STREAM RESTORATION PLAN

ABBOTT PROPERTY
Wake County, North Carolina

State Project No. 8.1402601
TIP Project No. R-2541

North Carolina Department of Transportation
Project Development and Environmental Analysis Branch

February 1999

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Prepared For

North Carolina Department of Transportation
Project Development and Environmental Analysis Branch

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1.0 INTRODUCTION

The North Carolina Department of Transportation (NCDOT) proposes to construct the NC 55, Holly Springs Bypass (R-2541) on a new location from SR 1114 (Ralph Stevens Loop Road) to SR 1448 (Bobbitt Road) in Wake County (Figure 1). Construction of this project will result in unavoidable impacts to 528 meters (1,733 feet) of stream.

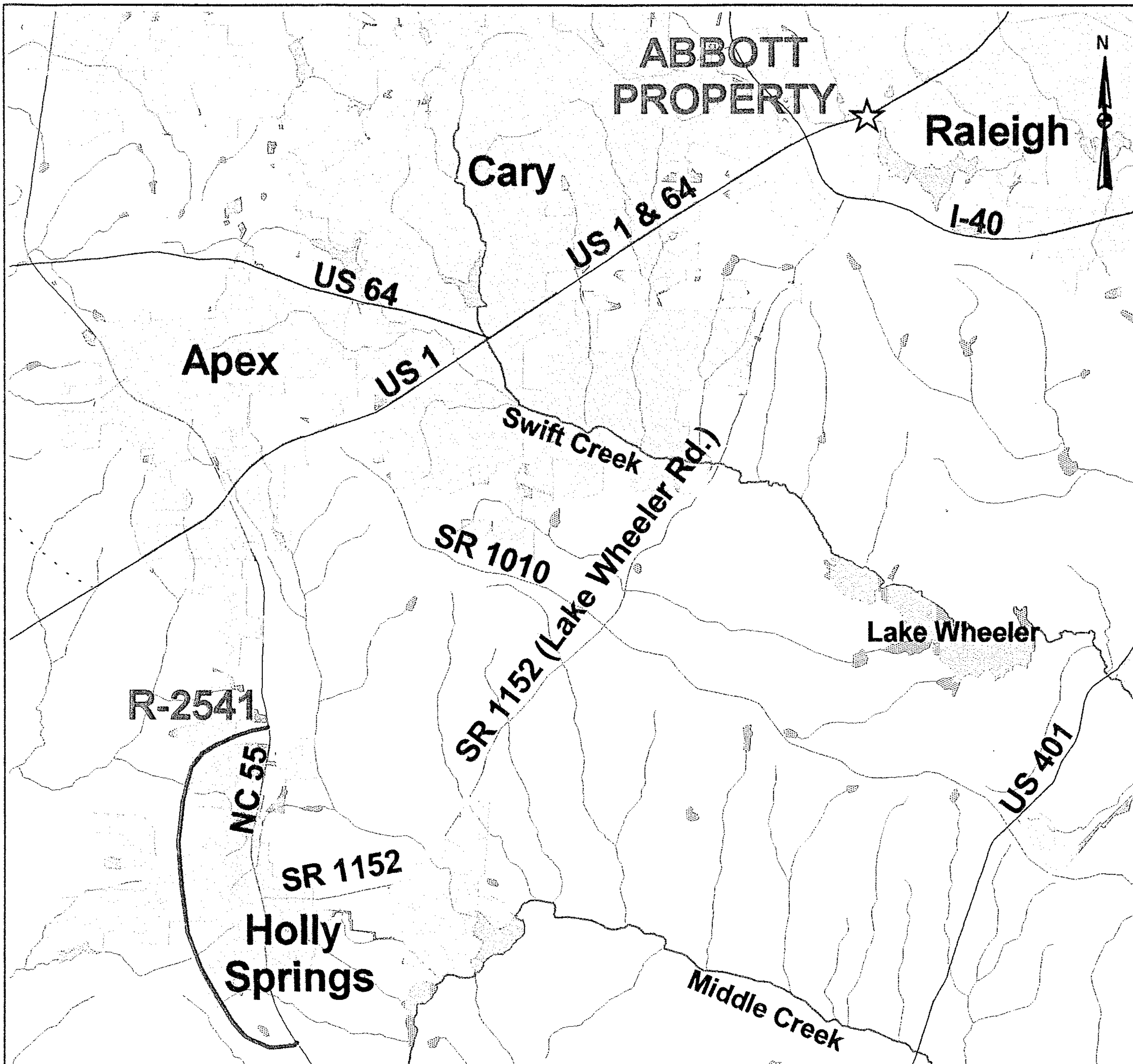
The NCDOT located the Abbott Site as a potential stream mitigation site (Figure 2). A feasibility study of the property was prepared in January 1998. The report concluded that approximately 300 linear meters (920 ft) (based on preliminary mapping) of the unnamed tributary on the Abbott Property was severely degraded resulting in degradation of water quality and loss of aquatic habitat on the site as well as downstream. Restoration will require determining how far the stream has departed from its natural stability, and what the stable form of the stream (channel dimension and pattern) is likely under the current hydrologic conditions within the drainage area. Once the stream's potential has been determined, restoration techniques on the Abbott Property include:

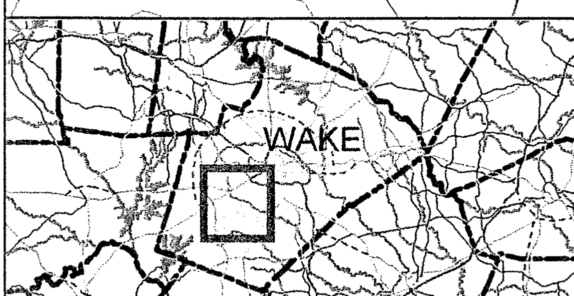
- Alteration of stream channel dimensions and meander geometry to achieve stream stability.
- Placement of root wads or other materials along the bank to reduce erosion and enhance aquatic habitat.
- Stabilization of stream banks with woody vegetation.

1.1 SITE DESCRIPTION

The Abbott Property, about 2.2 ha (5.5 ac) in size, is located north of US 1 between two residential communities in west Raleigh. The main feature of the property is a former pond about 1.3 ha (3.3 ac) in size that has been drained and is in various stages of revegetation. A small unnamed tributary to Walnut Creek flows through the property from north to south (Figure 3). Approximately 318 linear meters (1,018 ft) of this tributary is degraded, resulting in degradation of water quality and loss of aquatic habitat both onsite and downstream.

Forested floodplains are associated with the stream and at the northern end of the property exists a cleared, grassy area that serves as a neighborhood park. A wooden footbridge crosses the stream in the park area. An earthen dam, approximately 4.5 m (15 ft) high, 3 m (10 ft) wide at the top, and 6 m (20 ft) wide at the base was formerly constructed across the stream to create a pond. In 1996, Hurricane Fran destroyed a portion of the dam. Currently, the remainder of the dam is vegetated with saplings, forbs, and grasses and has an unpaved access road on the top. The destruction of the mid-portion of the dam caused the property to revert back to a stream channel with a floodplain varying in width from 1.5 to 7.6 m (5 to 25 ft). Portions of the riser





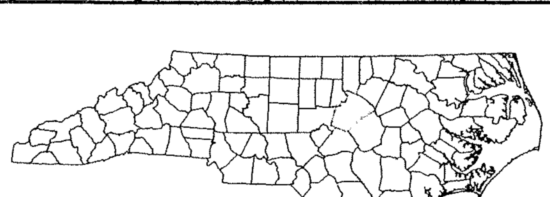


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FIGURE 1
Project Location Map
Abbott Property Stream Restoration
Wake County, North Carolina

1 0 1 2 3 Miles

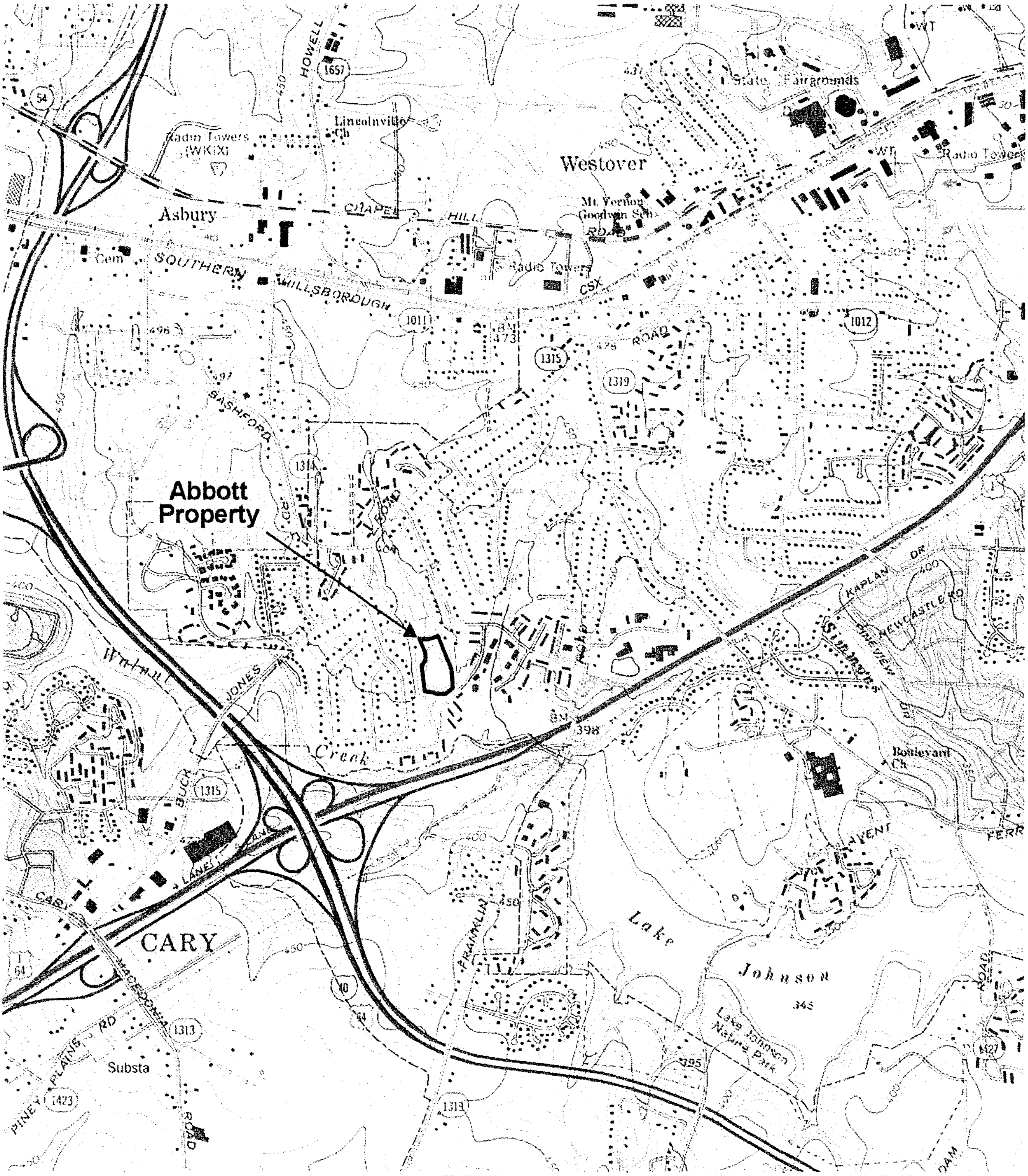

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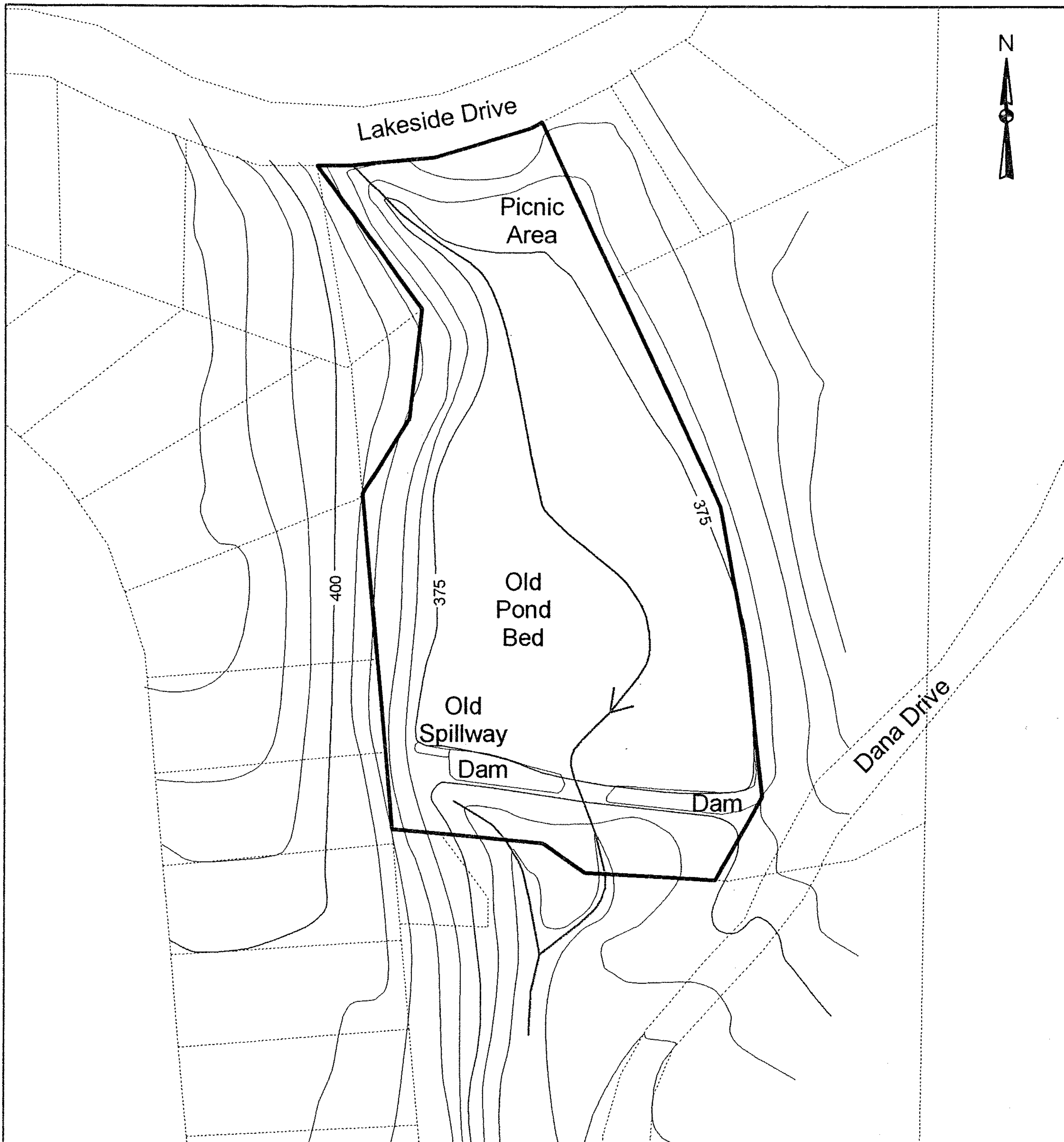
FIGURE 2
Site Vicinity Map
Abbott Property Stream Restoration
Wake County, North Carolina

2000 0 2000 4000 Feet

SOURCE: U.S. GEOLOGICAL SURVEY MAP:
7.5 MINUTE QUADRANGLE: RALEIGH WEST, NC (1987)



Abbott Property Boundary
Streams

Index Contour 25' Interval
Intermediate Contour 5' Interval
Property Lines

Cadastral and Topographical data:
Wake County GIS, 1997; Projection NAD83, m.

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FIGURE 3
Site Map
Abbott Property Stream Restoration
Wake County, North Carolina

50 0 50 100 150 200 250 Feet

and barrel exist at the base of the dam where the severely eroded stream channel is now located. An old emergency spillway is located in the southwestern corner of the basin. The spillway is consists of a concrete slab over the earthen dam. A large scour hole has been formed under the structure. A foot bridge which once provided access over the spillway has been damaged by fallen trees. Both these structures currently present a safety hazard.

A mixed hardwood-pine forest, approximately 50 to 75 years old, covers the floodplain of the tributary as it exits the former basin at the southern end of the property. A mixture of hardwood saplings and forbs covers the majority of the former pond basin.

1.2 SITE HISTORY

According to Mr. John Abbott, a longtime resident of the neighborhood adjacent to the site, the pond was originally a farm pond associated with a dairy operation. In the mid 1950's the dairy was sold and the land developed into a residential area. The pond was given to the neighborhood association (Lakeside Recreation Development Corporation), and for a number of years was a good place to fish. The pond eventually filled with silt and in the late 1980's the standpipe was opened and the pond completely drained. The dam was breached about two years ago. Mr. Abbott was not aware of any environmental problems with the property or of any dumping that might have occurred on the property. He indicated that the neighborhood "kept a good watch" on the property.

According to historic aerial photography in the Wake County Soil Survey (photography date: 1967), the Abbott Property contained a small pond. The area immediately to the east of the pond was cleared; further east was a wooded area (which is now developed as an apartment complex). The vicinity of the Abbott Property was generally more wooded and slightly less developed.

Aerial photography from NCDOT's photogrammetry unit was evaluated. According to photography dated 1974, the pond had not been drained at this time. However, aerial photography dated 1986, revealed that the pond had been drained. From the minimal amount of vegetation within the basin, it appears that the pond had been drained only a short time since the 1986 photograph. Aerial photography from NCDOT dated 1991 showed conditions similar to those in 1986.

Color and infrared aerial photography flown in November 1997 showed the basin had become more vegetated and appeared to have some shrubby species. The stream channel appears more defined in these photographs.

2.0 PROJECT DESCRIPTION

The purpose of this project is to restore the stream to the stable dimension, pattern, and profile for a C4 stream type as classified using Rosgen's stream classification methodology (Rosgen 1996). According to this methodology, a stream is considered stable if it maintains its dimension, pattern, and profile over time while consistently transporting its watershed's runoff and sediment load. Currently the stream on the Abbott Property is unstable. Prior to the dam breaching, silt at the bottom of the old pond basin was several feet above the existing stream channel at the toe of the dam. When the dam was breached, the stream began cutting down through the sediment. This abrupt change in elevation resulted in stream bank erosion known as headcutting. The channel will continue to headcut further upstream until a stable slope is established.

This project will be a Priority I restoration (Rosgen, 1997). Table 1 describes and summarizes the four priorities of incised river restoration (Rosgen, 1997). This type of restoration will re-establish the channel on a previous floodplain, or in this case, the basin of the old pond. Appropriate channel dimensions (width and depth), pattern (sinuosity, beltwidth, riffle-pool spacing), and profile (bed slope) of the new channel will be determined from reference reaches. The old channel will be filled in from excavation of the center dam wall. The opening in the center of the dam will be widened to allow for an expanded floodplain.

Table 1 Priorities, Description, and Summary For Incised River Restoration

DESCRIPTION	METHODS	ADVANTAGES	DISADVANTAGES
PRIORITY 1 Convert G and/or F stream types to C and/or E at previous elevation w/floodplain	Re-establish channel on previous floodplain using relic channel or construction of new bankfull discharge channel. Design new channel for dimension, pattern and profile characteristic of stable form. Fill in existing incised channel or with discontinuous oxbow lakes level with new floodplain elevation.	Re-establishment of floodplain and stable channel: 1) reduces bank height and streambank erosion 2) reduces land loss 3) raises water table 4) decreases sediment 5) improves aquatic and terrestrial habitats 6) improves land productivity, and 7) improves aesthetics.	1) floodplain re-establishment could cause flood damage to urban agricultural and industrial development. 2) downstream end of project could require grade control from new to previous channel to prevent head-cutting.
PRIORITY 2 Convert G and/or F stream types to C or E. Re-establishment of floodplain at existing or higher, but not at original level	If belt width provides for the minimum meander width ratio for C or E stream types, construct channel in bed of existing channel, convert existing bed to new floodplain. If belt width is too narrow, excavate streambank walls. End-hall material or place in streambed to raise bed elevation and create new floodplain in the deposition.	1) decreases bank height and streambank erosion 2) allows for riparian vegetation to help stabilize banks 3) establishes floodplain to help take stress of channel during flood 4) improves aquatic habitat 5) prevents wide-scale flooding of original land surface 6) reduces sediment 7) downstream grade transition for grade control is easier.	1) does not raise water table back to previous elevation 2) shear stress and velocity higher during flood due to narrower floodplain 3) upper banks need to be sloped and stabilized to reduce erosion during flood.
PRIORITY 3 Convert to a new stream type without an active floodplain, but containing a floodprone area. Convert G to B stream type, or F to Bc	Excavation of channel to change stream type involves establishing proper dimension, pattern and profile. To convert G to B stream involves an increase in width/depth and entrenchment ratio, shaping upper slopes and stabilizing both bed and banks. A conversion from F to Bc stream type involves a decrease in width/depth ratio and an increase in entrenchment ratio.	1) reduces the amount of land needed to return the river to a stable form. 2) developments next to river need not be re-located due to flooding potential 3) decreases flood stage for the same magnitude flood 4) improves aquatic habitat.	1) high cost of materials for bed and streambank stabilization 2) does not create the diversity of aquatic habitat 3) does not raise water table to previous levels.
PRIORITY 4 Stabilize channel in place	A long list of stabilization materials and methods have been used to decrease stream bed and bank erosion, including concrete, gabions, boulders and bio-engineering methods	1) excavation volumes reduced 2) land needed for restoration is minimal	1) high cost for stabilization 2) high risk due to excessive shear stress and velocity 3) limited aquatic habitat depending on nature of stabilization methods used.

3.0 GOALS AND OBJECTIVES

This stream restoration project should achieve the following goals and objectives:

1. Provide a stable stream channel that neither aggrades nor degrades while maintaining its dimension, pattern, and profile with the capacity to transport its watershed's water and sediment load.
2. Improve downstream water quality by reducing the amount of sediment being produced by the existing headcut, bank erosion, and mass wasting of the banks.
3. Improve aquatic habitat by reducing the silt and clay fines in the stream bed caused by bank erosion.
4. Improve fish habitat with the use of natural material stabilization structures such as root wads and rock vanes and a riparian buffer.

4.0 EXISTING CONDITIONS

4.1 WATERSHED

4.1.1 Description

The watershed which drains into the unnamed tributary is approximately 155 ha (385 ac) or 0.6 sq. mi. and is triangular in shape (Figure 4). Within the watershed exists a mixture of residential and commercial properties. This watershed is characterized with a SCS Curve Number of 75.

The northern boundary of the watershed is Hillsborough Street, which was constructed along a ridgeline. Overland flow drains into one of two small tributaries either in the northwest corner or in the northeast corner of the watershed. These small intermittent streams converge in the middle of the watershed, forming the tributary that flows through the study area. Eastern and western boundaries follow topography to the southern boundary, which is the point where the tributary flows into the head of the former pond.

Topography within the watershed ranges from gently sloping uplands to flat floodplains. The watershed gradient is approximately 2 percent. Development has been extensive within this area and topography has invariably been altered to accommodate buildings and roads. Drainage from impervious roads and driveways has been channeled through ditches and culverts.

Soils within the watershed are mainly Cecil sandy loams with variable slopes (Figure 5). Many of these soils are eroded according to the Wake County Soil Survey (1970). Pockets of Appling sandy loam exist in the northern portion of the watershed. Chewacla soils are dominant in the drainageways. Wehadkee and Bibb soils are present along the perennial stream directly above the project site.

4.1.2 Landuse and Zoning

Landuses within the watershed area have been identified in the Raleigh Comprehensive Plan (May 1998) as Community Focus, Residential Community Focus, Employment Area, Residential Retail, and Transit Corridor (Figure 6).

Zoning is primarily for residential use. Approximately 335 acres, nearly 87 percent, of the watershed area are zoned as Residential - 4, 10, and 15 District (Figure 6). Neighborhood Business District comprises the second largest zoned areas with 35 acres or 9 percent of the watershed. Areas zoned Shopping Center District make up approximately 15 acres or 4 percent of the watershed area. The following descriptions of permitted uses in zoning districts have been referenced from the City of Raleigh Zoning Code.

- **Residential-4 District**
  Single-family dwellings (10,890 sq. ft. minimum lot size) - maximum four (4) per acre; townhouses, group housing, multi-family, and condominiums as part of a Cluster Unit Development.

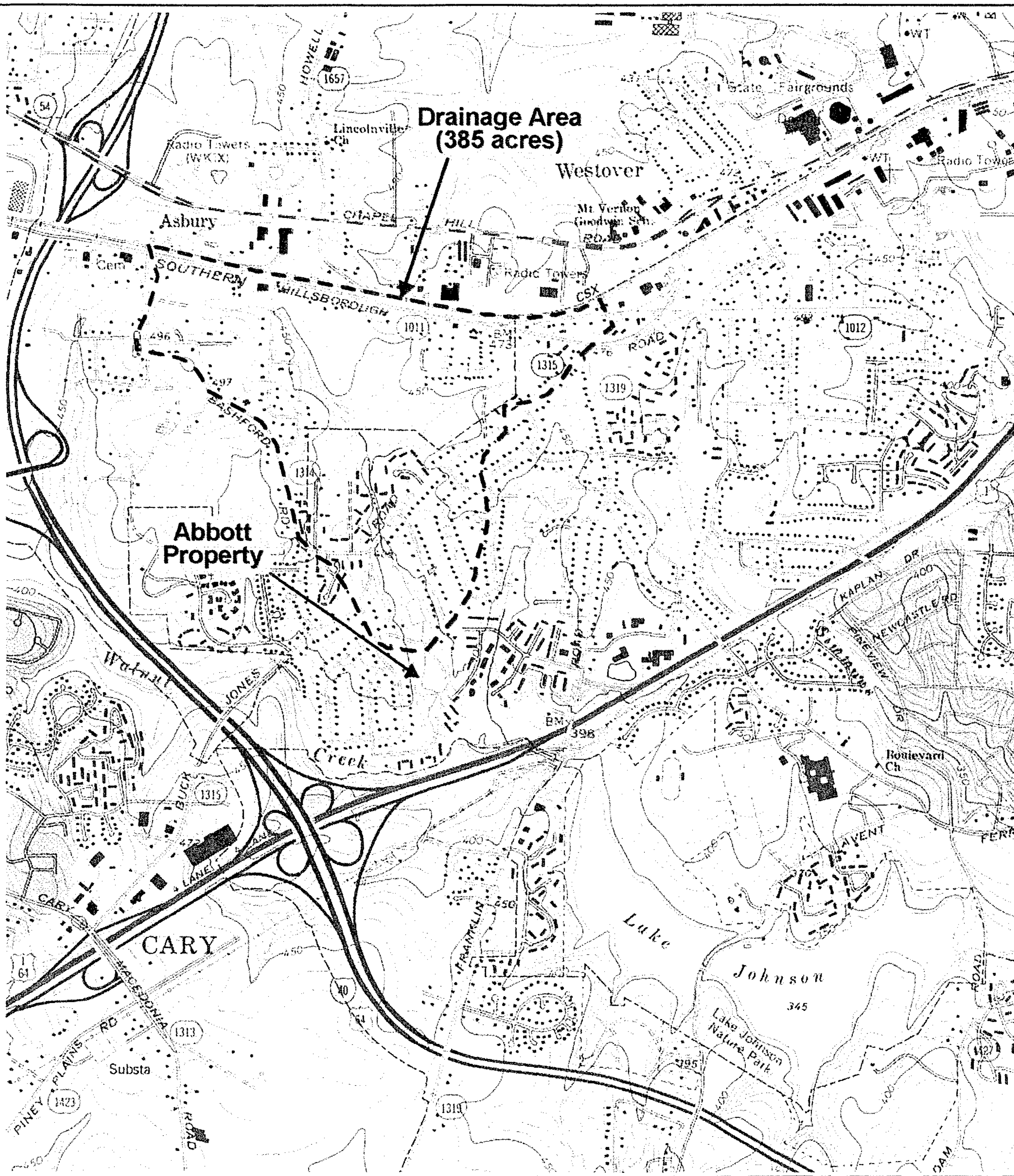

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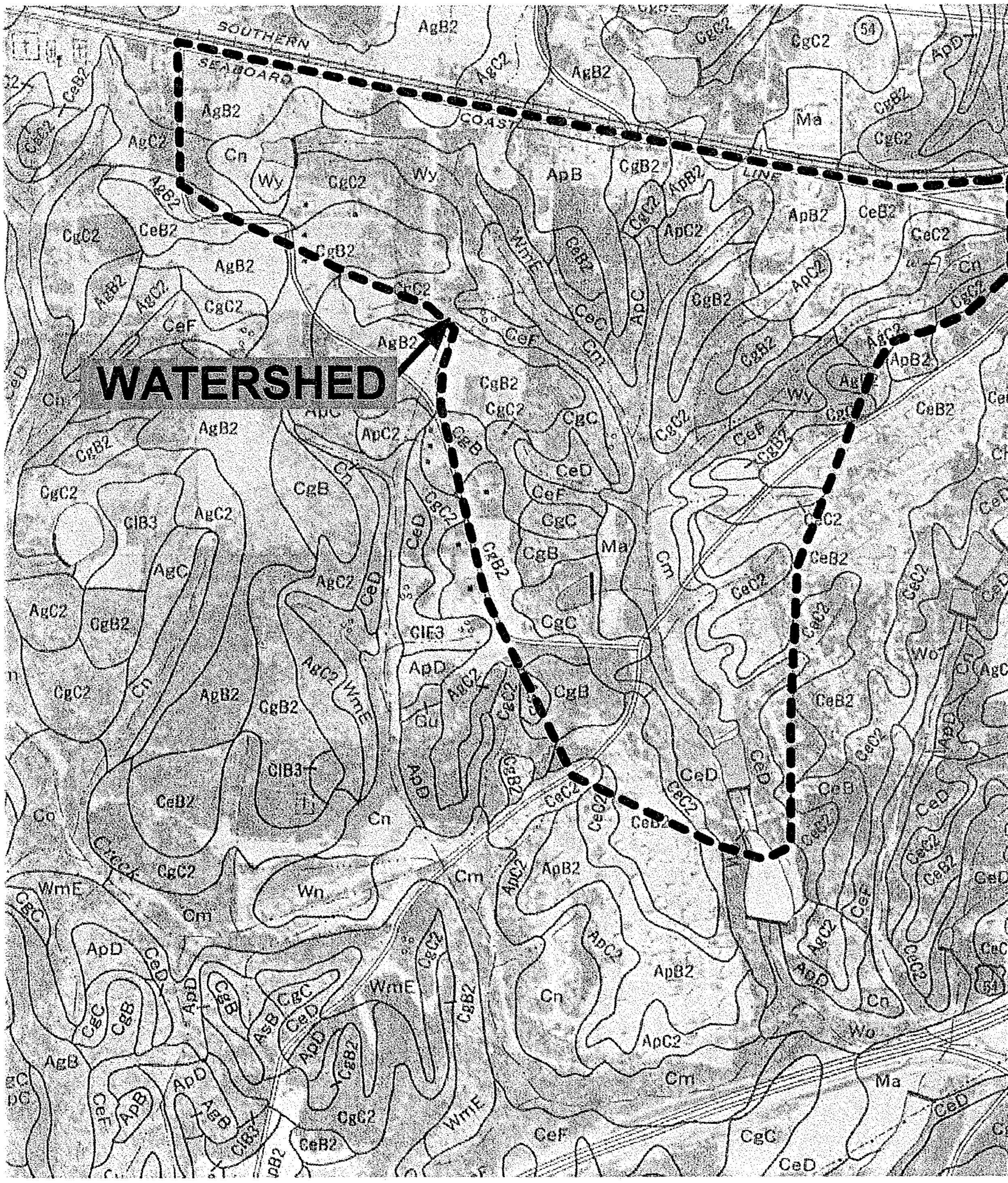
FIGURE 4
Abbott Property Drainage Area
Abbott Property Stream Restoration
Wake County, North Carolina

2000 0 2000 4000 Feet

SOURCE: U.S. GEOLOGICAL SURVEY MAP:
7.5 MINUTE QUADRANGLE: RALEIGH WEST, NC (1987)



SOURCE: WAKE COUNTY SOIL SURVEY, NRCS

LEGEND

AgB2 - Appling Gravelly Sandy Loam, 2-6% slope
AgC2 - Appling Gravelly Sandy Loam, 6-10% slope
ApB - Appling Sandy Loam, 2-6% slope
ApC - Appling Sandy Loam, 6-10% slope
CeB2 - Cecil Sandy Loam, 2-6% slope
CeC - Cecil Sandy Loam, 6-10% slope
CeD - Cecil Sandy Loam, 10-15% slope
CeF- Cecil Sandy Loam, 10-45% slope
CgB - Cecil Gravelly Sandy Loam, 2-6% slope
CgC - Cecil Gravelly Sandy Loam, 6-10% slope
Cm - Chewacla soils
Cn - Colfax Sandy Loam
Ma - Made land
WmE- Wedowee Sandy Loam, 15-25% slope
Wy - Worsham Sandy Loam

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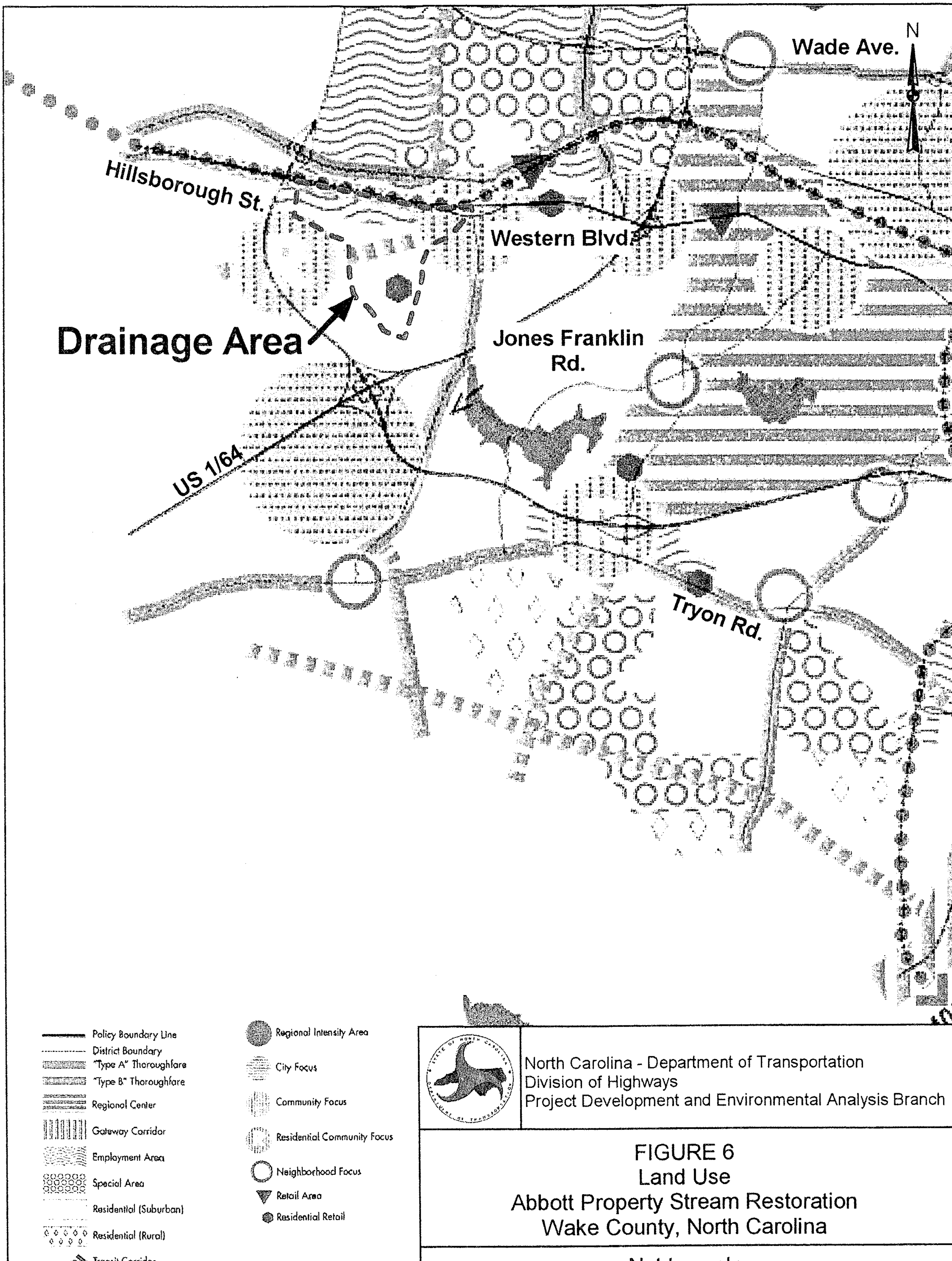
FIGURE 5
Soil Map
Abbott Property Stream Restoration
Wake County, North Carolina

Not to scale



Raleigh Comprehensive Plan, May 1998

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FIGURE 6
Land Use
Abbott Property Stream Restoration
Wake County, North Carolina

Not to scale

- **Residential-10 District**
  Single-family dwellings (5,000 sq. ft. minimum lot size), duplex; multi-family dwellings, townhouses, condominiums or group housing - maximum ten (10) units per acre; rooming house, boarding house, or tourist home; club for civic purposes.

- **Residential-15 District**
  Single-family dwellings (5,000 sq. ft. minimum lot size), duplex dwellings (6,500 sq. ft. minimum lot size); multi-family dwellings, townhouses, condominiums or group housing - maximum 15 units per acre.

- **Shopping Center District**
  Dwellings up to 30 units per acre; government buildings and grounds; charitable institutions, parking lots, funeral home, radio and TV studios, office or studio of a professional or business agent, or political, labor or service association; colleges; nonresidential related service facilities; profit-making recreational uses; emergency shelter type B; kennel or riding stable; garages and filling stations, retail sales of all kinds; custom manufacturing; shopping centers; individual storage facilities; adult establishments.

- **Neighborhood Business District**
  All Shopping Center uses (limited to 10 residential units per acre); emergency shelter type A.

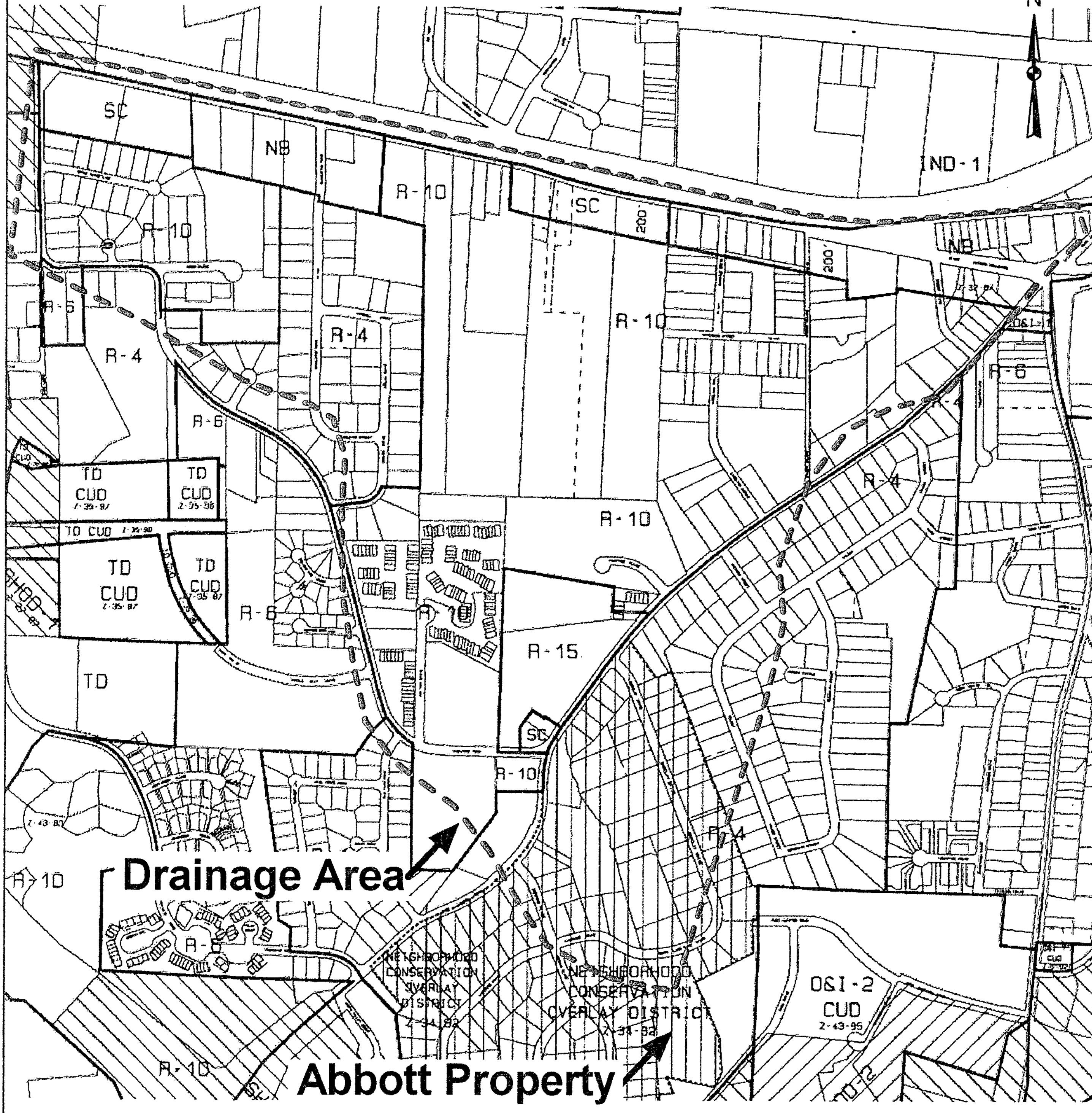
In an effort to make the zoning more compatible with actual development, Roylene Acres has been rezoned to Neighborhood Conservation Overlay District as specified in the Raleigh Comprehensive Plan (Figure 7). The following regulations apply to new construction only in the district:

- Minimum lot size of 20,000 square feet.
- Minimum lot frontage at the street of 100 feet.
- Minimum front yard setback of 50 feet.
- Maximum building height of 30 feet and no more than two and a half stories.

4.1.3 Development/Stability

Approximately 70 to 75 percent of the watershed has been developed with either apartment complexes or single family houses (see Figure 7). The southern portion of the watershed, including the old pond basin, is part of the Roylene Acres Neighborhood Conservation Overlay District. Birchtree Apartments are located in the center of the watershed. Westridge Woods, a housing subdivision, and Woodbridge Apartments are located in the northeastern corner of the watershed.

In the north-central portion exist several large undeveloped tracts, about 75 acres, that have no road frontage. Smaller tracts, which join these large tracts to the north, have been developed along Hillsborough Street. Because these large tracts are land-locked, it is assumed that development



LEGEND

R = Residential District
SC = Shopping Center District
NB = Neighborhood Business District

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FIGURE 7
Zoning Map
Abbott Property Stream Restoration
Wake County, North Carolina

1000 0 1000 2000 Feet

is unlikely. They are currently zoned Residential. In the center of the watershed area are several vacant lots totaling approximately 35 acres that have development potential. These lots are also currently zoned Residential.

Based on current zoning and development maps, it is concluded that approximately 25 to 30 percent or 110 acres of the watershed is not developed. Development is unlikely in approximately 20 to 25 percent of the watershed. Therefore, only about 5 percent of the watershed has development potential. Thus, this watershed is considered stable and increased runoff should not be caused by development activities.

4.2 STREAM

The main drainage on the Abbott property is a second order unnamed perennial tributary which originates approximately 2 km (1.25 mi) northwest of the property and flows for approximately 2.4 km (1.5 mi) to its confluence with Walnut Creek. The tributary flows under US 1 to Lake Johnson, approximately 610 m (2000 ft) to the southeast (see Figure 2). The total drainage area for this tributary is about 182 ha (450 ac). A low natural levee exists along the length of the tributary.

Draining from a 315 cm (124 in) diameter culvert, the main stream channel at the northern boundary of the project site has a width and bank height of approximately 1.2 m (4 ft). The substrate of the stream consists of silt, sand, pebbles, and cobbles. The water depth is approximately 2.4 cm (6 in).

The main channel meanders south through the former pond basin. The banks become 1.5 to 1.8 m (5 to 6 ft) high, vertical, partially vegetated, and severely eroded. The accumulation of silt and sand is evident along the channel banks in the middle portion of the basin.

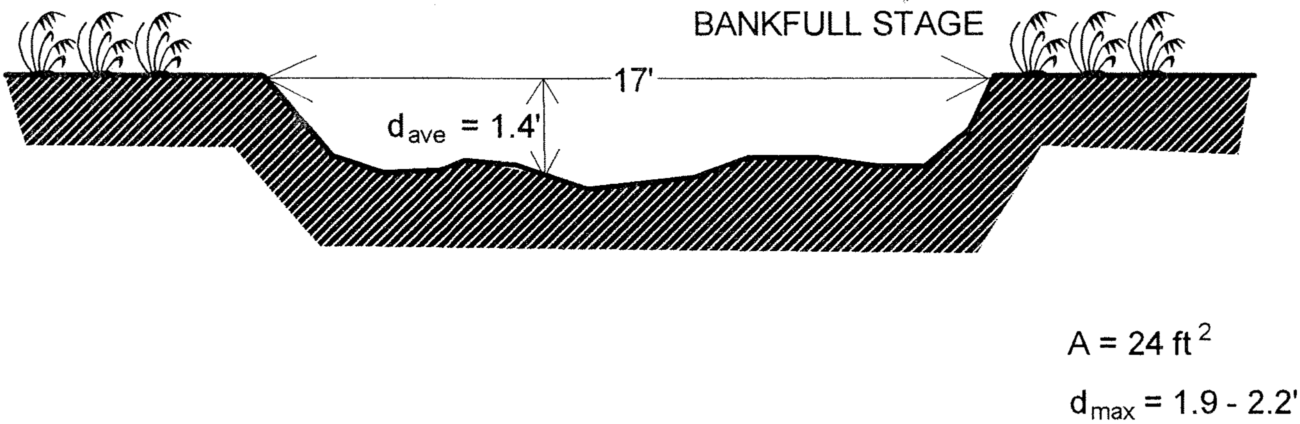
Just above the breached dam, the main channel widens to 1.5 m (5 ft) and has vertical, eroded banks approximately 1.2 m (4 ft) high. Just downstream from the dam, bank undercutting is occurring along the first meander below the dam on the left bank of the channel.

Below the dam in the southwest corner exists an old spillway channel that flows into the main channel below the property boundary. A large scour hole is present directly below the spillway and this channel has been silted in. No water flow was present during the site visit and only a standing pool of water remained in the spillway channel.

4.3 FORMER POND BASIN

Located within the former pond basin are a scrub/shrub community and an emergent community (Figure 8). Along the eastern edge lies an area that has recently been disturbed by mechanical means. This area is referred to as a "disturbed shrub thicket." Along the western boundary of the basin is a mature hardwood forest. The soils within the basin exhibit hydric characteristics, however no current indications of wetland hydrology exist. The hydric soils may reflect the

TYPICAL CROSS SECTION - RIFFLE



TYPICAL CROSS SECTION - POOL

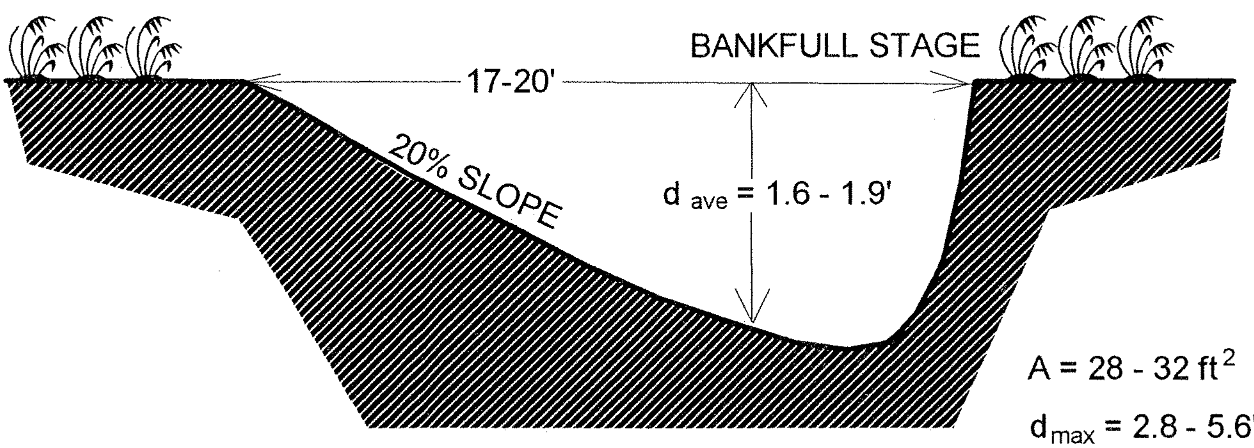


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FIGURE 13
Typical Cross Sections
Abbott Property Stream Restoration
Wake County, North Carolina

NOT TO SCALE

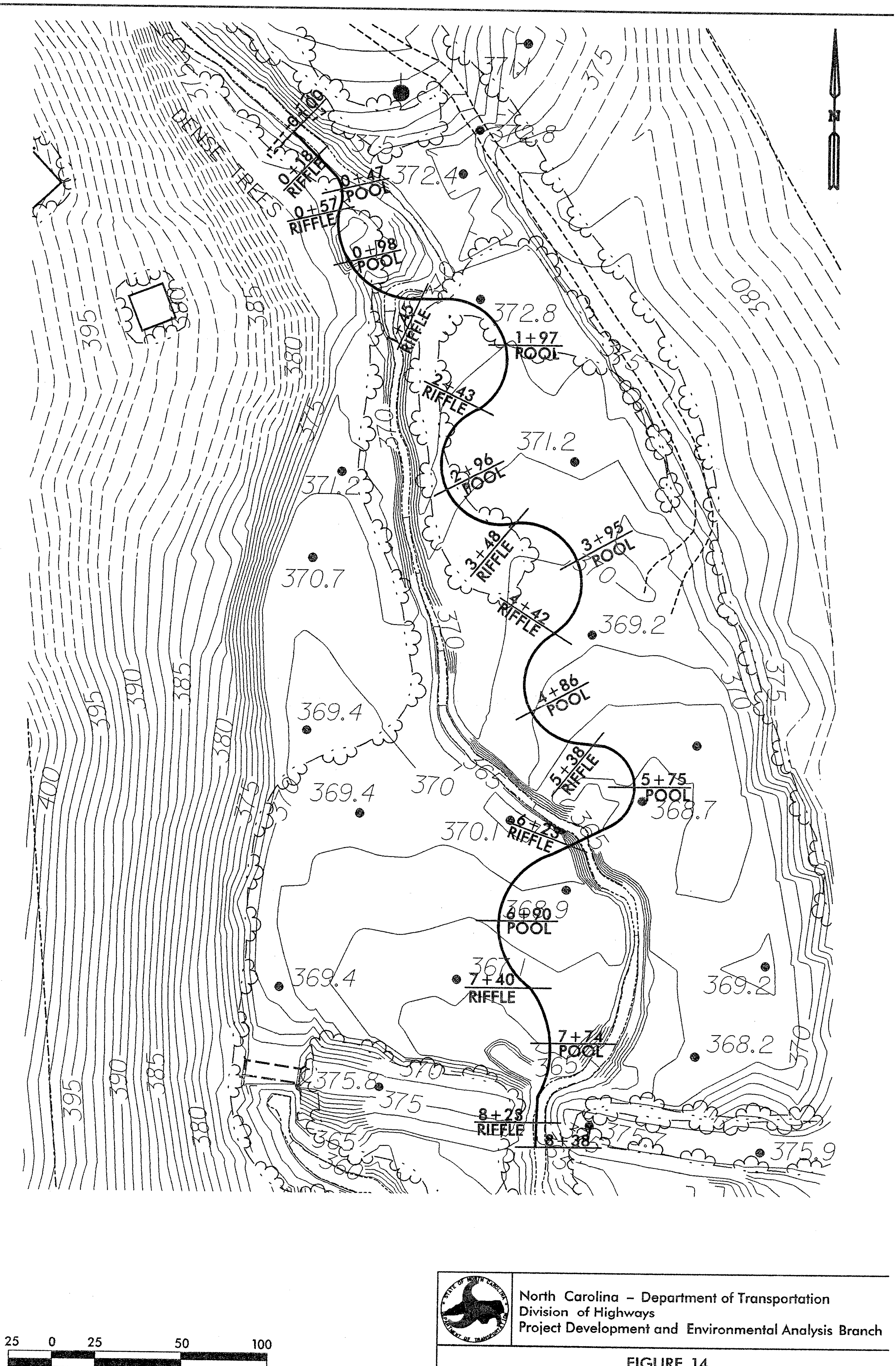

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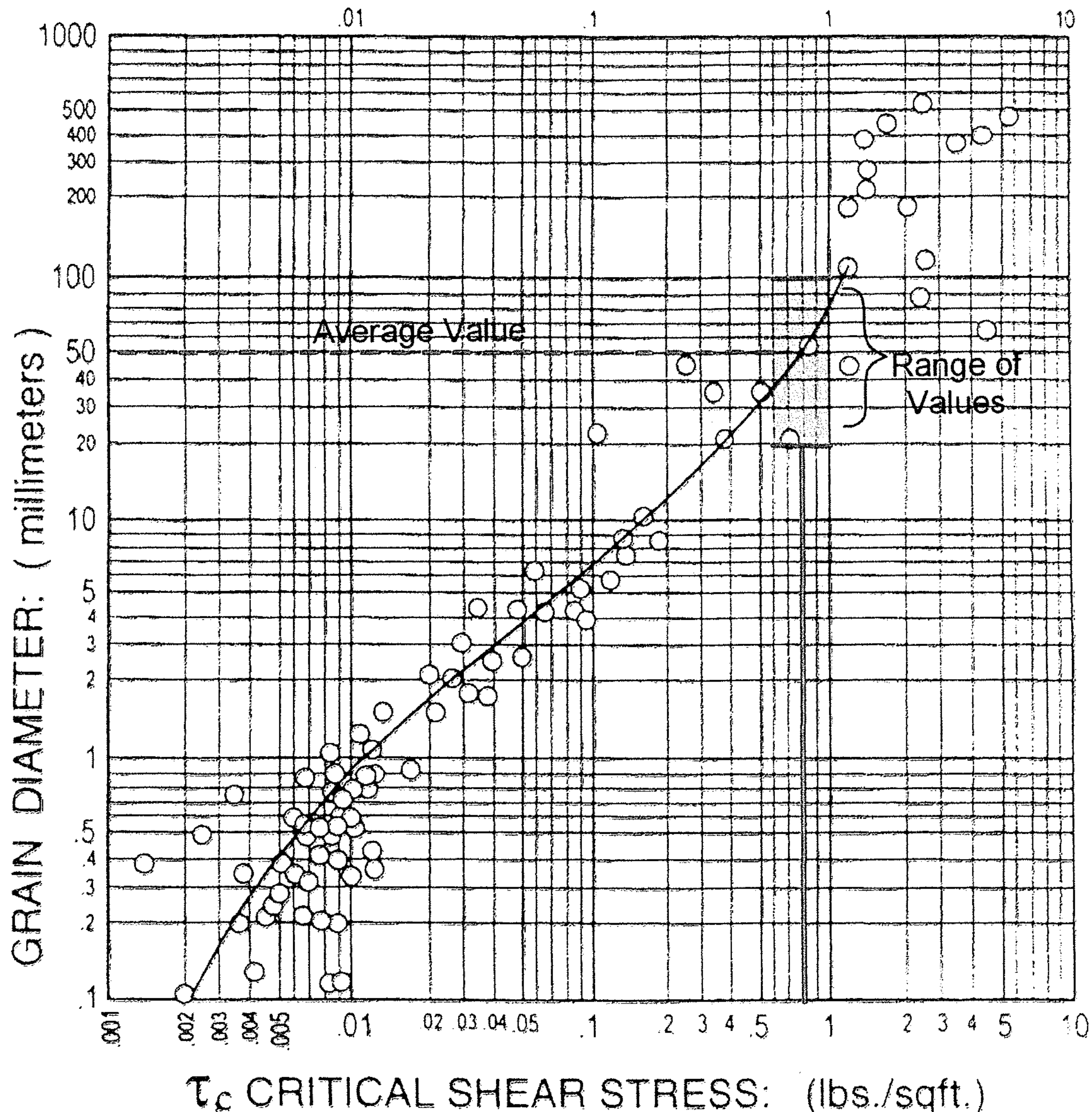
FIGURE 14
Riffle & Pool Locations
Abbott Property Stream Restoration
Wake County, North Carolina



Laboratory and field data on critical shear stress required to initiate movement of grains (Leopold, Wolman, & Miller 1964). The solid line is the Shields curve of the threshold of motion transposed from the θ versus R_r form into the present form, in which critical shear stress is plotted as a function of grain diameter.

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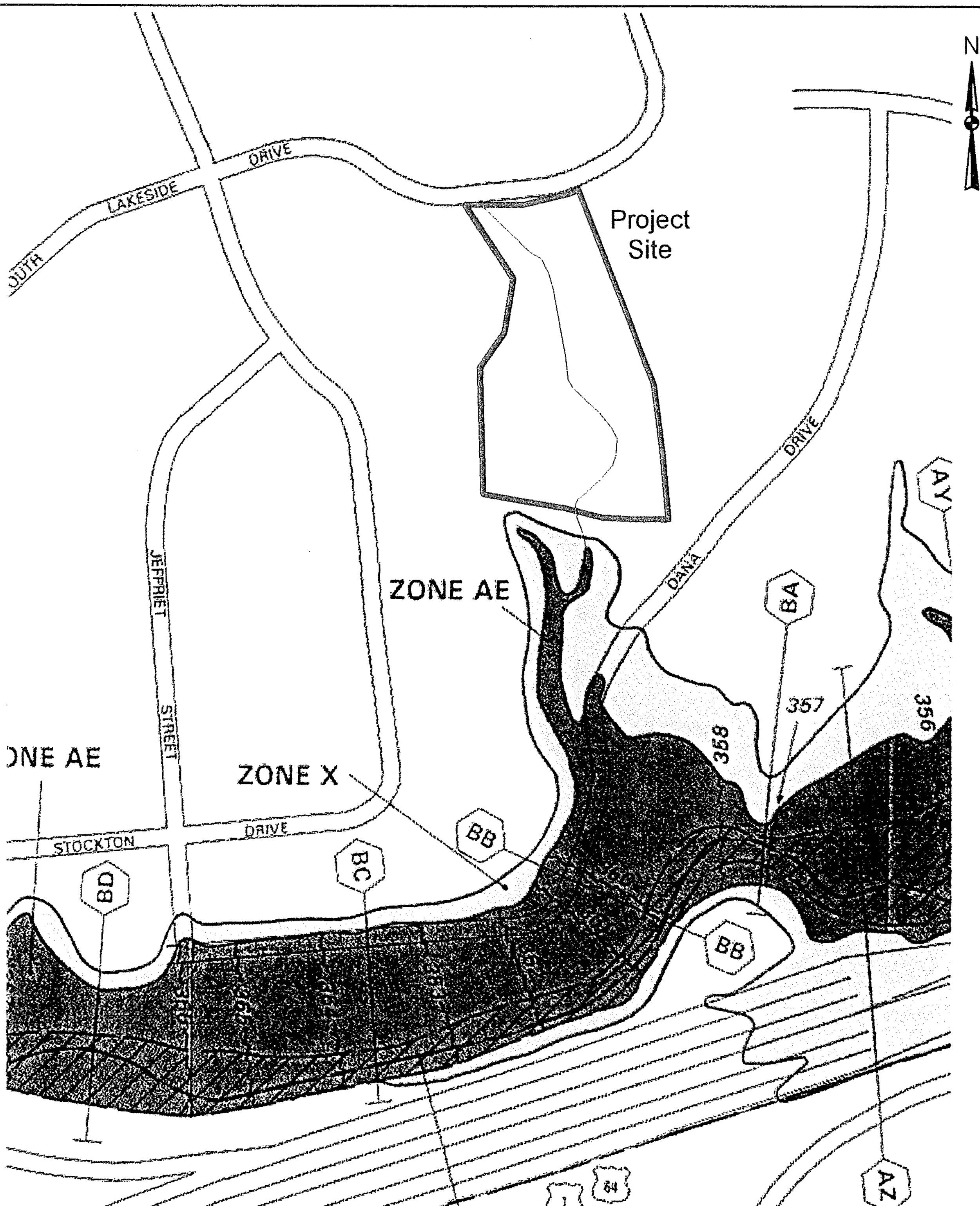
FIGURE 15
Shields Curve
Abbott Property Stream Restoration
Wake County, North Carolina

Log Scale



LEGEND

Zone AE -
100-Year Floodplain

Zone X -
500-Year Floodplain

FEMA Flood Insurance Rate Map 37183C0506 E, March 3, 1992

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FIGURE 16
Flood Insurance Rate Map
Abbott Property Stream Restoration
Wake County, North Carolina

50 0 50 100 150 200 250 Feet

Approximate limits of flooding for the existing and proposed channels were determined using HEC-RAS software from the US Army Corps of Engineers Hydrologic Engineering Center. Water surface profiles for the 2-year, 5-year, 10-year, 25-year, 50-year, and 100-year storm events were computed. Figure 17 shows the limits of flooding for the existing stream channel. Neither the existing nor proposed stream channel flood any private property owner.

The proposed channel does raise flood stage for some portions of the reach but mainly for a 2-year storm event. The change in the flood stage caused by the proposed channel is as follows:

Storm Event	Maximum Increase (ft)
2-year	2.9
5-year	2.1
10-year	1.5
25-year	0.7
50-year	0.5
100-year	0.5

Flood stage for the more frequent storms are increased due to the relocation of the stream bed on a higher elevation. The existing stream is incised and can transport higher flow in the channel. The proposed channel will use the floodplain to transport the large storm events.

Appendix E contains the water surface profiles and cross sections for the existing and proposed stream channels.

8.3 STRUCTURES

Three different structure types made of natural materials will be installed in the stream channel. These structures include cross vanes, j-hook rock vanes, and root wads. These will be made from natural materials either on-site or from off-site locations.

8.3.1 Cross Vanes

This structure serves to maintain the integrity of the upstream riffle while promoting scouring in the downstream pool (Figure 18). The design shape is roughly that of the letter "U" with the apex located on the upstream side at the foot of the riffle. Footer rocks are placed in the channel bottom for stability. Rocks are then placed on top of these footer rocks in the middle of the channel at approximately the same elevation as those rocks in the riffle. On either side of the channel, rocks are placed at an angle to the stream bank, gradually inclining in elevation until they are located above the bankfull surface directly adjacent to the stream bank (see Profile view, Figure 18). Water flowing downstream is forced over these rocks towards the middle of the channel on either side of the structure, effectively scouring out a pool below. Rocks placed at the apex hold back stream bed material and prevent them from washing downstream. A cross vane is primarily used for grade control.

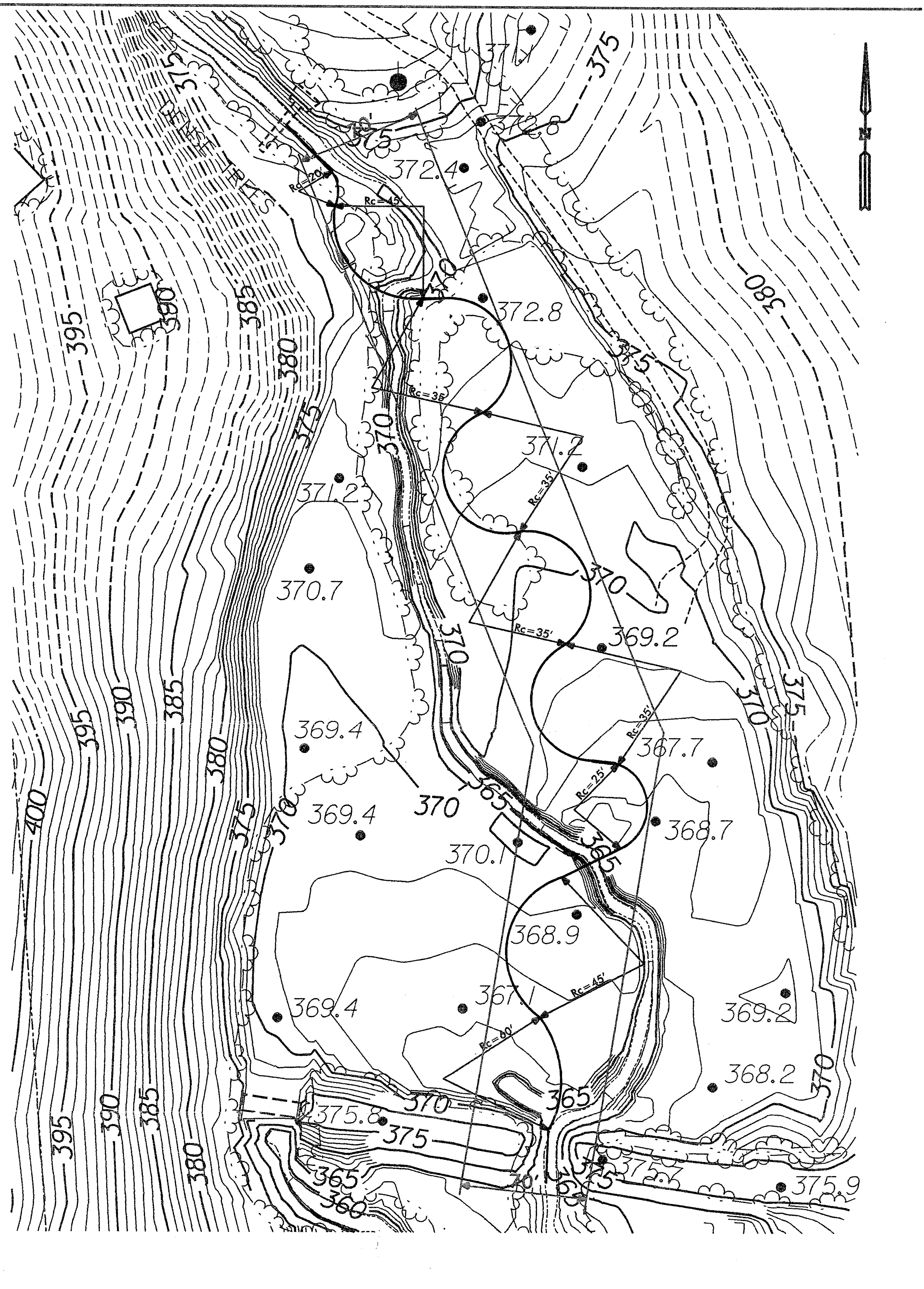

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FIGURE 12
Plan View
Abbott Property Stream Restoration
Wake County, North Carolina

previous conditions when the pond basin was inundated. Presently, the stream is deeply incised within the pond basin and there were no obvious signs of overbank flooding during the site visits.

4.3.1 Scrub/Shrub Area

Located in the upper portion of the basin, the scrub/shrub community comprises approximately 25 percent of the former pond basin. Young stands of river birch (*Betula nigra*), red maple (*Acer rubrum*), and black willow (*Salix nigra*), approximately 8 to 10 years old, comprise the canopy layer, with tag alder (*Alnus serrulata*) existing in the shrub layer and eulalia (*Microstegium vimineum*) dominating the understory.

During the site survey, bird species heard or observed included northern cardinal (*Cardinalis cardinalis*), common flicker (*Colaptes auratus*), slate-colored junco (*Junco hyemalis*), blue jay (*Cyanocitta cristata*), brown thrasher (*Toxostoma rufum*), common crow (*Corvus brachyrhynchos*), Carolina wren (*Thryothorus ludovicianus*), hairy woodpecker (*Picoides villosus*), red-bellied woodpecker (*Centurus carolinus*), Carolina chickadee (*Parus carolinensis*), ruby-crowned kinglet (*Regulus calendula*), and hermit thrush (*Catharus guttatus*).

Other faunal species which would be expected to utilize this habitat include raccoon, opossum, various rodents, and other songbirds, and snakes.

Soils sampled throughout the pond area appeared to be sediments deposited on the bottom of the pond. The texture of the soil was micaceous silt. Areas along the stream channel contained some coarser, sandy materials. The sediments were 1.2 to 1.5 m (4 to 5 ft) deep at the downstream edge of the pond, becoming less deep towards the north end. Hydric indicators, such as low chromas (10 YR 4/2), mottling (5 YR 4/6, 10%), and oxidized rhizospheres were evident to a depth of at least 40 cm (16 in).

4.3.2 Emergent Area

The emergent community, located in the middle and lower portions of the basin, comprises approximately 60 percent of the former pond area. The dominant plant species observed here included tearthumb (*Polygonum sagittatum*) and other polygonums (*Polygonum* spp.), jewelweed (*Impatiens capensis*), elderberry (*Sambucus canadensis*), soft rush (*Juncus effusus*), asters (*Aster* spp.), red maple saplings, cyperus (*Cyperus* spp.), and wool grass (*Scirpus cyperinus*).

Fauna observed in the emergent area were the same fauna observed in scrub/shrub area.

Soils sampled in the area were similar to that described in the scrub/shrub area. Hydric indicators, such as low chromas (10 YR 5/1), mottling (2.5 YR 4/8, 20%), and oxidized rhizospheres were evident. A small depressional area was identified on the eastern side of the basin, most likely formed by heavy equipment traversing the site. Shallow water was pooled in the depression.

4.3.3 Upland Forest

An upland forest, located along the western perimeter of the basin and to the east and south of the property, is comprised mostly of mature hardwoods which range from approximately 50 to 75 years in age. A few pines (*Pinus taeda*) are scattered along the edge of the stand. Dominant plant species in this community include tulip poplar (*Liriodendron tulipifera*), sweetgum (*Liquidambar styraciflua*), red maple, giant cane (*Arundinaria gigantea*), and greenbriar (*Smilax* spp.). A few river birch, *crossvine (Bignonia capreolata*), and Christmas fern (*Polystichum acrostichoides*) are also present.

Soils sampled in the area had a loamy silt texture and appeared to be alluvial depositions. The soils exhibited marginal chromas (10 YR 5/3) and some mottling. The soils did not have hydric indicators. A thick leaf layer was present on the ground surface at the time of the site visit.

5.0 METHODOLOGY

All field measurements, surveys, and analyses were performed using the Rosgen stream classification methodology.

5.1 SURVEYS

Field surveys of the existing stream channel were conducted on August 4, 14 and 15, 1998. These field measurements are critical to the classification and assessment of the existing stream type and provide data to classify the stream using the Rosgen classification method, Levels I and II (Rosgen 1996).

To establish arbitrary relative elevations for the field measurements, four temporary benchmarks were set:
1. Invert of the culvert on the downstream (south) side of Lakeside Drive
2. Invert of the culvert on the upstream (north) side of Lakeside Drive
3. The corner of the wooden platform on the upstream (north) side of the footbridge
4. A concrete post which was part of an old picnic table.

A longitudinal survey of the stream began south of the footbridge and continued along the stream length to the breached dam. The total length measured 263 m (868 ft). Three (3) permanent cross sections of the existing channel were established; across two riffles and one pool. A representative pebble count was taken to determine channel bed materials for classification.

5.2 DELINEATION CRITERIA

Stream channels are delineated using five criteria: width/depth ratio, entrenchment ratio, slope, sinuosity, and channel materials.

Width/Depth Ratio

The width/depth ratio is defined as the ratio of the bankfull surface width to the mean depth of the bankfull channel. Measurement of the width/depth ratio is important in describing the channel's cross-section shape. The width/depth (W/D) ratio is also the key to understanding energy distribution and sediment transport within the channel (Rosgen 1996).

In Chapter 5 of *Applied River Morphology*, author Dave Rosgen discusses the relationship between the width/depth ratio, energy, and sediment transport:

> *The distribution of energy within channels having high W/D ratios (i.e., shallow and wide channels) is such that stress is placed within the near bank region. As the W/D ratio value increases (i.e., the channel grows wider and more shallow), the hydraulic stress against the banks also increases and bank erosion is accelerated. The accelerated erosion process is generally the result of high velocity gradients and high boundary stress, as mean velocity, stream power, and*

shear stress decrease in the presence of an increase in width/depth ratio values. Increases in the sediment supply to the channel develop from bank erosion, which - by virtue of becoming an over widened channel - gradually loses its capacity to transport sediment. Deposition occurs, further accelerating bank erosion, and the cycle continues.

Entrenchment

Entrenchment is defined as the vertical containment of a stream and the degree to which it is incised in the valley floor. To measure entrenchment, the Rosgen methodology employs a dimensionless ratio (the entrenchment ratio) to quantify entrenchment. The entrenchment ratio is calculated by dividing the width of the floodprone area by the bankfull width. The flood prone area is defined as the area flooded by a stage twice the maximum depth between the bankfull stage and the thalweg of a riffle.

Slope

Slope of the water surface is defined as the change in water surface elevation per unit stream length. Stream length is measured in the channel's thalweg. The slope is measured by a longitudinal survey of the stream length. Slope measurements should be taken for at least 20 bankfull widths or a distance equal to two meander wavelengths.

Sinuosity

Sinuosity is the ratio of stream length to valley length. It can also be calculated as the ratio of valley slope to stream slope.

Channel Materials

Channel bed and bank materials influence the cross section, plan view, and longitudinal profile of the stream. They also determine the extent of sediment transport and provide the means of resistance to hydraulic stress. Field classification of the channel materials is done through a pebble count. The pebble count uses a systematic sampling system over a distance of at least 20-30 bankfull widths or two meander wavelengths. Ten sites with ten observations (100 samples total) are done proportionally in riffles and pool areas. In order to avoid an unrepresentative sampling, the materials are selected using a blind touch method.

The segmented particle size data is then added together for a composite total for stream classification purposes. The data is plotted on log-normal graph paper. The D-50 (50 % of the sampled population is equal to or finer than the representative particle size) is used to classify the bed materials.

5.3 EXISTING STREAM CHARACTERISTICS

The data for the existing channel is included in Appendix A. The stream had the following characteristics:

Width /Depth Ratio:	9.3
Entrenchment Ratio:	1.36
Slope:	0.012
Sinuosity:	1.45
Channel Materials (D-50):	0.5 - 1.0 mm Coarse Sand

Stream Type: **G-5c**

6.0 BANKFULL VERIFICATION

The bankfull stage was determined in the field using physical indicators. The following is a list of commonly used indicators (Rosgen, 1996):

- The presence of a floodplain at the elevation of incipient flooding.
- The elevation associated with the top of the highest depositional feature (e.g. point bars, central bars within the active channel). These depositional features are especially good stage indicators for channels in the presence of terrace or adjacent colluvial slopes.
- A break in slope of the bank and/or a change in the particle size distribution, since finer material is associated with deposition by overflow, rather than deposition of coarser material within the active channel.
- Evidence of an inundation feature such as small benches below bankfull.
- Staining of rocks.

The most common method of verifying bankfull stage is to compare the field determined bankfull stage with measured stages at a stream gage. This calibration can be performed if there is a stream gage within the study area's hydrophysiographic region. One gage was identified in the Walnut Creek Watershed. Station Number 02087359 was located at Sunnybrook Drive in Raleigh, North Carolina. The gage provided data from May through September, 1996. This short time period does not provide enough data to perform a flood frequency analysis. It is recommend the gage have 10 years of data. Therefore this gage data was not used to verify the field determined bankfull stage.

In ungaged areas, Dave Rosgen recommends verifying bankfull with the development of regional curves. The regional curves normally plot bankfull discharge (Q), cross-sectional area, width, and depth as a function of drainage area. The cross sectional areas of the Abbott Property stream and the reference reaches used for this report were plotted on the North Carolina regional curve developed by the North Carolina State University (NCSU) Water Quality Group, 1998 (Figure 9). All three plotted points are within the confidence region of the regional curve, verifying the field observation of bankfull.

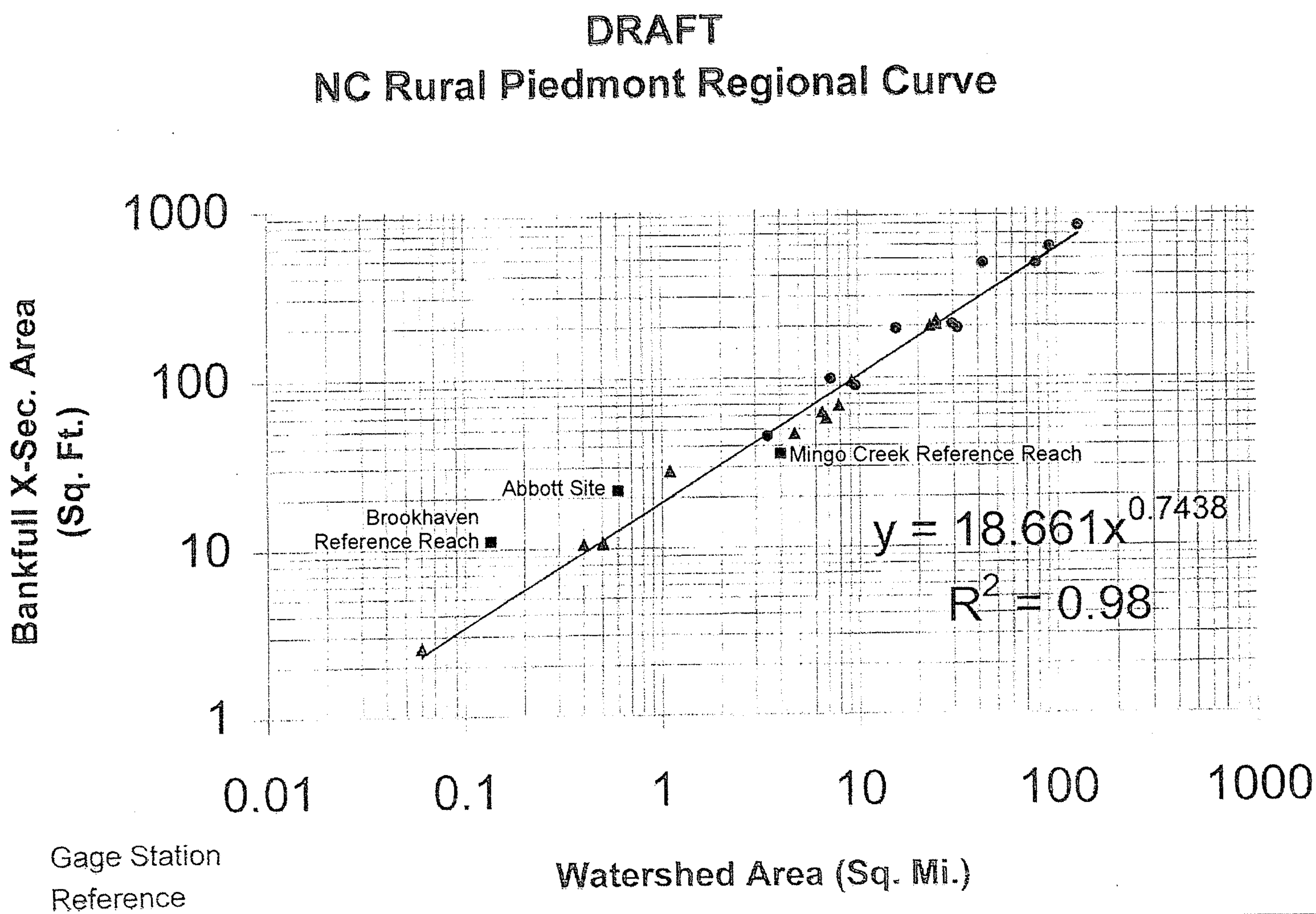

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FIGURE 9
NC Rural Piedmont Regional Curve
Abbott Property Stream Restoration
Wake County, North Carolina

Log Scale

SOURCE: NCSU Water Quality Group, August 7, 1998.

7.0 REFERENCE REACHES

Two reference reaches were chosen for this project. Criteria used in selecting these reaches included: (1) a stream in an urban setting of Wake County, (2) an older, established neighborhood with little to no current development, and (3) a similar stream type to the project stream. Urban sites with older, established residential neighborhoods were preferred due to similarity of the Abbott Property. Each site was selected based on topographic maps and field reconnaissance.

7.1 BROOKHAVEN

A first order unnamed tributary flowing through the Brookhaven Subdivision in North Raleigh was chosen as the first reference reach (Figure 10). This small stream is located approximately 1.3 km (0.8 mi) north of the US 70 and NC 50 intersection and directly above York School. Beginning at a small pond, the stream flows southwest approximately 910 m (3000 ft) before emptying into Hare Snipe Creek. Mean width of the stream channel is approximately 3 m (10 ft) and mean depth is about 20 cm (8 in). The section measured for reference was 47 m (155 ft) in length. Longitudinal profile, cross-sections, and the pebble count for this reference reach are located in Appendix B.

The watershed is approximately 36 ha (90 ac) and encompasses the Brookhaven Subdivision as well as York School, several industrial buildings, and large tracts of undeveloped wooded land. This watershed is oval in shape and includes the small tributary and pond. It is bounded to the east by Highway 50 and generally follows topographic ridgelines to complete the watershed boundary.

The majority of the development within this watershed has been established for a number of years and only in the extreme northern part of the watershed is evidence of recent development. A portion of the stream and surrounding woodlands has been incorporated into a park. Outside of the park exists an older residential neighborhood. Both the park and the neighborhood lend stability to the stream and watershed, as no new impervious surfaces have recently been built. Lack of construction, therefore lack of siltation, also helps with stream stability.

7.2 MINGO CREEK

Mingo Creek is located in eastern Wake County and was chosen as the second reference reach (Figure 11). This third order stream is located approximately 1.3 km (0.8 mi) south of the US 64 and 1.3 km (0.8 mi) north of Old Faison Road. Beginning just north of Knightdale, it flows southwest approximately 6 km (4 mi) before emptying into the Neuse River. Mean width of the stream channel is approximately 2 m (6 ft) and mean depth is about 23 cm (9 in). The section of the stream measured for reference was 105 m (345 ft) in length. Longitudinal profile, cross-sections, and the pebble count for this reference reach are located in Appendix C.

The watershed is approximately 1,030 ha (2,550 ac) and encompasses several newly constructed as well as formerly established dense subdivisions, industrial and retail buildings associated with the town of Knightdale, and large tracts of undeveloped wooded land near the Neuse River confluence. This watershed includes about 18 small tributaries and 14 ponds. It is bounded to the north by Highway 64, to the south and east by Old Faison Road, and to the west by Hodge Road and Norfolk Southern Railway. A small portion in the southwest corner follows a ridgeline to the Neuse River.

Development exists in various stages throughout this watershed. New housing developments are currently being built along the upper reach of the creek near Knightdale and middle reach east of Hodge Road. An older development exists in the northwest corner. Some subdivisions exist along the southern edge of the watershed, but the majority of this land is open farm pastures. To the extreme southwest corner along the lower reach lies undeveloped wooded acreage.

8.0 NATURAL CHANNEL DESIGN

The design was based upon Dave Rosgen's natural channel design methodology. This 40-step design procedure is provided in Appendix D. Morphological characteristics were measured on the existing stream and reference reaches to determine a range of values for the stable dimension, pattern, and profile of the proposed channel. The measured and proposed morphological characteristics are shown in Table 2.

A conceptual design was developed from the range of values listed in Table 2. Figure 12 shows the plan view of the proposed channel. Figure 13 shows a typical cross section of a riffle and pool and Figure 14 shows locations of the riffles and pools. Riffles are located at the inflection points between meanders while pools are located on the outside bend of the meander.

8.1 SEDIMENT TRANSPORT

A stable stream has the capacity to move its sediment load without aggrading or degrading. The total load of sediment can be divided into bed load and wash load. Wash load is normally composed of fine sands, silts and clay and transported in suspension at a rate that is determined by availability and not hydraulically controlled. Bed load is transported by rolling, sliding, or hopping (saltating) along the bed. At higher discharges, some portion of the bed load can be suspended, especially if there is a sand component in the bed load. Bed material transport rates are essentially controlled by the size and nature of the bed material and hydraulic conditions (Hey 1997).

The shear stress placed on the sediment particles is the force that entrains and moves the particles. The critical shear stress for the proposed channel has to be sufficient to move the D_{84} of the bed material. The critical shear stress was calculated and plotted on Shield's curve to determine the approximate size of particles that will be moved (Figure 15). Based on Shield's curve, particles from 20 mm to 100 mm could be moved with an average value 50 mm. The D_{84} of the existing stream is 25 mm. Therefore, the proposed design has sufficient shear stress to move the stream's bed load.

8.2 FLOODING ANALYSIS

The project's location was identified on the Federal Emergency Management Agency's Flood Insurance Rate Map, as shown in Figure 16. The project is not located within the limits of the 100-year floodplain.

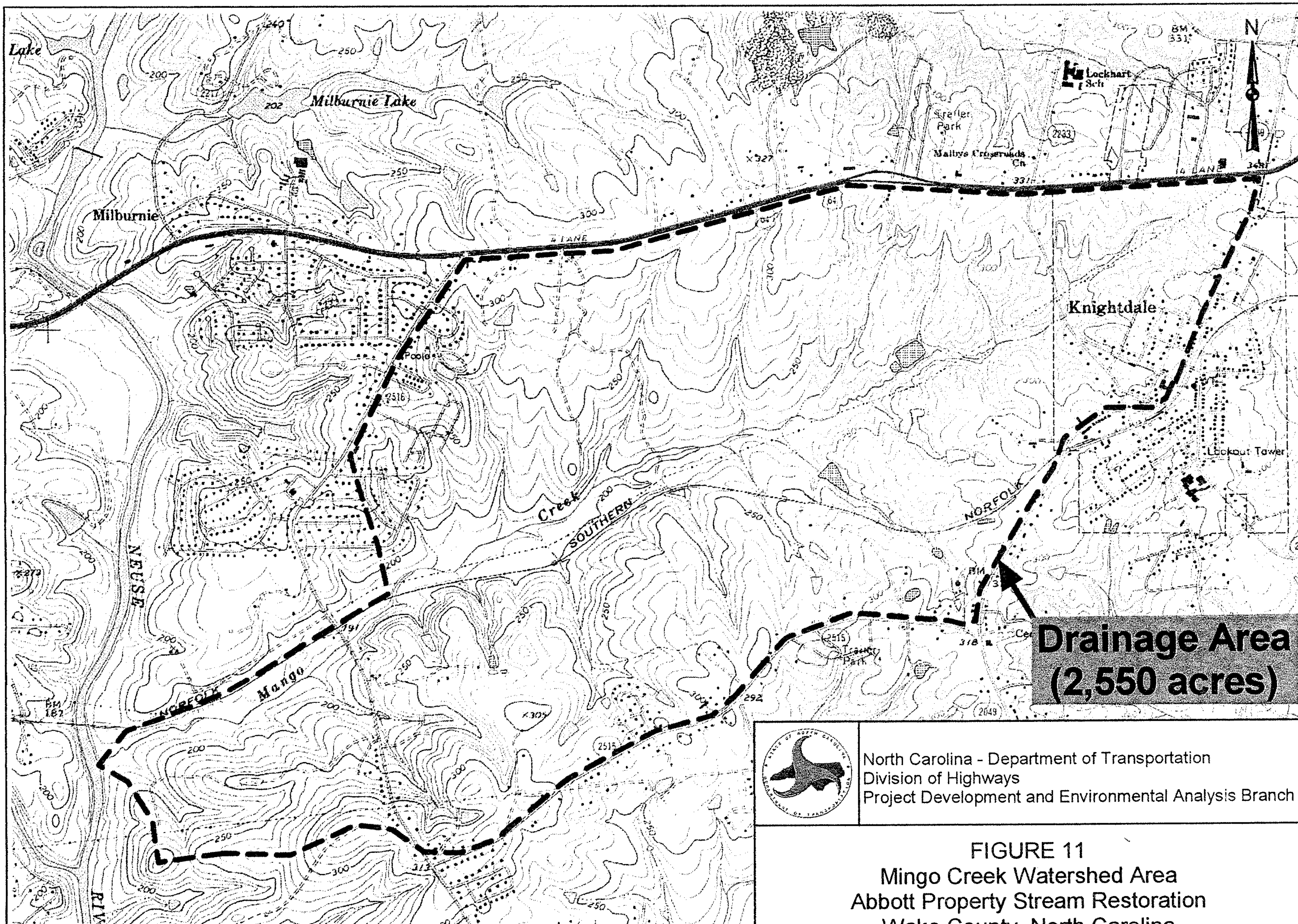
Stormwater runoff was estimated using the US Geological Survey's TR-55. Runoff was estimated for the 2-year, 5-year, 10-year, 25-year, 50-year, and 100-year storm events. The computer results are shown in Appendix E.

Table 2: Morphological Characteristics
Existing, Reference, and Proposed Reaches

	Variables	Existing Channel	Reference Reaches Brookhaven	Mingo Creek	Proposed Reach
1	Stream type (Rosgen)	G5c	C4	C/E5	C4/5
2	Drainage area (Sq. Mi.)	0.6	0.14	4.0	0.6
3	Bankfull width (W_{bkf}) ft	14.9	10.0	21.9	17.0
4	Bankfull mean depth (d_{bkf}) ft	1.6	0.55	1.6	1.4
5	Width/depth ratio (W_{bkf}/d_{bkf})	9.3	18.2	13.7	12.1
6	Bankfull cross-sectional area (A_{bkf}) sq ft	24.0	5.5	35.7	24.0
7	Bankfull mean velocity (V_{bkf}) fps	4.6	5.9	2.7	4.6
8	Bankfull discharge (Q_{bkf}) cfs from Manning	110	33	95	110
9	Bankfull maximum depth (d_{max}) ft	2.1	1.0	3.0	2.8
10	Width of flood prone area (W_{fpa}) ft	20.2	33.0	86.0	56.0
11	Entrenchment ratio (W_{fpa}/W_{bkf})	1.4	3.3	3.9	3.3
12	Meander Length (L_m) ft	n/a	47.0	89 -195	85 - 170
13	Ratio of meander length to bankfull width (L_m/W_{bkf})	n/a	4.7	4 - 8.9	5 - 10
14	Radius of curvature (R_c) ft	n/a	12 -35	29 - 53	20 - 60
15	Ratio of radius of curvature to bankfull width (R_c/W_{bkf})	n/a	1.2 - 3.5	1.3 - 2.4	1.2 - 3.5
16	Belt width (W_{blt}) ft	n/a	28 - 41	42 - 67	32 - 70
17	Meander width ratio (W_{blt}/W_{bkf})	n/a	2.8 - 4.1	1.9 - 3.1	1.9 - 4.1
18	Sinuosity (stream length / valley length) (k)	1.4	1.7	1.4	1.4
19	Valley slope (S_{valley})	0.017	0.028	0.003	0.017
20	Average slope (S_{ave}) = (S_{valley}/k)	0.012	0.016	0.002	0.012
21	Pool slope (S_{pool})	0.0	0.0	0.0	0.0

Table 2: Morphological Characteristics
Existing, Reference, and Proposed Reaches

Variables	Existing Channel	Reference Reaches Brookhaven	Reference Reaches Mingo Creek	Proposed Reach
22 Ratio pool slope to average slope (S_{pool}/S_{ave})	0	0	0	0
23 Maximum pool depth (d_{pool}) ft	3.0	2.2	3.0	2.8
24 Ratio of pool depth to ave. bankfull depth (d_{pool}/d_{bkf})	1.9	4.0	1.9	2.0
25 Pool width (W_{pool}) ft	11.4	8 - 11	15.2	11.9 - 18.7
26 Ratio of pool width to bankfull width (W_{pool}/W_{bkf})	0.8	.8 - 1.1	0.7	.7 - 1.1
27 Pool/pool spacing (p-p) ft	n/a	38 -48	65 -110	51 - 85
28 Ratio of p-p spacing to bankfull width ($p\text{-}p/W_{bkf}$)	n/a	3.8 - 4.8	3.0 - 5.0	3.0 - 5.0
Materials:				
Particle size distribution of channel material (mm)				
D 16	<.062	0.6	0.13	
D 35	0.20	4.0	0.4	
D 50	0.8	16.0	0.7	
D 84	25.0	70.0	2.0	
D 95	60.0	90.0	4.0	



SOURCE: U.S. GEOLOGICAL SURVEY MAP:
7.5 MINUTE QUADRANGLE: RALEIGH WEST, NC (1987)

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FIGURE 11
Mingo Creek Watershed Area
Abbott Property Stream Restoration
Wake County, North Carolina

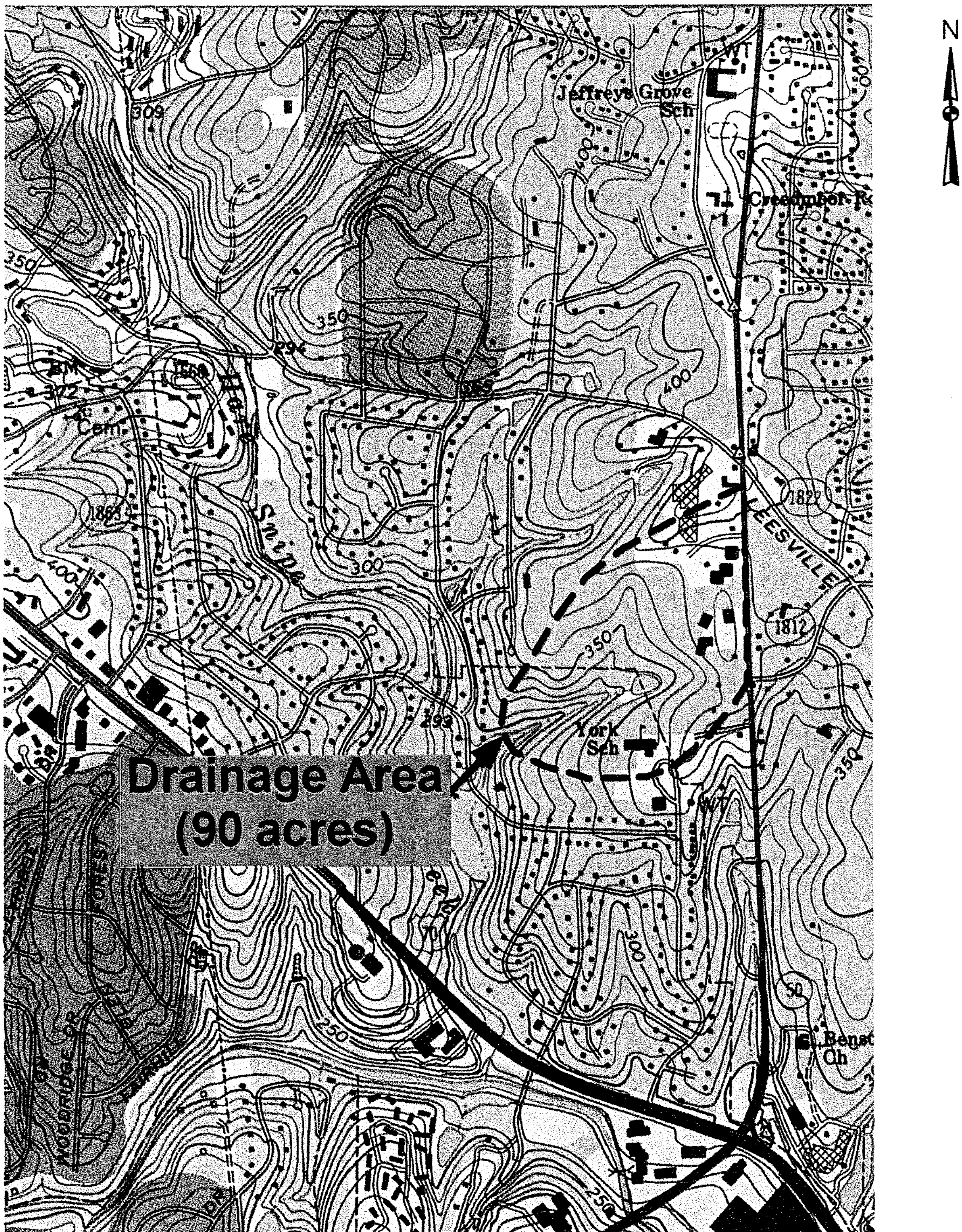

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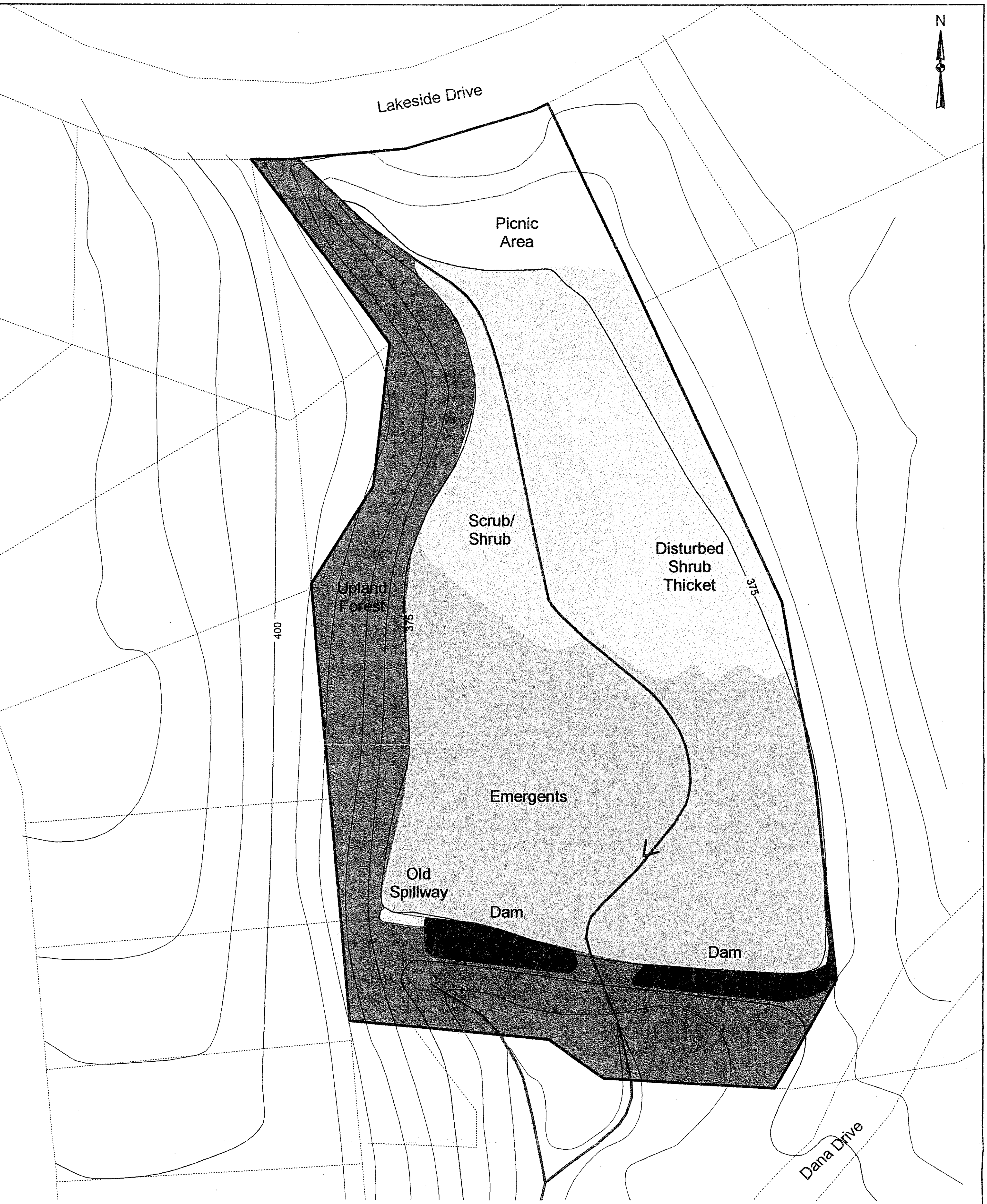
FIGURE 10
Brookhaven Drainage Area
Abbott Property Stream Restoration
Wake County, North Carolina

Not to scale

SOURCE: U.S. GEOLOGICAL SURVEY MAP:
7.5 MINUTE QUADRANGLE: RALEIGH WEST, NC (1987)



Abbott Property Boundary
Streams
Index Contour 25' Interval
Intermediate Contour 5' Interval
Property Lines
Bare Disturbed Area
Dam
Emergents
Old Spillway
Picnic Area
Shrub/Scrub
Upland Forest

Scale 1" = 75'

NOTES:
Natural Community Boundaries are approximate.
Wetlands are not delineated.

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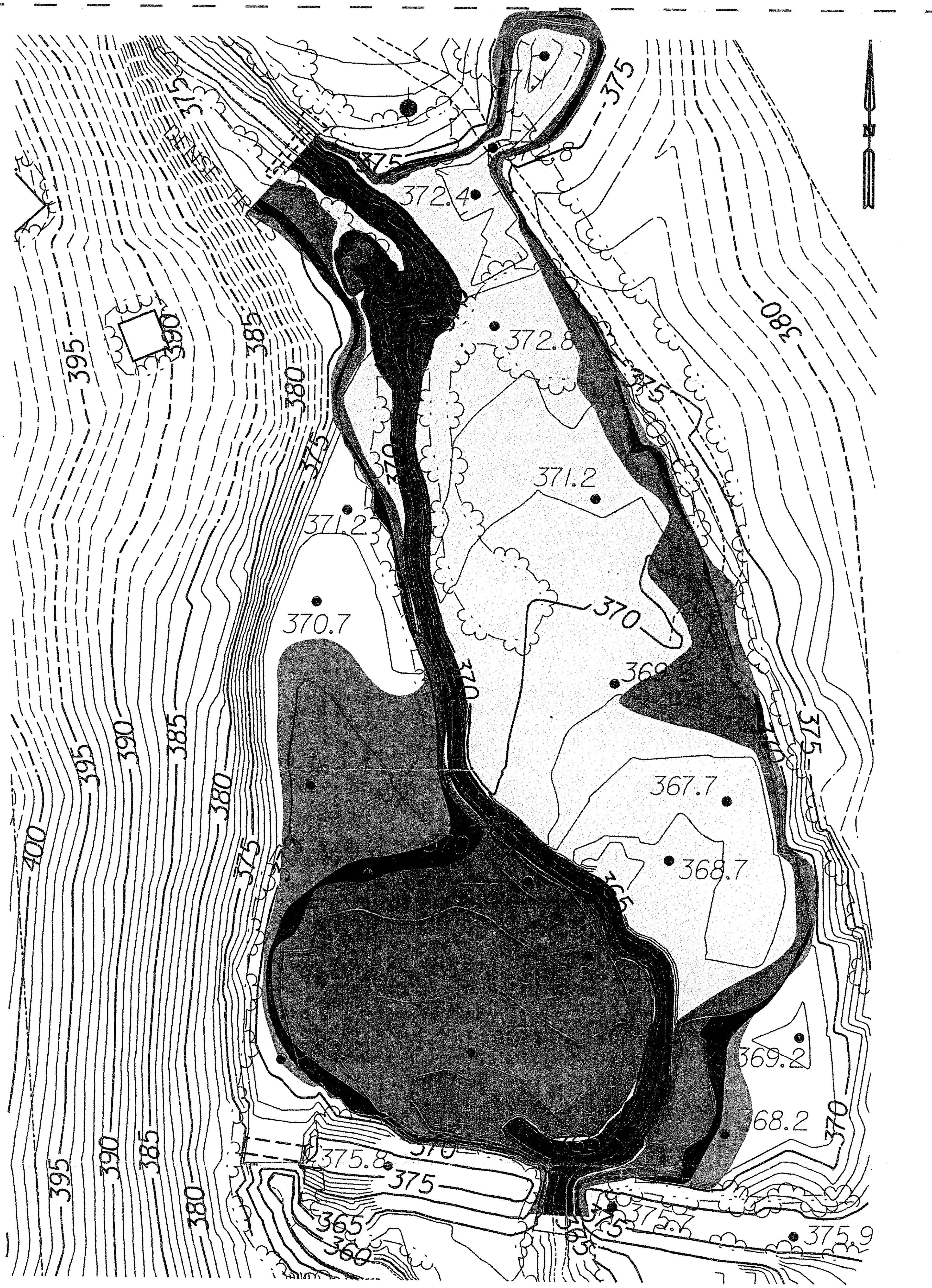
FIGURE 8
Current Natural Communities Map
Abbott Property Stream Restoration
Wake County, North Carolina

25 0 25 50 75 100 125 150 175 200 Feet

Cadastral and Topographical data: Wake County GIS, 1997; Projection NAD83, m.



LEGEND

- 2 Year Storm
- 5 Year Storm
- 10 Year Storm
- 25 Year Storm
- 50 Year Storm
- 100 Year Storm

25 0 25 50 100

SCALE 1" = 50'

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FIGURE 17
Approximate Flooding Limits
Existing Channel
Abbott Property Stream Restoration
Wake County, North Carolina

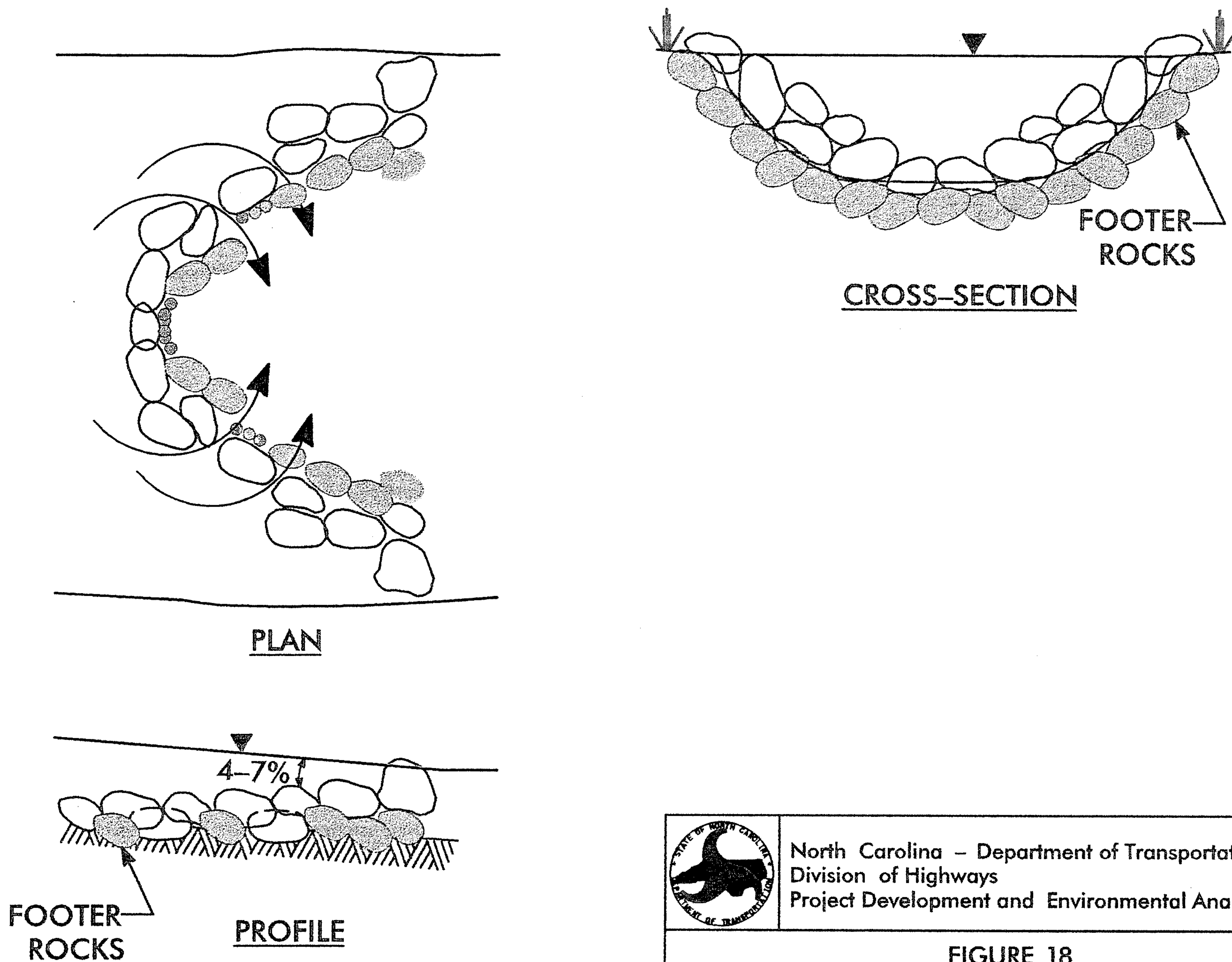

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FIGURE 18
Natural Material Structure – Cross Vane
Abbott Property Stream Restoration
Wake County, North Carolina

8.3.2 J-Hook Rock Vanes

This structure is designed to break up the secondary circulation cells which cause stress in the near bank region (Figure 19). It also forces the thalweg away from the bank and towards the middle of the stream channel. Similar in design to the cross vane, these structures are placed on the outside of curve meanders. Footer rocks are placed on one side of the channel bottom for stability. More rocks are then placed at an angle to the stream bank, gradually inclining in elevation until they are located above the bankfull surface directly adjacent to the stream bank (see Profile view, Figure 19). Additional rocks are placed to give the structure a "J" shape. These extra rocks are added to help create fish habitat. The j-hook vane helps relieve stress on the near bank region and provides fish habitat.

8.3.3 Root Wads

The objectives of these structure placements are to: (1) protect the streambank from erosion; (2) provide in-stream and overhead cover for fish; (3) provide shade, detritus, terrestrial insect habitat; (4) look natural, and (5) provide diversity of habitats (Rosgen 1996). A footer log and boulder are placed on the channel bottom and abut the stream bank along an outside meander (Figure 20). This provides support for the root wad and additionally stability to the bank. A large tree root wad is then placed on the stream bank with additional boulders and rocks on either side for stability. Flowing water is deflected away from the bank and towards the center of the channel.

Specific location of these structures will be determined during final design.

8.4 BANK STABILIZATION

Lakeside Drive borders the north end of the project area. The stream passes through a large culvert and then flows onto the site. The culvert is at a slight angle to the road. During high flow events water is directed to the western bank causing severe erosion of the bank. The stream bank in this area will be stabilized by terracing the bank and stabilizing it with geotextile fabric and planting with vegetation such as willow.

Additionally, immediately south of the existing dam, the stream bends toward the west. The stream is currently undercutting the bank in this area. A root wad will be placed in this bend to help stabilize the bank and prevent further erosion of the bank.

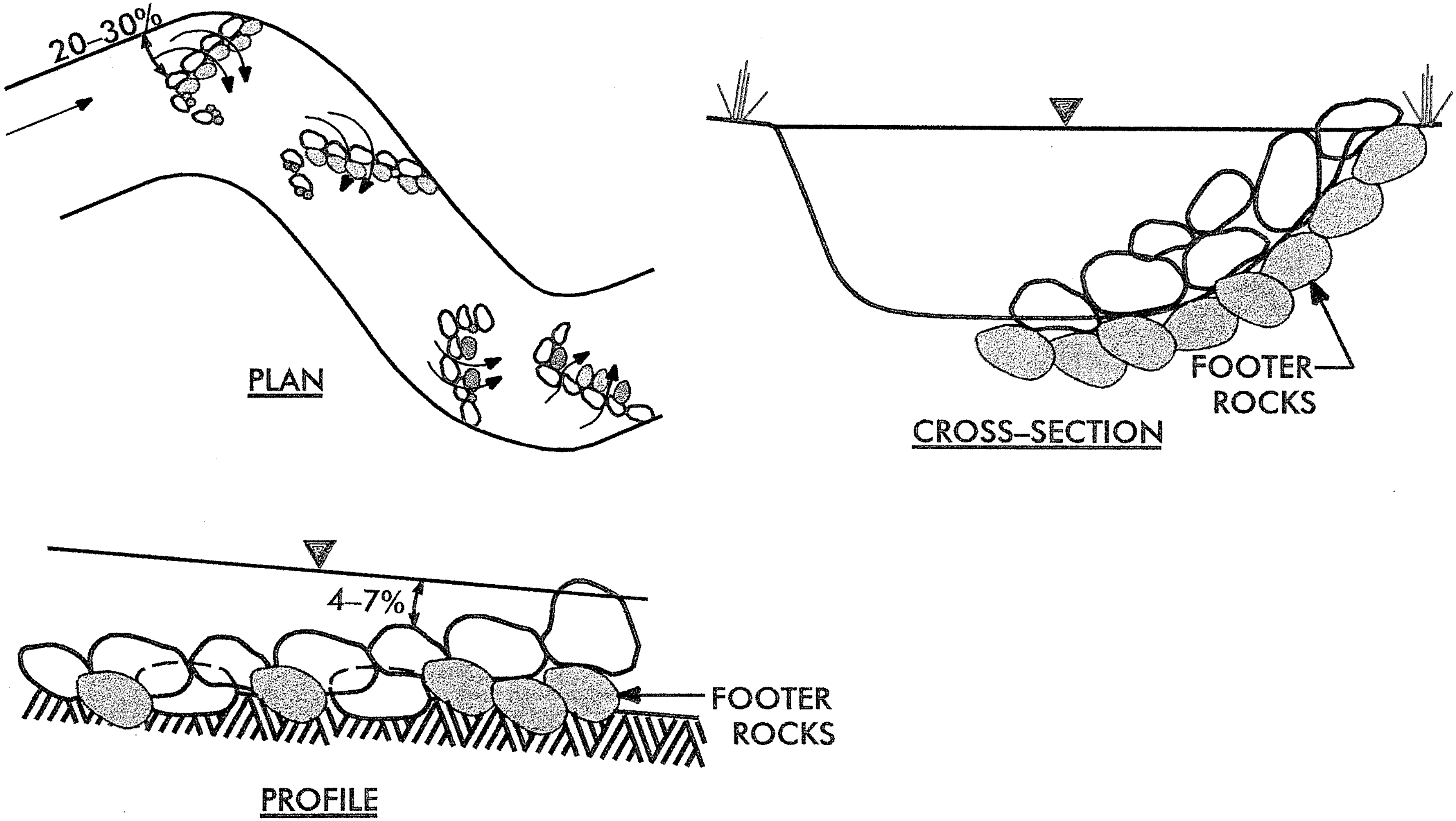

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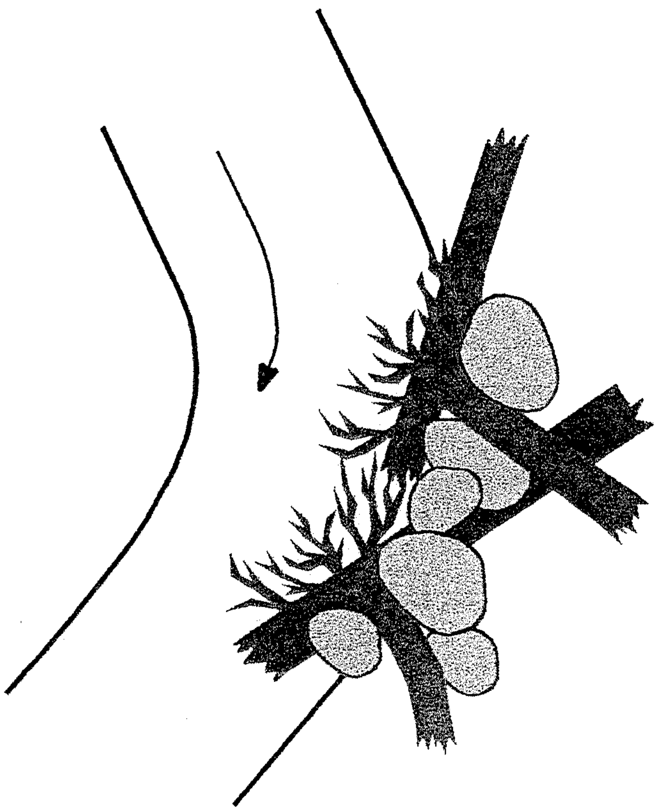
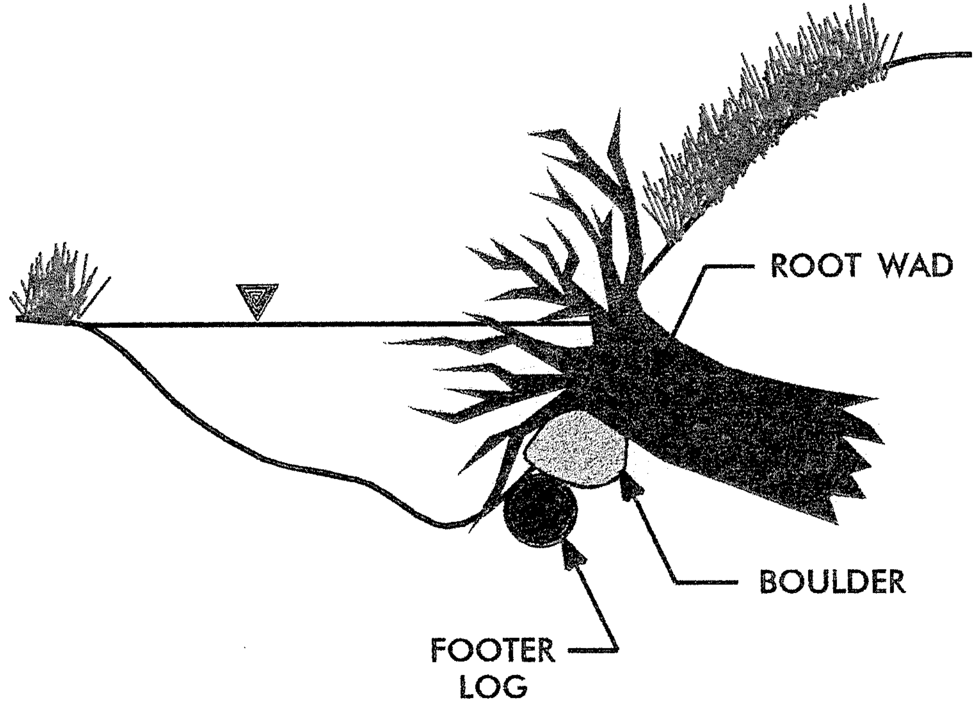
FIGURE 19
Natural Material Structure – J–Hook Rock Vane
Abbott Property Stream Restoration
Wake County, North Carolina



PLAN



CROSS–SECTION

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FIGURE 20
Natural Material Structure – Root Wad
Abbott Property Stream Restoration
Wake County, North Carolina

9.0 NATURAL COMMUNITIES

The target community for the site is a Piedmont alluvial forest (Schafale and Weakley 1990). The former pond basin will serve as the floodplain and is expected to revert to a bottomland forest with an open to dense understory and sparse to dense herb layer. Dominant canopy trees of this community type include river birch, black willow, red maple, sweetgum (*Liquidambar styraciflua*), sycamore (*Platanus occidentalis*), tulip-poplar (*Liriodendron tulipifera*), and American elm (*Ulmus americana*). Understory trees and shrubs included in this community are tag alder, southern sugar maple (*Acer barbatum*), boxelder (*Acer negundo*), and American holly (*Ilex opaca*). Because many of the trees and saplings of this natural community type are already established in areas within and around the former pond basin, natural regeneration is anticipated in the floodplain.

9.1 RIPARIAN BUFFER

A 15 meter (50 feet) riparian buffer, encompassing 0.76 ha (1.88 ac), will be established on either side of the new stream channel (Figure 21). This buffer zone is currently vegetated with a mix of herbaceous vegetation, scrub/shrubs, and small trees (See Section 4.3). Within this buffer, 0.14 ha (0.34 ac) of land disturbed from construction activities will be revegetated with hardwoods. Additionally, the old stream channel and dam area will be revegetated. Proposed species to be planted in these areas include the following:

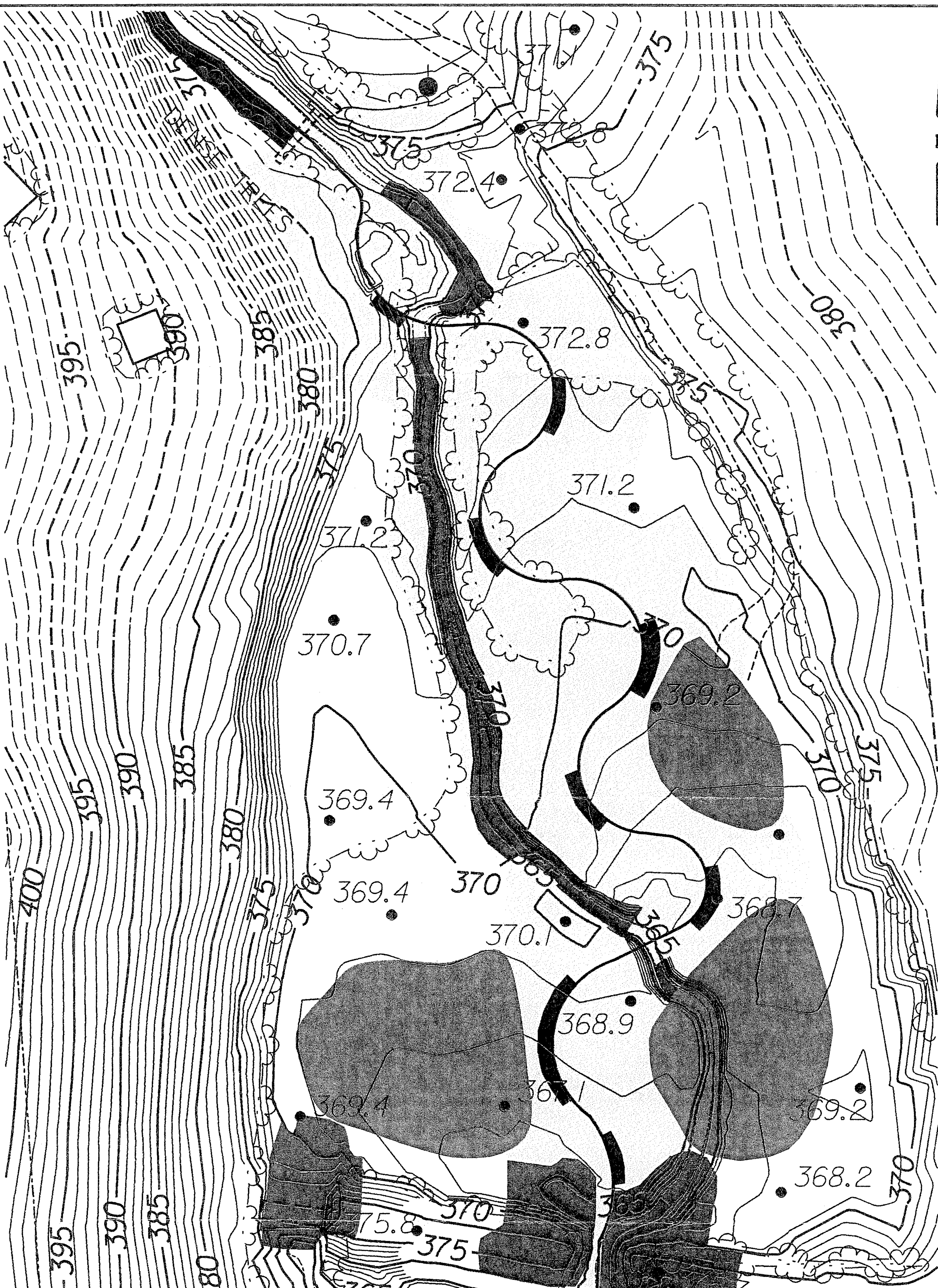
Bottomland Hardwoods (dry)

Black walnut (*Juglans nigra*)
Sycamore (*Platanus occidentalis*)
Bitternut hickory (*Carya cordiformis*)
Tulip-poplar (*Liriodendron tulipifera*)

Areas where these species are proposed are shown on Figure 21. Areas that are currently vegetated will remain undisturbed and succession allowed to proceed naturally.

9.2 WETLAND DEPRESSIONS

Two depressional areas currently exist on the site. These are located on the eastern portion of the basin. These areas were likely wet at one time however, with the downcutting of the stream, wetland hydrology was removed. By reestablishing the stream channel in the floodplain wetland hydrology should be restored to these areas. Minor grading is proposed to reestablish microtopographic relief in these two areas and a third wetland depression will be created on the on the western side of the basin (See Figure 21). These depressions, totaling 0.21 ha (0.53 ac) in size, will help retain surface water and serve as flood storage, as well as help diversify the natural communities on site. Proposed species to be planted within these depressions include the following:



LEGEND

Bottomland Hardwoods (wet) 0.21 ha (0.53 ac)

Bank Stabilization Vegetation 0.03 ha (0.07 ac)

Bottomland Hardwoods (dry) 0.14 ha (0.34 ac)

Riparian Buffer Zone 0.76 ha (1.88 ac)

25 0 25 50 100

SCALE 1" = 50'

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FIGURE 21
Revegetation Plan
Abbott Property Stream Restoration
Wake County, North Carolina

Bottomland Hardwoods (wet)	**Wetland Indicator Status**
Cherrybark oak (*Quercus pagoda*)	FAC+
Swamp chestnut oak (*Quercus michauxii*)	FACW-
Willow oak (*Quercus phellos*)	FACW-
Green ash (*Fraxinus pennsylvanica*)	FACW
Blackgum (*Nyssa sylvatica*)	FAC

Prior to planting the soil will be tested and amended as necessary with lime to achieve a pH between 5.5 and 7. The site will be seeded with seed rye grain to help stabilize the soil after initial site alterations and prior to planting of tree seedlings. Bare root seedlings of tree species will be planted at a density of 1680 stems per hectare (680 stems per acre) on approximately 2.4 meter (8 feet) centers. Seedlings will be at least one season old and 30 to 46 cm (12 to 18 in) in height. Planting will be performed between November and March to allow plants to stabilize during the dormant period and set root during the spring season.

9.3 STREAM BANK VEGETATION

Vegetation that develops a quick canopy, extensive rooting, and substantial plant structure is needed to help stabilize slopes of the new channel in order to reduce stream scour and runoff erosion. In riparian environments, pioneer plants that provide those functions are alder, birch, dogwood, and willow. Once established, these trees can create the environment required for succession of plant species including ash, maples, sycamores, and other riparian species.

In an effort to utilize current site resources, the upper half of the new stream channel has been designed to take advantage of existing vegetation. Outside bends of stream meanders have been placed in areas of young tree and shrub stands in order to improve bank stabilization. Vegetation along the old stream channel will carefully be lifted and placed along the banks of the lower half of the new channel, with concentrated planting along the outside bend of the meanders. The plant species currently on site include:

River birch (*Betula nigra*)
Red maple (*Acer rubrum*)
Tag alder (*Alnus serrulata*)
Black willow (*Salix nigra*)

This onsite vegetation has stem diameters ranging from 3 to 5 cm (1 to 2 in). Because some mortality is expected, additional plantings of cuttings, bareroot plants, or tube plants of other plant material is planned. This mixture of vegetation should provide greater stability to the stream banks. The total area of stream bank stabilization plantings is 0.03 ha (0.07 ac). These planting areas are shown on Figure 21.

Planting will be performed between November and March to allow plants to stabilize during the dormant period and set root during the spring season.

10.0 OTHER CONSIDERATIONS

10.1 CONSTRUCTION

The following is a recommended construction sequence of events:

1. Survey, stake, then dig the new channel, stockpiling fill and vegetation
2. Construct structures at appropriate locations in the new channel
3. Plant vegetation in specified locations – according to final design
4. Plug lower crossing of the existing stream diverting water into the new channel
5. Backfill old stream bed with fill from stockpiles and dam wall to the plug
6. Plug upper crossing of the new and old stream beds diverting water into the new channel
7. Backfill old stream bed to the upper plug with fill from stockpiles and dam wall
8. Repeat for the final reach at the top of property
9. Remove old footbridge over the spillway and the spillway structure which are safety hazards.
10. Perform final grading in wetland depression areas and along removed dam wall.

The old channel must be backfilled to prevent water from seeking the lowest elevation and re-establishing the old channel. Based on the cross sections taken approximately 1900 yards of fill will have to be excavated from the dam wall and place in the existing channel. It is estimated that there are over 3300 yards of fill in the breached dam wall, which is sufficient for this project.

Prior to construction all operators, engineers, and inspectors should be briefed on the environmental sensitivity of this construction. It is important for these individuals to know the dimensions specified in the design are critical to the success of the project. Experience has demonstrated the average equipment operator will oversize the channel, thinking he/she is helping by making the channel larger.

Operators should only operate equipment in designated areas and minimize damage to existing vegetation. They should be instructed where to stockpile fill and vegetation and must stay on designated temporary haul roads.

During construction strict sediment and erosion control measures should be employed to minimize increasing the sediment load to Walnut Creek.

10.2 MONITORING

The NCDOT proposes to monitor the stream mitigation site of one year. Two types of monitoring for the site is planned: vegetation and channel/stream bank stability. The NCDOT will establish photo reference points at the stream mitigation site. The photo reference sites will be located using Global Positioning System and included on the "As-Built" plan for the mitigation site. The NCDOT will submit a brief report with these photographs to the resource agencies regarding these two aspects of monitoring upon completion of the one year monitoring period.

The NCDOT will implement quarterly visits over one year after completion of the mitigation work to ensure channel/bank stability. Photographs of the vegetation will be taken at the end of the growing season. Photographs will show coverage/survivability of the vegetation and channel/stream bank stability. Any remediation action that is necessary will be initiated as soon as possible with consideration given to seasonal constraints. The NCDOT will contact the US Army Corps of Engineers about the remediation. Monitoring period extensions will be addressed on a case by case basis.

10.3 DISPENSATION OF PROPERTY

NCDOT will maintain ownership of the property until all mitigation activities are completed and the site is determined to be successful. Although no plan for dispensation of the Abbott mitigation site has been developed, NCDOT will deed the property to a resource agency (public or private) acceptable to the appropriate regulatory agencies. Covenants and/or restrictions on the deed will insure adequate management and protection of the site in perpetuity.

10.4 MITIGATION CREDITS

This mitigation plan is proposed to partially fulfill compensatory mitigation requirements for wetland impacts associated with R-2541. The project will impact 444 m (1,421 ft) of surface waters. The NCDOT plans to relocate 132 m (422 ft) of stream. Therefore, based on a 2:1 ratio NCDOT has a stream mitigation need of 542 m (1,733 ft) of stream restoration for R-2541. Once restoration activities are completed, 347.5 m (1,112 ft) of restored stream will be present on the Abbott Site.

11.0 REFERENCES

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Schafale, M. P., and A. S. Weakley. 1990. Classification of the Natural Communities of North Carolina, Third Approximation. North Carolina Natural Heritage Program, Division of Parks and Recreation, Dept. of Environment, Health and Natural Resources, Raleigh, NC.

United States Department of Agriculture, Soil Conservation Service. 1970. Soil Survey of Wake County, North Carolina.

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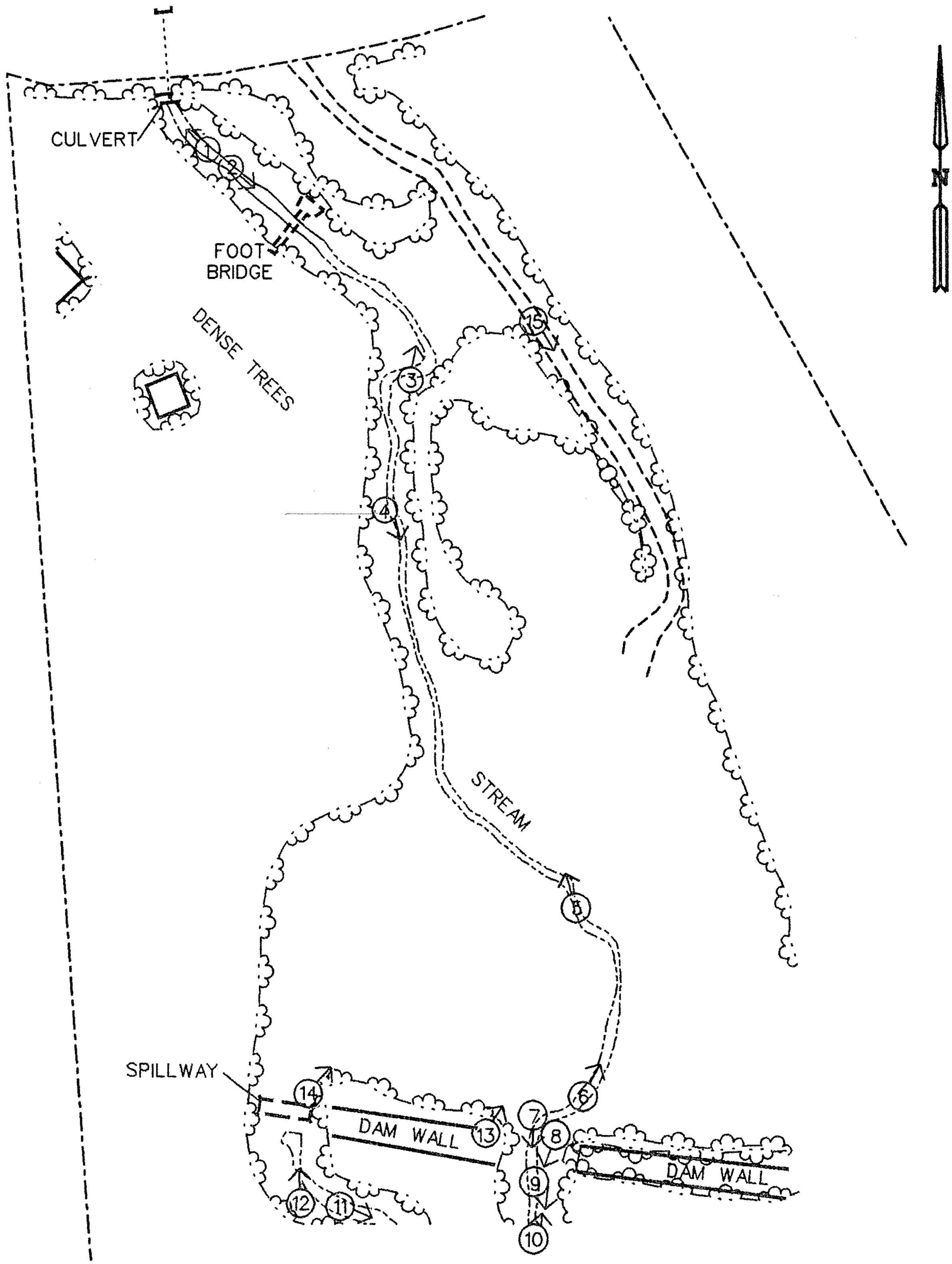
APPENDIX A

EXISTING STREAM CONDITIONS

Photo Log
Longitudinal Profile
Cross Sections
Pebble Count



North Carolina – Department of Transportation
Division of Highways
Planning and Environmental Branch

FIGURE A-1
Photo Locations
Abbott Property Stream Restoration
Wake County, North Carolina

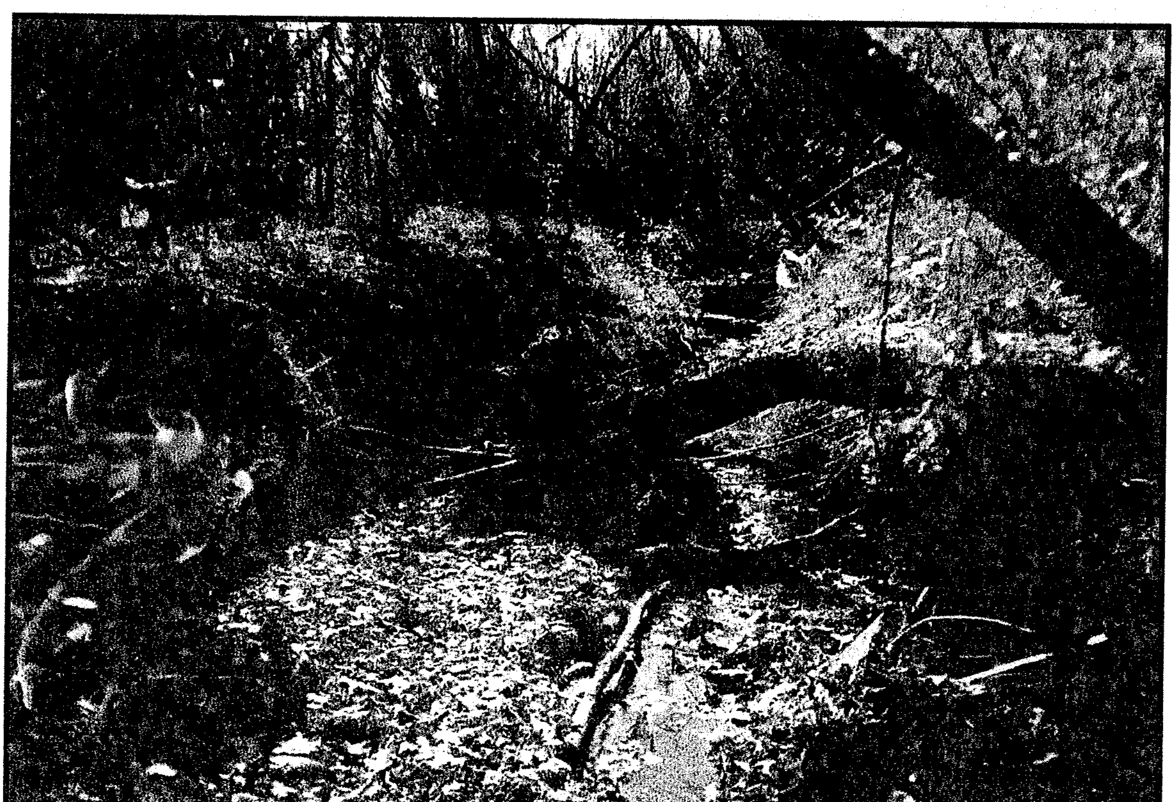
50 0 50 100 150 FEET

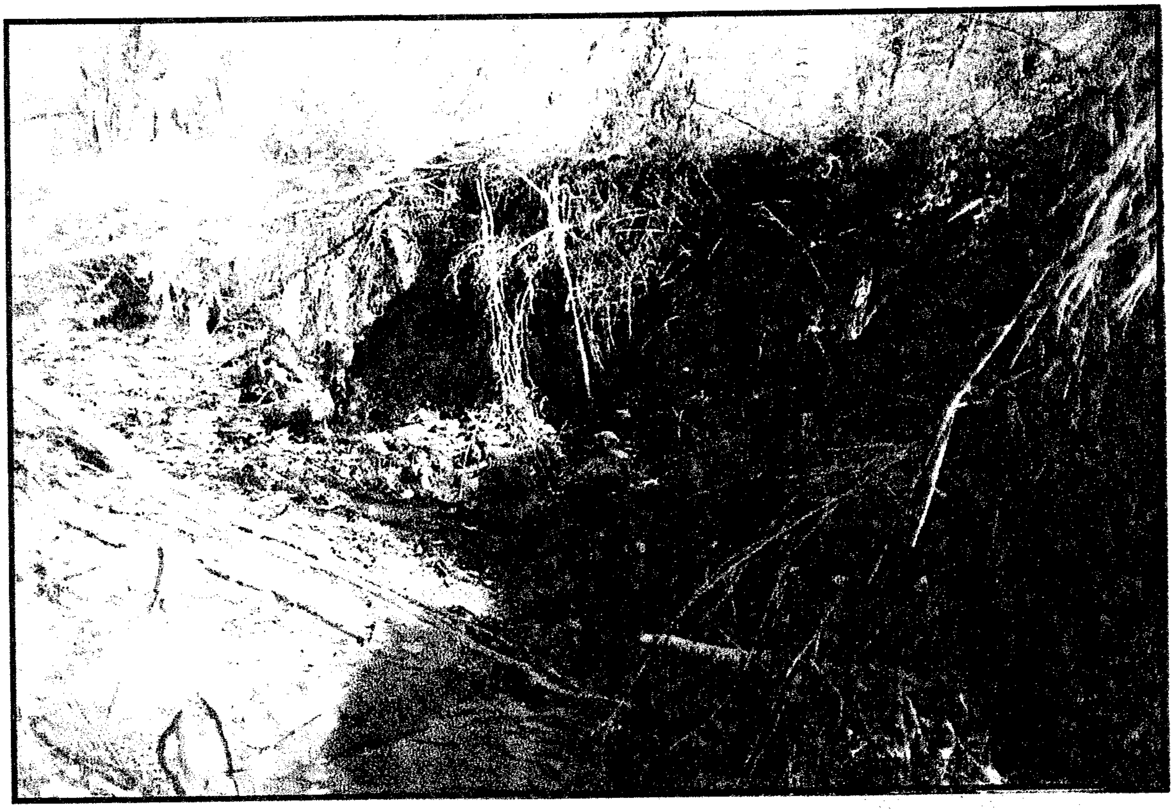
ABBOTT STREAM RESTORATION
PHOTO LOG

1. Culvert under Lakeside Drive. (Upstream View)

2. Wooden foot bridge in picnic area. (Downstream View)


3. Mass wasting of stream bank.


4. Severe bank erosion leading to loss of bank vegetation.



5. Vertical bank caused by head cut.

6. Severe down cut, resulting in vertical banks and loss of bank vegetation.

7. Breached center of dam wall. (Downstream View)

8. Downstream of dam wall, remains of outlet device.

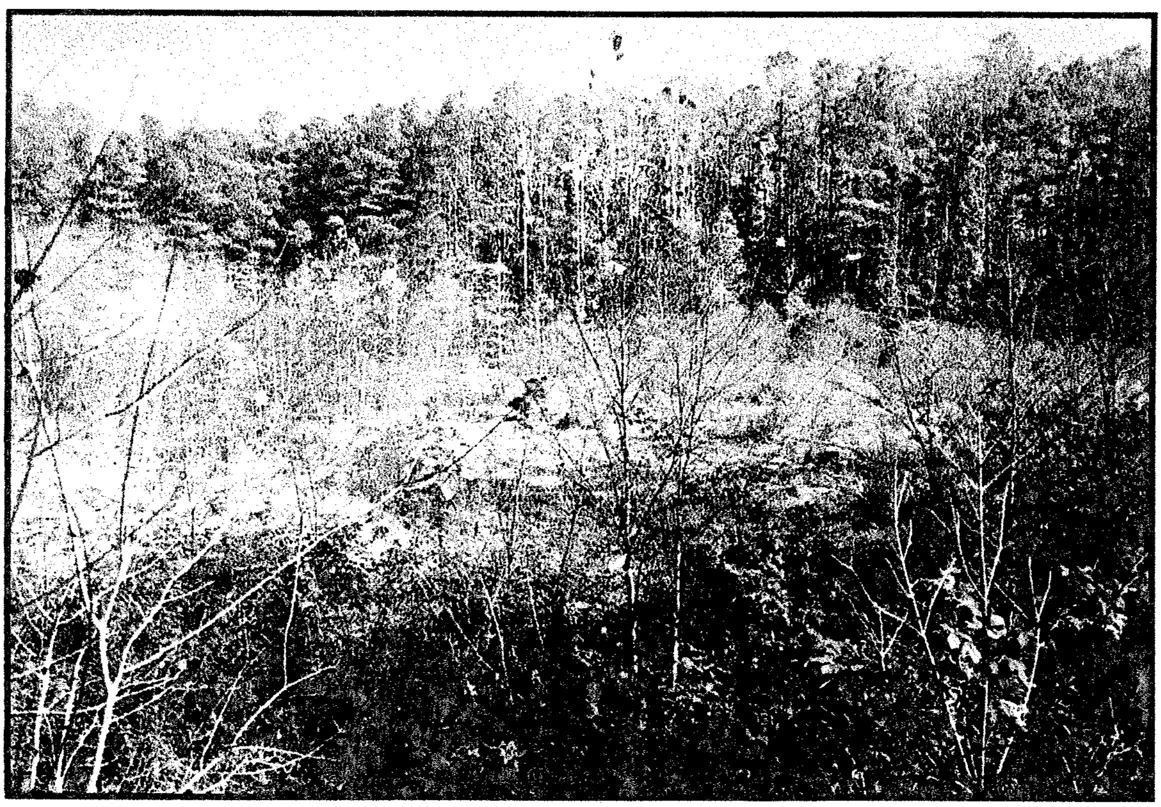
9. Bank erosion downstream of dam.

10. Breach in center of dam. Note level of deposited material in former bed of pond..

11. Spillway Channel

12. Bridge over spillway. Note scour hole below spillway.

13. Current vegetation in former bed of pond.



14. Current vegetation in former bed of pond.

15. Road on east side of property.

Longitudinal Profile
Abbott Property Stream Restoration

Station	Elevation-thalweg	Elevation-water surface
0	98.5	99.3
100	98.6	99.0
150	97.7	98.4
215	98.2	98.3
244	97.4	97.5
293	97.0	97.2
319	96.6	96.7
339	96.4	96.6
357	96.1	96.3
375	96.2	96.3
397	95.3	95.5
401	95.0	95.4
402	93.9	95.5
405	92.7	95.5
412	93.7	95.4
416	95.4	95.4
426	94.6	94.6
427	93.8	94.2
430	94.1	94.2
433	91.9	93.2
437	91.4	93.2
444	92.2	93.2
452	93.1	93.2
460	92.6	92.9
467	92.0	92.9
479	92.7	92.9
483	92.4	92.5
485	92.1	92.3
491	92.1	92.3
502	91.8	92.0
513	91.9	92.0
516	91.2	91.9
521	90.7	91.9
536	91.7	91.9
552	91.9	92.0
567	91.2	91.4
578	91.2	91.4
590	91.0	91.1
600	90.9	91.1
628	90.3	91.1
637	90.6	91.1
656	90.3	90.4
657	90.1	90.3
678	89.7	90.3
691	89.8	90.3
718	88.8	90.3
732	89.3	90.3
753	90.1	90.3
768	89.4	89.6
786	89.4	89.6
814	87.5	89.2
840	88.5	89.1
868	88.9	89.2

Survey Dates: August 4, 14, 1998

Survey Party: Jim Buck, Karen Hall,
Greg Jennings, Will Harman, Ron Johnson
Lynn Woerner

Jim Buck - Instrument
Karen Hall - Rod
Greg Jennings - Rod/Instrument
Will Harman - Recorder
Lynn Woerner - Recorder

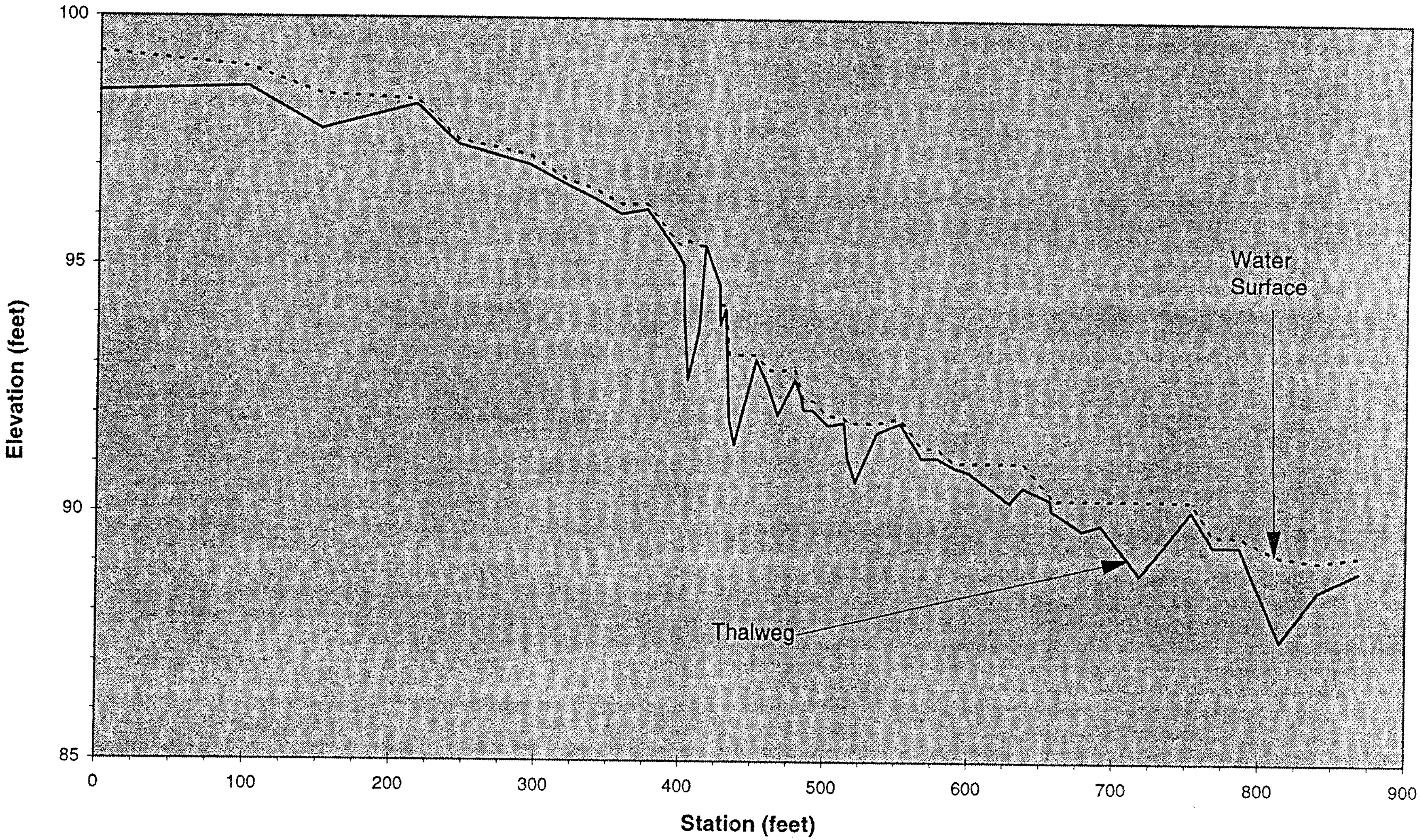
TBM - Invert of culvert on Lakeside Drive
TBM - Elevation = 100 feet

Water Surface Slope: 0.012

Stream Length: 868 feet
Valley Length: 600 feet

Sinuosity: 1.45

Longitudinal Profile
Abbott Property Stream Restoration



Cross Section Station 1+23 (Riffle)
Abbott Property Stream Restoration

Basin: Neuse River
Watershed: Walnut Creek Watershed
Reach: Unnamed Trib to Walnut Creek
Date: 8/4/98
Crew: Will, Greg, Jim, Karen, and Lynn
Purpose: Data Collection for Stream Classification and Restoration

Permanent Cross Section: Station 1+23

Station	HI Feet	FS Feet	Elevation Feet	Notes
0.0	111.28	5.5	105.8	
10.0		7.1	104.2	LPIN-GRD
16.7		8.8	102.5	LFP
18.0		9.6	101.7	LTOB
19.0		**10.5**	**100.8**	**LBKF**
19.1		**12.2**	**99.1**	
20.5		**12.4**	**98.9**	
21.0		**12.4**	**98.9**	**LEW**
21.9		**12.6**	**98.7**	**TW**
23.5		**12.4**	**98.9**	**REW**
25.8		**12.4**	**98.9**	
27.9		**12.0**	**99.3**	
30.1		**12.1**	**99.2**	
31.6		**11.7**	**99.6**	**SCOUR**
33.9		**11.0**	**100.3**	
33.9		**10.5**	**100.8**	**RBKF**
34.8		9.2	102.1	RTOB
36.0		8.9	102.4	
36.9		8.8	102.5	RFP
38.5		8.3	103.0	
42.0		8.5	102.8	
46.5		8.6	102.7	
51.5		8.3	103.0	
56.0		8.0	103.3	
67.0		6.9	104.4	
77.0		4.5	106.8	

BKF Hydraulic Geometry

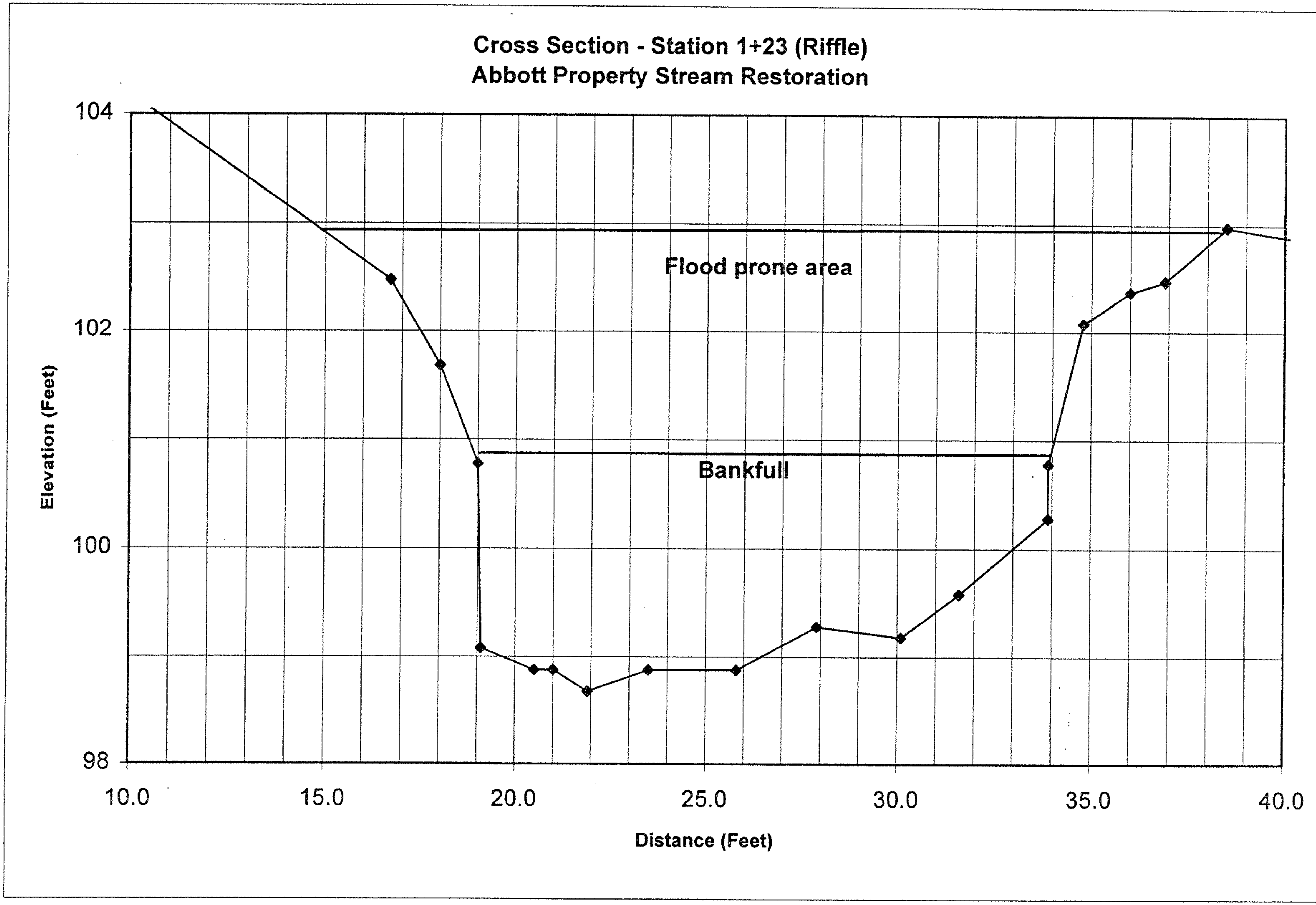
Width Feet	Depth Feet	Area Sq. Ft.
0	0	0.0
0.1	1.7	0.1
1.4	1.9	2.5
0.5	1.9	1.0
0.9	2.1	1.8
1.6	1.9	3.2
2.3	1.9	4.4
2.1	1.5	3.6
2.2	1.6	3.4
1.5	1.2	2.1
2.3	0.5	2.0
0	0.0	0.0
14.9		24.0

Summary Data

BKF A	24.0
BKF W	14.9
Max d	2.1
Mean d	1.6
W/D Ratio	9.3
FP W	20.2
ER	1.36
Str. Type	G5c

Regional Curve (Rural)

Watershed Size	0.6
Bkf A (Rural Curve)	14
Bkf W (Rural Curve)	13
Bkf D (Rural Curve)	1.1


Cross Section - Station 1+23 (Riffle)
Abbott Property Stream Restoration
104
102
100
98
Elevation (Feet)
10.0
15.0
20.0
25.0
30.0
35.0
40.0
Distance (Feet)
Flood prone area
Bankfull

Cross Section Station 3+39 (Riffle)
Abbott Property Stream Restoration

Basin: Neuse River
Watershed: Walnut Creek Watershed
Reach: Unnamed Trib to Walnut Creek
Date: 8/14/98
Crew: Will, Greg, Jim, Karen, and Lynn
Purpose: Data Collection for Stream Classification and Restoration
Permanent Cross Section 3+39

Station	HI Feet	FS Feet	Elevation Feet	Notes
0.6	106.45	6.00	100.5	LPIN-GRD
0.6		5.39	101.06	LPIN
6.0		6.4	100.1	
10.0		6.3	100.2	
14.0		6.1	100.4	
18.0		5.7	100.8	LFP
22.2		5.0	101.5	
25.0		5.2	101.3	LTOB
26.0		6.0	100.5	
28.7		**7.9**	**98.6**	**LBKF**
29.5		**8.2**	**98.3**	
29.9		**8.7**	**97.8**	
30.3		**10.1**	**96.4**	**LEW,TW**
30.3		**9.9**	**96.6**	
32.3		**10.0**	**96.5**	
34.6		**9.9**	**96.6**	**REW**
35.7		**9.8**	**96.7**	
35.9		**9.3**	**97.2**	
36.6		**8.6**	**97.9**	
36.9		**7.9**	**98.6**	**RBKF**
37.8		6.6	99.9	
39.0		5.6	100.9	
44.3		5.7	100.8	
50.0		6.1	100.4	
56.7		6.2	100.3	
59.0		6.2	100.3	
60.8		6.0	100.5	
61.5		5.8	100.7	
62.7		4.3	102.2	RTOB
63.7		4.2	102.25	RPIN-GRD
63.7		3.02	103.43	RPIN-TOP

BKF Hydraulic Geometry

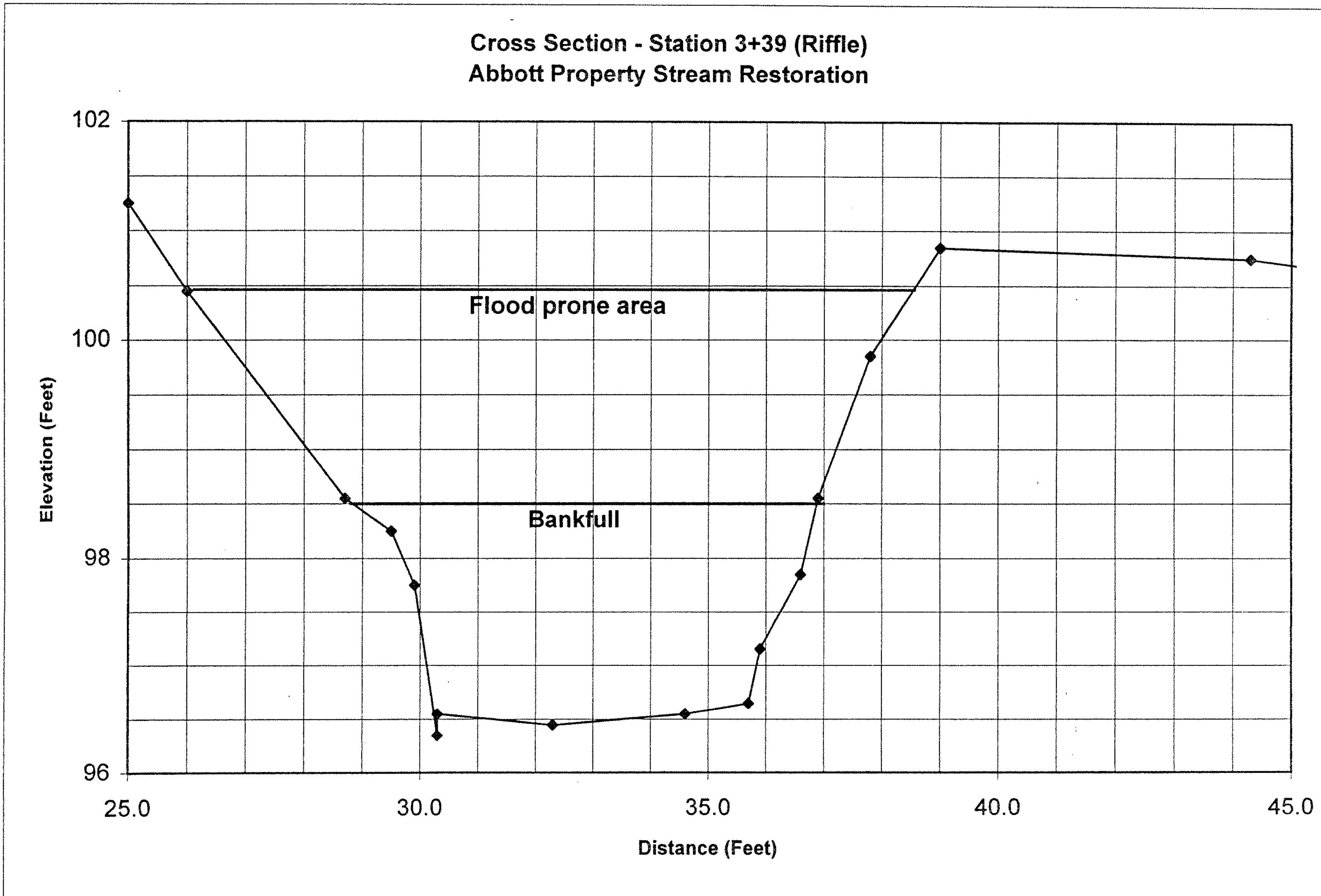
Width Feet	Depth Feet	Area Sq. Ft.
0	0	0.0
0.8	0.3	0.1
0.4	0.8	0.2
0.4	2.2	0.6
0	2.0	0.0
2	2.1	4.1
2.3	2.0	4.7
1.1	1.9	2.1
0.2	1.4	0.3
0.7	0.7	0.7
0.3	0.0	0.1
8.2		13.1

Summary Data

BKF A	13.1
BKF W	8.2
Max d	2.2
Mean d	1.6
W/D Ratio	5.1
FP W	13
ER	1.6
Str Type	G5c

Regional Curve (Rural)

Watershed Size	0.6
Bkf A (Rural Curve)	14
Bkf W (Rural Curve)	13
Bkf D (Rural Curve)	1.1


Cross Section - Station 3+39 (Riffle)
Abbott Property Stream Restoration
Flood prone area
Bankfull
Elevation (Feet)
102
100
98
96
Distance (Feet)
25.0
30.0
35.0
40.0
45.0

Cross Section - Station 7+32 (Pool)
Abbott Property Stream Restoration

Basin: Neuse River
Watershed: Walnut Creek Watershed
Reach: Unnamed Trib to Walnut Creek
Date: 8/14/98
Crew: Will, Greg, Jim, Karen, and Lynn
Purpose: Data Collection for Stream Classification and Restoration
Permanent Cross Section 7+32

Station	HI Feet	FS Feet	Elevation Feet	Notes
1.1	101.6	5.2	96.4	LPIN-GRD
1.1		4.16	97.4	LPIN
12		5.3	96.3	
28.5		5.3	96.3	LTOB
29.3		5.8	95.8	
30.6		6.6	95.0	
31.1		**9.4**	**92.2**	LBKF
31.6		**10.3**	**91.3**	
34.7		**10.7**	**90.9**	
35.1		**11.3**	**90.3**	WS
35.7		**11.7**	**89.9**	
36.4		**12.2**	**89.4**	
37.8		**12.4**	**89.2**	TW
39		**12.3**	**89.3**	
39.6		**12**	**89.6**	
40		**10.5**	**91.1**	
42		**10.2**	**91.4**	
42.5		**9.4**	**92.2**	RBKF
43		5.1	96.5	RTOB
60		5.2	96.4	
78		4.8	96.8	RPIN-GRD
78		4.14	97.5	RPIN-TOP

BKF Hydraulic Geometry

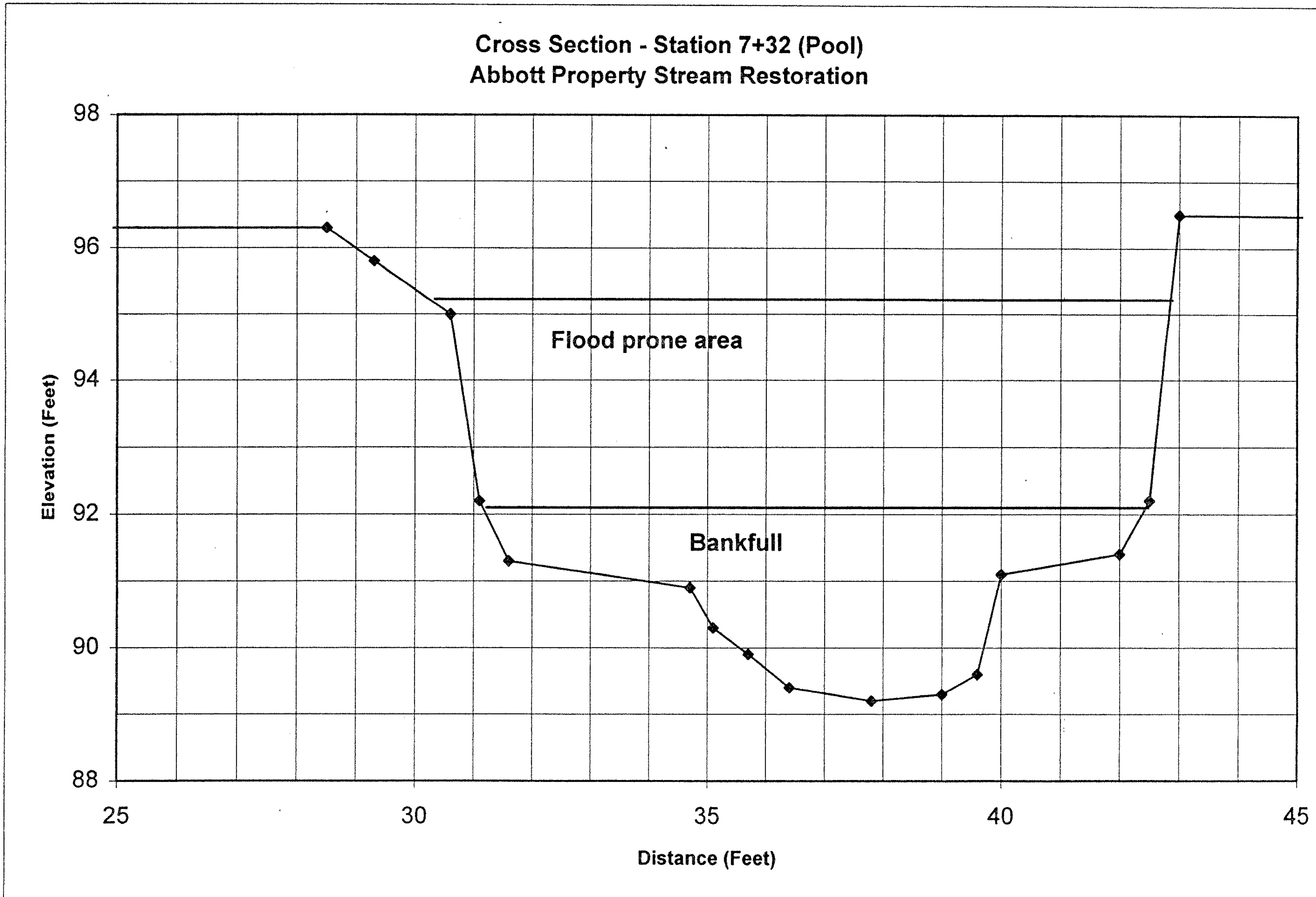
Width Feet	Depth Feet	Area Sq. Ft.
0.0	0.0	0
0.5	0.9	0.225
3.1	1.3	3.41
0.4	1.9	0.64
0.6	2.3	1.26
0.7	2.8	1.785
1.4	3.0	4.06
1.2	2.9	3.54
0.6	2.6	1.65
0.4	1.1	0.74
2.0	0.8	1.9
0.5	0.0	0.2
11.4		19.4

Summary Data

BKF A	19.4
BKF W	11.4
Max d	3.0
Mean d	1.7
W/D Ratio	6.7
FP W	12.4
ER	1.1

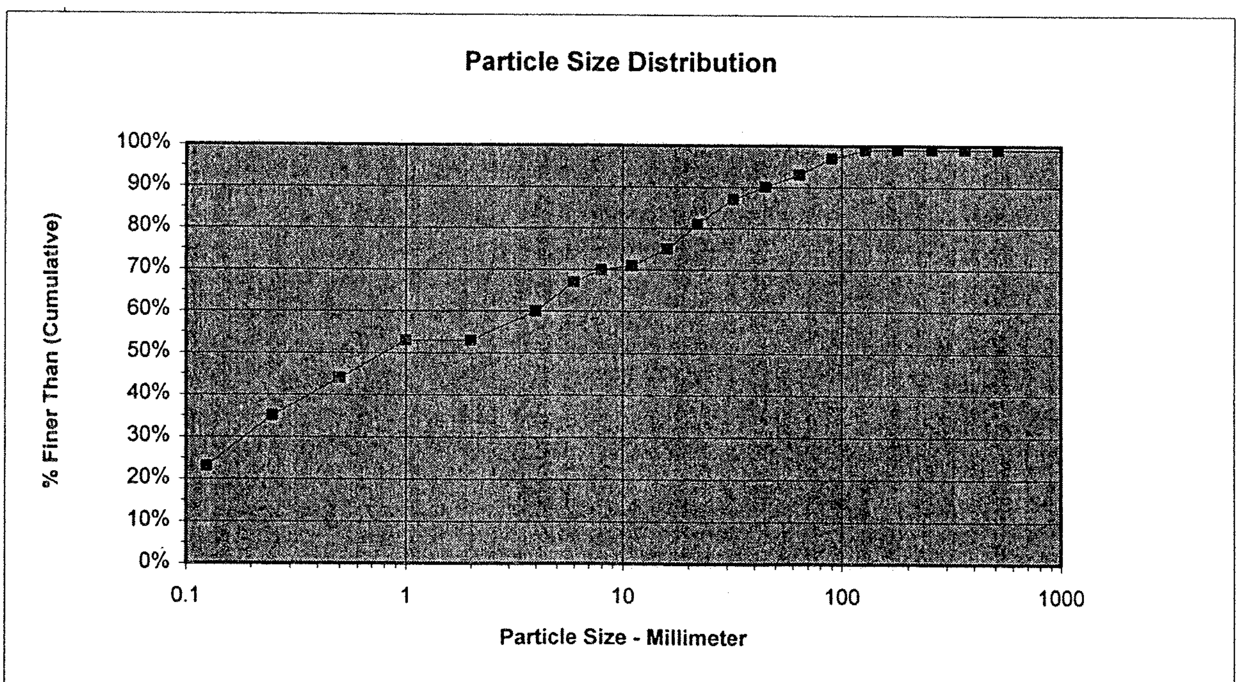
Regional Curve (Rural)

Watershed Size	0.6
Bkf A (Rural Curve)	14
Bkf W (Rural Curve)	13
Bkf D (Rural Curve)	1.1


Cross Section - Station 7+32 (Pool)
Abbott Property Stream Restoration
Elevation (Feet)
98
96
94
92
90
88
Flood prone area
Bankfull
25
30
35
40
45
Distance (Feet)

Pebble Count
Abbott Property Stream Restoration

PEBBLE COUNT								
Site: Abbott Property						Date: 8/4/98		
Party: Jim Buck, Karen Hall, Gregg Jennings, Will Harman						Reach: Unnamed Trib - Walnut Crk		
				Particle Counts				
Inches	Particle	Millimeter		Riffles	Pools	Total No.	Item %	% Cumulative
	Silt/Clay	< 0.062	S/C	5	14	19	19%	19%
	Very Fine	.062 - .125	S	2	2	4	4%	23%
	Fine	.125 - .25	A	2	10	12	12%	35%
	Medium	.25 - .50	N	4	5	9	9%	44%
	Coarse	.50 - 1.0	D	3	6	9	9%	53%
.04 -.08	Very Coarse	1.0 - 2.0	S	0	0	0	0%	53%
.08 - .16	Very Fine	2.0 - 4.0		2	5	7	7%	60%
.16 - .22	Fine	4.0 - 5.7	G	1	6	7	7%	67%
.22 - .31	Fine	5.7 - 8.0	R	2	1	3	3%	70%
.31 - .44	Medium	8.0 - 11.3	A	0	1	1	1%	71%
.44 - .63	Medium	11.3 - 16.0	V	2	2	4	4%	75%
.63 - .89	Coarse	16.0 - 22.6	E	3	3	6	6%	81%
.89 - 1.26	Coarse	22.6 - 32.0	L	5	1	6	6%	87%
1.26 - 1.77	Very Coarse	32.0 - 45.0	S	1	2	3	3%	90%
1.77 - 2.5	Very Coarse	45.0 - 64.0		2	1	3	3%	93%
2.5 - 3.5	Small	64 - 90	C	4	0	4	4%	97%
3.5 - 5.0	Small	90 - 128	O	1	1	2	2%	99%
5.0 - 7.1	Large	128 - 180	B	0	0	0	0%	99%
7.1 - 10.1	Large	180 - 256	L	0	0	0	0%	99%
10.1 - 14.3	Small	256 - 362	B	0	0	0	0%	99%
14.3 - 20	Small	362 - 512	L	0	0	0	0%	99%
20 - 40	Medium	512 - 1024	D	0	0	0	0%	99%
40 - 80	Lrg- Very Lrg	1024 - 2048	R	0	0	0	0%	99%
	Bedrock		BDRK	1	0	1	1%	100%
			Totals	**40**	**60**	**100**	**100%**	**100%**



APPENDIX B

BROOKHAVEN REFERENCE REACH

Longitudinal Profile
Cross Sections
Pebble Count

Longitudinal Profile
Brookhaven Reference Reach

Basin:	Neuse
Watershed:	Crabtree
Reach:	Brookhaven
Date:	8/15/98
Crew:	Will, Greg, Jim, Karen, Ron, and Lynn
Purpose:	Site Characterization - reference reach

Longitudinal Profile

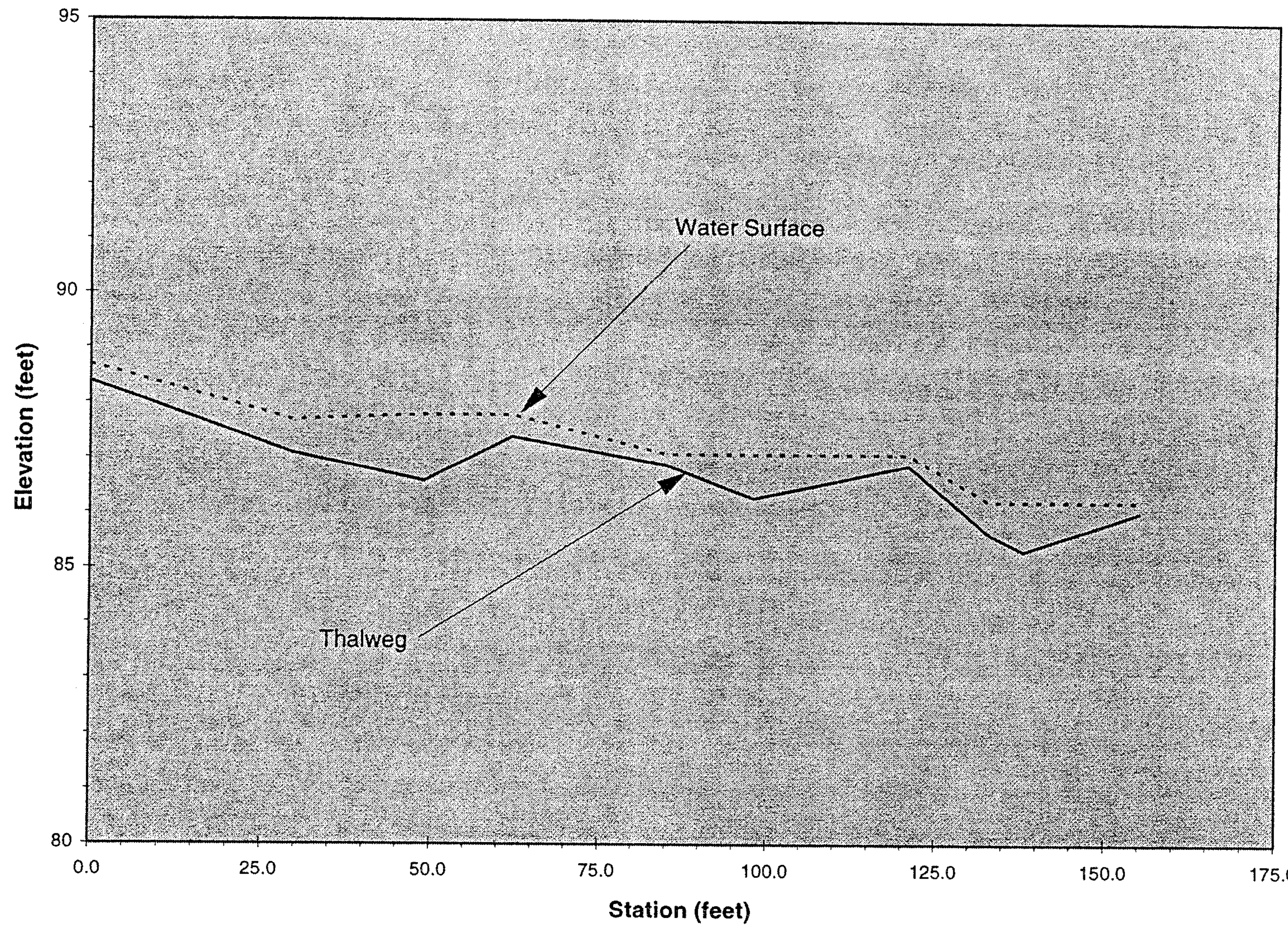
Station	Elevation-thalweg	Elevation-water surface
0	88.4	88.7
30	87.1	87.7
49	86.6	87.8
62	87.4	87.8
85	86.9	87.1
98	86.3	87.1
121	86.9	87.1
133	85.6	86.2
138	85.3	86.2
155	86.0	86.2

Water Surface Slope	**0.016**
Stream Length	155
Valley Length	91
Sinuosity	**1.7**

Channel Pattern:

Meander Length	47 feet
Belt Width	28 - 41 feet
Radius of Curvature	12 - 35 feet

Longitudinal Profile
Brookhaven Reference Reach



Cross Section - Station 0+12.5 (Riffle)
Brookhaven Reference Reach

Basin:	Neuse
Watershed:	Crabtree
Reach:	Brookhaven
Date:	8/15/98
Crew:	Will, Greg, Jim, Karen, Ron, and Lynn
Purpose:	Site Characterization - reference reach

Permanent Cross Section 0+12.5

Station	HI Feet	FS Feet	Elevation Feet	NOTES
0.0	93.99	1.5	92.5	
0.1		2.0	92.0	
1.5		2.5	91.5	
2.1		3.2	90.8	
2.2		4.3	89.7	
2.3		4.5	89.5	
2.8		**4.9**	**89.1**	**LBKF**
3.5		**5.2**	**88.8**	
4.1		**5.3**	**88.7**	
4.5		**5.5**	**88.5**	
5.5		**5.6**	**88.4**	
5.6		**5.6**	**88.4**	
6.0		**5.7**	**88.3**	
6.7		**5.7**	**88.3**	
7.6		**5.7**	**88.3**	
8.4		**5.6**	**88.4**	
8.7		**5.8**	**88.2**	
9.1		**5.9**	**88.1**	**TW**
9.5		**5.7**	**88.3**	
9.9		**5.5**	**88.5**	**REW**
10.6		**5.4**	**88.6**	
11.5		**5.1**	**88.9**	
12.0		**5.0**	**89.0**	
12.8		**4.9**	**89.1**	**RBKF**
14.3		4.6	89.4	
15.8		4.3	89.7	
18.0		4.1	89.9	

BKF Hydraulic Geometry

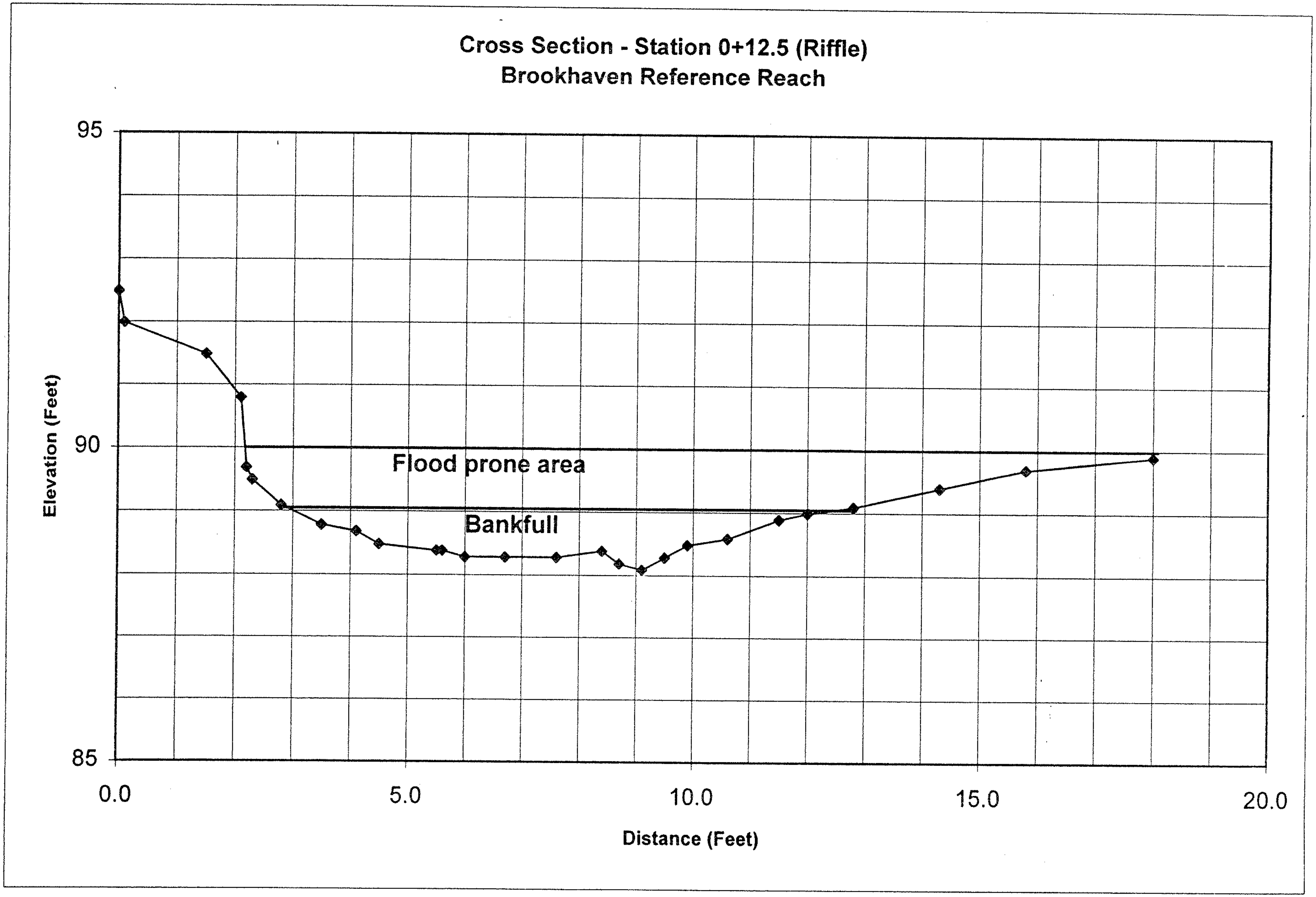
Width Feet	Depth Feet	Area Sq. Ft.
0	0.0	0.0
0.7	0.3	0.1
0.6	0.4	0.2
0.4	0.6	0.2
1	0.7	0.6
0.1	0.7	0.1
0.4	0.8	0.3
0.7	0.8	0.6
0.9	0.8	0.7
0.8	0.7	0.6
0.3	0.9	0.2
0.4	1.0	0.4
0.4	0.8	0.4
0.4	0.6	0.3
0.7	0.5	0.4
0.9	0.2	0.3
0.5	0.1	0.1
0.8	0.0	0.0
10		5.5

Regional Curve (Rural)

Watershed Size (sq mi)	0.14
Bkf A (Regional Curve)	4.5
Bkf W (Regional Curve)	6.5
Bkf D (Regional Curve)	0.7

Summary Data

BKF A	5.5
BKF W	10
Max d	1.0
Mean d	0.55
W/D Ratio	18.2
FP W	33
ER	3.3
Str Type	C4


Cross Section - Station 0+12.5 (Riffle)
Brookhaven Reference Reach
95
90
85
Elevation (Feet)
Flood prone area
Bankfull
0.0
5.0
10.0
15.0
20.0
Distance (Feet)

Cross Section - Station 0+49 (Pool)
Brookhaven Reference Reach

Basin: Neuse
Watershed: Crabtree
Reach: Brookhaven
Date: 8/15/98
Crew: Will, Greg, Jim, Karen, Ron, and Lynn
Purpose: Site Characterization - reference reach

Permanent Cross Section 0+49

Station	HI Feet	FS Feet	Elevation Feet	NOTES
0	93.99	2	92.0	LTOP
0.65		**5.1**	**88.9**	**LBKF**
1.3		**7.3**	**86.7**	**Undercut bank**
2.3		**7.3**	**86.7**	**TW**
3		**7.2**	**86.8**	
4.8		**6.5**	**87.5**	
5.7		**6.2**	**87.8**	**REW**
7.6		**5.5**	**88.5**	
8		**5.4**	**88.6**	
9		**5.1**	**88.9**	**RBKF**
10.8		4.9	89.1	
13.4		4.7	89.3	
15		4.4	89.6	
16.8		4.1	89.9	

BKF Hydraulic Geometry

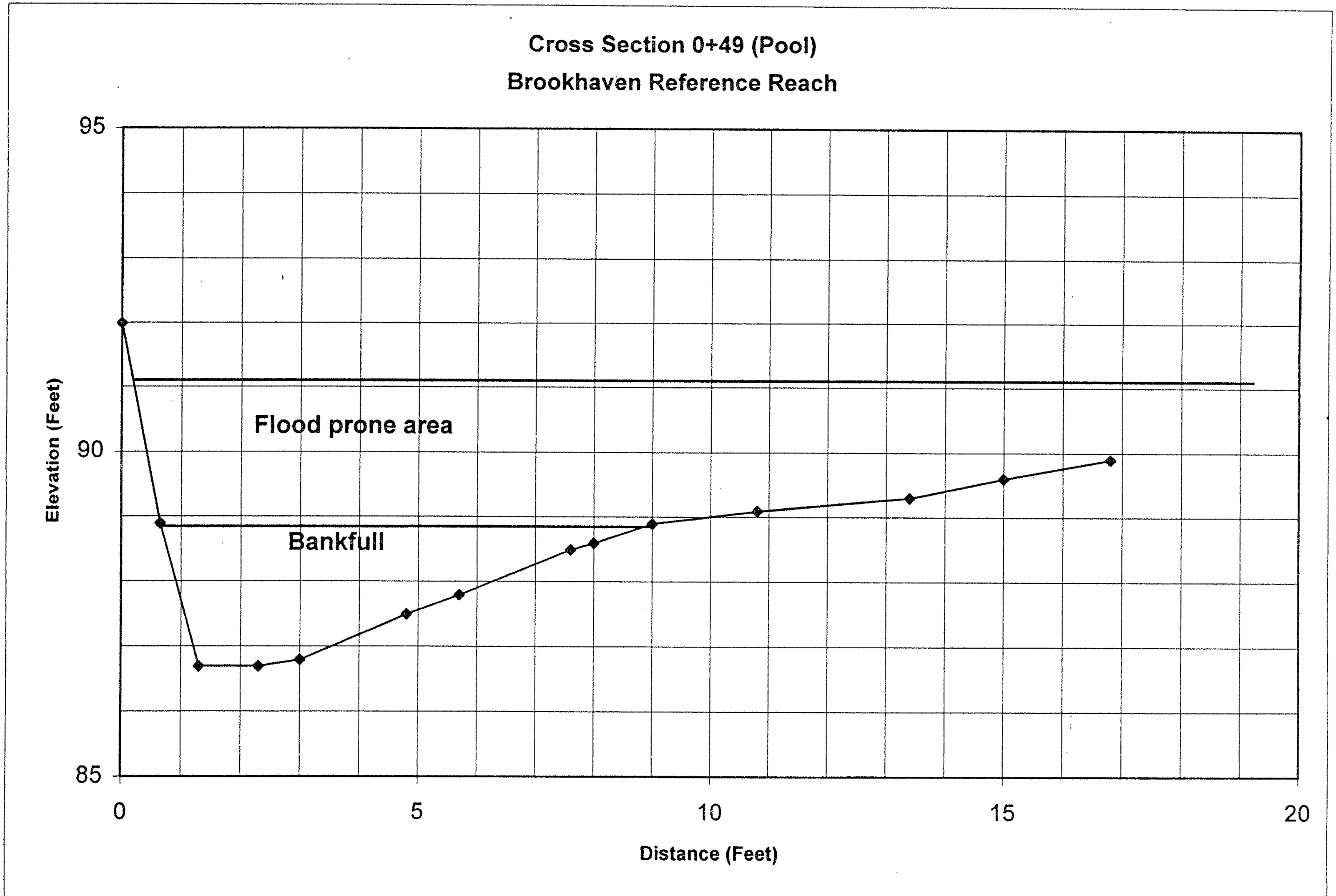
Width Feet	Depth Feet	Area Sq. Ft.
0	0	0
0.65	2.2	0.7
1	2.2	2.2
0.7	2.1	1.5
1.8	1.4	3.2
0.9	1.1	1.1
1.9	0.4	1.4
0.4	0.3	0.1
1	0	0.2
8.35		10.4

Regional Curve (Rural)

Watershed Size (sq mi)	0.14
Bkf A (Regional Curve)	4.5
Bkf W (Regional Curve)	6.5
Bkf D (Regional Curve)	0.7

Summary Data

BKF A	10.4
BKF W	8.35
Max d	2.2
Mean d	1.2
W/D Ratio	6.7
FP W	
ER	>2.2



Cross Section 0+49 (Pool)
Brookhaven Reference Reach
95
90
85
Elevation (Feet)
Flood prone area
Bankfull
0
5
10
15
20
Distance (Feet)

Cross Section - Station 0+97 (Pool)
Brookhaven Reference Reach

Basin:	Neuse
Watershed:	Crabtree
Reach:	Brookhaven
Date:	8/15/98
Crew:	Will, Greg, Jim, Karen, Ron, and Lynn
Purpose:	Site Characterization - reference reach

Permanent Cross Section 0+97

Station	HI Feet	FS Feet	Elevation Feet	NOTES
0	91.94	1.9	90.0	
4.5		3.5	88.4	
6.8		**3.8**	**88.1**	**LBKF**
10		**4.3**	**87.6**	
11.4		**4.9**	**87.0**	
12.6		**5.4**	**86.5**	
14.4		**5.7**	**86.2**	
17.2		**4.9**	**87.0**	**REW**
17.9		**4.3**	**87.6**	
18.1		**3.8**	**88.1**	**RBKF**
18.9		1.3	90.6	RTOB

BKF Hydraulic Geometry

Width Feet	Depth Feet	Area Sq. Ft.
0	0	0.0
3.2	0.5	0.8
1.4	1.1	1.1
1.2	1.6	1.6
1.8	1.9	3.2
2.8	1.1	4.2
0.7	0.5	0.6
0.2	0	0.1
11.3		11.5

Regional Curve (Rural)

Watershed Size (sq mi)	0.14
Bkf A (Regional Curve)	4.5
Bkf W (Regional Curve)	6.5
Bkf D (Regional Curve)	0.7

Summary Data

BKF A	11.5
BKF W	11.3
Max d	1.9
Mean d	1.0
W/D Ratio	11.1
FP W	
ER	>2.2

Cross Section - Station 0+97 (Pool)
Brookhaven Reference Reach

Basin:	Neuse
Watershed:	Crabtree
Reach:	Brookhaven
Date:	8/15/98
Crew:	Will, Greg, Jim, Karen, Ron, and Lynn
Purpose:	Site Characterization - reference reach

Permanent Cross Section 0+97

Station	HI Feet	FS Feet	Elevation Feet	NOTES
0	91.94	1.9	90.0	
4.5		3.5	88.4	
6.8		**3.8**	**88.1**	**LBKF**
10		**4.3**	**87.6**	
11.4		**4.9**	**87.0**	
12.6		**5.4**	**86.5**	
14.4		**5.7**	**86.2**	**TW**
17.2		**4.9**	**87.0**	**REW**
17.9		**4.3**	**87.6**	
18.1		**3.8**	**88.1**	**RBKF**
18.9		1.3	90.6	RTOB

BKF Hydraulic Geometry

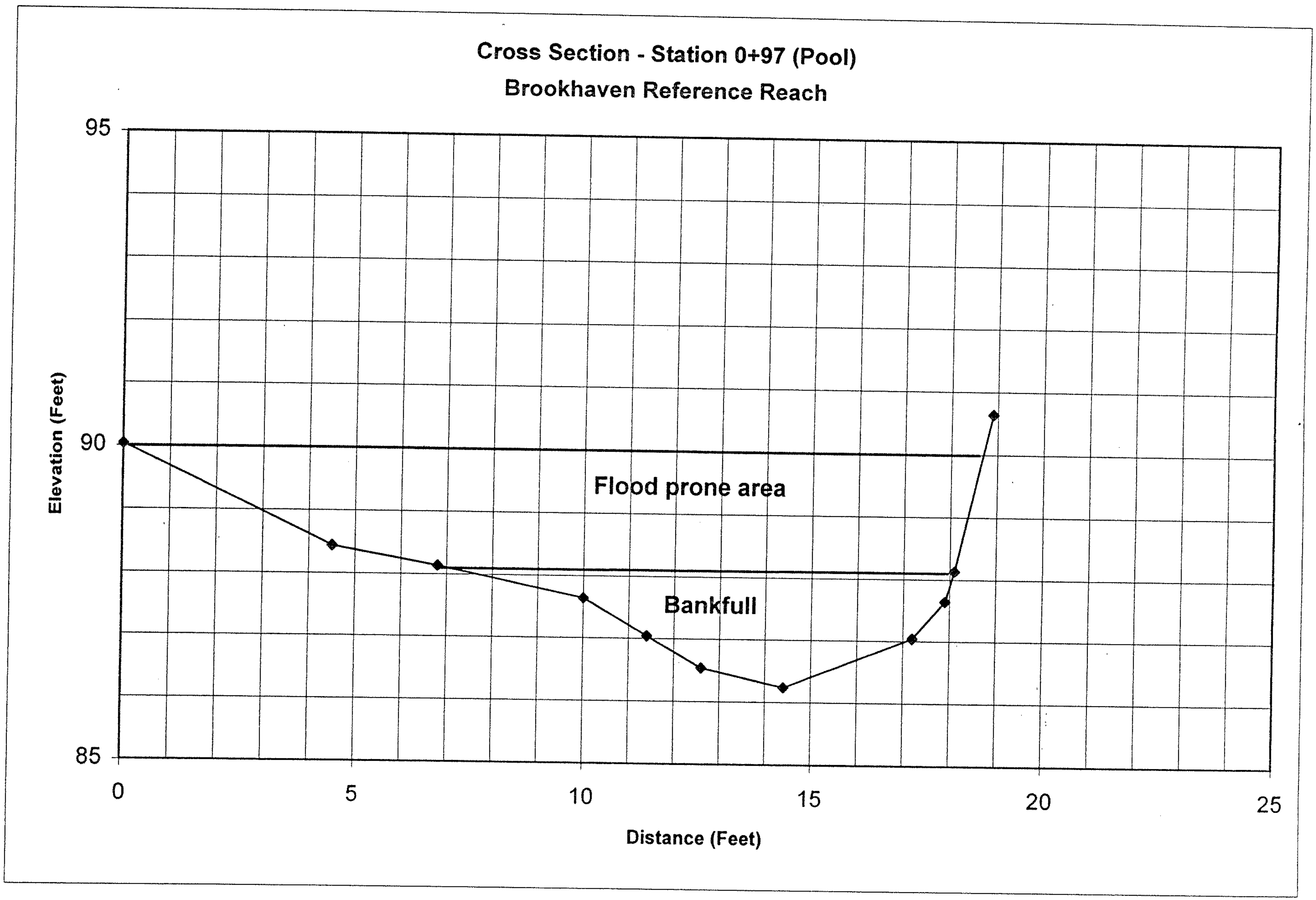
Width Feet	Depth Feet	Area Sq. Ft.
0	0	0.0
3.2	0.5	0.8
1.4	1.1	1.1
1.2	1.6	1.6
1.8	1.9	3.2
2.8	1.1	4.2
0.7	0.5	0.6
0.2	0	0.1
11.3		11.5

Regional Curve (Rural)

Watershed Size (sq mi)	0.14
Bkf A (Regional Curve)	4.5
Bkf W (Regional Curve)	6.5
Bkf D (Regional Curve)	0.7

Summary Data

BKF A	11.5
BKF W	11.3
Max d	1.9
Mean d	1.0
W/D Ratio	11.1
FP W	19
ER	1.7


Cross Section - Station 0+97 (Pool)
Brookhaven Reference Reach
95
90
85
Elevation (Feet)
Flood prone area
Bankfull
0
5
10
15
20
25
Distance (Feet)

Cross Section - Station 1+24 (Riffle)
Brookhaven Reference Reach

Basin: Neuse
Watershed: Crabtree
Reach: Brookhaven
Date: 8/15/98
Crew: Will, Greg, Jim, Karen, Ron, and Lynn
Purpose: Site Characterization - reference reach

Permanent Cross Section 1+24

Station	HI Feet	FS Feet	Elevation Feet	NOTES
0	95.47	4.8	90.7	LTOB
3.3		6.6	88.9	
9.4		7	88.5	
12.9		**7.4**	**88.1**	**LBKF**
16.8		**7.8**	**87.7**	
17.1		**8.3**	**87.2**	
19.8		**8.2**	**87.3**	
21.8		**8.5**	**87.0**	**LEW**
23.6		**8.6**	**86.9**	**TW**
26.6		**8.5**	**87.0**	**REW**
28		**7.8**	**87.7**	
28.5		**7.4**	**88.1**	**RBKF**
29.8		5.3	90.2	RTOB

BKF Hydraulic Geometry

Width Feet	Depth Feet	Area Sq. Ft.
0	0	0.0
3.9	0.4	0.8
0.3	0.9	0.2
2.7	0.8	2.3
2	1.1	1.9
1.8	1.2	2.1
3	1.1	3.5
1.4	0.4	1.1
0.5	0	0.1
15.6		11.8

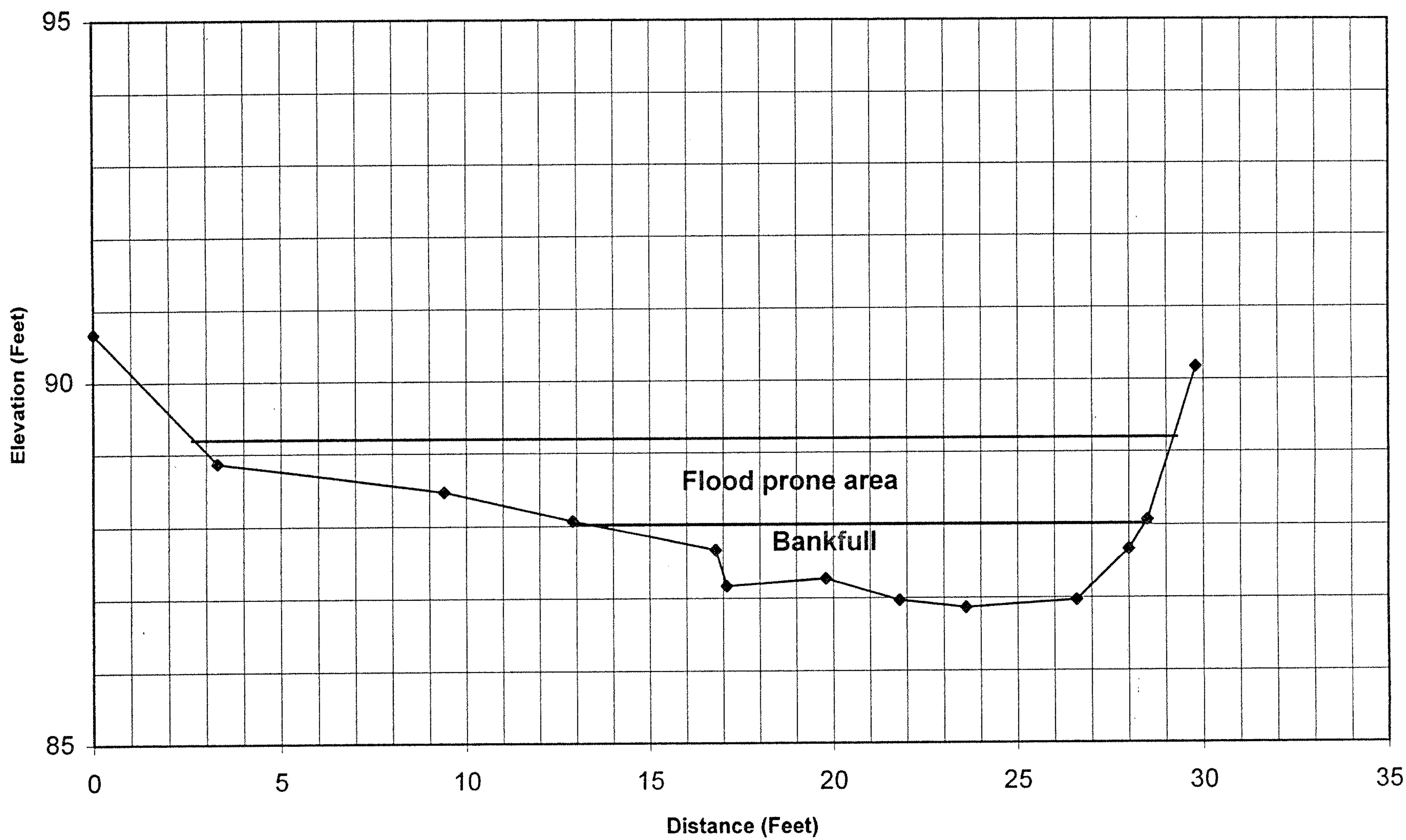
Regional Curve (Rural)

Watershed Size (sq mi)	0.14
Bkf A (Regional Curve)	4.5
Bkf W (Regional Curve)	6.5
Bkf D (Regional Curve)	0.7

Summary Data

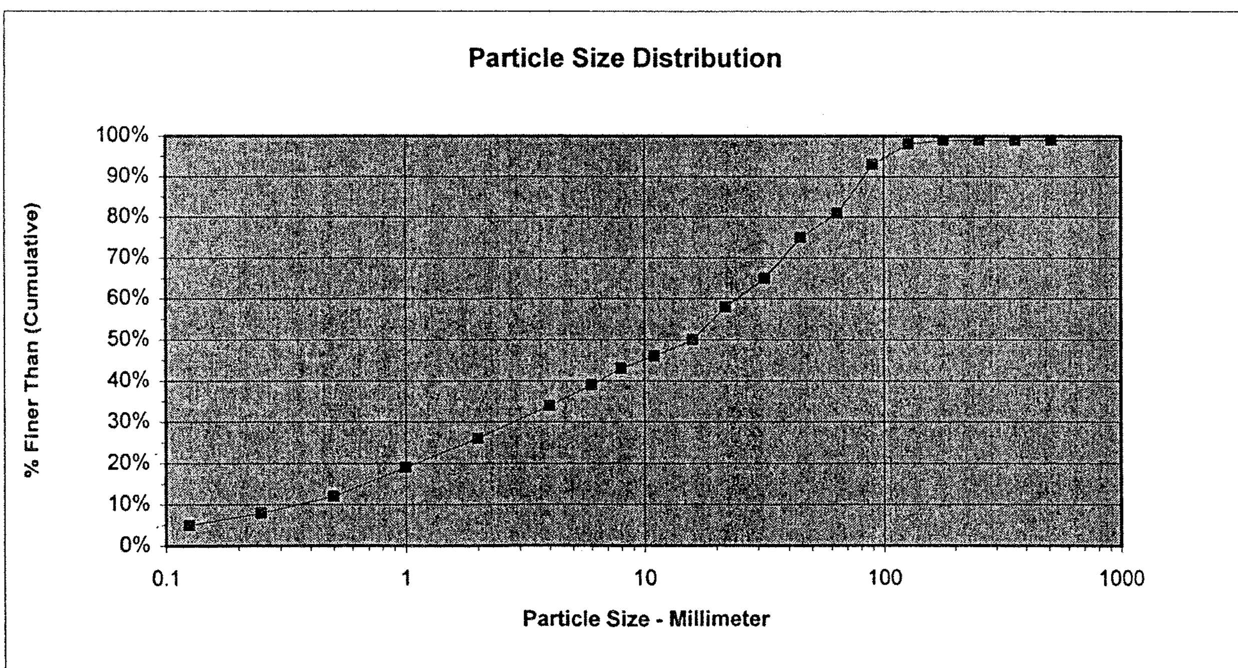
BKF A	11.8
BKF W	15.6
Max d	1.2
Mean d	0.8
W/D Ratio	20.6
FP W	29
ER	1.9
Str Type	C4

Cross Section - Station 1+24 (Riffle)
Brookhaven Reference Reach



Pebble Count
Brookhaven Reference Reach

PEBBLE COUNT								
Site: Brookhaven Nature Park						Date: 8/15/98		
Party: Jim Buck, Karen Hall, Gregg Jennings, Will Harman						Reach: Trib - Hare Snipe Creek		
				Particle Counts				
Inches	Particle	Millimeter		Riffles	Pools	Total No.	Item %	% Cumulative
	Silt/Clay	< 0.062	S/C	0	4	4	4%	4%
	Very Fine	.062 - .125	S	1	0	1	1%	5%
	Fine	.125 - .25	A	2	1	3	3%	8%
	Medium	.25 - .50	N	0	4	4	4%	12%
	Coarse	.50 - 1.0	D	0	7	7	7%	19%
.04 -.08	Very Coarse	1.0 - 2.0	S	5	2	7	7%	26%
.08 - .16	Very Fine	2.0 - 4.0		2	6	8	8%	34%
.16 - .22	Fine	4.0 - 5.7	G	0	5	5	5%	39%
.22 - .31	Fine	5.7 - 8.0	R	2	2	4	4%	43%
.31 - .44	Medium	8.0 - 11.3	A	1	2	3	3%	46%
.44 - .63	Medium	11.3 - 16.0	V	2	2	4	4%	50%
.63 - .89	Coarse	16.0 - 22.6	E	4	4	8	8%	58%
.89 - 1.26	Coarse	22.6 - 32.0	L	4	3	7	7%	65%
1.26 - 1.77	Very Coarse	32.0 - 45.0	S	2	8	10	10%	75%
1.77 - 2.5	Very Coarse	45.0 - 64.0		4	2	6	6%	81%
2.5 - 3.5	Small	64 - 90	C	7	5	12	12%	93%
3.5 - 5.0	Small	90 - 128	O	4	1	5	5%	98%
5.0 - 7.1	Large	128 - 180	B	0	1	1	1%	99%
7.1 - 10.1	Large	180 - 256	L	0	0	0	0%	99%
10.1 - 14.3	Small	256 - 362	B	0	0	0	0%	99%
14.3 - 20	Small	362 - 512	L	0	0	0	0%	99%
20 - 40	Medium	512 - 1024	D	0	0	0	0%	99%
40 - 80	Lrg- Very Lrg	1024 - 2048	R	0	0	0	0%	99%
	Bedrock		BDRK	0	1	1	1%	100%
			Totals	**40**	**60**	**100**	**100%**	**100%**



APPENDIX C

MINGO CREEK REFERENCE REACH

Longitudinal Profile
Cross Sections
Pebble Count

Longitudinal Profile
Mingo Creek Reference Reach

Basin:	Neuse
Watershed:	Neuse River
Reach:	Mingo Creek
Date:	10/1/98
Crew:	Will, Greg, Karen, and Ron
Purpose:	Site Characterization for Reference Reach

Longitudinal Profile

Station	Elevation-thalweg	Elevation-water surface
0	96.3	96.7
84	95.9	96.6
93	96.0	96.6
101	96.1	96.6
127	96.1	96.6
148	95.9	96.2
175	95.7	96.2
198	94.6	96.1
230	95.8	96.2
265	95.4	96.1
317	95.3	96.0
345	95.6	96.0

Water Surface Slope **0.0022**

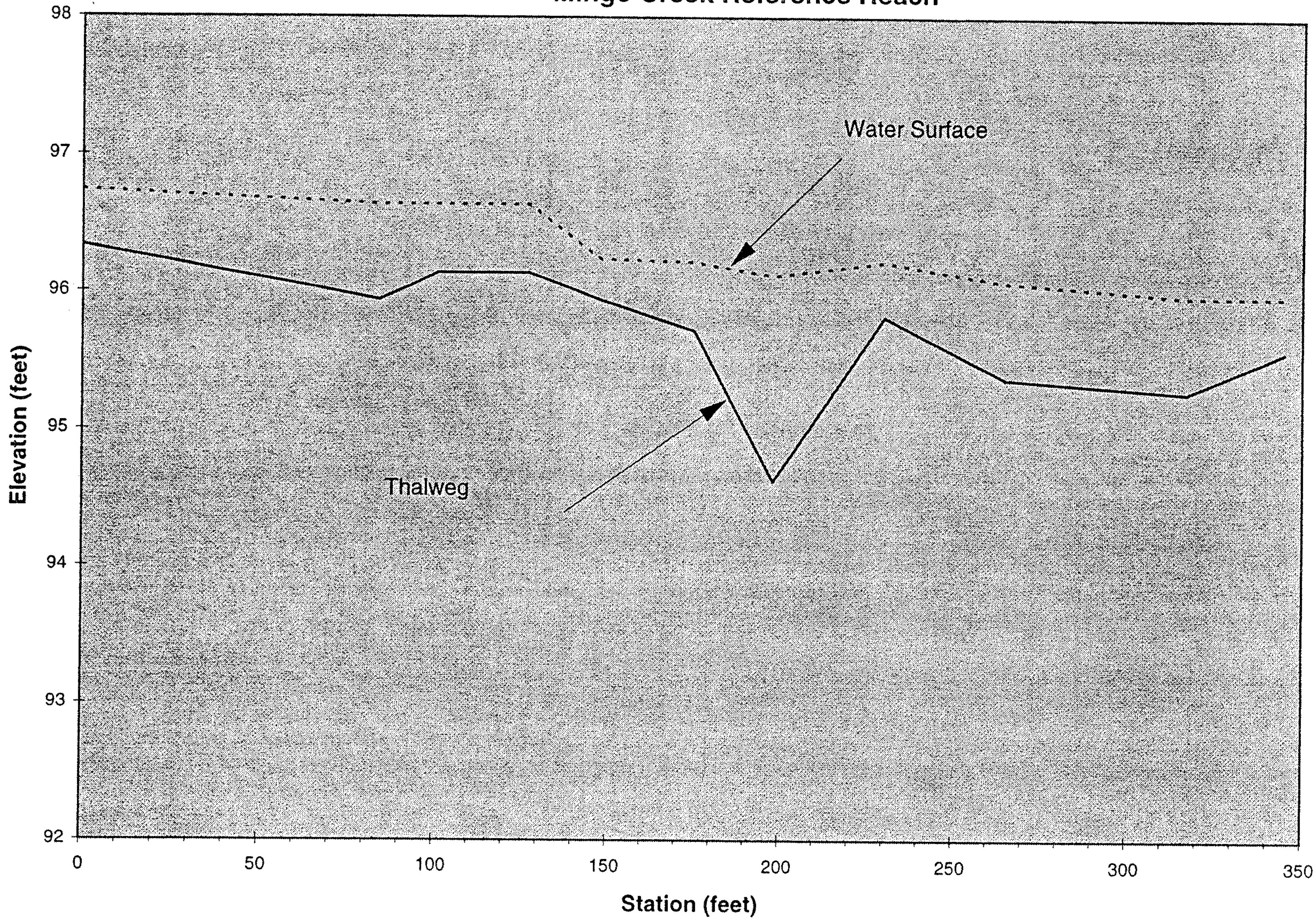
Stream Length 345 feet
Valley Length 240 feet

Sinuosity **1.44**

Channel Pattern:

Meander Length 89 - 195 feet
Belt Width 42 - 67 feet
Radius of Curvature 29 - 53 feet

Longitudinal Profile
Mingo Creek Reference Reach



Cross Section - Station 0+84
Mingo Creek Reference Reach

Basin: Neuse
Watershed: Neuse
Reach: Mingo Creek
Date: 10/1/98
Crew: Will, Greg, Karen, and Ron
Purpose: Site Characterization for Reference Reach

Permanent Cross Section 0+84

Station	HI Feet	FS Feet	Elevation Feet	Notes
0	102.64	3.8	98.8	LBKF
0.5		4.0	98.6	
0.9		6.0	96.6	LEW
5.0		6.2	96.4	
10.0		6.5	96.1	
12.0		6.7	95.9	TW
14.8		6.1	96.5	REW
15.2		3.8	98.8	RBKF

BKF Hydraulic Geometry

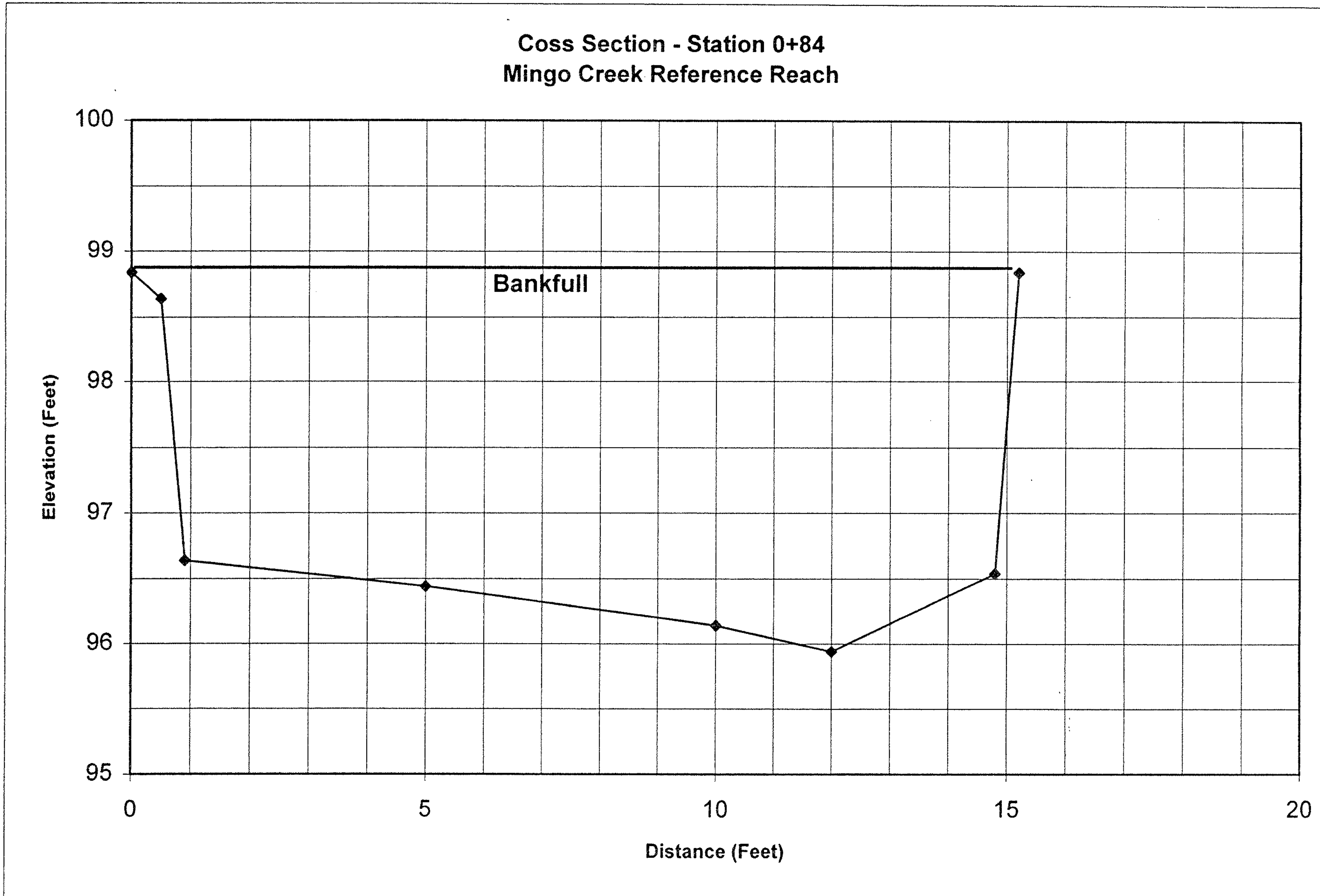
Width Feet	Depth Feet	Area Sq. Ft.
0	0	0.0
0.5	0.2	0.1
0.4	2.2	0.5
4.1	2.4	9.4
5.0	2.7	12.8
2.0	2.9	5.6
2.8	2.3	7.3
0.4	0.0	0.5
15.2		36.1

Summary Data

BKF A	36.1
BKF W	15.2
Max d	2.9
Mean d	2.4
W/D Ratio	6.4
FP W	86.0
ER	5.7
Str. Type	E5

Regional Curve (Rural)

Watershed Size	4.0
Bkf A (Rural Curve)	52
Bkf W (Rural Curve)	27
Bkf D (Rural Curve)	2.0



Coss Section - Station 0+84
Mingo Creek Reference Reach
Bankfull
Elevation (Feet)
100
99
98
97
96
95
0
5
10
15
20
Distance (Feet)

Cross Section - Station 3+17
Mingo Creek Reference Reach

Basin:	Neuse
Watershed:	Neuse River
Reach:	Mingo Creek
Date:	10/1/98
Crew:	Will, Greg, Karen, and Ron
Purpose:	Site Characterization for Reference Reach

Permanent Cross Section 3+17

Station	HI Feet	FS Feet	Elevation Feet	Notes
0.0	103.27	4.1	99.2	LTOB
2.3		5.0	98.3	LBKF
4.0		5.5	97.8	
6.4		6.0	97.3	
7.0		6.5	96.8	
10.6		6.7	96.6	
11.7		7.1	96.2	
13.8		7.3	96.0	LEW
15.5		7.5	95.8	
16.9		8.0	95.3	TW
19.0		8.0	95.3	
20.0		7.4	95.9	REW
21.0		6.0	97.3	
24.2		5.0	98.3	RBKF
29.0		4.4	98.9	RTOB

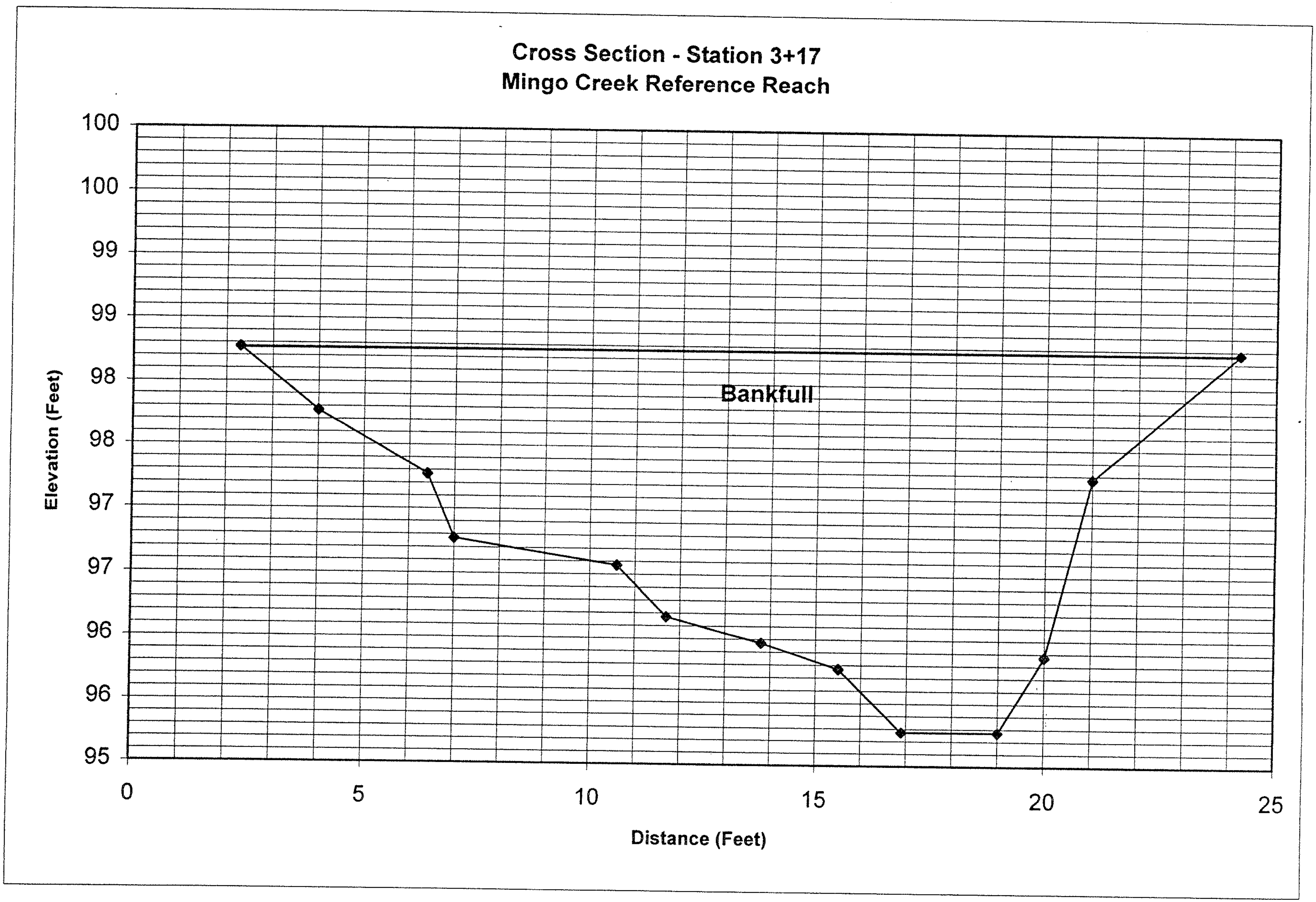
BKF Hydraulic Geometry

Width Feet	Depth Feet	Area Sq. Ft.
0	0	0.0
1.7	0.5	0.4
2.4	1.0	1.8
0.6	1.5	0.8
3.6	1.7	5.8
1.1	2.1	2.1
2.1	2.3	4.6
1.7	2.5	4.1
1.4	3.0	3.9
2.1	3.0	6.3
1	2.4	2.7
1	1.0	1.7
3.2	0.0	1.6
21.9		35.7

Summary Data

BKF A	35.7
BKF W	21.9
Max d	3.0
Mean d	1.6
W/D Ratio	13.4
FP W	86.0
ER	3.9
Str Type	C5

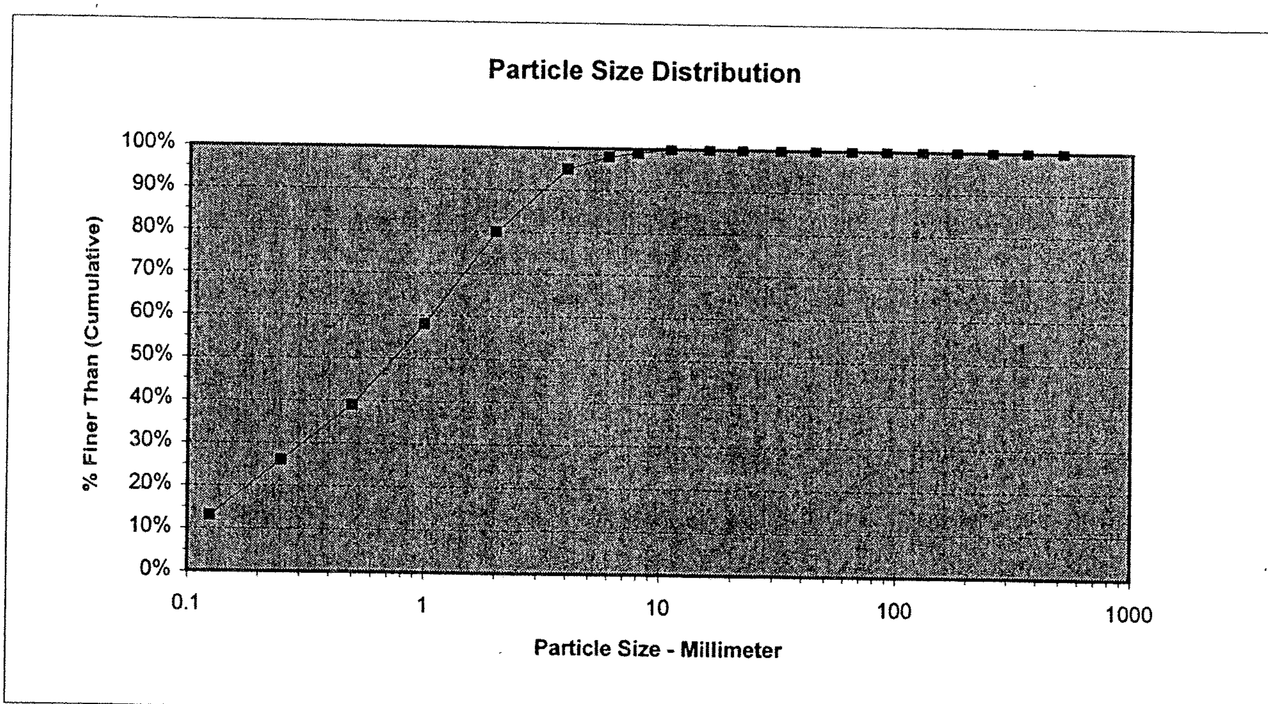
Regional Curve (Rural)	
Watershed Size	4.0
Bkf A (Rural Curve)	52
Bkf W (Rural Curve)	27
Bkf D (Rural Curve)	2.0



Cross Section - Station 3+17
Mingo Creek Reference Reach
Elevation (Feet)
100
100
99
99
98
98
97
97
96
96
95
Bankfull
0
5
10
15
20
25
Distance (Feet)

Pebble Count
Mingo Creek Reference Reach

PEBBLE COUNT								
Site: Abbott Property						Date: 10/1/98		
Party: Karen Hall, Gregg Jennings, Will Harman, Ron Johnson						Reach: Mingo Creek		
				Particle Counts				
Inches	Particle	Millimeter		Riffles	Pools	Total No.	Item %	% Cumulative
	Silt/Clay	< 0.062	S/C	0	1	1	1%	1%
	Very Fine	.062 - .125	S	4	8	12	12%	13%
	Fine	.125 - .25	A	4	9	13	13%	26%
	Medium	.25 - .50	N	4	9	13	13%	39%
	Coarse	.50 - 1.0	D	10	9	19	19%	58%
.04 -.08	Very Coarse	1.0 - 2.0	S	12	10	22	22%	80%
.08 - .16	Very Fine	2.0 - 4.0		12	3	15	15%	95%
.16 - .22	Fine	4.0 - 5.7	G	3	0	3	3%	98%
.22 - .31	Fine	5.7 - 8.0	R	1	0	1	1%	99%
.31 - .44	Medium	8.0 - 11.3	A	0	1	1	1%	100%
.44 - .63	Medium	11.3 - 16.0	V	0	0	0	0%	100%
.63 - .89	Coarse	16.0 - 22.6	E	0	0	0	0%	100%
.89 - 1.26	Coarse	22.6 - 32.0	L	0	0	0	0%	100%
1.26 - 1.77	Very Coarse	32.0 - 45.0	S	0	0	0	0%	100%
1.77 - 2.5	Very Coarse	45.0 - 64.0		0	0	0	0%	100%
2.5 - 3.5	Small	64 - 90	C	0	0	0	0%	100%
3.5 - 5.0	Small	90 - 128	O	0	0	0	0%	100%
5.0 - 7.1	Large	128 - 180	B	0	0	0	0%	100%
7.1 - 10.1	Large	180 - 256	L	0	0	0	0%	100%
10.1 - 14.3	Small	256 - 362	B	0	0	0	0%	100%
14.3 - 20	Small	362 - 512	L	0	0	0	0%	100%
20 - 40	Medium	512 - 1024	D	0	0	0	0%	100%
40 - 80	Lrg- Very Lrg	1024 - 2048	R	0	0	0	0%	100%
	Bedrock		BDRK	0	0	0	0%	100%
			Totals	**50**	**50**	**100**	**100%**	**100%**



APPENDIX D

NATURAL CHANNEL DESIGN METHODOLOGY

NATURAL CHANNEL DESIGN METHODOLOGY

The following 40-step design procedure developed by Dave Rosgen was used for this natural channel design. Variations or omission of certain steps are noted in italics. Appendices listed below are found in Section F of the course manual for Fluvial Geomorphology for Engineers by Richard Hey and David Rosgen and also in Dave Rosegn's River Restoration and Natural Channel Design Manual.

Step 1. Perform a watershed analysis to determine the past history and search for the reasons of altered channel state/dis-equilibrium. This includes changes in the vegetation, location, development, and other landscape and vegetative changes that reflect on peak flows, duration of high flows and precipitation/runoff response. Sediment sources for introduced sediment from landslides, roads, and surface runoff from exposed surfaces (agriculture) are also identified. Procedures in WRENSS, 1980 may help you quantify these cumulatively. If TR 20 or TR 55 is used to simulate a peak flow, verify the model by back calculating the corresponding storm intensity/duration that generates the 1.5 year return period discharge (or the return period associated with field calibrated bankfull discharge from your local USGS gage station data). Any excess flows predicted beyond the bankfull value should be considered as flood flows and treated accordingly (see rest of steps). *Watershed analysis is in Section 4.1.*

Step 2. If the river is regulated by a storage reservoir and/or diversion, obtain the operational hydrology of the installation. Compare the hydrograph with the field evidence of bankfull discharge. Back calculate the streamflow from the cross-sectional area of the bankfull channel using morphological evidence. Determine change in timing of the tributaries. *Although a dam once existed on the Abbott property, the breach in the dam not longer hydraulically controls the stream.*

Step 3. Travel to the nearest stream gaging stations in a similar hydro-physiographic province. Follow the steps in Appendix I for field calibration of the bankfull stage and development of regional curves of drainage area vs bankfull discharge and drainage area vs bankfull dimensions. This procedure is used to not only develop regional curves, but to establish the return period of the flows that shape and maintain the channel. This information is critical when designing a stream where streamflow records are not available. *A stream gage with sufficient data was not available. Consequently, the regional curve developed by NCSU's Water Quality Group was used.*

Step 4. Plot the hydraulic geometry for the gage station. *Step 4 was not done.*

Step 5. Classify the stream type at the streamgage location and morphological characterization using the procedures outlined in Appendix II (Use the stream classification form for use at streamgage locations for this purpose. *Step 5 was not done.*

Step 6. Plot Manning's "n" for bankfull stage by stream type on the relation in Figure 5. *This step was performed for both the Mingo Creek and Brookhaven reference reaches, C5 - n=0.035; C4 – n=0.02.*

Step 7. Obtain the following information for stream classification at the gage site:

A. Bankfull discharge return period (years), operational hydrology, and altered flows.

B. Valley type, landform/landtype.

C. Valley slope.

D. Dimensions, Pattern and Profile

1. Stream type (level II)
2. Drainage area (square miles)
3. Bankfull width (W_{bkf})(taken at riffle)
4. Bankfull mean depth (d_{bkf})
5. Width/depth ratio (W_{bkf}/d_{bkf})
6. Bankfull cross-sectional area (A_{bkf})
7. Bankfull velocity (U_{bkf})
8. Bankfull discharge (Q_{bkf})
9. Bankfull maximum depth (d_{max})(taken at riffle)
10. Ratio of bankfull max depth to bankfull mean depth (d_{max}/d_{bkf})
11. Width of flood prone area (W_{fpa})
12. Entrenchment ratio (W_{fpa}/W_{bkf})
13. Meander length (L_m)
14. Ratio of meander length to bankfull width (L_m/W_{bkf})
15. Radius of Curvature (R_c)
16. Ratio of Radius of Curvature to bankfull width (R_c/W_{bkf})
17. Belt width (W_{blt})
18. Meander width ration (W_{blt}/W_{bkf})
19. Sinuosity (stream length/valley distance)
20. Average slope (S_{ave})
21. Riffle slope (S_{riff})
22. Ratio of riffle slope to mean
23. Pool slope (S_{pool})
24. Ratio of pool slope to average slope (S_{pool}/S_{ave})
25. Maximum pool depth (d_{pool})
26. Ratio of pool depth to average bankfull depth (d_{pool}/d_{bkf})
27. Pool width (W_{pool})
28. Ratio pool width to bankfull width (W_{pool}/W_{bkf})
29. Pool/pool spacing
30. P/P spacing/W_{bkf}

See Table 2, Morphological Characteristics.

E. Materials

1. Particle size of channel material (riffles and pools) (Wolman pebble count – frequency distribution) D15, D35, D50, D84, D95:
2. Particle size of channel material (riffle) (Wolman pebble count – frequency distribution) D15, D35, D50, D84, D95:
3. Particle size analysis of bar material (weight/size from field sieves) D15, D35, D50, D84, D95:

4. Largest size particle at toe of bar (mm)
See Table 2 and Appendices for pebble count data. Note: lack of point bars prevented an analysis of the point bar materials.

Step 8. Calculate the bankfull critical shear stress = (62.4 #'s/cu.ft.) x (hydraulic radius) x (slope), then compare size of sediment potentially entrained (obtained from Figure 7) to largest size as measured in bar sample. If values are not similar, plot the largest size found in bar and the corresponding bankfull shear stress on the relationship presented in Figure 7 (note the stream type and width/depth ratio and gradation ratio {D84/D35}). This computation is applied to the riffle reach. *Shear stress is discussed in Section 8.1, Sediment Transport.*

Evaluation of impacted reach. The next steps are designed to determine existing condition, potential condition (reference reach) and the proposed dimension, pattern and profile for the natural channel design.

Step 9. Determine the valley type, land type and corresponding stream type commensurate with the landform for the study reach.

Step 10. Locate a reference reach in the immediate area or in an adjacent watershed for a similar hydro-physiographic province.

Step 11. Obtain and analyze aerial photographs for a reference reach to observe time trends in stability (before vs after major floods, above vs below impacts, etc.)

Step 12. Complete the morphological characterization information (Table 2). This data from the reference reach is extremely important, as it will provide the appropriate ratios for the dimension, pattern and profile of the stable stream type, to be used for the natural channel design.

Step 13. Complete a level III analysis for the reference reach to determine the relationships associated with the natural stable channel, including bank erodibility, stress in the near-bank-region, and estimates of lateral erosion rates. Use form summary (Table 3), and summary of rating procedures in Appendix III. *A Level III analysis was not done.*

Step 14. Repeat **Step 11** through **Step 13** for the *impacted study reach* to determine existing morphology and condition, using Table 2 to document morphological relations for *existing* and *proposed* conditions.

Step 15. Once the stable reference reach stream type is selected, obtain the drainage area for the area immediately upstream of the impacted reach.

Step 16. Obtain the bankfull discharge from the drainage area/discharge relationships from the regional curves as verified in **Step 3.**

Step 17. Obtain the cross-sectional area associated with the bankfull discharge. This can be obtained from regional curves, hydraulic geometry by stream type from gage stations, (**Step 4**), or from obtaining bankfull velocity (**Step 4, 6,** or other methods) and calculating

$$A_{bkf} = Q_{bkf}/U_{bkf}.$$

Step 18. Calculate proposed bankfull width

$$W_{bkf} = ((A_{bkf}) \times (W/D))^{1/2}$$

or from hydraulic geometry for same stream type and same relative size (**Step 4**).

Step 19. Calculate proposed bankfull mean depth, $D_{bkf} = W/D$, or A_{bkf}/W_{bkf}.

Step 20. Calculate mean bankfull velocity, $U_{bkf} = Q_{bkf}/A_{bkf}$.

Step 21. Calculate bankfull max depth (obtained at the riffle). Obtain from refernce reach by obtaining the ratio of

$$D_{max}/D_{bkf}/D_{max} = (D_{max}/D_{bkf}) \times D_{bkf}$$

Step 22. Calculate flood prone area width (from cross-section of stream and valley),

$$W_{fpa} = @ \text{ an elevation } 2 \times D_{max}.$$

Step 23. Computation of flood stage levels are often used with HEC 2 or HEC-RAS procedures when more detail is required due to FEMA requirements. This procedure only provides an approximate flood stage level and does not intend to substitute for the FEMA procedures. At gage stations, however, it is necessary to plot various return period floods and their corresponding depths on the flood prone area on the relationship in Figure 8. *A HEC-RAS analysis was completed and is included in Appendix D and in Section 8.2.*

Step 24. Calculate meander wavelength ($L_m = L_m$ ratio x W_{bkf}). L_m ratio is obtained from the reference reach data, as L_m ratio = L_m/W_{bkf}.

Step 25. Calculate radius of curvature ($R_c = R_c$ ratio x W_{bkf}). R_c ratio is obtained from the reference reach information.

Step 26. Calculate Belt width. Obtain stable meander width ratio, (MWR), from reference reach or from Figure 9, (W_{blt} = MWR x W_{bkf}). If the river is confined, use actual belt width and backcalculate meander width ration (MWR = W_{blt}/W_{bkf}). Make sure MWR is within acceptable lower limits for that stream type.

Step 27. Calculate sinuosity. Layout proposed pattern on aerial photograph or map. Obtain stream length. Sinuosity = stream length / valley distance. (Be certain that valley distance is obtained along the fall line of the valley).

Step 28. Calculate average slope (S_{ave} = valley slope / sinuosity).

Step 29. Calculate riffle slope ($S_{riff} = S_{riff}$ ratio x S_{ave})(S_{riff} ratio from reference reach).

Step 30. Calculate the bankfull shear stress of proposed channel at the riffle (repeat Step 8). If the corresponding size as obtained from Figure 9 is larger than the largest size on the bar, repeat Step 18 to calculate a new bankfull width using a lower width/depth ratio. This will result in a larger hydraulic radius (mean depth) and may result in a shear stress that will potentially move the sizes of sediment made available to the channel. A sub-pavement sample may also be obtained to go along with the bar sample that indicates the size distribution and largest size of bedload that moves at bankfull discharge. If the reduction in width/depth ratio and the corresponding increase in shear stress does not meet the entrainment size of the largest particle in the bar, then the next priority is to decrease sinuosity and meander width ratio, increase meander length and radius of curvature. This will result in an increase in slope, hopefully balancing the sediment transport competency of the river. (Note: This does require a validation).

Step 31. Calculate Pool slope ($S_{pool} = S_{pool}$ ratio x S_{ave})(S_{pool} ratio from reference reach).

Step 32. Calculate Max pool depth ($d_{pool} = d_{pool}$ ratio x d_{bkf})(d_{pool} ratio from reference reach).

Step 33. Calculate W_{pool} ($W_{pool} = W_{pool}$ ratio x W_{bkf})(W_{pool} ratio from reference reach).

Step 34. Calculate sequence of pool/pool spacing for step/pool stream types (from reference reach based on relationship of bankfull width and inverse proportion to average water surface slope). Obtain from reference reach.

Step 35. Layout proposed plan view over existing channel with the appropriate bankfull width, pool width, meander wavelength, radius, and belt width. Adjust dimensions to take into account existing vegetation, landform changes, avoidance of high banks such as conditions where a stream would extend laterally against a terrace or alluvial fan. Adjust alignment to match natural variability – avoid a totally symmetrical layout for visual/natural appearance objectives.

Step 36. Plot longitudinal profiles for both existing and proposed condition. Overlay the profiles for comparison purposes. Use stationing from longitudinal profile to identify (name) cross-section locations and for implementation for implementation layout. On the profile show proposed depths and slopes of bed features (riffles, steps, and pools) and as previously computed. Locate position of pools from plan view layout (i.e. for C stream types, pools are located on the outside of meander bends).

Step 37. Plot cross sections for existing and proposed condition using an overlay. Plot typical cross sections for riffles, pools, steps, glides or other features. Calculate earthwork (cut/fill) volumes from the cross-sections and use stream length appropriate for the persistence of a particular cross-section. Make sure dimensions are properly scaled, and that point bar slopes, entrenchment ratio, and side slope gradients are shown. *Some* *earthwork calculations are contained in Section 13, Construction, final earthwork calcualtions will be done in final design.*

Step 38. Select specific stabilization structures such as grade control structures, streambank revetment, riparian vegetation, and other design features. Locate these features on the plan, profile and section views. *This step will be performed in final design.*

Step 39. Develop detailed design drawings for the specific stabilizing features such as cross-vane for grade control and bank stabilization. These drawings, used for inserts into the design package, need to show all dimensions, and installation details. Each stabilization feature needs to have a plan, profile and section view. *This step will be performed in final design.*

Step 40. Each design should have a monitoring plan layout (See Section 10) which will insure that the design implementation will be evaluated to:

a. Insure stabilization structures are functioning properly
b. Monitor channel response in dimension, pattern and profile, channel stability (aggradation/degradation), particle size distribution of channel materials, sediment transport and streambank erosion rates.
c. Determine biological response (food chains, standing crop, species diversity, etc.)
d. Determine if all of the specific objectives as part of the restoration have been met.

APPENDIX E

FLOODING ANALYSIS (HEC-RAS)

TR-55

Change in Flood Stages

Existing:
Water Surface Profiles
Profile tables
Cross Sections

Proposed:
Water Surface Profiles
Profile tables
Cross Sections

USGS TR-55

GRAPHICAL PEAK DISCHARGE METHOD Version 2.00

roject : Abbott Steam Restoration User: Buck Date: 01-06-99
ounty : Wake State: NC Checked: ____ Date: ________
Subtitle:

Data: Drainage Area : 385 * Acres
Runoff Curve Number : 75 *
Time of Concentration: 0.54 * Hours
Rainfall Type : I
Pond and Swamp Area : NONE

Storm Number	1	2	3	4	5	6
Frequency (yrs)	2	5	10	25	50	100
24-Hr Rainfall (in)	3.6	4.65	5.38	6.41	7.21	8.00
Ia/P Ratio	0.19	0.14	0.12	0.10	0.09	0.08
Used	0.19	0.14	0.12	0.10	0.10	0.10
Runoff (in)	1.37	2.17	2.76	3.63	4.33	5.04
Unit Peak Discharge (cfs/acre/in)	0.371	0.397	0.410	0.423	0.425	0.425
Pond and Swamp Factor 0.0% Ponds Used	1.00	1.00	1.00	1.00	1.00	1.00
Peak Discharge (cfs)	196	332	436	591	710	825

* - Value(s) provided from TR-55 system routines

TIME OF CONCENTRATION AND TRAVEL TIME Version 2.00

roject : Abbott Steam Restoration User: Buck Date: 01-06-99
County : Wake State: NC Checked: ____ Date: ________
Subtitle:

Flow Type	2 year rain	Length (ft)	Slope (ft/ft)	Surface code	n	Area (sq/ft)	Wp (ft)	Velocity (ft/sec)	Time (hr)
Sheet	3.6	200	.05	e					0.186
hallow Concent'd		900	.03	u					0.089
pen Channel		5800	.014		.03524		18.1		0.265

Time of Concentration = 0.54*
=====

--- Sheet Flow Surface Codes ---

A Smooth Surface
B Fallow (No Res.)
C Cultivated < 20 % Res.
D Cultivated > 20 % Res.
E Grass-Range, Short
F Grass, Dense
G Grass, Burmuda
H Woods, Light
I Woods, Dense
J Range, Natural

--- Shallow Concentrated ---
--- Surface Codes ---

P Paved
U Unpaved

* - Generated for use by GRAPHIC method

RUNOFF CURVE NUMBER COMPUTATION Version 2.00

roject : Abbott Steam Restoration User: Buck Date: 01-06-99
ounty : Wake State: NC Checked: ____ Date: ________
ubtitle:
ubarea : 385

COVER DESCRIPTION		A	B	C	D
		Hydrologic Soil Group Acres (CN)			
ULLY DEVELOPED URBAN AREAS (Veg Estab.)					
esidential districts	Avg % imperv				
(by average lot size)					
1/4 acre	38	-	385(75)	-	-
otal Area (by Hydrologic Soil Group)			385		
			====		

UBAREA: 385 TOTAL DRAINAGE AREA: 385 Acres WEIGHTED CURVE NUMBER: 75*

* - Generated for use by GRAPHIC method

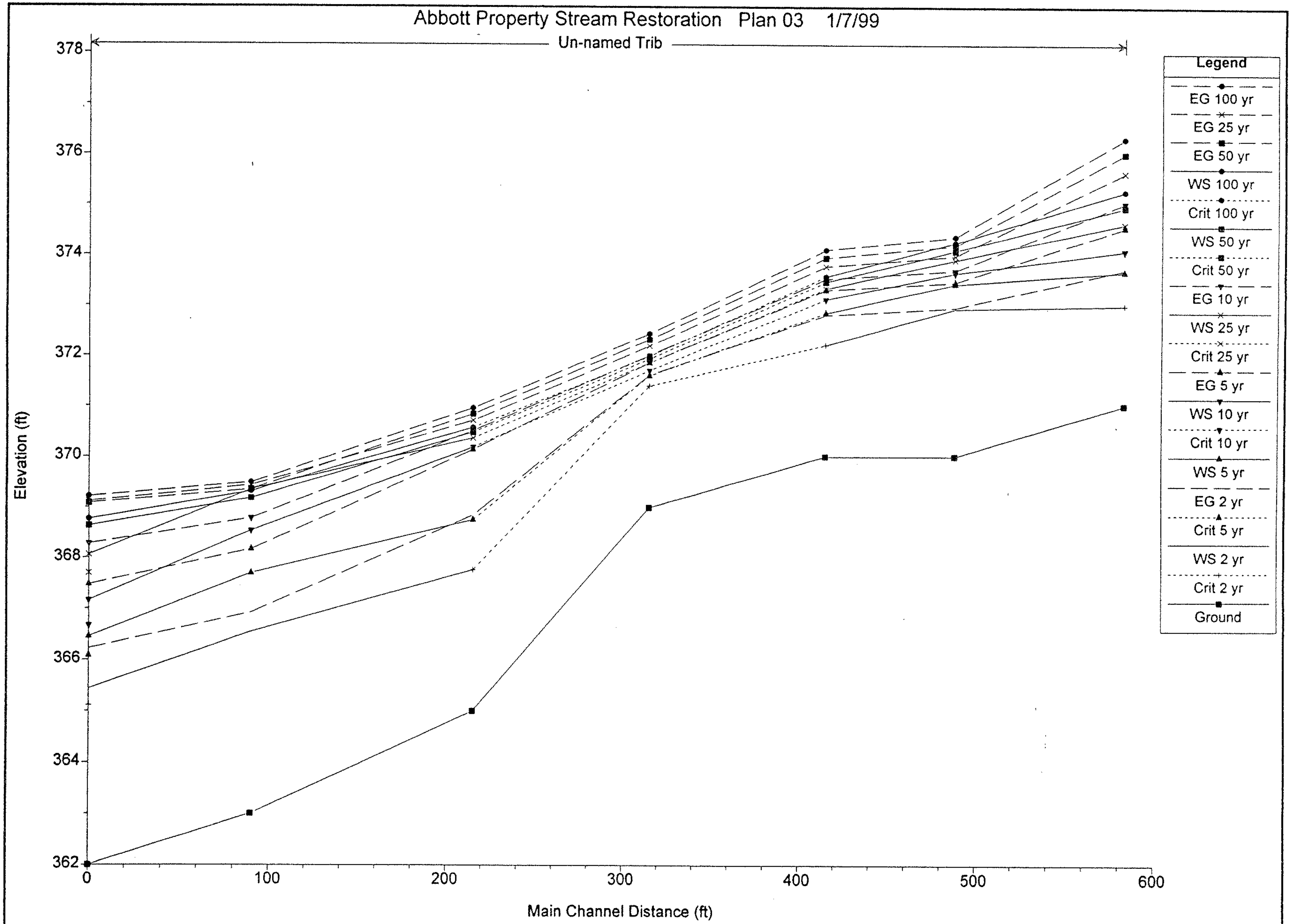
Change in Flood Stages

Change in Flood Stage
Abbott Property Stream Restoration

Proposed			Existing				
Reach	River Sta	W.S. Elev (ft)	Reach	River Sta	W.S. Elev (ft)	**Difference**	Storm
Un-named	10	373.34	Un-named	10	372.99	**0.35**	2-yr
Un-named	10	373.65	Un-named	10	373.65	**0**	5-yr
Un-named	10	374.07	Un-named	10	374.07	**0**	10-yr
Un-named	10	374.6	Un-named	10	374.6	**0**	25-yr
Un-named	10	374.94	Un-named	10	374.94	**0**	50-yr
Un-named	10	375.25	Un-named	10	375.25	**0**	100-yr
Un-named	9	373.6	Un-named	9	372.93	**0.67**	2-yr
Un-named	9	373.91	Un-named	9	373.42	**0.49**	5-yr
Un-named	9	374.1	Un-named	9	373.63	**0.47**	10-yr
Un-named	9	374.35	Un-named	9	373.9	**0.45**	25-yr
Un-named	9	374.51	Un-named	9	374.08	**0.43**	50-yr
Un-named	9	374.66	Un-named	9	374.24	**0.42**	100-yr
Un-named	8	373.31	Un-named	8	372.2	**1.11**	2-yr
Un-named	8	373.54	Un-named	8	372.84	**0.7**	5-yr
Un-named	8	373.67	Un-named	8	373.11	**0.56**	10-yr
Un-named	8	373.83	Un-named	8	373.33	**0.5**	25-yr
Un-named	8	373.95	Un-named	8	373.46	**0.49**	50-yr
Un-named	8	374.04	Un-named	8	373.56	**0.48**	100-yr
Un-named	7	370.91	Un-named	7	371.4	**-0.49**	2-yr
Un-named	7	371.45	Un-named	7	371.6	**-0.15**	5-yr
Un-named	7	371.4	Un-named	7	371.7	**-0.3**	10-yr
Un-named	7	371.61	Un-named	7	371.85	**-0.24**	25-yr
Un-named	7	371.74	Un-named	7	371.93	**-0.19**	50-yr
Un-named	7	371.86	Un-named	7	371.99	**-0.13**	100-yr
Un-named	6	370.32	Un-named	6	367.77	**2.55**	2-yr
Un-named	6	370.47	Un-named	6	368.75	**1.72**	5-yr
Un-named	6	370.56	Un-named	6	370.18	**0.38**	10-yr
Un-named	6	370.68	Un-named	6	370.36	**0.32**	25-yr
Un-named	6	370.75	Un-named	6	370.47	**0.28**	50-yr
Un-named	6	370.82	Un-named	6	370.57	**0.25**	100-yr
Un-named	5	368.47	Un-named	5	366.55	**1.92**	2-yr
Un-named	5	368.68	Un-named	5	367.7	**0.98**	5-yr
Un-named	5	368.81	Un-named	5	368.54	**0.27**	10-yr
Un-named	5	368.98	Un-named	5	369.35	**-0.37**	25-yr
Un-named	5	369.1	Un-named	5	369.18	**-0.08**	50-yr
Un-named	5	369.21	Un-named	5	369.32	**-0.11**	100-yr
Un-named	4	368.35	Un-named	4	365.44	**2.91**	2-yr
Un-named	4	368.52	Un-named	4	366.45	**2.07**	5-yr
Un-named	4	368.63	Un-named	4	367.17	**1.46**	10-yr
Un-named	4	368.78	Un-named	4	368.06	**0.72**	25-yr
Un-named	4	368.87	Un-named	4	368.64	**0.23**	50-yr
Un-named	4	368.96	Un-named	4	368.77	**0.19**	100-yr

HEC-RAS Existing Stream Channel

Water Surface Profile
Profile Table
Cross Sections

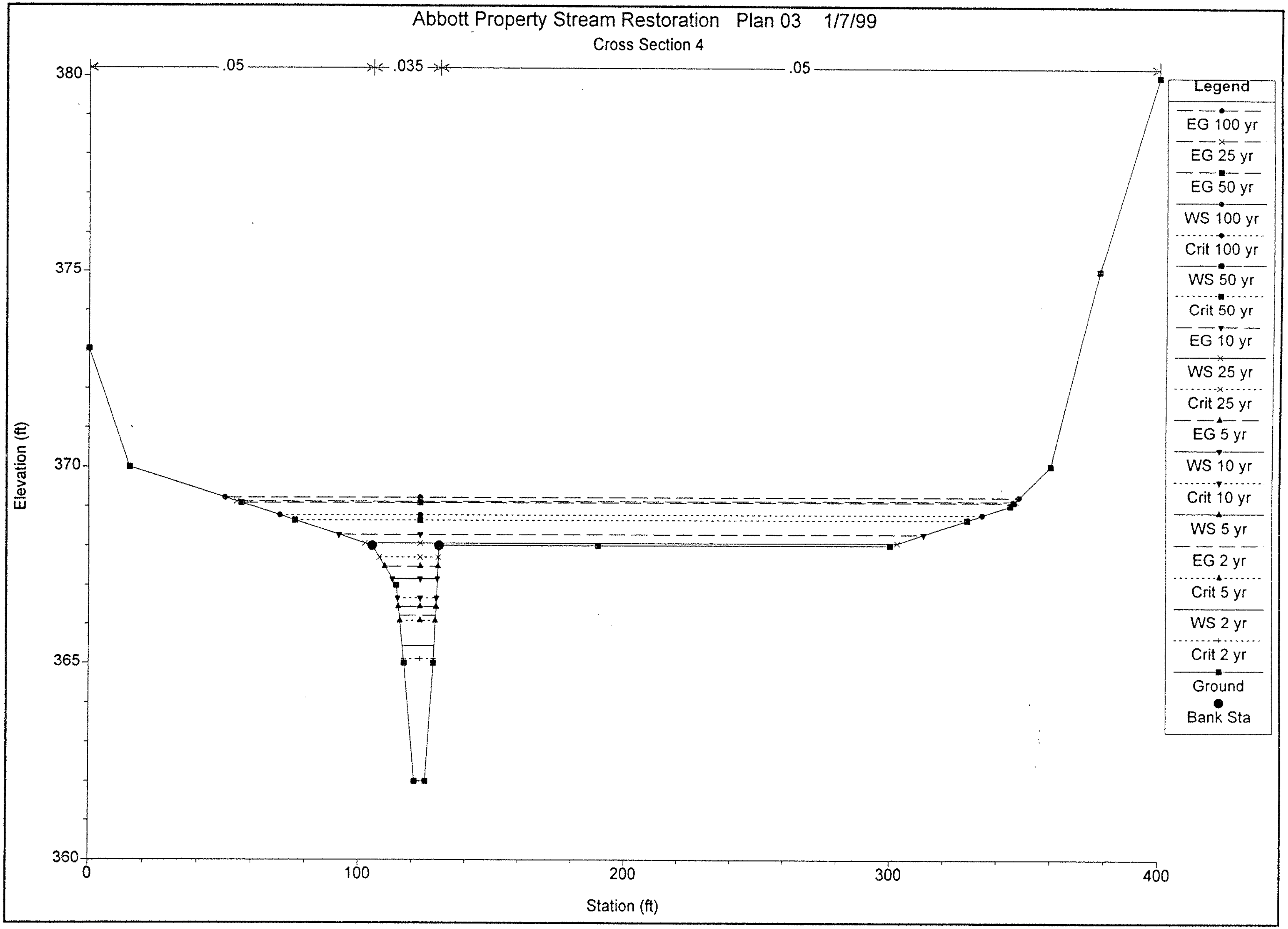

Abbott Property Stream Restoration Plan 03 1/7/99
Un-named Trib
Legend
EG 100 yr
EG 25 yr
EG 50 yr
WS 100 yr
Crit 100 yr
WS 50 yr
Crit 50 yr
EG 10 yr
WS 25 yr
Crit 25 yr
EG 5 yr
WS 10 yr
Crit 10 yr
WS 5 yr
EG 2 yr
Crit 5 yr
WS 2 yr
Crit 2 yr
Ground
Elevation (ft)
Main Channel Distance (ft)
378
376
374
372
370
368
366
364
362
0
100
200
300
400
500
600

HEC-RAS Plan: Plan 02 River: Walnut Creek Reach: Un-named Trib

Reach	River Sta	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
		(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Un-named Trib	10	196.00	371.00	372.99	372.99	373.70	0.016960	6.75	29.04	20.94	1.01
Un-named Trib	10	332.00	371.00	373.65	373.65	374.53	0.012778	7.59	46.78	32.74	0.94
Un-named Trib	10	436.00	371.00	374.07	374.07	375.02	0.011107	8.01	62.13	40.49	0.90
Un-named Trib	10	591.00	371.00	374.60	374.60	375.62	0.009564	8.47	86.58	51.40	0.86
Un-named Trib	10	710.00	371.00	374.94	374.94	376.00	0.009004	8.82	104.77	58.20	0.85
Un-named Trib	10	825.00	371.00	375.25	375.25	376.30	0.008201	8.94	123.64	60.88	0.82
Un-named Trib	9	196.00	370.00	372.90		372.93	0.000368	1.53	187.16	104.05	0.17
Un-named Trib	9	332.00	370.00	373.38		373.42	0.000545	2.08	241.09	115.42	0.21
Un-named Trib	9	436.00	370.00	373.59		373.64	0.000723	2.51	265.17	116.90	0.24
Un-named Trib	9	591.00	370.00	373.84		373.92	0.000986	3.07	295.09	118.72	0.29
Un-named Trib	9	710.00	370.00	374.02		374.12	0.001176	3.46	315.62	119.96	0.32
Un-named Trib	9	825.00	370.00	374.17		374.29	0.001353	3.81	333.92	121.04	0.34
Un-named Trib	8	196.00	370.00	372.20	372.20	372.80	0.012789	6.27	33.52	45.92	0.89
Un-named Trib	8	332.00	370.00	372.84	372.84	373.30	0.007456	6.04	90.38	130.40	0.72
Un-named Trib	8	436.00	370.00	373.11	373.11	373.52	0.006396	6.05	129.93	152.15	0.68
Un-named Trib	8	591.00	370.00	373.33	373.33	373.77	0.006900	6.64	162.85	154.30	0.72
Un-named Trib	8	710.00	370.00	373.46	373.46	373.94	0.007482	7.13	182.43	155.56	0.75
Un-named Trib	8	825.00	370.00	373.56	373.56	374.09	0.008022	7.57	199.36	156.65	0.78
Un-named Trib	7	196.00	369.00	371.40	371.40	371.61	0.006211	4.61	88.29	181.93	0.61
Un-named Trib	7	332.00	369.00	371.60	371.60	371.85	0.008067	5.52	125.73	193.89	0.70
Un-named Trib	7	436.00	369.00	371.70	371.70	372.00	0.009726	6.20	145.62	199.95	0.77
Un-named Trib	7	591.00	369.00	371.85	371.85	372.19	0.010865	6.77	177.22	209.21	0.82
Un-named Trib	7	710.00	369.00	371.93	371.93	372.31	0.012495	7.38	193.42	213.81	0.88
Un-named Trib	7	825.00	369.00	371.99	371.99	372.43	0.014363	8.00	205.66	217.22	0.95
Un-named Trib	6	196.00	365.00	367.77	367.77	368.85	0.018577	8.35	23.48	10.98	1.01
Un-named Trib	6	332.00	365.00	368.75	368.75	370.13	0.017617	9.44	35.18	12.75	1.00
Un-named Trib	6	436.00	365.00	370.18	370.18	370.51	0.004143	5.44	165.27	267.06	0.50
Un-named Trib	6	591.00	365.00	370.36	370.36	370.71	0.004761	6.02	213.56	272.07	0.54
Un-named Trib	6	710.00	365.00	370.47	370.47	370.84	0.005158	6.39	244.85	275.27	0.57
Un-named Trib	6	825.00	365.00	370.57	370.57	370.95	0.005573	6.75	270.46	277.87	0.59
Un-named Trib	5	196.00	363.00	366.55		366.92	0.004888	4.92	39.86	16.26	0.55

HEC-RAS Plan: Plan 02 River: Walnut Creek Reach: Un-named Trib (Continued)

Reach	River Sta	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
		(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Un-named Trib	5	332.00	363.00	367.70		368.17	0.004555	5.50	60.37	19.42	0.55
Un-named Trib	5	436.00	363.00	368.56		368.80	0.002396	4.36	182.02	229.82	0.41
Un-named Trib	5	591.00	363.00	369.37		369.45	0.000955	3.05	412.76	329.47	0.26
Un-named Trib	5	710.00	363.00	369.28		369.42	0.001672	3.97	381.49	328.32	0.35
Un-named Trib	5	825.00	363.00	369.43		369.56	0.001671	4.07	430.89	330.12	0.35
Un-named Trib	4	196.00	362.00	365.44	365.11	366.23	0.012003	7.11	27.55	11.95	0.83
Un-named Trib	4	332.00	362.00	366.45	366.09	367.48	0.012017	8.14	40.76	14.15	0.85
Un-named Trib	4	436.00	362.00	367.17	366.67	368.28	0.011985	8.47	51.50	16.93	0.86
Un-named Trib	4	591.00	362.00	368.06	367.71	369.12	0.012002	8.31	80.81	200.38	0.87
Un-named Trib	4	710.00	362.00	368.64	368.64	369.08	0.005130	6.16	212.28	252.62	0.59
Un-named Trib	4	825.00	362.00	368.77	368.77	369.22	0.005292	6.41	244.92	263.99	0.60



Abbott Property Stream Restoration Plan 03 1/7/99
Cross Section 4
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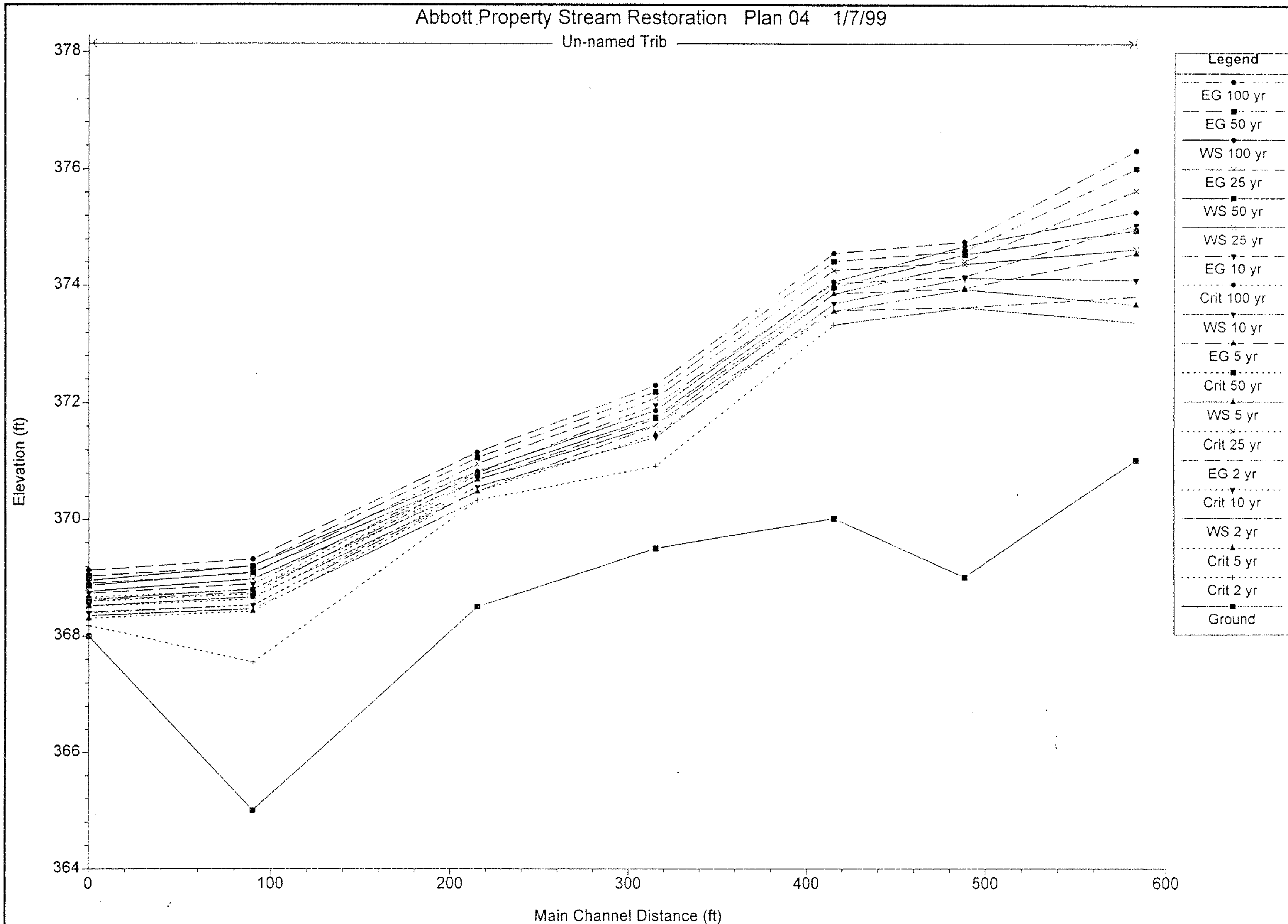
.035
.05
Elevation (ft)
380
375
370
365
360
0
100
200
300
400
Station (ft)
Legend
EG 100 yr
EG 25 yr
EG 50 yr
WS 100 yr
Crit 100 yr
WS 50 yr
Crit 50 yr
EG 10 yr
WS 25 yr
Crit 25 yr
EG 5 yr
WS 10 yr
Crit 10 yr
WS 5 yr
EG 2 yr
Crit 5 yr
WS 2 yr
Crit 2 yr
Ground
Bank Sta

HEC-RAS Proposed Stream Channel

Water Surface Profile
Profile Table
Cross Sections



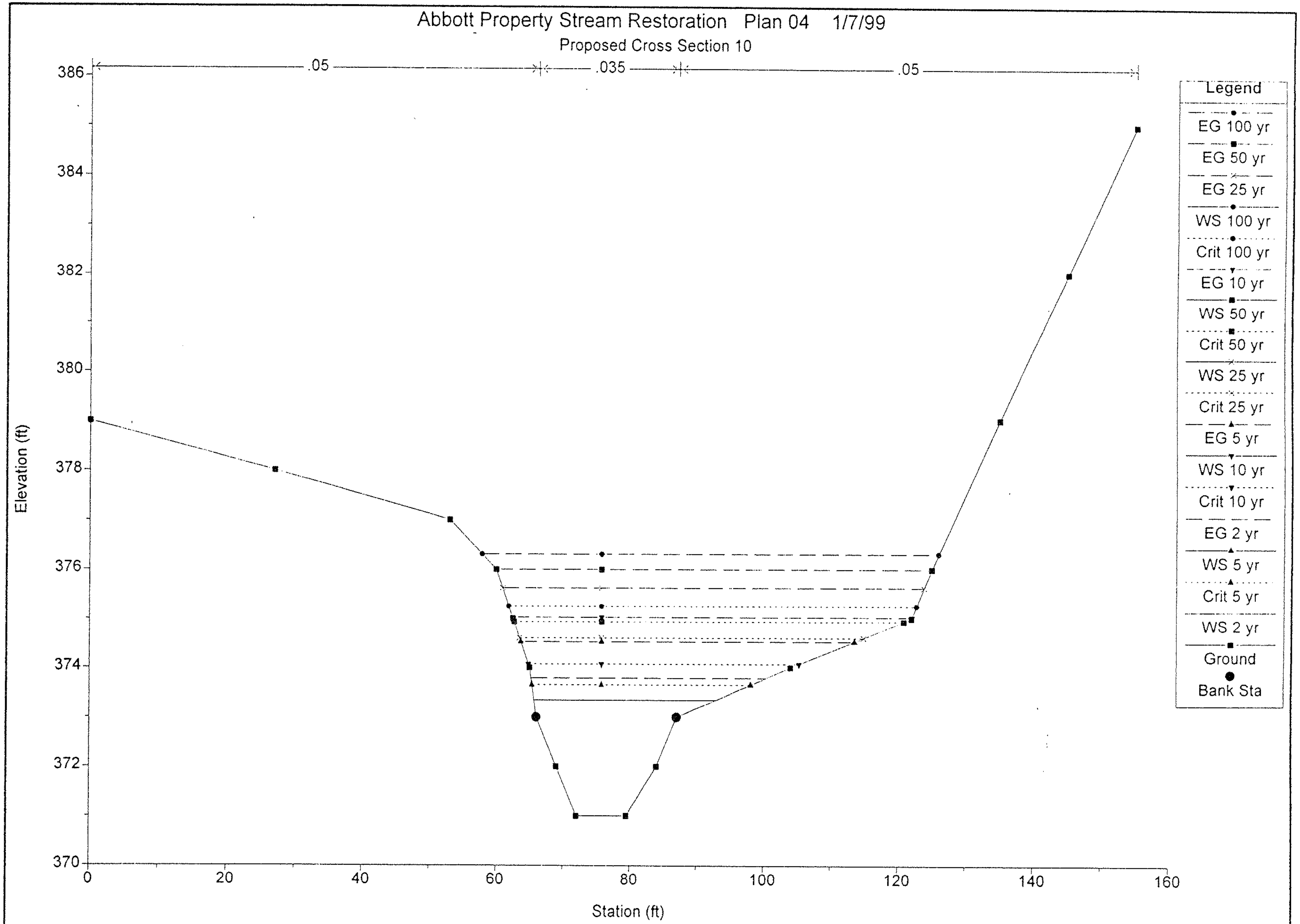
Abbott Property Stream Restoration Plan 04 1/7/99
Un-named Trib
Elevation (ft)
378
376
374
372
370
368
366
364
0
100
200
300
400
500
600
Main Channel Distance (ft)
Legend
EG 100 yr
EG 50 yr
WS 100 yr
EG 25 yr
WS 50 yr
WS 25 yr
EG 10 yr
Crit 100 yr
WS 10 yr
EG 5 yr
Crit 50 yr
WS 5 yr
Crit 25 yr
EG 2 yr
Crit 10 yr
WS 2 yr
Crit 5 yr
Crit 2 yr
Ground

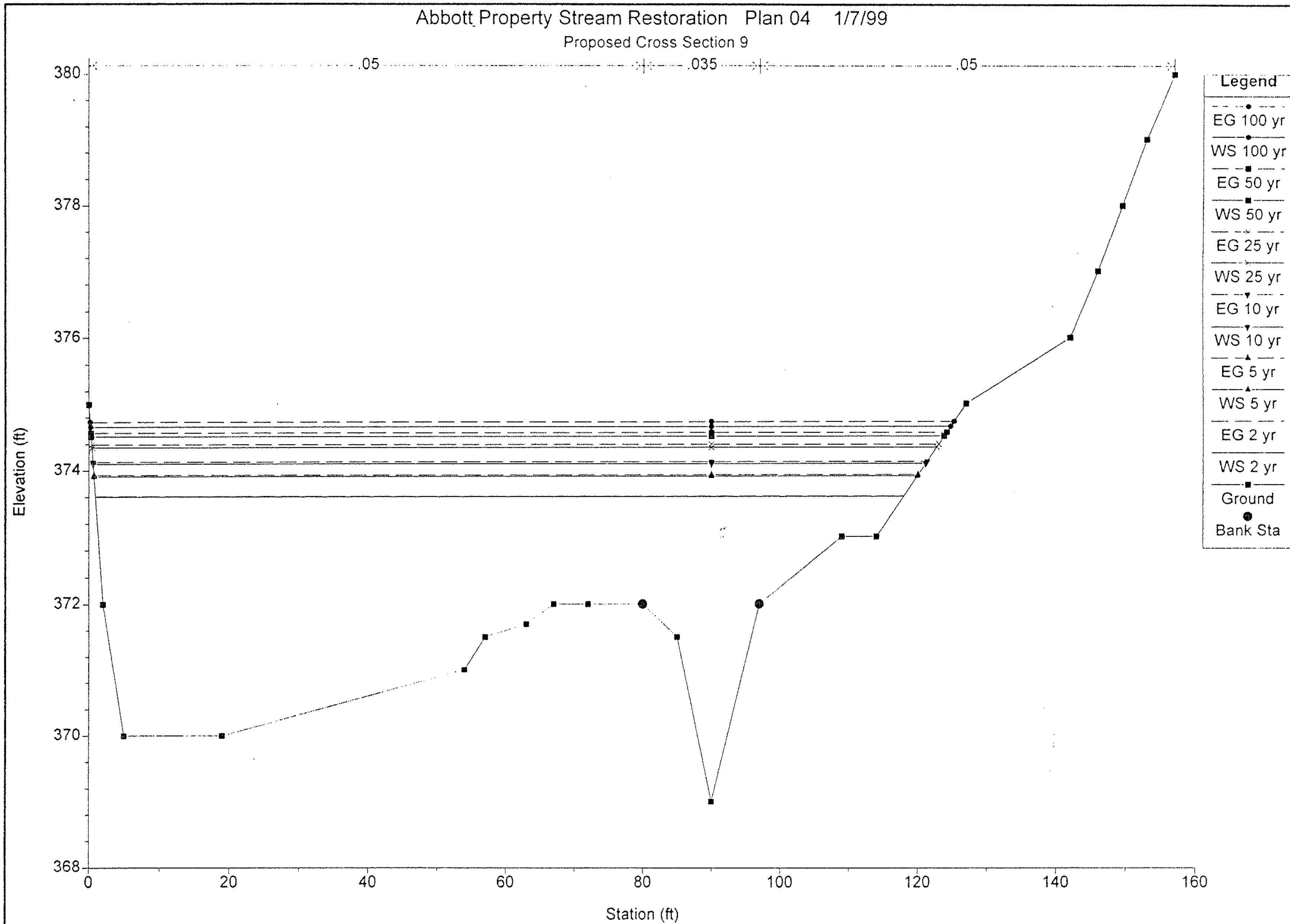
HEC-RAS Plan: Plan 02 River: Walnut Creek Reach: Un-named Trib

Reach	River Sta	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
		(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Un-named Trib	10	196.00	371.00	373.34		373.79	0.007893	5.35	37.54	27.20	0.72
Un-named Trib	10	332.00	371.00	373.65	373.65	374.53	0.012778	7.59	46.78	32.74	0.94
Un-named Trib	10	436.00	371.00	374.07	374.07	375.02	0.011107	8.01	62.13	40.49	0.90
Un-named Trib	10	591.00	371.00	374.60	374.60	375.62	0.009564	8.47	86.58	51.40	0.86
Un-named Trib	10	710.00	371.00	374.94	374.94	376.00	0.009004	8.82	104.77	58.20	0.85
Un-named Trib	10	825.00	371.00	375.25	375.25	376.30	0.008201	8.94	123.64	60.88	0.82
Un-named Trib	9	196.00	369.00	373.60		373.61	0.000140	0.95	279.93	116.99	0.10
Un-named Trib	9	332.00	369.00	373.91		373.93	0.000277	1.44	316.26	119.20	0.14
Un-named Trib	9	436.00	369.00	374.10		374.13	0.000387	1.77	339.04	120.56	0.17
Un-named Trib	9	591.00	369.00	374.35		374.39	0.000551	2.21	368.79	122.32	0.21
Un-named Trib	9	710.00	369.00	374.51		374.57	0.000674	2.53	389.27	123.51	0.23
Un-named Trib	9	825.00	369.00	374.66		374.73	0.000792	2.81	407.70	124.58	0.25
Un-named Trib	8	196.00	370.00	373.31	373.31	373.55	0.005931	4.59	77.94	154.09	0.60
Un-named Trib	8	332.00	370.00	373.54	373.54	373.84	0.007389	5.55	113.65	156.39	0.68
Un-named Trib	8	436.00	370.00	373.67	373.67	374.01	0.008372	6.15	134.37	157.71	0.73
Un-named Trib	8	591.00	370.00	373.83	373.83	374.24	0.009642	6.93	160.23	159.34	0.80
Un-named Trib	8	710.00	370.00	373.95	373.95	374.40	0.010398	7.42	178.13	160.46	0.83
Un-named Trib	8	825.00	370.00	374.04	374.04	374.54	0.011092	7.87	193.67	161.26	0.87
Un-named Trib	7	196.00	369.50	370.91	370.91	371.59	0.017888	6.63	29.54	21.88	1.01
Un-named Trib	7	332.00	369.50	371.45	371.45	371.71	0.006583	5.01	130.11	222.14	0.64
Un-named Trib	7	436.00	369.50	371.40		371.95	0.014026	7.18	118.26	221.18	0.94
Un-named Trib	7	591.00	369.50	371.61		372.06	0.011669	7.05	165.74	225.01	0.87
Un-named Trib	7	710.00	369.50	371.74		372.17	0.010937	7.11	195.82	227.40	0.85
Un-named Trib	7	825.00	369.50	371.86		372.28	0.010636	7.25	221.17	229.40	0.85
Un-named Trib	6	196.00	368.50	370.32	370.32	370.48	0.004889	4.03	109.61	271.00	0.54
Un-named Trib	6	332.00	368.50	370.47	370.47	370.68	0.006714	5.00	150.68	275.21	0.64
Un-named Trib	6	436.00	368.50	370.56	370.56	370.80	0.007986	5.61	174.31	277.60	0.70
Un-named Trib	6	591.00	368.50	370.68	370.68	370.95	0.009212	6.27	207.45	280.92	0.76
Un-named Trib	6	710.00	368.50	370.75	370.75	371.06	0.010194	6.75	228.38	283.00	0.81
Un-named Trib	6	825.00	368.50	370.82	370.82	371.15	0.010754	7.09	249.32	285.06	0.84
Un-named Trib	5	196.00	365.00	368.47	367.54	368.53	0.001399	2.64	172.15	304.74	0.30

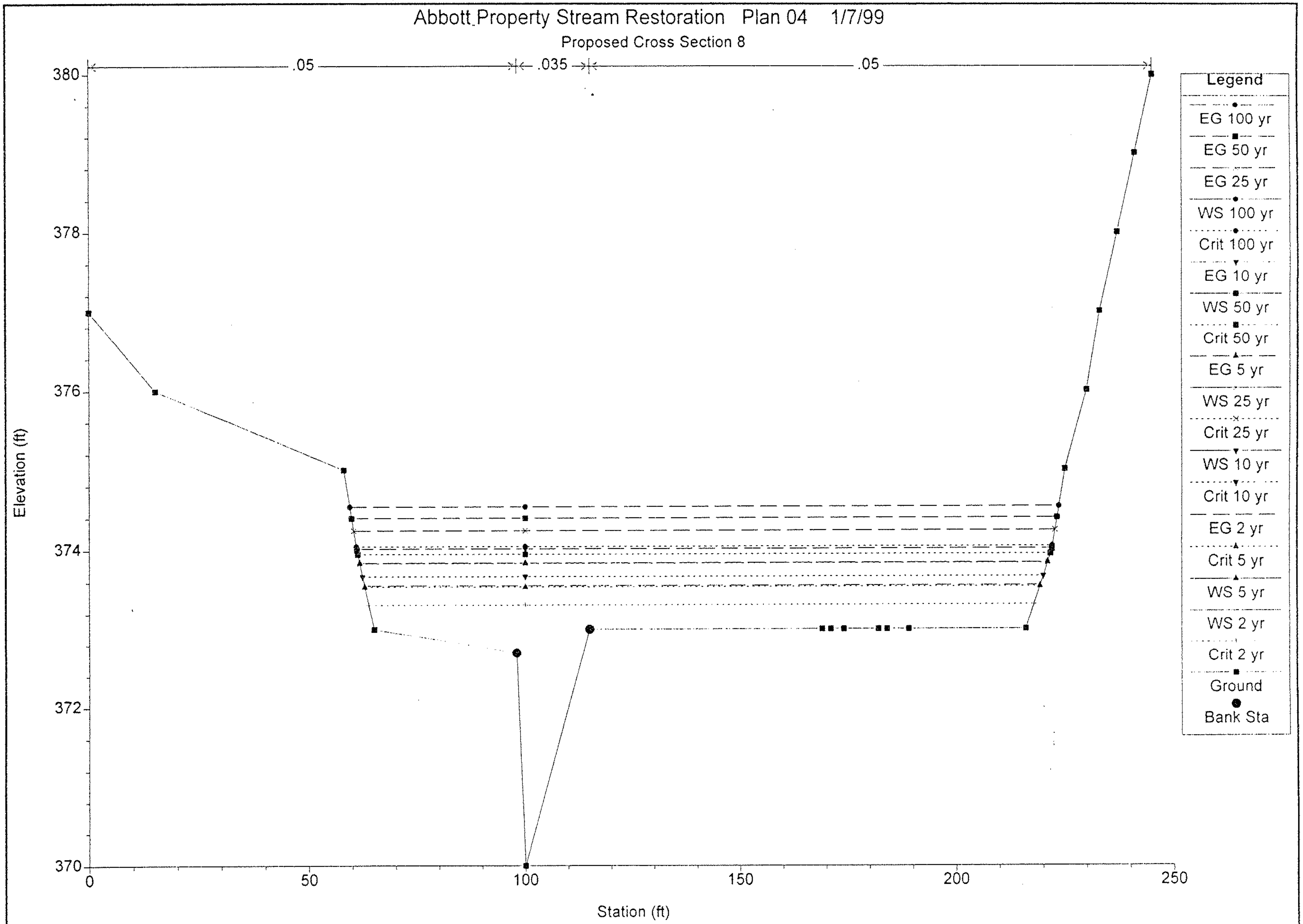
HEC-RAS Plan: Plan 02 River: Walnut Creek Reach: Un-named Trib (Continued)

Reach	River Sta	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
		(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Un-named Trib	5	332.00	365.00	368.68	368.43	368.76	0.001892	3.24	236.41	312.65	0.35
Un-named Trib	5	436.00	365.00	368.81	368.53	368.90	0.002137	3.55	278.44	317.72	0.37
Un-named Trib	5	591.00	365.00	368.98	368.64	369.08	0.002402	3.92	333.96	324.29	0.40
Un-named Trib	5	710.00	365.00	369.10	368.73	369.21	0.002536	4.14	372.87	326.21	0.41
Un-named Trib	5	825.00	365.00	369.21	368.80	369.32	0.002644	4.32	407.59	327.49	0.42
Un-named Trib	4	196.00	368.00	368.35	368.18	368.41	0.012004	2.31	99.47	226.58	0.69
Un-named Trib	4	332.00	368.00	368.52	368.31	368.61	0.012009	3.02	139.66	242.02	0.74
Un-named Trib	4	436.00	368.00	368.63	368.40	368.74	0.012003	3.43	166.90	251.94	0.76
Un-named Trib	4	591.00	368.00	368.78	368.51	368.92	0.012024	3.93	203.93	264.85	0.79
Un-named Trib	4	710.00	368.00	368.87	368.60	369.03	0.012013	4.26	230.56	273.74	0.80
Un-named Trib	4	825.00	368.00	368.96	368.67	369.14	0.012014	4.54	255.04	281.68	0.81


Abbott Property Stream Restoration Plan 04 1/7/99
Proposed Cross Section 10
.05
.035
.05
Legend
EG 100 yr
EG 50 yr
EG 25 yr
WS 100 yr
Crit 100 yr
EG 10 yr
WS 50 yr
Crit 50 yr
WS 25 yr
Crit 25 yr
EG 5 yr
WS 10 yr
Crit 10 yr
EG 2 yr
WS 5 yr
Crit 5 yr
WS 2 yr
Ground
Bank Sta
Elevation (ft)
386
384
382
380
378
376
374
372
370
Station (ft)
0
20
40
60
80
100
120
140
160



Abbott Property Stream Restoration Plan 04 1/7/99
Proposed Cross Section 9
.05
.035
.05
Legend
EG 100 yr
WS 100 yr
EG 50 yr
WS 50 yr
EG 25 yr
WS 25 yr
EG 10 yr
WS 10 yr
EG 5 yr
WS 5 yr
EG 2 yr
WS 2 yr
Ground
Bank Sta
Elevation (ft)
380
378
376
374
372
370
368
0
20
40
60
80
100
120
140
160
Station (ft)


Abbott Property Stream Restoration Plan 04 1/7/99
Proposed Cross Section 8
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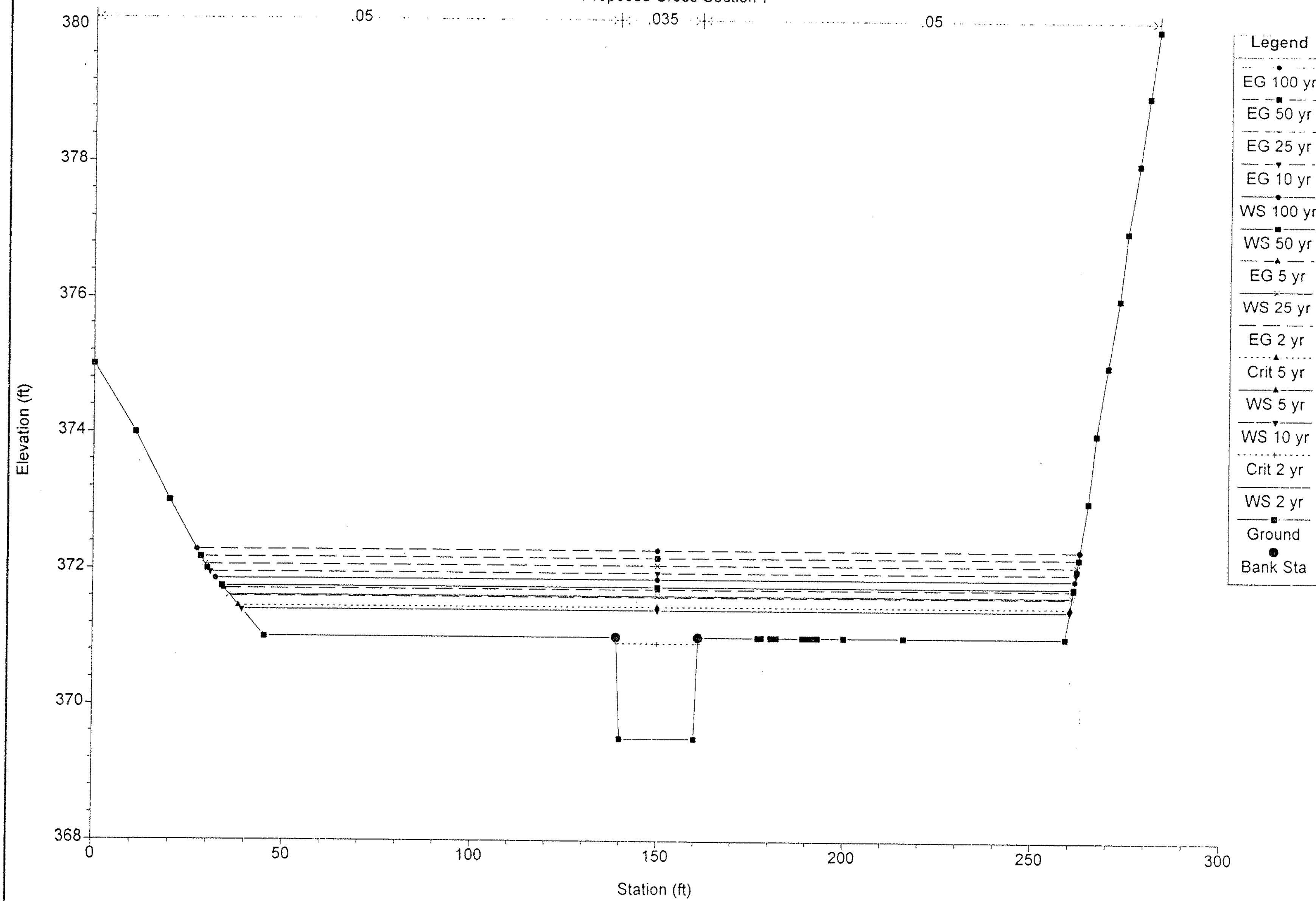
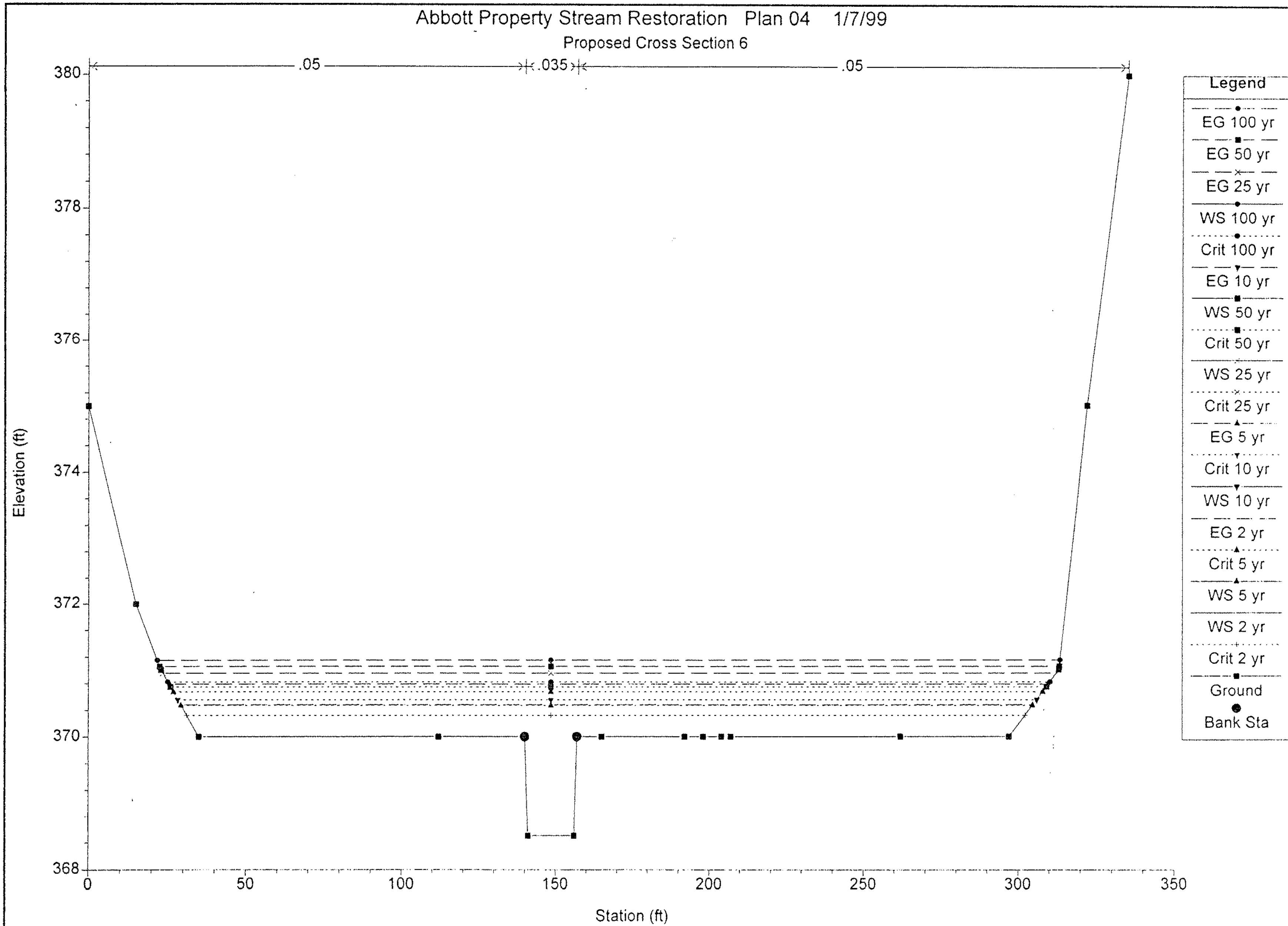
.035
.05
380
378
376
374
372
370
Elevation (ft)
0
50
100
150
200
250
Station (ft)
Legend
EG 100 yr
EG 50 yr
EG 25 yr
WS 100 yr
Crit 100 yr
EG 10 yr
WS 50 yr
Crit 50 yr
EG 5 yr
WS 25 yr
Crit 25 yr
WS 10 yr
Crit 10 yr
EG 2 yr
Crit 5 yr
WS 5 yr
WS 2 yr
Crit 2 yr
Ground
Bank Sta

Abbott Property Stream Restoration   Plan 04   1/7/99

Proposed Cross Section 7





Abbott Property Stream Restoration Plan 04 1/7/99
Proposed Cross Section 6
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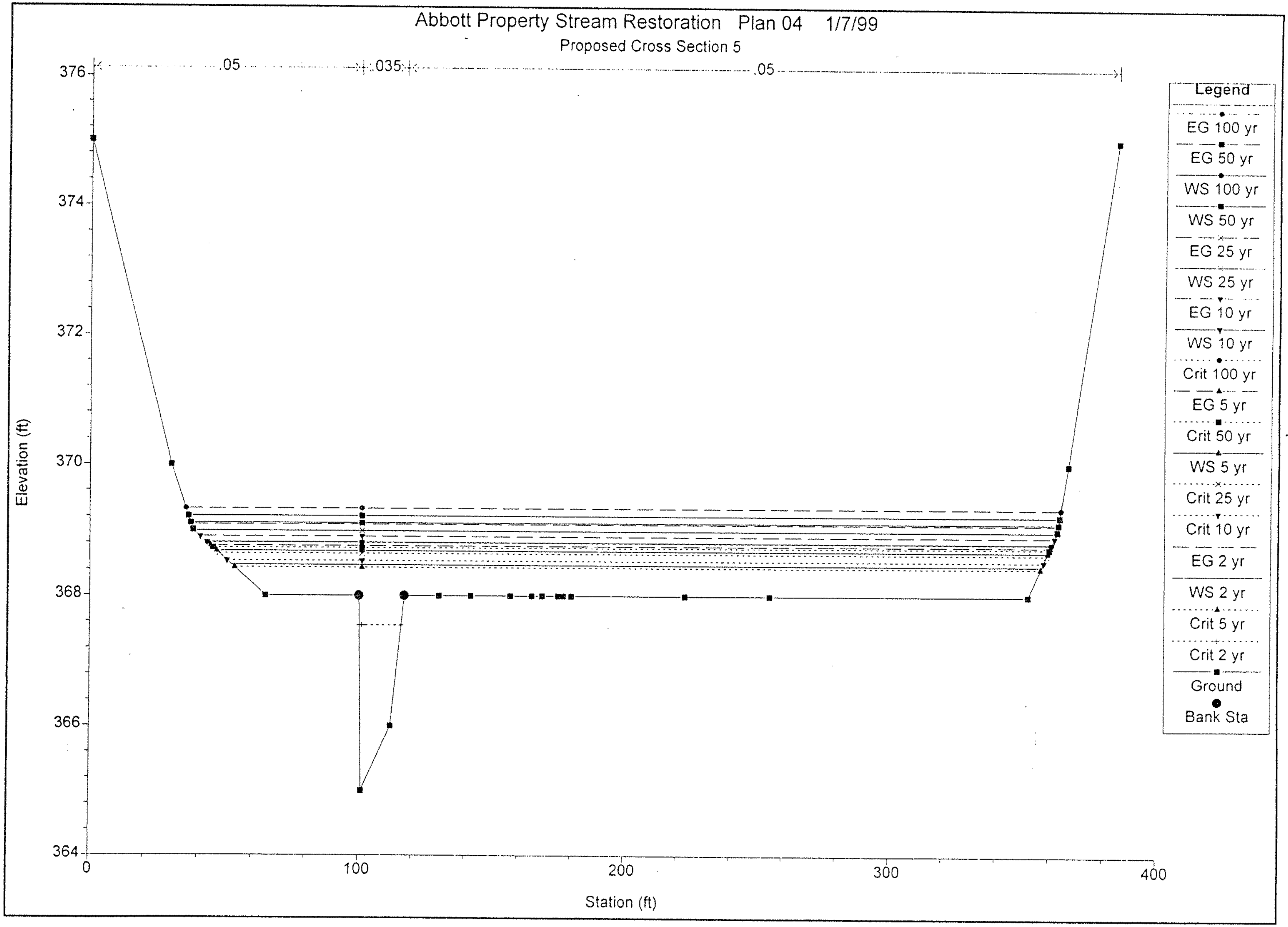
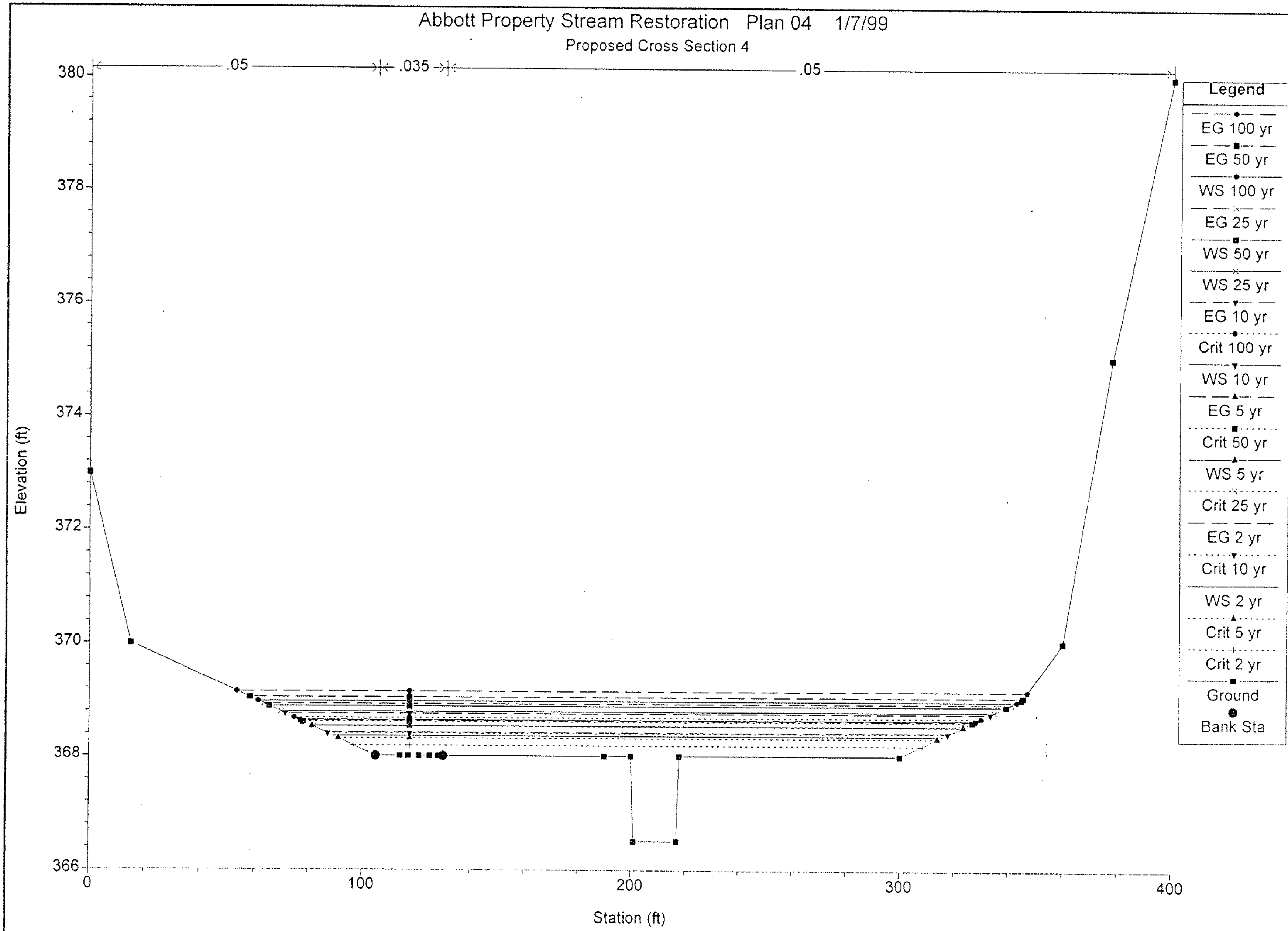
.035
.05
Elevation (ft)
380
378
376
374
372
370
368
0
50
100
150
200
250
300
350
Station (ft)
Legend
EG 100 yr
EG 50 yr
EG 25 yr
WS 100 yr
Crit 100 yr
EG 10 yr
WS 50 yr
Crit 50 yr
WS 25 yr
Crit 25 yr
EG 5 yr
Crit 10 yr
WS 10 yr
EG 2 yr
Crit 5 yr
WS 5 yr
WS 2 yr
Crit 2 yr
Ground
Bank Sta



Abbott Property Stream Restoration Plan 04 1/7/99
Proposed Cross Section 5
.05
.035
.05
Elevation (ft)
376
374
372
370
368
366
364
0
100
200
300
400
Station (ft)
Legend
EG 100 yr
EG 50 yr
WS 100 yr
WS 50 yr
EG 25 yr
WS 25 yr
EG 10 yr
WS 10 yr
Crit 100 yr
EG 5 yr
Crit 50 yr
WS 5 yr
Crit 25 yr
Crit 10 yr
EG 2 yr
WS 2 yr
Crit 5 yr
Crit 2 yr
Ground
Bank Sta



Abbott Property Stream Restoration Plan 04 1/7/99
Proposed Cross Section 4
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.035
.05
Elevation (ft)
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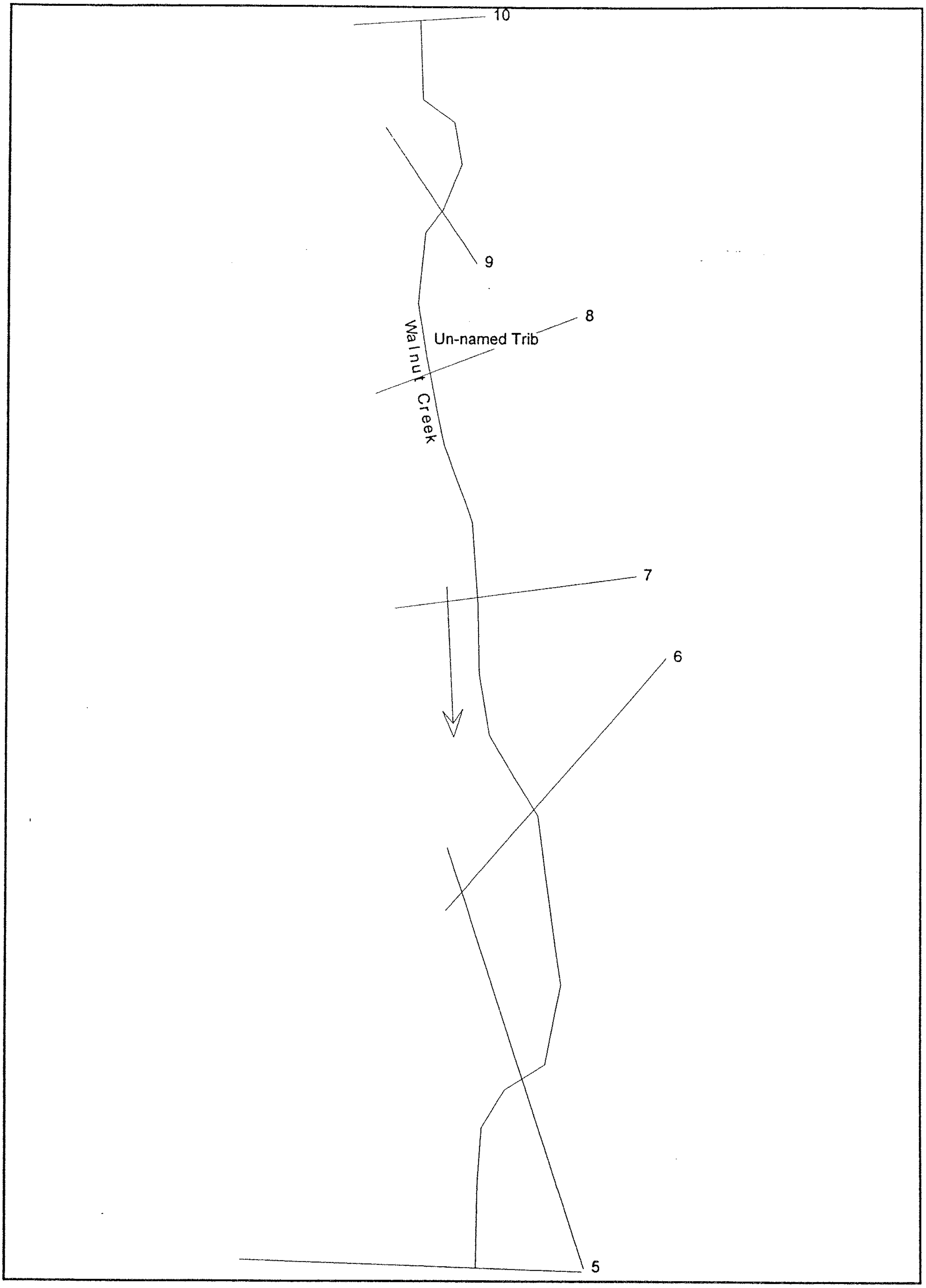
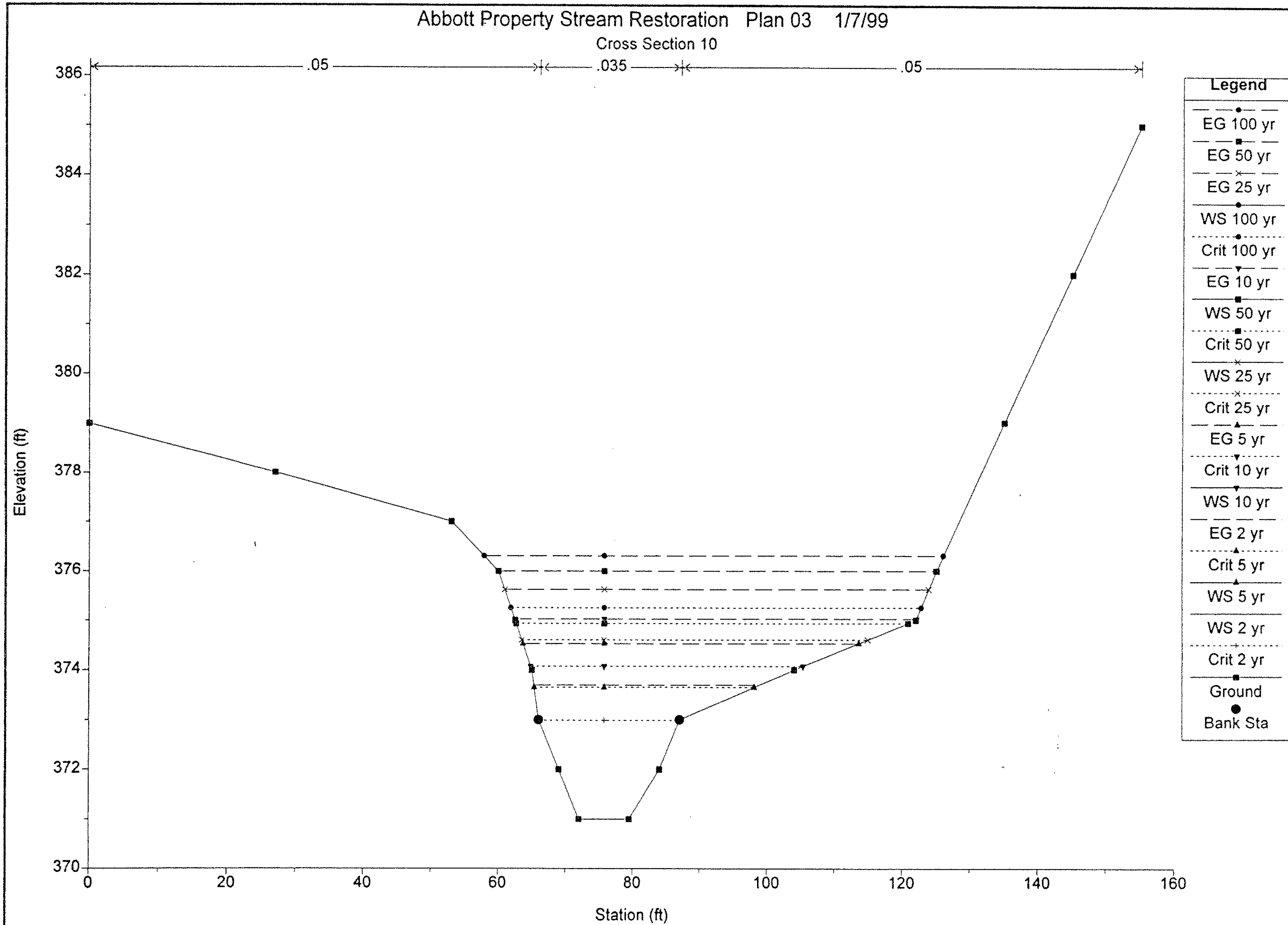
378
376
374
372
370
368
366
Station (ft)
0
100
200
300
400
Legend
EG 100 yr
EG 50 yr
WS 100 yr
EG 25 yr
WS 50 yr
WS 25 yr
EG 10 yr
Crit 100 yr
WS 10 yr
EG 5 yr
Crit 50 yr
WS 5 yr
Crit 25 yr
EG 2 yr
Crit 10 yr
WS 2 yr
Crit 5 yr
Crit 2 yr
Ground
Bank Sta


10
9
8
Un-named Trib
Walnut Creek
7
6
5


Abbott Property Stream Restoration Plan 03 1/7/99
Cross Section 10
.05
.035
.05
Elevation (ft)
386
384
382
380
378
376
374
372
370
0
20
40
60
80
100
120
140
160
Station (ft)
Legend
EG 100 yr
EG 50 yr
EG 25 yr
WS 100 yr
Crit 100 yr
EG 10 yr
WS 50 yr
Crit 50 yr
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WS 10 yr
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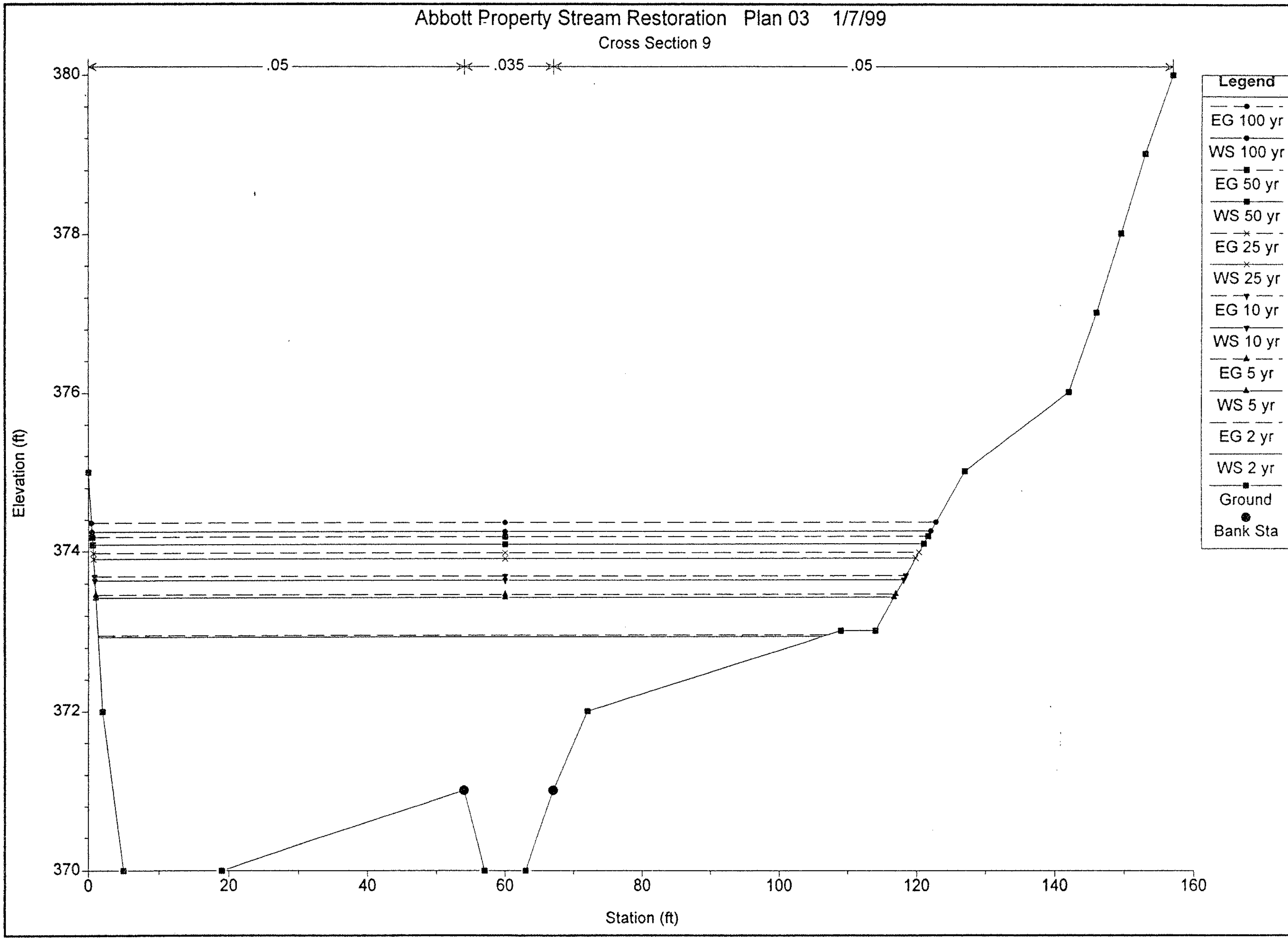
Crit 5 yr
WS 5 yr
WS 2 yr
Crit 2 yr
Ground
Bank Sta


Abbott Property Stream Restoration Plan 03 1/7/99
Cross Section 9
.05
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Elevation (ft)
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100
120
140
160
Station (ft)
Legend
EG 100 yr
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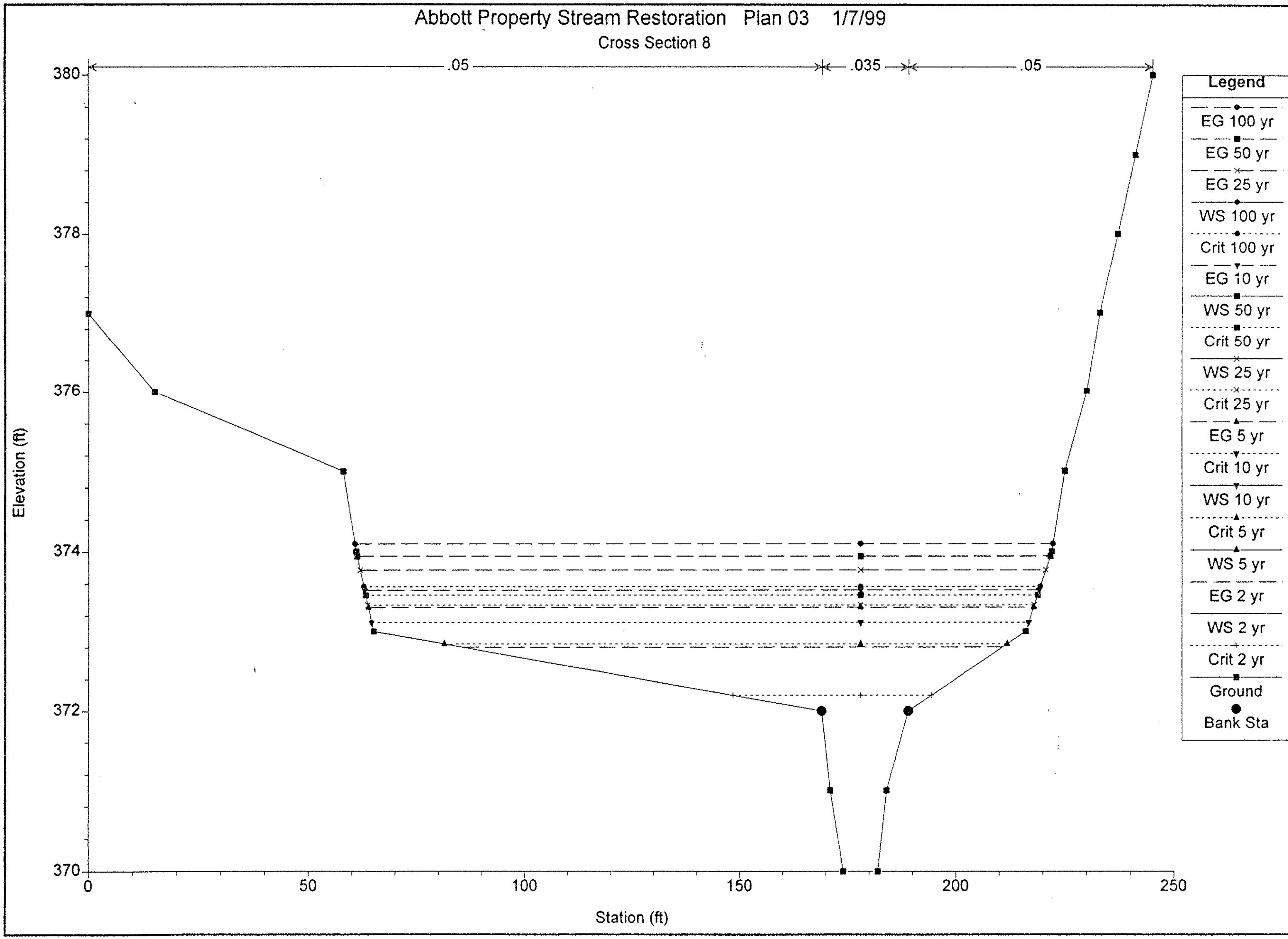
WS 2 yr
Ground
Bank Sta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EG 50 yr
EG 25 yr
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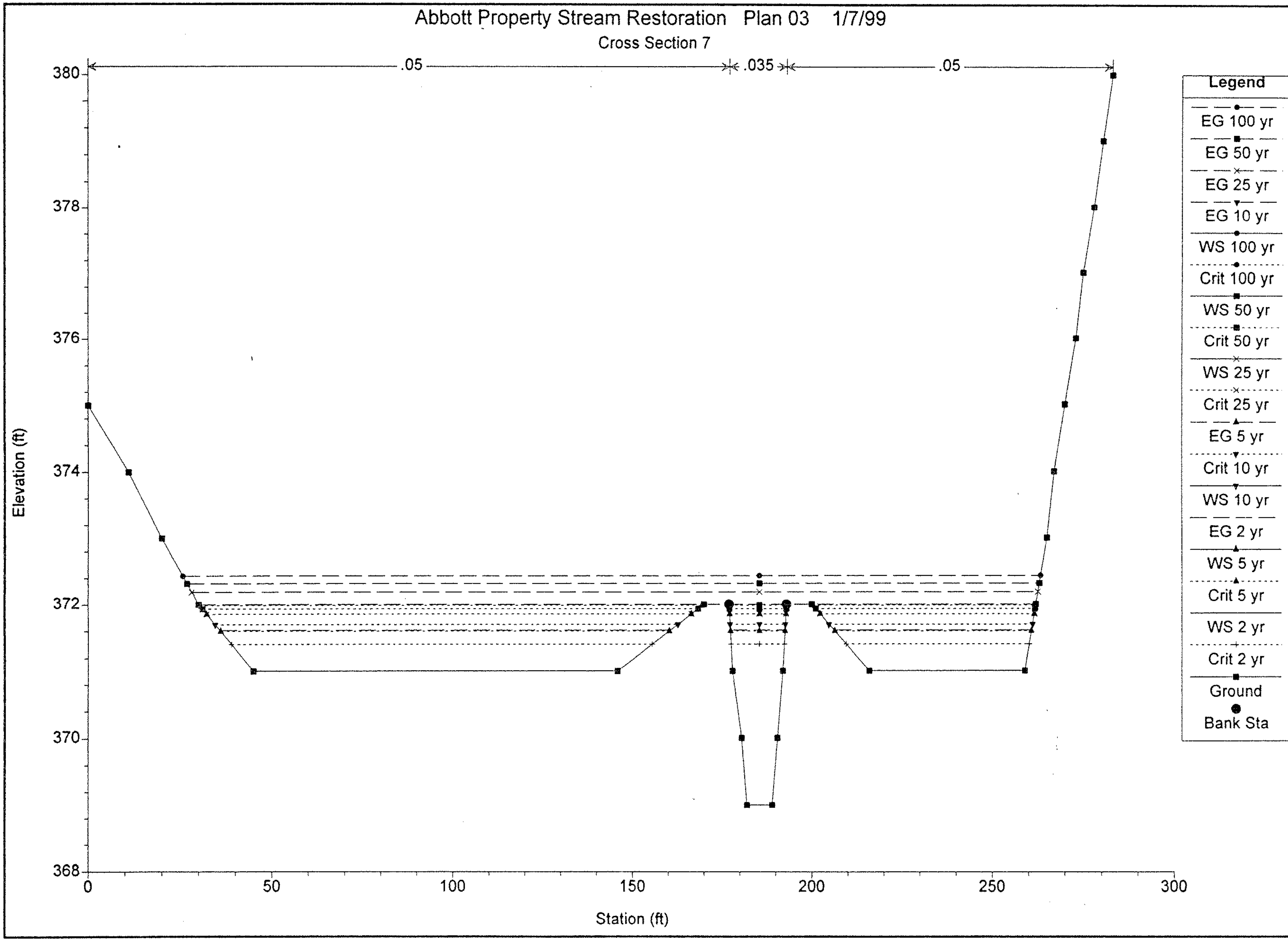
Crit 10 yr
WS 10 yr
Crit 5 yr
WS 5 yr
EG 2 yr
WS 2 yr
Crit 2 yr
Ground
Bank Sta
Elevation (ft)
370
372
374
376
378
380
0
50
100
150
200
250
Station (ft)



Abbott Property Stream Restoration Plan 03 1/7/99
Cross Section 7
.05
.035
.05
Elevation (ft)
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378
376
374
372
370
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Station (ft)
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50
100
150
200
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300
Legend
EG 100 yr
EG 50 yr
EG 25 yr
EG 10 yr
WS 100 yr
Crit 100 yr
WS 50 yr
Crit 50 yr
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Crit 25 yr
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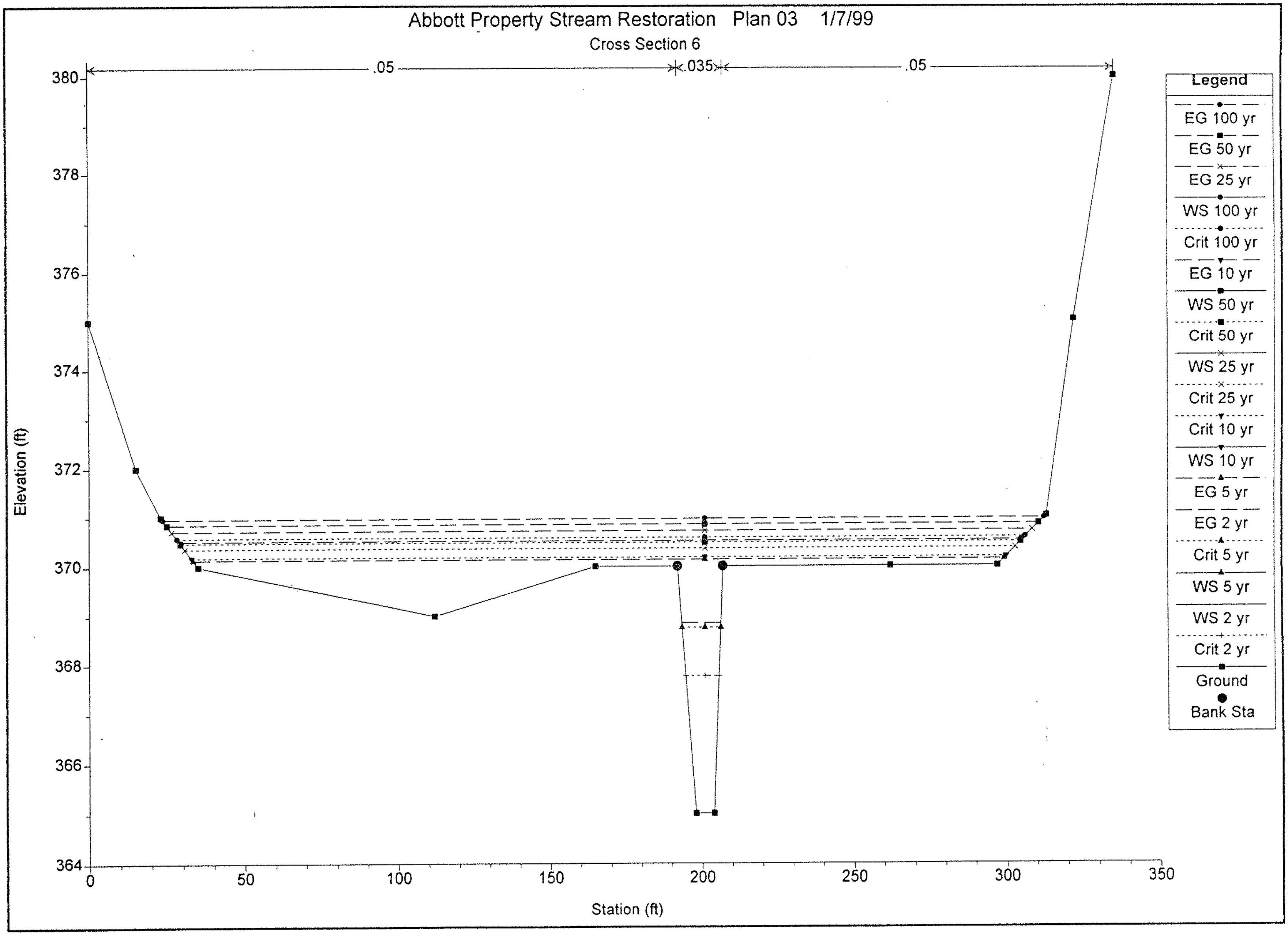
WS 10 yr
EG 2 yr
WS 5 yr
Crit 5 yr
WS 2 yr
Crit 2 yr
Ground
Bank Sta



Abbott Property Stream Restoration Plan 03 1/7/99
Cross Section 6
.05
.035
.05
Elevation (ft)
380
378
376
374
372
370
368
366
364
Station (ft)
0
50
100
150
200
250
300
350
Legend
EG 100 yr
EG 50 yr
EG 25 yr
WS 100 yr
Crit 100 yr
EG 10 yr
WS 50 yr
Crit 50 yr
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Crit 25 yr
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WS 10 yr
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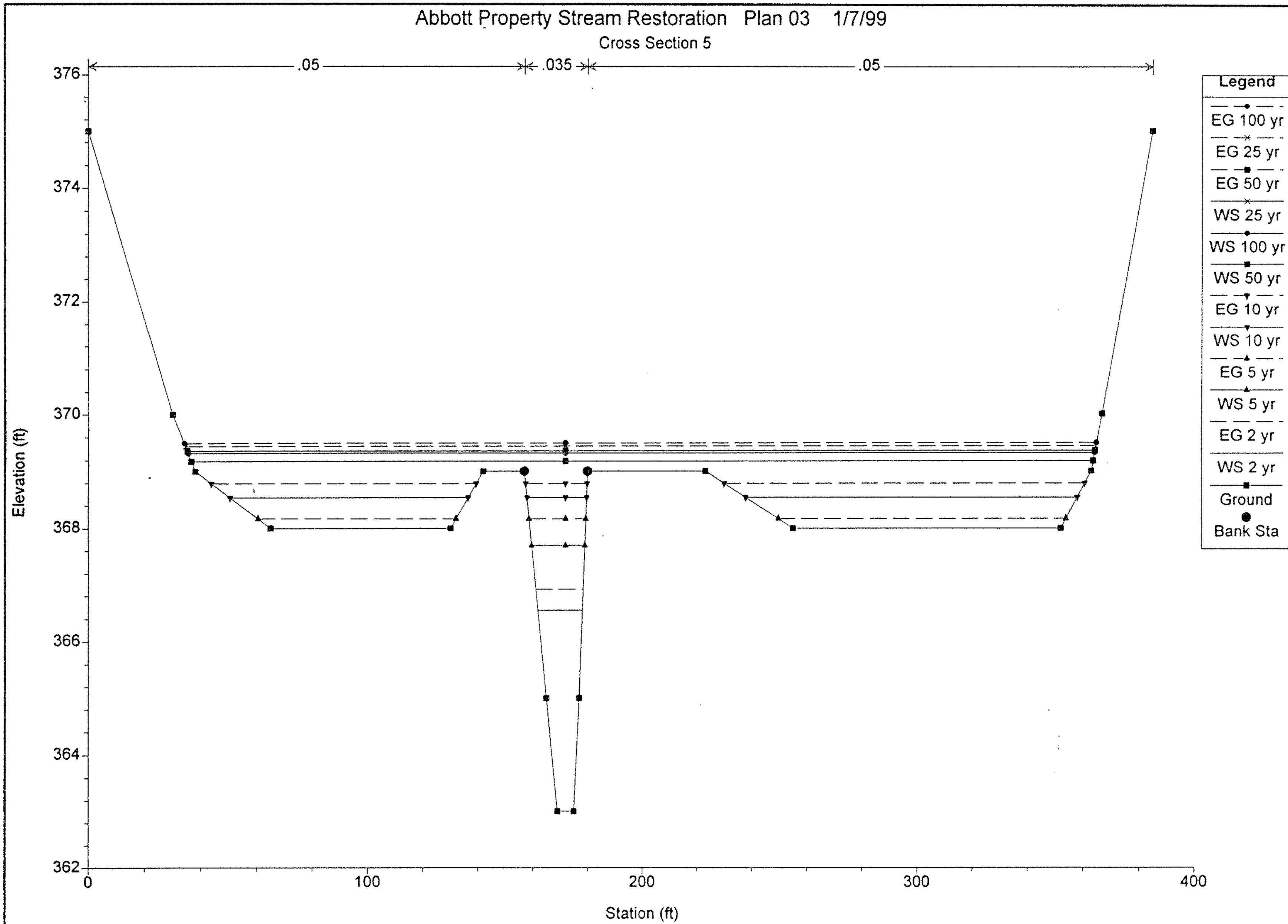
EG 2 yr
Crit 5 yr
WS 5 yr
WS 2 yr
Crit 2 yr
Ground
Bank Sta


Abbott Property Stream Restoration Plan 03 1/7/99
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EG 25 yr
EG 50 yr
WS 25 yr
WS 100 yr
WS 50 yr
EG 10 yr
WS 10 yr
EG 5 yr
WS 5 yr
EG 2 yr
WS 2 yr
Ground
Bank Sta
Elevation (ft)
376
374
372
370
368
366
364
362
0
100
200
300
400
Station (ft)