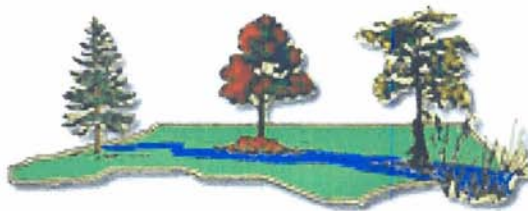


# Buffalo Creek Watershed Stream Restoration Projects Greensboro, North Carolina

North Carolina Department of Environment and Natural Resources  
Wetlands Restoration Program



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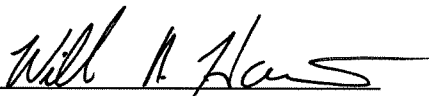
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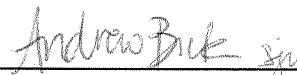
NC Department of Environment and Natural Resources,  
Wetlands Restoration Program

June 5, 2002

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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.

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

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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.**

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

## 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.

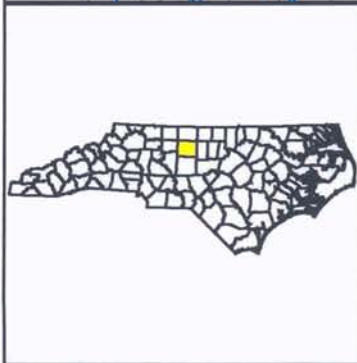
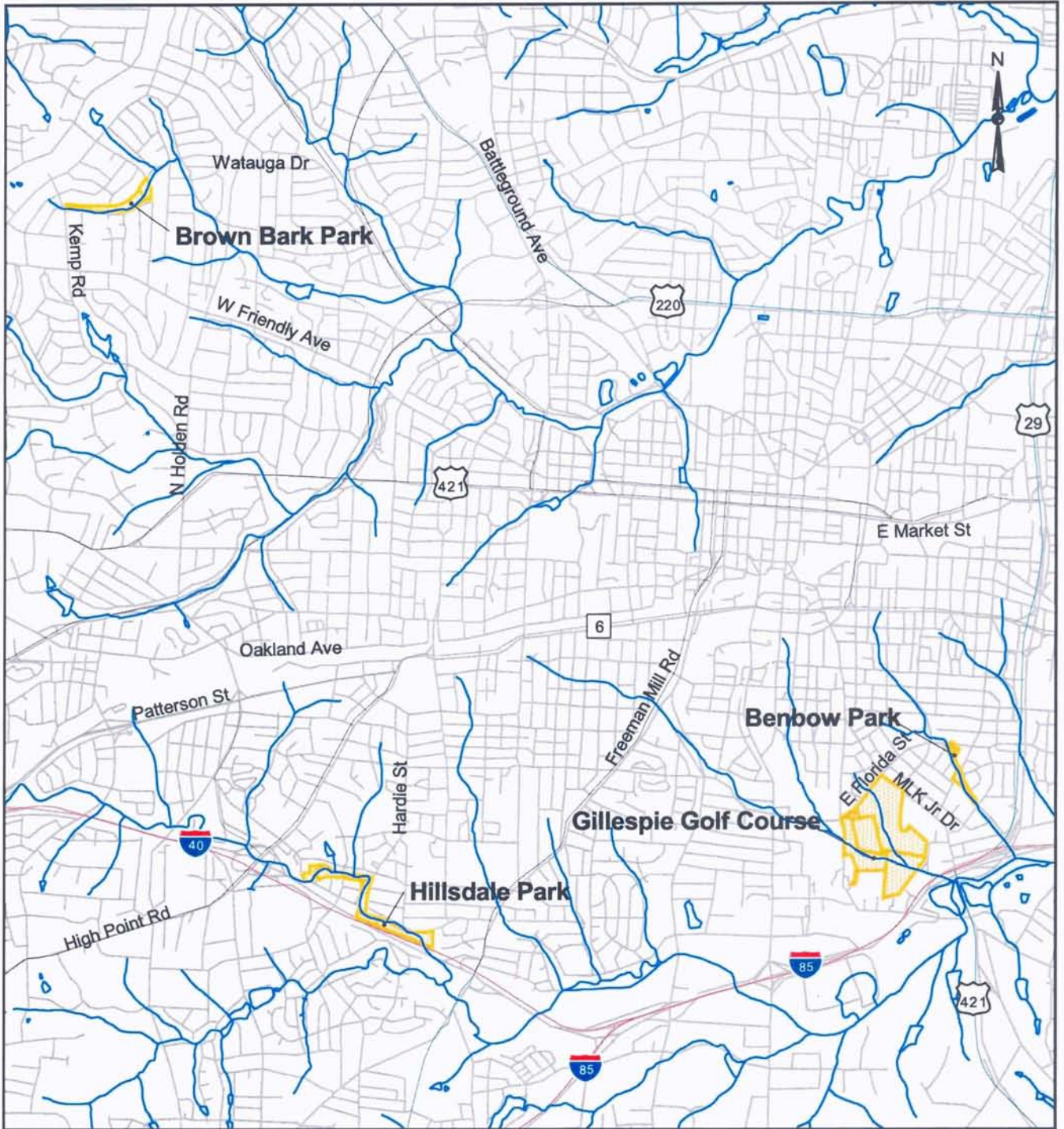
Elevations at the Hillsdale Park project site range from approximately 750 feet to 830 feet with a relative relief of 80 feet. Soils at the site are mapped as Congaree (Co) series. The Congaree series consists of nearly level well-drained soils on long, narrow floodplains of streams. Congaree soils are 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  
 Wetlands Restoration Program

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 headward 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).**

| <b>Stability Rating</b>             | <b>Bank Height Ratio</b> |
|-------------------------------------|--------------------------|
| 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<sup>2</sup> 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   |           | Reach 2   |           |
|----------------------------------|----------------------------------|-----------|-----------|-----------|-----------|
|                                  |                                  | Riffle    | Pool      | Riffle    | Pool      |
| Rosgen Stream Type               |                                  | E5        |           | E5        |           |
| Drainage Area (mi <sup>2</sup> ) |                                  | 0.7       |           | 0.7       |           |
| Reach Length (ft)                |                                  | 776       |           | 976       |           |
| <i>Dimension</i>                 | Bankfull Area (ft <sup>2</sup> ) | 24 - 26   | 25        | 39 - 45   | 23 - 85   |
|                                  | Bankfull Width (ft)              | 13.6-15.3 | 19 - 22   | 18 - 22   | 17 - 31   |
|                                  | Width/Depth Ratio (ft)           | 7 - 10    | 14 - 19   | 8 -11     | 7 - 29    |
|                                  | Bankfull Mean Depth (ft)         | 1.6 - 1.9 | 1.2 - 1.3 | 2.0 - 2.2 | 0.9 - 2.8 |
|                                  | Bank Height Ratios               | 1.5 - 1.7 | 1.7 - 1.9 | 1.2 - 1.8 | 1.3 - 1.8 |
| <i>Pattern</i>                   | Meander Length Ratio             | N/A       | N/A       | N/A       | N/A       |
|                                  | Radius of Curvature Ratio        | N/A       | N/A       | N/A       | N/A       |
|                                  | Meander Width Ratio              | N/A       | N/A       | N/A       | N/A       |
|                                  | Sinuosity                        | 1.04      |           | 1.07      |           |
| <i>Profile</i>                   | Valley Slope (ft/ft)             | 0.0053    |           | 0.0060    |           |
|                                  | 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<sup>2</sup> with one pool bankfull cross sectional area of 85 ft<sup>2</sup> 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<sup>2</sup> 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    | Pool      |
| Rosgen Stream Type               |                                  | E5/C5     | E5/C5     |
| Drainage Area (mi <sup>2</sup> ) |                                  | 2.2       |           |
| Reach Length (ft)                |                                  | 2,877     |           |
| <i>Dimension</i>                 | Bankfull Area (ft <sup>2</sup> ) | 62 - 88   | 102 - 113 |
|                                  | Bankfull Width (ft)              | 29 - 32   | 29 - 44   |
|                                  | Width/Depth Ratio (ft)           | 10 - 17   | 8 - 19    |
|                                  | Bankfull Mean Depth (ft)         | 1.9 - 3.1 | 2.3 - 4.9 |
|                                  | Bank Height Ratios               | 1.2 - 1.3 | 1.3 - 1.4 |
| <i>Pattern</i>                   | Meander Length Ratio             | N/A       | N/A       |
|                                  | Radius of Curvature Ratio        | N/A       | N/A       |
|                                  | Meander Width Ratio              | N/A       | N/A       |
|                                  | Sinuosity                        | 1.09      |           |
| <i>Profile</i>                   | Valley Slope (ft/ft)             | 0.0030    |           |
|                                  | 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<sup>2</sup>. 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<sup>2</sup> 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   |           | Reach 2   |      | Reach 3 |
|----------------------------------|----------------------------------|-----------|-----------|-----------|------|---------|
|                                  |                                  | Riffle    | Pool      | Riffle    | Pool | Riffle  |
| Rosgen Stream Type               |                                  | E4/B4c    |           | B4c/E4/F4 |      | E4      |
| Drainage Area (mi <sup>2</sup> ) |                                  | 10        |           | 10        |      | 0.1     |
| Reach Length (ft)                |                                  | 3037      |           | 2265      |      | 529     |
| <i>Dimension</i>                 | Bankfull Area (ft <sup>2</sup> ) | 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     |
| <i>Pattern</i>                   | 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     |
| <i>Profile</i>                   | 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<sup>2</sup> 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<sup>2</sup>. 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    | Pool      |
| Rosgen Stream Type               |                                  | C4/E4     |           |
| Drainage Area (mi <sup>2</sup> ) |                                  | 0.3       |           |
| Reach Length (ft)                |                                  | 2748      |           |
| Dimension                        | Bankfull Area (ft <sup>2</sup> ) | 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).

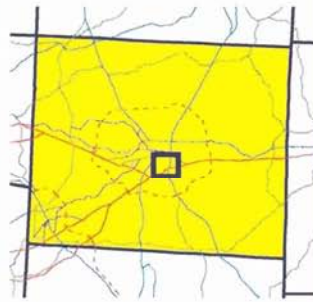
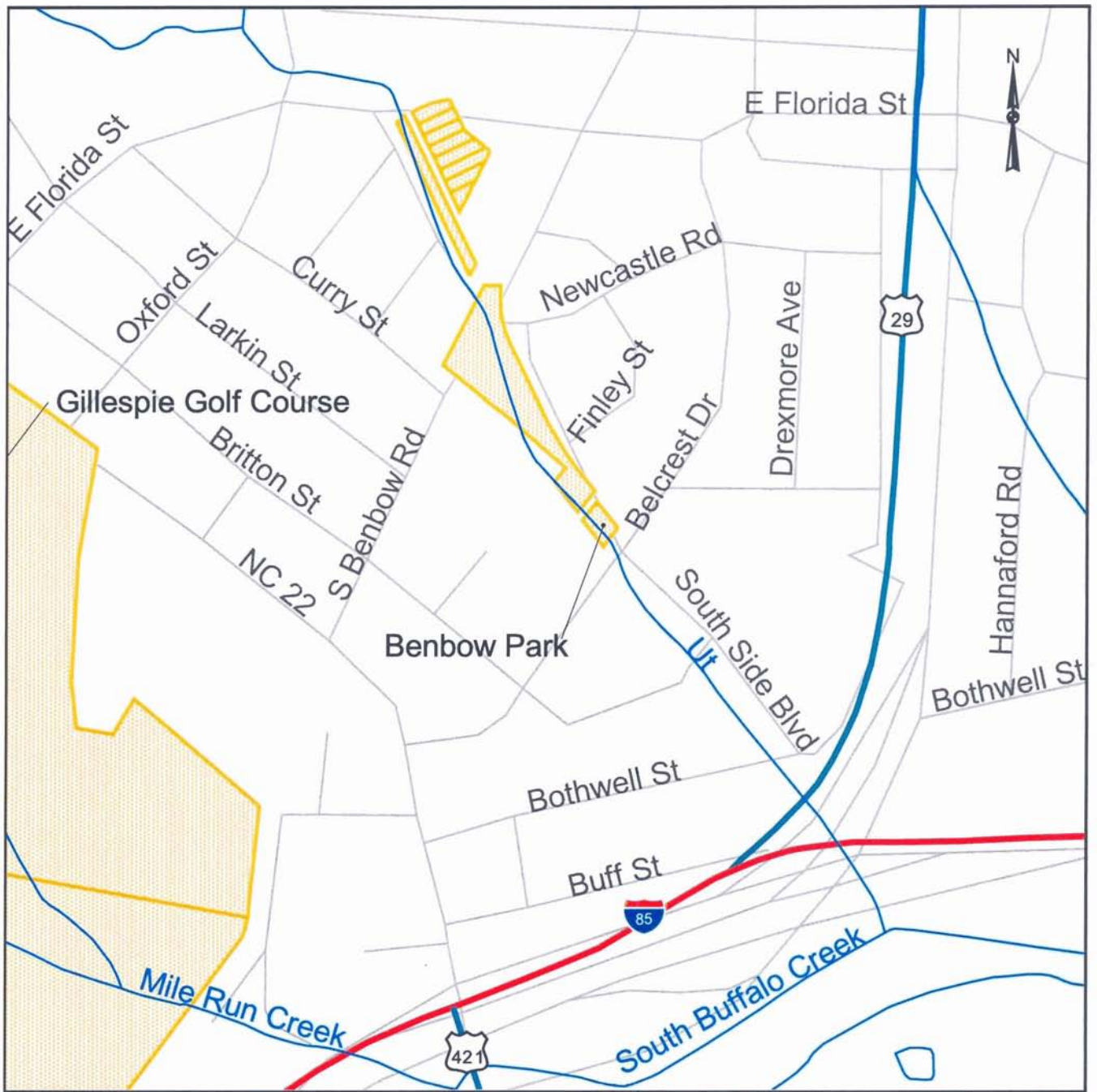
Similar to the other parks, woody vegetation is lacking in many areas along the channel. Where trees are present, they are directly along the streambanks. Woody species found along the bank include black willow, silky dogwood, elderberry, river birch, sycamore, black cherry, and tag alder. Additional 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 Constraints**

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



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





**LEGEND**

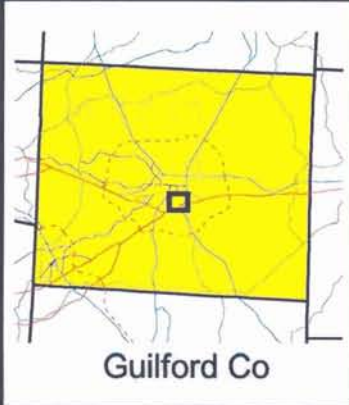
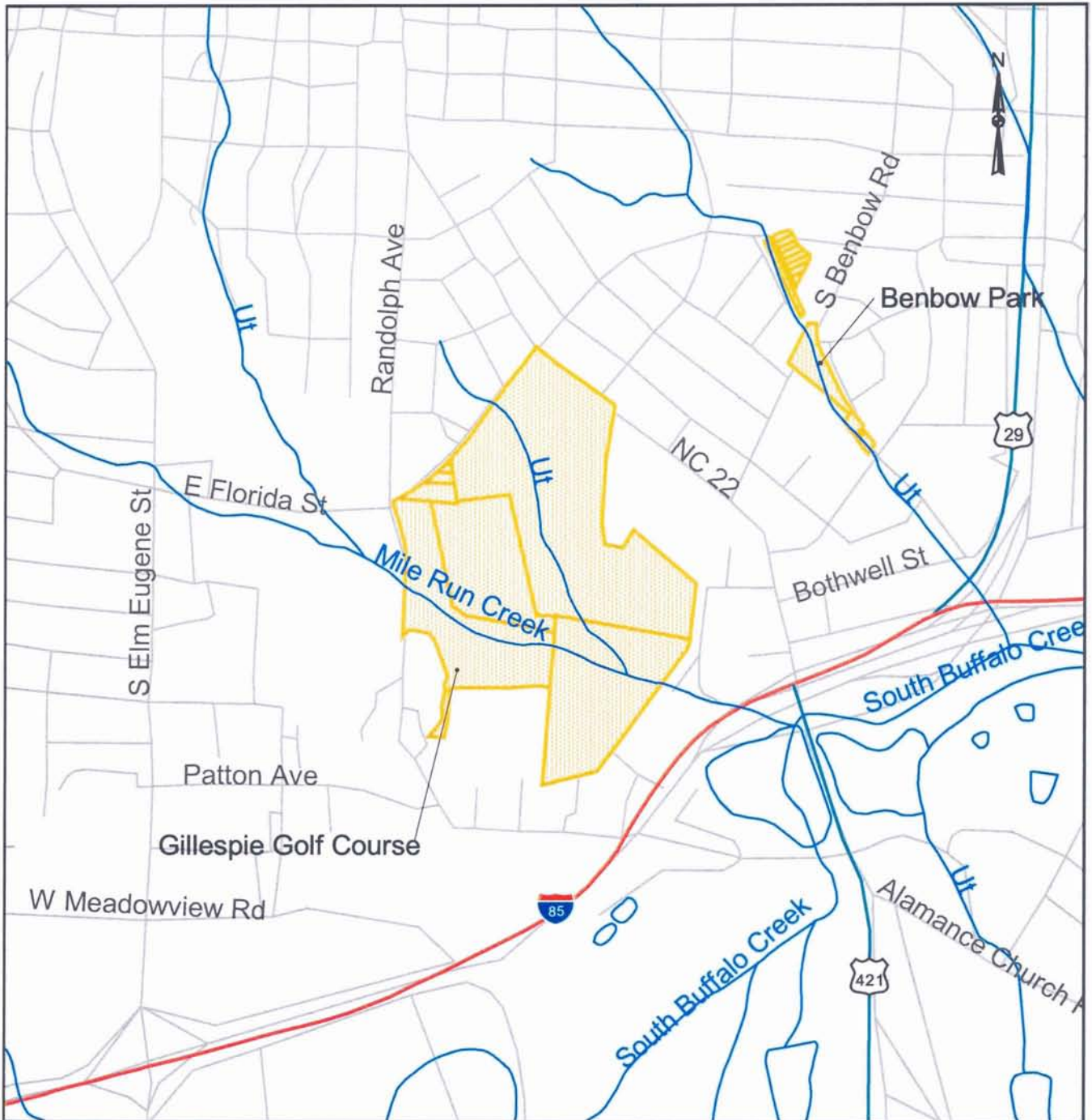
- |  |   |
|--|---|
|  Benbow Watershed |  Land Cover                |
|  Roads            |  Open Space                |
|  Park Boundaries  |  Residential - <= 1/8 acre |
|  BENBOW           |  Residential - 2 acre      |
|  CLINTON HILLS    |  Industrial                |
|  |  Paved Spaces              |



North Carolina  
Wetlands Restoration Program

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

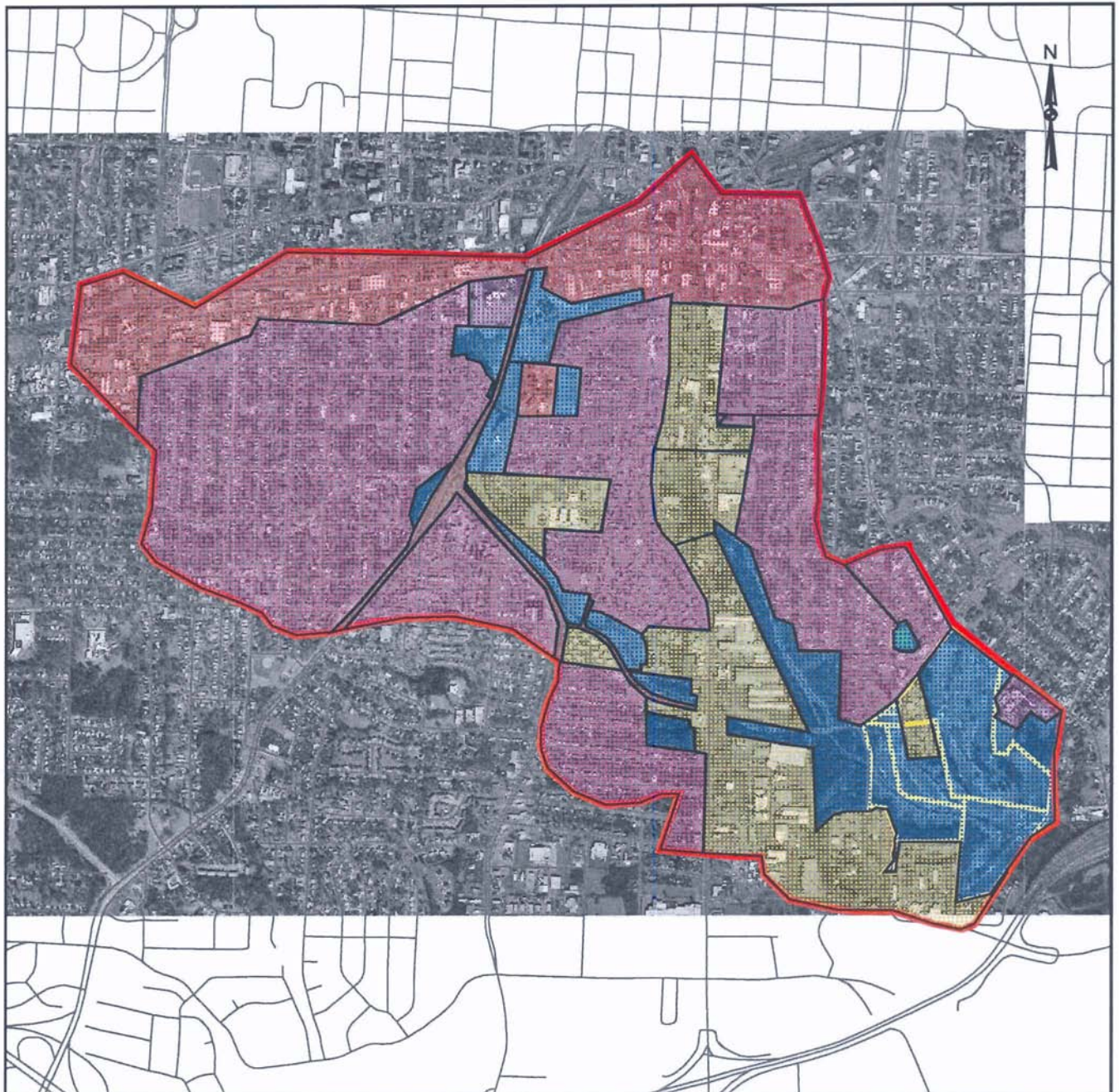





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Wetlands Restoration Program**

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





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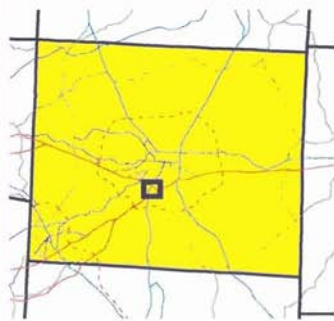
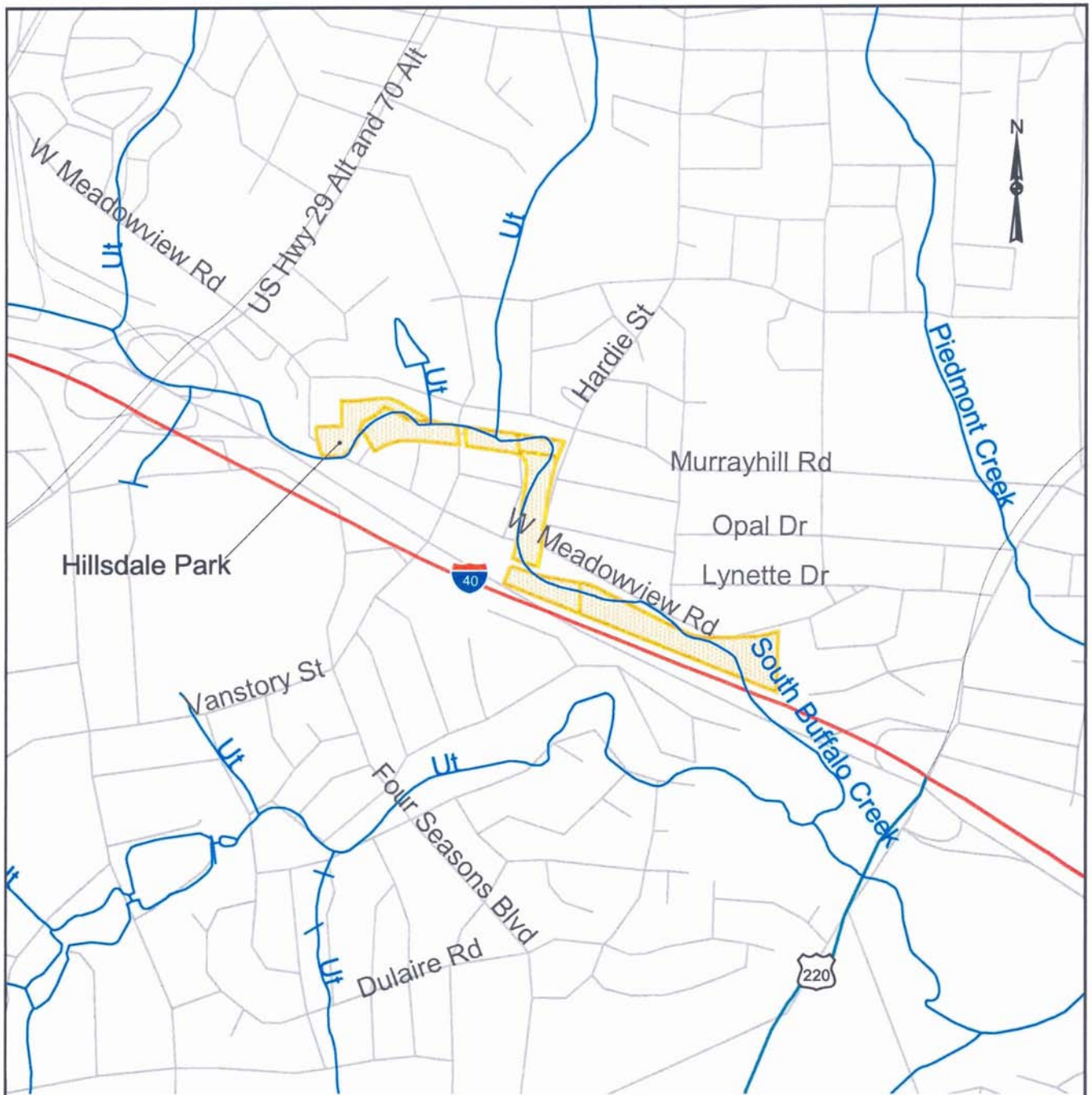
- |                       |                          |
|-----------------------|--------------------------|
| Gillespie Watershed   | Open Space               |
| Roads                 | Residential - <=1/8 acre |
| Park Boundaries       | Residential - 2 acre     |
| GILLESPIE GOLF COURSE | Commercial               |
| WARD ST               | 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





Guilford Co

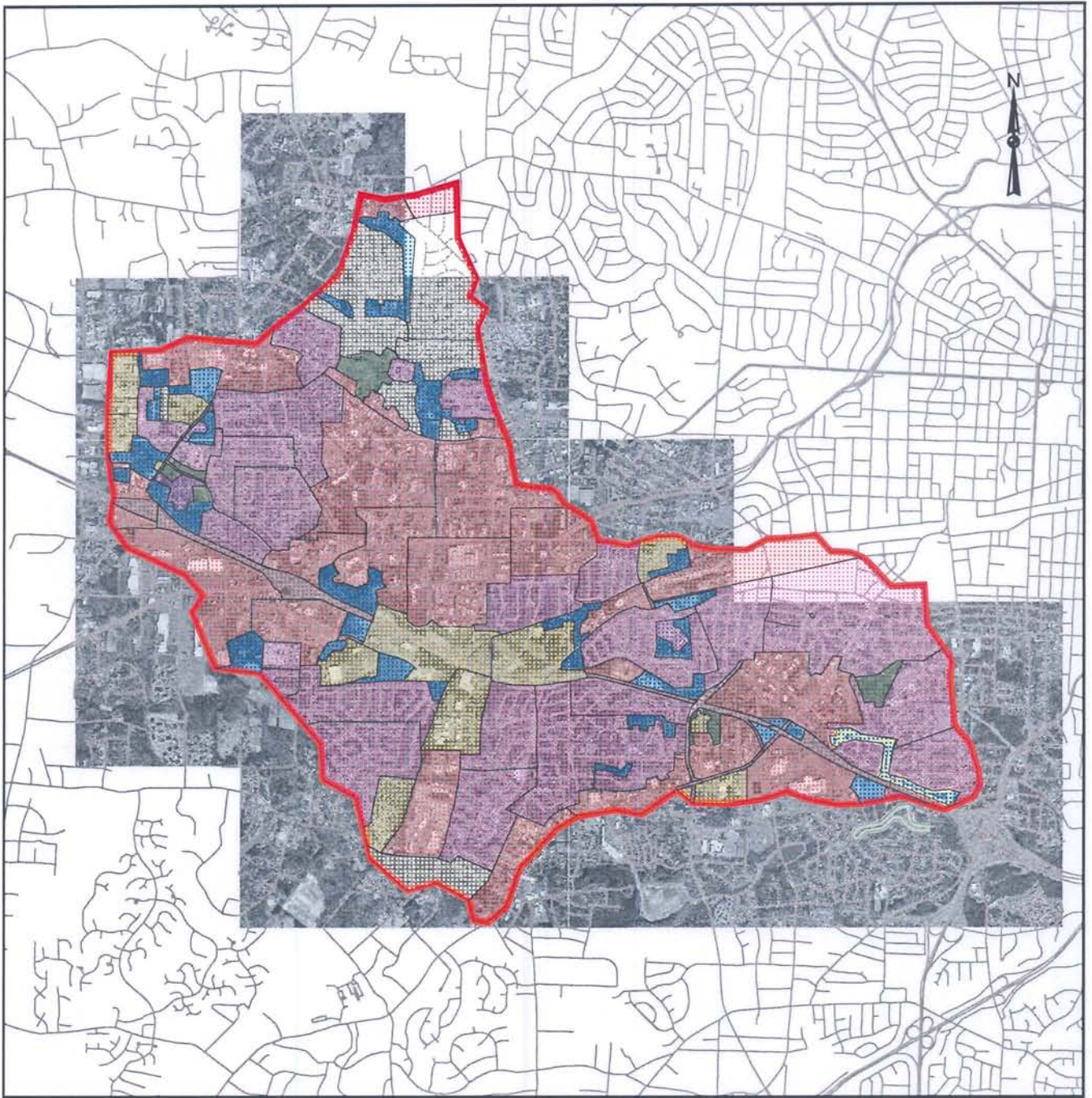


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Wetlands Restoration Program

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
-  HILLSDALE
-  ROLLING ROADS

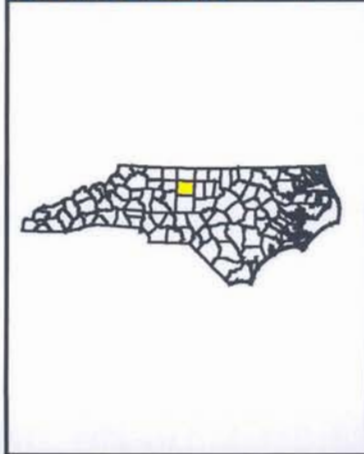
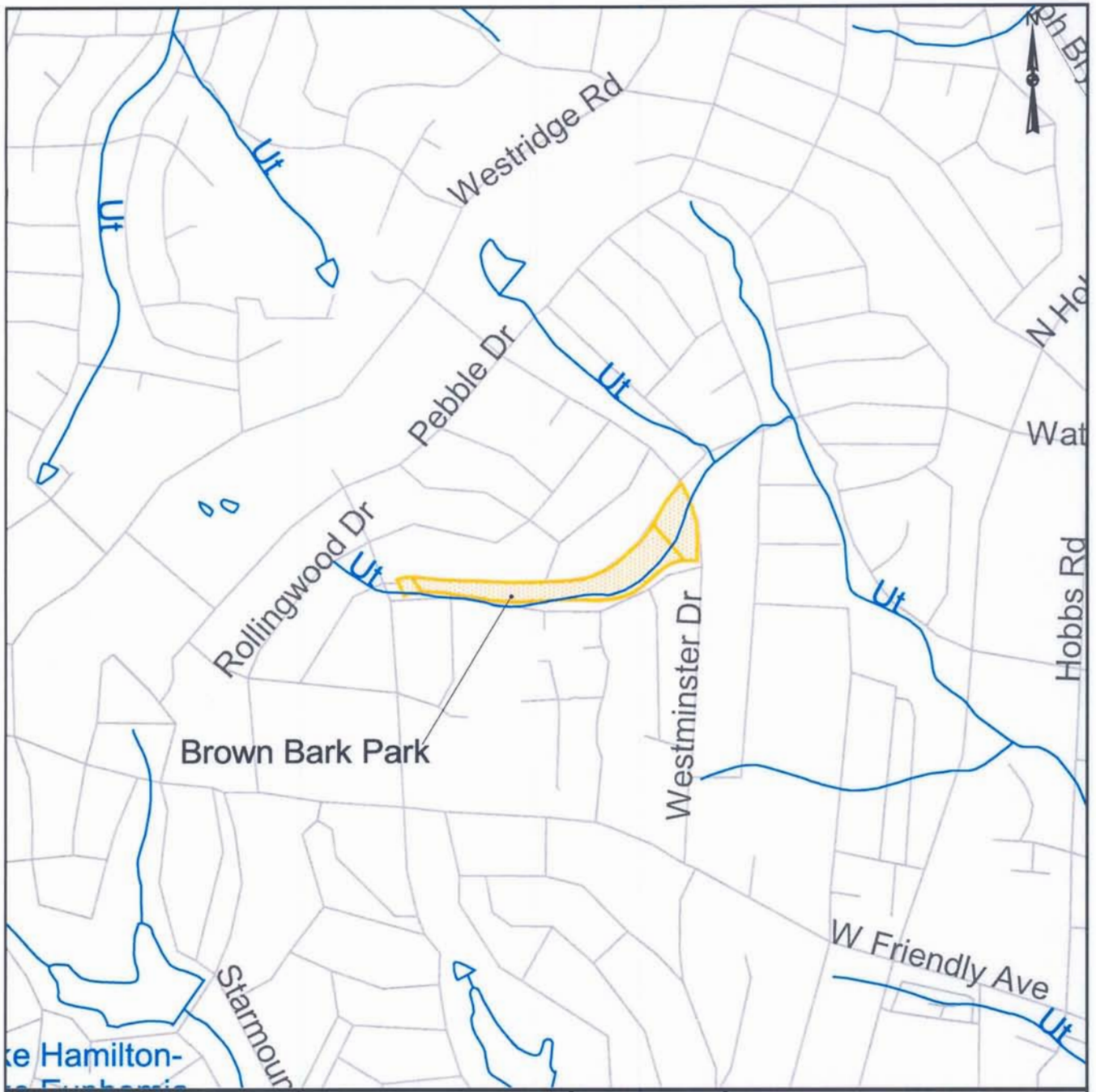
- Land Cover**
-  Forested
  -  Open Space
  -  Residential - <=1/8 acre
  -  Residential - 1/4 acre
  -  Residential - 2 acre
  -  Commercial
  -  Industrial
  -  Paved Spaces



North Carolina  
Wetlands Restoration Program

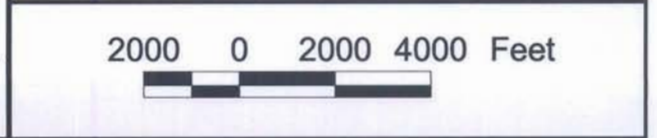
Figure 2.6: Hillsdale Park Watershed Map  
Buffalo Creeks Stream Restoration Projects  
Greensboro, NC  
Guilford County

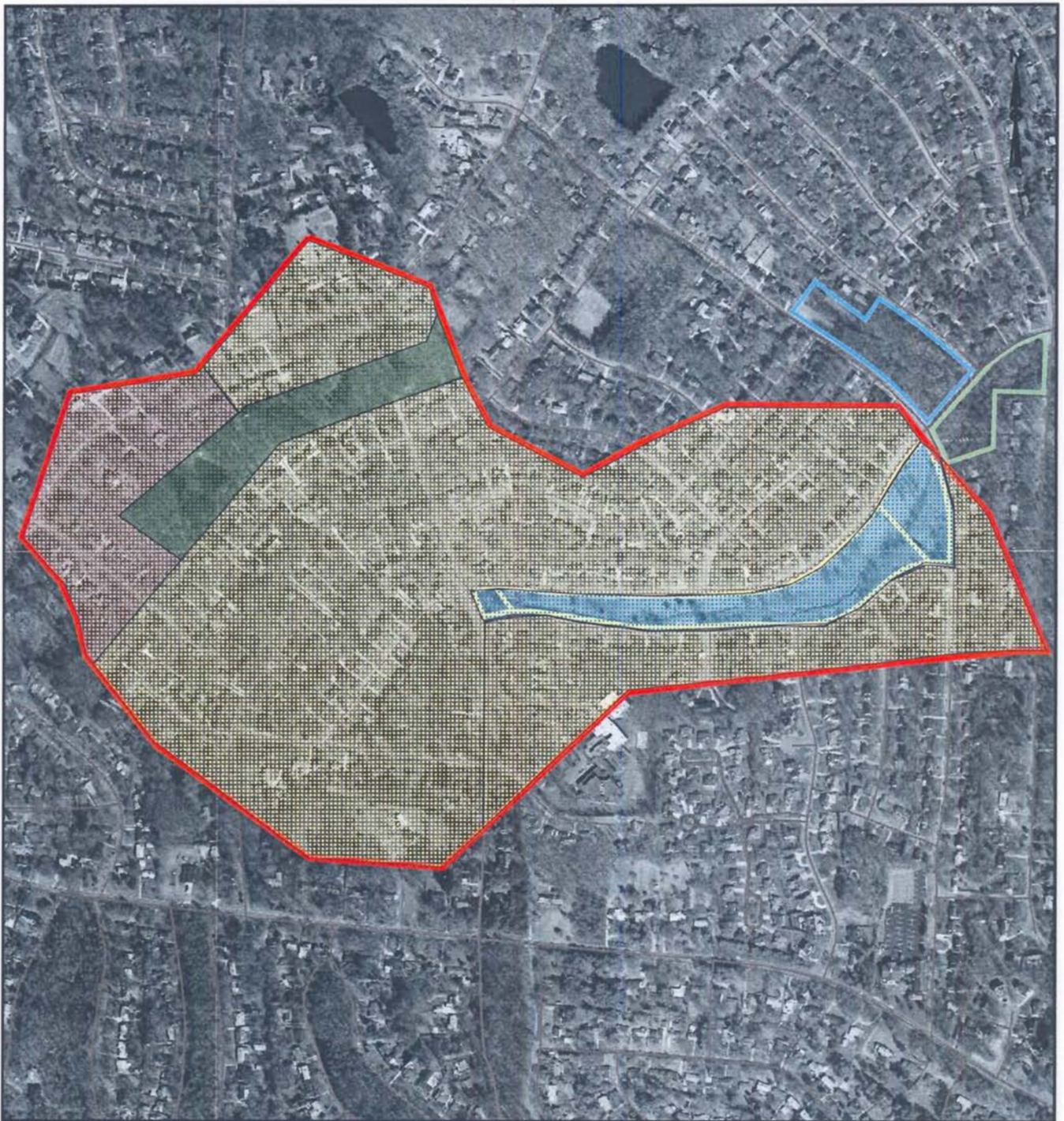




North Carolina  
Wetlands Restoration Program

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





**LEGEND**

- |  |  |
|--|--|
|  Brown Bark Watershed |  Forest                 |
|  Roads                |  Open Space             |
|  Park Boundaries      |  Residential - 1/3 acre |
|  BROWN BARK           |  Residential - 1/4 acre |
|  CHATFIELD            |  |
|  FOREST HILL          |  |



North Carolina  
Wetlands Restoration Program

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





## 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.**

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

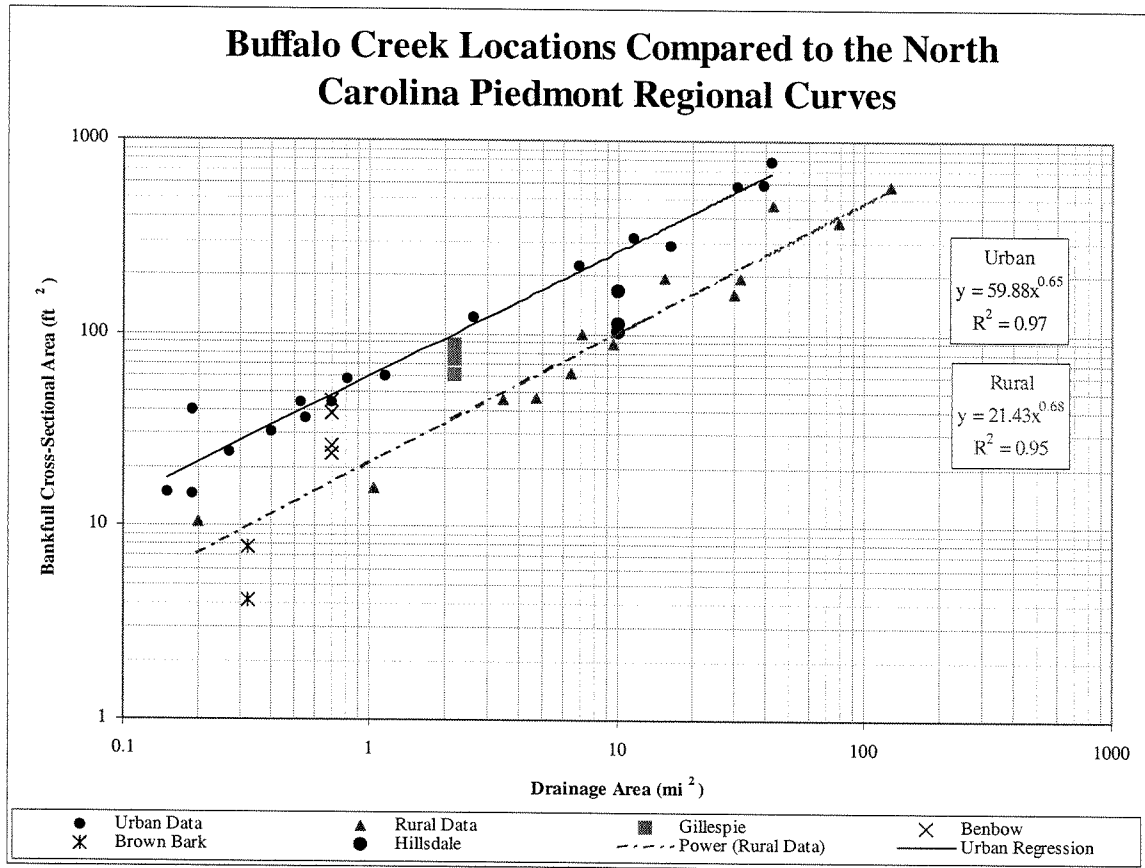
### 3.3 Bankfull Verification in the Buffalo Creek Watershed

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<sup>2</sup> 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.**

| <b>Sub-Project</b> | <b>Reference Stream Type</b> | <b>Rationale</b>   |
|--------------------|------------------------------|--|
| 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          |
| <i>Dimension</i>      | 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         |
| <i>Pattern</i>        | 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          |
| <i>Profile</i>        | 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                 | ---          | ---          |
| <i>Bed Material</i>   | 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.)**

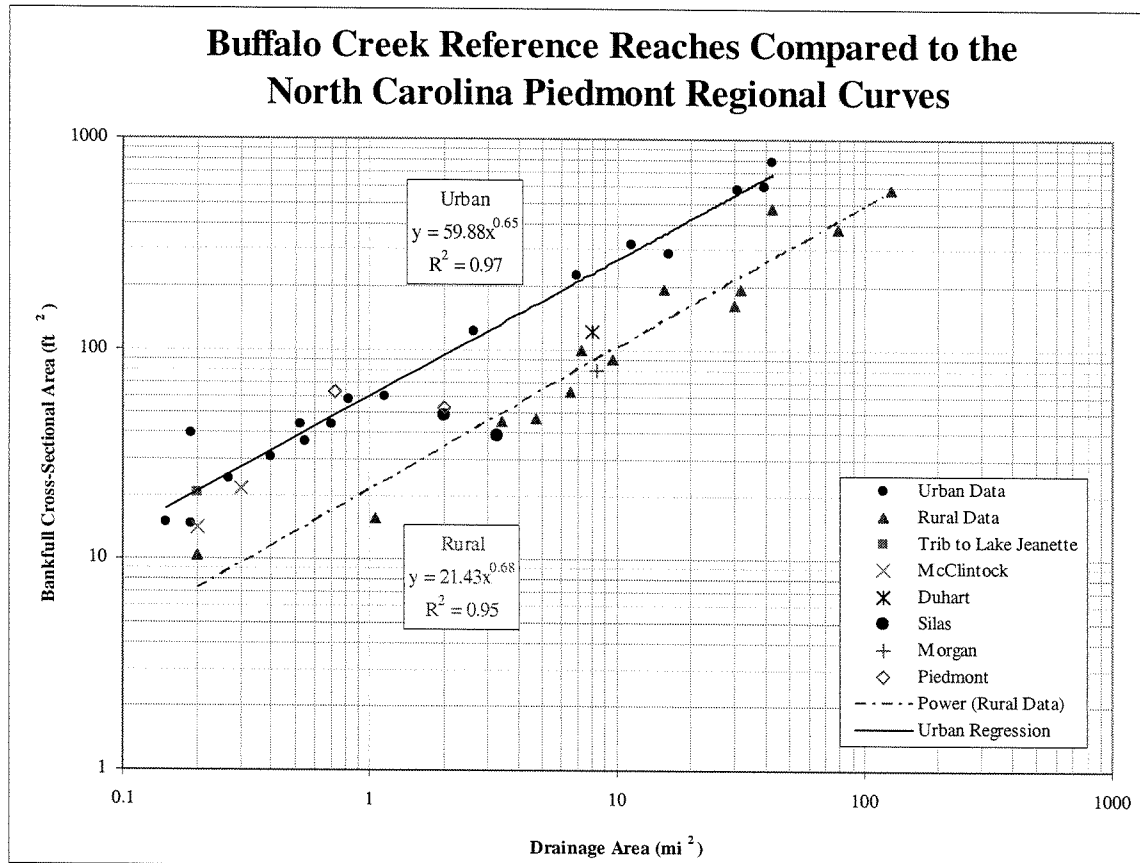


Table 4.3 shows the reference reach values for the B stream types. Location maps are included in Appendix 2. DuHart Creek was surveyed by Buck Engineering and is located in Cramerton, NC. Silas Creek was surveyed by the Natural Resources Conservation Service and is located in Winston-Salem, NC. Morgan 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.**

| <b>Parameters</b>          |                          | <b>Reference</b> | <b>Reference</b> | <b>Reference</b> | <b>Reference</b> |
|----------------------------|--------------------------|------------------|------------------|------------------|------------------|
| 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              |
| <i>Dimension / Pattern</i> | 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              |
| <i>Profile</i>             | 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              |
| <i>Bed Material</i>        | 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:

- Priority 1 – 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.
- Priority 2 – 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.
- Priority 3 – 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.
- Priority 4 – 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 ( $\leq 0.5$ ft) 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 than 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          |
| <i>Dimension \ Pattern</i> | 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            |
| <i>Profile</i>             | Bank Height Ratio                               | 1.2-1.3  | 1.0            |
|                            | Sinuosity                                       | 1.1      | 1.1            |
|                            | 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 Planting Design**

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 than 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        |
| <i>Dimension</i>                                | 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       |              |
| <i>Pattern</i>                                  | 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    |
| <i>Profile</i>                                  | 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 the stream buffer shall not exceed 25% of the available land space on publicly owned land with a "cross sectional land space" less than 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 coarse 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<sup>2</sup>. 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 Competency Analysis

Median substrate size has an important influence on the mobility of particles in streambeds. Critical dimensionless shear stress ( $\tau^*_{ci}$ ) 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).  $\tau^*_{ci}$  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  $D_{50}/D^{\wedge}_{50}$

Where:  $D_{50}$  = median diameter of the riffle bed (from 100 count in the riffle or pavement sample)

$D^{\wedge}_{50}$  = median diameter of the bar sample (or subpavement)

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

$$\tau_{ci}^* = 0.0834 (D_{50}/D^{50})^{-0.872} \quad \text{(Equation 1)}$$

- b) If the ratio  $D_{50}/D^{50}$  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.

$$\tau_{ci}^* = 0.0384 (D_i/D_{50})^{-0.887} \quad \text{(Equation 2)}$$

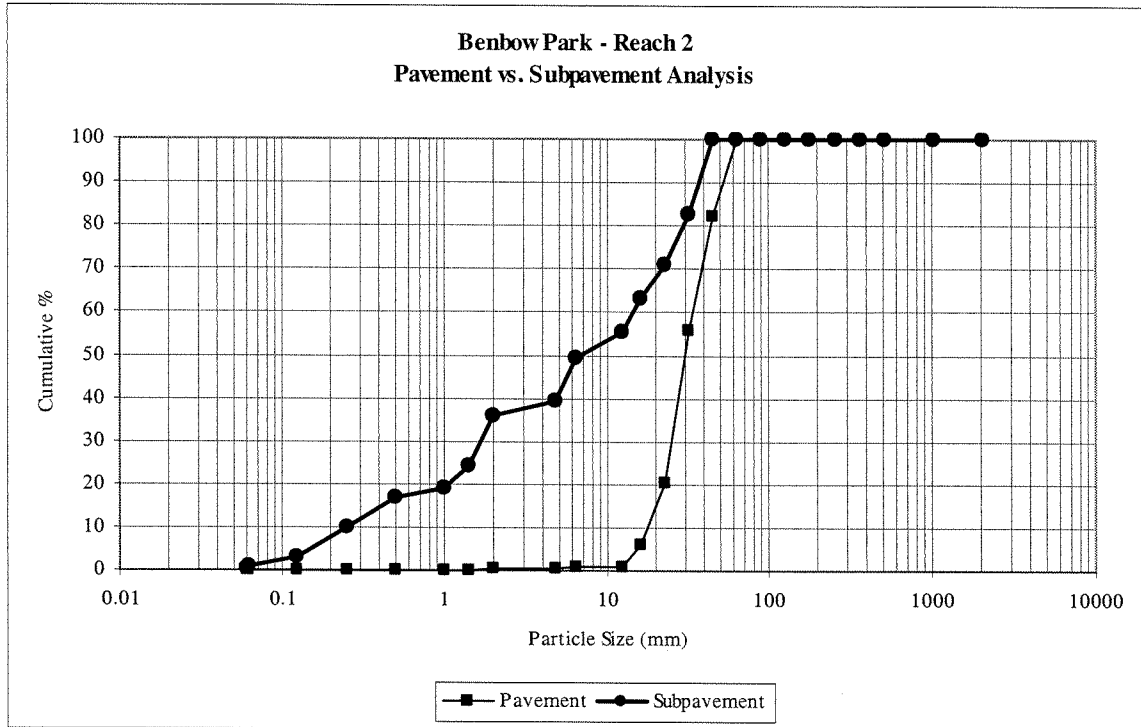
Entrainment analyses were conducted for the Benbow Park and Brown Bark Park reaches to ensure that the design streambed neither aggrades nor degrades during bankfull flows. A separate capacity analysis follows for the Gillespie Golf Course. A sediment transport analysis was not completed for Hillsdale 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  $D_{50}/D^{50}$  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:

$$d_r = \frac{1.65\tau_{ci}^*D_i}{S_e} \tag{Equation 3}$$

$$s_r = \frac{1.65\tau_{ci}^*D_i}{d_e} \tag{Equation 4}$$

- 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)
  - $\tau_{ci}^*$  = 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**

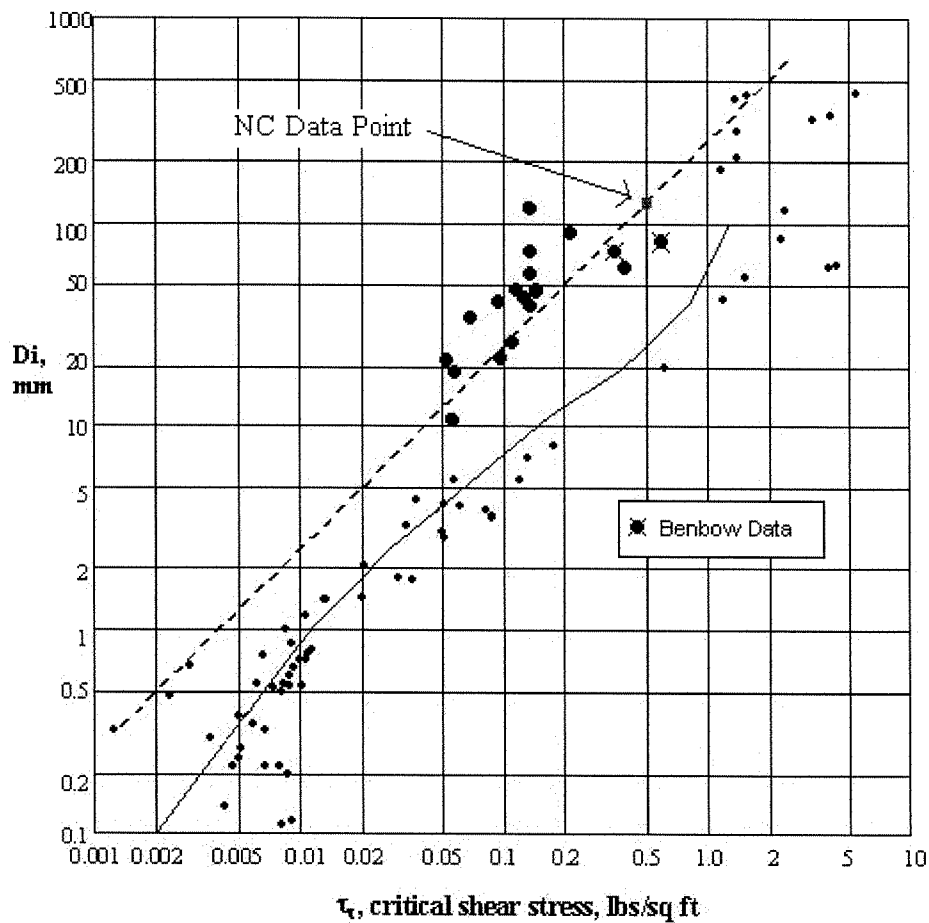
As a compliment to the required depth and slope calculations, we calculated boundary shear stresses for design riffle cross sections and compared with a modified Shield's Curve to predict sediment transport competency. The shear stress placed on the sediment particles is the force that entrains and moves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

$$\tau = \gamma R s \quad \text{(Equation 5)}$$

Where,

- $\tau$  = shear stress (lb/ft<sup>2</sup>)
- $\gamma$  = specific gravity of water (62.4 lb/ft<sup>3</sup>)
- 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<sup>2</sup>. 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<sup>2</sup> 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<sub>95</sub> 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<br>(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 <sup>3</sup> /sec) | 107                     | 107    |
| Flow velocity, v (ft/sec)                    | 2.4                     | 2.4    |
| Boundary Shear Stress, $\tau$ (lbs/sq ft)    | 0.63                    | 0.62   |

### 6.3 Gillespie Golf Course

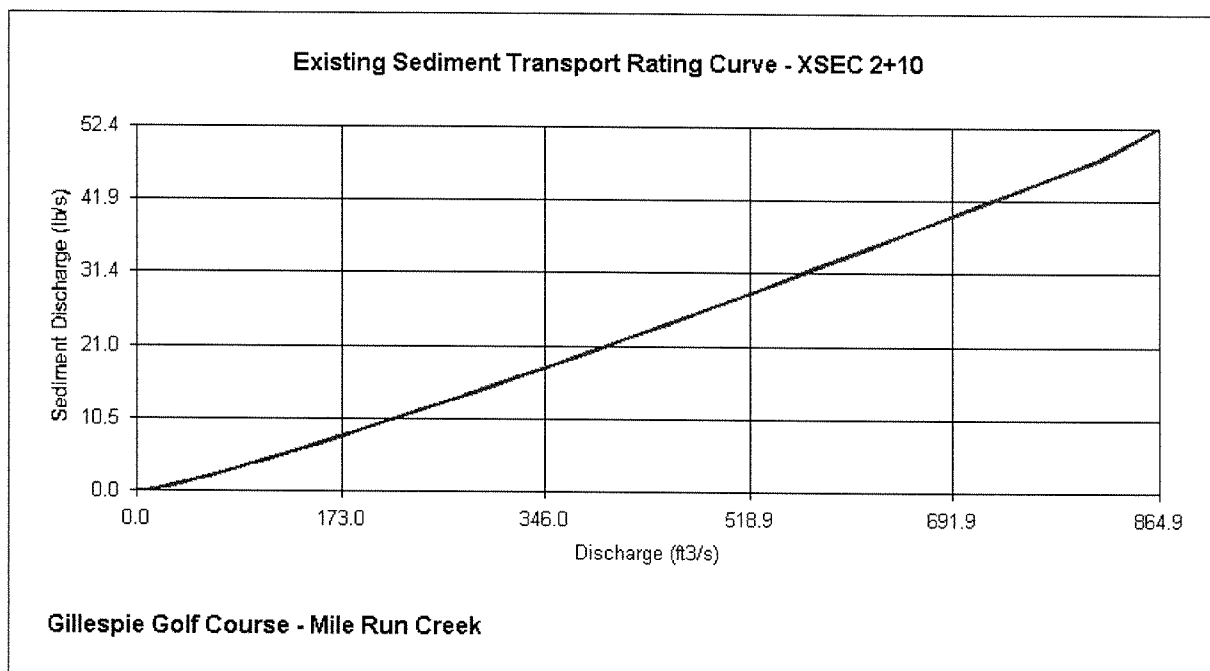
We did not perform sediment transport competency analyses for the Gillespie Golf Course because the bulk of the bed material is sand and the design does not change pattern or overall slope. The bankfull cross sectional area, width, and depth will change in areas where a smaller cross sectional area is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

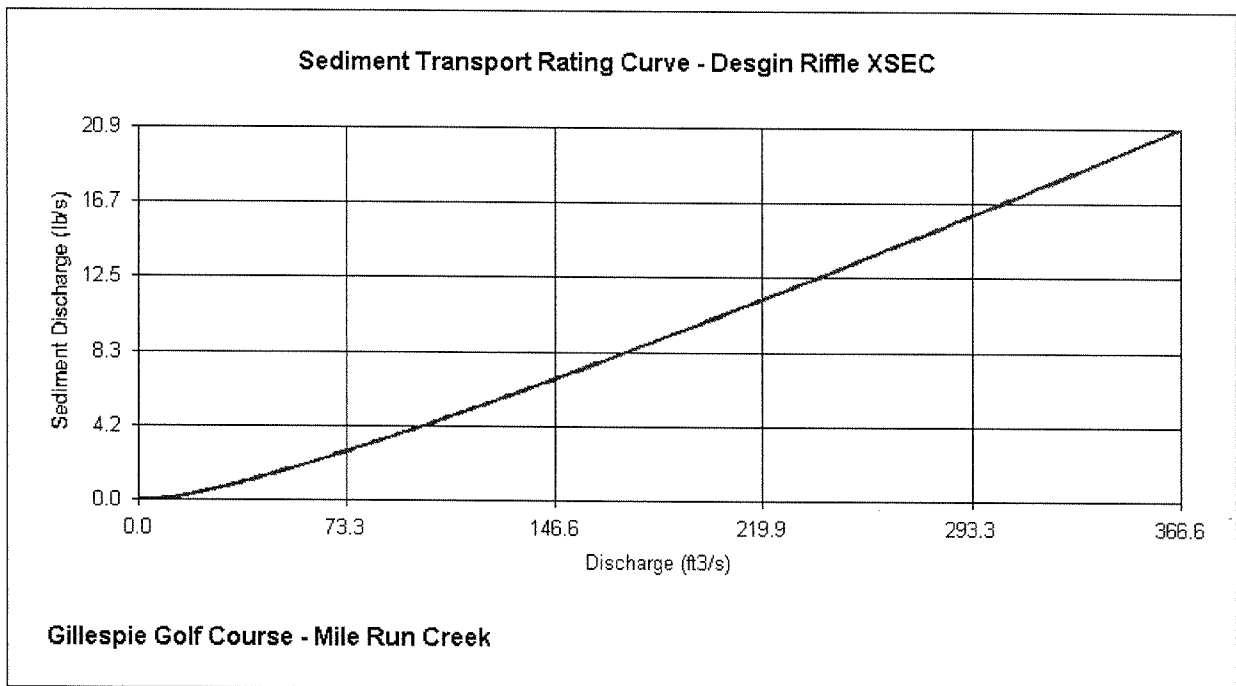
A sediment transport capacity analysis was completed on the project reach to determine if the design cross section had the same sediment transport rate of a stable existing cross section. Total sediment load was estimated using the Ackers and White (1973) function and data collected from the field survey. 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 given 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

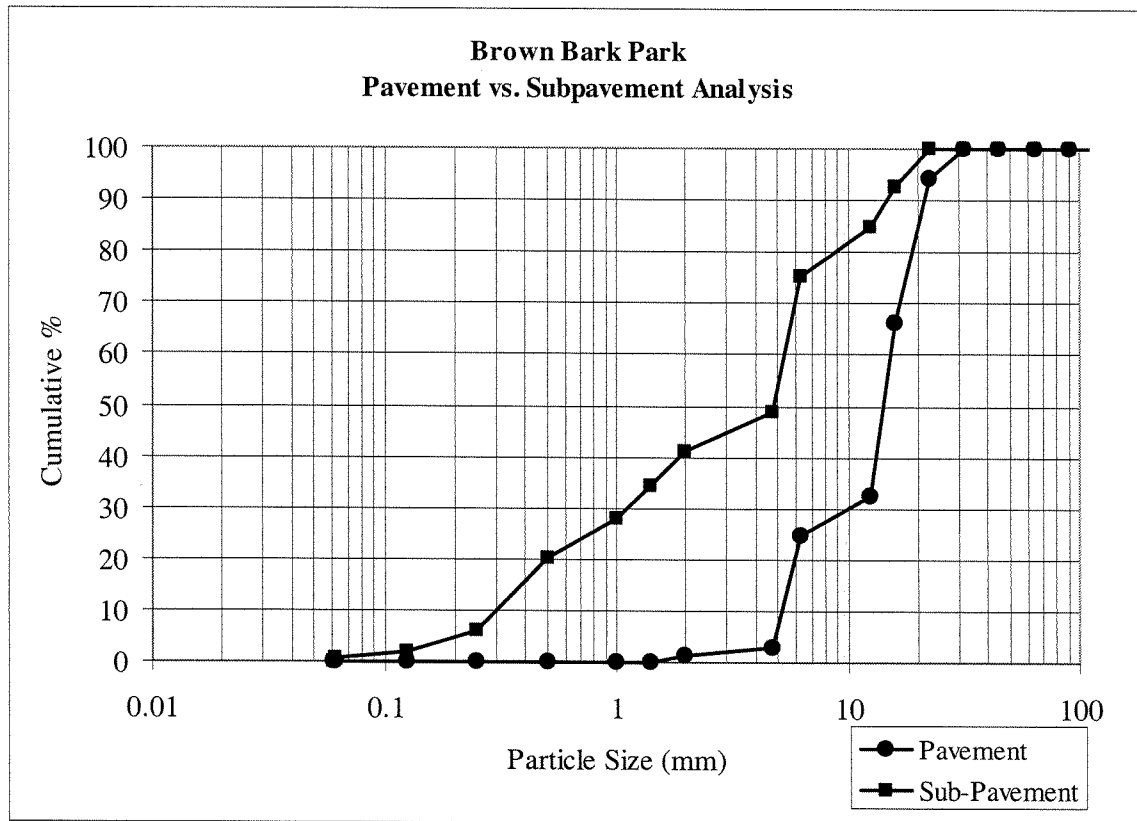
Data presented in Figure 6.5 were used to determine particle sizes for the various calculations. Using a pavement  $d_{50}$  of 11 mm and a subpavement  $d_{50}$  of 1.7 mm, the  $D_{50}/D_{50}$  equaled 6.5, indicating that Equation 1 was valid. Critical dimensionless shear stress was calculated using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

### 6.4.1 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 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<sup>2</sup>. 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<sup>2</sup>. 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 <sup>3</sup> /sec) | 40          | 40     |
| Flow velocity, v (ft/sec)                    | 4.3         | 3.3    |
| Boundary Shear Stress, $\tau$ (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.

Success Criteria: 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.

Success Criteria: 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.

Success Criteria: 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.

Success Criteria: 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.

Longitudinal reference photos: 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

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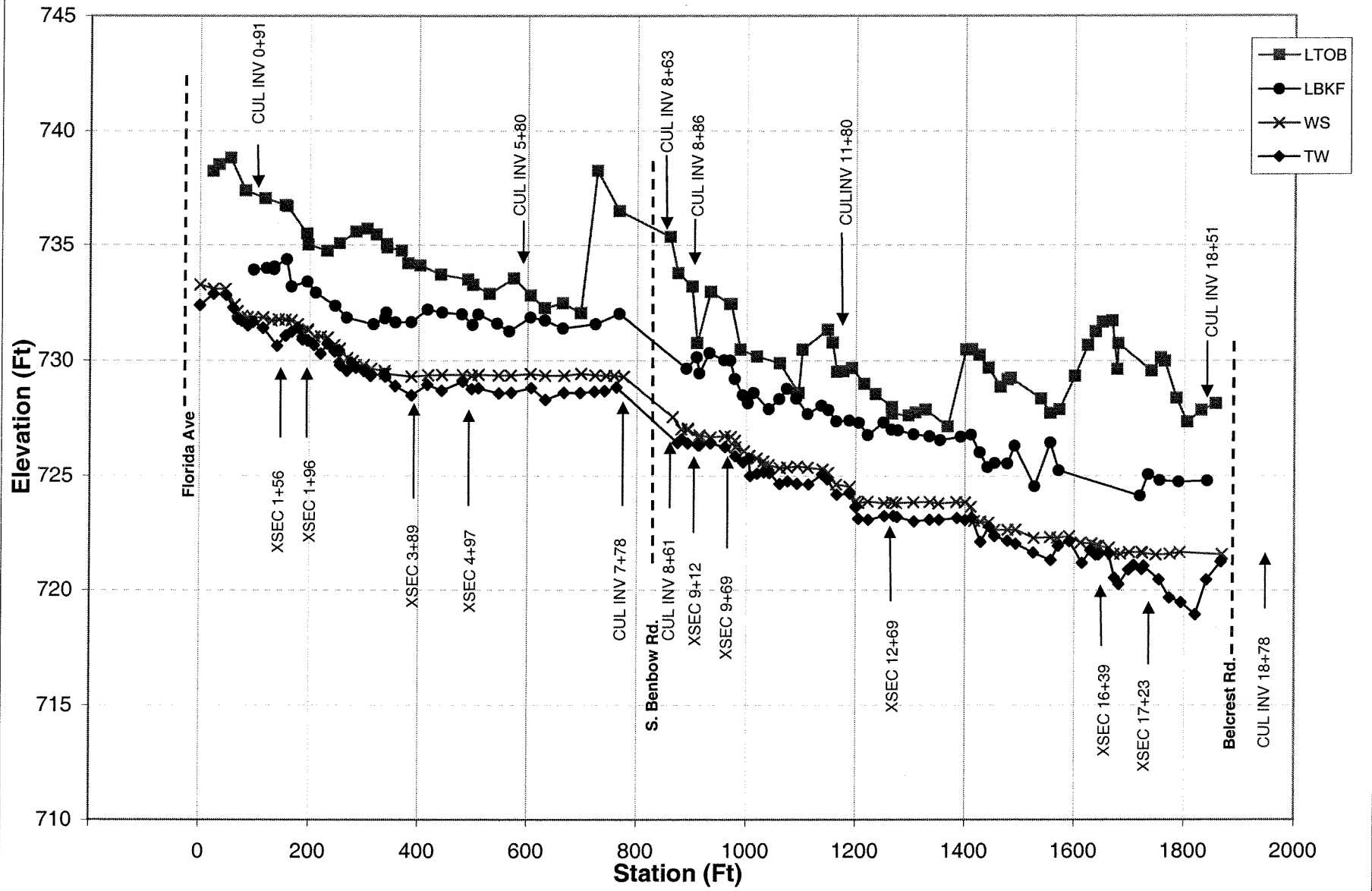
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## Appendix 1 Existing Condition Data

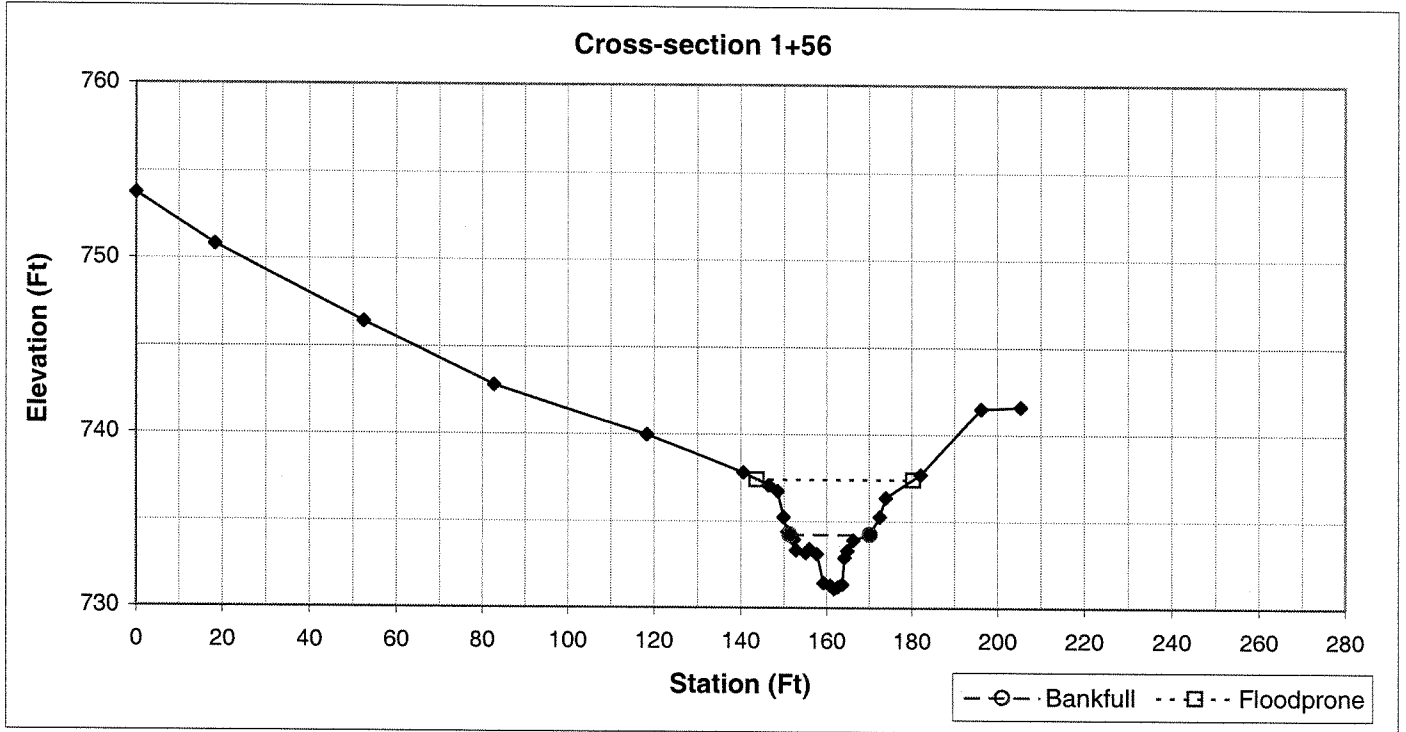
**Existing Condition Data  
Benbow Park**

### Benbow Park -- Unnamed Tributary to South Buffalo Creek Longitudinal Profile



# 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   |



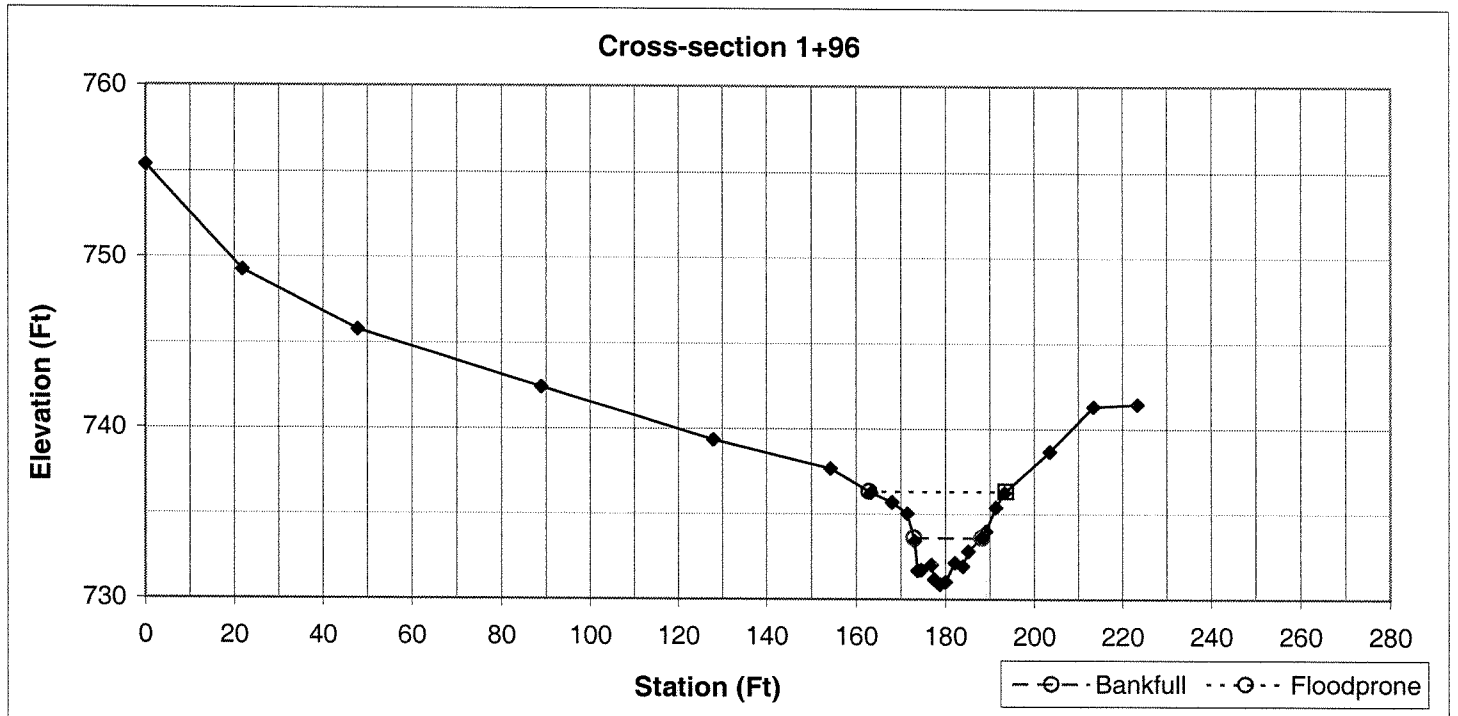
| Pt # | North     | East       | Elevation | Note    | Station |
|------|-----------|------------|-----------|---------|---------|
| 145  | 839529.23 | 1771077.82 | 753.75    | X01     | 0.00    |
| 146  | 839522.66 | 1771060.74 | 750.81    | X01     | 18.29   |
| 147  | 839510.51 | 1771028.73 | 746.41    | 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  |

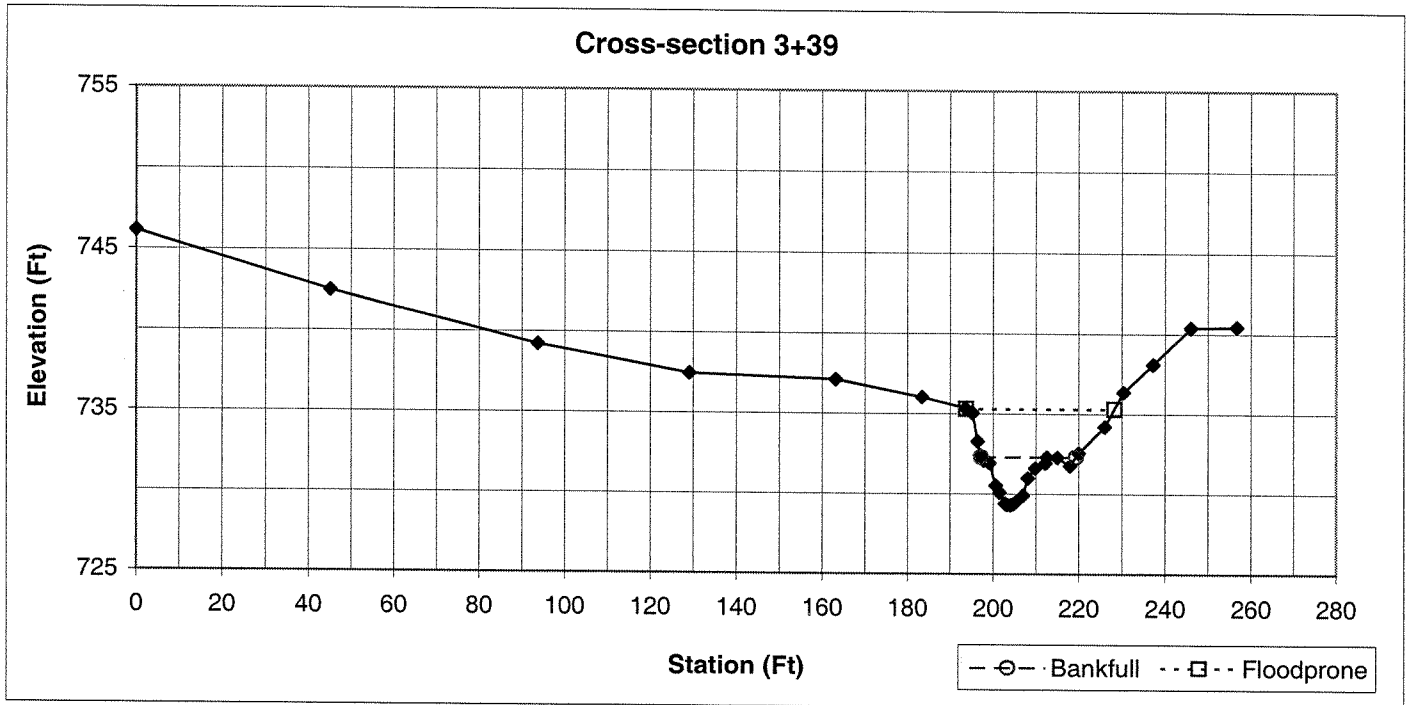
| Bankfull Line |           |
|---------------|-----------|
| Station       | Elevation |
| 172.98        | 733.59    |
| 188.22        | 733.59    |

| 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   |



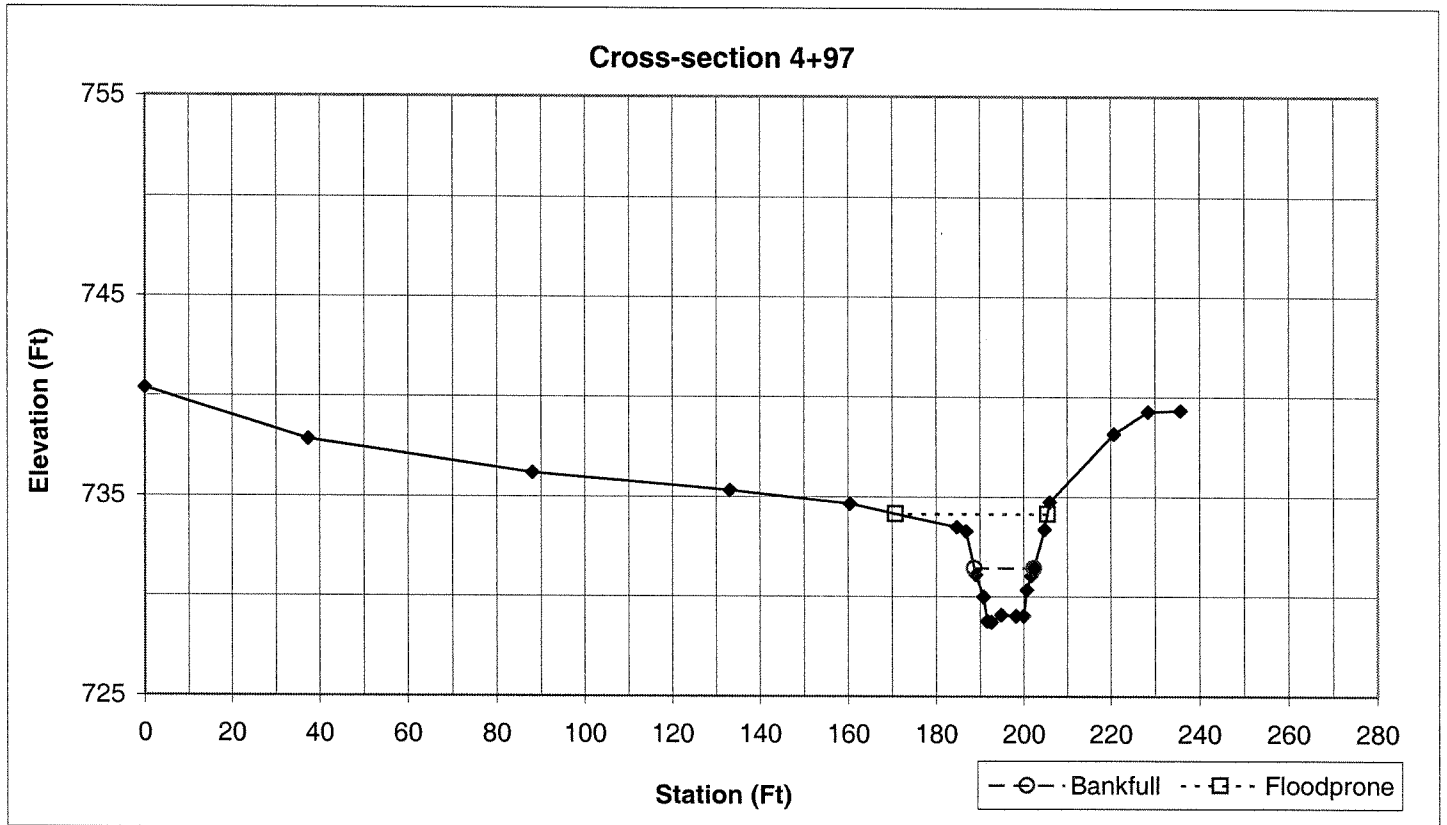
| Pt # | North     | East       | Elevation | Note   | Station |
|------|-----------|------------|-----------|--------|---------|
| 337  | 839403.06 | 1771194.18 | 746.14    | X3     | 0.00    |
| 338  | 839381.22 | 1771154.59 | 742.47    | X3     | 45.16   |
| 339  | 839357.64 | 1771112.09 | 739.21    | 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   |



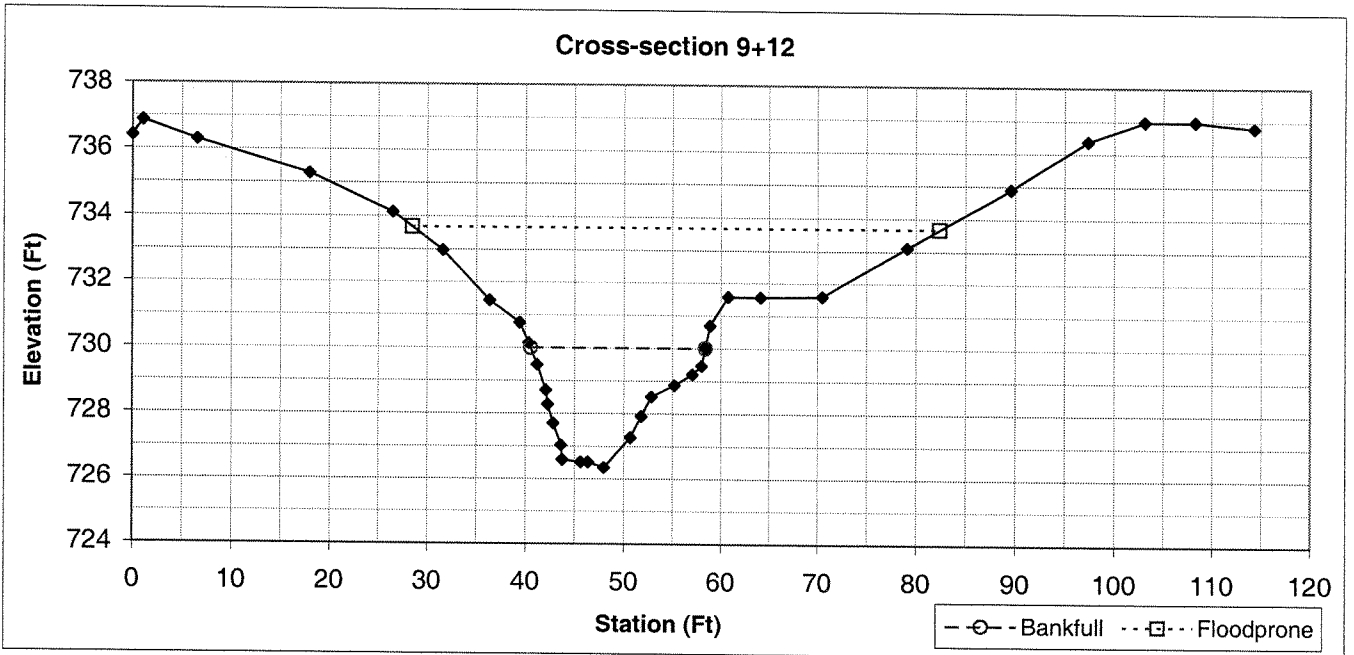
| Pt # | North     | East       | Elevation | Note   | Station |
|------|-----------|------------|-----------|--------|---------|
| 370  | 839269.46 | 1771232.09 | 740.39    | X4     | 0.00    |
| 371  | 839248.16 | 1771201.33 | 737.84    | X4     | 37.38   |
| 372  | 839214.10 | 1771162.86 | 736.18    | 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   |



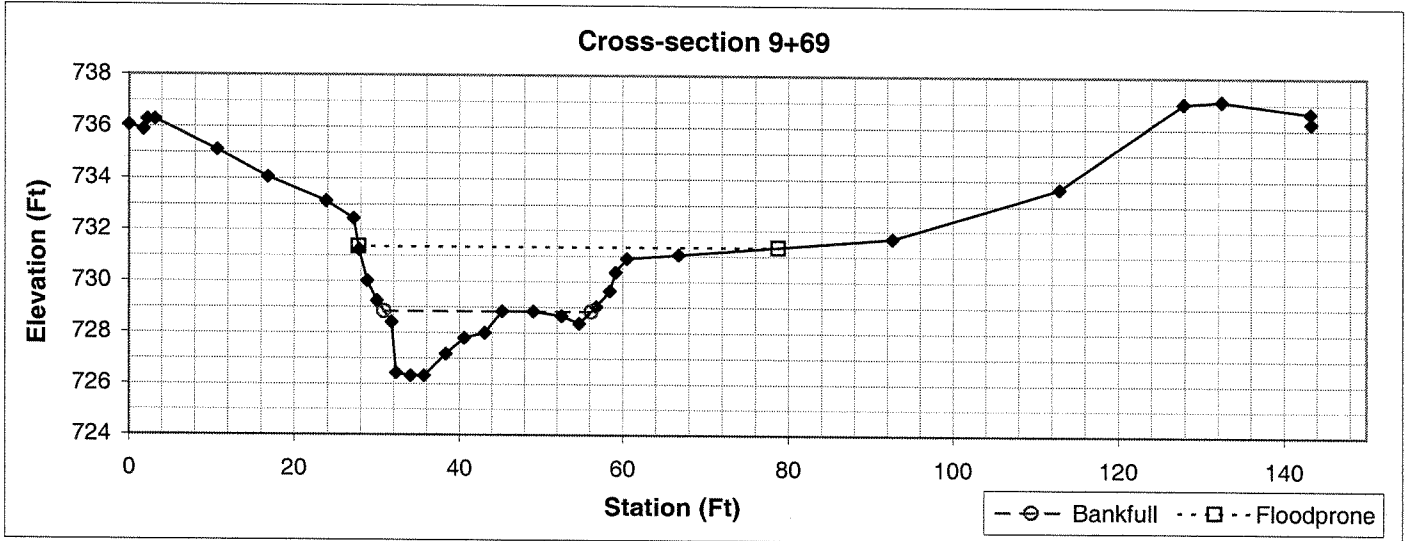
| Pt # | North     | East       | Elevation | Note        | Station |
|------|-----------|------------|-----------|-------------|---------|
| 802  | 838804.24 | 1771292.72 | 736.40    | X5B-CURB    | 0.00    |
| 803  | 838804.08 | 1771291.69 | 736.86    | X5TOP-CURB  | 1.05    |
| 804  | 838804.63 | 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   |



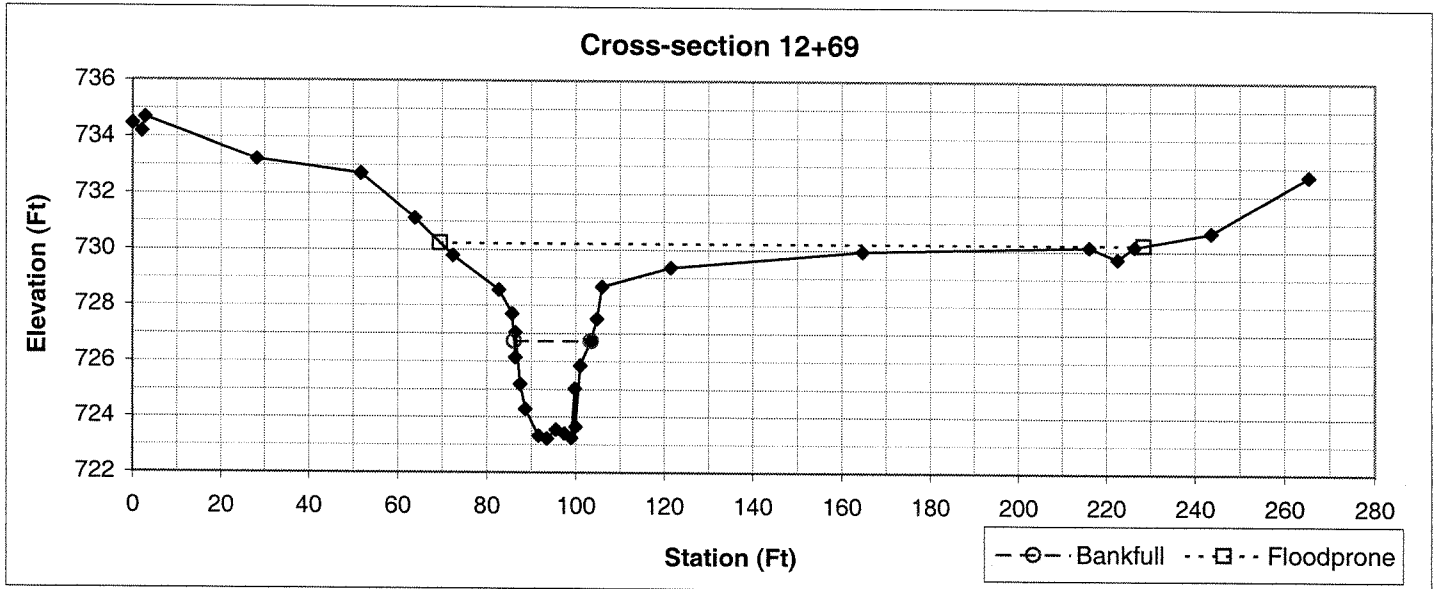
| Pt # | North     | East       | Elevation | Note          | Station |
|------|-----------|------------|-----------|---------------|---------|
| 841  | 838743.67 | 1771294.00 | 736.05    | X6EP          | 0.00    |
| 842  | 838743.52 | 1771292.23 | 735.88    | X6B-CURB      | 1.77    |
| 843  | 838743.56 | 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   |



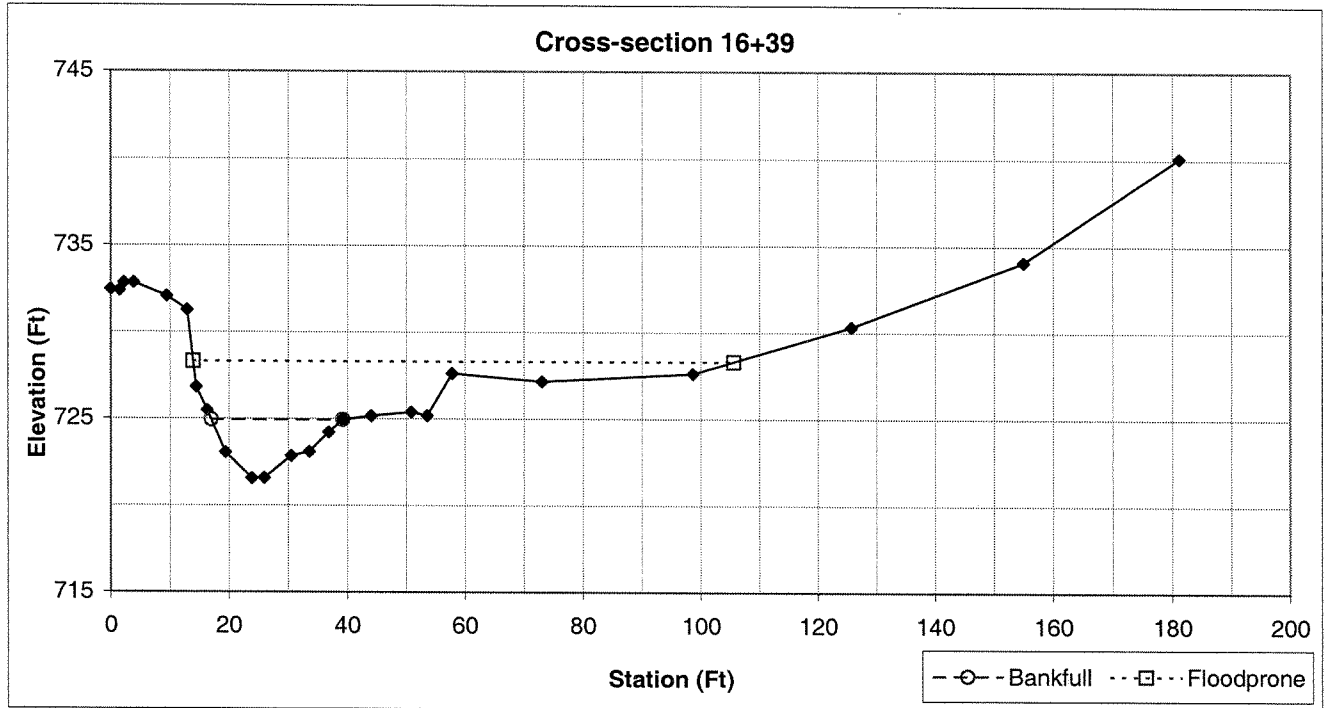
| Pt # | North     | East       | Elevation | Note     | Station |
|------|-----------|------------|-----------|----------|---------|
| 875  | 838493.75 | 1771390.63 | 734.45    | X7EP     | 0.00    |
| 876  | 838492.72 | 1771388.82 | 734.18    | X7B-CURB | 2.08    |
| 877  | 838491.78 | 1771388.52 | 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    | X7LTOB   | 216.10  |
| 903  | 838389.71 | 1771193.64 | 729.72    | X7CL-D   | 222.51  |
| 904  | 838386.63 | 1771190.97 | 730.17    | X7RTOB   | 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   |



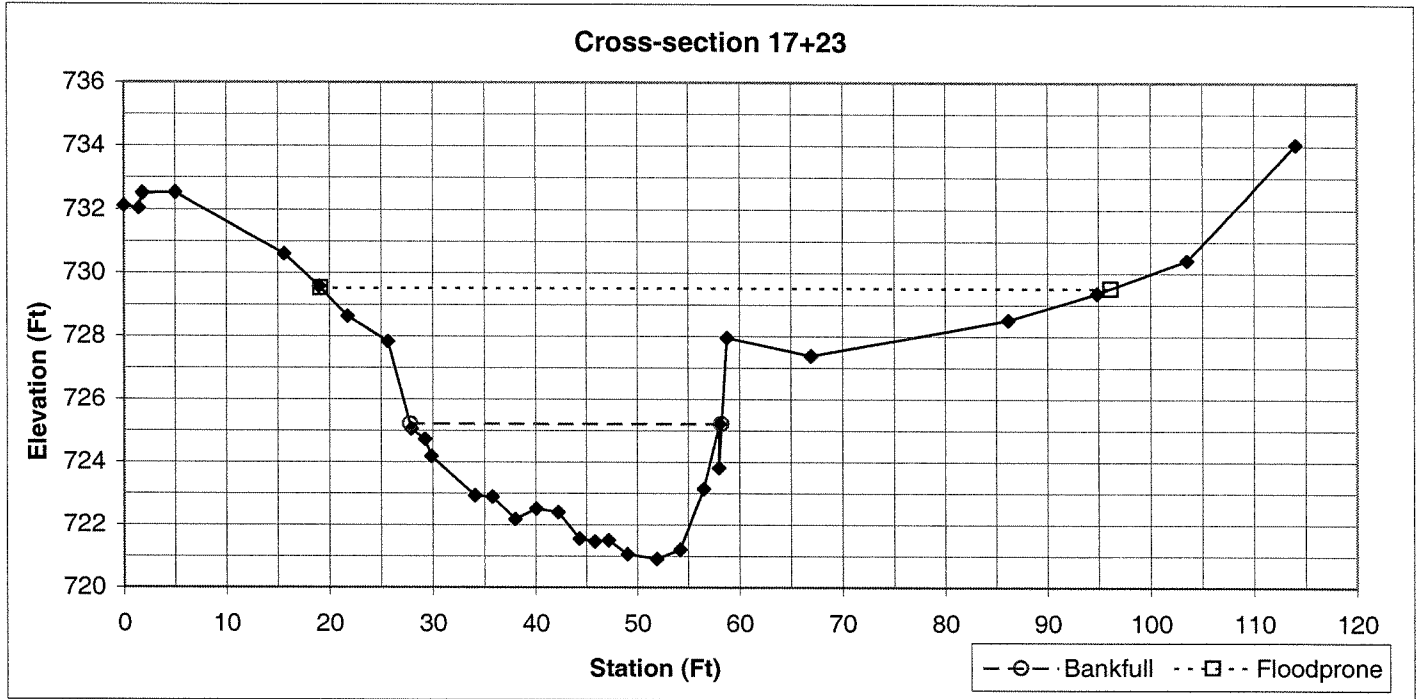
| Pt # | North     | East       | Elevation | Note     | Station |
|------|-----------|------------|-----------|----------|---------|
| 1155 | 838193.97 | 1771540.38 | 732.45    | X9EP     | 0.00    |
| 1156 | 838193.31 | 1771539.05 | 732.40    | X9BCURB  | 1.46    |
| 1157 | 838192.87 | 1771538.38 | 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   |



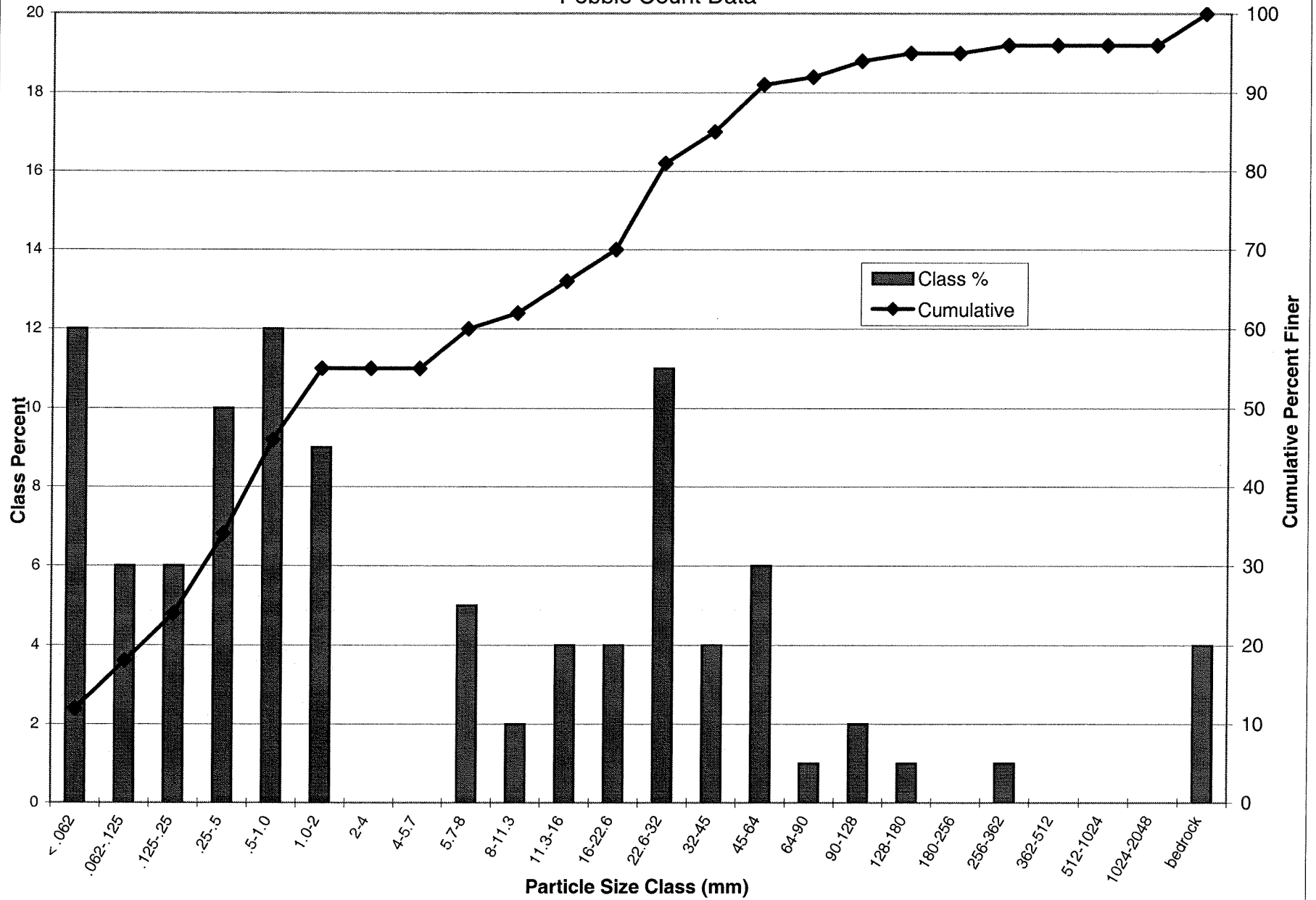
| Pt # | North     | East       | Elevation | Note     | Station |
|------|-----------|------------|-----------|----------|---------|
| 1182 | 838137.24 | 1771578.29 | 732.12    | X10EP    | 0.00    |
| 1183 | 838136.36 | 1771577.09 | 732.04    | X10-BOC  | 1.48    |
| 1184 | 838136.09 | 1771576.89 | 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

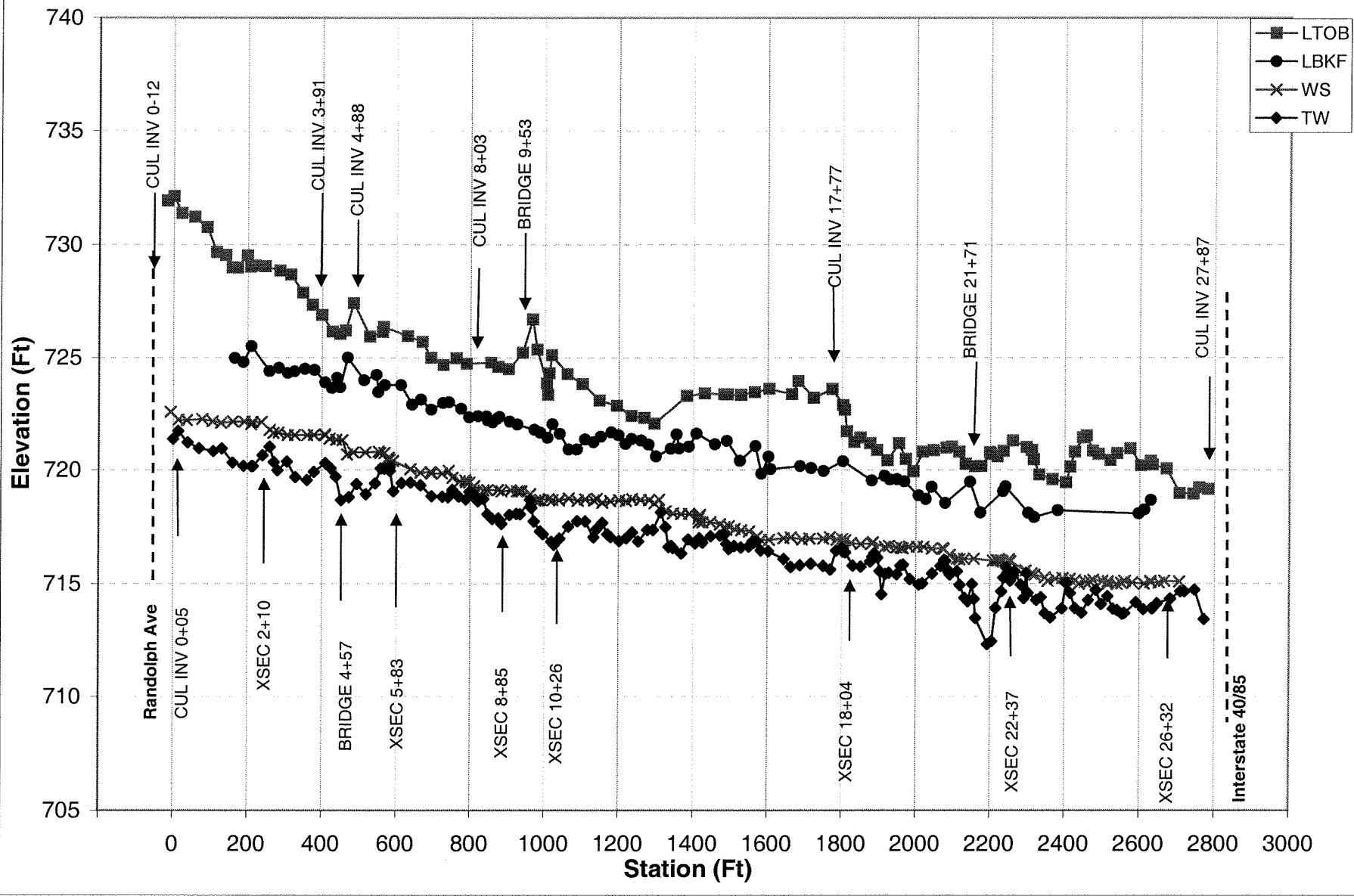
## Pebble Count Data





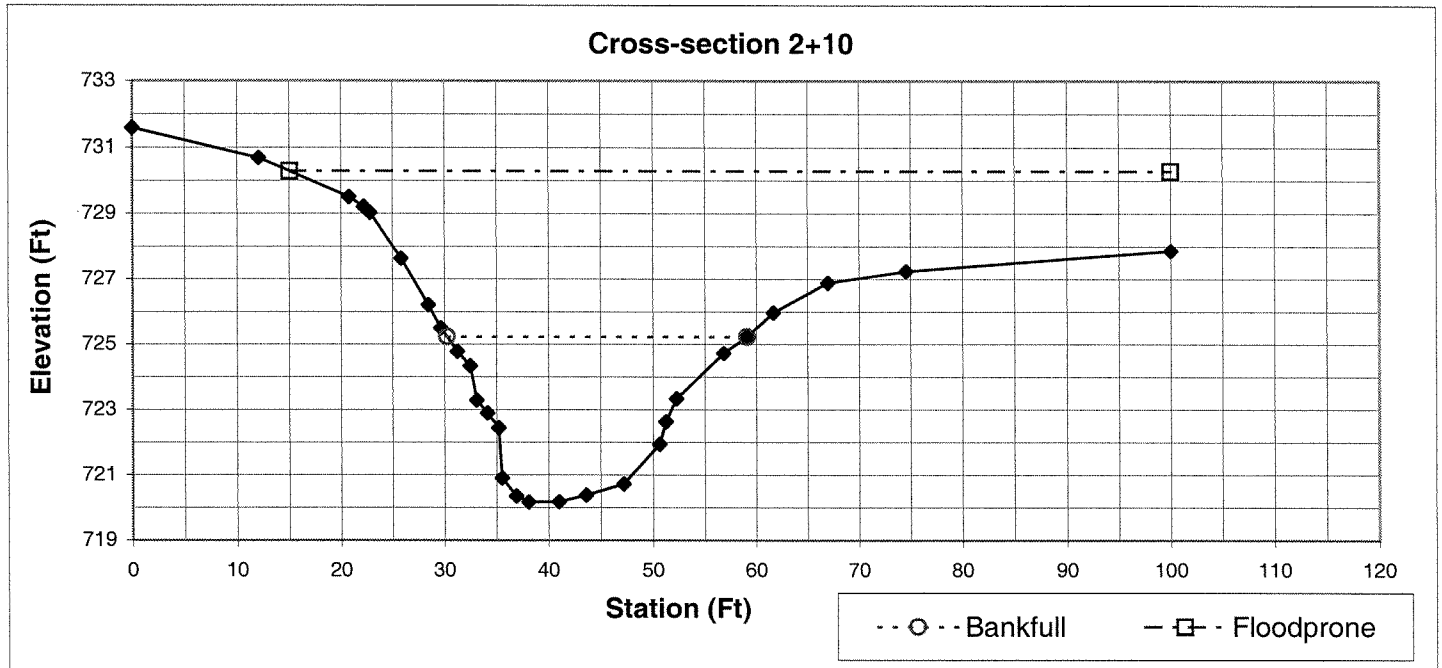
**Existing Condition Data  
Gillespie Golf Course**

Gillespie Golf Course -- Mile Run Creek Longitudinal Profile



# 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   |



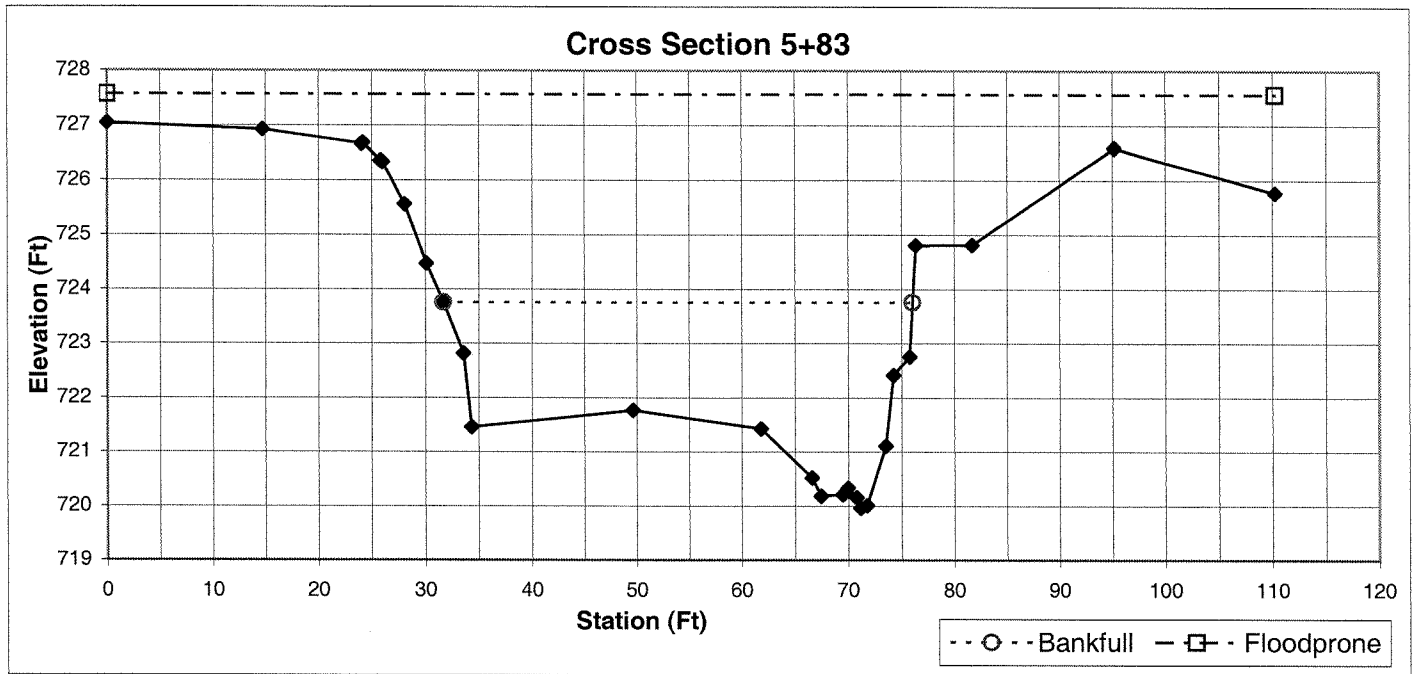
| Pt # | North     | East       | Elevation | Note       | Station |
|------|-----------|------------|-----------|------------|---------|
| 1545 | 836722.80 | 1768240.27 | 731.59    | X1-LEYLAND | 0.00    |
| 1546 | 836713.76 | 1768232.21 | 730.68    | X1         | 12.10   |
| 1547 | 836707.80 | 1768225.79 | 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   |



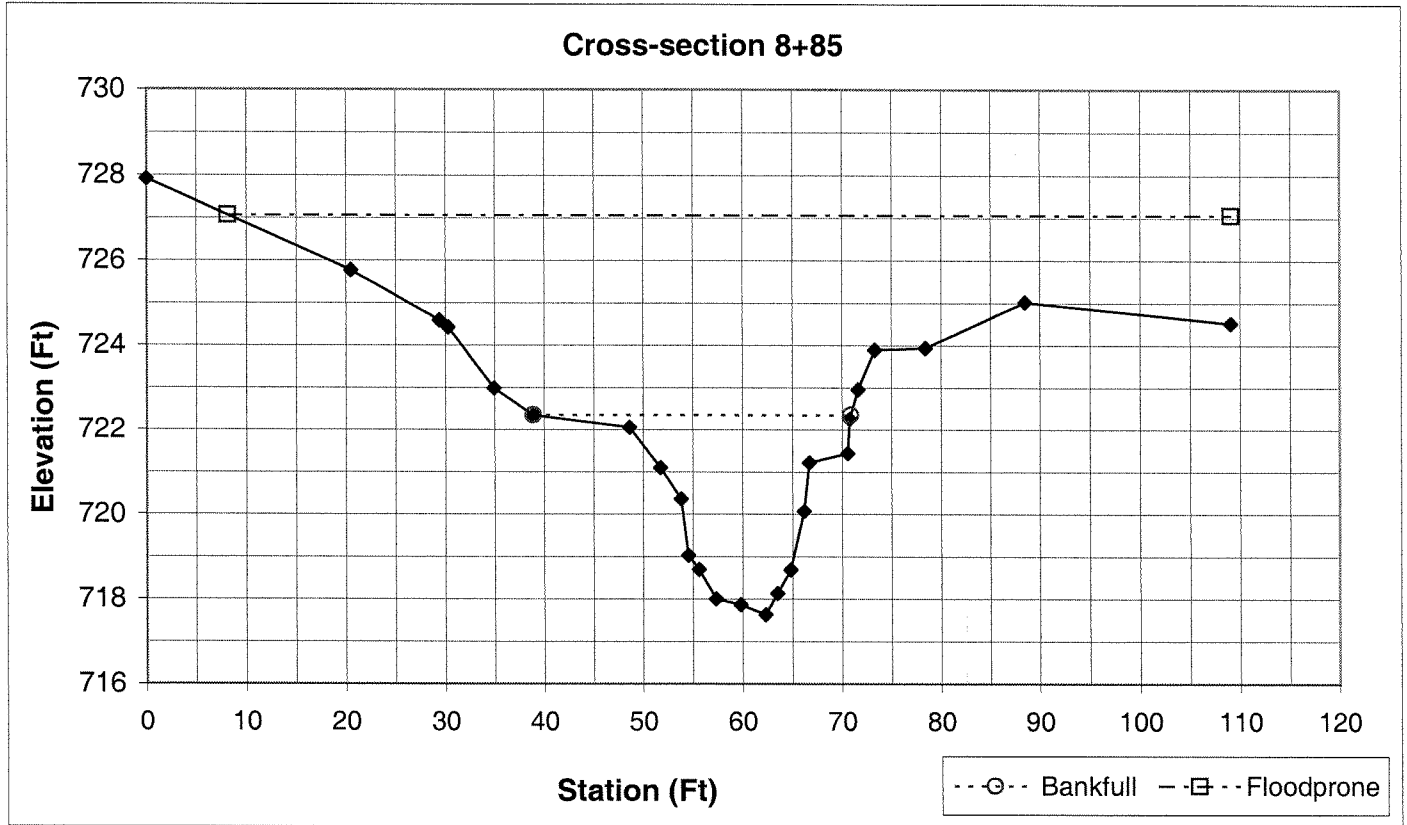
| Pt # | North     | East       | Elevation | Note       | Station |
|------|-----------|------------|-----------|------------|---------|
| 538  | 836541.58 | 1768524.20 | 727.04    | X2         | 0.00    |
| 1518 | 836531.13 | 1768513.74 | 726.93    | X2         | 14.73   |
| 539  | 836523.32 | 1768508.54 | 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   |



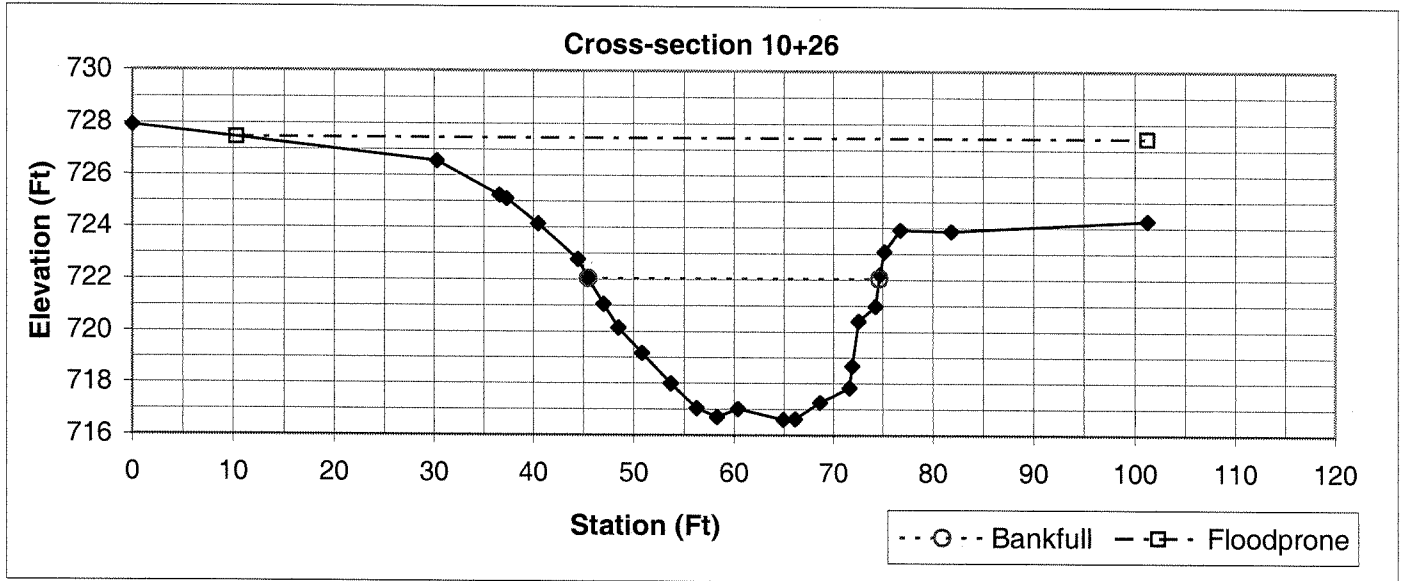
| Pt # | North     | East       | Elevation | Note       | Station |
|------|-----------|------------|-----------|------------|---------|
| 1492 | 836418.70 | 1768750.82 | 727.92    | X3         | 0.00    |
| 1493 | 836398.81 | 1768745.96 | 725.77    | X3         | 20.47   |
| 1494 | 836390.17 | 1768743.67 | 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   |



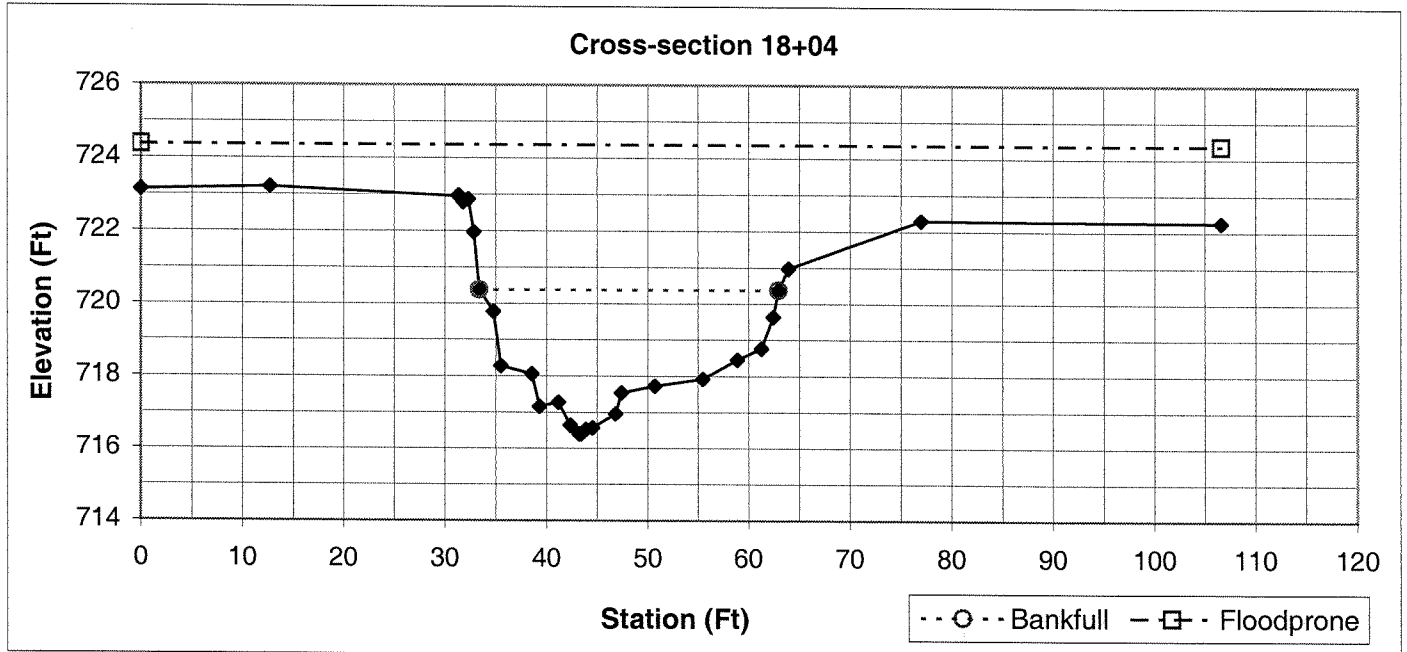
| Pt # | North     | East       | Elevation | Note         | Station |
|------|-----------|------------|-----------|--------------|---------|
| 1459 | 836393.28 | 1768888.19 | 727.92    | X4-CART-PATH | 0.00    |
| 1460 | 836364.15 | 1768879.93 | 726.55    | X4           | 30.28   |
| 1461 | 836358.10 | 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   |



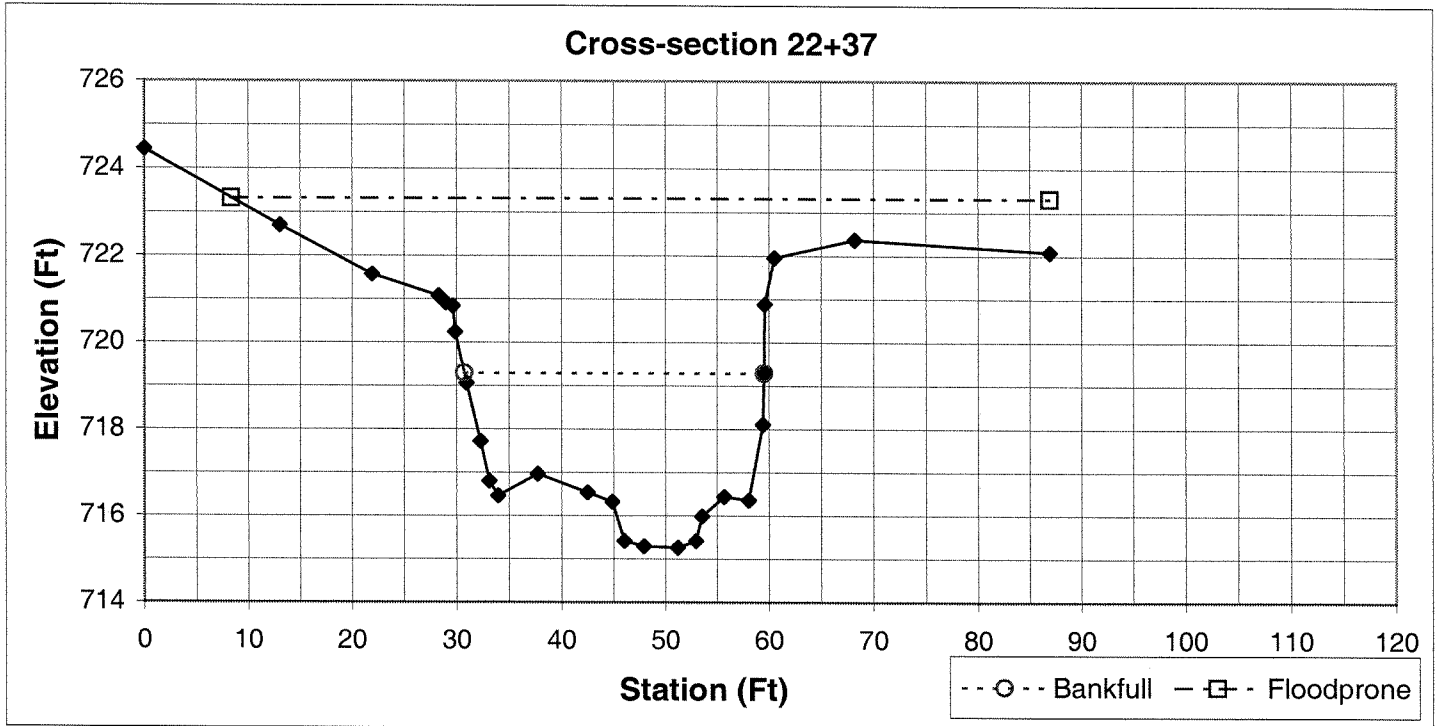
| Pt # | North     | East       | Elevation | Note     | Station |
|------|-----------|------------|-----------|----------|---------|
| 1322 | 836219.99 | 1769619.82 | 723.14    | X5       | 0.00    |
| 1323 | 836208.98 | 1769613.53 | 723.22    | X5-TREEL | 12.68   |
| 1352 | 836192.92 | 1769604.01 | 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   |

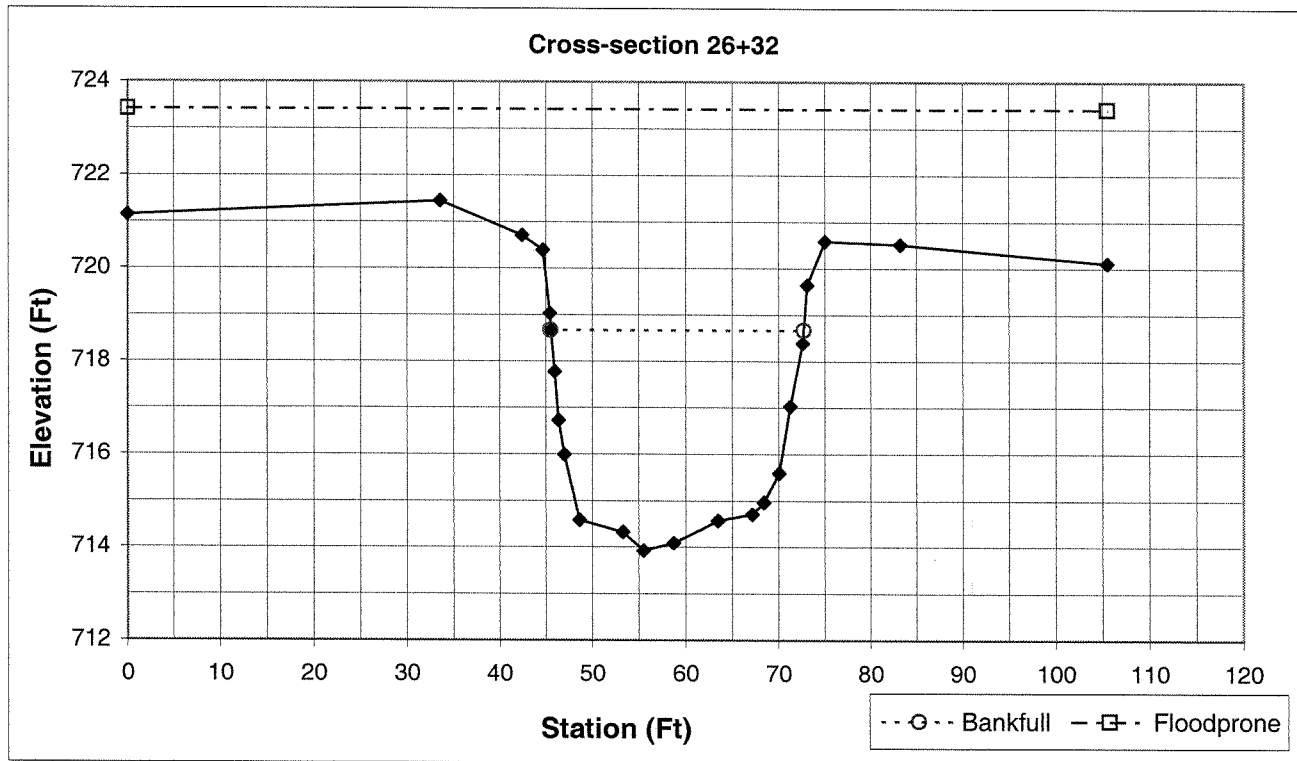
| Bankfull Line |           |
|---------------|-----------|
| Station       | Elevation |
| 30.74         | 719.29    |
| 59.55         | 719.29    |

| 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   |



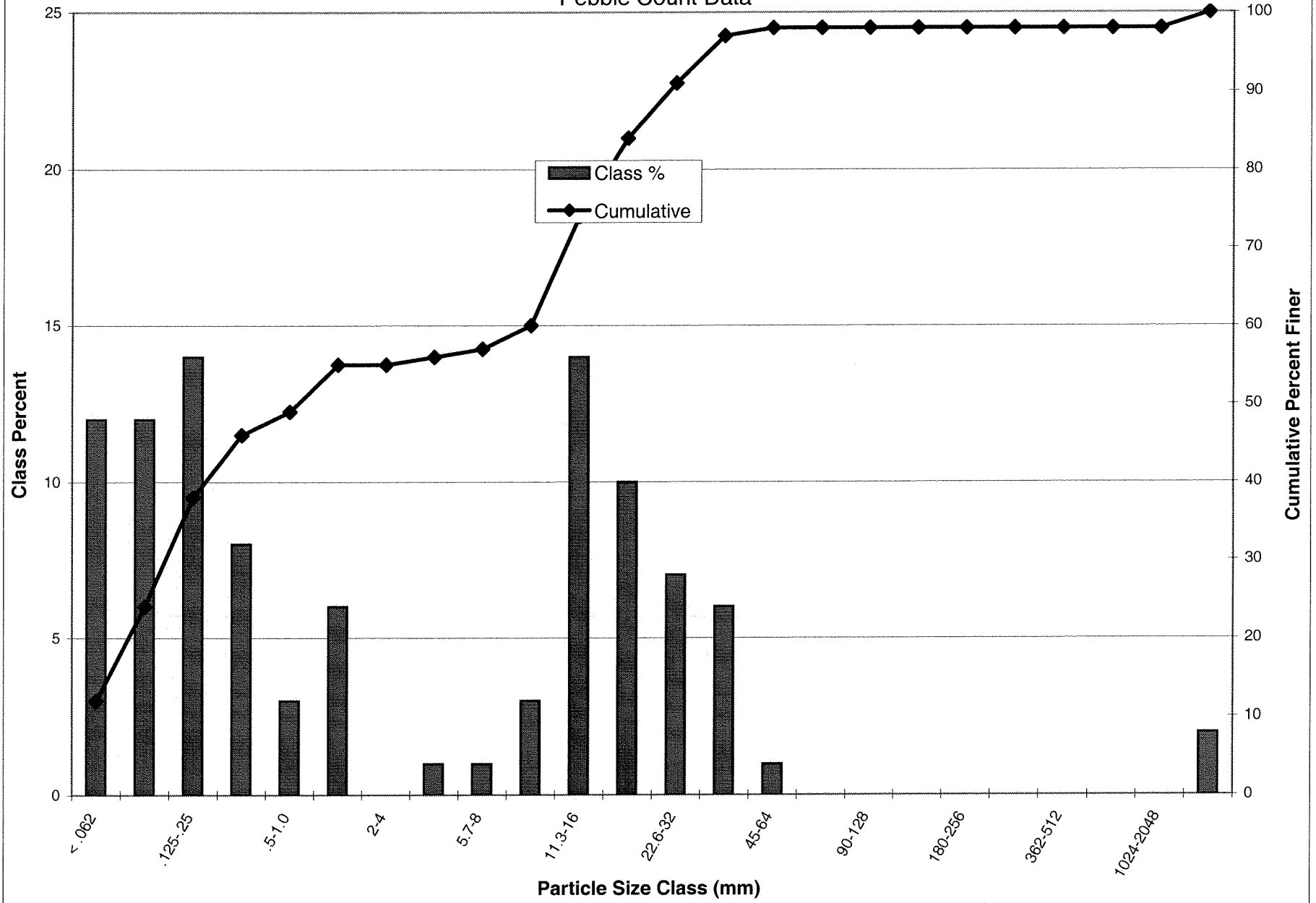
| Pt # | North     | East       | Elevation | Note   | Station |
|------|-----------|------------|-----------|--------|---------|
| 1199 | 835977.51 | 1770310.39 | 721.14    | X7     | 0.00    |
| 1200 | 835946.61 | 1770296.49 | 721.45    | X7     | 33.57   |
| 1201 | 835938.07 | 1770294.11 | 720.70    | 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    |

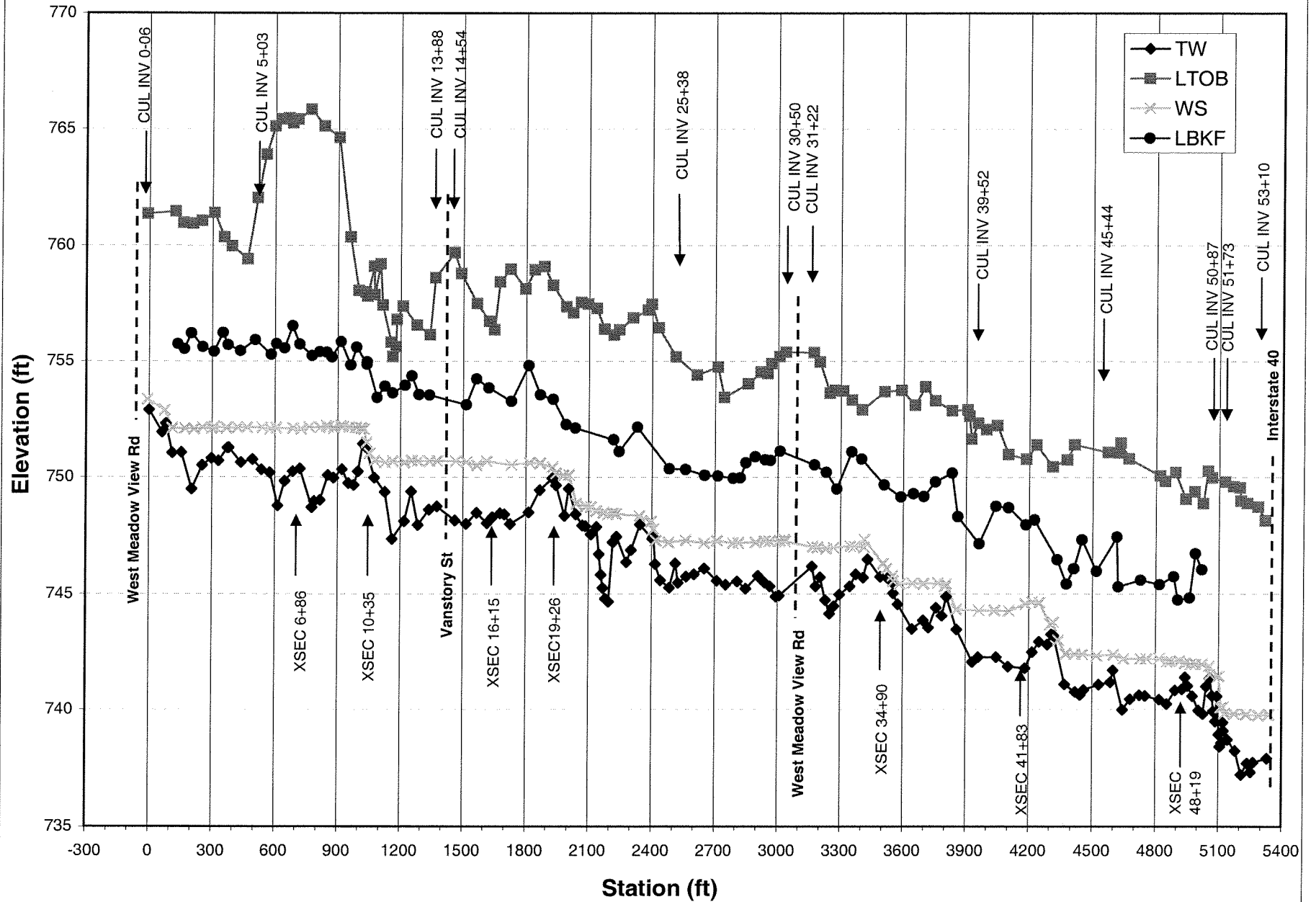
# Gillespie Golf Course - Mile Run Creek

## Pebble Count Data



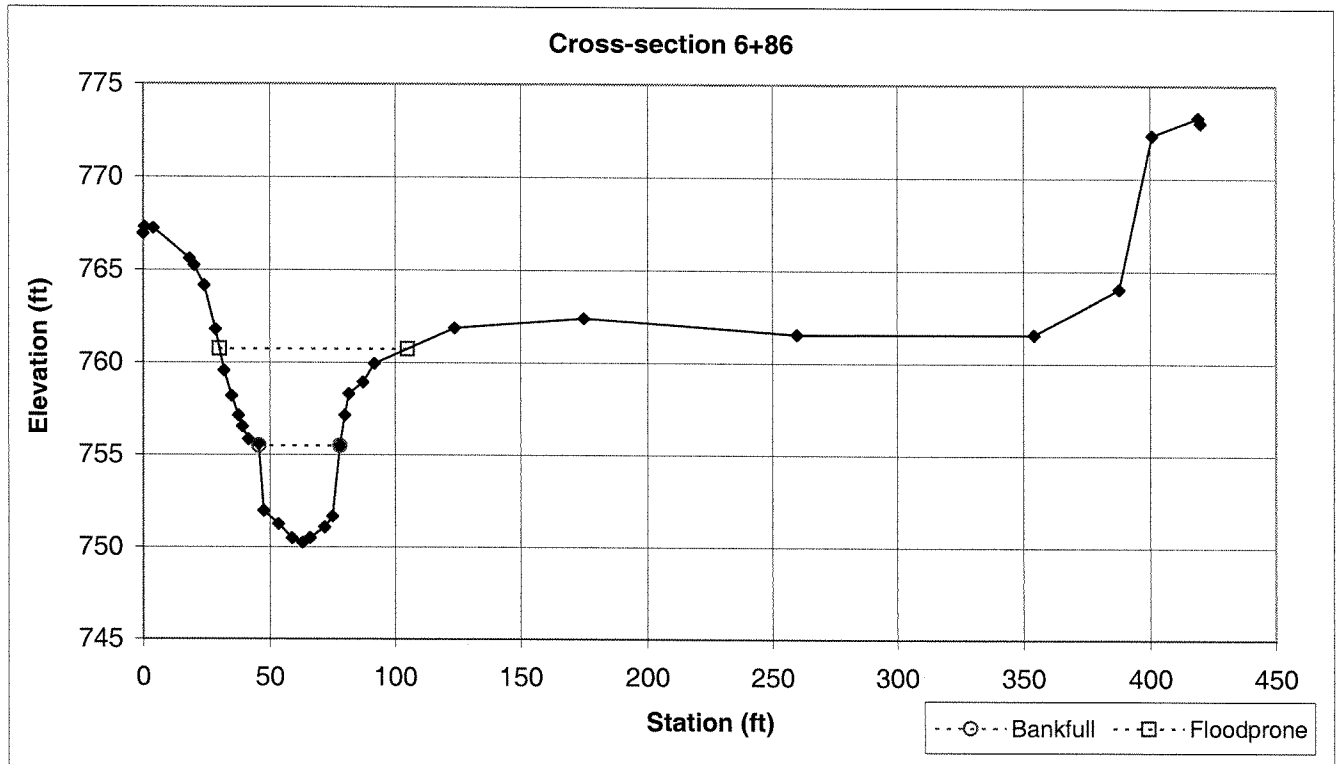
**Existing Condition Data  
Hillsdale Park**

### Hillsdale Park -- South Buffalo Creek Longitudinal Profile



### 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   |



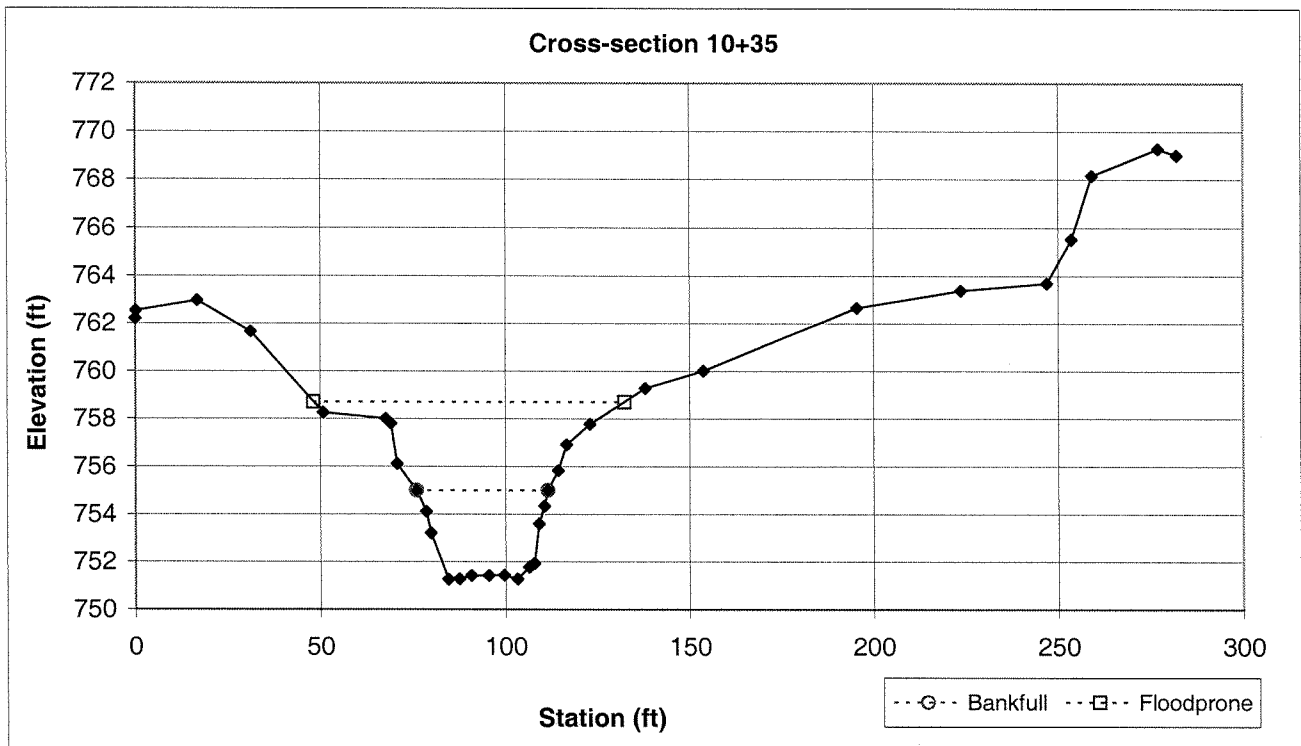
| Pt # | North     | East       | Elevation | Note      | Station |
|------|-----------|------------|-----------|-----------|---------|
| 132  | 836134.59 | 1753428.43 | 766.95    | X1EP      | 0.00    |
| 133  | 836134.25 | 1753428.07 | 767.31    | X1-T-CURB | 0.50    |
| 134  | 836130.78 | 1753427.46 | 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  | <del>ECA</del> | 103.2    | 35.5      | 2.9       | 3.7           | 12.2 | 1.7      | 2.4 | 754.99   | 757.77   |



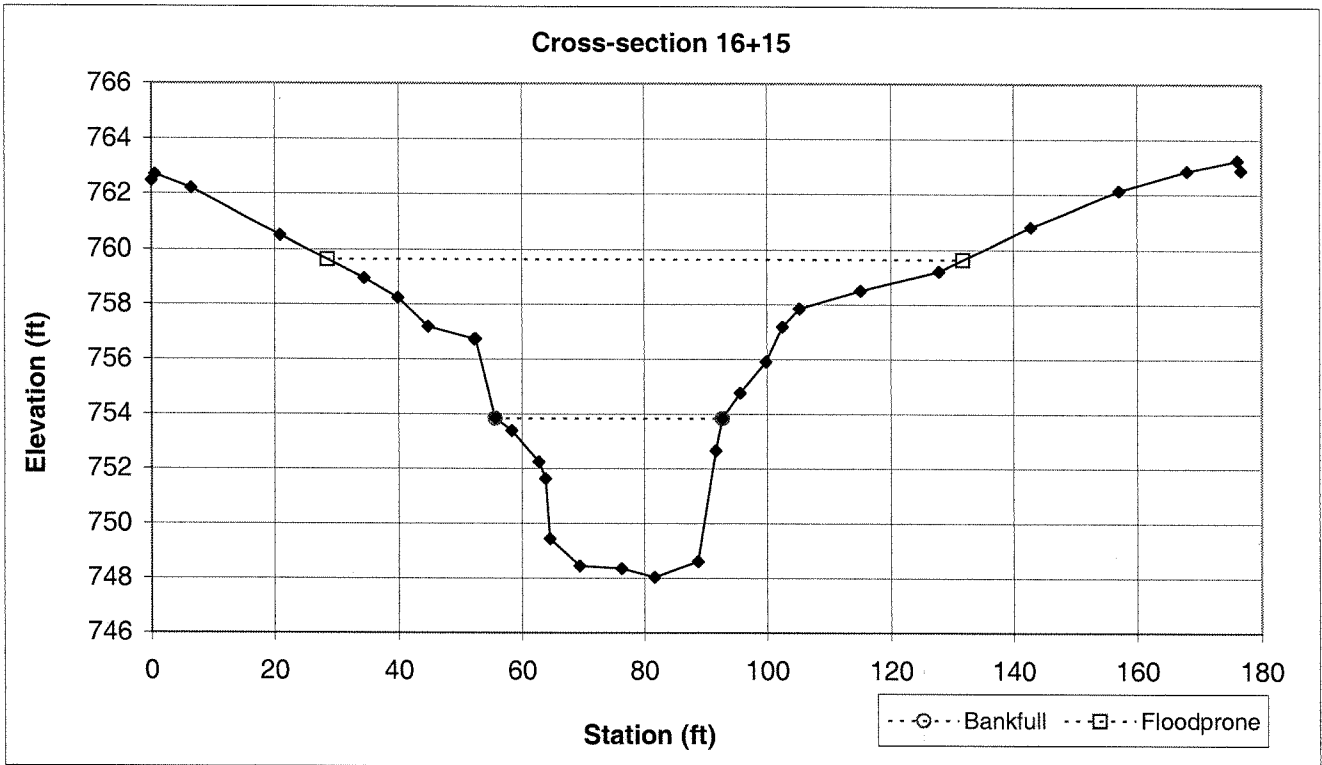
| Pt # | North     | East       | Elevation | Note     | Station |
|------|-----------|------------|-----------|----------|---------|
| 292  | 835981.85 | 1753779.73 | 762.20    | X2-EPAV  | 0.00    |
| 293  | 835981.64 | 1753779.75 | 762.52    | X2-TCURB | 0.21    |
| 294  | 835968.73 | 1753769.43 | 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   |



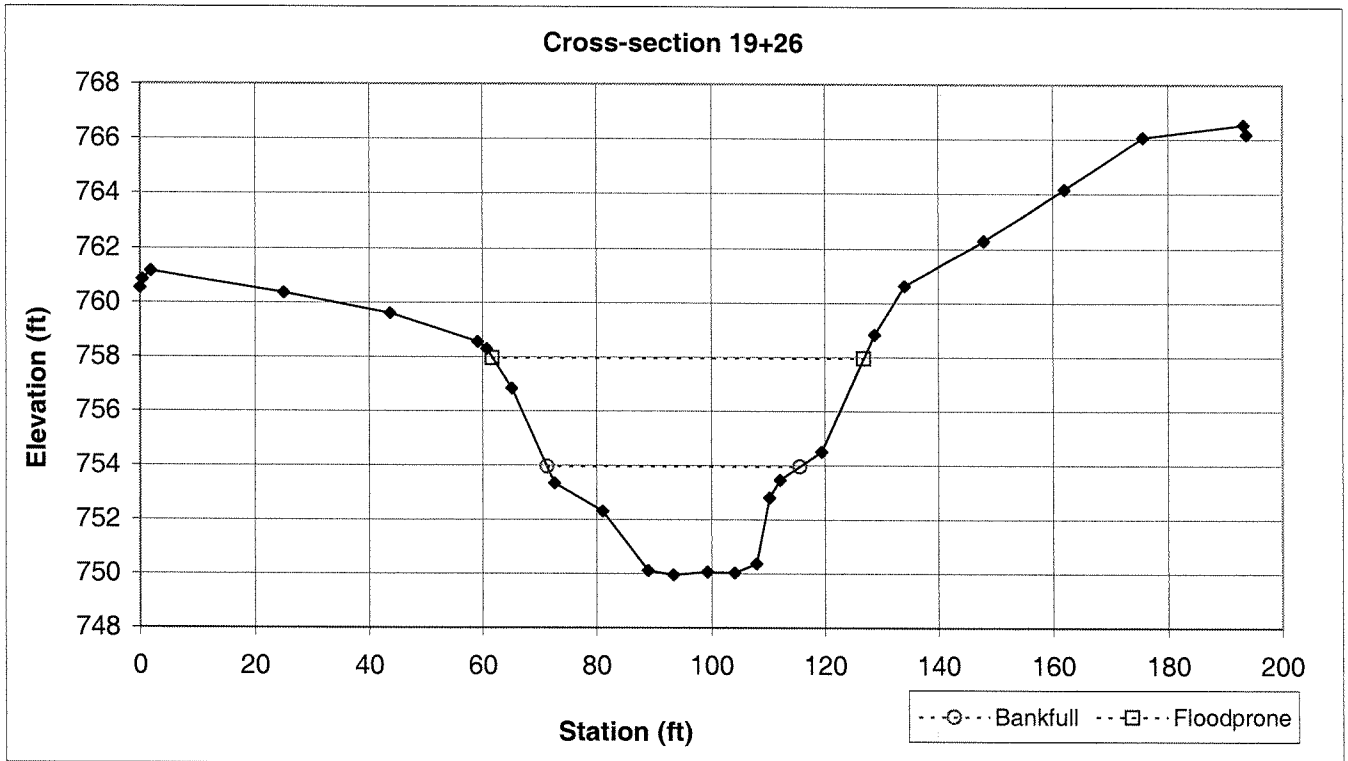
| Pt # | North     | East       | Elevation | Note     | Station |
|------|-----------|------------|-----------|----------|---------|
| 411  | 835888.64 | 1754261.46 | 762.47195 | X3-EPAV  | 0.00    |
| 412  | 835888.22 | 1754261.84 | 762.69995 | X3-TCURB | 0.57    |
| 413  | 835882.34 | 1754262.31 | 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  |

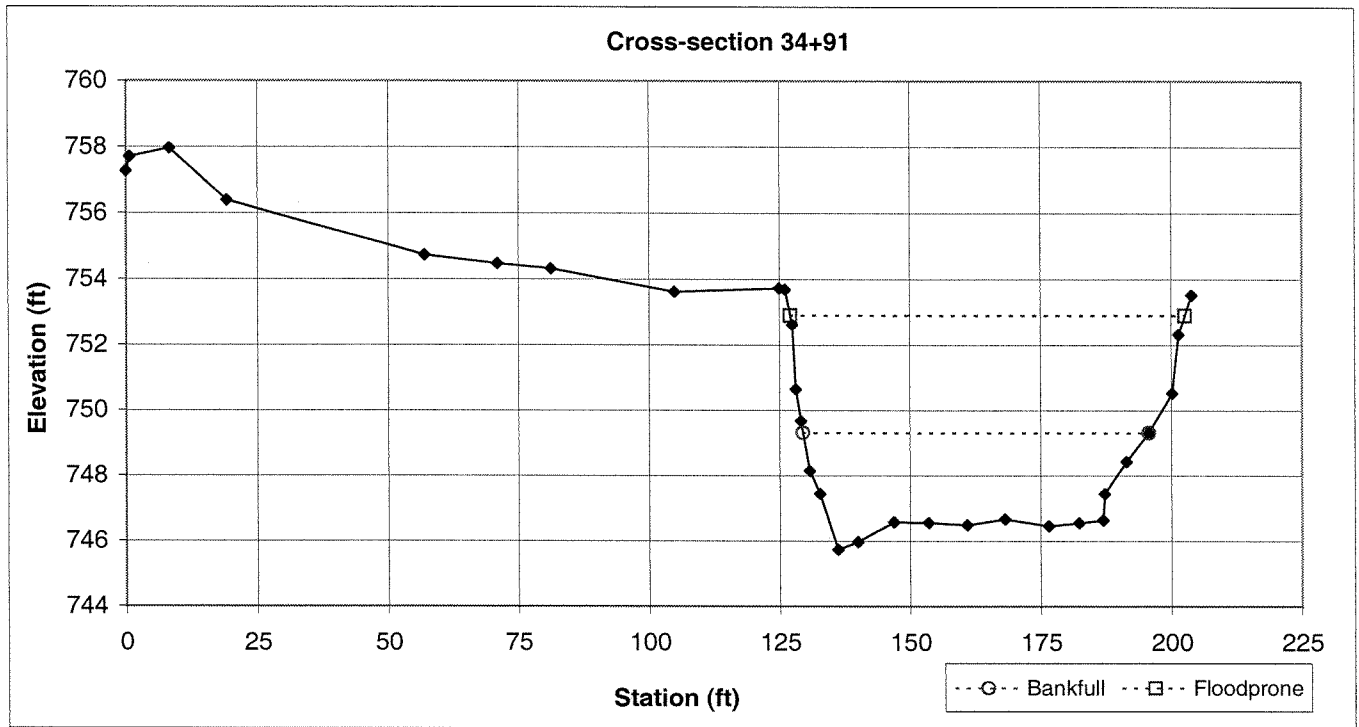
| Bankfull Line |           |
|---------------|-----------|
| Station       | Elevation |
| 71.37         | 753.96    |
| 115.60        | 753.96    |

| 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   |



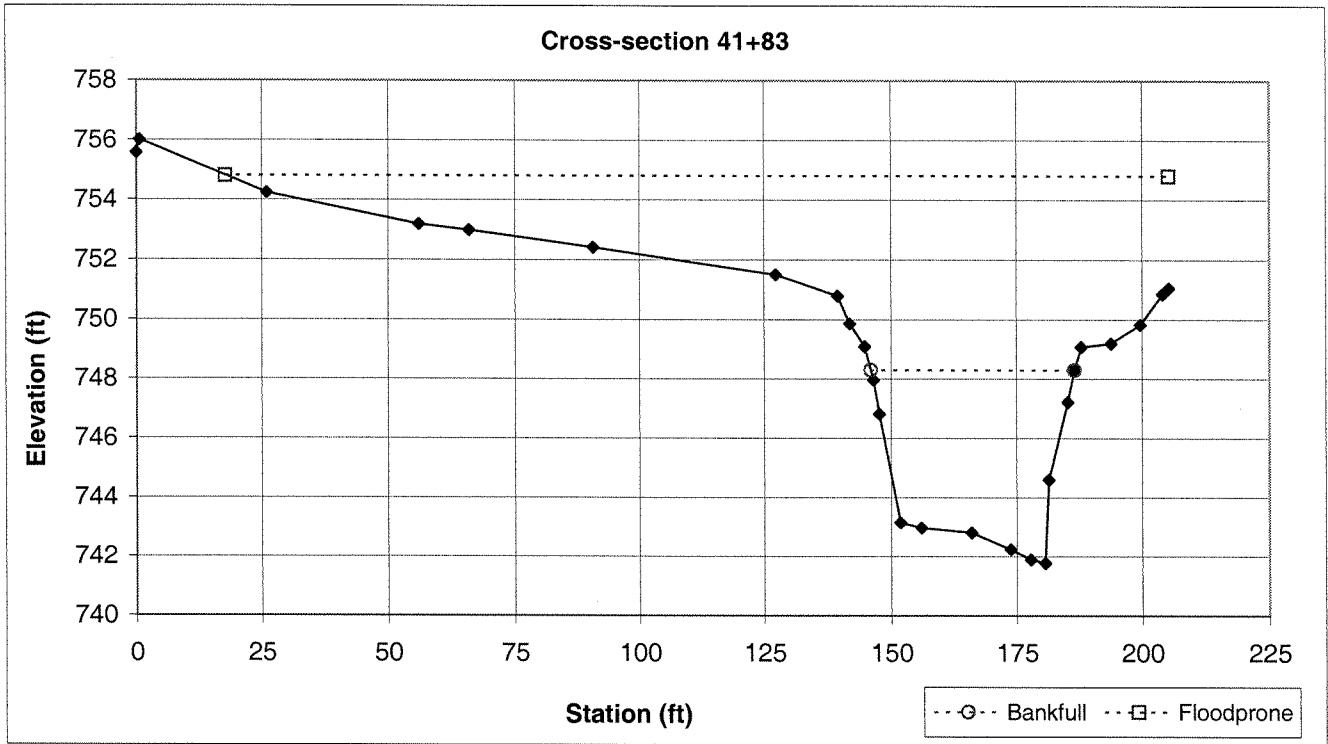
| Pt # | North     | East       | Elevation | Note         | Station |
|------|-----------|------------|-----------|--------------|---------|
| 916  | 834690.14 | 1754854.54 | 757.26    | X5-EP        | 0.00    |
| 917  | 834689.47 | 1754854.46 | 757.70    | X5-T-CURB    | 0.68    |
| 918  | 834681.97 | 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   |



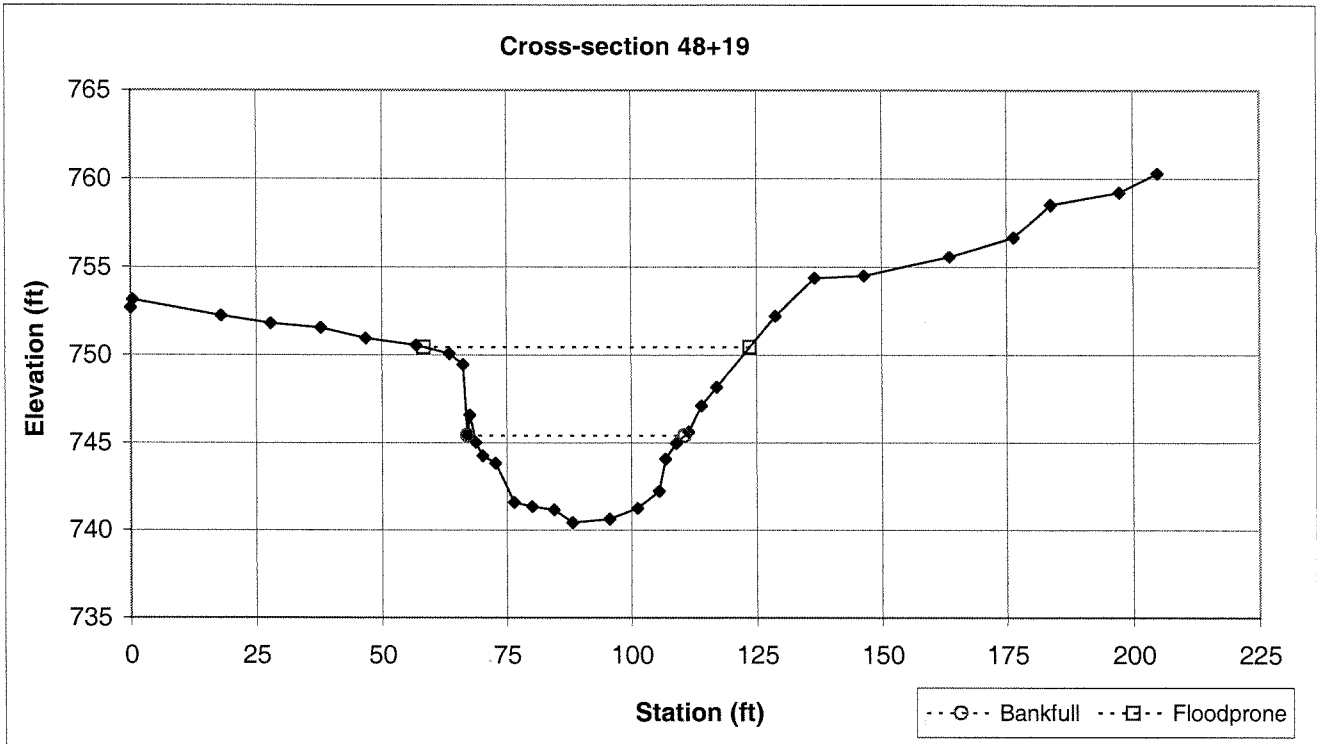
| Pt # | North     | East       | Elevation | Note     | Station |
|------|-----------|------------|-----------|----------|---------|
| 1087 | 834440.20 | 1755484.08 | 755.57    | X6EP     | 0.00    |
| 1088 | 834439.77 | 1755483.64 | 756.01    | X6T-CURB | 0.62    |
| 1089 | 834416.75 | 1755472.88 | 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   |



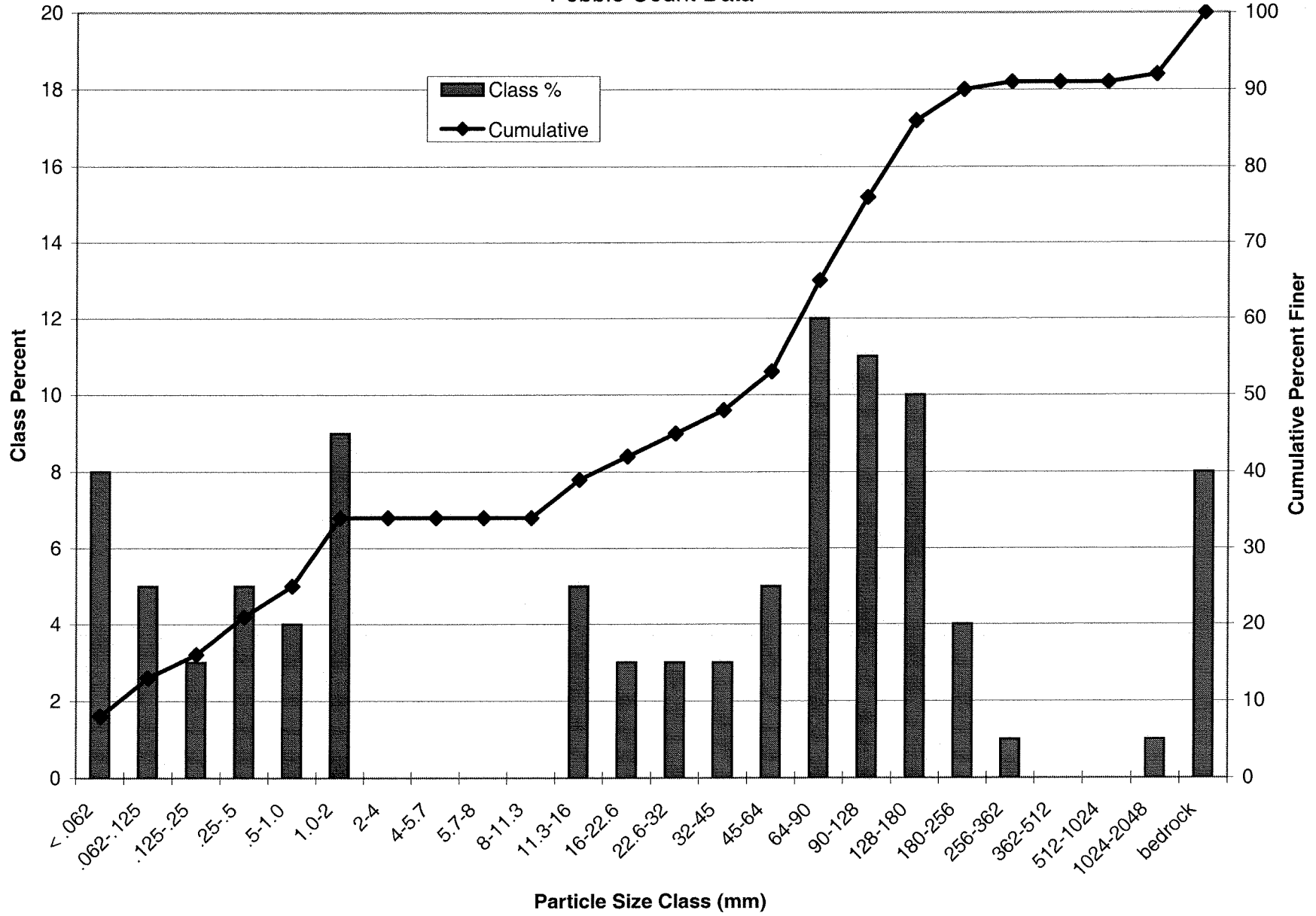
| Pt # | North     | East       | Elevation | Note      | Station |
|------|-----------|------------|-----------|-----------|---------|
| 1197 | 834213.22 | 1756026.22 | 752.69    | X7EP      | 0.00    |
| 1198 | 834212.89 | 1756025.99 | 753.16    | X7-T-CURB | 0.41    |
| 1199 | 834195.40 | 1756024.57 | 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    |

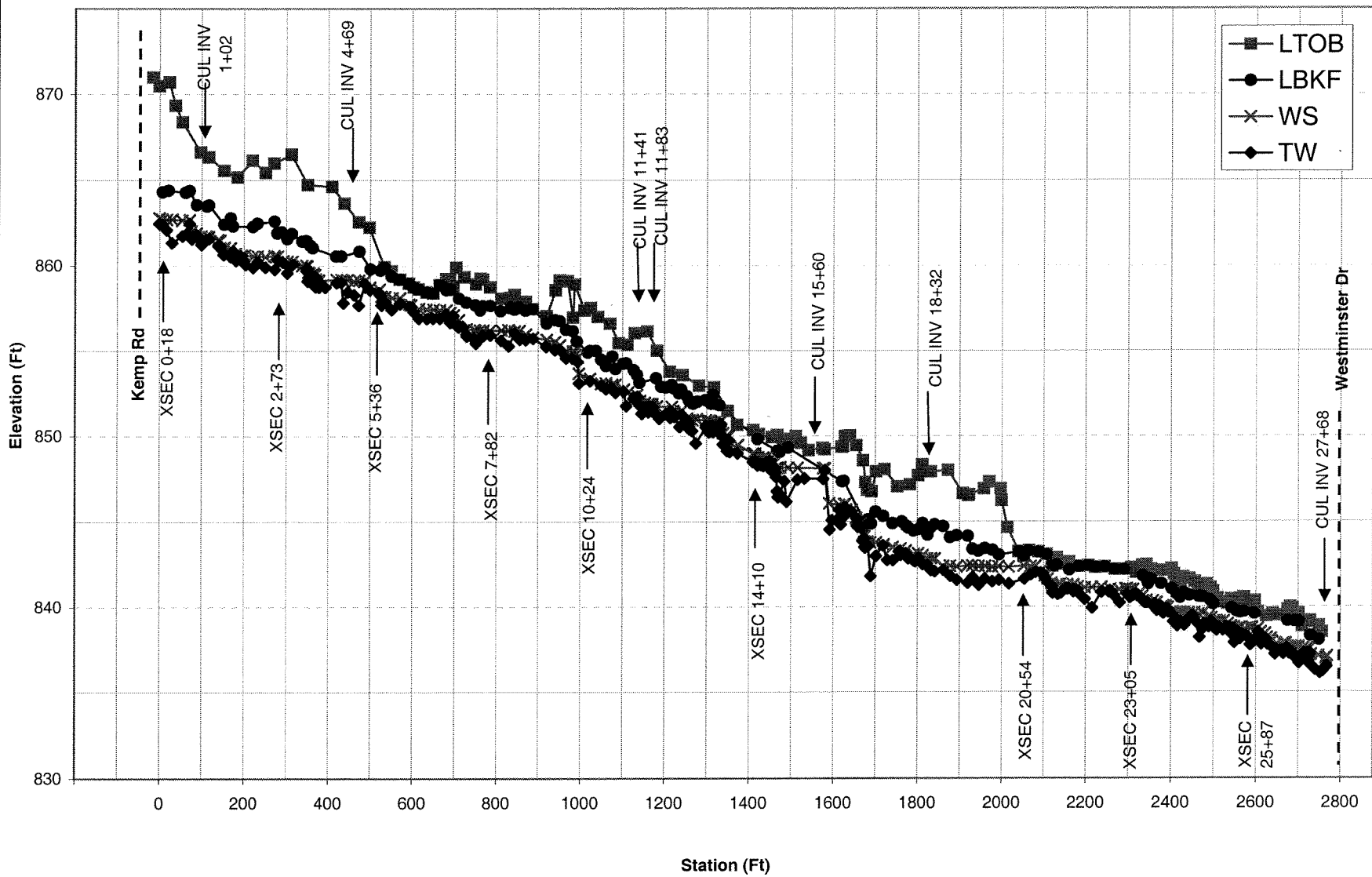
# Hillsdale Park - South Buffalo Creek

## Pebble Count Data



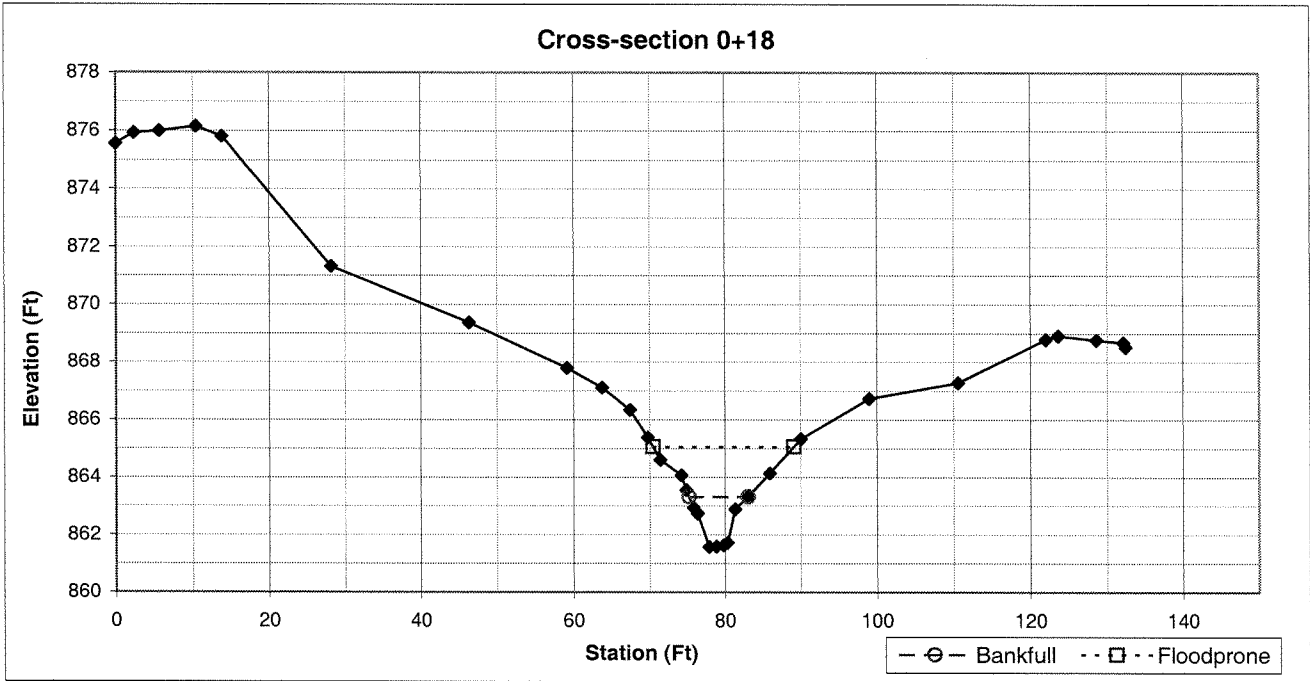
**Existing Condition Data  
Brown Bark Park**

### 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  | <i>PAEA</i> | 7.7      | 7.9       | 1.0       | 1.7           | 8.1 | 2.2      | 2.4 | 863.31   | 865.32   |



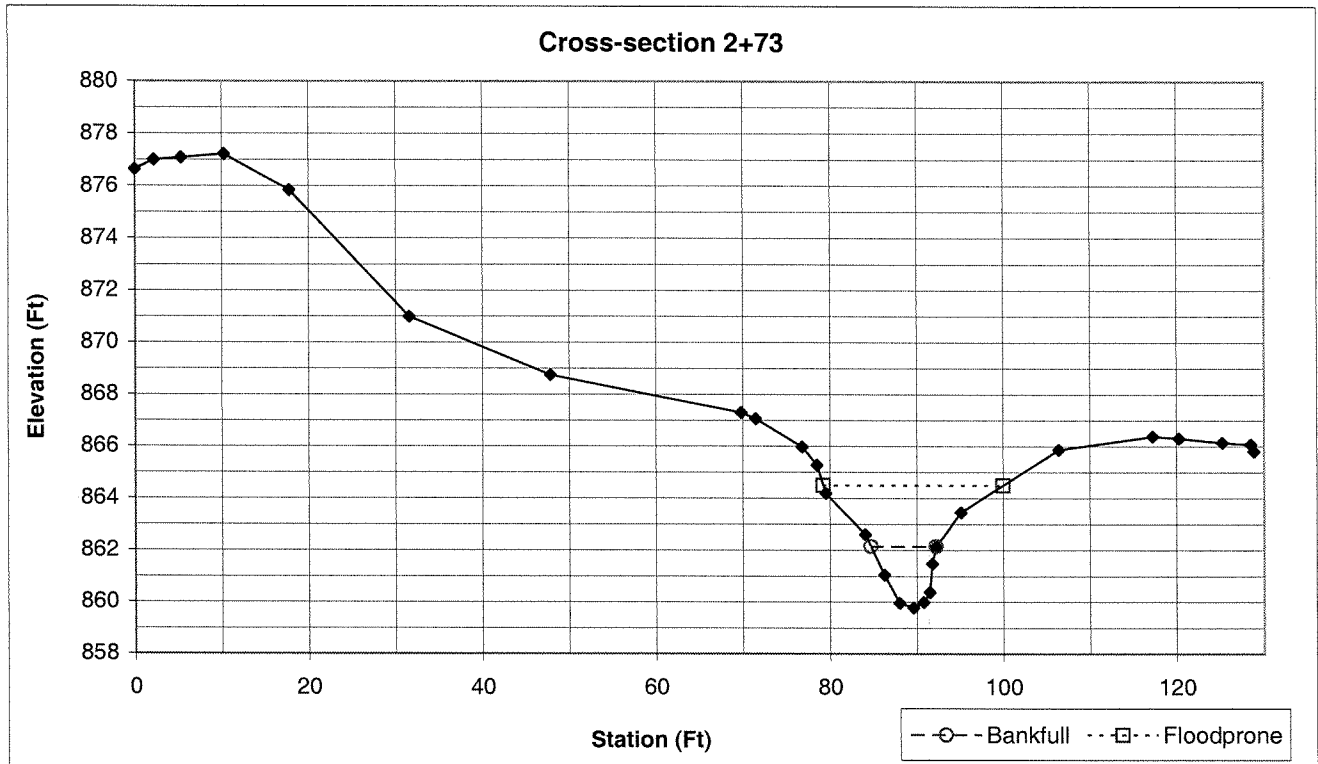
| Pt # | North     | East       | Elevation | Note    | Station |
|------|-----------|------------|-----------|---------|---------|
| 98   | 854817.07 | 1746478.25 | 875.54    | X1-EPAV | 0.00    |
| 99   | 854814.70 | 1746478.11 | 875.92    | X1TCURB | 2.38    |
| 100  | 854811.46 | 1746478.67 | 875.99    | 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 Run | Stream Type | BKF Area | BKF Width | BKF Depth | Max BKF Depth | W/D | BH Ratio | ER  | BKF Elev | TOB Elev |
|-------------|-------------|----------|-----------|-----------|---------------|-----|----------|-----|----------|----------|
|             | E4          | 6.0      | 6.5       | 0.9       | 1.7           | 7.1 | 1.3      | 3.5 | 859.5    | 859.92   |

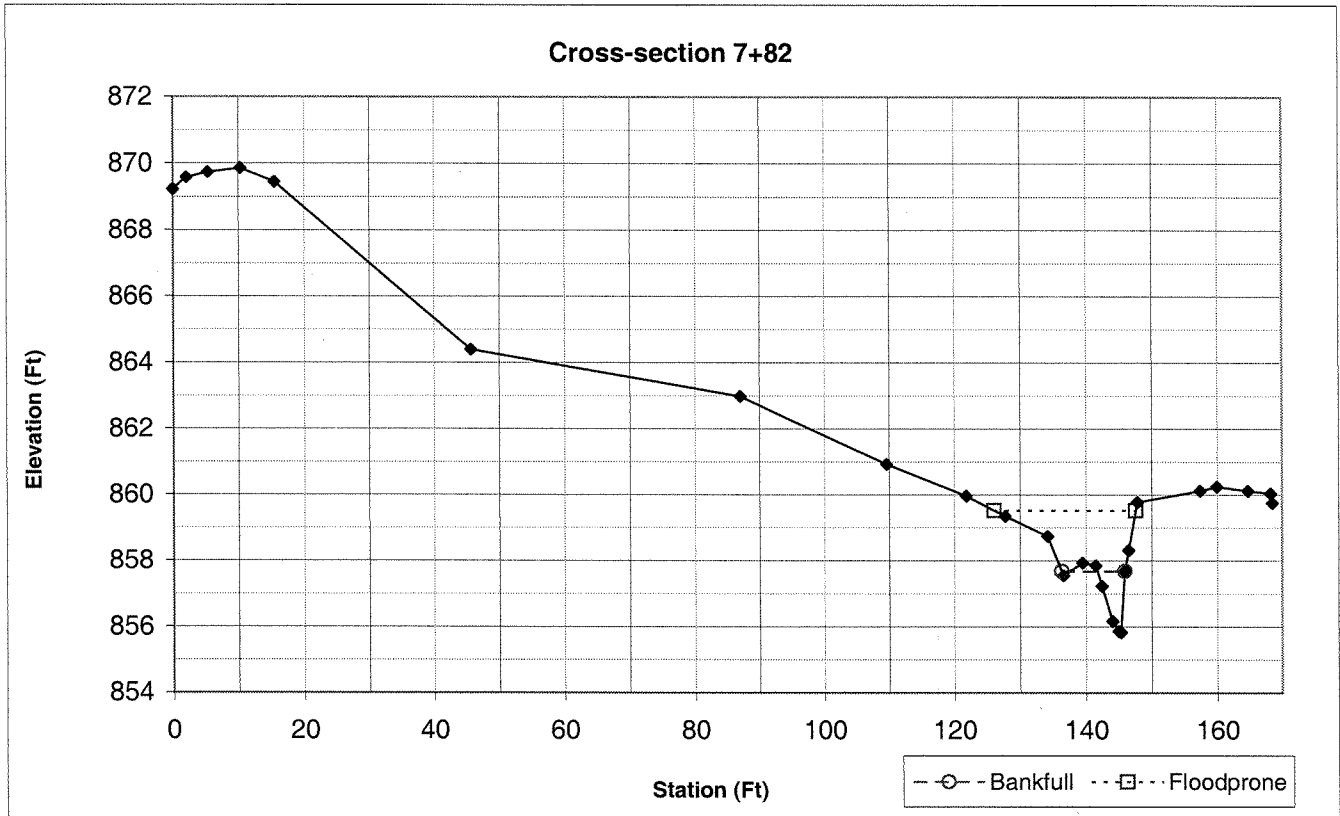


| Pt # | North     | East       | Elevation | Note         | Station |
|------|-----------|------------|-----------|--------------|---------|
| 327  | 854792.11 | 1746866.07 | 873.39    | X3-EPAV      | 0.00    |
| 328  | 854789.97 | 1746866.13 | 873.76    | X3-TCURB     | 2.14    |
| 329  | 854786.63 | 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   |



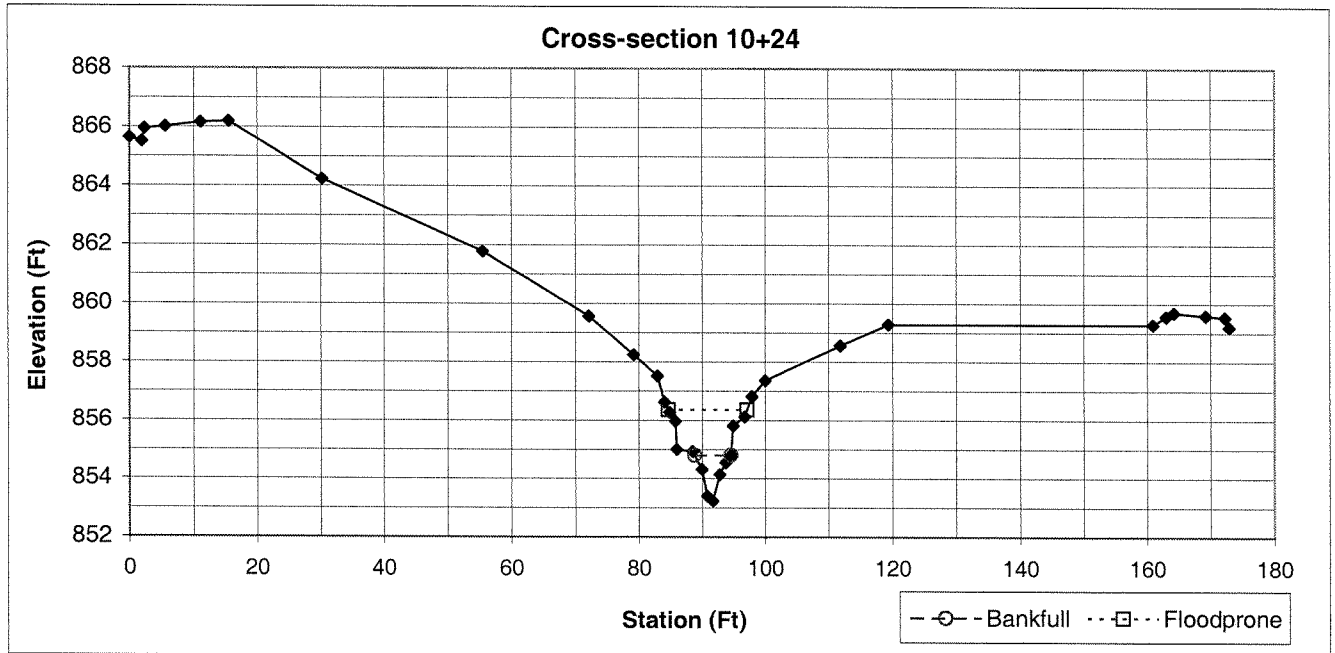
| Pt # | North     | East       | Elevation | Note     | Station |
|------|-----------|------------|-----------|----------|---------|
| 437  | 854782.49 | 1747052.25 | 869.21    | X4-EPAV  | 0.00    |
| 438  | 854780.41 | 1747051.97 | 869.58    | X4-TCURB | 2.10    |
| 439  | 854777.19 | 1747051.87 | 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   |



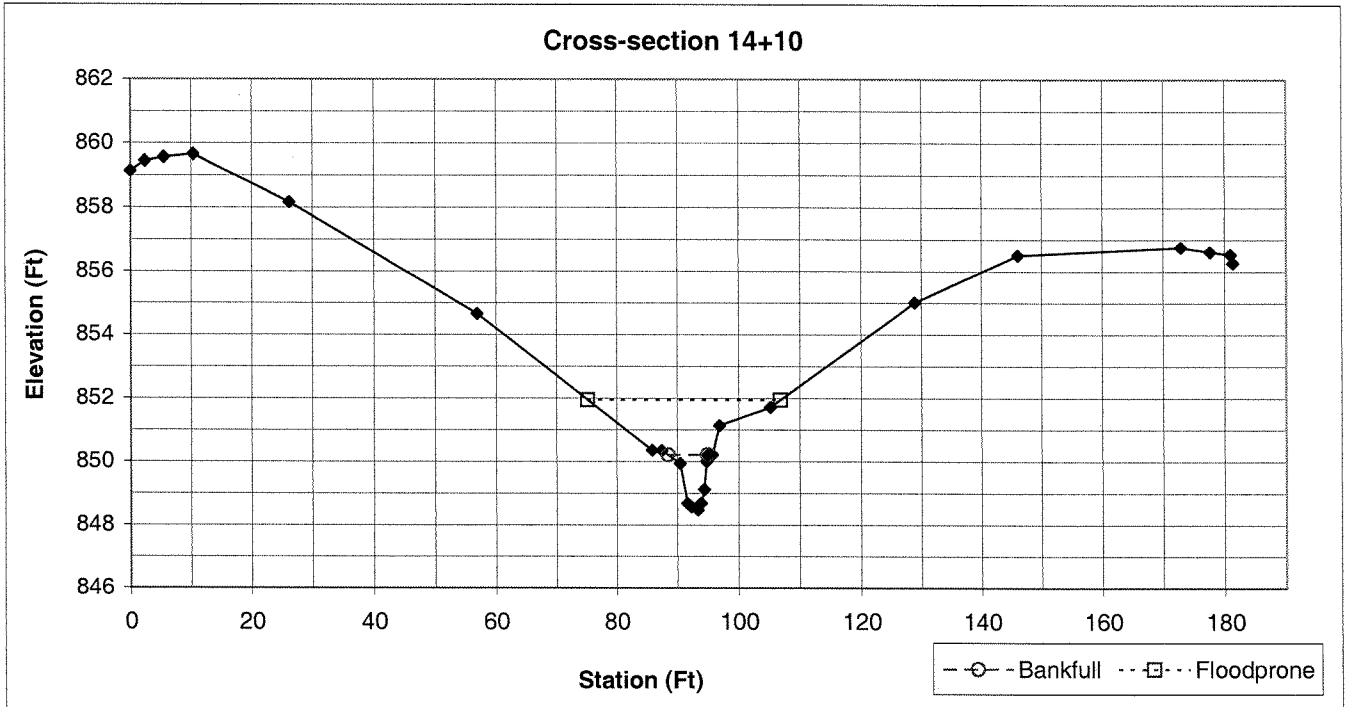
| Pt # | North     | East       | Elevation | Note      | Station |
|------|-----------|------------|-----------|-----------|---------|
| 633  | 854785.16 | 1747319.30 | 865.63    | X5EP      | 0.00    |
| 634  | 854783.25 | 1747319.37 | 865.50    | X5BCURB   | 1.91    |
| 635  | 854782.96 | 1747319.10 | 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   |



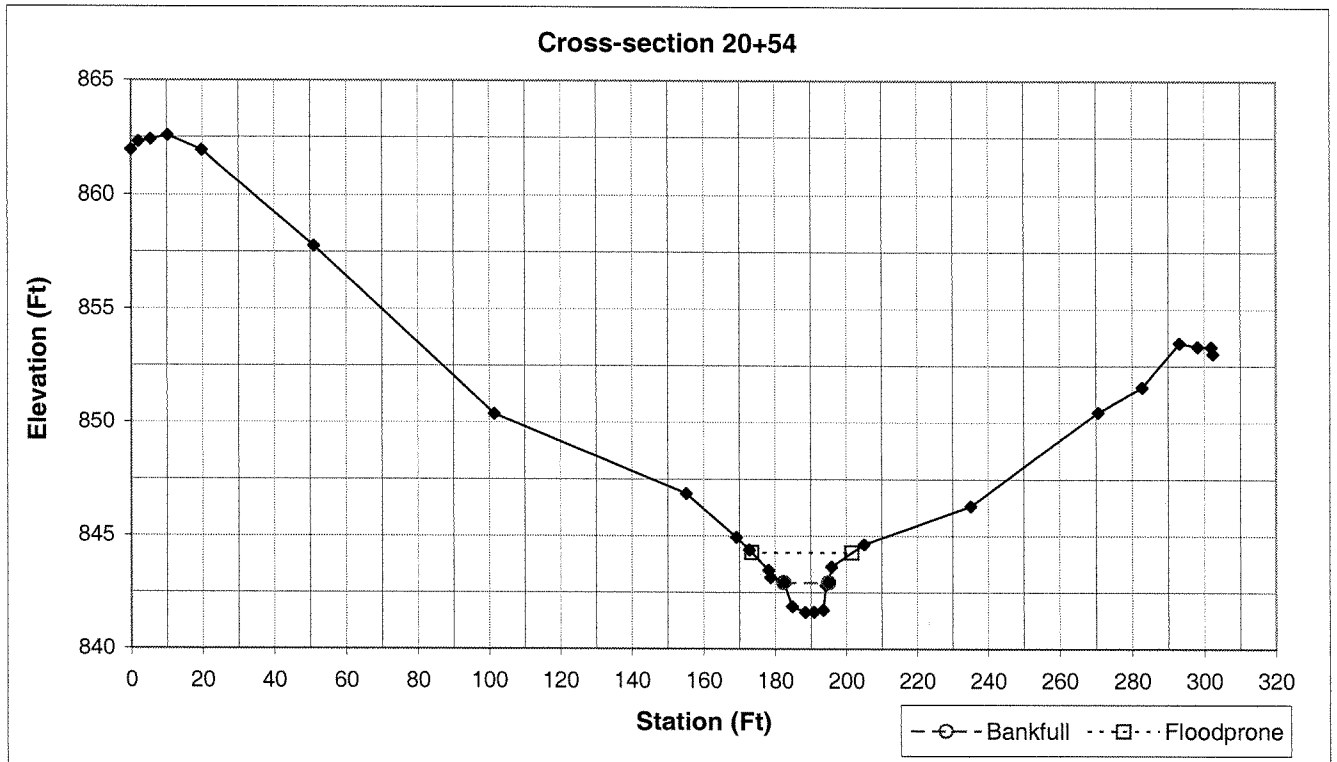
| Pt # | North     | East       | Elevation | Note       | Station |
|------|-----------|------------|-----------|------------|---------|
| 900  | 854806.78 | 1747694.93 | 859.13    | X6EP       | 0.00    |
| 901  | 854804.40 | 1747695.10 | 859.45    | X6T-CURB   | 2.39    |
| 902  | 854801.32 | 1747695.24 | 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   |



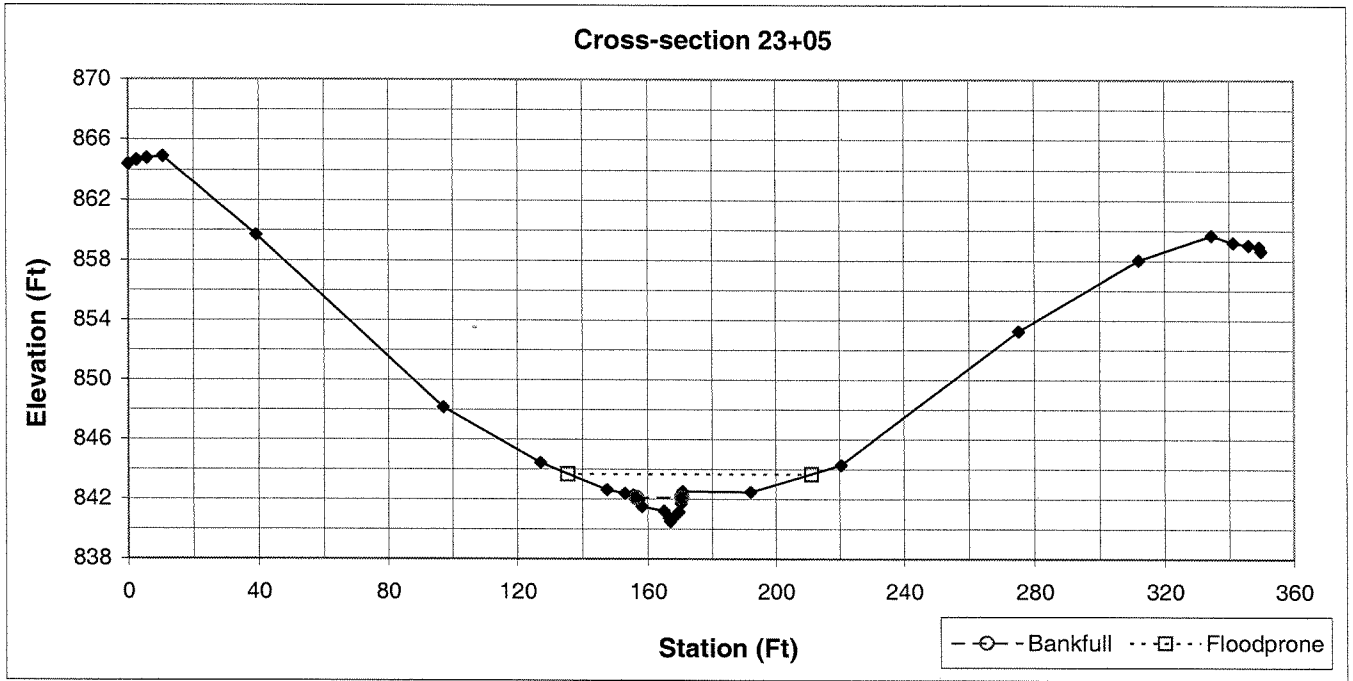
| Pt # | North     | East       | Elevation | Note     | Station |
|------|-----------|------------|-----------|----------|---------|
| 1318 | 855006.12 | 1748080.96 | 861.93    | X8-EPAV  | 0.00    |
| 1319 | 855004.71 | 1748082.50 | 862.31    | X8-TCURB | 2.08    |
| 1320 | 855002.50 | 1748085.09 | 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   |



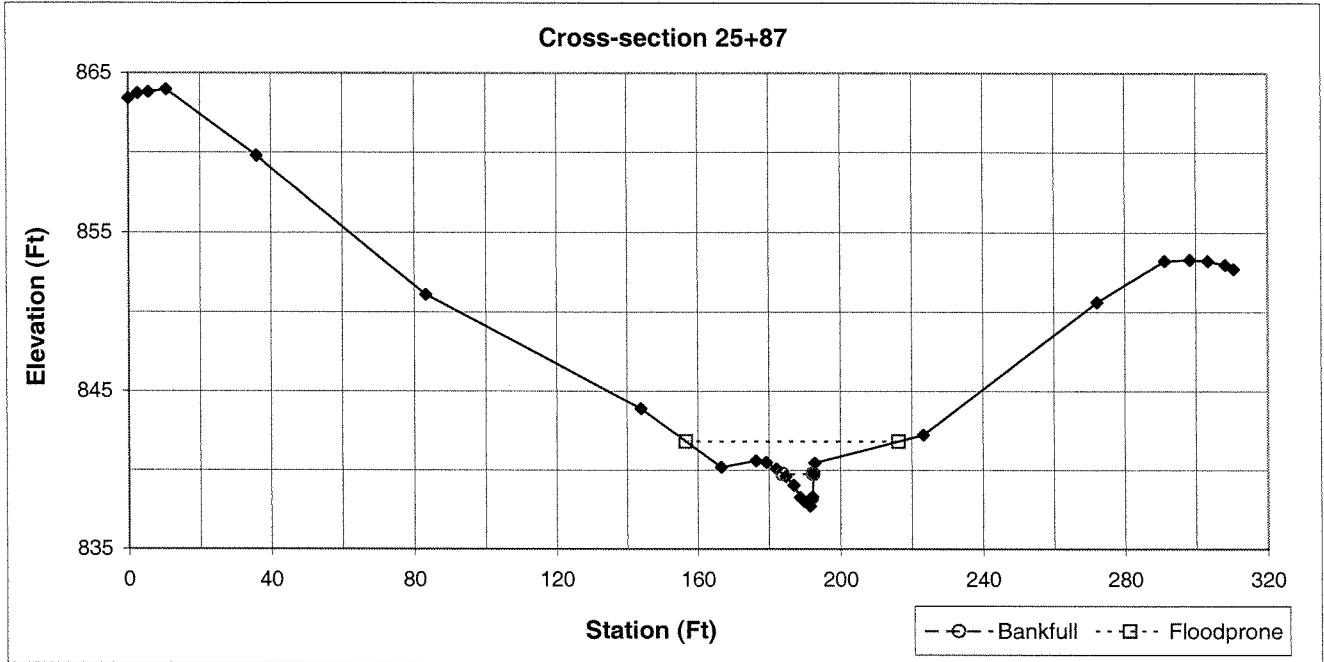
| Pt # | North     | East       | Elevation | Note       | Station |
|------|-----------|------------|-----------|------------|---------|
| 1454 | 855174.11 | 1748245.89 | 864.39    | X9EP       | 0.00    |
| 1455 | 855172.88 | 1748248.12 | 864.65    | X9T-CURB   | 2.54    |
| 1456 | 855170.84 | 1748250.67 | 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   |



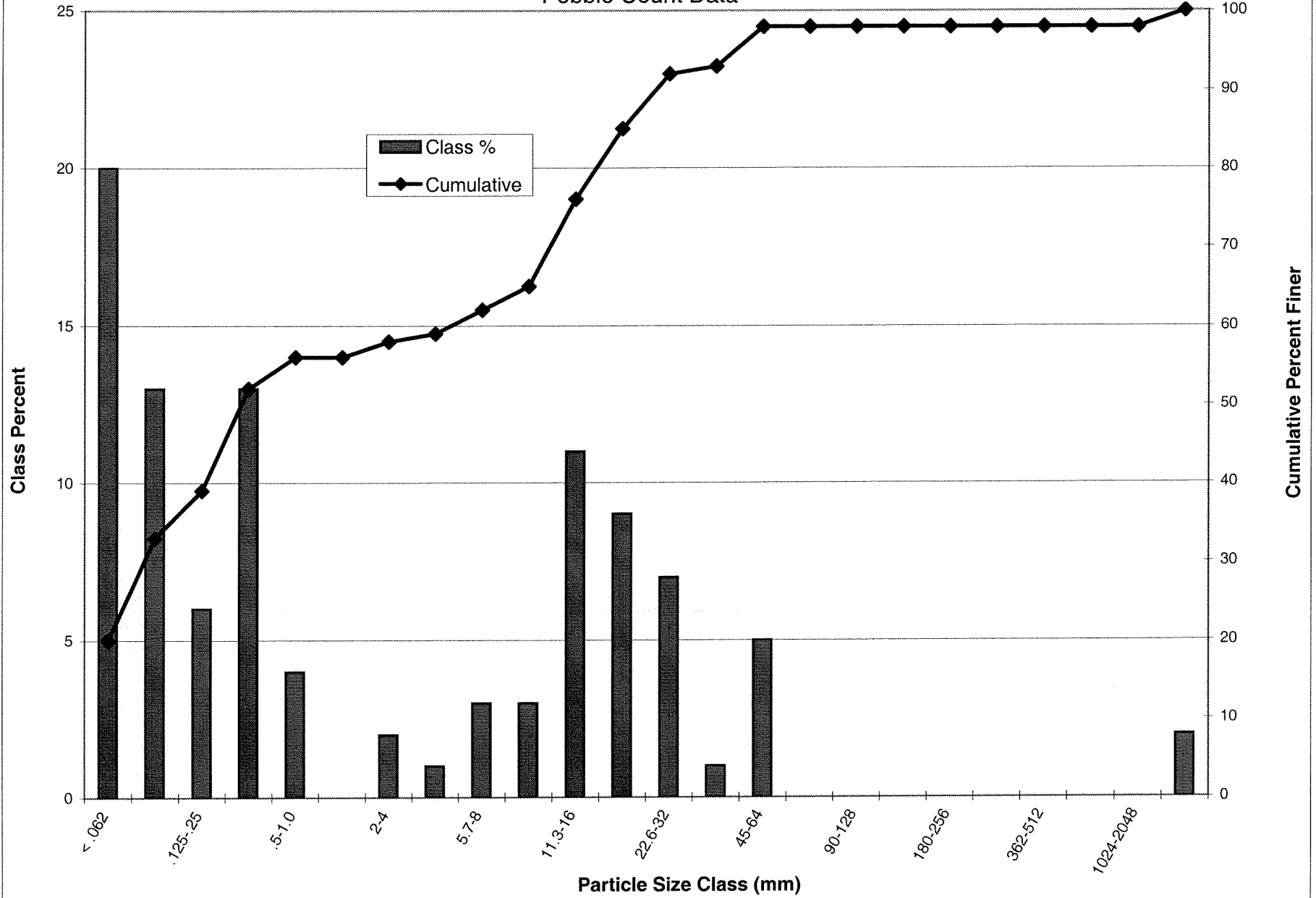
| Pt # | North     | East       | Elevation | Note         | Station |
|------|-----------|------------|-----------|--------------|---------|
| 1717 | 855363.03 | 1748356.11 | 863.40    | X10EP        | 0.00    |
| 1718 | 855362.39 | 1748358.64 | 863.72    | X10-T-CURB   | 2.62    |
| 1719 | 855360.92 | 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    |

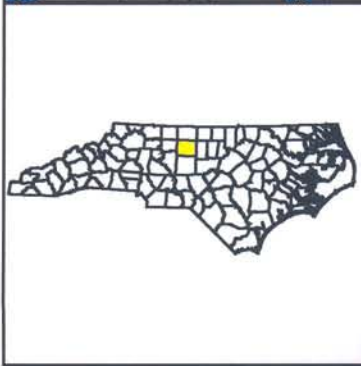
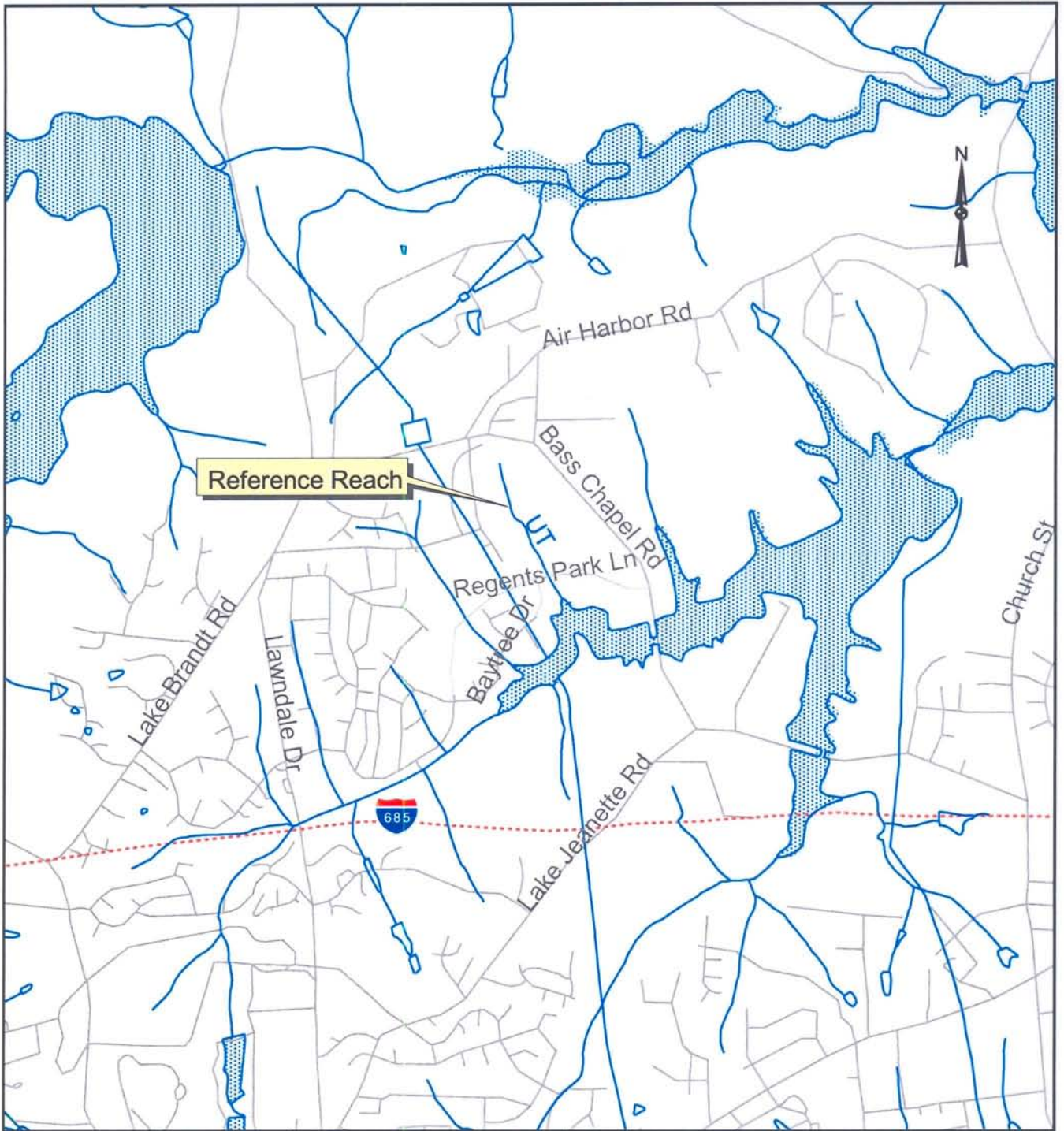
Brown Bark Park - Unnamed Tributary to North Buffalo Creek

Pebble Count Data





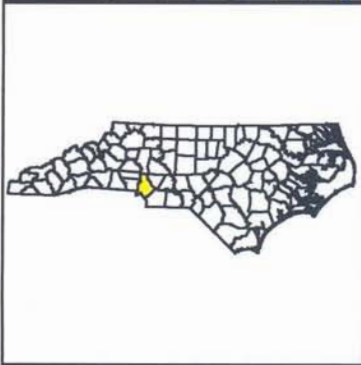
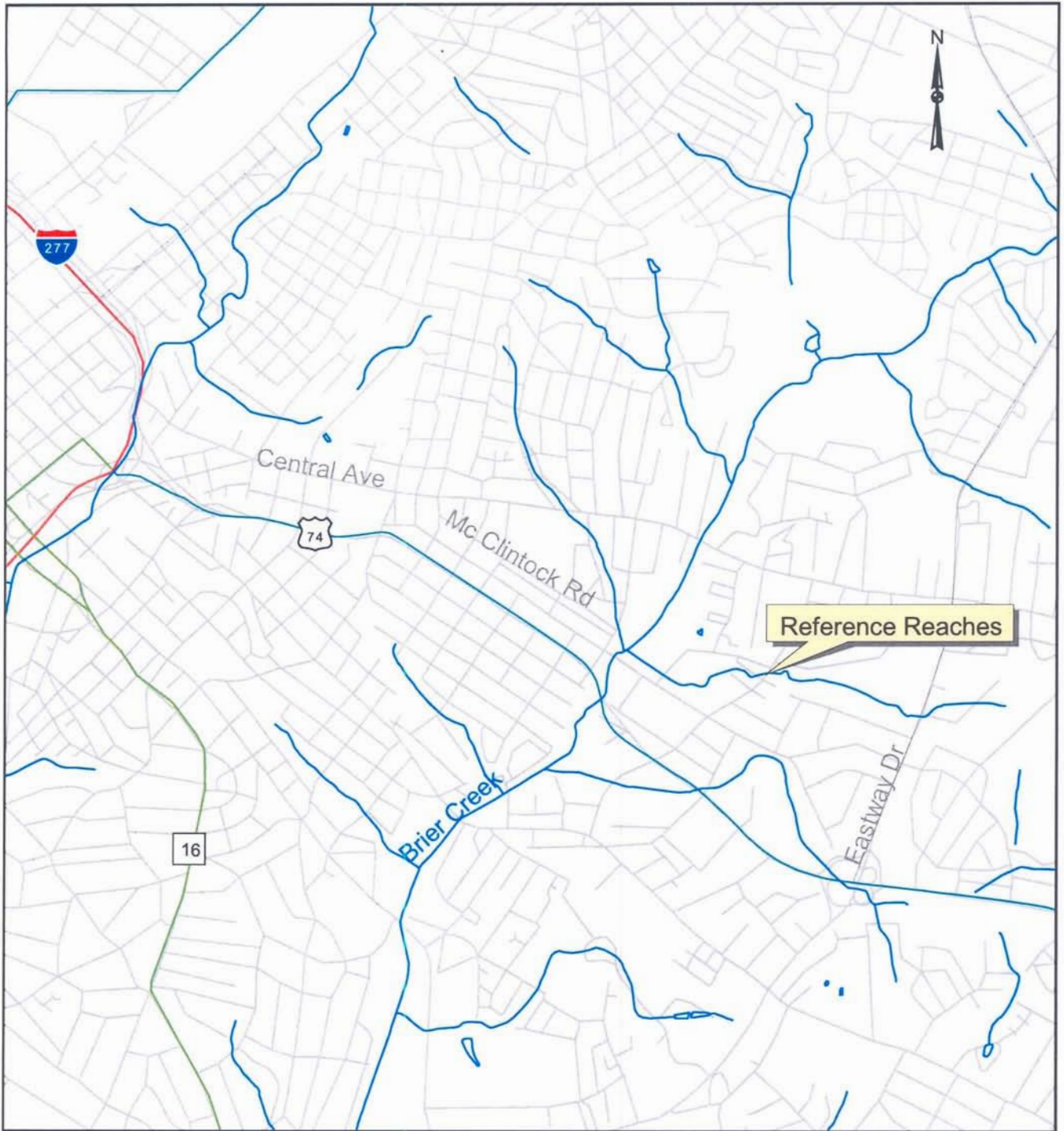
## Appendix 2 Reference Reach Locations




**North Carolina  
Wetlands Restoration Program**

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

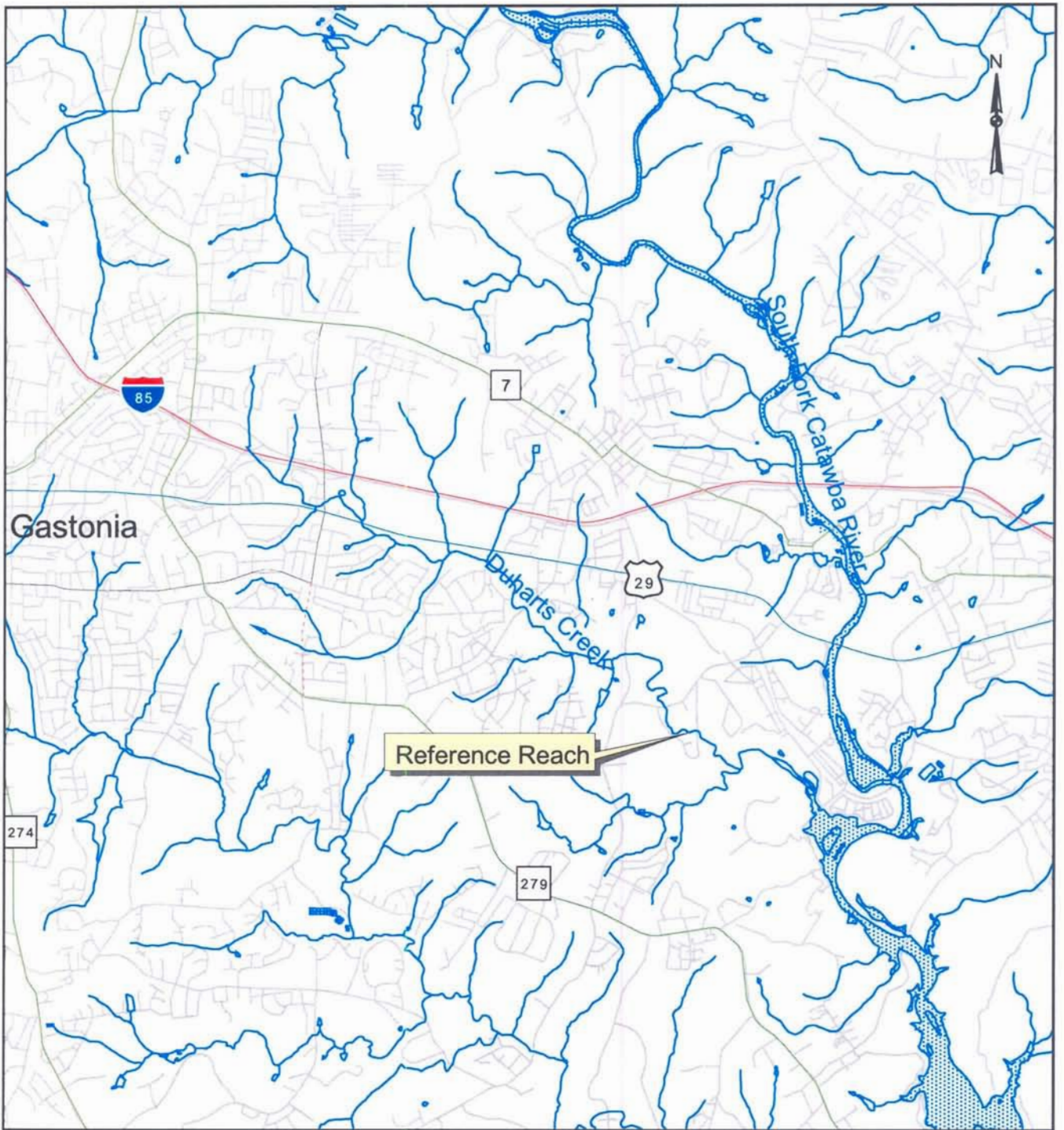





 North Carolina  
 Wetlands Restoration Program

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

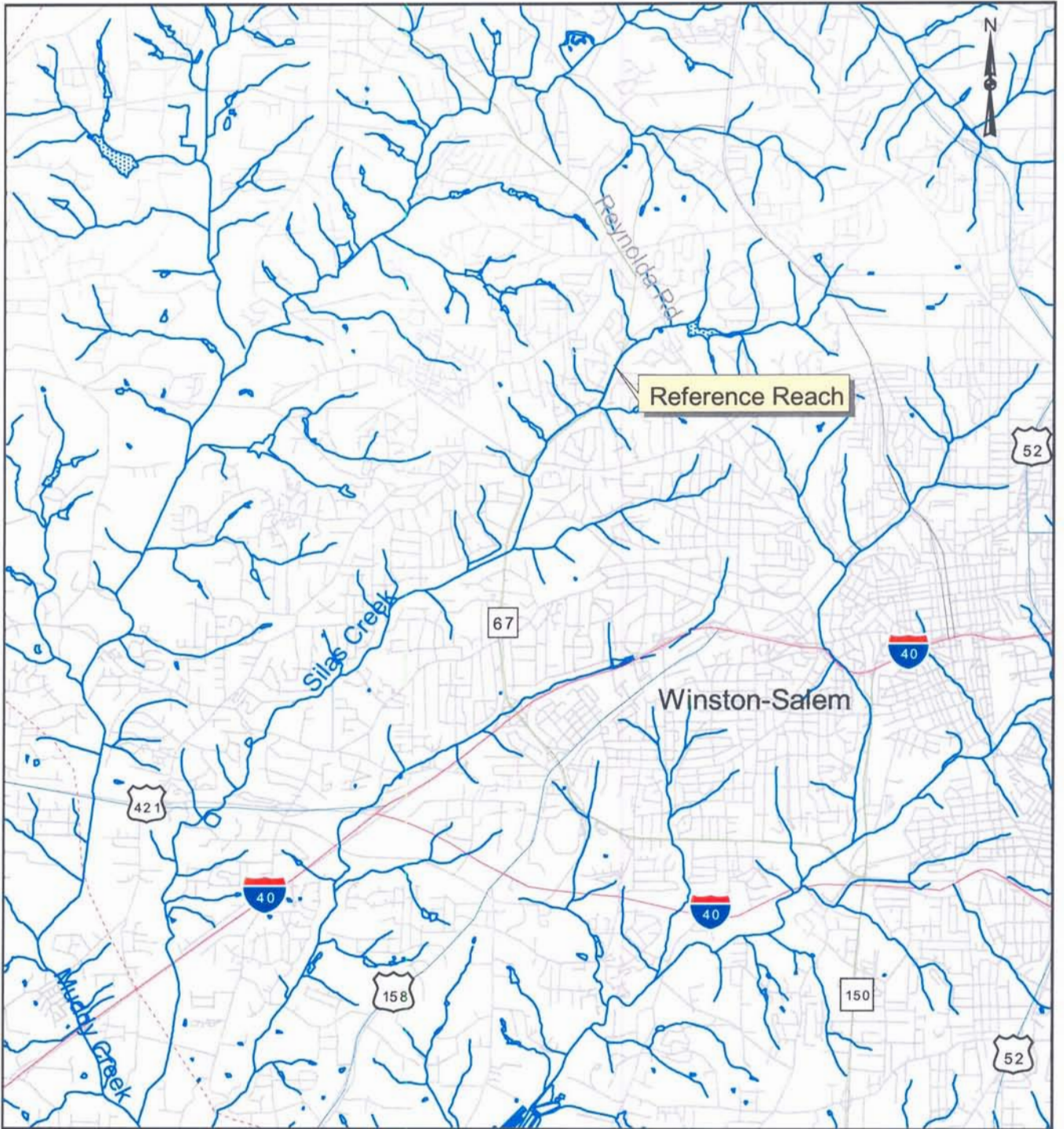





 North Carolina  
 Wetlands Restoration Program

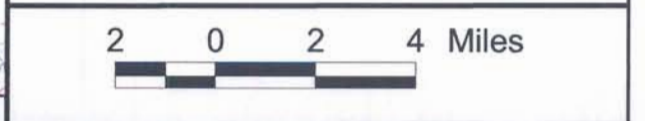
Reference Reach Location Map - Duhart Creek  
 Buffalo Creeks Stream Restoration Projects  
 Greensboro, NC  
 Guilford County

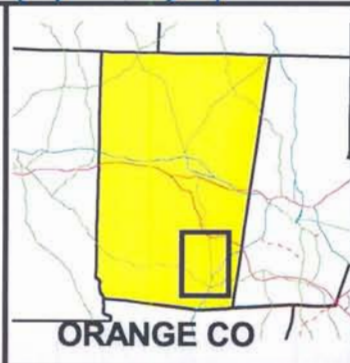
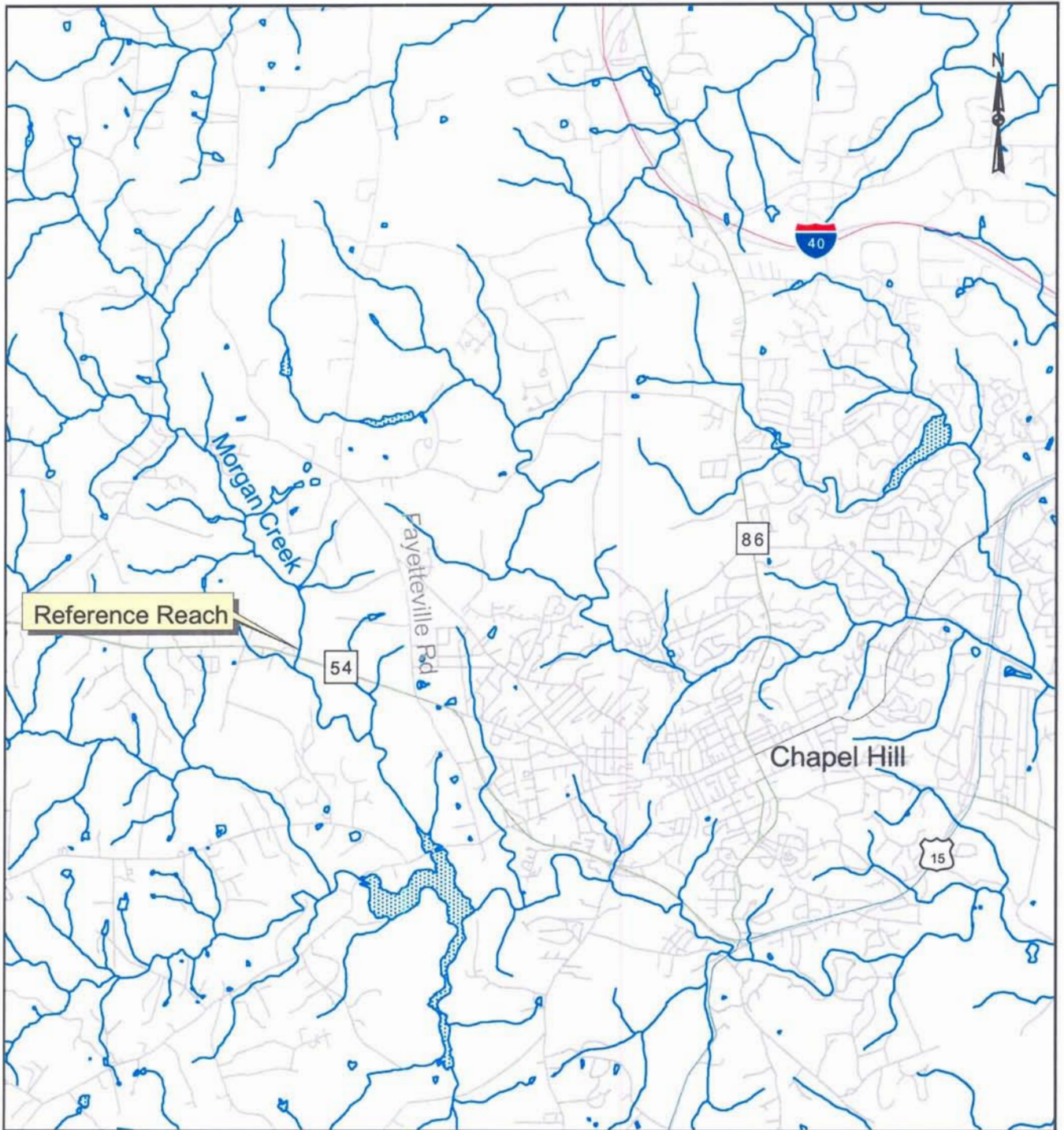





North Carolina  
Wetlands Restoration Program

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

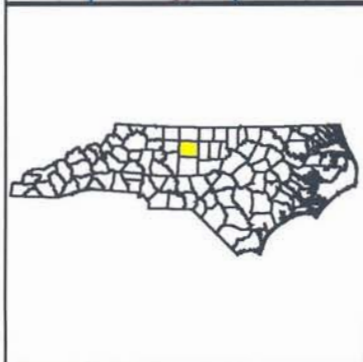
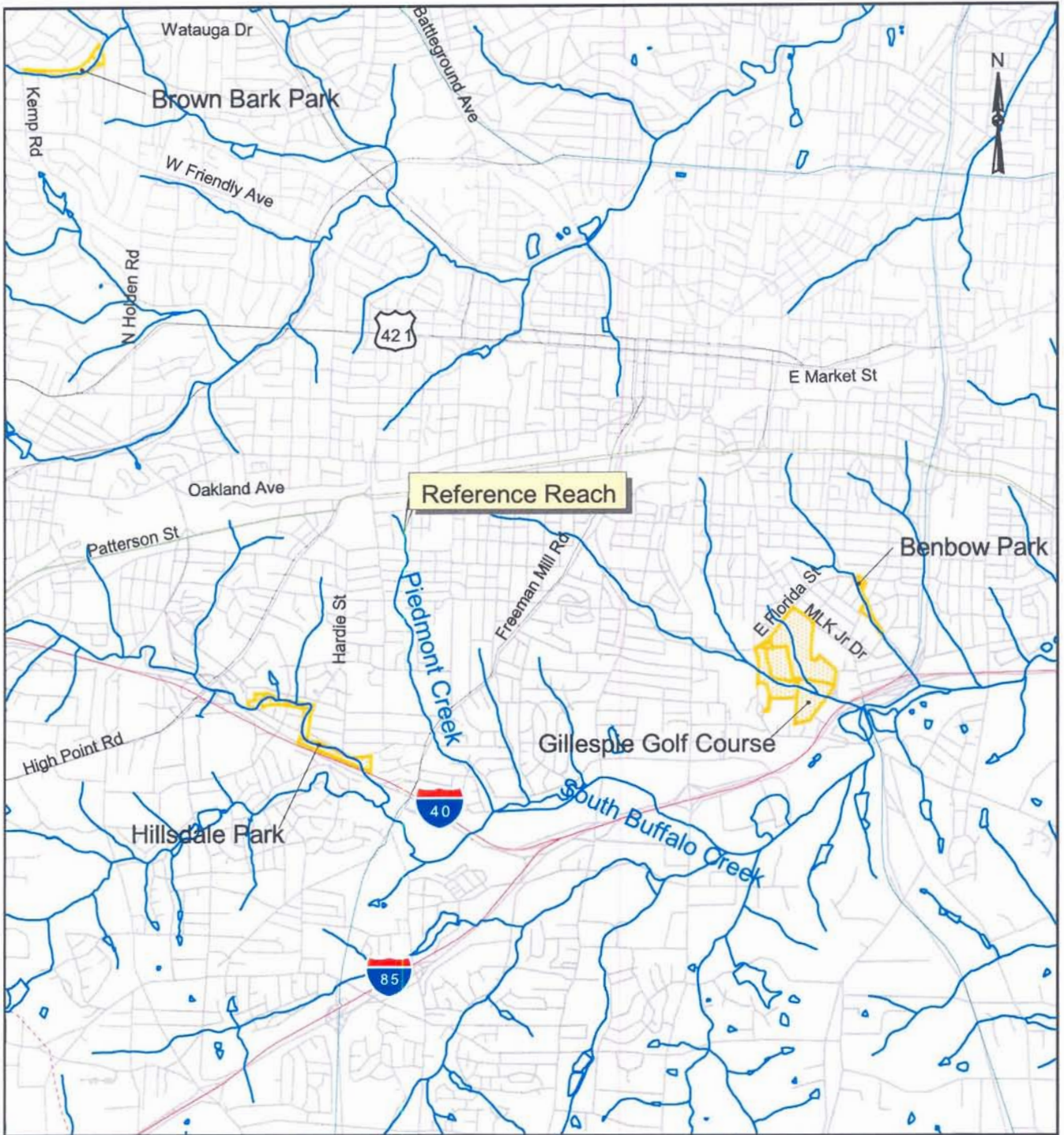




North Carolina  
Wetlands Restoration Program

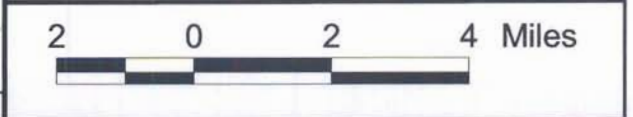
Reference Reach Location Map - Morgan Creek  
Buffalo Creeks Stream Restoration Projects  
Greensboro, NC  
Guilford County






**North Carolina  
Wetlands Restoration Program**

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



## 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



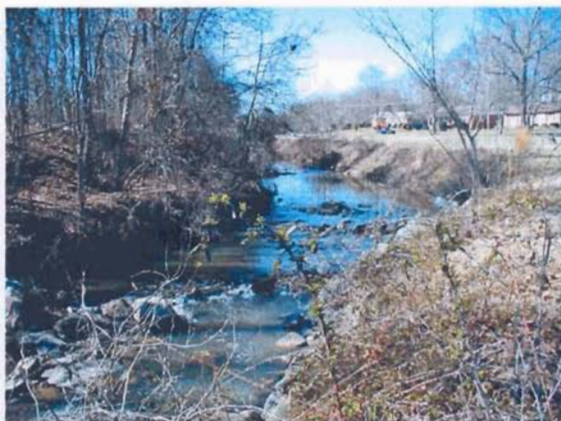
Reach 1 - Pool



Reach 2



Sewer line



Riffle in Reach 3 Downstream



Downstream Tributary