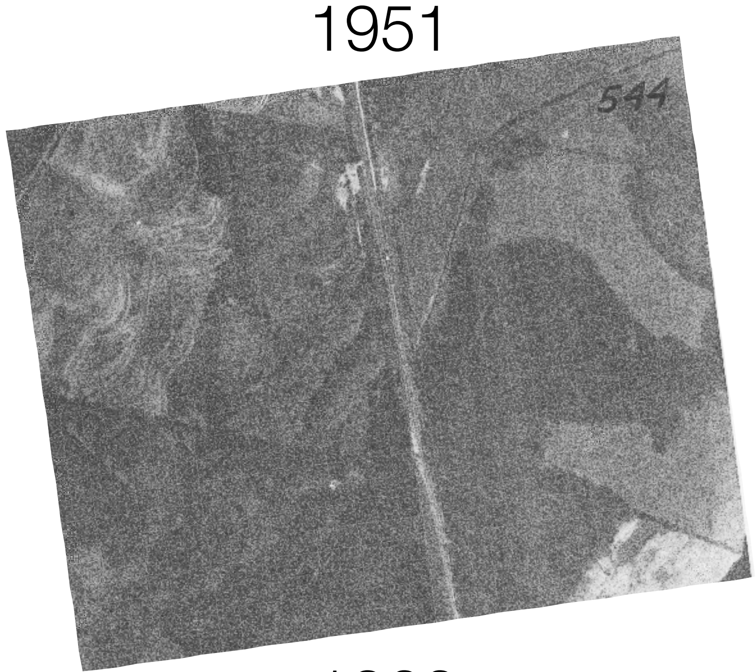
1938



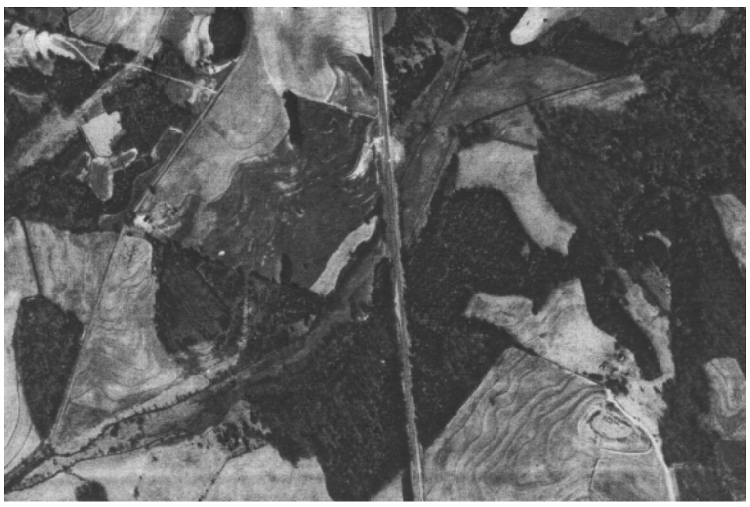
1951



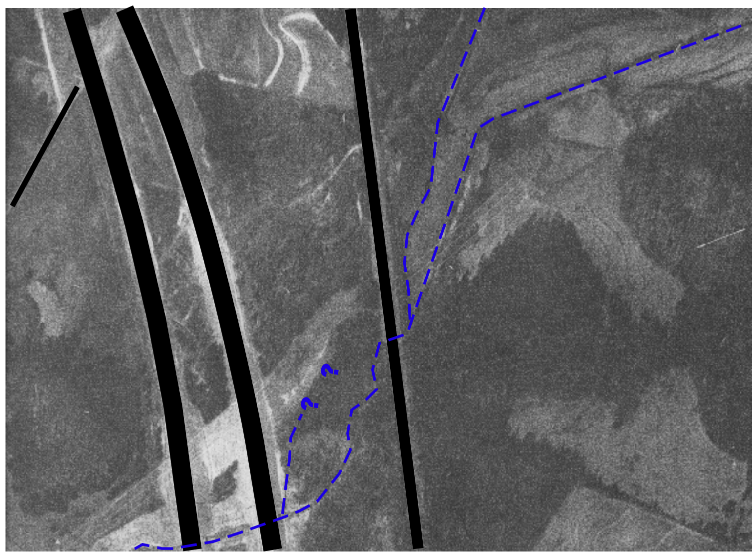
1956



1966

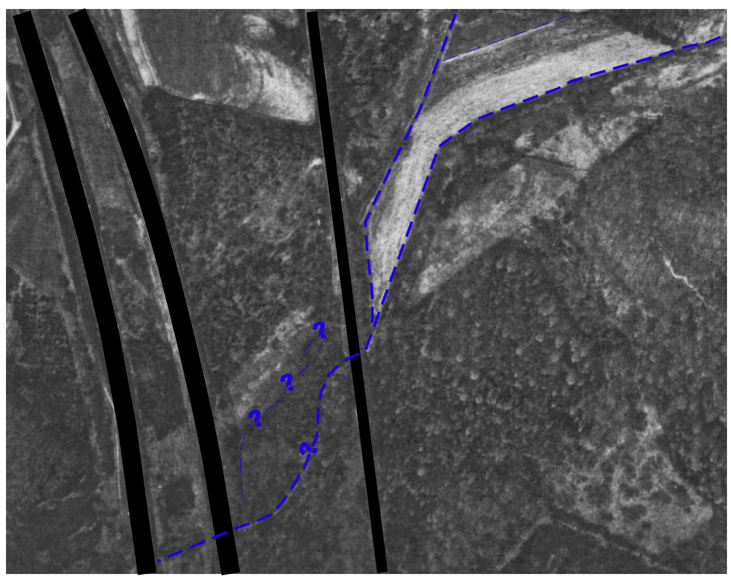


1968



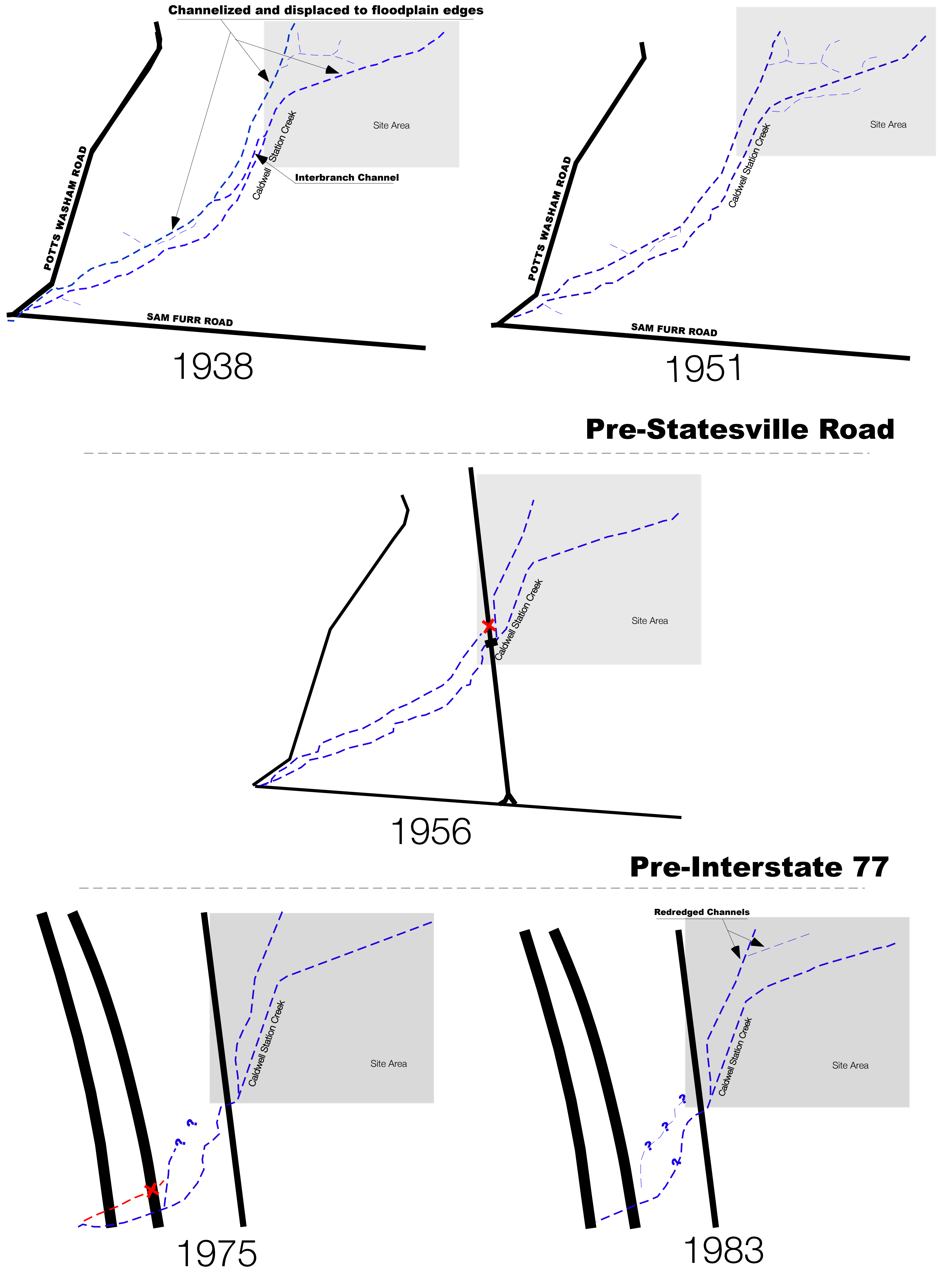
1975

1980



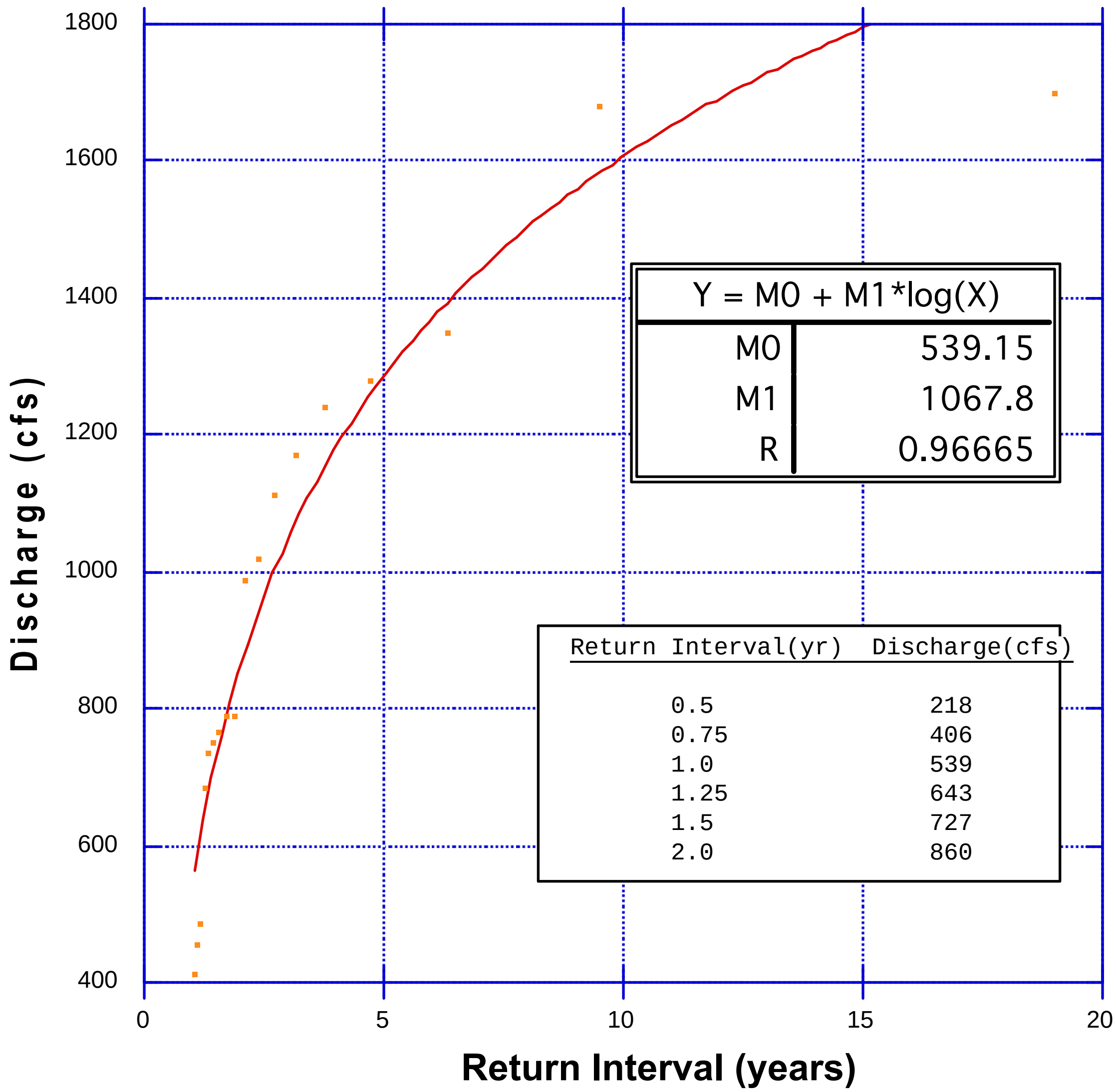
1983

HDR ONE COMPANY Many Solutions and Habitat Assessment and Restoration Program Inc.	NCEEP Caldwell St. Creek Restoration Site Mecklenburg Co., NC	Figure 6. Historical Conditions 1938 - 1983 Aerial Photography	Jan. 2004



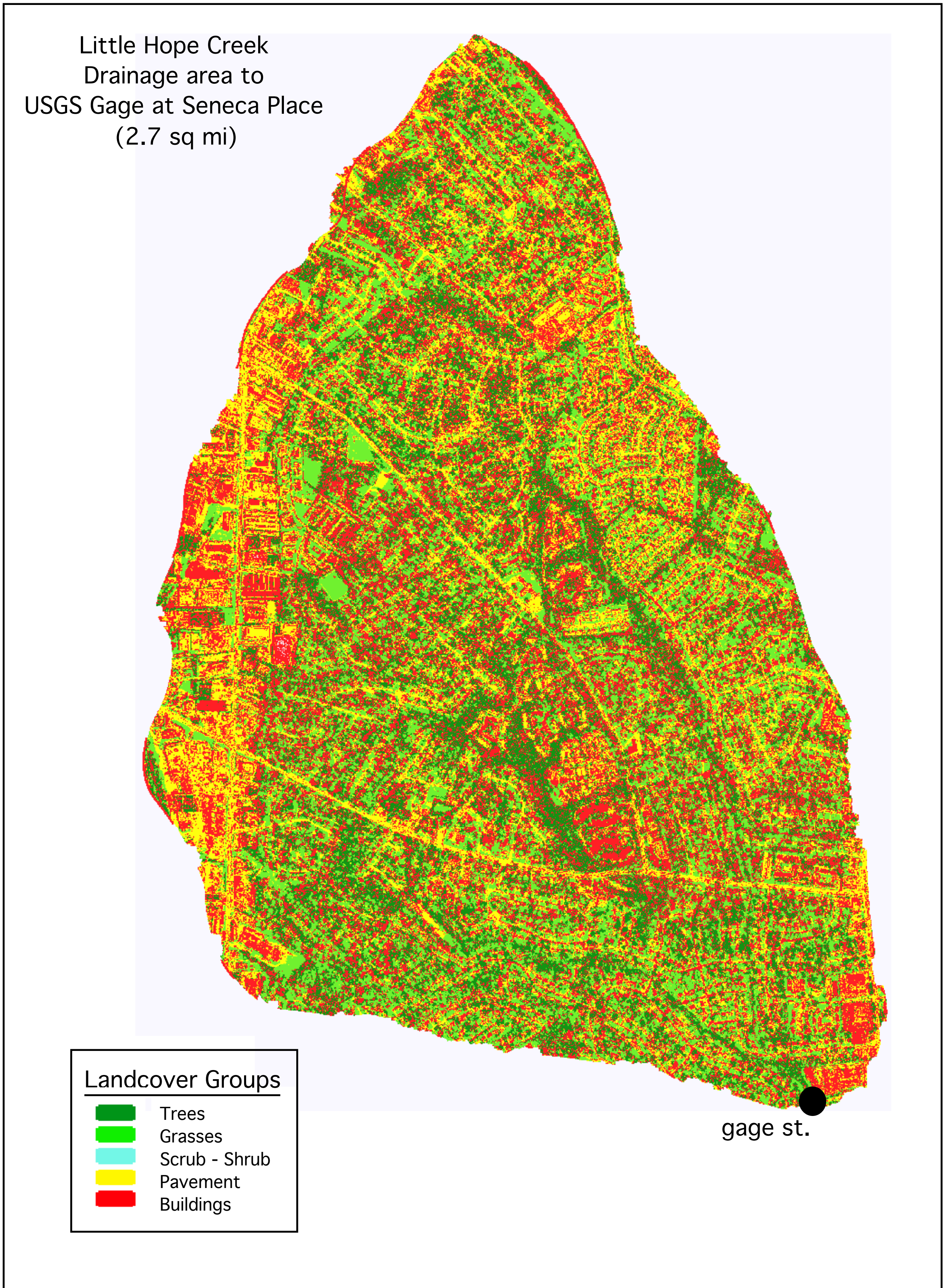
HDR ONE COMPANY | Many Solutions and Habitat Assessment and Restoration Program Inc.	NCEEP Caldwell St. Creek Restoration Site Mecklenburg Co., NC	Figure 7. Historical Conditions 1938 - 1983 Aerial Photography	Jan. 2004

Little Hope Creek, at Seneca Place
USGS STATION 2146470 1967 - 2002



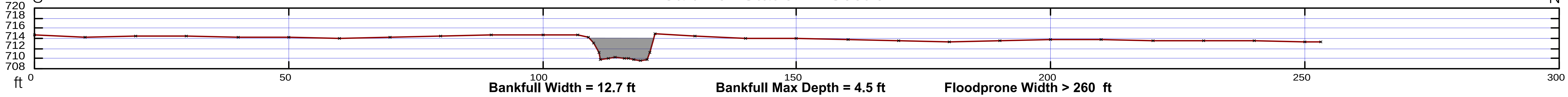
Return Interval(yr)	Discharge(cfs)
0.5	218
0.75	406
1.0	539
1.25	643
1.5	727
2.0	860

HDR and Habitat Assessment and Restoration Program Inc.	NCEEP Caldwell Station Creek Site Mecklenburg County, NC	Figure 8. Estimate of Discharge and Return Interval USGS Gaged Stream of Similar Drainage Area	4/04



HDR and Habitat Assessment and Restoration Program	NCEEP Caldwell Station Creek Site Mecklenburg County, NC	Figure 9. Landcover in the Little Hope Ck. Watershed - "Supervised" Spectral Maximum Likelihood Classification Algorithm	4/04

Caldwell Station X-Section #1

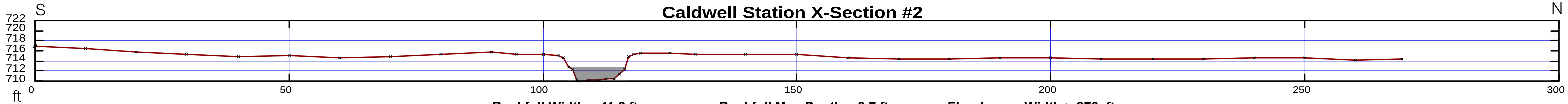


Bankfull Width = 12.7 ft
Bankfull Area = 43.8 sq. ft

Bankfull Max Depth = 4.5 ft
Bankfull Avg. Depth = 3.4 ft

Floodprone Width > 260 ft
Entrenchment Ratio > 20.4
W/D = 3.7

Caldwell Station X-Section #2

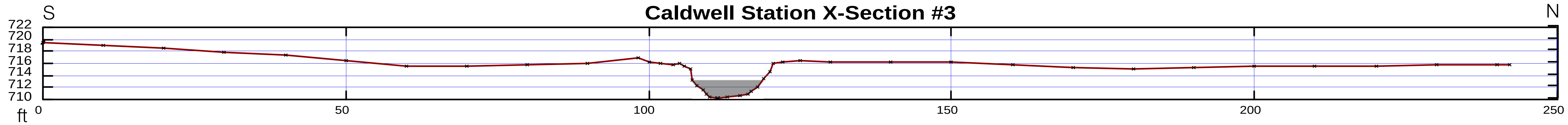


Bankfull Width = 11.2 ft
Bankfull Area = 22.7 sq. ft

Bankfull Max Depth = 2.7 ft
Bankfull Avg. Depth = 2.0 ft

Floodprone Width > 270 ft
Entrenchment Ratio > 24.1
W/D = 5.5

Caldwell Station X-Section #3

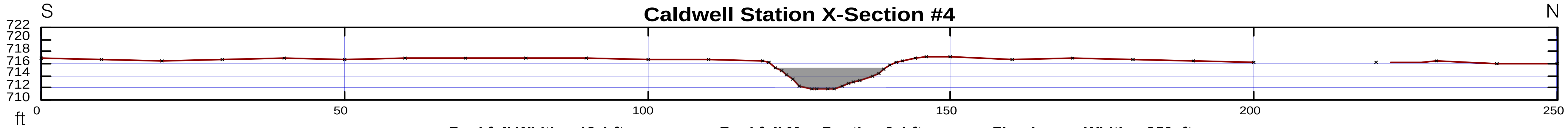


Bankfull Width = 11.6 ft
Bankfull Area = 23.9 sq. ft

Bankfull Max Depth = 2.9 ft
Bankfull Avg. Depth = 2.1 ft

Floodprone Width > 242 ft
Entrenchment Ratio > 20.7
W/D = 5.6

Caldwell Station X-Section #4

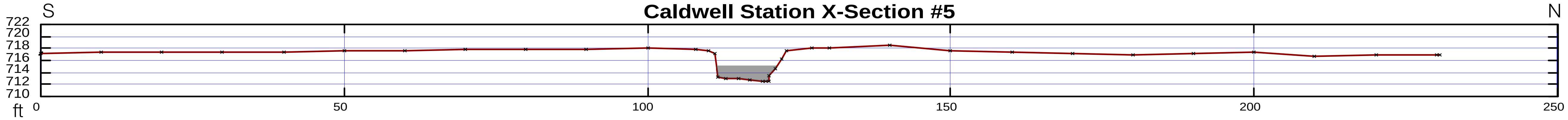


Bankfull Width = 18.1 ft
Bankfull Area = 40.6 sq. ft

Bankfull Max Depth = 3.4 ft
Bankfull Avg. Depth = 2.2 ft

Floodprone Width > 250 ft
Entrenchment Ratio > 13.8
W/D = 8.1

Caldwell Station X-Section #5

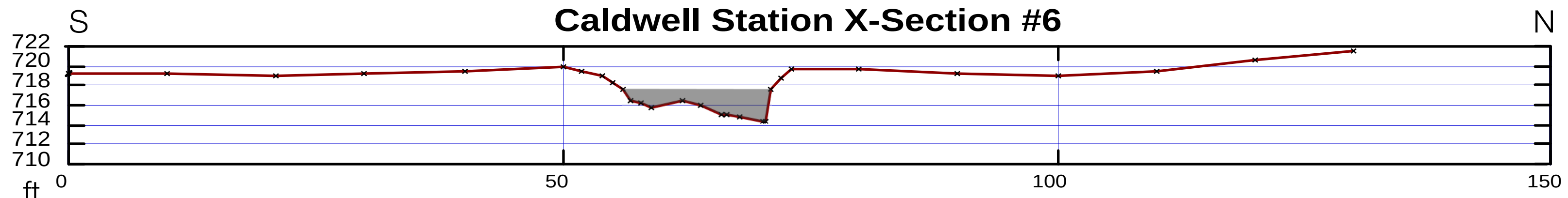


Bankfull Width = 9.6 ft
Bankfull Area = 20.1 sq. ft

Bankfull Max Depth = 2.6 ft
Bankfull Avg. Depth = 2.1 ft

Floodprone Width > 230 ft
Entrenchment Ratio > 24.0
W/D = 4.6

Caldwell Station X-Section #6



Bankfull Width = 14.9 ft
Bankfull Area = 28.5 sq. ft

Bankfull Max Depth = 3.3 ft
Bankfull Avg. Depth = 1.9 ft

Floodprone Width > 130 ft
Entrenchment Ratio > 8.7
W/D = 7.8

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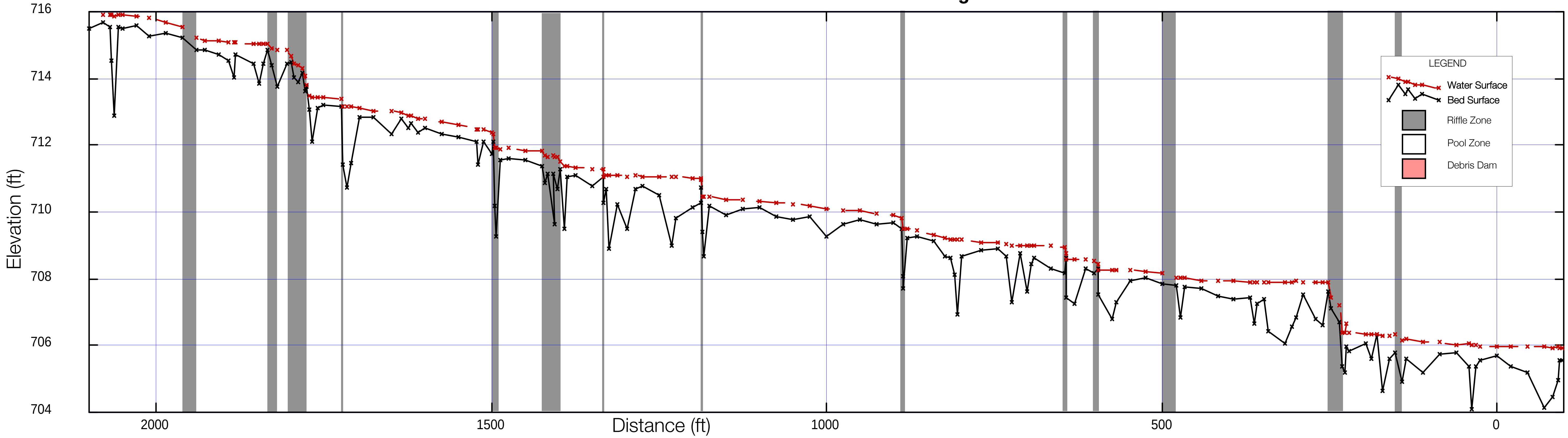
and
Habitat Assessment and Restoration Program Inc.

NCEEP Caldwell St. Creek Restoration Site - Mecklenburg Co., NC

Figure 10. Cross Sections Existing Conditions Caldwell Station Ck.

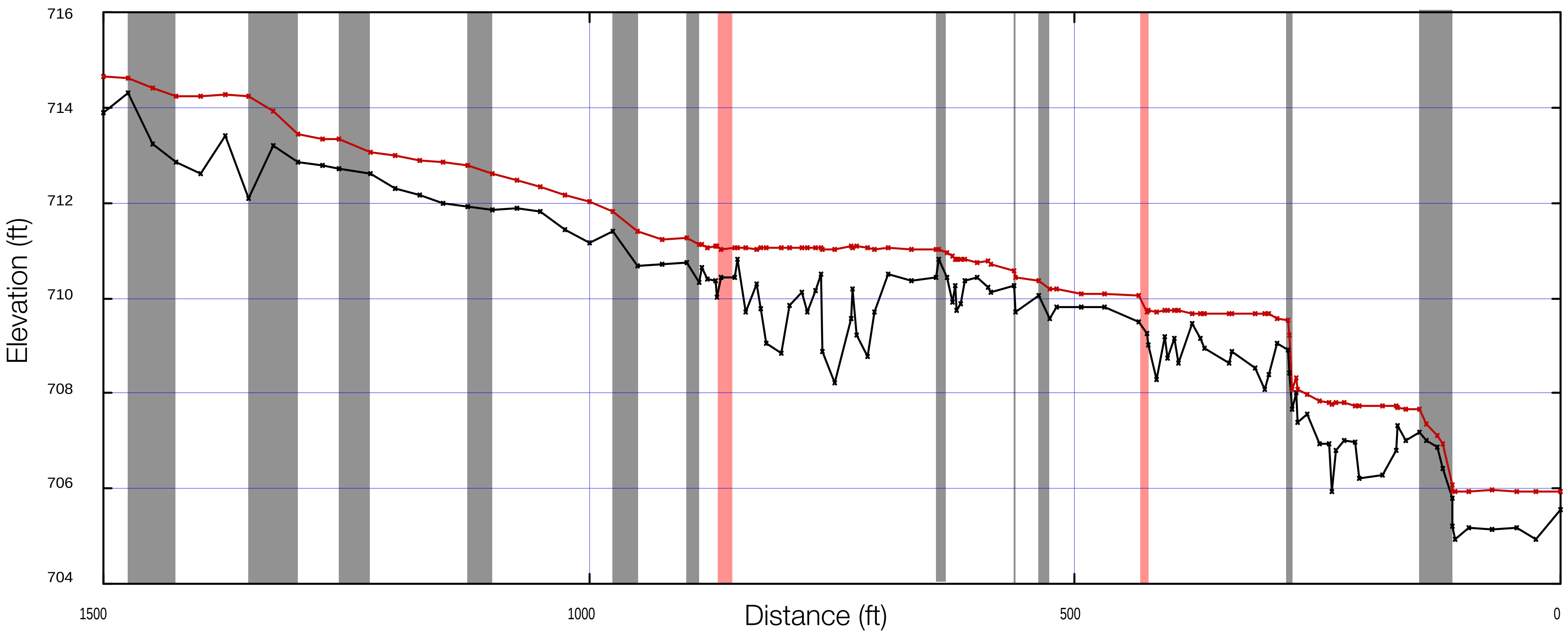
Jan. 2004

Caldwell Station Creek Above 21 Longitudinal



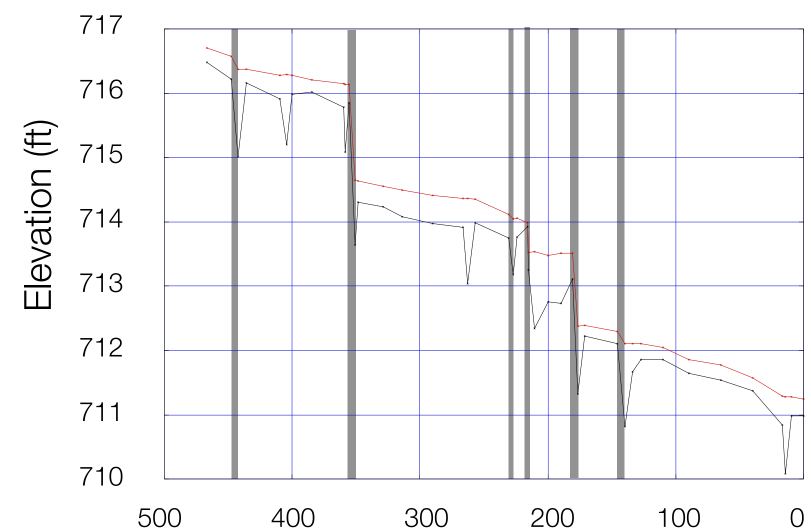
Overall Grade CS = 0.0040 **Overall Grade CS Above 21 = 0.0046** **Overall Grade CS Below 21 = 0.0026**

Caldwell Station Tributary #1 Longitudinal



Overall Grade = 0.0058

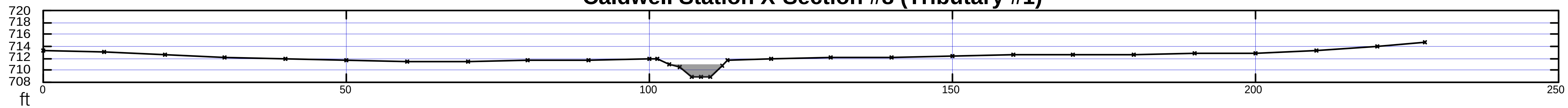
Caldwell Station Tributary #2 Longitudinal



Overall Grade = 0.012

HDR ONE COMPANY Many Solutions and Habitat Assessment and Restoration Program Inc.	**NCEEP Caldwell St. Creek Restoration Site - Mecklenburg Co., NC**	**Figure 11. Longitudinal Profiles, Caldwell Station Ck. and Assoc. Tributaries**	**Jan. 2004**

Caldwell Station X-Section #8 (Tributary #1)

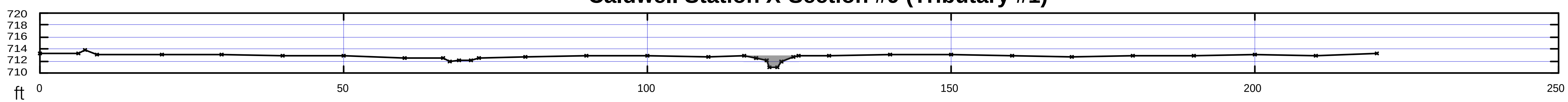


Bankfull Width = 8.9 ft
Bankfull Area = 12.7 sq. ft

Bankfull Max Depth = 2.3 ft
Bankfull Avg. Depth = 1.4 ft

Floodprone Width > 230 ft
Entrenchment Ratio > 25.8
W/D = 6.2

Caldwell Station X-Section #9 (Tributary #1)

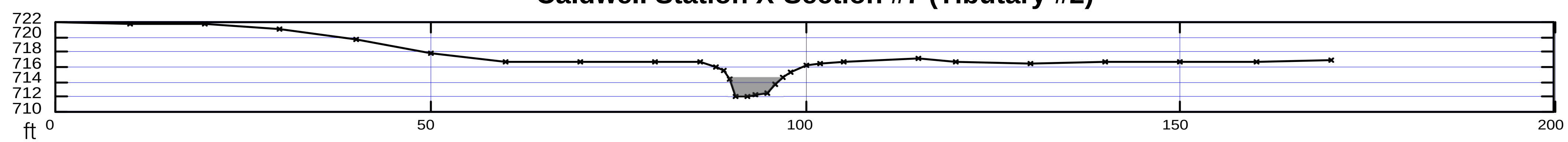


Bankfull Width = 9.0 ft
Bankfull Area = 8.1 sq. ft

Bankfull Max Depth = 2.3 ft
Bankfull Avg. Depth = 0.9 ft

Floodprone Width > 220 ft
Entrenchment Ratio > 24.4
W/D = 10

Caldwell Station X-Section #7 (Tibutary #2)

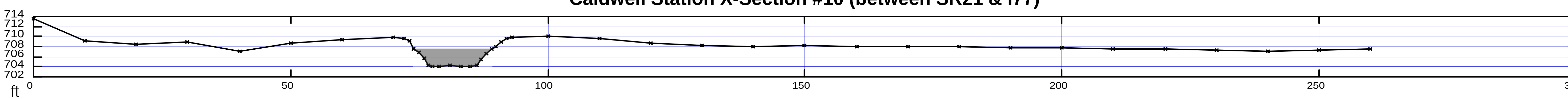


Bankfull Width = 7.3 ft
Bankfull Area = 13.2 sq. ft

Bankfull Max Depth = 2.5 ft
Bankfull Avg. Depth = 1.8 ft

Floodprone Width > 170 ft
Entrenchment Ratio > 23.8
W/D = 4

Caldwell Station X-Section #10 (between SR21 & I77)

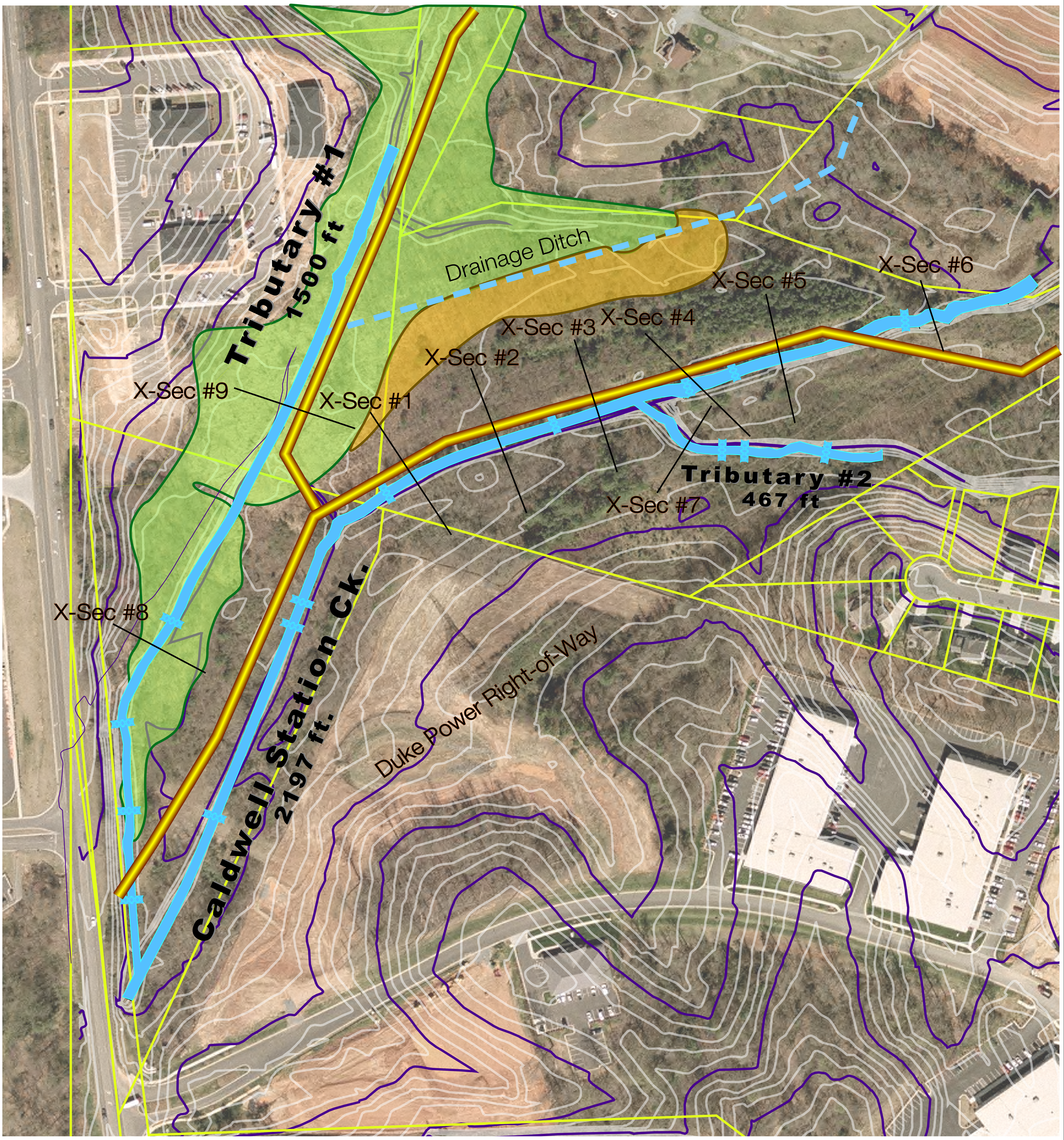


Bankfull Width = 15.3 ft
Bankfull Area = 39.4 sq. ft

Bankfull Max Depth = 3.4 ft
Bankfull Avg. Depth = 2.6 ft

Floodprone Width > 260 ft
Entrenchment Ratio > 17.0
W/D = 5.9

HDR ONE COMPANY | Many Solutions and Habitat Assessment and Restoration Program Inc.	NCEEP Caldwell St. Creek Restoration Site - Mecklenburg Co., NC	Figure 12. Cross Sections, Existing Conditions Caldwell Station Ck. and Assoc. Tributaries	Jan. 2004



Legend

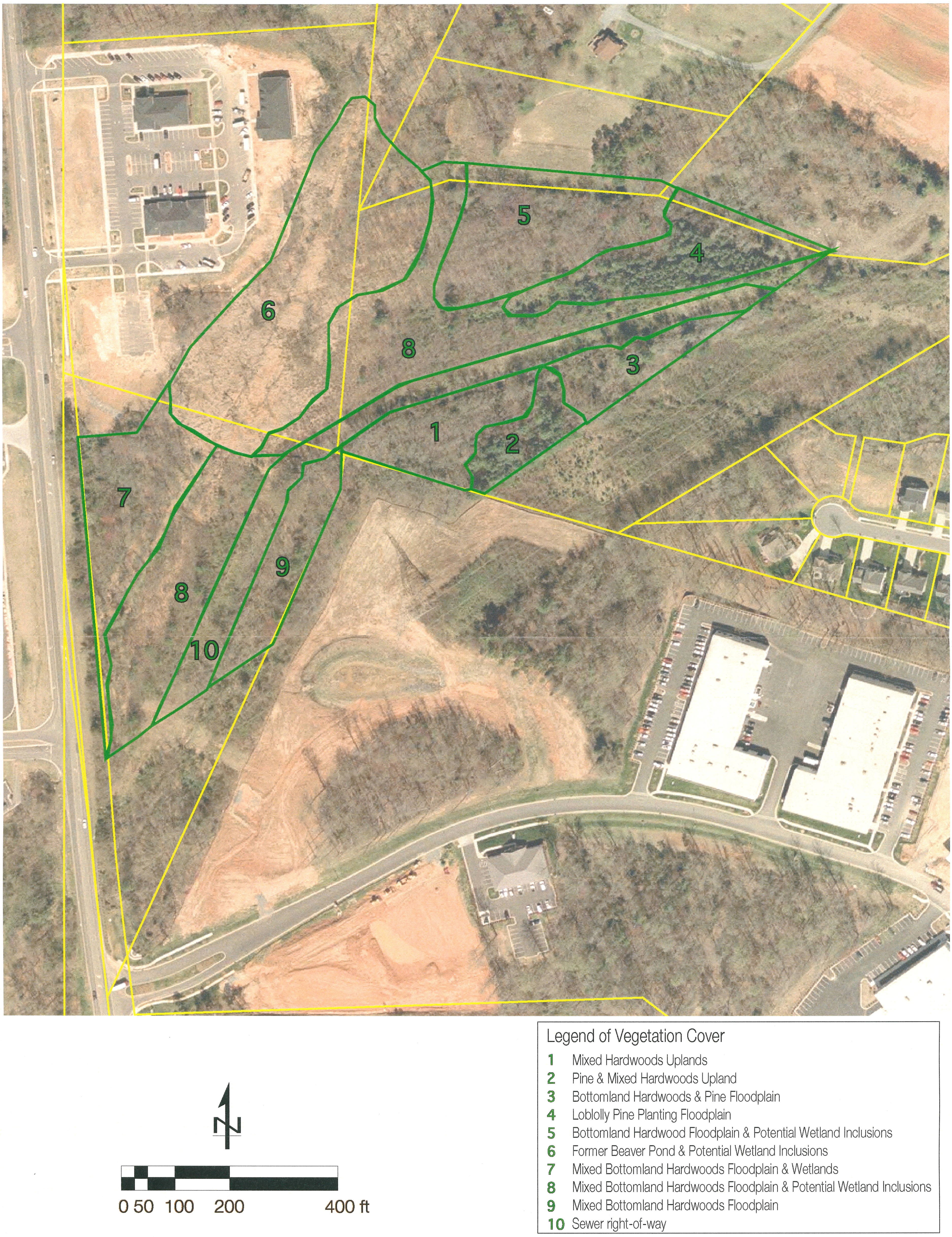
- Existing Channels
- Debris Blockage
- Existing Wetlands*
- Existing Transitional Wetlands
- Sewer Line
- 10 ft Contours
- 2 ft Contours
- Parcel Boundaries
- X-Section

N

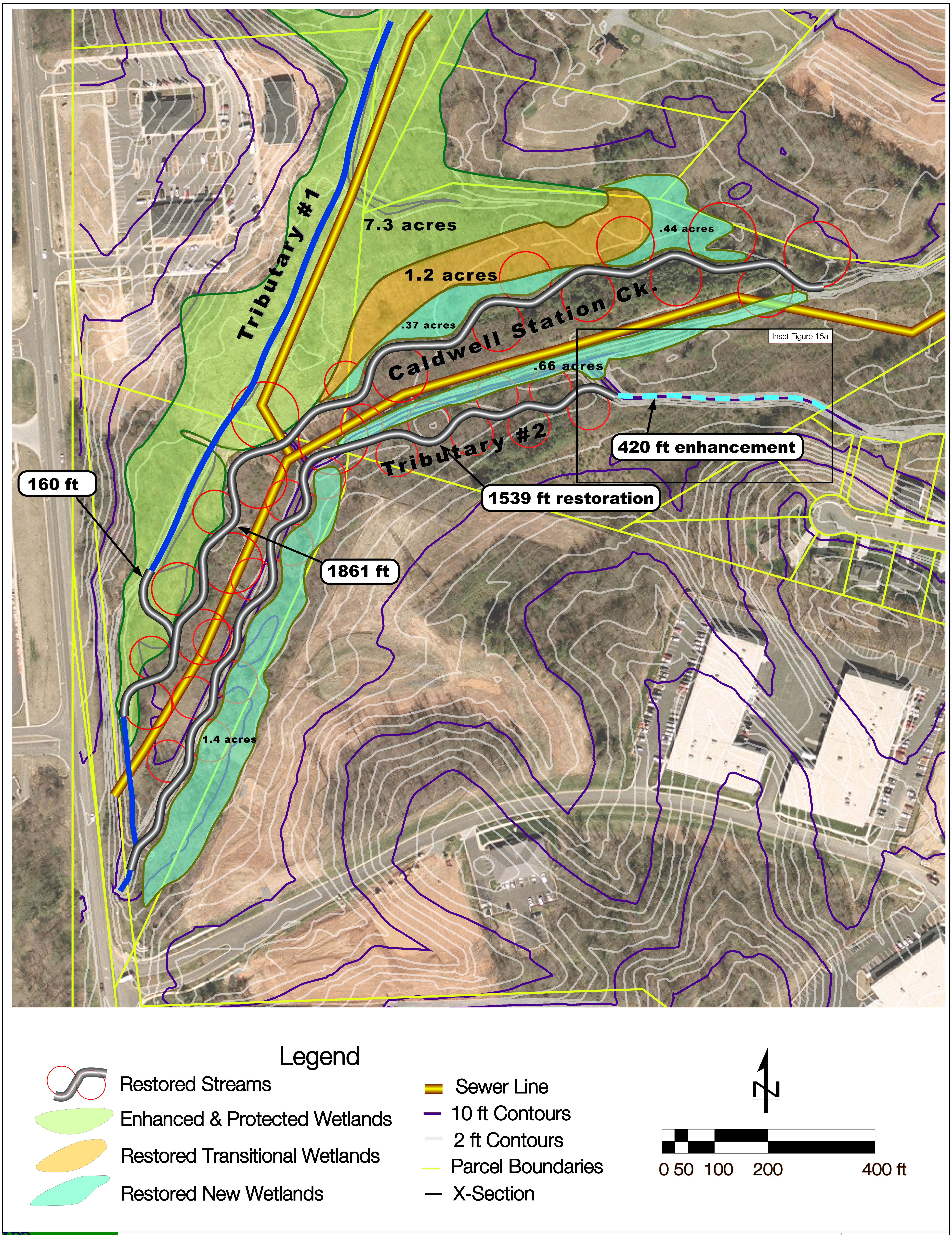
0 50 100 200 400 ft

*Jurisdictional wetland criteria subject to verification

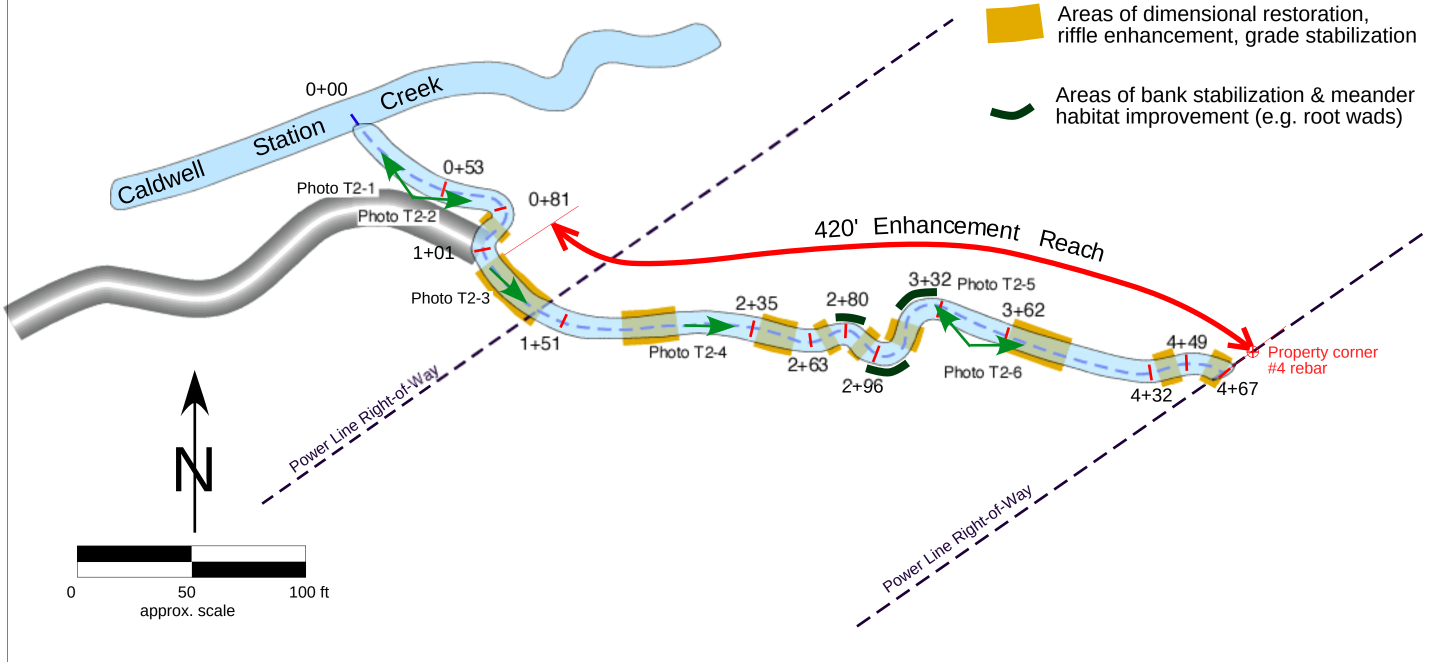
HDR ONE COMPANY Many Solutions and Habitat Assessment and Restoration Program Inc.	NCEEP Caldwell Station Creek Restoration Site, Mecklenburg Co., NC	Figure 13. Planform View of Existing Stream Channels and Wetlands*	Mar. 2004



FDR and Habitat Assessment and Restoration Program Inc.	NCEEP Caldwell Station Creek Restoration Site, Mecklenburg Co., NC	**Figure 14. Planview of Plant Communities**	Mar. 2004



HDR ONE COMPANY | Many Solutions and Habitat Assessment and Restoration Program Inc.	NCEEP Caldwell Station Creek Restoration Site, Mecklenburg Co., NC	Figure 15. Proposed Stream & Wetland Enhancement & Restoration: Planform View	March 2005



Photos are found at end of Appendix B

HDR ONE COMPANY | Many Solutions
and
Habitat Assessment and Restoration Program Inc.

NCEEP Caldwell Station Creek Restoration Site, Mecklenburg Co., NC

Figure 15a. Proposed stream enhancement along 420' reach of UT to Caldwell Station Creek (Trib.#2)

March 2005

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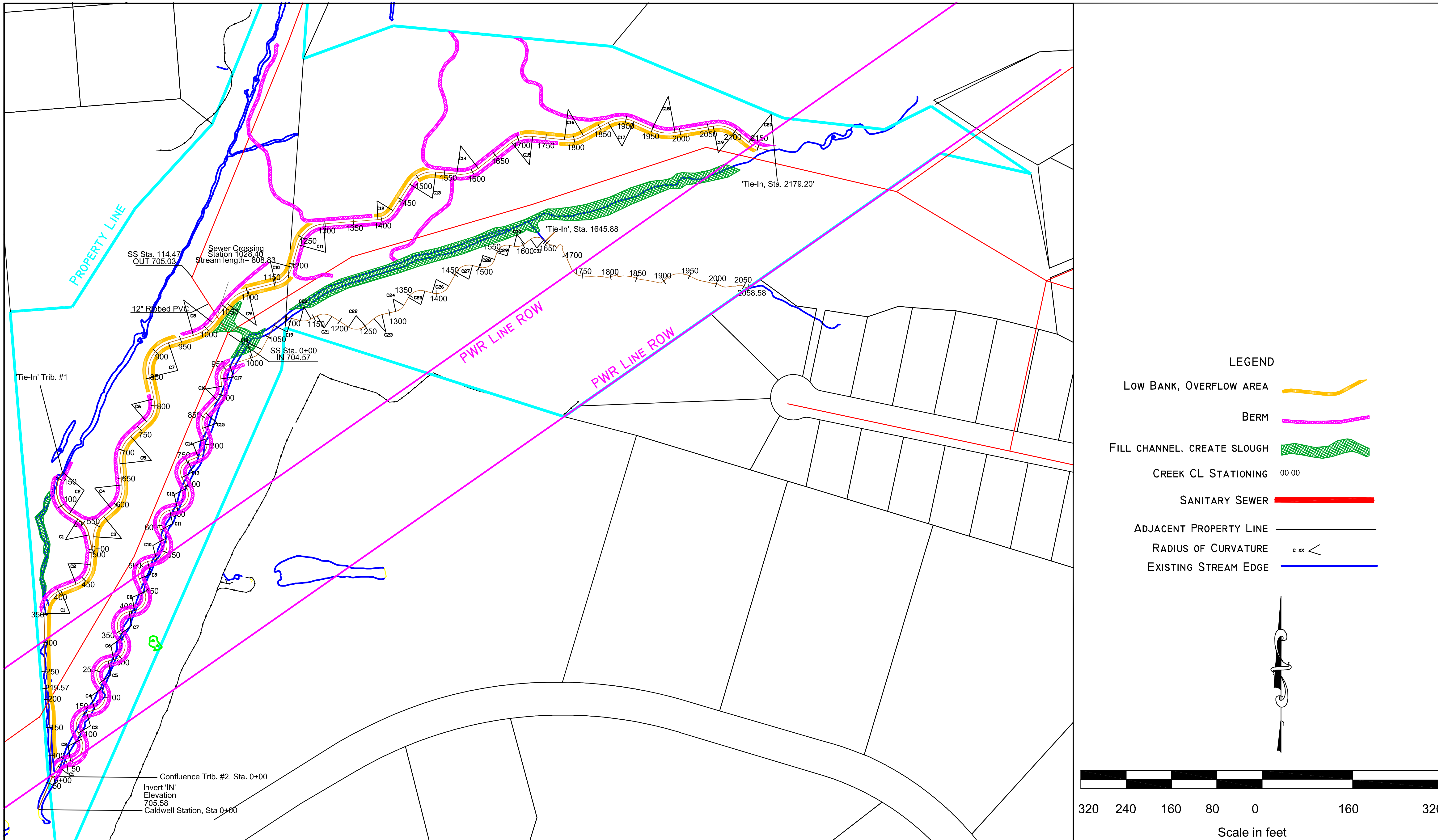

HDR ONE COMPANY | Many Solutions

Habitat Assessment and Restoration Program

NCEEP CALDWELL STATION CREEK RESTORATION SITE
MECKLENBURG COUNTY, NC

Figure 15b. Channel Restoration Planform Map Overview

JUNE 2005

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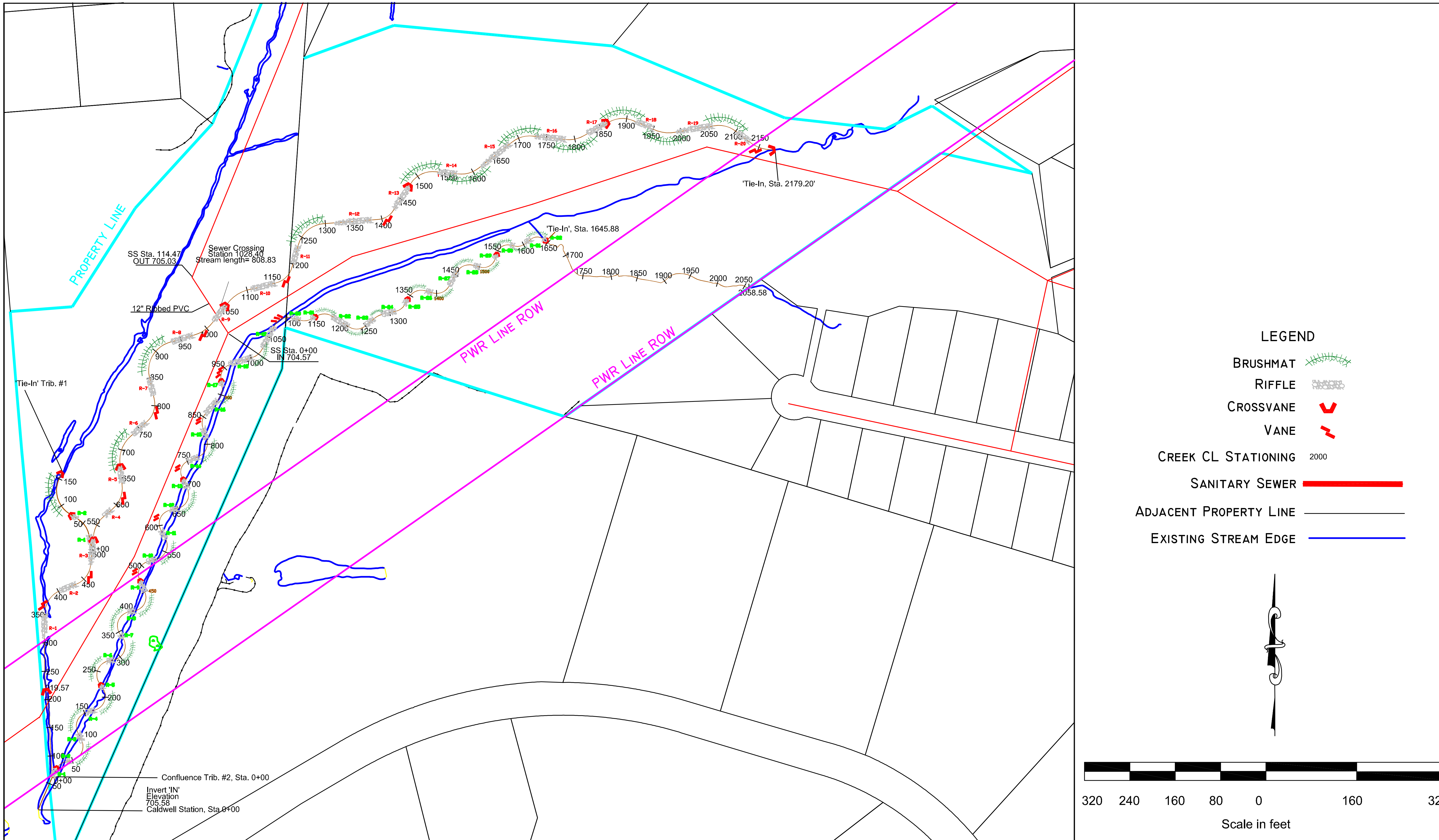


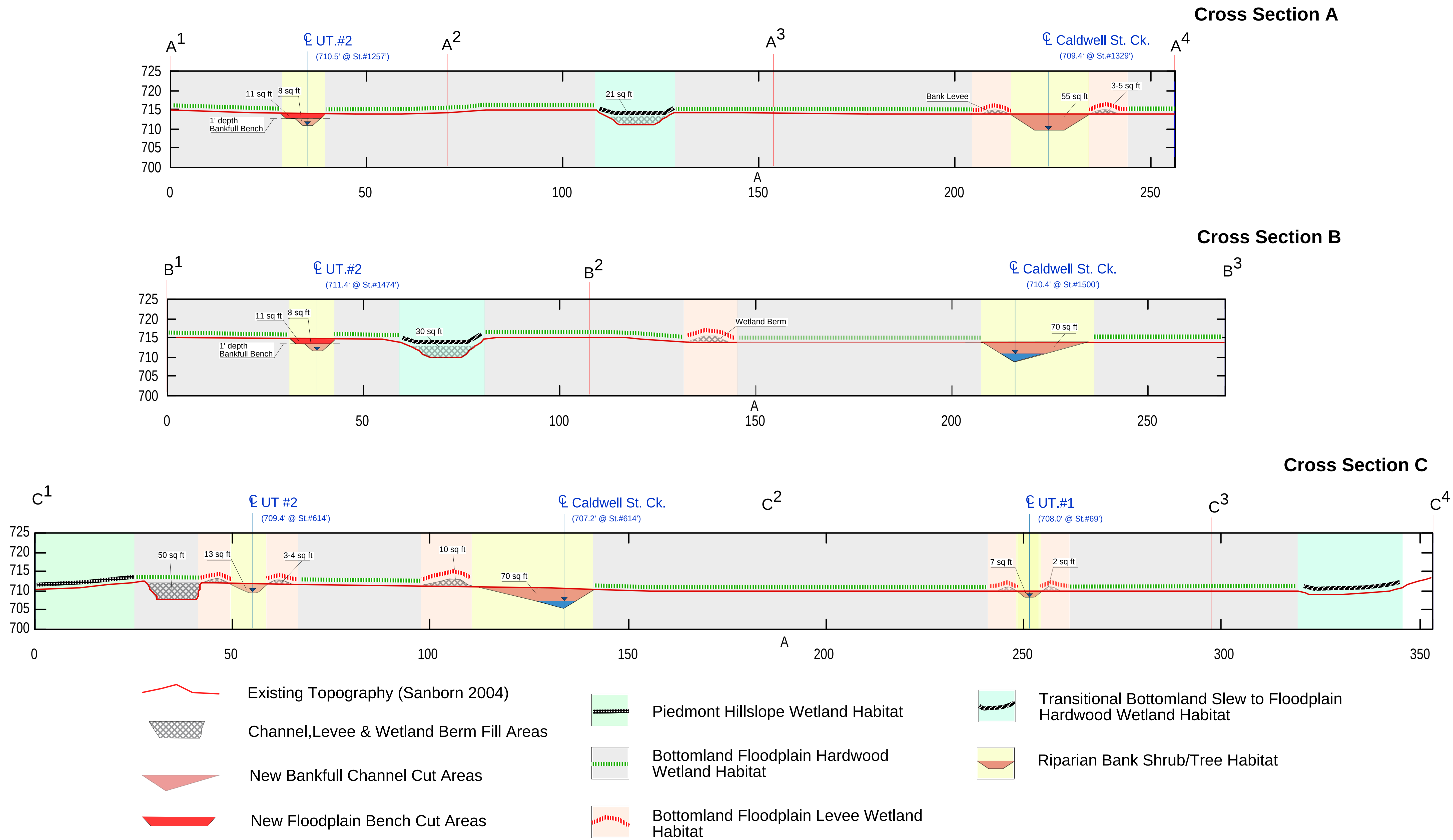
HDR ONE COMPANY | Many Solutions

HABITAT ASSESSMENT AND RESTORATION PROGRAM

NCEEP CALDWELL STATION CREEK RESTORATION SITE
MECKLENBURG COUNTY, NC

Figure 15c.
CHANNEL RESTORATION PLANFORM MAP
INSTREAM STRUCTURES

JUNE 2005



HDR ONE COMPANY *Many Solutions*

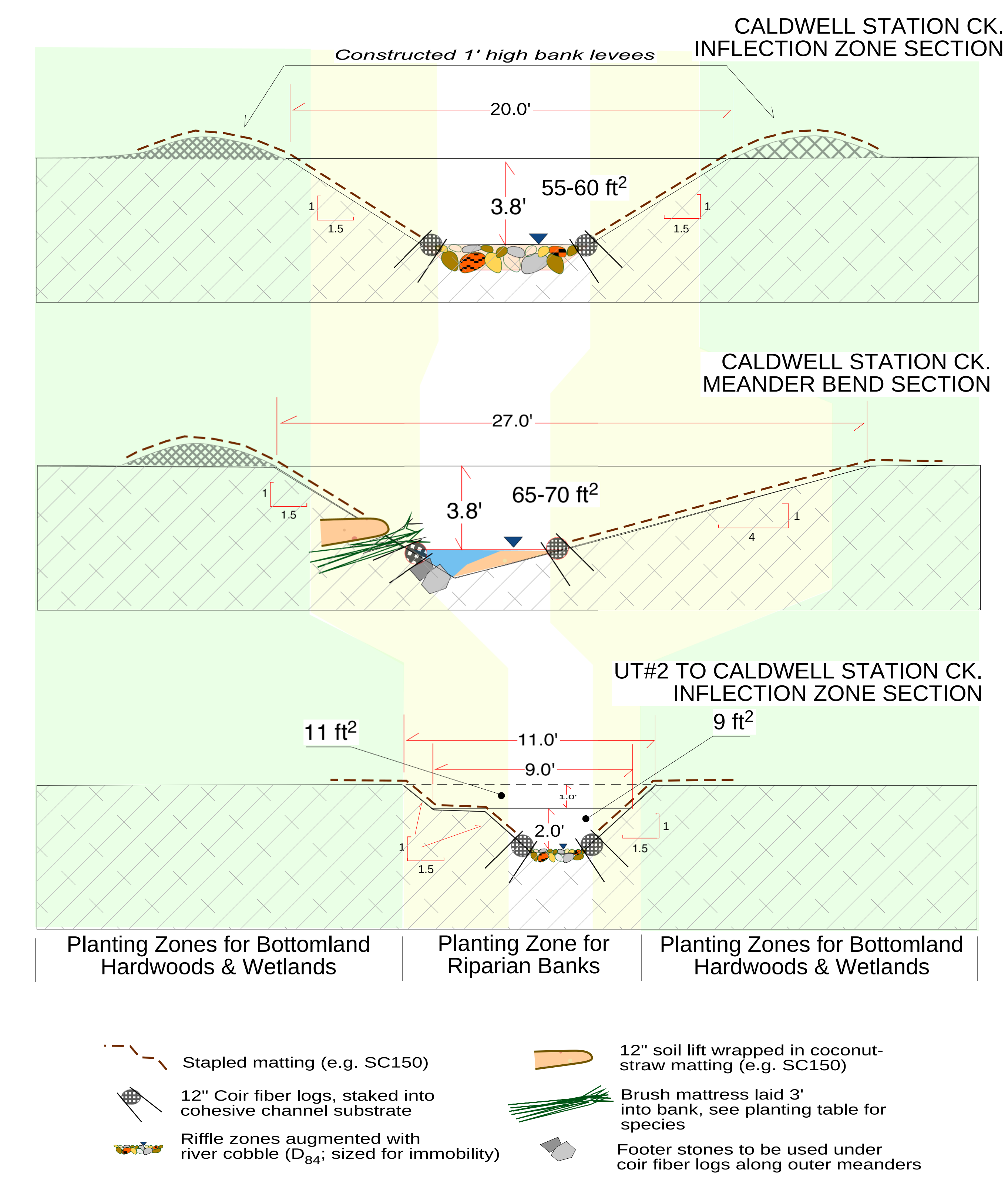
and

Habitat Assessment and Restoration Program Inc.

NCEEP Caldwell Station Creek Restoration Site, Mecklenburg County, NC

Figure 16a. Design Cross Sections (see Fig. 15 for the locations)
Wetland and Riparian Habitat Zones
Cut and Fill Areas Superimposed on 2004 Topography

May 2005

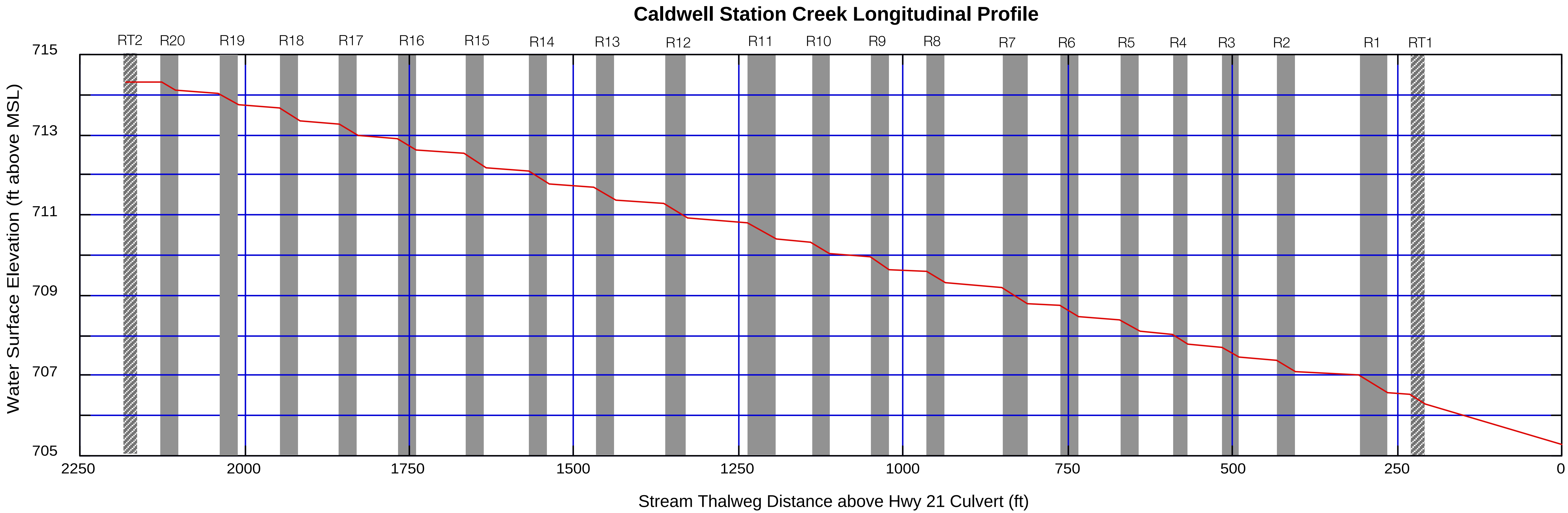


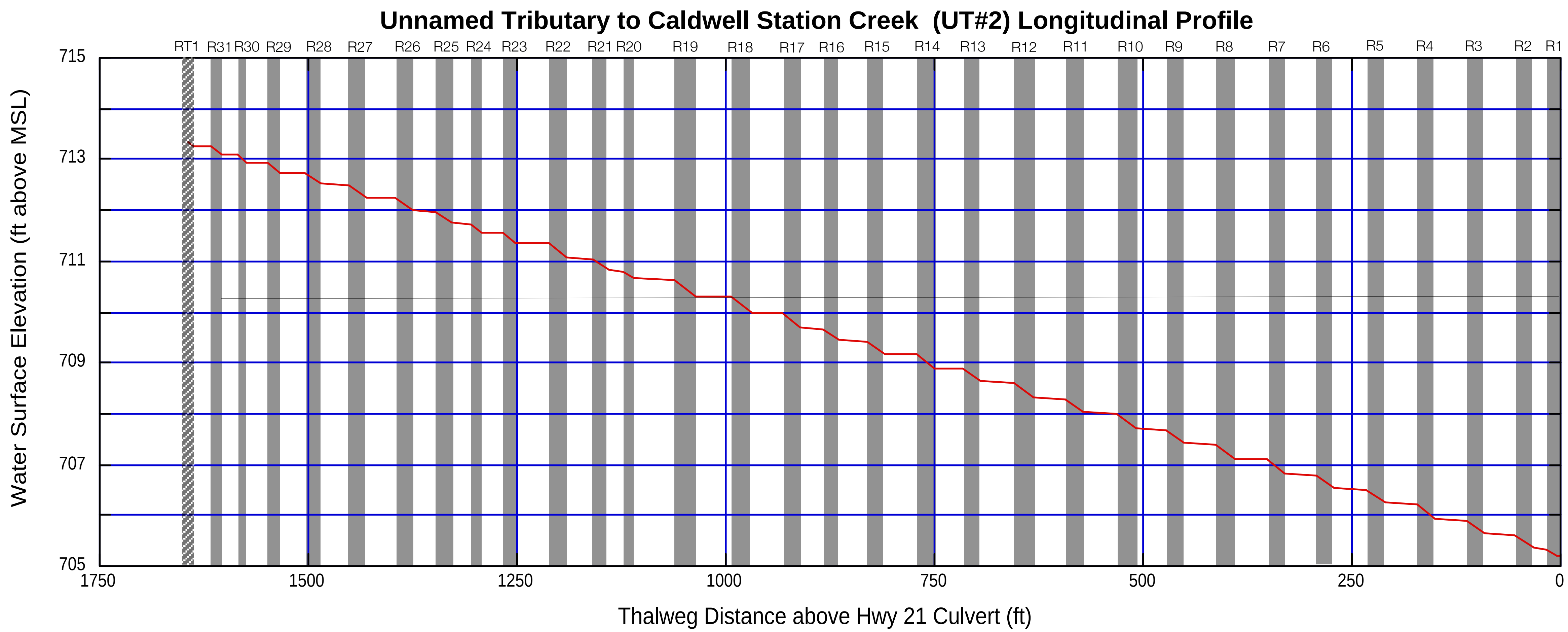
HDR ONE COMPANY | Many Solutions and Habitat Assessment and Restoration Program Inc.

NCEEP Caldwell Station Creek Restoration Site, Mecklenburg County, NC

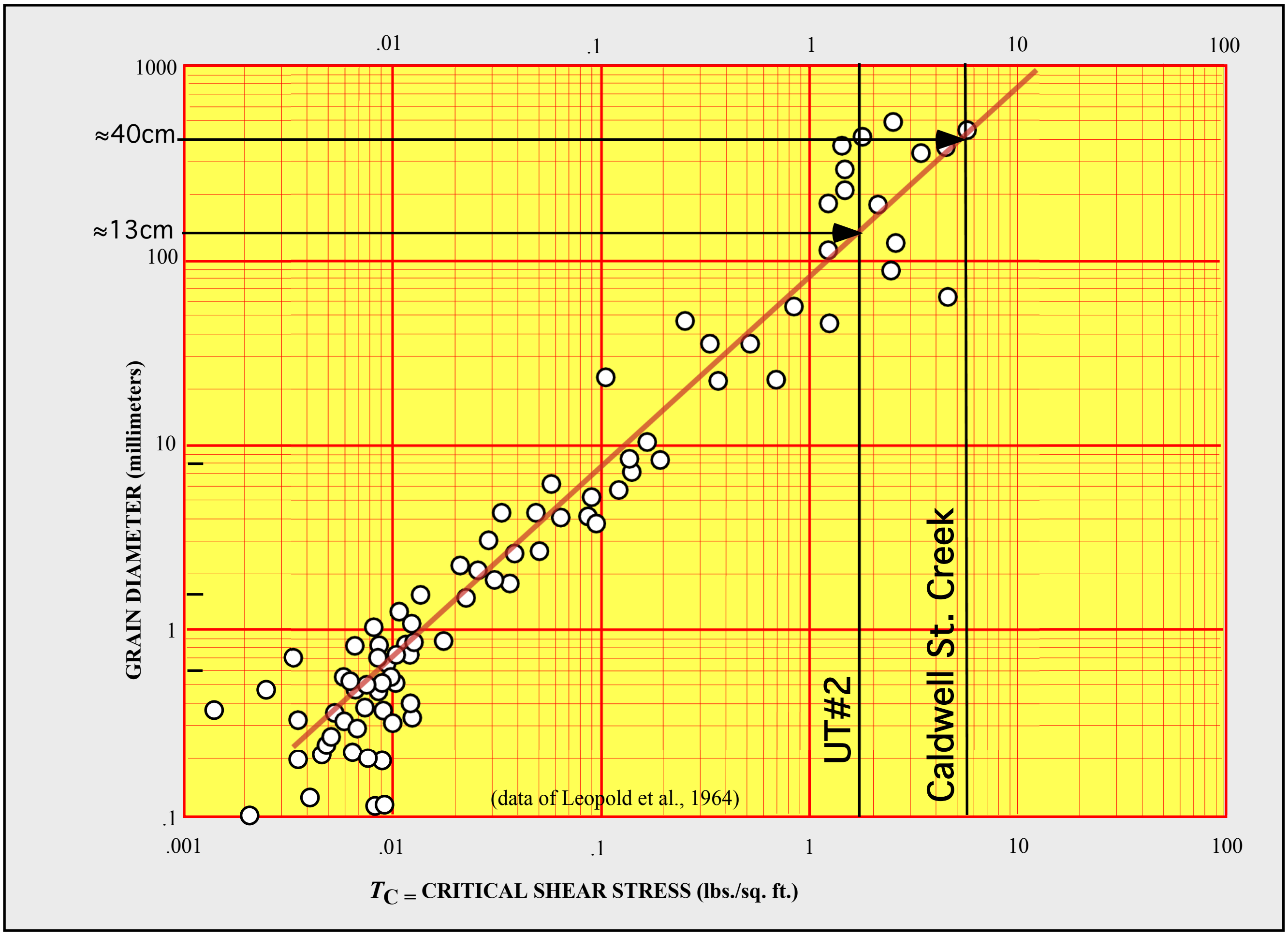
Figure 16b. Channel Cross Sections Detailed Schematic

May 2005



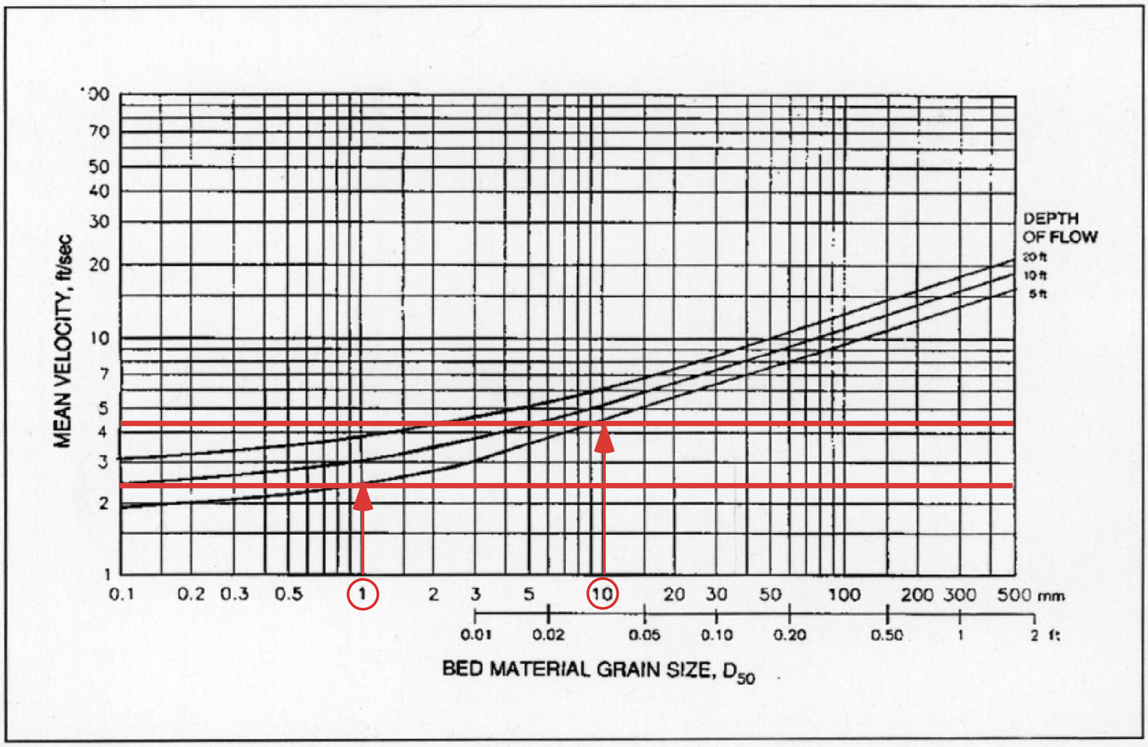


HDR ONE COMPANY | *Many Solutions* and Habitat Assessment and Restoration Program Inc.	NCEEP Caldwell Station Creek Restoration Site, Mecklenburg County, NC	Figure 17. Restored Longitudinal Profiles, Caldwell Station Ck. and UT#2	May 2005



HDR ONE COMPANY | Many Solutions and Habitat Assessment and Restoration Program Inc.	NCEEP Caldwell Station Creek Restoration Site, Mecklenburg County, NC	Figure 18. Shield Curve with Range of Conditions for Caldwell Station Ck. and UT#2 Restoration Reaches	May 2005

EM 1110-2-1418
31 Oct 94

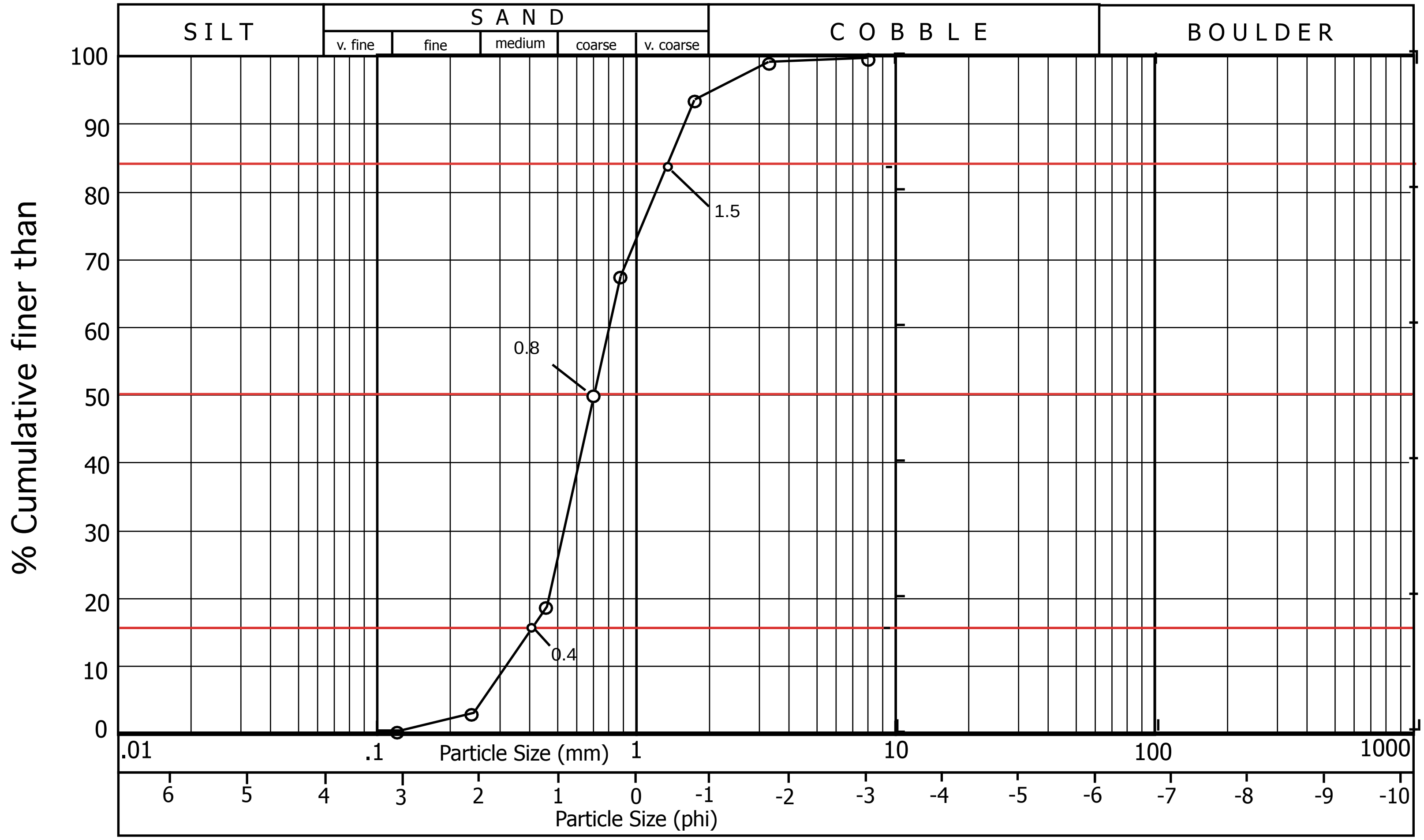


Example of allowable velocity-depth data for granular materials.
From USACOE 1994 Appendix A and B.

Range of estimated velocities for Caldwell Station and UT#2 bankfull storm plotted on the Mean Velocity vs Bed Material Size (D 50) chart from the USACOE 1994 guide to stream stabilization.

HDR ONE COMPANY | Many Solutions and Habitat Assessment and Restoration Program Inc.	NCEEP Caldwell Station Creek Restoration Site, Mecklenburg County, NC	Figure 19. Sediment Stability Curve (USACOE 1994) shown with estimated mean velocities for restoration reaches	May 2005

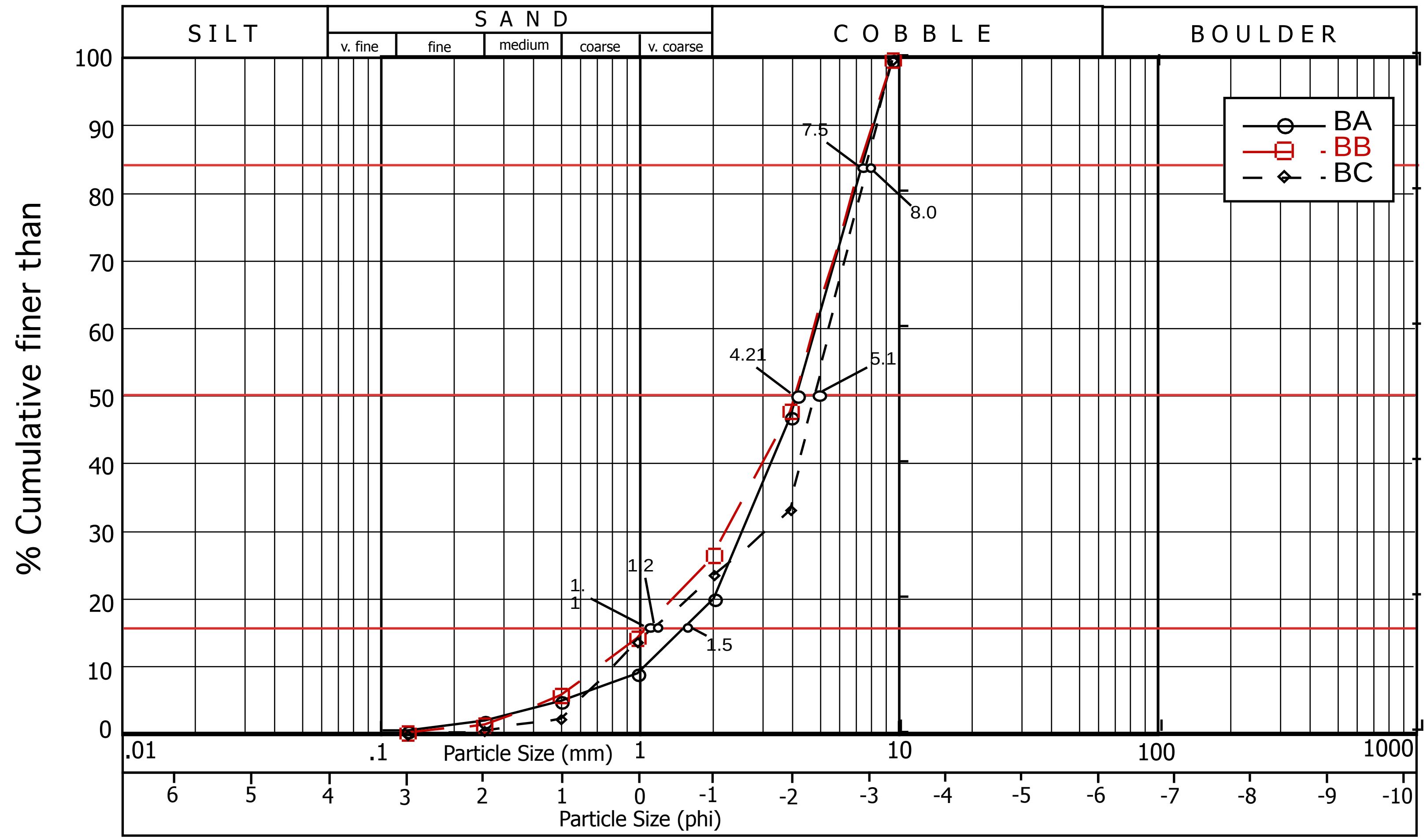
LOCALITY	Caldwell Station Reach - Typical Bar Grain Size Sample
SITE	Sample CS-BA



$D_{84(min)}$ 0.4 mm D_{50} 0.8 mm $D_{84(max)}$ 1.5 mm

HDR ONE COMPANY Many Solutions and Habitat Assessment and Restoration Program Inc.	NCEEP Caldwell Station Creek Restoration Site, Mecklenburg County, NC	Figure 20a. Grain size curve for Typical Bar (Existing Conditions) Caldwell St. Ck.	May 2005

LOCALITY	Caldwell Station Reference Reach - Bar Grain Size Samples
SITE	Samples CSR-BA, CSR-BB, & CSR-BC



$D_{84(min)}$ 1.26 mm

D_{50} 4.5 mm

$D_{84(max)}$ 7.3 mm

HDR ONE COMPANY | Many Solutions and Habitat Assessment and Restoration Program Inc.

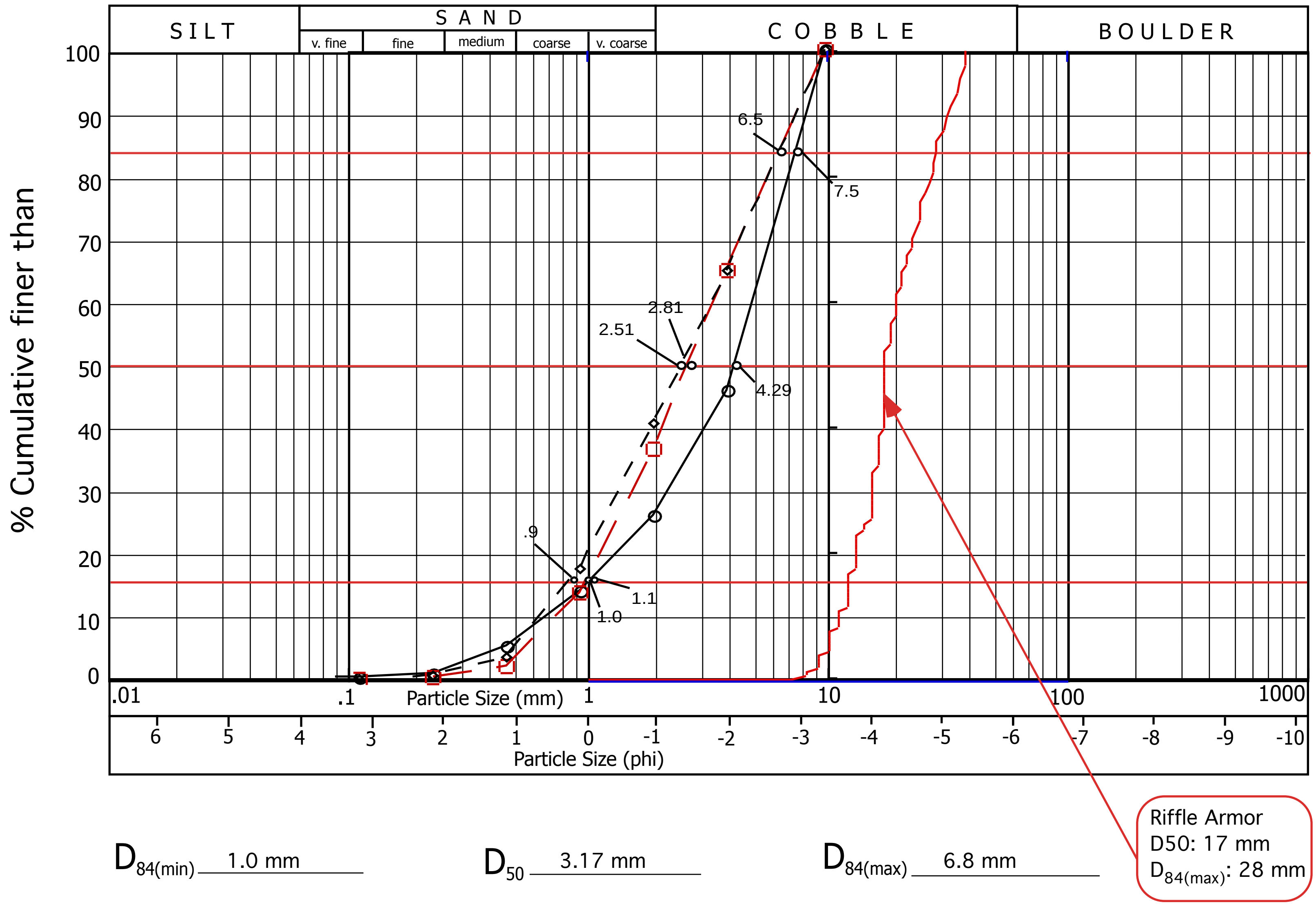
NCEEP Caldwell St. Creek Restoration Site, Mecklenburg County, NC

Figure 20b. Grain size curves for Typical Bars - Reference Reach (W. Fork Reeds Ck.)

May 2005

LOCALITY Caldwell Station Reference Reach - Riffle Substrate Grain Size Samples

SITE Samples CSR-RA, CSR-RB, & CSR-RC



$D_{84(min)}$ 1.0 mm

D_{50} 3.17 mm

$D_{84(max)}$ 6.8 mm

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NCEEP Caldwell Station Creek Restoration Site, Mecklenburg County, NC

Figure 20c. Grain size curves for Typical Riffles - Reference Reach (W. Fork Reeds Ck.)

May 2005

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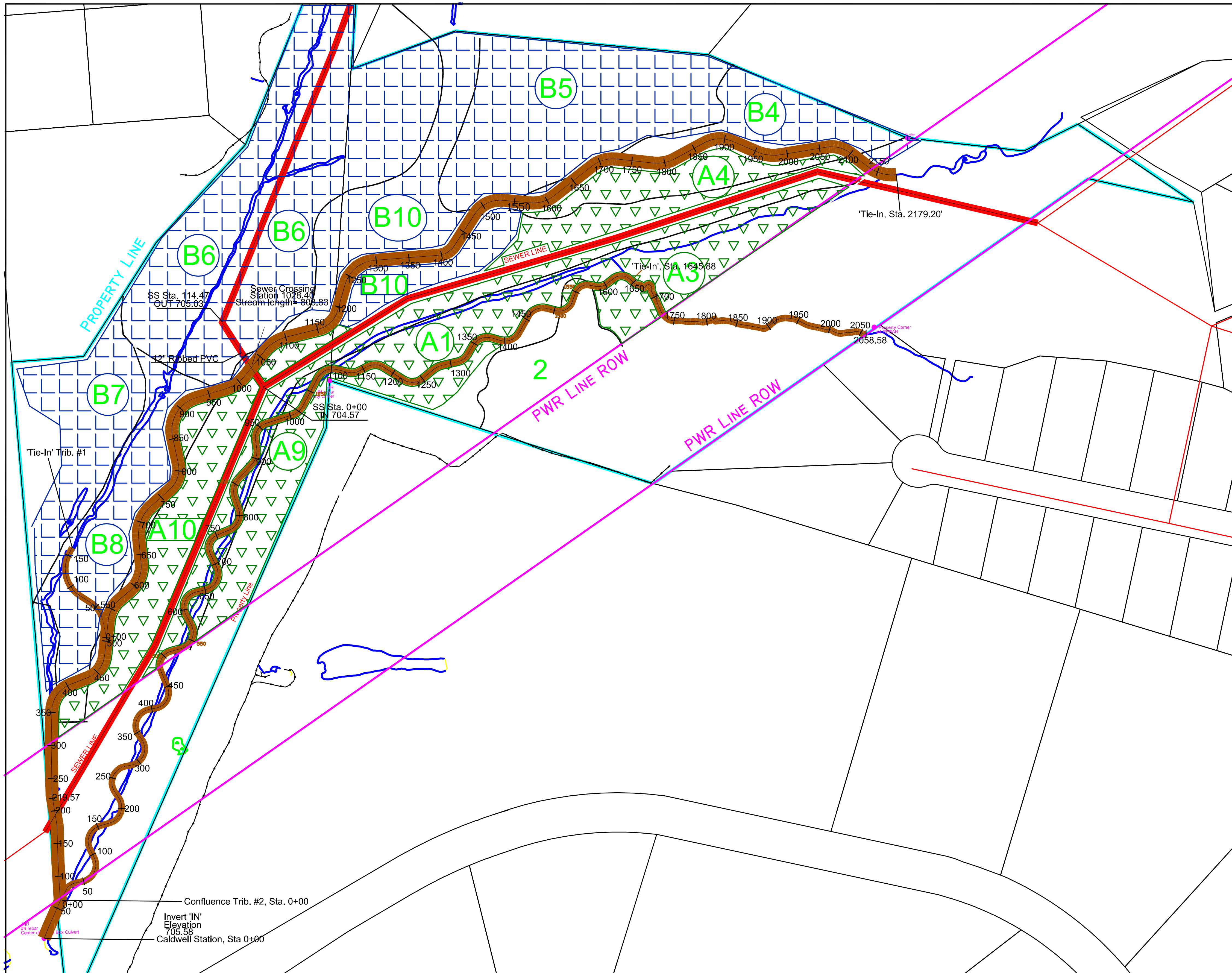


Existing Communities

1 Mixed Hardwood Upland
2 Pine and Mixed Hardwood Upland
3 Bottomland Hardwoods w/ Pine Flood Plain
4 Loblolly Pine Planting Flood Plain
5 Bottomland Hardwoods Flood Plain w/ Potential Wetlands
6 Former Beaver Pond w/ Potential Wetlands
7 Mixed Bottomland Hardwoods Flood Plain w/ Wetlands
8 Mixed Bottomland Hardwoods Flood Plain w/ Potential Wetlands
9 Mixed Bottomland Hardwoods Flood Plain
10 Mixed Bottomland Hardwoos Flood Plain w/ Potential Wetlands

LEGEND

Zone A. Bottomland
Zone B. Wet Bottomland
Zone C. Stream, Bank to Bank
Zone D. Easements/Planting Required due to Disturbance
Creek CL Stationing 2000
Sanitary Sewer
Adjacent Property Line
Existing Stream Edge

320 240 160 80 0 160 320

Scale in feet

HDR ONE COMPANY | Many Solutions

Habitat Assessment and Restoration Program

NCEEP CALDWELL STATION CREEK RESTORATION SITE
MECKLENBURG COUNTY, NC

Figure 21.
Existing Communities
Proposed Planting Zones

JUNE 2005

APPENDIX A

Appendix A

Vegetative Cover and Approximate Wetland Limits

List of Figures

CALDWELL STATION CREEK

Vegetative Cover

Area 1 is **Mixed Hardwoods Upland** with an average diameter breast height (dbh) of 10”. The canopy contains Sweetgum (*Liquidambar styraciflua*) to 14”dbh, Green ash (*Fraxinus pennsylvanica*) to 14” dbh, American elm (*Ulmus americana*) to 18” dbh, Persimmon (*Diospyros virginiana*) to 12” dbh, Red maple (*Acer rubrum*) to 18” dbh, Sycamore (*Platanus occidentalis*) to 14” dbh, White oak (*Quercus alba*) to 14” dbh, Southern red oak (*Q. falcata*) to 30” dbh, Swamp red oak (*Q. shumardii*) to 40” dbh, and Hackberry (*Celtis laevigata*) to 12” dbh. The subcanopy and shrub layers are poorly developed, but do contain Cane (*Arundinaria gigantea*) and Autumn Olive (*Elaeagnus umbellata*). The largest trees are situated in the western corner of this area. See Figure A2.

Area 2 is **Pine and Mixed Hardwoods Upland** with an average dbh of 8”. The canopy is dominated by Loblolly pine (*Pinus taeda*) to 12” dbh, with Sweet gum to 8” dbh, Sycamore to 10” dbh, and Red maple to 10” dbh. The subcanopy contains Red cedar (*Juniperus virginiana*) to 8” dbh, Tag alder (*Alnus serrulata*) and Pawpaw (*Asimina triloba*). The shrub layer is open and contains Cane and Autumn Olive. Vines are Catbrier (*Smilax* spp.). See Figure A3.

Area 3 is mixed **Bottomland Hardwoods with Pine Flood Plain** and has an average dbh of 8”. The canopy is fairly open and contains Sweet gum to 16” dbh, Yellow poplar (*Liriodendron tulipifera*) to 10” dbh, Black walnut (*Juglands nigra*) to 10” dbh, Wild cherry (*Prunus serotina*) to 8” dbh, and Loblolly pine to 16” dbh. The subcanopy contains Red cedar. The shrub layer is open to dense with Privet (*Ligustrum sinense*), Cane, and Tag alder. See Figure A4.

Area 4 is a relatively young **Loblolly Pine Planting Flood Plain** with an average dbh of 6”. The stand is Loblolly pine to 8” with a subcanopy of young hardwoods. See Figure A5.

Area 5 is a relatively young, even aged, mixed **Bottomland Hardwoods Flood Plain with potential wetland inclusions**, with an average dbh of 6”. The canopy is dominated by Sweet gum to 14” dbh, and Yellow poplar to 10” dbh, with Sycamore to 8” dbh, Willow oak (*Q. phellos*) to 6” dbh, Red maple to 12” dbh, American elm to 8” dbh, and Black willow (*Salix nigra*) to 12” dbh. A few Loblolly pines to 12” dbh are scattered within the canopy. The subcanopy and shrub layers are absent. Standing water and a de-watering ditch are also in this area. See Figure A6.

Area 6 in an old **Former Beaver pond with potential wetland inclusions**, which was drained a year or more ago. It is dominated by grasses and sedges with a fringe of small caliper trees and shrubs around the perimeter. These are dominated by Black willow with Silky dogwood (*Cornus amomum*), Arrow wood (*Viburnum dentatum*), Tag alder, Red maple, Green ash, and Elderberry (*Sambucus canadensis*). See Figure A7.

Area 7 is **Mixed Bottomland Hardwoods Flood Plain with wetlands**, with an average dbh of 8”. It is dominated by Red maple to 10” dbh, with Black willow and Green ash also present in the canopy. The shrub layer consists of Tag alder, Arrow wood and Silky dogwood. See Figure A8.

Area 8 is **Mixed Bottomland Hardwoods Flood Plain with potential wetland inclusions,** a swale-like area below the Beaver dam. It is comprised of even aged small caliper trees with an average dbh of 4". The canopy contains Black willow to 10", Green ash to 4" dbh, Red maple to 3" dbh, Sycamore to 4" dbh, and a few scattered Loblolly pines to 10" dbh. The shrub layer contains Tag alder and Button bush (*Cephalanthus occidentalis*). See Figure A9.

Area 9 is **Mixed Bottomland Hardwoods Flood Plain**, has a fairly open canopy dominated by Green ash with an average dbh of 8". The canopy contains Green ash to 8" dbh, Sycamore to 12" dbh, Red maple to 24" dbh and Yellow poplar to 10" dbh. The subcanopy consists of Red maple to 8" dbh. The shrub layer contains Black berry (*Rubus* spp.), Cane and Arrow wood. See Figure A10

Area 10 is **Mixed Bottomland Hardwoods Flood Plain with potential wetland inclusions,** similar to area 8. It is comprised of even aged small caliper trees with an average dbh of 4". The canopy contains Black willow to 6", Green ash to 4" dbh, Red maple to 3" dbh, and Sycamore to 4" dbh. The shrub layer contains Tag alder and Silky dogwood. See Figure A11.

The sewer line that parallels Caldwell Station Creek is overgrown with small caliper trees, Black berry and Japanese honeysuckle (*Lonicera japonica*).

The power line right-of-way is overgrown with a number of small caliper weedy species such as Sweet gum and Black locust (*Robinia pseudo-acacia*).

The undisturbed creek bank is lined with trees that range is size from small shrubs to 30" dbh, with an average dbh of 12" to 14".

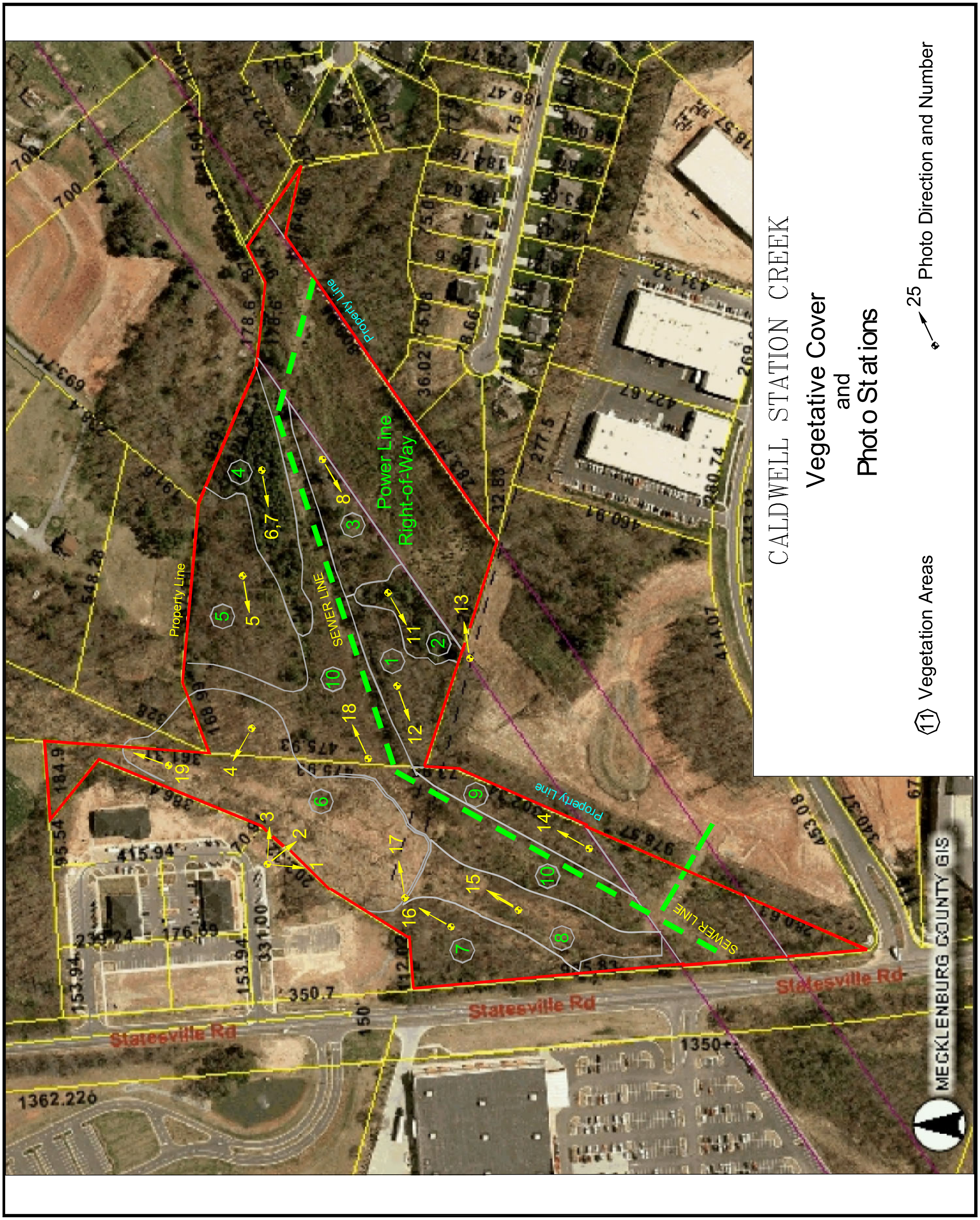


Figure A1 Map of Vegetative Cover and Photo Stations

Figure A2 Area 1, Photo #12, Mixed Hardwoods Upland

Figure A3 Area 2, Photo #11, Pine and Mixed Hardwoods Upland

Figure A4 Area 3, Photo #8, Bottomland Hardwoods with Pine Floodplain

Figure A5 Area 4, Photo #7, Loblolly Pine Planting Flood Plain

Figure A6 Area 5, Photo #5, Bottomland Hardwood Flood Plain

Figure A7 Area 6, Photo #2, Former Beaver Pond

Figure A8 Area 7, Photo #16, Mixed Bottomland Hardwoods Flood Plain

Figure A9 Area 8, Photo #15, Mixed Bottomland Hardwoods Flood Plain

Figure A10 Area 9, Photo #14, Mixed Bottomland Hardwoods Flood Plain

Figure A11 Area 10, Photo #18, Mixed Bottomland Hardwoods Flood Plain

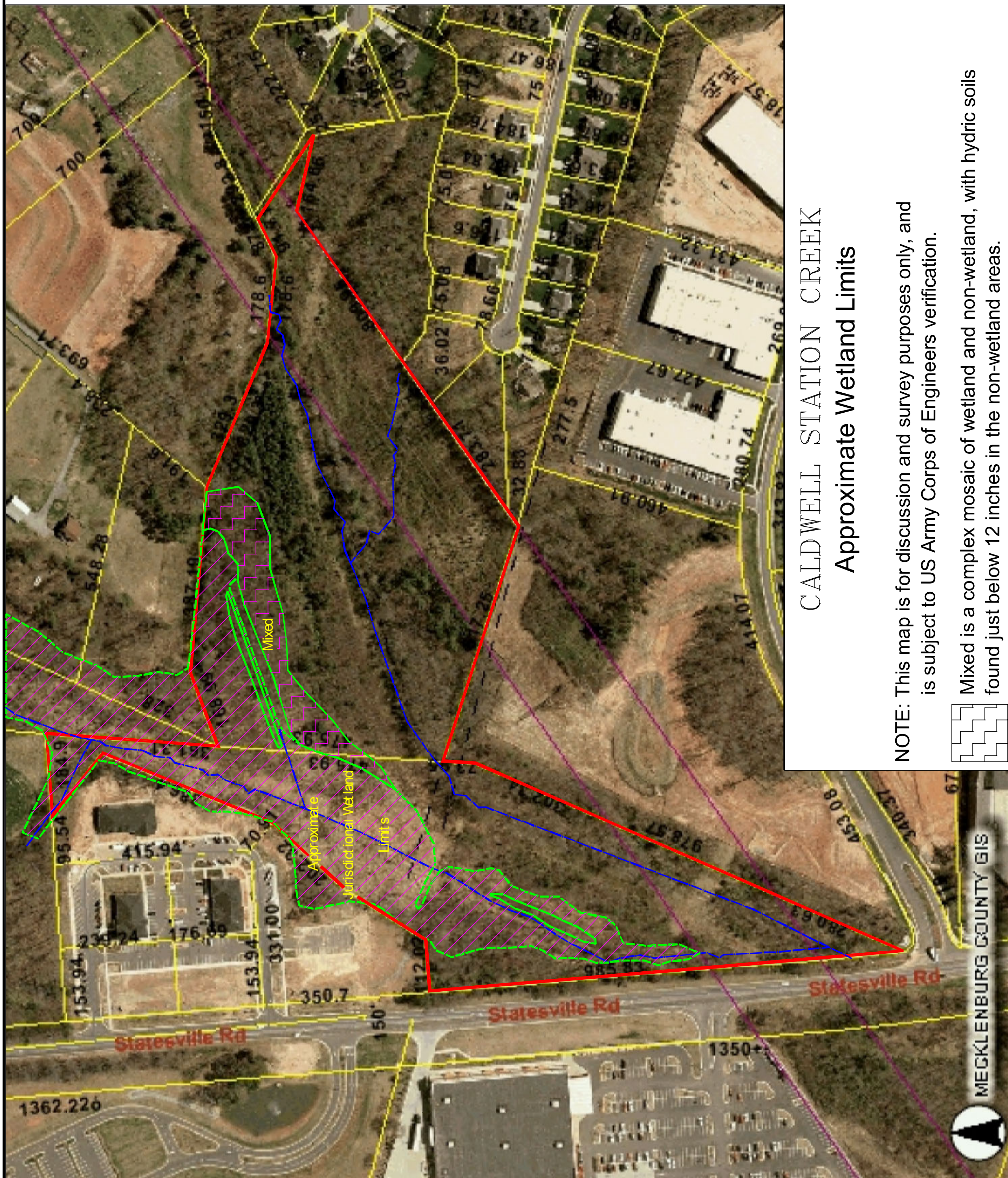


Figure A12 Map of Approximate Jurisdictional Wetland Areas

APPENDIX B

Caldwell Station Main Reach between I-77 and Interstate 21 looking upstream

Caldwell Station Main Reach -- 550 ft upstream of Interstate 21 culvert looking upstream

Caldwell Station Main Reach – 1000 ft upstream of Interstate 21 culvert looking upstream

Caldwell Station Main Reach – 1700 ft upstream of Interstate 21 culvert looking upstream

Caldwell Station Tributary #1 – 375 ft upstream of confluence with Caldwell Station looking downstream

Caldwell Station Tributary #1 – 1200 ft upstream of confluence with Caldwell Station looking upstream


Caldwell Station Tributary #2 – 200 ft upstream of confluence with Caldwell Station looking upstream


Caldwell Station Tributary #2 – 475 ft upstream of confluence with Caldwell Station looking downstream


Caldwell Station Tributary #1 Relic, between I-77 and Interstate 21 looking upstream


Caldwell Station Tributary #1 Relic, between I-77 and Interstate 21 looking downstream

Photo T2-1, South UT to Caldwell Station Crk. Looking downstream to confluence

Photo T2-2, South UT to Caldwell Station Crk. Looking upstream.

Photo T2-3, South UT to Caldwell Station Crk. Looking upstream.

Photo T2-4, South UT to Caldwell Station Crk. Looking upstream at debris jam.

Photo T2-5, South UT to Caldwell Station Crk. Looking downstream at debris jam.

Photo T2-6, South UT to Caldwell Station Crk. Looking upstream to property line.

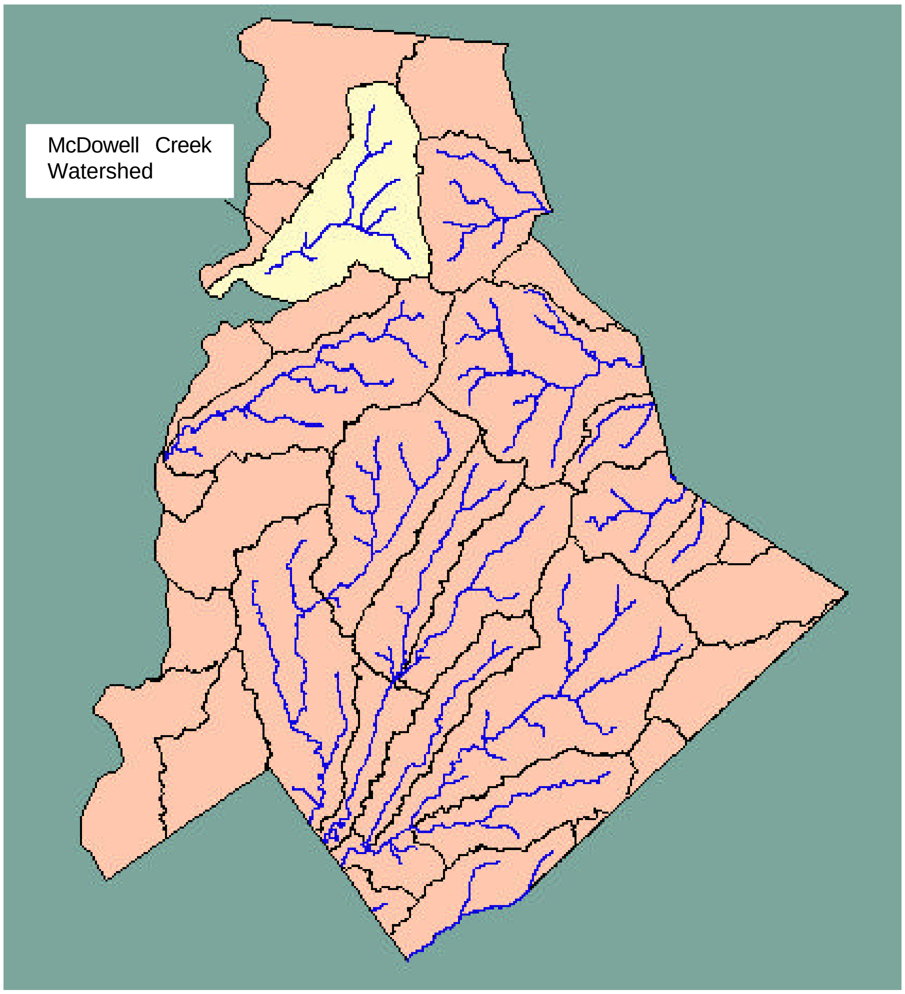
APPENDIX C

Watershed Study No. 6

McDowell Creek Watershed

Preliminary Engineering Report

MCSWS Project No. 28001



January 2002

Prepared For:

Charlotte-Mecklenburg STORM WATER Services

Prepared By:

WatershedConcepts
A Total Water Resource
6201 Fairview Rd., Suite 400
Charlotte, NC 28210

MECKLENBURG COUNTY
STORM WATER SERVICES

PRELIMINARY ENGINEERING REPORT
FOR
MECKLENBURG COUNTY MITIGATION PLANS

MCDOWELL CREEK WATERSHED

ACKNOWLEDGEMENT

The project staff of Watershed Concepts, a Division of HSMM, Inc., would like to give thanks to Mecklenburg County Storm Water Services (MCSWS) for its assistance and support during this project.

DISCLAIMER

This watershed-wide study is for planning purposes only. These study results and recommendations are preliminary and should not be used for construction without additional detailed engineering design analysis.

CERTIFICATION

I hereby certify that this Preliminary Engineering Report for Mecklenburg County Mitigation Plans was prepared by me or under my direct supervision.

Signed, sealed, and dated this 11th day of January 2002.

By:_____________________________
Joseph B. Chapman, P.E.
Senior Vice President

MECKLENBURG COUNTY
STORM WATER SERVICES

PRELIMINARY ENGINEERING REPORT
FOR
MECKLENBURG COUNTY MITIGATION PLANS

MCDOWELL CREEK WATERSHED

TABLE OF CONTENTS

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GLOSSARY

Term used in this report	Definition
100-year Flood	The flood that has a 1% probability of being equaled or exceeded in any given year.
Base Flood Elevation (BFE)	Water surface elevation for the 1% probability flood (100-year flood).
Existing Conditions	The land use condition of the watershed based on the state of development as of the date of this study.
Existing Condition Floodplain (ECF)	The floodplain delineated for the 1% probability flood (100-year flood) using the current land use conditions in the watershed (existing conditions).
Flood Fringe Areas	A buffer area bounded by the ECF (elevation of the BFE) and a point where the land elevation if 2 ft above the BFE.
Future Conditions	The land use condition of the watershed based on the projected ultimate buildout in the watershed.
Future 100-year Flood	The flood that has a 1% probability of being equaled or exceeded in any given year under the future conditions of land use
Future Condition Floodplain (FCF)	The floodplain delineated for the 1% probability flood (future 100-year flood).
MCSWS	Mecklenburg County Storm Water Services
MCDEP	Mecklenburg County Department of Environmental Protection
NALGEP	National Association of Local Government Environmental Professionals
CMUD	Charlotte-Mecklenburg Utilities District

EXECUTIVE SUMMARY

MCDOWELL CREEK WATERSHED

This Preliminary Engineering Report briefly describes a study of McDowell Creek morphology, bank stability problems, flood hazard areas, and potential mitigation measures. Public records from the Mecklenburg County website, aerial photographs, interviews with public officials, and specific references listed at the end of this report have been consulted in preparation of this report. The gathering of information has been supplemented by several field visits, surveys, and photography of the areas under study.

Currently, the McDowell Creek watershed, shown in Figure E1, is not as highly developed as some of the other sections of Mecklenburg County. However, rapid development is visible virtually everywhere in the watershed, and conditions in this drainage basin will soon resemble those in other highly developed sections of the County. This watershed includes the tributaries of Caldwell Station Creek, Torrence Creek, Torrence Creek Tribs 1 and 2, and McDowell Creek Tribs 1 and 2.

McDowell Creek and its tributaries are in reasonably stable condition due to four main factors:

1. Stream banks stabilized by riprap or other means to safeguard a sewer main line that extends along the creek

2. Heavily vegetated banks and floodplains

3. Numerous road crossings and other man-made structures which form grade controls that limit stream scour and head-cutting

4. Past stabilization efforts along McDowell Creek and its tributaries

Flooding potential within the existing 100-year floodplain (ECF) can be identified in four general neighborhoods along McDowell Creek. A total of 15 residential structures are affected, none of which experience inundation because the finished floor elevations are above the BFE. All structures are located in the flood fringe areas (within 2 ft of BFE) as shown in Table E1. All structures are post-FIRM (built after 1981) and are shown in Figures E2 and E3. Three mitigation measures were considered for the four neighborhoods shown in Table E1 and Figures E2-E3: elevating the structures two feet above the BFE, berm construction, and acquisition.

McDowell Creek is approximately 9.2 miles long with an additional 10.3 miles of tributaries flowing into the creek. The watershed extends in a general northeast to southwest direction within the boundaries of the City of Huntersville, which is north of the City of Charlotte. McDowell Creek discharges into the Catawba River in the west side of Mecklenburg County, upstream of Mountain Island Lake, which is the primary source of Charlotte's drinking water supply. The banks and floodplains of McDowell Creek and its tributaries are densely vegetated and in some parts heavily wooded, creating a stable stream. The flow is mostly shallow and tranquil in a well-defined channel with relatively steep banks. Compared to other creeks, McDowell is less urbanized, although the rapid pace of development is evident along the stream and its tributaries. Frequent occurrence of point bars is indicative of increased sediment transport due to heavy development activity.

Table E1. Structures with ECF Flooding Potential in McDowell Creek Watershed							
No. of Structures	**Project Neighborhood/Area**	**No. Flooded**	**No. within 2ft of BFE**	**Avg. Fld. Depth***	**Median Depth***	**Highest Depth***	**Lowest Depth***
9	Henderson Park Rd/Leisure Ln/Lullwater Cv	0	9	-0.87	-1.30	-0.11	-1.63
2	Gilead Road	0	2	-1.39	-1.39	-0.86	-1.91
3	Cumbria Ct/Stonegreen Ln	0	3	-0.43	-0.63	-0.08	-0.78
1	Delancey Ln	0	1	-0.01	-0.01	-0.01	-0.01

* Negative numbers indicate that the finished floor elevation is above the 100-yr flood elevation; depths are in feet.

The Rosgen stream classification system was utilized to provide an initial assessment of the morphology of McDowell Creek. The majority of McDowell Creek is classified as a type G channel with some reaches possibly being classified as type F. Generally, the channel displays a low width/depth ratio, low sinuosity and relatively low channel slope. Indicators of a new bankful flow line were observed below the historic top-of-bank, which imply that the channel has incised within the historic floodplain. This has most likely resulted from a combination of urbanization of the watershed and manual re-grading of the channel. The historic floodplain, which was formed as an alluvial plain bounded by gentle slopes of upland soils, currently forms a terrace that confines the channel.

McDowell Creek discharges into the Catawba River between the Cowins Ford Dam and Mountain Island Lake, the primary source of Charlotte's drinking water supply. This location on the Catawba River is also vital for the cities of Gastonia and Mount Holly, which have water supply intakes near the mouth of McDowell Creek. This watershed is actively being studied by various groups, including MCSWS (this study), Local Watershed Management Plan (NC Wetlands Restoration Program and CH2M-Hill), Water Quality Computer Model Simulation (MCDEP and TetraTech), and McDowell Creek Watershed Smart Growth for Clean Water Partnership (NALGEP, Charlotte, Mecklenburg County, Cornelius, Huntersville, Trust for Public Lands). It is important to note that these initiatives have different objectives, and as each initiative progresses, the participants are sharing information, communicating, and coordinating their efforts.

Primary pollutants from land development activities along McDowell Creek and its tributaries include nutrients, fecal coliform, and sediment. The Mountain Island Lake Marine Commission has already noted the introduction of Hydrilla (Hydrilla L.C. Rich). A Hydrilla-eating carp has been introduced to combat the problem. However, the direct cause of the problem stems from the abundant source of nutrients that fertilize this plant, flowing downstream through the McDowell Creek watershed. There are various land acquisition programs underway to protect and buffer the watershed from non-point source pollutants and development, including the Trust for Public Lands and the Mecklenburg County Park and Recreation Department. Together, through the Mountain Island Lake Initiative, each is purchasing large tracts of land to be preserved as open space.

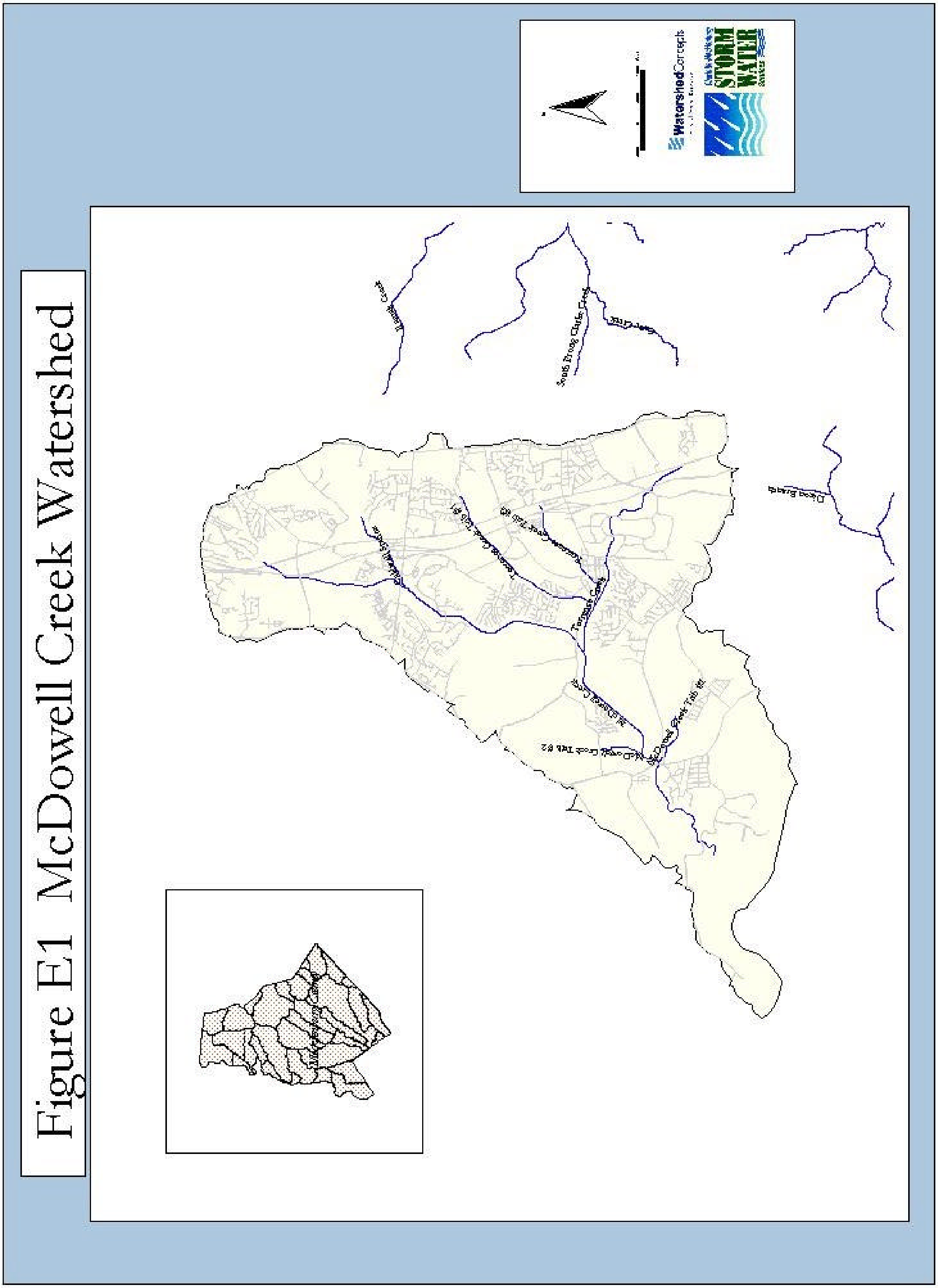


Figure E1 McDowell Creek Watershed

MCDEP maintains several monitoring stations along McDowell Creek and its tributaries. While the Macroinvertebrate Taxa Richness sampling and the Fish Bioassesment sampling has produced Poor and Fair ratings since 1994, the overall Water Quality Index has consistently ranked as Average, Good and Good-Excellent. The overall water quality has remained generally consistent in the watershed since 1996. One flow monitoring station, USGS Gage 0214266000, located at McDowell Creek and Beatties Ford Road crossing, has been in operation since November 1996.

Presently, there are no major capital improvement projects in the watershed that may affect its hydrology. There are plans for the construction of approximately 8.7 miles of greenway trail along McDowell Creek and its tributaries, of which currently approximately 0.7 mile has been completed. The analyses and mitigation alternatives considered in this report will not be affected by the planned capital improvement projects of the County.

Flooding hazards for the structures lining the banks of the creek may be identified in four general neighborhoods affecting a total of 15 structures. All of the structures have finished floor elevations in the flood fringe areas (within 2 ft of BFE). Inundation damages in the case of a 100-year flood are nonexistent. **Three flood mitigation alternatives and a no-action alternative were considered for the affected structures in the McDowell Creek watershed. None of the mitigation measures resulted in a benefit:cost ratio greater than 1.0, therefore no flood mitigation measures are recommended for this watershed.**

There are several road crossings that are subject to overtopping in case of a 100-year flood. Flood depths over the roadway may be as high as 6.3 ft in one case for the future 100-year flood (FCF). Two smaller crossings on non-public roads would also be flooded severely. Several mitigation measures should be considered for the road crossings of this watershed, which include warning signs for the approaching motorists, tall guardrails or indicators to guide the vehicles away from the edge of the road in case of a flash flood, raising the elevation of road at the stream crossing, and emergency response team notification. Regular maintenance at man-made structures such as road crossings and storm water outfalls will be necessary to maintain the stream capacity and stability.

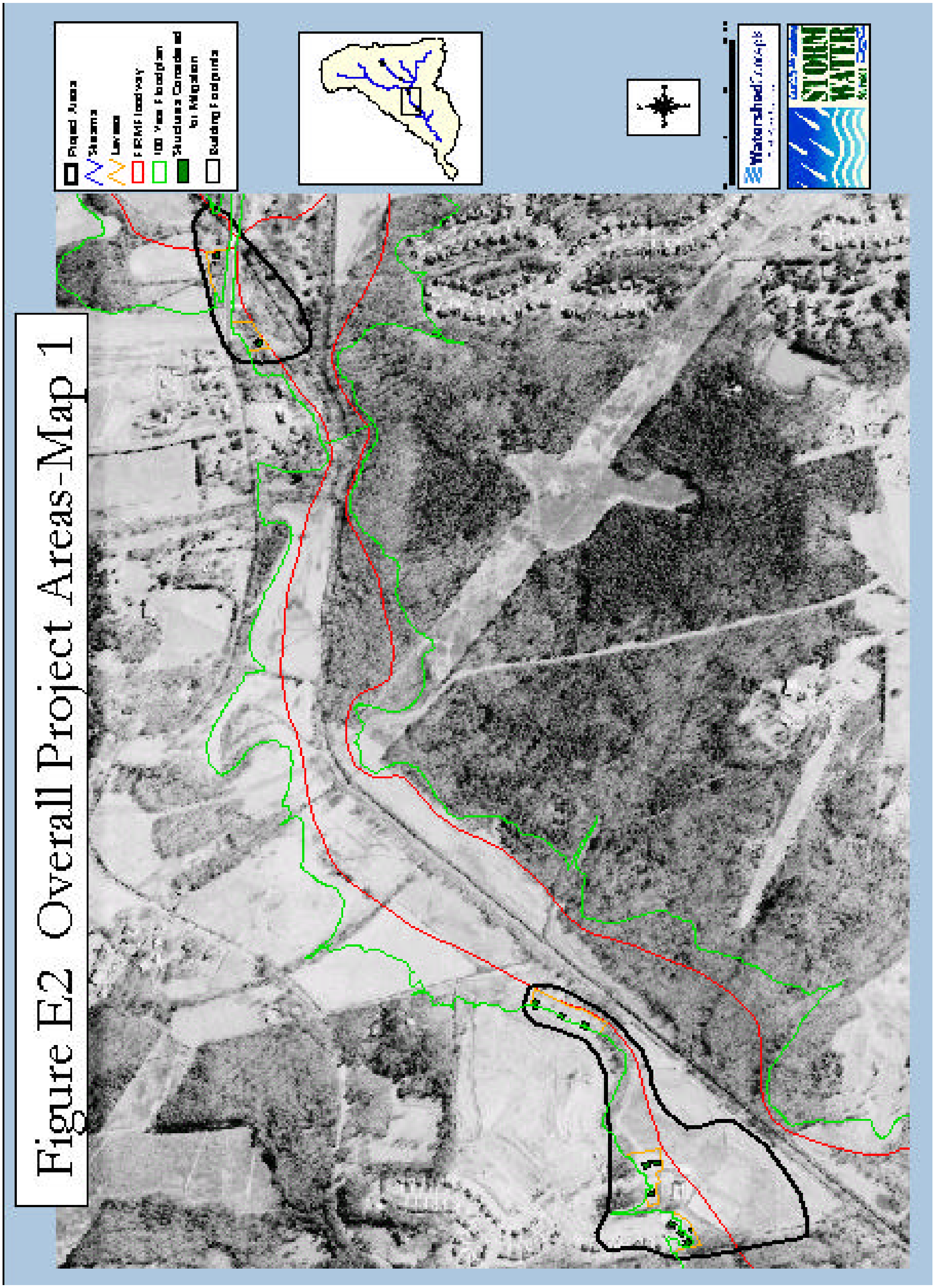


Figure E2 Overall Project Areas-Map 1


Figure E3 Overall Project Areas-Map 2

1. GENERAL WATERSHED CONDITIONS

1.1 Watershed Characteristics

The McDowell Creek basin includes a watershed of about 26.3 mi^2 in the northwestern part of Mecklenburg County. This basin includes the main stem of McDowell Creek as well as the adjoining streams of Caldwell Station Creek, Torrence Creek, Torrence Creek Tribs 1 and 2, and McDowell Creek Tribs 1 and 2.

McDowell Creek

McDowell Creek's main stem is approximately 9.2 miles long. The system flows in a general northeast to southwest direction north of the City of Charlotte. McDowell Creek discharges into the Catawba River on the west side of Mecklenburg County. Due to its distance from the center of town, existing development along the river is not as dense as that experienced in the other watersheds within the city. However, extensive residential and commercial development is occurring at the present time. Under the existing 100-year flood conditions (ECF), adjacent property suffers from a flooding potential in a number of residential sites.

Fig.1 At Statesville Road

Rosgen classification of McDowell Creek is presented in Section 1.4 of this report. Qualitative descriptions of the creek and its tributaries are given in the following paragraphs. Similar to the other creeks in the City of Charlotte, there is a sewer trunk line along McDowell Creek and its tributaries. Installation of these trunk lines has resulted in stabilized banks and trained stream alignment throughout the length of the McDowell Creek system. The banks and floodplains are densely vegetated and in some parts heavily wooded, creating a stable stream. Figure 1 shows the stream at its upstream end at Statesville Road crossing. The flow is shallow and tranquil in a well-defined floodway with relatively steep banks. Figure 2 shows the creek downstream, past the confluence with McDowell Trib 1 at Beatties Ford Road. The flow in this area is shallow and tranquil with stabilized banks and a relatively straight main channel alignment. The sewer trunk line is on the right bank of the

Fig. 2 Near Beatties Ford Road

Fig. 3 McDowell Creek near McDowell Trib 1

Fig. 4 Torrence Creek Trib 2 near McDowell Creek

Fig. 5 Caldwell Station Creek at Statesville Road

creek. Vegetation is taking over the riprap and is dense along the more gently sloped banks in this section. Compared to other creeks, McDowell is in a less urbanized setting, although the rapid pace of development is evident along the stream and its tributaries. Frequent occurrence of point bars is indicative of increased sediment transport due to heavy development activity.

The McDowell Creek system was observed under base flow conditions when the photos of this report were taken. Under the observed conditions, the flow is mostly tranquil and shallow. The floodway is lined with heavy brush and tree growth making access to the stream difficult in most places, although the banks must have been disturbed and cleared at one time for the installation of the sewer main line. By visual observation, the manholes of the sewer line seem to be below the 100-year flood level in many places visited. There is a greenway along the creek near the intersection of Bradford Hill Lane and Gilead Road, further stabilizing the banks and floodplain in that region of the creek.

The most significant tributary of McDowell Creek is Torrence Creek. The nature of the banks, the vegetation, flow conditions, and floodplain of the two streams are very similar. Figure 3 shows McDowell Creek further upstream from where Figure 2 was taken. Figure 4 shows Torrence Creek Trib 2 near Gilead Road Crossing. The tranquil nature of the creek with an occasional point or middle bar and heavily vegetated banks are similar conditions in both cases.

Although MCSWS regularly maintains areas of known flooding problems, the tendency of vegetation to establish over depositions in the streambed can affect the hydraulic capacity of the stream. Figure 5 shows Caldwell Station Creek at Statesville Road crossing. Deposition has occurred immediately in front of one of the two box culverts. Vegetation has taken root and now sizable trees and brush line the deposits. Flood flows may not be able to uproot the trees and the capacity of the culvert may be compromised. Figure 6 shows Torrence Creek at Bradford Hill Lane crossing. The flow of the entire creek is occurring in the right barrel of the triple circular culvert. Signs of vegetation taking root on the deposited sediments are visible. If floods of sufficient magnitude that flush the sediments downstream of the culvert do not occur, more vegetation may stabilize the deposits and eventually compromise the capacity of the culvert. In order to maintain full capacity for the stream and ensure the safe passage of a flash flood, it may be necessary for the County to undertake a stream maintenance program or install hydraulic structures for sediment exclusion from the structures at road crossings. The maintenance program would include keeping the road crossing free of unwanted vegetation, other obstructions, and sediment deposits, and assuring that bridges and culverts will operate at or near their design capacity during a flood. Further discussion of a creek maintenance program will be presented later in this report.

Fig. 6 Torrence Creek Trib 1 at Bradford Hill Lane

Fig. 7 Near Westmoreland Road

Fig. 8 At Glenwyck Lane

As mentioned before, the banks and floodplain of this stream are very well vegetated and stable. This is clear throughout the figures shown above, and the remainder of this report. The typical cross section of the floodway in the upstream reaches of the creek has vertical walls and a flat bed (a U-section), about 8-10 feet wide and about 8-10 feet deep (Figs. 1 and 4). At its downstream reaches, the floodway becomes wider and the banks are less vertical, acquiring side slopes of 1½:1 or so (Figs. 2 and 3). The floodplain along most of this stream is fairly wide and very gently sloping, and generally heavily vegetated or wooded. The minimum vegetative cover is thick tall grass. Occasionally, there are signs of human activity on the floodplain such as earth moving and construction. However, unless very current activity has occurred, vegetation seems to be able to take hold, and erosion of the banks or floodplain does not seem to be a serious problem. The floodplains in two sections of the creek are shown in Figure 7 (near Westmoreland Road) and Figure 8 (at Glenwyck Lane, off Bud Henderson Road).

McDowell Creek Tributaries

The tributaries of McDowell Creek, with a combined total of 10.3 miles, constitute longer total stream mileage than McDowell Creek's main stem. The main tributaries are Caldwell Station Creek, Torrence Creek, Torrence Creek Tribs 1 and 2, and McDowell Creek Tribs 1 and 2. The general geologic, hydrologic, climatologic and botanical conditions of these tributaries are similar to those of McDowell Creek. As a result, the morphological characteristics of these streams are also similar. At a field visit on May 2, 2001 the morphologic similarity of McDowell Creek and its tributaries was studied and documented. In addition to similar morphology between the main stem and the tributaries, the general pattern of development along the streams is also similar. Because of this similarity in behavior of the entire system, McDowell Creek and its tributaries are treated as a single unit.

1.2 Development in the Watershed

Development along McDowell Creek and its tributaries is less intense than other basins of the City of Charlotte at present. However, heavy commercial and residential development activity is underway. Visual judgment based on the site visit of May 2, 2001 suggested that a number of residential and commercial buildings are near or within the floodplain. Four cases of such structures in the flood fringe areas are presented in the next four figures, although sites with flooding potential are not limited to those shown in these figures. Figure 9 shows houses on Stawell Drive. These are three of 7 houses whose footprints plot within the ECF. Figure 10 shows houses on the intersection of

Fig. 9 At Stawell Drive

Fig. 10 At Bradford Hill Lane

Fig. 11 Gilead Road Crossing

Torrence Crossing Drive and Bradford Hill Lane. Several houses in this neighborhood are in the flood fringe areas. Figure 11 shows an older house on Gilead Road. The elevation certificate for this house places the finished floor elevation above the BFE. However, the lower level garage could be flooded. There are other older houses in the same neighborhood with footprints in the ECF or the FCF. Figure 12 shows houses on Leisure Lane, off Bud Henderson Road. In plan view, the entire row of houses on the creek side of this street is located within the ECF. There was extensive development activity with earth moving at the time of the site visit in this neighborhood.

Fig. 12 At Leisure Lane

General statistics of development in the McDowell Creek watershed are summarized in Table 1. The table includes temporal distribution of development in the watershed as well as the development type according to the information available as of the year 2000. Table 1 indicates that about 80% of the parcels in the basin are in single-family or other residential categories and about 14% of the parcels are still undeveloped (as of the year 2000). The table also indicates the accelerating pace of development in the watershed since about one third of the parcels were developed in the 1990's.

Table 1. Development in the McDowell Creek Watershed*

	Year Developed					Total
	Before 1970	1970-1979	1980-1989	1990-2000	Not Specified	
Parcels	4,938	390	1,323	4,908	3,880	15,439
Percentage	32.0%	2.5%	8.6%	31.8%	25.1%	100%

	Land Use as of 2000				
	Single Family	Other Residential	Non-Residential	Vacant/ Unclassified	Total
Parcels	11,179	1,082	983	2,195	15,439
Percentage	72.4%	7.0%	6.4%	14.2%	100%

* Entire watershed, including all tributaries

Existing sanitary sewer trunk lines, completed in the mid 1980's, are installed along the entire length of FEMA-regulated portions of McDowell Creek and its tributaries. Currently, no additional capital sewer improvements are planned along the creek based on the Charlotte-Mecklenburg Utility Department 2002 Capital Improvement Plan (CIP). A greenway trail is planned along the creek, which will be explained in more detail later. Development of such trails is announced for public information similar to the example shown in Figure 13.

Fig. 13 Example of Proposed Greenway Trail

A review of the capital improvement plans (CIP) was completed for various City and County agencies including the following:

- ?? City and County Storm Water Services
- ?? Neighborhood Development
- ?? Charlotte Department of Transportation
- ?? Mecklenburg County Park and Recreation
- ?? Charlotte-Mecklenburg Planning Commission

Currently, the only planned CIP in the McDowell Creek basin includes the creation of three greenway trails (See Fig. 13) consisting of:

1. Approximately 2.4 miles along Torrence Creek from Bradford Hill Lane towards upstream
2. Approximately 2.7 miles along Torrence Creek Trib 1, from its confluence with Torrence Creek towards upstream
3. Approximately 3.6 miles along McDowell Creek from Bradford Hill Lane towards downstream.

The general locations of these trails and their proximity to the potentially flooded structures within the basin are shown in Figure 14. The full length of some of the proposed greenway trails extend beyond the limits of Figure 14, and have been eliminated so that the potentially flooded areas can be shown in as much detail as possible.

Of the above list, approximately 0.7 mile of item 1, from Bradford Hill Lane to McCoy Road has been completed, and another 0.6 mile from Bradford Hill Lane to the confluence with McDowell Creek is under construction. The remaining trails have been proposed for future construction. The construction of these greenway trails is not expected to alter the drainage and flooding patterns in the watershed and the flood mitigation analyses of this report will be valid unless other major alterations are planned for the watershed due to newly planned CIP's.

A condensed view and lists of the capital improvement projects for Mecklenburg County are shown in Figure 15.

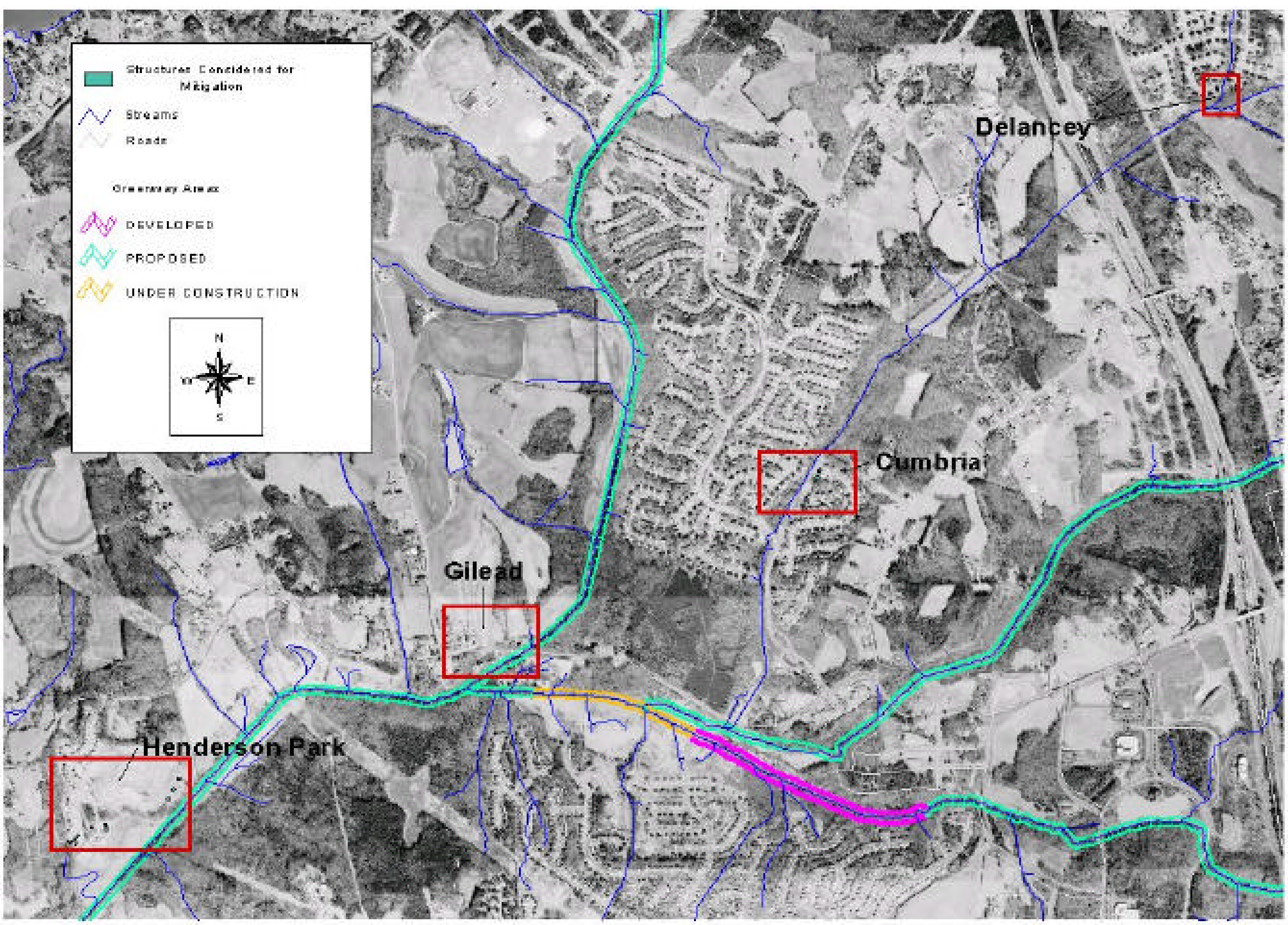


Fig. 14 Greenway Trails and their Relationships to Potential Flood Areas

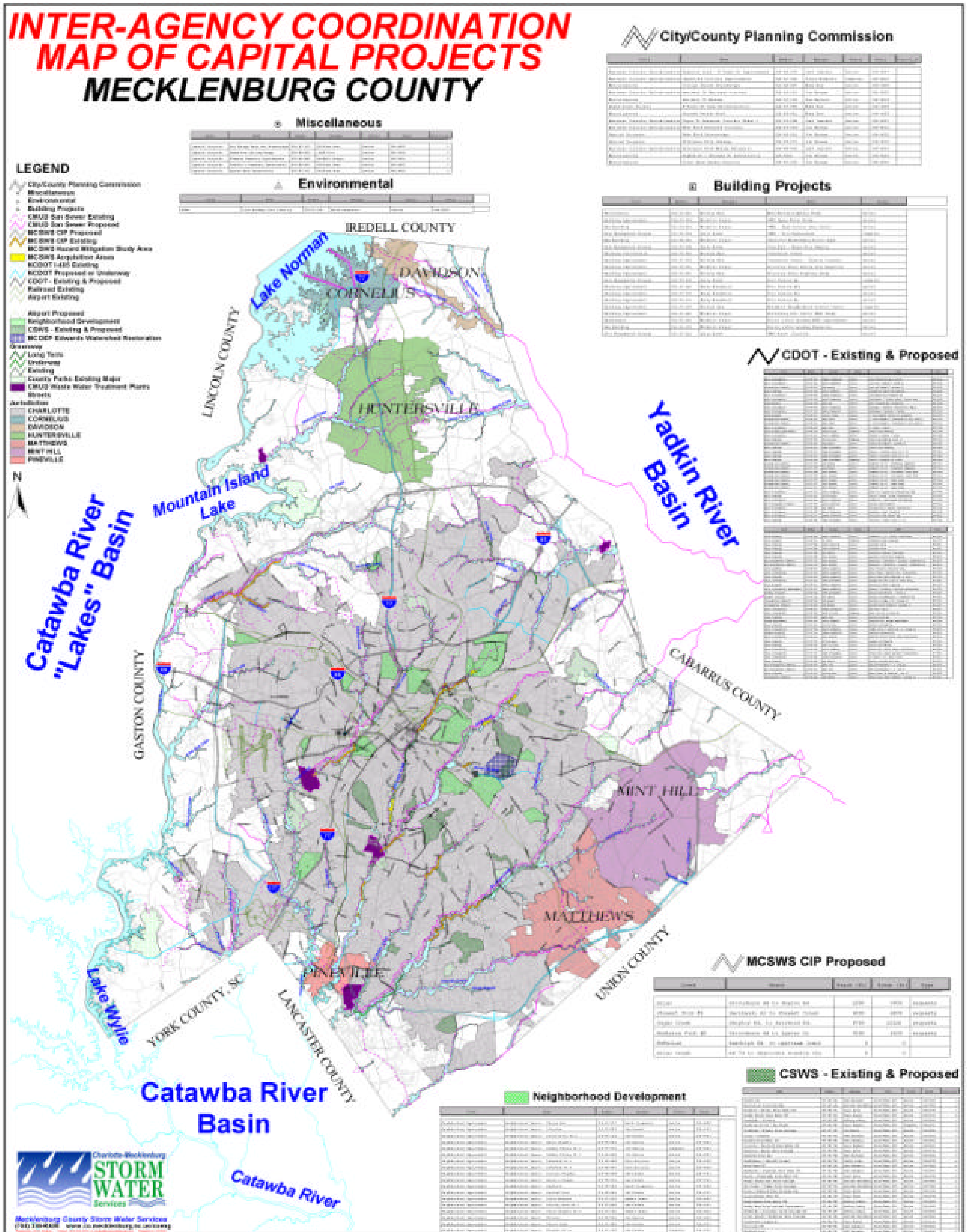


Fig. 15 Summary of City-County Capital Improvement Projects, 1999

1.3 Aquatic Habitat and Environmental Monitoring

The McDowell Creek watershed drains in a westerly direction into the Catawba River between the Cowins Ford Dam that forms Lake Norman (Charlotte drinking water supply) and the upper reaches of Mountain Island Lake (Charlotte's primary drinking water supply). This location on the Catawba River is also vital for Charlotte's neighbors to the west, as the cities of Gastonia and Mount Holly also have water supply intakes near the mouth of the McDowell Creek. This watershed is actively being studied by various groups. Active studies at this time include:

?? Mecklenburg County Storm Water Services (MCSWS) and Watershed Concepts (this report)

?? Local Watershed Management Plan (NC Wetlands Restoration Program and CH2M-Hill)

?? Water Quality Computer Model Simulation (MCDEP and TetraTech)

?? McDowell Creek Watershed Smart Growth for Clean Water Partnership (NALGEP, Charlotte, Mecklenburg County, Cornelius, Huntersville, Trust for Public Lands)

It is important to note that while various initiatives are underway, each has a different objective. Yet as each initiative progresses, the participants are communicating and coordinating their efforts and sharing information. Parallel with these studies, CMUD is performing wastewater master planning for the watershed to make sure that the availability of sewer capacity does not impact future watershed growth. As of the date of this report, none of these initiatives has final reports to supplement the information presented.

There are various land acquisition programs underway to protect and buffer the watershed from non-point source pollutants and development, including the Trust for Public Lands and the Mecklenburg County Park and Recreation Department. Together, through the Mountain Island Lake Initiative, each is purchasing large tracts of land to be preserved as open space.

Primary pollutants from land development activities include nutrients (phosphorus and nitrogen from fertilizers), fecal coliform (animal waste and sanitary sewer overflows) and sediment (bank erosion and construction activities). The Mountain Island Lake Marine Commission has already noted the introduction of Hydrilla (Hydrilla L.C. Rich), an extremely aggressive, invasive aquatic plant that chokes the oxygen from a water body and directly impacts water quality. A Hydrilla-eating carp has been introduced to combat the problem. However, the direct cause of the problem stems from the abundance of nutrients that fertilize this plant, flowing downstream through the McDowell Creek watershed.

During the site visit to McDowell Creek in May 2001, fish of 4-5 inches long and frogs of various sizes were observed in a few sites. In addition, other signs of riparian wildlife were present along the stream. These included the teeth marks of beavers, footprints of small hoofed animals, and mammalian droppings. These observations point to the existence of a number of animals along the creek. The list would include varieties of reptiles, rodents, small mammals, birds, insects and other species that thrive in this environment. The dense vegetative growth along the creek was found to be heavily infested with ticks, suggesting that there is sufficient warm-blooded animal life for the survival and proliferation of the ticks.

Mecklenburg County Department of Environmental Protection (MCDEP) maintains several monitoring stations along McDowell Creek and its tributaries. A summary of the collected water quality data is shown in Table 2. While the Macroinvertebrate Taxa Richness sampling and the Fish Bioassesment sampling do include Poor and Fair ratings since 1994, the overall Water Quality Index has consistently ranked as Average, Good and Good-Excellent. The overall water quality has generally remained consistent in the watershed since 1996. One flow monitoring station, USGS Gage 0214266000, has been in operation since November 1996 at the MC3 site, located at McDowell Creek and Beatties Ford Road crossing.

Table 2. MCDEP Water Quality Monitoring Summary

NC Piedmont Macroinvertebrate Taxa Richness		Jul-94		Sep-97		Jun-98		May-99		Jul-00	
Site	Location	S_{EPT}	WQ Rating	S_{EPT}	WQ Rating	S_{EPT}	WQ Rating	S_{EPT}	WQ Rating	S_{EPT}	WQ Rating
MC4	McDowell Cr @ Beatties Ford Rd	14	Good/Fair	8	Fair	5	Poor	8	Fair	7	Fair
MC2A	McDowell Cr @ Sam Furr Rd	5	Poor	8	Fair						
MC2A1	McDowell Cr @ Gilead Rd	8	Fair	6	Poor	6	Poor	7	Fair	6	Fair
MC3E	Torrence Cr @ Bradford Hill Rd	12	Fair	12	Fair	7	Fair	10	Fair	7	Fair

Fish Bioassessment		May-96	
Site	Location	NCIB I	WQ Rating
MC4	McDowell Cr @ Beatties Ford Rd	42	Fair
MC4A	McDowell Cr @ Neck Rd	46	Fair/Good
MC2A	McDowell Cr @ Sam Furr Rd	46	Fair/Good
MC2A1	McDowell Cr @ Gilead Rd	46	Fair/Good
MC3E	Torrence Cr @ Bradford Hill Rd	46	Fair/Good

Water Quality Index		May-96		May-97		May-98		Jun-99		May-00	
Site	Location	WQI	WQI Rating	WQI	WQI Rating	WQI	WQI Rating	WQI	WQI Rating	WQI	WQI Rating
MC4	McDowell Cr @ Baetties Ford Rd	71	Good	73	Good	70	Good	74	Good	76	Good /Exc.
MC4A	McDowell Cr @ Neck Rd	62	Average	66	Good	69	Average	70	Good	77	Good /Exc.
MC2A1	McDowell Cr @ Gilead Rd	72	Good	77	Good/Exc.	75	Good/Exc.	80	Excellent	--	--
MC3E	Torrence Cr @ Bradford Hill Ln	73	Good	79	Good/Exc.	71	Good	71	Good	71	Good

1.4 Rosgen Applied River Morphology Assessment

The Rosgen stream classification system was utilized to provide an initial assessment of the morphology of McDowell Creek. The Rosgen system uses field measurements of stream features to describe a stream by morphologic type. An array of stream types is presented under the system that is delineated by slope, channel materials, width/depth ratio, sinuosity and entrenchment ratio. For the assessment of McDowell Creek, the stream type is described at the geomorphic characterization level (Level I) of the hierarchical system of classification. At this level of inventory, the channel pattern, shape and slope are described (Rosgen, 1996). Information utilized as a part of this classification included field observations, aerial photography, USGS quadrangle maps, and other digital topographic information for investigation of the channel pattern and valley form.

The data for Rosgen classification of McDowell Creek is summarized in Table 3. The low sinuosity of the channel is primarily due to the installation of the sewage main line and straight alignment of the stream in many reaches. Generally, the channel displays a low width/depth ratio, low sinuosity and relatively low channel slope. However, after careful examination of the tendencies within the creek, the majority of McDowell Creek was classified as a type G channel with some reaches possibly being classified as type F. Indicators of a new bankful flow line were observed below the historic top-of-bank, which imply that the channel has incised within the historic floodplain. This has most likely resulted from a combination of urbanization of the watershed and manual re-grading of the channel. The historic floodplain, which was formed as an alluvial plain bounded by gentle slopes of upland soils, currently forms a terrace that confines the channel.

Table 3. Rosgen Level 1 Classification Parameters McDowell Creek	
Channel Length	48,714 ft
Downstream Invert	641.49 ft
Upstream Invert	724.18 ft
Channel Slope	0.17%
Valley Length	48,405 ft
Sinuosity	1.01
Average Bankful Depth	5 ft

The channel bank slopes are relatively steep with the slopes ranging from 1:1 to vertical. Despite these steep slopes, the banks appear to be fairly stable. The cohesive bank material and dense riparian vegetation act to stabilize the banks and resist erosive forces. In some locations, riprap has been placed along the toe of the banks to provide additional stability. Along reaches where riprap is not present and the bank material is less cohesive, channel widening processes are evident. This channel widening is resulting in an evolutionary transition to a type F channel. There are occasional reaches where the channel has developed sufficient belt width to begin to form a meandering pattern with stable point bars as shown in Figures 4 and 5.

The channel profile appears to be relatively stable and not subject to excessive degradation or aggradation. There is evidence, however, of a significant sediment load that is being transported by the stream. Depositional features such as mid-channel bars, side bars and embryonic point bars are evident along many reaches of the stream. It is likely that the primary source of this depositional material is from construction activities within the watershed and that this material is being transported though the stream system without significant aggradation of the channel bed.

1.5 Bank Stability Problem Identification

As described before, the stream and its tributaries have a wide densely vegetated floodplain. The floodplain and the channel itself are stabilized against severe floods and serious erosion. The main floodway channel and the adjoining floodplain seem to be in a stable state.

Moderate to low deposition of sediments was observed in a field visit to McDowell Creek on May 2, 2001. The flat creek slopes do not provide sufficient grade for the flow to carry large suspended or bed sediment loads. Occasionally, there would be point or middle bars on the stream as shown in Figures 3 and 4. This is an indication of good vegetative cover along the stream, relatively stable channel, and low erosion of the banks. In general, bank instability does not seem to be a major problem along McDowell Creek.

2. BENEFIT:COST ECONOMIC ANALYSIS

2.1 Riverine Flood Model Overview

FEMA's Riverine Flood Model (Version 1.11, February 1996) was utilized to perform flood damage and benefit:cost analysis. This model is based on Quattro-Pro spreadsheet and its results are consistent with Mecklenburg County's previous analyses that used the same program. In this model, built-in probability based damages are calculated for a structure given the finished floor elevation of that structure. The model calculates benefits (damages avoided by undertaking a certain mitigation measure) vs. the estimated cost of that particular mitigation measure.

There are no structures in the McDowell Creek watershed with finished floor elevations below the BFE. Structures analyzed for potential flood damage are limited to those with finished floor elevations in the flood fringe areas. The benefit:cost model estimates damages on the basis of the 10-, 50-, 100- and 500-year floods and hence calculates damages for structures with finished floor elevations above the current BFE. The flood elevations were determined using the US Army Corps of Engineers model HEC-RAS (Version 2.2, March 1999). The future 100-year flood elevations were based on the County's projected land use estimates for the year 2020.

The benefit:cost model utilizes two levels of data input; a level 1 with minimal data requirements (using default values) and a level 2, with detailed data regarding a structure type, use, replacement value, contents value, and relocation costs. For the purposes of this study, level 2 analysis was adopted for two reasons: 1) this level of analysis produces more realistic damage estimate information, and 2) the analyses are consistent with the County's previous benefit:cost analyses. The program uses the input flood elevations and flows to determine a probabilistic estimate of the damages to the structure based on the finished floor elevation of the structure. The probabilistic tables are built into the program and are not altered by the user.

2.2 Economic Data

To perform the level 2 benefit:cost analysis, the model utilizes several attributes and values for each structure. This type of information was gathered for each affected structure from the GIS data at the Mecklenburg County website. Information provided to the model included:

Building Type: Structures are categorized as single story without basement, two-story with basement, etc. The structure type is used by the model for selecting the specific built-in lookup table for flood depth vs. damage as percent of the structure value.

Building Value: The building values as given in the Mecklenburg County GIS website were multiplied by 1.25 to reflect the building values in 2001 dollars. These values were used as the replacement values for the affected structures.

Content Value: The content value of each structure was assumed to be 25% of the current (2001) replacement value of the structure. This assumption is consistent with previous benefit:cost analyses of Mecklenburg County.

Floor Elevation: For each affected structure, the elevation of the lowest finished floor was provided to the model. The model uses this parameter as the zero damage elevation for the structure. The finished floor elevation data were obtained from the Mecklenburg County GIS data and elevation certificate files, supplemented by surveys performed by ESP Associates Surveyors.

Relocation Cost: A constant relocation cost per household was used as the basis for economic analysis. This relocation cost was determined by Mecklenburg County and had been used in previous benefit:cost analyses.

The present value of all benefit and cost figures were calculated using a 7.0% discount rate, a 30-year project life for the elevate and levee mitigation option, and a 100-year project life for the acquisition option. These assumptions are consistent with the specifications of the Riverine Flood Model (1996, p. 6-15).

2.3 Hydraulic Data

In order to determine the level of flooding at each structure, the model requires flow and elevation data to be entered for 10-, 50-, 100-, and 500-year floods. This information already existed for McDowell Creek from HEC-RAS modeling of the creek performed earlier by Watershed Concepts. However, HEC-RAS output files list elevations at specific cross sections along the stream. Therefore, water surface elevations were extrapolated for each individual structure. To perform this task, a line was manually drawn from each structure to the creek centerline. The Watershed Concepts WISE program was then utilized to perform the extrapolation and output of elevations for the different frequency floods for each individual structure. The flows and their corresponding water surface elevations are the required data for the model to determine flood damages to each structure.

2.4 Modeling Process

The benefit:cost model includes a series of default depth-damage curves based on nationwide flood loss information. Specific depth-damage curves for Mecklenburg County were developed and used for this analysis utilizing flood loss data from the storm event of July 1997. Damages to each structure are calculated by the model based on the flood depth above the finished floor elevation of the structure, and the probability (or frequency) of occurrence of that flood in a given span of time. Damages are annualized for the benefit:cost analysis.

2.5 Economic Analysis

For any mitigation measure considered, the *avoided* flooding damage is the benefit derived from that particular mitigation measure. This benefit, when compared to the cost of undertaking the mitigation measure, constitutes the basis for the benefit:cost analysis. When the ratio of benefit to cost is greater than 1.0, the measure is deemed feasible, and when the ratio is smaller than 1.0, the measure is rejected.

The benefit:cost program has built-in data for the costs of acquisition or elevating the structure for Mecklenburg County. However, for other mitigation measures, the cost was separately determined and the benefit:cost ratio calculated. Due to the fact that only a few residential structures are affected in the McDowell Creek watershed, the only other mitigation measure considered was the construction of flood levees, as described in the next section of the report.

As suggested by Mecklenburg County Storm Water Services (MCSWS), it was decided that mitigation measures should not be concentrated on individual buildings. Instead, MCSWS preferred the concept of "mitigation projects," whereby the mitigation measures were considered for the improvement of a project area or a neighborhood community. On the basis of this concept, the mitigation measures have been proposed for project areas (or problem neighborhoods). Four such project areas are identified for the McDowell Creek watershed as described in the next section of the report.

2.6 Improvements

There are no severe flooding problems in the McDowell Creek watershed. Only four neighborhoods were identified with flooding potential, as reported in the next section of this report. Preliminary analyses indicated that only a few structures are involved in the affected areas, and the least expensive mitigation measures would be the only feasible ones. Therefore three basic mitigation measures were considered for this watershed: elevating the structure, acquisition of the property, or construction of flood levees. **None of the three measures provided a benefit:cost ratio higher than 1.0. Therefore, no action is recommended for this watershed.**

3. FLOOD HAZARD MITIGATION

3.1 FEMA Regulated Stream Service Requests

There have been 91 Service Requests filed through the City/County Customer Service system (336-RAIN) hotline in the McDowell Creek watershed. The majority of the service requests involve channel bank erosion. For each request a severity category has been specified. However, except for 3 cases, the exact type of the request has not been identified. Instead, only the severity of the requested service is recorded in the system database. Table 4 summarizes the flood related service requests by severity in the McDowell Creek watershed. Only one of the requests is for property that has been identified in this report as having a flood potential (15130 Stonegreen Ln.). A total of 10 of the complaints are for property located immediately adjacent to the McDowell Creek floodplain. However, except for 15130 Stonegreen Lane, no structures on the remaining nine parcels have been identified as being in the flood fringe areas.

Table 4. Service Requests in McDowell Creek Watershed

Severity of Service Requested[1]	Frequency	No. in Potential Flood Zone[2]	No. in B:C Analysis[3]
A	4	0	0
B	20	0	0
C	67	1	1

1 A to C: Most to least severe; categorized by the Charlotte-Mecklenburg Storm Water Services

2 Lots with structures whose footprints intersected with the flood boundaries

3 Lots with structures that were analyzed for benefit:cost ratio for mitigation measures

3.2 Repetitive Loss Structures

According to information provided by Mecklenburg County Storm Water Services, no reports of repetitive losses exist within the McDowell Creek watershed.

3.3 Permanent Storm Water Easements

There are no permanent Storm Water Easements in the McDowell Creek watershed that provide access to the creek or its tributaries.

3.4 Roadway Overtopping Problem Locations

From HEC-RAS modeling results of McDowell Creek watershed, roadway overtopping locations were investigated based on the existing and future 100-year flood conditions. Table 5 summarizes the roadway overtopping problem locations for the study streams and tributaries. Locations of the overtopping roads are shown in Figure 16. Several conclusions and recommendations can be derived from Table 5:

1. Considering the fact that a flow depth of 24 inches (2 ft) can sweep away a moving vehicle, there will be several problem locations in case of a 100-year flood. The most prominent of these is McIlwaine Road. The crossing will be in 3.2 and 6.3 ft of water, respectively, for the existing and future 100-year floods. However, this is due to a backwater effect from

McDowell Creek, not a high-velocity floodwater of equivalent depth. Among measures to mitigate this hazard are warning signs for approaching motorists and consideration for raising the elevation of the stream crossing as a future CIP for the Huntersville DOT. Other problem spots for large depths of water are on private crossings, identified as a farm bridge and a foot bridge, which should be abandoned in case of a flood. All other problem areas listed in Table 5 would require warning signs to alert motorists to avoid the crossing in case of a flood.

2. Flood hazards at road crossings could be minimized by assuring that culverts and bridges along the entire stream system have the maximum capacity to pass the flood flows. Regular inspection and maintenance schedules should be established at all stream crossings to assure that sediment and other debris such as fallen trees or urban trash do not collect at the upstream face of the culverts and bridges, compromising their flow capacity.

3. Guardrails (or other indicators) should be provided at all problem sites such that drivers could be guided away from the edge of the road in case of a flood. The protection should be adequate so that if a vehicle is stranded or swept away, it can be stopped by the guardrail, preventing the vehicle from entering deeper and faster moving flow regions and allowing for rescue crews to reach the stranded vehicle.

4. Depth sensors and a relay system could be installed on or near the crossings such that they would alert emergency response teams to the high water depth and allow them to re-route traffic or prepare for emergencies at the site.

Table 5. Roadway Overtopping Problem Locations

Stream/Road	Crossing Structure Type	Culvert Size No. @ Size (ft)	Top of Road Elevation (ft NAVD)	100-Yr Flood Elevation Existing (ft NAVD)	Flood Depth Existing (ft)	100-Yr Flood Elevation Future (ft NAVD)	Flood Depth Future (ft)
McDowell Creek							
Sam Furr Road	Bridge		701.3	700.5	--	702.3	1.0
Torrence Creek							
Farm Bridge	Bridge		669.5	673.7	4.2	674.8	5.3
Torr. Cr, Trib 1							
Foot Bridge	Bridge		669.3	673.2*	3.9	674.1*	4.8
Gilead Road	Culvert	2@ 8X7.5 Box	679.5	679.5	--	680.0	0.5
Stumptown Road	Culvert	2@6 Cir	705.8	706.5	0.7	707.0	1.2
McDowell Cr Trib 1							
McIlwaine Road	Bridge		661.8	665.0**	3.2	668.1**	6.3
Caldwell Station Creek							
Statesville Road	Culvert	3@8X7 Box	718.7	717.0	--	718.9	0.2

* Backwater from Torrence Creek
** Backwater from McDowell Creek

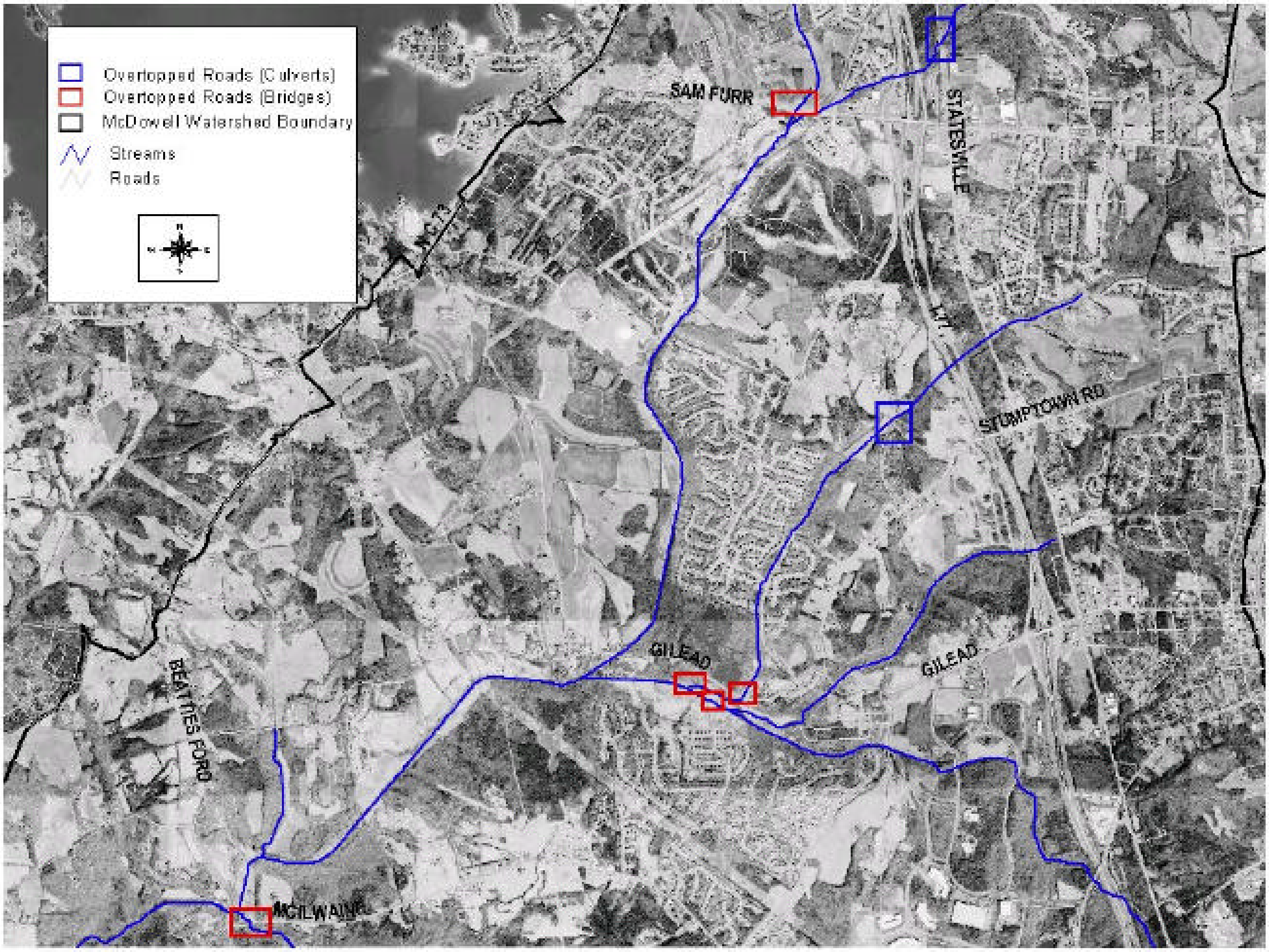


Fig. 16 Road Overtopping Location Map

3.5 Flood Mitigation Improvement Analysis

Three flood mitigation measures were recognized as the only viable options for the structures that are in the flood fringe areas (within two feet of the BFE) in the McDowell Creek watershed. These measures were acquisition, elevating the finished floor of the structure two feet above the BFE, or construction of a berm or dike to contain the floodwater. The benefit:cost analysis for the four project areas, shown in Figures E2 and E3, were performed using the standard methods described in FEMA's Manual 259, Engineering Principles and Practices for Retrofitting Flood Prone Residential Buildings (FEMA, January 1995), and the Riverine Flood model (Version 1.11, February 10, 1996) developed by FEMA. Details of the analysis will be presented later. The summary of the benefit:cost analysis is shown in Table 6. The benefit and cost values in this table are the present values of the annual benefits and costs of each mitigation option. The low benefit:cost ratios of these neighborhoods and structures is indicative of the fact that all of the structures have finished floor elevations above the BFE. None of the structures would actually experience inundation in case of a 100-year flood. The small amount of damages calculated by the benefit:cost program for these structures results from the statistical probability of occurrence of a 500-year flood.

Also included in Table 6 are the highest benefit:cost ratios for individual structures to provide a means of judging the range of variation. Because only benefit:cost ratios greater than 1.0 were considered economically feasible, it is clear from these figures that no mitigation measure is going to be economically justified, either for an entire project area or for individual structures.

Table 6. Summary of the Benefit:Cost Analysis for the Four Mitigation Project Areas										
		Mitigation Options*								
		Acquisition			Elevation			Levee		
No. of Structures	Project Neighborhood/Area	Benefit	Cost	B:C	Benefit	Cost	B:C	Benefit	Cost	B:C
9	Henderson Park Rd/Leisure Ln/Lullwater Cv	54,016	1,597,405	0.03	26,615	407,750	0.07	42,858	265,672	0.2
Highest individual	7641 Henderson Park	8,450	146,479	0.06	4,349	35,867	0.12	--	--	--
2	Gilead Rd	3,855	196,051	0.02	2,210	69,460	0.03	3,212	112,001	0.03
Highest individual	8010 Gilead Rd	2,745	107,056	0.03	1,623	45,410	0.04	--	--	--
3	Cumbria Ct/Stonegreen Ln	24,821	998,853	0.03	17,267	226,768	0.08	21,201	50,507	0.42
Highest individual	15129 Stonegreen Ln	13,652	347,509	0.04	10,077	82,508	0.12	--	--	--
1	Delancey Ln	32,310	344,039	0.09	10,526	74,423	0.14	18,816	44,216	0.43
Highest individual	15701 Delancey Ln	32,310	344,039	0.09	10,526	74,423	0.14	18,816	44,216	0.43

*Benefits and costs are in dollars

Compared to other basins within Mecklenburg County, the McDowell Creek watershed is in a younger state of development and does not suffer from severe flooding problems. Based on the latest County elevation certificate data and survey results, a total of 15 structures would be within the fringe of the ECF or the FCF. Table 7 shows the flooding statistics for these structures, all of which are residential and post-FIRM (built after 1981). The flooded homes can be grouped into four project areas, listed in Table 7. The four groups have been treated separately in Table 7 and in applying mitigation measures so that individual benefit:cost analyses could be performed for each project area.

Table 7. Structures Within Existing 100-year Floodplain							
No. of Structures	Project Neighborhood/Area	No. Flooded	No. within 2ft of BFE	Avg. Flood Depth*	Median Depth*	Highest Depth*	Lowest Depth*
9	Henderson Park Rd/Leisure Ln/Lullwater Cv	0	9	-0.87	-1.30	-0.11	-1.63
2	Gilead Road	0	2	-1.39	-1.39	-0.86	-1.91
3	Cumbria Ct/Stonegreen Ln	0	3	-0.43	-0.63	-0.08	-0.78
1	Delancey Ln	0	1	-0.01	-0.01	-0.01	-0.01

* Negative numbers indicate that the finished floor elevation is above the 100-yr flood elevation; depths are in feet.

Alternative Evaluation

Within the McDowell Creek watershed there are a total of 15 structures, which are in the flood fringe areas (within 2 ft of BFE). These structures have been clustered into four project areas as shown in Table 7. A total of four alternatives were analyzed for these project areas. Additional alternatives were considered, but ruled out as economically infeasible after preliminary analyses.

Alternative 1 - Acquisition

In this alternative, the structure in danger of flooding is purchased and removed. FEMA regulations specify this alternative to be adopted if the benefit:cost ratio equals or exceeds 1.0. Calculations for determining the cost of this alternative are programmed into the benefit:cost program as described in Section 2 of this report. A return rate of 7% and project life of 100 years were used for this alternative. As indicated in Table 7, none of the project areas or individual structures meets this requirement and hence this alternative is not feasible.

Alternative 2 - Elevation

This alternative involves elevating the potentially flooded structure 2 ft above the BFE. The costs of elevating structures in Mecklenburg County are programmed in the benefit:cost program as well. The adoption criteria for this alternative is also a benefit:cost ratio of 1.0 or higher. Table 7 shows that none of the project areas or individual structures meets the limiting criteria of this alternative, and hence this alternative is abandoned as well.

Alternative 3 **–** Flood Barrier

In this alternative, the cost of the construction of an earthen levee as a flood barrier is considered. The levee is designed with a 3-ft freeboard, i.e., the elevation of the top of the levee is placed at 3 ft above the BFE. By its nature, this alternative is better suited to project areas or a cluster of structures than for individual units. Calculations for the cost of a levee are carried out outside the benefit:cost program, and involve estimations of material needed, haul distances, placement, and equipment mobilization and demobilization. Results of the calculations are summarized in Table 7 and indicate that this alternative is also too expensive and should be abandoned.

Alternative 4 **–** No Action

This is the default alternative, when the benefit:cost analysis shows that adopting any of the other mitigation measures results in more costs than benefits. **After elimination of the other alternatives as described above, this alternative is the only acceptable one for the McDowell Creek watershed.**

Although the No-Action alternative is the only feasible one recommended for McDowell Creek, results of the benefit:cost analysis for the individual project areas are summarized below.

Henderson Park/Leisure/Lullwater Neighborhood

The summary of the benefit:cost analysis for the Henderson Park Road, Leisure Lane and Lullwater Cove neighborhood is shown in Table 8. The general neighborhood is shown in Figure 17. A total of 9 structures in this neighborhood are in flood fringe areas. The highest benefit:cost ratio for any of the mitigation measures for the neighborhood is 0.161 for the levee (flood barrier) alternative, well below the acceptable level of 1.0 for adoption of the mitigation measure. The highest benefit:cost ratio for an individual structure in this neighborhood is 0.12 for the elevation option for 7641 Henderson Park. The levees in this neighborhood are used for a cluster of houses, and hence individual costs for this option cannot be used for comparison of structures.

Table 8. Mitigation Measures for Henderson Park/Leisure/Lullwater Neighborhood

Possible Mitigation Project								
Acquisition			Elevation			Levee		
Benefit	Cost	Ratio	Benefit	Cost	Ratio	Benefit	Cost	Ratio
$54,016	$ 1,597,405	0.034	$ 26,615	$ 407,750	0.065	$ 42,858	$ 265,672	0.161

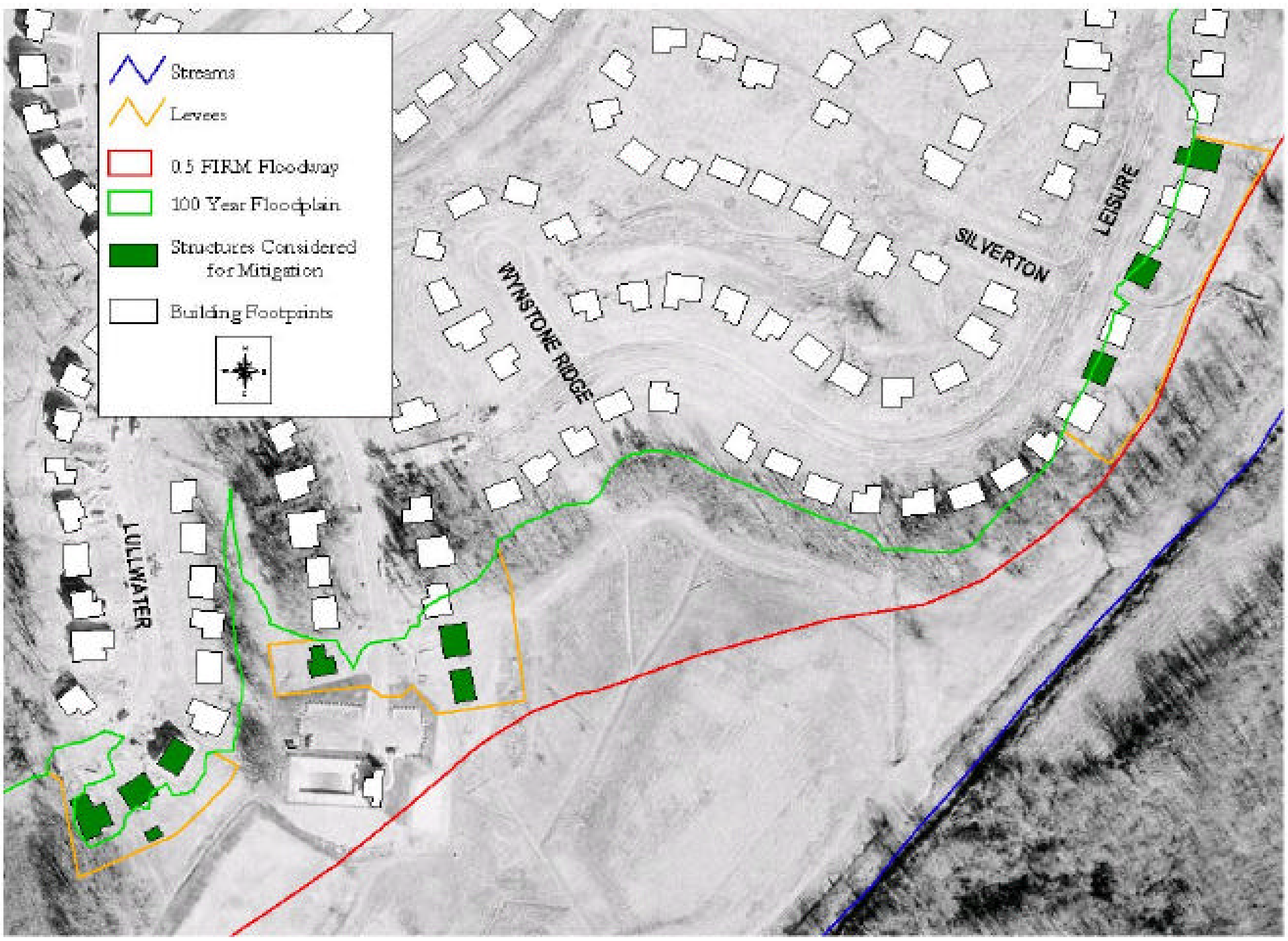


Fig. 17 Houses with Flooding Potential in Henderson Park/Leisure/Lullwater Neighborhood

Gilead Neighborhood

The summary of the benefit:cost analysis for the Gilead Road neighborhood is shown in Table 9. The general neighborhood is shown in Figure 18. Two structures in this neighborhood are in flood fringe areas. The highest benefit:cost ratio for any of the mitigation measures for the neighborhood is 0.03, well below the acceptable level of 1.0 for adoption of the mitigation measure. The low benefit:cost ratio indicates that the finished floor elevations of these houses are above the BFE, and the small benefit figures result from the low probability of flooding in case of a 500-year flood. The highest benefit:cost ratio for an individual structure in this neighborhood is 0.04, still well below the feasible level of 1.0.

Table 9. Mitigation Measures for Gilead Neighborhood								
Possible Mitigation Project								
Acquisition			Elevation			Levee		
Benefit	Cost	Ratio	Benefit	Cost	Ratio	Benefit	Cost	Ratio
$ 3,855	$ 196,051	0.020	$ 2,210	$ 69,460	0.032	$ 3,212	$ 112,001	0.029

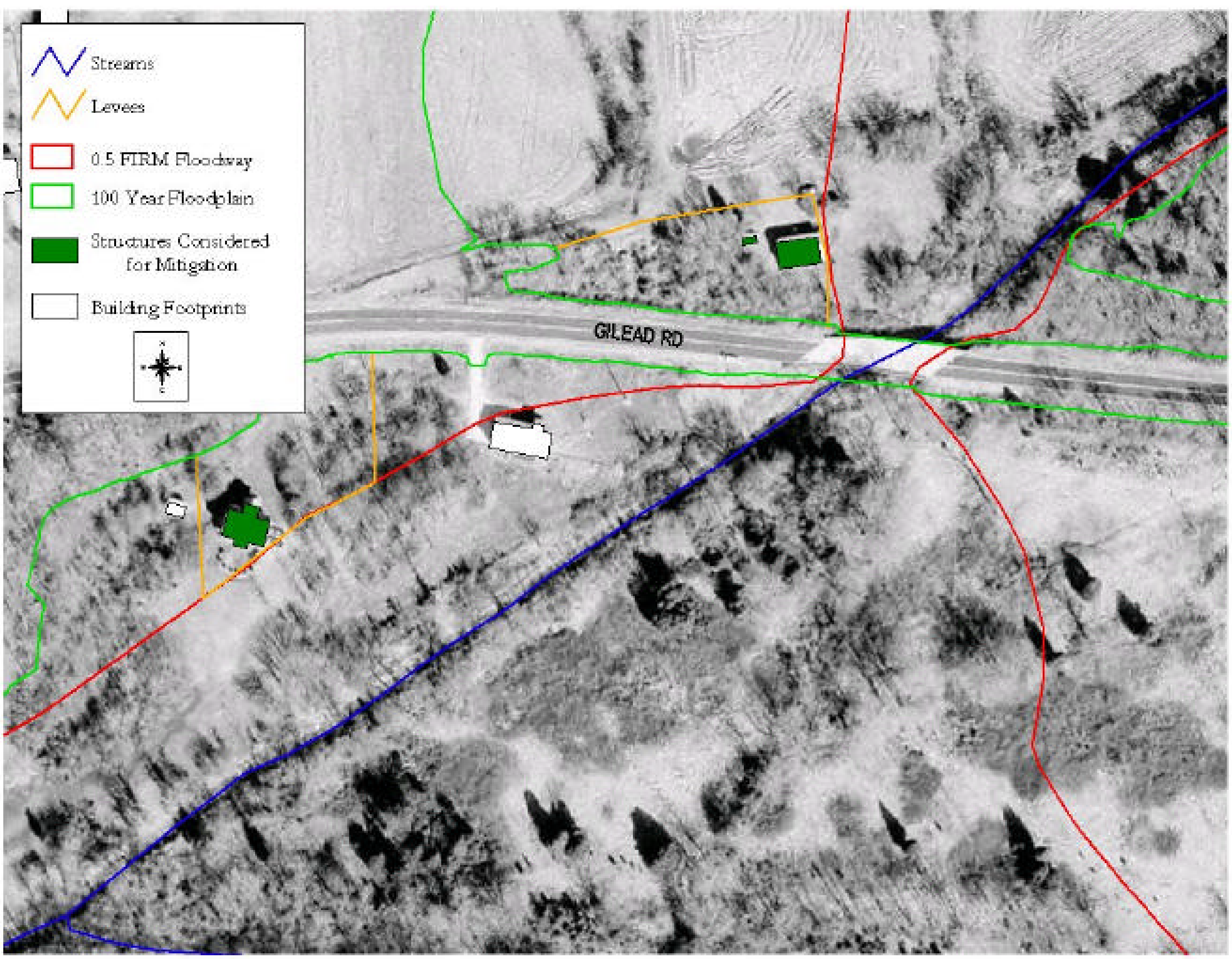


Fig. 18 Houses with Flooding Potential in Gilead Neighborhood

Cumbria/Stonegreen Neighborhood

The summary of the benefit:cost analysis for the Cumbria Ct and Stonegreen Ln neighborhood is shown in Table 10. The general neighborhood is shown in Figure 19. Three structures in this neighborhood are in flood fringe areas. The highest benefit:cost ratio is 0.42 for the levee alternative, decidedly below the acceptable level of 1.0 for feasibility of the mitigation measure. The highest benefit:cost ratio for an individual structure in this neighborhood is 0.12, still well below the feasible level of 1.0.

Table 10. Mitigation Measures for Cumbria/Stonegreen Neighborhood

Possible Mitigation Project								
Acquisition			Elevation			Levee		
Benefit	Cost	Ratio	Benefit	Cost	Ratio	Benefit	Cost	Ratio
$ 24,821	$ 998,853	0.025	$ 17,267	$ 226,768	0.076	$ 21,201	$ 50,507	0.420

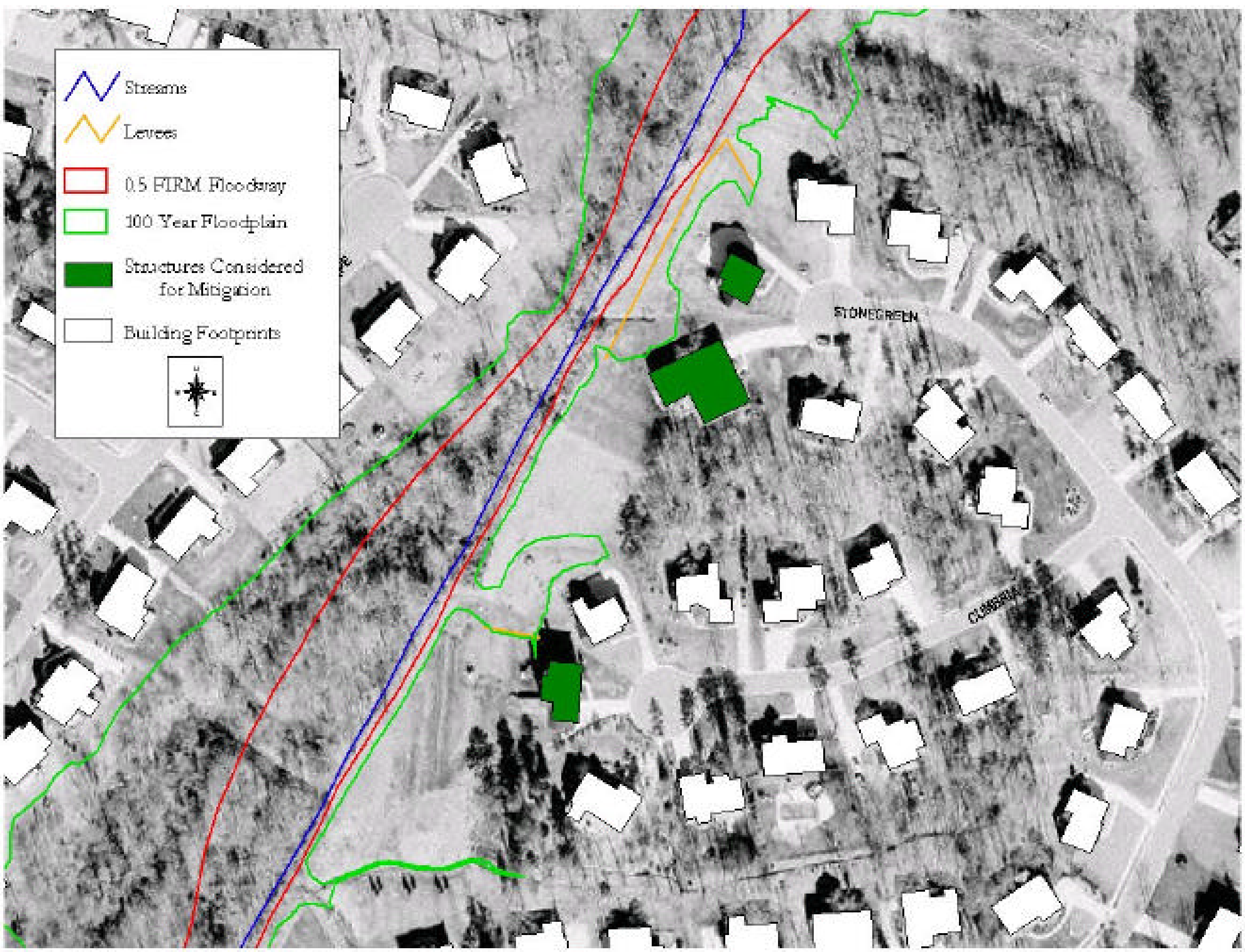


Fig. 19 Houses with Flooding Potential in Cumbria/Stonegreen Neighborhood

Delancey Neighborhood

The summary of the benefit:cost analysis for the Delancey Lane neighborhood is shown in Table 11. The general neighborhood is shown in Figure 20. A single structure in this neighborhood is in flood fringe area. The highest benefit:cost ratio of any of the mitigation measures considered is 0.43 for the levee (flood barrier) alternative, which is below the acceptable level of 1.0 for the alternative to be economically feasible. This benefit:cost ratio of 0.43 is also the highest individual value since only one house is affected in this area. The levee option is included in the analysis for this neighborhood since the levee would be constructed for the protection of this structure only, and all the costs can be attributed to this single structure.

Table 11. Mitigation Measures for Delancey Neighborhood								
Possible Mitigation Project								
Acquisition			Elevation			Levee		
Benefit	Cost	Ratio	Benefit	Cost	Ratio	Benefit	Cost	Ratio
$ 32,310	$ 344,039	0.09	$ 10,526	$ 74,423	0.14	$ 18,816	$ 44,216	0.43

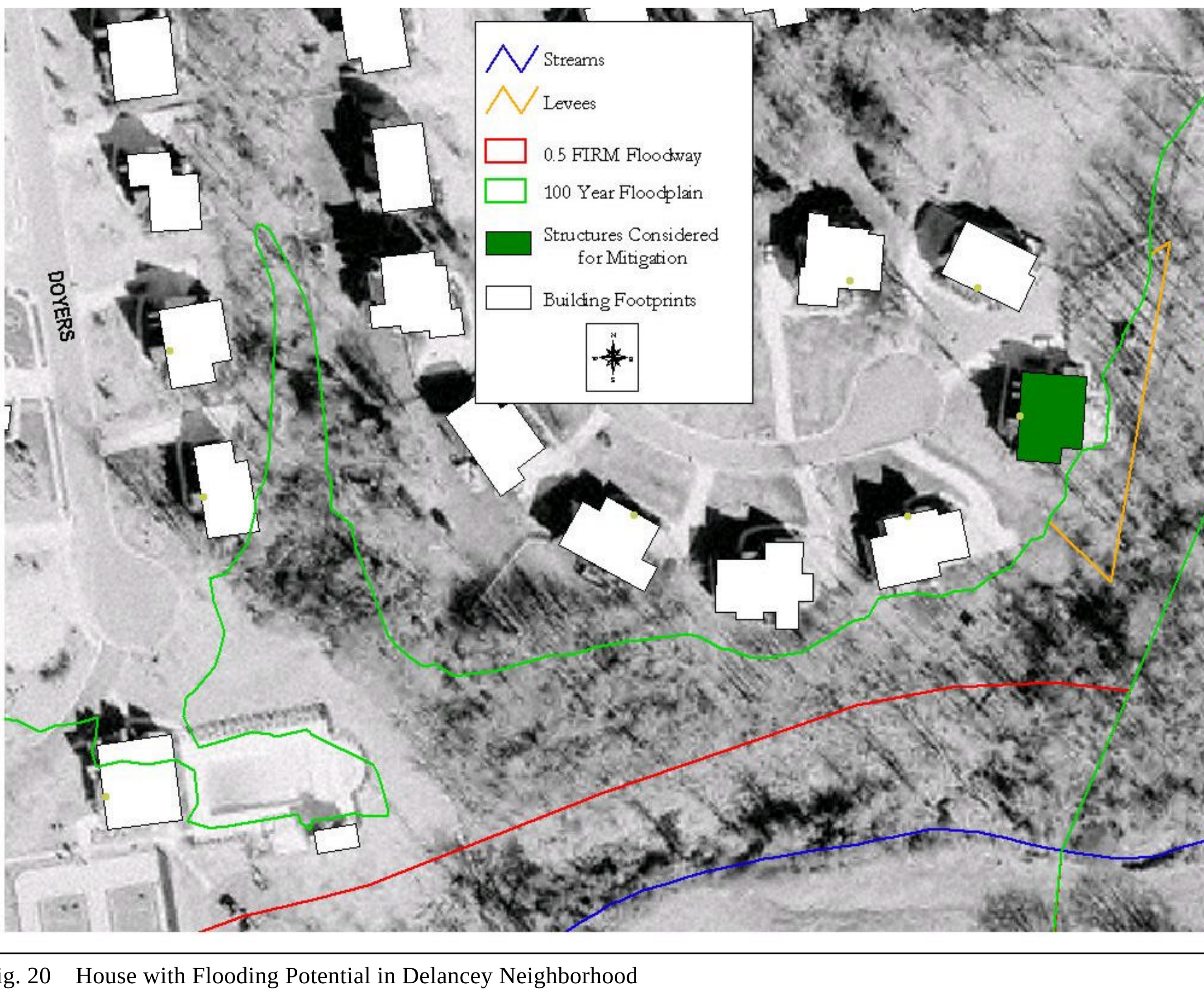


Fig. 20 House with Flooding Potential in Delancey Neighborhood

4. CONCLUSIONS AND RECOMMENDATIONS

The McDowell Creek basin constitutes a young but fast developing section of Mecklenburg County. McDowell Creek and its main tributaries, McDowell Trib.1, Caldwell Station, Torrence Creek, and Torrence Creek Tribs. 1 and 2 are all in a reasonably stable condition due to four main factors:

1. Stream banks stabilized by riprap or other means to safeguard a sewer main line that extends along the creek

2. Heavily vegetated banks and floodplains

3. Numerous road crossings and other man-made structures that form grade controls and limit bank erosion or stream scour

4. Past stabilization efforts along McDowell Creek and its tributaries

In the event of a 100-year flood, flooding hazard for the structures lining the banks of the creek may be identified in four general neighborhoods. A total of 15 structures are affected, all of which are located in the flood fringe areas (within 2 ft of BFE). Flood inundation damages are nonexistent. Of the three mitigation measures considered for these two neighborhoods, namely elevating the structures, berm construction, and acquisition, none proved to be economically justifiable. No flood mitigation measures are recommended for this watershed.

There are several road crossings that are subject to overtopping in case of a 100-year flood. Flood depths over the roadway may be as high as 6.3 ft in one case for the future 100-year flood (backwater effect). Two smaller crossings on non-public roads would also be flooded severely. Several mitigation measures should be considered for the road crossings of this watershed, which include warning signs for the approaching motorists, tall guardrails or indicators to guide the vehicles away from the edge of the road in case of a flash flood, raising the elevation of road at the stream crossing, and emergency response team notification. Regular maintenance at man-made structures such as road crossings and storm water outfalls will be necessary to maintain the stream capacity and stability.

5. REFERENCES

The following sources have been consulted in the preparation of this report:

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

Federal Emergency Management Agency 1995. *Engineering Principles and Practices for Retrofitting Flood Prone Residential Buildings*, Manual 259, FEMA Mitigation Directorate, January.

Federal Emergency Management Agency 1996. *Benefit-Cost Program , Riverine Flood Module*, Version 1.11, Revised February 10 (software distributed by FEMA).

R.S. Means 2000. *Site Work and Landscape Cost Data*, 20th Annual Edition, Construction Publishers & Consultants, Kingston, MA 02364-0800

County of Mecklenburg, North Carolina Website, www. co.mecklenburg.nc.us/.

APPENDIX D

Reed's Creek West Fork Meander X-Section 1 (Fore) and Inflection X-Section 2 (Back) looking upsteam

Reed's Creek West Fork Meander X-Section 3 (Fore) and Inflection X-Section 4 (Back) looking upsteam

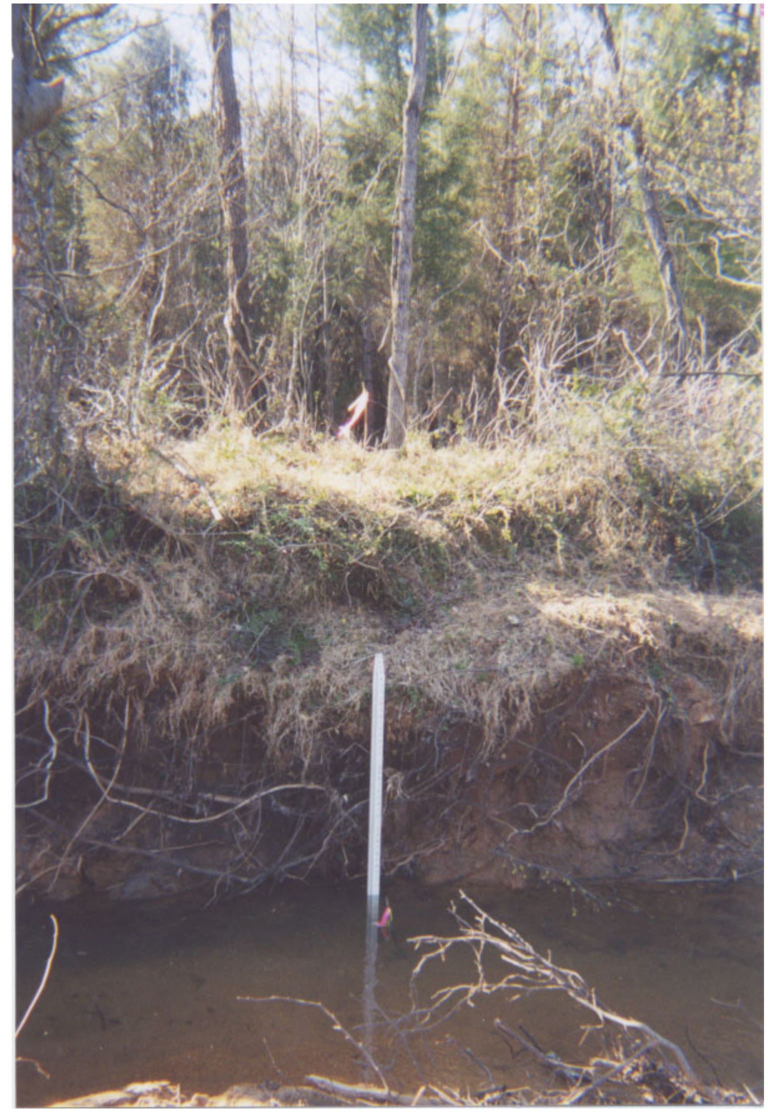
Reed's Creek West Fork Meander X-Section 5 looking downsteam

Reed's Creek West Fork Inflection X-Section 6 looking upsteam


Reed’s Creek West Fork Meander X-Section 1 Left Bank


Reed’s Creek West Fork Meander X-Section 1 Right Bank


Reed’s Creek West Fork Meander X-Section 3 Left Bank


Reed’s Creek West Fork Meander X-Section 3 Right Bank

Reed’s Creek West Fork Inflection X-Section 4 Left Bank

Reed’s Creek West Fork Inflection X-Section 4 Right Bank

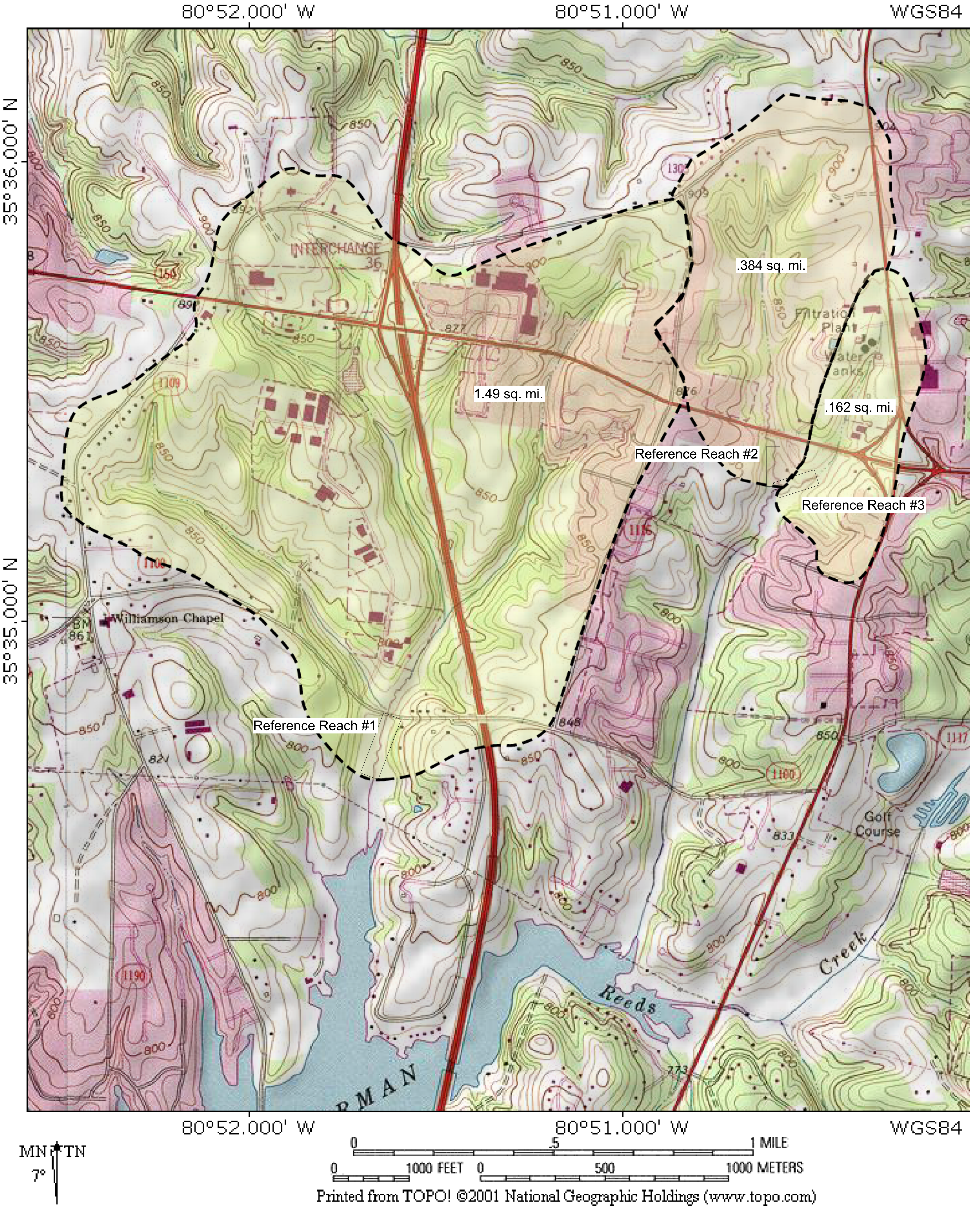
Reed’s Creek West Fork Meander X-Section 5 Left Bank

Reed’s Creek West Fork Meander X-Section 5 Right Bank

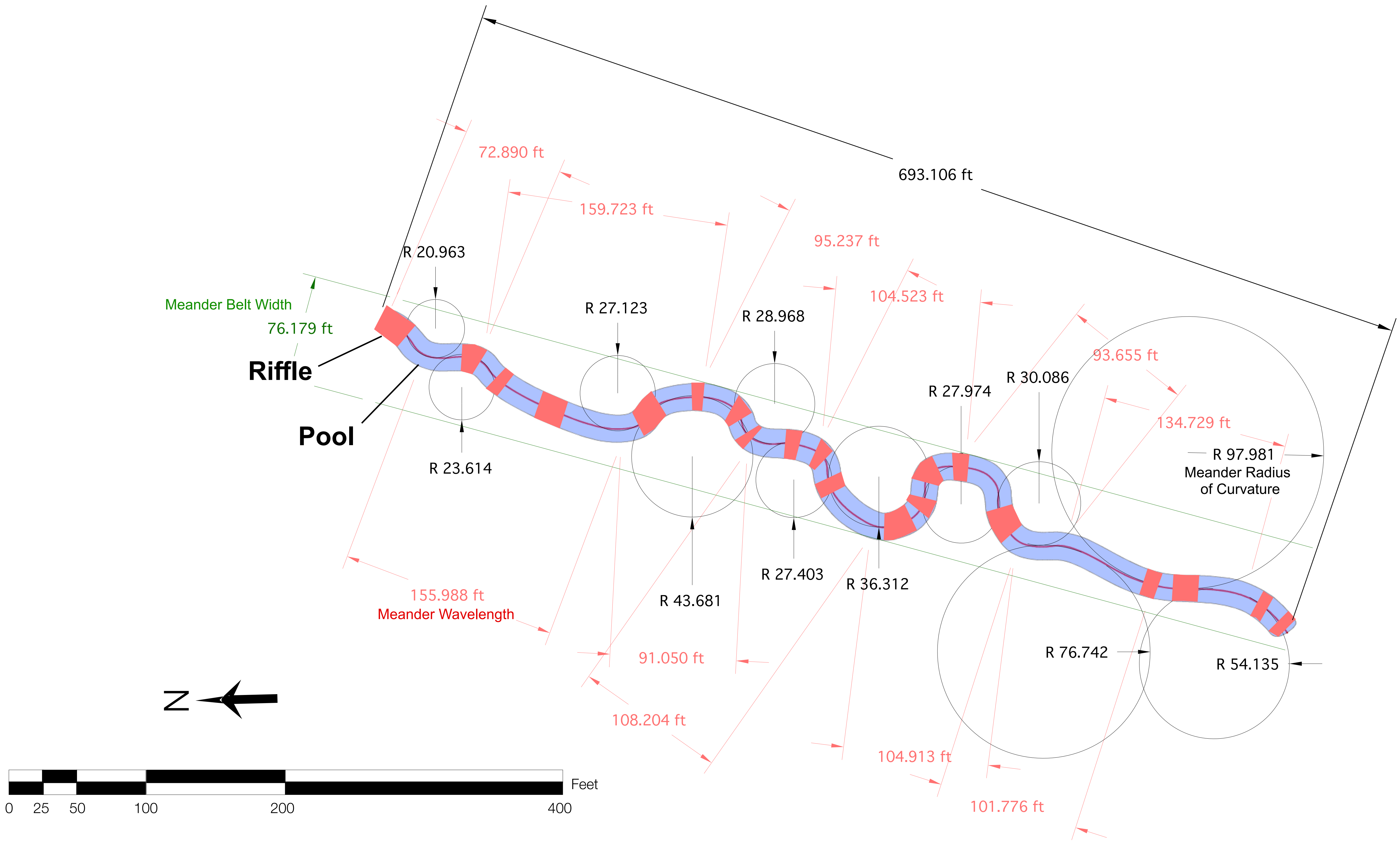
Reed’s Creek West Fork Riffle Point A at approximately 233 feet on the Longitudinal

Reed’s Creek West Fork Riffle Point B at approximately 545 feet on the Longitudinal

Reed’s Creek West Fork Riffle Point C 15 feet beyond the Longitudinal Profile



HDR / Habitat Assessment and Restoration Program Inc.	NCEEP Stream Restoration Project: Caldwell Station Ck., Mecklenburg, CO., NC	Figure D1. Reference Reach Sites, Un-named Tributaries to Reeds Creek Cove, Lake Norman, Iredell Co. N.C.	March 2004

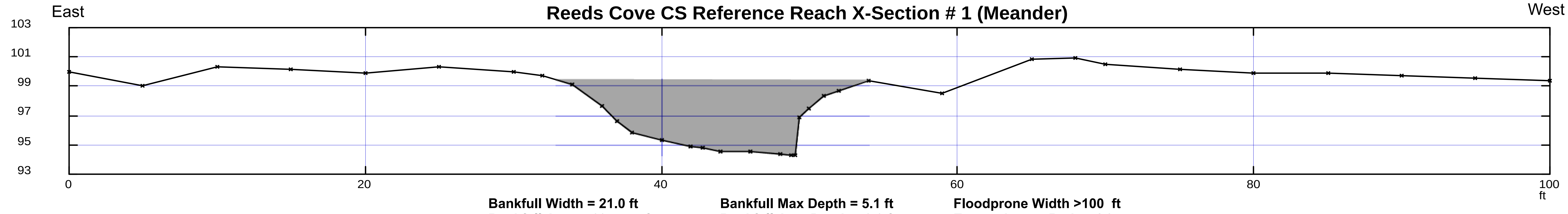


NCEEP Caldwell Station Creek Restoration Site, Mecklenburg Co., NC

Figure D2. West Fork Reeds Creek Reference Reach Planview

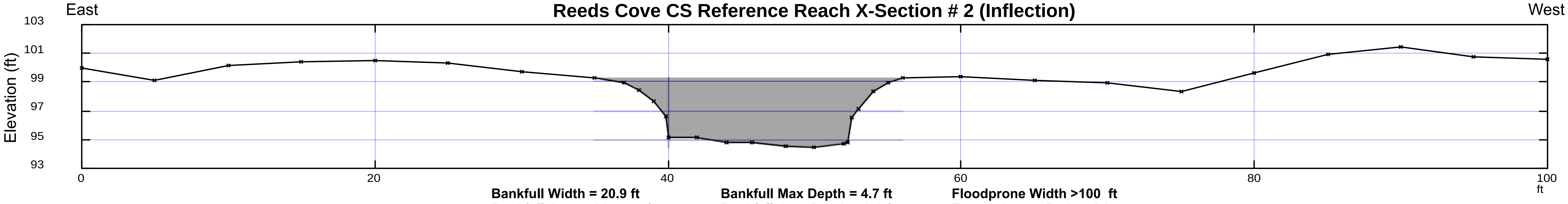
04/2004

Reeds Cove CS Reference Reach X-Section # 1 (Meander)



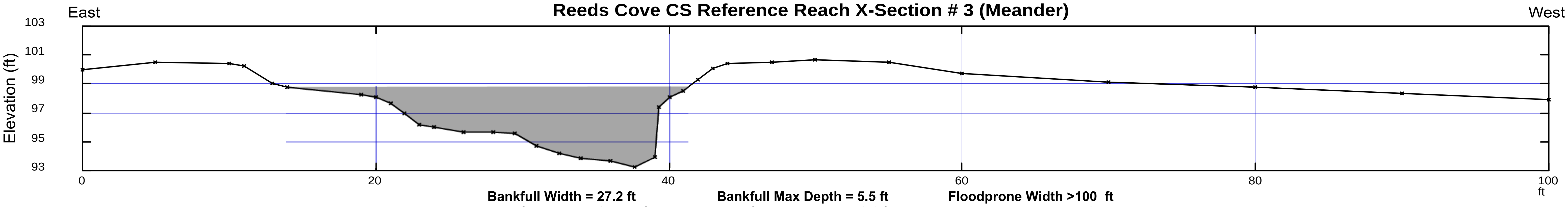
Bankfull Width = 21.0 ft
Bankfull Area = 63.7 sq. ft
Bankfull Max Depth = 5.1 ft
Bankfull Avg. Depth = 3.0 ft
Floodprone Width >100 ft
Entrenchment Ratio >4.8
W/D = 6.9

Reeds Cove CS Reference Reach X-Section # 2 (Inflection)



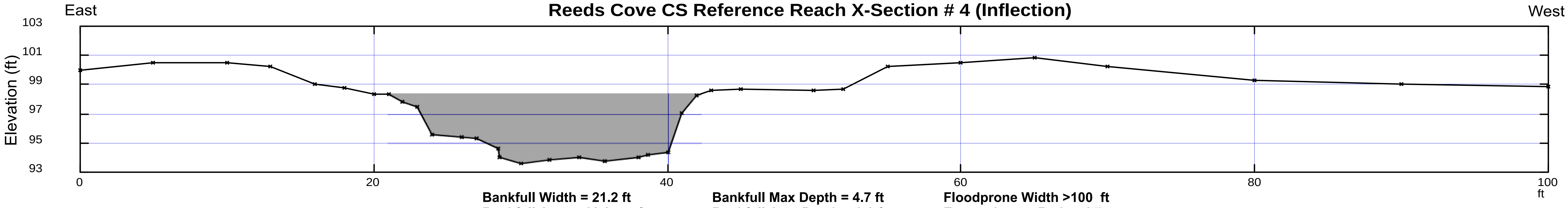
Bankfull Width = 20.9 ft
Bankfull Area = 62.5 sq. ft
Bankfull Max Depth = 4.7 ft
Bankfull Avg. Depth = 3.0 ft
Floodprone Width >100 ft
Entrenchment Ratio >4.8
W/D = 7.0

Reeds Cove CS Reference Reach X-Section # 3 (Meander)



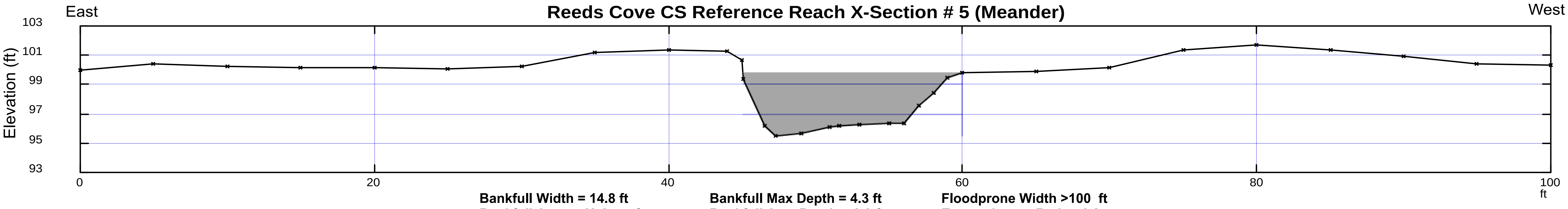
Bankfull Width = 27.2 ft
Bankfull Area = 71.5 sq. ft
Bankfull Max Depth = 5.5 ft
Bankfull Avg. Depth = 2.6 ft
Floodprone Width >100 ft
Entrenchment Ratio >3.7
W/D = 10.3

Reeds Cove CS Reference Reach X-Section # 4 (Inflection)



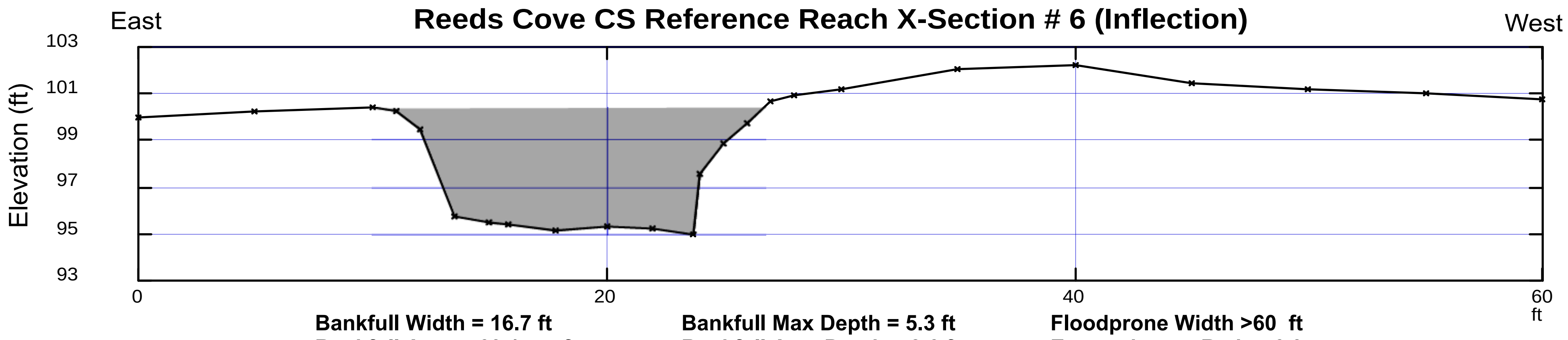
Bankfull Width = 21.2 ft
Bankfull Area = 69.8 sq. ft
Bankfull Max Depth = 4.7 ft
Bankfull Avg. Depth = 3.3 ft
Floodprone Width >100 ft
Entrenchment Ratio >4.7
W/D = 6.4

Reeds Cove CS Reference Reach X-Section # 5 (Meander)



Bankfull Width = 14.8 ft
Bankfull Area = 43.6 sq. ft
Bankfull Max Depth = 4.3 ft
Bankfull Avg. Depth = 2.9 ft
Floodprone Width >100 ft
Entrenchment Ratio >6.8
W/D = 5.0

Reeds Cove CS Reference Reach X-Section # 6 (Inflection)



Bankfull Width = 16.7 ft
Bankfull Area = 60.1 sq. ft
Bankfull Max Depth = 5.3 ft
Bankfull Avg. Depth = 3.6 ft
Floodprone Width >60 ft
Entrenchment Ratio >6.0
W/D = 4.6

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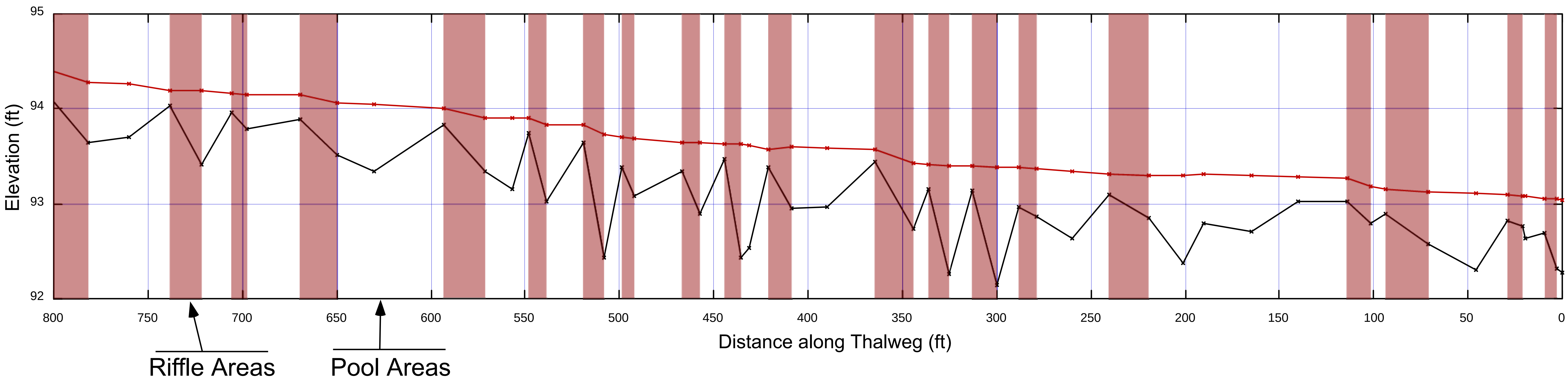
NCEEP Caldwell St. Creek Restoration Site - Mecklenburg Co., NC

Figure D3. Cross Sections

West Fork Reeds Creek Reference Reach - Iredell Co., NC

Mar. 2004



NCEEP Caldwell Station Creek Restoration Site, Mecklenburg Co., NC

Figure D4. West Fork Reeds Creek Reference Reach Longitudinal Profile

04/ 2004

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