Buffalo Creek Watershed Stream Restoration Projects Greensboro, North Carolina

North Carolina Department of Environment and Natural Resources
Wetlands Restoration Program

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Executive Summary

The North Carolina Wetlands Restoration Program (WRP) proposes to restore 17,227 feet of streams at 4 sites in the Buffalo and South Buffalo Creeks Watershed in Greensboro, North Carolina. The specific reaches are located in Benbow Park, Gillespie Golf Course, Hillsdale Park, and Brown Bark Park.

The existing stream channels have low sinuosity and varying levels of incision due to historic channelization. The proposed stream restoration design is based on natural channel design principles and considers differences in drainage area, adjacent land uses, urban constraints, and future development potential. The design addresses the channel dimension, pattern, and profile based on reference reach parameters and hydraulic geometry relationships. When considering design alternatives, every effort was made to create a stable meandering channel with bankfull stage located at the existing floodplain elevation. Where valley or development restrictions do not allow for new channel pattern to be established, the existing incised channels will be enhanced by excavating new floodplain benches at the bankfull stage and installing structures to improve bed features and control channel grade.

A summary of existing and design reach lengths with proposed restoration design approaches is provided in the table below.

Sub-Project	Existing Length (ft)	Restored Length (ft)	Restoration Approach
Benbow Park	1,752	2,060	Reach 1 - combined Priority 2 & 3 Reach 2 – Priority 1
Gillespie Golf Course (Main channel)	2,877	2,877	Bankfull benches & In-stream structures
Gillespie Golf Course (Tributaries)	3,427	3,427	Priority 3 – Buffer restoration & Bank stabilization
Hillsdale Park (Main channel)	5,434	5,434	Priority 3
Hillsdale Park (Tributary)	529	529	Priority 3
Brown Bark Park	2,748	2,900	Priority 1 & 3 & Bank stabilization
Total	**16,767**	**17,227**	

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1 Introduction

1.1 Project Description

The North Carolina Wetlands Restoration Program (WRP) proposes to restore 17,227 feet of streams at four sites in the Buffalo and South Buffalo Creek Watersheds. The project streams are located in four parks in the city of Greensboro in Guilford County, North Carolina. These streams are tributaries to the Haw River (USGS Hydrologic Unit 03030002) and are in the Cape Fear River basin.

The project is divided into four sub-projects: Benbow Park, Gillespie Golf Course, Hillsdale Park, and Brown Bark Park. The sub-project sites are shown in Figure 1.1. Their lengths and respective drainage areas are listed in Table 1.1.

Table 1.1 Sub-Projects with Existing Stream Lengths and Drainage Areas.

Sub-Project Name and Location	Existing Length (ft)	Drainage Area (mi^2)
Benbow Park	1,752	0.7
Gillespie Golf Course – main channel Tributaries	2,877 3,427	2.2
Hillsdale Park – main channel Tributary	5,434 529	10.0
Brown Bark Park	2,748	0.3
Total	**16,767**	

1.2 Project Objectives

The objectives of the Buffalo Creek Stream Restoration Projects are to:
1. Restore unstable stream channels to natural stable forms by modifying dimension, pattern, and profile based on reference reach parameters;
2. Improve floodplain functionality by matching bankfull stage with floodplain elevation;
3. Establish native floodplain vegetation through a forested riparian buffer; and
4. Improve the natural aesthetics of the stream corridor.

1.3 Watershed Characterization

The four project sites are located in the city of Greensboro in the urban Piedmont Physiographic Region. The topography is characterized by gently rolling hills with a dendritic drainage pattern and wide alluvial valleys. The underlying geology consists of intrusive granite and well foliated (metamorphosed) granitic rock with hornfels.

Over the last two decades, land use in the project vicinity has undergone a rapid conversion from rural and open space to urban. The City of Greensboro Planning Department is responsible for the future growth and development of the city. Information on land use planning in Greensboro can be found at:

http://www.ci.greensboro.nc.us/planning/

More detailed information for each project watershed is presented in the sections below. Characterizations were performed by gathering information on topography, soils, land use, and percent impervious. The percent impervious of each watershed was estimated using aerial photography and GIS analysis.

1.3.1 Benbow Park

The Benbow Park project watershed area is approximately 0.7 square miles. Land use outside the park is almost entirely residential, with approximately 87% of the area developed into 1/8-acre lots. The watershed has approximately 61% impervious land cover. About 7% of the total land cover is open space.

Elevations at the Benbow Park project site range from approximately 720 feet to 780 feet with a relative relief of 60 feet. Based on the North Carolina Soil Survey for Guilford County (ref., 1977), soils at the project site are mapped as Enon-Urban Land Complex (EnB), which have gentle to strong (2-10%) slopes. The Enon series consists of deep well-drained soils usually found on broad, smooth inter-stream divides and long, narrow slopes. Typically the water table remains below the A horizon, but a perched water table can exist during the wet season due to the low permeability of the subsoil. The surface layer typically extends to a depth of 8 inches and is dark brown. The subsoil is a strong brown color with yellow mottles with the clay content increasing with increasing depth of the soil profile.

1.3.2 Gillespie Golf Course

The Gillespie Golf Course project watershed area is approximately 2.2 square miles with about 59% impervious land cover. The predominant land use outside the golf course is high-density residential, with approximately 48% of the watershed developed into lots of 1/8-acre or less. The watershed also has significant commercial and industrial development that accounts for approximately 33% of the land cover. About 16% of the watershed is open space.

Elevations at the Gillespie Golf Course project site range from approximately 720 feet to 800 feet with a relative relief of 80 feet. Soils at the site are mapped primarily as Chewacla (Cm). The Chewacla series is a nearly level, somewhat poorly drained soil typically found on the floodplains of streams. The surface layer is typically a sandy loam that is 4 to 12 inches deep and brown to grayish brown or yellowish brown in color. The subsoil ranges from 10 to more than 40 inches thick. Texture analysis indicates that the subsoil ranges from a sandy loam to a clay loam. The Enon (EnB) series is also present on the site. The Enon series consists of deep well-drained soils usually found on broad, smooth inter-stream divides and long, narrow slopes. Typically the water table remains below the A horizon, but a perched water table can exist during the wet season due to the low permeability of the subsoil. The surface layer typically extends to a depth of 8 inches and is dark brown. The subsoil is a strong brown color with yellow mottles. Typically, the clay content increases with depth increasing depth of the soil profile.

1.3.3 Hillsdale Park

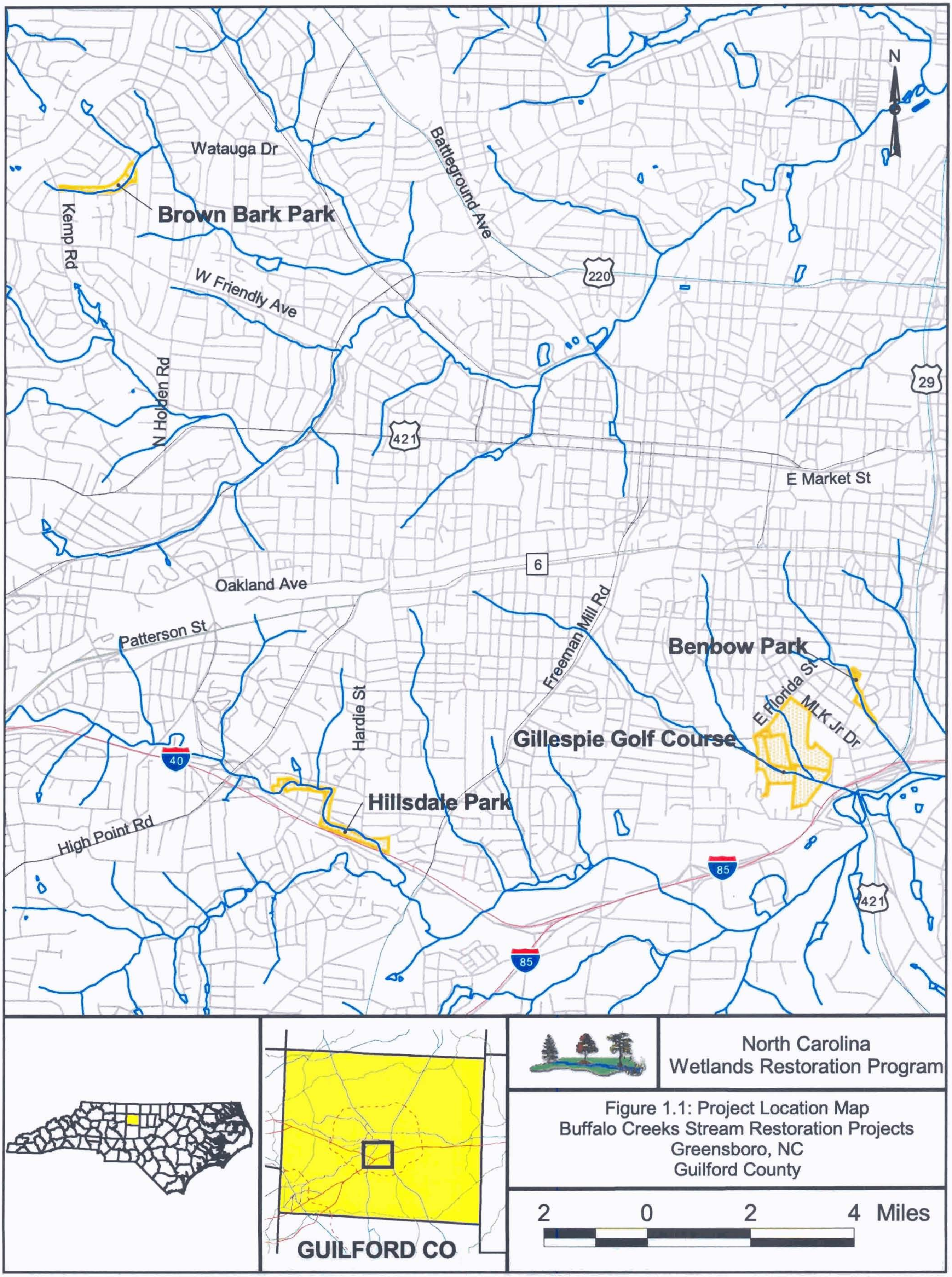
The Hillsdale Park project watershed is approximately 10 square miles with about 65% impervious land cover. Land use outside the park is a mix of residential, commercial, and industrial development. About 8% of the watershed is forested or open space. Commercial and industrial development accounts for approximately 43% of land use. This development is located primarily along Interstate 40 and other major roads. Residential development accounts for about 47% of the land cover, with the largest amount (38%) in lots of 1/8-acre or less. About 8% of the watershed land cover is residential development of 1/4-acre lots and only 1% are residential lots larger than 1/4-acre.

Elevations at the Hillsdale Park project site range from approximately 750 feet to 830 feet with a relative relief of 80 feet. Soils at the site are mapped as Congaree (Co) series. The Congaree series consists of nearly level well-drained soils on long, narrow floodplains of streams. Congaree soils are moderately permeable and exhibit a high available water capacity. The seasonally high water table is typically 36 inches from the soil surface. The surface layer, a sandy loam, is typically 5 to 20 inches deep with a color ranging from gray to grayish brown. The subsoil is typically 15 to 50 inches thick and is clay or clay loam. Subsurface colors range from olive yellow to strong brown with some gray mottling. The sub-soil is slightly acidic to strongly acidic.

1.3.4 Brown Bark Park

The Brown Bark Park project watershed is approximately 0.3 square miles with about 32% impervious land cover. Land use outside the park is almost entirely residential, with about 78% of the watershed area developed into 1/4-acre lots and 9% into 1/3-acre lots. Approximately 13% of the watershed is forested or open space.

Elevations at the Brown Bark Park project site range from approximately 840 feet to 910 feet with a relative relief of 70 feet. Soils at the site are mapped as Cecil-Urban series (CeB). The Cecil-Urban series has 2-10% slopes and consists of well-drained soils usually found on the uplands of large streams. The surface layer (3 to 12 inches thick) is typically a dark brown to yellowish-brown sandy loam. The subsoil exists as a red clay (28 to 50 inches thick) that is slightly to strongly acidic. Another soil mapped in the park is the Madison (MdD) sandy loam. The Madison sandy loam consists of gently sloping to moderately steep, deep well-drained soils. Typically the surface layer ranges from 3 to 10 inches deep and is dark brown in color. The subsoil depth ranges from 20 to 40 inches thick and is a dark red clay loam.



North Carolina
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Figure 1.1: Project Location Map
Buffalo Creeks Stream Restoration Projects
Greensboro, NC
Guilford County

2 Existing Condition Survey

The primary purposes of the existing condition survey are to determine the stability of the project stream reach and its potential for restoration (if needed). This is accomplished through a quantitative and qualitative investigation of the stream corridor, including channel dimension, pattern, and profile. This analysis provides information that is used to assess the potential for restoration. Data collected during the existing condition survey are used to determine if the stream is moving towards stability or instability and if the cause of instability is localized or system wide. Examples of localized instability include removal of riparian vegetation and/or trampling of the streambanks by livestock or people. System-wide instability is often caused by channel incision, which causes head-ward erosion until stopped by a knickpoint.

2.1 Channel Stability Assessment

Buck Engineering used a modified stream channel stability assessment methodology developed by Rosgen (2001) The Rosgen 2001 method is a field assessment of the following variables:

1. Stream Channel Condition or "State" Categories,
2. Vertical Stability – Degradation/Aggradation,
3. Lateral Stability,
4. Channel Pattern,
5. River Profile and Bed Features,
6. Channel Dimension Relations,
7. Stream Channel Scour/Deposition Potential (Sediment Competence),
8. Dimensionless Ratio Sediment Rating Curves,
9. Channel Evolution

A description of each variable is provided below.

2.1.1 Stream Channel Condition or "State" Categories

Seven categories are included in this step and include: a) riparian vegetation, b) sediment depositional patterns, c) debris occurrence, d) meander patterns, e) stream size/stream order, f) flow regime, and g) altered states due to direct disturbance. These condition categories are determined from field inspection and measurement of stream channel condition characteristics.

2.1.2 Vertical Stability – Degradation/Aggradation

The bank height and entrenchment ratios are measured in the field to determine vertical stability. The bank height ratio is measured as the ratio of the lowest bank height divided by a maximum bankfull depth. Table 2.1 shows the relationship between bank height ratio and vertical stability developed by Rosgen (2001).

Table 2.1. Conversion of Bank Height Ratio (Degree of Incision) to Adjective Rankings of Stability (Rosgen, 2001).

Stability Rating	Bank Height Ratio
Stable (low risk of degradation)	1.0 – 1.05
Moderately unstable	1.06 – 1.3
Unstable (high risk of degradation)	1.3 – 1.5
Highly unstable	> 1.5

The entrenchment ratio is calculated by dividing the flood-prone area (area measured at twice the maximum bankfull depth) by the bankfull width. If the entrenchment ratio is less than 1.4 (+/- 0.2), the stream is entrenched (Rosgen, 1996).

2.1.3 Lateral Stability

The degree of lateral containment (confinement) and potential lateral accretion are determined in the field by measuring the meander width ratio and Bank Erosion Hazard Index (BEHI). The meander width ratio is the meander belt width divided by the bankfull channel width, and provides insight into channel adjustment processes depending on stream type and degree of confinement. BEHI ratings can be used to estimate the annual, lateral streambank erosion rate.

2.1.4 Channel Pattern

Channel pattern is assessed in the field by measuring the meander width ratio (described above), ratio of radius of curvature to bankfull width, sinuosity, and meander wavelength ratio (meander wavelength divided by bankfull width). These dimensionless ratios are compared to reference reach data for the same valley and stream type to determine where channel adjustment has occurred due to instability.

2.1.5 River Profile and Bed Features

A longitudinal profile is created by measuring elevations of the bed, water surface, bankfull, and low bank height along the reach. This profile can be used to determine changes in river slope compared to valley slope, which are sensitive to sediment transport, competence, and the balance of energy. For example, the removal of large woody debris may increase the step/pool spacing and result in excess energy and subsequent channel degradation.

2.1.6 Channel Dimension Relations

The bankfull width/depth ratio (bankfull width divided by mean bankfull depth) is measured in the field. The ratio provides an indication of departure from the reference reach and relates to channel instability. An increase in width/depth ratio indicates accelerated streambank erosion, excessive sediment deposition, streamflow changes, and alteration of channel shape (e.g., from channelization). Channel widening is also associated with an increase in width/depth ratio due to evolutionary shifts in stream type (e.g., from G4 to F4 to C4). Table 2.2 shows the relationship between the degree of width/depth ratio increases and channel stability developed by Rosgen (2001).

Table 2.2. Conversion of Width/Depth Ratios to Adjective Rankings of Stability from Stability Conditions (Rosgen, 2001).

Stability Rating	Ratio of W/D Increase
Very stable	1.0
Stable	1.0 – 1.2
Moderately unstable	1.21 – 1.4
Unstable	> 1.4

While an *increase* in width/depth ratio is associated with channel *widening*, a *decrease* in width/depth ratio is associated with channel *incision*. Hence, for incised channels, the ratio of channel width/depth ratio to reference reach width/depth ratio will be less than 1.0. The reduction in width/depth ratio indicates excess shear stress and an adjustment of the channel toward an unstable condition.

2.1.7 Stream Channel Scour/Deposition Potential (Sediment Competence)

This methodology is discussed in detail in Chapter 6 of this report.

2.1.8 Dimensionless Ratio Sediment Rating Curves

Sediment transport relationships have not been developed to complete this analysis for North Carolina.

2.1.9 Channel Evolution

A common sequence of physical adjustments has been observed in many streams following disturbance. This adjustment process is often referred to as channel evolution. Disturbance can result from channelization, increase in runoff, removal of streamside vegetation, as well as other changes that negatively affect stream stability. All of these disturbances are common in the urban environment. Several models have been used to describe this process of physical adjustment for a stream. Simon's channel evolution model (1989) characterizes evolution in six steps, including 1) sinuous, premodified, 2) channelized, 3) degradation, 4) degradation and widening, 5) aggradation and widening, and 6) quasi equilibrium.

The channel evolution process is initiated once a stable, well-vegetated stream that frequently interacts with its floodplain is disturbed. Disturbance commonly results in an increase in stream power that causes degradation, often referred to as channel incision. Incision eventually leads to over-steepening of banks, and when critical bank heights are exceeded, the banks begin to fail and mass wasting of soil and rock leads to channel widening. Incision and widening continue moving upstream, commonly known as a head-cut. Eventually the mass wasting slows and the stream begins to aggrade. A new low-flow channel begins to form in the sediment deposits. By the end of the evolutionary process, a stable stream with dimension, pattern, and profile similar to those of undisturbed channels forms in the deposited alluvium. The new channel is at a lower elevation than its original form with a new floodplain constructed of alluvial material. The old floodplain remains a dry terrace (FISRWG, 1998). Most urban streams are at some stage of this evolutionary process. The time period required to reach a state of quasi equilibrium is highly variable and has not yet been determined.

2.2 Benchmarks and Underground Utilities

Two temporary benchmarks were established at each site by Arcadis G&M. Their locations and coordinates are shown on the enclosed plan view. Topographic and planimetric information and aerial photographs were obtained from the City of Greensboro in GIS format. The topographic mapping included 2-foot contours. MA Engineering located all underground utilities and Arcadis G&M provided the utility mapping to overlay with the topographic and planimetric data. Buck Engineering supplemented the existing mapping with a longitudinal profile and cross sectional surveys of the existing channel. We also collected additional topographic data in areas where intensive grading may take place, e.g. a new channel or stormwater BMP.

2.3 Benbow Park

An unnamed tributary to South Buffalo Creek flows through Benbow Park. The project drainage area is 0.7 mi^2 and is divided into two project reaches. Reach 1 is from Florida Avenue to South Benbow Road and Reach 2 is from South Benbow Road to Belcrest Drive. A project location map is shown in Figure 2.1 and the watershed with land cover is shown in Figure 2.2. A plan view drawing is shown on the attached plan sheets. The summary data are shown in Table 2.3.

Table 2.3. Existing Condition Parameters for the Unnamed Tributary to South Buffalo Creek at Benbow Park.

	Parameter	Reach 1 Riffle	Reach 1 Pool	Reach 2 Riffle	Reach 2 Pool
	Rosgen Stream Type	E5		E5	
	Drainage Area (mi^2)	0.7		0.7	
	Reach Length (ft)	776		976	
Dimension	Bankfull Area (ft^2)	24 - 26	25	39 - 45	23 - 85
Dimension	Bankfull Width (ft)	13.6-15.3	19 - 22	18 - 22	17 - 31
Dimension	Width/Depth Ratio (ft)	7 - 10	14 - 19	8 -11	7 – 29
Dimension	Bankfull Mean Depth (ft)	1.6 - 1.9	1.2 - 1.3	2.0 - 2.2	0.9 - 2.8
Dimension	Bank Height Ratios	1.5 - 1.7	1.7 - 1.9	1.2 - 1.8	1.3 - 1.8
Pattern	Meander Length Ratio	N/A	N/A	N/A	N/A
Pattern	Radius of Curvature Ratio	N/A	N/A	N/A	N/A
Pattern	Meander Width Ratio	N/A	N/A	N/A	N/A
Pattern	Sinuosity	1.04		1.07	
Profile	Valley Slope (ft/ft)	0.0053		0.0060	
Profile	Channel Slope (ft/ft)	0.0051		0.0056	

2.3.1 Stability Assessment

As part of the stability assessment, nine cross sections were surveyed at stable and unstable riffles and pools throughout both reaches. The cross sections and survey data are provided in Appendix 1. Bankfull cross sectional area varies widely throughout the reach from 24 to 45 ft^2 with one pool bankfull cross sectional area of 85 ft^2 near the Belcrest Road culvert. This variability is indicative of an unstable channel that is adjusting to hydrologic changes in the watershed. The bankfull width/depth ratio is also variable, ranging from 7 to 14 in the riffles and up to 29 in one pool. The increase in bankfull width/depth ratio is indicative of a channel that is trying to widen and increase its floodplain width. Lateral bars and point bars are located in areas with high bankfull width/depth ratios, evidence of channel widening.

In addition to the channel being overly wide in places, the channel is moderately incised. Bank height ratios range from 1.2 to 1.8 and entrenchment ratios range from 1.6 to 4.1. These values demonstrate that the stream varies from slightly incised to highly incised; however, the stream is not severely entrenched (no values below 1.4). There is a wide flood prone area on the left bank of the upstream reach and on the right bank of the downstream reach.

The longitudinal profile, shown in Appendix 1, varies over the project length. The overall average channel slope across both reaches is 0.0063 ft/ft or 0.63%. The upstream section of Reach 1 from the culvert at Florida Avenue to Station 3+87 is almost twice as steep with a slope of 0.010 ft/ft or 1.0%. There is some diversity in riffle-pool sequence in the upstream section on Reach 1. From Station 3+87 to the culvert at Station 7+76 the streambed is flat and slightly below the culvert invert. This is causing backwater and deposition of fine sediments with no diversity of riffles and pools. Downstream of the Benbow road culvert (Reach 2) the slope is more uniform and closer to the overall average at 0.0051 ft/ft or 0.51%. Several bedrock knickpoints and the Belcrest Road culvert provide grade control for Reach 2.

The modified Wolman pebble count was used to characterize the bankfull channel bottom. Transects were sampled throughout the reach and were stratified by the proportion of riffles and pools. Ten particles were sampled at ten different cross sections spread throughout each reach. The pebble count data show that the D50 is 1mm, on the border between gravel and sand. The D84 is 45 mm indicating that large gravel is present in the stream channel. The histogram shows that large percentages of sediment sizes are present in the sand, coarse sand, and gravel size ranges. Most of the fines are located in the pools and runs, whereas the riffles are much coarser (see separate riffle and pool graphs in Appendix 1). The source of the fine sediment supply is likely from streambank erosion, which is prevalent throughout the reach.

Overall, the unnamed tributary to South Buffalo Creek within Benbow Park is a channelized, moderately incised stream with moderate access to its floodplain. Stream types range from an E5 to a G5c depending on the severity of incision and entrenchment. The channel is in stage IV/V of the Simon Channel Evolution model, where downcutting has ceased due to existing culvert elevations and knickpoints. The stream continues to widen in areas lacking good vegetation and develop lateral bars (inner berm) as the channel tries to develop a new floodplain at a lower elevation. Left unchecked, this widening and aggradational process will continue until the stream establishes a new floodplain with a sufficient belt width to create a stable dimension, pattern, and profile.

The riparian area within the park consists primarily of maintained grass. Woody species found along the banks include black willow (*Salix nigra*), silky dogwood (*Cornus amomum*), elderberry (*Sambucus canadensis*), box elder (*Acer negundo*), sycamore (*Platanus occidentalis*), river birch (*Betula nigra*), and black cherry (*Prunus serotina*).

While these species were present in both reaches they were more prevalent in Reach 1. Blackberry (*Rubus spp.*) and rush (*Juncus spp.*) were also present along with exotic species such as chinese privet (*Ligustrum sinense*), rose (*Rosa sp.*), and japanese honeysuckle (*Lonicera japonica*). Additional species observed in the park and surrounding woods were sweetgum (*Liquidambar styraciflua*), tulip poplar (*Liriodendron tulipifera*), beech (*Fagus grandifolia*), maple (*Acer spp.*), and oak (*Quercus spp.*). Ornamental species planted in the park include crape myrtle (*Lagerstroemia indica*) and pear (*Pyrus calleryana*).

2.3.2 Constraints

Constraints to achieving the highest level of stream restoration in Benbow Park include the following:

- The property line for a private home at the downstream end of Reach 1 comes very close to the stream (left side).
- There is a sanitary sewer manhole near the left bank of Reach 1.
- The fill slope for South Side Boulevard forms the right bank of Reach 1.
- The stream crosses through a culvert under South Benbow Road.
- The fill slope for South Side Boulevard forms the left bank of Reach 2.
- There is a basketball court and park playground equipment along Reach 2.
- The first house on the right in Reach 2 is fairly low and could prevent a Priority 1 restoration due to the risk of flooding.
- There are a number of storm sewer outfalls located along the project.

2.4 Gillespie Golf Course

Mile Run Creek flows through the Gillespie Golf Course and is adjoined by four tributaries (see the plan view drawing on the attached plan sheets). The project drainage area is 2.2 mi^2 and is divided into 5 reaches. Reach 1 is the main channel of Mile Run Creek through Gillespie Golf Course. The summary data for this reach are shown in Table 2.4.

Reaches 2 through 5 are small tributaries that will undergo bank stabilization and buffer re-establishment. Reach 2 joins Mile Run Creek at Station 16+92, Reach 3 at Station 20+47, and Reach 4 at Station 19+29. Reach 5 is a tributary to Reach 4, entering just upstream of the confluence of Reach 4 and Mile Run Creek.

Table 2.4. Existing Condition Parameters for Mile Run Creek at Gillespie Golf Course.

	Parameter	Reach 1 Riffle	Reach 1 Pool
	Rosgen Stream Type	E5/C5	E5/C5
	Drainage Area (mi^2)	2.2	
	Reach Length (ft)	2,877	
Dimension	Bankfull Area (ft^2)	62 - 88	102 – 113
Dimension	Bankfull Width (ft)	29 – 32	29 - 44
Dimension	Width/Depth Ratio (ft)	10 – 17	8 – 19
Dimension	Bankfull Mean Depth (ft)	1.9 - 3.1	2.3 - 4.9
Dimension	Bank Height Ratios	1.2 - 1.3	1.3 - 1.4
Pattern	Meander Length Ratio	N/A	N/A
Pattern	Radius of Curvature Ratio	N/A	N/A
Pattern	Meander Width Ratio	N/A	N/A
Pattern	Sinuosity	1.09	
Profile	Valley Slope (ft/ft)	0.0030	
Profile	Channel Slope (ft/ft)	0.0028	

2.4.1 Stream Stability Assessment

Seven cross sections were surveyed along Reach 1 and are shown in Appendix 1. Riffle cross sectional areas for Reach 1 vary from 62 to 88 ft^2. The width/depth ratios in riffles range from 9.5 to 16.6 with the highest width/depth ratios in sections with significant streambank erosion. Bedrock knickpoints throughout Reach 1 control the grade of the channel. Although this channel was likely straightened in the past, these structures have prevented the channel from further down-cutting. Bank height ratios range from 1.2 to 1.4 throughout Reach 1. There are areas with high bank erosion throughout the reach. Although these areas do not have very high bank height ratios (greater than 1.5), the erosion is likely due to the lack of vegetation along the streambank and very high bank angles. The eroded banks have caused the channel to become overly wide in some areas, resulting in the formation of mid-channel bars and lateral bars.

The longitudinal profile shows a fair amount of diversity in the riffle/pool sequence. Pools are primarily formed by the presence of bedrock knickpoints. Most of the pools; however, function more like long runs rather than deep pools. The bed material is composed mostly of sand, with a D50 of 1mm. However, the D84 is approximately 20 mm, which is medium gravel.

Maintained grass borders the entire length of Reach 1, 3, 4, and 5 through the golf course. Vegetation in the downstream section of Reach 1, below the golf course and above the culvert at Interstate 40/85, consists of red maple (*Acer rubrum*), black willow, persimmon (*Diospyros virginiana*), sycamore, japanese honeysuckle, and chinese privet. Native and ornamental plants in the vicinity of the channel include sweetgum, sycamore, river birch, oak (spp.), maple, leyland cypress (*X Cupressocyparis leylandii*), weeping willow (*Salix babylonica*), and crape myrtle. The upstream section of Reach 2 also has some existing buffer, which includes the plants listed above as well as black cherry, and mulberry (*Morus rubra*).

2.4.2 Constraints

Constraints to achieving the highest level of stream restoration at Gillespie Golf Course include the following:

- A fiber optic line owned by MCI/WorldCom runs along the right bank of Mile Run Creek for the length of the project. The easement requires MCI/WorldCom to move the fiber optic line on an as-needed basis at their cost for public projects supported by the City.
- The adjacent land use (golfing) precludes changes to pattern (e.g., the stream cannot be meandered through fairways) and high-growing vegetation in the riparian buffer (because it would obstruct views and hinder retrieval of golf balls).
- The existing golf cart bridges cannot be relocated.
- There is a golf course irrigation line that must be avoided.
- There are a number of storm sewer outfalls located along the project.

2.5 Hillsdale Park

South Buffalo Creek flows through Hillsdale Park and is adjoined by two tributaries (see the plan view drawing in the attached plan sheets). The project drainage area is 10 mi^2 and is divided into 3 reaches. Reach 1 is South Buffalo Creek from the upstream park boundary to West Meadowview Road and Reach 2 is South Buffalo Creek from West Meadowview Road to I-40. Reach 3 is a tributary that enters Reach 2 near the I-40 culvert at Station 51+38. The summary data for the three reaches are shown in Table 2.5.

Table 2.5. Existing Condition Parameters for South Buffalo Creek at Hillsdale Park.

Parameter		Reach 1 Riffle	Reach 1 Pool	Reach 2 Riffle	Reach 2 Pool	Reach 3 Riffle
Rosgen Stream Type		E4/B4c		B4c/E4/F4		E4
Drainage Area (mi^2)		10		10		0.1
Reach Length (ft)		3037		2265		529
Dimension	Bankfull Area (ft^2)	103 – 113	134 - 150	166	193	6
	Bankfull Width (ft)	36 – 44	32 – 37	66	41	7
	Width/Depth Ratio (ft)	12 - 17	8 – 9	26	9	9
	Bankfull Mean Depth (ft)	2.6 - 2.9	4.0 - 4.2	2.5	4.8	0.8
	Bank Height Ratios	1.8 - 2.1	1.5 – 1.9	2.2	1.1	1.9
Pattern	Meander Length Ratio	N/A	N/A	N/A	N/A	N/A
	Radius of Curvature Ratio	N/A	N/A	N/A	N/A	N/A
	Meander Width Ratio	N/A	N/A	N/A	N/A	N/A
	Sinuosity	1.1		1.1		1.1
Profile	Valley Slope (ft/ft)	0.0018		0.0039		0.0018
	Channel Slope (ft/ft)	0.0016		0.0035		0.0017

2.5.1 Stream Stability Assessment

Seven cross sections were surveyed at stable and unstable riffles and pools throughout Reaches 1 and 2 and are shown in Appendix 1. Bankfull cross sectional areas varied from 103 to 166 ft^2 in riffles. This change in cross sectional area is mainly due to changes in the width to depth ratio, which ranges from 12.2 to 26.4. The variability is likely due to channel widening resulting from the lack of streambank vegetation. Entrenchment ratios range from 1.1 to 2.4 and the bank height ratios range from 1.8 to 2.2, indicating the channel is highly incised. Channelization and prior upstream urbanization are the likely cause of the channel entrenchment. However, the channel is not likely to down-cut further because of the presence of bedrock knickpoints and culverts.

Woody vegetation in the riparian zone is sparse throughout most of the project, usually existing just along the streambanks. The right bank in Reach 2 (downstream of West Meadowview Road) is the only area with an extended buffer. Predominant woody species include black willow, river birch, silky dogwood, elderberry (*Sambucus canadensis*), box elder, and tag alder (*Alnus serrulata*). Other woody species found in the riparian area are green ash (*Fraxinus pennsylvanica*), black cherry, sweetgum, beech, maple (spp.), and oak (spp.). Exotic species consist of Japanese honeysuckle, kudzu (*Pueria lobata*), chinese privet, rose, and elaeagnus (sp.). Japanese honeysuckle and kudzu are especially prevalent throughout the project. Brier (Smilax spp.), blackberry, and rush are also found along the channel. Vegetation on reach 3 (downstream tributary) includes sedge (carex spp.), rush, and grasses.

2.5.2 Constraints

Constraints to achieving the highest level of stream restoration in Hillsdale Park include the following:

- The fill slope for Emerald Drive forms the left bank of South Buffalo Creek at some locations along Reach 1.
- The stream crosses through a culvert under West Meadowview Road.
- The fill slope for Interstate 40 forms the right bank of South Buffalo Creek along Reach 2.
- There is playground equipment along the left bank of Reach 2.
- There are a number of storm sewer outfalls located along the project.
- Bankfull bench excavation may be limited at sewer crossings.

2.6 Brown Bark Park

An unnamed tributary to North Buffalo Creek flows through Brown Bark Park. The project drainage area is 0.3 mi^2. The project reach extends from Kemp Road to Westminster Drive. A project location map is shown in Figure 2.7 and the watershed with land cover is shown in Figure 2.8. A plan view drawing is shown included in the attached plan sheets. The summary data for the Brown Bark reach are shown in Table 2.6.

Table 2.6. Existing Condition Parameters for the Unnamed Tributary to North Buffalo Creek at Brown Bark Park.

Parameter		Reach: Riffle	Reach: Pool
Rosgen Stream Type		C4/E4	
Drainage Area (mi^2)		0.3	
Reach Length (ft)		2748	
Dimension	Bankfull Area (ft^2)	4 – 9	5 – 9
	Bankfull Width (ft)	6 – 9	9 - 10
	Width/Depth Ratio (ft)	8	8 – 20
	Bankfull Mean Depth (ft)	0.7 - 1.0	0.5 - 1.1
	Bank Height Ratios	2.2 - 2.6	1.2 - 1.9
Pattern	Meander Length Ratio	N/A	N/A
	Radius of Curvature Ratio	N/A	N/A
	Meander Width Ratio	N/A	N/A
	Sinuosity	1.20	
Profile	Valley Slope (ft/ft)	0.0112	
	Channel Slope (ft/ft)	0.0093	

2.6.1 Stream Stability Assessment

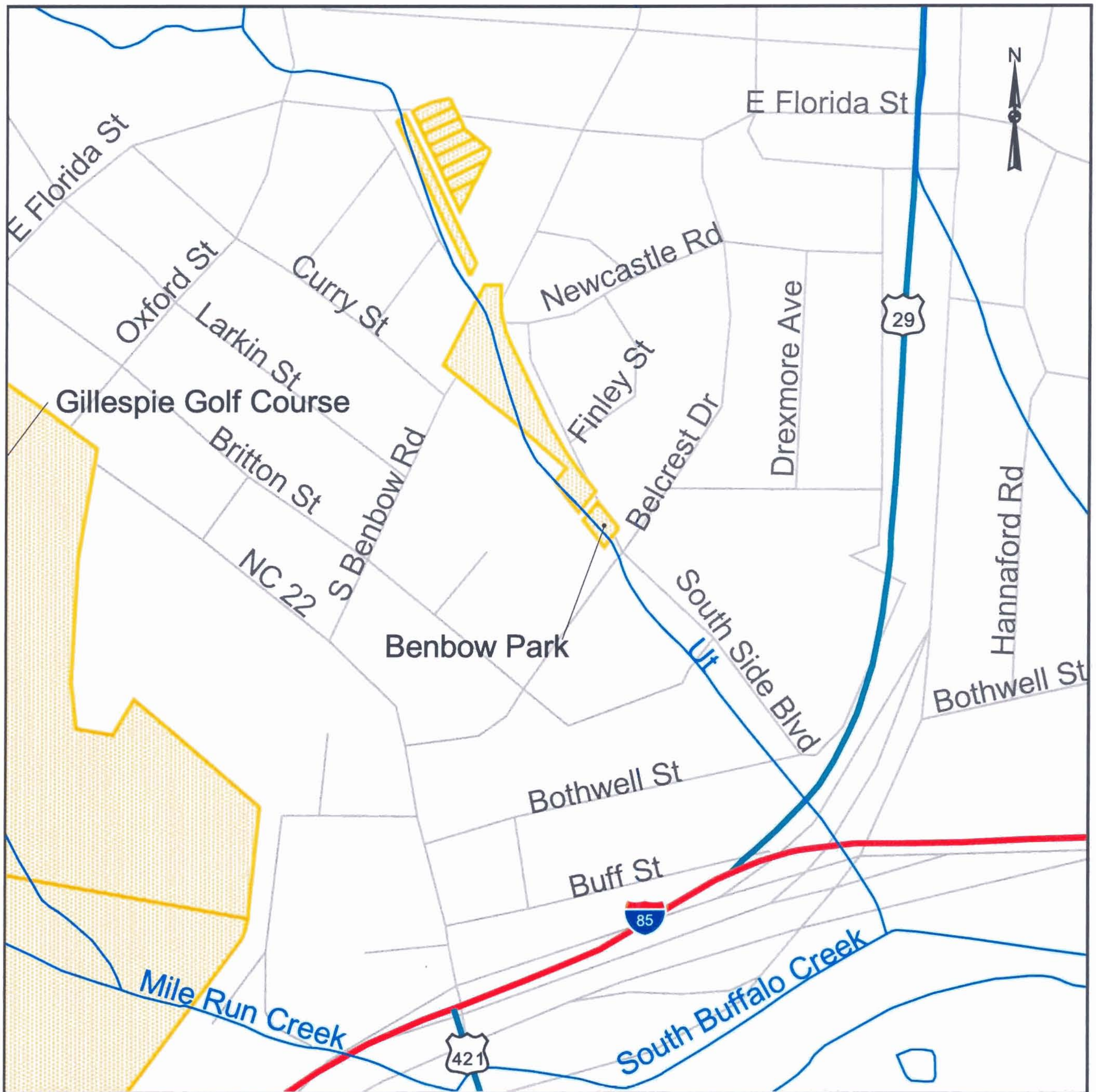
The unnamed tributary classifies as an incised E or C throughout most of the reach depending on the W/D ratio. However, the stream is much straighter than natural C or E channels. In addition, the bank height ratios in the upper sections are very high (over 2.0 in some sections). The existing profile and cross sections are shown in Appendix 1. Based on the high degree of incision and low sinuosity, this stream functions more like a G stream type than a C or E stream type. The moderate to high entrenchment ratios are most likely caused by mechanical bank sloping rather than natural floodplain creation (refer to cross sections).

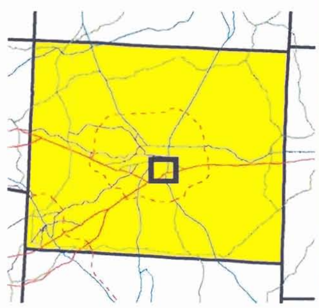
Similar to the other parks, woody vegetation is lacking in many areas along the channel. Where trees are present, they are directly along the streambanks. Woody species found along the bank include black willow, silky dogwood, elderberry, river birch, sycamore, black cherry, and tag alder. Additional woody species in the park are sweetgum, tulip poplar (*Liriodendron tulipifera*), white pine (*Pinus strobes*), maple, oak, weeping willow, crape myrtle, and pear. The shrubby and herbaceous vegetation includes blackberry, rush, and exotic species Japanese honeysuckle and rose.

2.6.2 <u>Constraints</u>

Constraints to achieving the highest level of stream restoration in Brown Bark Park include the following:

- There is a basketball court located about one-third of the way down the reach on the right side.
- There are a number of storm sewer outfalls located along the project.



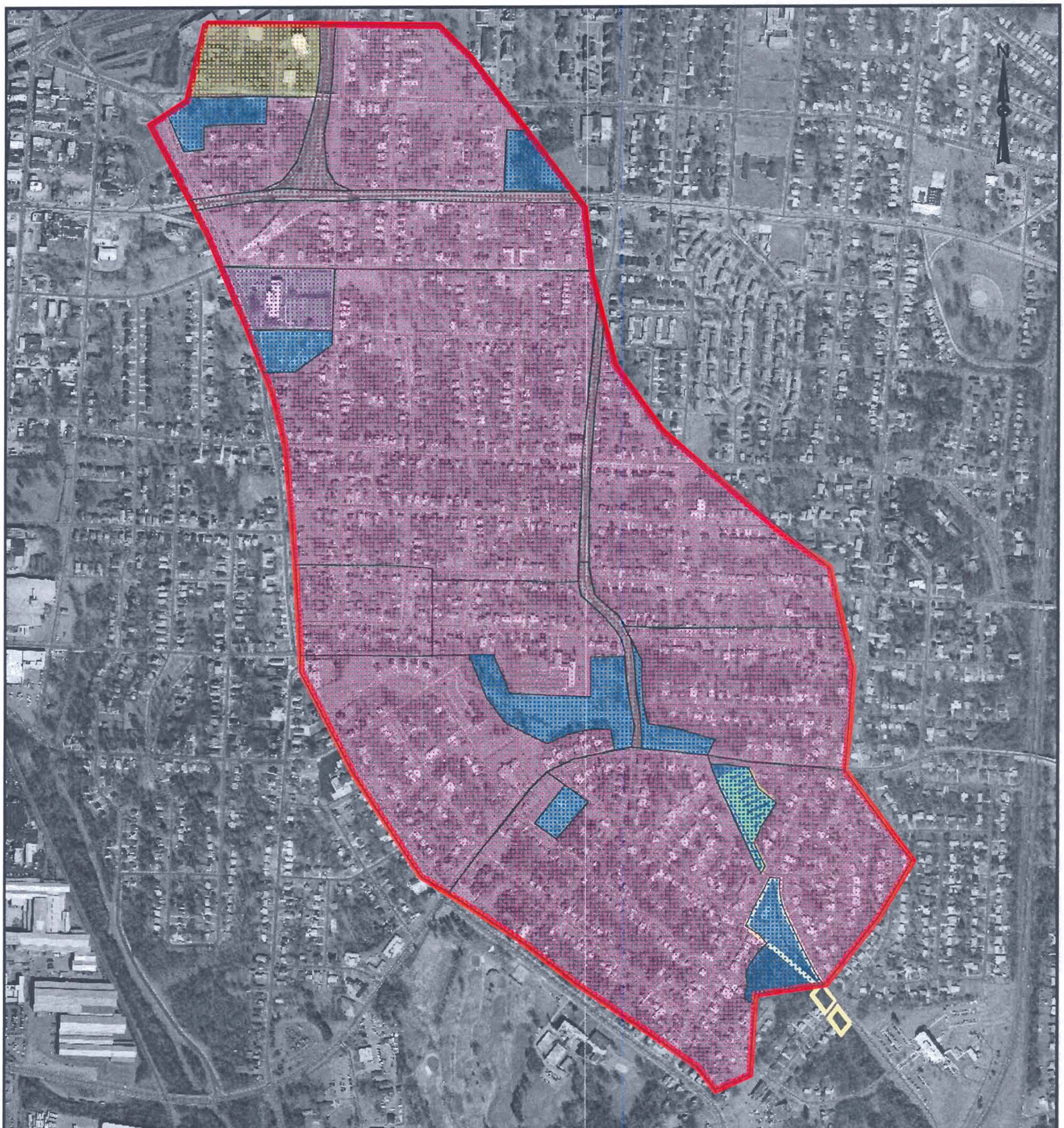


Guilford Co

North Carolina
Wetlands Restoration Program

Figure 2.1: Benbow Park Vicinity Map
Buffalo Creeks Stream Restoration Projects
Greensboro, NC
Guilford County

1000 0 1000 2000 Feet



LEGEND

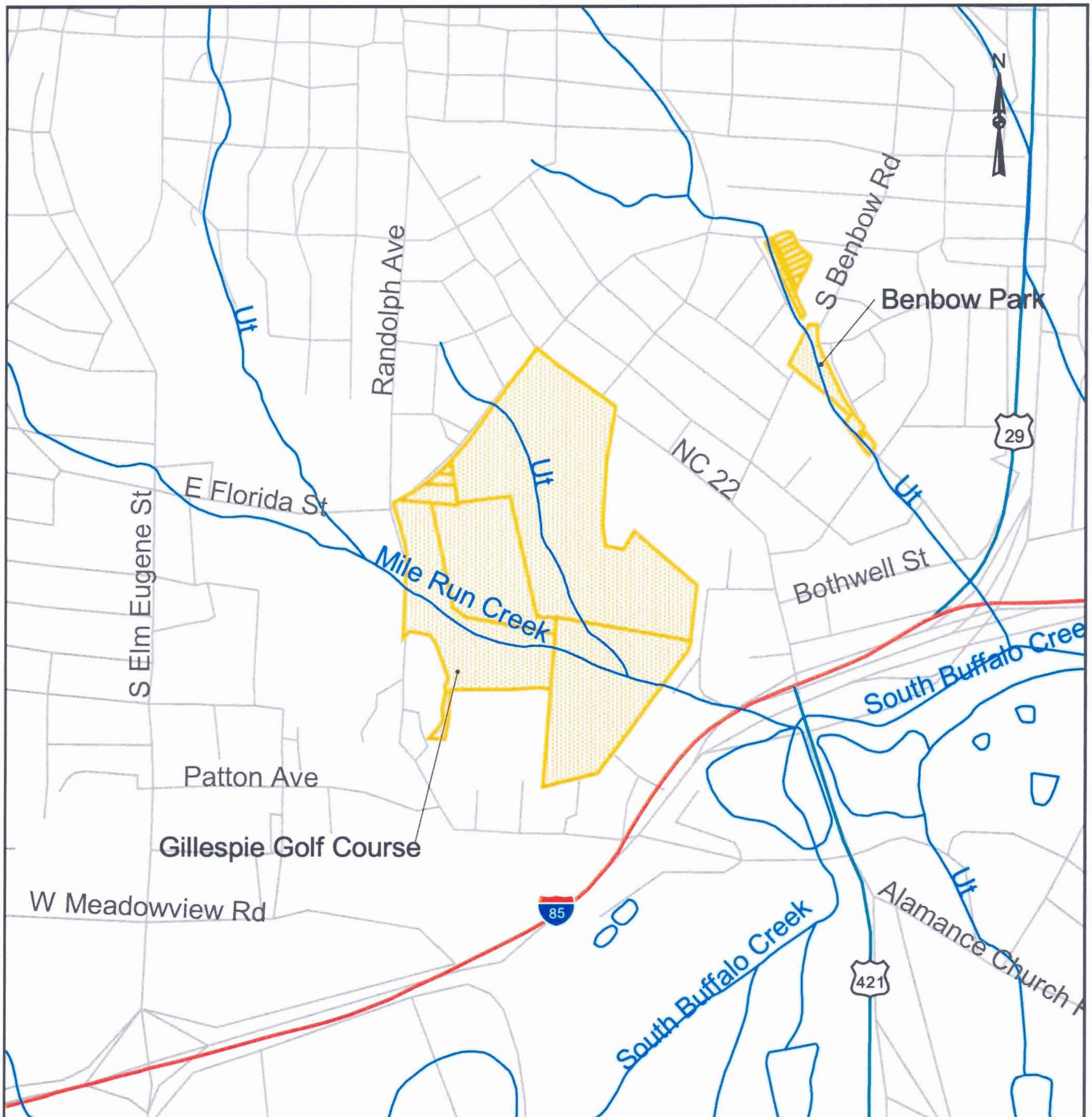
Benbow Watershed
Roads
Park Boundaries
BENBOW
CLINTON HILLS

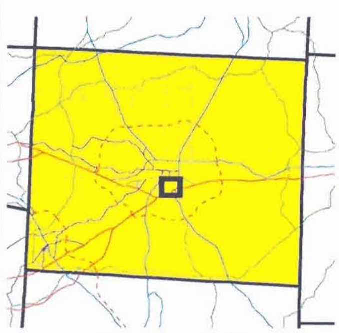
Land Cover
Open Space
Residential - <= 1/8 acre
Residential - 2 acre
Industrial
Paved Spaces

North Carolina
Wetlands Restoration Program

Figure 2.2: Benbow Park Watershed Map
Buffalo Creeks Stream Restoration Projects
Greensboro, NC
Guilford County

800 0 800 1600 Feet



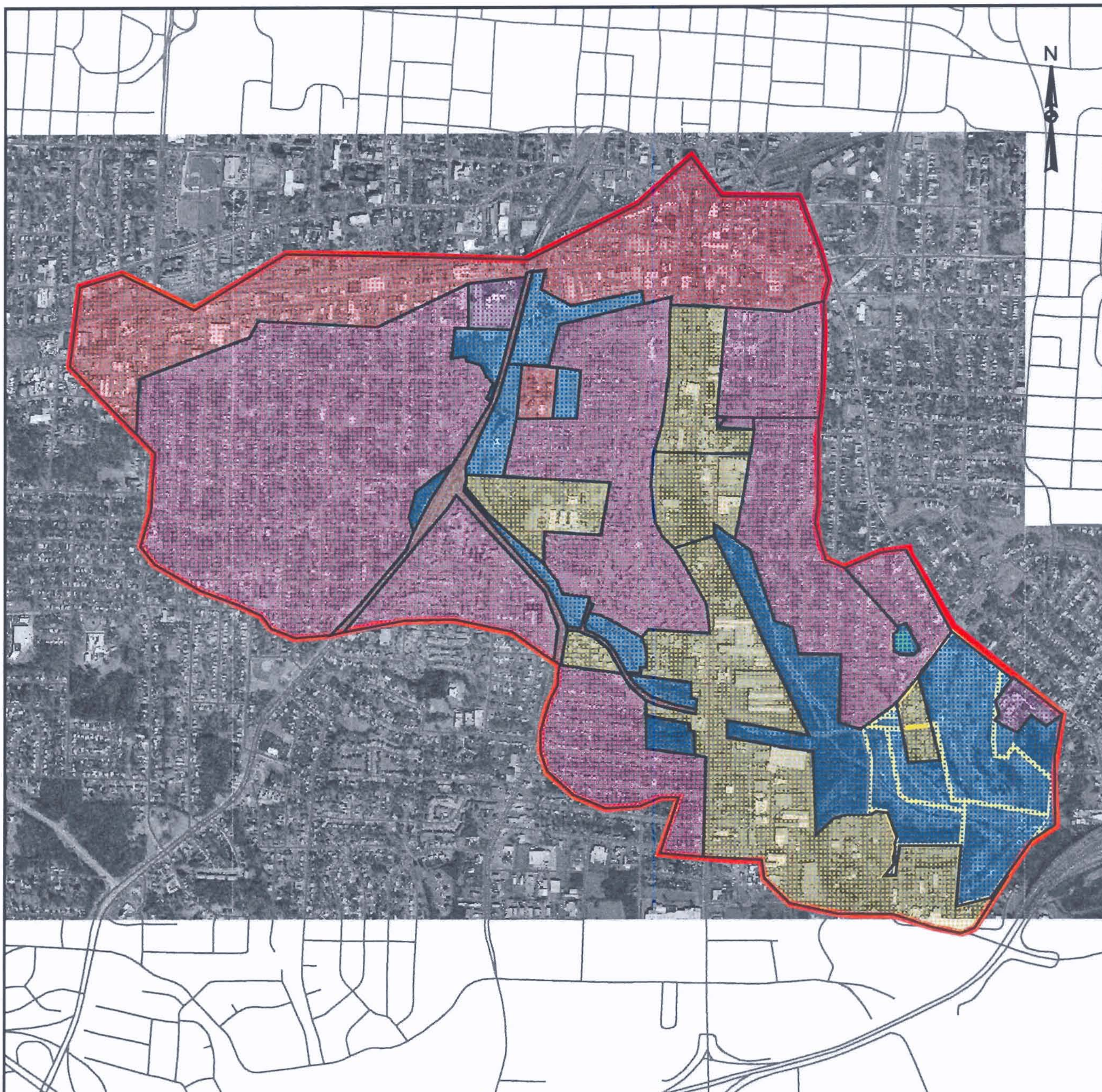


Guilford Co

North Carolina
Wetlands Restoration Program

Figure 2.3: Gillespie Golf Course Vicinity Map
Buffalo Creeks Stream Restoration Projects
Greensboro, NC
Guilford County

2000 0 2000 4000 Feet



LEGEND

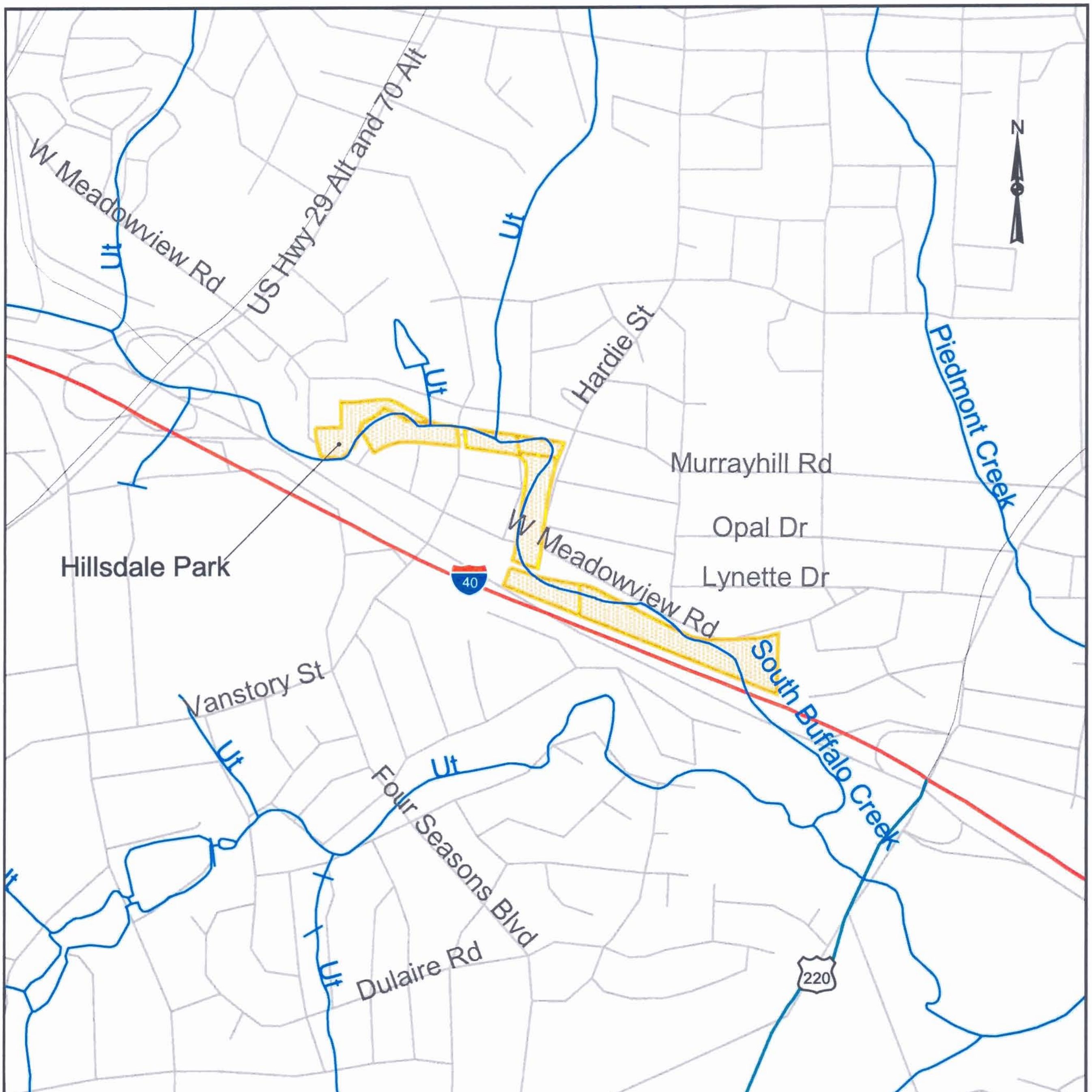
Gillespie Watershed
Roads
Park Boundaries
GILLESPIE GOLF COURSE
WARD ST

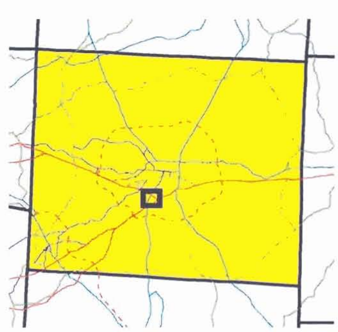
Land Cover
Open Space
Residential - <=1/8 acre
Residential - 2 acre
Commercial
Industrial
Paved Spaces

North Carolina
Wetlands Restoration Program

Figure 2.4: Gillespie Golf Course Watershed Map
Buffalo Creeks Stream Restoration Projects
Greensboro, NC
Guilford County

1000 0 1000 2000 3000 Feet

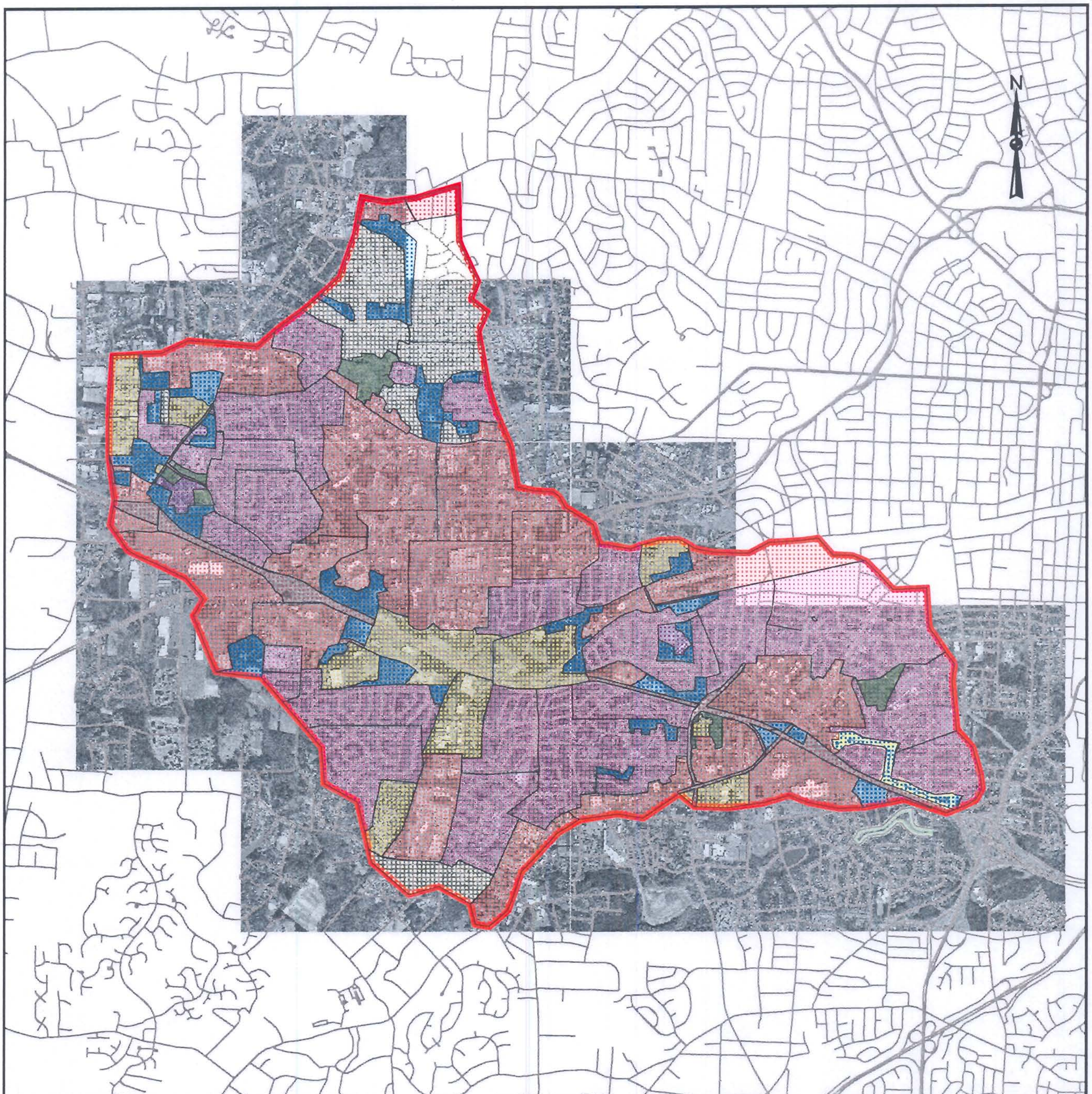




North Carolina
Wetlands Restoration Program

Figure 2.5: Hillsdale Park Vicinity Map
Buffalo Creeks Stream Restoration Projects
Greensboro, NC
Guilford County

2000 0 2000 4000 Feet



LEGEND

- Hillsdale Watershed
- Roads

Park Boundaries

- HILLSDALE
- ROLLING ROADS

Land Cover

- Forested
- Open Space
- Residential - <=1/8 acre
- Residential - 1/4 acre
- Residential - 2 acre
- Commercial
- Industrial
- Paved Spaces

North Carolina
Wetlands Restoration Program

Figure 2.6: Hillsdale Park Watershed Map
Buffalo Creeks Stream Restoration Projects
Greensboro, NC
Guilford County

3000 0 3000 6000 Feet

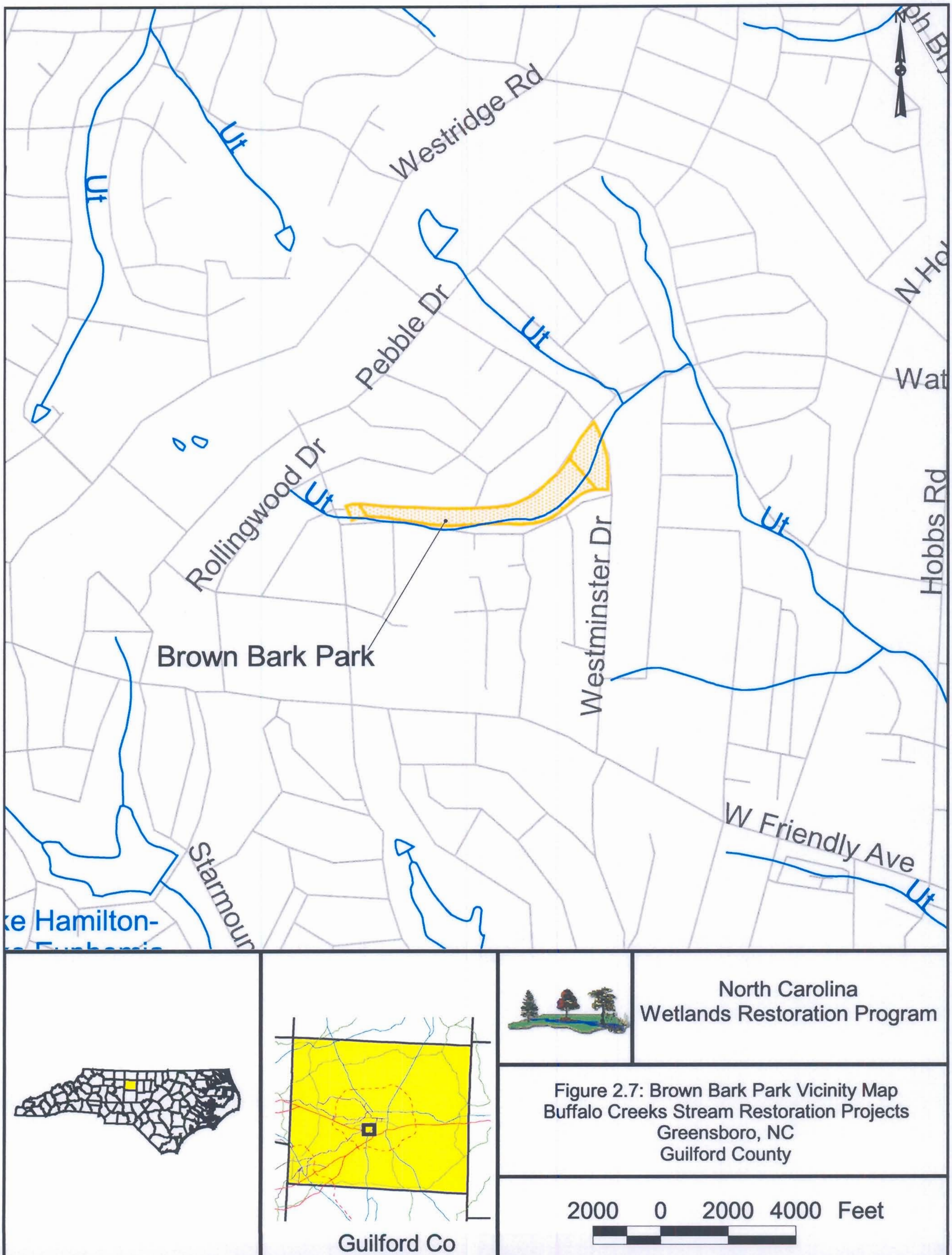


Figure 2.7: Brown Bark Park Vicinity Map
Buffalo Creeks Stream Restoration Projects
Greensboro, NC
Guilford County

LEGEND

- Brown Bark Watershed
- Roads
- Park Boundaries
  - BROWN BARK
  - CHATFIELD
  - FOREST HILL

Land Cover
- Forest
- Open Space
- Residential - 1/3 acre
- Residential - 1/4 acre

North Carolina
Wetlands Restoration Program

Figure 2.8: Brown Bark Park Watershed Map
Buffalo Creeks Stream Restoration Projects
Greensboro, NC
Guilford County

600 0 600 1200 Feet

3 Bankfull Stage Verification

3.1 Bankfull Stage and Discharge

Bankfull stage and its corresponding discharge are the primary variables used to develop a natural channel design. However, the correct identification of the bankfull stage in the field can be difficult and subjective (Williams, 1978; Knighton, 1984; and Johnson and Heil, 1996). Numerous definitions exist of bankfull stage and methods for its identification in the field (Wolman and Leopold, 1957; Nixon, 1959; Schumm, 1960; Kilpatrick and Barnes, 1964; and Williams, 1978). The identification of bankfull stage in the humid Southeast is especially difficult because of dense understory vegetation and a long history of channel modification and subsequent adjustment in channel morphology. It is generally accepted that bankfull stage corresponds with the discharge that fills a channel to the elevation of the active floodplain. The bankfull discharge is considered to be the channel forming agent that maintains channel dimension and transports the bulk of sediment over time. Field indicators include the back of point bars, significant breaks in slope, changes in vegetation, the highest scour line, or the top of the bank (Leopold, 1994). **The most consistent bankfull indicators for streams in the Piedmont of North Carolina are the highest scour line and the back of the point bar. The indicator is rarely the top of the bank or the lowest scour or bench.**

3.2 Bankfull Hydraulic Geometry Relationships (Regional Curves)

Hydraulic geometry relationships are often used to predict channel morphology features and their corresponding dimensions. The stream channel hydraulic geometry theory developed by Leopold and Maddock (1953) describes the interrelations between dependent variables such as width, depth, and area as functions of independent variables such as watershed area or discharge. These relationships can be developed at a single cross-section or across many stations along a reach (Merigliano, 1997). Hydraulic geometry relationships are empirically derived and can be developed for a specific river or watershed in the same physiographic region with similar rainfall/runoff relationships (FISRWG, 1998).

Bankfull hydraulic geometry relationships, also called regional curves, were first developed by Dunne and Leopold (1978) and related bankfull channel dimensions to drainage area. A primary purpose for developing regional curves is to aid in identifying bankfull stage and dimension in un-gaged watersheds and to help estimate the bankfull dimension and discharge for natural channel designs (Rosgen, 1994). Gage station analyses throughout the United States have shown that the bankfull discharge has an average return interval of 1.5 years or 66.7% annual exceedance probability (Dunne and Leopold, 1978; Leopold, 1994).

Regional curve equations developed from the North Carolina rural and urban Piedmont study are provided by Harman et al., (1999) and Doll et al., (in-press) and are shown in Table 3.1.

Table 3.1. Piedmont Rural and Urban Regional Curve Equations.

North Carolina Piedmont Rural Regional Curve Equations	
$Q_{bkf} = 89.04\ A_w^{0.72}$	R^2=0.95
$A_{bkf} = 21.43\ A_w^{0.72}$	R^2=0.91
$W_{bkf} = 13.69\ A_w^{0.38}$	R^2=0.92
$d_{bkf} = 1.57\ A_w^{0.30}$	R^2=0.88
North Carolina Piedmont Urban Regional Curve Equations	
$Q_{bkf} = 340.66\ A_w^{0.57}$	R^2=0.95
$A_{bkf} = 61.16\ A_w^{0.64}$	R^2=0.97
$W_{bkf} = 24.95\ A_w^{0.32}$	R^2=0.88
$d_{bkf} = 2.46\ A_w^{032}$	R^2=0.85

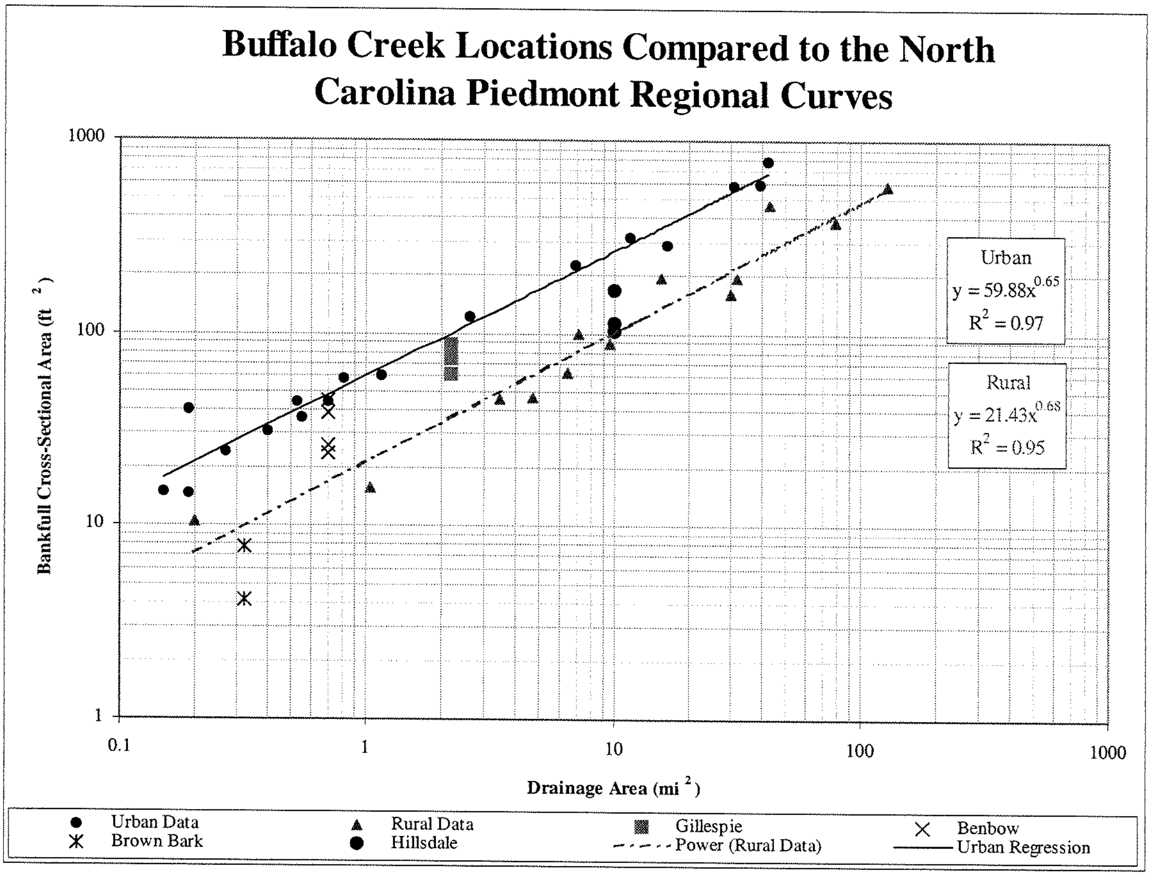
3.3 Bankfull Verification in the Buffalo Creek Watershed

The bankfull indicators for the Buffalo Creek Watershed included the back of a depositional bench and an upper scour line. These indicators are consistent with other Piedmont streams that are at a Stage IV/V in Simon's Channel Evolution Model. Data for all the project sites are shown on Figure 3.1.

It should be noted that the cross-sectional area of 5 ft^2 measured at Brown Bark Park was taken at a cross-section near the beginning of the channel, e.g. the section upstream of the channel was culverted. The difference in water surface and the bankfull stage was similar here to other cross sections; however, the cross sectional area was low.

Bankfull discharge was determined for each site using a combination of the regional curves and HEC-RAS. HEC-RAS was the primary tool used and the flow was cross referenced with the regional curve. Results from the HEC-RAS analysis are provided in a separate flood study report.

Figure 3.1. Rural and Urban Piedmont Regional Curves with Surveyed Bankfull Cross-Section Areas for Project Reaches. (Project data points were not used in determining the regression line.)



4 Reference Reach Analyses

The reference reach provides the basis for a natural channel design. A reference reach is a segment of river that has a stable dimension, pattern, and profile within an appropriate valley type. A reference reach is selected after the determination of the potential for restoration for the project reach and the selection of a design valley/stream type. The parameters measured at the reference reach are converted into dimensionless ratios for comparison and are used across stream reaches with varying drainage areas.

The selection of reference reach information for this project included reference reach surveys, evaluation of a reference reach database, and professional judgment based on "lessons learned" from the evaluation of past projects. Two Rosgen stream types were selected for the project and are shown in Table 4.1. These stream types were selected based on the valley type, available belt width, constraints, and channel incision.

Table 4.1 Project Design Stream Types.

Sub-Project	**Reference Stream Type**	**Rationale**
Benbow	E5	Sufficient belt width to re-create pattern.
Gillespie	E5	Based on dimension only. Lateral constraints imposed by the golf course prevent pattern.
Hillsdale	B4c	Lateral constraints imposed by roads and park.
Brown Bark Reach 1	E5	Sufficient belt width to re-create pattern.
Brown Bark Reach 2	B5c/E5	Confined valley type except for two short sub-reaches.

The streams shown in Table 4.2 were taken from a reference reach database and represent stable urban Piedmont streams. The tributary to Lake Jeanette was surveyed by NC State University and is located near Greensboro, NC. Both reaches of McClintock Creek were surveyed by Buck Engineering and are located in Charlotte, NC (see Appendix 2 for location maps). These streams were overlaid with the North Carolina Piedmont Regional Curve to show that they are part of the same hydrophysiographic region (see Figure 4.1); however, some are closer to the urban curve and some are closer to the rural curve. This matches our study reaches fairly well in that Gillespie and Benbow are closer to the urban curve and Hillsdale and Brown Bark are closer to the rural curve.

Table 4.2 Summary of Stream Type E Reference Reach Data.

Parameters		Reference	Reference	Reference
Reach Name		UT to Lake Jeanette	McClintock 1	McClintock 2
Rosgen Stream Type		E5	E5	E5
Drainage Area (sq mi)		0.2	0.3	0.2
Dimension	Bankfull Width (ft)	12.8	9.1	10.6
	Bankfull Mean Depth (ft)	1.6	1.6	2.0
	Width/Depth Ratio (ft)	8.0	6.0	5.0
	Bankfull Area (sq ft)	20.5	14.2	21.8
Pattern	Meander Length (ft)	35 - 69	47	60
	Meander Length Ratio	2.7 – 5.4	5.2	5.7
	Radius of Curvature (ft)	18 - 23	18 - 25	27 - 30
	Radius of Curvature Ratio	1.4 – 1.8	2.0 – 2.7	2.6 -2.8
	Meander Belt Width (ft)	44 - 45	32 - 45	34
	Meander Width Ratio	3.4 – 3.5	3.5 – 5.0	3.2
	Pool Depth (ft)	3.2	2.8	3.2 – 3.4
	Pool Depth Ratio	2.0	1.8	1.6 – 1.7
	Pool Width (ft)	20.5	13.9	11.4 – 12.5
	Pool Width Ratio	1.6	1.5	1.1 – 1.2
	Pool Spacing (ft)	18 – 35	---	39 - 51
	Pool Spacing Ratio	1.4 – 2.7	---	3.7 – 4.8
	Sinuosity	---	1.3	2.4
Profile	Valley Slope (ft/ft)	---	0.008	0.019
	Channel Slope (ft/ft)	0.0033	0.006	0.008
	Riffle Slope (ft/ft)	0.0066-0.011		
	Riffle Slope Ratio	0.2-3.4		
	Pool Slope (ft/ft)	---	---	---
	Pool Slope Ratio	0.0	---	---
Bed Material	D16	---	---	---
	D35	0.13	0.3	0.19
	D50	0.50	0.4	0.28
	D84	3.5	10	2.5
	D95	7.8	36	11.3

Figure 4.1. Rural and Urban Piedmont Regional Curves with Surveyed Bankfull Cross-Section Areas for Project Reference Reaches. (Project data points were not used in determining the regression line.)

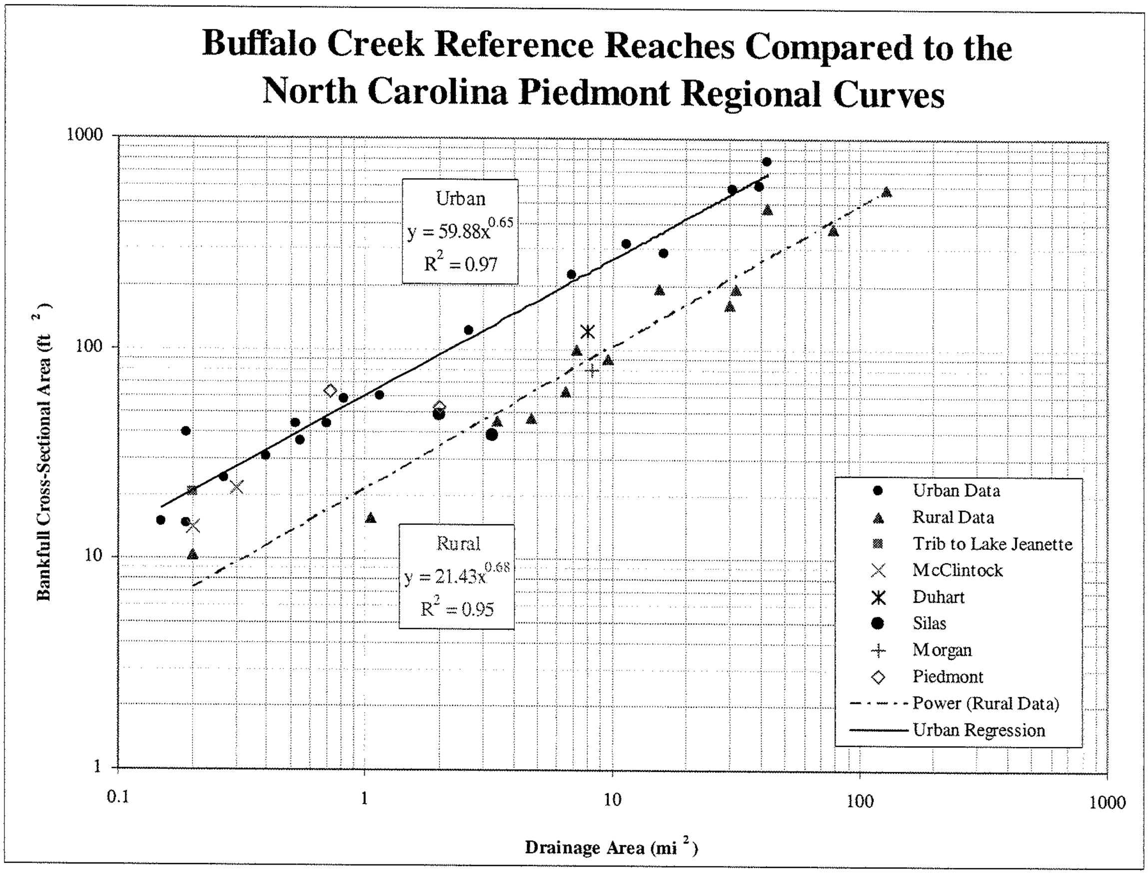


Table 4.3 shows the reference reach values for the B stream types. Location maps are included in Appendix 2. DuHart Creek was surveyed by Buck Engineering and is located in Cramerton, NC. Silas Creek was surveyed by the Natural Resources Conservation Service and is located in Winston-Salem, NC. Morgan Creek was surveyed by NC State University and is located near Chapel Hill, NC. Piedmont Creek was surveyed by Buck Engineering and is located in Greensboro, NC near the project reaches. It is included in the B stream type reference reach table because it has low sinuosity and is more similar to a Bc stream than an E stream. It serves as the reference reach for Gillespie Golf Course. Again, these streams were overlaid with the regional curve to show that they are representative of the North Carolina Piedmont and are similar to the project streams (see Figure 4.1).

Table 4.3 Summary of Stream Type B Reference Reach Data.

Parameters		Reference	Reference	Reference	Reference
Reach Name		DuHart	Silas	Morgan	Piedmont
Rosgen Stream Type		B4c	B4c	B4c	E3
Drainage Area (sq mi)		8.0	3.3	8.3	0.7
Dimension / Pattern	Bankfull Width (ft)	46.0	25.6	33.5	22.2
	Bankfull Mean Depth (ft)	2.6	1.7	2.4	2.4
	Width/Depth Ratio (ft)	17.0	15.1	14.0	9.3
	Bankfull Area (sq ft)	122.0	43.5	80.0	53.0
	Pool Depth (ft)	6.1	1.4	---	3.5
	Pool Depth Ratio	2.3	2.9	1.7	1.5
	Pool Width (ft)	35.2	23.3	---	26.8
	Pool Width Ratio	0.8	0.9 – 1.1	0.8 – 1.1	1.1 – 1.2
	Pool Spacing (ft)	140	61	146	64
	Pool Spacing Ratio	3.0	2.4	4.4	2.9
	Sinuosity	1.1	1.1	1.1	1.1
Profile	Valley Slope (ft/ft)	0.012	0.009	0.008	0.0134
	Channel Slope (ft/ft)	0.011	0.008	0.007	0.0124
	Pool Slope (ft/ft)	0.0	0.0	0.0	0.0
	Pool Slope Ratio	0.0	0.0	0.0	0.0
Bed Material	D16	---	---	---	0.125
	D35	0.75	0.83	1.2	22.6
	D50	64	19.1	3.0	64
	D84	Bedrock	157.5	77	180
	D95	Bedrock	300.2	800	2000

The reference reaches compare fairly well in terms of ratios; however, some contain values that are inappropriate for design. This is due to the fact that the reference reaches have floodplains with mature bottomland forest, while the design reaches will have a newly planted floodplain. For example, the radius of curvature ratios for the Type E reference reaches are sometimes less than 2. The design reaches should have a larger ratio because the banks will not initially have the necessary vegetation to prevent bank erosion.

The final design ratios are shown in Chapter 5 and are based on bracketing the values from the reference reaches and applying professional judgment to ensure appropriate values are used.

5 Natural Channel Design

5.1 Design Summary

For each stream reach in the Buffalo Creek Watershed Project, the proposed natural channel design is the highest level of restoration feasible given the valley type, stream type, land use and urban constraints. For the incised reaches, selection of restoration type follows Rosgen's priority restoration approaches for incised streams (Rosgen, 1997) with the overriding objective of re-establishing contact between the channel and a floodplain. For the purposes of this discussion the four Rosgen restoration approaches have been defined below in order of decreasing priority:

- <u>Priority 1</u> – Re-establish the channel on a previous floodplain (e.g., raise channel elevation); meander new channel to achieve dimension, pattern, and profile characteristic of a stable stream for the particular valley type; fill or isolate existing incised channel.
- <u>Priority 2</u> – Establish a new floodplain for the existing bankfull elevation (e.g., excavate a new floodplain); meander channel to achieve dimension, pattern, and profile characteristic of a stable stream for the particular valley type; fill or isolate existing incised channel.
- <u>Priority 3</u> – Establish a new floodplain at the existing bankfull elevation (e.g., using bankfull benches); leave existing channel in place. Use in-stream structures to dissipate energy through a step/pool channel type.
- <u>Priority 4</u> – Stabilize the channel in place using in-stream structures and bioengineering to decrease streambed and streambank erosion.

5.2 Benbow Park Natural Channel Design

Refer to the plan sheets for the detailed design.

The proposed natural channel design for Benbow Park Reach 1 is based on a combination of a Rosgen Priority 2 and Priority 3 approach. A new meandering E5 channel will be constructed from Station 1+82 to 5+89 at a lower elevation than the existing terrace. A floodplain will be excavated along the left side of the channel. The new channel will cross a sewer line; however, the existing depth of the sewer is lower than the proposed bed elevation. Cross vanes, J-hook vanes and root wads will be used to stabilize the new channel and areas of the existing channel that will be left in place. The streambank, bankfull bench, and terrace scarp will be seeded with millet or rye, depending on the season for temporary erosion control. The streambank and terrace scarp will be covered with erosion control matting. The rest of Reach 1 will be left at its existing location because of the presence of utility lines, adjoining property lines, and high fill slopes that would result in excessive grading if the channel were moved from its current location.

The proposed natural channel design for Reach 2 of Benbow Park is based on a Priority 1 restoration approach. A new meandering channel at the existing flood plain will replace the existing straight channel. The channel will be removed from its current location at design station 11+61 and the new channel bed will be raised approximately 2 feet so that the channel will have better access to its current floodplain with reduced bank heights. A setback berm will be constructed at the edge of the floodplain to protect a garage. A detailed flood study is provided in a separate report.

The new channel will cross a sewer line in Reach 2 as well as Reach 1. If required by the City, we will design protection devices, such as piers, as specified by the City. At the downstream end of the project, a step/pool structure will be constructed to match the design profile with the existing profile. The step/pool design has been modified from earlier designs to minimize the drop between steps (</= 0.5ft) and prevent piping. See the design drawings for more detail. Additionally, the City will relocate park structures that are located in the proposed channel or bankfull bench.

Table 5.1. Natural Channel Design Parameters for Benbow Park.

Parameters		**Existing Reach 1**	**Design Reach 1**	**Existing Reach 2**	**Design Reach 2**
Rosgen Stream Type		B5c/E5	E5	E5	E5
Drainage Area (sq mi)		0.7	0.7	0.7	0.7
Reach Length (ft)		776	882	976	1,178
Dimension	Bankfull Width (ft)	14-15	16	18-22	21
	Bankfull Mean Depth (ft)	1.6-1.9	1.6	2.0-2.2	2.1
	Width/Depth Ratio (ft)	7.1-9.7	10.0	8.3-11.1	10.0
	Bankfull Area (sq ft)	24-26	25	39-45	45
	Bankfull Mean Velocity (ft/sec)	4.3	4.3	2.9	2.7
	Bankfull Discharge (cfs)	107	107	120	120
	Bankfull Max Depth (ft)	2.9	2.3	3.5	2.8
	Width of Floodprone Area (ft)	34	80	87	140
	Entrenchment Ratio	3.0	5.0	4.2	6.7
	Max Pool Depth (ft)	3.2	3.2 – 4.8	4.3	4.2 – 6.3
	Ratio of Pool Depth to Bankfull Depth	1.8-2.0	2 - 3	2.0-2.2	2 – 3
	Pool Width (ft)	19-22	19	17-31	25
	Ratio of Pool Width to Bankfull Width	1.3-1.5	1.2	0.9-1.6	1.2
	Pool to Pool Spacing (ft)	--	64 - 96	--	84 - 126
	Ratio of Pool to Pool Spacing to Bankfull Width	--	4 - 6	--	4 - 6
	Bank Height Ratio	1.7-1.9	1.0	2.0-9.2	1.0

Pattern	Meander Length (ft)	N/A	128-192	N/A	168-252
	Meander Length Ratio	N/A	8-12	N/A	8-12
	Radius of Curvature (ft)	N/A	32-48	N/A	42-63
	Radius of Curvature Ratio	N/A	2-3	N/A	2-3
	Meander Belt Width (ft)	N/A	48-64	N/A	63-84
	Meander Width Ratio	N/A	3-4	N/A	3-4
	Sinuosity	1.04	1.1	1.07	1.3
Profile	Valley Slope (ft/ft)	0.0053	0.0053	0.0060	0.0060
	WS Slope (ft/ft)	0.0051	0.0048	0.0056	0.0046
	Pool Slope (ft/ft)	0.0033	0	0.0020	0
	Ratio of pool slope to WS slope	0.6	0.1	0.4	0.1
	Riffle Slope	0.01-0.04	0.0072	0.01-0.02	0.0069
	Riffle Slope Ratio	2-7.8	1.5	1.8-3.6	1.5

5.2.1 Planting Design

A combination of native herbaceous and woody vegetation will be established in the riparian buffer along the Benbow Park project reaches. The buffer width will range between 15 and 25 feet depending on space restrictions due to park boundaries. This buffer width will be in accordance with the City of Greensboro's stream buffer recommendations (1999) which include a variance stating that a stream buffer shall not exceed 25% of the available land space on publicly owned property with a "cross sectional land space" less then 400 feet. In addition, areas around utilities in the buffer zone will be left free of woody vegetation to a minimum length of 10 feet and a maximum length of 30 feet. These will also act as public access areas along with a path (10-15 feet wide) leading to and from the footbridge. All access areas may need to be periodically maintained by the City of Greensboro (Greensboro 1999).

Permanent seeding may include, but not be limited to, switch grass (*Panicum virgatum*), soft rush (*Juncus effusus*), fox sedge (*Carex vulpinoides*), rice cut-grass (*Leersia oryzoides*) and virginia wildrye (*Elymus virginicus*).

Trees and shrubs that may be used include, but are not limited to, river birch (*Betula nigra*), green ash (*Fraxinus pennsylvanica*), persimmon (*Diospyros virginiana*), sycamore (*Platanus occidentalis),* willow oak (*Quercus phellos*), blackgum (*Nyssa sylvatica*), witch-hazel (*Hamamelis virginiana*), and tag alder (*Alnus serrulata*). Species used for seeding and woody vegetation will depend upon availability and cost at the time of planting. Temporary vegetation for erosion control will include annual rye (cool season) or millet (warm season) depending on the construction schedule. Planting details are provided in the plan sheets.

In addition to the above plantings, live stakes will be installed between the toe of the streambank and bankfull to improve bank stability. Species to be used may include black willow (*Salix nigra*), silky willow (*Salix sericea*), silky dogwood (*Cornus ammomum*), and elderberry (*Sambucus Canadensis*). Live staking material should be harvested and installed while plant material is dormant.

5.3 Gillespie Golf Course Natural Channel Design

Refer to the plan sheets for the detailed design.

The proposed natural channel design for Mile Run Creek includes bankfull benches and in-stream structures. In terms of dimension, the stream type will remain an E5, e.g. W/D less than 12 and an entrenchment ratio greater than 2.2. However, given the golf course constraints, pattern is not proposed. Therefore the design is a straight E that will function more like a Bc (energy is dissipated through step/pool structures rather than meanders).

A 10 to 20 foot wide bankfull bench will be constructed on both sides of the existing channel, depending on space constraints. The streambank and terrace scarp will be covered with erosion control matting. In-stream structures including cross vanes, double wing deflectors, and root wads will be used to repair eroding streambanks, narrow the channel in areas where the stream has become overly wide, and improve the channel profile (step/pool sequence). Cross vanes will be installed upstream and downstream of the golf cart bridges to prevent bank erosion near the bridges. There will be steps leading up from the cross vanes to the top of the bank so that golfers may access the stream. The stormwater outfalls will be stabilized using the step / pool channel detail shown on the plan sheets. Additionally, reaches 2 and 3 will be stabilized by excavating bankfull benches and installing cross vanes.

5.3.1 Planting Design

Two types of riparian areas, managed and forested, will be planted in the golf course depending on location. A low growing managed buffer area will be used in areas where golfers are required to play across the stream or tributary in order to complete a hole. The managed riparian area will range between 15 and 25 feet on the main channel depending on limits set by the fairway and cart paths. A forested buffer will be planted in all other areas along the main channel. Forested and managed buffers will also be established on the tributaries throughout the golf course. Forested buffer widths along tributaries will be approximately 15 feet with an additional 10 feet of managed buffer where space is available. In areas where low growing vegetation is necessary, a managed buffer will be planted to a width of approximately 25 feet.

The permanent seeding mix for the managed buffer may include switch grass, soft rush, fox sedge, rice cut-grass, virginia wildrye, swamp milkweed (*Asclepias incarnata,*) and joe-pye weed (*Eupatorium fistulosum*). Live stakes will be installed between the toe of the streambank and bankfull on the main channel. Species to be used include silky willow and silky dogwood.

Permanent seeding in the forested buffers along the main channel and tributaries may include switch grass, soft rush, fox sedge, rice cut-grass, and virginia wildrye. Trees and shrubs that may be used include, but are not limited to, river birch, green ash, persimmon, sycamore, willow oak, blackgum, witch-hazel, and tag alder. Live staking material may include black willow, silky willow, silky dogwood, and elderberry.

Table 5.2. Natural channel design parameters for Mile Run Creek at the Gillespie Golf Course.

Parameters		Existing	Design Reach 1
Rosgen Stream Type		B5c/E5	E5
Drainage Area (sq mi)		0.7	0.7
Reach Length (ft)		1,867	1,867
Dimension \ Pattern	Bankfull Width (ft)	29-32	27
	Bankfull Mean Depth (ft)	1.9-3.1	2.7
	Width/Depth Ratio (ft)	9.5-16.6	10
	Bankfull Area (sq ft)	62-88	74
	Bankfull Mean Velocity (ft/sec)	4.7	4.7
	Bankfull Discharge (cfs)	350	350
	Bankfull Max Depth (ft)	4.0-5.1	3.4
	Width of Floodprone Area (ft)	85-107	85-107
	Entrenchment Ratio	3.0-3.6	3.0-3.6
	Max Pool Depth (ft)	3.8-5.4	4.1-5.4
	Ratio of Pool Depth to Bankfull Depth	1.4-1.6	1.5–2.0
	Pool Width (ft)	29-44	27
	Ratio of Pool Width to Bankfull Width	1.0-1.5	1.0
	Pool to Pool Spacing (ft)	--	54-108
	Ratio of Pool to Pool Spacing to Bankfull Width	--	2-4
	Bank Height Ratio	1.2-1.3	1.0
	Sinuosity	1.1	1.1
Profile	Valley Slope (ft/ft)	0.0025	0.0025
	WS Slope (ft/ft)	0.0028	0.0028
	Pool Slope (ft/ft)	0.0018	0.00028
	Ratio of pool slope to WS slope	0.6	0.1

Species used for seeding and woody vegetation will depend upon availability and cost at the time of planting. Temporary vegetation for erosion control will include annual rye (cool season) or millet (warm season) depending on the construction schedule. Planting details are provided on the plan sheets.

5.4 Hillsdale Park Natural Channel Design

Refer to the plan sheets for the detailed design.

The proposed natural channel design for Reaches 1 and 2 of South Buffalo Creek at Hillsdale Park is based on a Priority 3 restoration approach. The design parameters are shown in Table 5.3.

Table 5.3. Natural channel design parameters for Hillsdale Park.

Parameters		Existing Reach 1	Design Reach 1	Existing Reach 2	Design Reach 2
Rosgen Stream Type		E4/B4c	E4/B4c	E4/B4c/F4	E4/B4c
Drainage Area (sq mi)		10.0	10.0	10.0	10.0
Reach Length (ft)		3,037	3,037	2,265	2,265
Dimension	Bankfull Width (ft)	36-44	36-44	66	66
	Bankfull Mean Depth (ft)	2.6-2.9	2.6-2.9	2.5	2.5
	Width/Depth Ratio (ft)	12.2-17.3	12.2-17.3	26.4	26.4
	Bankfull Area (sq ft)	103-113	103-113	166	166
	Bankfull Mean Velocity (ft/sec)	8.3	8.3	5.4	5.4
	Bankfull Discharge (cfs)	900	900	900	900
	Bankfull Max Depth (ft)	3.7-4.0	3.7-4.0	3.6	3.6
	Width of Floodprone Area (ft)	65-84	74	76	152
	Entrenchment Ratio	1.5-2.4	2.3	1.1	2.3
	Max Pool Depth (ft)	5.3-5.8	4.2-8.4	6.5	4.2-8.4
	Ratio of Pool Depth to Bankfull Depth	1.3-1.5	1.5-3.0	1.4	1.5-3.0
	Pool Width (ft)	32-37	40	41	40
	Ratio of Pool Width to Bankfull Width	0.8-0.9	1.0	0.6	1.0
	Pool to Pool Spacing (ft)	--	76-152	--	76-152
	Ratio of Pool to Pool Spacing to Bankfull Width	--	2-4	--	2-4
	Bank Height Ratio	1.8-2.1	1.0	1.1-2.1	1.0
	Sinuosity	1.1	1.1	1.1	1.1
Profile	Valley Slope (ft/ft)	0.0018	0.0018	0.0039	0.0039
	WS Slope (ft/ft)	0.0016	0.0016	0.0035	0.0035
	Pool Slope (ft/ft)	0.0025	0.0025	0.0044	0.0044
	Ratio of pool slope to WS slope	1.6	0.1	1.3	0.1

A 10 to 20 foot wide bankfull bench will be constructed intermittently along both sides of the channel on Reach 1, depending on space constraints. A 10-foot wide bankfull bench will be constructed on the left bank of Reach 2. The streambank, bankfull bench, and terrace scarp will be seeded with millet or rye to provide temporary erosion control. The streambank and terrace scarp will be covered with erosion control matting.

Cross vanes will be used throughout the reach to provide grade control, provide bank protection, narrow the low flow channel and improve the riffle/pool sequence. J-hooks and root wads will divert velocity vectors in the channel away from the banks. Double wing deflectors will be used to narrow the low flow channel and provide some bank protection. The stormwater outfalls will be stabilized by mimicking a step / pool channel as shown in the plan sheets.

5.4.1 <u>Planting Design</u>

Along the Hillsdale Park reaches, the buffer width will range between 15 and 25 feet depending on the park boundaries. This buffer width will be in accordance with the City of Greensboro's stream buffer recommendations (1999) which include a variance stating that a stream buffer shall not exceed 25% of the available space on publicly owned property with a "cross sectional land space" less then 400 feet. In addition, 10 to 30 feet around utilities in the buffer zone and 30 feet surrounding any playground equipment will be left free of woody vegetation. These will act as public access areas along with a path (10-15 feet wide) leading to and from the footbridge and may be periodically maintained by the City of Greensboro (Greensboro 1999).

Permanent seeding may include, but not be limited to, switch grass, soft rush, fox sedge, rice cut-grass, and virginia wildrye. Trees and shrubs that may be used include, but are not limited to, river birch, green ash, persimmon, sycamore, willow oak, blackgum, witch-hazel, and tag alder. Live staking species consist of black willow, silky willow, silky dogwood, and elderberry. Species used for seeding and woody vegetation will depend upon availability and cost at the time of planting. Temporary vegetation for erosion control will include annual rye (cool season) or millet (warm season) depending on the construction schedule. Planting details are provided in the plan sheets.

5.5 Brown Bark Park Natural Channel Design

Refer to the plan sheets for the detailed design.

The Brown Bark Park natural channel design includes a combination of bankfull benches, full floodplain excavation, bank stabilization and re-development of meanders. The design summary values are shown in Table 5.4. The bankfull benches will be installed from station 0+00 to 6+00. Cross vanes, root wads and vegetation will be used to stabilize the streambanks. The stream type will not change from a straight E; however, the bank height ratio will be reduced to 1.0. A new floodplain will be excavated from 6+00 to 10+00 and a meandering E channel will be constructed. In-stream structures will be used to stabilize the newly constructed channel. The design parameters are shown in Table 5.4.

Table 5.4. Natural Channel Design Parameters for Brown Bark Park.

	Parameters	**Existing**	**Design**
	Rosgen Stream Type	C4/E4	E4
	Drainage Area (sq mi)	0.3	
	Reach Length (ft)	2,748	2,872
Dimension	Bankfull Width (ft)	6 -9	13
	Bankfull Mean Depth (ft)	0.7 – 1.0	1.1
	Width/Depth Ratio (ft)	8	10
	Bankfull Area (sq ft)	4 – 9	12
	Bankfull Mean Velocity (ft/sec)	5.7	3.3
	Bankfull Discharge (cfs)	40	40
	Bankfull Max Depth (ft)	1.2	1.7
	Width of Floodprone Area (ft)	50	50
	Entrenchment Ratio	5.6	3.9
	Max Pool Depth (ft)	2.0	2.3
	Ratio of Pool Depth to Bankfull Depth	2.0	2.1
	Pool Width (ft)	9 – 10	15
	Ratio of Pool Width to Bankfull Width	1 – 1.1	1.2
	Pool to Pool Spacing (ft)	N/A	50 – 75
	Ratio of Pool to Pool Spacing to Bankfull Width	N/A	3.8 – 5.8
	Bank Height Ratio	1.2 – 2.6	1.0
Pattern	Meander Length (ft)	N/A	78 – 117
	Meander Length Ratio	N/A	6 – 9
	Radius of Curvature (ft)	N/A	26 – 39
	Radius of Curvature Ratio	N/A	2 – 3
	Meander Belt Width (ft)	N/A	39 – 52
	Meander Width Ratio	N/A	3 – 4
	Sinuosity	1.1 – 1.2	1.2 – 1.4
Profile	Valley Slope (ft/ft)	0.0112	0.0112
	WS Slope (ft/ft)	0.0093	0.0067
	Pool Slope (ft/ft)	0.00	0.00
	Ratio of pool slope to WS slope	0.00	0.00
	Riffle Slope	0.015	0.007 – 0.01
	Riffle Slope Ratio	1.7	1.1 – 1.5

This section is not incised, so bankfull benches and a lower floodplain are not proposed. The valley width narrows again at station 10+00 and the design changes back to intermittent bankfull benches and stabilization using vegetation through station 20+00. At this point, the valley widens again, and a new meandering channel is proposed through station 27+00. Essentially, pattern will be restored to an existing channelized E stream type. This will increase stream length, decrease slope, and increase bedform diversity through a stable riffle-pool sequence. Again, in-stream structures and vegetation will be used to stabilize the newly constructed channel.

5.5.1 Planting Design

Buffer widths in Brown Bark Park will be approximately 25 feet for the majority of the reach. The exception is along the right upstream bank, which is confined by Brown Bark Drive. In this section, the riparian buffer will only be about 15 feet wide. This buffer width will be in accordance with the City of Greensboro's stream buffer recommendations (1999) which include a variance stating that a the stream buffer shall not exceed 25% of the available land space on publicly owned land with a "cross sectional land space" less then 400 feet. In addition, areas around utilities found in the buffer zone will be left free of woody vegetation to a minimum distance of 10 feet and maximum a distance of 30 feet. These will also act as public access areas along with a path (10-15 feet wide) leading to and from the footbridge. All access areas may need to be periodically maintained by the City of Greensboro (Greensboro 1999).

Permanent seeding may include, but not be limited to, switch grass, soft rush, fox sedge, rice cut-grass, and virginia wildrye. Trees and shrubs that may be used include river birch, green ash, persimmon, sycamore, willow oak, blackgum, witch-hazel, and tag alder. Species used for seeding and woody vegetation will depend upon availability and cost at the time of planting. Temporary vegetation for erosion control will include annual rye (cool season) or millet (warm season) depending on the construction schedule. Planting details are provided in plan sheets.

Live stakes will be installed in addition to the above plantings. Species to be used include black willow, silky willow, silky dogwood, and elderberry. Live staking material should be harvested and installed while plant material is dormant.

6 Sediment Transport Analysis

6.1 Background

A stable stream has the ability to move its sediment load without aggrading or degrading over long periods of time. The total volume of sediment transported through a cross section consists of bedload and suspended load fractions. Suspended load is normally composed of fine sand, silt and clay particles transported in the water column. Bedload is generally composed of larger particles, such as course sand, gravels and cobbles, transported by rolling, sliding, or hopping (saltating) along the bed.

The ability of the stream to transport its total sediment load is quantified through two measures; sediment transport competency and sediment transport capacity. Competency is a stream's ability to move particles of a given size and is a measurement of force, often expressed as units of lbs/ft^2. Sediment transport capacity is a stream's ability to move a quantity of sediment and is a measurement of stream power, often expressed as units of lbs/ (ft•sec). Sediment transport capacity is also calculated as a sediment transport rating curve, which provides an estimate of the quantity of total sediment load transported through a cross section per unit time. The curve is provided as a sediment transport rate in lbs/sec versus discharge or stream power.

6.1.1 <u>Competency Analysis</u>

Median substrate size has an important influence on the mobility of particles in streambeds. Critical dimensionless shear stress (τ^*_{ci}) is the measure of force required to initiate general movement of particles in a bed of a given composition. At shear stresses exceeding this critical value, essentially all grain sizes are transported at rates in proportion to their presence in the bed (Wohl, 2000). τ^*_{ci} can be calculated for gravel-bed stream reaches using surface and subsurface particle samples from a stable, representative riffle in the reach (Andrews, 1983). Critical dimensionless shear stress is calculated as follows (Jessup, pers. comm.., 2002):

1. Using the following equations, determine the critical dimensionless shear stress required to mobilize and transport the largest particle from the bar sample (or subpavement sample).

   a) Calculate the ratio $D_{50}/D\hat{}_{50}$
   Where: D_{50} = median diameter of the riffle bed (from 100 count in the riffle or pavement sample)
   $D\hat{}_{50}$ = median diameter of the bar sample (or subpavement)

   If the ratio $D_{50}/D\hat{}_{50}$ is between the values of 3.0 and 7.0, then calculate the critical dimensionless shear stress using Equation 1.

$$\tau^*_{ci} = \mathbf{0.0834\ (D_{50}/D\hat{\ }_{50})^{-0.872}} \qquad \textbf{(Equation 1)}$$

b) If the ratio $D_{50}/D\hat{\ }_{50}$ is not between the values of 3.0 and 7.0, then calculate the ratio of D_i/D_{50}

Where: D_i = Largest particle from the bar sample (or subpavement)
D_{50} = median diameter of the riffle bed (from 100 count in the riffle or the pavement sample)

If the ratio D_i/D_{50} is between the values of 1.3 and 3.0, then calculate the critical dimensionless shear stress using Equation 2.

$$\tau^*_{ci} = \mathbf{0.0384\ (D_i/D_{50})^{-0.887}} \qquad \textbf{(Equation 2)}$$

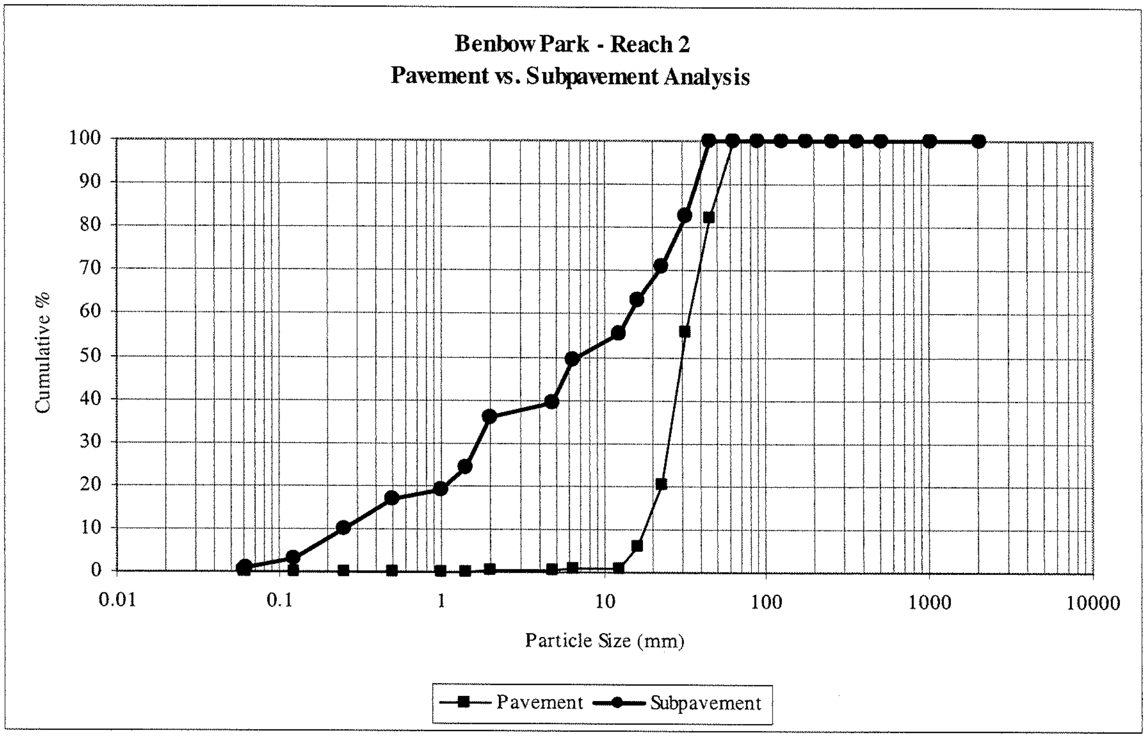
Entrainment analyses were conducted for the Benbow Park and Brown Bark Park reaches to ensure that the design streambed neither aggrades nor degrades during bankfull flows. A separate capacity analysis follows for the Gillespie Golf Course. A sediment transport analysis was not completed for Hillsdale because the dimension, pattern, and profile below bankfull have minimal change.

6.2 Benbow Park

Because the designs for both Benbow reaches are similar, we examined conditions at Reach 2 only. The critical dimensionless shear stress for Benbow Park Reach 2 was calculated using bed material samples from a stable riffle. The samples were taken near cross section 9+69 (existing stationing). The cumulative frequency curves of the samples are shown on Figure 6.1.

Data presented in Figure 6.1 was used to determine particle sizes for the various calculations. The $D_{50}/D\hat{\ }_{50}$ ratio is 5 for Reach 2, so Equation 1 is valid. Critical dimensionless shear stress was calculated using Equation 1 as $\tau^*_{ci} = 0.022$. This value of dimensionless shear stress is used in the aggradation analysis presented below.

Figure 6.1. Benbow Reach 2 Pavement / Subpavement Analysis



6.2.1 Aggradation Analysis Through Critical Depth and Slope Calculation

An aggradation analysis was performed to predict whether the channel depth and slope proposed in the design will cause the stream to aggrade. The aggradation analysis is based on calculations of the required depth and slope needed to transport large sediment particles, in this case defined as the largest particle of the riffle subpavement sample. Required depth can be compared with the design mean riffle depth and required slope can be compared to the design slope to verify that the stream has sufficient competency to move large particles and thus prevent thalweg aggradation. The required depth and slope are calculated by:

$$d_r = \frac{1.65\tau^*_{ci}D_i}{S_e} \qquad \textbf{(Equation 3)}$$

$$s_r = \frac{1.65\tau^*_{ci}D_i}{d_e} \qquad \textbf{(Equation 4)}$$

Where: d_r (ft) = Required bankfull mean depth
d_e (ft)= Design bankfull mean depth
1.65 = Sediment density (submerged specific weight)
= density of sediment (2.65) – density of water (1.0)
τ^*_{ci} = Critical dimensionless shear stress

D_i (ft) = Largest particle from bar sample (or subpavement)
s_r (ft/ft) = Required bankfull water surface slope
s_e (ft/ft) = Design bankfull water surface slope

Using a design slope of 0.0050 ft/ft and the largest subpavement particle diameter of 85 mm, Equation 3 indicates a required depth of 2.0 feet. The mean design bankfull riffle depth along Reach 2 is 2.1 ft (Table 6.2), approximately equal to the required depth and thus sufficient to transport the larger materials and prevent aggradation. Using the design depth, the slope check indicates a required slope of 0.0048, which is less than the design slope.

6.2.2 Competency Analysis Through Boundary Shear Stress and Shield's Curve Comparison

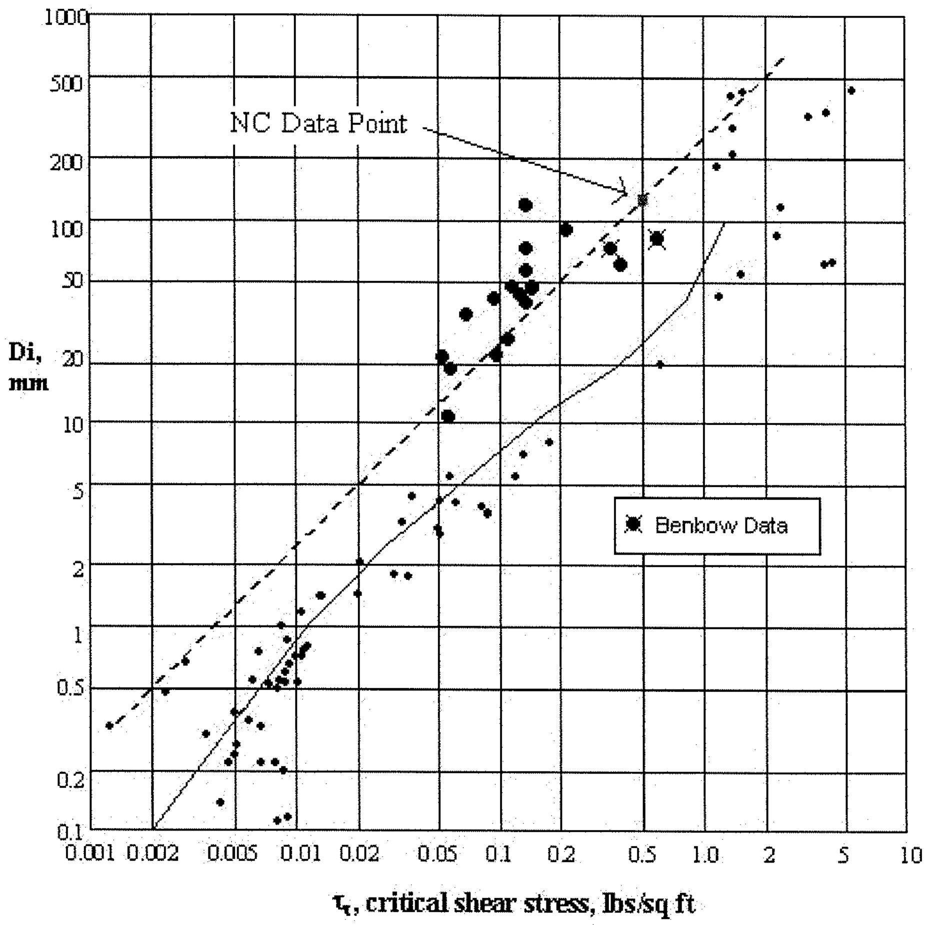
As a compliment to the required depth and slope calculations, we calculated boundary shear stresses for design riffle cross sections and compared with a modified Shield's Curve to predict sediment transport competency. The shear stress placed on the sediment particles is the force that entrains and moves the particles, given by:

$$\tau = \gamma R s \qquad \textbf{(Equation 5)}$$

Where,

τ = shear stress (lb/ft^2)
γ = specific gravity of water (62.4 lb/ft^3)
R = hydraulic radius (ft)
s = average channel slope (ft/ft)

The boundary shear stress estimated for the design cross-section at Reach 2 is 0.58 lb/ft^2. The measured D_i of the subpavement was 85 mm. As shown on the Modified Shield's Curve (Figure 6.3), this value of shear stress and D_i are well within the range of values used to calculate the regression equation. The Shield's Curve analysis supports the critical depth based conclusion that the design-cross sections can move sediment competently and prevent aggradation.



(Data from: Leopold, Wolman, and Miller 1964; Rosgen, personal commun.; and Harman, personal commun.)

Figure 6.2. Modified Shield's Curve for Grain Diameter of Transported Particle in Relation to Critical Shear Stress.

6.2.3 Degradation Analysis

We performed a degradation analysis in order to assess whether the design cross sections would result in scour and bed downcutting. We evaluated the potential for degradation by examining the upper competency limits for design cross sections and by reviewing existing and design grade control at the site.

The calculated shear stress discussed in Section 6.2.2 can be used to describe the upper competency limits for the design channel. The estimated boundary shear stress was 0.62 lbs/ft^2 at Reach 2. Based on the Modified Shield's Curve (Figure 6.3), shear stress in this range will move particles up to about 150 mm in size, which corresponds to roughly the D_{95} of the reach-wide pebble count sample. Preferably, this stress would correspond to the D84, but the concern for degradation is addressed through existing and design grade control. Reach wide confidence in vertical stability of the streambed comes from a review of grade control at the project site. The existing culverts at the start and end of the project length, as well as bedrock knickpoints throughout, control the overall slope and will prevent reach-wide degradation. Rock cross vanes throughout the projects will help control grade locally.

Table 6.1 Boundary shear stresses for existing and design riffle cross sections at Benbow Park.

Shear Stress Analysis	XSEC 16+39 (Reach 2)	
	Existing	Design
Bankfull Area (sq ft)	45	44
Bankfull Width, W (ft)	22	21
Bankfull Mean Depth, D (ft)	2.0	2.1
Wetted Perimeter	25	22
Hydraulic Radius, R (ft)	1.81	1.98
Slope (ft/ft)	0.0056	0.0050
Bankfull Discharge, Q (ft^3/sec)	107	107
Flow velocity, v (ft/sec)	2.4	2.4
Boundary Shear Stress, τ (lbs/sq ft)	0.63	0.62

6.3 Gillespie Golf Course

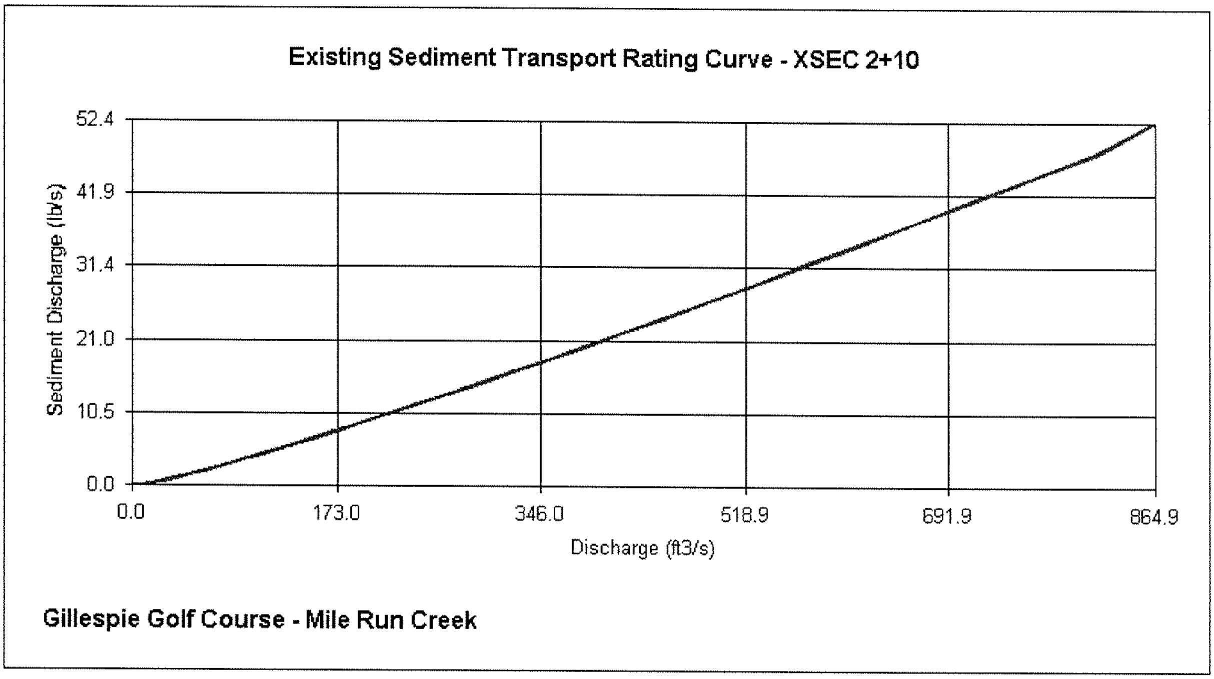
We did not perform sediment transport competency analyses for the Gillespie Golf Course because the bulk of the bed material is sand and the design does not change pattern or overall slope. The bankfull cross sectional area, width, and depth will change in areas where a smaller cross sectional area is proposed and where in-stream structures and bankfull benches are placed.

Cross vanes will improve the competency and capacity of the stream at low flow and encourage deposition along the bank toe rather than the center of the channel. However, the overall sediment transport competency of the reaches will not change.

6.3.1 Gillespie Sediment Transport Capacity Analysis

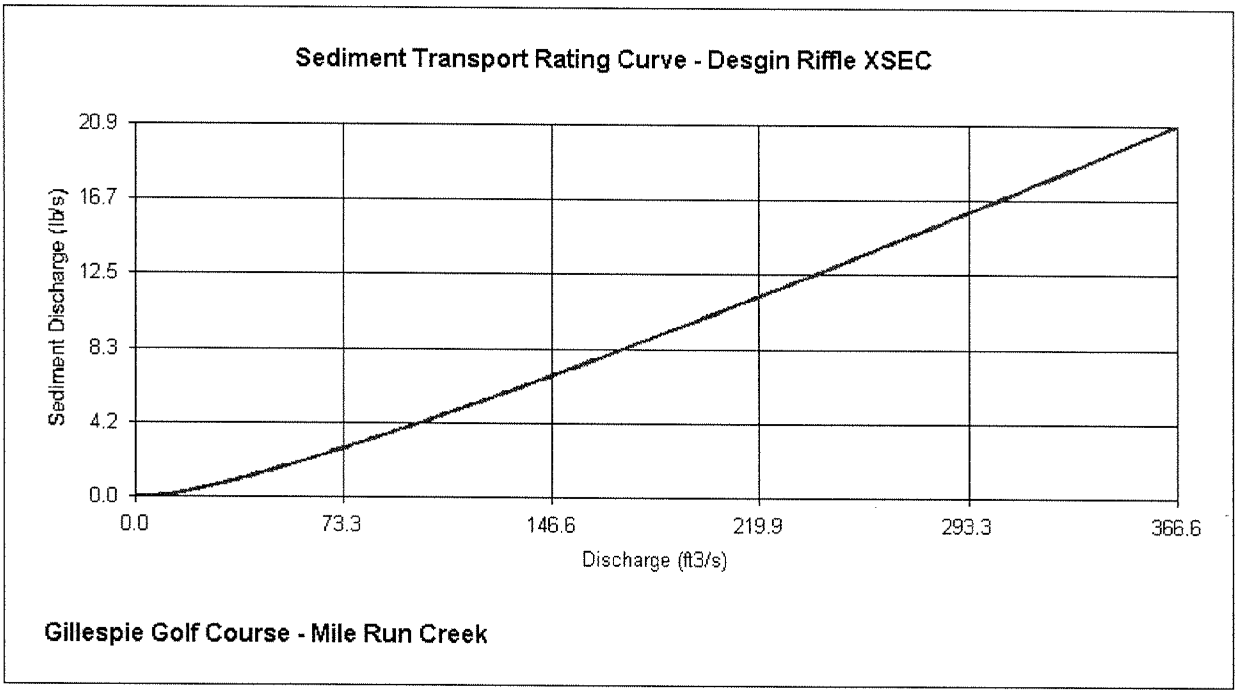
A sediment transport capacity analysis was completed on the project reach to determine if the design cross section had the same sediment transport rate of a stable existing cross section. Total sediment load was estimated using the Ackers and White (1973) function and data collected from the field survey. For a detailed report of the Ackers and White method, the reader is referred to Bunte (1994). The field data included an existing stable cross section and the cumulative frequency curve from the bed material sample. Cross section 2+10 was used as the existing stable section. Using a bankfull discharge of 350 cfs, the corresponding existing sediment discharge rate was 18 lb/sec. The existing sediment rating curve for the full range of flows is shown in Figure 6.3.

Figure 6.3. Gillespie Golf Course: Existing Sediment Transport Rating Curve



As a comparison, the design riffle cross section was also modeled. Again, using a bankfull discharge of 350 cfs, the corresponding design sediment transport rate was 20 lb/sec. This is almost identical to the stable existing cross section. While these results are encouraging, it is not surprising give that the slope is the same for both the existing and design. The analysis does show; however, that the smaller design cross sectional area has the same amount of sediment transport capacity, which is likely due to the higher bankfull velocity. The design sediment transport rating curve is shown in Figure 6.4.

Figure 6.4. Gillespie Golf Course: Design Sediment Transport Rating Curve



6.4 Brown Bark Park

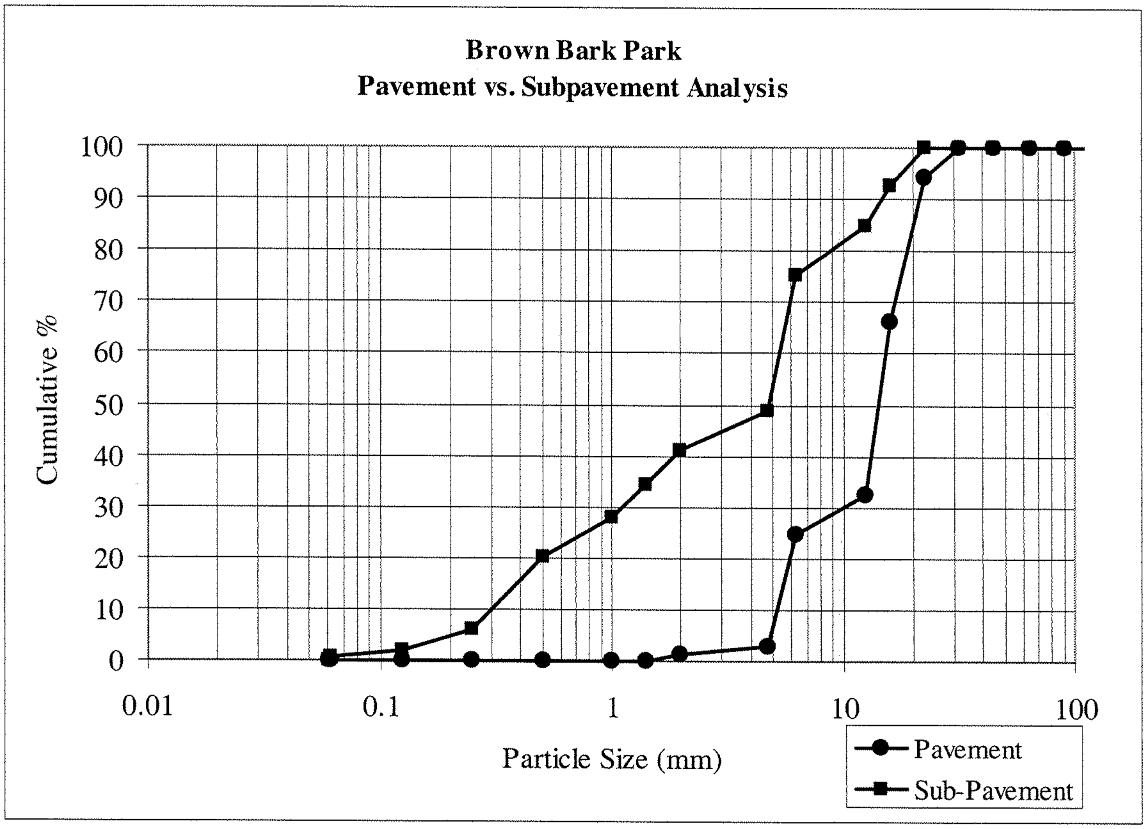
Since Brown Bark Park is a gravel bed stream, the same competency and capacity analyses used for Benbow Park were completed. The critical dimensionless shear stress for the Brown Bark Park reach was calculated using bed material samples from a stable riffle within the project reach near station 9+00 (existing stationing). The cumulative frequency curve of the sample is shown in Figure 6.5

Data presented in Figure 6.5 were used to determine particle sizes for the various calculations. Using a pavement d_{50} of 11 mm and a subpavement d_{50} of 1.7 mm, the $D_{50}/D\hat{}_{50}$ equaled 6.5, indicating that Equation 1 was valid. Critical dimensionless shear stress was calculated using Equation 1 as $\tau^*_{ci} = 0.032$. The values of dimensionless shear stress are used in the aggradation analysis presented below.

6.4.1 <u>Aggradation Analysis Through Critical Depth and Slope Calculation</u>

An aggradation analysis was performed to predict whether the channel depth and slope proposed in the design of Brown Bark Park would cause the stream to aggrade. Using a design slope of 0.0067 ft/ft and the largest subpavement particle diameter of 32 mm, Equation 1 indicates a critical depth of 0.83 feet. This means that at a water depth of 0.83 feet, particles up to 32 mm would be mobile in the design channel.

Figure 6.5. Brown Bark Pavement / Subpavement Analysis



The mean design bankfull riffle depth along the Brown Bark reach is 1.1 ft (Table 6.2), greater than the required depth and thus sufficient to transport the larger materials and prevent aggradation. Using the design depth, the slope check indicates a required slope of 0.0050, which is less than the design slope. Again, this indicates that the channel has sufficient competency to prevent aggradation.

6.4.2 Competency Analysis Through Boundary Shear Stress and Shield's Curve Comparison

Using Equation 5, the boundary shear stress estimated for the design cross-section is 0.43 lb/ft^2. The measured D_i of the subpavement was 32 mm. As shown on the Modified Shield's Curve (Figure 6.3), these values of shear stress and D_i are below the modified curve. The Shield's Curve analysis supports the critical depth based conclusion that the design-cross sections can move sediment competently and prevent aggradation.

6.4.3 Degradation Analysis

The calculated shear stresses discussed in Section 6.4.2 can be used to describe the upper competency limits for the design channel. The estimated boundary shear stress was 0.43 lbs/ft^2. Based on the Modified Shield's Curve (Figure 6.3), shear stress values in this range will move particles up to about 120 mm in size. This is larger than the largest subpavement particle and raises concerns about degradation. Reach wide confidence in vertical stability of the streambed comes from a review of grade control at the project site. The existing culverts at the start and end of the project length, as well as bedrock knickpoints throughout, control the overall slope and will prevent reach-wide degradation. Rock cross vanes throughout the projects will help control grade locally.

Table 6.2 Boundary shear stresses for existing and design riffle cross sections at Brown Bark Park.

Shear Stress Analysis	**Riffle XSEC**	
	Existing	**Design**
Bankfull Area (sq ft)	9	12
Bankfull Width, W (ft)	9	11
Bankfull Mean Depth, D (ft)	1.1	1.1
Wetted Perimeter	11	12
Hydraulic Radius, R (ft)	0.83	1.02
Slope (ft/ft)	0.0093	0.0067
Bankfull Discharge, Q (ft^3/sec)	40	40
Flow velocity, v (ft/sec)	4.3	3.3
Boundary Shear Stress, τ (lbs/sq ft)	0.48	0.43

7 Benthic Macroinvertebrate Surveys

The NC Division of Water Quality is providing the benthic macroinvertebrate study. Therefore, a macroinvertebrate assessment is not provided in this report.

8 Flooding Analyses

The four project streams were located on the Federal Emergency Management Agency's (FEMA) Flood Insurance Rate Maps. The unnamed tributaries at Benbow and Brown Bark Parks are not located within the limits of a designated FEMA 100-year floodplain. Mile Run Creek at Gillespie Golf Course and South Buffalo Creek at Hillsdale Park are located in FEMA detailed flood study areas (designated Zone AE).

Existing and proposed models using the US Army Corps of Engineers Hydrologic Engineering Center's River Analysis System (HEC-RAS) will be developed from available topography for Benbow and Brown Bark Parks. Discharges will then be estimated for the 10-year, 50-year, 100-year, and 500-year storm events. In order to verify that the proposed stream restoration does not adversely impact the existing floodplain elevations, a comparison will be made between the existing and proposed conditions.

A representative from the Greensboro Stormwater Management Division stated that if the proposed stream restoration at Gillespie Golf Course and Hillsdale Park does not cause a rise in the 100-year floodplain elevation, then a FEMA Conditional Letter of Map Revision is not required. The existing condition stream models will be developed in HEC-RAS from a combination of available topography and the data provided from the existing FEMA generated HEC-2 models. The proposed stream restoration condition will be compared to the existing stream condition to verify that an increase has not occurred to the 100-year floodplain elevations.

A separate report will be prepared showing the results of the flood study.

9 Monitoring and Evaluation

Environmental components monitored in this project will be those that allow an evaluation of channel stability and riparian survivability. Specifically, the success of channel modification, erosion control, seeding, and woody vegetation plantings will be evaluated. This will be accomplished through the following activities for 5 years after the project is built.

9.1 Cross-sections

Permanent cross-sections (either surveyed or located using a GPS) will be established at a spacing of one per 20 bankfull-width lengths, with an effort made to include both riffles and pools. These cross-sections may be the same as ones taken to develop construction plans or they may be new. Each cross-section will be marked on both banks with permanent pins to establish the exact transect used. A common benchmark will be used for cross-sections and consistently used to facilitate easy comparison of year-to-year data. The annual cross-section survey will include points measured at all breaks in slope, including top of bank, bankfull, inner berm, edge of water, and thalweg. Calculations will be made of width/depth ratio, entrenchment ratio, and low bank height ratio. Riffle cross-sections will be classified using the Rosgen stream classification system.

<u>Success Criteria</u>: There should be little or no change in as-built cross-sections. If changes do take place they should be evaluated to determine if they represent a movement toward a more unstable condition (down-cutting, erosion) or are minor changes that represent an increase in stability (settling, vegetative changes, deposition along the banks, decrease in width/depth ratio).

9.2 Pattern

Annual measurements taken for the plan view of the restoration site will include sinuosity, meander width ratio, and radius of curvature (on newly constructed meanders only for the first year of monitoring).

9.3 Materials

Annual pebble counts will be performed on all gravel-bed project reaches based on the percent of pools and riffles.

<u>Success Criteria</u>: Established D50 and D85 should increase in coarseness in riffles, and increase fineness in pools.

9.4 Longitudinal Profiles

A complete longitudinal profile will be completed once the first year and then every two years for a total of five years (for a total of 3 times). Measurements will include slope (average, pool, riffle) and pool-to-pool spacing. Survey points will include thalweg, water surface, inner berm, bankfull, and top of low bank. Each of these points will be taken at the head of each feature, e.g. riffle, run, pool, and glide, and the max pool depth. The survey will be tied to a permanent benchmark.

<u>Success Criteria</u>: The as-built longitudinal profiles should show that the bedform features are remaining stable, e.g. they are not aggrading or degrading. The pools should remain deep with flat water surface slopes and the riffles should remain steeper and shallower.

9.5 Bank Erosion Estimates

Permanent bank erosion pins and bank profiles will be made at each permanent cross-section. A bank toe pin will be installed close to the observed bank. The bank profile toe pin will be tied to a station in the longitudinal profile. Measurements will be made once per year at the same time the cross-section is measured. A bank erodibility hazard index (BEHI) score will also be made. An estimate of near-bank shear stress will be made by measuring the water surface slope along the observed bank length, as well as for the entire feature length, following the thalweg.

<u>Success Criteria</u>: The BEHI score should be low by the second year of restoration. Bank erosion measurements should be less than 0.1 ft/year.

9.6 Photo Reference Sites

Photographs used to evaluate restored sites will be made with a 35-mm camera using slide film or a digital camera. There will be one photo reference site per cross-section showing both banks and the stream channel. Several of the in-stream structures (e.g., rock vanes, cross vanes, and root wads) will also be photographed. Reference sites will be photographed before construction and continued once per year for at least 5 years following construction. After construction has taken place, reference sites will be marked with wooden stakes.

<u>Longitudinal reference photos</u>: The stream will be photographed longitudinally beginning at the downstream end of the mitigation site and moving upstream to the end of the site. Photographs will be taken looking upstream at delineated locations. Reference photo locations will be marked and described for future reference. Points will be close enough together to get an overall view of the reach. The angle of the shot will depend on what angle provides the best view and will be noted and continued in future shots. When modifications of stream position have to be made due to obstructions or other reasons, the position will be noted along with any landmarks and the same position used in the future.

Lateral reference photos: Reference photo transects will be taken at each permanent cross-section. Photographs will be taken of both banks at each cross-section. The survey tape will be centered in the photographs of the bank. The water line will be located in the lower edge of the frame and as much of the bank as possible included in each photo. Photographers should make an effort to consistently maintain the same area in each photo over time. Photos of areas that have been treated differently should also be included; for example two different types of erosion control material used. This will allow for future comparisons.

Success Criteria: Photographs will be used to subjectively evaluate channel aggradation or degradation, bank erosion, success of riparian vegetation and effectiveness of erosion control measures. Longitudinal photos should indicate the absences of developing bars within the channel or an excessive increase in channel depth. Lateral photos should not indicate excessive erosion or continuing degradation of the bank over time. A series of photos over time should indicate successional maturation of riparian vegetation. Vegetative succession should include initial herbaceous growth, followed by increasing densities of woody vegetation and then ultimately a mature overstory with herbaceous understory.

9.7 Survival Plots

Survival of planted vegetation will be evaluated using survival plots or counts. Survival of live stakes will be evaluated using enough plots or a size plot, that allows evaluating at least 100 live stakes. Evaluations of live stake survival will continue for at least 5 years. When stakes do not survive a determination will be made as to the need for replacement; in general if greater than 25% die replacement will be done.

All rooted vegetation will be flagged and evaluated for at least 5 years to determine survival. At least 2 staked survival plots will be evaluated. Plots will be 25 ft by 100 ft and all flagged stems will be counted in those plots. Success will be defined as 320 stems per acre after 5 years. When rooted vegetation does not survive, a determination will be made as to the need for replacement; in general, if greater than 25% die, replacement will be done.

9.8 Benthic Macroinvertebrate Monitoring

Benthic macroinvertebrate monitoring will be conducted by the NC Division of Water Quality.

10 References

Ackers, P. and W.R. White. 1973. Sediment transport: new approach and analysis. Journal of the Hydraulics Division, ASCE, Vol. 99, No. HY11, pp. 2041-2060.

Andrews, E. D., Entrainment of gravel from naturally sorted river bed material, Geological Society of America Bulletin, 94, 1225-1231, 1983.

Bunte, Kristin. 1994. Draft of "Modeling Bedload Sediment Transport in Sand-bed Streams using the Ackers and White (1973) Sediment Transport Formula." Prepared for the Stream Technology Center, Rocky Mountain Forest and Range Experiment Station, U.S. Forest Service, Fort Collins, Colorado

Clinton, D. R. (2001). *Stream morphology relationships from reference streams in North Carolina.* Thesis, North Carolina State University, Raleigh, North Carolina.

Doll, Barbara A., Dani E. Wise-Frederick, Carolyn M. Buckner, Shawn D. Wilkerson, William A. Harman and Rachel E. Smith. 2000. Hydraulic Geometry Relationships for Urban Streams Throughout the Piedmont of North Carolina. Riparian Ecology and Management in Multi-Land Use Watersheds. American Water Resources Association Summer Symposium. Portland, Oregon. Dates: September 28-31, 2000. Pp: 299-304.

Doll, B. A., D.E. Wise-Frederick, C.M. Buckner, S.D. Wilkerson, W.A. Harman, R.E. Smith, and J. Spooner, 2002. Hydraulic Geometry Relationships for Urban Streams throughout the Piedmont of North Carolina. *In Press.*

Dunne, T. and L. B. Leopold, 1978. Water in Environmental Planning. New York: W. H. Freeman and Company.

Federal Interagency Stream Restoration Working Group (FISRWG). 1998. Stream Corridor Restoration: Principles, Processes and Practices. National Technical Information Service, Springfield, VA.

City of Greensboro, NC, Stormwater Management Division. 1999. *Why are our Stream Banks "growing up" in Greensboro?* Available from World Wide Web: (http://www.ci.greensboro.nc.us/stormwater/why_are_stream_banks.htm)

Harman, W.A., G.D. Jennings, J.M. Patterson, D.R. Clinton, L.O. Slate, A.G. Jessup, J.R. Everhart, and R.E. Smith, 1999. Bankfull Hydraulic Geometry Relationships for North Carolina Streams. Wildland Hydrology. AWRA Symposium Proceedings. Edited by: D.S. Olsen and J.P. Potyondy. American Water Resources Association. June 30-July 2, 1999. Bozeman, MT.

Harmel, R. D., C. T. Haan, and R. C. Dutnell. 1999. Evaluation of Rosgen's streambank erosion potential assessment in Northeastern Oklahoma. Journal AWRA 35(1):113-121.

Harrelson, C. C., C. L. Rawlins, and J. P. Potyondy. 1994. Stream Channel Reference Sites: An Illustrated Guide to Field Technique. General Technical Report RM-245. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO.

Jennings, G. D., and W. A. Harman. 2000. Stream corridor restoration experiences in North Carolina. ASAE Paper 002012, ASAE Annual International Meeting, Milwaukee, WI. Am. Soc. Agr. Eng., St. Joseph, MI.

Johnson, P.A., and T.M. Heil, 1996. Uncertainty in Estimating Bankfull Conditions. Water Resources Bulletin. Journal of the American Water Resources Association 32(6):1283-1292.

Kilpatrick, F.A., and H.H. Barnes Jr. 1964, Channel Geometry of Piedmont Streams as Related to Frequency of Floods. Professional Paper 422-E. US Geological Survey, Washington, DC.

Knighton, David. 1984. Fluvial Forms and Processes. Rutledge, Chapman, and Hall, Inc. New York, NY.

Leopold, L. B., M. G. Wolman and J. P. Miller. 1992. Fluvial Processes in Geomorphology. Dover Publications, Inc. New York, NY.

Leopold, L.B., 1994. A View of the River. Harvard University Press, Cambridge, Mass.

Leopold, L.B., and T. Maddock Jr., 1953. The Hydraulic Geometry of Stream Channels and Some Physiographic Implications. U.S. Geological Survey Professional Paper 252, 57 pp.

Merigliano, M.F. 1997. Hydraulic Geometry and Stream Channel Behavior: An Uncertain Link. Journal of the American Water Resources Association 33(6):1327-1336.

Nixon, M., 1959. A Study of Bankfull Discharges of Rivers in England and Wales. In Proceedings of the Institution of Civil Engineers, vol. 12, pp. 157-175.

North Carolina Division of Water Quality. 1997. Standard Operating Procedures Biological Monitoring. North Carolina Department of Environment and Natural Resources, Raleigh, NC.

North Carolina Division of Water Quality. 2000. Benthic Macroinvertebrate Monitoring Protocols for Compensatory Stream Restoration Projects. North Carolina Department of Environment and Natural Resources, Raleigh, NC.

Patterson, J. M., D. R. Clinton, W. A. Harman, G. D. Jennings, and L. O. Slate. 1999. Development of streambank erodibility relationships for North Carolina stream. In: Olson, D. S., and J. P. Potyondy (Eds.). Wildland Hydrology, Proc. AWRA Specialty Conf., Bozeman, MT. pp. 117-123.

Rinaldi, M. and P.A. Johnson, 1997. Stream Meander Restoration. Journal of the American Water Resources Association 33:855-866.

Rosgen, D. L. 1994. A classification of natural rivers. Catena 22:169-199.

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

Rosgen, D.L., 1997. A geomorphological approach to restoration of incised rivers. In: Wang, S.S.Y, E.J. Langendoen, and F.D. Shields, Jr. (Eds.). Proceedings of the Conference on Management of Landscapes Disturbed by Channel Incision. pp. 12-22.

Rosgen, D.L., 1998. The Reference Reach - a Blueprint for Natural Channel Design. Draft Presented at ASCE Conference on River Restoration in Denver Colorado - March, 1998. ASCE. Reston, VA.

Rosgen, D.L. 2001. A stream channel stability assessment methodology. Proceedings of the Federal Interagency Sediment Conference, Reno, NV, March, 2001.

Schafale, M.P. and A.S. Weakley, 1990. Classification of the Natural Communities of North Carolina. Third Approximation. NCDEHNR Natural Heritage Program, Raleigh, NC.

Schumm, S.A., 1960. The Shape of Alluvial Channels in Relation to Sediment Type. U.S. Geological Survey Professional Paper 352-B. U.S. Geological Survey, Washigton, DC.

Simon, A. 1989. A model of channel response in disturbed alluvial channels. Earth Surface Processes and Landforms 14(1):11-26.

Wilkerson, S.D., Karl G. Linden, James D. Bowen, Craig J. Allan. 1998. Development and Analysis of Hydraulic Geometry Relationships for the Urban Piedmont of North Carolina. University of North Carolina at Charlotte.

Williams, G.P., 1978. Bankfull Discharge of Rivers. Water Resources Research 14(6):1141-1154.

Williams, G.P., 1986. River Meander and Channel Size. Journal of Hydrology 88:147-164.

Wilson, M.P. 1983. Erosion of Banks Along Piedmont Urban Streams. Water Resources Research Institute of the University of North Carolina.

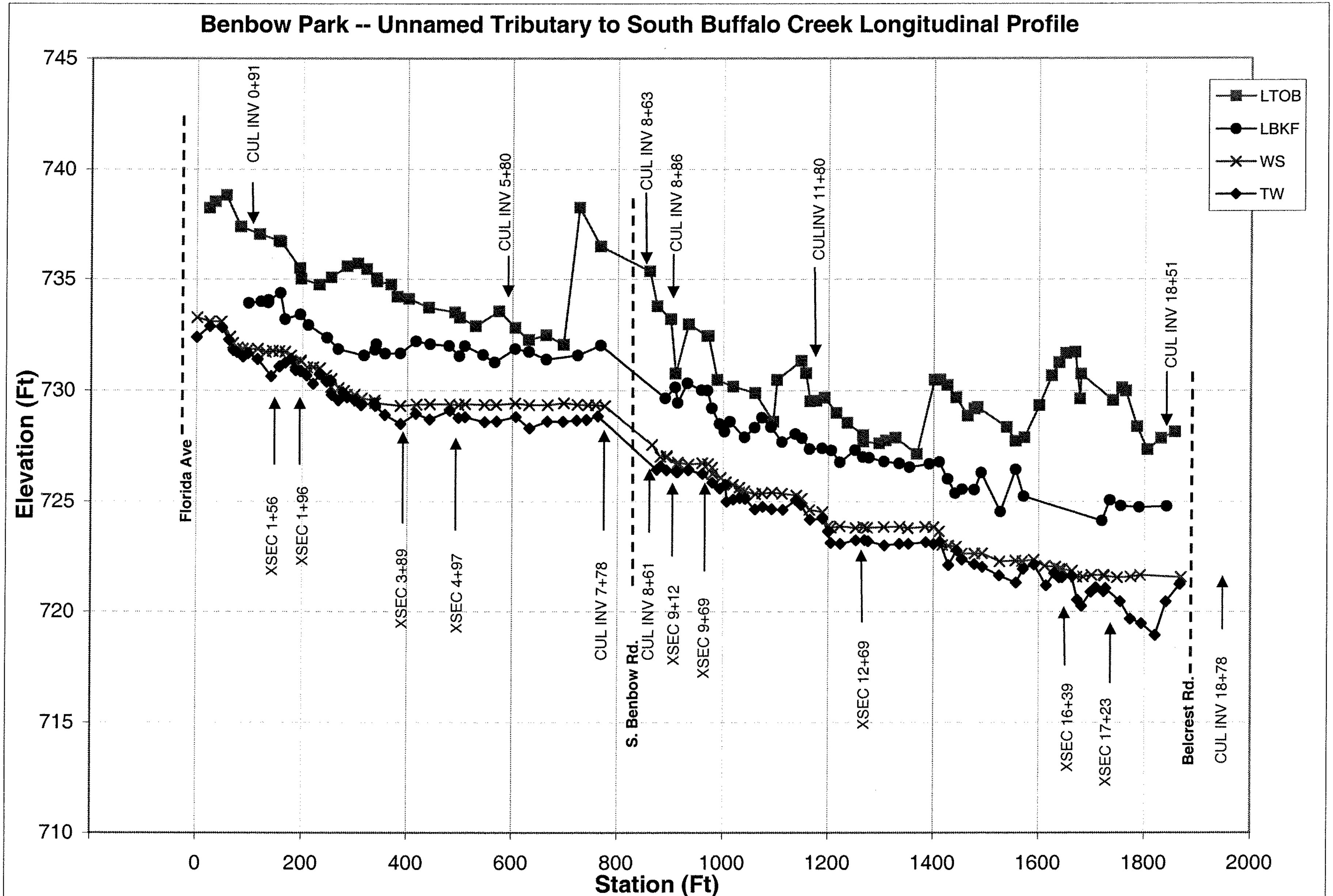
Wohl, E.E. 2000. Mountain rivers. Am. Geophys. Union Press, 320 pp.

Wolman, M.G., 1954. A Method of Sampling Course River-Bed Material. Transactions of American Geophysical Union 35: 951-956.

Wolman, M.G. and L.B. Leopold., 1957. River Floodplains: Some Observations on their Formation. USGS Professional Paper 282-C. U.S. Geological Survey, Washington, DC.

Appendix 1 Existing Condition Data

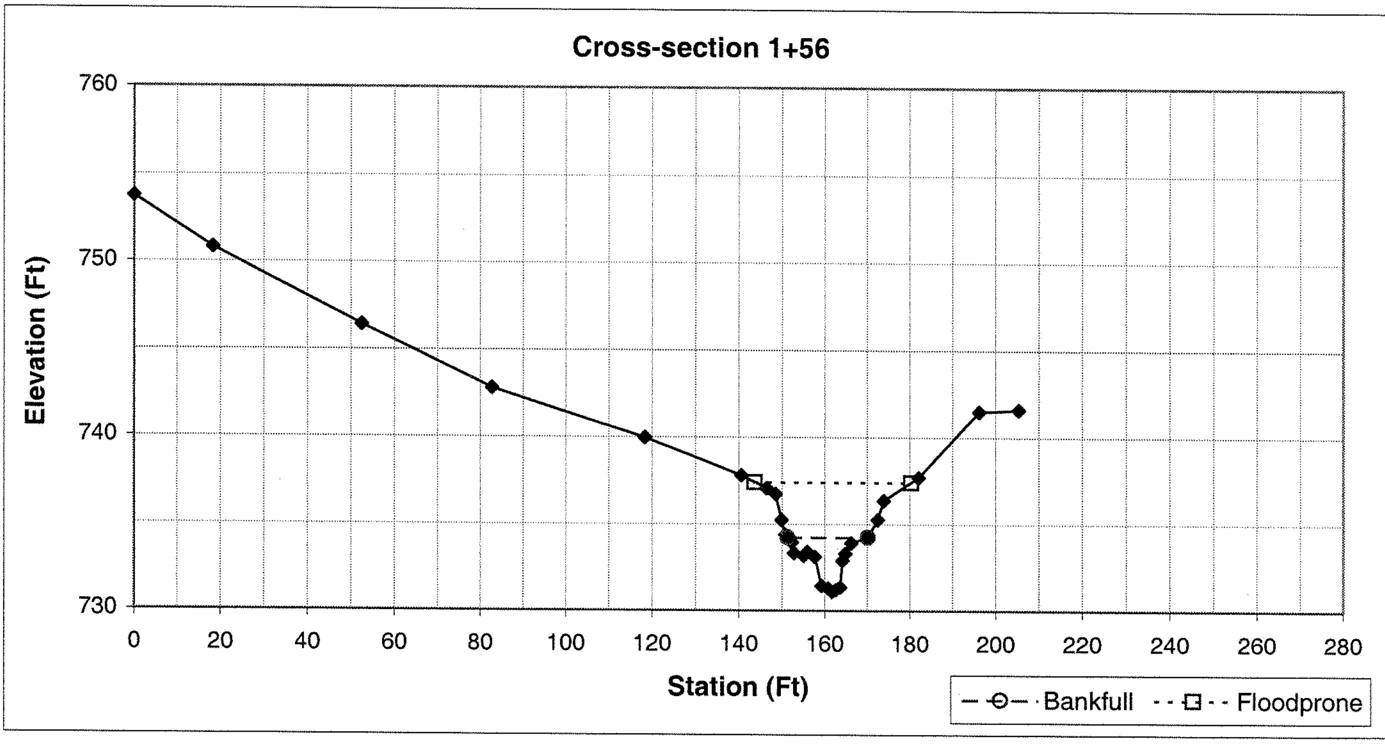
Existing Condition Data
Benbow Park



Benbow Park -- Unnamed Tributary to South Buffalo Creek Longitudinal Profile
Elevation (Ft)
Station (Ft)
745
740
735
730
725
720
715
710
0
200
400
600
800
1000
1200
1400
1600
1800
2000
LTOB
LBKF
WS
TW
Florida Ave
CUL INV 0+91
CUL INV 5+80
CUL INV 8+63
CUL INV 8+86
CULINV 11+80
CUL INV 18+51
XSEC 1+56
XSEC 1+96
XSEC 3+89
XSEC 4+97
CUL INV 7+78
S. Benbow Rd.
CUL INV 8+61
XSEC 9+12
XSEC 9+69
XSEC 12+69
XSEC 16+39
XSEC 17+23
Belcrest Rd.
CUL INV 18+78

Benbow Park Cross-Sectional Data

Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Pool	B5c	24.9	18.9	1.3	3.2	14.3	1.7	1.9	734.24	736.33



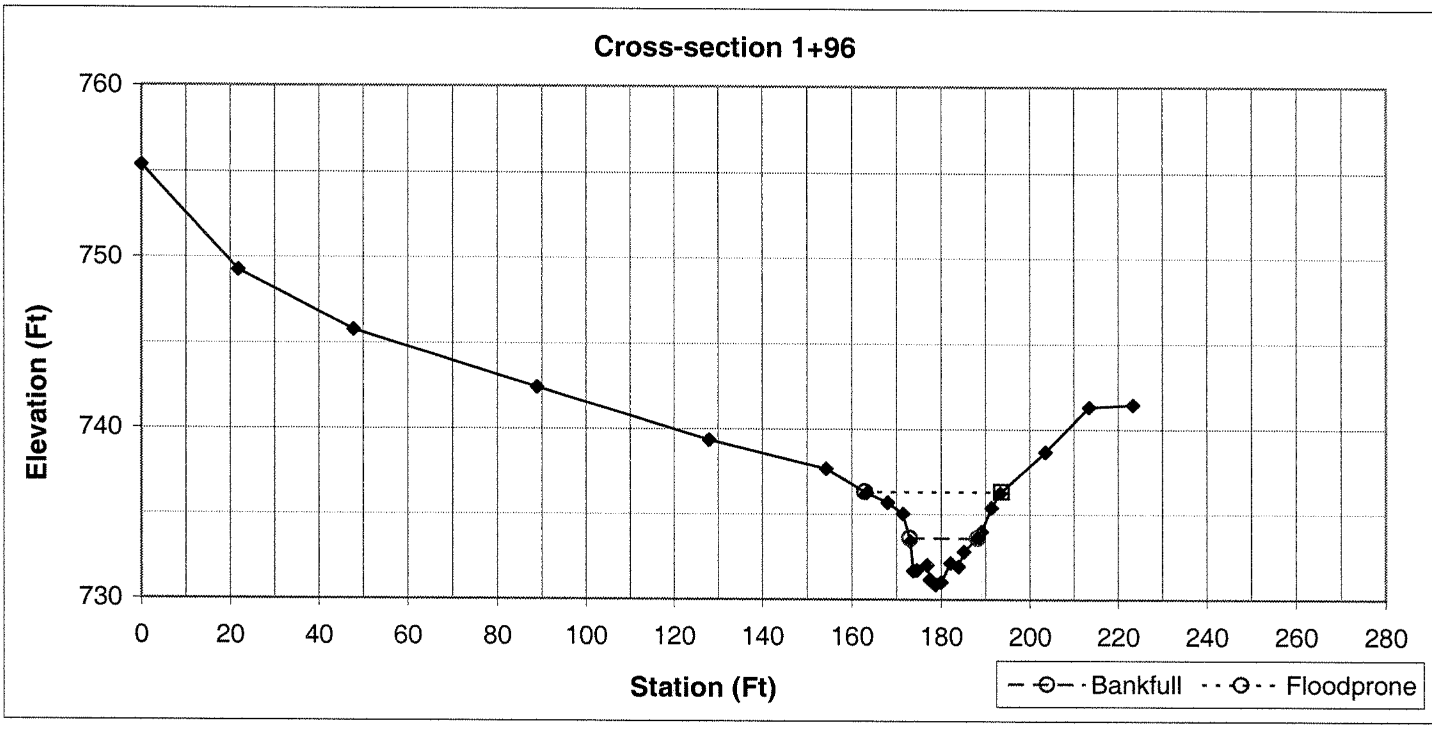
Pt #	North	East	Elevation	Note	Station
145	839529.23	1771077.82	753.75	X01	0.00
146	839522.66	1771060.74	750.81	X01	18.29
147	839510.51	1771028.73	746.41	X01	52.50
148	839499.44	1771000.58	742.79	X01	82.74
149	839485.42	1770967.84	739.94	X01	118.35
150	839477.09	1770947.23	737.77	X01	140.58
151	839474.67	1770941.94	737.04	X01LPIN	146.39
152	839473.76	1770939.99	736.71	X01LTOB	148.54
153	839473.29	1770938.74	735.24	X01	149.88
154	839473.56	1770937.64	734.38	X01LBKF	150.79
155	839473.45	1770936.00	733.93	X01	152.34
156	839473.12	1770935.67	733.32	X01	152.77
157	839472.14	1770933.56	733.16	X01	155.10
158	839471.80	1770932.86	733.38	X01	155.87
159	839471.06	1770931.19	733.10	X01LIB	157.70
161	839470.20	1770929.83	731.44	X01	159.29
162	839469.42	1770928.49	731.29	X01	160.83
163	839468.87	1770927.73	731.09	X01TW	161.74
164	839468.20	1770927.09	731.20	X01	162.59
165	839467.48	1770926.26	731.35	X01RCH	163.64
166	839466.97	1770925.90	732.88	X01	164.17
167	839466.53	1770925.34	733.29	X01	164.86
168	839466.06	1770923.99	733.90	X01	166.28
169	839463.62	1770920.82	734.24	X01RBKF	170.15
170	839461.94	1770919.03	735.25	X01	172.46
171	839461.67	1770917.61	736.33	X01RTOB	173.87
172	839458.50	1770910.01	737.68	X01	182.11
173	839452.92	1770897.03	741.47	X01	196.23
174	839448.82	1770888.79	741.58	X01EP	205.42

Bankfull Line	
Station	Elevation
151.27	734.24
170.15	734.24

Floodprone Line	
Station	Elevation
143.69	737.38
180.30	737.38

Benbow Park Cross-Sectional Data

Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Riffle	E5	23.9	15.3	1.6	2.7	9.7	1.5	2.0	733.59	735.01



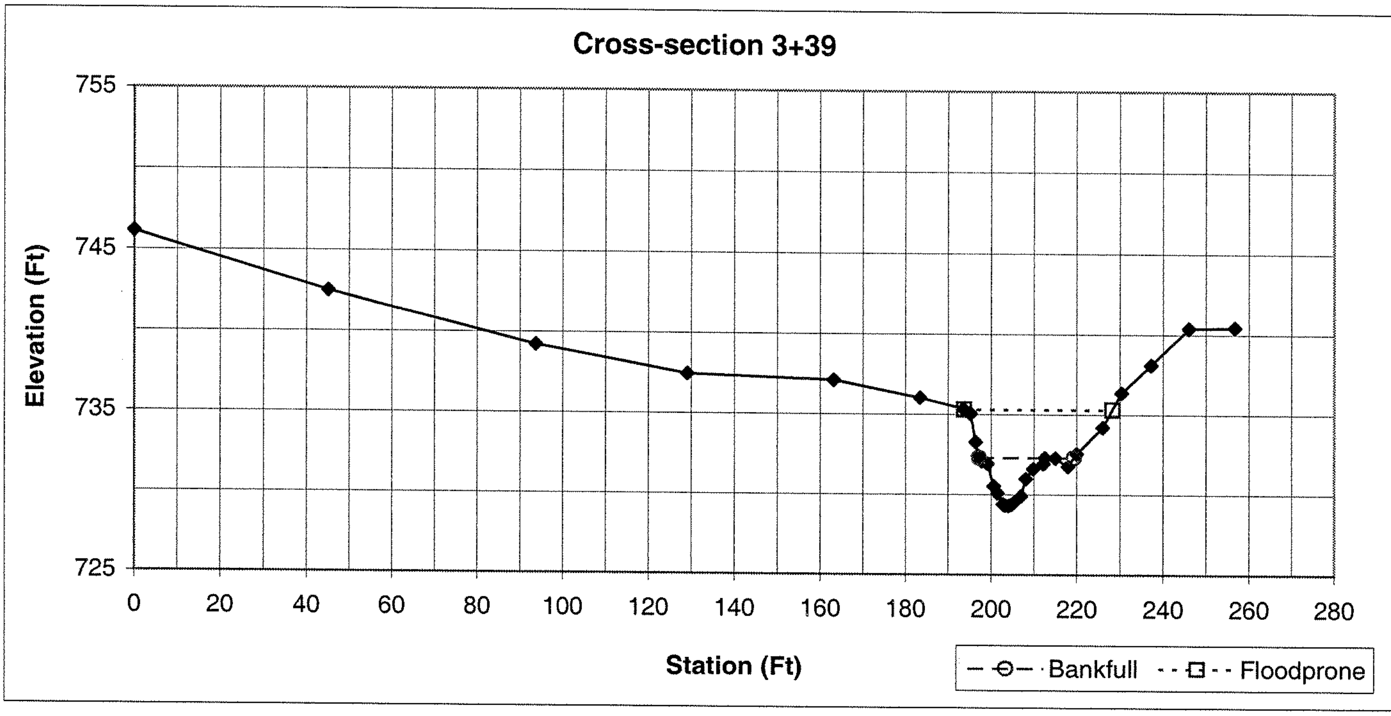
Pt #	North	East	Elevation	Note	Station
178.00	839501.85	1771110.76	755.38	X2	0.00
179.00	839491.91	1771091.30	749.25	X2	21.82
180.00	839481.21	1771067.63	745.75	X2	47.79
181.00	839465.91	1771029.46	742.41	X2	88.89
182.00	839452.96	1770992.45	739.33	X2	127.97
183.00	839443.65	1770967.81	737.66	X2	154.27
184.00	839440.21	1770959.40	736.24	X2	163.36
185.00	839438.58	1770954.99	735.67	X2LPIN	168.05
186.00	839436.53	1770952.12	735.01	X2LTOB	171.50
187.00	839437.41	1770949.91	733.40	X2LBKF	173.17
188.00	839436.82	1770949.45	731.66	X2	173.82
189.00	839436.41	1770948.76	731.70	X2	174.63
190.00	839435.03	1770946.85	732.00	X2LIB	176.93
191.00	839434.60	1770946.46	731.15	X2LCH	177.46
192.00	839434.40	1770945.90	731.02	X2	178.05
193.00	839434.04	1770945.21	730.87	X2TW	178.83
194.00	839433.23	1770944.28	731.00	X2	180.01
196.00	839431.98	1770942.54	732.10	X2RIB	182.11
197.00	839431.13	1770940.93	731.90	X2	183.92
198.00	839430.17	1770939.97	732.78	X2	185.19
199.00	839428.91	1770937.21	733.59	X2RBKF	188.22
200.00	839428.58	1770936.36	733.96	X2	189.14
201.00	839428.24	1770934.05	735.37	X2	191.38
202.00	839426.84	1770932.50	736.24	X2RTOB	193.36
203.00	839421.83	1770923.57	738.66	X2	203.56
204.00	839416.64	1770914.98	741.30	X2	213.52
205.00	839411.49	1770906.41	741.42	X2EP	223.44

Bankfull Line	
Station	Elevation
172.98	733.59
188.22	733.59

Floodprone Line	
Station	Elevation
162.92	736.31
193.65	736.31

Benbow Park Cross-Sectional Data

Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Pool	B5c	25.4	22.2	1.2	3.0	19.3	1.9	1.6	732.31	735.04



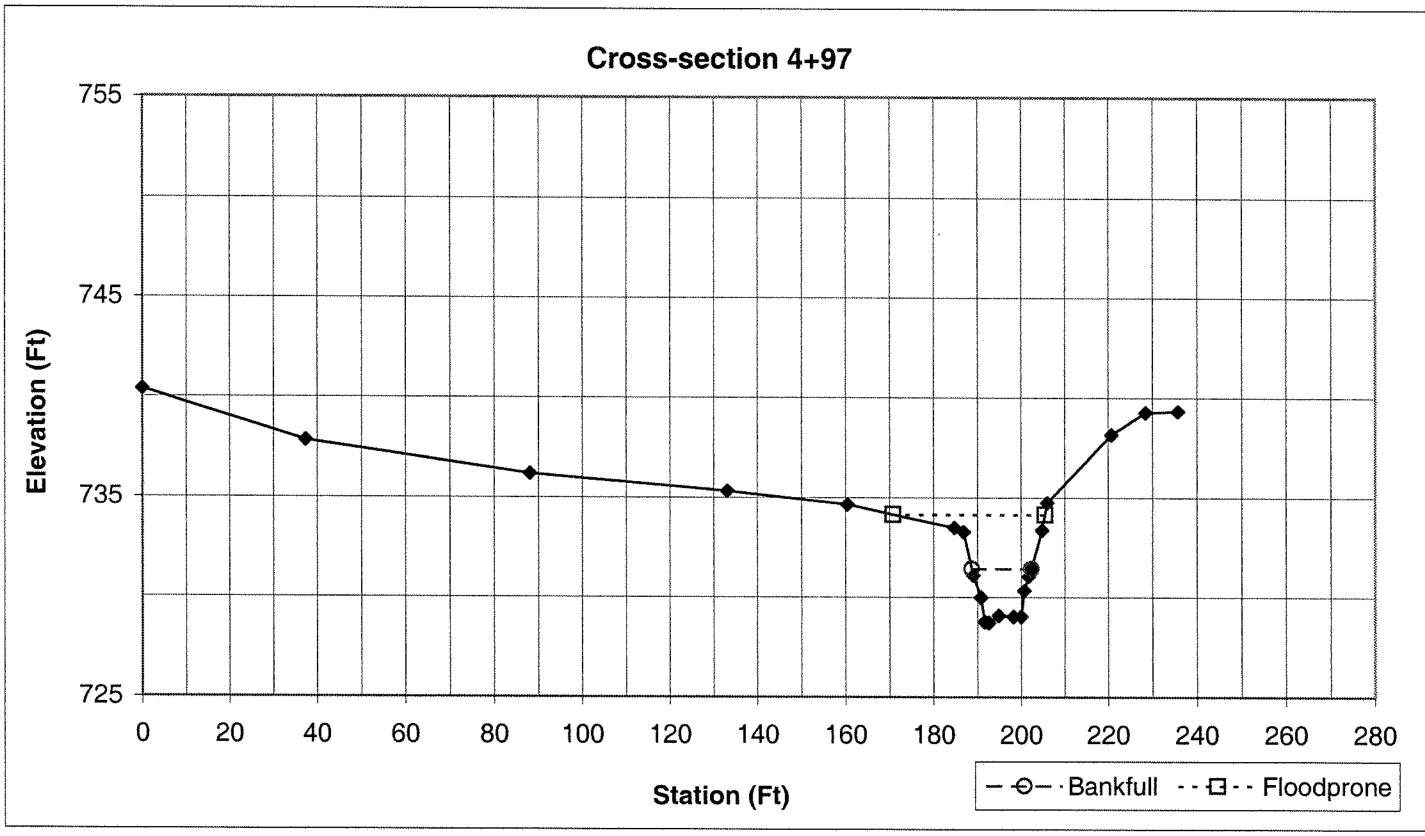
Pt #	North	East	Elevation	Note	Station
337	839403.06	1771194.18	746.14	X3	0.00
338	839381.22	1771154.59	742.47	X3	45.16
339	839357.64	1771112.09	739.21	X3	93.69
340	839340.83	1771080.96	737.45	X3	129.05
341	839324.56	1771050.90	737.10	X3	163.19
342	839316.38	1771032.37	736.04	X3	183.43
343	839313.07	1771022.73	735.35	X3LPIN	193.55
344	839312.31	1771021.26	735.04	X3LTOB	195.20
345	839312.21	1771019.95	733.29	X3	196.42
346	839311.78	1771019.58	732.42	X3	196.94
347	839311.77	1771018.59	732.08	X3LBKF	197.84
348	839311.59	1771017.18	731.92	X3	199.19
349	839311.37	1771015.66	730.53	X3	200.65
350	839311.24	1771014.70	730.07	X3	201.57
352	839310.53	1771013.66	729.41	X3	202.81
353	839310.45	1771013.09	729.32	X3	203.37
354	839310.20	1771012.42	729.31	X3TW	204.07
355	839310.19	1771011.69	729.36	X3	204.73
356	839309.90	1771011.06	729.51	X3RCH	205.43
357	839309.73	1771009.41	729.91	X3	206.98
358	839309.35	1771008.32	730.99	X3	208.13
359	839309.00	1771006.54	731.60	X3	209.89
360	839307.72	1771004.49	731.93	X3	212.29
361	839307.66	1771004.21	732.31	X3	212.56
362	839306.58	1771001.93	732.29	X3	215.09
363	839304.58	1770999.66	731.77	X3	218.01
364	839303.24	1770998.09	732.56	X3RBKF	220.01
365	839301.02	1770992.47	734.20	X3	226.03
366	839300.01	1770988.16	736.36	X3RTOB	230.35
367	839298.70	1770981.15	738.09	X3	237.22
368	839295.67	1770972.91	740.36	X3	245.96
369	839290.45	1770963.47	740.43	X3EP	256.72

Bankfull Line	
Station	Elevation
197.24	732.31
219.38	732.31

Floodprone Line	
Station	Elevation
193.73	735.31
228.26	735.31

Benbow Park Cross-Sectional Data

Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Riffle	E5	25.9	13.6	1.9	2.7	7.1	1.7	2.6	731.44	733.27



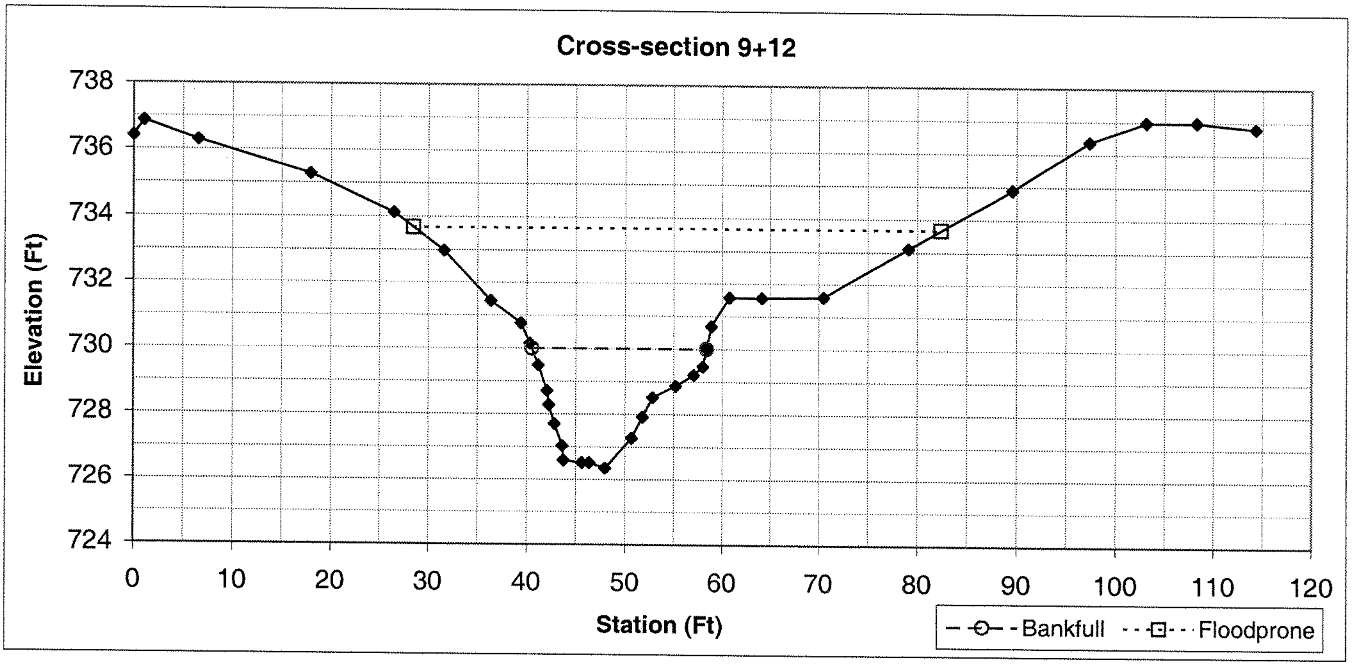
Pt #	North	East	Elevation	Note	Station
370	839269.46	1771232.09	740.39	X4	0.00
371	839248.16	1771201.33	737.84	X4	37.38
372	839214.10	1771162.86	736.18	X4	88.05
373	839190.95	1771124.18	735.31	X4	133.12
374	839177.72	1771100.22	734.64	X4	160.45
375	839167.33	1771078.05	733.48	X4LPIN	184.76
376	839166.50	1771076.05	733.27	X4LTOB	186.89
378	839167.04	1771073.11	731.09	X4	189.10
379	839166.41	1771071.41	729.99	X4	190.87
381	839166.03	1771070.75	728.78	X4TW	191.64
382	839165.65	1771069.85	728.74	X4	192.60
383	839164.73	1771067.78	729.09	X4	194.84
384	839163.43	1771064.60	729.04	X4	198.23
385	839162.64	1771063.03	729.04	X4RCH	199.98
386	839162.11	1771062.47	730.33	X4	200.74
387	839161.86	1771061.46	731.04	X4	201.73
388	839161.55	1771060.93	731.44	X4RBKF	202.34
389	839162.03	1771057.66	733.36	X4	204.85
390	839161.67	1771056.54	734.73	X4RTOB	206.00
391	839150.34	1771046.27	738.15	X4	220.71
392	839147.41	1771038.90	739.26	X4	228.51
393	839144.53	1771032.16	739.33	X4EP	235.76

Bankfull Line	
Station	Elevation
188.74	731.44
202.34	731.44

Floodprone Line	
Station	Elevation
170.8	734.14
205.51	734.14

Benbow Park Cross-Sectional Data

Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Riffle	E5	38.7	17.9	2.2	3.7	8.3	1.2	3.0	730.00	730.77



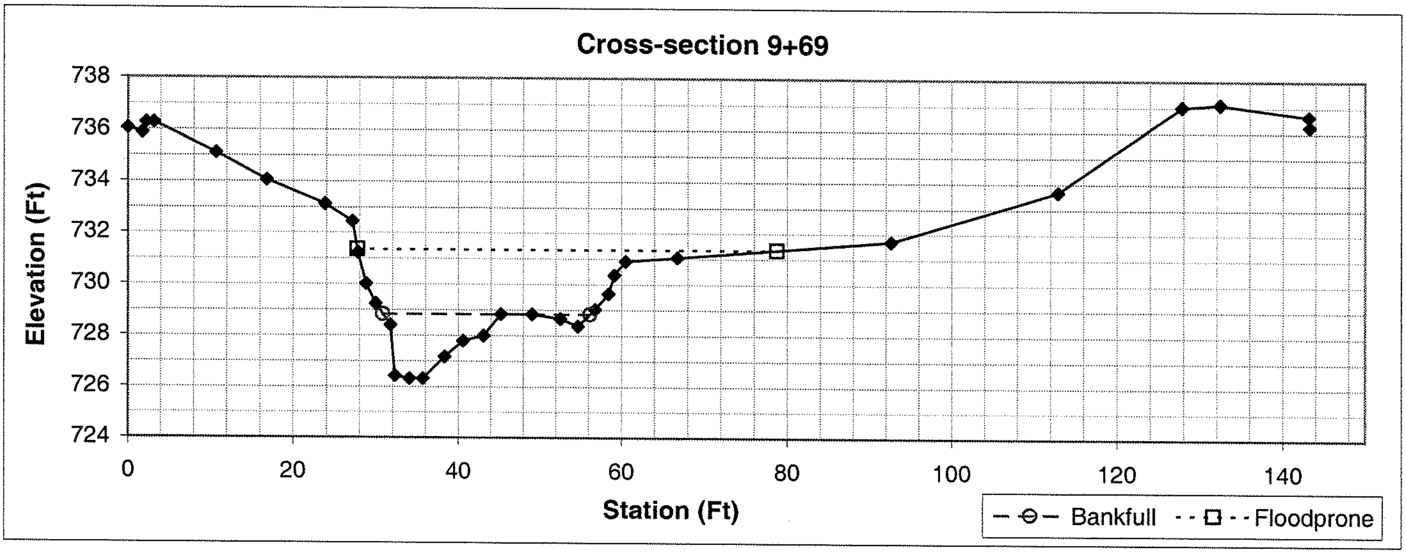
Pt #	North	East	Elevation	Note	Station
802	838804.24	1771292.72	736.40	X5B-CURB	0.00
803	838804.08	1771291.69	736.86	X5TOP-CURB	1.05
804	838804.63	1771286.06	736.29	X5	6.54
805	838804.79	1771274.51	735.27	X5	17.96
806	838804.57	1771265.93	734.12	X5	26.48
807	838804.12	1771260.84	732.96	X5LPIN	31.59
808	838802.52	1771256.25	731.44	X5	36.36
809	838801.33	1771253.34	730.77	X5LTOB	39.40
810	838801.71	1771252.36	730.15	X5LBKF	40.32
811	838801.41	1771251.54	729.48	X5	41.17
813	838801.29	1771250.64	728.71	X5	42.08
814	838801.07	1771250.50	728.26	X5	42.25
815	838800.67	1771249.99	727.70	X5LIB	42.82
816	838800.40	1771249.23	727.02	X5	43.60
817	838800.22	1771249.10	726.57	X5LCH	43.75
818	838799.04	1771247.39	726.51	X5	45.62
819	838798.24	1771246.75	726.51	X5	46.36
820	838797.37	1771245.24	726.34	X5TW	47.97
822	838795.99	1771242.70	727.27	X5	50.68
823	838795.10	1771241.72	727.91	X5	51.78
824	838794.76	1771240.69	728.52	X5RIB	52.85
825	838794.20	1771238.39	728.86	X5	55.20
826	838794.11	1771236.53	729.20	X5	57.05
827	838793.84	1771235.59	729.47	X5	58.02
828	838793.71	1771235.21	730.00	X5RBKF	58.42
829	838793.50	1771234.74	730.70	X5	58.91
830	838793.25	1771232.90	731.58	X5RTOB	60.77
831	838791.59	1771229.72	731.57	X5	64.15
832	838792.15	1771223.25	731.60	X5	70.48
833	838790.42	1771214.77	733.11	X5	79.11
834	838791.95	1771203.98	734.89	X5	89.59
835	838790.13	1771196.39	736.37	X5	97.36
836	838786.65	1771191.09	736.98	X5LSIDEWALK	103.09
837	838787.76	1771185.71	736.98	X5RSIDEWALK	108.27
838	838788.34	1771179.54	736.80	X5	114.29

Bankfull Line	
Station	Elevation
40.51	730
58.42	730

Floodprone Line	
Station	Elevation
28.47	733.67
82.41	733.67

Benbow Park Cross-Sectional Data

Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Pool	B5c	22.6	25.4	0.9	2.5	28.5	1.8	2.0	728.83	730.89



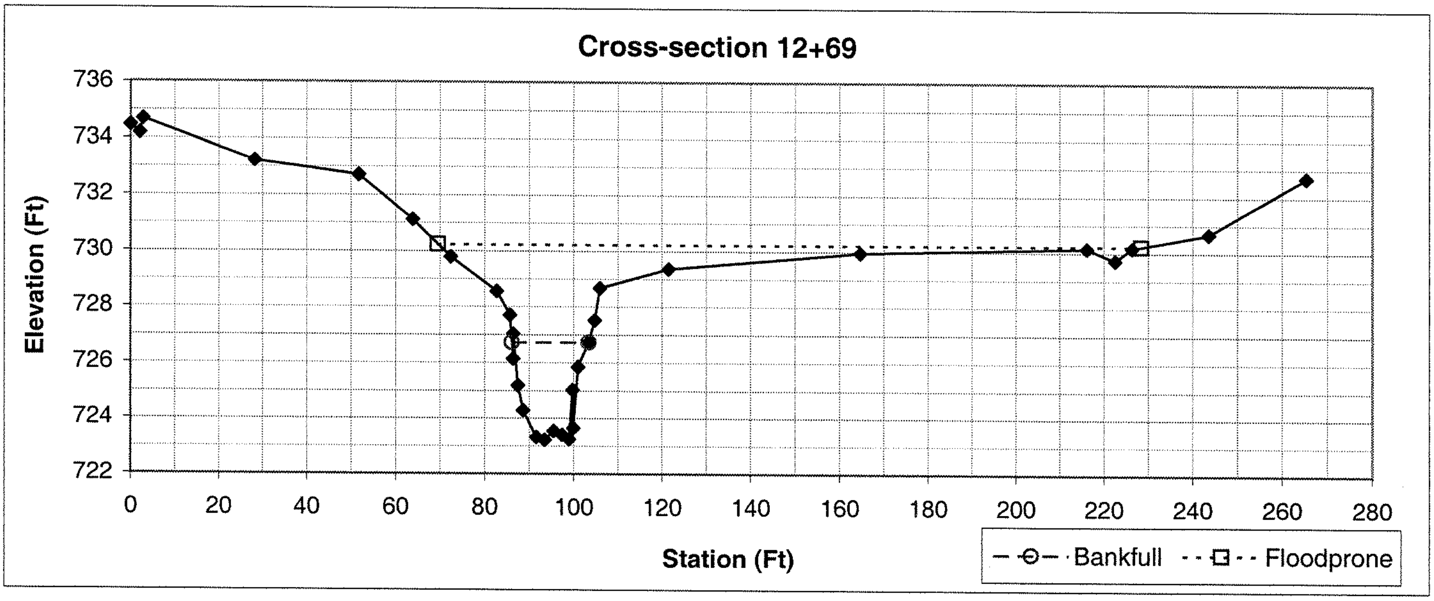
Pt #	North	East	Elevation	Note	Station
841	838743.67	1771294.00	736.05	X6EP	0.00
842	838743.52	1771292.23	735.88	X6B-CURB	1.77
843	838743.56	1771291.78	736.29	X6TOP-CURB	2.22
844	838743.02	1771290.84	736.28	X6	3.18
845	838742.35	1771283.33	735.10	X6	10.70
846	838741.77	1771277.22	734.04	X6	16.83
847	838741.20	1771270.23	733.12	X6LPIN	23.83
848	838741.46	1771266.92	732.45	X6LTOB	27.13
849	838741.48	1771266.24	731.22	X6	27.81
850	838741.25	1771265.30	730.01	X6LBKF	28.76
851	838741.20	1771264.11	729.23	X6	29.95
852	838741.65	1771262.30	728.40	X6	31.75
853	838741.22	1771261.76	726.43	X6LCH	32.30
854	838741.34	1771260.01	726.31	X6	34.04
855	838740.87	1771258.37	726.31	X6	35.69
857	838740.18	1771255.75	727.16	X6	38.33
858	838740.03	1771253.49	727.79	X6RIB	40.59
859	838739.02	1771251.02	727.99	X6	43.09
860	838739.35	1771248.87	728.83	X6	45.24
861	838738.81	1771245.03	728.83	X6RBKF	49.09
862	838738.88	1771241.58	728.65	X6	52.53
863	838739.23	1771239.41	728.37	X6	54.69
864	838739.32	1771237.30	729.02	X6	56.80
865	838738.89	1771235.65	729.63	X6	58.46
866	838738.95	1771234.96	730.36	X6	59.15
867	838738.83	1771233.58	730.89	X6RTOB	60.53
868	838738.60	1771227.34	731.05	X6	66.78
869	838738.01	1771201.53	731.70	X6	92.59
870	838739.39	1771181.15	733.67	X6	112.93
871	838737.39	1771166.30	737.01	X6-L-SIDEWALK	127.83
872	838739.33	1771161.69	737.10	X6-R-SIDEWALK	132.38
873	838739.53	1771150.92	736.65	X6TOP-CURB	143.14
874	838739.55	1771150.81	736.26	X6EP	143.25

Bankfull Line	
Station	Elevation
30.82	728.83
56.19	728.83

Floodprone Line	
Station	Elevation
27.73	731.35
78.73	731.35

Benbow Park Cross-Sectional Data

Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Pool	E5	42.3	17.4	2.4	3.5	7.1	1.3	9.2	726.73	727.71



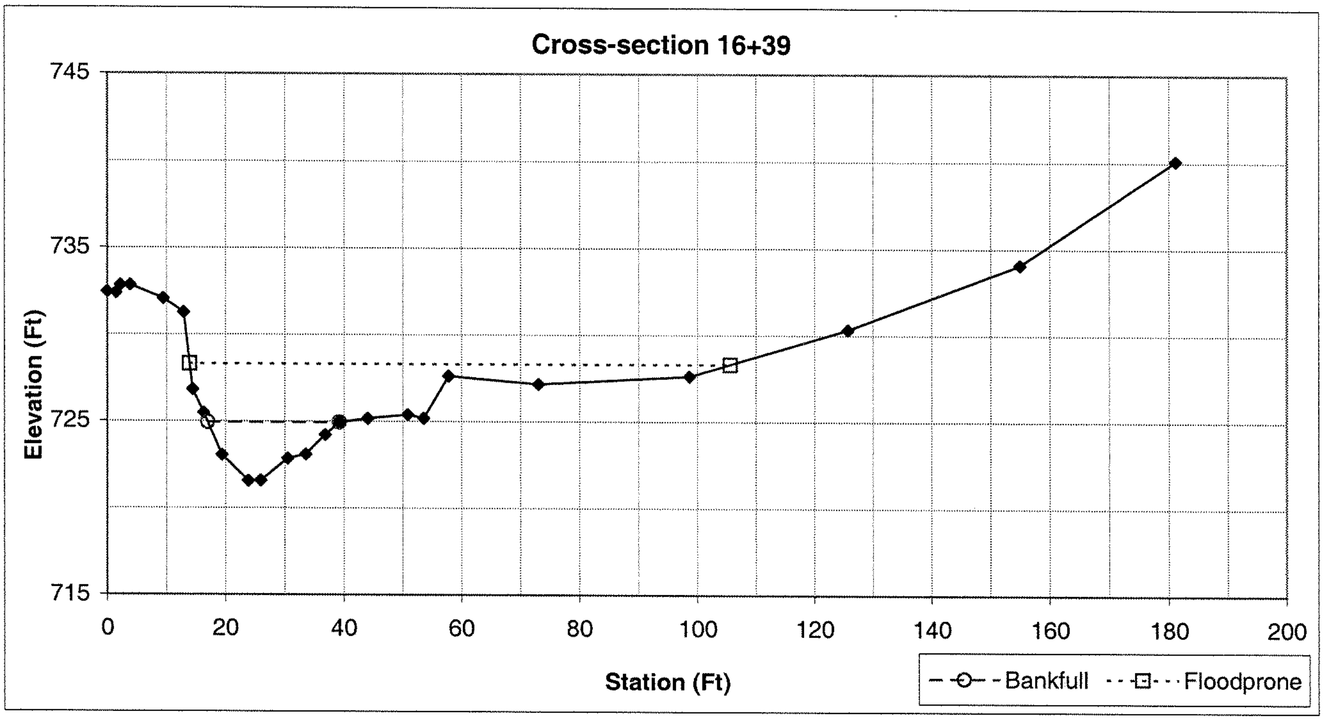
Pt #	North	East	Elevation	Note	Station
875	838493.75	1771390.63	734.45	X7EP	0.00
876	838492.72	1771388.82	734.18	X7B-CURB	2.08
877	838491.78	1771388.52	734.67	X7T-CURB	2.82
878	838483.36	1771364.00	733.21	X7	28.21
879	838474.62	1771341.82	732.72	X7	51.75
880	838470.50	1771330.20	731.11	X7	63.85
881	838467.20	1771322.30	729.77	X7	72.33
882	838462.21	1771313.28	728.55	X7LPIN	82.63
883	838461.21	1771310.41	727.71	X7LTOB	85.61
885	838461.44	1771309.38	726.14	X7	86.38
884	838461.56	1771309.34	727.02	X7LBKF	86.35
886	838461.41	1771308.15	725.19	X7	87.45
887	838460.77	1771307.21	724.28	X7	88.59
889	838459.04	1771304.71	723.32	X7	91.62
890	838458.30	1771302.95	723.22	X7	93.51
891	838457.48	1771301.13	723.54	X7	95.49
892	838456.70	1771299.38	723.40	X7	97.40
893	838455.93	1771298.02	723.24	X7TW	98.96
895	838455.52	1771297.31	725.02	X7RSCOUR	99.78
894	838455.31	1771297.24	723.65	X7RCH	99.95
896	838454.98	1771296.21	725.84	X7	101.00
897	838453.20	1771294.43	726.73	X7RBKF	103.44
898	838452.50	1771293.22	727.51	X7	104.83
899	838452.36	1771292.04	728.67	X7RTOB	105.93
900	838445.97	1771277.73	729.37	X7	121.50
901	838423.02	1771241.14	729.95	X7	164.67
902	838393.75	1771198.70	730.14	X7LTOD	216.10
903	838389.71	1771193.64	729.72	X7CL-D	222.51
904	838386.63	1771190.97	730.17	X7RTOD	226.38
905	838372.71	1771179.18	730.67	X7	243.62
906	838358.64	1771162.28	732.71	X7	265.32

Bankfull Line	
Station	Elevation
86.09	726.73
103.44	726.73

Floodprone Line	
Station	Elevation
69.45	730.23
228.38	730.23

Benbow Park Cross-Sectional Data

Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Riffle	E5	44.50	22.26	2.00	3.38	11.13	1.80	4.10	724.92	727.61



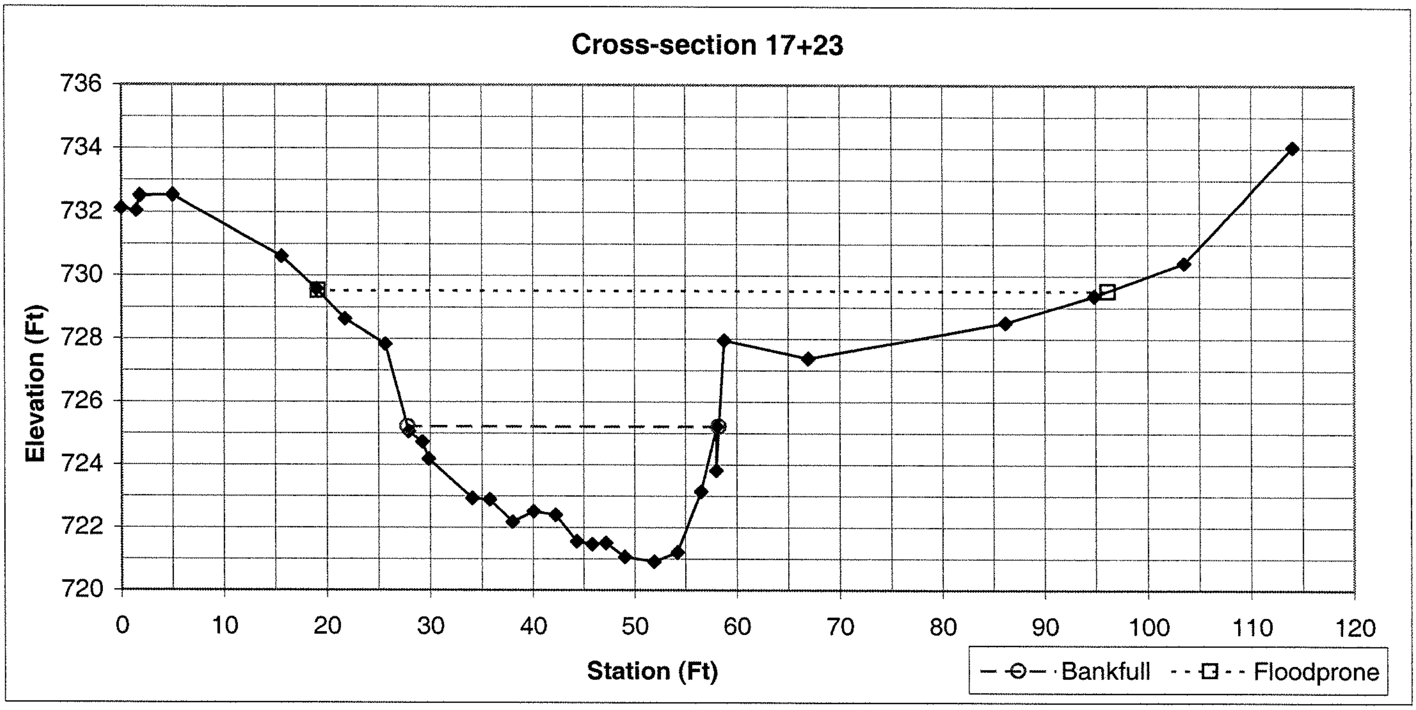
Pt #	North	East	Elevation	Note	Station
1155	838193.97	1771540.38	732.45	X9EP	0.00
1156	838193.31	1771539.05	732.40	X9BCURB	1.46
1157	838192.87	1771538.38	732.83	X9T-CURB	2.26
1158	838191.88	1771537.13	732.82	X9	3.85
1159	838188.48	1771532.68	732.06	X9LPIN	9.45
1160	838186.29	1771529.99	731.26	X9LTOB	12.91
1161	838185.18	1771528.90	726.82	X9	14.44
1162	838184.19	1771527.36	725.46	X9	16.27
1163	838181.89	1771525.12	723.04	X9	19.43
1165	838180.13	1771520.91	721.54	X9TW	23.88
1166	838178.71	1771519.38	721.56	X9	25.96
1168	838176.57	1771515.32	722.84	X9RIB	30.50
1169	838174.76	1771512.90	723.07	X9	33.53
1170	838172.44	1771510.48	724.20	X9	36.83
1171	838170.48	1771508.95	724.92	X9RBKF	39.22
1172	838167.64	1771505.05	725.14	X9	44.05
1173	838163.78	1771499.40	725.37	X9	50.88
1174	838162.20	1771497.22	725.17	X9	53.58
1175	838158.31	1771494.78	727.61	X9RTOB	57.81
1176	838147.22	1771483.91	727.15	X9	73.08
1177	838134.50	1771461.59	727.61	X9	98.66
1178	838117.60	1771440.38	730.31	X9	125.72
1179	838102.99	1771414.91	734.08	X9	154.96
1180	838089.60	1771392.32	740.09	X9	181.14

Bankfull Line	
Station	Elevation
16.97	724.92
39.22	724.92

Floodprone Line	
Station	Elevation
13.93	728.3
105.63	728.3

Benbow Park Cross-Sectional Data

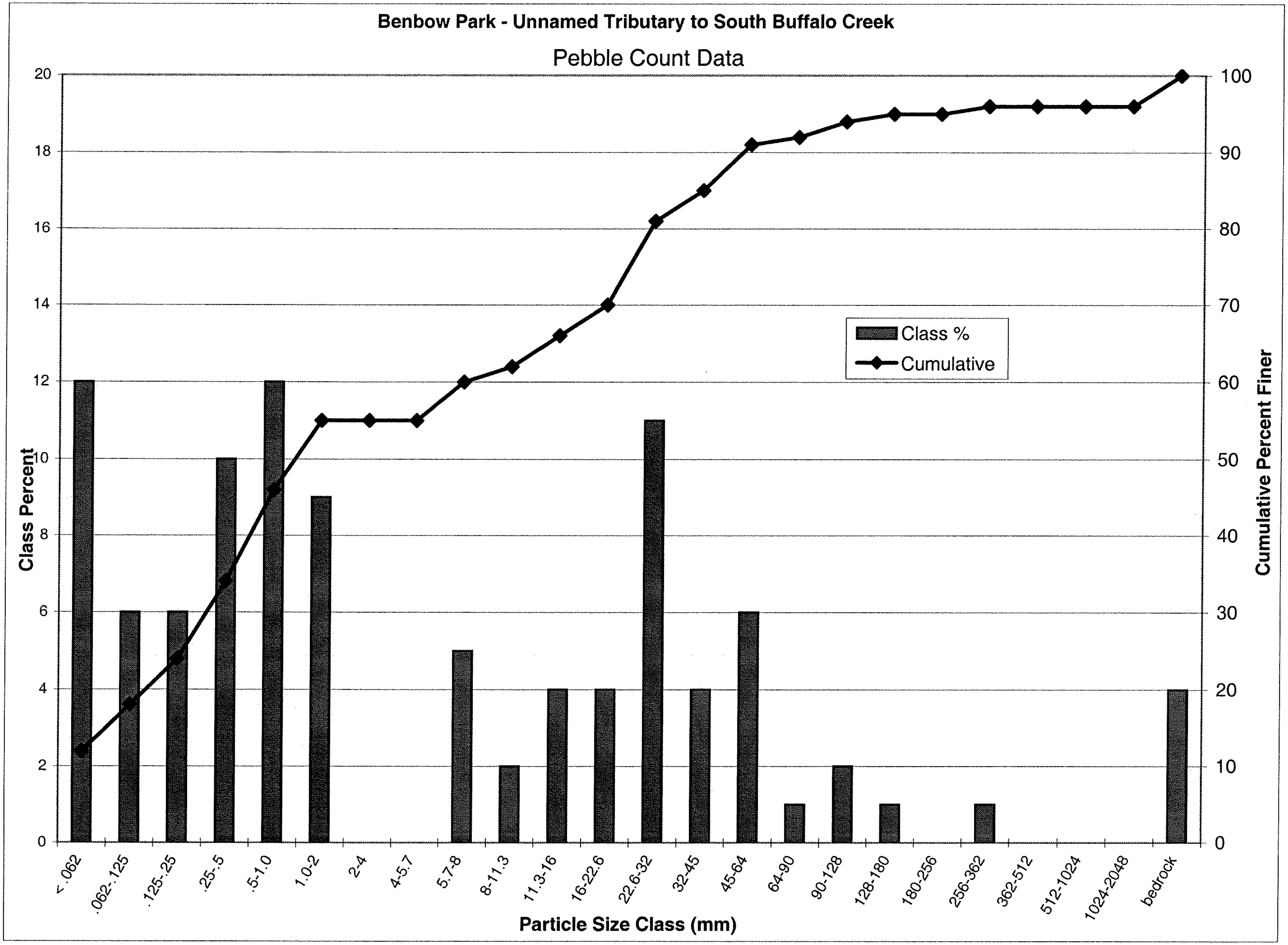
Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Pool	E5	84.9	30.5	2.8	4.3	10.9	1.6	2.5	725.21	727.95



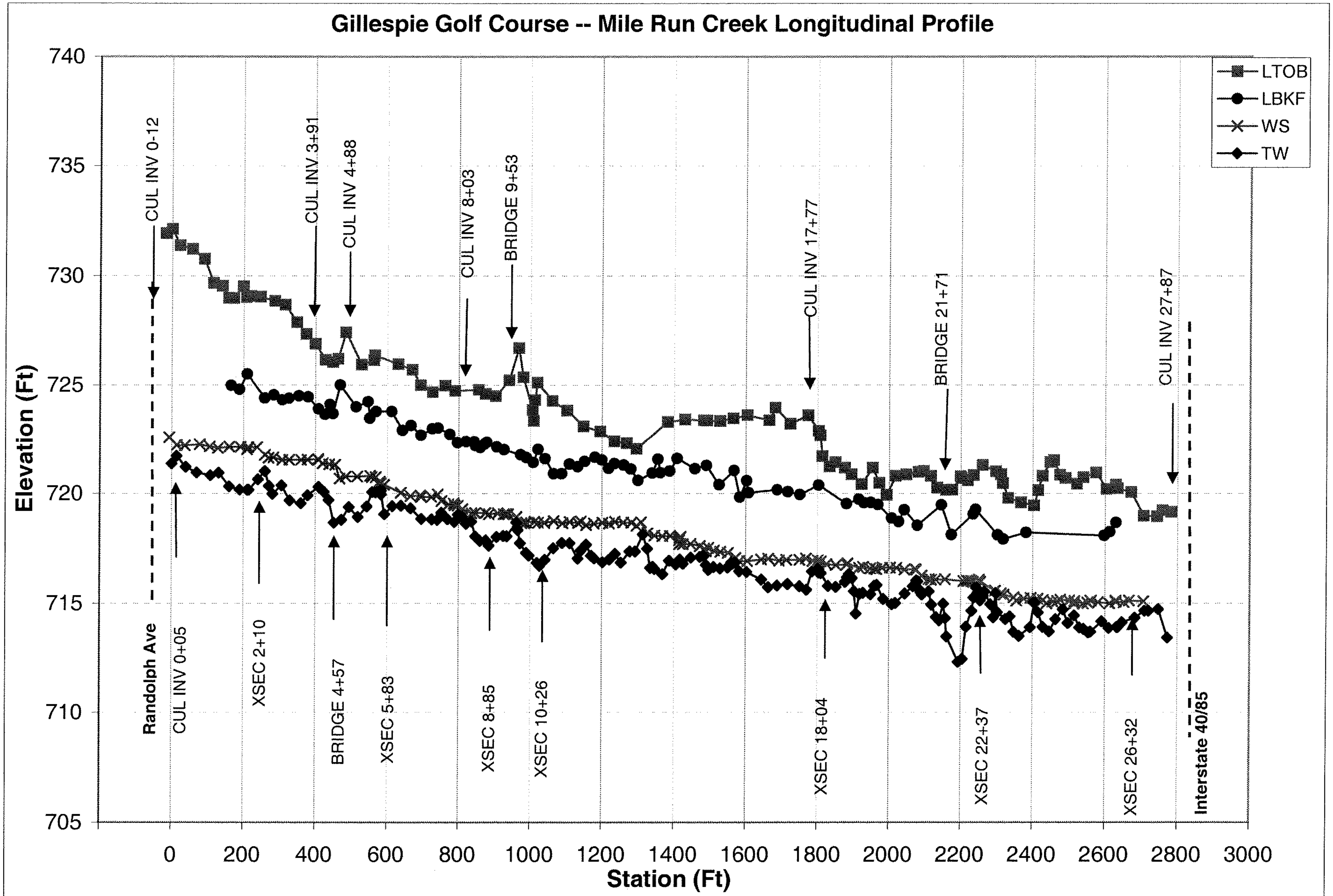
Pt #	North	East	Elevation	Note	Station
1182	838137.24	1771578.29	732.12	X10EP	0.00
1183	838136.36	1771577.09	732.04	X10-BOC	1.48
1184	838136.09	1771576.89	732.51	X10-TOC	1.82
1185	838134.06	1771574.39	732.53	X10	5.03
1186	838127.80	1771565.81	730.60	X10LPIN	15.62
1187	838125.83	1771563.05	729.57	X10LTOB	19.00
1188	838124.49	1771560.56	728.62	X10	21.77
1189	838122.44	1771557.18	727.83	X10	25.67
1190	838121.11	1771555.34	725.06	X10LBKf	27.93
1191	838120.63	1771554.05	724.72	X10	29.22
1192	838120.13	1771553.65	724.19	X10	29.85
1193	838117.73	1771550.16	722.93	X10	34.07
1194	838116.35	1771549.09	722.89	X10	35.78
1195	838115.19	1771547.18	722.17	X10	37.98
1196	838114.34	1771545.16	722.51	X10	40.07
1197	838113.41	1771543.11	722.40	X10LIB	42.23
1198	838112.26	1771541.34	721.55	X10LCH	44.33
1199	838111.08	1771540.37	721.45	X10	45.83
1200	838110.19	1771539.35	721.50	X10	47.19
1201	838108.65	1771538.24	721.06	X10	49.03
1202	838106.16	1771536.58	720.90	X10TW	51.91
1203	838104.85	1771534.65	721.21	X10	54.22
1205	838103.09	1771533.11	723.14	X10	56.54
1207	838101.91	1771532.11	725.21	X10RBKF	58.07
1206	838101.76	1771532.30	723.82	X10	58.02
1208	838100.64	1771532.25	727.95	X10RTOB	58.78
1209	838096.14	1771525.34	727.37	X10	66.96
1210	838082.93	1771511.33	728.51	X10	86.19
1211	838077.89	1771504.23	729.37	X10	94.86
1212	838072.82	1771497.15	730.41	X10	103.54
1213	838063.31	1771491.44	734.06	X10-YARD	114.05

Bankfull Line	
Station	Elevation
27.80	725.21
58.27	725.21

Floodprone Line	
Station	Elevation
19.14	729.52
96.15	729.52

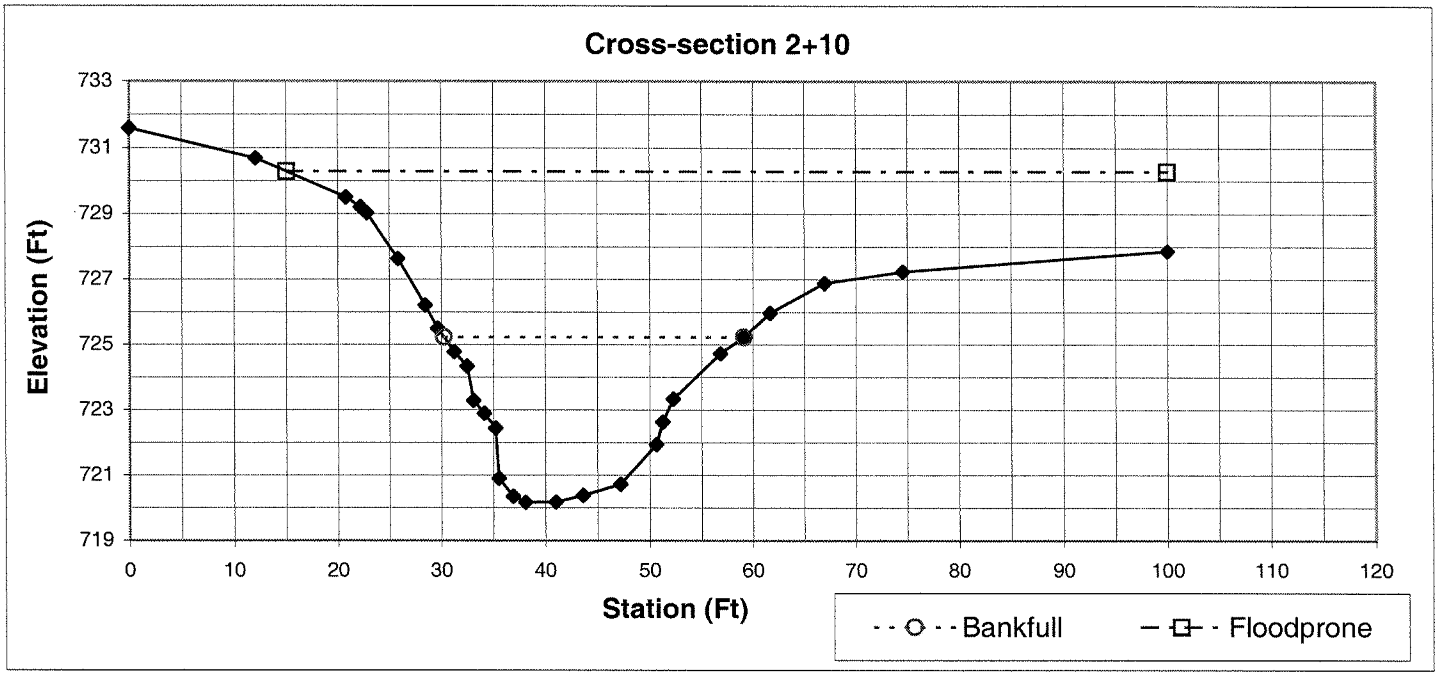

Benbow Park - Unnamed Tributary to South Buffalo Creek
Pebble Count Data
Class Percent
Cumulative Percent Finer
Class %
Cumulative
Particle Size Class (mm)
< .062
.062-.125
.125-.25
.25-.5
.5-1.0
1.0-2
2-4
4-5.7
5.7-8
8-11.3
11.3-16
16-22.6
22.6-32
32-45
45-64
64-90
90-128
128-180
180-256
256-362
362-512
512-1024
1024-2048
bedrock
0
2
4
6
8
10
12
14
16
18
20
0
10
20
30
40
50
60
70
80
90
100

Existing Condition Data
Gillespie Golf Course


Gillespie Golf Course -- Mile Run Creek Longitudinal Profile
Elevation (Ft)
Station (Ft)
LTOB
LBKF
WS
TW
740
735
730
725
720
715
710
705
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000
CUL INV 0-12
CUL INV 3+91
CUL INV 4+88
CUL INV 8+03
BRIDGE 9+53
CUL INV 17+77
BRIDGE 21+71
CUL INV 27+87
Randolph Ave
CUL INV 0+05
XSEC 2+10
BRIDGE 4+57
XSEC 5+83
XSEC 8+85
XSEC 10+26
XSEC 18+04
XSEC 22+37
XSEC 26+32
Interstate 40/85

Gillespie Golf Course Cross-Sectional Data

Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Riffle	E5	88.0	28.8	3.1	5.1	9.5	1.3	>2.9	725.23	726.88



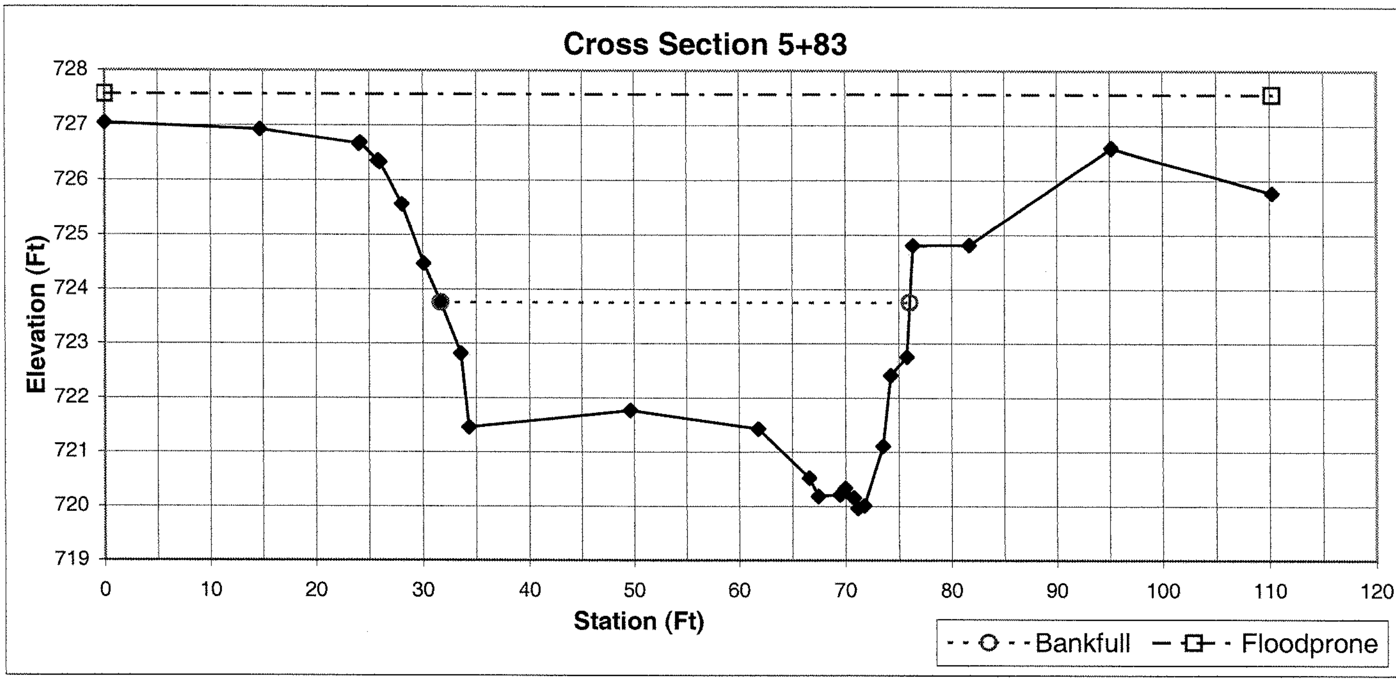
Pt #	North	East	Elevation	Note	Station
1545	836722.80	1768240.27	731.59	X1-LEYLAND	0.00
1546	836713.76	1768232.21	730.68	X1	12.10
1547	836707.80	1768225.79	729.50	X1	20.79
1548	836706.80	1768224.77	729.21	X1LPIN	22.20
1549	836706.26	1768224.46	729.02	X1LTOB	22.82
1550	836704.06	1768222.39	727.62	X1	25.84
1551	836701.71	1768221.10	726.20	X1	28.47
1552	836700.87	1768220.23	725.50	X1LBKF	29.68
1553	836699.54	1768219.35	724.78	X1	31.26
1554	836698.66	1768218.49	724.34	X1	32.48
1555	836698.15	1768218.12	723.29	X1	33.12
1556	836697.36	1768217.45	722.89	X1	34.14
1557	836696.75	1768216.50	722.44	X1	35.22
1558	836696.46	1768216.38	720.90	X1LCH	35.53
1559	836695.39	1768215.53	720.36	X1	36.89
1560	836694.62	1768214.61	720.17	X1TW	38.07
1561	836692.50	1768212.59	720.18	X1	40.99
1562	836690.70	1768210.67	720.39	X1	43.60
1563	836688.44	1768207.79	720.72	X1	47.18
1565	836685.80	1768205.53	721.95	X1	50.65
1566	836685.34	1768205.16	722.63	X1	51.25
1567	836684.64	1768204.41	723.34	X1	52.26
1568	836681.14	1768201.46	724.73	X1	56.84
1569	836679.21	1768200.23	725.23	X1RBKF	59.11
1570	836677.07	1768198.79	725.97	X1	61.68
1571	836672.76	1768195.67	726.88	X1RTOB	66.98
1572	836666.53	1768191.32	727.23	X1-FO-LINE	74.56
1573	836645.79	1768176.49	727.86	X1	99.99

Bankfull Line	
Station	Elevation
30.27	725.23
59.11	725.23

Floodprone Line	
Station	Elevation
15.06	730.28
99.99	730.28

Gillespie Golf Course Cross-Sectional Data

Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Pool	C5	102.3	44.4	2.3	3.8	19.3	1.3	>2.5	723.76	724.81



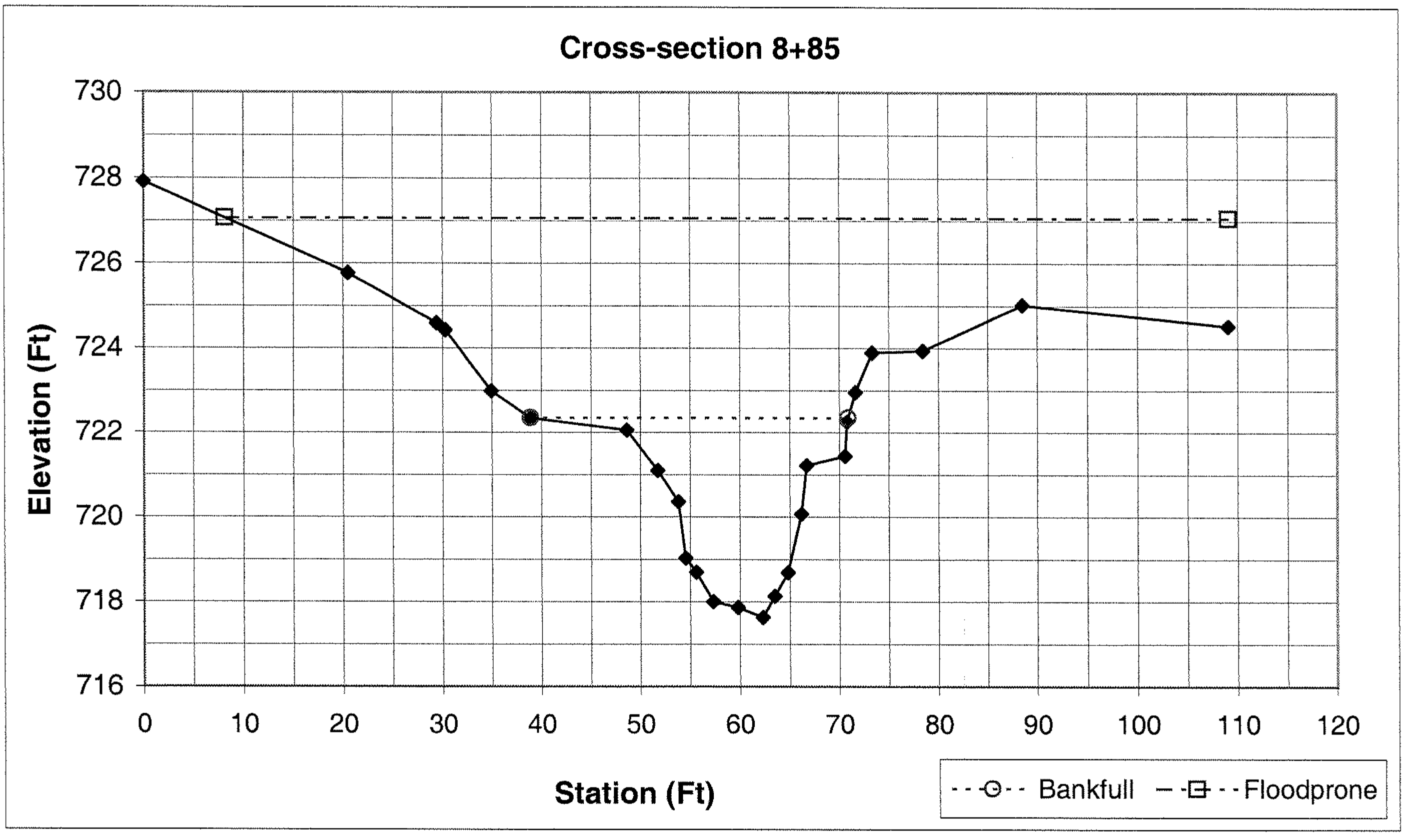
Pt #	North	East	Elevation	Note	Station
538	836541.58	1768524.20	727.04	X2	0.00
1518	836531.13	1768513.74	726.93	X2	14.73
539	836523.32	1768508.54	726.66	X2LPIN	24.06
1519	836523.29	1768508.42	726.68	X2LPIN	24.16
1520	836521.97	1768507.44	726.36	X2LTOB	25.80
540	836521.71	1768507.43	726.34	X2	26.00
1521	836519.91	1768506.39	725.56	X2	28.05
1522	836518.17	1768505.29	724.47	X2	30.09
1523	836516.85	1768504.39	723.76	X2LBKF	31.67
1524	836515.38	1768503.20	722.81	X2	33.56
1525	836514.75	1768502.76	721.45	X2	34.34
1526	836502.64	1768493.36	721.77	X2	49.65
1527	836492.96	1768485.98	721.42	X2	61.80
1528	836490.24	1768481.78	720.52	X2LCH	66.59
1529	836490.02	1768480.75	720.18	X2	67.42
1530	836488.85	1768478.94	720.21	X2	69.48
1531	836488.89	1768478.15	720.33	X2	69.97
1532	836488.62	1768477.21	720.15	X2	70.78
1533	836488.48	1768476.82	719.96	X2TW	71.14
1534	836488.11	1768476.33	720.01	X2	71.74
1536	836487.44	1768474.38	721.10	X2	73.51
1537	836487.38	1768473.33	722.42	X2	74.23
1538	836486.61	1768471.85	722.76	X2	75.78
1539	836486.44	1768471.18	724.81	X2RTOB	76.34
1540	836481.17	1768469.12	724.81	X2-FO-LINE	81.70
1541	836470.39	1768460.95	726.59	X2	95.20
1542	836457.42	1768453.01	725.78	X2	110.23

Bankfull Line	
Station	Elevation
31.67	723.76
76.05	723.76

Floodprone Line	
Station	Elevation
0	727.57
110.23	727.57

Gillespie Golf Course Cross-Sectional Data

Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Riffle	C5	61.5	32.0	1.9	4.7	16.6	1.3	>3.2	722.35	723.89



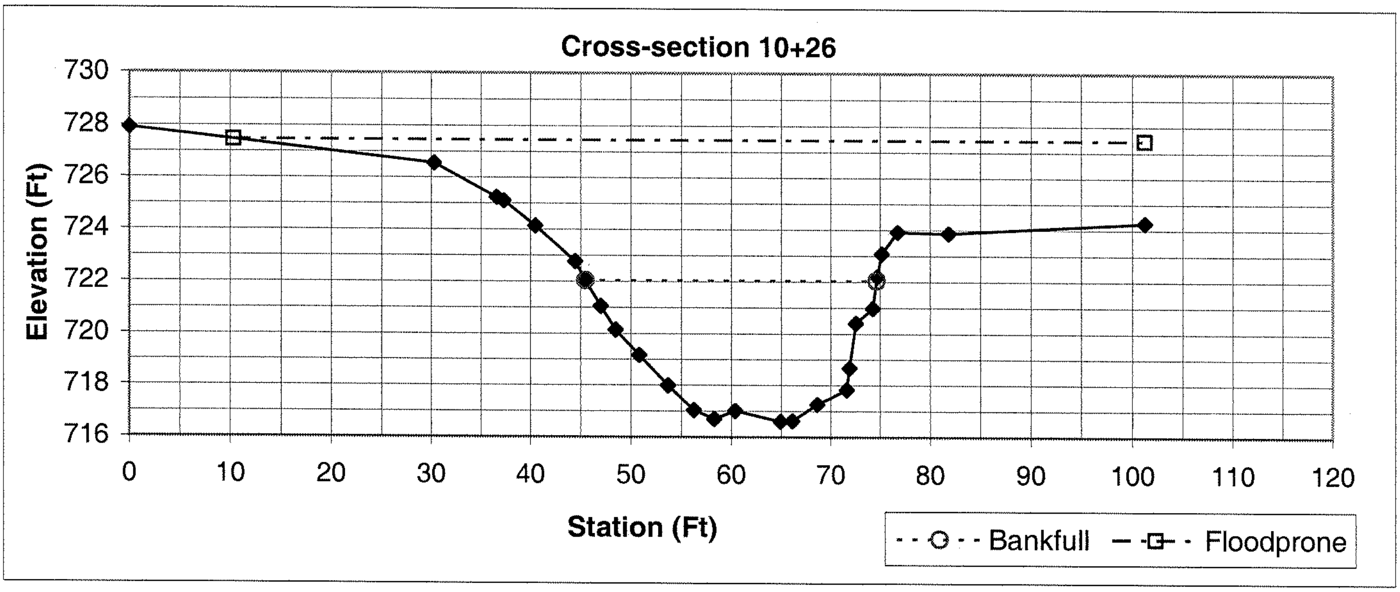
Pt #	North	East	Elevation	Note	Station
1492	836418.70	1768750.82	727.92	X3	0.00
1493	836398.81	1768745.96	725.77	X3	20.47
1494	836390.17	1768743.67	724.59	X3LTOB	29.41
1495	836389.31	1768743.38	724.42	X3LPIN	30.31
1496	836384.79	1768742.39	722.98	X3	34.94
1497	836380.78	1768742.15	722.35	X3LBKF	38.89
1498	836371.08	1768740.70	722.06	X3	48.64
1499	836367.97	1768740.40	721.10	X3	51.74
1500	836365.92	1768739.93	720.37	X3	53.84
1501	836365.30	1768739.51	719.03	X3LCH	54.54
1502	836364.25	1768739.34	718.70	X3	55.60
1503	836362.69	1768738.54	718.00	X3	57.31
1504	836360.25	1768738.09	717.86	X3	59.78
1505	836357.69	1768738.04	717.63	X3TW	62.28
1506	836356.58	1768737.50	718.13	X3	63.49
1507	836355.21	1768737.56	718.69	X3	64.80
1509	836353.83	1768737.37	720.07	X3	66.19
1510	836353.37	1768737.16	721.23	X3	66.68
1511	836349.63	1768736.11	721.45	X3	70.57
1512	836349.38	1768736.28	722.26	X3RBKF	70.77
1513	836348.47	1768736.44	722.95	X3	71.61
1514	836346.73	1768736.47	723.89	X3RTOB	73.29
1515	836341.81	1768734.94	723.94	X3-FO-LINE	78.44
1516	836332.09	1768732.33	725.02	X3	88.50
1517	836312.99	1768724.02	724.52	X3	109.05

Bankfull Line	
Station	Elevation
38.89	722.35
70.88	722.35

Floodprone Line	
Station	Elevation
8.12	727.07
109.05	727.07

Gillespie Golf Course Cross-Sectional Data

Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Pool	E5	112.8	29.2	3.9	5.4	7.5	1.3	>3.1	722.03	723.92



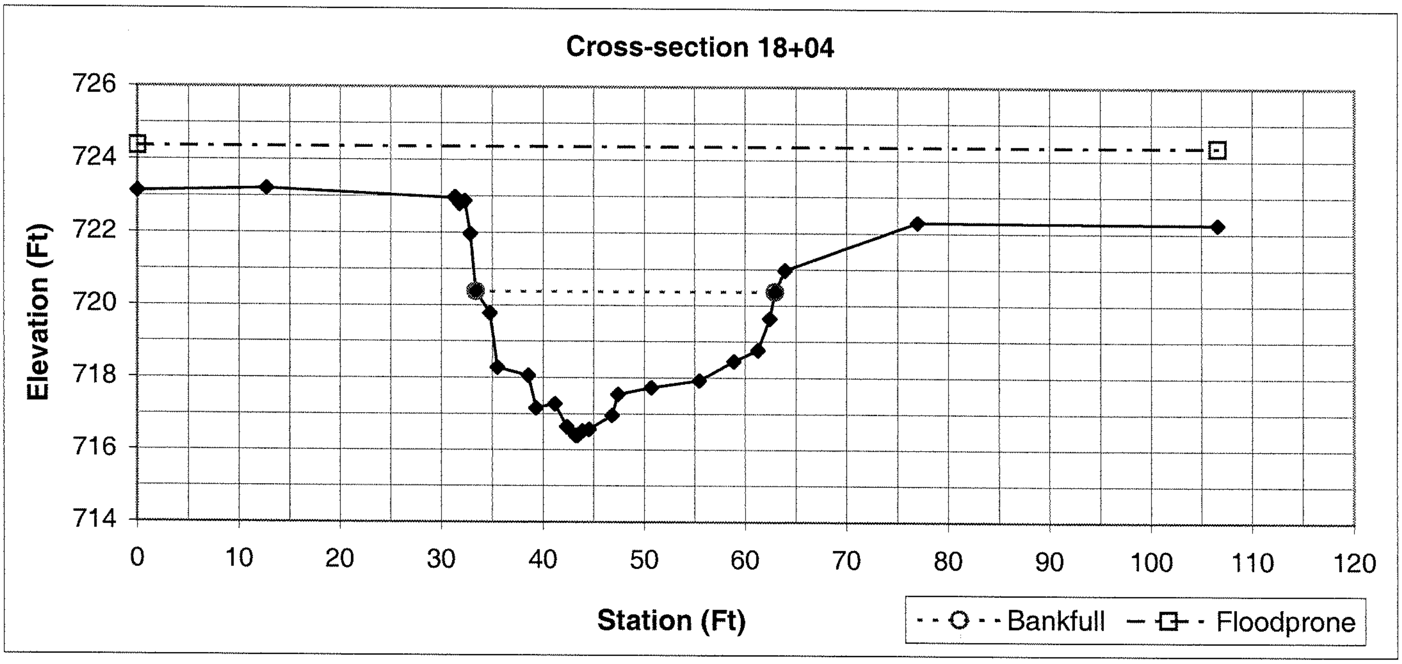
Pt #	North	East	Elevation	Note	Station
1459	836393.28	1768888.19	727.92	X4-CART-PATH	0.00
1460	836364.15	1768879.93	726.55	X4	30.28
1461	836358.10	1768878.10	725.24	X4LPIN	36.59
1462	836357.34	1768878.24	725.10	X4LTOB	37.29
1463	836354.35	1768877.16	724.14	X4	40.46
1464	836350.40	1768876.48	722.76	X4	44.46
1465	836349.39	1768876.27	722.03	X4LBKF	45.48
1466	836347.95	1768875.86	721.04	X4	46.98
1467	836346.45	1768875.65	720.14	X4	48.48
1468	836344.23	1768874.87	719.16	X4	50.83
1470	836341.47	1768874.11	717.99	X4	53.70
1471	836339.00	1768873.43	717.04	X4	56.25
1472	836337.06	1768872.81	716.70	X4TW	58.29
1473	836335.13	1768871.93	717.02	X4	60.38
1474	836330.67	1768871.02	716.61	X4	64.93
1475	836329.48	1768870.79	716.63	X4	66.14
1476	836327.06	1768870.08	717.26	X4	68.66
1477	836324.09	1768869.66	717.83	X4	71.64
1478	836323.80	1768869.74	718.67	X4RCH	71.89
1479	836323.18	1768869.52	720.41	X4	72.55
1480	836321.55	1768869.04	720.97	X4	74.25
1481	836321.07	1768869.08	722.20	X4	74.70
1482	836320.62	1768868.96	723.08	X4	75.17
1483	836319.10	1768868.39	723.92	X4RTOB	76.78
1484	836314.26	1768866.82	723.86	X4FO-LINE	81.86
1485	836295.47	1768862.11	724.27	X4	101.23

Bankfull Line	
Station	Elevation
45.48	722.03
74.64	722.03

Floodprone Line	
Station	Elevation
10.32	727.45
101.23	727.45

Gillespie Golf Course Cross-Sectional Data

Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Riffle	E5	73.3	29.6	2.5	4.0	11.9	1.1	>3.6	720.38	720.97



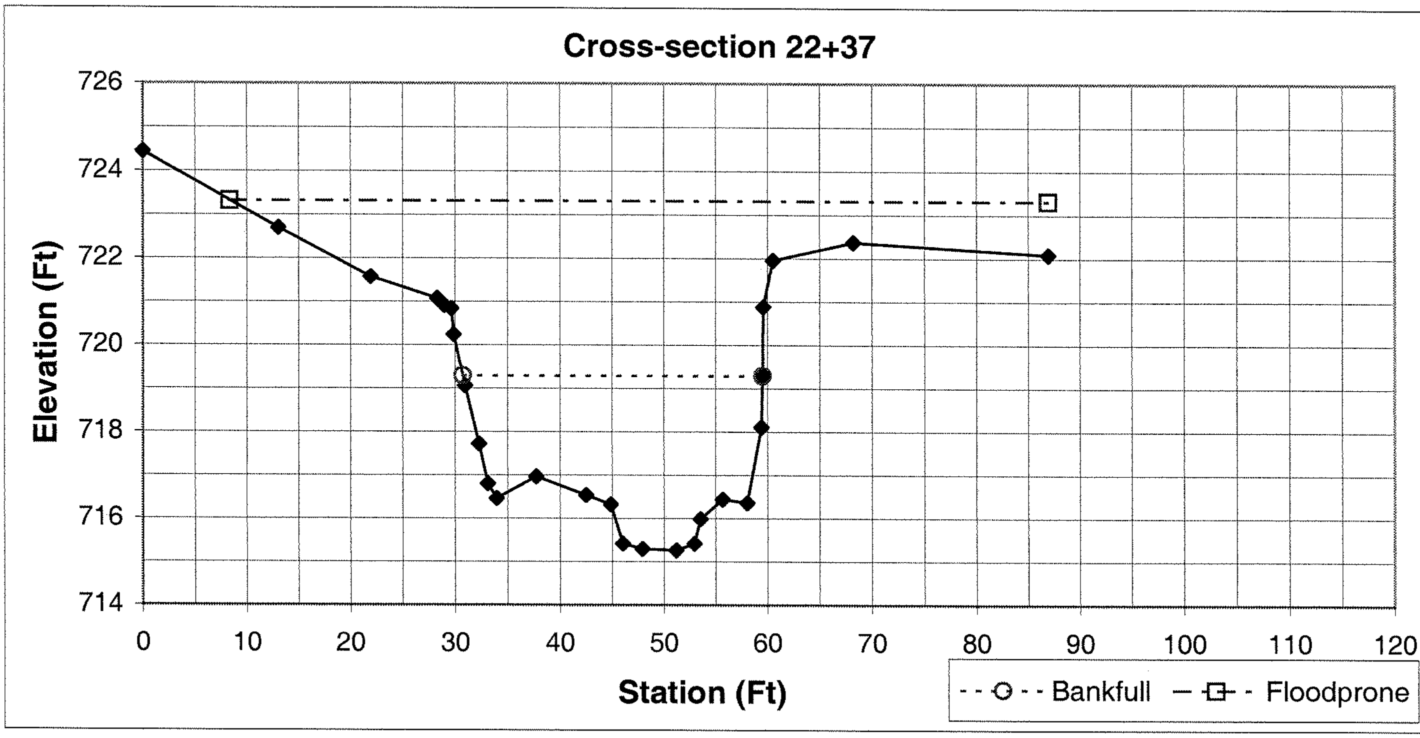
Pt #	North	East	Elevation	Note	Station
1322	836219.99	1769619.82	723.14	X5	0.00
1323	836208.98	1769613.53	723.22	X5-TREEL	12.68
1352	836192.92	1769604.01	722.95	X5LPIN	31.35
1324	836192.92	1769604.01	722.98	X5-LPIN	31.35
1457	836192.38	1769604.07	722.80	X5LPIN	31.78
1325	836192.09	1769603.53	722.87	X5LTOB	32.31
1326	836191.85	1769602.89	721.97	X5	32.84
1327	836191.26	1769602.83	720.38	X5-LBKF	33.38
1328	836190.11	1769602.03	719.77	X5	34.77
1329	836189.61	1769601.43	718.27	X5	35.51
1330	836187.17	1769599.62	718.05	X5	38.54
1331	836186.83	1769598.68	717.15	X5	39.31
1332	836185.20	1769597.77	717.28	X5	41.17
1333	836184.31	1769596.93	716.63	X5-LCH	42.37
1334	836183.73	1769596.26	716.39	X5-	43.21
1335	836183.63	1769596.06	716.39	X5-TW	43.40
1336	836183.27	1769595.72	716.52	X5	43.88
1337	836182.75	1769595.29	716.56	X5	44.55
1339	836180.46	1769594.69	716.95	X5	46.82
1340	836179.96	1769594.39	717.54	X5	47.41
1341	836177.34	1769592.36	717.73	X5	50.69
1342	836173.60	1769589.31	717.92	X5	55.47
1343	836170.13	1769588.44	718.45	X5	58.90
1344	836168.33	1769586.82	718.76	X5	61.27
1345	836167.19	1769586.46	719.63	X5-RBKF	62.43
1346	836166.70	1769586.28	720.38	X5	62.95
1347	836165.75	1769585.98	720.97	X5-RTOB	63.92
1348	836154.25	1769579.75	722.31	X5	76.99
1349	836128.56	1769565.00	722.25	X5	106.60

Bankfull Line	
Station	Elevation
33.38	720.38
62.95	720.38

Floodprone Line	
Station	Elevation
0	724.36
106.6	724.36

Gillespie Golf Course Cross-Sectional Data

Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Run	E5	83.8	28.8	2.9	4.0	9.9	1.4	>2.7	719.29	720.83



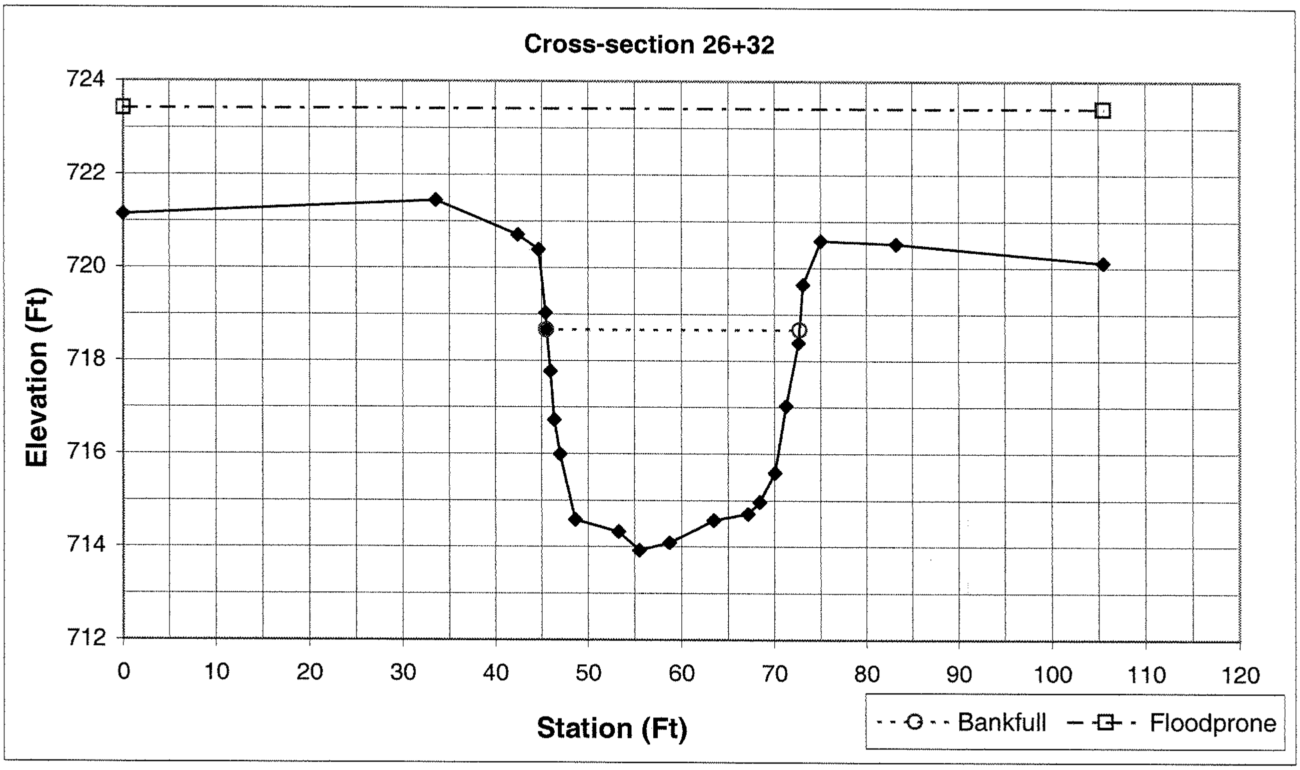
Pt #	North	East	Elevation	Note	Station
1228	836054.29	1769988.66	724.44	X6	0.00
1229	836043.29	1769981.56	722.70	X6	13.04
1230	836035.85	1769976.61	721.57	X6	21.94
1231	836030.90	1769972.63	721.07	X6-LPIN	28.30
1232	836030.37	1769972.23	720.91	X6	28.97
1233	836029.71	1769971.93	720.83	X6-LTOB	29.67
1234	836029.60	1769971.72	720.24	X6	29.88
1235	836029.58	1769970.03	719.06	X6-LBKF	30.94
1236	836028.75	1769968.90	717.72	X6	32.30
1237	836027.65	1769968.99	716.80	X6	33.10
1238	836027.13	1769968.30	716.46	X6	33.94
1239	836023.86	1769966.33	716.96	X6	37.73
1240	836020.09	1769963.40	716.53	X6	42.50
1241	836018.06	1769962.11	716.32	X6	44.89
1243	836016.81	1769961.82	715.42	X6	46.06
1244	836015.66	1769960.25	715.29	X6	47.93
1245	836013.26	1769958.00	715.26	X6-TW	51.21
1246	836011.78	1769957.01	715.42	X6	52.98
1247	836011.37	1769956.61	715.98	X6-RCH	53.55
1248	836010.01	1769954.88	716.44	X6	55.69
1249	836008.42	1769953.05	716.36	X6	58.07
1250	836007.44	1769952.12	718.10	X6	59.42
1251	836007.52	1769951.80	719.29	X6-RBKF	59.55
1252	836007.42	1769951.83	720.88	X6-	59.61
1253	836006.80	1769951.14	721.96	X6-RTOB	60.52
1254	836001.96	1769944.83	722.37	X6-	68.22
1255	835985.84	1769935.07	722.09	X6-	86.93

Bankfull Line	
Station	Elevation
30.74	719.29
59.55	719.29

Floodprone Line	
Station	Elevation
8.37	723.32
86.93	723.32

Gillespie Golf Course Cross-Sectional Data

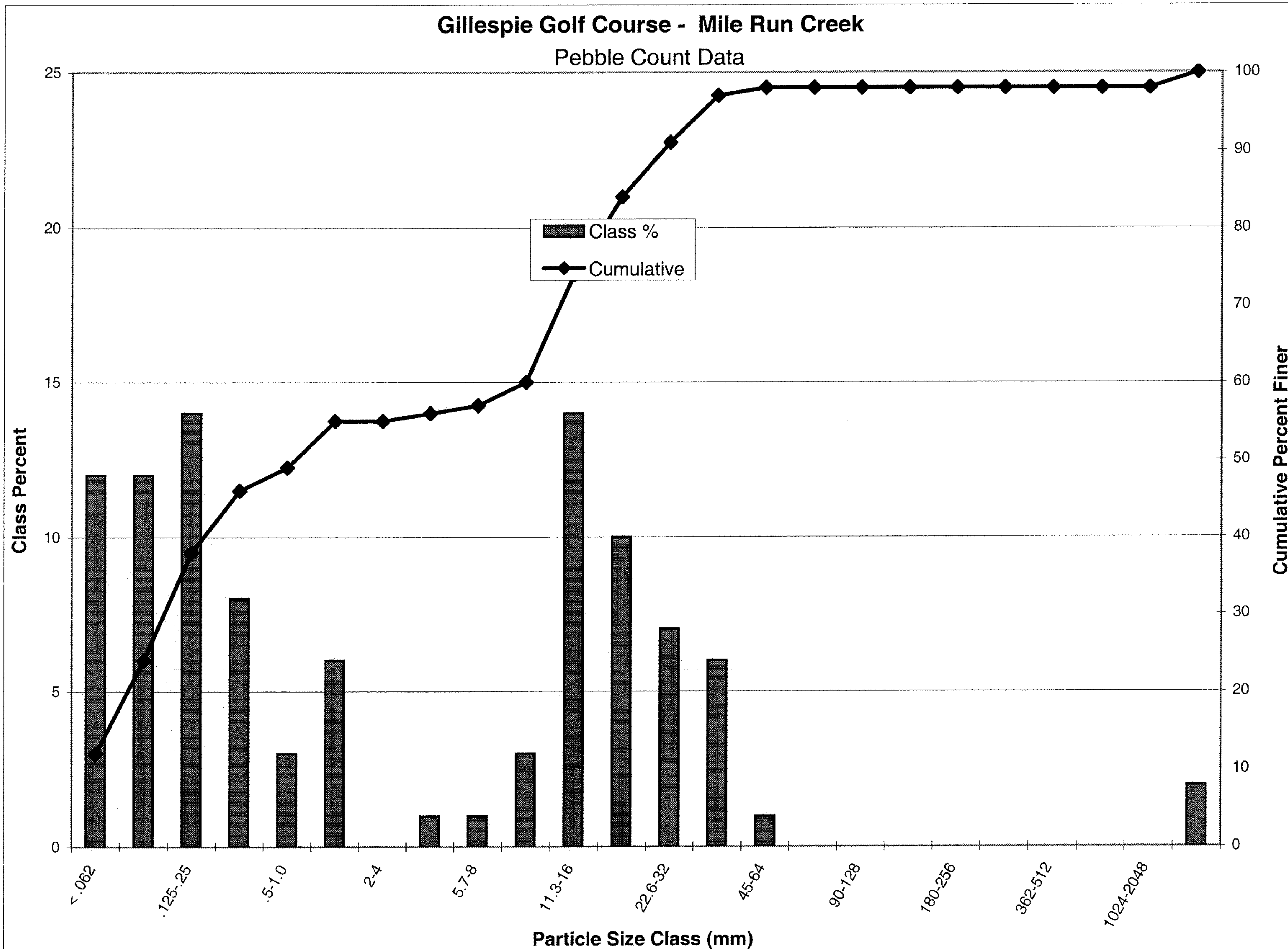
Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Run	E5	102.6	27.2	3.8	4.8	7.2	1.4	>3.9	718.67	720.39



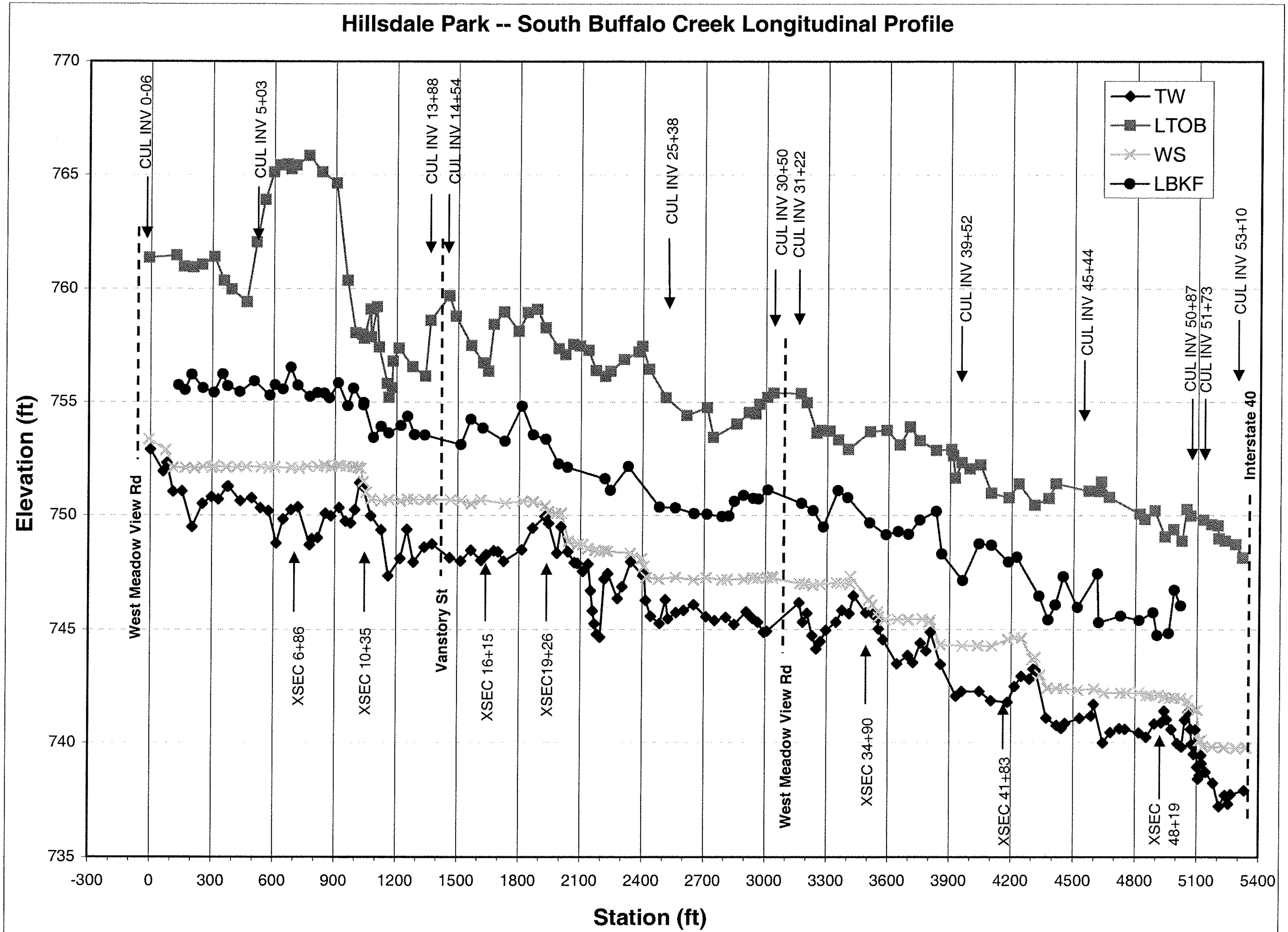
Pt #	North	East	Elevation	Note	Station
1199	835977.51	1770310.39	721.14	X7	0.00
1200	835946.61	1770296.49	721.45	X7	33.57
1201	835938.07	1770294.11	720.70	X7	42.43
1202	835935.76	1770294.05	720.39	X7LTOB	44.66
1203	835934.96	1770294.00	719.03	X7	45.44
1204	835934.83	1770294.17	718.67	X7LBKF	45.52
1205	835934.45	1770293.91	717.77	X7	45.96
1206	835934.08	1770293.76	716.72	X7	46.36
1207	835933.47	1770293.57	715.98	X7	46.99
1209	835931.92	1770293.10	714.58	X7	48.62
1210	835927.32	1770292.11	714.33	X7	53.31
1211	835925.17	1770291.64	713.92	X7TW	55.50
1212	835922.06	1770290.79	714.08	X7	58.73
1213	835917.83	1770288.38	714.57	X7	63.47
1214	835914.16	1770287.84	714.71	X7	67.14
1215	835912.97	1770287.37	714.97	X7RCH	68.41
1216	835911.32	1770287.16	715.59	X7	70.06
1217	835910.34	1770286.16	717.03	X7	71.28
1218	835908.88	1770286.43	718.39	X7	72.61
1219	835908.34	1770286.54	719.64	X7	73.10
1220	835906.41	1770286.19	720.58	X7RTOB	75.04
1221	835898.55	1770283.77	720.51	X7	83.26
1222	835876.24	1770280.73	720.11	X7	105.53

Bankfull Line	
Station	Elevation
45.52	718.67
72.72	718.67

Floodprone Line	
Station	Elevation
0	723.42
105.53	723.42


Gillespie Golf Course - Mile Run Creek
Pebble Count Data
Class %
Cumulative
Class Percent
Cumulative Percent Finer
Particle Size Class (mm)
0
5
10
15
20
25
0
10
20
30
40
50
60
70
80
90
100
< .062
.125-.25
.5-1.0
2-4
5.7-8
11.3-16
22.6-32
45-64
90-128
180-256
362-512
1024-2048

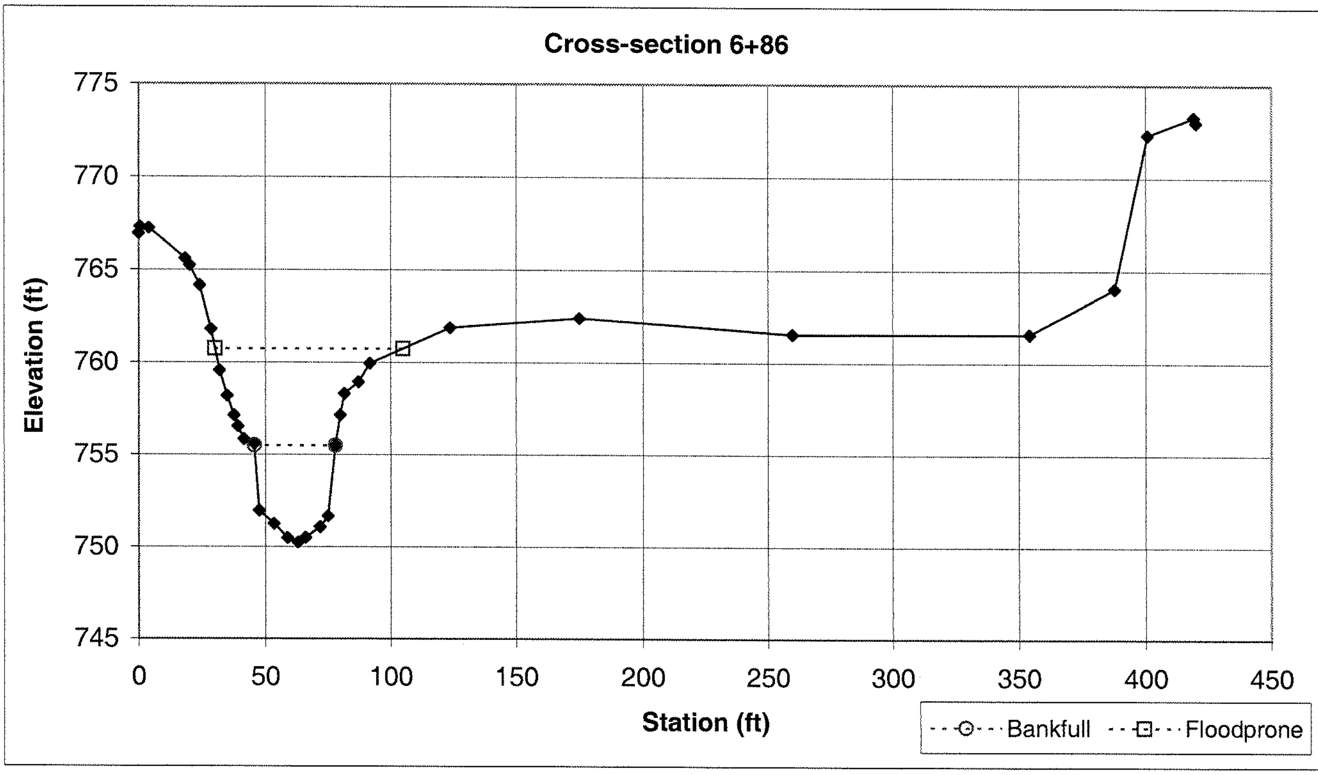
Existing Condition Data
Hillsdale Park



Hillsdale Park -- South Buffalo Creek Longitudinal Profile
Elevation (ft)
Station (ft)
TW
LTOB
WS
LBKF
CUL INV 0-06
CUL INV 5+03
CUL INV 13+88
CUL INV 14+54
CUL INV 25+38
CUL INV 30+50
CUL INV 31+22
CUL INV 39+52
CUL INV 45+44
CUL INV 50+87
CUL INV 51+73
CUL INV 53+10
Interstate 40
West Meadow View Rd
Vanstory St
West Meadow View Rd
XSEC 6+86
XSEC 10+35
XSEC 16+15
XSEC19+26
XSEC 34+90
XSEC 41+83
XSEC 48+19
770
765
760
755
750
745
740
735
-300
0
300
600
900
1200
1500
1800
2100
2400
2700
3000
3300
3600
3900
4200
4500
4800
5100
5400

Hillsdale Park Cross-Sectional Data

Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Pool	E4	134.0	32.3	4.2	5.3	7.8	1.8	2.3	755.49	759.94



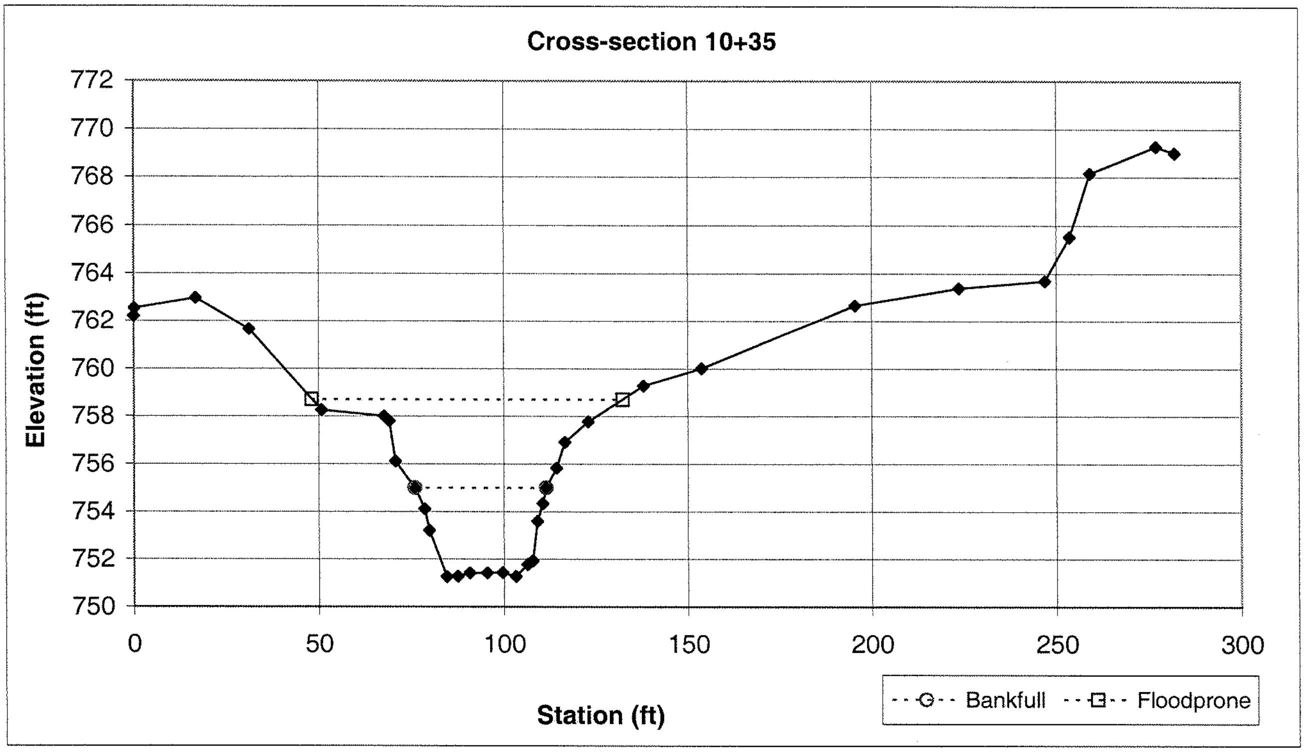
Pt #	North	East	Elevation	Note	Station
132	836134.59	1753428.43	766.95	X1EP	0.00
133	836134.25	1753428.07	767.31	X1-T-CURB	0.50
134	836130.78	1753427.46	767.24	X1	4.02
135	836116.50	1753428.16	765.61	X1-LPIN	18.33
136	836114.69	1753428.03	765.25	X1LTOB	20.14
137	836110.86	1753427.61	764.17	X1	23.99
138	836106.45	1753428.34	761.78	X1	28.45
139	836103.15	1753427.95	759.56	X1	31.78
140	836100.05	1753427.68	758.17	X1	34.90
141	836097.33	1753428.02	757.12	X1	37.63
143	836095.84	1753428.40	756.53	X1LBKF	39.17
144	836093.59	1753428.82	755.84	X1	41.47
145	836089.51	1753428.95	755.57	X1	45.55
146	836087.59	1753429.44	751.95	X1LCH	47.53
147	836081.70	1753430.39	751.24	X1	53.49
148	836076.41	1753429.36	750.47	X1	58.88
149	836072.43	1753430.20	750.24	X1TW	62.95
150	836069.41	1753429.96	750.49	X1	65.98
151	836063.76	1753429.06	751.07	X1	71.70
152	836060.49	1753428.96	751.66	X1	74.97
154	836057.54	1753428.92	755.49	X1RBKF	77.92
155	836055.71	1753429.01	757.14	X1	79.75
156	836054.01	1753429.24	758.30	X1	81.47
157	836048.44	1753428.82	758.93	X1	87.05
158	836043.83	1753429.51	759.94	X1RTOB	91.72
159	836011.78	1753431.19	761.87	X1	123.81
160	835960.64	1753433.16	762.42	X1	174.99
161	835875.97	1753427.75	761.54	X1	259.83
162	835781.54	1753428.78	761.56	X1	354.27
163	835748.31	1753425.42	764.04	X1	387.67
164	835736.12	1753430.32	772.31	X1	400.80
165	835719.10	1753436.99	773.29	X1	419.08
166	835718.36	1753437.31	772.98	X1EP	419.89

Bankfull Line	
Station	Elevation
45.59	755.49
77.92	755.49

Floodprone Line	
Station	Elevation
30.02	760.74
104.98	760.74

Hillsdale Park Cross-Sectional Data

Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Riffle	~~E4~~ C4	103.2	35.5	2.9	3.7	12.2	1.7	2.4	754.99	757.77



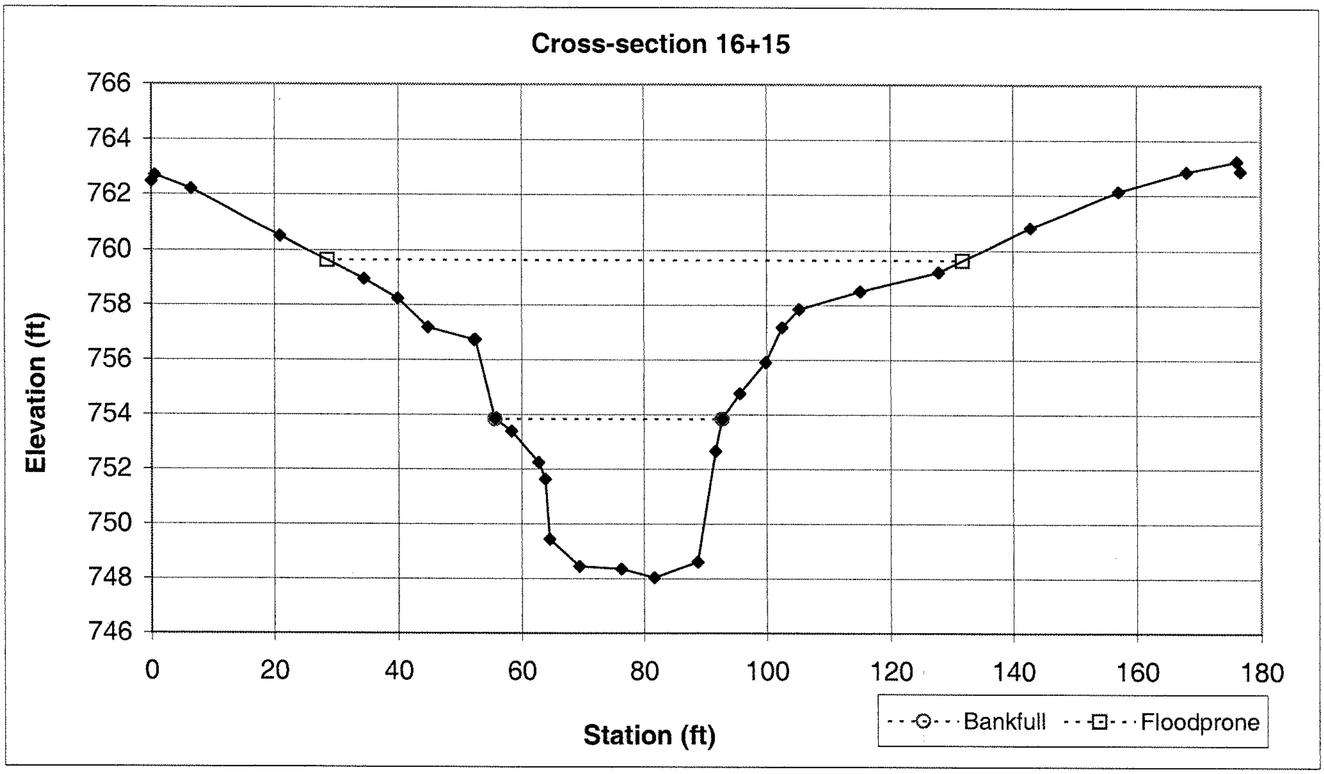
Pt #	North	East	Elevation	Note	Station
292	835981.85	1753779.73	762.20	X2-EPAV	0.00
293	835981.64	1753779.75	762.52	X2-TCURB	0.21
294	835968.73	1753769.43	762.96	X2	16.73
295	835959.03	1753758.75	761.65	X2	31.16
296	835946.66	1753743.51	758.26	X2	50.79
297	835935.70	1753730.63	758.01	X2-LPIN	67.70
298	835934.79	1753729.58	757.81	X2-LTOB	69.09
299	835933.54	1753728.46	756.11	X2	70.77
300	835930.25	1753724.31	754.97	X2-LBKF	76.06
301	835929.15	1753721.97	754.10	X2	78.65
302	835928.30	1753721.15	753.21	X2	79.83
304	835924.91	1753717.82	751.27	X2	84.58
305	835923.00	1753715.62	751.27	X2	87.50
306	835920.94	1753713.16	751.43	X2	90.71
307	835917.39	1753710.08	751.42	X2	95.40
308	835914.30	1753707.28	751.44	X2	99.58
309	835911.81	1753704.68	751.27	X2-TW	103.17
310	835909.50	1753702.49	751.78	X2	106.36
311	835908.07	1753702.04	751.94	X2-RCH	107.86
312	835906.96	1753701.63	753.60	X2	109.04
313	835905.79	1753700.70	754.33	X2	110.54
314	835904.97	1753700.21	754.99	X2-RBKF	111.49
315	835903.09	1753698.19	755.83	X2	114.25
316	835901.26	1753696.84	756.92	X2	116.52
317	835896.57	1753692.53	757.77	X2-RTOB	122.89
318	835886.31	1753681.51	759.28	X2	137.95
319	835875.61	1753669.74	760.01	X2	153.85
320	835846.24	1753640.21	762.64	X2	195.51
321	835826.20	1753620.36	763.37	X2	223.71
322	835809.55	1753604.25	763.68	X2	246.88
323	835802.85	1753603.39	765.52	X2	253.64
324	835797.26	1753603.50	768.16	X2	259.23
325	835779.34	1753603.15	769.26	X2-TCURB	277.15
326	835778.17	1753598.19	769.00	X2-EPAV	282.24

Bankfull Line	
Station	Elevation
75.97	754.99
111.49	754.99

Floodprone Line	
Station	Elevation
48.18	758.71
132.28	758.71

Hillsdale Park Cross-Sectional Data

Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Pool	E4	150.0	37.1	4.0	5.8	9.2	1.5	2.8	753.83	756.73



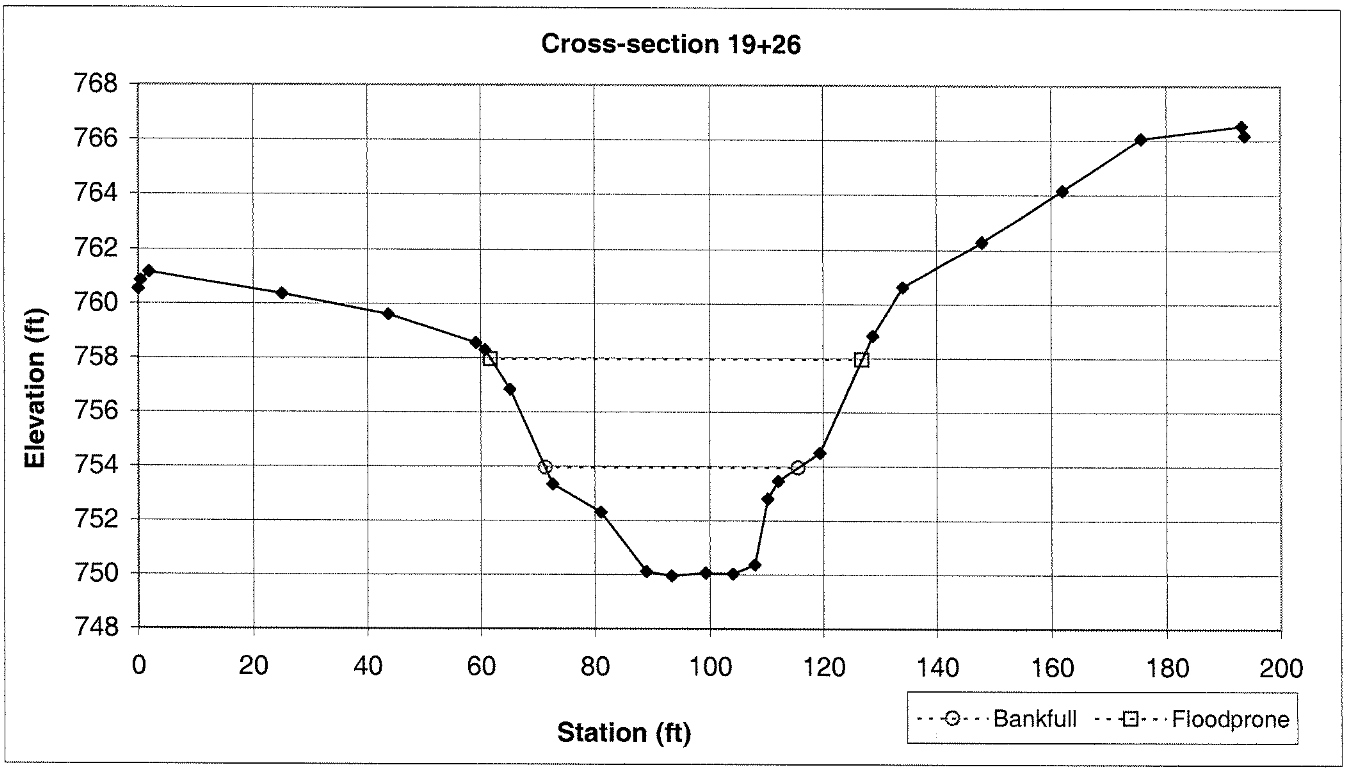
Pt #	North	East	Elevation	Note	Station
411	835888.64	1754261.46	762.47195	X3-EPAV	0.00
412	835888.22	1754261.84	762.69995	X3-TCURB	0.57
413	835882.34	1754262.31	762.20695	X3	6.46
414	835867.94	1754261.42	760.50195	X3	20.89
415	835854.38	1754260.58	758.95095	X3	34.48
416	835848.98	1754261.17	758.24395	X3	39.91
417	835844.10	1754261.29	757.18695	X3	44.78
418	835836.65	1754261.53	756.73095	X3-LTOB	52.24
419	835836.64	1754261.32	756.73995	X3-LPIN	52.45
420	835833.54	1754260.67	753.83795	X3-LBKF	55.62
421	835830.82	1754260.68	753.39095	X3	58.34
422	835826.38	1754260.27	752.25195	X3	62.79
423	835825.30	1754260.39	751.62495	X3	63.89
424	835824.73	1754260.06	749.43495	X3LCH	64.55
425	835819.86	1754259.99	748.44995	X3	69.42
426	835813.05	1754259.08	748.35495	X3	76.29
427	835807.69	1754258.34	748.04195	X3-TW	81.70
428	835800.62	1754257.72	748.61795	X3	88.80
430	835797.75	1754257.16	752.65695	X3	91.72
431	835796.74	1754256.81	753.83395	X3-RBKF	92.79
432	835793.91	1754257.03	754.76495	X3	95.63
433	835789.95	1754255.61	755.90595	X3	99.83
434	835787.29	1754255.49	757.18395	X3	102.50
435	835784.60	1754255.52	757.85495	X3-RTOB	105.19
436	835775.36	1754251.99	758.51095	X3	115.08
437	835763.81	1754246.57	759.20795	X3	127.84
438	835748.85	1754245.37	760.82395	X3	142.85
439	835734.85	1754242.64	762.12595	X3	157.11
440	835724.06	1754240.80	762.85395	X3	168.05
441	835716.05	1754239.66	763.24495	X3-TCURB	176.14
442	835715.47	1754239.67	762.88595	X3-EPAV	176.72

Bankfull Line	
Station	Elevation
55.65	753.83
92.79	753.83

Floodprone Line	
Station	Elevation
28.56	759.63
131.72	759.63

Hillsdale Park Cross-Sectional Data

Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Riffle	B4c	113.4	44.2	2.6	4.0	17.3	2.1	1.5	753.96	758.28



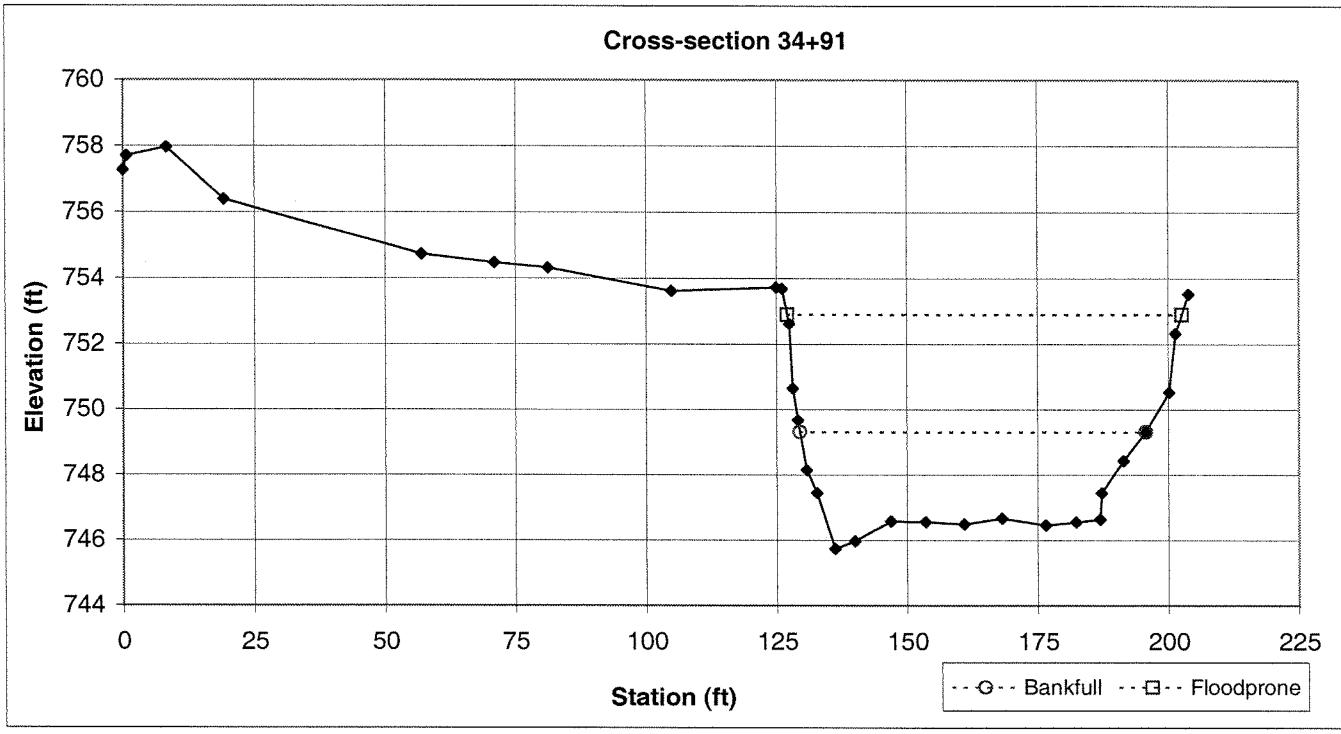
Pt #	North	East	Elevation	Note	Station
472	835844.80	1754578.73	760.53	X4-EPAV	0.00
473	835844.42	1754578.66	760.85	X4-TCURB	0.39
474	835842.99	1754578.35	761.16	X4	1.86
475	835820.61	1754572.47	760.35	X4	24.99
476	835802.28	1754568.62	759.60	X4	43.72
477	835787.26	1754565.15	758.55	X4-LPIN	59.14
478	835785.64	1754565.01	758.28	X4-LTOB	60.77
479	835781.43	1754563.75	756.83	X4	65.16
480	835773.99	1754562.53	753.34	X4-LBKF	72.70
481	835766.14	1754559.66	752.31	X4	81.06
483	835758.91	1754556.53	750.11	X4-	88.94
484	835754.58	1754555.58	749.95	X4-TW	93.37
485	835748.84	1754554.20	750.06	X4	99.27
486	835744.15	1754553.17	750.03	X4	104.08
487	835740.40	1754552.28	750.36	X4-RCH	107.93
488	835738.53	1754550.90	752.81	X4	110.26
489	835736.70	1754550.78	753.46	X4-RBKF	112.09
490	835730.59	1754546.73	754.50	X4	119.42
491	835721.23	1754546.62	758.83	X4	128.78
492	835715.99	1754547.62	760.62	X4-RTOB	134.11
493	835702.65	1754543.69	762.28	X4	148.02
494	835689.88	1754537.99	764.15	X4	162.00
495	835676.47	1754535.34	766.06	X4-PP	175.68
496	835660.98	1754527.23	766.54	X4-TCURB	193.16
497	835660.45	1754527.27	766.17	X4-EPAV	193.69

Bankfull Line	
Station	Elevation
71.37	753.96
115.60	753.96

Floodprone Line	
Station	Elevation
61.75	757.96
126.90	757.96

Hillsdale Park Cross-Sectional Data

Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Riffle	F4	166.0	66.2	2.5	3.6	26.4	2.2	1.1	749.32	753.51



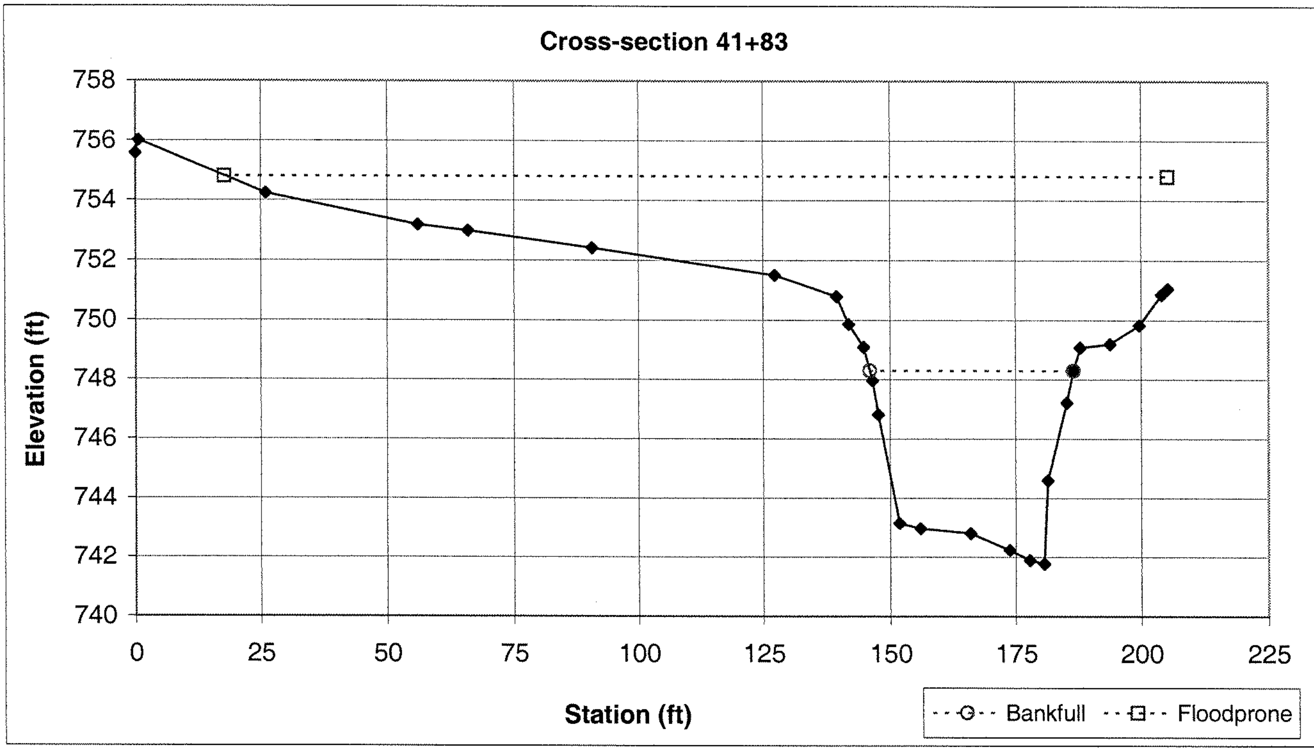
Pt #	North	East	Elevation	Note	Station
916	834690.14	1754854.54	757.26	X5-EP	0.00
917	834689.47	1754854.46	757.70	X5-T-CURB	0.68
918	834681.97	1754853.35	757.96	X5	8.26
919	834673.18	1754846.88	756.38	X5	19.18
920	834636.26	1754838.35	754.73	X5	57.07
921	834622.34	1754838.22	754.48	X5-SW	71.00
922	834612.27	1754840.00	754.32	X5-SW	81.22
923	834589.32	1754834.48	753.62	X5	104.82
924	834569.38	1754831.87	753.72	X5LPIN	124.93
925	834568.28	1754831.50	753.68	X5LTOB	126.09
926	834566.90	1754831.31	752.61	X5	127.49
927	834566.37	1754830.94	750.64	X5	128.13
928	834565.38	1754830.82	749.67	X5LBKF	129.13
929	834563.90	1754829.99	748.15	X5	130.83
930	834562.31	1754828.87	747.44	X5	132.77
932	834558.88	1754828.66	745.74	X5TW	136.21
933	834555.31	1754827.25	745.97	X5	140.05
934	834549.20	1754824.00	746.58	X5	146.96
935	834543.28	1754821.00	746.56	X5	153.60
936	834536.10	1754819.32	746.49	X5	160.97
937	834529.53	1754816.34	746.66	X5	168.19
938	834522.01	1754812.82	746.46	X5	176.49
939	834516.30	1754812.37	746.55	X5	182.22
940	834512.01	1754810.64	746.63	X5RCH	186.84
941	834511.66	1754810.64	747.44	X5	187.19
942	834507.56	1754810.00	748.44	X5	191.35
943	834503.89	1754807.71	749.32	X5RBKF	195.67
944	834499.99	1754805.49	750.52	X5	200.16
945	834498.93	1754804.89	752.30	X5	201.37
946	834497.90	1754802.56	753.51	X5RTOB-FENCE	203.93

Bankfull Line	
Station	Elevation
129.52	749.32
195.67	749.32

Floodprone Line	
Station	Elevation
127.11	752.90
202.63	752.90

Hillsdale Park Cross-Sectional Data

Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Pool	E4	193.1	40.5	4.8	6.5	8.5	1.1	>4.6	748.3	749.08



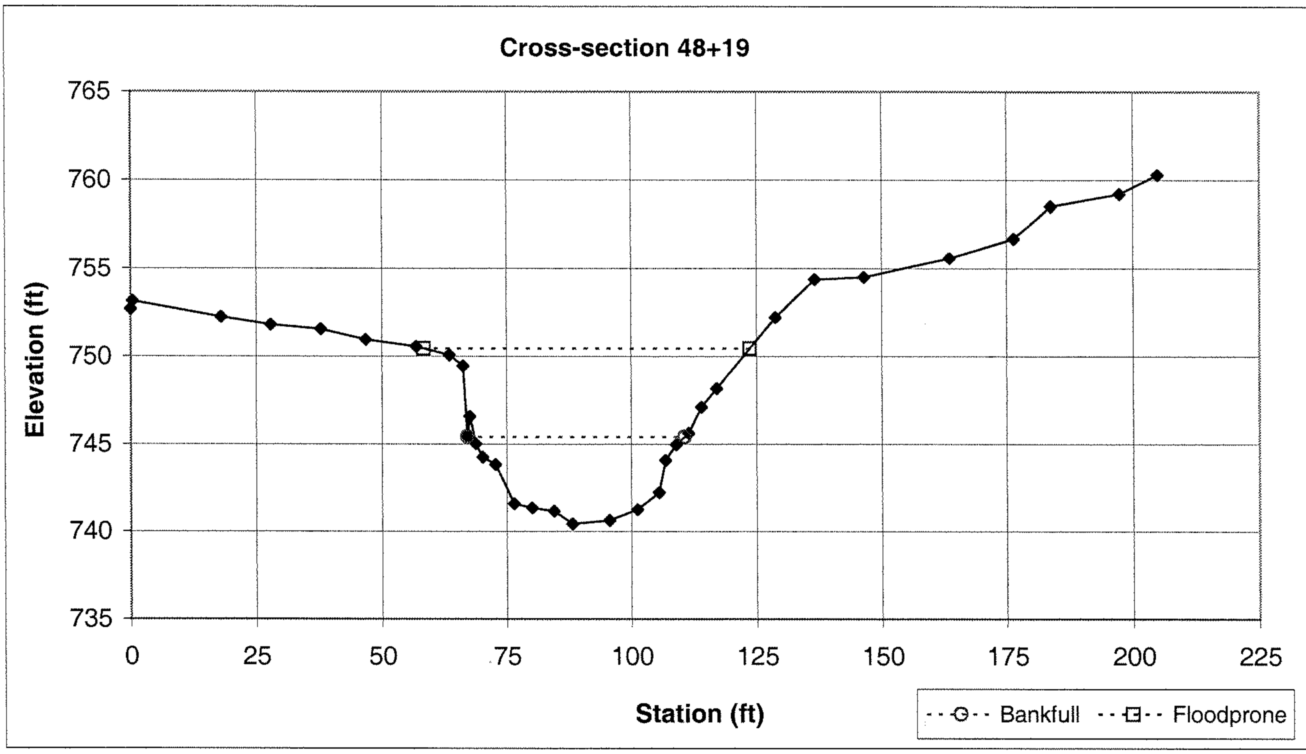
Pt #	North	East	Elevation	Note	Station
1087	834440.20	1755484.08	755.57	X6EP	0.00
1088	834439.77	1755483.64	756.01	X6T-CURB	0.62
1089	834416.75	1755472.88	754.24	X6	26.03
1090	834388.55	1755462.42	753.19	X6SW	56.11
1091	834379.40	1755458.73	753.00	X6SW	65.97
1092	834356.83	1755448.53	752.41	X6	90.74
1093	834322.92	1755434.92	751.50	X6LPIN	127.28
1094	834311.26	1755431.39	750.78	X6LTOB	139.46
1095	834309.11	1755430.31	749.86	X6	141.86
1096	834306.49	1755429.05	749.09	X6	144.77
1097	834304.73	1755429.33	747.96	X6LBKF	146.56
1098	834303.62	1755429.09	746.81	X6	147.70
1100	834299.83	1755427.42	743.14	X6	151.84
1101	834295.74	1755426.55	742.97	X6	156.02
1102	834286.39	1755423.22	742.80	X6	165.94
1103	834278.95	1755420.70	742.24	X6	173.80
1104	834275.13	1755419.58	741.89	X6	177.78
1105	834272.42	1755418.61	741.78	X6TW	180.66
1106	834271.64	1755418.37	744.59	X6RCH	181.48
1107	834270.58	1755414.79	747.21	X6	185.21
1108	834269.41	1755414.15	748.30	X6RBKF	186.54
1109	834268.07	1755414.03	749.08	X6RTOB	187.88
1110	834262.26	1755412.69	749.20	X6	193.84
1111	834256.53	1755411.71	749.83	X6	199.65
1112	834252.40	1755410.05	750.85	X6	204.12
1113	834251.24	1755409.98	751.04	X6-FENCE	205.27

Bankfull Line	
Station	Elevation
146.03	748.30
186.54	748.30

Floodprone Line	
Station	Elevation
17.81	754.81
205.27	754.81

Hillsdale Park Cross-Sectional Data

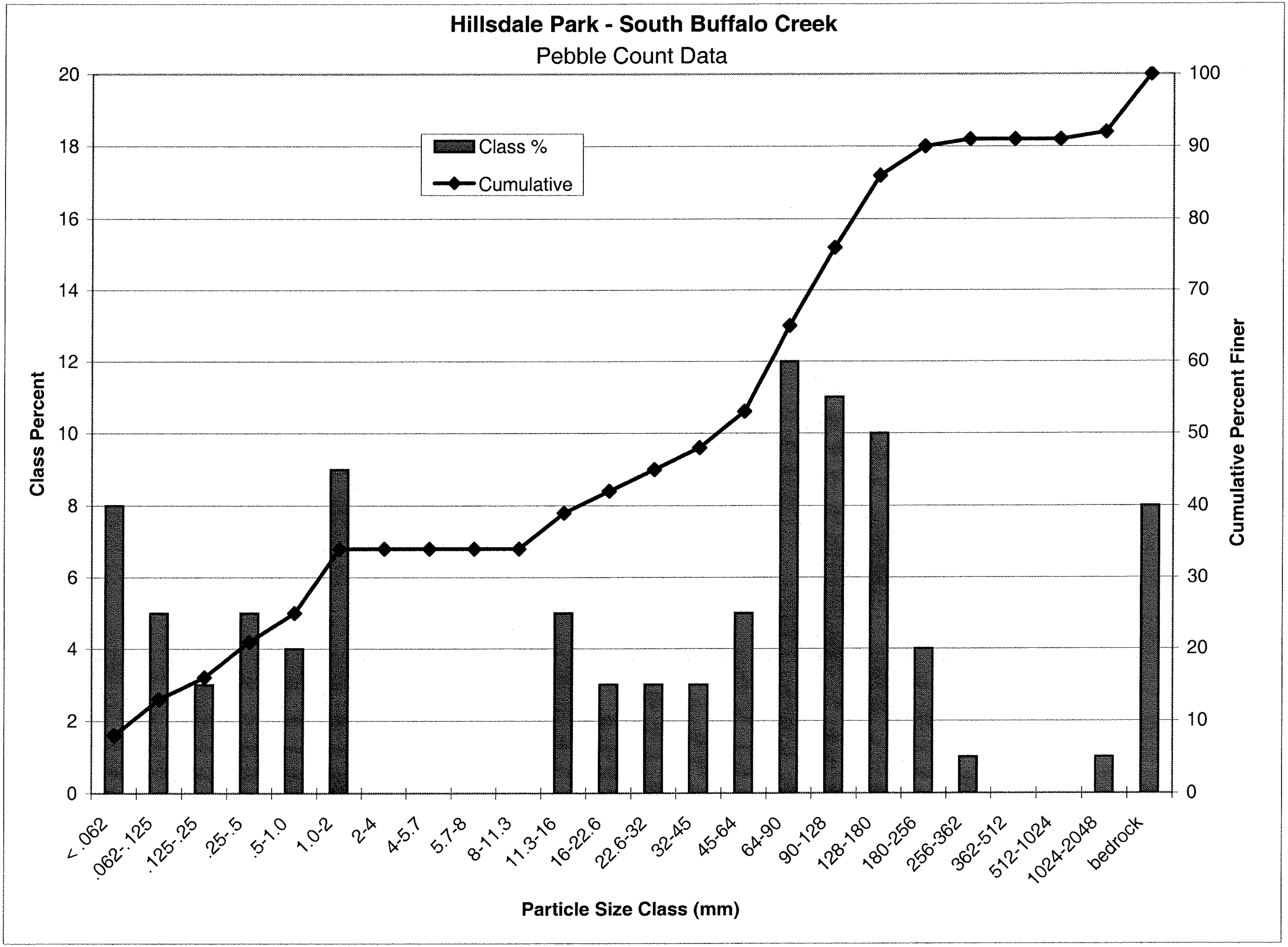
Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Run	B4c	147.9	43.6	3.4	5.0	12.9	1.9	1.5	745.43	750.07



Pt #	North	East	Elevation	Note	Station
1197	834213.22	1756026.22	752.69	X7EP	0.00
1198	834212.89	1756025.99	753.16	X7-T-CURB	0.41
1199	834195.40	1756024.57	752.25	X7	17.95
1200	834185.56	1756023.50	751.82	X7SW	27.85
1201	834175.65	1756022.76	751.56	X7SW	37.79
1202	834166.65	1756021.93	750.96	X7	46.82
1203	834156.62	1756020.81	750.54	X7LPIN	56.92
1204	834150.28	1756019.05	750.07	X7LTOB	63.50
1205	834147.65	1756018.09	749.44	X7	66.30
1207	834147.12	1756017.49	745.41	X7LBKF	67.10
1206	834146.81	1756017.10	746.58	X7	67.60
1208	834145.97	1756016.27	745.01	X7	68.78
1209	834144.55	1756016.14	744.24	X7	70.21
1210	834142.03	1756015.65	743.82	X7	72.77
1212	834138.53	1756014.44	741.58	X7	76.47
1213	834134.99	1756014.01	741.34	X7	80.04
1214	834130.60	1756013.81	741.15	X7	84.44
1215	834126.91	1756013.19	740.42	X7TW	88.18
1216	834119.49	1756012.56	740.62	X7	95.63
1217	834114.08	1756011.37	741.25	X7	101.17
1218	834109.65	1756011.52	742.21	X7RCH	105.60
1219	834108.56	1756010.93	744.06	X7	106.84
1220	834106.51	1756010.27	744.96	X7	108.99
1221	834104.07	1756010.67	745.63	X7RBKF	111.47
1222	834101.53	1756010.16	747.11	X7	114.06
1223	834098.69	1756009.11	748.16	X7	117.08
1224	834088.74	1756002.86	752.21	X7	128.84
1225	834082.43	1755998.25	754.37	X7	136.65
1226	834073.12	1756001.46	754.50	X7RTOB	146.50
1227	834057.12	1755995.31	755.59	X7	163.64
1228	834045.20	1755990.60	756.68	X7	176.45
1229	834038.08	1755988.64	758.51	X7	183.84
1230	834025.64	1755983.34	759.22	X7	197.36
1231	834018.56	1755980.76	760.30	X7FENCE	204.90

Bankfull Line	
Station	Elevation
67.10	745.43
110.73	745.43

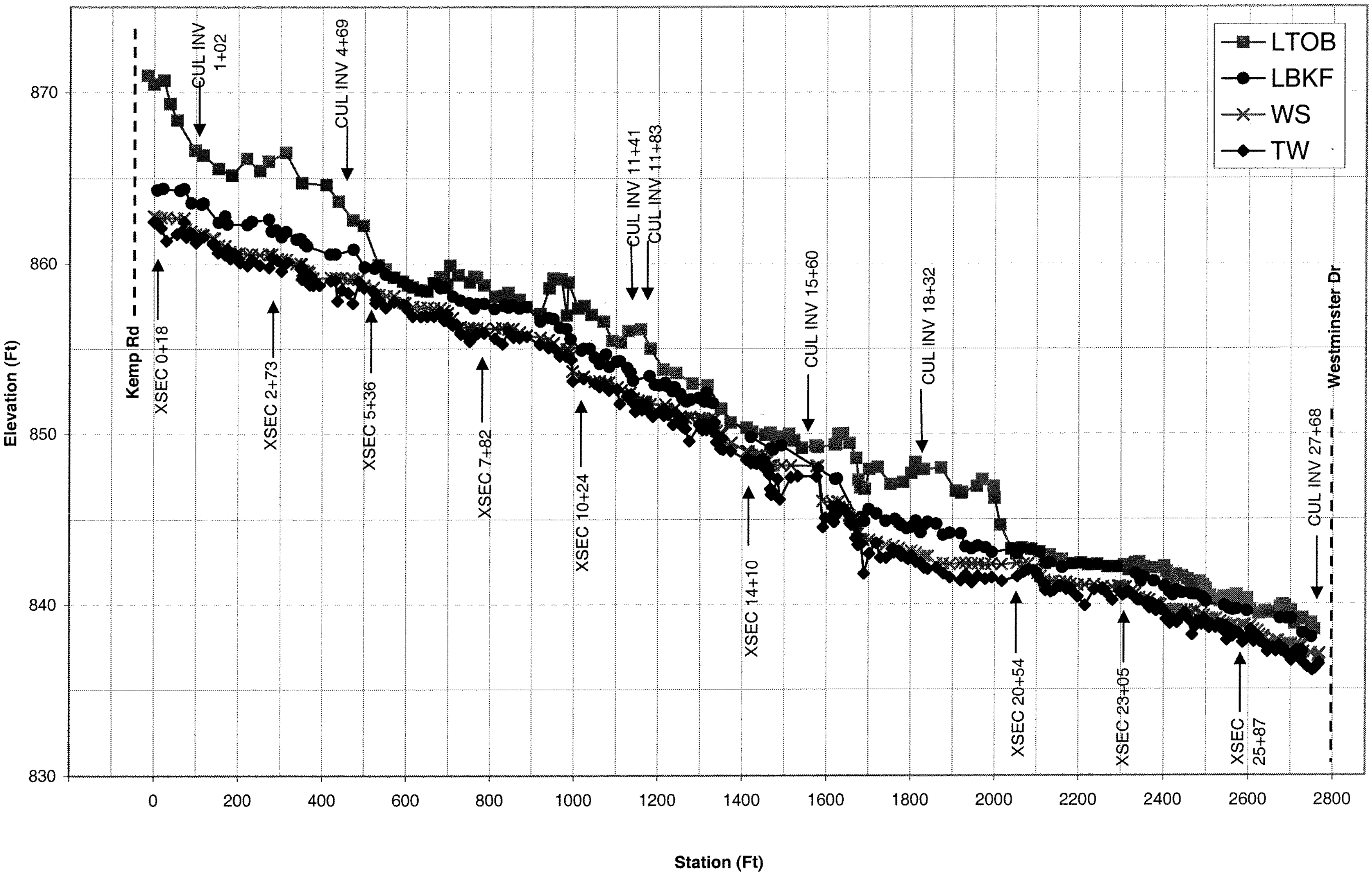
Floodprone Line	
Station	Elevation
58.38	750.44
123.68	750.44



Hillsdale Park - South Buffalo Creek
Pebble Count Data
Class %
Cumulative
Class Percent
Cumulative Percent Finer
0
2
4
6
8
10
12
14
16
18
20
0
10
20
30
40
50
60
70
80
90
100
< .062
.062-.125
.125-.25
.25-.5
.5-1.0
1.0-2
2-4
4-5.7
5.7-8
8-11.3
11.3-16
16-22.6
22.6-32
32-45
45-64
64-90
90-128
128-180
180-256
256-362
362-512
512-1024
1024-2048
bedrock
Particle Size Class (mm)

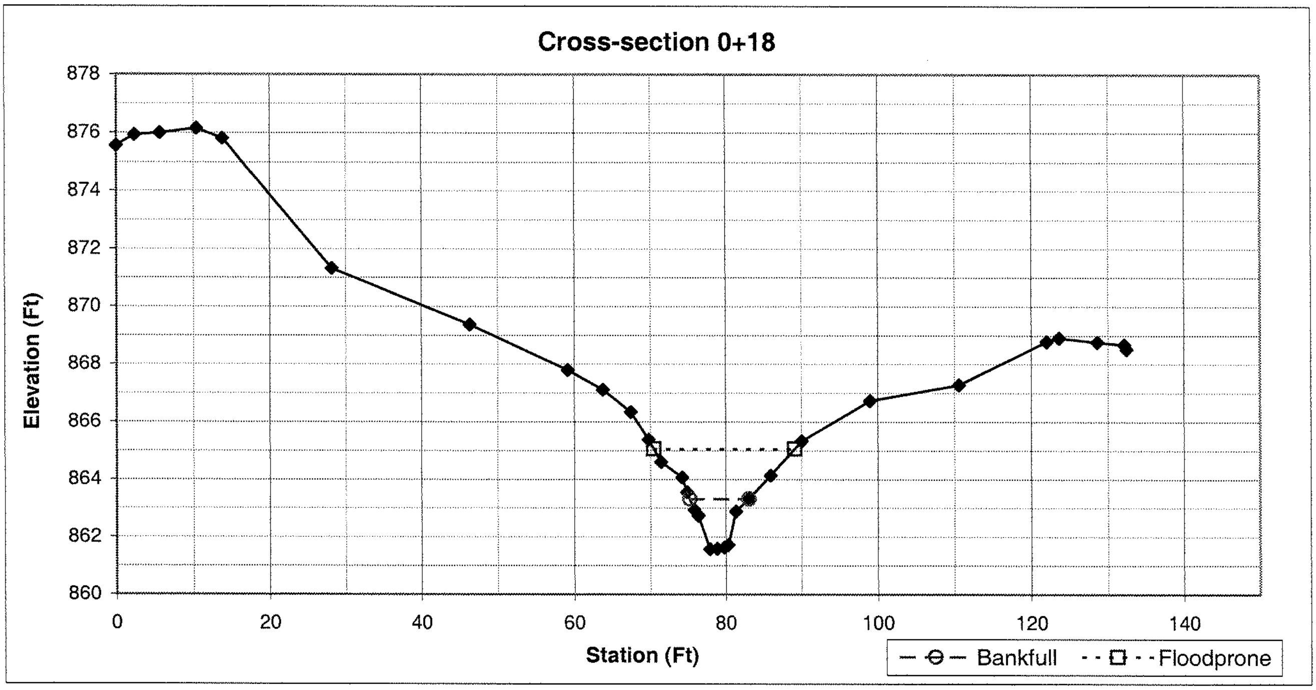
Existing Condition Data
Brown Bark Park

Brown Bark Park -- Unnamed Tributary to North Buffalo Creek Longitudinal Profile



Brown Bark Park Cross-sectional Data:

Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Riffle	~~C4~~ E4	7.7	7.9	1.0	1.7	8.1	2.2	2.4	863.31	865.32



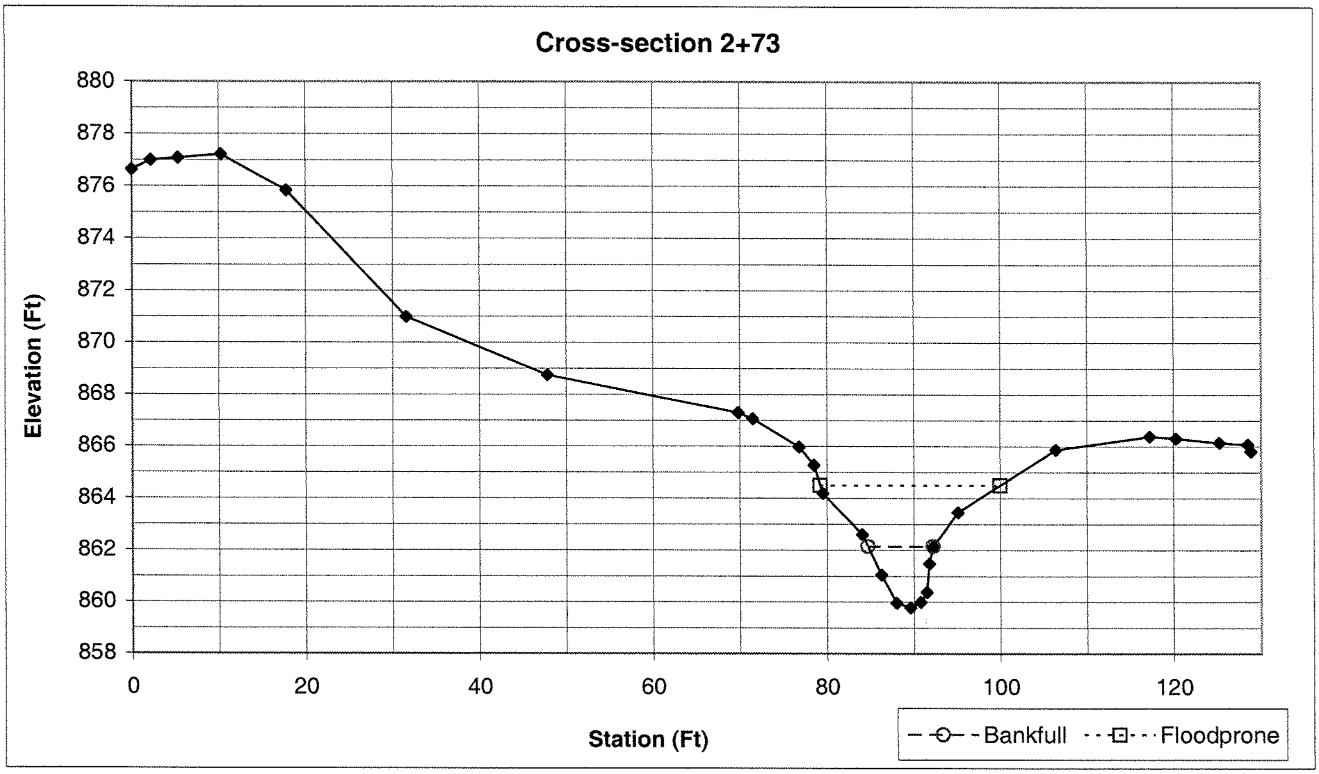
Pt #	North	East	Elevation	Note	Station
98	854817.07	1746478.25	875.54	X1-EPAV	0.00
99	854814.70	1746478.11	875.92	X1TCURB	2.38
100	854811.46	1746478.67	875.99	X1SIDEW	5.66
101	854806.69	1746479.04	876.15	X1SIDEW	10.44
102	854803.36	1746478.67	875.80	X1	13.80
103	854789.02	1746479.70	871.31	X1	28.18
104	854771.11	1746476.65	869.37	X1	46.34
105	854758.31	1746476.01	867.78	X1	59.16
106	854753.72	1746476.08	867.10	X1LPIN	63.75
107	854750.08	1746475.57	866.34	X1LTOB	67.42
108	854747.82	1746475.05	865.38	X1	69.75
109	854746.15	1746474.99	864.59	X1	71.41
110	854743.48	1746474.15	864.07	X1	74.22
111	854742.86	1746474.10	863.54	X1LBKF	74.84
112	854741.93	1746473.81	862.94	X1	75.82
113	854741.65	1746473.34	862.74	X1	76.36
115	854740.13	1746473.25	861.58	X1	77.87
116	854739.15	1746473.28	861.59	X1TW	78.85
117	854738.27	1746473.01	861.63	X1	79.77
118	854737.73	1746472.89	861.72	X1RCH	80.33
119	854736.86	1746472.41	862.87	X1	81.33
120	854735.13	1746472.07	863.31	X1RBKF	83.08
121	854732.30	1746472.41	864.13	X1	85.94
122	854728.23	1746471.89	865.32	X1RTOB	90.05
123	854719.29	1746471.19	866.73	X1	99.01
124	854708.26	1746467.74	867.27	X1	110.57
125	854696.80	1746467.53	868.78	X1	122.03
126	854695.18	1746467.47	868.90	X1SIDEW	123.65
127	854690.20	1746467.35	868.76	X1SIDEW	128.63
128	854686.67	1746466.97	868.67	X1TCURB	132.18
129	854686.46	1746466.78	868.52	X1EPAV	132.46

Bankfull Line	
Station	Elevation
75.21	863.31
83.08	863.31

Floodprone Line	
Station	Elevation
70.44	865.05
89.10	865.05

Brown Bark Park Cross-sectional Data:

Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Run	E4	11.9	7.5	1.6	2.4	4.8	1.6	2.8	862.14	863.46



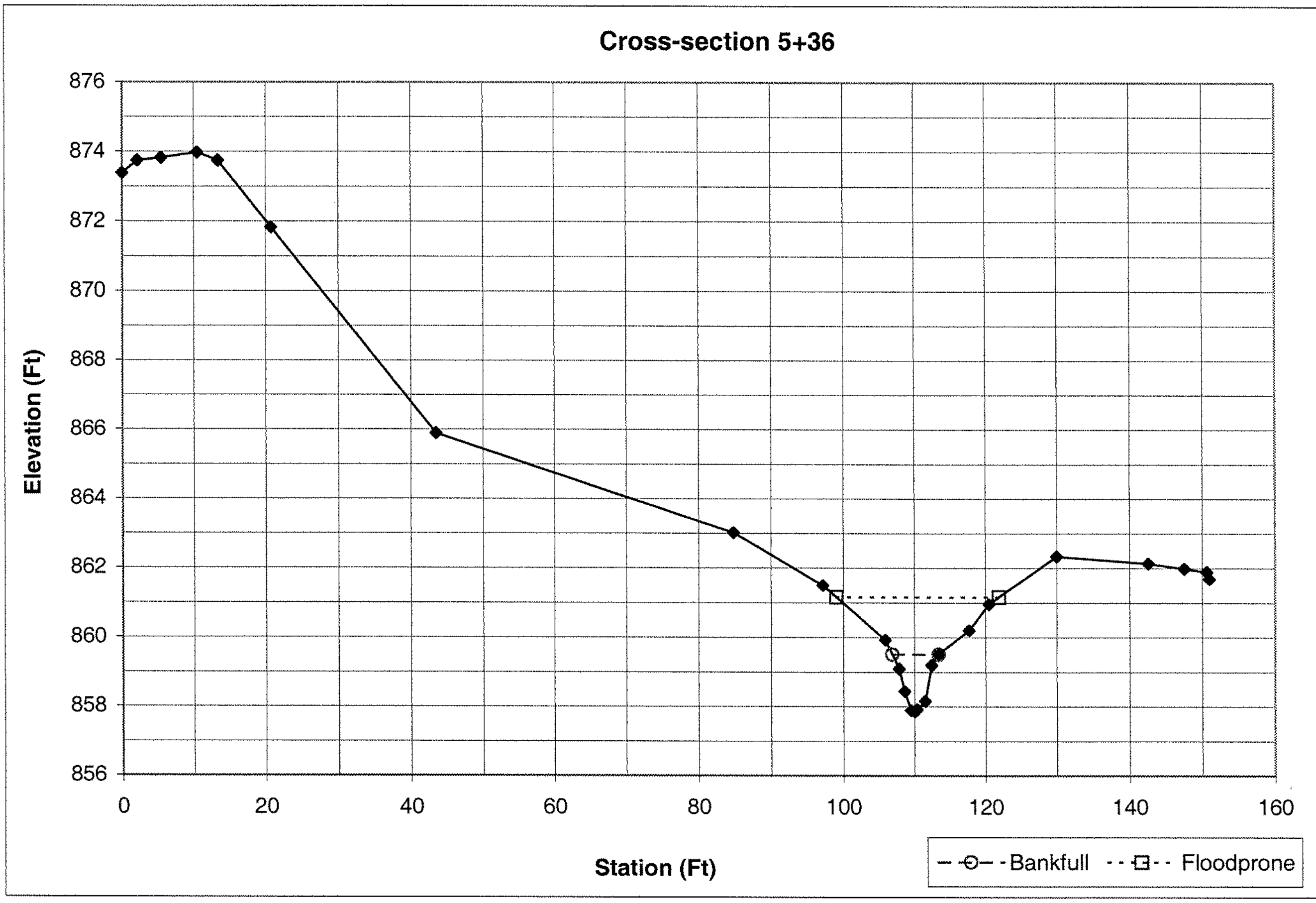
Pt #	North	East	Elevation	Note	Station
177	854806.72	1746636.79	876.65	X2-EPAV	0.00
178	854804.54	1746636.58	877.01	X2-TCURB	2.19
179	854801.41	1746636.39	877.08	X2-SIDEW	5.32
180	854796.43	1746636.14	877.21	X2-SIDEW	10.31
181	854788.99	1746635.14	875.85	X2	17.82
182	854775.34	1746633.11	870.98	X2	31.62
183	854759.30	1746630.74	868.74	X2	47.84
184	854737.57	1746627.32	867.30	X2	69.83
185	854735.94	1746627.00	867.06	X2-LPIN	71.50
186	854730.63	1746626.52	865.97	X2-LTOB	76.83
187	854728.94	1746626.25	865.28	X2	78.53
188	854727.95	1746626.22	864.18	X2	79.53
189	854723.41	1746625.87	862.60	X2-LBKF	84.08
190	854721.29	1746625.40	861.04	X2	86.26
192	854719.55	1746625.61	859.96	X2	88.00
193	854717.97	1746625.65	859.78	X2-TW	89.59
194	854716.76	1746625.54	859.99	X2	90.80
195	854716.11	1746625.34	860.38	X2-RCH	91.49
196	854715.80	1746625.28	861.48	X2	91.80
197	854715.35	1746625.25	862.14	X2-BKF	92.25
198	854712.49	1746625.06	863.46	X2-RTOB	95.12
199	854701.29	1746623.65	865.87	X2	106.40
200	854690.49	1746622.24	866.38	X2	117.30
201	854687.51	1746622.30	866.30	X2-SIDEW	120.28
202	854682.57	1746621.72	866.15	X2-SIDEW	125.25
203	854679.35	1746621.09	866.07	X2-TCURB	128.54
204	854679.05	1746621.05	865.81	X2-EPAV	128.84

Bankfull Line	
Station	Elevation
84.73	862.14
92.25	862.14

Floodprone Line	
Station	Elevation
79.24	864.5
99.98	864.5

Brown Bark Park Cross-sectional Data:

Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Run	E4	6.0	6.5	0.9	1.7	7.1	1.3	3.5	859.5	859.92



Pt #	North	East	Elevation	Note	Station
327	854792.11	1746866.07	873.39	X3-EPAV	0.00
328	854789.97	1746866.13	873.76	X3-TCURB	2.14
329	854786.63	1746866.05	873.83	X3-SIDEW	5.49
330	854781.62	1746866.06	873.98	X3-SIDEW	10.49
331	854778.70	1746866.11	873.75	X3	13.41
332	854771.41	1746866.90	871.83	X3	20.75
333	854748.75	1746865.13	865.89	X3	43.48
334	854707.55	1746861.81	863.02	X3	84.81
335	854695.20	1746860.92	861.49	X3-LPIN	97.19
336	854686.52	1746860.49	859.92	X3-LTOB-LBKF	105.88
337	854684.56	1746860.80	859.09	X3	107.86
338	854683.83	1746860.76	858.45	X3	108.60
340	854682.99	1746861.03	857.88	X3	109.48
341	854682.45	1746861.12	857.85	X3-TW	110.02
342	854682.12	1746861.06	857.92	X3	110.36
343	854680.98	1746860.88	858.15	X3-RCH	111.52
344	854680.12	1746860.52	859.19	X3	112.45
345	854679.23	1746860.18	859.50	X3-RBKF	113.40
346	854675.42	1746858.24	860.20	X3RTOB	117.68
347	854672.59	1746858.39	860.94	X3	120.51
348	854663.36	1746856.32	862.34	X3	129.97
349	854651.51	1746852.03	862.13	X3-SIDEW	142.57
350	854646.66	1746851.08	861.98	X3-SIDEW	147.51
351	854643.63	1746850.42	861.89	X3-TCURB	150.62
352	854643.36	1746850.23	861.69	X3-EPAV	150.95

Bankfull Line	
Station	Elevation
106.88	859.50
113.40	859.50

Floodprone Line	
Station	Elevation
99.07	861.15
121.92	861.15

Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Pool	C4	4.5	9.5	0.5	1.8	20.2	1.9	2.3	857.68	859.34

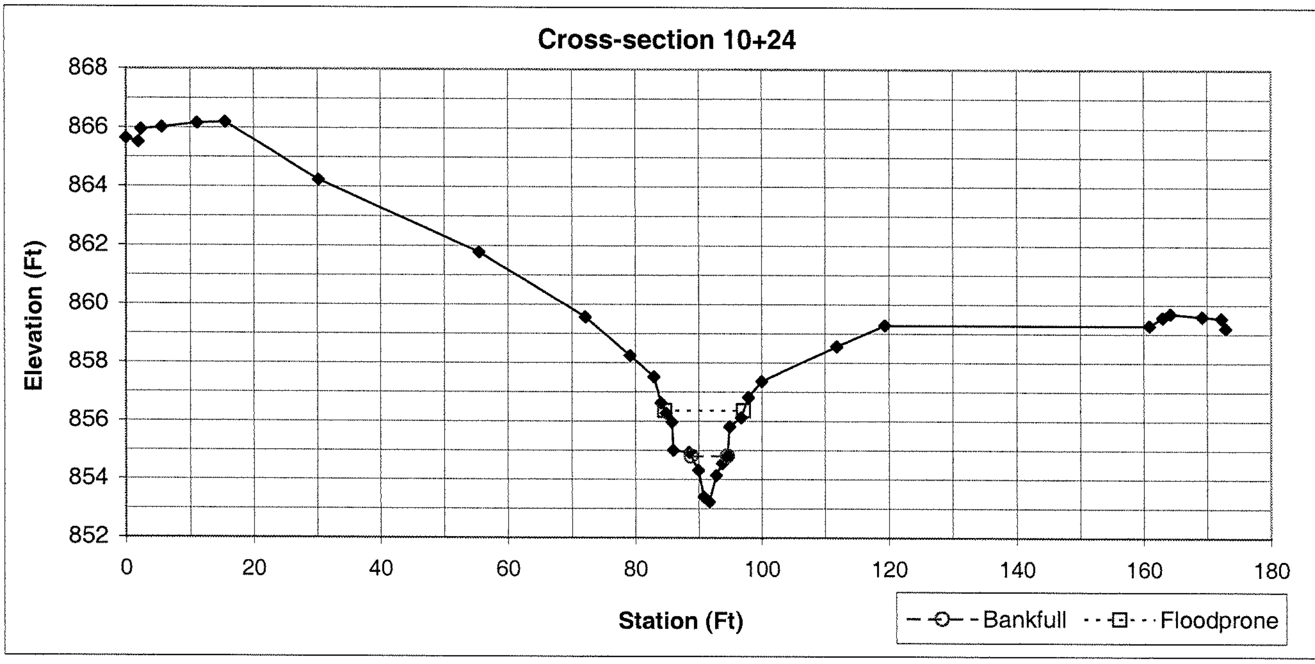
Pt #	North	East	Elevation	Note	Station
437	854782.49	1747052.25	869.21	X4-EPAV	0.00
438	854780.41	1747051.97	869.58	X4-TCURB	2.10
439	854777.19	1747051.87	869.73	X4-SIDEW	5.33
440	854772.24	1747052.00	869.85	X4-SIDEW	10.27
441	854767.03	1747051.84	869.44	X4	15.49
442	854736.89	1747050.86	864.39	X4	45.64
443	854695.57	1747048.25	862.97	X4	87.05
444	854673.05	1747046.55	860.92	X4	109.63
445	854660.90	1747045.52	859.95	X4-LPIN	121.82
446	854654.97	1747045.59	859.34	X4-LTOB	127.76
447	854648.50	1747045.30	858.74	X4	134.23
448	854646.13	1747045.45	857.55	X4	136.60
449	854643.29	1747045.68	857.93	X4	139.45
450	854641.27	1747045.41	857.85	X4-LBKF	141.49
451	854640.33	1747045.23	857.22	X4	142.45
453	854639.00	1747046.05	856.16	X4	144.02
454	854638.07	1747046.22	855.86	X4-TW	144.95
455	854637.74	1747046.17	855.83	X4-RCH	145.29
456	854637.16	1747046.10	857.68	X4-RBKF	145.88
457	854636.56	1747046.11	858.31	X4	146.48
458	854635.25	1747046.11	859.77	X4-RTOB	147.79
459	854626.18	1747042.86	860.11	X4	157.42
460	854623.62	1747043.09	860.24	X4-SIDEW	159.99
461	854618.94	1747042.21	860.11	X4-SIDEW	164.75
462	854615.44	1747042.20	860.03	X4-TCURB	168.25
463	854615.16	1747042.16	859.75	X4-EPAV	168.54

Bankfull Line	
Station	Elevation
136.34	857.68
145.88	857.68

Floodprone Line	
Station	Elevation
126.05	859.52
147.56	859.52

Brown Bark Park Cross-sectional Data:

Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Riffle	E4	4.1	5.7	0.7	1.6	8.0	2.6	2.2	854.80	857.36



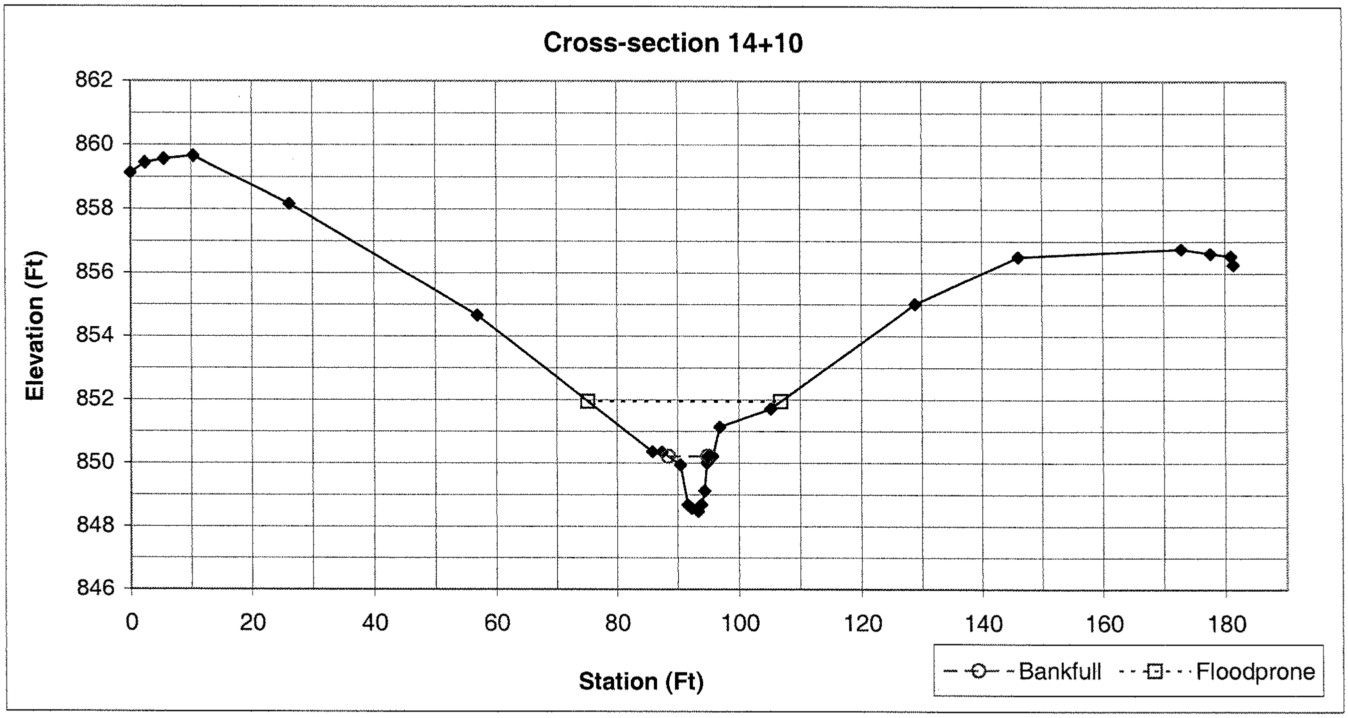
Pt #	North	East	Elevation	Note	Station
633	854785.16	1747319.30	865.63	X5EP	0.00
634	854783.25	1747319.37	865.50	X5BCURB	1.91
635	854782.96	1747319.10	865.94	X5T-CURB	2.30
636	854779.69	1747319.31	866.01	X5-SIDEW	5.58
637	854774.31	1747318.25	866.15	X5-SIDEW	11.07
638	854769.90	1747318.51	866.19	X5	15.48
639	854755.19	1747319.58	864.23	X5	30.23
640	854730.03	1747321.61	861.77	X5	55.48
641	854713.42	1747323.00	859.56	X5	72.14
642	854706.40	1747323.54	858.24	X5LPIN	79.18
643	854702.66	1747323.53	857.52	X5LTOB	82.93
644	854701.57	1747323.68	856.63	X5	84.02
645	854700.78	1747323.86	856.27	X5	84.83
646	854699.91	1747323.60	855.97	X5	85.74
647	854699.88	1747323.41	854.99	X5LBKF	85.94
648	854697.43	1747324.05	854.93	X5	88.47
649	854696.01	1747324.46	854.31	X5	89.95
650	854695.16	1747324.53	853.40	X5LCH	90.80
651	854694.35	1747324.79	853.23	X5TW	91.65
653	854693.27	1747325.10	854.14	X5	92.78
654	854692.33	1747325.23	854.54	X5	93.73
655	854691.59	1747325.55	854.80	X5RBKF	94.54
656	854691.24	1747325.64	855.81	X5	94.89
657	854689.42	1747325.82	856.12	X5	96.73
658	854688.23	1747325.89	856.82	X5	97.92
659	854686.12	1747326.15	857.36	X5RTOB	100.05
660	854674.34	1747325.49	858.57	X5	111.84
661	854666.81	1747325.81	859.29	X5-BBALL	119.38
662	854625.28	1747327.06	859.29	X5-BBALL	160.92
663	854623.23	1747327.11	859.56	X5	162.98
664	854622.02	1747327.29	859.70	X5-SIDEW	164.20
665	854616.99	1747327.05	859.59	X5-SIDEW	169.23
666	854613.98	1747326.83	859.54	X5-T-CURB	172.25
667	854613.34	1747326.73	859.20	X5-EP	172.90

Bankfull Line	
Station	Elevation
88.80	854.80
94.54	854.80

Floodprone Line	
Station	Elevation
84.62	856.36
97.14	856.36

Brown Bark Park Cross-sectional Data:

Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Run	E4	6.0	6.6	0.9	1.7	7.2	1.1	4.8	850.21	850.34



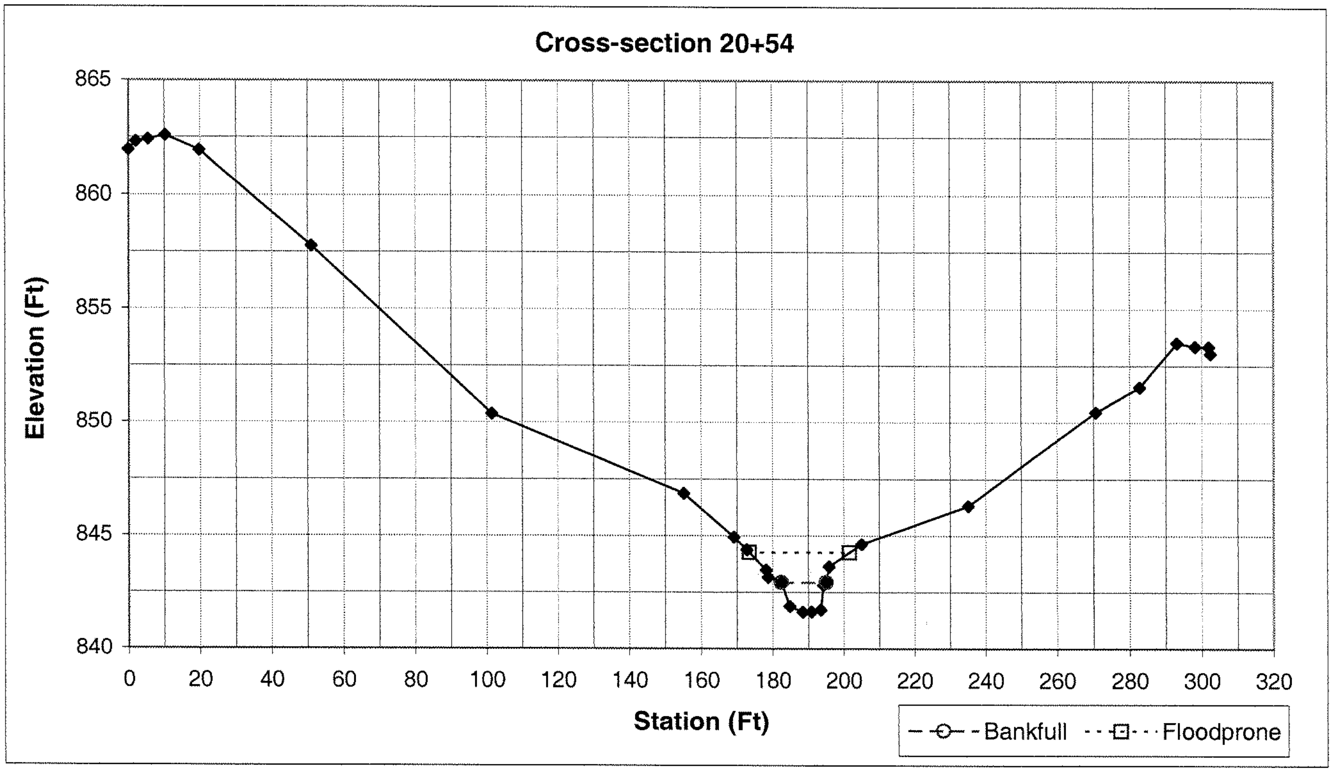
Pt #	North	East	Elevation	Note	Station
900	854806.78	1747694.93	859.13	X6EP	0.00
901	854804.40	1747695.10	859.45	X6T-CURB	2.39
902	854801.32	1747695.24	859.56	X6SIDEW	5.48
903	854796.47	1747695.82	859.65	X6SIDEW	10.36
904	854780.59	1747695.89	858.16	X6	26.24
905	854749.97	1747695.68	854.66	X6	56.85
906	854721.00	1747697.35	850.36	X6LPIN	85.87
907	854719.43	1747697.27	850.34	X6LTOB-BKF	87.45
908	854716.54	1747696.55	849.93	X6	90.43
910	854715.30	1747696.57	848.67	X6	91.67
911	854714.91	1747696.14	848.58	X6	92.25
912	854713.79	1747696.28	848.47	X6TW	93.38
913	854713.42	1747695.95	848.68	X6RCH	93.88
914	854712.90	1747696.14	849.12	X6	94.43
915	854712.56	1747696.17	850.00	X6	94.77
916	854712.37	1747696.03	850.21	X6RBKF	95.01
917	854711.64	1747695.98	850.21	X6	95.74
918	854710.47	1747695.96	851.13	X6RTOB	96.91
919	854702.18	1747695.56	851.71	X6	105.21
920	854678.60	1747692.99	855.01	X6	128.92
921	854661.48	1747691.62	856.50	X6	146.10
922	854634.73	1747689.81	856.76	X6SIDEW	172.91
923	854629.97	1747689.49	856.61	X6SIDEW	177.69
924	854626.66	1747689.33	856.53	X6-T-CURB	180.99
925	854626.27	1747689.23	856.27	X6EP	181.40

Bankfull Line	
Station	Elevation
88.44	850.21
95.01	850.21

Floodprone Line	
Station	Elevation
75.18	851.94
106.86	851.94

Brown Bark Park Cross-sectional Data:

Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Run	C4	12.6	12.6	1.0	1.3	12.7	1.0	2.2	842.94	842.95



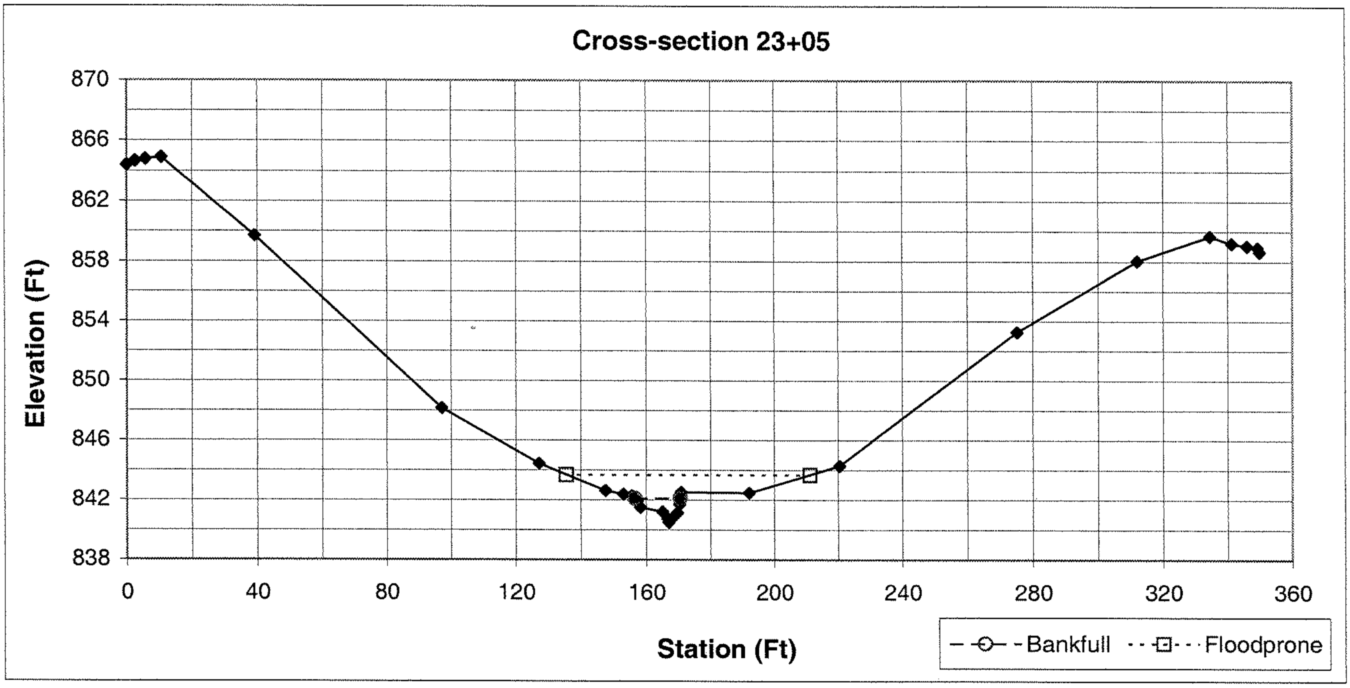
Pt #	North	East	Elevation	Note	Station
1318	855006.12	1748080.96	861.93	X8-EPAV	0.00
1319	855004.71	1748082.50	862.31	X8-TCURB	2.08
1320	855002.50	1748085.09	862.41	X8-SIDEW	5.49
1321	854999.05	1748088.43	862.58	X8-SIDEW	10.29
1322	854992.44	1748095.22	861.92	X8	19.77
1323	854972.21	1748119.09	857.76	X8	51.06
1324	854939.22	1748157.21	850.37	X8	101.47
1325	854907.92	1748200.91	846.86	X8	155.22
1327	854900.18	1748212.55	844.93	X8-LPIN	169.20
1328	854897.98	1748215.46	844.37	X8	172.85
1329	854894.65	1748219.74	843.47	X8	178.27
1330	854894.34	1748220.14	843.17	X8	178.78
1331	854891.77	1748222.73	842.95	X8-LTOB	182.42
1331	854891.77	1748222.73	842.94	X8-LBKF	182.42
1333	854890.21	1748224.56	841.88	X8	184.83
1334	854888.52	1748227.78	841.63	X8-TW	188.47
1335	854886.92	1748229.59	841.64	X8	190.88
1336	854884.61	1748230.85	841.73	X8-RCH	193.51
1337	854884.27	1748231.46	842.81	X8	194.21
1338	854883.52	1748231.87	842.94	X8-RBKF	195.07
1339	854882.81	1748232.16	843.63	X8-RTOB	195.84
1340	854879.28	1748240.71	844.62	X8	205.08
1341	854864.62	1748266.95	846.31	X8	235.14
1342	854848.57	1748298.61	850.46	X8	270.64
1343	854841.19	1748308.30	851.56	X8	282.81
1344	854835.31	1748316.85	853.50	X8-SIDEW	293.20
1345	854831.74	1748320.36	853.35	X8-SIDEW	298.21
1346	854830.18	1748323.79	853.33	X8-TCURB	301.97
1347	854830.01	1748324.20	853.04	X8-EPAV	302.42

Bankfull Line	
Station	Elevation
182.42	842.94
195.07	842.94

Floodprone Line	
Station	Elevation
173.55	844.25
201.66	844.25

Brown Bark Park Cross-sectional Data:

Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Run	C4	11.5	14.1	0.8	1.6	17.3	1.1	5.4	842.10	842.29



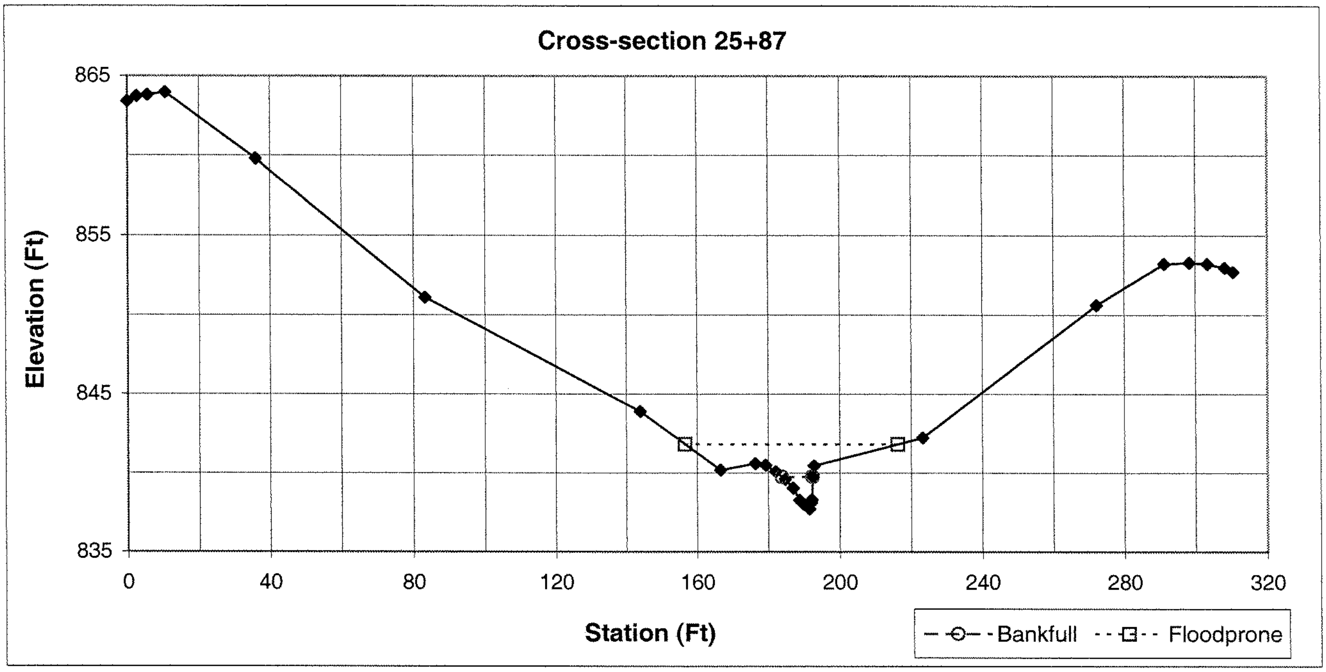
Pt #	North	East	Elevation	Note	Station
1454	855174.11	1748245.89	864.39	X9EP	0.00
1455	855172.88	1748248.12	864.65	X9T-CURB	2.54
1456	855170.84	1748250.67	864.76	X9SIDEW	5.81
1457	855168.79	1748255.08	864.88	X9SIDEW	10.68
1458	855149.18	1748275.75	859.67	X9	39.17
1459	855117.13	1748324.03	848.15	X9	97.11
1460	855100.49	1748349.03	844.44	X9	127.14
1461	855088.16	1748365.35	842.63	X9	147.60
1462	855084.56	1748369.38	842.40	X9LPIN	153.01
1463	855083.10	1748371.59	842.29	X9LTOB-BKF	155.66
1464	855081.80	1748372.59	841.91	X9	157.29
1465	855081.10	1748373.22	841.50	X9	158.24
1466	855076.57	1748378.40	841.20	X9	165.12
1468	855075.74	1748379.72	840.73	X9	166.68
1469	855075.62	1748380.02	840.50	X9TW	167.01
1470	855075.40	1748380.42	840.67	X9	167.45
1471	855074.47	1748381.38	840.94	X9RCH	168.80
1472	855074.04	1748382.17	841.14	X9	169.70
1474	855073.92	1748382.63	842.10	X9RBKF	170.17
1473	855073.77	1748382.62	841.70	X9	170.32
1475	855073.43	1748383.08	842.53	X9RTOB	170.89
1476	855056.61	1748395.99	842.47	X9	192.10
1477	855033.66	1748412.65	844.29	X9	220.46
1478	854993.58	1748449.91	853.26	X9	275.18
1479	854963.85	1748471.70	858.04	X9	312.04
1480	854942.74	1748479.39	859.67	X9	334.51
1481	854936.34	1748481.59	859.20	X9SIDEW	341.27
1482	854931.62	1748482.45	859.02	X9SIDEW	346.07
1483	854928.35	1748482.97	858.93	X9-T-CURB	349.38
1484	854927.81	1748483.03	858.64	X9EP	349.93

Bankfull Line	
Station	Elevation
156.47	842.1
170.59	842.1

Floodprone Line	
Station	Elevation
135.57	843.69
211.24	843.69

Brown Bark Park Cross-sectional Data:

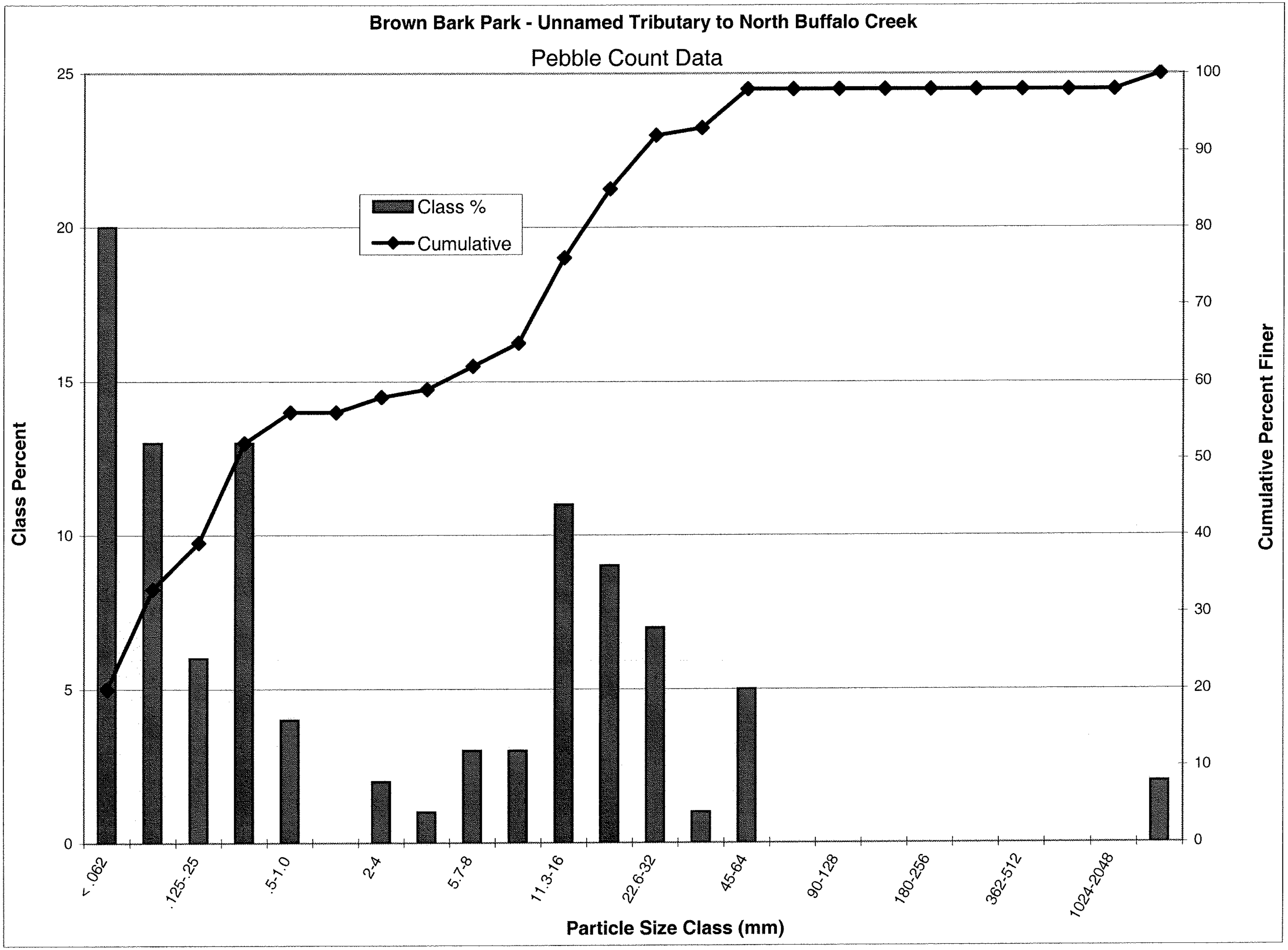
Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Riffle	E4	9.4	8.6	1.1	2.1	7.8	1.1	7.0	839.76	840.07



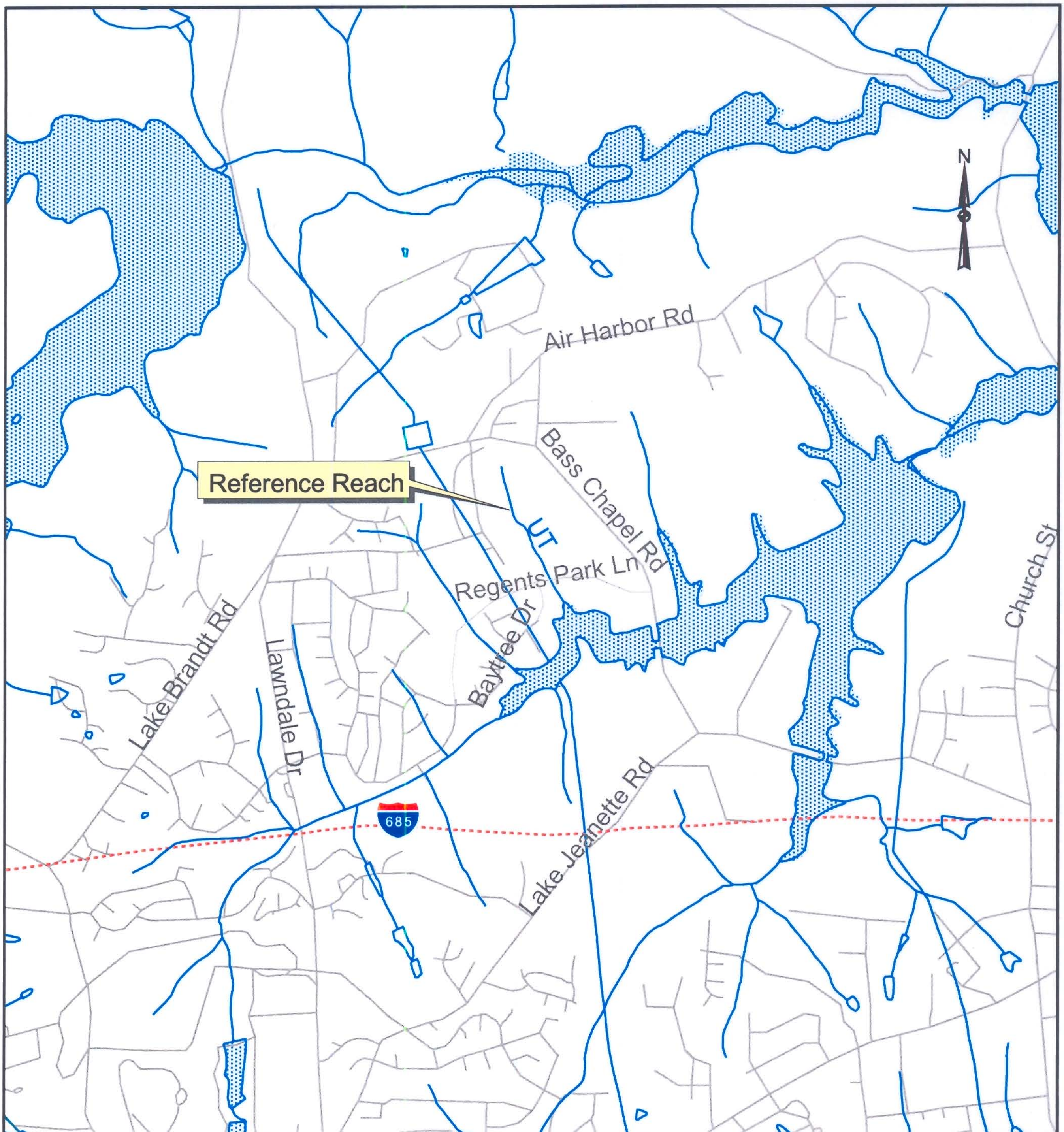
Pt #	North	East	Elevation	Note	Station
1717	855363.03	1748356.11	863.40	X10EP	0.00
1718	855362.39	1748358.64	863.72	X10-T-CURB	2.62
1719	855360.92	1748361.24	863.80	X10-SIDEW	5.60
1720	855357.95	1748365.25	863.97	X10-SIDEW	10.59
1721	855345.66	1748387.50	859.80	X10	36.00
1722	855323.95	1748429.54	851.09	X10	83.33
1723	855298.28	1748484.54	843.88	X10	144.02
1724	855286.10	1748503.61	840.18	X10	166.64
1725	855285.27	1748513.33	840.59	X10-LPIN	176.40
1726	855285.42	1748516.15	840.48	X10	179.23
1727	855286.41	1748518.86	840.07	X10-LTOB-BKF	182.11
1728	855287.31	1748521.40	839.59	X10	184.80
1729	855287.85	1748523.50	839.04	X10	186.97
1731	855288.56	1748525.11	838.27	X10	188.73
1732	855289.01	1748526.00	838.03	X10	189.73
1733	855288.93	1748527.70	837.72	X10-TW	191.44
1734	855289.21	1748528.25	838.11	X10	192.05
1735	855289.20	1748528.42	838.29	X10RCH	192.23
1736	855289.18	1748528.57	839.76	X10RBKF	192.38
1737	855288.94	1748528.96	840.45	X10RTOB	192.83
1738	855285.78	1748559.15	842.22	X10	223.19
1739	855277.80	1748607.57	850.61	X10	272.26
1740	855281.29	1748626.33	853.22	X10	291.34
1741	855282.72	1748633.23	853.30	X10-SIDEW	298.39
1742	855283.31	1748638.24	853.23	X10-SIDEW	303.43
1743	855284.48	1748642.91	852.97	X10-T-CURB	308.25
1744	855284.59	1748645.24	852.71	X10-EP	310.58

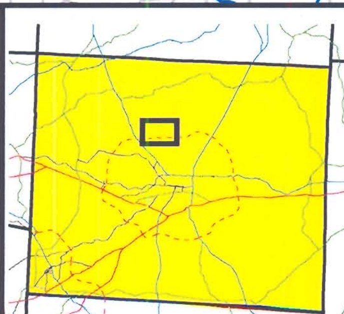
Bankfull Line	
Station	Elevation
183.81	839.76
192.38	839.76

Floodprone Line	
Station	Elevation
156.68	841.81
216.22	841.81


Brown Bark Park - Unnamed Tributary to North Buffalo Creek
Pebble Count Data
Class %
Cumulative
Class Percent
Cumulative Percent Finer
Particle Size Class (mm)
0
5
10
15
20
25
0
10
20
30
40
50
60
70
80
90
100
< .062
.125-.25
.5-1.0
2-4
5.7-8
11.3-16
22.6-32
45-64
90-128
180-256
362-512
1024-2048

Appendix 2 Reference Reach Locations

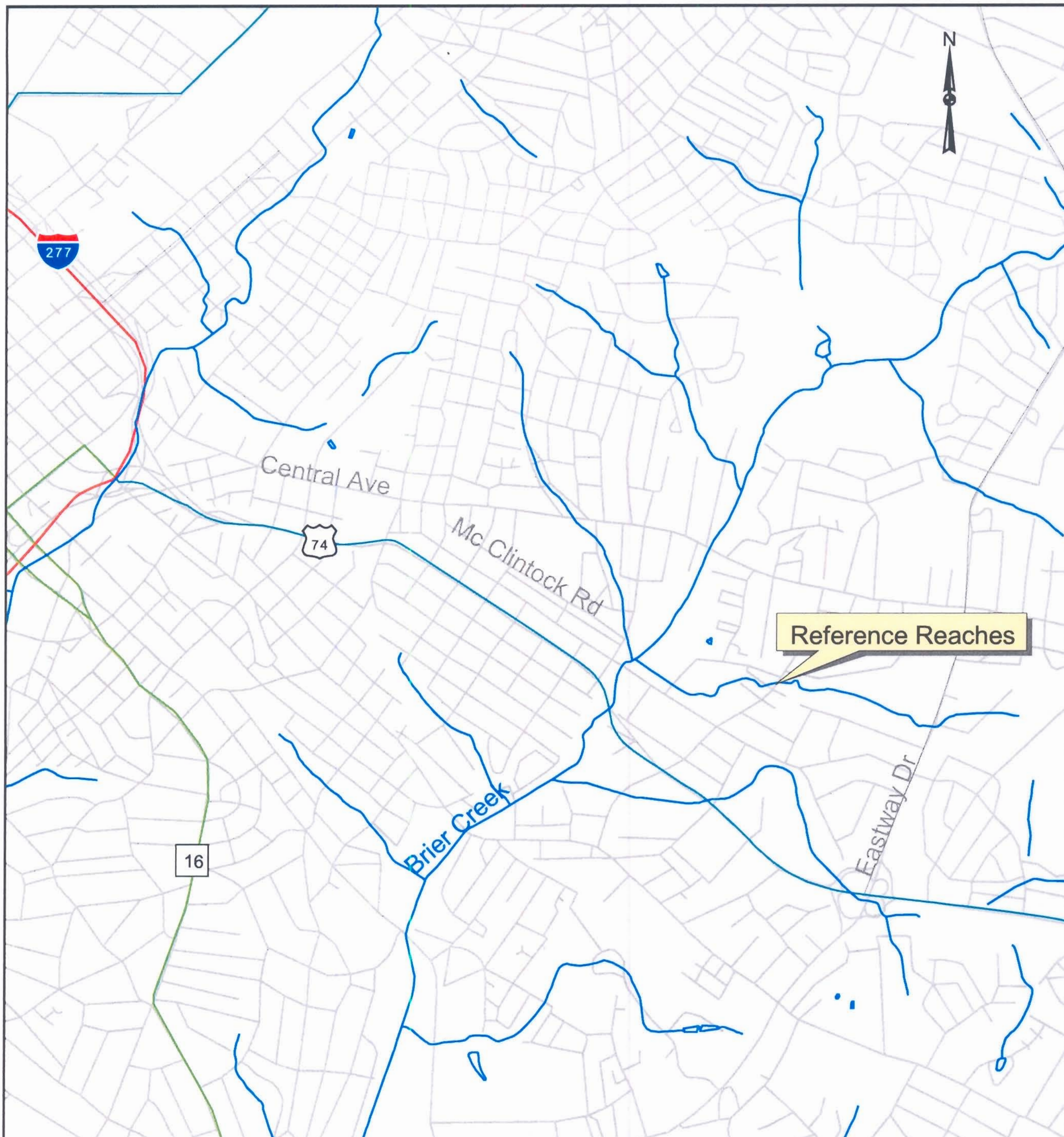


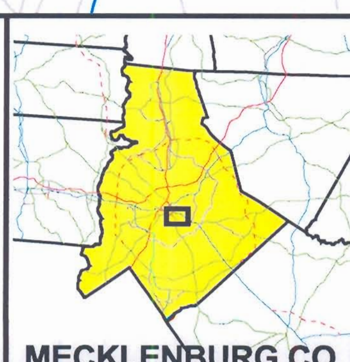


North Carolina
Wetlands Restoration Program

Reference Reach Location Map - UT to Lake Jeanette
Buffalo Creeks Stream Restoration Projects
Greensboro, NC
Guilford County

2 0 2 Miles

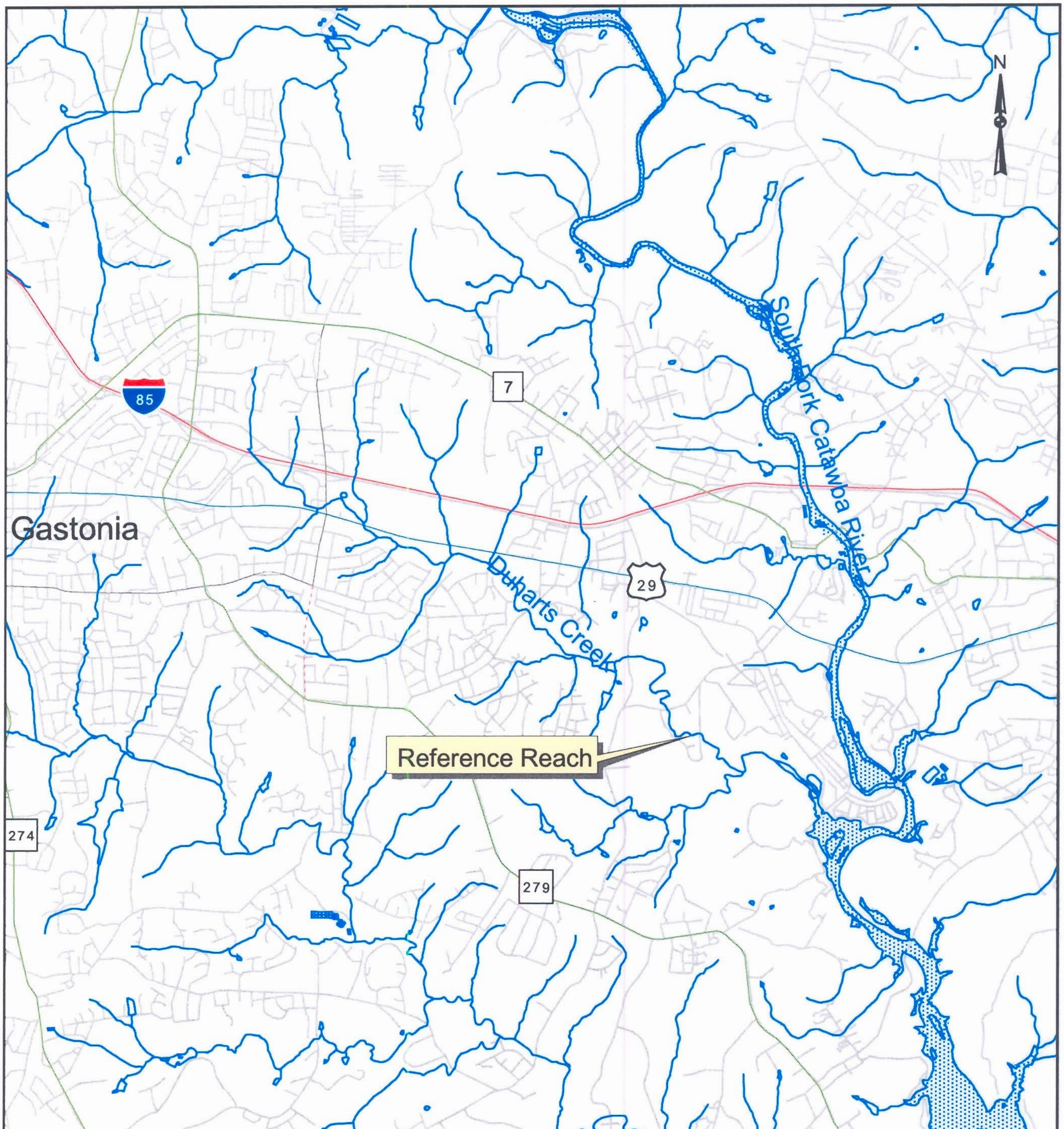


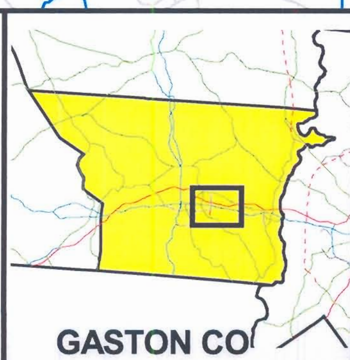


North Carolina
Wetlands Restoration Program

Reference Reach Location Map - McClintock Creek
Buffalo Creeks Stream Restoration Projects
Greensboro, NC
Guilford County

1 0 1 2 Miles

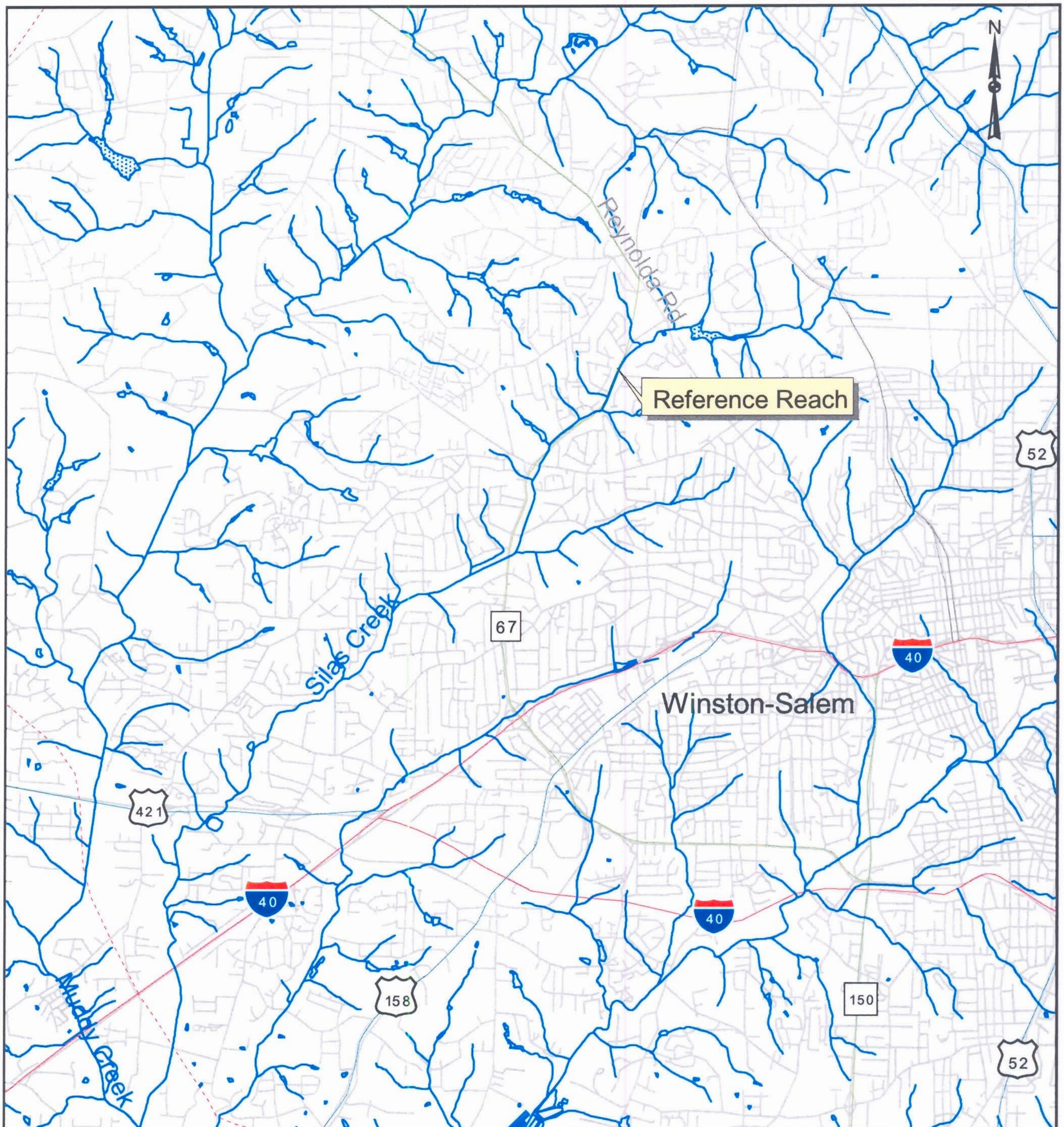


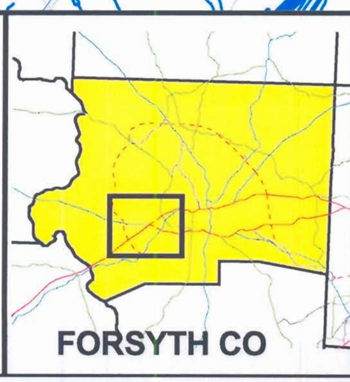


North Carolina
Wetlands Restoration Program

Reference Reach Location Map - Duhart Creek
Buffalo Creeks Stream Restoration Projects
Greensboro, NC
Guilford County

2 0 2 4 Miles

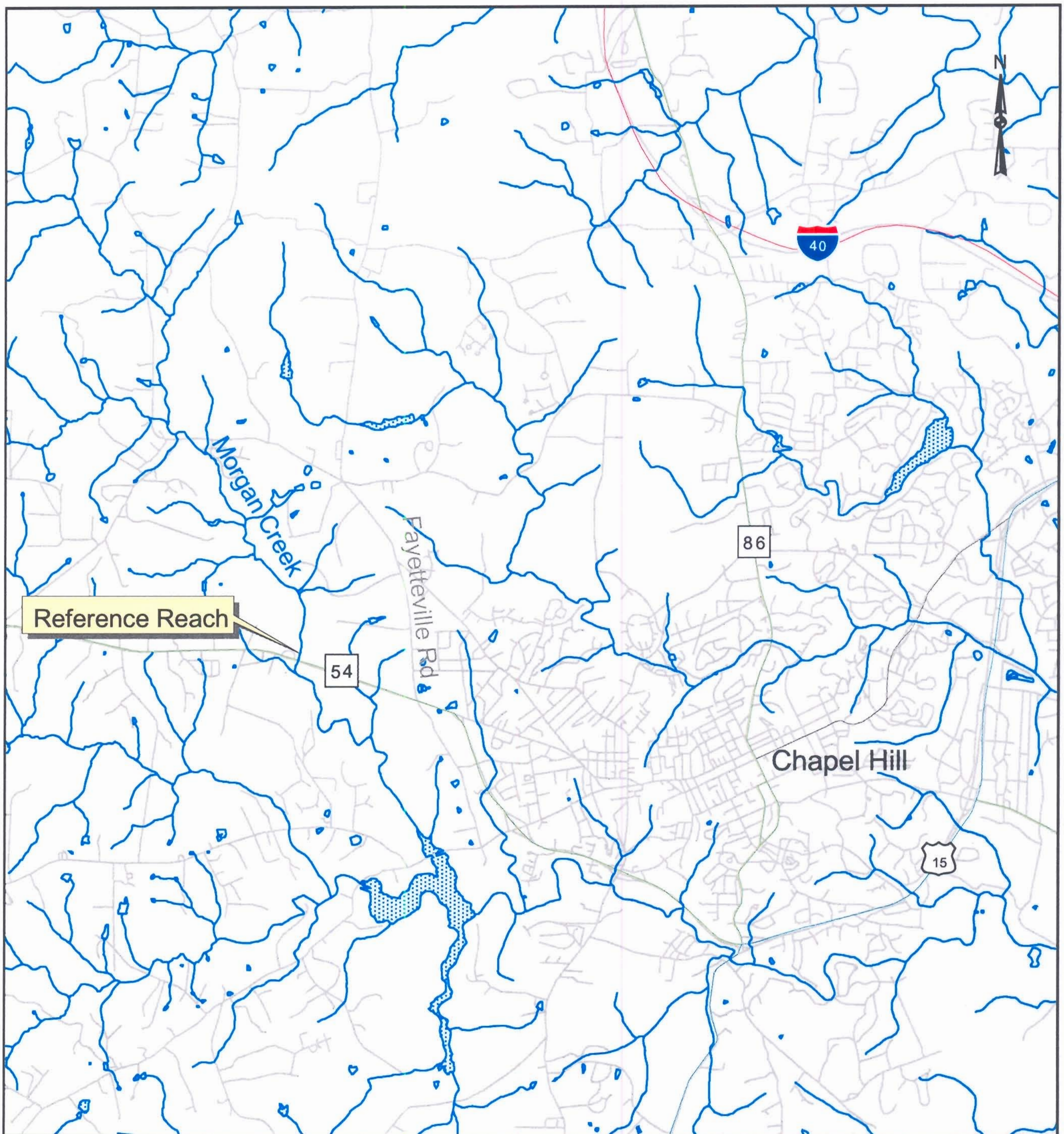


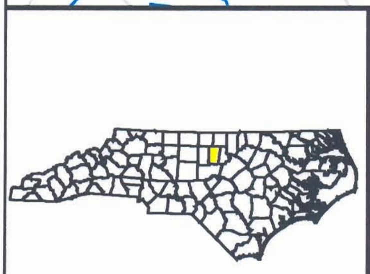


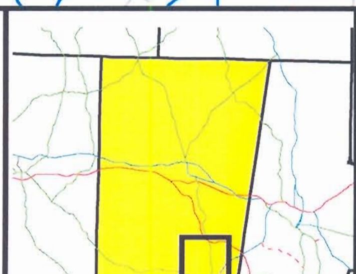
North Carolina
Wetlands Restoration Program

Reference Reach Location Map - Silas Creek
Buffalo Creeks Stream Restoration Projects
Greensboro, NC
Guilford County

2 0 2 4 Miles



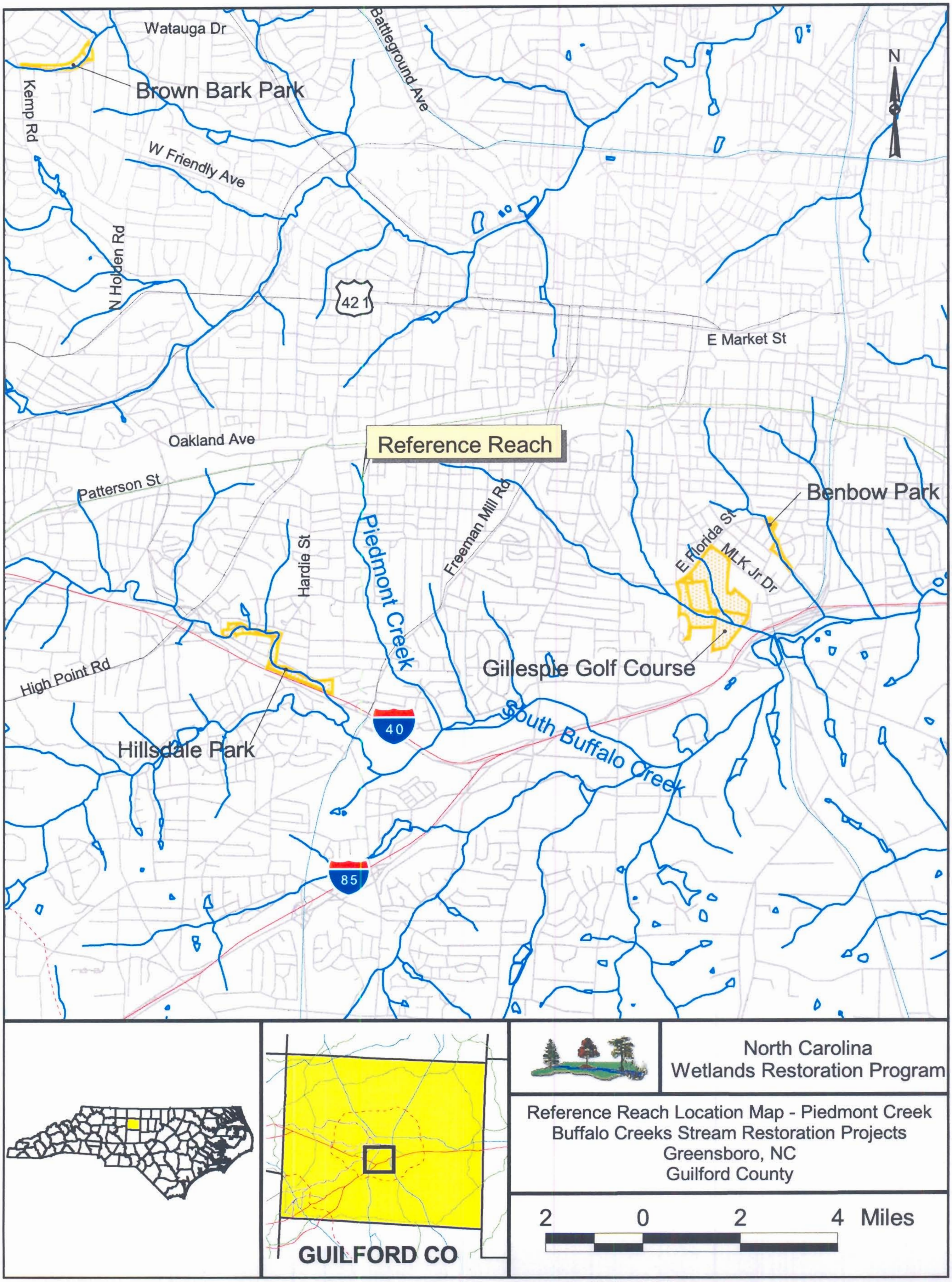




North Carolina
Wetlands Restoration Program

Reference Reach Location Map - Morgan Creek
Buffalo Creeks Stream Restoration Projects
Greensboro, NC
Guilford County

2 0 2 4 Miles



Watauga Dr
Battleground Ave
Brown Bark Park
Kemp Rd
W Friendly Ave
N Holden Rd
421
E Market St
N
Reference Reach
Oakland Ave
Patterson St
Piedmont Creek
Freeman Mill Rd
Hardie St
Benbow Park
E Florida St
MLK Jr Dr
High Point Rd
Gillespie Golf Course
40
South Buffalo Creek
Hillsdale Park
85
GUILFORD CO
North Carolina
Wetlands Restoration Program
Reference Reach Location Map - Piedmont Creek
Buffalo Creeks Stream Restoration Projects
Greensboro, NC
Guilford County
2 0 2 4 Miles

Appendix 3 Photograph Log

Benbow Park


Upstream Knickpoint


Cross Section 4+97


Culvert Downstream of S. Benbow Rd.


Foot Bridge


Bank Erosion Downstream


Sewer Line

Gillespie Golf Course

Upstream Section on Golf Course

Mid-Channel Bar Forming

Sewer Line

Bank Erosion

Above Bridge 3

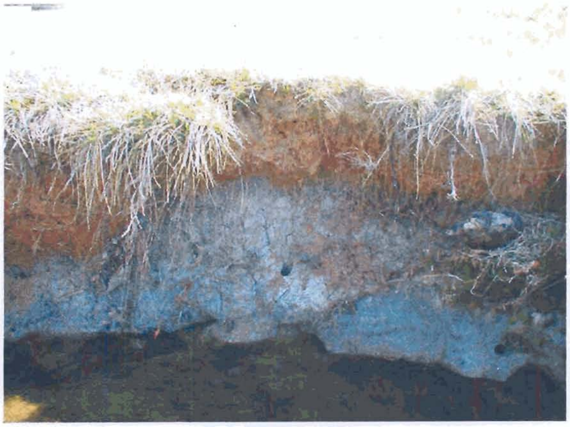
Downstream of Golf Course


Tributary 2


Tributary 3

Brown Bark

Downstream



Bank Erosion

Upstream of Foot Bridge

Bedrock Knickpoint

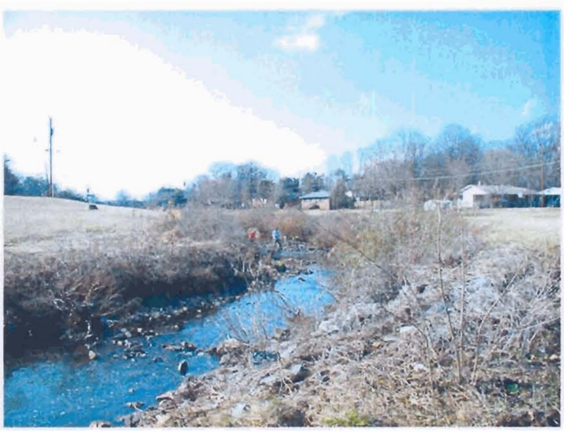
Bedrock Knickpoint

Bank Erosion - Downstream

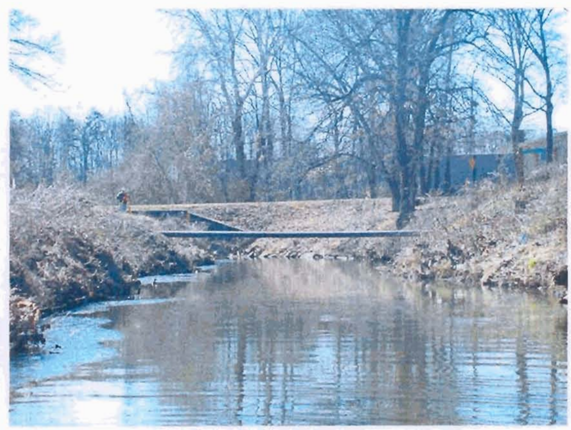
Hillsdale Park

Reach 1
Downstream of Culvert at W. Meadowview

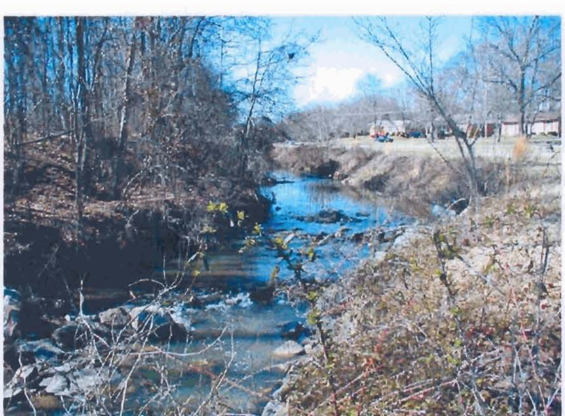
Reach 1 - Pool



Reach 2



Sewer line



Riffle in Reach 3 Downstream

Downstream Tributary