City Pond Site
Stream Restoration Plan
Anson County, NC

Prepared For:

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Executive Summary

The City Pond project site is located near the town of Wadesboro in Anson County, North Carolina. The site lies in the Yadkin River Basin within North Carolina Division of Water Quality sub-basin 03-07-17 and United States Geologic Survey (USGS) hydrologic unit 030402010200200. The North Carolina Ecosystem Enhancement Program lists this hydrologic unit as a targeted local watershed.

A total of nine reaches are located on the site, comprised of one main channel and six tributary channels. Reach designations are based on the characteristics of each reach, such as breaks in stream type, slope, bed material, and restoration potential. Streams across the low valley portions of the site were channelized and straightened in the past. The main channel begins off-site and enters the site from the northeast. It flows across the site from the north/northeast, turns in the center of the site, and exits the site to the south. After exiting the project site, the main channel flows approximately 3,200 feet before discharging into City Pond. City Pond is the water supply reservoir for the Town of Wadesboro.

Five of the on-site reaches are unnamed "blue-line" streams on the USGS topographic map of the area. There are four additional smaller tributaries that do not appear on the USGS topographic map, but have significant flow and are considered perennial based on site assessments. The total current length of all of the streams on the project property is approximately 8,836 feet. The cumulative drainage area at the point where the main channel exits the site is 936 acres (1.46 square miles). The main channel is approximately 3,274 feet in length. The total length of all of the tributaries within the project limits is approximately 5,562 feet.

The design goal of the City Pond project is to re-establish contact between the stream channels on the site and the floodplain. All but one reach of the mainstem will result in Priority 1 stream restoration.

TABLE ES-1
Restoration Overview

Reach	Existing Length (ft)	Design Length (ft)	Approach
R1	940	704	Priority 3 Restoration
R2	1,653	2,610	Priority 1 Restoration (with short Priority 2 Transition Area)
R3	681	752	Priority 1 Restoration (with short Priority 2 Transition Area)
S1	730	735	Non-Incised Stream Restoration (similar to Priority 1 Restoration)
S2	876	1,022	Non-Incised Stream Restoration (similar to Priority 1 Restoration)
S3	591	639	Priority 1 Restoration
S4	1,188	1,770	Priority 1 Restoration (with short Priority 2 Transition Area)
S5	1,939	1,783	Priority 1 Restoration
S6	238	344	Priority 1 Restoration
Total	8,836	10,359	

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1 Introduction and Background

1.1 Brief Project Description and Location

Environmental Banc and Exchange, LLC (EBX) proposes to restore and/or enhance 8,836 feet of channelized stream for the purpose of fulfilling stream restoration requirements for the North Carolina Ecosystem Enhancement Program (NCEEP). The project will result in 10,359 feet of stream restoration (Figure 1.1).

The City Pond stream restoration site is located south of Wadesboro in Anson County, North Carolina (Figure 1.2). The site has a recent history of pasture and hay production, preceded by row crop production, which ended in the 1950s. Ditches were used to increase land use and improve drainage when the land was under crop production. The main channelized stream (3,274 linear feet) flows through the center of the site and 5,562 feet of tributaries drain to the main channel (Figure 1.3). The watershed for the main channel is 180 acres (0.3 square miles) at the upstream end of the project and 936 acres (1.5 square miles) at the downstream end (Figure 1.4).

1.2 Project Goals and Objectives

The specific goals for the City Pond site are as follows:

- Restore a natural dimension, pattern, and profile to the main creek and tributaries,
- Improve bedform diversity,
- Restore a wooded riparian buffer zone,
- Raise the local water table and restore site hydrology, and
- Fill drainage ditches.

To accomplish these goals, the existing incised, eroded, and channelized streams will be filled and new meandering channels will be constructed across the abandoned floodplain.

1.3 Report Overview

This report has been arranged and formatted to maximize its utility. Section 2 provides new readers with a review of the background science and methodologies applied by Buck Engineering in the practice of natural channel design. This section can be passed over by those readers already familiar with our design processes and procedures. Sections 3, 4, 5, and 6 of the report are specific to the project site. These sections cover the site assessment findings, selection and application of design criteria, and site design. Section 7 presents the monitoring and evaluation procedures for the post-implementation period.

2 Background Science and Methods

2.1 Application of Fluvial Processes to Stream Restoration

A stream and its floodplain comprise a dynamic environment where the floodplain, channel, and bedform evolve through natural processes. Weather and hydraulic processes erode, transport, sort, and deposit alluvial materials throughout the riparian system. The size and flow of a stream are directly related to its watershed area. Other factors that affect channel size and stream flow are geology, land use, soil types, topography, and climate. The morphology, or size and shape, of the channel reflect all of these factors (Leopold et al., 1992; Knighton, 1988). The result is a dynamic equilibrium where the stream maintains its dimension, pattern, and profile over time, and neither degrades nor aggrades. Land use changes in the watershed, including increases in imperviousness, channelization, and removal of riparian vegetation, can upset this balance. A new equilibrium may eventually result, but not before large adjustments in channel form can occur, such as extreme bank erosion or incision (Lane, 1955; Schumm, 1960). By understanding and applying natural stream processes to stream restoration projects, a self-sustaining stream can be designed and constructed that maximizes stream and biological potential (Leopold et al., 1992; Leopold, 1994; Rosgen, 1996).

In addition to transporting water and sediment, natural streams also provide the habitat for many aquatic organisms including fish, amphibians, insects, mollusks, and plants. Trees and shrubs along the banks provide a food source and regulate water temperatures. Channel features such as pools, riffles, steps, and undercut banks provide diversity of habitat, oxygenation, and cover (Dune and Leopold, 1978). Stream restoration projects can repair these features in concert with the return of a stable dimension, pattern, and profile. The following sections provide an overview of the dominant channel forming process and typical stream morphology.

2.1.1 Channel Forming Discharge

The channel forming discharge, also referred to as bankfull discharge, effective discharge, or dominant discharge creates a natural and predictable channel size and shape (Leopold et al., 1992; Leopold, 1994). Channel forming discharge theory states that there is a unique flow that over a long period of time would yield the same channel morphology that is shaped by the natural sequence of flows. At this discharge, equilibrium is most closely approached and the tendency to change is the least (Inglis, 1947). Uses of the channel forming discharge include channel stability assessment, river management using hydraulic geometry relationships, and natural channel design (Soar and Thorne, 2001).

Proper determination of bankfull stage in the field is vital to stream classification and the natural channel design process. The bankfull discharge is the point at which flooding occurs on the floodplain (Leopold 1994). This may or may not be the top of the stream bank. On average, bankfull discharge occurs every 1.5 years (Leopold 1994; Harman et al., 1999; McCandless 2003). If the stream has incised due to changes in the watershed or streamside vegetation, the bankfull stage may be a small depositional bench or scour line on the stream bank (Harman et al., 1999). In this case, the top of the bank, which was formerly the floodplain, is called a terrace. A stream with terraces near the top of its banks is incised.

2.1.2 Bedform Diversity and Channel Substrate

The profile of a stream bed and its bed materials are largely dependent on valley slope and geology. In simple terms, steep, straight streams are found in steep, colluvial valleys, while flat, meandering streams are found in flat, alluvial valleys. Colluvial valleys have slopes between 2 and 4%, while alluvial channels have slopes less than 2%. A colluvial valley forms through hillslope processes. Sediment supply in colluvial valleys is controlled by hillslope erosion and mass wasting, i.e., the sediments in the stream bed originated from the hillslopes. Sediments reaching the channel in a colluvial valley are typically poorly sorted mixtures of fine and coarse grained materials ranging in size from sand to boulders. In contrast, an alluvial valley forms through stream and floodplain processes. Sediments in alluvial valleys include some coarse gravel and cobble transported from steeper upland areas, but are predominantly fine grained particles such as gravel and sand. Grain size generally decreases with valley slope (Leopold et al., 1992).

2.1.2.1. Step/Pool Streams

A step/pool bed profile is characteristic of steep streams formed within colluvial valleys. Steep mountain streams demonstrate step/pool morphology as a result of episodic sediment transport mechanisms. Because of the high energy associated with the steep channel slope, the substrate in step/pool streams contains significantly larger particles than streams in flatter alluvial valleys. Steps form from accumulations of boulders and cobbles that span the channel, resulting in a backwater pool upstream and plunge pool downstream. Smaller particles collect in the interstices of steps creating stable, interlocking structures (Knighton, 1988).

In contrast to meandering streams that dissipate energy through meander bends, step/pool streams dissipate energy through drops and turbulence. Step/pool streams have relatively low sinuosity. Pattern variations are commonly the result of debris jams, topographic features, and bedrock outcrops.

2.1.2.2. Gravel Bed Streams

Meandering gravel bed streams in alluvial valleys have sequences of riffles and pools that maintain channel slope and bed stability. The riffle is a bed feature composed of gravel or larger size particles. During low flow periods, the water depth at a riffle is relatively shallow and the slope is steeper than the average slope of the channel. At low flows, water moves faster over riffles, providing oxygen to the stream. Riffles control the stream bed elevation and are usually found entering and exiting meander bends. The inside of the meander bend is a depositional feature called a point bar, which also helps maintain channel form (Knighton, 1988). Pools are typically located on the outside bends of meanders between riffles. Pools have a flat slope and are much deeper than the average depth of the channel. At low flows, pools are depositional features and riffles are scour features.

At high flows, the water surface becomes more uniform, i.e., the water surface slope at the riffles decreases and the water surface slope at the pools increases. The increase in pool slope coupled with the greater water depth at the pools causes an increase in shear stress at the bed elevation. The opposite is true at riffles. With a relative increase in shear stress, pools scour. The relative decrease in shear stress at riffles causes bed material deposits at these features during the falling limb of the hydrograph.

2.1.2.3. Sand Bed Streams

While gravel bed streams have riffle/pool sequences, with riffles composed of gravel size particles, sand bed channels are characterized by median bed material sizes less than 2 mm (Bunte and Abt, 2001). Bed material features called ripples, dunes, planebeds, and antidunes characterize the sand bedform. Although sand bed streams technically do not have riffles, the term is often used to describe the crossover reach between pools. We use "riffle" in this report as equivalent to the crossover section.

The size, stage, and variation of sand bedforms are formed by changes in unit stream power as described below. These bedforms are symptomatic of local variations in the sediment transport rate and cause minor to major variations in aggradation and degradation (Gomez, 1991). Sand bedforms can be divided between low flow regimes and high flow regimes with a transitional zone between the two. Ripples occur at low flows where the unit stream power is just high enough to entrain sand size particles. This creates small wavelets from random accumulation of sediment that are triangular in profile with gently upstream and steep downstream slopes. The dimensions are independent of flow depth and heights are less than 0.02 meters.

As unit stream power increases, dunes eventually replace ripples. Dunes are the most common type of sand bedform and have a larger height and wavelength than ripples. Unlike ripples, dune height and wavelength are proportional to flow depth. The movement of dunes is the major cause of variability in bed-load transport rates in sand bed streams. Dunes are eventually washed out to leave an upper-flow plane bed characterized by intense bedload transport. This prevents the patterns of erosion and deposition required for dune development. This stage of bedform development is called the transitional flow regime between the low flow features and the high flow regime features (Knighton, 1998).

As flow continues to increase, standing waves develop at the water surface and the bed develops a train of sediment waves (antidunes), which mirror the surface forms. Antidunes migrate upstream through scour on the downstream face and deposition on the upstream face, a process that is opposite of ripples and dunes. Antidunes can also move downstream or remain stationary for short periods (Knighton, 1998).

2.1.3 Stream Classification

2.1.3.1. Rosgen Stream Classification System

The Rosgen stream classification system categorizes essentially all types of channels based on measured morphological features (Rosgen, 1994, 1996). The system presents several stream types (A, B, C, D, DA, E, F, and G) based on a hierarchical system (Figure 2.1). The first level distinguishes between single and multiple thread channels. Streams are then separated based on degrees of entrenchment, width/depth ratio, and sinuosity (see Section 2.3.3). Slope range and channel materials are also evaluated to subdivide the streams. Stream types are further described according to average riparian vegetation, organic debris, blockages, flow regimes, stream size, depositional features, and meander pattern.

Bankfull stage is the basis for measuring the width/depth and entrenchment ratios, two of the most important delineative criteria. Therefore, it is critical to correctly identify bankfull stage when classifying streams and designing stream restoration measures. A detailed discussion of bankfull stage was provided in Section 2.1.1.

2.1.4 Stream Stability

A naturally stable stream must be able to transport the sediment load supplied by its watershed while maintaining dimension, pattern, and profile over time so that it does not degrade or aggrade (Rosgen, 1994). Stable streams migrate across alluvial landscapes slowly over long periods of time while maintaining their form and function. Instability occurs when scouring causes the channel to incise (degrade) or excessive deposition causes the channel bed to rise (aggrade). A generalized relationship of stream stability proposed by Lane (1955) is shown as a schematic drawing in Figure 2.2. The drawing shows that the product of sediment load and sediment size is proportional to the product of stream slope and discharge or stream power. A change in any one of these variables causes a rapid physical adjustment in the stream channel.

2.1.5 Channel Evolution Model for Incised Streams

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 due to development in the watershed, removal of streamside vegetation, and other changes that negatively affect stream stability. All of these disturbances occur in both urban and rural environments. Several models have been used to describe this process of physical adjustment for a stream. The Simon (1989) channel evolution model characterizes evolution in six steps, including 1) sinuous, pre-modified, 2) channelized, 3) degradation, 4) degradation and widening, 5) aggradation and widening, and 6) quasi-equilibrium (Figure 2.3).

The channel evolution process is initiated once a stable, well-vegetated stream that interacts frequently with its floodplain is disturbed. Disturbance commonly results in an increase in stream power that causes degradation, often referred to as channel incision (Lane, 1955). Incision eventually leads to over-steepening of the 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 in the form of 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 (FISRWG, 1998).

2.1.6 Priority Levels of Restoring Incised Rivers

Though incised streams can occur naturally in certain landforms, they are often the product of disturbance. High, steep stream banks, poor or absent in-stream or riparian habitat, increased erosion and sedimentation, and low sinuosity are all characteristics of incised streams. Complete restoration of the stream, where the incised channel's grade is raised so that an abandoned floodplain terrace is reclaimed, is ideally the overriding project objective. There may be scenarios, however, where such an objective is impractical due to encroachment into the abandoned floodplain terrace by homes, roadways, utilities, etc. A "priority system" for the restoration of incised streams, developed and used by Rosgen (1997), considers a range of options to provide the best level of stream restoration possible for the given setting. Figure 2.4 presents various restoration/stabilization options for incised channels within the framework of the Rosgen's "priority system." Generally:

- Priority 1 – Re-establishes the channel on a previous floodplain (i.e., raises channel elevation); meanders a new channel to achieve the dimension, pattern, and profile characteristic of a stable stream for the particular valley type; and fills or isolates existing incised channel. This option requires that the upstream start point of the project not be incised (see item 'a' in Figure 2.4).
- Priority 2 – Establishes a new floodplain at the existing bankfull elevation (i.e., excavates a new floodplain); meanders channel to achieve the dimension, pattern, and profile characteristic of a stable stream for the particular valley type; and fills or isolates existing incised channel (see items 'b' and 'c' in Figure 2.4).
- Priority 3 – Converts a straight channel to a different stream type while leaving the existing channel in place by excavating bankfull benches at the existing bankfull elevation. Effectively, the valley for the stream is made more bowl-shaped. It uses in-stream structures to dissipate energy through a step/pool channel type (see items 'd' and 'e' in Figure 2.4).
- Priority 4 – Stabilizes the channel in place using in-stream structures and bioengineering to decrease stream bed and stream bank erosion. This is typically used in highly constrained environments (see item 'f' in Figure 2.4).

2.2 Natural Channel Design Overview

Restoration design of degraded stream reaches first involves accurately diagnosing their current condition. Understanding valley type, stream type, channel stability, bedform diversity, and potential for restoration is essential to developing adequate restoration measures (Rosgen, 1996). This combination of assessment and design is often referred to as natural channel design.

The first step in a stream restoration design is to assess the reach, its valley, and its watershed to understand the relationship between the stream and its drainage basin and determine the causes of stream impairment. Bankfull discharge is estimated for the watershed. After sources of stream impairment are identified and channel geometry is determined, a plan for restoration can be formulated.

Design commences at the completion of the assessment stage. A series of iterative calculations are performed using data from reference reaches, pertinent literature, and evaluation of past projects to determine the appropriate stable cross-section, profile, and plan form dimensions for the design reach. A thorough discussion of design parameter selection is provided in Section 2.5. The alignment should avoid an entirely symmetrical layout to mimic natural variability, create a diversity of aquatic habitats, and improve aesthetics.

Once a dimension, pattern, and profile have been developed for the project reach, the design is tested to ensure that the new channel will not aggrade or degrade. A discussion of sediment transport methodology is provided in Section 2.6.

After the sediment transport assessment, additional structural elements are then added to the design to provide grade control, protect stream banks, and enhance habitat. Section 2.7 describes these in-stream structures in detail.

Once the design is finalized, detailed drawings are prepared showing dimension, pattern, profile, and location of additional structures. These drawings are used in the construction of the project.

Following the implementation of the design, a monitoring plan is established to:

- Ensure that stabilization structures are functioning properly,
- Monitor channel response in dimension, pattern and profile, channel stability (aggradation/degradation), particle size distribution of channel materials, and sediment transport and stream bank erosion rates,
- Determine biological response (food chains, standing crop, species diversity, etc.), and
- Determine the extent to which the restoration objectives have been met.

2.3 Geomorphic Characterization Methodology

Geomorphic characterization of stream features includes the bankfull identification, bed material characterization and analysis, and stream classification.

2.3.1 Bankfull Identification

Correct identification of bankfull is important to the determination of geomorphic criteria such as stream type, bank height ratios, width to depth ratios, and entrenchment ratios. Buck Engineering's field techniques for bankfull are as follows:

- Identify the most consistent bankfull indicators along the reach that were obviously formed by the stream, such as a point bar or lateral bar. Bankfull is usually the back of this feature, unless sediment supply is high. In that case, the bar may flatten and bankfull will be the front of the feature at the break in slope. The indicator is rarely the top of the bank or lowest scour mark.
- Measure the difference in height between the water surface and the bankfull indicator. For example, the indicator may be 2.2 feet above water surface. Bankfull stage corresponds to a flow depth. It should not vary by more than a few tenths of a foot throughout the reach, unless a tributary enters the reach and increases the size of the watershed.

- Go to a stable riffle. If a bankfull indicator is not present at this riffle, use the height measured in the previous step to establish the indicator. For example, measure 2.2 feet above water surface and place a flag in both the right and left bank.
- Measure the distance from the left bank to the right bank between the indicators. Calculate the cross sectional area.
- Obtain the appropriate regional curve (i.e., rural Piedmont, urban Piedmont, Mountain, or Coastal Plain) and determine the cross sectional area associated with the drainage area of the reach.
- Compare the measured cross sectional area to the regional curve cross sectional. If the measured cross sectional area is not a close fit, look for other bankfull indicators and test them. If there are no other indicators, look for reasons to explain the difference between the two cross sectional areas. For example, if the cross sectional area of the stable riffle is lower than the regional curve area, look for upstream impoundments, wetlands, or a mature forested watershed. If the cross sectional area is higher than the regional curve area, look for stormwater drains, parking lots, or signs of channelization.

It is important to perform the bankfull verification at a stable riffle using indicators from depositional features. The cross sectional area will change with decreasing stability. In some streams, bankfull indicators will not be present due to incision or maintenance. In such cases, it is important to verify bankfull through other means such as a gauge station and/or reference bankfull information that is specific to the geographic location. The gauge information can be used, along with regional curve information, to estimate bankfull elevation in the project reaches that contained no bankfull indicators.

2.3.2 Bed Material Characterization

Buck Engineering performs bed material characterization using a modified Wolman procedure (Wolman, 1954; Rosgen, 1996). A 100-count pebble count is performed based on the percentage of riffles and pools within the longitudinal distance of a given stream type. As stream type changes, a separate pebble count is performed. The median value of the modified Wolman procedure is known as the D_{50}. The D_{50} particle size determines the bed material classification for that reach.

Bed material classifications are as follows:

- 1 = Bedrock
- 2 = Boulder
- 3 = Cobble
- 4 = Gravel
- 5 = Sand
- 6 = Silt

2.3.3 Stream Classification

Cross-sections are surveyed along stable riffles for the purpose of stream classification. Values for entrenchment ratio and width/depth ratio, along with sinuosity and slope, are used to classify the stream. The entrenchment ratio (ER) is calculated by dividing the flood-prone width (width measured at twice the maximum bankfull depth) by the bankfull width. The width/depth ratio (w/d ratio) is calculated by dividing bankfull width by mean bankfull depth) Figure 2.5 shows examples of the channel dimension measurements used in the Rosgen stream classification system.

Finally, the numbers that coincide with each bed material classification are to further classify the stream type. For example, a Rosgen E3 stream type is a narrow and deep cobble-dominated channel with access to a floodplain that is greater than two times its bankfull width.

2.4 Channel Stability Assessment Methodology

Buck Engineering uses a modified version of stream channel stability assessment methodology developed by Rosgen (2001). The Rosgen method is a field assessment of the following stream channel characteristics:

- Stream Channel Condition,
- Vertical Stability,
- Lateral Stability,
- Channel Pattern,
- River Profile and Bed Features,
- Channel Dimension Relations, and
- Channel Evolution.

This field exercise is followed by the evaluation of various channel dimension relationships (ratios).

Evaluation of the above categories and ratios leads to a determination of a channel's current state, potential for restoration, and appropriate restoration activities. A description of each category is provided in the following sections.

2.4.1 Stream Channel Condition Observations

Stream channel conditions are observed during initial field inspection ("stream walks"). Buck Engineering notes the follow characteristics:

1) Riparian vegetation – concentration, composition, and rooting depth and density;
2) Sediment depositional patterns – such as mid-channel bars and other depositional features that indicate aggradation and can lead to negative geomorphic channel adjustments;
3) Debris occurrence – presence or absence of woody debris;
4) Meander patterns – general observations with regard to the type of adjustments a stream will make to reach equilibrium; and
5) Altered states due to direct disturbance – such as channelization, berm construction, and floodplain alterations.

These qualitative observations are useful in the assessment of channel stability. They provide a consistent method of documenting stream conditions that allows comparison across different sets of conditions. The observations also help explain the quantitative measurements described below.

2.4.2 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 (BHR) and vertical stability developed by Rosgen (2001).

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

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

The entrenchment ratio is measured as the width of the floodplain at twice the maximum bankfull depth. If the entrenchment ratio is less than 1.4 (+/- 0.2), the stream is considered entrenched (Rosgen, 1996).

2.4.3 Lateral Stability

The degree of lateral containment (confinement) and potential lateral erosion are determined in the field by measuring the meander width ratio (MWR) and the Bank Erosion Hazard Index (BEHI) (Rosgen, 2001a). The MWR is the meander belt width divided by the bankfull channel width, and provides insight into lateral channel adjustment processes depending on stream type and degree of confinement. For example, a MWR of 3.0 often corresponds with a sinuosity of 1.2, which is the minimum value for a meandering stream. If the MWR is less than 3.0, lateral adjustment is probable. BEHI ratings along with near bank shear stress estimates can be compared to data from monitored sites and used to estimate the annual lateral stream bank erosion rate.

2.4.4 Channel Pattern

Channel pattern is assessed in the field by measuring the stream's plan features including radius of curvature, meander wavelength, meander belt width, stream length, and valley length. Results are used to compute 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 whether channel pattern has been impacted.

2.4.5 River Profile and Bed Features

A longitudinal profile is created by measuring and plotting elevations of the channel bed, water surface, bankfull, and low bank height. This profile can be used to determine changes in river slope compared to valley slope, which affect sediment transport, stream 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. Facet (e.g., riffle, run, pool) slopes of each individual feature are important for stability assessment and design and can be determined as the data are analyzed.

2.4.6 Channel Dimension Relations

The bankfull width/depth ratio provides an indication of departure from reference reach conditions and relates to channel instability. A greater width/depth ratio compared to reference conditions may indicate accelerated stream bank erosion, excessive sediment deposition, stream flow changes, and alteration of channel shape (e.g., from channelization). A smaller width/depth ratio compared to reference conditions may indicate channel incision and down-cutting. Both increases and decreases in width/depth ratio can indicate evolutionary shifts in stream type (i.e., transition of one stream type to another). Table 2.2 shows the relationship between the degree of width/depth ratio increase and channel stability developed by Rosgen (2001).

TABLE 2.2
Conversion of Width/Depth Ratios to Adjective Ranking of Stability from Stability Conditions (Rosgen, 2001a)

Stability Rating	Ratio of Project to Reference Width/Depth
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 movement of the channel toward an unstable condition.

2.4.7 Channel Evolution

Simon's channel evolution model (introduced in Section 2.1.5) relies on a qualitative, visual assessment of the existing stream channel characteristics (bank height, evidence of degradation/aggradation, presence of bank slumping, direction of bed and bank movement, etc.). Establishing the evolutionary stage of the channel helps ascertain whether the system is moving towards greater stability or instability. The model also provides a better understanding of the cause and effect of channel change. This information, combined with Rosgen's (1994) priority levels of restoration aids in determining the restoration potential unstable reaches.

2.5 Design Parameter Selection Methodology

Buck Engineering uses a combination of approaches to develop design criteria for channel dimension, pattern, and profile. These approaches are described in the following sections. A flow chart for selecting design criteria is shown in Figure 2.6.

2.5.1 Upstream Reference Reaches

The best option for developing design criteria is to locate a reference reach upstream of the project site. A reference reach is a channel segment that is stable—neither aggrading nor degrading— and is of the same morphological "type" as the channel under consideration for restoration. The reference reach should also have a similar valley slope as the project reach. The reference reach is then used as the "blueprint" for the channel design (Rosgen, 1998). To account for differences in drainage area and discharge between a reference site and a project site, data on channel characteristics (dimension, pattern, and profile), in the form of dimensionless ratios, are developed for the reference reach. If the reach upstream of the project does not have sufficient pattern, but does have a stable riffle cross section, only dimension ratios are calculated. It is ideal to measure a reference bankfull dimension that was formed under the same environmental influences as the project reach.

2.5.2 Reference Reach Searches

If a reference reach cannot be located upstream of the project reach, a review of a reference reach database is performed. A database search is conducted to locate known reference reaches within close proximity to the project site. The search includes streams with the same valley as the project reach and stream type as the design. If references are found meeting these criteria, the reference reach is field surveyed for validation and comparison with the database values which may have been originally collected and provided by a third party. If a search of the database reveals no references which meet the appropriate criteria, a field search is performed locally to identify a reference reach which has not yet been surveyed.

Potential reference reaches are identified by first evaluating USGS topographic quadrangles and aerial photography for an area. In general, the search is limited to watersheds within or adjacent to the project watershed. In certain cases, a reference reach may be identified farther away that matches the same valley and stream type as the proposed design of the project site. In such a case, care is taken to ensure that the potential reference reach lies within the same physiographic region as the project reach. Potential reference sites identified on maps are then field evaluated to determine if they are stable systems of the appropriate stream and valley type. If appropriate, reference reach surveys are conducted. When potential sites are located on private property, landowner permission is acquired prior to any survey work being conducted.

2.5.3 Reference Reach Databases

If a reference reach is not found in close proximity to the project site, a reference reach database is consulted and summary ratios are acquired for all streams with the same valley and stream type within the project's physiographic region. These ratios are then compared to literature values and regime equations along with ratios developed through the evaluation of successful projects.

2.5.4 Regime Equations

Buck Engineering uses a variety of published journals, books, and design manuals to cross reference North Carolina database values with peer-reviewed regime equations. Examples include *Fluvial Forms and Processes* by David Knighton (1998), *Mountain Rivers* by Ellen Wohl (2000), and the *Hydraulic Design Manual for Stream Restoration Projects* by the US Army Corps of Engineers (Copeland et al., 2001). The most common regime equations used in our designs are for pattern. For example, most reference reach surveys in the eastern United States show radius of curvature divided by bankfull width ratios much less than 1.5. However, the corps manual recommends a ratio greater than 2.0 to maintain stability in free-forming systems. Since most stream restoration projects are constructed on floodplains denude of woody vegetation, we often use the corps recommended value rather than reference reach data. Meander wavelength and pool-to-pool spacing ratios are examples of other parameters that are sometimes designed with higher ratios than those observed on reference reaches, for similar reasons as described for radius of curvature.

2.5.5 Comparison to Past Projects

All of the above techniques for developing ratios and/or regime equations are compared to past projects built with similar conditions. Ultimately, these sites will provide the best pattern and profile ratios because they better reflect site conditions after construction. While most reference reaches are in mature forests, restoration sites are in floodplains with little or no mature woody vegetation. This severely alters floodplain processes and stream bank conditions. If past ratios did not provide adequate stability or bedform diversity, they are not used. Conversely, if past project ratios create stable channels with optimal bedform diversity; they will be incorporated into the design. Ultimately, the design criteria are selections of ratios and equations made upon a thorough evaluation of the above tasks. Combinations of approaches may be used to optimize the design. The final selection of design criteria for the restoration site is discussed in Section 5.

2.6 Sediment Transport Competency and Capacity Methodology

Stream restoration designs must be tested to ensure that the new channel dimensions (in particular, the design bankfull mean depth) create a stream that has the ability to move its sediment load without aggrading or degrading over long periods of time. 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 pounds per square foot (lbs/ft^2). Sediment transport capacity is a stream's ability to move a quantity of sediment and is a measurement of stream power, often expressed as units of watts/square meter. 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 pounds per second (lbs/sec) versus discharge or stream power.

The total volume of sediment transported through a cross section consists of bedload plus suspended load fractions. Suspended load is normally composed of fine sand, silt, and clay particles transported in the water column. Bedload is generally composed of larger particles, such as course sand, gravels, and cobbles, which are transported by rolling, sliding, or hopping (saltating) along the bed.

2.6.1 Competency Analysis

Median substrate size has an important influence on the mobility of particles in stream beds. Critical dimensionless shear stress (τ^*ci) is the measure of force required to initiate general movement of particles in a bed of a given composition. At shear stresses exceeding this critical value, essentially all grain sizes are transported at rates in proportion to their presence in the bed (Wohl, 2000). τ^*ci can be calculated for gravel-bed stream reaches using surface and subsurface particle samples from a stable, representative riffle in the reach (Andrews, 1983). Critical dimensionless shear stress is calculated as follows (Rosgen, 2001a):

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 D50/D^50

Where: D50 = median diameter of the riffle bed (from 100 count in the riffle or pavement sample)

D^50 = median diameter of the bar sample (or subpavement)

If the ratio D50/D^50 is between the values of 3.0 and 7.0, then calculate the critical dimensionless shear stress using Equation 1.

$$\tau^*ci = 0.0834\ (D50/D\hat{\ }50)^{-0.872} \quad \text{(Equation 1)}$$

b) If the ratio D50/D^50 is not between the values of 3.0 and 7.0, then calculate the ratio of Di/D50

Where: Di = largest particle from the bar sample (or subpavement)

D50 = median diameter of the riffle bed (from 100 count in the riffle or the pavement sample)

If the ratio Di/D50 is between the values of 1.3 and 3.0, then calculate the critical dimensionless shear stress using Equation 2.

$$\tau^*ci = 0.0384\ (Di/D50)-0.887 \qquad \text{(Equation 2)}$$

2.6.2 Aggradational Analysis

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 existing/design mean riffle depth and required slope can be compared to the existing/design slope to verify that the stream has sufficient competency to move large particles and thus prevent thalweg aggradation. The required depth and slope are calculated by:

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

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

Where: dr (ft) = Required bankfull mean depth

de (ft)= Design bankfull mean depth

1.65 = Sediment density (submerged specific weight)

= density of sediment (2.65) – density of water (1.0)

t*ci = Critical dimensionless shear stress

Di (ft) = Largest particle from bar sample (or subpavement)

sr (ft/ft) = Required bankfull water surface slope

se (ft/ft) = Design bankfull water surface slope

2.6.3 Sediment Transport Capacity

For sand bed streams, sediment transport capacity is much more important than competency. Sediment transport capacity refers to the stream's ability to move a mass of sediment past a cross section per unit time in pounds/second or tons/year. Sediment transport capacity can be assessed directly using actual monitored data from bankfull events if a sediment transport rating curve has been developed for the project site. Since this is extremely difficult, other empirical relationships are used to assess sediment transport capacity. The most common capacity equation is stream power. Stream power can be calculated a number of ways, but the most common is:

$w = gQS/W$, where (Equation 5)

w = mean stream power in W/m^2

g = specific weight of water (9810 N/m3). $g = rg$ where r is the density of the water-sediment mixture (1,000 kg/m^3) and g is the acceleration due to gravity (9.81 m/s^2)

Q = bankfull discharge in m^3/s

S = Design channel slope (dimensionless)

W = Bankfull channel width in meters

Note: 1 $ft\text{-}lb/sec/ft^2 = 14.56\ W/m^2$

Equation 5 does not provide a sediment transport rating curve; however, it does describe the stream's ability to accomplish work, e.g., move sediment.

2.7 In-Stream Structures

There are a variety of in-stream structural elements used in restoration (Figure 2.7). These elements are comprised of natural materials such as stone, wood, and live vegetation. Their shape and location works with the flow dynamics to reinforce, stabilize, and enhance the function of the stream channel. In-stream structures provide three primary functions: grade control, stream bank protection, and habitat enhancement.

2.7.1 Grade Control

Grade control pertains mainly to the design bed profile. A newly excavated gravel stream bed with a slope greater than 0.5% is seldom able to maintain the desired slopes and bed features (riffles, runs, pools and glides) until a pavement/subpavement layer has been established. Stone and/or log structures installed at the bed elevation and at critical locations in the plan view help to set up the new stream bed for long-term vertical stability. Over time as the new channel adjusts to its sediment transport regime and vegetative root mass establishes on the banks, the need for grade control diminishes.

2.7.2 Bank Protection

Bank protection is critical during and after construction as bank and floodplain vegetation is establishing a reinforcing root mass. This vegetation establishment lasts for several years, but vegetation is typically providing meaningful bank protection after two to four growing seasons. Bank protection structures generally provide both reinforcement to the stream banks and re-direction of flow away from the banks and toward the center of the channel.

2.7.3 Habitat Enhancement

Habitat enhancement can take several forms and is often a secondary function of grade control and bank protection structures. Flow over vanes and wing deflectors create scour pools, which provide diversity of in-stream habitat. Boulder clusters form eddies that provide resting places for aquatic species. Constructed riffles and vane structures encourage oxygenation of the water. Root wads provide cover and shade, and encourage the formation of deep pools at the outside of meander bends.

2.7.4 Selection of Structure Types

Table 2.3 summarizes the names and functions of several in-stream structures.

TABLE 2.3
Functions of In-Stream Structures

Structure	Function (Primary = 1, Secondary = 2)		
	Grade Control	**Bank Protection**	**Habitat Enhancement**
Cross Vane	1	1	2
Single Arm Vane		1	2
J-Hook Vane	2	1	2
Constructed Riffle	1	1	2
Wing Deflector	2	1	1
Boulder Cluster			1
Root Wad		1	1
Brush Mattress		1	2

The selection of structure types and locations typically follows dimension, pattern, and profile design. In some situations, structures comprise the main, or possibly only, effort to restore a stream. More often, structures are used in conjunction with grading, realignment, and planting in an effort to improve channel stability and aquatic habitat.

2.8 Vegetation

The planting of additional and/or more desirable vegetation is an important aspect of the restoration plan. Vegetation helps stabilize stream banks, creates habitat and a food source for wildlife, lowers water temperature by stream shading, improves water quality by filtering overland flows, and improves the aesthetics of the site.

The reforestation component of a restoration project typically includes live dormant staking of the stream banks, riparian buffer plantings, invasive species removal, and seeding for erosion control. The stream banks and the riparian area are typically planted with both woody and herbaceous vegetation to establish a diverse streamside buffer. Vegetating the stream banks is a very desirable means of erosion control because of the dynamic, adaptive, and self-repairing qualities of vegetation. Vegetative root systems stabilize channel banks by holding soil together, increasing porosity and infiltration, and reducing soil saturation through transpiration. During high flows, plants lie flat and stems and leaves shield and protect the soil surface from erosion. In most settings, vegetation is more aesthetically appropriate than engineered stabilization structures.

Stream banks are delineated into four zones when considering a planting scheme:

1. Channel bottom - extending up to the low flow stage. Emergent, aquatic plants dominate bank range, extending from the low flow stage to the bankfull stage
2. Lower bank - frequently flooded, extending from the low flow stage to the bankfull stage. A mix of herbaceous and woody plants including sedges, grasses, shrubs and trees
3. Upper bank – occasionally flooded, but most often above water. Dominated by shrubs and small trees.
4. Riparian area – infrequently flooded, terrestrial and naturally forested with canopy-forming trees.

The most appropriate source of plant material for any project is the site itself. Desirable plants that need to be removed in the course of construction should be salvaged and transplanted as part of the restoration plan. The next best alternative is to obtain permission to collect and transplant native plants from areas nearby. This ensures that the plants are native and adapted to the locale. Finally, plants may need to be purchased. They should be obtained from a nearby reputable nursery that guarantees that the plants are native and appropriate for the locale and climate of the project site.

2.8.1 Live Staking

Live staking is a method of revegetation that utilizes live, dormant cuttings from appropriate species to cheaply, and effectively established vegetation. The installation of live stakes on stream banks serves to protected the banks from erosion and at the same time provide habitat, shade and improved aesthetics. Live staking must take place during the dormant season (November – March). Live stakes can be gathered locally or purchased from a reputable commercial supplier. Stakes should be at least ½ inches and no more than 2 inches in diameter, between 2 and 3 feet in length, and living based on the presence of young buds and green bark. Stakes are cut at an angle on the bottom end and driven into the ground with a rubber mallet. Split and damaged stakes must be replaced.

2.8.2 Riparian Buffer Re-Vegetation

Riparian buffers are naturally occurring ecosystems adjacent to rivers and streams and are associated with a number of benefits. Buffers are important in nutrient and pollutant removal in overland flow and may provide for additional subsurface water quality improvement in the shallow ground water flow. Buffers also provide habitat and travel corridors for wildlife populations and are an important recreational resource, as well. It is also important to note that riparian buffer areas help to moderate the quantity and timing of runoff from the upland landscape and contribute to the groundwater recharge process.

Buffers are most valuable and effective when comprised of a combination of trees, shrubs, and herbaceous plants. Although width generally increases the capacity of riparian buffers to improve water quality and provide greater habitat value, even buffers less than 85 feet wide have been shown to improve water quality and habitat (Budd et al., 1987). An estimated minimum width of 30 feet is required for creating beneficial forest structure and riparian habitat. In general, agency requirements provide for a minimum 50 foot buffer on each side of the stream beginning from the top of the stream channel banks.

In stream and wetland restoration, where buffer width is often limited, the following design principals apply:

- Design for sheet flow into and across the riparian buffer area.
- If possible, the width of the riparian buffer area should be relative to the watershed area and the slope of the terrain (i.e. the velocity of the flow through the buffer).
- Forest structure should include understory and canopy species. Canopy species are particularly important adjacent to waterways to moderate stream temperatures and to create habitat.
- Use native plants that are adapted to the site conditions (e.g., climate, soils, and hydrology). In suburban and urban settings riparian forested buffers do not need to resemble natural ecosystems to improve water quality and habitat.

2.9 Risk Recognition

It is important to recognize the risks inherent in the assessment, design, and construction of environmental restoration projects. Such endeavors involve the interpretation of existing conditions to deduce appropriate design criteria, the application of those criteria to design, and, most importantly, the execution of the construction phase. There are many factors that ultimately determine the success of these projects and many of the factors are beyond the influence of an engineer. To compile all of the factors is beyond the scope of this report. Further, it is impossible to consider and to design for all of them. However, it is important to acknowledge that factors such as daily temperatures, the amount and frequency of rainfall during and following construction, subsurface conditions, and changes in watershed characteristics, are beyond the control of the design engineer.

Many restoration sites will require some post-construction maintenance, primarily because newly planted vegetation plays a large role in channel and floodplain stability. Stream restoration projects are most vulnerable to adjustment and erosion immediately after construction, before vegetation has had a chance to establish fully. Risk of instability diminishes with each growing season. Streams and floodplains usually become self maintaining after the second year of growth. However, unusually heavy floods often cause erosion, deposition and/or loss of vegetation in even the most stable channels and forested floodplains.

3 Watershed Assessment Results

3.1 Watershed Delineation

The City Pond project site is located near the town of Wadesboro, in Anson County, North Carolina (see Figure 1.2). The site lies in the Yadkin River Basin within NC Division of Water Quality sub-basin 03-07-17 and hydrologic unit 03040201020020. The North Carolina Ecosystem Enhancement Program (NCEEP) lists this hydrologic unit as a targeted local watershed.

The main channel has a drainage area of 180 acres as it enters the project site. Five tributary streams discharge into the main channel as it flows across the site. At the downstream end of the project, the drainage area increases to 936 acres. The main channel then flows into City Pond, the municipal water source for Wadesboro, approximately 3,200 feet downstream from the project site. Figures 1.2, 1.3, and 1.4 show the project, its hydrography and watershed, and its proximity to City Pond.

3.2 Site Hydrology/Hydraulics

3.2.1 Surface Water Classification

The North Carolina Division of Water Quality (NCDWQ) designates surface water classifications for water bodies such as streams, rivers, and lakes, which define the best uses to be protected within these waters (e.g., swimming, fishing, and drinking water supply). These classifications carry with them an associated set of water quality standards to protect those uses. All surface waters in North Carolina waters must at least meet the standards for Class C (fishable/swimmable) waters. The other primary classifications provide additional levels of protection for primary water contact recreation (Class B) and drinking water supplies (WS). Class C waters are protected for secondary recreation, fishing, wildlife, fish and aquatic life propagation and survival, agriculture and other uses suitable for Class C. Classifications and their associated protection rules may also be designed to protect the free flowing nature of a stream or other special characteristics. Supplemental classifications are sometimes added by NCDWQ to the primary classifications to provide additional protection to waters with special uses or values.

The project reaches are unnamed tributaries to City Pond, which is the water supply reservoir for the Town of Wadesboro. City Pond was sampled by NCDWQ on August 9, 1989, and August 30, 1995, and determined to be eutrophic but fully supporting its designated uses. Both City Pond and its major inflow, North Fork Jones Creek, are identified by NCDWQ index number 13-42-1-(0.3). City Pond and North Fork Jones Creek have been assigned surface water classifications of WS-II HQW Critical Area (CA). The project reaches also have the WS-II classification. WS-II waters are used as sources of potable water where the more restrictive WS-I classification is not feasible. WS-II waters are generally in predominantly undeveloped watersheds and only general permits for discharges are allowed. All WS-II waters are also protected for Class C uses and are high quality waters (HQW) by definition. This supplemental classification is intended to protect waters with quality higher than state water quality standards. There are associated wastewater treatment and development controls for HQW enforced by NCDWQ. The CA classification indicates that the water body is a drinking water supply critical area. The critical area extends approximately one mile from a water supply reservoir and has associated development restrictions to maintain a predominantly undeveloped land use density pattern. The project reaches are outside the critical area for the reservoir and their drainages are therefore subject to the less restrictive development rules associated with the non-critical (balance) area of a WS-II watershed.

3.2.2 Site Hydrologic and Hydraulic Characteristics

The Federal Emergency Management Agency Flood Insurance Rate Map (FIRM) designates the City Pond site as Zone X, areas outside the 500-year floodplain. There are no digital FIRM data available for Anson County.

3.3 Geology

The City Pond site is located within the Wadesboro Triassic Basin in the rural Piedmont physiographic region. Geologic formations in the area are part of the Chatham Group, consisting of conglomerate, fanglomerate, sandstone, and mudstone. Local relief within the project site is approximately 80 feet, with the highest point located at the northeast corner of the site (400 ft above mean sea level (MSL)) and the lowest point located at the southeast corner of the site (320 ft above MSL). Topographic information is shown on Figure 1.2.

The project site contains upland ridges and alluvial valleys that were formed by the streams that flow through the site. The low lying valleys of stream reaches R1, R2, R3, S3, S4, and S5 were formed by the deposition of alluvial sediments. Reaches S1, S2, and S6 are smaller tributaries that flow down steep gradient slopes of valleys formed from colluvial processes.

3.4 Soils

Soils at the site were determined using NRCS Soil Survey data for Anson County, along with preliminary on-site evaluations to determine any hydric soil areas (USDA 2000). A map depicting the boundaries of each soil type is presented in Figure 3.1. There are four general soil types found at the site. These soils will support stream restoration activities. A discussion of each soil type and its locations is presented in Table 3.1.

In some areas along the main stream channel that flows through the site, a distinct gravel/cobble layer can be found at a depth of approximately 1.5 to 2.0 feet below the average ground elevation. This layer is apparently the historic stream bed elevation of the main channel.

Soils within the lower floodplain areas are mapped primarily as the Chewacla series (Figure 3.1) and contain several areas of hydric inclusions. Preliminary soil borings indicate that the hydric inclusions match most closely with the soil description of the Chastain series. The Chastain series can comprise up to 15% or more of the areas mapped as Chewacla. According to the Anson County Soil Survey, Chastain soils occur in concave areas such as the topographic depressions identified on the project site. On-site observations indicate that the general composition of these depressional areas closely matches the description for the Chastain series presented in the soil survey.

Soils on the higher elevation areas of the site include the Creedmoor, Mayodan, and Pacolet series. Descriptions of these series, as given in the county soil survey, are provided in Table 3.1 below.

TABLE 3.1
Project Soil Types and Descriptions
From Anson County Soil Survey, USDA-NRCS, 2000

Soil Name	Location	Description
Chewacla – Chewacla Loam	Main channel – R1, R2, R3 Tributary Channels - S3, S4, S5; and parts of S1, S2, and S6	The Chewacla series consists of very deep, somewhat poorly drained, moderate permeability soils on floodplains in the Piedmont, upper Coastal Plain, and Sand Hills. Slopes range from 0 to 2 percent and are frequently flooded. Chewacla soils are typically brown with a surface layer about 6 inches thick. The subsoil extends to a depth of 60 inches. The Chewacla soil series is classified as an "A" list hydric soil by the NRCS (1995).
Creedmoor – Creedmoor Fine Sandy Loam	Most upstream portion of the main channel - R1	The Creedmoor series consists of very deep, somewhat poorly drained, very slow permeability soils on broad ridges in the Triassic Basin. Slopes range from 2 to 8 percent. Creedmoor soils are typically yellowish brown with a surface layer about 8 inches thick. The subsoil yellowish brown clay and extends to a depth of 62 inches
Mayodan – Mayodan Gravelly Sandy Loam	Parts of S1, S2 Half of S6	Mayodan series consists of very deep, well drained, moderate permeability soils on broad ridges, hill slopes, and narrow ridges in the Triassic Basin. Slopes range from 2 to 8 percent and they have a surface layer of brown gravelly sandy loam that extends 3 inches. The subsoil extends approximately 60 inches and is red, yellow, and light gray clay. Mayodan fine sandy loam has a yellowish brown surface layer of about 6 inches and the subsoil extends a depth of 72 inches.
Pacolet – Pacolet Clay Loam	Parts of S1, S2	The Pacolet series consists of well drained soil on side slopes next to drainageways. They are moderately steep to steep with a surface layer of very dark grayish brown sandy loam and subsoil of red clay and clay loam. Pacolet soils are not suitable for most crops with erosion and slope being the biggest limitations. The series has moderate potential for woodland and low potential for urban uses. Native species include loblolly pine, shortleaf pine, Virginia pine, red oak, white oak, and yellow-poplar. Understory species include flowering dogwood and eastern redbud. The Pacolet clay loam series consists of very deep, well drained, moderate permeability soils on broad ridges in the Piedmont. They have a surface layer of very reddish brown clay loam with a subsoil of red clay and clay loam.

3.5 Wetlands

No areas of existing jurisdictional wetlands are found on the City Pond project site. However, it appears as though the site may have supported wetlands prior to ditching and deepening of the stream channels, which lowered the water table and allows the site to drain more quickly and completely. Some areas of the project site are mapped as the Chewacla soils series (Figure 3.1). These areas were investigated and hydric inclusions were found within this series. Hydric inclusions Chastain soils have also been preliminarily identified using a combination of field verification and aerial photography. The Chastain series can make up to 15% or more of the areas mapped as Chewacla and are generally smaller than the two acre minimum mapping requirement used by the NRCS. According to the Anson County Soil Survey, Chastain soils occur in concave areas similar to the topographic depressions identified on the project site. On-site observations indicate that the general composition of these depressional areas closely matches the description for the Chastain series presented in the soil survey.

3.6 Land Use

While there are residential homes along the roadways in the area, land use in the watershed is predominately agriculture and forested. The result is an impervious land cover of less than 1% of the watershed. The recent land use of the project site has been primarily pasture for cattle production, and there is a lack of riparian vegetation along most of the channel lengths. Accounts from the landowner indicate that the land was used for crop production prior to the 1950s. Population growth in the vicinity of Wadesboro is slow to moderate and development pressure for the area is not significant. Land use in the project area is likely to remain stable for the foreseeable future.

3.7 Vegetation

A large portion of the site is pasture that is clearly visible in Figure 1.3. The main channel (R1, R2 and R3) and the majority of reaches S2, S3 and S4 traverse the pasture area. Riparian vegetation is mostly pasture and stream bank vegetation consisting mainly of grasses, blackberry (*Rubrus* spp.), rush (*Juncus* spp.), sedge (*Carex* spp.), privet (*Ligustrum sinense*), and small saplings of sweetgum *(Liquidambar nigra).*

Figure 1.3 also shows that reaches S5 and S6, and the left banks of S1 and R1, are generally wooded. Trees observed on site consist of sweetgum , red maple (*Acer rubrum*), tulip poplar (*Liriodendron tulipifera*), loblolly pine (*Pinus taeda*), persimmon (*Diospyros virginiana*), willow oak (*Quercus phellos*), water oak (*Quercus nigra*), blackjack oak (*Quercus marilandica*), American holly (*Ilex opaca*), black walnut (*Juglans nigra*), hickory (*Carya* spp.), American elm (*Ulmus americana*), and eastern cedar (*Juniperus virginiana*). Shrubs include flowering dogwood (Cornus florida), autumn olive (Elaeagnus umbellate), Chinese privet (*Ligustrum sinense*), hearts-a-burstin (*Euonymus americana*), tag alder (*Alnus serrulata*) and ironwood (*Carpinus carolinia*). The herb and vines layers consist of greenbriar (*Smilax* spp.), grape (*Vitis* spp.), blackberry (*Rubrus* spp.), needlerush (*Juncus* spp.), goldenrod (*Solidage* spp.), hempweed (*Mikania scandens*), poison ivy (*Toxicodendron radicans*), smartweed (*Polygonum* spp.), tearthumb (*Polygonum sagittatum*), dogfennel (*Eupatorium* spp.), Japanese honeysuckle (*Lonicera japonica*), and Christmas fern (*Polystichum acrostichoides*). Some of the wooded potions of the site have been clear-cut in the recent past. The re-established woody vegetation is young and consists primarily of the more invasive species.

3.8 Endangered/Threatened Species

Throughout the world, some populations of plants and animals are declining either as a result of natural forces or their difficulty competing with humans for resources. Plants and animals with a federal classification of Endangered (E), Threatened (T), Proposed Endangered (PE), and Proposed Threatened (PT) are protected under the provisions of Section 7 and Section 9 of the Endangered Species Act of 1973. Federally classified species listed for Anson County, and any likely impacts to these species as a result of the proposed project construction, are discussed in the following sections.

Species that the North Carolina Natural Heritage Program (NHP) lists under federal protection for Anson County as of January 14, 2004, are listed in Table 3.2. Other Federal Species of Concern are also included. A brief description of the characteristics and habitat requirements of these species follow the table, along with a conclusion regarding potential project impact.

Wetland and Natural Resource Consultants, Inc. sent a letter requesting that the NHP review the potential for endangered and threatened species in the vicinity of the City Pond restoration site. A response was received on October 21, 2003, indicating that no record of rare species, significant natural communities, or priority natural areas are within 1 mile of the site (Appendix A).

TABLE 3.2
Species Under Federal Protection and Species of Concern in Anson County
City Pond Site Restoration Plan

Family	Scientific Name	Common Name	Federal Status	Date Listed	State Status	Habitat Present / Biological Conclusion
			Vertebtrates			
Acipenseridae	*Acipenser brevirostrum*	Shortnose sturgeon	E	3-11-1967	E	No /No Effect
Accipitridae	*Haliaeetus leucocephalus*	Bald eagle	T (PD)	3-11-1967 (PD: 7-6-1999)	T	No /No Effect
Picidae	*Picoides borealis*	Red-cockaded woodpecker	E	10-13-1970	E	No /No Effect
	Moxostoma robustum	Robust redhorse	FSC		SR	No /No Effect
	Moxostoma sp. 2	Carolina redhorse	FSC		SC (PD)	No /No Effect
			Invertebrates			
			Vascular Plants			
Asteraceae	*Helianthus schweinitzii*	Schweinitz's sunflower	E	5-7-1991	E	Yes /Unresolved
	Lindera subcoriacea	Bog spicebush	FSC			No /No Effect

Notes:

E	An Endangered species is one whose continued existence as a viable component of the state's flora or fauna is determined to be in jeopardy.
T	Threatened
PE	Proposed Endangered
PT	Proposed Threatened
PD	These species have been proposed for delisting from the current status.
FSC	Federal Species of Concern
SC	A Special Concern species is one that requires monitoring but may be taken or collected and sold under regulations adopted under the provisions of Article 25 of Chapter 113 of the General Statutes (animals) and the Plant Protection and Conservation Act (plants).
SR	A Significantly Rare species is not listed as "E," "T," or "SC," but which exists in the state in small numbers and has been determined to need monitoring.

3.8.1 Federally Protected Species

3.8.1.1. Vertebrates

Shortnose Sturgeon

The shortnose sturgeon is usually less than three feet long. It is dark above and light below with a wide mouth pointed downward beneath a short snout. Five rows of sharp, pointed plates along the sides of its body provide protection from predators.

The sturgeon inhabits the lower sections of larger rivers and coastal waters along the Atlantic coast from southern Canada to northeastern Florida. It may spend most of the year in brackish or salt water and move into fresh water only to spawn. The fish feeds on invertebrates (shrimp, worms, etc.) and stems and leaves of macrophytes.

The streams on site are small systems and do not provide the habitat needed for the Shortnose sturgeon. Therefore, the proposed project is not anticipated to have an effect on this species.

Bald Eagle

Bald eagles are large raptors, 32 to 43 inches long, with a white head, white tail, yellow bill, yellow eyes, and yellow feet. The lower section of the leg has no feathers. Wingspread is about seven feet. The characteristic plumage of adults is dark brown to black with young birds completely dark brown. Juveniles have a dark bill, pale markings on the belly, tail, and under the wings and do not develop the white head and tail until five to six years old.

Bald eagles in the Southeast frequently build their nests in the transition zone between forest and marsh or open water. Nests are cone-shaped, six to eight feet from top to bottom, and six feet or more in diameter. They are typically constructed of sticks lined with a combination of leaves, grasses, and Spanish moss. Nests are built in dominant live pines or cypress trees that provide a good view and clear flight path, usually less than 0.5 miles from open water. Winter roosts are usually in dominant trees, similar to nesting trees, but may be somewhat farther from water. In North Carolina, nest building takes place in December and January, with egg laying (clutch of one to three eggs) in February and hatching in March. Bald eagles are opportunistic feeders consuming a variety of living prey and carrion. Up to 80% of their diet is fish, which is self caught, scavenged, or robbed from osprey. They may also take various small mammals and birds, especially those weakened by injury or disease.

Potential habitat for the bald eagle does not exist in the proposed project area. The site lies primarily within open fields and water onsite exists only in streams too small to provide foraging habitat for the eagle. In addition, a search of the NHP database on January 14, 2004, found no known occurrence within the vicinity of the proposed project. Therefore, the proposed project is not anticipated to have an effect on this species.

Red-Cockaded Woodpecker

The red-cockaded woodpecker once occurred from New Jersey to southern Florida and west to eastern Texas. It occurred inland in Kentucky, Tennessee, Arkansas, Oklahoma, and Missouri. The red-cockaded woodpecker is now found only in coastal states of its historic range and inland in southeastern Oklahoma and southern Arkansas. In North Carolina moderate populations occur in the Sand Hills and southern Coastal Plain. The few populations found in the Piedmont and northern Coastal Plain are believed to be relics of former populations.

The red-cockaded woodpecker is approximately eight inches long with a wingspan of 14 inches. Plumage includes black and white horizontal stripes on its back, with white cheeks and under parts. Its flanks are streaked black. The cap and stripe on the throat and side of neck are black, with males having a small red spot on each side of the cap. Eggs are laid from April through June. Maximum clutch size is seven eggs with an average of three to five.

Red-cockaded woodpeckers are found in open pine stands that are between 80 and 120 years old. Longleaf pine stands are most commonly utilized. Dense stands are avoided. A forested stand must contain at least 50% pine, lack a thick understory, and be contiguous with other stands to be appropriate habitat for the red-cockaded woodpecker. These birds forage in pine and pine hardwood stands, with preference given to pine trees that are 10 inches or larger in diameter. The foraging range of the red cockaded woodpecker is up to 500 acres. The acreage must be contiguous with suitable nesting sites. While other woodpeckers bore out cavities in dead trees where the wood is rotten and soft, the red-cockaded woodpecker is the only one that excavates cavities exclusively in living pine trees. The older pines favored by the red-cockaded woodpecker often suffer from a fungus called red heart disease which attacks the center of the trunk, causing the inner wood to become soft. Cavities generally take one to three years to excavate. The red-cockaded woodpecker feeds mainly on beetles, ants, roaches, caterpillars, wood-boring insects and spiders, and occasionally fruits and berries.

Potential habitat for the red-cockaded woodpecker does not exist in the proposed project area. The site lies primarily within open fields with no open pine stands. In addition, a search of the NHP database on January 14, 2004, found no known occurrence within the vicinity of the proposed project. Therefore, the proposed project is not anticipated to have an effect on this species.

3.8.1.2. Invertebrates

Carolina Heelsplitter

The Carolina heelsplitter was historically known to exist in South Carolina in the Savannah River system and in North Carolina in streams and ponds in the Catawba River System around the Charlotte and Mecklenburg County area, as well as one small stream in Cabarrus County and one pond in Union County within the Pee Dee River System. Currently, only six populations are known to exist. In North Carolina, one remnant population exists in the Catawba River System in Union County and one in the Pee Dee River System in Union County.

The Carolina Heelsplitter has an ovate, trapezoid shaped shell measuring 4.6 inches in length, 1.6 inches in width, and 2.7 inches in height. The outer shell color varies from greenish brown to dark brown. The inside of the shell (nacre) is usually pearly white to bluish white sometimes grading to orange. Older specimens maybe mottled pale orange. Historically, it was reported in both small and large streams and rivers as well as ponds (probably mill ponds on small streams). Currently, this species is only known to occur in small streams usually with mud, muddy sand, or muddy gravel substrate along stable, well-shaded stream banks.

Most of the tributaries on the City Pond site are too small to support populations of the Carolina Heelsplitter. The main channel, while large enough to support populations, has no shading, is incised, and receives substantial sedimentation from upstream. Therefore, suitable habitat does not exist for the Carolina Heelsplitter within the project area. In addition, a search of the NHP database on January 14, 2004, found no known occurrence within the vicinity of the proposed project. Therefore, the proposed project is not anticipated to have an effect on this species.

3.8.1.3. Vascular Plants

Schweintz's Sunflower

Schweintz's sunflower, usually three to six feet tall, is a perennial herb with one to several fuzzy purple stems growing from a cluster of carrot-like tuberous roots. Leaves are two to seven inches long, 0.4 to 0.8 inches wide, lance shaped, and usually opposite, with upper leaves alternate. Flowers are yellow and generally smaller then other sunflowers in North America. Flowering and fruiting occurs from mid-September to frost.

The Schweintz's sunflower grows in clearings and along edges of upland woods, thickets, and pastures. It is also found along roadsides, powerline clearings, and woodland openings. It prefers full sunlight or partial shade and is intolerant of full shade.

While the NHP database (checked on January 14, 2004) does not indicate any occurrences of Schweinitz's sunflower within the project vicinity, suitable habitat for the Schweinitz's sunflower does exist within the project area. Therefore, the biological conclusion should remain unresolved until surveys are performed to determine the presence of Schweinitz's sunflower. Prior to project construction, plant by plant surveys should be conducted from mid-September to mid-October, during peak blooming season.

3.8.2 Federal Species of Concern and State Status

Federal Species of Concern (FSC) are not legally protected under the Endangered Species Act and are not subject to any of its provisions, including Section 7, until they are formally proposed or listed as Threatened or Endangered. Table 3.2 includes FSC species listed for Anson County and their state classifications. Organisms that are listed as Endangered (E), Threatened (T), or Special Concern (SC) on the NHP list of Rare Plant and Animal Species are afforded state protection under the State Endangered Species Act and the North Carolina Plant Protection and Conservation Act of 1979. However, the level of protection given to state-listed species does not apply to NCDOT activities.

No FSC species have been recorded within 1.0 mile of the project area based upon the NHP database checked on January 14, 2004.

3.9 Cultural Resources

Wetland and Natural Resource Consultants, Inc. sent a letter on October 7, 2003, requesting that the North Carolina State Historic Preservation Office (SHPO) review the potential for cultural resources in the vicinity of the City Pond restoration site. A response was received on November 24, 2003, indicating that the SHPO had reviewed the proposed project and was aware of no historic resources which would be affected by the project (Appendix A).

3.10 Potentially Hazardous Environmental Sites

Buck Engineering obtained an EDR Transaction Screen Map Report that identifies and maps real or potential hazardous environmental sites within the distance required by the American Society of Testing and Materials (ASTM) Transaction Screen Process (E 1528). A copy of the report with an overview map is included in Appendix B. The overall environmental risk for this site was determined to be low. Environmental sites including Superfund (National Priorities List, NPL); hazardous waste treatment, storage, or disposal facilities; the Comprehensive Environmental Response, Compensation, and Liability Act Information System (CERCLIS); suspect state hazardous waste, solid waste or landfill facilities; or leaking underground storage tanks were not identified by the report in the proposed project area. During field data collection, there was no evidence of these sites in the proposed project vicinity and conversations with landowners did not reveal any further knowledge of hazardous environmental sites in the area.

3.11 Potential Constraints and Risks

Buck Engineering assessed the City Pond project site in regards to potential fatal flaws and site constraints. No constraints or fatal flaws have been identified during project design development.

3.11.1 Property Ownership and Boundary

EBX has entered into an Agreement of Sale for acquisition of an easement or land purchase with the four individual landowners for the City Pond project site. The agreements allow EBX to proceed with the restoration and restrict the land use through a conservation easement. EBX is prepared to close on the land acquisition and anticipates doing so by May 1, 2004.

3.11.2 Hydrologic Trespass

The topography of the site supports the design without creating the potential for hydrologic trespass. Site topography will limit overbank flooding to the designed stream corridor. No backwater or ponded areas will be created under the design scenario.

3.11.3 Site Access

The project site can be accessed at two locations as shown on the attached design plan sheets. One access is at the most upstream location of Reach R1 at the northern limit of the project. This location allows access to the site directly off a public road. Because the road is an unimproved, dead-end road, traffic is not a concern. This location allows easy access to Reaches R1, R2, S1, S2, and S3.

The second location is located at the western edge of the project site at the end of a trailer park. This access will need to be coordinated with the owner of trailer park because the road is not public. This access will also minimize concerns in regards to traffic and public safety. This location will allow easy access to Reaches S4, S5, S6, and R3.

3.11.4 Utilities

No known utilities are located on site.

3.11.5 Threatened and Endangered Species

Rare, threatened and endanger species occurrences were examined as part of the existing conditions survey and was discussed earlier. No rare, threatened or endanger species will be affected by this project, with the possible exception of Schweinitz's sunflower, which is unresolved at this time.

3.11.6 Cultural Resources

No known cultural or archaeological sites are recorded within the property boundary. It is anticipated that this project will have no impact on such sites.

3.11.7 Farm Operations

The City Pond project site is used for agricultural purposes. Therefore, the project must not interfere with the operational needs of the farm. The final project design will need to incorporate stream crossings, fencing, field access and other needs identified by the site owner.

3.11.8 Soils

Soils have been investigated and no constraints or fatal flaws were identified.

4 Stream Corridor Assessment Results

4.1 Reach Identification

A total of nine reaches, comprised of one main channel (R1, R2, and R3) and six tributary channels (S1 through S6), are located on the site (Figure 1.3). Reach designations are based on the characteristics of each reach, such as breaks in stream type, slope, bed material, and restoration potential. Five tributary channels enter into the main channel and one (S6) discharges into another tributary (S5). The main channel begins off-site and enters the site from the northeast. It flows across the site from the north/northeast, turns in the center of the site and exits the site to the south. After exiting the project site, the main channel flows approximately 3,200 feet before discharging into City Pond (Figure 1.3). Streams across the low valley portions of the site were channelized and straightened in the past.

Five of the reaches (R1, R2, R3, S4, and S5) are unnamed "blue-line" streams on the US Geological Survey (USGS) topographic map of the area (Figure 1.2). There are four additional smaller tributaries (S1, S2, S3, and S6) that do not appear on the USGS topographic map, but have significant flow and are considered perennial based on field assessments. The total current length of all of the streams on the project property is approximately 8,836 feet. The cumulative drainage area at the point the main channel exits the site is 936 acres (1.5 square miles). The main channel (R1 – R3) is approximately 3,274 feet in length. The total length of all of the tributaries within the project limits is approximately 5,562 feet.

4.2 Geomorphic Characterization Results

4.2.1 Main Channel Geomorphology

The main channel and its three reaches are depicted in Figures 1.1 and 1.3. Watershed size was calculated at the point where the main channel enters the site and at the terminus of each reach (see Figure 1.3 and Table 4.1).

TABLE 4.1
Reach Descriptions – Main Channel
City Pond Site Restoration Plan

Reach	Reach Length	Size (Acres)
R1a [1]	4,400	181
R1	940	228
R2	1,653	372
R3 [2]	681	936

NOTES:

1 R1a is at the point the main channel enters the project site

2 R3 accounts for the entire project

4.2.1.1. Main Channel R1

R1 exhibits a stream evolution scenario that is very common in the Southeast. The stream appears to have been straightened at some point in the past. This straightening led to incision, which eventually led to lateral instability and some widening as described by the Simon channel evolution model (1989). The stream has incised down to a layer of dense clay and mudstone, which is providing grade control for much of the reach. Knickpoints and associated plunge pool features have developed, which allow some dissipation of stream energy at high flows. Stream banks have eroded to a relatively stable bank angle and are well vegetated in most areas with predominantly herbaceous vegetation. The reach has achieved some degree of stability, although additional lateral erosion and instability is probable over the long term. The western bank of R1 is open field dominated by fescue and typical pasture species. The eastern bank is forested. This forested area has been previously cleared and is now dominated by successional species.

4.2.1.2. Main Channel R2

R2 also appears to have been straightened at some point in the past. As with R1, this has led to incision, which in turn caused lateral instability and widening. The stream remains at this stage with active erosion, undercut banks, and sections of the bank continuing to collapse into the channel. The substrate is a mixture of fine clay particles, sand, gravel, and small cobble. Depositional features are common throughout this reach, indicating the stream is beginning to develop a new floodplain at an elevation lower than the original floodplain. This is represented in the Simon channel evolution model (1989) as Stage 5. The reach flows through open pasture, which contains mostly herbaceous vegetation dominated by fescue. A few invasive shrubs such as privet have become established along the top of the stream banks in some areas.

4.2.1.3. Main Channel R3

R3 also remains at a stage with active erosion similar to that in R2. The substrate, however, is larger in average size, with gravel and cobble more common. The stream channel is overly wide and deeply incised. The reach flows through open pasture and contains mostly herbaceous vegetation dominated by fescue. A few invasive shrubs such as privet, along with greenbrier and raspberry, have become established along the top of the stream banks.

Table 4.2 summarizes the geomorphology of R1, R2, and R3. More detailed morphological information can be found in Appendix C.1.

TABLE 4.2
Geomorphologic Data for Main Channel Reaches R1 through R3 - Stream Channel Classification Level II
City Pond Site Restoration Plan

Parameter	Value			Units
		Reach [1]		
	R1	R2	R3	
Bankfull Width (Wbkf)	11.1 – 11.8	11.9 – 15.7	15.4 – 18.9	Feet
Bankfull Mean Depth (d bkf)	1.2 – 1.3	0.9 – 1.3	1.0 – 1.5	Feet
Cross Sectional Area (Abkf)	14.1 – 14.2	12.5 – 20.6	18.4 – 22.4	Ft^2
Width/Depth Ratio (w/d ratio)	8.7 – 9.8	11.3 – 14.8	10.6 – 19.5	
Bankfull Max. Depth (dmbkf)	1.9 – 2.3	1.7 – 2.6	1.6 – 2.1	Feet
Floodprone Area Width (Wfpa)	15.6 – 15.9	17.0 – 25.5	27.0 – 34.1	Feet
Entrenchment Ratio (ER)	1.4 – 1.4	1.4 – 1.8	1.7 – 1.8	
Channel Materials (Particle Size Index – d50)	Md. Gravel [2]	Md. Gravel [2]	Sm. Cobble	
D15	0.11	0.11	0.25	mm
D34	0.33	0.33	1.58	mm
D50	0.61	0.61	2.76	mm
D84	16.0	16.0	17.39	mm
D95	Bedrock	Bedrock	39.67	mm
Water Surface Slope (s)	0.0085	0.0073	0.0044	Feet per foot
Channel Sinuosity (k)	1.0	1.05	1.02	
Rosgen Stream Type	**G4(6)c / F4(6)** [3]	**G4(6)c / F4(6)** [3]	**G4c/F4**	

NOTES:

1 Where multiple cross-sections were surveyed in a single reach and data varied, the data are presented as a range of values.

2 One representative bed material sample was taken from Reaches 1 and 2.

3 Although the beds of Reaches 1 and 2 are dominated by gravel substrate which is transported through the reaches, the beds have downcut into a dense clay layer along much of their length. Therefore, the 4(6) designation is used to classify the dominant bed material.

4.2.2 Tributary Geomorphology

Six distinct tributaries are located on the project site, five of which discharge directly into the main channel and are designated S1 through S5. One additional reach is a tributary to S5 and is designated S6. The six tributaries are depicted in Figures 1.1 and 1.3. Watershed sizes are detailed in Figure 1.3 and Table 4.3.

TABLE 4.3
Reach Descriptions – Tributary Channels
City Pond Site Restoration Plan

Reach	Reach Length	Size (Acres)
S1	730	29
S2	876	36
S3	591	74
S4	1188	312
S5	1939	242
S6	238	100

The tributary channels can be divided into two general categories – those that traverse comparatively steep, wooded slopes (colluvial valleys) and those which cross relatively gentle gradient pasture land (alluvial valleys). Tributaries S1 and S2 flow into the main channel from the more confined side of the stream valley and traverse a steeper gradient than the other tributaries. Much of the area adjacent to S1 and S2 is wooded.

4.2.2.1. Tributary S1

S1 enters the site from the east, flows west, and discharges into R1. S1 has been ditched and straightened and is in a stage of active erosion with undercut banks and sections of the bank continuing to collapse into the channel. There are several locations along S1 with active head-cuts. S1 is fed by spring flow and runoff from a large clear-cut area from the adjacent property parcel. The substrate is fine material comprised mostly of fine sands and silts. S1 runs through a forested area. The area was timbered approximately five years ago and vegetation is comprised of trees and shrubs typical of successional species.

4.2.2.2. Tributary S2

S2 also enters the site from the east, flows west, and discharges into R2. Like S1, S2 is fed primarily from groundwater seeps that discharge into the headwaters of the stream and runoff from adjacent slopes. S2 has been ditched and straightened and is in a stage of active erosion with undercut banks and sections of the bank continuing to collapse into the channel. There are several locations along S2 with active head-cuts. The substrate is fine material comprised mostly of fine sands and silts. S2 runs through a forested area for the first half of its length before opening up into pasture area. The forested area was timbered approximately five years ago and vegetation is comprised of trees and shrubs typical of successional species. The pasture area is mostly fescue grasses.

4.2.2.3. Tributary S3

S3 enters the site from the west, flows east, and discharges into R2. S3 has been ditched and straightened. It is apparent that the stream used to enter the site farther north and flowed across the pasture to enter the main channel. S3 was diverted to travel along the property boundary, most likely to increase pasture area. The section that has been ditched is in a stage of active erosion with undercut banks and sections of the bank continuing to collapse into the channel. There are several locations along S3 with active head-cuts. The substrate is fine material comprised mostly of fine sands and silts. S3 runs along the property boundary, which is the edge of a forested area, before turning to enter the pasture area and discharging into R2.

4.2.2.4. Tributary S4

S4 also enters the site from the west, flows east, and discharges into R2. S4 has been ditched and straightened, most likely to increase pasture area. This straightening led to incision, which eventually led to lateral instability and widening. The stream is seeking stability by increasing pattern and establishing bankfull benches within the overly large channel. However, areas of active bank erosion are present due to the highly incised condition of the channel. The riparian area of S4 is open field dominated by fescue and typical pasture species. The substrate is larger that that found in the other tributary channels with gravel and cobbles more common.

4.2.2.5. Tributary S5

S5 enters the site from the west and flows east, discharging into R3. On the downstream end of the reach, S5 has been ditched and straightened to travel along the pasture edge, most likely to increase pasture area. This straightening led to incision, which in turn led to lateral instability and some widening. This disturbance initiated a head-cut that migrated upstream through the wooded portions of Reach S5, resulting in channel incision along the entire project length. The stream remains at a stage of active erosion with undercut banks and sections of the bank continuing to collapse into the channel. The substrate is a mixture of fine clay particles, sand, gravel, and small cobble. The upstream portion of S5 runs through a forested area before flowing out of the woods and flowing adjacent to the pasture area. The forested area is comprised of trees and shrubs typical of successional species. The pasture area is mostly fescue grasses.

4.2.2.6. Tributary S6

S6 enters the site from the southwest and flows only a short distance before discharging into S5. S6 has incised as a result of the head-cut that migrated upstream through S5. The stream remains at a stage with active erosion, undercut banks, and sections of the bank continuing to collapse into the channel. The substrate is a mixture of fine clay particles, sand, gravel, and small cobble. S6 begins as groundwater seepage and runoff from a diverse pattern of ruts in the forested area. The forested area is comprised of young trees and shrubs typical of successional species.

Table 4.4 presents the summary geomorphologic data for reaches S1 through S6. Detailed information for the reaches is presented in Appendix C.2.

TABLE 4.4
Geomorphologic Data for Tributary Channel Reaches S1 through S6 - Stream Channel Classification Level II
City Pond Site Restoration Plan

Parameter	Value						Units
	Reach[1]						
	S1	S2	S3	S4	S5	S6[2]	
Bankfull Width (Wbkf)	4.4 – 5.6	3.5 – 4.8	11.7	10.8	7.1 – 9.9	6.0	Feet
Bankfull Mean Depth (d bkf)	0.7	0.6 – 0.9	0.5	1.3	1.3 – 2.4	0.9	Feet
Cross Sectional Area (Abkf)	3.1 – 4.0	2.8 – 3.3	5.5	13.8 – 14.5	11.6 – 17.1	5.5	Ft^2
Width/Depth Ratio (w/d ratio)	6.2 – 7.7	3.7 – 8.2	25.0	8.0 – 8.5	3.0 – 7.4	6.5	
Bankfull Max. Depth (dmbkf)	1.1 – 1.2	1.0 – 1.6	1.6	2.3 – 2.6	2.5 – 3.1	1.3	Feet
Floodprone Area Width (Wfpa)	8.4 – 9.6	9.2 – 83.4	17.6	15.0 – 18.4	16.9 – 135.5	9.8	Feet
Entrenchment Ratio (ER)	1.7 – 1.9	1.9 – 24.0	1.5	1.4	1.7 – 19.0	1.6	
Channel Materials (d50)	Sand/Silt[2]	Sand/Silt[2]	Sand/Silt[2]	Sand/Silt[2]	Coarse Gravel	Sand/ Silt[2]	
D15	--	--	--	--	N/A	--	mm
D34	--	--	--	--	0.29	--	mm
D50	--	--	--	--	1.2	--	mm
D84	--	--	--	--	31.5	--	mm
D95	--	--	--	--	43.81	--	mm
Water Surface Slope (s)	0.0356	0.0297	0.0102	0.0067	0.0088	0.0168	Feet per foot
Channel Sinuosity (k)	1.07	1.0	1.04	1.02	1.04	1.08	
Rosgen Stream Type	**G5**	**G5/E5b**	**F5**	**G5c**	**G5c/E5**	**G5c**	

NOTES:

1 Where multiple cross-sections were surveyed in a single reach and data varied, the data are presented as a range of values.

2 No pebble counts were performed in Reaches S1, S2, S3, S4, and S6 because they are sand/silt-dominated.

4.3 Channel Stability Assessment Results

4.3.1 Main Channel Stability

The main channel within the project area is a perennial, channelized stream with a flow regime dominated by storm water runoff. Along the upstream portion of the stream (R1), the channel has incised to a layer of dense clay and mudstone that is providing grade control; however, there are still areas of active bank erosion. This reach is in stages 2 and 3 of the Simon channel evolution model (1989). Along the rest of the channel (R2 and R3), there are few debris blockages and the stream exhibits poor sediment transport capacity as evidenced by the formation mid channel and lateral bars forming in some areas. These sections are in stages 4 and 5 of the Simon channel evolution model and are, therefore, further along in their evolution than the upstream reach. Bank erosion and aggradation will continue until a new floodplain is developed at a lower elevation.

As part of the stability assessment, eight cross sections were surveyed on the main project reach. The cross sections are provided in Appendix C.1 and summarized in Table 4.5 below.

TABLE 4.5
Stability Indicators – Main Channel
City Pond Site Restoration Plan

Parameter	Reach [1]		
	R1	R2	R3
Stream Type	G4(6)c/F4(6)	G4(6)c/F4(6)	G4(6)c/F4(6)
Riparian Vegetation	Open field dominated by fescue and typical pasture species.	Open pasture of mostly herbaceous vegetation dominated by fescue and a few invasive shrubs such as privet.	Open pasture of mostly herbaceous vegetation dominated by fescue and with few invasive shrubs such as privet, greenbrier, and raspberry.
Channel Dimension			
Bankfull Area (ft^2)	14.1 – 14.2	12.5 – 20.6	18.4 – 22.4
Width/Depth Ratio	8.7 – 9.8	11.3 – 14.8	10.6 – 19.5
Channel Pattern			
Meander Width Ratio [2]	-- [2]	-- [2]	-- [2]
Sinuosity	1.01	1.05	1.02
Vertical Stability			
Bank Height Ratio	2.0 – 3.0	1.8 – 3.0	3.0 – 3.5
Entrenchment Ratio	1.4	1.4 – 1.8	1.7 – 1.8
Bank Erosion			
BEHI	High	High	High
Evolution Scenario	E-G-F-C-E	E-G-F-C-E	E-G-F-C-E

NOTES:

1 Where multiple cross-sections were surveyed in a single reach the data are presented as a range of values.

2 No pattern related parameters were computed for the main channel as very little pattern was observed in the field (i.e., the channel is straight).

The width/depth ratios range from low (w/d ratio < 12) to moderate-to-high (w/d ratio >18). These values indicate the channels have begun to widen. A bankfull w/d ratio of 10 is common for similar streams in alluvial channels of the North Carolina Piedmont. The project streams appear to exhibit stages 4 and 5 of the Simon channel evolution model, in which widening occurs to allow the creation of an accessible floodplain.

The ER values show that the stream is entrenched (ER < 1.4) to moderately entrenched (1.4 < ER < 2.2) based on the Rosgen (1996) classification system. Entrenched streams do not have frequent access to their floodplains, where excess energy can be dissipated, and are thus described as vertically contained. For this reason, entrenched streams tend toward instability, unless the presence of grade control prevents degradation of the stream bed.

The BHR values demonstrate that the stream is vertically unstable. The lowest observed ratio stream bank height divided by bankfull maximum depth is 1.8, a value with a bank erodibility adjective rating of "High."

4.3.2 Tributary Channel Stability

The tributary channels within the project area are channelized, like the main channel, and their flow regime is also dominated by storm water runoff. In most cases the channels have active head-cuts and their stream banks are also actively eroding. S4 differs because the reach has incised to a layer of weathered rock, which provides grade control.

As part of the stability assessment, eleven cross sections were surveyed on the tributary reaches. The cross sections are provided in Appendix C.2 and summarized in Table 4.6 below.

TABLE 4.6
Stability Indicators – Tributary Channels
City Pond Site Restoration Plan

Parameter	Reach [1]					
	S1	**S2**	**S3**	**S4**	**S5**	**S6**
Stream Type	G5	G5/E5b	F5	G5c	G5c/E5	G5c
Riparian Vegetation	Forested	Forested with young successional species	Forest with pasture	Pasture	Pasture	Pasture with forest of young successional species
Channel Dimension						
Bankfull Area (ft^2)	3.0 – 4.0	2.8 – 3.3	5.5	13.8 – 14.5	11.6 – 17.1	5.5
Width/Depth Ratio	6.2 – 7.7	3.7 – 8.2	25.0	8.0 – 8.5	3.0 – 7.4	6.5
Channel Pattern						
Meander Width Ratio [2]	-- [2]	-- [2]	-- [2]	-- [2]	-- [2]	6.8
Sinuosity	1.07	1.0	1.04	1.02	1.04	1.08
Vertical Stability						
Bank Height Ratio	3.0 – 4.2	1.6 – 3.9	2.6	2.4 – 2.5	1.2 – 2.2	1.8
Entrenchment Ratio	1.7 – 1.9	1.9 – 24.0	1.5	1.4 – 1.7	1.7 – 19.0	1.6
Bank Erosion						
BEHI	High	High	High	Moderate/ High	High	High
Evolution Scenario	E-G-B	E-G-B	E-G-F-C-E	E-G-F-C-E	E-G-F-C-E	E-G-F-C-E

NOTES:

1 Where multiple cross-sections were surveyed in a single reach the data are presented as a range of values.

2 No pattern related parameters were computed as very little pattern was observed in the field (i.e., the channel is straight).

The width/depth ratios are low (w/d ratio < 12), with the exception of S3, which has a high w/d ratio (w/d ratio = 25). These low values are typical of channels that are laterally stable. The high value at S3 is indicative of a widening channel.

The ER values show that the streams are, for the most part, moderately to slightly entrenched (ER > 1.4) based on the Rosgen (1996) classification system. The tributaries have frequent access to their floodplains, where excess energy can be dissipated. They are thus described as vertically un-contained. For this reason, moderately to slightly entrenched streams tend toward stability.

The above stability indicators alone could appear to demonstrate that the site's tributary channels are somewhat stable. However, this is not the case. The BHR values demonstrate that the stream is incised and laterally unstable because critical bank heights have been exceeded. The lowest observed ratio of bankfull stage to the stream bank height is 1.2, a value with a bank erodibility adjective rating of "Moderate." Most of the observed BHR values are high, however, with a "Very High" to "Extreme" value appearing in each tributary reach.

4.4 Bankfull Verification

The bankfull stage in the main channel, as well as the tributary channels, was identified in the field. The indicators were a break in slope on flat depositional features and the back of point bars. These indicators are consistent with those commonly seen in Piedmont streams. Bankfull data for the project reach is compared with the North Carolina Piedmont regional curve in Figure 4.1. The cross-sectional areas consistently plot within acceptable limits.

The USGS website was consulted to locate gages within the Yadkin River Basin (HUC 03040201-020020). Only two active gages exist within this basin and both are on very large river systems. These gages were considered improper for comparison with the project reach due to the different physiographic setting. No other appropriate active gages were located in adjacent basins.

With no useful gage data available, an alternative method to verify bankfull discharge was developed. This method analyzed local bankfull cross sectional area versus drainage area relationships, and then compared those relationships to the Piedmont regional curves to determine if the relationships are similar. If the relationships are similar, the bankfull relationships used elsewhere in the Piedmont are considered valid for the subject site.

Two streams located close to the project site were used as additional local sites: Jones Creek and Cabin Branch (Figure 4.2). These sites were selected based on the confidence with which bankfull features were identified, the apparent cross-section stability, and natural state of the stream. These streams were used for reference cross-sections only and not for reference quality pattern and profile. Both of these sites had clear bankfull indicators located at, or near, the top of banks. Significant morphological measurements of each cross-section are shown in Table 4.7. One representative riffle cross section was surveyed at the each site. The drainage areas were determined based on watershed delineation from USGS topographic quadrangles. These points were plotted on the Piedmont regional curves, along with the data from the City Pond Site. These data plotted within acceptable limits and thus verify that the relationships in this basin are similar to those of the Piedmont region. It is concluded that because the surveyed cross-sectional areas of the stream reaches correlate well with regional curve data, bankfull was correctly identified on the stream reaches.

TABLE 4.7
Dimension Data for Two Reference Streams Near the Project Site
City Pond Site Restoration Plan

Parameter	Value		Units
	Reach [1]		
	Jones Creek	Cabin Branch	
Drainage Area	25.3	3.8	Mi^2
Bankfull Width (Wbkf)	36.4	24.4	Feet
Bankfull Mean Depth (d bkf)	4.5	2.4	Feet
Cross Sectional Area (Abkf)	162.1	58.0	Ft^2
Width/Depth Ratio (w/d ratio)	8.2	10.3	
Bankfull Max. Depth (dmbkf)	5.8	3.2	Feet
Floodprone Area Width (Wfpa)	>100	>100	Feet
Entrenchment Ratio (ER)	>2.2	>2.2	
Stream Type	E	E	

5 Selected Design Criteria

5.1 Potential for Restoration

There are few potential obstacles for achieving Priority 1 restoration at the majority of the City Pond site. The project is located in a rural watershed, with no plans indicating land use changes in the foreseeable future. Therefore, there are no present or future constraints at the site associated with structure and/or infrastructure encroachments.

Otherwise, there are two situations where site conditions necessitate the use of techniques that will not fully reclaim the abandoned floodplain at the site. The downstream reach of the project will have to tie in to the existing downstream channel. In order to effect this transition, the stream bed cannot be elevated to the level of the existing abandoned floodplain. Therefore, a section of Priority 2 restoration will be required, creating an active floodplain at a lower elevation. In addition, two tributaries to the project traverse a comparatively steep, wooded section of the site. In order to preserve as much of the woody riparian zone, a less sinuous, step-pool system will need to be implemented.

5.1.1 Main Channel Restoration Potential

The main channel is exhibiting a clear evolutionary sequence. It is incising, then widening, then building benches and forming a new, stable channel within the widened boundary. It is likely following the evolution pattern of E-G-F-C-E. Most of the channels are currently in the G or F state, with a few reaches beginning to build benches and tending toward a C stream type. As a result, the majority of the restoration on the main channel at the City Pond site should attempt to speed up the evolutionary process already occurring. Rosgen C stream types should be constructed. C stream types are more easily constructed than E stream types. E stream types have steeper banks and, as a result, more soil bioengineering structural reinforcement and revetment is often needed. Stable C stream types will transition into E stream types relatively easily if the cross sectional area is designed with enough room to allow point bars to build.

The major portion of the main channel design (R2) should not, however, create a new E/C stream type within the boundary of the incised and widened existing channel. Because there are no homes, businesses, or infrastructure adjacent to the streams, the channel bed should be raised and a sinuous pattern re-established. Only at the lower end of the main channel (R3), where the restoration project must transition back to match the existing, incised cross section downstream, should the channel be built with a confined floodplain.

The upper portion of the main channel (R1) has incised to a layer of partially weathered rock. This layer is providing grade control, thus preventing further stream bed degradation. The lack of deep-rooting riparian vegetation is, however, preventing the stream banks from stabilizing. The Priority 3 restoration for this section of the main channel should preserve the stabilizing channel and revegetate the riparian zone with trees and shrubs.

5.1.2 Tributary Channels Restoration Potential

5.1.2.1. Reach S1 and S2

The tributary channel reaches S1 and S2, which are both straightened, incising streams with active bank erosion, are likely evolving according the Rosgen's (2002) E-G-B scenario. As the streams down-cut, the banks are eroding to a more stable angle of repose. Restoration at these reaches should use this central tendency as guidance. Conversion of these two gully reaches into step-pool B stream types would speed S1 and S2 toward stability. This type of conversion is similar to a Rosgen (1997) Priority 1 restoration; however, the Rosgen priority system is used to describe incised channels. S1 and S2 are in the process of incising, but still have access to their floodplains.

5.1.2.2. Reaches S3 through S6

The remaining tributary reaches – S3, S4, S5, and S6 – are evolving in a pattern more like that of the main channel. However, the E-G-F-C-E process is not as far along in the tributaries. The tributaries are not as incised as the main channel, but still exhibit characteristics of G type streams. These reaches are attempting to regain a natural meandering pattern, which will be achieved in the Priority 1 approaches proposed for these stream segments.

5.2 Design Criteria Selection Method

Selection of natural channel design criteria is based on a combination of approaches including reference reach surveys, review of reference reach databases, regime equations, and evaluation of results from past projects, as discussed in Section 2.3. Use of multiple techniques provide "converging lines of evidence" to select a final set of design criteria.

Selection of a general restoration approach was the first step in selecting design criteria at City Pond. The approach was based on each reach's potential for restoration as determined during the site assessment. After selection of the general restoration approach, specific design criteria were developed so each reach's plan view layout, cross-section dimensions, and profile could be described for the purpose of developing construction documents. At City Pond, no upstream reference reaches were available, and none were identified off the project site in surrounding watersheds. Therefore, specific design criteria were developed using a combination of regime equations, database reference reach data, past project experiences, and best professional judgment (i.e., the "converging lines of evidence" method mentioned above). Dimensionless ratios were taken from an internal reference reach database to develop the design numbers.

The design criteria are presented in Sections 6.2.1 and 6.2.2 in Tables 6.1 through 6.3, along with existing and proposed measurements, so that comparisons can be quickly made between the three.

5.3 Design Criteria for City Pond Site

After examining the assessment data collected at the City Pond site and exploring the site's potential for restoration, a determination of how to accomplish the stream restoration was developed. First, an appropriate stream type for the valley type present at the site was selected based on restoration potential evaluation of the existing conditions survey. The design stream types were further refined based on the channel evolution sequence exhibited by the stream after examination of existing conditions survey data and other field observations, as well as conditions observed on reference streams under similar conditions. Available belt width and channel incision were also considered. Proposed stream types are summarized in Table 5.1. Design parameters are typically altered to accommodate specific local conditions and project requirements.

TABLE 5.1
Project Design Stream Types
City Pond Site Restoration Plan

Reach	Proposed Stream Type	Rationale
R1	n/a	Stream bed is stable because reach has incised to a dense clay and mudstone layer. Enhancement of the reach by excavating a bankfull bench along the right bank and establishing adequate vegetation in the stream side buffer zone is all that is needed to aid in reaching a stable state.
R2	E	Reach is exhibiting an E-G-F-C-E evolution sequence. Priority 1 / Priority 2 restoration will return the reach to its original stream type with functioning floodplain on abandoned floodplain terrace. The Priority 2 section will transition from R1 until Priority 1 restoration commences.
R3	E	Reach is exhibiting an E-G-F-C-E evolution sequence. Priority 1 / Priority 2 restoration will return the reach to its original stream type with functioning floodplain on abandoned floodplain terrace. The Priority 2 restoration will transition from the Priority 1 section to tie into the elevation of the downstream reach.
S1	B	Reach is exhibiting an E-G-B evolution sequence. Constructing a B type stream will speed the evolutionary process and take advantage of the comparatively steep gradient this tributary must traverse to tie into the main channel.
S2	B	Reach is exhibiting an E-G-B evolution sequence. Constructing a B type will speed the evolutionary process and take advantage of the comparatively steep gradient this tributary must traverse to tie into the main channel.
S3	E	Reach is exhibiting an E-G-F-C-E evolution sequence. Priority 1 restoration will return the reach to its original stream type with functioning floodplain on the now abandoned floodplain terrace.
S4	E	Reach is exhibiting an E-G-F-C-E evolution sequence. Priority 1 / Priority 2 restoration will return the reach to its original stream type with functioning floodplain on the now abandoned floodplain terrace. The Priority 2 restoration will begin at the wood line and transition into the Priority 1 restoration.
S5	E	Reach is exhibiting an E-G-F-C-E evolution sequence. Priority 1 restoration will return the reach to its original stream type with functioning floodplain on the now abandoned floodplain terrace.
S6	E	Reach is exhibiting an E-G-F-C-E evolution sequence. Priority 1 restoration will return the reach to its original stream type with functioning floodplain on the now abandoned floodplain terrace.

6 Natural Channel Design

6.1 Restoration Approach

The overriding objective of the City Pond restoration plan is to re-establish contact between the stream channels at the site and the floodplain. The proposed natural channel design for the main reach and tributaries on the City Pond site will include the following elements:

- Priority 1 Stream Restoration
  - Reach R2 – all but a short section of the reach will be restored to E stream type
  - Reach R3 – all but a short section of the reach will be restored to E stream type
  - Reach S3 – entire reach will be restored to E stream type
  - Reach S4 – all but a short section of the reach will be restored to E stream type
  - Reach S5 – entire reach will be restored to E stream type
  - Reach S6 – entire reach will be restored to E stream type
- Non-Incised Stream Restoration (similar to Priority 1 Restoration)
  - Reach S1 – designed to create step-pool channel
  - Reach S2 – designed to create step-pool channel
- Priority 2 Stream Restoration
  - Reach R2 – short upstream section will use Rosgen Priority 2 restoration in order to transition to Priority 1 restoration
  - Reach R3 – short downstream section will use Rosgen Priority 2 restoration in order to tie in with the receiving incised downstream channel
  - Reach S4 – short upstream section will use Rosgen Priority 2 restoration in order to transition to Priority 1 restoration
- Priority 3 Stream Restoration
  - Reach R1 – channel cross-section will be re-shaped and a bankfull bench will be excavated
- Riparian Buffer Enhancement
  - Project-wide planting and preservation of the riparian zone.

Detailed plans for the City Pond site are provided in the attached plan sheets. Details of the design are discussed in the following sections.

6.2 Design Rationale (Dimension, Pattern, and Profile)

6.2.1 Main Channel Restoration

The main channel at the City Pond site will be addressed as follows:

- R1 – This uppermost section of the main channel at the site has a relatively stable stream bed due to the presence of a dense clay and mudstone layer. The stream banks, however, are unstable largely due to the incised nature of the channel and the lack of root mass in the adjacent soil. This G stream type will be converted to an E stream type by re-shaping the channel and excavating a bankfull bench along the right bank. Additional vertical control will be provided by structures, which will supplement the partially weathered rock and improve bedform diversity.
- R2 – The middle section of the main channel presents a good opportunity for reclamation of the abandoned floodplain. The existing stream is incised with some partially weathered rock grade control. There are very few pools and riffles. The riparian zone on both sides of the stream is pasture. The stream

will be meandered through the pasture, with a Priority 2 restoration at the upstream end that will transition to a Priority 1 restoration on the downstream sections.

- R3 – The downstream section of the main channel is similar to the upstream section, with a lack of pool/riffle diversity and a buffer zone comprised only of pasture. Again, a Priority 1 restoration is proposed; however, more bench construction will be necessary as the restoration project has to transition back to an incised cross section to match the existing stream at the terminus of the project. This lower end of R3 will be constructed as a Priority 2 restoration.

Table 6.1 presents the stream restoration dimensions for the main channel. Existing data and design criteria are shown also.

TABLE 6.1
Morphological Characteristics of the Existing and Proposed Main Channel Reaches [1]
City Pond Site Restoration Plan

	Existing R1		Existing R2		Existing R3		Design Criteria [2]		Proposed R1		Proposed R2		Proposed R3	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
1. Stream Type	G4(6)c / F4(6)		G4(6)c / F4(6)		G4c / F4		--	--	C4		C4		C4	
2. Drainage Area (sq. mi.)	0.4		0.6		1.5		--	--	0.4		0.6		1.5	
3. Bankfull Width (Wbkf) – feet	11.1	11.8	11.9	15.7	15.4	18.9	--	--	12.0	12.0	13.4	13.4	18.4	18.4
4. Bankfull Mean Depth (d bkf) – feet	1.2	1.3	0.9	1.3	1.0	1.5	--	--	1.0	1.0	1.1	1.1	1.5	1.5
5. Width/Depth Ratio (w/d ratio)	8.7	9.8	11.3	14.8	10.6	19.5	12	12	12	12	12	12	12	12
6. Cross Sectional Area (Abkf) – SF	14.1	14.2	12.5	20.6	18.4	22.4	--	--	11.9	11.9	15	15	28.2	28.2
7. Bankfull mean velocity (v bkf) - fps	3.4		4.8		6.0				4.0		4.0		3.9	
8. Bankfull discharge (Q bkf) – cfs	48		60		110				48		60		110	
9. Bankfull Max. Depth (d mbkf) - feet	1.9	2.3	1.7	2.6	1.6	2.1	--	--	1.2	1.5	1.3	1.7	1.8	2.3
10. Max. d riff/d bkf ratio	1.6	1.9	1.8	2.8	1.6	2.2	1.2	1.5	1.2	1.5	1.2	1.5	1.2	1.5
11. Low bank height to max. d bkf ratio	2.4	3.0	1.8	3.0	3.0	3.5	1	1	1	1	1	1	1	1
12. Floodprone Area Width (Wfpa) – feet	15.6	15.9	17	25.5	27.0	34.1	--	--	36	50	40	150	55	200
13. Entrenchment Ratio (ER)	1.4	1.4	1.4	1.79	1.75	1.8	>2.2	>2.2	3	4.2	3	11.2	3	10.9
14. Meander length (Lm) – feet	--	--	--	--	--	--	--	--	83.7	137.4	93.9	154.3	128.8	184.0
15. Ratio of meander length to bankfull width (Lm/W bkf)	--	--	--	--	--	--	7	11.5	7	11.5	7	11.5	7	10
16. Radius of curvature (Rc) – feet	--	--	--	--	--	--	--	--	30.0	41.8	33.5	47.0	46.0	64.4
17. Ratio of radius of curvature to bankfull width (Rc/W bkf)	--	--	--	--	--	--	2.5	3.5	2.5	3.5	2.5	3.5	2.5	3.5
18. Belt width (W blt) – feet	--	--	--	--	--	--	--	--	41.8	95.6	47.0	107.3	64.4	110.4

TABLE 6.1
Morphological Characteristics of the Existing and Proposed Main Channel Reaches [1]
City Pond Site Restoration Plan

	Existing R1		Existing R2		Existing R3		Design Criteria [2]		Proposed R1		Proposed R2		Proposed R3	
19. Meander width ratio (W blt/W bkf)	--	--	--	--	--	--	3.5	8	3.5	8	3.5	8	3.5	6
20. Sinuosity (K = stream length/valley distance)	1.01	--	1.05	--	1.02	--	1.2	1.5	--	1.01	--	1.42	--	1.23
21. Valley slope – ft./ft.	0.009	--	0.008	--	0.005	--	--	--	--	0.009	--	0.008	--	0.005
22. Average slope (s avg = svalley/k) – ft./ft.	0.008	--	0.007	--	0.004	--	--	--	--	0.008	--	0.005	--	0.004
23. Pool slope (s pool) – ft./ft.	--	--	--	--	--	--	--	--	0	0.0004	0	0.0003	0	0.0002
24. Ratio of pool slope to average slope (s pool/s bkf)	--	--	--	--	--	--	0	0.05	0	0.05	0	0.05	0	0.05
25. Maximum pool depth (d pool) – feet	--	--	--	--	--	--	--	--	2.0	3.0	2.2	3.4	3.1	4.6
26. Ratio of pool depth to average bankfull depth (d pool/d bkf)	--	--	--	--	--	--	2	3	2	3	2	3	2	3
27. Pool width (W pool) – feet	--	--	--	--	--	--	--	--	14.3	17.9	16.1	20.1	22.1	27.6
28. Ratio of pool width to bankfull width (W pool/W bkf)	--	--	--	--	--	--	1.2	1.5	1.2	1.5	1.2	1.5	1.2	1.5
29. Pool Area (A pool) – square feet	--	--	--	--	--	--	--	--	14.3	2.4	18	30.0	33.8	56.4
30. Ratio of pool area to bankfull area (A pool/A bkf)	--	--	--	--	--	--	1.2	2	1.2	2	1.2	2	1.2	2
31. Pool-to-pool spacing – feet	--	--	--	--	--	--	--	--	23.9	47.8	26.8	67.1	39.8	92.0
32. Ratio of p-p spacing to bankfull width (p-p/Wbkf)	--	--	--	--	--	--	2	5	2	4	2	5	2	5
33. Ratio of riffle slope to average slope (s riff/ s bkf)	--	--	--	--	--	--	1.2	2	1.2	2	1.2	2	1.2	2

Particle Size Distribution of Channel Material							
Material (D50)			--	--	--	--	--
D16 – mm	0.11	0.11	0.25	--	--	--	--
D35 – mm	0.33	0.33	1.58	--	--	--	--
D50 – mm	0.61	0.61	2.76	--	--	--	--
D84 – mm	16.0	16.0	17.39	--	--	--	--
D95 – mm	Bedrock	Bedrock	39.67	--	--	--	--

NOTES:

1 If data are not presented, they were not collected, not calculated, or not applicable.

2 Specific remarks regarding selection of design criteria follow in the detailed design narratives on dimension, pattern, and profile.

6.2.1.1. Dimension

The existing channel dimension is unstable throughout the project area due to excessive velocities and shear stresses within the channel and lack of dense and deep root structure from an intact woody riparian buffer. To address the erosion throughout the project, the stream cross-section (dimension) will be adjusted in order to reduce velocities and near-bank shear stress. A Rosgen E/C stream with a w/d ratio of 12 will be created with the cross section. The ratio of low bank height to bank height (BHR) will be maintained at 1. In areas along the main channel where bank height might exceed bankfull stage because of localized topography or a low stream bed elevation, benches will be constructed at the bankfull stage. Once flood water rises above the bankfull stage, erosion-causing stress in the near bank region can be greatly reduced if the storm flow is able to spread out and slow down on a floodplain or a bench. Root wads and rock/log vanes will be used to provide bank protection at the outside of stream bends where necessary. Typical cross-sections are shown on the plan sheets.

6.2.1.2. Pattern

The existing main channel through the City Pond site is extremely straight (k=1). The proposed project will increase the sinuosity of the stream (k=1.2), adding hundreds of linear feet of stream in the process. Currently, the main channel at the City Pond site is 3,274 linear feet; restored the stream will be approximately 4,067 linear feet. On the majority of the main channel, the meander length ratio will be between 7 and 11.5. These more lengthy meanders will allow the channel to dissipate energy, thereby reducing erosion. The lower section of the channel will not meander as much as the upper section because it must transition back to match the existing incised reach downstream. Curve radii will range between approximately 30 to 60 feet or 2.5 to 3.5 times larger than the channels bankfull width. Finally, the meander width ratio (MWR) of the stream will be increased as part of the restoration. MWRs will be 3.5 to 8 times wider than bankfull width except in the downstream reach where the belt width must be narrower as the stream restoration transitions to match existing downstream conditions. Plan views of the main channel are shown on the plan sheets.

6.2.1.3. Profile/Bedform

The profile of the existing main channel at the City Pond site is relatively stable at R1, but becomes increasingly unstable in a downstream direction (R2 and R3). The stream gradient is controlled in R1 by a dense clay layer and mudstone. There is, however, very little diversity in the existing channel bedform – pools, riffles, glides, runs, etc. are nearly indistinguishable from each other with few exceptions. The stream restoration will include the construction of a riffle-pool stream bed, with additional habitat and diversity provided by constructed riffles and cross vanes at certain locations. The J-hook and cross vane locations are shown on the plan sheets.

6.2.2 Tributary Channel Restoration

As discussed in Section 4, the tributaries at the City Pond site can be divided based on the valleys they traverse. This difference prompted the development of distinct designs for the tributaries. The tributary channels at the City Pond site will be addressed in two ways:

- S1 and S2 – These tributaries flow into the main channel from the more confined side of the stream valley. They traverse a steeper gradient than the other tributaries. Also, the area adjacent to much of S1and S2 is wooded. For these reasons, S1 and S2 are proposed as B stream types. The steeper gradient, step-pool morphology of the B channel suits the terrain and will allow for a narrower construction zone, reducing impacts to adjacent trees.
- S3 through S6 – These tributaries are G and F stream types. In a few instances, the streams are trying to recover, forming lower gradient meandering channels within overly widened existing cross sections. The

restoration of these tributaries will follow the central tendency these tributaries exhibit toward self-stabilization.

6.2.2.1. Tributaries S1 and S2

Dimension

The existing tributary channel dimensions at S1 and S2 are unstable even though there is some dense and deep root structure from an intact woody riparian buffer. Bank height ratios are so high that stream banks are collapsing because of the excessive velocities generated during storm flows. To address the erosion and entrenchment in S1 and S2 tributary system, and to use the wooded character of the site in this area to the best advantage, the tributary cross-sections (dimensions) will be adjusted to a less entrenched system, but one that is still narrow enough to reduce impact to the buffer. Steps and pools created with cross vanes and log weirs will reduce velocities and near-bank shear stress. The Rosgen B streams will be created with the cross section having a w/d ratio of 14. The ratio of low bank height to bank height (BHR) will be maintained at 1. In areas along the main channel where bank height might exceed bankfull stage because of localized topography or a low stream bed elevation, benches will be constructed at the bankfull stage. Once storm water rises above the bankfull stage, erosion-causing stress in the near bank region can be greatly reduced if the storm flow is able to spread out and slow down on a floodplain or a bench. Typical cross-sections are shown on the plan sheets.

Pattern

S1 and S2 are extremely straight (k=1). The proposed project will slightly increase the sinuosity of these tributaries; however, these tributaries will not exhibit meander geometry due to the high channel slope. Restoration of S1 and S2 will increase overall stream length of the two tributaries from 1,606 feet to 1,757 feet. Proposed plan views of S1 and S2 are shown on the plan sheets.

Profile/Bedform

The profiles of S1 and S2 at the City Pond site are highly unstable and have no natural material that provides grade control. There is very little diversity in the existing channel bedforms – pools, riffles, glides, runs, etc. are nearly indistinguishable from each other with few exceptions. The stream restoration will include the construction of a step-pool stream bed. The cross vane locations are shown on the plan sheets.

Table 6.2 presents the stream restoration dimensions for S1 and S2. Existing data and design criteria are shown also.

TABLE 6.2
Morphological Characteristics of the Existing and Proposed Tributary Channel Reaches – S1 and S2 [1]
City Pond Site Restoration Plan

	Existing S1		Existing S2		Design Criteria [2]		Proposed S1		Proposed S2	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
1. Stream Type	G5		G5 / E5b		--	--	B5		B5	
2. Drainage Area (sq. mi.)	0.04		0.06		--		0.04		0.06	
3. Bankfull Width (Wbkf) - feet	4.4	5.6	3.5	4.8	--	--	5.8	5.8	6.7	6.7
4. Bankfull Mean Depth (d bkf) - feet	0.7	0.7	0.6	0.9	--	--	0.4	0.4	0.5	0.5
5. Width/Depth Ratio (w/d ratio)	6.2	7.7	3.7	8.2	14	14	14	14	14	14
6. Cross Sectional Area (Abkf) - SF	3.1	4.0	2.8	3.3	--	--	2.4	2.4	3.2	3.2
7. Bankfull mean velocity (v bkf) - fps	2.9		4.3		--	--	3.7		3.8	
8. Bankfull discharge (Q bkf) - cfs	8.8		12		--	--	8.8		12	
9. Bankfull Max. Depth (d mbkf) - feet	1.1	1.2	1.0	1.6	--	--	0.5	0.6	0.6	0.7
10. Max. d riff/d bkf ratio	1.6	1.7	1.6	2.7	1.2	1.5	1.2	1.5	1.2	1.5
11. Low bank height to max. d bkf ratio	3.0	4.2	1.6	3.9	1	1	1	1	1	1
12. Floodprone Area Width (Wfpa) – feet	8.4	9.6	9.2	83.4	--	--	17.4	50	20.1	83.4
13. Entrenchment Ratio (ER)	1.7	1.9	1.9	24.0	1.4	--	3.0	8.6	3.0	24.0
14. Meander length (Lm) - feet	--	--	--	--	--	--				
15. Ratio of meander length to bankfull width (Lm/W bkf)	--	--	--	--	--	--				
16. Radius of curvature (Rc) – feet	--	--	--	--	--	--				
17. Ratio of radius of curvature to bankfull width (Rc/W bkf)	--	--	--	--	--	--				
18. Belt width (W blt) – feet	--	--	--	--	--	--	--	--		

TABLE 6.2
Morphological Characteristics of the Existing and Proposed Tributary Channel Reaches – S1 and S2 [1]
City Pond Site Restoration Plan

	Existing S1		Existing S2		Design Criteria [2]		Proposed S1		Proposed S2	
19. Meander width ratio (W blt/W bkf)	--	--	--	--						
20. Sinuosity (K = stream length/valley distance)	1.07	--	1.003	--	1.2	--	1.05	--	1.07	--
21. Valley slope – ft./ft.	0.0382	--	0.0298	--	--	--	0.038	--	0.03	--
22. Average slope (s avg = svalley/k) – ft./ft.	0.0356	--	0.0297	--	--	--	0.036	--	0.028	--
23. Pool slope (s pool) – ft./ft.	--	--	--	--	--	--				
24. Ratio of pool slope to average slope (s pool/s bkf)	--	--	--	--						
25. Maximum pool depth (d pool) – feet	--	--	--	--	--	--	0.8	1.2	1.0	1.4
26. Ratio of pool depth to average bankfull depth (d pool/d bkf)	--	--	--	--	2	3	2	3	2	3
27. Pool width (W pool) – feet	--	--	--	--	--	--	7.0	8.7	8.0	10.0
28. Ratio of pool width to bankfull width (W pool/W bkf)	--	--	--	--	1.2	1.5	1.2	1.5	1.2	1.5
29. Pool Area (A pool) – square feet	--	--	--	--	--	--	2.9	4.3	3.8	5.8
30. Ratio of pool area to bankfull area (A pool/A bkf)	--	--	--	--	1.2	2	1.2	2	1.2	2
31. Pool-to-pool spacing – feet	--	--	--	--	--	--	20.3	29.0	13.4	33.5
32. Ratio of p-p spacing to bankfull width (p-p/Wbkf)	--	--	--	--	3.5	5	3.5	5	2	5
33. Ratio of riffle slope to average slope (s riff/ s bkf)	--	--	--	--	1.2	2	1.2	2	1.2	2

TABLE 6.2
Morphological Characteristics of the Existing and Proposed Tributary Channel Reaches – S1 and S2 [1]
City Pond Site Restoration Plan

	Existing S1	Existing S2	Design Criteria [2]	Proposed S1	Proposed S2
		Particle Size Distribution of Channel Material			
Material (D50)	--	--	--	--	--
D16 – mm	--	--	--	--	--
D35 – mm	--	--	--	--	--
D50 – mm	--	--	--	--	--
D84 – mm	--	--	--	--	--
D95 – mm	--	--	--	--	--

NOTES:

1 If data are not presented, they were not collected, not calculated, or not applicable.

2 Specific remarks regarding selection of design criteria follow in the detailed design narratives on dimension, pattern, and profile.

6.2.2.2. Tributaries S3 through S6

Dimension

The existing tributary channel dimensions along S3 through S6 are unstable at almost every location within the pasture where there is a lack of intact woody riparian buffer. Even on segments within the tree line, bank height ratios are so high that stream banks are collapsing because of the excessive velocities generated during storm flows. One reach, S3, has over-widened to an F stream type and there is evidence of the formation of a low flow channel. To address the erosion and entrenchment throughout the tributaries S3 through S6, the tributary cross-sections (dimensions) will be adjusted, reducing velocities and near-bank shear stress. Rosgen E/C streams will be created with the cross section having a w/d ratio of 11 or 12. The ratio of low bank height to bank height (BHR) will be maintained at 1. In areas along the main channel where bank height might exceed bankfull stage because of localized topography or a low stream bed elevation, benches will be constructed at the bankfull stage. Once storm water rises above the bankfull stage, erosion-causing stress in the near bank region can be greatly reduced if the storm flow is able to spread out and slow down on a floodplain or a bench. Root wads will be used to provide bank protection at the outside of stream bends where necessary. A typical cross-section is shown on the attached plan sheets.

Pattern

The existing tributary channels through the City Pond site are extremely straight (k=1). The proposed project will increase the sinuosity of the tributaries (k=1.2 to 1.5), adding additional stream feet in the process. Restoration of tributaries S3 through S6 will increase stream length from 3,956 feet to 4,536 feet. On the majority of the S3, S4, S5, and S6, the meander length ratio will be between 7 and 11. These more lengthy meanders will allow the channel to dissipate energy, thereby reducing erosion. Curve radii will range between approximately 20 to 45 feet, or 2.5 to 3.5 times larger than the channels bankfull width. Finally, the meander width ratio (MWR) of the stream will be increased as part of the restoration. MWRs will be 3.5 to 8.0 times wider than bankfull width. Proposed plan views of S3 through S6 are shown on the plan sheets.

Profile/Bedform

The profiles of S3 through S6 at the City Pond site are highly unstable; most of them have no natural material that will provide grade control. There is very little diversity in the existing channel bedforms – pools, riffles, glides, runs, etc. are nearly indistinguishable from each other with few exceptions. The stream restoration will include the construction of a riffle-pool stream bed.

Table 6.3 presents the stream restoration dimensions for S3 through S6. Existing data and design criteria are shown also.

TABLE 6.3
Morphological Characteristics of the Existing and Proposed Tributary Channel Reaches – S3 through S6 [1]
City Pond Site Restoration Plan

	Existing S3		Existing S4		Existing S5		Existing S6		Design Criteria [2]		Proposed S3		Proposed S4		Proposed S5		Proposed S6	
	Min	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**
1. Stream Type	F5		G5c		G5c		G5		--	--	E5		C5		C5		C5	
2. Drainage Area (sq. mi.)	0.1		0.5		0.4		0.2		--		0.1		0.5		0.4		0.2	
3. Bankfull Width (Wbkf) – feet	11.7	--	10.8	10.8	7.1	9.9	6.0	--	--	--	7.9	7.9	12.7	12.7	11.5	11.5	8.6	8.6
4. Bankfull Mean Depth (d bkf) - feet	0.5	--	1.3	1.3	1.4	2.4	0.9	--	--	--	0.7	0.7	1.1	1.1	1.0	1.0	0.7	0.7
5. Width/Depth Ratio (w/d ratio)	25.0	--	8.0	8.5	3.0	7.4	6.5	--	11	12	11	11	12	12	12	12	12	12
6. Cross Sectional Area (Abkf) - SF	5.5	--	13.8	14.5	11.6	17.1	5.5	--	--	--	5.7	5.7	13.4	13.4	11.1	11.1	6.2	6.2
7. Bankfull mean velocity (v bkf) – fps	3.8		4.0		3.9		4.5				3.7		4.1		4.1		4.0	
8. Bankfull discharge (Q bkf) – cfs	21		55		45		25				21		55		45		25	
9. Bankfull Max. Depth (d mbkf) - feet	1.6	--	2.3	2.6	2.5	3.1	1.3	--	--	--	0.9	1.1	1.3	1.6	1.2	1.4	0.9	1.1
10. Max. d riff/d bkf ratio	3.4	--	1.8	2.0	1.8	2.3	1.4	--	1.2	1.5	1.2	1.5	1.2	1.5	1.2	1.5	1.2	1.5
11. Low bank height to max. d bkf ratio	2.6	--	2.4	2.5	1.2	2.2	1.8	--	1	1	1	1	1	1	1	1	1	1
12. Floodprone Area Width (Wfpa) - feet	17.6	--	15.0	18.4	16.9	135.5	9.8	--	--	--							--	--

TABLE 6.3
Morphological Characteristics of the Existing and Proposed Tributary Channel Reaches – S3 through S6 [1]
City Pond Site Restoration Plan

	Existing S3		Existing S4		Existing S5		Existing S6		Design Criteria [2]		Proposed S3		Proposed S4		Proposed S5		Proposed S6	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
13. Entrenchment Ratio (ER)	1.5	--	1.4	1.7	1.7	19.0	1.6	--	1.4	--								
14. Meander length (Lm) - feet	--	--	--	--	--	--	--	--			55.4	79.2	88.8	139.5	80.8	121.2	60.4	90.6
15. Ratio of meander length to bankfull width (Lm/W bkf)	--	--	--	--	--	--	--	--	7	10.5	7	10	7	11	7	10.5	7	10.5
16. Radius of curvature (Rc) – feet	--	--	--	--	--	--	--	--			19.8	27.7	31.7	44.4	28.9	40.4	21.6	30.2
17. Ratio of radius of curvature to bankfull width (Rc/W bkf)	--	--	--	--	--	--	--	--	2.5	3.5	2.5	3.5	2.5	3.5	2.5	3.5	2.5	3.5
18. Belt width (W blt) – feet	--	--	--	--	--	--	--	--			27.7	63.4	44.4	101.5	40.4	92.3	30.2	69
19. Meander width ratio (W blt/W bkf)	--	--	--	--	--	--	--	--	3.5	8	3.5	8	3.5	8	3.5	8	3.5	8
20. Sinuosity (K = stream length/valley distance)	1.04	--	1.02	--	1.039	--	1.08	--	1.5	--	1.27	--	1.43	--	1.4	--	1.34	--
21. Valley slope ft./ft.	0.0106	--	0.0069	--	0.0091	--	0.0181	--	--	--	0.011	--	0.007	--	0.009	--	0.018	--
22. Average slope (s avg = svalley/k) – ft./ft.	0.0102	--	0.0067	--	0.0088	--	0.0168	--	--	--	0.008	--	0.005	--	0.006	--	0.013	--

TABLE 6.3
Morphological Characteristics of the Existing and Proposed Tributary Channel Reaches – S3 through S6 [1]
City Pond Site Restoration Plan

	Existing S3		Existing S4		Existing S5		Existing S6		Design Criteria [2]		Proposed S3		Proposed S4		Proposed S5		Proposed S6	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
23. Pool slope (s pool) – ft./ft.	--	--	--	--	--	--	--	--	--	--	0	0.0004	0	0.0002	0	0.0003	0	0.0007
24. Ratio of pool slope to average slope (s pool/s bkf)	--	--	--	--	--	--	--	--			0	0.05	0	0.05	0	0.05	0	0.05
25. Maximum pool depth (d pool) – feet	--	--	--	--	2.6	3.3	--	--	--	--	1.4	2.2	2.1	3.2	1.9	2.9	1.4	2.2
26. Ratio of pool depth to average bankfull depth (d pool/d bkf)	--	--	--	--	1.5	1.9	--	--	2	3	2	3	2	3	2	3	2	3
27. Pool width (W pool) – feet	--	--	--	--	10.7	14.6	--	--	--	--	9.5	11.9	15.2	19.0	13.9	17.3	10.4	12.9
28. Ratio of pool width to bankfull width (W pool/W bkf)	--	--	--	--	1.3	1.7	--	--	1.2	1.5	1.2	1.5	1.2	1.5	1.2	1.5	1.2	1.5
29. Pool Area (A pool) – square feet	--	--	--	--	24.7	27.2	--	--	--	--	6.8	11.1	16.1	26.8	14.4	22.2	8.1	12.4
30. Ratio of pool area to bankfull area (A pool/A bkf)	--	--	--	--	1.8	1.9	--	--	1.2	2.0	1.2	2.0	1.2	2.0	1.3	2.0	1.3	2.0
31. Pool-to-pool spacing feet	--	--	--	--	--	--	--	--	--	--	15.8	39.6	25.4	63.4	40.4	57.7	30.2	43.1

TABLE 6.3
Morphological Characteristics of the Existing and Proposed Tributary Channel Reaches – S3 through S6 [1]
City Pond Site Restoration Plan

	Existing S3		Existing S4		Existing S5		Existing S6		Design Criteria [2]		Proposed S3		Proposed S4		Proposed S5		Proposed S6	
	Min	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**
32. Ratio of p-p spacing to bankfull width (p-p/Wbkf)	--	--	--	--	--	--	--	--	2	5	2	5	2	5	3.5	5	3.5	5
33. Ratio of riffle slope to average slope (s riff/ s bkf)	--	--	--	--	--	--	--	--	1.2	2	1.2	2	1.2	2	1.2	2	1.2	2
33. Ratio of glide depth to average bankfull depth (d glide/d bkf)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
34. Ratio of glide slope to average slope (s glide/s bkf)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
35. Ratio of run depth to average bankfull depth (d run/d bkf)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
36. Ratio of average run slope to average slope (s run/s bkf)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Particle Size Distribution of Channel Material

Material (D50)	--	--	--	--	--	--	--	--
D16 – mm	--	N/a	--	--	--	--	--	--
D35 – mm	--	0.29	--	--	--	--	--	--
D50 – mm	--	1.2	--	--	--	--	--	--
D84 – mm	--	31.5	--	--	--	--	--	--
D95 – mm	--	43.81	--	--	--	--	--	--

NOTES:

1 If data are not presented, they were not collected, not calculated, or not applicable.

2 Specific remarks regarding selection of design criteria follow in the detailed design narratives on dimension, pattern, and profile.

6.3 Sediment Transport

6.3.1 Main Channel Analysis

R1 (D_{50} =0.61 mm) and R2 (D_{50}=0.61 mm) have median particle sizes that result in their classification as sand bed streams. R3 has a D_{50} of 2.76 mm resulting in a classification as a small gravel bed stream. While this median particle size indicates that material in this reach is similar to that of the gravel bed tributaries, a significant quantity of fine material was observed in R3. Coarse material does not appear to control grade and subsequently sediment transport as it does in the tributaries. R3, with its larger drainage area, receives significant quantities of fine materials from both bank erosion and contributions from upstream catchments outside the project area. While restoration of the channel will reduce localized bank erosion, the system will still need to be able to transport the fine materials from upstream sources. Due to the need to transport this material, sediment transport capacity in all mainstem channels is considered more important than competency, and shear stress (lbs/ft^2) and stream power (W/m^2) were analyzed.

Sediment transport capacity, measured as unit stream power (W/m^2), was compared for the existing stream channel and the design conditions for R1, R2, and R3. Table 6.4 shows bankfull boundary shear stress and stream power values for existing and design conditions. Stream power values for the existing and design conditions all compare well to values for similar streams and valley types described in Nanson and Croke (1992). According to their classification system, all mainstem channels are classified as B3a valley types (gravel, sand, and silt bed streams in wide alluvial valleys). The range of stream powers for this valley type in the Nanson and Croke study is 10 to 60 W/m^2. Figure 6.1 shows shear stress as a function of stage for the existing and proposed channel conditions. Figure 6.2 shows average channel velocity as a function of stage for the two channel conditions. Both shear stress and velocity are significantly higher at higher stages for the existing conditions channel due to the higher bank height ratios. Flows higher than bankfull are trapped in the existing incised channel resulting in excess shear stress and velocities. The design channel will allow flows greater than bankfull to spread out on the floodplain thus dissipating this excess energy. The break point on the graphs for both the existing and proposed channel conditions occurs at the top of bank stage.

TABLE 6.4
Boundary Shear Stresses and Stream Power for Existing and Design Conditions for R1, R2, and R3

Parameter	Value (Existing/Design)		
	R1	R2	R2
Bankfull Q (cfs)	45	62	120
Bankfull Area (sq ft)	14.1 / 11.9	14.1 / 15	22.4 / 28.2
Bankfull Width, W (ft)	11.8 / 12	13.1 / 13.4	15.4 / 18.4
Bankfull Mean Depth, D (ft)	1.2 / 1.0	1.1 / 1.1	1.45 / 1.5
Width to Depth Ratio, W/D (ft/ft)	9.8 / 12	11.9 / 12	10.6 / 12
Wetted Perimeter	14.2 / 14	15.3 / 15.6	18.3 / 21.4
Hydraulic Radius, R (ft)	1.0 / 0.9	0.9 / 1.0	1.2 / 1.3
Slope (ft/ft)	0.008 / 0.008	0.007 / 0.005	0.004 / 0.004
Boundary Shear Stress, τ (lbs/ft^2)	0.53 / 0.42	0.42 / 0.30	0.34 / 0.33
Stream Power (W/m^2)	29.4 / 27.2	31.3 / 21	31.1 / 23.7

6.3.2 Tributary Analysis

An evaluation of channel competency was performed using procedures outlined in Section 2.6.1. Pavement/subpavement data from Reaches S4 and S5 were used because these reaches were the only two with particle sizes large enough to perform the pavement/subpavement procedure. The purpose of the evaluation was to determine the ability of the proposed design to move 41 mm particles, which is the largest particle size found in the subpavement. The pavement D_{50} divided by the subpavement D_{50} was 1.4. Because this value is not between 3.0 and 7.0, the largest particle of the subpavement divided by the D_{50} from the pavement sample was calculated as 2.38. Because this value is between 1.3 and 3.0, Equation 2 was used to calculate a critical dimensionless shear stress value of 0.0178. This value was used in Equation 3 to calculate a required depth of 0.7 feet. The design mean depth is 1.0. A difference of 0.3 feet is small enough to not require changes in the design dimension or pattern. In fact, as the stream banks become vegetated, the bankfull width will narrow and mean depth will naturally increase. This is a more conservative approach than designing a low width/depth ratio with a higher mean depth, which can lead to bank erosion prior to vegetative colonization.

The required slope was calculated using Equation 4 and compared to the design slope. The required slope equaled 0.004 ft/ft and the design slope is 0.006 ft/ft. A design slope that is 0.002 greater than the required slope is not great enough to change the design pattern. A summary of the existing condition and design competency values is shown in Table 6.5.

TABLE 6.5
Existing Condition and Design Sediment Competency Values

Shear Stress Analysis	Existing	Design
Bankfull Xsec Area, Abkf (sq ft)	11.6	11.1
Bankfull Width, Wbkf (ft)	8.3	8.3
Bankfull Mean Depth, Dbkf (ft)	1.4	1.0
Wetted Perimeter, WP=W+2D (ft)	11.1	10.2
Hydraulic Radius, R (ft)	1.0	1.1
Schan (ft/ft)	**0.009**	**0.006**
Boundary/Bankfull Shear Stress, τ (lb/sq ft)	**0.57**	**0.41**
D_{50} 100 ct/pavement (mm), D_{50pve}	17.26	17.26
D_{50} (mm) - bar sample/subpavement, $D_{50subpve}$	11.99	11.99
ratio – D_{50pve} / $D_{50subpve}$	1.44	1.44
ratio – di/ D_{50pve}	2.38	2.38
τ*ci – Equation 2	0.0178	0.0178
D100 subpavement (mm)	41	41
d bar large (ft)	0.13	0.13
Dcrit (ft)	**0.4**	**0.7**
Scrit	**0.003**	**0.004**

6.4 In-Stream Structures

As described earlier, a variety of in-stream structures are proposed for the City Pond Site. Structures such as root wads, constructed riffles, rock and log vanes, and cross vanes will be used to stabilize the newly restored stream. Table 6.6 summarizes the use of in-stream structures at the site.

TABLE 6.6
In-Stream Structure Types and Functions
City Pond Site Restoration Plan Report

Structure Type	Function
Cross Vane	Provide Grade Control and Pool Habitat, Protect Stream Banks
Root Wad	Provide Habitat, Protect Stream Banks
Constructed Riffle	Provide Grade Control, Provide Riffle Habitat
Log Weir	Provide Grade Control, Provide Pool Habitat
Rock Vane	Protect Stream Banks, Provide Pool Habitat

6.4.1 Cross Vanes

Cross vanes are used to provide grade control, keep the thalweg in the center of the channel, and protect the stream bank. A cross vane consists of two rock vanes joined by a center structure installed perpendicular to the direction of flow. This center structure sets the invert elevation of the stream bed. Vanes are located just downstream of the point where the stream flow intercepts the bank at acute angles. These structures will be placed in the main channel at both the upstream and downstream project limits. They are also a critical component of the restoration of tributary streams S1 and S2.

6.4.2 Log/Rock Vanes

Log and rock vanes are used to protect the stream bank. The length of a single vane structure can span one-half to two-thirds the bankfull channel width. Vanes are located just downstream of the point where the stream flow intercepts the bank at acute angles. These structures will be placed in several of the tributary streams as well as in the downstream portion of the main channel.

6.4.3 Root Wads

Root wads are placed at the toe of the stream bank in the outside of meander bends for the creation of habitat and for stream bank protection. Root wads include the root mass or root ball of a tree plus a portion of the trunk. They are used to armor a stream bank by deflecting stream flows away from the bank. In addition to stream bank protection, they provide structural support to the stream bank and habitat for fish and other aquatic animals. They also serve as a food source for aquatic insects. Root wads will be placed throughout the City Pond project.

6.4.4 Constructed Riffles

A constructed riffle consists of the placement of appropriate sized bed material into the stream at the specific locations along the profile. The purpose is to provide grade control and improve riffle habitat. Constructed riffles will be placed in the re-designed portion of the main channel and in the tributary channels S3, S4, S5, and S6.

6.4.5 Log Weir

A log weir consists of placing header and footer logs in the bed of the stream channel, perpendicular to the stream flow. The log extends into the stream banks to prevent erosion and bypassing of the structure. The log is flush with the channel bottom upstream of the log and does not back water up. Footer logs are placed to depth of scour to prevent undermining of the structure. Although pools are often created during installation, they will also form naturally downstream of the structure. Log weirs provide bed form diversity, maintain channel profile, and provide pool and cover habitat. These structures will be used extensively in the tributary channels S1 and S2.

6.5 Vegetation

The vegetative components of this project include riparian buffer planting, invasive species management, and temporary seeding for erosion control. In addition, any areas of the site that are disturbed, lack diversity, or would be adversely impacted by the construction process will be replanted.

The restoration of the streams may result in a raised water table, a longer retention time of rainfall runoff, and the restoration of a natural flooding regime, which in turn may allow the natural return of wetlands to the project site.

6.5.1 Stream Bank and Riparian Area Re-Vegetation at City Pond Site

The stream banks and the adjacent riparian area of the proposed project will be planted with both woody and herbaceous vegetation as shown on the plan sheets. Any stream banks above bankfull with a 2:1 slope or steeper will be vegetated using the live stake technique. A buffer of woody and herbaceous species will be installed adjacent to both sides of the proposed stream throughout the project reach. The remainder of the site will be stabilized with herbaceous vegetation in accordance with the North Carolina Erosion and Sedimentation Control Ordinance.

A schedule of plants for use on this project is shown in Table 6.7.

TABLE 6.7
Plant Schedule
City Pond Site Restoration Plan

COMMON NAME	BOTANICAL NAME
Trees for Buffer Planting	
Quercus phellos	Willow Oak
Quercus nigra	Water Oak
Carya ovata	Shagbark Hickory
Platanus occidentalis	Sycamore
Ulmus Americana	American Elm
Fraxinus pennsylvanica	Green Ash
Diospyros virginiana	Persimmon
Native Species for Stream Banks and Buffers	
Carex vulpinoidea	Fox Sedge
Carex lupulina	Hop sedge
Juncus effusus	Soft Rush
Elymus virginica	Virginia Wild Rye
Panicum virgatum	Switchgrass
Woody Vegetation for Live Stakes	
Salix nigra	Black Willow
Cornus amomum	Silky Dogwood
Sambueus canadensis	Elderberry

6.5.2 Temporary Seeding

Temporary seeding of any area disturbed longer than 14 days shall follow the guidelines specified in the *North Carolina Erosion and Sedimentation Control Manual.* All permanent seeding of grasses within the buffer and on the stream banks shall be in accordance with Table 6.8. The seeding schedule for temporary stabilization or in areas not including the stream banks and buffer is shown in Table 20.

TABLE 6.8
Seeding Schedule
Grass Stabilization for Temporary Erosion Control and Project Areas Outside of the Easement Boundary

PERMANENT SPECIES				**WINTER**	**SPRING**	**SUMMER**	**FALL**
				Nov. 1 - Mar 15	**Mar 15 - May 15**	**May 15 – Aug 15**	**Aug 15 - Nov 1**
COMMON NAME	**BOTANICAL NAME**	**UNITS**	**QUANTITY**				
Redtop	*Agorstis alba*	lbs	25	X	X	X	X
Reed Canarygrass	*Phalans arundinaceae*	lbs	40	X	X	X	X
	TOTAL	**lbs**	**215**				
SOIL AMENDMENTS		**UNITS**	**QUANTITY**				
Agricultural Lime		lbs	4,000	X	X	X	X
Superphosphate		lbs	500	into seedbed at preparation			
10-10-10 Fertilizer		lbs	1,000	X	X	X	X
MULCH		**UNITS**	**QUANTITY**				
Small Grain Straw Mulch		lbs	3,000	X	X	X	X
STARTER SPECIES (nurse seed)		**UNITS**	**QUANTITY**				
Rye Grain	*Secale cereale*	lbs	40	X			
Common Millet		lbs	15			X	
German Millet		lbs	10			X	

Notes:

All quantities shown are per acre.

6.5.3 Invasive Species

The site has little existing riparian vegetation other than field grasses, although blackberry (*Rubus* spp.), multiflora rosa (*Rosa multiflora)* and privet (*Ligustrum sinense*) are present. These invasive species could potentially become a nuisance. If these or other invasive species become problematic and persist beyond three years after the stream restoration has been constructed, measures should be taken to suppress these species with hand cutting and herbicide.

7 Monitoring and Evaluation

Environmental components monitored in this project will be those that allow an evaluation of channel stability and survivability of riparian vegetation. Post-restoration monitoring will be conducted for five years following the completion of construction to document project success.

An as-built report will be produced for the site within 90 days following completion of construction on the site. The report will include elevations, photographs, sampling plot locations, and a list of the species planted and the associated densities. Following the as-built report, monitoring reports will be produced annually for five years. These reports will be prepared and submitted to the NCEEP by November 30 during each monitoring year. Annual monitoring reports will document the parameters described below.

7.1 Vegetation Monitoring

All woody vegetation will be flagged and evaluated for at least five years to determine survival. At least two staked survival plots shall be evaluated. Plots should include both live staked and other planted areas. Plots will be 25 feet by 100 feet and all flagged stems will be counted in those plots. Success of woody vegetation plantings will be defined as 320 stems per acre after five years. When woody 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 required.

Herbaceous vegetation, typically native grasses, planted at the site shall have at least 95% coverage of the seeded/planted area. No bare patches shall exceed 10 square feet. Any herbaceous vegetation not meeting these criteria shall be replaced. At a minimum, at all times ground cover at the project site shall be in compliance with the North Carolina Erosion and Sedimentation Control Ordinance.

7.2 Stream Monitoring

Geomorphic monitoring of restored stream reaches will be conducted for a five years to evaluate the effectiveness of the restoration practices. Monitored stream parameters include stream dimension (cross-sections), pattern (longitudinal survey), profile (profile survey), and photographic documentation. The methods used and any related success criteria are described below for each parameter.

7.2.1 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.

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

7.2.2 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).

7.2.3 Longitudinal Profile

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 maximum pool depth. The survey will be tied to a permanent benchmark.

The as-built longitudinal profiles should show that the bedform features are remaining stable, i.e., they are not aggrading or degrading. The pools should remain deep with flat water surface slopes and the riffles should remain steeper and shallower.

7.2.4 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.

The stream will be photographed longitudinally beginning at the downstream end of the restoration 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.

Reference photo transects will also 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.

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.

7.3 Maintenance Issues

Maintenance requirements vary from site to site and are driven by the following conditions:

- Projects without established woody floodplain vegetation are more susceptible to erosion from floods than those with a mature hardwood forest.
- Projects with sandy non-cohesive soils are more prone to short-term bank erosion than cohesive soils or soils with high gravel and cobble content.
- Urban/suburban sites with rapidly changing hydrology are more prone to short-term bank and floodplain erosion than forested watersheds.
- Alluvial valley channels with wide floodplains are less vulnerable than confined channels.
- Wet weather during construction can make accurate channel and floodplain excavations difficult.
- Extreme and/or frequent flooding can cause floodplain and channel erosion.
- Cold weather during and after construction can limit vegetation growth, particularly temporary and permanent seed.
- The presence and aggressiveness of invasive species can affect the extent to which a native vegetative buffer can be established.

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Figures

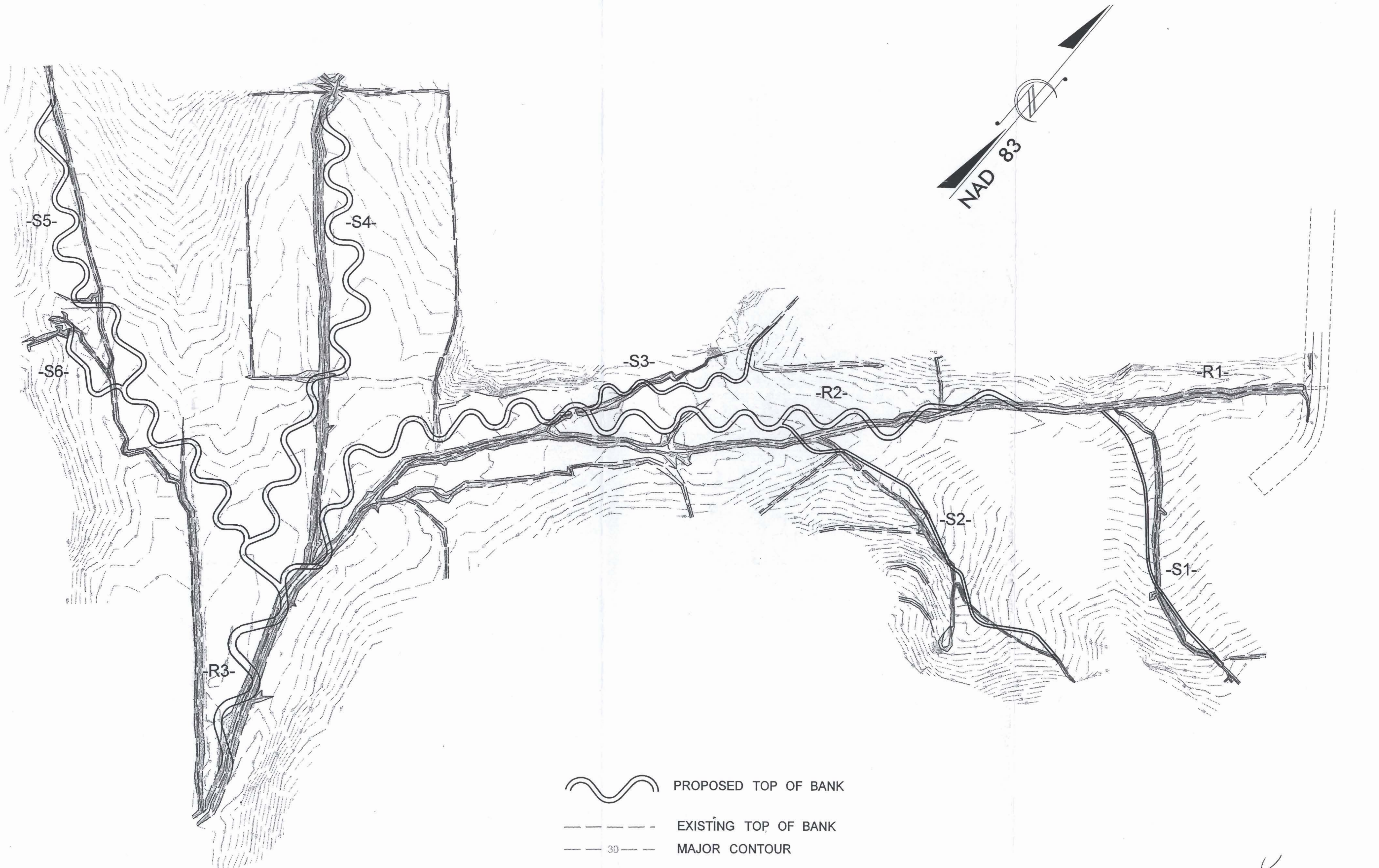


FIGURE 1.1
SITE OVERVIEW

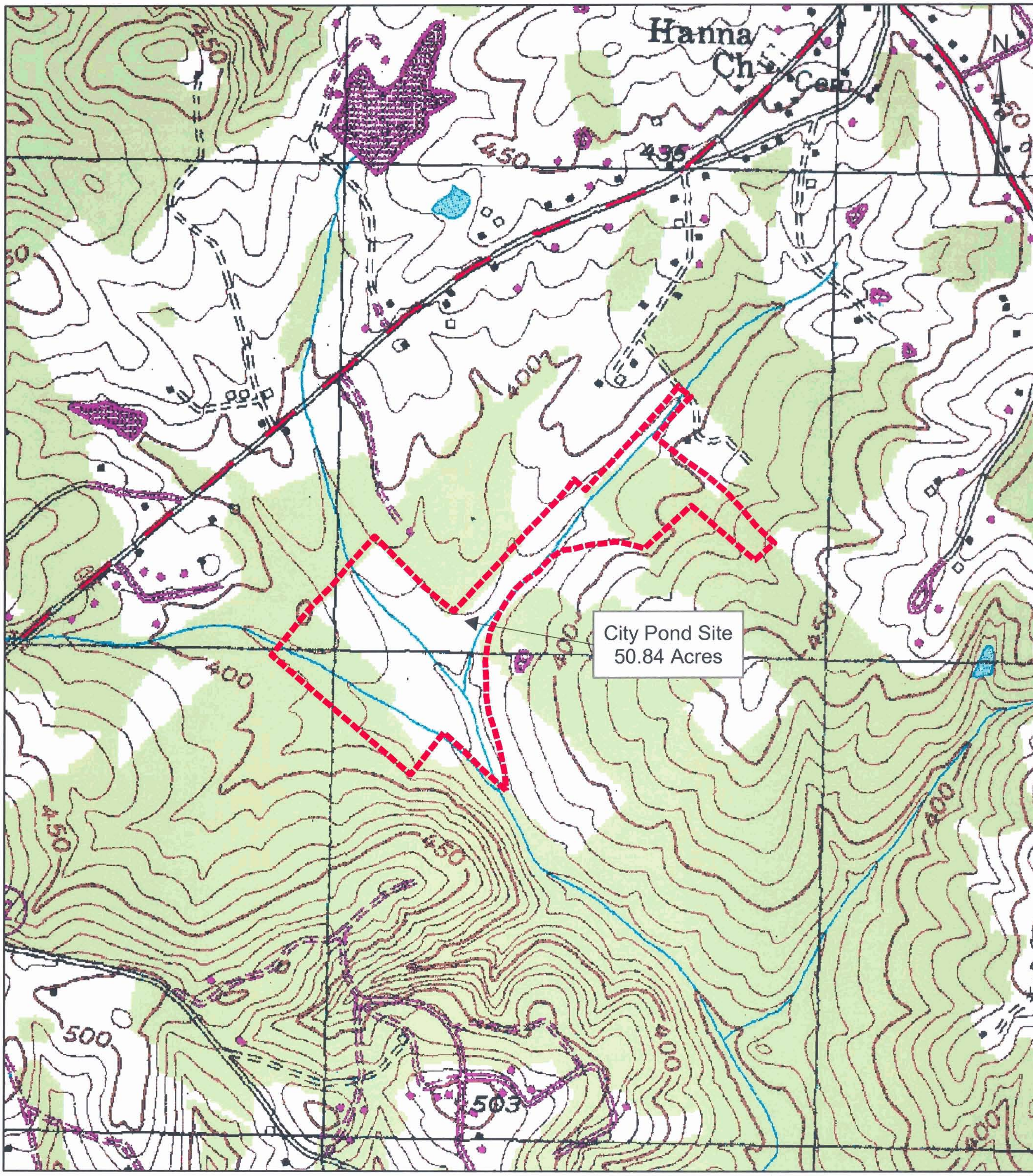
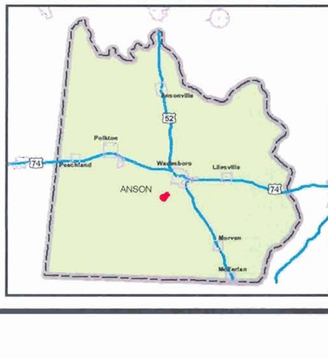


Figure 1.2. Project Vicinity Map

Environmental Banc and Exchange, LLC
8000 Regency Parkway, Suite 200A
Cary, NC 27511

0 500 1,000 2,000 Feet



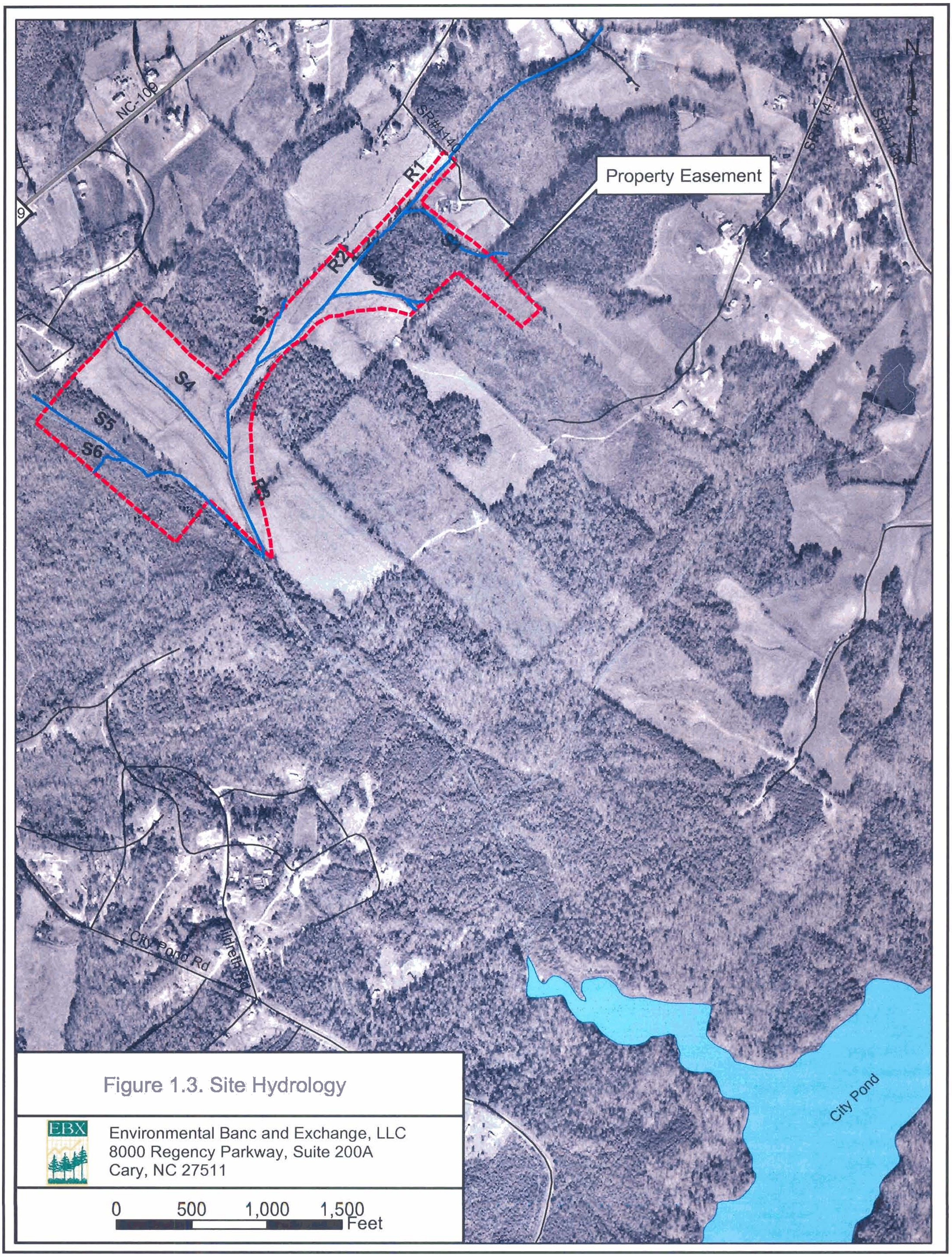


Figure 1.3. Site Hydrology

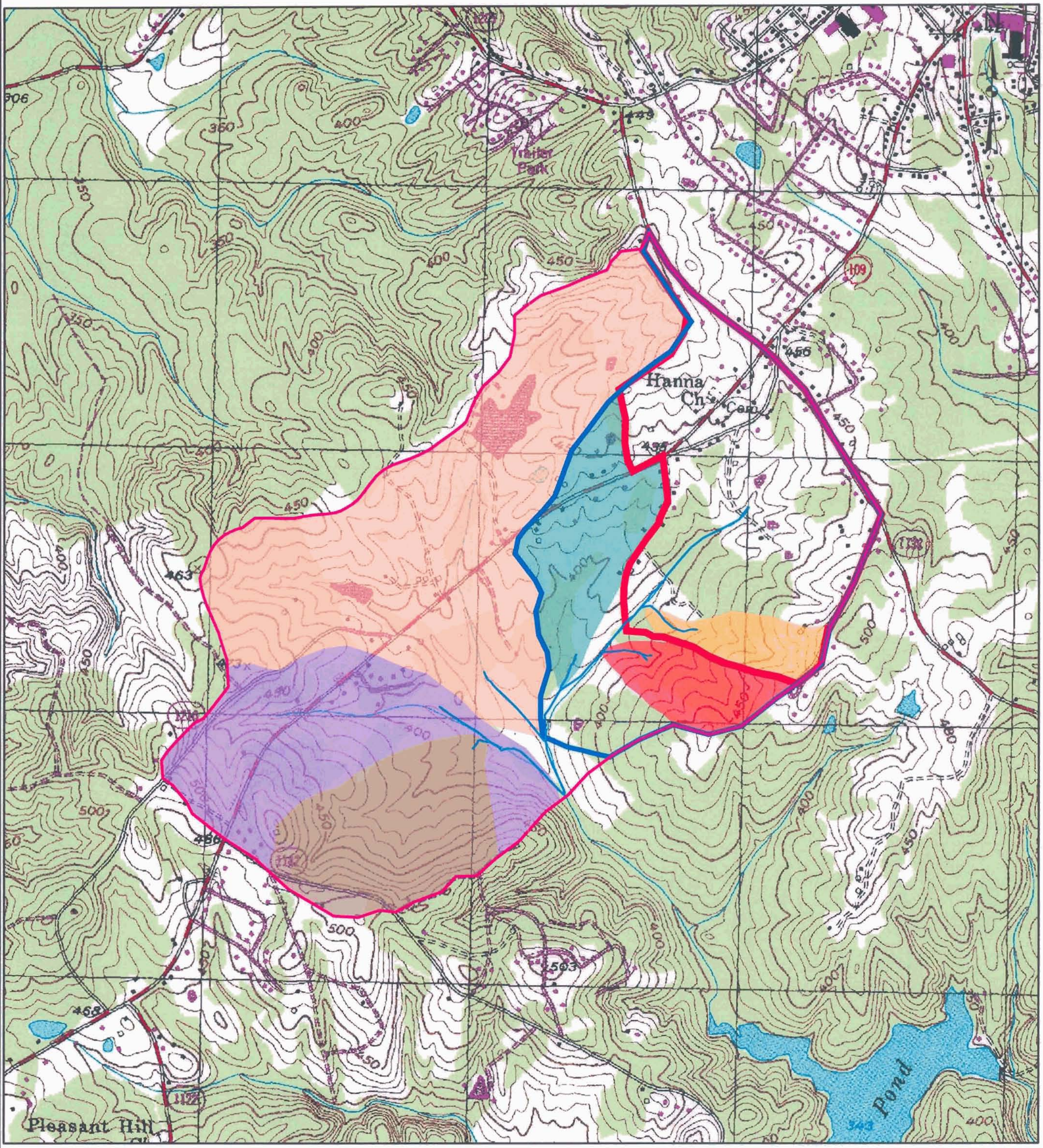
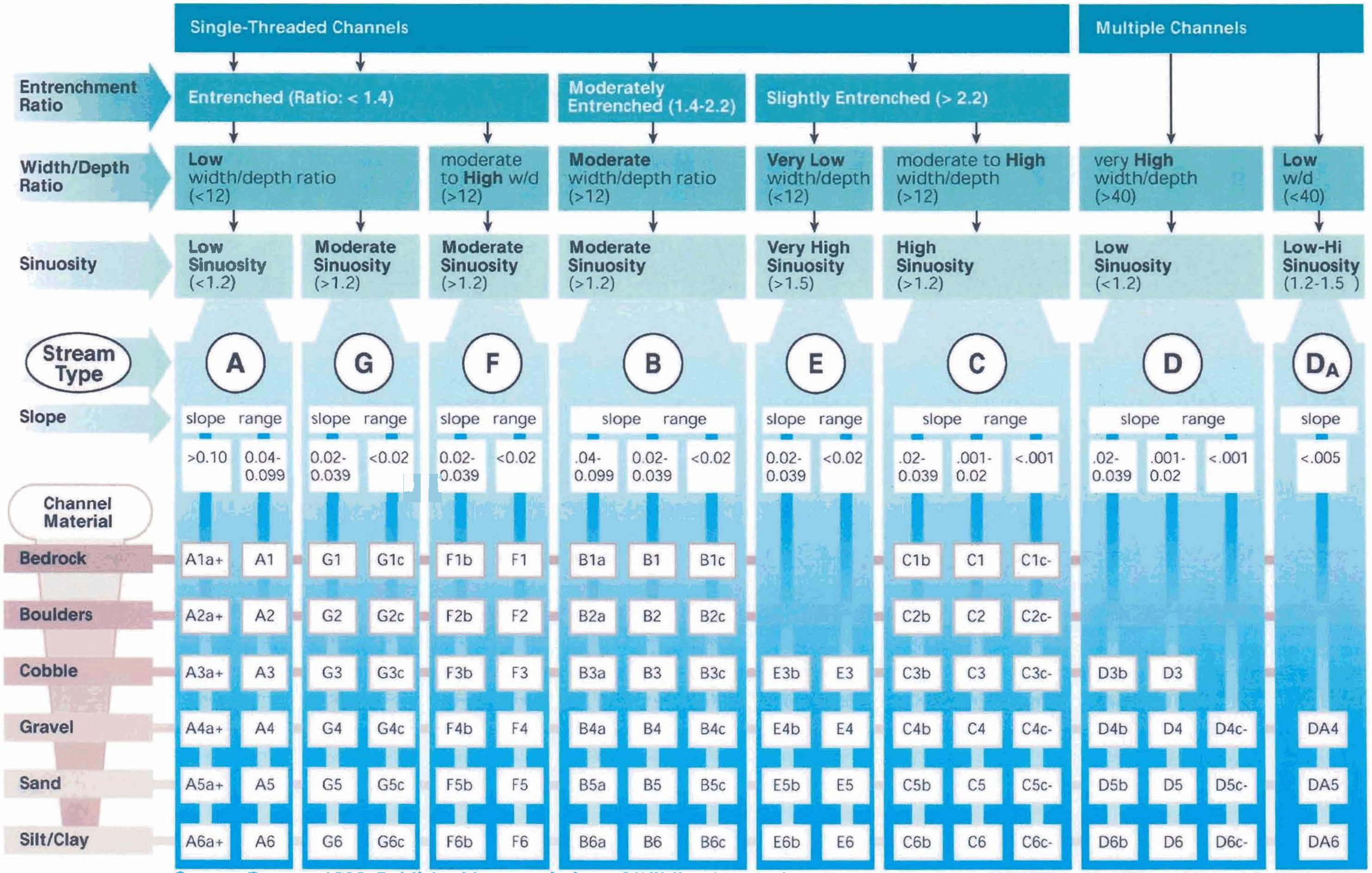


Figure 1.4. Watershed Map

Environmental Banc and Exchange, LLC
8000 Regency Parkway, Suite 200A
Cary, NC 27511

0 1,000 2,000 3,000 Feet

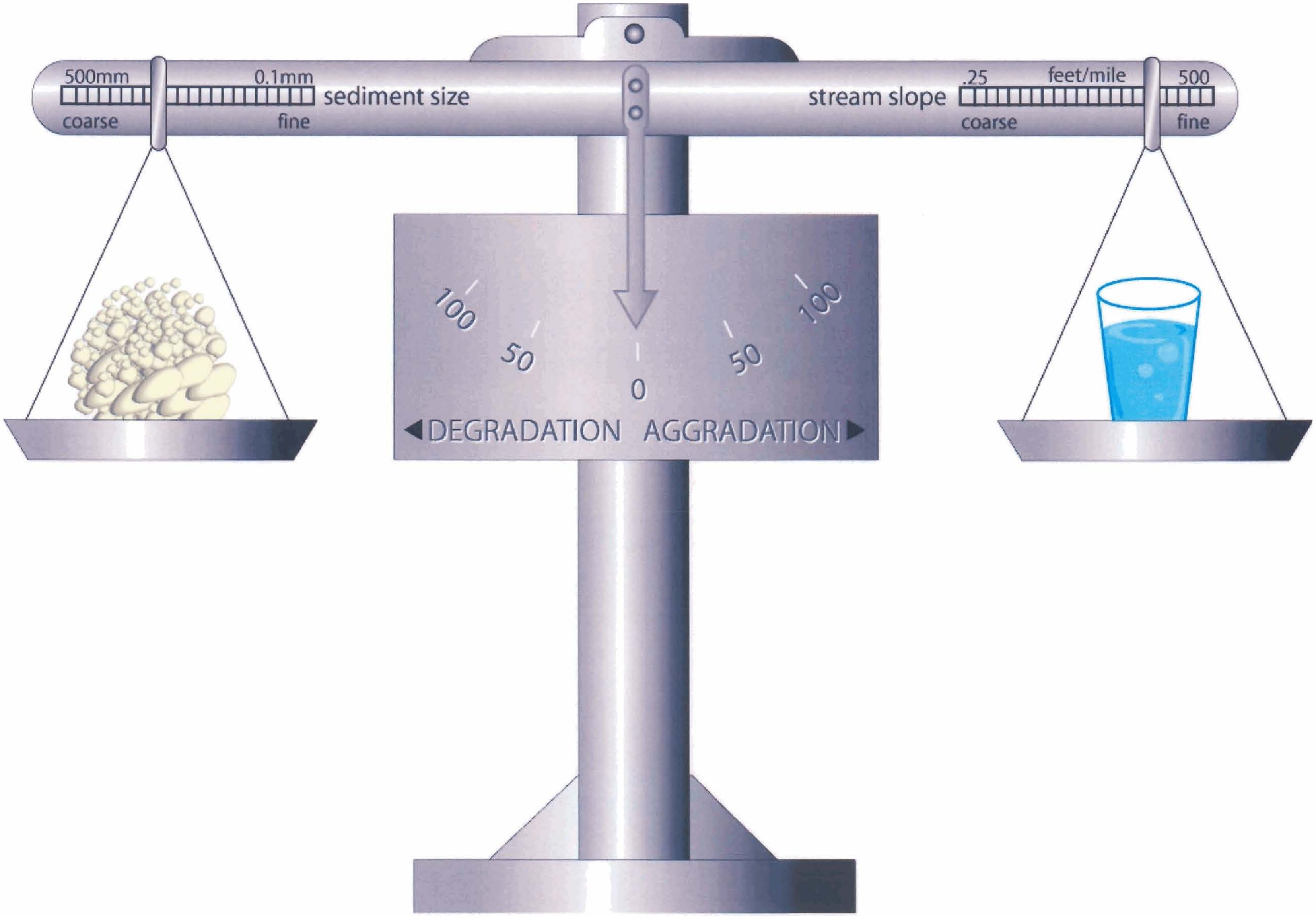


Source: Rosgen 1996. Published by permission of Wildland Hydrology.

Fig. 7.12 -- Rosgen's stream classification system (Level II).
In Stream Corridor Restoration: Principles, Processes, and Practices, 10/98.
Interagency Stream Restoration Working Group (FISRWG)(15 Federal agencies of the US).

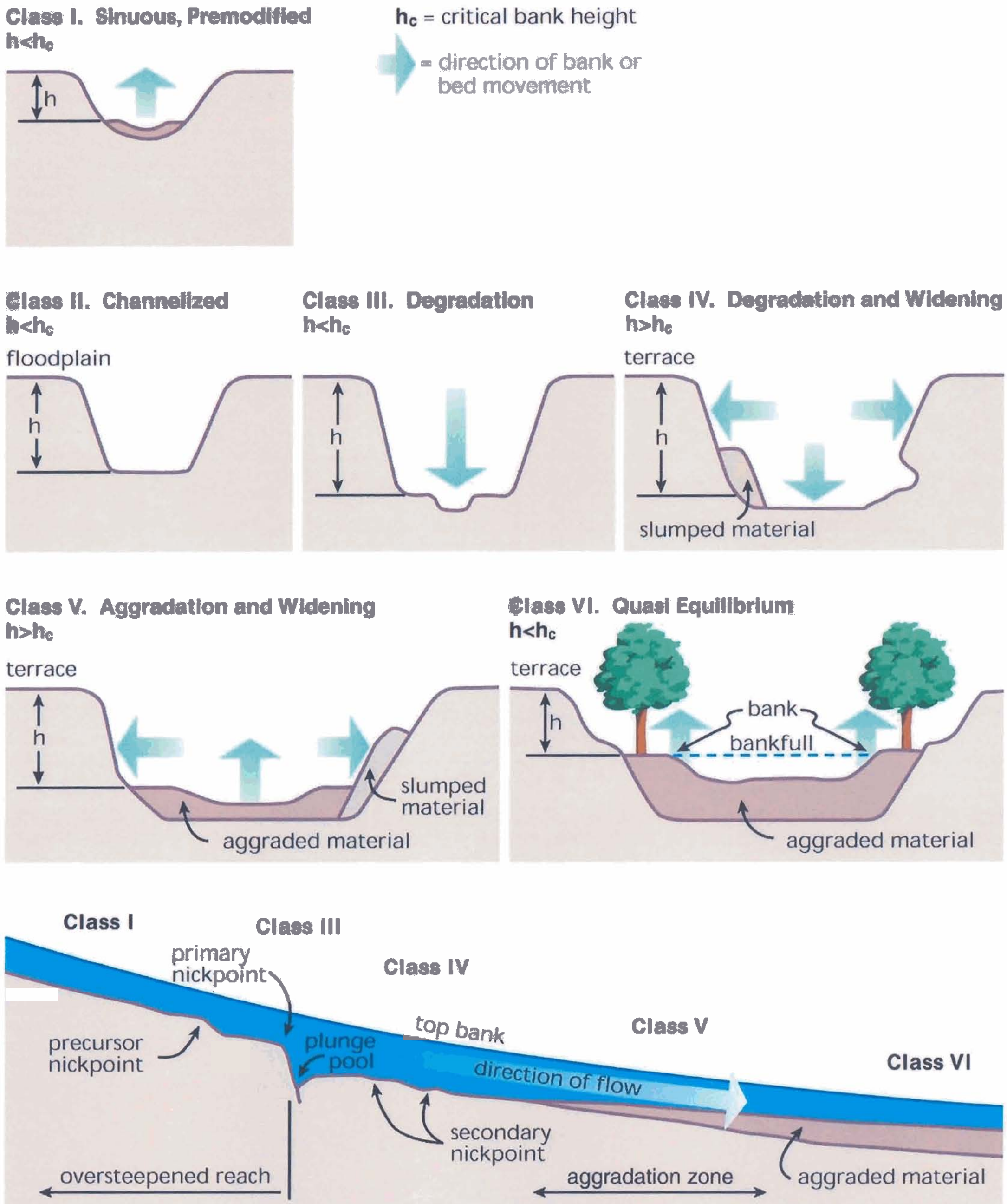
Figure 2.1
Rosgen Stream Classification
City Pond Site Restoration Plan

Source: Rosgen, David L., *Applied River Morphology*, Wildland Hydrology, 1996



After: Lane, 1955

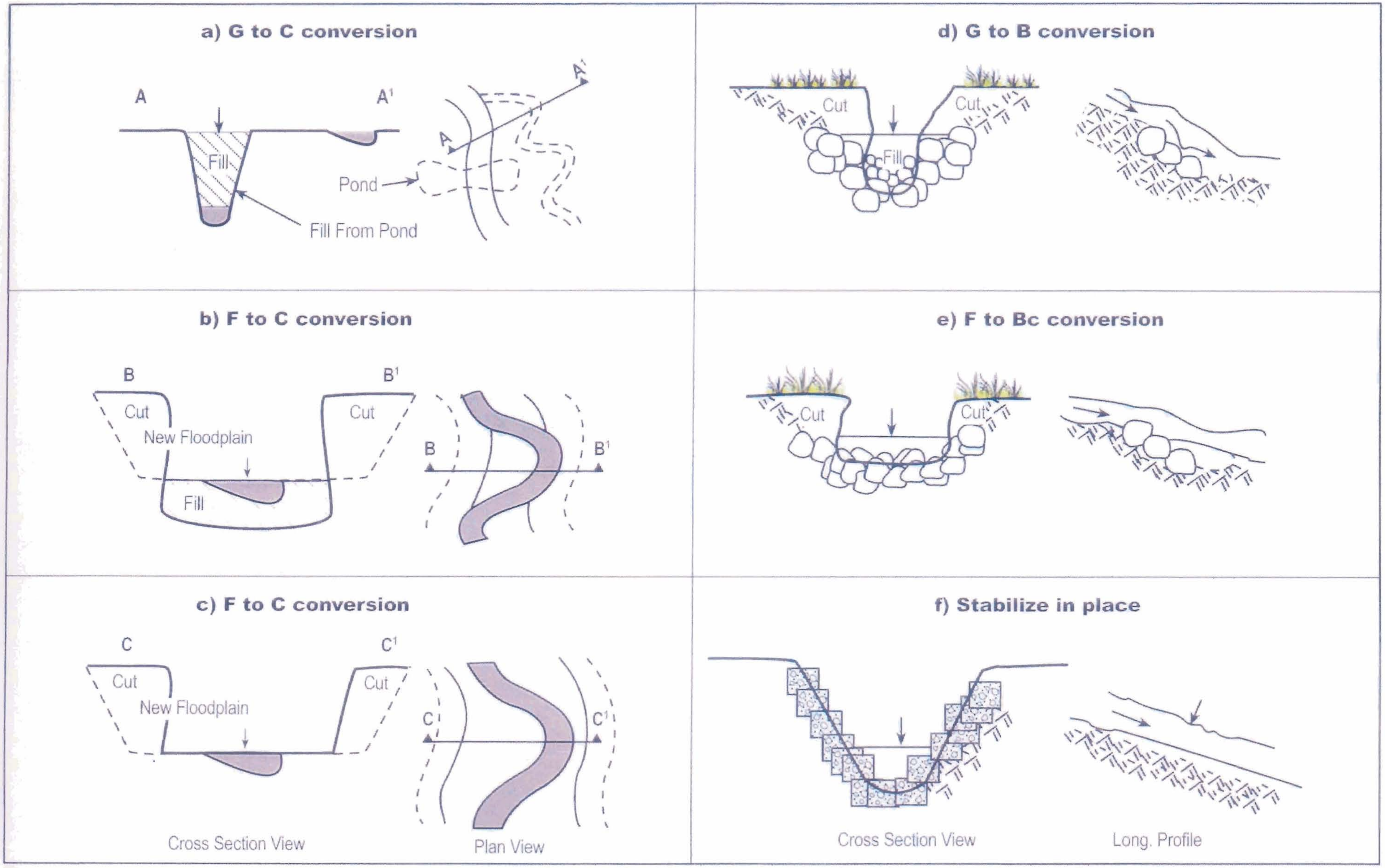
Figure 2.2
Factors Influencing Stream Stability
City Pond Site Restoration Plan



Source: Simon, 1989; US Army Corps of Engineers, 1990.
Fig. 7.14 -- Channel evolution model..
In Stream Corridor Restoration: Principles, Processes, and Practices, 10/98.
Interagency Stream Restoration Working Group (FISRWG)(15 Federal agencies of the US).

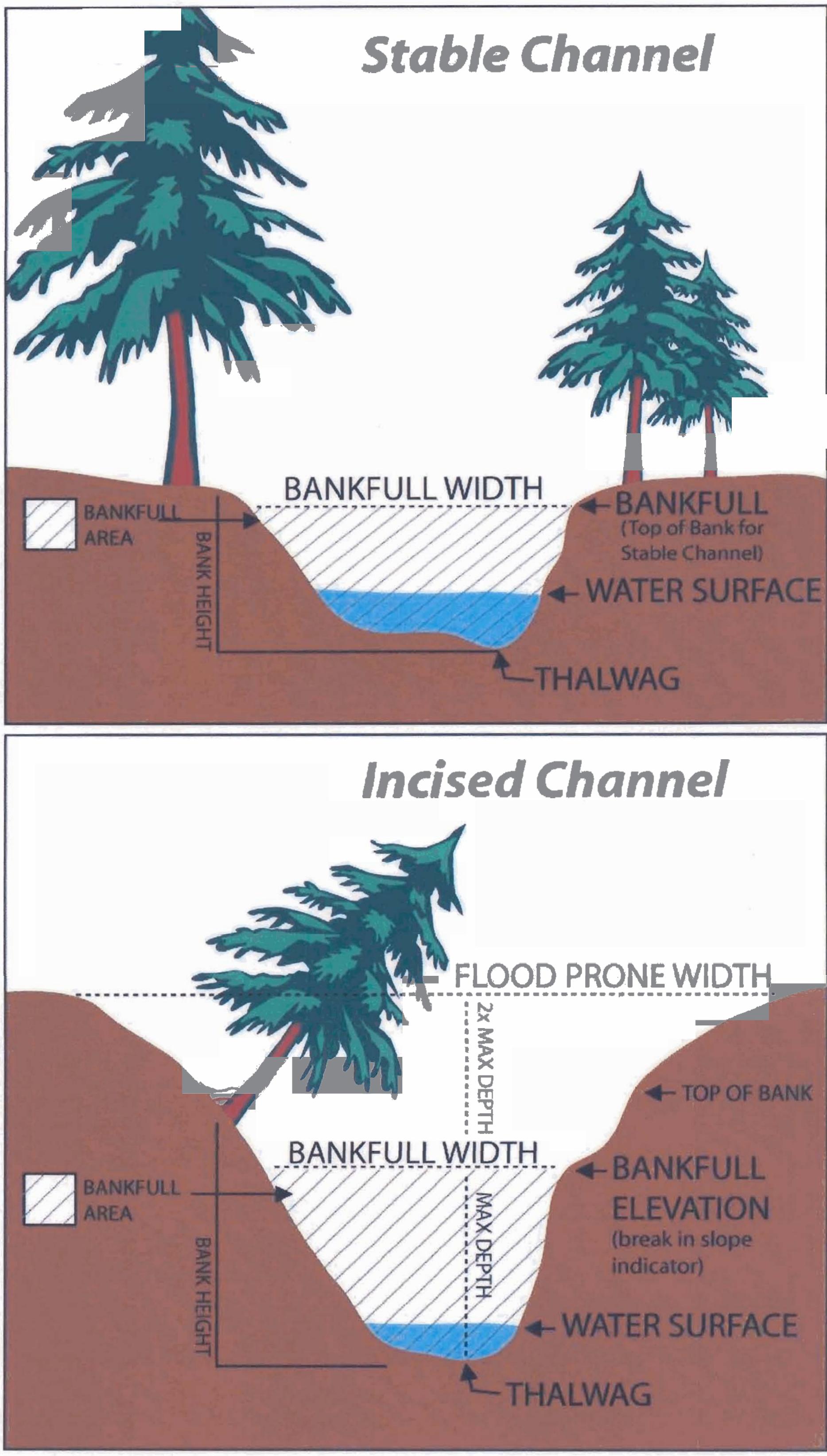
Figure 2.3
Simon Channel Evolution Model

Source: Simon, 1989



Source: Rosgen, David L., "A Geomorphological Approach to Restoration of Incised Rivers," *Proceedings of the Conference on Management of Landscapes Disturbed by Channel Incision*, 1997

Figure 2.4
Restoration Priorities for Incised Channels
City Pond Restoration Plan



Channel Dimension Measurements

Bankfull Elevation is associated with the channel forming discharge. It is the point where channel processes and flood plain processes begin.

Bankfull width: the distance between the left bank bankfull elevation and the right bank bankfull elevation

Bankfull mean depth: the average depth from bankfull elevation to the bottom of the stream channel

the deepest point within the cross-section measured to the bankfull elevation

Width to Depth Ratio: Bankfull width ÷ Bankfull mean depth

Bank Height Ratio: Bank height (measured from top of bank to the bottom of the stream channel) ÷ the max depth of the bankfull elevation (dmax)

Flood Prone Width: Width measured at the elevation of two times (2x) the maximum depth at bankfull (dmax)

Entrenchment Ratio: Floodprone width ÷ bankfull width

Figure 2.5
Channel Dimension Measurements
City Pond Site Restoration Plan

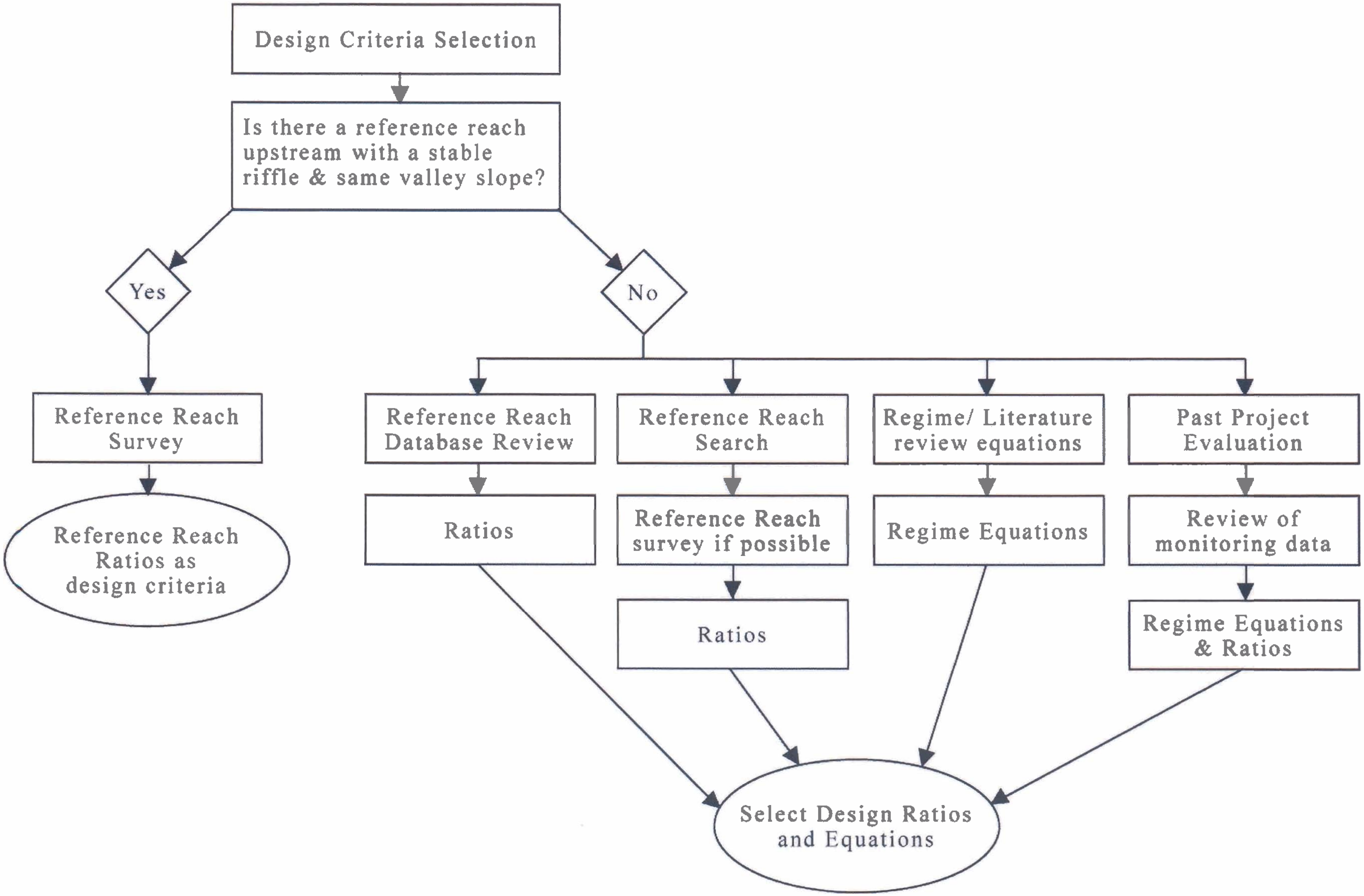


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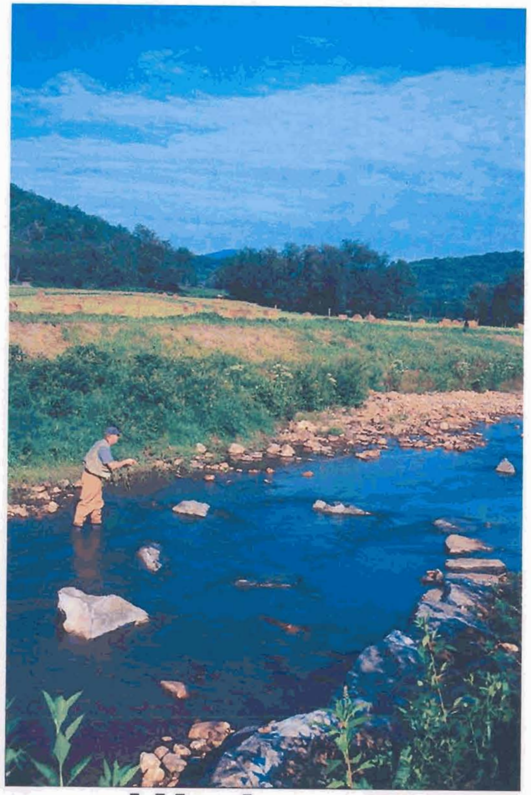
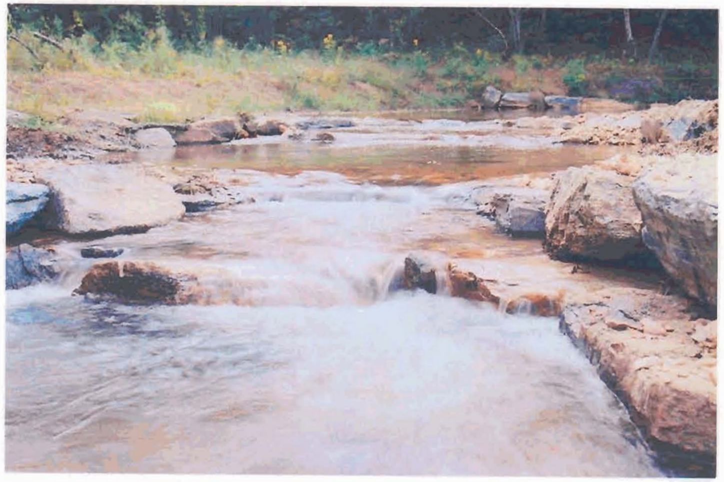
Figure 2.6
Design Criteria Selection
City Pond Site Restoration Plan



J-Hook

Double Wing Deflector

Rock Vane



Double Drop Rock Cross Vane

Figure 2.7
Examples of Instream Structures
City Pond Site Restoration Plan

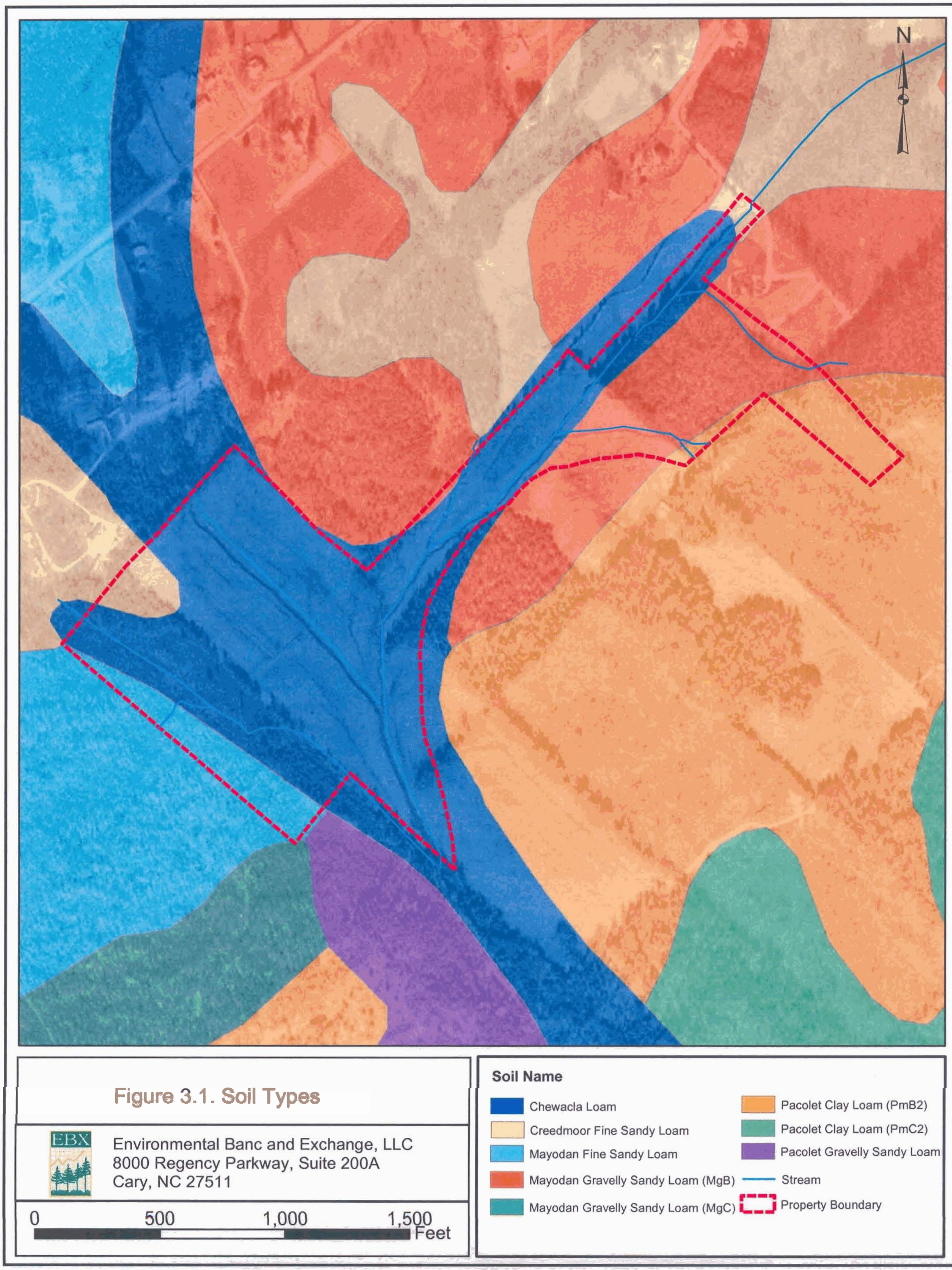
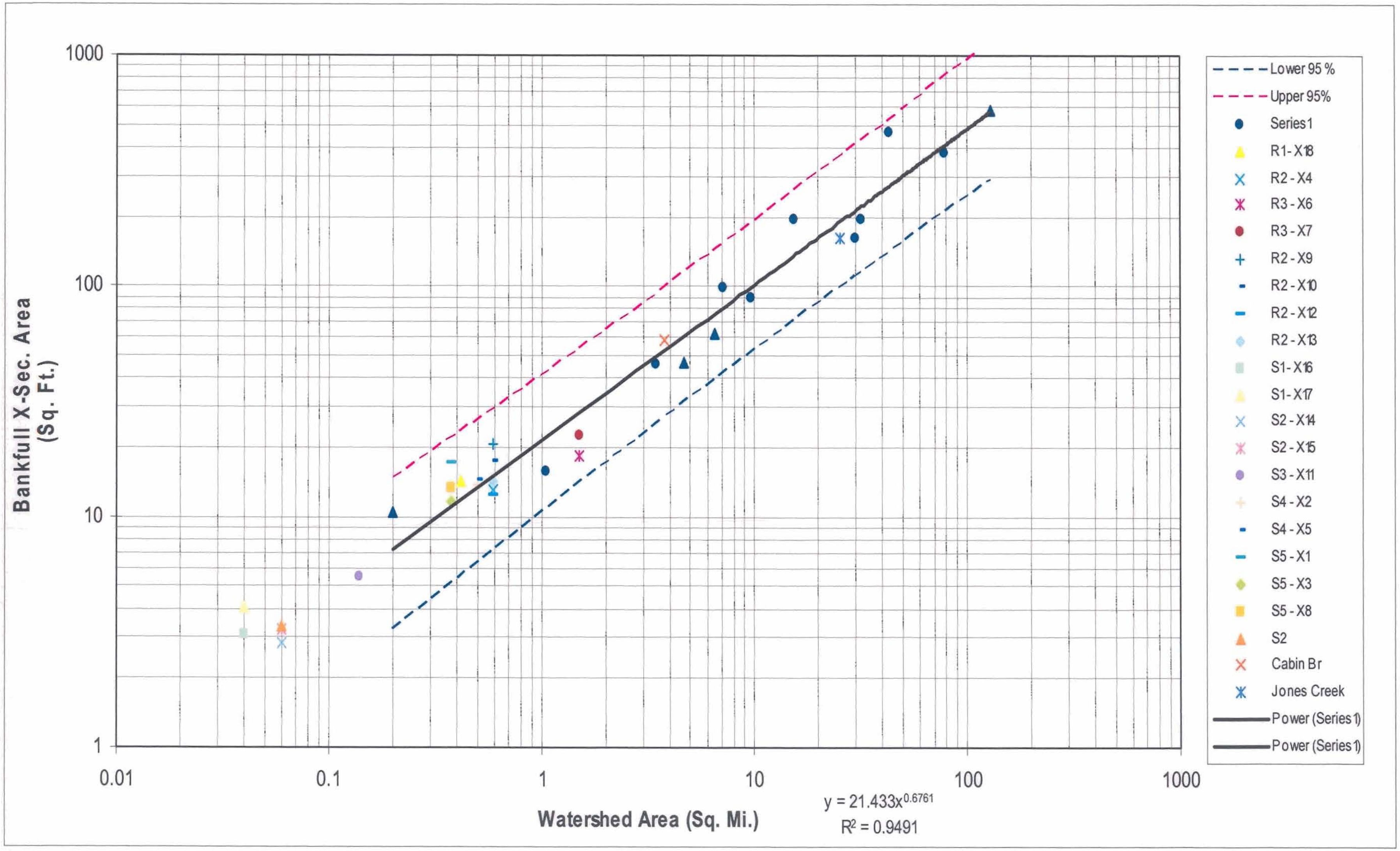


Figure 3.1. Soil Types

Environmental Banc and Exchange, LLC
8000 Regency Parkway, Suite 200A
Cary, NC 27511



Note: Project data points were not used in determining the regression line

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Figure 4.1
NC Rural Piedmont Regional Curves with Bankfull Discharge for Project Reaches and Reference Cross-Sections
City Pond Site Restoration Plan

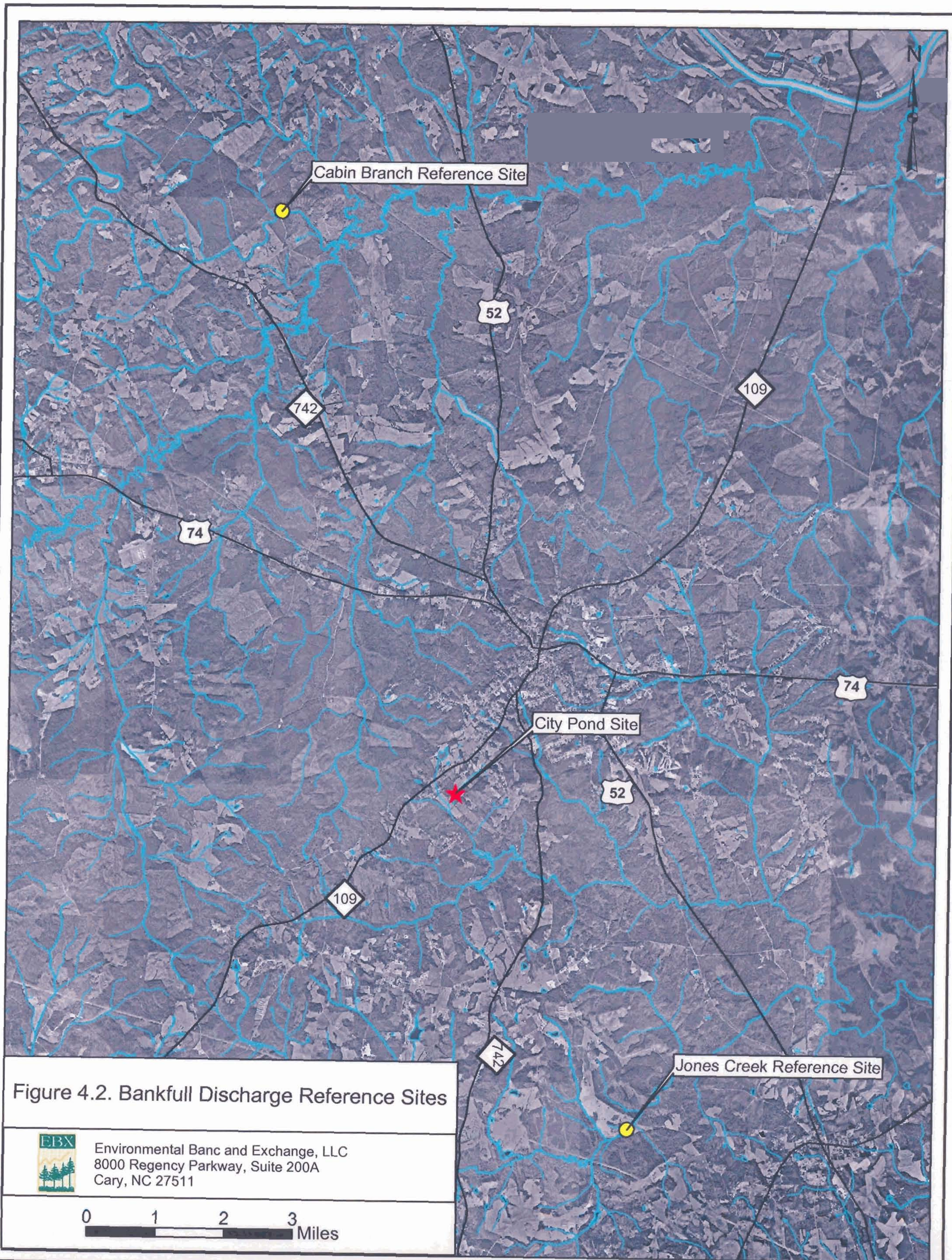

Figure 4.2. Bankfull Discharge Reference Sites

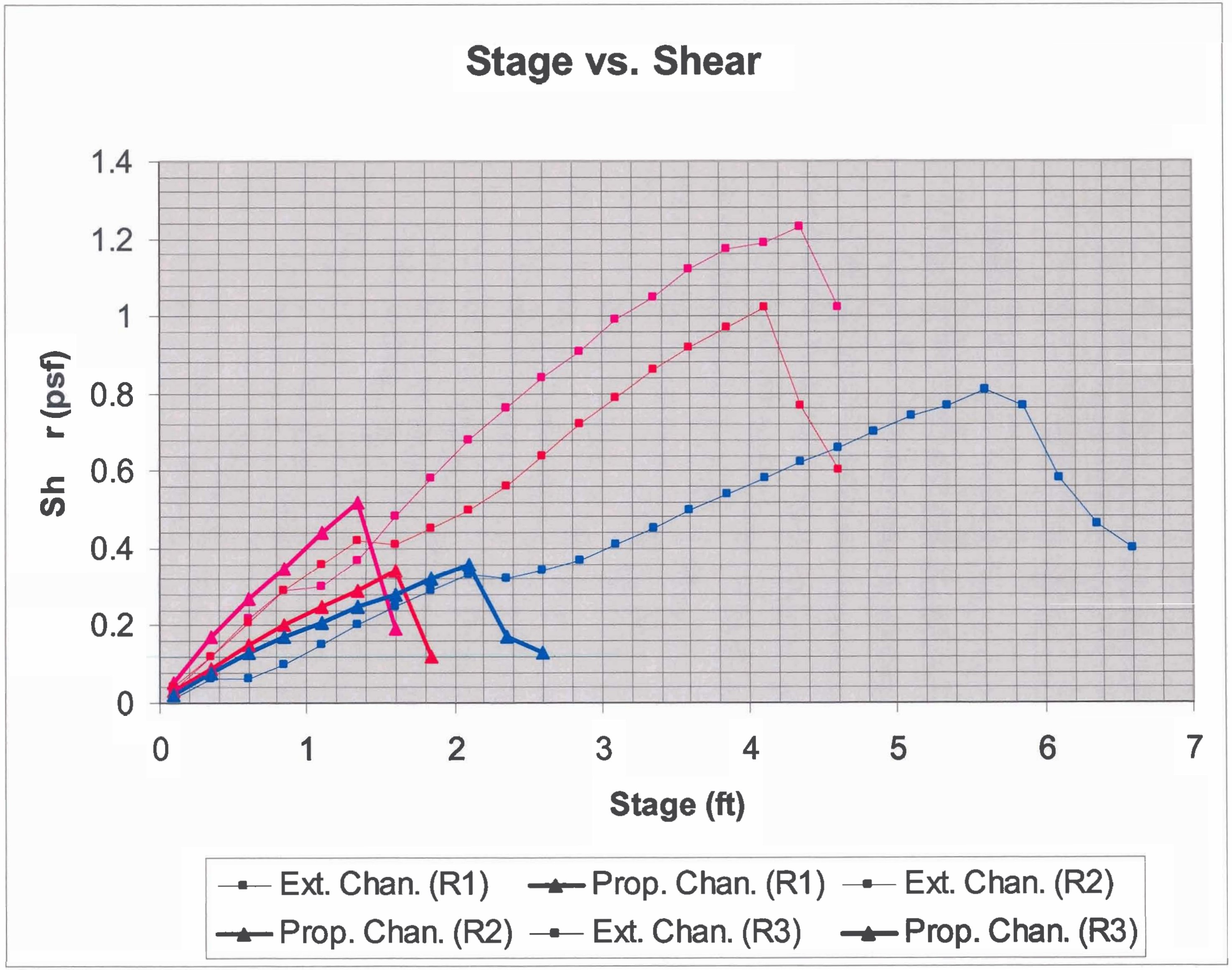

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Figure 6.1
Stage vs. Shear for R1, R2, and R3 (Existing and Proposed Channel)
City Pond Site Restoration Plan

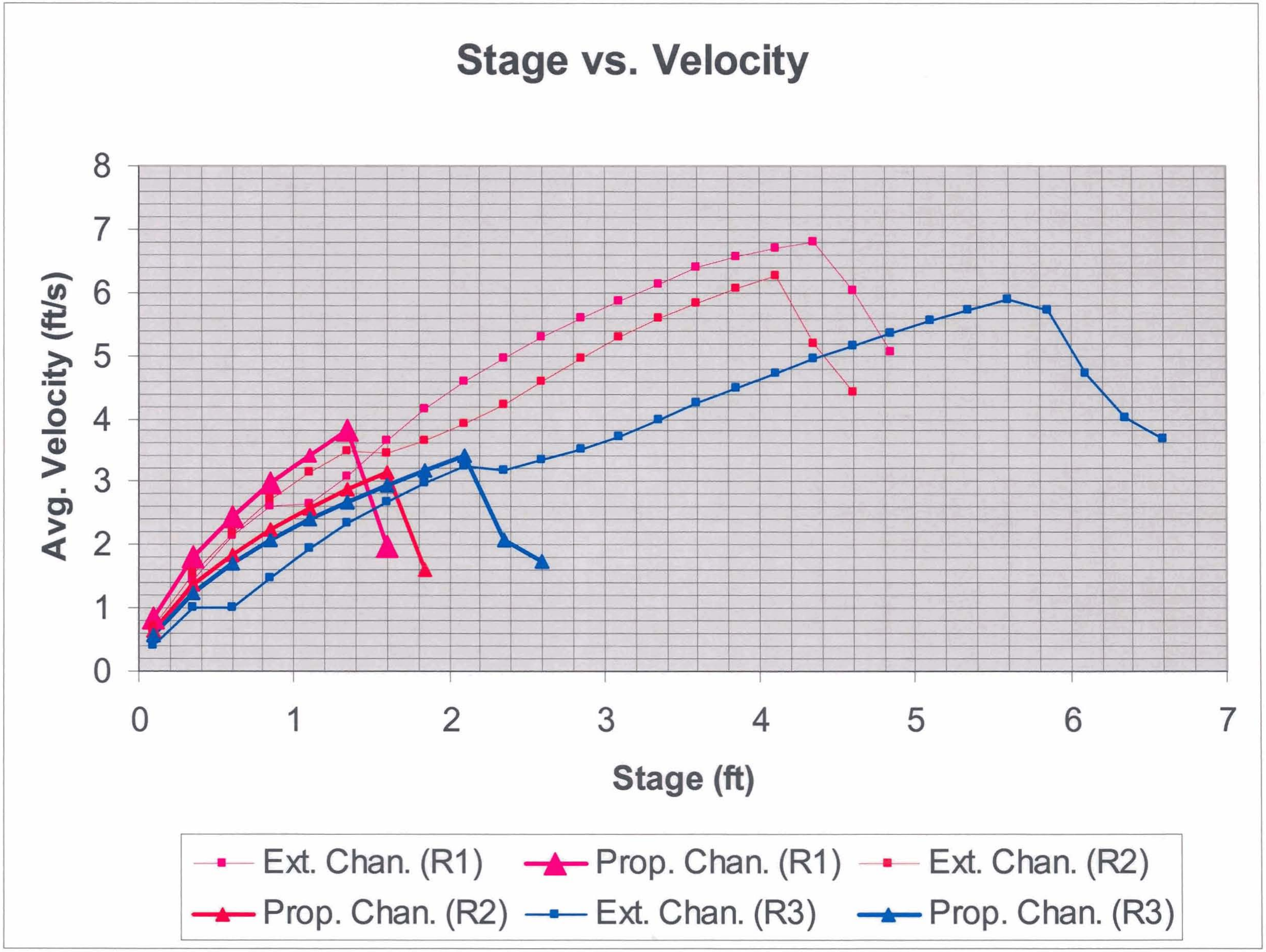

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Figure 6.2
Stage vs. Velocity for R1, R2, and R3 (Existing and Proposed Channel)
City Pond Site Restoration Plan

Appendix A

Cultural Resources Correspondence

North Carolina Department of Cultural Resources
State Historic Preservation Office
David L. S. Brook, Administrator

Michael F. Easley, Governor
Lisbeth C. Evans, Secretary
Jeffrey J. Crow, Deputy Secretary
Office of Archives and History

Division of Historical Resources

November 24, 2003

Chris Huysman
Wetland and Natural Resource Consultants, Inc.
Newton Office
PO Box 224
Newton, NC 28658

Re: Reviews of County Stream Restoration Sites and One Review for Tar-Pam Wetland Mitigation and Stream Restoration Sites, Multi-County, ER03-3022 through ER03-3026

Dear Mr. Huysman:

Thank you for your letters of October 7, 2003, concerning the above project.

We have conducted a review of the proposed undertaking and are aware of no historic resources which would be affected by the project. Therefore, we have no comment on the undertaking as proposed.

The above comments are made pursuant to Section 106 of the National Historic Preservation Act and the Advisory Council on Historic Preservation's Regulations for Compliance with Section 106 codified at 36 CFR Part 800.

Thank you for your cooperation and consideration. If you have questions concerning the above comment, please contact Renee Gledhill-Earley, environmental review coordinator, at 919/733-4763. In all future communication concerning this project, please cite the above-referenced tracking number.

Sincerely,

Renee Gledhill-Earley
David Brook

www.hpo.dcr.state.nc.us

	Location	Mailing Address	Telephone/Fax
ADMINISTRATION	507 N. Blount St., Raleigh NC	4617 Mail Service Center, Raleigh NC 27699-4617	(919) 733-4763 • 733-8653
RESTORATION	515 N. Blount St., Raleigh NC	4617 Mail Service Center, Raleigh NC 27699-4617	(919) 733-6547 • 715-4801
SURVEY & PLANNING	515 N. Blount St., Raleigh NC	4617 Mail Service Center, Raleigh NC 27699-4617	(919) 733-6545 • 715-4801

NCDENR

North Carolina Department of Environment and Natural Resources

Michael F. Easley, Governor

William G. Ross, Jr., Secretary

October 21, 2003

Mr. Chris Huysman
Wetland and Natural Resource Consultants, Inc.
P.O. Box 224
Newton, NC 28658

Subject: Anson County Stream Restoration Sites; Wadesboro quadrangle, Anson County

Dear Mr. Huysman:

The Natural Heritage Program has no record of rare species, significant natural communities, or priority natural areas at the sites nor within a mile of the sites. Although our maps do not show records of such natural heritage elements in the project area, it does not necessarily mean that they are not present. It may simply mean that the area has not been surveyed. The use of Natural Heritage Program data should not be substituted for actual field surveys, particularly if the project area contains suitable habitat for rare species, significant natural communities, or priority natural areas.

You may wish to check the Natural Heritage Program database website at <www.ncsparks.net/nhp/search.html> for a listing of rare plants and animals and significant natural communities in the county and on the topographic quad map. Please do not hesitate to contact me at 919-715-8697 if you have questions or need further information.

Sincerely,

Harry E. LeGrand, Jr.

Harry E. LeGrand, Jr., Zoologist
Natural Heritage Program

HEL/hel

1601 Mail Service Center, Raleigh, North Carolina 27699-1601
Phone: 919-733-4984 \ Fax: 919-715-3060 \ Internet: www.enr.state.nc.us

Appendix B

EDR Transaction Screen Map Report

Environmental Data Resources, Inc.

The EDR-Transaction Screen™ Map Report

With Toxicheck/® Analysis

City Pond
Hwy 109
Wadesboro, NC 28135

Inquiry Number: 01058691.1r

October 03, 2003

***The* Source For Environmental Risk Management Data**

3530 Post Road
Southport, Connecticut 06890

Nationwide Customer Service

Telephone: 1-800-352-0050
Fax: 1-800-231-6802
Internet: www.edrnet.com

FORM-HOW

TABLE OF CONTENTS

Thank you for your business.
Please contact EDR at 1-800-352-0050
with any questions or comments.

TOXICHECK®

Subject Property: CITY POND
HWY 109
WADESBORO, NC 28135

Environmental Risk Code: LOW

This code results from the subject property not being listed in those databases as indicated in the Report and not located within : 1/2 mile of a reported Superfund Site (NPL) ; 1/2 mile of a reported Hazardous Waste Treatment, Storage or Disposal Facility (RCRIS-TSDF); 1/4 mile of a reported known or suspect CERCLIS hazardous waste site ; 1/4 mile of a reported known or suspect State Hazardous Waste site (SHWS); 1/2 mile of a reported Solid Waste Facility or Landfill (SWF/LF); or 1/8 mile of a site with a reported Leaking Underground Storage Tank incident (LUST).

This code is based solely on the results of searches of databases comprised of certain governmental records as made available to EDR and reflected in the attached report. Without further confirmation by completing the ASTM Standard E-1528 Transaction Screen and/or a Phase I Environmental Site Assessment, the conditions affecting the property are unknown. Further investigation by an environmental professional may be appropriate. **This Report is not a substitute for a Phase I Environmental Site Assessment conducted by an environmental professional.** Nothing in this Report should be construed to mean that any environmental remediation is or is not necessary with respect to the subject property.

If this information is being used for a commercial property transaction, the government records searched complies with the requirements of the ASTM Standard E-1528 Transaction Screen. However, the ASTM Standard's requirements are not fulfilled until the Applicant Questionnaire and Site Visit (including an investigation of the property's historical use) are completed and reviewed. If this information is being used for an industrial property transaction, the ASTM Standard requires that a Phase I Environmental Site Assessment be performed by an environmental professional.

EXECUTIVE SUMMARY

The EDR-Transaction Screen Map Report is a screening tool which maps sites with potential liability or existing environmental liabilities. Specified government databases are searched in accordance with ASTM Standard E 1528-00.

The ASTM E 1528-00 Transaction Screen property due diligence standard consists of four major components: a government records check, an historical inquiry, an owner/occupant questionnaire, and a site survey. This report contains the results of the government records search on the target property and surrounding area in accordance with the government records search requirements of the ASTM E 1528-00 standard.

The results of the government records search in accordance with **QUESTIONS 21 and 22** (page 15, E 1528-00) of the standard indicated the following:

QUESTION 21
*Do any of the following **Federal** government record systems list the property or any property within the circumference of the area noted below:*

National Priorities List (NPL)	☐ on the property	☐ Within 1 Mile
CERCLIS List	☐ on the property	☐ Within 1/2 Mile
CERCLIS NFRAP List	☐ on the property	☐ Within 1/4 Mile
RCRA-CORRACTS Facilities	☐ on the property	☐ Within 1 Mile
RCRA-TSD Non-CORRACTS Facilities	☐ on the property	☐ Within 1/2 Mile
RCRA LQG Facilities	☐ on the property	☐ Within 1/4 Mile
RCRA SQG Facilities	☐ on the property	☐ Within 1/4 Mile
ERNS	☐ on the property	

QUESTION 22
*Do any of the following **state** government record systems list the property or any property within the circumference of the area noted below:*

State equivalent to NPL	☐ on the property	☐ Within 1 Mile
State equivalent to CERCLIS	☐ on the property	☐ Within 1/2 Mile
Solid Waste/Landfill Facilities (SWF/LS)	☐ on the property	☐ Within 1/2 Mile
Leaking Underground Storage Tank List (LUST)	☐ on the property	☐ Within 1/2 Mile
Underground Storage Tank List (UST)	☐ on the property	☐ Within 1/4 Mile

*In accordance with Section 5.6 (page 10, E 1528) if the answer is **(yes) or unknown,** then the user will have to decide what further action, if any, is appropriate. Answers should be evaluated in light of the other information obtained in the transaction screen process. If the user decides no further inquiry is warranted, the rationale must be documented. If the user decides that further inquiry is warranted, it may be necessary to contact an environmental professional.*

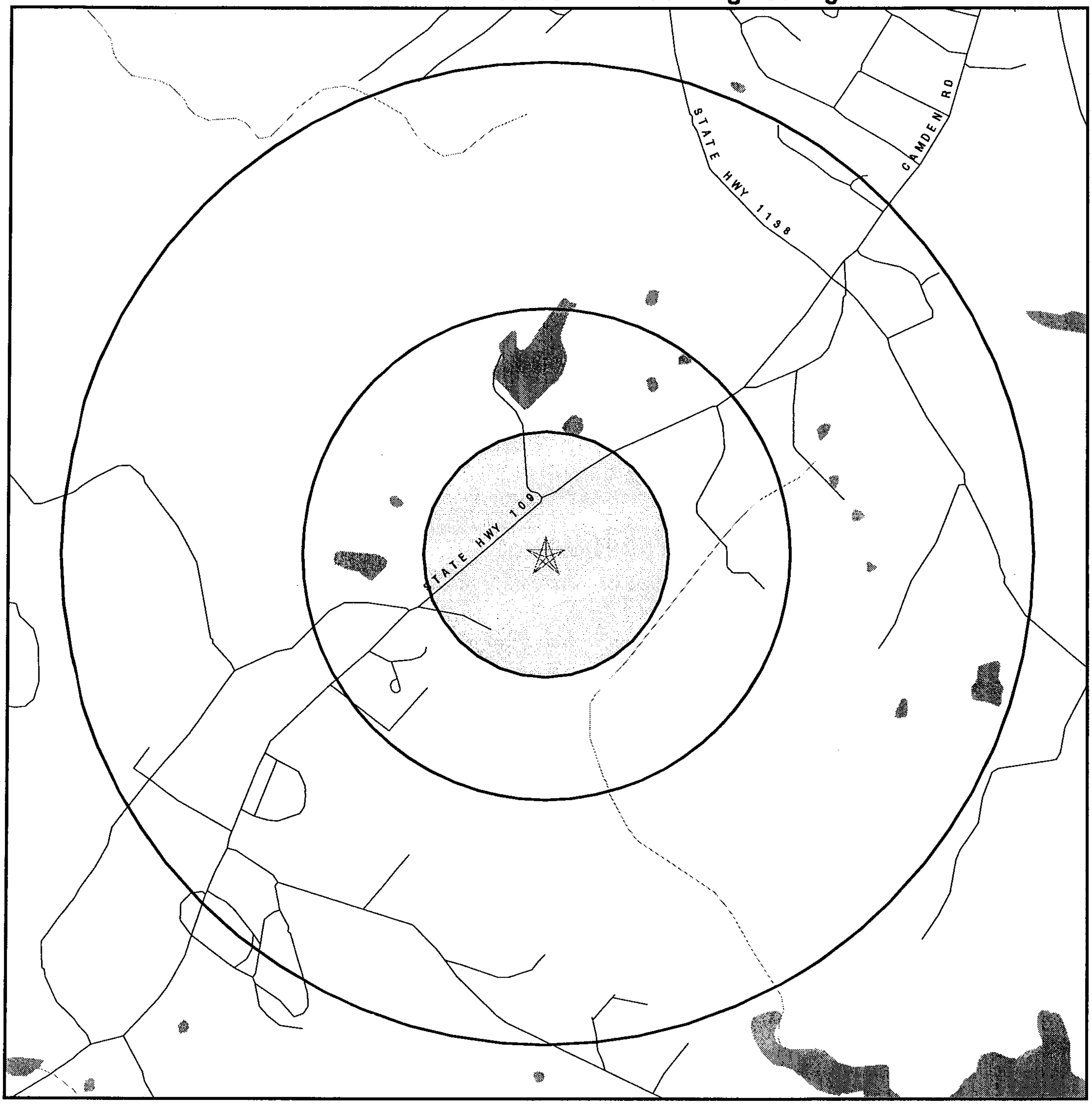
Additional Research - ASTM Supplemental Government Databases

To provide additional information which may assist in the assessment of other components of the ASTM E 1528-00 Transaction Screen, EDR also searches government databases ***not*** included in Questions 21 and 22 of ASTM E 1528-00. This information may be useful in completing the owner/occupant questionnaire.

The results of the search of these additional government records indicated affirmative **(yes)** responses on the target property for the following government databases:

No affirmative responses found in the non-ASTM E 1528-00 government databases.

OVERVIEW MAP - 01058691.1r - Buck Engineering



- Target Property
- Sites at elevations higher than or equal to the target property
- Sites at elevations lower than the target property
- Coal Gasification Sites
- National Priority List Sites
- Landfill Sites
- Dept. Defense Sites
- Oil & Gas pipelines
- Federal Wetlands
- Hazardous Substance Disposal Sites

TARGET PROPERTY:	City Pond	CUSTOMER:	Buck Engineering
ADDRESS:	Hwy 109	CONTACT:	Jessica Rohrbach
CITY/STATE/ZIP:	Wadesboro NC 28135	INQUIRY #:	01058691.1r
LAT/LONG:	34.9396 / 80.1004	DATE:	October 03, 2003 1:04 pm

MAP FINDINGS SUMMARY

Database	Target Property	Search Distance (Miles)	< 1/8	1/8 - 1/4	1/4 - 1/2	1/2 - 1	> 1	Total Plotted
FEDERAL ASTM STANDARD								
NPL		1.000	0	0	0	0	NR	0
Proposed NPL		1.000	0	0	0	0	NR	0
CERCLIS		0.500	0	0	0	NR	NR	0
CERC-NFRAP		0.250	0	0	NR	NR	NR	0
CORRACTS		1.000	0	0	0	0	NR	0
RCRIS-TSD		0.500	0	0	0	NR	NR	0
RCRIS Lg. Quan. Gen.		0.250	0	0	NR	NR	NR	0
RCRIS Sm. Quan. Gen.		0.250	0	0	NR	NR	NR	0
ERNS		TP	NR	NR	NR	NR	NR	0
STATE ASTM STANDARD								
State Haz. Waste		1.000	0	0	0	0	NR	0
State Landfill		0.500	0	0	0	NR	NR	0
LUST		0.500	0	0	0	NR	NR	0
UST		0.250	0	0	NR	NR	NR	0
OLI		0.500	0	0	0	NR	NR	0
INDIAN UST		0.250	0	0	NR	NR	NR	0
VCP		0.500	0	0	0	NR	NR	0
FEDERAL ASTM SUPPLEMENTAL								
Delisted NPL		1.000	0	0	0	0	NR	0
FINDS		TP	NR	NR	NR	NR	NR	0
HMIRS		TP	NR	NR	NR	NR	NR	0
MLTS		TP	NR	NR	NR	NR	NR	0
MINES		TP	NR	NR	NR	NR	NR	0
NPL Liens		TP	NR	NR	NR	NR	NR	0
PADS		TP	NR	NR	NR	NR	NR	0
US BROWNFIELDS		0.500	0	0	0	NR	NR	0
DOD		1.000	0	0	0	0	NR	0
RAATS		TP	NR	NR	NR	NR	NR	0
TRIS		TP	NR	NR	NR	NR	NR	0
TSCA		TP	NR	NR	NR	NR	NR	0
SSTS		TP	NR	NR	NR	NR	NR	0
FTTS		TP	NR	NR	NR	NR	NR	0
STATE OR LOCAL ASTM SUPPLEMENTAL								
NC HSDS		1.000	0	0	0	0	NR	0
AST		TP	NR	NR	NR	NR	NR	0
LUST TRUST		0.500	0	0	0	NR	NR	0
IMD		TP	NR	NR	NR	NR	NR	0
EDR PROPRIETARY HISTORICAL DATABASES								
Coal Gas		1.000	0	0	0	0	NR	0

MAP FINDINGS SUMMARY

Database	Target Property	Search Distance (Miles)	< 1/8	1/8 - 1/4	1/4 - 1/2	1/2 - 1	> 1	Total Plotted
BROWNFIELDS DATABASES								
US BROWNFIELDS		0.500	0	0	0	NR	NR	0
Brownfields		0.500	0	0	0	NR	NR	0
INST CONTROL		0.250	0	0	NR	NR	NR	0
VCP		0.500	0	0	0	NR	NR	0

NOTES:

TP = Target Property

NR = Not Requested at this Search Distance

Sites may be listed in more than one database

Map ID Direction Distance Distance (ft.) Elevation	Site	Database(s)	EDR ID Number EPA ID Number

Coal Gas Site Search: No site was found in a search of Real Property Scan's ENVIROHAZ database.

NO SITES FOUND

ORPHAN SUMMARY

City	EDR ID	Site Name	Site Address	Zip	Database(s)
ANSONVILLE	U001201227	WILLIAM LEE GRAIN BINS	ROUTE 2, BOX 254	28135	UST
POLKTON	U001200671	NORMAN J. HUTTON	ROUTE 1, BOX 88/HWY 74	28135	UST
POLKTON	S104907692	CHAMBERS DEVELOPMENT MSWLF	RT. 1, BOX 235	28135	SWF/LF
POLKTON	U001200734	WADE HOWARD. JR.	S.R. 1121	28135	UST
POLKTON	S105485442	POLKTON DUMP	SR 1415, 2 MI N OF TOWN	28135	OLI
POLKTON	U001200729	TAYLOR'S GROCERY	S.R. 1438	28135	UST
POLKTON	1006809285	PH3 LABORATORIES INC	ROUTE 2 BOX 256 D	28135	RCRIS-SQG, FINDS
POLKTON	U001202282	BURNSVILLE GEN. STORE	RT 2/HWY 42 & BURNSVILLE RD	28135	UST
POLKTON	U001186587	POLKTON GULF SER	HWY 218	28135	UST
POLKTON	U003137823	WHITS	HIGHWAY 74	28135	UST
POLKTON	U002217229	HILDRETH SERVICE STATION	HWY 74 & 218	28135	LUST, UST
POLKTON	1004747325	ANSON COMMUNITY COLLEGE	HWY 74	28135	RCRIS-SQG, FINDS
POLKTON	1001215050	SOUTHERN FABRICATORS INC	HWY 74	28135	RCRIS-SQG, FINDS
POLKTON	S105891817	NATIONWIDE RECYCLERS	HIGHWAY 74	28135	SWRCY
POLKTON	U003147373	FAST SHOP OF BURNSVILLE	HWY 742	28135	UST
POLKTON	U001200732	E.T. SIKES GROCERY	HIGHWAY 742	28135	UST
POLKTON	S105040802	BROWN CREEK CORRECTIONAL FACILITY	US HWY 74	28135	SWF/LF
POLKTON	U003137409	NC DOT - POLKTON (DIV TEN)	PRISON CAMP RD SR #1249	28135	UST
POLKTON	U001186589	BURNSVILLE SERVICE CENTER	S.R.1610	28135	UST
WADESBORO	S104919015	HIGHTOWER ROAD	SR 1101	28170	SHWS
WADESBORO	S105485443	WADESBORO LANDFILL	HWY 52 1/2 MI N OF TOWN		OLI
WADESBORO	S102089421	JACK'S TEXACO #2	HWY 74 W.		IMD, LUST
WADESBORO	S104918919	VC CHEMICAL	STAMBACK FERRY RD	28170	SHWS

AREA RADON INFORMATION

No records reported for ZIP:28135 NC

- Federal EPA Radon Zone for ANSON County, NC: 3

Note : Zone 1 indoor average level > 4 pCi/L.
: Zone 2 indoor average level >= 2 pCi/L and <= 4 pCi/L.
: Zone 3 indoor average level < 2 pCi/L.

- Federal Area Radon Information for ANSON County, NC

Number of sites tested: 2

Area	Average Activity	% <4 pCi/L	% 4-20 pCi/L	% >20 pCi/L
Living Area - 1st Floor	0.100 pCi/L	100%	0%	0%
Living Area - 2nd Floor	Not Reported	Not Reported	Not Reported	Not Reported
Basement	Not Reported	Not Reported	Not Reported	Not Reported

GOVERNMENT RECORDS SEARCHED / DATA CURRENCY TRACKING

To maintain currency of the following federal and state databases, EDR contacts the appropriate governmental agency on a monthly or quarterly basis, as required.

Elapsed ASTM days: Provides confirmation that this EDR report meets or exceeds the 90-day updating requirement of the ASTM standard.

FEDERAL ASTM STANDARD RECORDS

NPL: National Priority List
Source: EPA
Telephone: N/A
National Priorities List (Superfund). The NPL is a subset of CERCLIS and identifies over 1,200 sites for priority cleanup under the Superfund Program. NPL sites may encompass relatively large areas. As such, EDR provides polygon coverage for over 1,000 NPL site boundaries produced by EPA's Environmental Photographic Interpretation Center (EPIC) and regional EPA offices.

Date of Government Version: 07/22/03
Date Made Active at EDR: 08/26/03
Database Release Frequency: Semi-Annually

Date of Data Arrival at EDR: 08/04/03
Elapsed ASTM days: 22
Date of Last EDR Contact: 08/04/03

NPL Site Boundaries

Sources:

EPA's Environmental Photographic Interpretation Center (EPIC)
Telephone: 202-564-7333

EPA Region 1
Telephone 617-918-1143

EPA Region 3
Telephone 215-814-5418

EPA Region 4
Telephone 404-562-8033

EPA Region 6
Telephone: 214-655-6659

EPA Region 8
Telephone: 303-312-6774

Proposed NPL: Proposed National Priority List Sites
Source: EPA
Telephone: N/A

Date of Government Version: 06/10/03
Date Made Active at EDR: 08/26/03
Database Release Frequency: Semi-Annually

Date of Data Arrival at EDR: 08/04/03
Elapsed ASTM days: 22
Date of Last EDR Contact: 08/04/03

CERCLIS: Comprehensive Environmental Response, Compensation, and Liability Information System
Source: EPA
Telephone: 703-413-0223
CERCLIS contains data on potentially hazardous waste sites that have been reported to the USEPA by states, municipalities, private companies and private persons, pursuant to Section 103 of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). CERCLIS contains sites which are either proposed to or on the National Priorities List (NPL) and sites which are in the screening and assessment phase for possible inclusion on the NPL.

Date of Government Version: 06/16/03
Date Made Active at EDR: 08/01/03
Database Release Frequency: Quarterly

Date of Data Arrival at EDR: 06/23/03
Elapsed ASTM days: 39
Date of Last EDR Contact: 06/23/03

CERCLIS-NFRAP: CERCLIS No Further Remedial Action Planned
Source: EPA
Telephone: 703-413-0223
As of February 1995, CERCLIS sites designated "No Further Remedial Action Planned" (NFRAP) have been removed from CERCLIS. NFRAP sites may be sites where, following an initial investigation, no contamination was found, contamination was removed quickly without the need for the site to be placed on the NPL, or the contamination was not serious enough to require Federal Superfund action or NPL consideration. EPA has removed approximately 25,000 NFRAP sites to lift the unintended barriers to the redevelopment of these properties and has archived them as historical records so EPA does not needlessly repeat the investigations in the future. This policy change is part of the EPA's Brownfields Redevelopment Program to help cities, states, private investors and affected citizens to promote economic redevelopment of unproductive urban sites.

Date of Government Version: 06/11/03 | Date of Data Arrival at EDR: 06/23/03
Date Made Active at EDR: 08/01/03 | Elapsed ASTM days: 39
Database Release Frequency: Quarterly | Date of Last EDR Contact: 06/23/03

CORRACTS: Corrective Action Report
Source: EPA
Telephone: 800-424-9346
CORRACTS identifies hazardous waste handlers with RCRA corrective action activity.

Date of Government Version: 08/13/03 | Date of Data Arrival at EDR: 08/22/03
Date Made Active at EDR: 09/18/03 | Elapsed ASTM days: 27
Database Release Frequency: Semi-Annually | Date of Last EDR Contact: 09/08/03

RCRIS: Resource Conservation and Recovery Information System
Source: EPA
Telephone: 800-424-9346
Resource Conservation and Recovery Information System. RCRIS includes selective information on sites which generate, transport, store, treat and/or dispose of hazardous waste as defined by the Resource Conservation and Recovery Act (RCRA). Conditionally exempt small quantity generators (CESQGs): generate less than 100 kg of hazardous waste, or less than 1 kg of acutely hazardous waste per month. Small quantity generators (SQGs): generate between 100 kg and 1,000 kg of hazardous waste per month. Large quantity generators (LQGs): generate over 1,000 kilograms (kg) of hazardous waste, or over 1 kg of acutely hazardous waste per month. Transporters are individuals or entities that move hazardous waste from the generator off-site to a facility that can recycle, treat, store, or dispose of the waste. TSDFs treat, store, or dispose of the waste.

Date of Government Version: 09/10/03 | Date of Data Arrival at EDR: 09/11/03
Date Made Active at EDR: 10/01/03 | Elapsed ASTM days: 20
Database Release Frequency: Varies | Date of Last EDR Contact: 09/11/03

ERNS: Emergency Response Notification System
Source: National Response Center, United States Coast Guard
Telephone: 202-260-2342
Emergency Response Notification System. ERNS records and stores information on reported releases of oil and hazardous substances.

Date of Government Version: 12/31/02 | Date of Data Arrival at EDR: 01/27/03
Date Made Active at EDR: 02/03/03 | Elapsed ASTM days: 7
Database Release Frequency: Annually | Date of Last EDR Contact: 07/28/03

FEDERAL ASTM SUPPLEMENTAL RECORDS

BRS: Biennial Reporting System
Source: EPA/NTIS
Telephone: 800-424-9346
The Biennial Reporting System is a national system administered by the EPA that collects data on the generation and management of hazardous waste. BRS captures detailed data from two groups: Large Quantity Generators (LQG) and Treatment, Storage, and Disposal Facilities.

Date of Government Version: 12/31/99 | Date of Last EDR Contact: 06/16/03
Database Release Frequency: Biennially | Date of Next Scheduled EDR Contact: 09/15/03

DELISTED NPL: National Priority List Deletions
Source: EPA
Telephone: N/A
The National Oil and Hazardous Substances Pollution Contingency Plan (NCP) establishes the criteria that the EPA uses to delete sites from the NPL. In accordance with 40 CFR 300.425.(e), sites may be deleted from the NPL where no further response is appropriate.

Date of Government Version: 07/22/03
Database Release Frequency: Quarterly
Date of Last EDR Contact: 08/04/03
Date of Next Scheduled EDR Contact: 11/03/03

FINDS: Facility Index System/Facility Identification Initiative Program Summary Report
Source: EPA
Telephone: N/A
Facility Index System. FINDS contains both facility information and 'pointers' to other sources that contain more detail. EDR includes the following FINDS databases in this report: PCS (Permit Compliance System), AIRS (Aerometric Information Retrieval System), DOCKET (Enforcement Docket used to manage and track information on civil judicial enforcement cases for all environmental statutes), FURS (Federal Underground Injection Control), C-DOCKET (Criminal Docket System used to track criminal enforcement actions for all environmental statutes), FFIS (Federal Facilities Information System), STATE (State Environmental Laws and Statutes), and PADS (PCB Activity Data System).

Date of Government Version: 07/25/03
Database Release Frequency: Quarterly
Date of Last EDR Contact: 07/02/03
Date of Next Scheduled EDR Contact: 10/06/03

HMIRS: Hazardous Materials Information Reporting System
Source: U.S. Department of Transportation
Telephone: 202-366-4555
Hazardous Materials Incident Report System. HMIRS contains hazardous material spill incidents reported to DOT.

Date of Government Version: 03/31/03
Database Release Frequency: Annually
Date of Last EDR Contact: 07/23/03
Date of Next Scheduled EDR Contact: 10/20/03

MLTS: Material Licensing Tracking System
Source: Nuclear Regulatory Commission
Telephone: 301-415-7169
MLTS is maintained by the Nuclear Regulatory Commission and contains a list of approximately 8,100 sites which possess or use radioactive materials and which are subject to NRC licensing requirements. To maintain currency, EDR contacts the Agency on a quarterly basis.

Date of Government Version: 07/16/03
Database Release Frequency: Quarterly
Date of Last EDR Contact: 07/02/03
Date of Next Scheduled EDR Contact: 10/06/03

MINES: Mines Master Index File
Source: Department of Labor, Mine Safety and Health Administration
Telephone: 303-231-5959

Date of Government Version: 06/07/03
Database Release Frequency: Semi-Annually
Date of Last EDR Contact: 06/30/03
Date of Next Scheduled EDR Contact: 09/29/03

NPL LIENS: Federal Superfund Liens
Source: EPA
Telephone: 202-564-4267
Federal Superfund Liens. Under the authority granted the USEPA by the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) of 1980, the USEPA has the authority to file liens against real property in order to recover remedial action expenditures or when the property owner receives notification of potential liability. USEPA compiles a listing of filed notices of Superfund Liens.

Date of Government Version: 10/15/91
Database Release Frequency: No Update Planned
Date of Last EDR Contact: 08/25/03
Date of Next Scheduled EDR Contact: 11/24/03

PADS: PCB Activity Database System
Source: EPA
Telephone: 202-564-3887
PCB Activity Database. PADS Identifies generators, transporters, commercial storers and/or brokers and disposers of PCB's who are required to notify the EPA of such activities.

Date of Government Version: 06/30/03
Database Release Frequency: Annually
Date of Last EDR Contact: 08/13/03
Date of Next Scheduled EDR Contact: 11/10/03

DOD: Department of Defense Sites
Source: USGS
Telephone: 703-648-5920
This data set consists of federally owned or administered lands, administered by the Department of Defense, that have any area equal to or greater than 640 acres of the United States, Puerto Rico, and the U.S. Virgin Islands.

Date of Government Version: 04/01/03
Database Release Frequency: Semi-Annually
Date of Last EDR Contact: 08/15/03
Date of Next Scheduled EDR Contact: 11/10/03

US BROWNFIELDS: A Listing of Brownfields Sites
Source: Environmental Protection Agency
Telephone: 202-566-2777
Included in the listing are brownfields properties addresses by Cooperative Agreement Recipients and brownfields properties addressed by Targeted Brownfields Assessments. Targeted Brownfields Assessments-EPA's Targeted Brownfields Assessments (TBA) program is designed to help states, tribes, and municipalities--especially those without EPA Brownfields Assessment Demonstration Pilots--minimize the uncertainties of contamination often associated with brownfields. Under the TBA program, EPA provides funding and/or technical assistance for environmental assessments at brownfields sites throughout the country. Targeted Brownfields Assessments supplement and work with other efforts under EPA's Brownfields Initiative to promote cleanup and redevelopment of brownfields. Cooperative Agreement Recipients-States, political subdivisions, territories, and Indian tribes become BCRLF cooperative agreement recipients when they enter into BCRLF cooperative agreements with the U.S. EPA. EPA selects BCRLF cooperative agreement recipients based on a proposal and application process. BCRLF cooperative agreement recipients must use EPA funds provided through BCRLF cooperative agreement for specified brownfields-related cleanup activities.

Date of Government Version: 07/15/03
Database Release Frequency: Semi-Annually
Date of Last EDR Contact: 09/15/03
Date of Next Scheduled EDR Contact: 12/15/03

RAATS: RCRA Administrative Action Tracking System
Source: EPA
Telephone: 202-564-4104
RCRA Administration Action Tracking System. RAATS contains records based on enforcement actions issued under RCRA pertaining to major violators and includes administrative and civil actions brought by the EPA. For administration actions after September 30, 1995, data entry in the RAATS database was discontinued. EPA will retain a copy of the database for historical records. It was necessary to terminate RAATS because a decrease in agency resources made it impossible to continue to update the information contained in the database.

Date of Government Version: 04/17/95
Database Release Frequency: No Update Planned
Date of Last EDR Contact: 09/08/03
Date of Next Scheduled EDR Contact: 12/08/03

TRIS: Toxic Chemical Release Inventory System
Source: EPA
Telephone: 202-260-1531
Toxic Release Inventory System. TRIS identifies facilities which release toxic chemicals to the air, water and land in reportable quantities under SARA Title III Section 313.

Date of Government Version: 12/31/01
Database Release Frequency: Annually
Date of Last EDR Contact: 06/27/03
Date of Next Scheduled EDR Contact: 09/22/03

TSCA: Toxic Substances Control Act
Source: EPA
Telephone: 202-260-5521
Toxic Substances Control Act. TSCA identifies manufacturers and importers of chemical substances included on the TSCA Chemical Substance Inventory list. It includes data on the production volume of these substances by plant site.

Date of Government Version: 12/31/98
Database Release Frequency: Every 4 Years
Date of Last EDR Contact: 09/02/03
Date of Next Scheduled EDR Contact: 12/08/03

FTTS INSP: FIFRA/ TSCA Tracking System - FIFRA (Federal Insecticide, Fungicide, & Rodenticide Act)/TSCA (Toxic Substances Control Act)
Source: EPA
Telephone: 202-564-2501

Date of Government Version: 08/21/03
Database Release Frequency: Quarterly

Date of Last EDR Contact: 09/23/03
Date of Next Scheduled EDR Contact: 12/22/03

SSTS: Section 7 Tracking Systems
Source: EPA
Telephone: 202-564-5008
Section 7 of the Federal Insecticide, Fungicide and Rodenticide Act, as amended (92 Stat. 829) requires all registered pesticide-producing establishments to submit a report to the Environmental Protection Agency by March 1st each year. Each establishment must report the types and amounts of pesticides, active ingredients and devices being produced, and those having been produced and sold or distributed in the past year.

Date of Government Version: 12/31/01
Database Release Frequency: Annually

Date of Last EDR Contact: 07/24/03
Date of Next Scheduled EDR Contact: 10/20/03

FTTS: FIFRA/ TSCA Tracking System - FIFRA (Federal Insecticide, Fungicide, & Rodenticide Act)/TSCA (Toxic Substances Control Act)
Source: EPA/Office of Prevention, Pesticides and Toxic Substances
Telephone: 202-564-2501
FTTS tracks administrative cases and pesticide enforcement actions and compliance activities related to FIFRA, TSCA and EPCRA (Emergency Planning and Community Right-to-Know Act). To maintain currency, EDR contacts the Agency on a quarterly basis.

Date of Government Version: 08/21/03
Database Release Frequency: Quarterly

Date of Last EDR Contact: 09/23/03
Date of Next Scheduled EDR Contact: 12/22/03

STATE OF NORTH CAROLINA ASTM STANDARD RECORDS

SHWS: Inactive Hazardous Sites Inventory
Source: Department of Environment, Health and Natural Resources
Telephone: 919-733-2801
State Hazardous Waste Sites. State hazardous waste site records are the states' equivalent to CERCLIS. These sites may or may not already be listed on the federal CERCLIS list. Priority sites planned for cleanup using state funds (state equivalent of Superfund) are identified along with sites where cleanup will be paid for by potentially responsible parties. Available information varies by state.

Date of Government Version: 07/14/03
Date Made Active at EDR: 08/18/03
Database Release Frequency: Quarterly

Date of Data Arrival at EDR: 07/22/03
Elapsed ASTM days: 27
Date of Last EDR Contact: 07/11/03

SWF/LF: List of Solid Waste Facilities
Source: Department of Environment and Natural Resources
Telephone: 919-733-0692
Solid Waste Facilities/Landfill Sites. SWF/LF type records typically contain an inventory of solid waste disposal facilities or landfills in a particular state. Depending on the state, these may be active or inactive facilities or open dumps that failed to meet RCRA Subtitle D Section 4004 criteria for solid waste landfills or disposal sites.

Date of Government Version: 04/29/03
Date Made Active at EDR: 05/08/03
Database Release Frequency: Semi-Annually

Date of Data Arrival at EDR: 04/29/03
Elapsed ASTM days: 9
Date of Last EDR Contact: 07/28/03

LUST: Incidents Management Database
Source: Department of Environment and Natural Resources
Telephone: 919-733-1315
Leaking Underground Storage Tank Incident Reports. LUST records contain an inventory of reported leaking underground storage tank incidents. Not all states maintain these records, and the information stored varies by state.

Date of Government Version: 08/15/03
Date Made Active at EDR: 09/24/03
Database Release Frequency: Quarterly

Date of Data Arrival at EDR: 09/08/03
Elapsed ASTM days: 16
Date of Last EDR Contact: 09/08/03

UST: Petroleum Underground Storage Tank Database
Source: Department of Environment and Natural Resources
Telephone: 919-733-1308
Registered Underground Storage Tanks. UST's are regulated under Subtitle I of the Resource Conservation and Recovery Act (RCRA) and must be registered with the state department responsible for administering the UST program. Available information varies by state program.

Date of Government Version: 07/18/03
Date Made Active at EDR: 09/19/03
Database Release Frequency: Quarterly
Date of Data Arrival at EDR: 09/08/03
Elapsed ASTM days: 11
Date of Last EDR Contact: 09/08/03

OLI: Old Landfill Inventory
Source: Department of Environment & Natural Resources
Telephone: 919-733-4996

Date of Government Version: 07/02/03
Date Made Active at EDR: 08/27/03
Database Release Frequency: Varies
Date of Data Arrival at EDR: 07/28/03
Elapsed ASTM days: 30
Date of Last EDR Contact: 07/28/03

VCP: Responsible Party Voluntary Action Sites
Source: Department of Environment and Natural Resources
Telephone: 919-733-4996

Date of Government Version: 06/05/03
Date Made Active at EDR: 06/26/03
Database Release Frequency: Semi-Annually
Date of Data Arrival at EDR: 06/05/03
Elapsed ASTM days: 21
Date of Last EDR Contact: 06/05/03

INDIAN UST: Underground Storage Tanks on Indian Land
Source: EPA Region 4
Telephone: 404-562-9424

Date of Government Version: N/A
Date Made Active at EDR: N/A
Database Release Frequency: Varies
Date of Data Arrival at EDR: N/A
Elapsed ASTM days: 0
Date of Last EDR Contact: N/A

STATE OF NORTH CAROLINA ASTM SUPPLEMENTAL RECORDS

HSDS: Hazardous Substance Disposal Site
Source: North Carolina Center for Geographic Information and Analysis
Telephone: 919-733-2090
Locations of uncontrolled and unregulated hazardous waste sites. The file includes sites on the National Priority List as well as those on the state priority list.

Date of Government Version: 06/21/95
Database Release Frequency: Biennially
Date of Last EDR Contact: 09/02/03
Date of Next Scheduled EDR Contact: 12/01/03

AST: AST Database
Source: Department of Environment and Natural Resources
Telephone: 919-715-6170
Facilities with aboveground storage tanks that have a capacity greater than 21,000 gallons.

Date of Government Version: 06/05/03
Database Release Frequency: Semi-Annually
Date of Last EDR Contact: 07/23/03
Date of Next Scheduled EDR Contact: 10/20/03

LUST TRUST: State Trust Fund Database
Source: Department of Environment and Natural Resources
Telephone: 919-733-1315
This database contains information about claims against the State Trust Funds for reimbursements for expenses incurred while remediating Leaking USTs.

Date of Government Version: 08/08/03 | Date of Last EDR Contact: 08/11/03
Database Release Frequency: Semi-Annually | Date of Next Scheduled EDR Contact: 11/10/03

IMD: Incident Management Database
Source: Department of Environment and Natural Resources
Telephone: 919-733-1315
Groundwater and/or soil contamination incidents

Date of Government Version: 07/24/03 | Date of Last EDR Contact: 07/28/03
Database Release Frequency: Quarterly | Date of Next Scheduled EDR Contact: 10/27/03

EDR PROPRIETARY HISTORICAL DATABASES

Former Manufactured Gas (Coal Gas) Sites: The existence and location of Coal Gas sites is provided exclusively to EDR by Real Property Scan, Inc. ©Copyright 1993 Real Property Scan, Inc. For a technical description of the types of hazards which may be found at such sites, contact your EDR customer service representative.

Disclaimer Provided by Real Property Scan, Inc.

The information contained in this report has predominantly been obtained from publicly available sources produced by entities other than Real Property Scan. While reasonable steps have been taken to insure the accuracy of this report, Real Property Scan does not guarantee the accuracy of this report. Any liability on the part of Real Property Scan is strictly limited to a refund of the amount paid. No claim is made for the actual existence of toxins at any site. This report does not constitute a legal opinion.

BROWNFIELDS DATABASES

Brownfields: Brownfields Projects Inventory
Source: Department of Environment and Natural Resources
Telephone: 919-733-4996
A brownfield site is an abandoned, idled, or underused property where the threat of environmental contamination has hindered its redevelopment. All of the sites in the inventory are working toward a brownfield agreement for cleanup and liabitliy control.

Date of Government Version: 12/31/02 | Date of Last EDR Contact: 08/18/03
Database Release Frequency: Varies | Date of Next Scheduled EDR Contact: 11/03/03

VCP: Responsible Party Voluntary Action Sites
Source: Department of Environment and Natural Resources
Telephone: 919-733-4996

Date of Government Version: 06/05/03 | Date of Last EDR Contact: 06/05/03
Database Release Frequency: Semi-Annually | Date of Next Scheduled EDR Contact: 10/13/03

INST CONTROL: No Further Action Sites With Land Use Restrictions Monitoring
Source: Department of Environment, Health and Natural Resources
Telephone: 919-733-2801

Date of Government Version: 07/14/03 | Date of Last EDR Contact: 07/22/03
Database Release Frequency: Quarterly | Date of Next Scheduled EDR Contact: 10/13/03

US BROWNFIELDS: A Listing of Brownfields Sites
Source: Environmental Protection Agency
Telephone: 202-566-2777
Included in the listing are brownfields properties addresses by Cooperative Agreement Recipients and brownfields properties addressed by Targeted Brownfields Assessments. Targeted Brownfields Assessments-EPA's Targeted Brownfields Assessments (TBA) program is designed to help states, tribes, and municipalities--especially those without EPA Brownfields Assessment Demonstration Pilots--minimize the uncertainties of contamination often associated with brownfields. Under the TBA program, EPA provides funding and/or technical assistance for environmental assessments at brownfields sites throughout the country. Targeted Brownfields Assessments supplement and work with other efforts under EPA's Brownfields Initiative to promote cleanup and redevelopment of brownfields. Cooperative Agreement Recipients-States, political subdivisions, territories, and Indian tribes become BCRLF cooperative agreement recipients when they enter into BCRLF cooperative agreements with the U.S. EPA. EPA selects BCRLF cooperative agreement recipients based on a proposal and application process. BCRLF cooperative agreement recipients must use EPA funds provided through BCRLF cooperative agreement for specified brownfields-related cleanup activities.

Date of Government Version: N/A
Database Release Frequency: Semi-Annually

Date of Last EDR Contact: N/A
Date of Next Scheduled EDR Contact: N/A

OTHER DATABASE(S)

Depending on the geographic area covered by this report, the data provided in these specialty databases may or may not be complete. For example, the existence of wetlands information data in a specific report does not mean that all wetlands in the area covered by the report are included. Moreover, the absence of any reported wetlands information does not necessarily mean that wetlands do not exist in the area covered by the report.

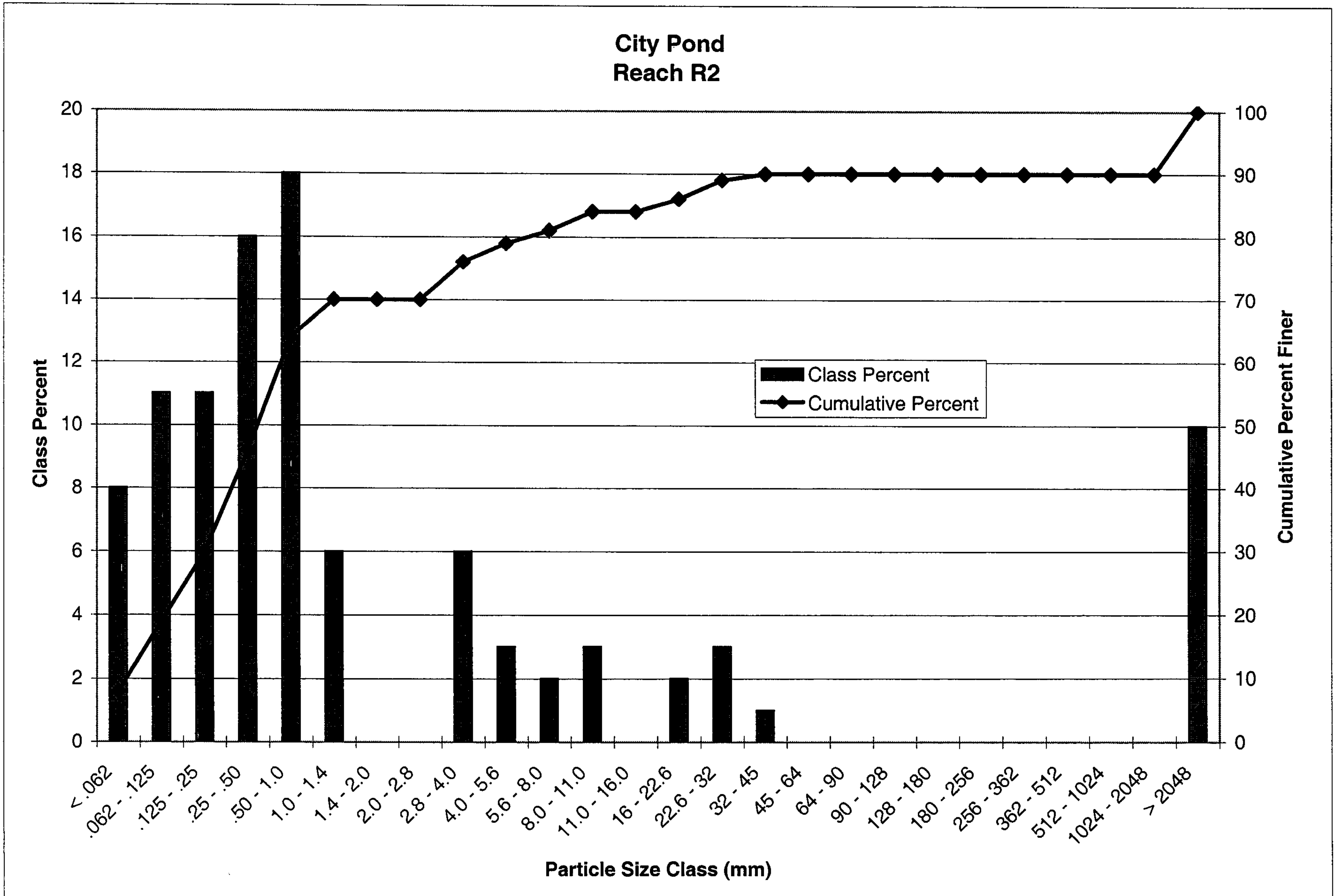
Flood Zone Data: This data, available in select counties across the country, was obtained by EDR in 1999 from the Federal Emergency Management Agency (FEMA). Data depicts 100-year and 500-year flood zones as defined by FEMA.

NWI: National Wetlands Inventory. This data, available in select counties across the country, was obtained by EDR in 2002 from the U.S. Fish and Wildlife Service.

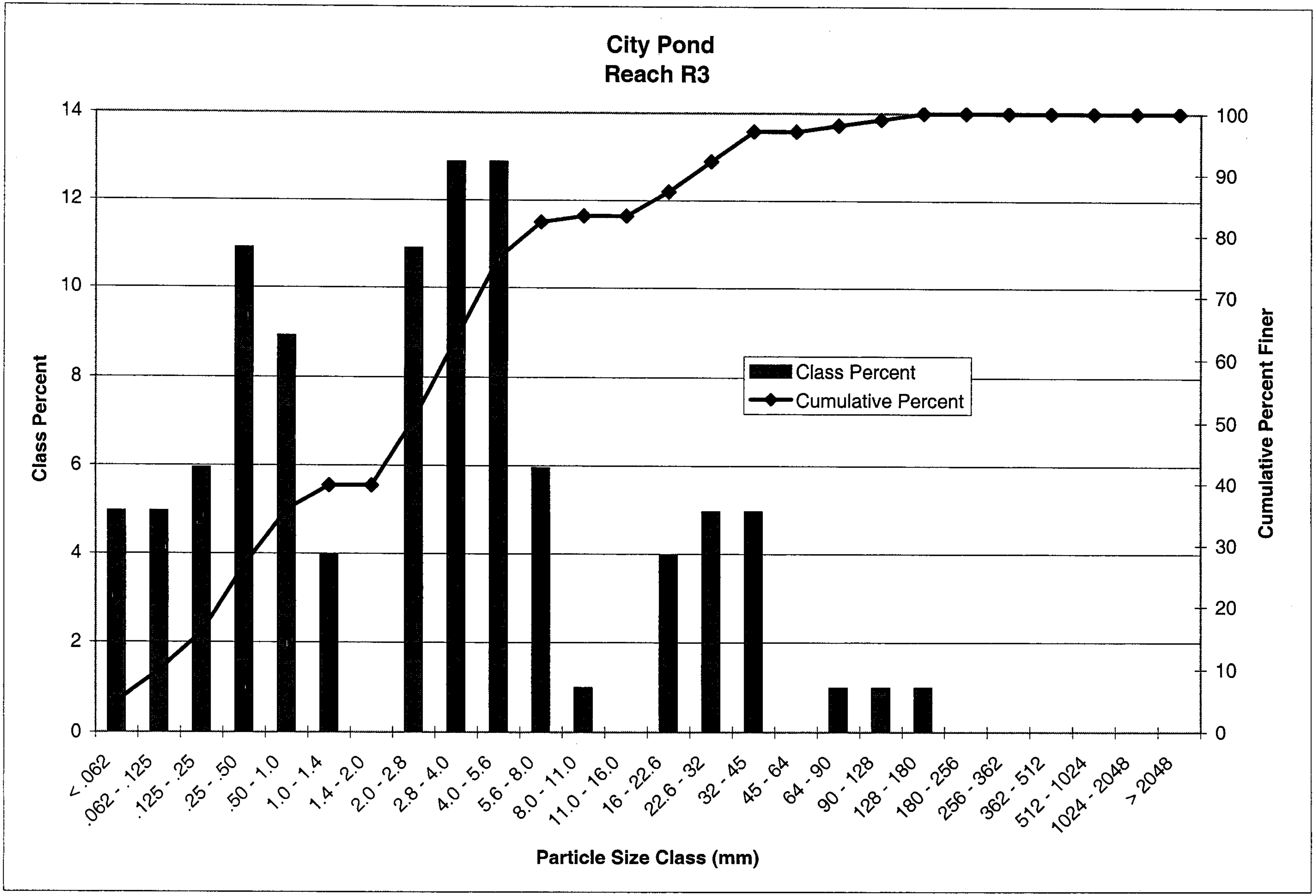
STREET AND ADDRESS INFORMATION

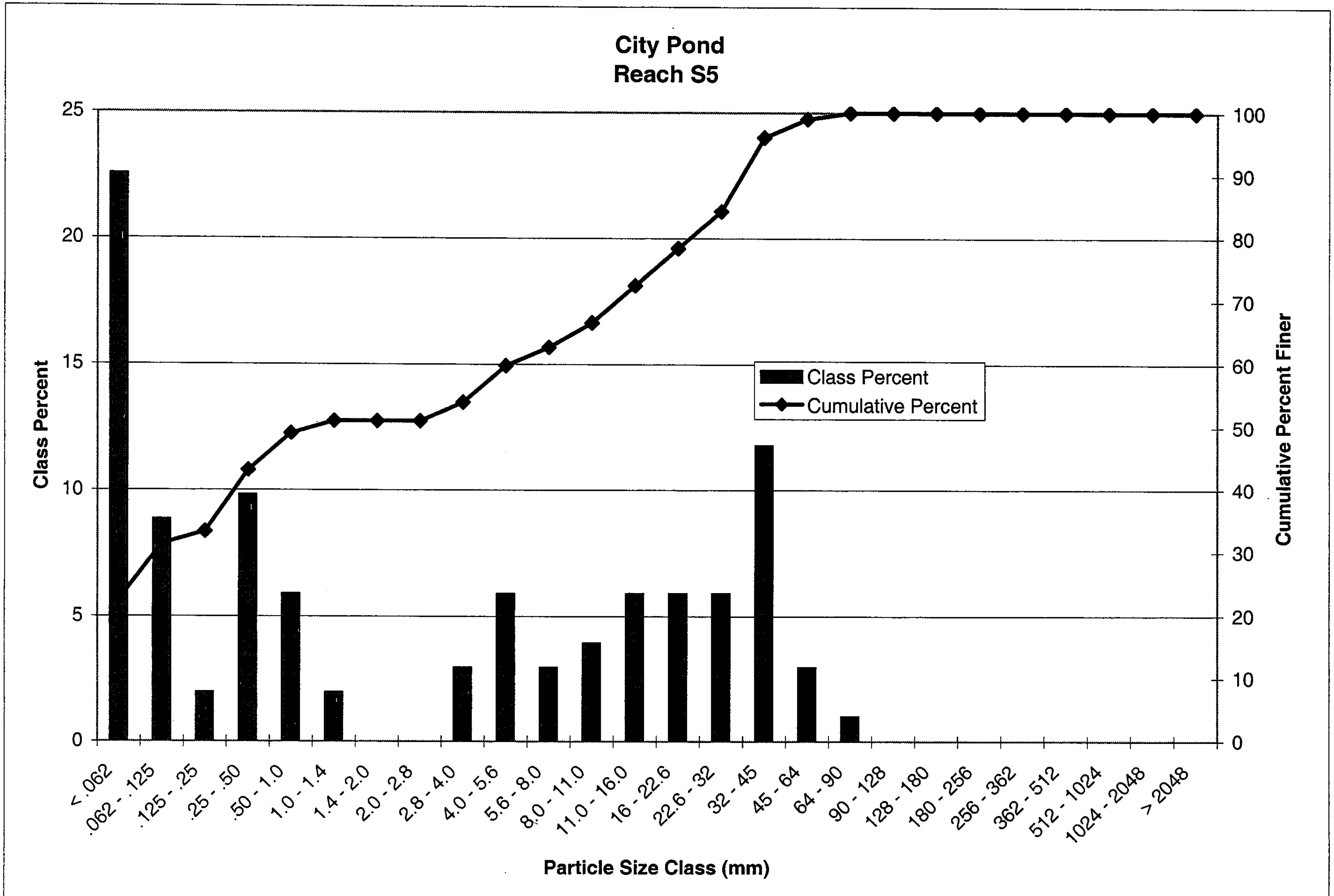
Appendix C

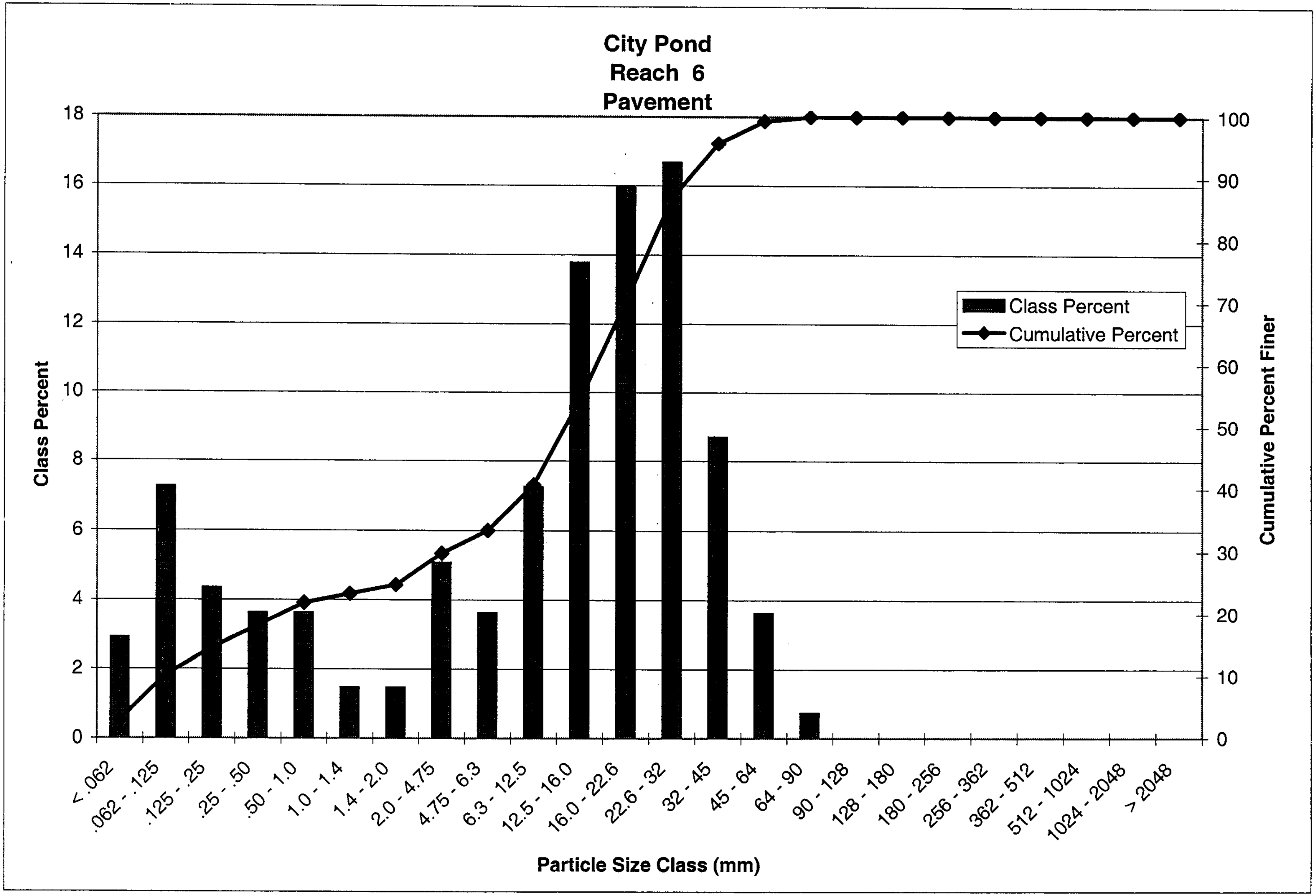
Existing Condition Data

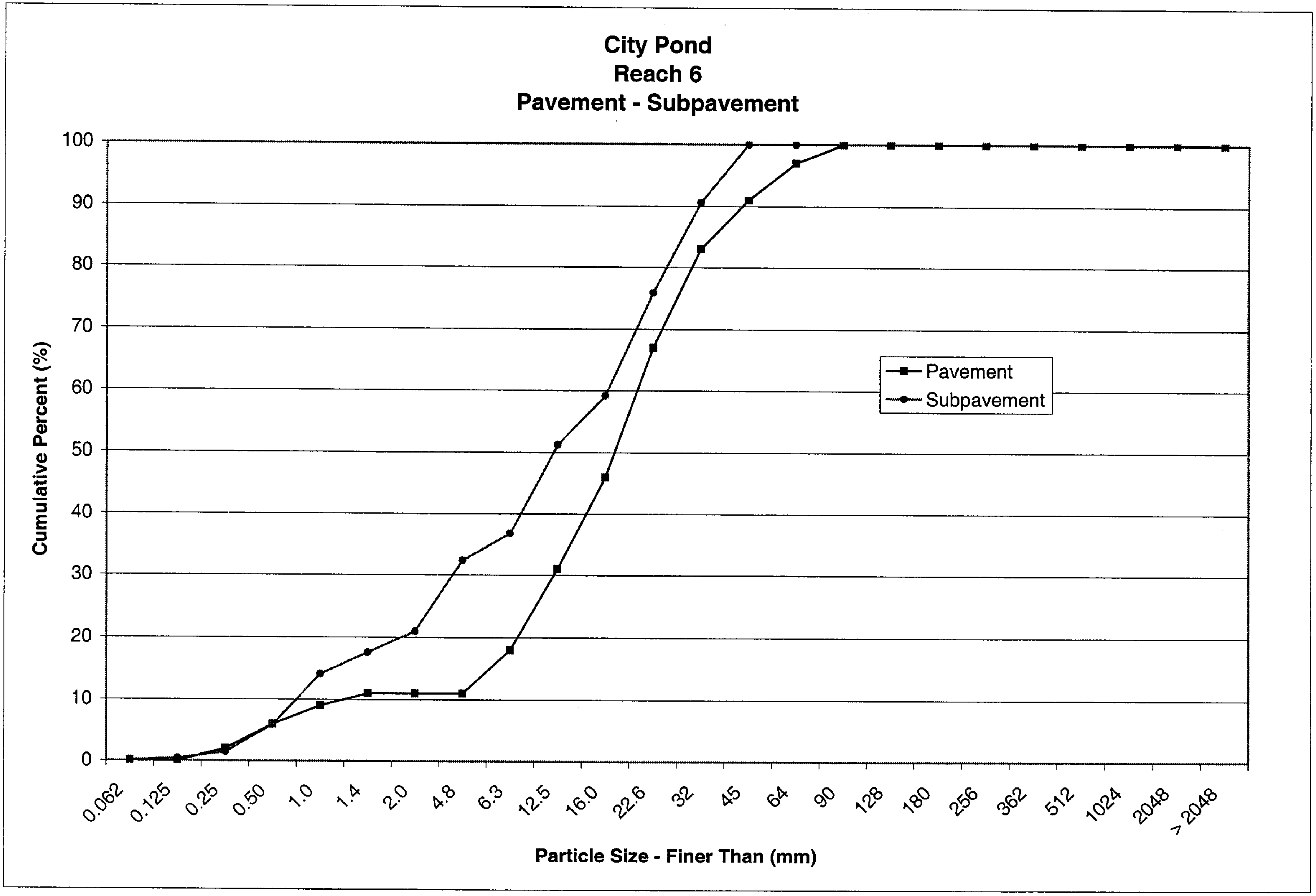


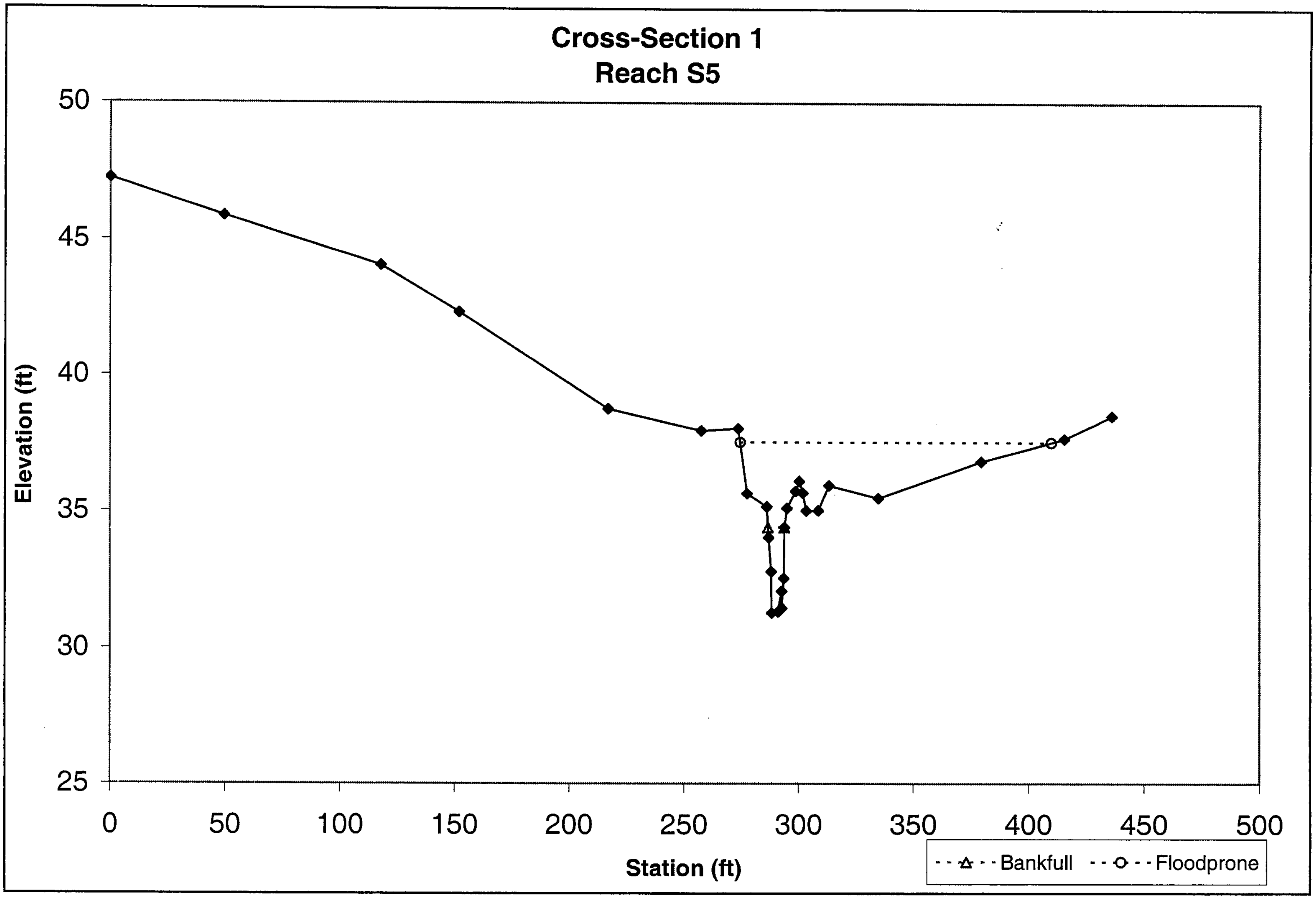
City Pond
Reach R2
Class Percent
Cumulative Percent Finer
Class Percent
Cumulative Percent
0
2
4
6
8
10
12
14
16
18
20
0
10
20
30
40
50
60
70
80
90
100
< .062
.062 - .125
.125 - .25
.25 - .50
.50 - 1.0
1.0 - 1.4
1.4 - 2.0
2.0 - 2.8
2.8 - 4.0
4.0 - 5.6
5.6 - 8.0
8.0 - 11.0
11.0 - 16.0
16 - 22.6
22.6 - 32
32 - 45
45 - 64
64 - 90
90 - 128
128 - 180
180 - 256
256 - 362
362 - 512
512 - 1024
1024 - 2048
> 2048
Particle Size Class (mm)


City Pond
Reach R3
Class Percent
Cumulative Percent Finer
Class Percent
Cumulative Percent
Particle Size Class (mm)
0
2
4
6
8
10
12
14
0
10
20
30
40
50
60
70
80
90
100
< .062
.062 - .125
.125 - .25
.25 - .50
.50 - 1.0
1.0 - 1.4
1.4 - 2.0
2.0 - 2.8
2.8 - 4.0
4.0 - 5.6
5.6 - 8.0
8.0 - 11.0
11.0 - 16.0
16 - 22.6
22.6 - 32
32 - 45
45 - 64
64 - 90
90 - 128
128 - 180
180 - 256
256 - 362
362 - 512
512 - 1024
1024 - 2048
> 2048

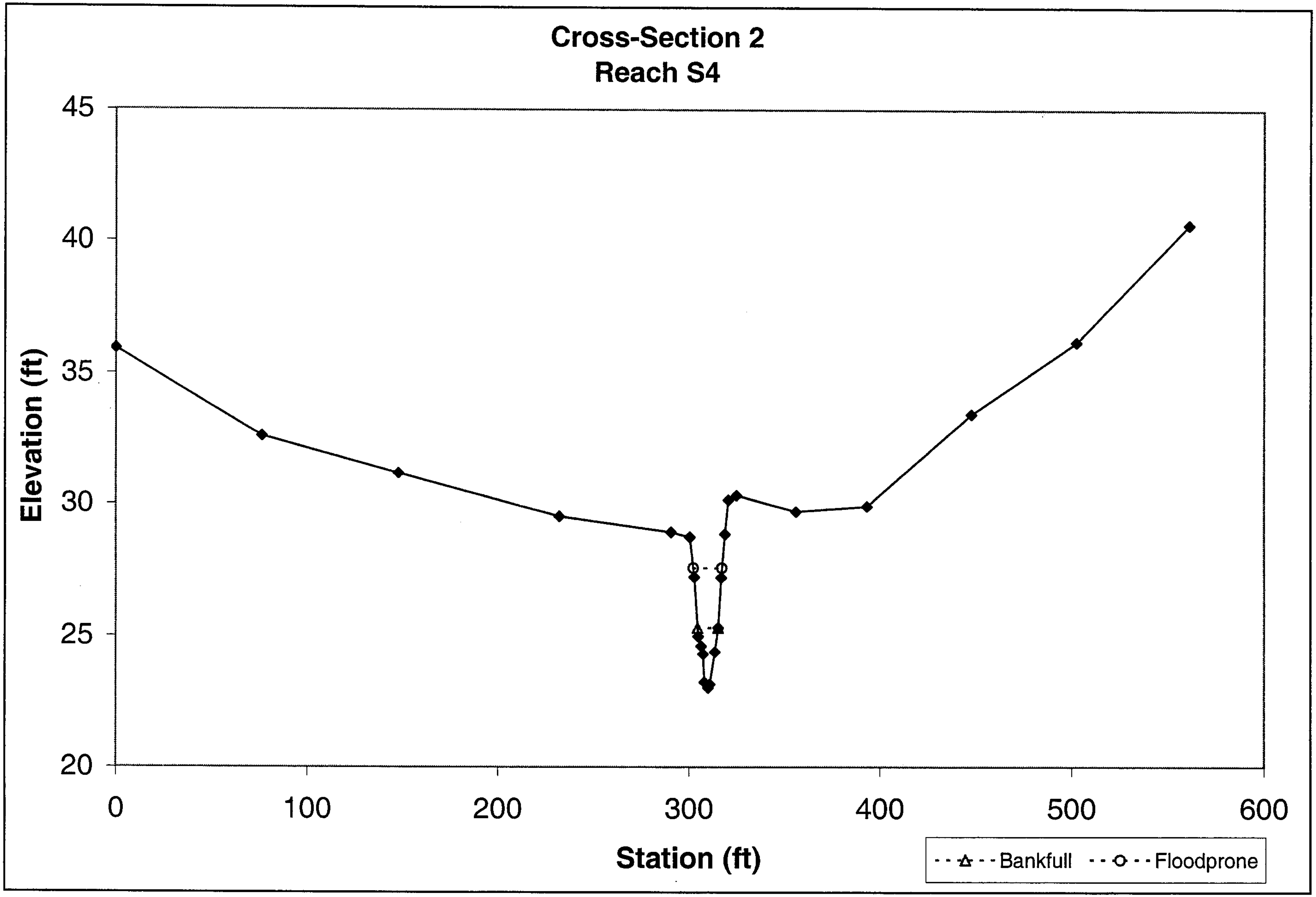

City Pond
Reach S5
Class Percent
Cumulative Percent
Cumulative Percent Finer
Particle Size Class (mm)
0
5
10
15
20
25
0
10
20
30
40
50
60
70
80
90
100
< .062
.062 - .125
.125 - .25
.25 - .50
.50 - 1.0
1.0 - 1.4
1.4 - 2.0
2.0 - 2.8
2.8 - 4.0
4.0 - 5.6
5.6 - 8.0
8.0 - 11.0
11.0 - 16.0
16 - 22.6
22.6 - 32
32 - 45
45 - 64
64 - 90
90 - 128
128 - 180
180 - 256
256 - 362
362 - 512
512 - 1024
1024 - 2048
> 2048

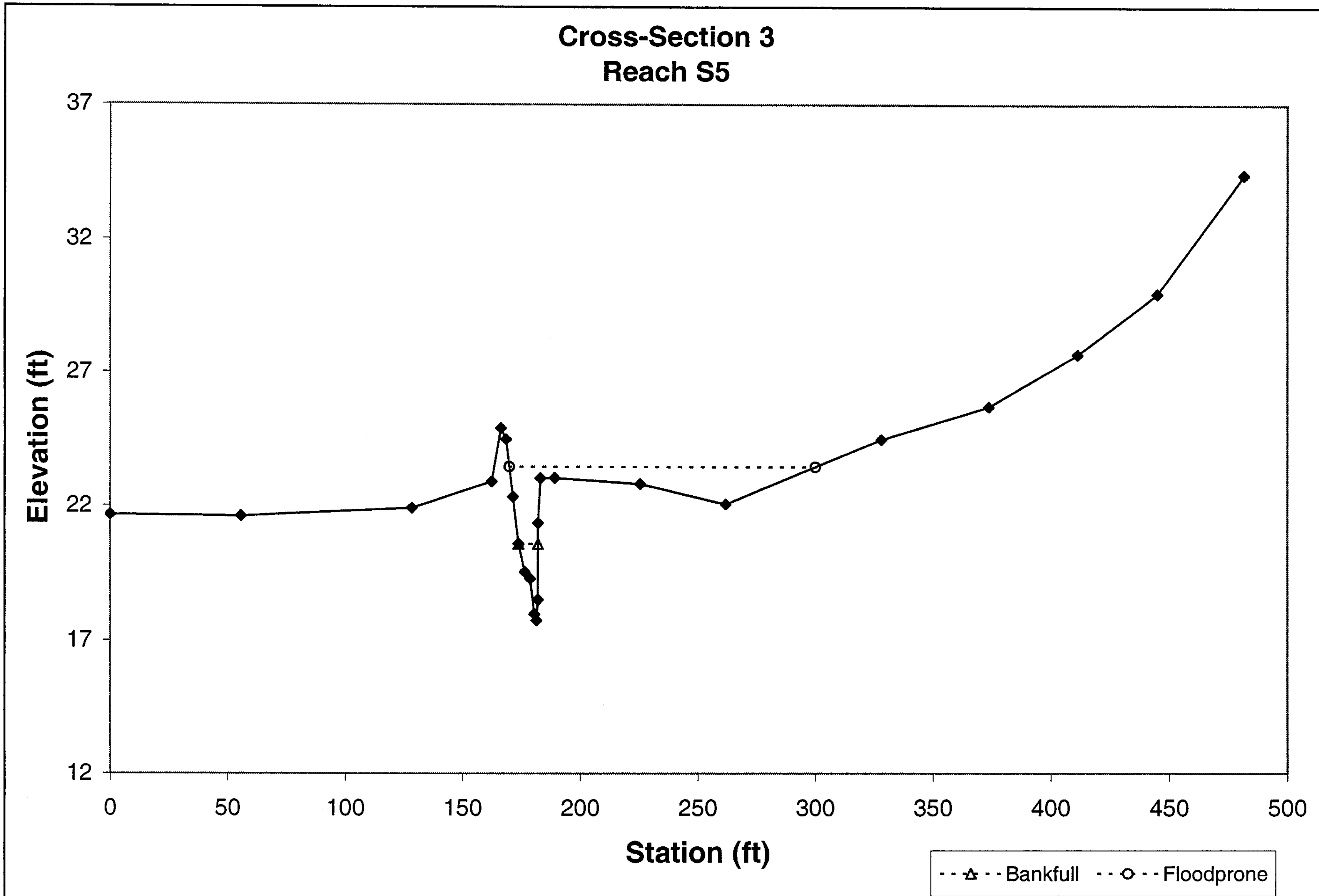

City Pond
Reach 6
Pavement
Class Percent
Cumulative Percent
Class Percent
Cumulative Percent Finer
Particle Size Class (mm)
0
2
4
6
8
10
12
14
16
18
0
10
20
30
40
50
60
70
80
90
100
< .062
.062 - .125
.125 - .25
.25 - .50
.50 - 1.0
1.0 - 1.4
1.4 - 2.0
2.0 - 4.75
4.75 - 6.3
6.3 - 12.5
12.5 - 16.0
16.0 - 22.6
22.6 - 32
32 - 45
45 - 64
64 - 90
90 - 128
128 - 180
180 - 256
256 - 362
362 - 512
512 - 1024
1024 - 2048
> 2048


City Pond
Reach 6
Pavement - Subpavement
Cumulative Percent (%)
0
10
20
30
40
50
60
70
80
90
100
0.062
0.125
0.25
0.50
1.0
1.4
2.0
4.8
6.3
12.5
16.0
22.6
32
45
64
90
128
180
256
362
512
1024
2048
> 2048
Particle Size - Finer Than (mm)
Pavement
Subpavement

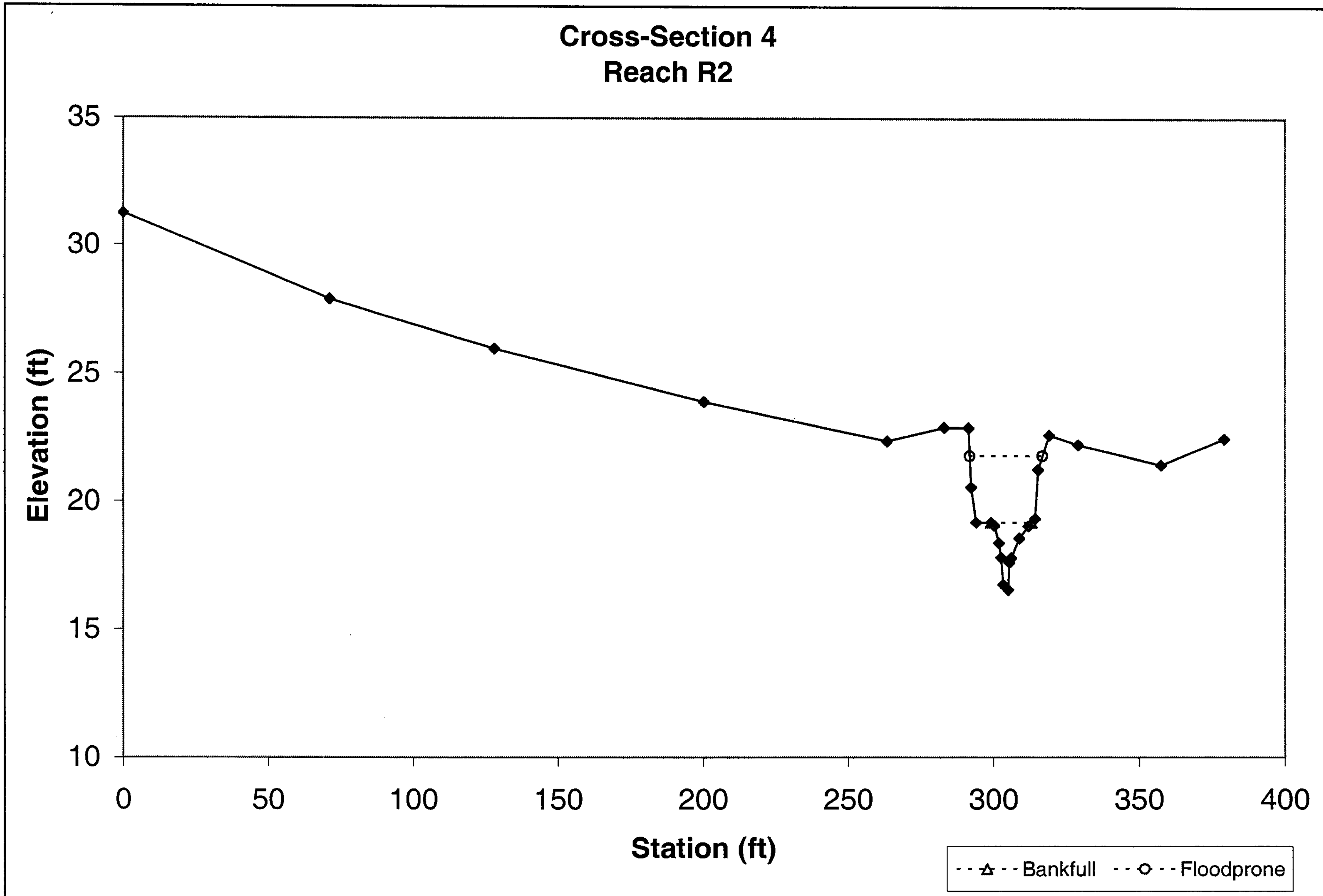


Cross-Section 1
Reach S5
Elevation (ft)
50
45
40
35
30
25
0
50
100
150
200
250
300
350
400
450
500
Station (ft)
Bankfull
Floodprone

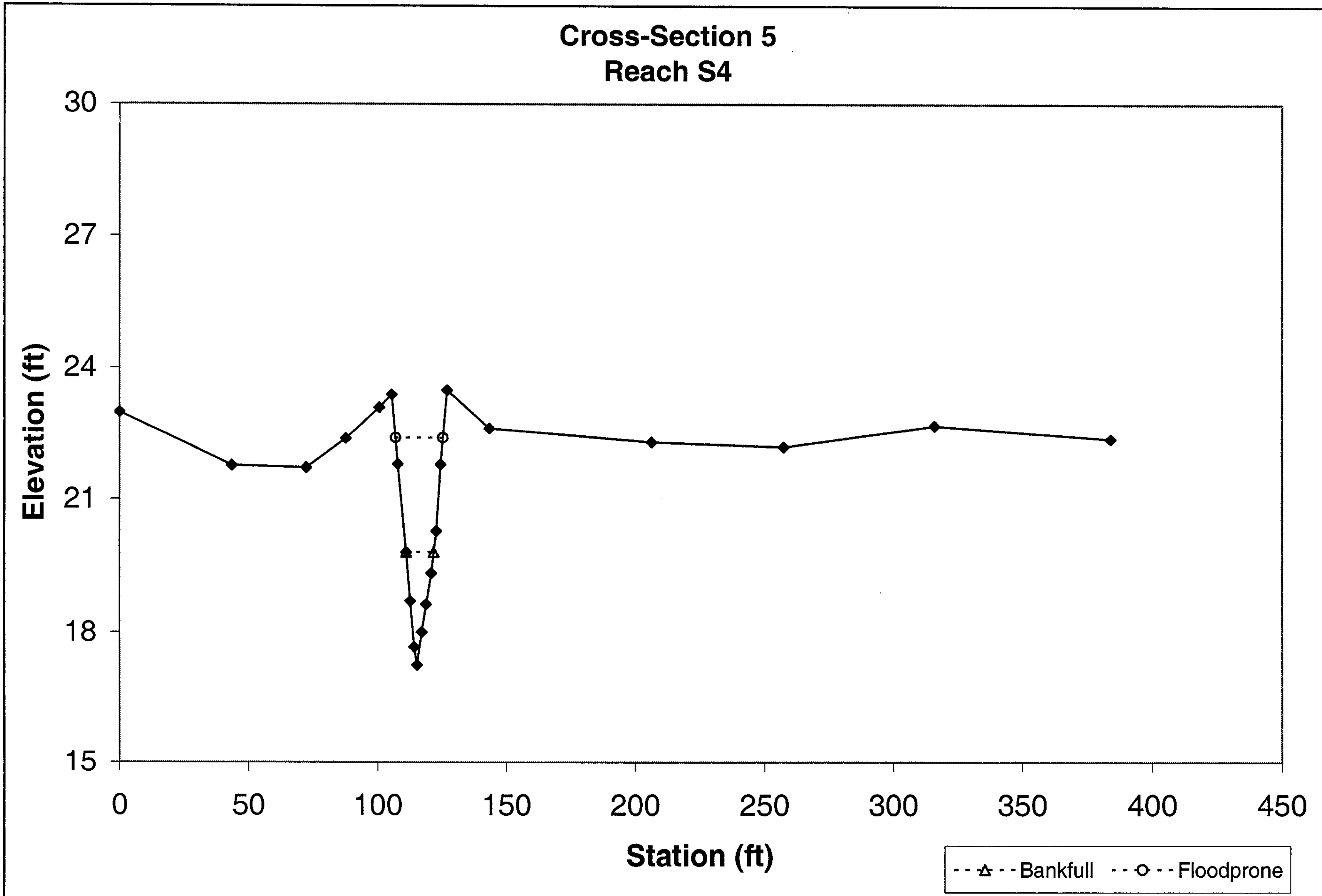

Cross-Section 2
Reach S4
45
40
35
30
25
20
Elevation (ft)
0
100
200
300
400
500
600
Station (ft)
Bankfull
Floodprone



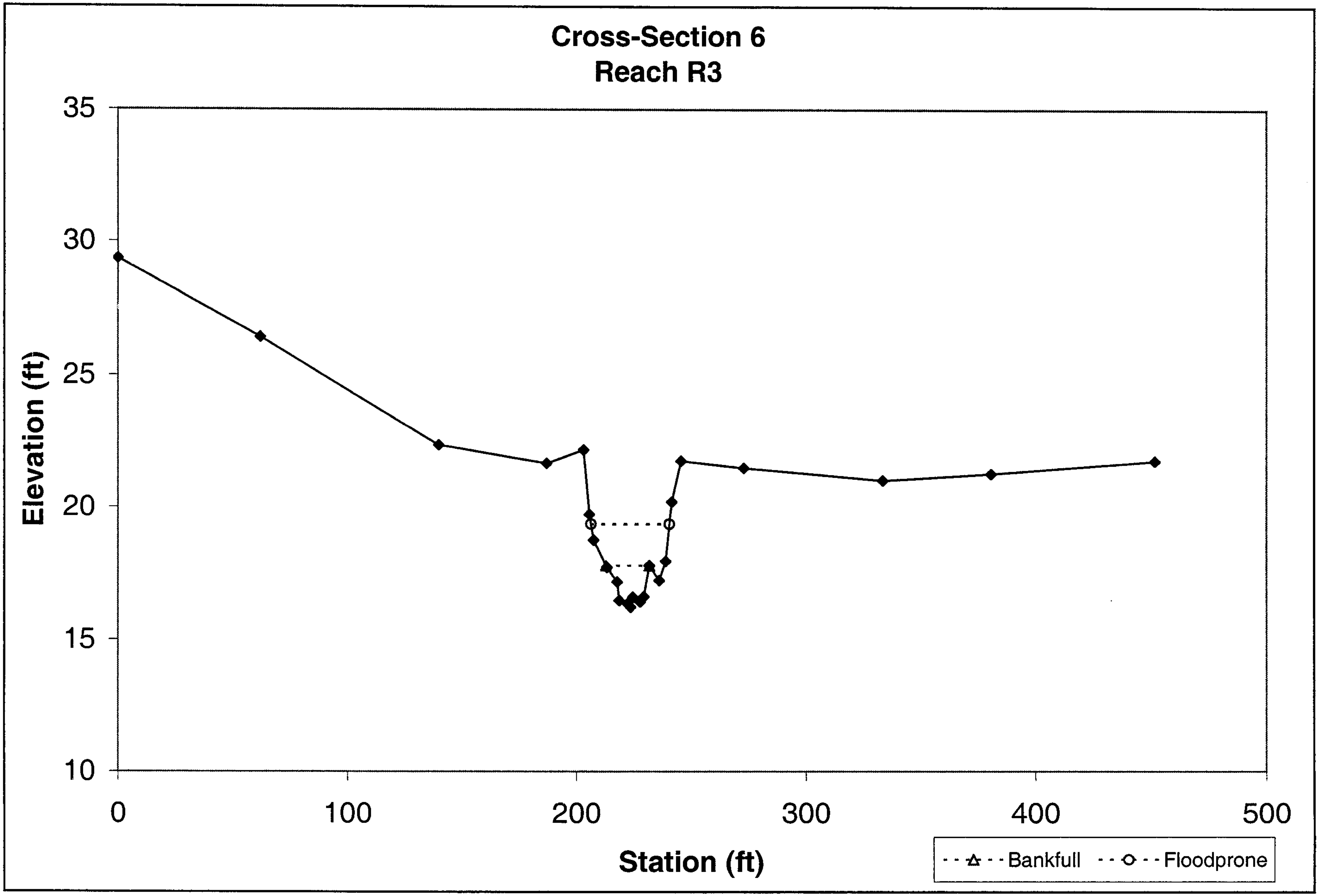
Cross-Section 3
Reach S5
37
32
27
22
17
12
Elevation (ft)
0
50
100
150
200
250
300
350
400
450
500
Station (ft)
Bankfull
Floodprone

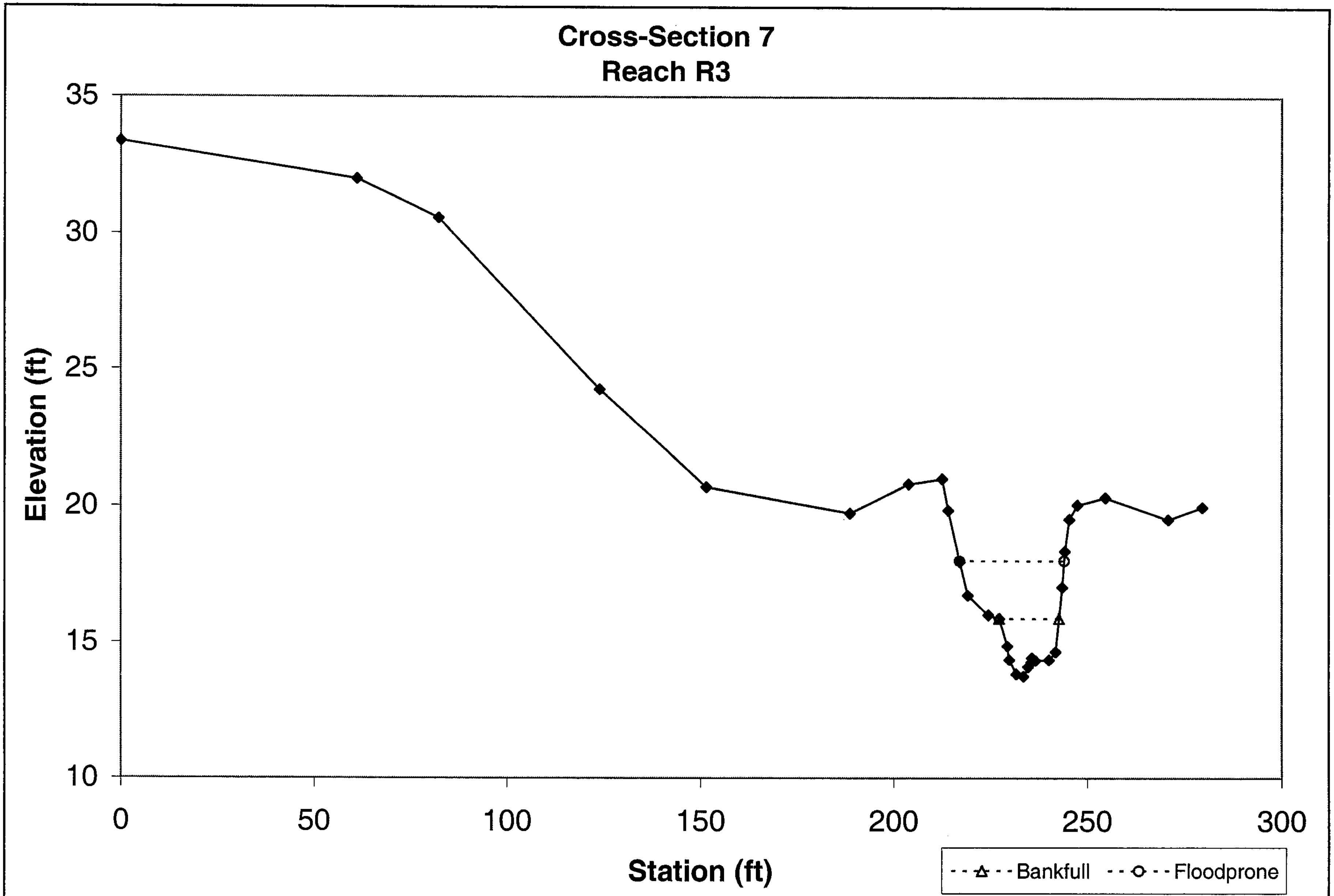


Cross-Section 4
Reach R2
Elevation (ft)
35
30
25
20
15
10
0
50
100
150
200
250
300
350
400
Station (ft)
Bankfull
Floodprone

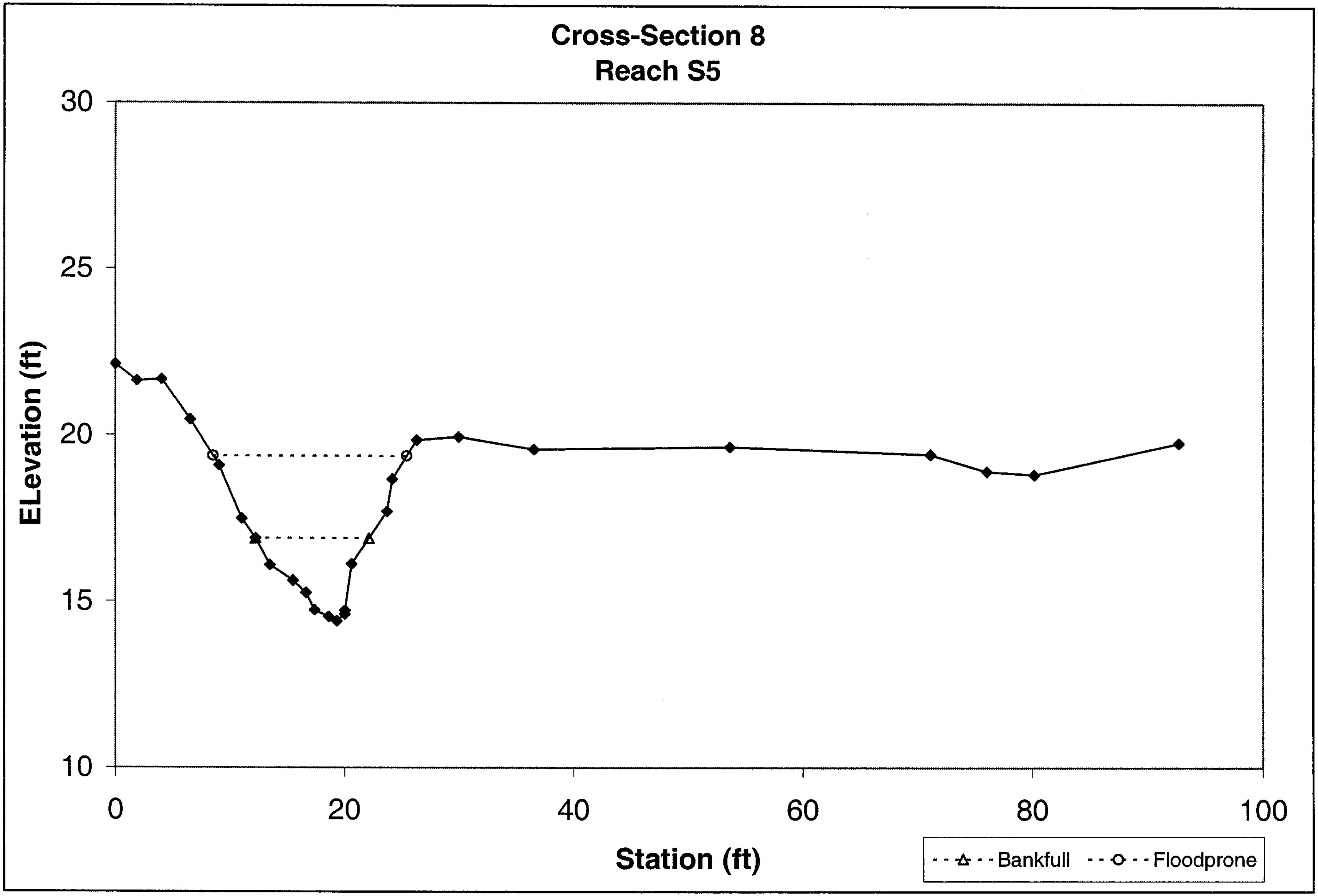


Cross-Section 5
Reach S4
Elevation (ft)
30
27
24
21
18
15
0
50
100
150
200
250
300
350
400
450
Station (ft)
Bankfull
Floodprone

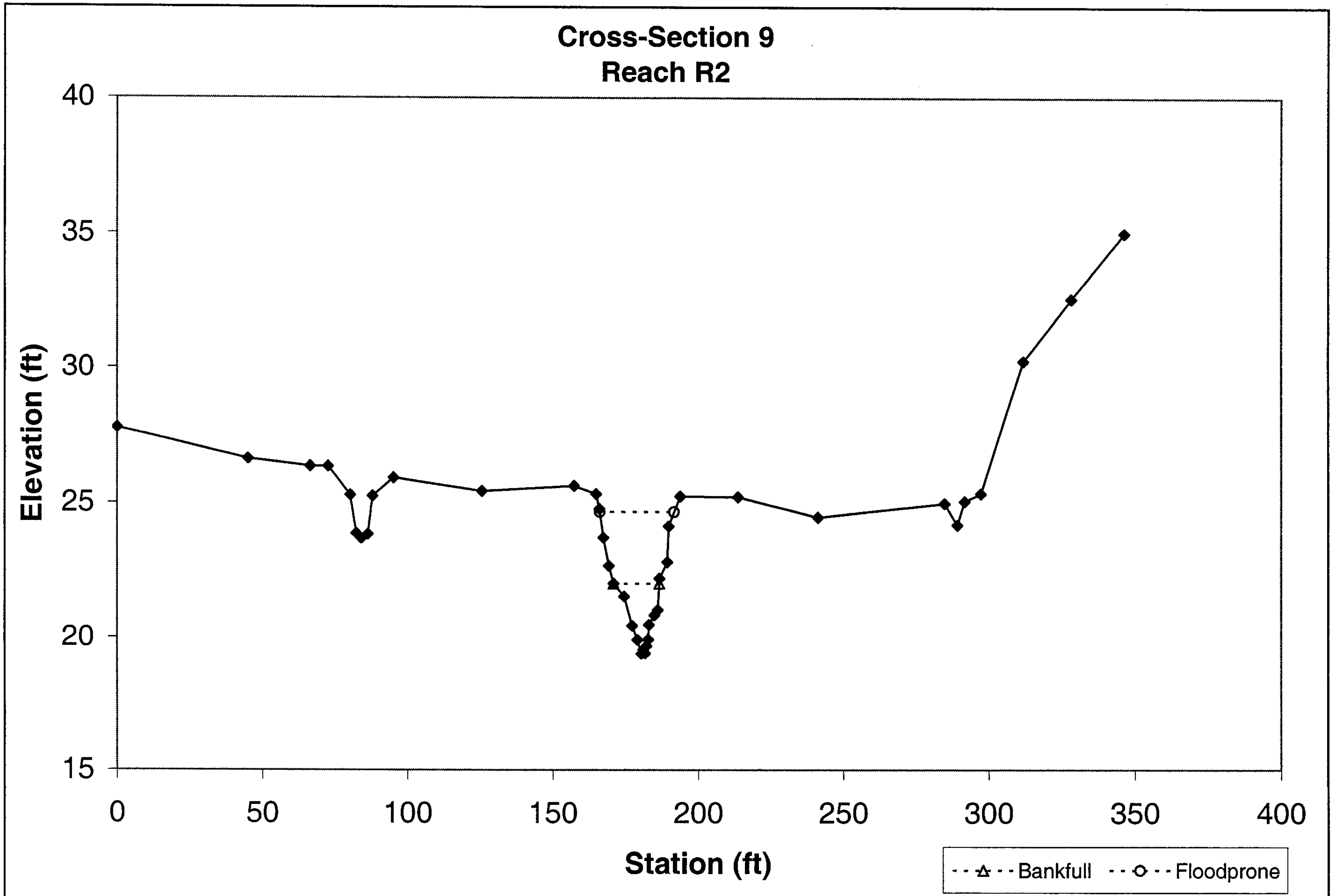

Cross-Section 6
Reach R3
Elevation (ft)
35
30
25
20
15
10
0
100
200
300
400
500
Station (ft)
Bankfull
Floodprone



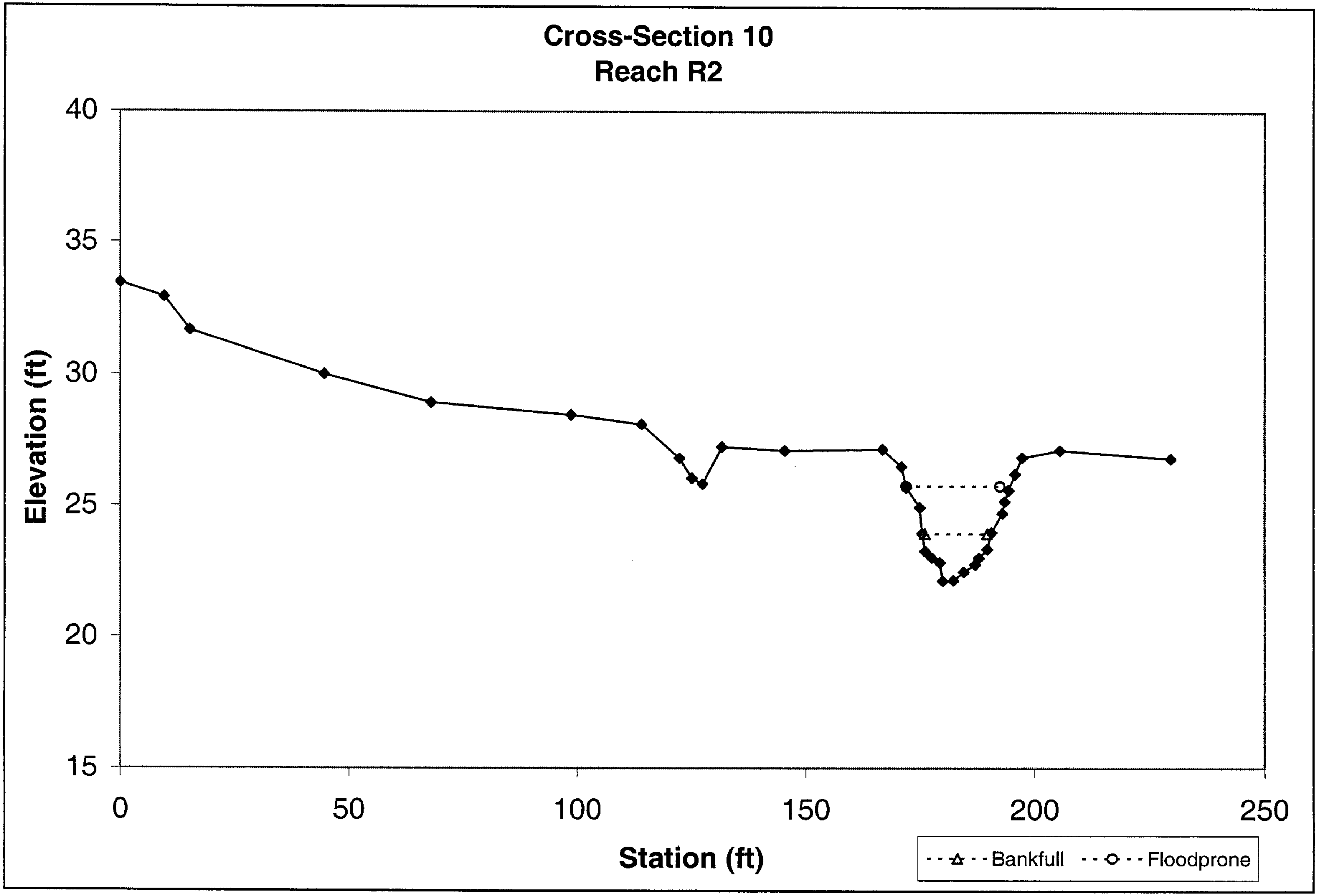
Cross-Section 7
Reach R3
35
30
25
20
15
10
Elevation (ft)
0
50
100
150
200
250
300
Station (ft)
Bankfull
Floodprone



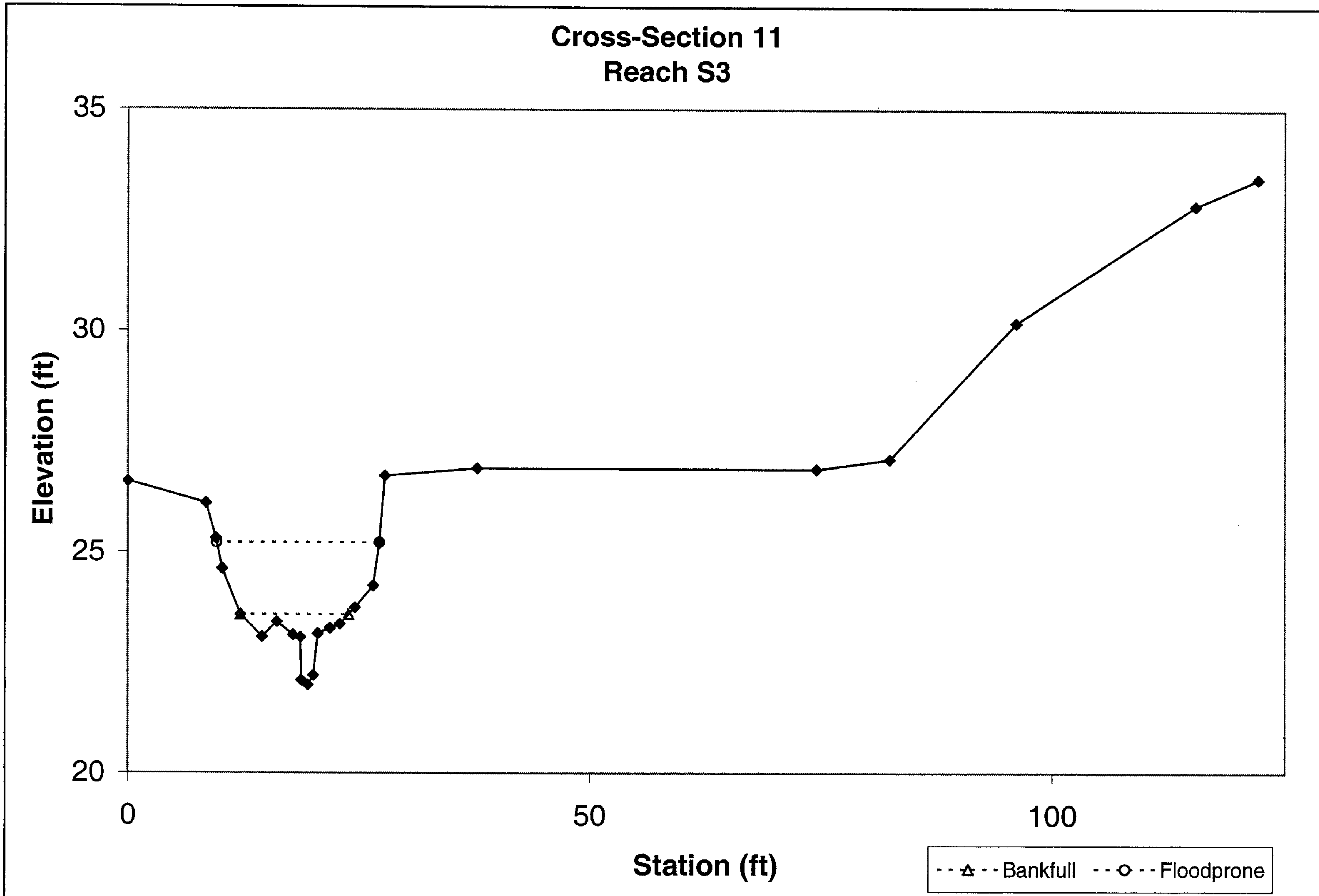
Cross-Section 8
Reach S5
30
25
20
15
10
ELevation (ft)
0
20
40
60
80
100
Station (ft)
Bankfull
Floodprone

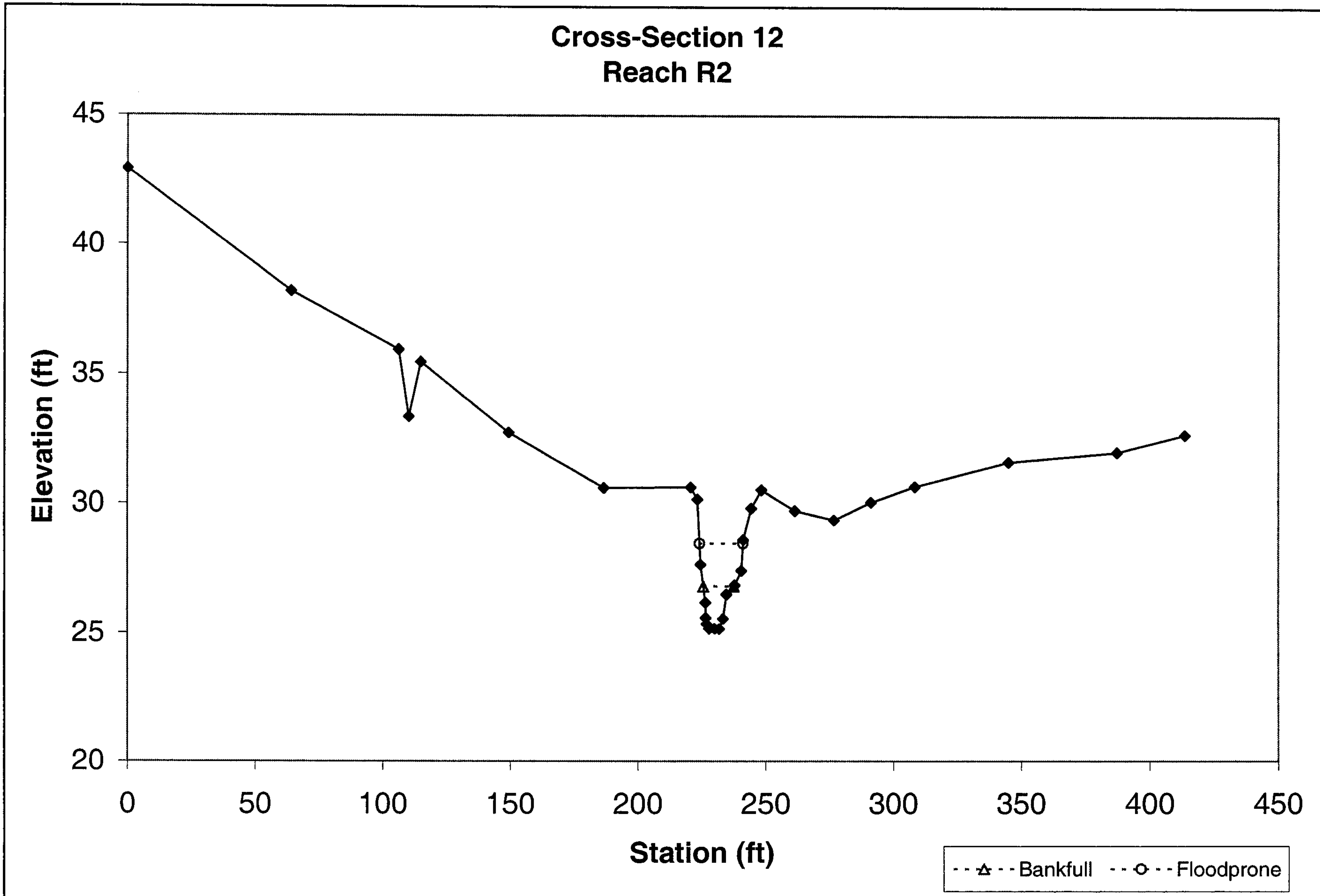


Cross-Section 9
Reach R2
Elevation (ft)
40
35
30
25
20
15
0
50
100
150
200
250
300
350
400
Station (ft)
Bankfull
Floodprone

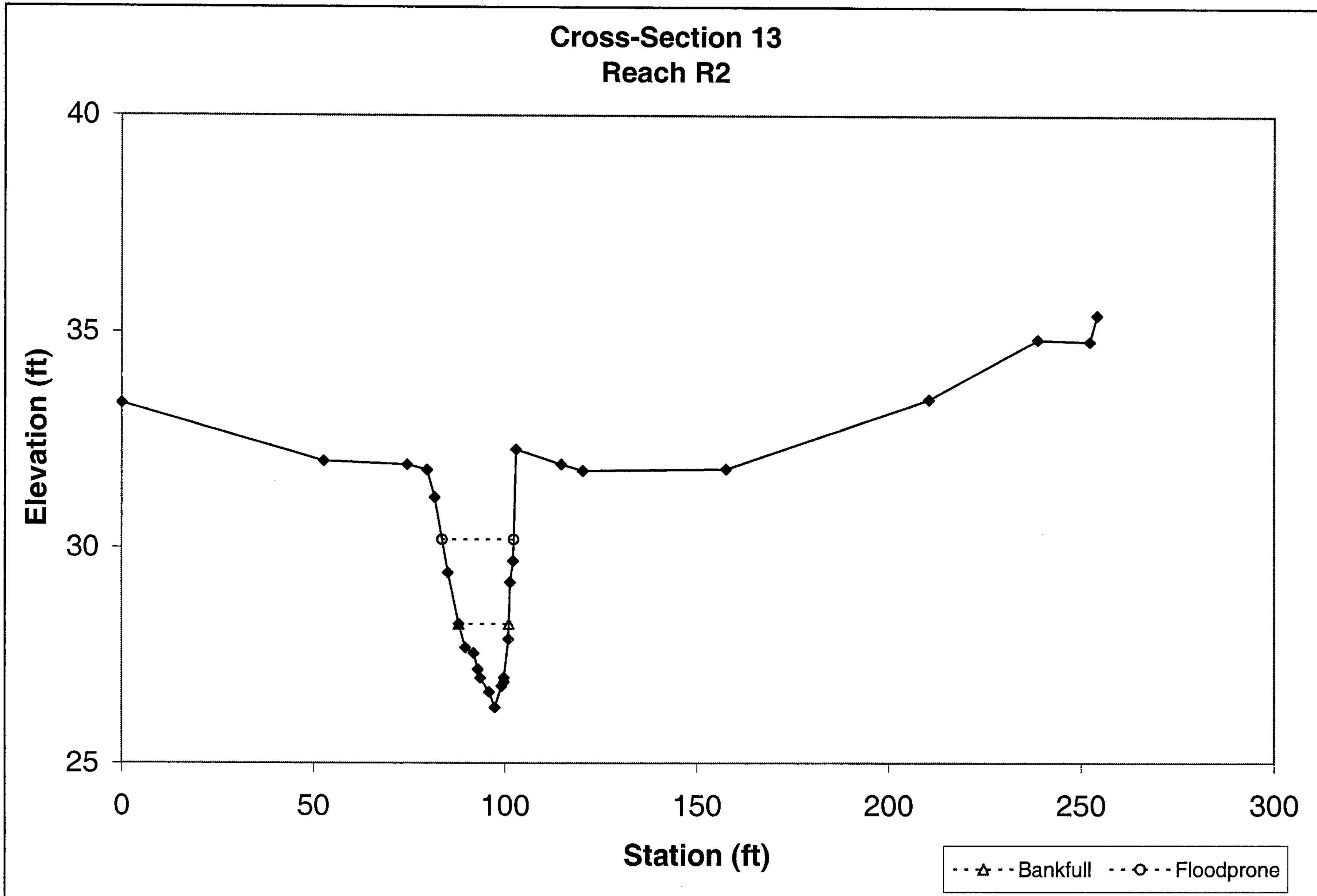


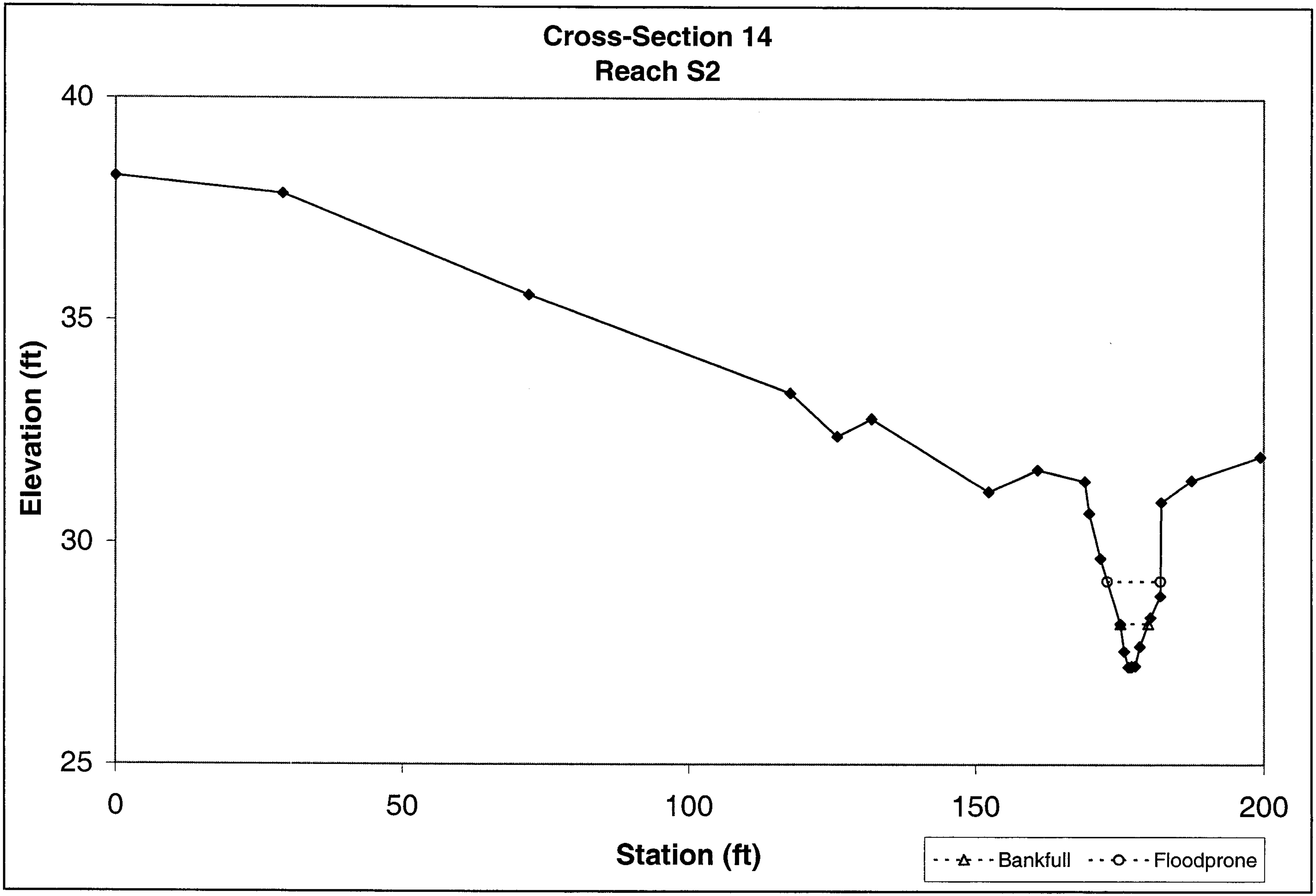
Cross-Section 10
Reach R2
Elevation (ft)
40
35
30
25
20
15
0
50
100
150
200
250
Station (ft)
Bankfull
Floodprone


Cross-Section 11
Reach S3
35
30
25
20
Elevation (ft)
0
50
100
Station (ft)
Bankfull
Floodprone

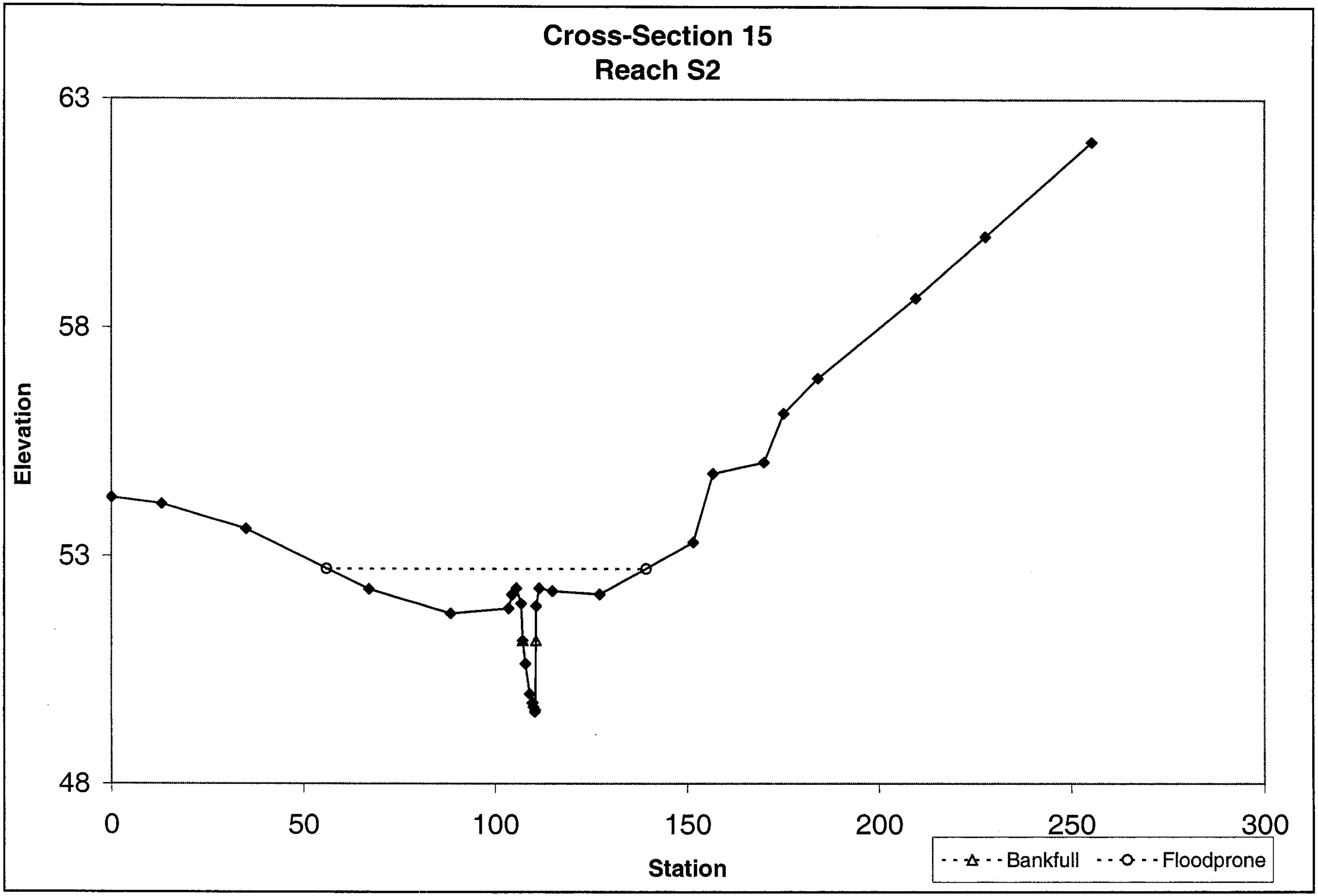


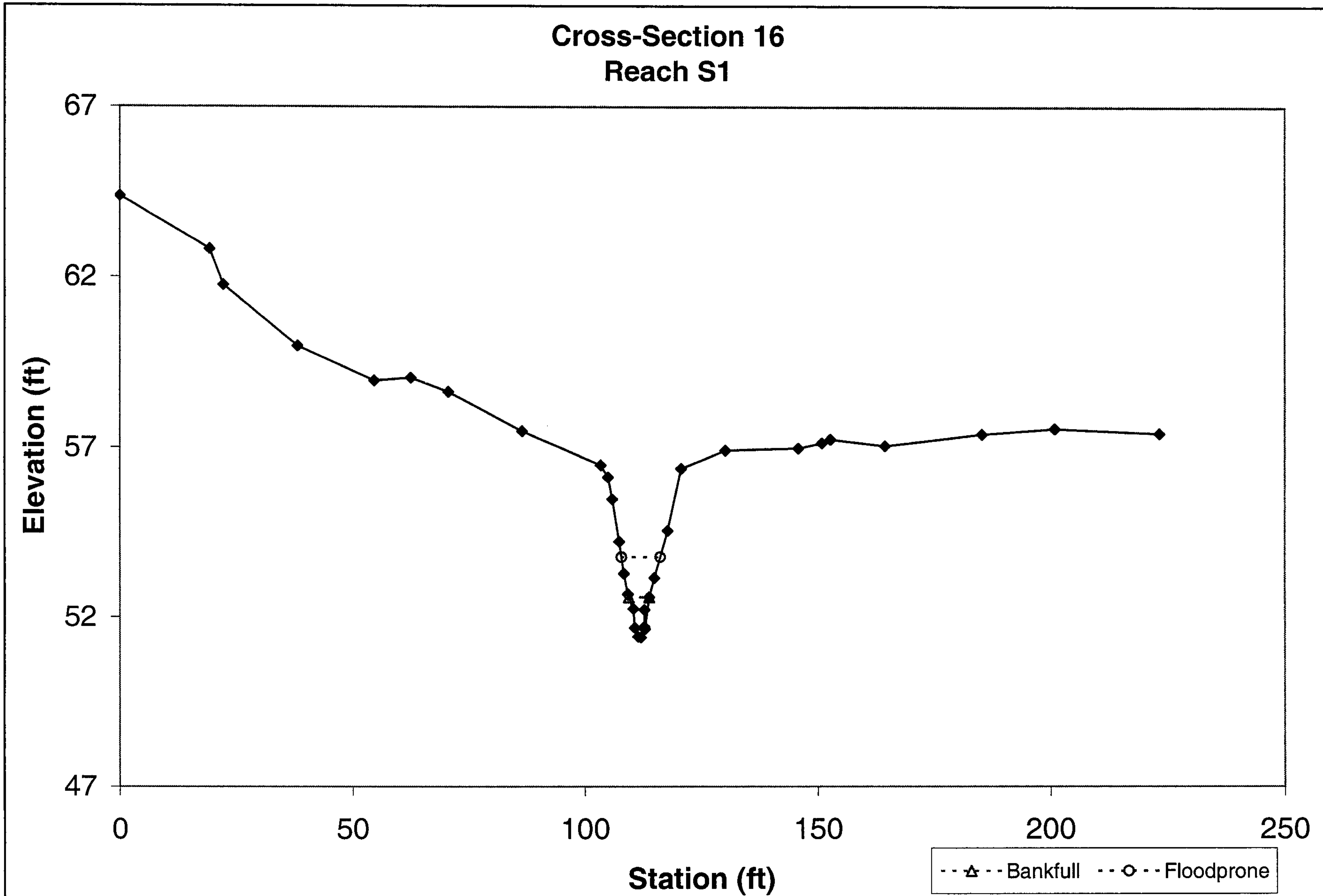
Cross-Section 12
Reach R2
Elevation (ft)
45
40
35
30
25
20
0
50
100
150
200
250
300
350
400
450
Station (ft)
Bankfull
Floodprone


Cross-Section 13
Reach R2
40
35
30
25
Elevation (ft)
0
50
100
150
200
250
300
Station (ft)
Bankfull
Floodprone

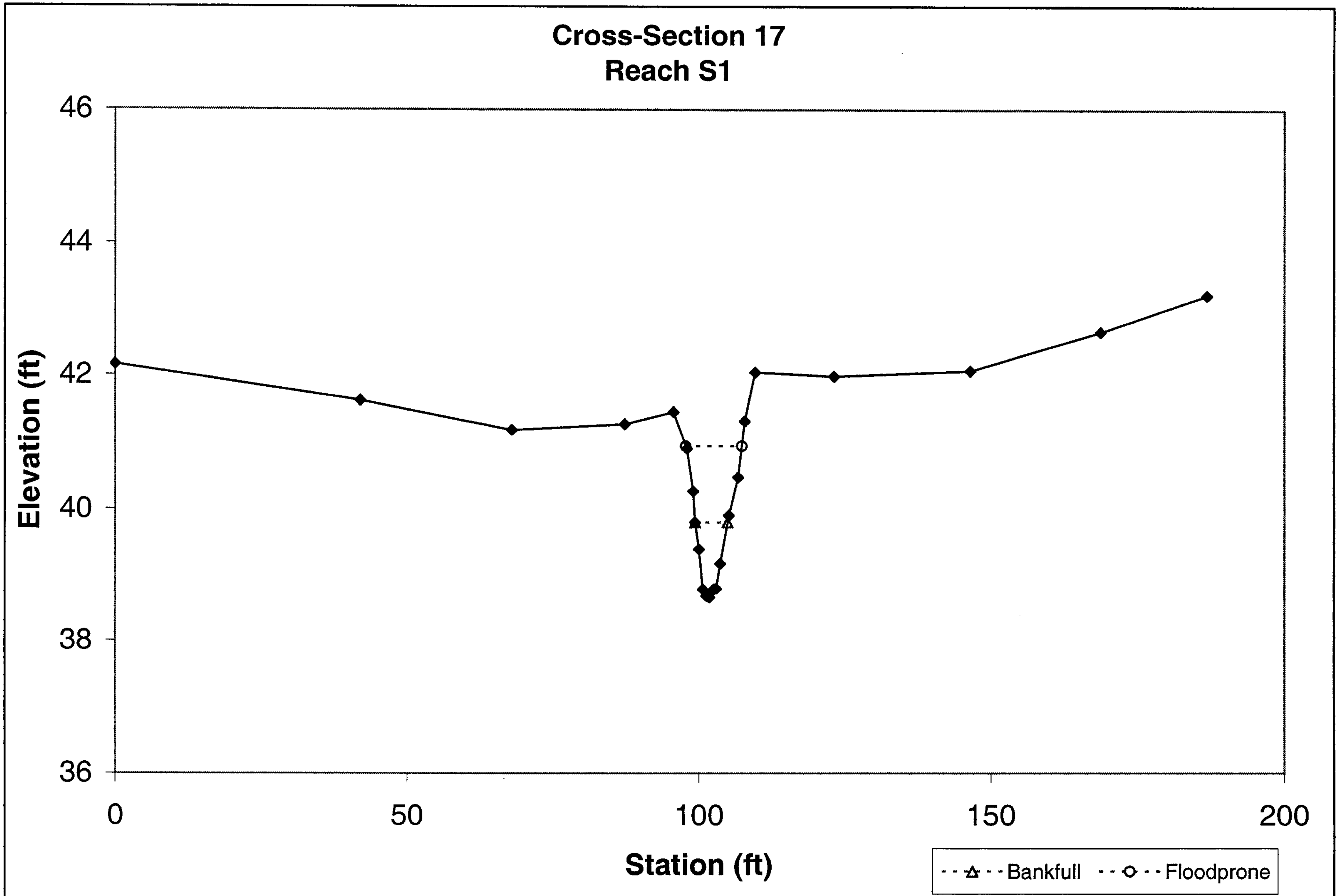


Cross-Section 14
Reach S2
Elevation (ft)
40
35
30
25
0
50
100
150
200
Station (ft)
Bankfull
Floodprone

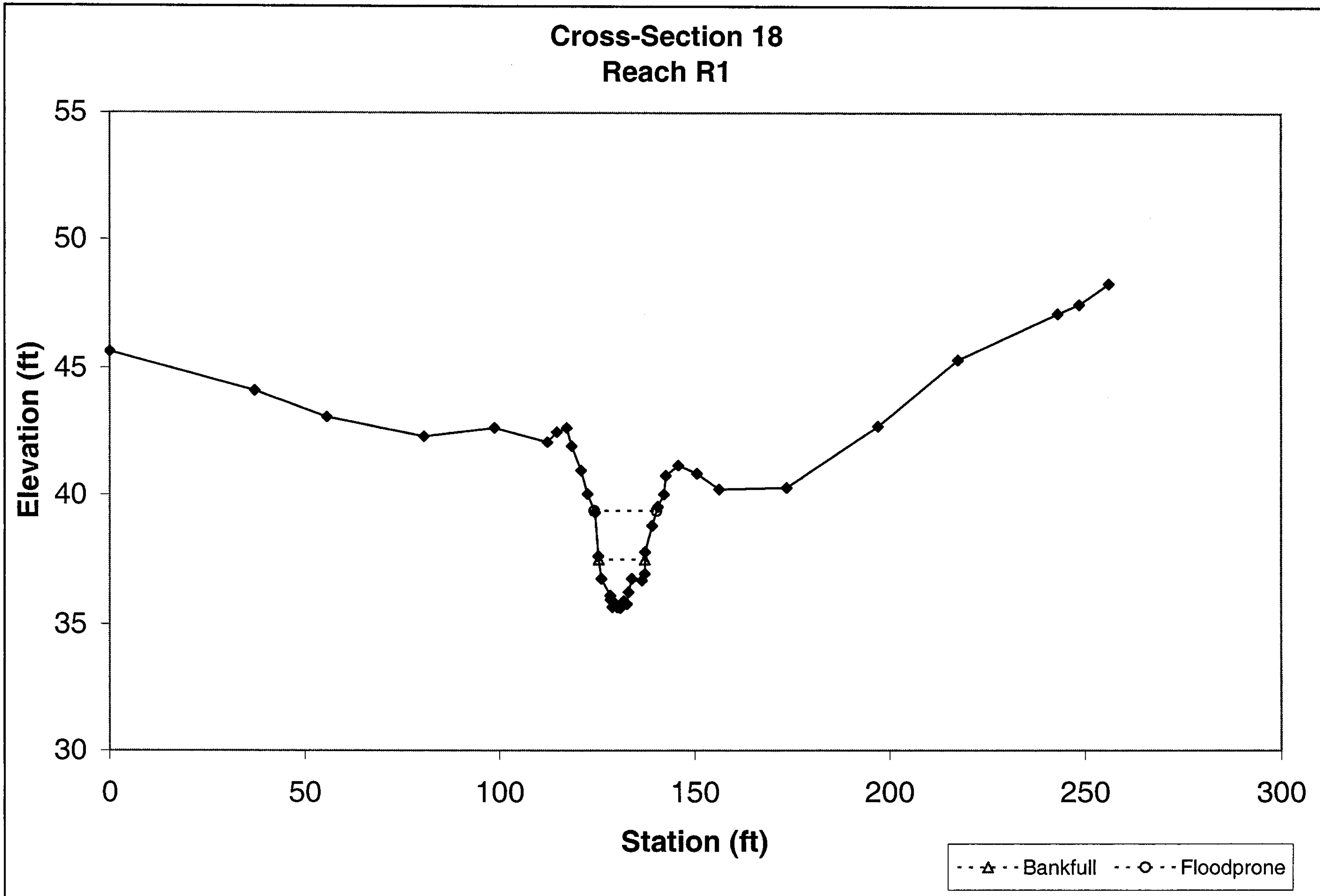

Cross-Section 15
Reach S2
Elevation
Station
63
58
53
48
0
50
100
150
200
250
300
Bankfull
Floodprone



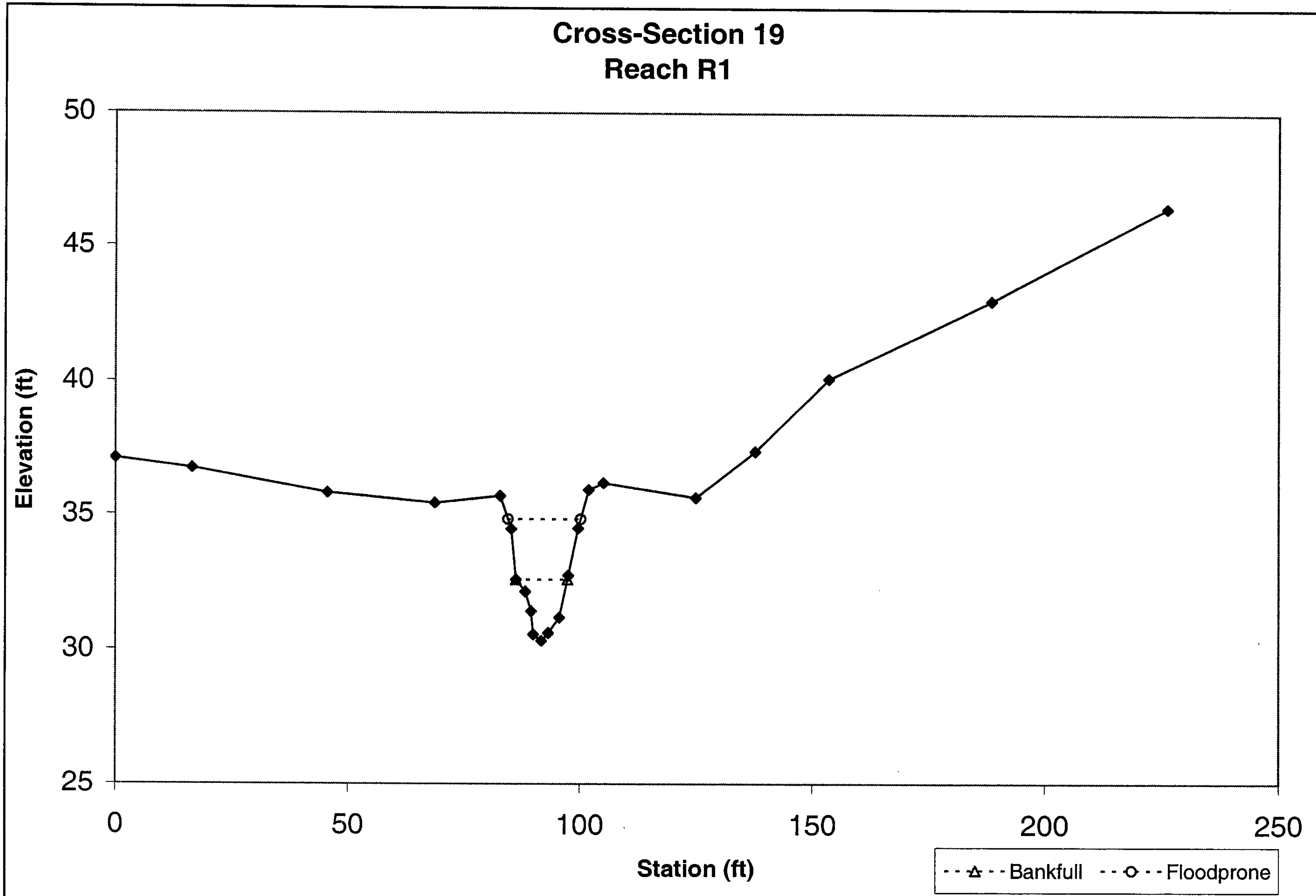
Cross-Section 16
Reach S1
67
62
57
52
47
Elevation (ft)
0
50
100
150
200
250
Station (ft)
Bankfull
Floodprone

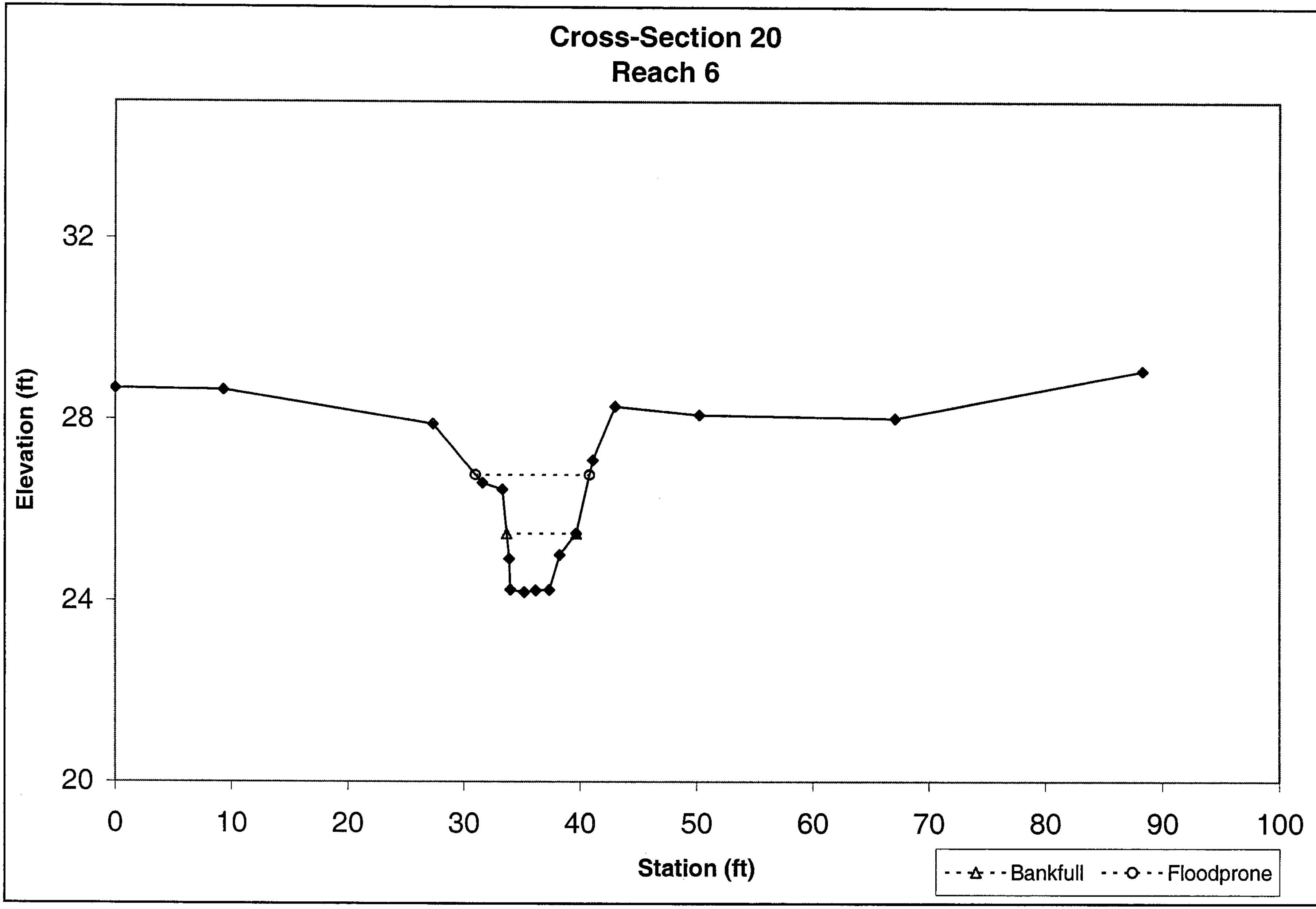


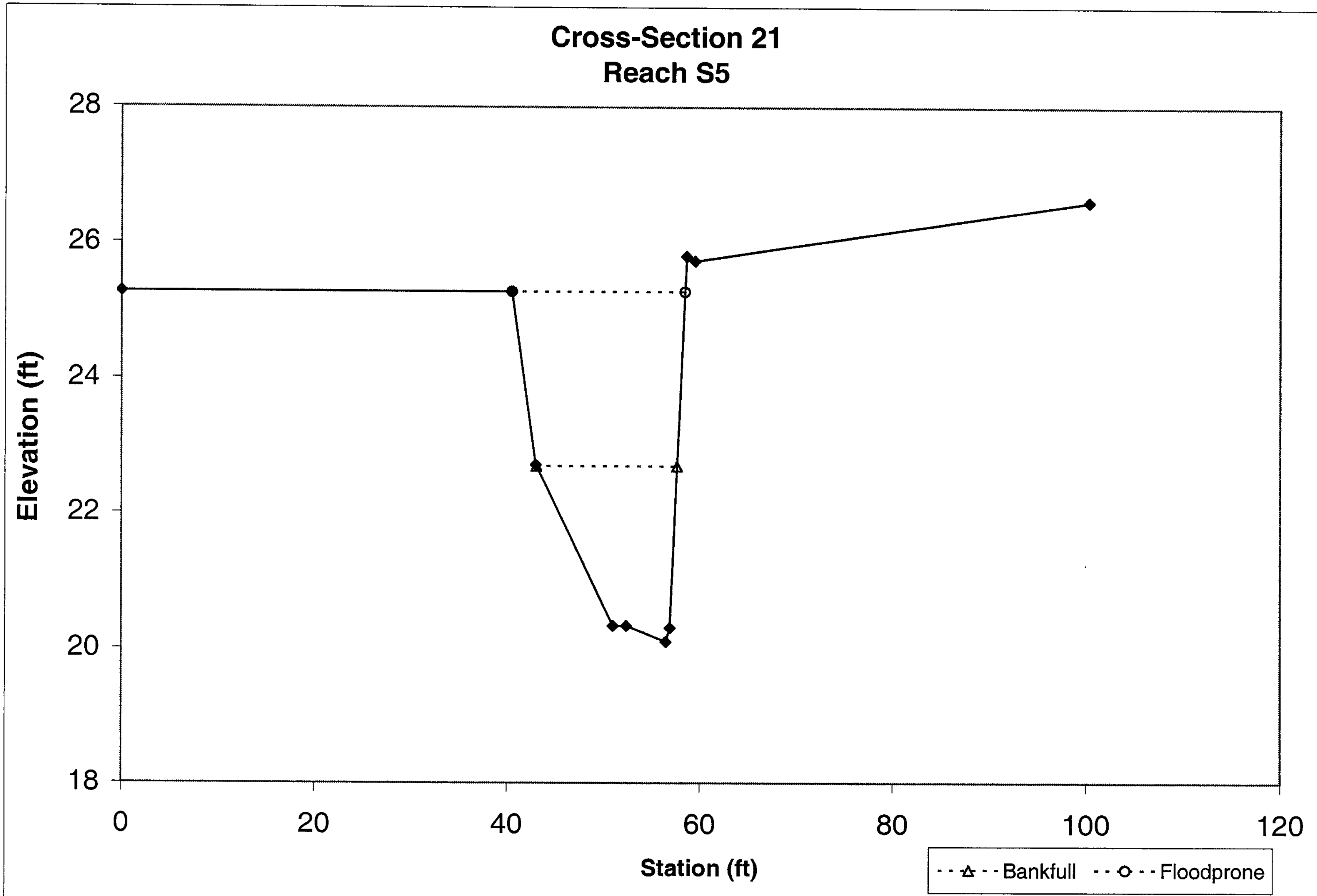
Cross-Section 17
Reach S1
46
44
42
40
38
36
Elevation (ft)
0
50
100
150
200
Station (ft)
Bankfull
Floodprone

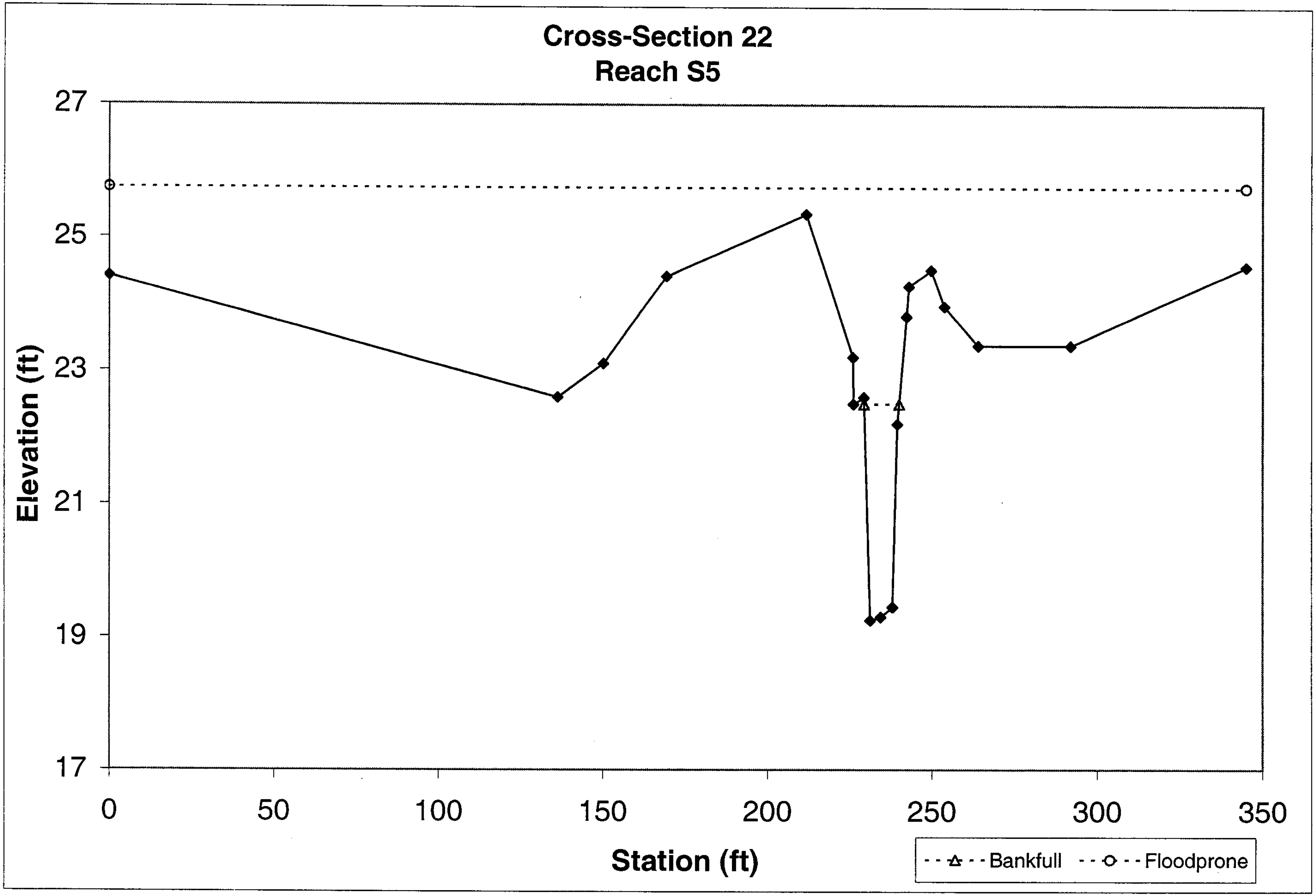


Cross-Section 18
Reach R1
55
50
45
40
35
30
Elevation (ft)
0
50
100
150
200
250
300
Station (ft)
Bankfull
Floodprone

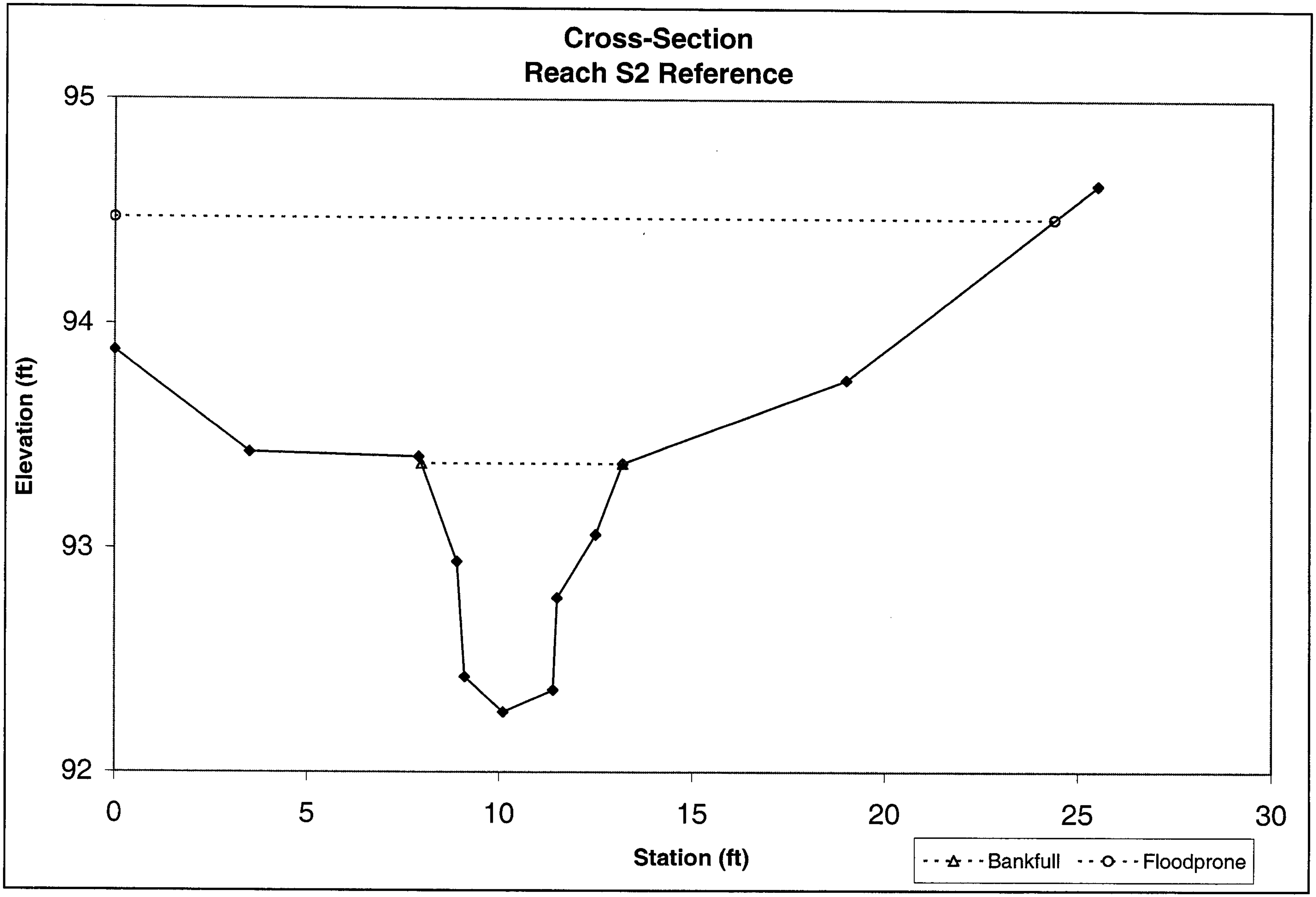

Cross-Section 19
Reach R1
Elevation (ft)
50
45
40
35
30
25
0
50
100
150
200
250
Station (ft)
Bankfull
Floodprone

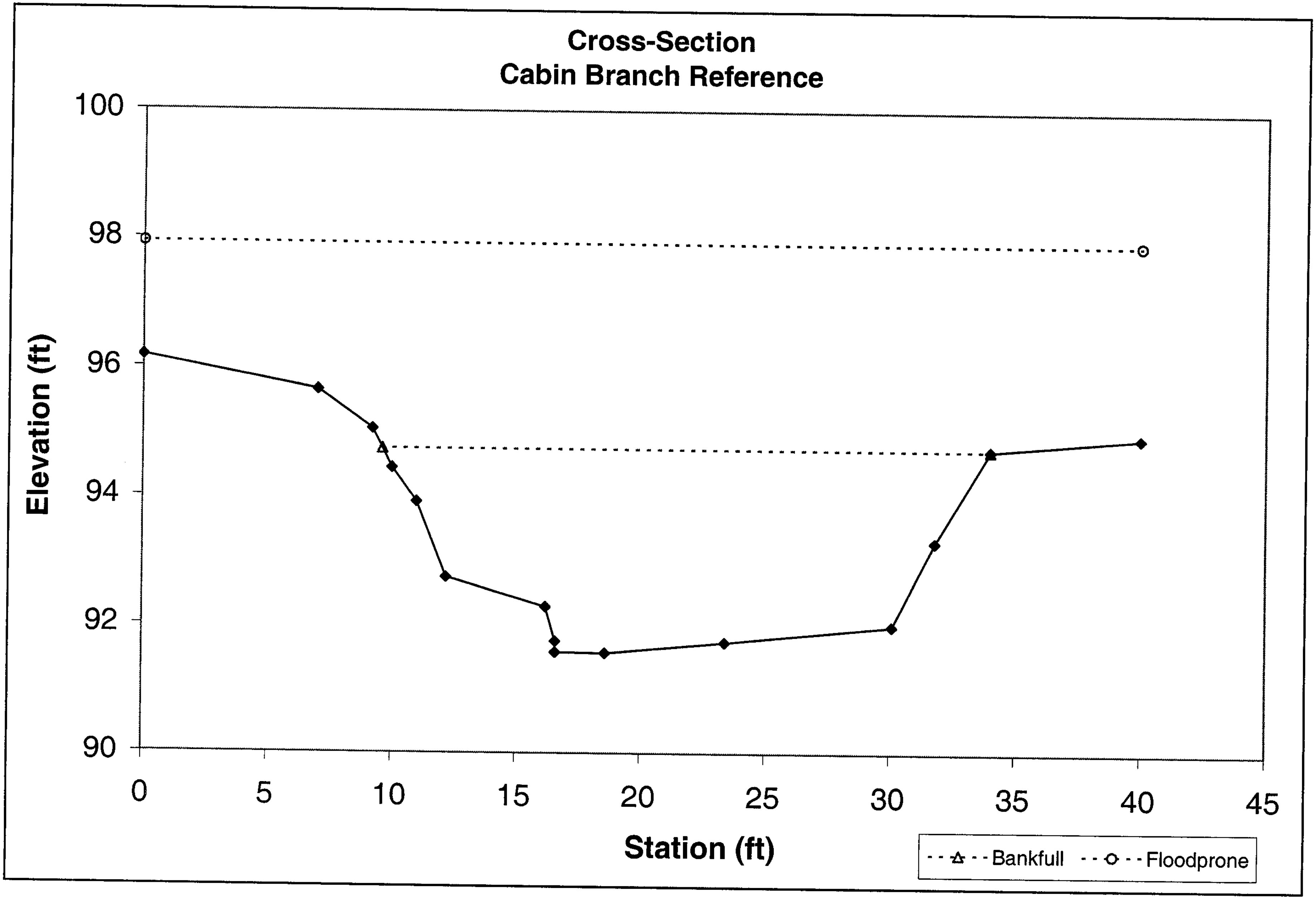

Cross-Section 20
Reach 6
Elevation (ft)
32
28
24
20
0
10
20
30
40
50
60
70
80
90
100
Station (ft)
Bankfull
Floodprone

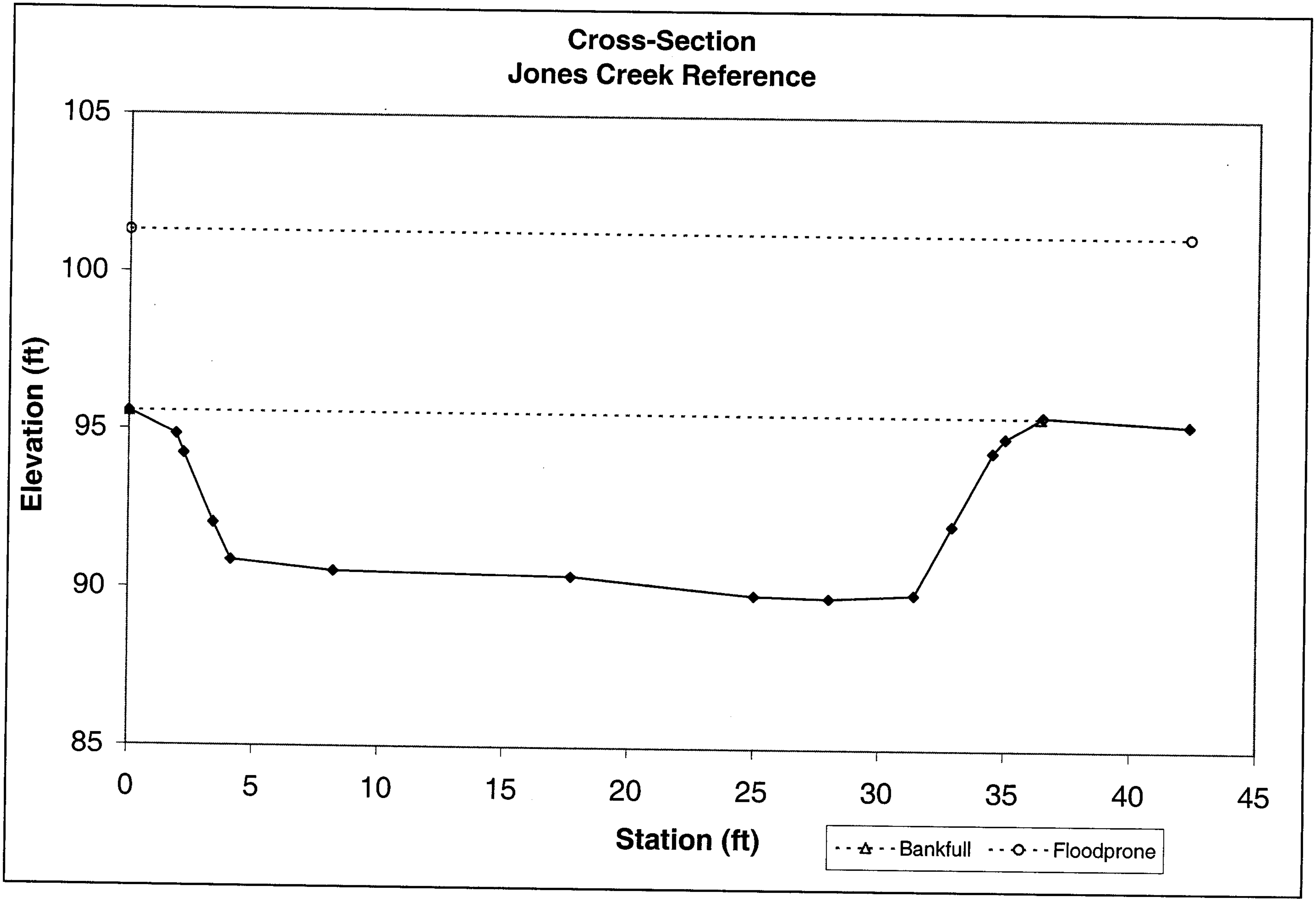

Cross-Section 21
Reach S5
Elevation (ft)
28
26
24
22
20
18
0
20
40
60
80
100
120
Station (ft)
Bankfull
Floodprone



Cross-Section 22
Reach S5
Elevation (ft)
27
25
23
21
19
17
0
50
100
150
200
250
300
350
Station (ft)
Bankfull
Floodprone


Cross-Section
Reach S2 Reference
95
94
93
92
0
5
10
15
20
25
30
Elevation (ft)
Station (ft)
Bankfull
Floodprone


Cross-Section
Cabin Branch Reference
Elevation (ft)
100
98
96
94
92
90
0
5
10
15
20
25
30
35
40
45
Station (ft)
Bankfull
Floodprone

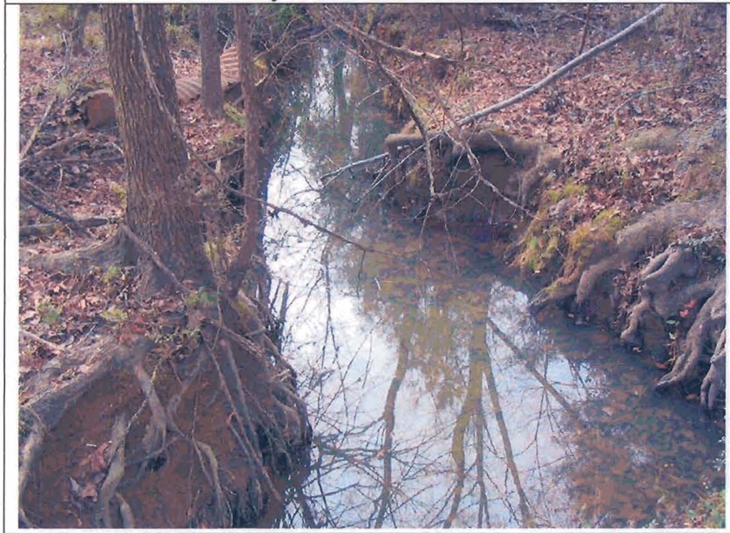

Cross-Section
Jones Creek Reference
105
100
95
90
85
Elevation (ft)
0
5
10
15
20
25
30
35
40
45
Station (ft)
Bankfull
Floodprone

Appendix D

Site Photographs

City Pond – Reach S1

City Pond – Reach S2



City Pond – Reach S3

City Pond – Reach S4

City Pond – Reach S5

City Pond – Reach S6

City Pond – Reach R1, weathered bedrock

City Pond – Reach R2

City Pond – Reach R3

City Pond – Reach R3

City Pond – Reach S4

City Pond – Reach S4