Helms 00043

# UNNAMED TRIBUTARY TO DUTCH BUFFALO CREEK
# DETAILED STREAM MITIGATION PLAN
# ROWAN COUNTY, NORTH CAROLINA

**Prepared for:**

North Carolina Department of Transportation
Raleigh, North Carolina

**Prepared by:**

EcoScience Corporation
1101 Haynes Street, Suite 101
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July 2003

# EXECUTIVE SUMMARY

The North Carolina Department of Transportation is currently evaluating stream restoration and wetland enhancement on an unnamed tributary (UT) to Dutch Buffalo Creek in Rowan County, North Carolina. This detailed mitigation document will outline plans to restore both stream and wetland functions associated with water quality.

This document details stream restoration, as well as wetland enhancement procedures on the Helms and Pless properties located approximately 1.5 miles southwest of the Town of Bostion Heights. An approximately 15-acre conservation easement, hereafter referred to as the Site, has been proposed for mitigation activities. The Site encompasses approximately 2322 linear feet of stream and 0.55 acre of jurisdictional wetlands in the adjacent floodplain. The Site watershed, consisting of approximately 0.6 square mile, is comprised of mixed hardwood forest, agricultural land, and low-density residential development. Land use within the Site includes pasture and hay production.

Under existing conditions, the UT to Dutch Buffalo Creek has been dredged and straightened. Natural vegetation within the floodplain, including stream buffer zones, is currently maintained through regular mowing and active grazing. A significant increase in nutrient and sediment loads is expected as a result of current land use practices. In response to these modifications, nutrient recycling associated with adjacent wetlands and floodplains has been severely diminished or negated.

Restoration activities have been designed to restore historic stream and wetland functions which existed on-site prior to dredging and vegetation removal. Site restoration includes floodplain grading and construction of approximately 2840 linear feet of meandering E-type (highly sinuous) stream channel on new location. These activities will reintroduce surface water flood hydrodynamics from the 0.6-mile watershed along the restored length of stream and floodplain. Characteristic wetland soil features, groundwater wetland hydrology, and hydrophytic vegetation communities are expected to develop in areas adjacent to the constructed channel. The existing, degraded channel will be abandoned and backfilled. Subsequently, Site reforestation of streamside and bottomland hardwood forest communities have been included along the entire on-site stream and floodplain to further protect water quality and enhance opportunities for wildlife.

A Monitoring Plan has been prepared that entails a detailed analysis of stream geomorphology, wetland hydrology, and Site vegetation. Success of the project will be based on criteria set forth under each of the three monitored parameters.

After implementation, restoration activities are expected to result in 1) restoration of approximately 2840 linear feet of stream through excavation of channel on new location, 2) enhancement of approximately 0.55 acre of wetlands, and 3) restoration of approximately 15 acres of streamside buffer, floodplain, and adjacent upland slopes throughout the Site within an approximately 15-acre conservation easement.

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# UNNAMED TRIBUTARY TO DUTCH BUFFALO CREEK
# DETAILED STREAM MITIGATION PLAN

## 1.0 INTRODUCTION

The North Carolina Department of Transportation (NCDOT) is currently evaluating stream restoration and wetland enhancement on an unnamed tributary (UT) to Dutch Buffalo Creek in Rowan County. The mitigation area is located south of the Town of Bostian Heights between U.S. Interstate Route 85 (I-85) and N.C. State Route 152 (NC 152) (Figure 1). The property encompasses 2322 linear feet of an unnamed tributary to Dutch Buffalo Creek and 0.55 acre of jurisdictional wetlands in the adjacent floodplain. The mitigation area, hereafter referred to as the Site, encompasses approximately 15 acres of land (proposed easement area) which has been degraded by past land management practices including land clearing, dredging/straightening of the on-site streams, and livestock production.

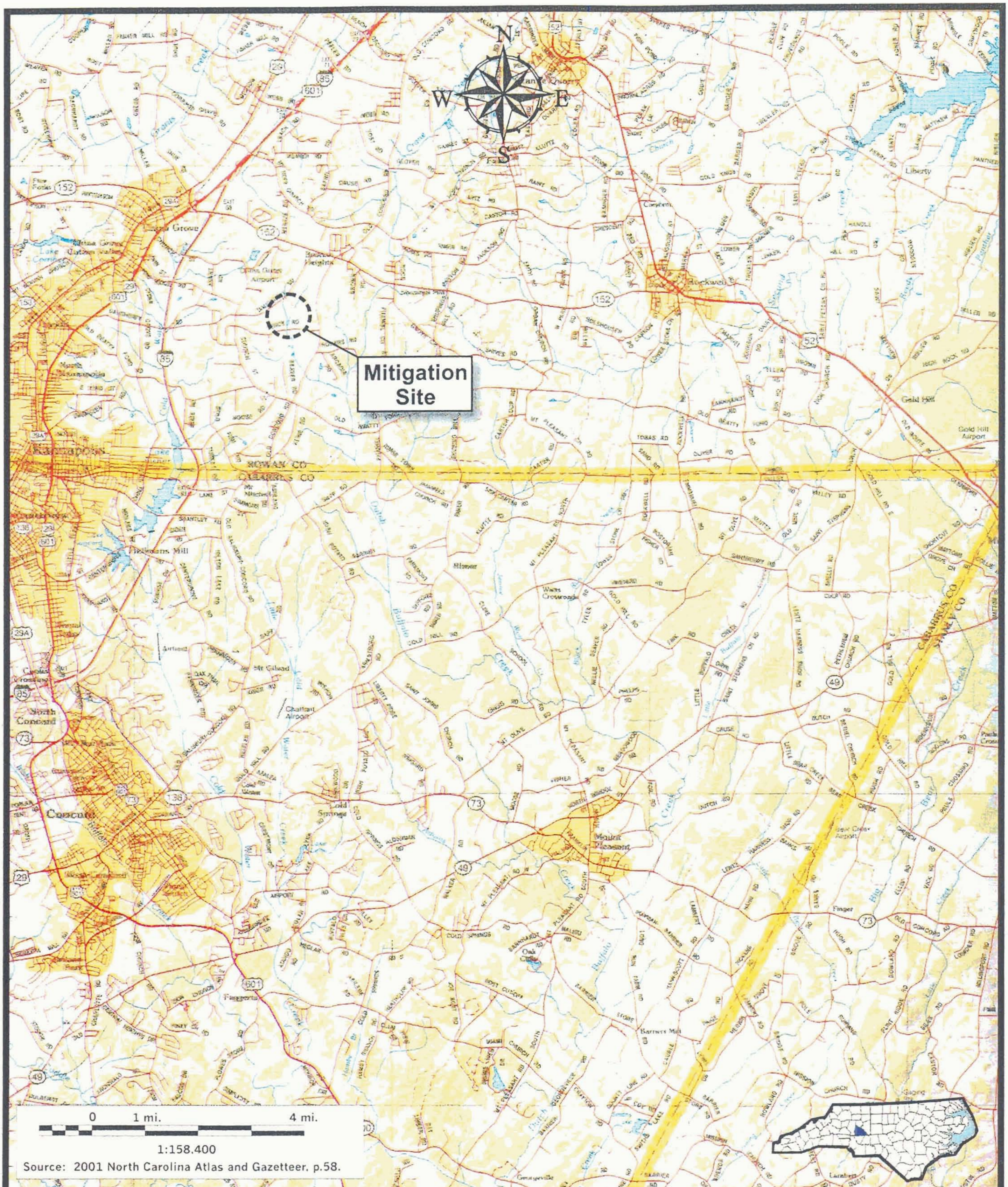
The purpose of this study is to establish a detailed Site mitigation plan for stream restoration and wetland enhancement alternatives. The objectives of this study are as follows:

- Classify the on-site stream based on fluvial geomorphic principles.
- Identify a suitable reference forest and stream to model Site mitigation attributes.
- Develop a detailed plan of stream restoration and wetland enhancement activities within the proposed 15 acre conservation easement boundary.
- Establish success criteria and a method of monitoring the Site upon completion of mitigation construction.

The goals of the restoration/enhancement efforts are as follows:

- Restore approximately 2840 linear feet of stream through excavation of channel on new location (Priority 1). Channel dimension, pattern, and profile will be modified after natural reference conditions. Restoration of on-site streams will 1) reduce sediment and nutrient loading, 2) increase the frequency of pools and associated micro-habitat, 3) provide energy dissipation for peak flow events, and 4) enhance/restore wetland function adjacent to the channel.

- The flood-prone area and adjacent upland slopes will be reforested with native species to 1) increase channel bank stability; 2) serve as a wildlife corridor by providing connectivity to forested areas adjacent to the Site; 3) provide increased habitat for aquatic and terrestrial wildlife; 4) increase organic matter, carbon export, and woody debris in the stream corridor; 5) restore characteristic macroinvertebrate species populations in the channel; and 6) restore shade.

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Raleigh, North Carolina

**SITE LOCATION**
**UT to Dutch Buffalo Creek**
**DETAILED MITIGATION STUDIES**
Rowan County, North Carolina

| | |
|---|---|
| Dwn. by: | MAF |
| Ckd by: | WGL |
| Date: | NOV 2002 |
| Project: | 00-046.26 |

FIGURE 1

- Wetland enhancement will reestablish natural vegetative and hydrologic conditions to the Site in order to 1) provide unique habitat for aquatic and terrestrial wildlife, 2) increase biodiversity, 3) increase floodwater storage, 4) reduce downstream flood peaks, 5) maintain seasonal high water table, and 6) serve as a retention area for sediment and nutrients.

This document represents a detailed mitigation plan summarizing activities proposed within the Site. The plan includes 1) descriptions of existing conditions, 2) reference stream reach studies, 3) restoration plans, and 4) Site monitoring and success criteria. Upon approval of this plan by regulatory agencies, engineering construction plans will be prepared and activities implemented as outlined. Proposed mitigation activities may be modified during the civil design stage due to constraints such as access issues, sediment-erosion control measures, drainage needs (floodway constraints), or other design considerations.

## 2.0 METHODS

Natural resource information was obtained from available sources. U.S. Geological Survey (USGS) 7.5 minute topographic mapping (China Grove, NC, Southmont, NC, and Harrisburg, NC), U.S. Fish and Wildlife Service (USFWS) National Wetlands Inventory (NWI) mapping, Natural Resource Conservation Service (NRCS [formerly the Soil Conservation Service]) soils mapping for Rowan County (NRCS 1995), historic and recent aerial photography, and digital, 1-foot topographic mapping were utilized to evaluate existing landscape, stream, and soil information prior to on-site inspection.

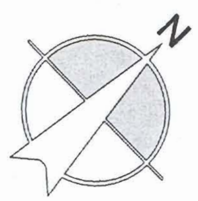
Reference stream geometry methods have been used to orient channel reconstruction design. Reference stream and floodplain systems were identified and measured in the field to quantify stream geometry, substrate, and hydrodynamics. Stream characteristics and detailed mitigation plans were developed according to constructs outlined in Rosgen (1996), Dunne and Leopold (1978), Harrelson *et al.* (1994), Chang (1988), and North Carolina Wildlife Resources Commission (NCWRC) (1996). Stream pattern, dimension, and profile under stable environmental conditions were measured along reference (relatively undisturbed) stream reaches and applied to the degraded channel within the Site. Reconstructed stream channels and hydraulic geometry relationships have been designed to mimic stable channels identified and evaluated in the region.

North Carolina Natural Heritage Program (NHP) data bases were evaluated for the location of designated natural areas which may serve as reference wetlands for enhancement design. Characteristic and target natural community patterns were classified according to Schafale and Weakley's *Classification of the Natural Communities of North Carolina* (1990).

Detailed field investigations were performed in July, August, and September 2002, consisting of Site channel cross-sections, profile, and plan-view; valley cross-sections; soil survey; and mapping of on-site resources. Project scientists evaluated stream parameters to determine the stability of the existing channel. Hydrology, vegetation, and soil attributes were analyzed to determine the status of jurisdictional areas. Plant communities were delineated and described by structure and composition.

NRCS soil mapping was modified to identify hydric soil boundaries and to predict (target) biological diversity prior to human disturbances. NRCS soil map units were ground truthed by a licensed soil scientist to verify existing soil mapping units and to map inclusions.

Historical aerial photographs (1958, 1967, and 1979) were utilized to identify land use patterns and floodplain dynamics at the Site and in the watershed (Figures 2, 3, and 4). Disturbances to streams and wetlands during watershed development were tracked, where feasible. However, none of these historical photographs exhibit riparian forest structure or historic stream pattern prior to significant disturbance. Recent (1999) aerial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Raleigh, North Carolina 27605

Client:

NCDOT

Project:

UT to
DUTCH BUFFALO
CREEK

DETAILED
MITIGATION
STUDIES

ROWAN COUNTY,
NORTH CAROLINA

Title:

1958
AERIAL
PHOTOGRAPH

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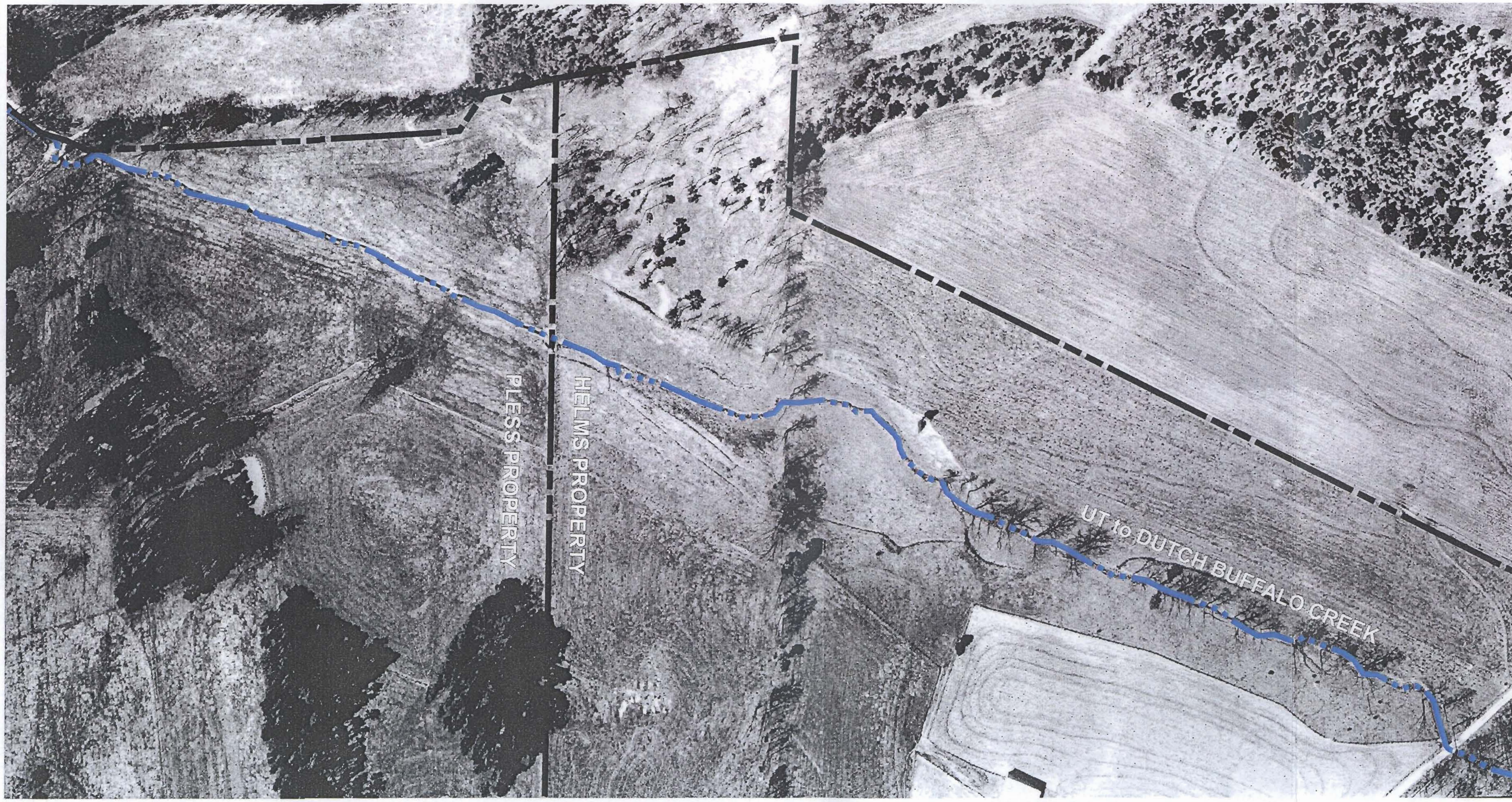
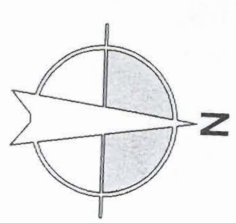
| Dwn By: MAF | Date: NOV 2002 |
| Ckd By: WGL | Scale: As Shown |
| ESC Project No.: 00-046.26 | |

FIGURE

2

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Raleigh, North Carolina 27605

Client:

**NCDOT**

Project:

**UT to DUTCH BUFFALO CREEK**

**DETAILED MITIGATION STUDIES**

ROWAN COUNTY, NORTH CAROLINA

Title:

**1967 AERIAL PHOTOGRAPH**

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| Dwn By: MAF | Date: NOV 2002 |
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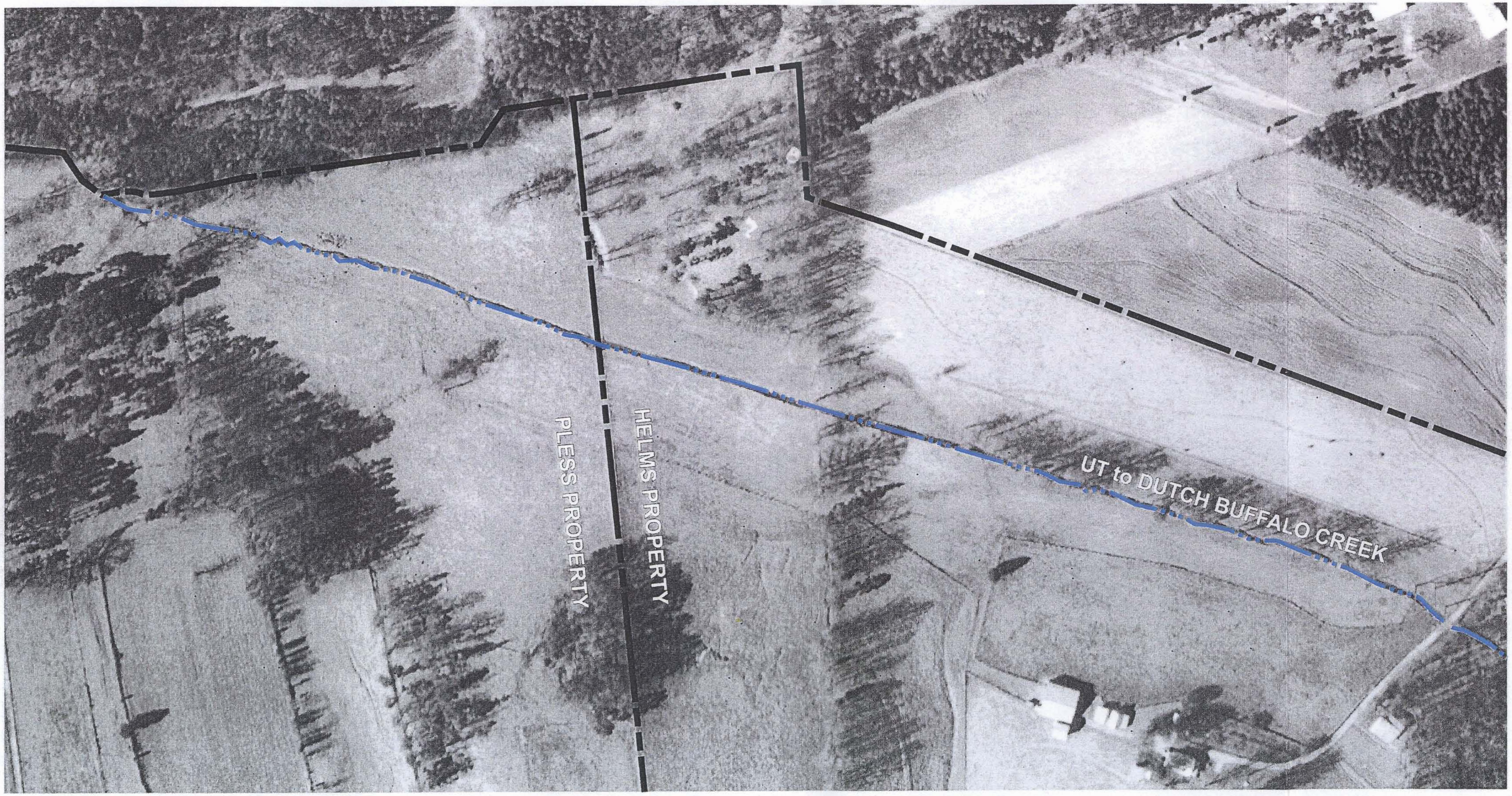
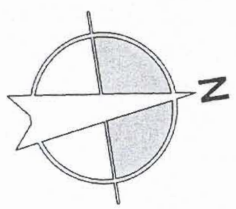
| ESC Project No.: 00-046.26 | |

FIGURE

3

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Client:

NCDOT

Project:

UT to DUTCH BUFFALO CREEK

DETAILED MITIGATION STUDIES

ROWAN COUNTY, NORTH CAROLINA

Title:

1979 AERIAL PHOTOGRAPH

| | |
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| Dwn By: MAF | Date: NOV 2002 |
| Ckd By: WGL | Scale: As Shown |
| ESC Project No.: | 00-046.26 |

FIGURE

4

photography was evaluated to determine primary hydrologic features and to map relevant environmental features.

Stream flows were modeled by interpreting USGS stream gauge data in the region and by the Hydrology Engineering Center's – River Analysis System (HEC-RAS) models, which also determined stream geometry calculations and estimates of projected storm water flows. The projected flows were used to assist in-field identification of bankfull stage, dimensioning of the on-site tributary, and to assess potential for hydrologic trespass onto adjacent properties or structures.

Information collected, reference ecosystem analyses, and drainage models were compiled in a database and incorporated with field observations to evaluate the on-site stream under existing conditions. Subsequently, this mitigation plan was developed to facilitate restoration success and to provide stream and wetland mitigation for various NCDOT projects in the region.

# 3.0 EXISTING CONDITIONS

## 3.1 Physiography, Topography, and Land Use

The Site is located in the southern portion of Rowan County, approximately 1.5 miles southwest of the town of Bostian Heights (Figure 1). This portion of the state is underlain by the metamorphic rocks of the Charlotte Belt geologic formation within the Southern Outer Piedmont ecoregion of North Carolina (USGS Subbasin 03040105). This hydrophysiographic region is characterized by broad, rolling, interstream divides intermixed with steeper slopes along well-defined drainage ways (Figure 5). This region is characterized by moderately high rainfall with precipitation averaging approximately 46 inches per year (NRCS 1995).

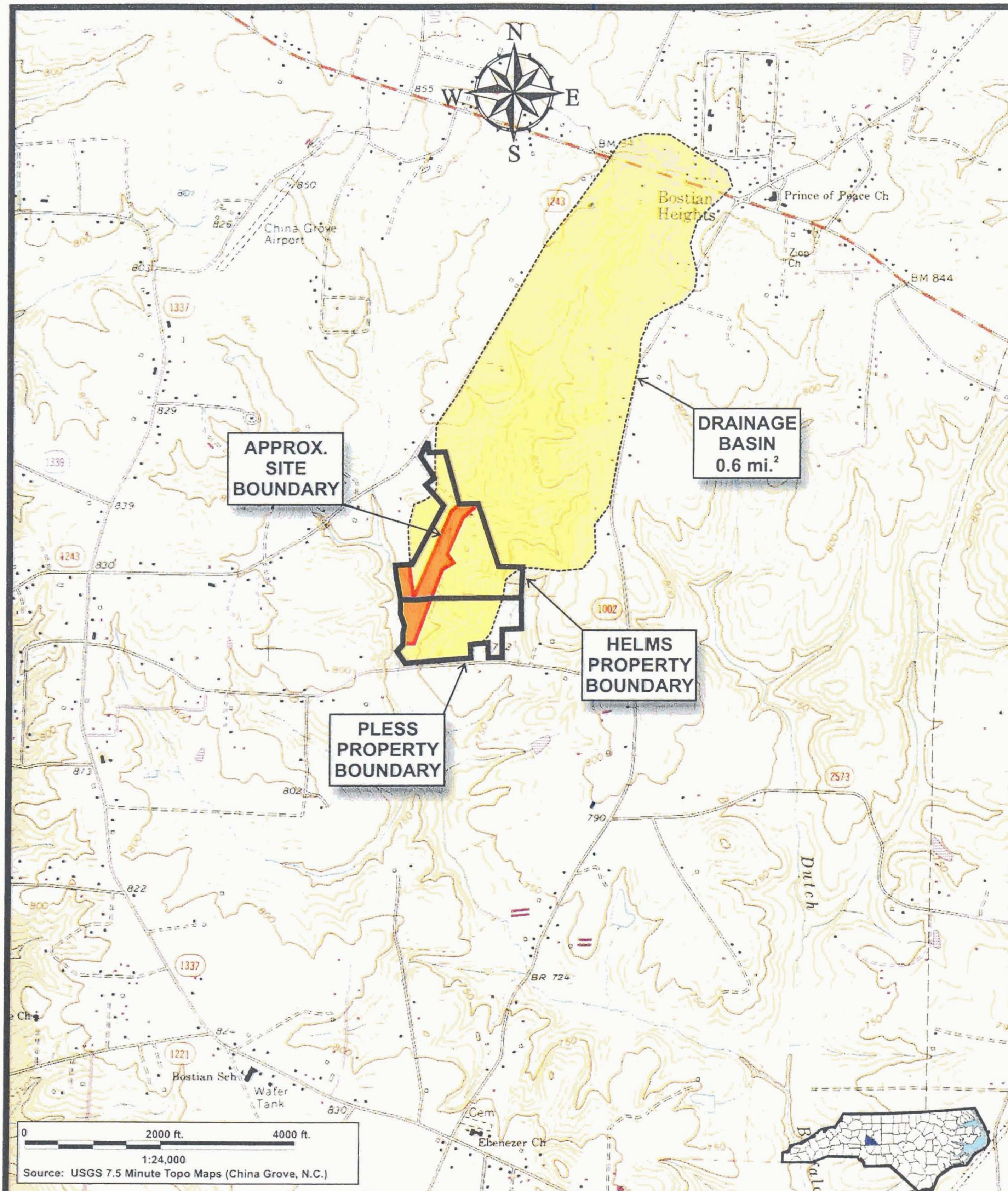
The Site encompasses a reach of a UT to Dutch Buffalo Creek, the associated floodplain, and two wetland pockets located in the floodplain. The UT flows in a northeast to southwest direction for 2322 linear feet through the Site prior to its outfall at the southern property boundary. ESC biologists mapped two wetland pockets, totaling approximately 0.55 acre, within the Site floodplain.

The UT is a second-order stream that flows through an alluvial valley (Valley Type VIII). The Site upper reaches are characterized by a moderately steep valley (0.0076 rise/run) that is relatively narrow (flood-prone area of approximately 195 feet). As the UT descends towards its convergence with Dutch Buffalo Creek, the valley flattens (0.0056 rise/run) and widens (flood-prone area of approximately 265 feet).

The upstream drainage area for the UT (depicted in Figure 5) encompasses approximately 0.6 square mile at the Site outfall. The upstream watershed is comprised of mixed hardwood forest, agricultural land (livestock, row crops, and hay production), and low-density residential development. Impervious surfaces appear to account for less than 10 percent of the upstream land coverage (Figure 6).

On-site land use includes pasture and hay production. A residential building and a complex of barns and hay storage structures are located adjacent to the northeastern Site boundary. The Site is primarily characterized by open pasture and hay fields along with small, isolated forest stands (Figure 7). The pasture is heavily grazed by livestock. It is assumed active grazing has occurred at the Site for at least 44 years (1958 historic aerial photography indicate livestock utilization of the floodplain). Livestock have access to the entire on-site stream and the adjacent floodplain. No exclusionary barriers occur adjacent to the on-site stream or floodplain, and livestock appear to have degraded stream banks and removed hydrophytic vegetation.

Current land use within the Site watershed remains rural with few developments. However, due to the close proximity of the cities of Kannapolis and Salisbury, there is potential for development opportunists to attempt watershed land use conversion. If future watershed development occurs, increased sedimentation from construction may induce additional peak discharge and sediment supply within the Site.

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**TOPOGRAPHY**
**UT to Dutch Buffalo Creek**
**DETAILED MITIGATION STUDIES**
Rowan County, North Carolina

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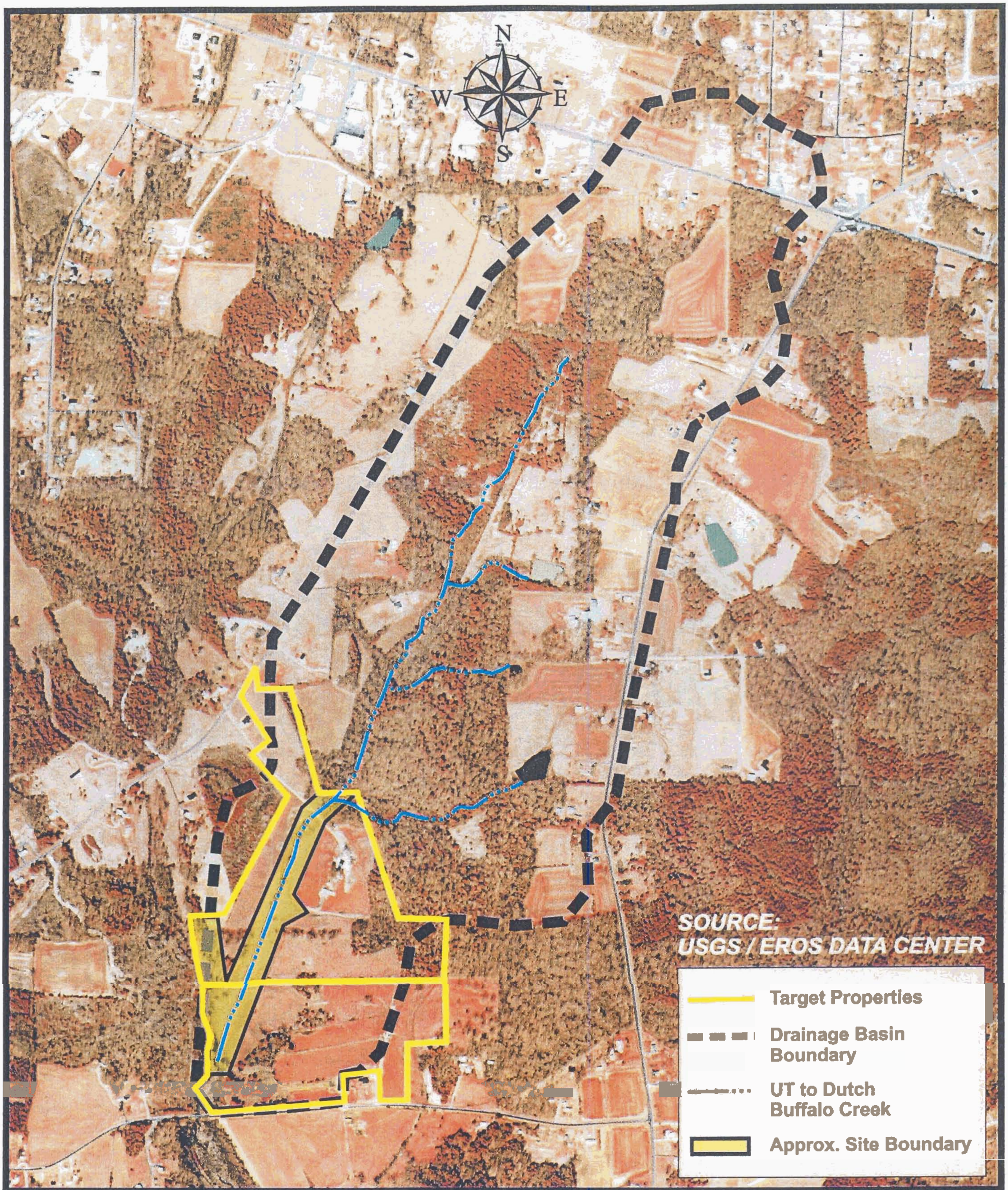
| Project: | 00-046.26 |

FIGURE
5

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**DRAINAGE BASIN LAND USE**
**UT to Dutch Buffalo Creek**
**DETAILED MITIGATION STUDIES**
Rowan County, North Carolina

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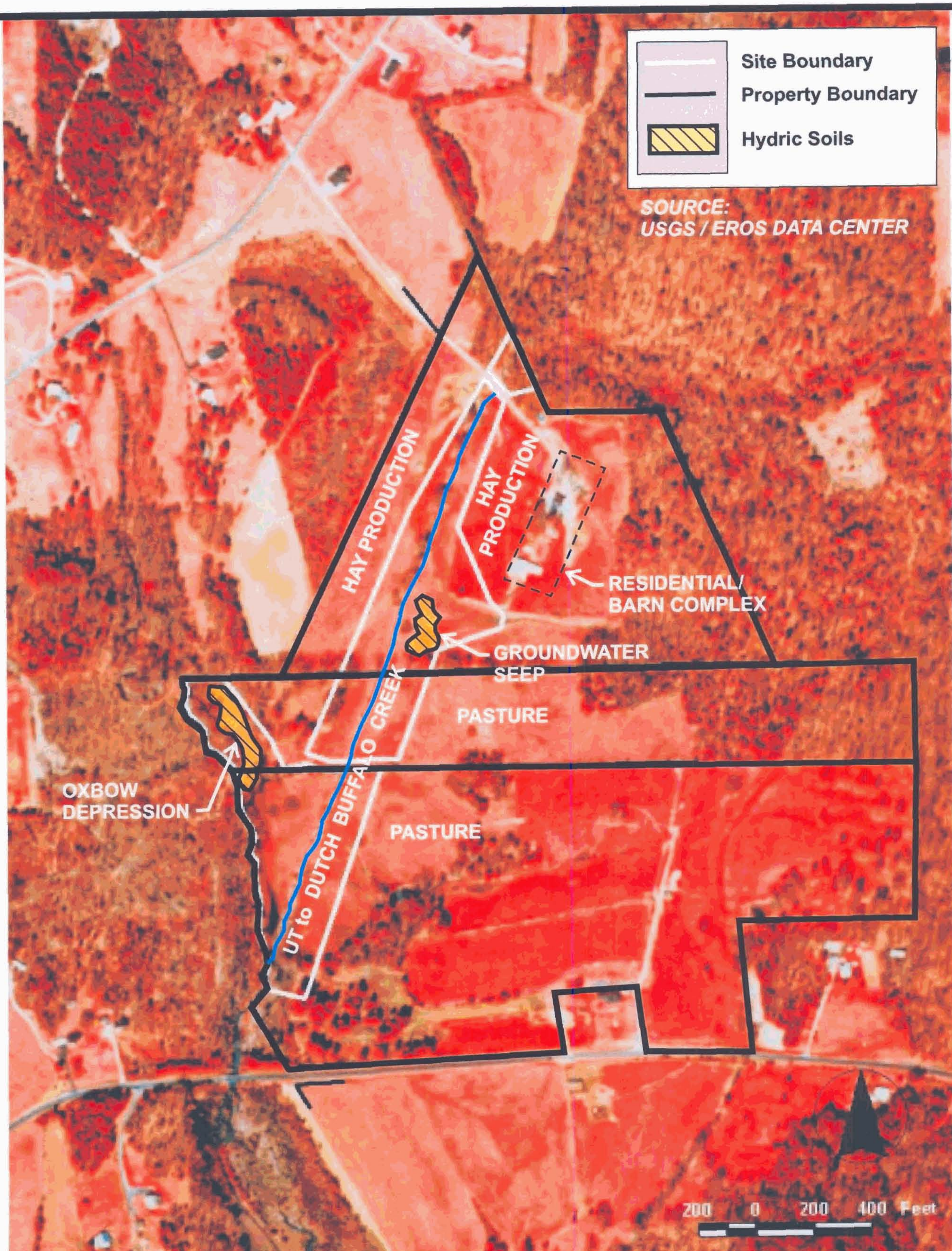
| Ckd by: | WGL |
| Date: | NOV 2002 |
| Project: | 00-046.26 |

FIGURE
6

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**ON-SITE LAND USE**
**UT to Dutch Buffalo Creek**
**DETAILED MITIGATION STUDIES**
Rowan County, North Carolina

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| Dwn. by: | MAF |
| Ckd by: | WGL |
| Date: | NOV 2002 |
| Project: | 00-046.26 |

FIGURE 7

### 3.2 Soils

On-site soils have been mapped by the NRCS (NRCS 1995) (Figure 8). Soils were verified in the summer of 2002 by a licensed soil scientist to refine soil map units and to locate inclusions and tax-adjunct areas. The areas most intensely surveyed include low-lying floodplain areas. Systematic transects were established and sampled to ensure proper coverage. Soils were sampled for color, texture, consistency, and depth at each documented horizon. As depicted in Figure 9, three soil map units were identified: Chewacla, Cecil, and Enon/Mecklenburg.

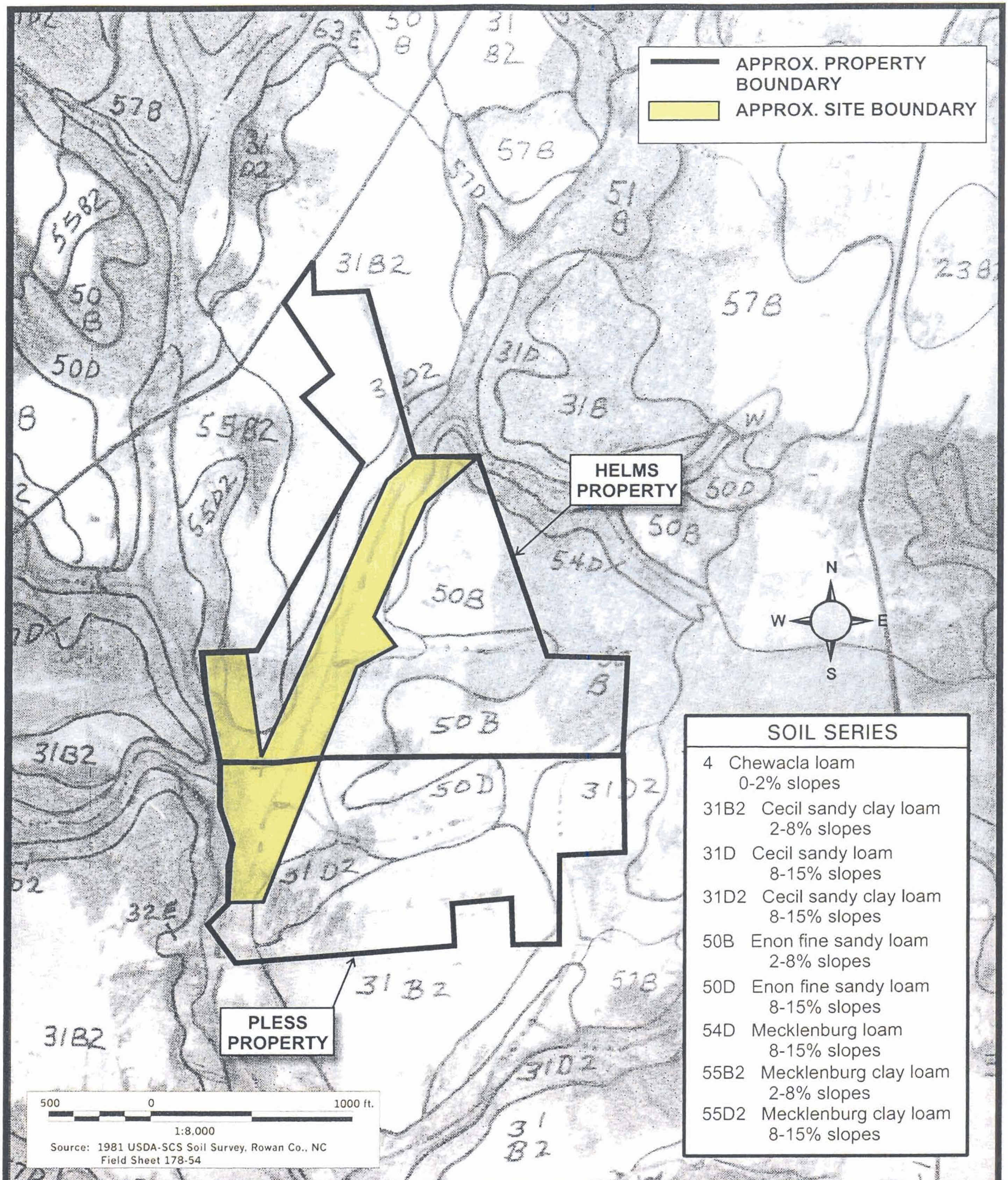
Chewacla loam is the prevailing Site soil, encompassing approximately 12.1 acres while dominating the floodplain. Chewacla loam consists of nearly level, somewhat poorly drained soils. These are very deep soils that are frequently flooded. Permeability is moderate, available water capacity is high, and runoff is slow. The root zone within these soils is moderately deep and the depth to the seasonal high water table ranges from 0.5 to 1.5 feet (NRCS 1995). The interior portions of the floodplain are made up of silty clay loams while the floodplain edges exhibit sand textured-loams and clays (Figure 10). Although not listed as hydric, Chewacla loam is listed as containing inclusions of hydric soils. The normal location for inclusions is adjoining upland side slopes and depressions (NRCS 1997).

Hydric soils are defined as "soils that are saturated, flooded, or ponded long enough during the growing season to develop anaerobic conditions in the upper soil layer" (SCS 1987). Hydric soil map units were not identified within the Site. However, inclusions of hydric soils were identified during ground truthing of soil map units. Two pockets of hydric soils were found in the Chewacla soil mapping unit, occupying approximately 0.6 acre of the Site. The first is a groundwater seep abutting a side slope in the eastern portion of the floodplain. The second is near the western terminus of the Site in an oxbow depression. The groundwater seep consists mainly of silty clay loams, while the oxbow depression is characterized by sandy clay / clay loams (Figure 10). Within the oxbow depression, unconsolidated gravel was found at depths of 40 inches, suggesting the presence of a relict stream bed.

The Cecil series is located in the northwest and southeast portions of the Site on side slopes adjacent to the floodplain. Encompassing approximately 1.4 acres, these are very deep, well-drained soils with moderate permeability. The Enon/Mecklenburg complex consists of very deep, well-drained soils with slow permeability. Located on the west-facing slopes of the Site, these soils encompass approximately 0.9 acre.

### 3.3 Plant Communities

Distribution and composition of plant communities reflect landscape-level variations in topography, soils, hydrology, and past or present land use practices. Three plant communities have been identified on the Site and include: 1) successional agricultural fields, 2) mesic hardwood forest, and 3) hydrophytic assemblage.

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**NRCS SOILS MAP**
**UT to Dutch Buffalo Creek**
**DETAILED MITIGATION STUDIES**
Rowan County, North Carolina

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| Dwn. by: | MAF |
| Ckd by: | WGL |
| Date: | NOV 2002 |
| Project: | 00-046.26 |

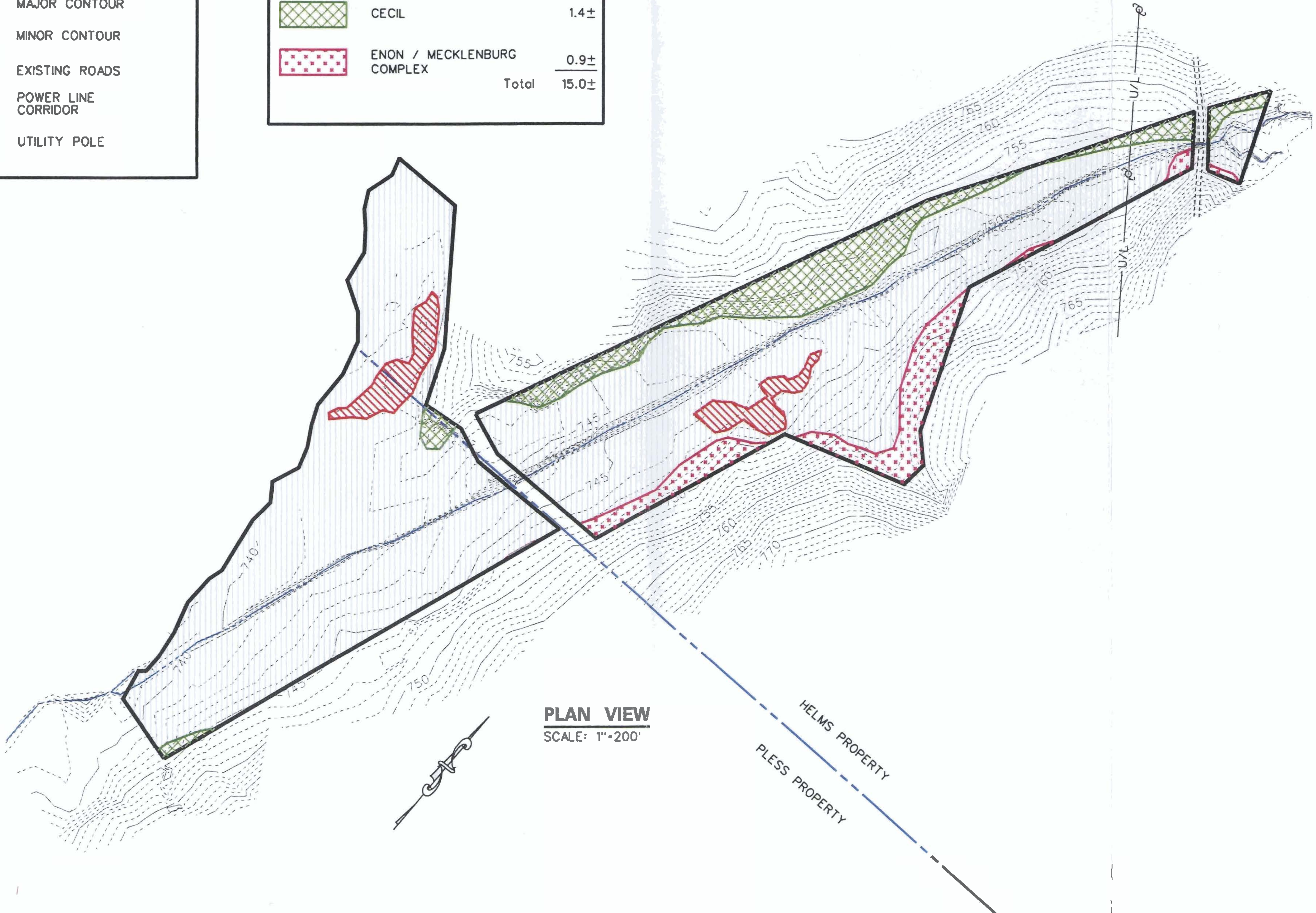
FIGURE
8

## LEGEND

| | |
|---|---|
| (heavy solid line) | SITE BOUNDARY |
| (dashed line) | PROPERTY LINE |
| ——120—— | MAJOR CONTOUR |
| (dotted line) | MINOR CONTOUR |
| (double dashed line) | EXISTING ROADS |
| ——U/L—— | POWER LINE CORRIDOR |
| (symbol) | UTILITY POLE |

## SOILS LEGEND

| | | acres |
|---|---|---|
| | HYDRIC INCLUSIONS/ CHEWACLA | 0.6± |
| | CHEWACLA | 12.1± |
| | CECIL | 1.4± |
| | ENON / MECKLENBURG COMPLEX | 0.9± |
| | Total | 15.0± |




**PLAN VIEW**
SCALE: 1"=200'

EcoScience Corporation
Raleigh, North Carolina

REVISIONS

Client:
**NCDOT**

Project:
**UT to DUTCH BUFFALO CREEK**

**DETAILED MITIGATION STUDIES**

ROWAN COUNTY, NORTH CAROLINA

Title:
**MODIFIED SOIL UNITS**

| Dwn By: MAF | Date: NOV 2002 |
|---|---|
| Ckd By: WGL | Scale: 1"= 200' |

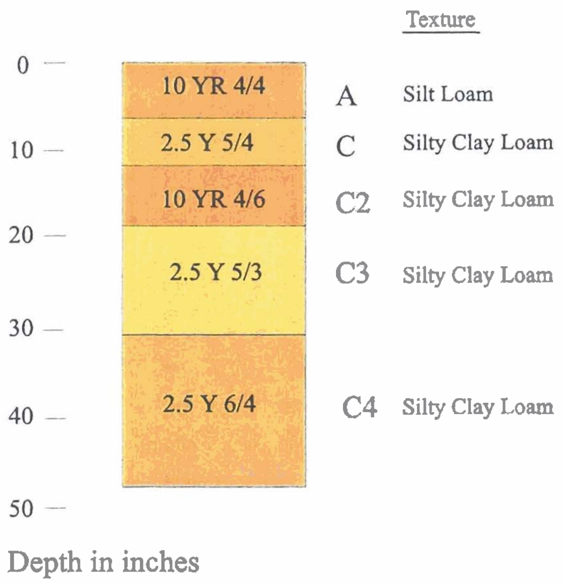
ESC Project No.: 00-046.26

FIGURE
**9**

# SOIL PROFILES

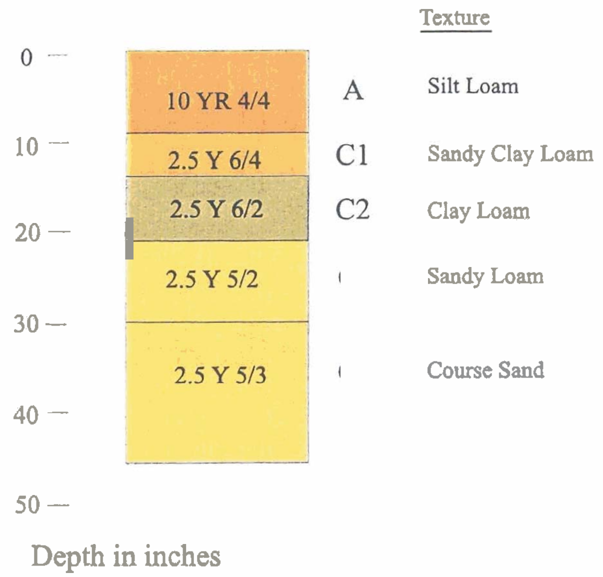
## Chewacla Loam

### (INNER FLOODPLAIN) - Upland



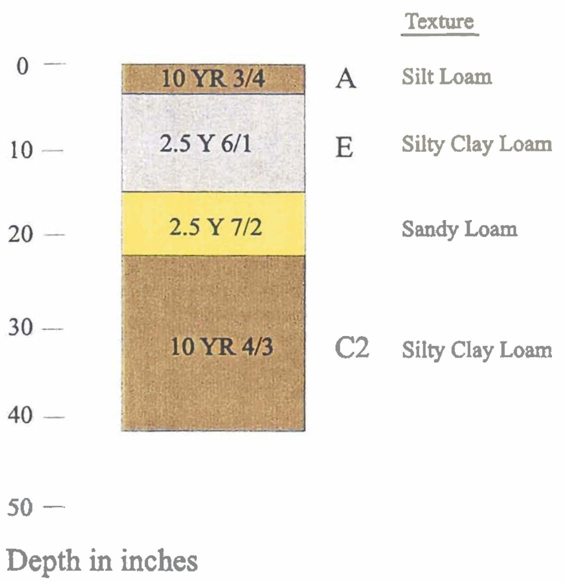

## Chewacla Loam

### (OUTER FLOODPLAIN) - Upland



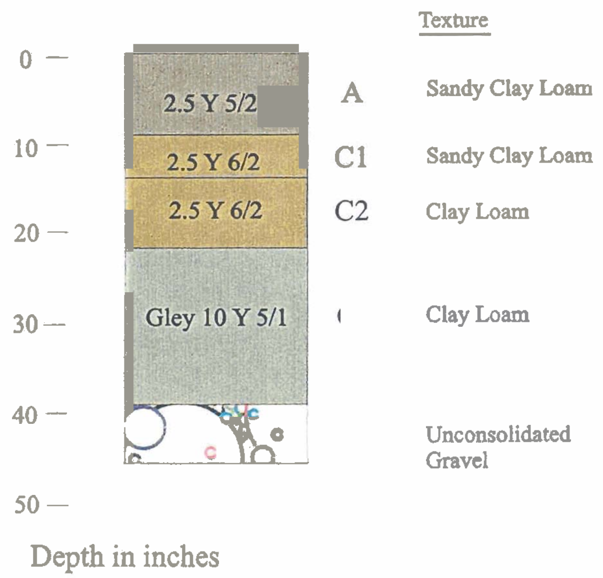

## Chewacla Loam

### (GROUNDWATER SEEPAGES) - Hydric Inclusion




## Chewacla Loam

### (OXBOW DEPRESSIONS) - Hydric Inclusion




| | | | |
|---|---|---|---|
| EcoScience Corporation<br>Raleigh, North Carolina | **SOIL PROFILES**<br>**UT to Dutch Buffalo Creek**<br>**DETAILED MITIGATION PLANNING**<br>Rowan County, North Carolina | Dwn. by: WGL<br>Ckd by: WGL<br>Date: NOV 2002<br>Project: 00-046.26 | Figure<br>10 |

Successional agricultural fields dominate the Site, accounting for more than 90 percent of the area. This community varies in composition from fallow hay fields to livestock pasture. Hay fields are characterized by maintained planted grasses such as alfalfa (*Medicago sativa*), fescue (*Festuca octiflora*), and bluegrass (*Poa pratensis*). Pasture land consists of similar grass species; however, selective grazing appears to have lowered densities of the palatable grass species. Natural recruitment of ruderal species such as broomsedge (*Andropogon virginicus*), violet (*Viola papilionacea*), plantain (*Plantago rugelii*), goldenrods (*Solidago* spp.), wild onion (*Allium canadense*), ox-eye daisy (*Chrysanthemum leucanthemum*), and joe-pye-weed (*Eupatorium fistulosum*) appear to be quickly re-colonizing the Site since bush hogging has been halted.

Mesic hardwood forest exists as small, isolated stands sparsely located throughout the Site. The majority of this community is found in the western portion of the Site, on a topographically elevated area. This is a mature community and includes species such as pignut hickory (*Carya glabra*), shagbark hickory (*Carya ovata*), white ash (*Fraxinus americana*), sweetgum (*Liquadambar styraciflua*), tulip poplar (*Liriodendron tulipifera*), Virginia pine (*Pinus virginiana*), flowering dogwood (*Cornus florida*), and eastern red cedar (*Juniperus virginiana*). A few individuals are found adjacent to the degraded channel in the northern portion of the Site. A line of individuals also runs east to west in the center of the Site and appears connected to relic fencing.

Two hydrophytic assemblage communites are located within the Site boundaries and are associated with Site hydric soils (Section 3.2). The first is at the toe of a side slope, adjacent to the eastern portion of the floodplain. This area is dominated by regularly mowed rushes (*Juncus* spp.) and sedges (*Carex* spp.). The second is located in the western portion of the Site and is believed to be the result of a relict oxbow. Species include tearthumb (*Polygonum sagitatum*), swamp smartweed (*Polygonum hydropiperoides*), Virginia knotweed (*Polygonum virginianum*), false nettle (*Boehmeria cylindrica*), various sedges and rushes, and jewel weed (*Impatiens capensis*). There are few, small, woody species present, most likely owing to infrequent maintenance. Woody species include tag alder (*Alnus serrulata*), boxelder (*Acer negundo*), and American elm (*Ulmus americana*).

## 3.4 Hydrology

Site hydrology is composed of surface water flows, groundwater migration into open water conveyances, and, to a lesser extent, precipitation. Surface water flows result primarily from upstream drainage basin catchment, discharge into upstream feeder tributaries, and surface water flows into and through the Site. No active seeps or springs have been identified within the Site which lend significant hydrology to the UT; however, two on-site wetland depressions may indicate a coalescing of on-site groundwater which may function for hydrologic storage during drought or flood events.

### 3.4.1 Drainage Area

This hydrophysiographic region is considered characteristic of the Piedmont Physiographic Province, which extends throughout central portions of North Carolina. The region is characterized by moderately high rainfall and broad, rolling, interstream divides intermixed with steeper slopes along well-defined drainage ways. In the Rowan County area, precipitation averages 46 inches annually, distributed evenly throughout the year (NRCS 1995). The Site is located in USGS Hydrologic Unit #03040105 (USGS 1974).

The Site drainage area encompasses approximately 320 acres (0.5 square mile) at the upstream terminus and approximately 385 acres (0.6 square mile) at the Site downstream outfall. The drainage area is dominated by rural land uses including mature bottomland forest and agriculture. Impervious surfaces have been estimated as less than 10 percent of the land area within the watershed.

The channel originates in the upper watershed immediately south of NC 152 and continues for approximately 7900 linear feet to a confluence with Dutch Buffalo Creek. The valley, in portions of the upper watershed, supports a relatively narrow floodplain with relatively steep valley slopes (approximately 0.0076 rise/run). As the tributary descends towards Dutch Buffalo Creek, the valley widens and flattens to a slope of 0.0056 (rise/run) at the bottom of the Site.

### 3.4.2 Discharge

Discharge estimates for the Site utilize an assumed definition of "bankfull" and the return interval associated with the bankfull discharge. For this study, the bankfull channel is defined as the channel dimensions designed to support the "channel forming" or "dominant" discharge (Gordon *et al.* 1992). Research indicates that a stable stream channel may support a return interval for bankfull discharge, or channel-forming discharge, of between 1 to 2 years (Gordon *et al.* 1992, Dunne and Leopold 1978). The methods of Rosgen (1996) indicate calibration of bankfull dimensions based on a potential bankfull return interval of between 1.3 and 1.7 years for rural conditions.

Based on available regional curves, bankfull discharge for the on-site UT (0.6 square mile watershed) averages approximately 61.6 cubic feet per second (cfs) (Harman *et al.* 1999). To verify regional curves, three gauged streams (Dutchmans Creek, Norwood Creek, and Big Bear Creek) of similar watershed area to the Site were analyzed to determine a return interval for momentary peak discharges. Momentary peak discharges (return interval between 1.3 and 1.7 years) were calculated from the gauge data and plotted against the regional curve (Appendix A). Momentary peak discharges were accurately predicted at two of the three stream gauges. The other stream gauge predicted a lower discharge (based on regional curve predictions of discharge) suggesting higher discharges than predicted by the regional curve.

Bankfull indicators in the field have also been utilized to predict bankfull discharge. The cross-sectional area associated with field indicators has been compared to regression equations that relate discharge to cross-sectional area in rural Piedmont streams. The average bankfull cross-sectional area in the channel has been estimated at approximately 14.4 square feet, suggesting a bankfull discharge of approximately 58.2 cubic feet per second (cfs). For this project, the stable "design" channel is assumed to support a bankfull discharge (1.3-year return interval) of between 55 and 62 cfs at the Site outfall under existing watershed conditions.

The UT to Dutch Buffalo Creek watershed, the primary hydroligic feature within the Site, has experienced drought-like conditions over the past year. As a result, the UT was unable to express flow during the summer and early fall of 2002. Mr. Helms senior, who has lived on this land for nearly 70 years, revealed to EcoScience Corporation (ESC) biologists that this is only the second time in his life he has witnessed the on-site channel devoid of surface water flows.

### 3.4.3 Flood Frequency and Water Surface Elevations

Flood elevations have been approximated by use of a Hydraulic Engineering Center's – River Analysis System (HEC-RAS) computer model. The purpose of the analysis is to predict flood extent for the 1-, 2-, 10-, 25-, 50-, and 100-year storms under existing conditions. Subsequently, the model was applied to proposed conditions, after stream restoration, to assess potential for impacts to adjacent properties or structures, and to assess potential for increased safety risk to the community associated with large floods. The existing flood elevations for each storm and the proposed, post restoration storm flow elevations are depicted in Table 1 and Figure 11.

Existing Conditions

In summary, the model suggests that channel flooding is confined within the existing channel for 1- and 2-year storm events. However, larger (10-, 25-, 50-, and 100-year) storm events appear to top the existing banks and flow onto the adjacent floodplain (Figure 11). In the upstream portion of the Site, flooding associated with these storms is confined by steep valley walls to the relatively narrow valley floor; however, in the downstream portion of the Site, flooding extends into the Dutch Buffalo Creek floodplain. No structures or state-maintained roadways occur within the floodplain; therefore, flooding impacts are expected to be minimal, including agricultural field inundation and potential crop loss.

Projected, Post-Restoration Conditions

On-site channel restoration may raise storm flow elevations by 1) increasing floodplain roughness through vegetative planting, 2) decreasing channel cross-sectional area, 3) raising the channel bed, and 4) increasing sinuosity. Elevation of channel water surfaces may potentially effect upstream properties; therefore, the effects of upstream, off-site, flooding have been evaluated.

# Table 1

**WATER SURFACE ELEVATIONS FOR VARIOUS FLOOD FREQUENCIES**

| Run | Station | 1-year | | 2-year | | 10-year | | 25-year | | 50-year | | 100-year | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Existing | Proposed | Existing | Proposed | Existing | Proposed | Existing | Proposed | Existing | Proposed | Existing | Proposed |
| Existing<br>Proposed | 286.3<br>238.7 | 742.20 | 739.21 | 742.57 | 739.71 | 743.91 | 741.00 | 744.61 | 741.54 | 745.16 | 741.92 | 745.74 | 742.30 |
| Existing<br>Proposed | 428.6<br>400.8 | 742.21 | 740.25 | 742.59 | 740.74 | 743.93 | 741.97 | 744.63 | 742.53 | 745.18 | 742.90 | 745.75 | 743.29 |
| Existing<br>Proposed | 587.8<br>595.0 | 742.55 | 741.59 | 742.74 | 742.28 | 744.01 | 743.18 | 744.67 | 743.52 | 745.21 | 743.83 | 745.78 | 744.16 |
| Existing<br>Proposed | 886.7<br>1038.7 | 744.13 | 743.67 | 744.84 | 744.30 | 744.59 | 744.99 | 745.36 | 745.42 | 745.36 | 745.72 | 745.90 | 746.02 |
| Existing<br>Proposed | 1245.2<br>1500.0 | 746.61 | 746.64 | 747.13 | 747.00 | 748.33 | 747.77 | 748.14 | 748.12 | 748.46 | 748.39 | 748.37 | 748.66 |
| Existing<br>Proposed | 1386.5<br>1707.9 | 747.52 | 747.87 | 748.05 | 748.26 | 748.81 | 748.89 | 749.20 | 749.23 | 749.35 | 749.51 | 749.68 | 749.79 |
| Existing<br>Proposed | 1778.9<br>2237.3 | 749.18 | 750.77 | 749.79 | 750.88 | 751.08 | 751.47 | 751.46 | 751.81 | 751.82 | 752.07 | 752.02 | 752.35 |
| Existing<br>Proposed | 1929.3<br>2413.8 | 750.51 | 751.68 | 751.06 | 752.04 | 752.57 | 752.61 | 753.04 | 752.92 | 753.22 | 753.17 | 753.45 | 753.42 |

## LEGEND

SITE BOUNDARY

PROPERTY LINE

EXISTING STREAM

120 MAJOR CONTOUR

MINOR CONTOUR

EXISTING ROADS

U/L POWER LINE CORRIDOR

FLOOD ELEVATIONS
interval

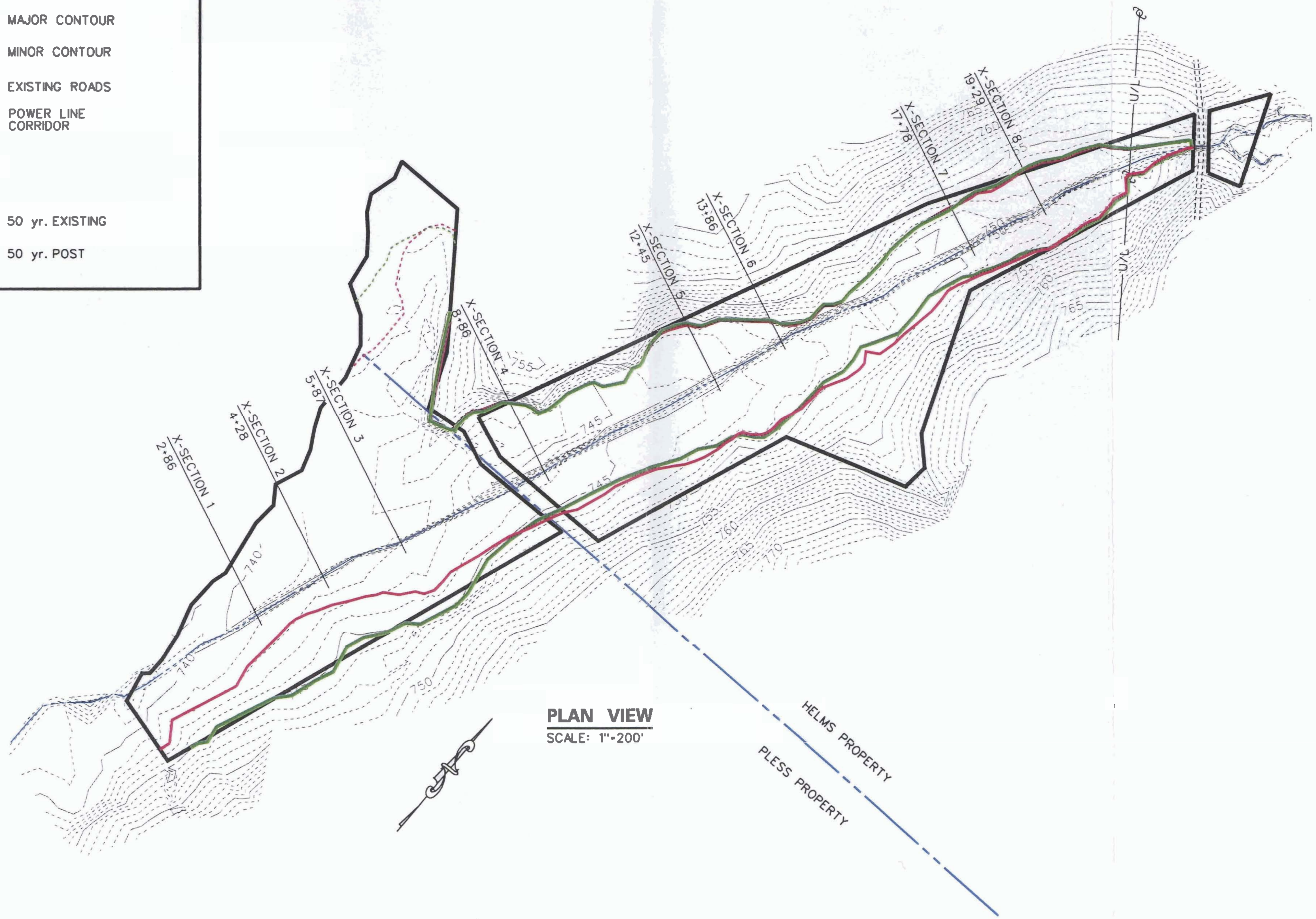
50 yr. EXISTING

50 yr. POST

**NOTE:**

CROSS-SECTION LOCATIONS INDICATED ON THIS SHEET MATCH EXISTING LOCATIONS (SEE FIGURE 12).

CROSS-SECTION STATIONING ON THIS SHEET BEGINS AT THE DOWNSTREAM TERMINUS OF THE PROJECT AREA TO FACILITATE HYDROLOGIC MODELLING. THE NUMBERING HAS CHANGED ACCORDINGLY.




**PLAN VIEW**
SCALE: 1"=200'

EcoScience Corporation
Raleigh, North Carolina

REVISIONS

Client: **NCDOT**

Project: **UT to DUTCH BUFFALO CREEK**

**DETAILED MITIGATION STUDIES**

ROWAN COUNTY, NORTH CAROLINA

Title: **FLOOD FREQUENCY AND WATER SURFACE ELEVATIONS**

| Dwn By: MAF | Date: NOV 2002 |
|---|---|
| Ckd By: WGL | Scale: 1"= 200' |

ESC Project No.: 00-046.26

FIGURE

**11**

The deleterious effects of elevated stormwater flows may be offset through 1) excavating floodplains and/or floodplain benches adjacent to the channel, thereby increasing the effective storm flow channel; 2) decreasing the width to depth ratio of the channel; 3) reducing the roughness of the excavated channel as compared to the existing channel; and 4) initiation of stream restoration activities downstream from the upstream Site boundary.

Based on the flood frequency analysis (Table 1 and Figure 11), the model predicts a 0.98-foot elevation of stormwater flows for the 2-year event (751.06 to 752.04 feet of elevation) at the upper extent of the Site. However, stormwater flows for the 50-year and 100-year events are predicted to be lowered at the upper extent of the Site by 0.05 foot (753.22 to 753.17) and 0.03 foot (753.45 to 753.42), respectively. This reduction in storm flow elevations results primarily from floodplain excavation adjacent to the first 2100 feet of the proposed channel. At the downstream terminus of the Site, the model predicts a reduction of stormwater flows for all respective events. The 2-year storm event is predicted to be lowered by 2.86 feet (742.57 to 739.71) while the 50-year and 100-year events are predicted to be lowered by 3.24 feet (745.16 to 741.92) and 3.44 feet (745.74 to 742.30), respectively, indicating that proposed mitigation alternatives are not expected to adversely impact adjacent properties or structures.

### 3.4.4 Shear Stress and Sediment Transport

Shear stress, expressed as force per unit area, is a measure of the frictional force that water exerts on a stream channel. Critical shear stress relates to the magnitude of shear stress required to entrain various sediment sizes into the water column. Shear stress and sediment entrainment are affected by sediment supply (size and amount), energy distribution within the channel, and frictional resistance of the stream bed and bank on water within the channel. These variables ultimately determine the ability of a stream to efficiently transport bedload and suspended sediment.

Shear stress represents a difficult variable to predict due to variability of channel slope, dimension, and pattern. Typically, as valley slope decreases channel depth and sinuosity increase to maintain adequate shear stress values for bedload transport. Channels which have higher shear stress values than necessary for bedload transport scour bed and bank materials resulting in channel degradation. Channels with lower shear stress values than necessary for bedload transport deposit sediment resulting in channel aggradation.

Shear stress and sediment transport were estimated utilizing various methods including 1) entrainment calculations based on fluvial geomorphic principles (Rosgen 1996), 2) HEC-RAS models, and 3) Stream Power. Data for each method is included in Appendix B.

#### 3.4.4.1 Entrainment Calculations

Shear stress and sediment transport were estimated utilizing fluvial geomorphic principles. Values of critical shear stress and sediment entrainment were calculated by collecting sediment from a depositional bar feature in the upstream reference reach. The depositional bar feature is expected to represent the characteristic sediment load in the channel. The median particle size measured in the depositional bar feature is 6 millimeters and the largest particle size is 38 millimeters. The design channel is expected to be constructed to effectively transport sediment up to 38 millimeters in size through the reconstructed reach.

Utilizing bedload estimates obtained in the upstream depositional bar feature, and assuming a fixed average water surface slope of 0.0057 rise/run in the upstream reach and 0.0042 rise/run in the downstream reach, entrainment calculations indicate that a mean bankfull channel depth of approximately 1.3 feet (upstream) and 1.8 feet (downstream) are required to transport a 38 millimeter particle through the Site. Proposed median depths of the upstream reach are 1.4 feet. Proposed median depths of the downstream reach are 1.6 feet.

Analysis of the proposed profile indicates that the average slope (a reach of eight riffles) ranges from 0.0051 to 0.0064 rise/run in the upper reach and 0.0037 to 0.0052 rise/run in the lower reach. This would indicate that the mean bankfull depth required to effectively transport sediment may range from 1.2 to 1.5 feet in the upstream reach and 1.4 to 2.1 feet in the downstream reach.

Based on this analysis, it appears that design depths for the proposed channel vary a maximum of 0.2 feet for the range of slopes predicted in the upstream reach. This would indicate that the upper reach will adequately transport sediment through the Site without aggrading or degrading. However, downstream design depths for the proposed channel vary from 0.2 to 0.5 feet for the range of slopes predicted by the entrainment evaluation. This may indicate possible aggradation in the lower one-third of the downstream reach. Excavation of this portion of the downstream reach to greater depths in support of this conclusion is not possible however, due to off-site tie in elevations located in an aggraded reach of the mainstem channel.

#### 3.4.4.2 HEC-RAS Model

Shear stress was calculated in the proposed design channel utilizing a HEC-RAS model to verify shear stress and critical design depth values. Calculated shear stress values for the upstream reach ranged from 0.24 to 0.65 pounds per square foot. Shear stress values for the downstream reach ranged from 0.28 to 0.45 pounds per square foot. The allowable shear stress for a vegetated bank is approximately 2 pounds per square foot and the permissible shear stress for bare earth is approximately 0.18 pounds per square foot. Based on these results, the channel may require a temporary linear until vegetation is established. Shear stress values appear within the constraints of a vegetated stream bank and utilization of a coir fiber matting on the stream banks should allow for adequate stabilization until vegetation has established.

The HEC-RAS analysis was utilized to calculate critical depths for the proposed design channel. Critical depths calculated by the HEC-RAS model range from approximately 1.6 to 1.9 feet in the upper reach and 2.1 to 2.2 feet in the downstream reach. Proposed channel maximum depths in the upstream and downstream reach are approximately 1.8 and 2.1 feet, respectively. Based on results of this analysis, critical depths of the proposed design channel are suitable for shear values and expected channel velocities within the Site.

#### 3.4.4.3 Stream Power

Stability of a stream refers to its ability to adjust itself to in-flowing water and sediment load. One form of instability occurs when a stream is unable to transport its sediment load, leading to the condition referred to as aggradation. Conversely, when the ability of the stream to transport sediment exceeds the availability of sediments entering a reach and/or stability thresholds for materials forming the channel boundary are exceeded, erosion or degradation occurs.

Stream power is the measure of a stream's capacity to move sediment over time. Stream power can be used to evaluate the longitudinal profile, channel pattern, bed form, and sediment transport of streams. Stream power may be measured over a stream reach (total stream power) or per unit of channel bed area. The total stream power equation is defined as:

$$\Omega = \rho g Q s$$

where $\Omega$ = total stream power (lb-ft/s$^2$), $\rho$ = density of water, g = gravitational acceleration, Q = discharge (cfs), and s = energy slope (rise/run). The specific weight of water ($\gamma$ = 62.4 pounds per cubic foot [lb/ft$^3$]) is equal to the product of water density and gravitational acceleration, $\rho g$. A general evaluation of power for a particular reach can be calculated using bankfull discharge and water surface slope for the reach. As slopes become steeper and/or velocities increase, stream power increases and more energy is available for re-working channel materials. Straightening and clearing channels increases slope and velocity and thus stream power. Alterations to the stream channel may conversely decrease stream power. In particular, over widening of a channel will dissipate energy of flow over a larger area. This process will decrease stream power, allowing sediment to fall out of the water column, possibly leading to aggradation of the streambed.

The relationship between a channel and its floodplain is also important in determining stream power. Streams that remain within their banks at high flows tend to have higher stream power and relatively coarser bed materials. In comparison, streams that flood over their banks onto adjacent floodplains have lower stream power, transport finer sediments, and are more stable. Stream power assessments can be useful in evaluating sediment discharge within a stream and the deposition or erosion of sediments from the streambed.

Shear stress, expressed as force per unit area, is a measure of the frictional force that flowing water exerts on a streambed. Shear stress and sediment entrainment are affected by sediment supply (size and amount), energy distribution within the channel, and frictional resistance of the streambed and bank on water within the channel. These variables ultimately determine the ability of a stream to efficiently transport bedload and suspended sediment.

For flow that is steady and uniform, the average boundary shear stress exerted by water on the bed is defined as follows:

$$\tau = \gamma Rs$$

where $\tau$ = shear stress (pounds per square foot [lb/ft$^2$]), $\gamma$ = specific weight of water, R = hydraulic radius (ft), and s = the energy slope (rise/run). Shear stress calculated in this way is a spatial average and does not necessarily provide a good estimate of bed shear at any particular point. Adjustments to account for local variability and instantaneous values higher than the mean value can be applied based on channel form and irregularity. For a straight channel, the maximum shear stress can be assumed from the following equation:

$$\tau_{max} = 1.5\tau$$

for sinuous channels, the maximum shear stress can be determined as a function of plan form characteristics:

$$\tau_{max} = 2.65\tau(R_c/W_{bkf})^{-0.5}$$

where $R_c$ = radius of curvature (ft) and $W_{bkf}$ = bankfull width (ft).

The actual amount of work accomplished by a stream per unit of bed area depends on the available power divided by the resistance offered by the channel sediments, plan form, and vegetation. The stream power equation can thus be written as follows:

$$\omega = \rho gQs = \tau v$$

where $\omega$ = stream power per unit of bed area (N/ft-sec, Joules/sec/ft$^2$), $\tau$ = shear stress, and v = average velocity (ft/sec). Similarly,

$$\omega = \Omega/W_{bkf}$$

where $W_{bkf}$ = width of stream at bankfull (ft).

### 3.4.4.4 Stream Power and Shear Stress Methods and Results

Channel degradation or aggradation occurs when hydraulic forces exceed or do not approach the resisting forces in the channel. The amount of degradation or aggradation is a function of relative magnitude of these forces over time. The interaction of flow within the boundary of open channels is only imperfectly understood. Adequate analytical expressions describing this interaction have yet to be developed for conditions in natural channels. Thus, means of characterizing these processes rely heavily upon empirical formulas.

Traditional approaches for characterizing stability can be placed in one of two categories: 1) maximum permissible velocity and 2) tractive force, or stream power and shear stress. The former is advantageous in that velocity can be measured directly. Shear stress and stream power cannot be measured directly and must be computed from various flow parameters. However, stream power and shear stress are generally better measures of fluid force on the channel boundary than velocity.

Using the aforementioned equations, stream power and shear stress were estimated for 1) the existing on-site stream reach (taken at three cross-sections), 2) the upstream reference reach, and 3) proposed on-site conditions. Important input values and output results (including stream power, shear stress, and per unit shear power and shear stress) are presented in Table 2.

Average stream velocity and discharge values were calculated for the existing on-site stream reach, reference streams, and proposed conditions. Stream roughness coefficients (n) were estimated using a modified version of Jarrett's (1985) weighted method for Cowan's (1956) roughness-component values and applied to Manning's equation (Manning 1981).

Table 2. Stream Power ($\Omega$) and Shear Stress ($\tau$) Values

| | Discharge ($ft^3/s$) | Water surface Slope (ft/ft) | Total Stream Power ($\Omega$) | $\Omega/W$ | Hydraulic Radius | Shear Stress | Velocity | $\tau V$ | $\tau_{max}$ |
|---|---|---|---|---|---|---|---|---|---|
| **UT to Dutch Buffalo Creek (Existing)** | | | | | | | | | |
| Upstream G-type | 58 | 0.0076 | 27.5 | 2.8 | 1.0 | 0.47 | 4.5 | 2.1 | NA |
| Upstream E-type | 58 | 0.0076 | 27.5 | 2.5 | 1.0 | 0.47 | 4.1 | 1.9 | NA |
| Downstream Aggrading | 62 | 0.0025 | 9.7 | 0.9 | 1.1 | 0.17 | 4.3 | 0.7 | NA |
| **Upstream Reference** | | | | | | | | | |
| UT Reference | 50 | 0.0062 | 19.3 | 1.9 | 0.9 | 0.35 | 4.5 | 1.6 | 0.57 |
| **Proposed Conditions** | | | | | | | | | |
| Upstream | 58 | 0.0057 | 20.6 | 2.0 | 1.0 | 0.36 | 4.5 | 1.6 | 0.61 |
| Downstream | 62 | 0.0042 | 16.2 | 1.8 | 1.2 | 0.31 | 4.3 | 1.3 | 0.51 |

Calculations were performed on-site for the upstream straightened G-type reach, the upstream straightened E-type reach, the downstream aggrading reach, a reference reach and, proposed channel conditions. As would be expected, stream power and shear stress are lowest in the downstream aggrading reach (0.9 and 0.17, respectively). Conversely, stream power and shear stress are highest in the upstream G-type degrading reach (2.8 and 0.47, respectively) were slopes have been steepened by dredging and straightening activities and the channel has been maintained at a higher cross-sectional area and low width/depth ratio.

In order to maintain sediment transport functions of a stable stream system, the proposed channel should exhibit stream power and shear stress values between the aggrading and degrading on-site reaches of the Site. Results of the analysis indicate that the proposed channel is expected to maintain stream power values ranging from 1.8 to 2.0 and shear stress values ranging from 0.31 to 0.36. These values reside between values for unstable reaches measured for this study. In addition, these values are comparable to stream power and shear stress values identified in the upstream reference reach. Therefore, the design channel is expected to effectively transport sediment through the Site, resulting in stable channel characteristics.

### 3.4.5 Groundwater

Groundwater seepage results from upland terrestrial catchment, subsurface lateral groundwater flow, and expression of the groundwater table in jurisdictional wetland pockets or area stream margins. Groundwater seepage is related to the size and characteristics of the catchment basin while subsurface lateral flow is related to the porosity/conductivity of drainage basin soils. The drainage basin upstream of the Site is characterized largely by mature forest and open pasture with little impervious surface. With the exception of roads and roadside ditches, precipitation is expected to penetrate area soils and enter the groundwater table to be discharged into area streams. One groundwater seep occurs within the Site. This seep, depicted in Figure 7, is located at the base of the valley wall in a concave, water collection slope. The result is a wetland pocket approximately 0.23 acre in size.

Oxbow depressions are the result of shoot cutoffs and abandonment of an outer meander bend. When a tight bend in the stream becomes severed from the parent stream, a crescent-shaped oxbow lake is formed, and its character immediately begins to change. As sediment is deposited into the oxbow from periodic flooding the lake becomes shallower and, over time, evolves into a depressional wetland. A 0.32-acre, oxbow depression occurs in the inner-stream flat between Dutch Buffalo Creek and the UT to Dutch Buffalo Creek. Judging from the orientation of the depression, it appears that the oxbow was spawned from Dutch Buffalo Creek. This crescent-shaped feature, depicted in Figure 7, appears to support a growing layer of undecomposed organic matter and long-term, surface inundation. Soils within this depressional feature exhibit evidence of fluvial processes such as lateral stream migration. Buried surface horizons, buried organic debris, buried stream-bed substrate, and linear sand deposits suggest that the wetland surface has been periodically re-worked by stream dynamics. Studies indicate that under certain conditions, over 50 percent of a floodplain may be re-worked by stream shifts within a period of 70 years (Everitt 1968).

### 3.5 Stream Characterization

Stream characterization is intended to orient stream restoration based on a classification utilizing fluvial geomorphic principles (Rosgen 1996). This classification stratifies streams into comparable groups based on pattern, dimension, profile, and substrate characteristics. Primary components of the classification include degree of entrenchment, width/depth ratio, sinuosity, channel slope, and stream substrate composition. The stream classes characterizing existing reaches within the Site include G-type (gully) and E-type (low width to depth ratio) streams. Each stream type is modified by a number 1 through 6 (ex. E5) denoting a stream type which supports a substrate dominated by 1) bedrock, 2) boulders, 3) cobble, 4) gravel, 5) sand, or 6) silt/clay. The Site channel bed is dominated by gravel and sand (subclassification 4/5). Historically, the channel may have supported an E 4/5 stream type typical of those found in the North Carolina Piedmont under similar watershed conditions.

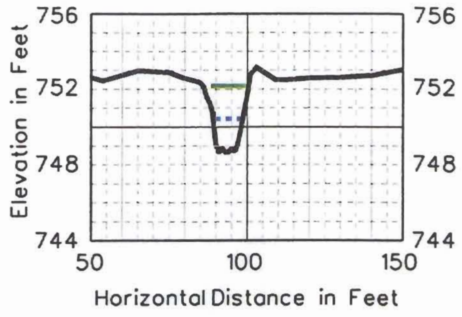
#### 3.5.1 Stream Geometry and Substrate

Stream geometry measurements under existing conditions are depicted in Figures 12 and 13 and summarized in Tables 3A and 3B. Individual cross-section data and other morphological data (including a morphological measurement table) are included in Appendix C. The upstream portion of the Site contains a transitional reach supporting characteristics of a G-type (gully) stream. G-type streams are characterized as highly entrenched streams with a low width/depth ratio (<12). Typically, G-type streams downcut and widen by eroding laterally into channel banks during peak flows. Over time, the widened gully develops into an F-type stream that supports a relatively high width/depth ratio (>12) and the presence of developing point and mid-channel bars. The increase in width/depth ratio in the bottom of the gully, due to bank erosion, will allow for development of a new floodplain at a lower elevation in the future. Subsequently, a meandering (C or E) channel would be expected to develop within the re-established floodplain.

The G-type reach of the upstream channel supports a flood-prone area of 16 feet in width with an entrenchment ratio ranging from 1.5 to 1.7. Livestock activity on the channel banks has eroded banks throughout the upstream channel. Without bank vegetation to reduce erosion, the banks are expected to continue eroding into a broad, widened gully with intermittent point and mid-channel bars (F-type stream).

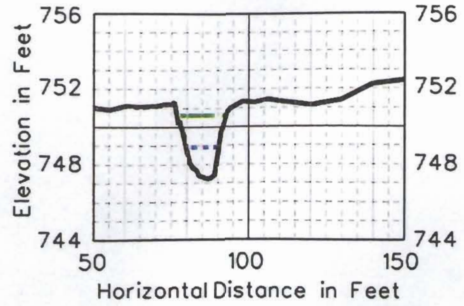
The upstream portion of the channel transitions from a G-type stream into an E-type (low width to depth ratio) stream. An E-type stream type is characterized as slightly entrenched with a very low width/depth ratio (<12). The E-type reach of the upstream channel supports a flood-prone area ranging from 190 to 200 feet in width with an entrenchment ratio ranging from 15 to 20.

3+50 CROSS-SECTION 1
(Riffle)



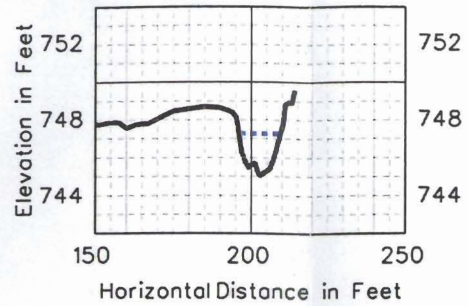

Bankfull Width: 9.4'
Bankfull Maximum Depth: 1.8'
Bankfull Average Depth: 1.4'
Bankfull Cross-sectional Area: 13.0 ft.sq.
Width of Flood Prone Area: 16.0'±

5+02 CROSS-SECTION 2
(Riffle)



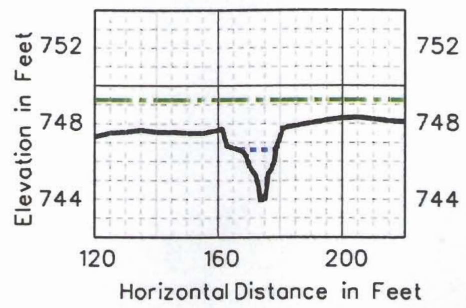

Bankfull Width: 10.5'
Bankfull Maximum Depth: 1.7'
Bankfull Average Depth: 1.2'
Bankfull Cross-sectional Area: 13.0 ft.sq.
Width of Flood Prone Area: 16.0'±

8+89 CROSS-SECTION 3
(Pool)




Bankfull Width: 13.4'
Bankfull Maximum Depth: 2.3'
Bankfull Average Depth: 1.5'
Bankfull Cross-sectional Area: 20.5 ft.sq.

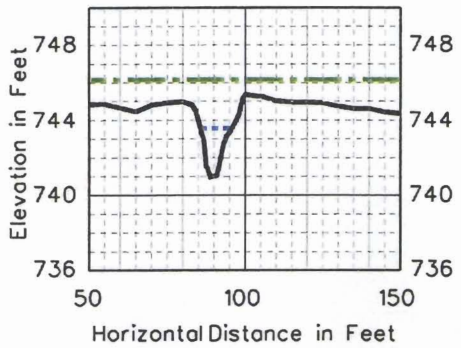
10+23 CROSS-SECTION 4
(Riffle)




Bankfull Width: 12.4'
Bankfull Maximum Depth: 2.7'
Bankfull Average Depth: 1.2'
Bankfull Cross-sectional Area: 14.3 ft.sq.
Width of Flood Prone Area: 190.0'±

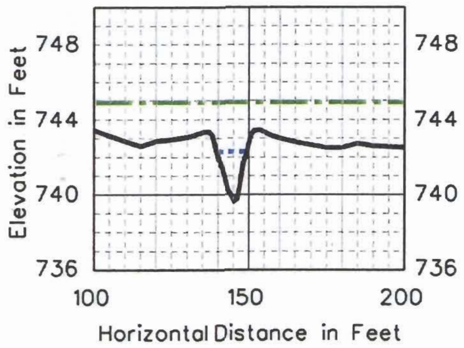
BANKFULL
EXISTING GRADE
FLOOD PRONE AREA

13+90 CROSS-SECTION 5
(Riffle)



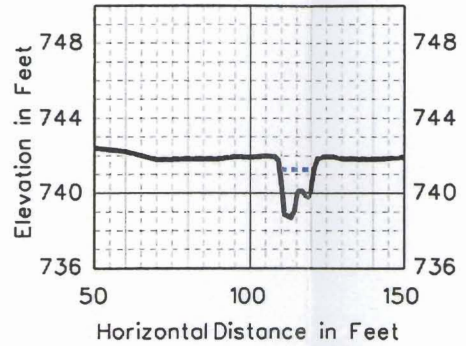

Bankfull Width: 10.0'
Bankfull Maximum Depth: 2.6'
Bankfull Average Depth: 1.4'
Bankfull Cross-sectional Area: 14.2 ft.sq.
Width of Flood Prone Area: 200.0'±

16+88 CROSS-SECTION 6
(Riffle)



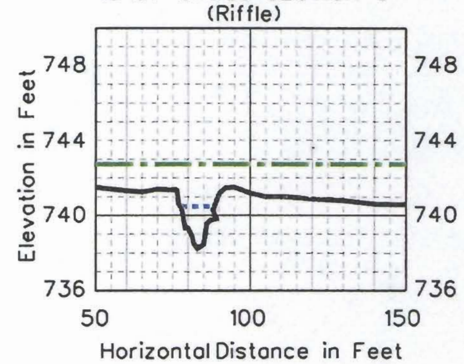

Bankfull Width: 9.7'
Bankfull Maximum Depth: 2.6'
Bankfull Average Depth: 1.5'
Bankfull Cross-sectional Area: 14.2 ft.sq.
Width of Flood Prone Area: 265.0'±

18+45 CROSS-SECTION 7
(Pool)




Bankfull Width: 11.6'
Bankfull Maximum Depth: 2.5'
Bankfull Average Depth: 1.5'
Bankfull Cross-sectional Area: 17.8 ft.sq.

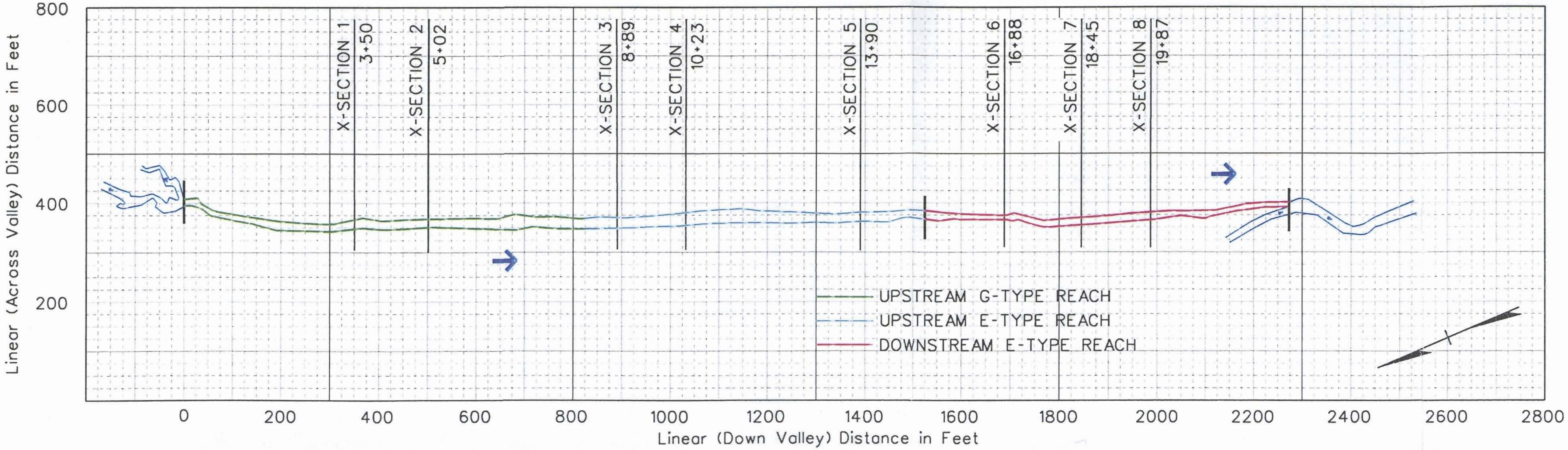
19+87 CROSS-SECTION 8
(Riffle)




Bankfull Width: 12.0'
Bankfull Maximum Depth: 2.2'
Bankfull Average Depth: 1.2'
Bankfull Cross-sectional Area: 14.6 ft.sq.
Width of Flood Prone Area: 220.0'±

NOTES:

1. All Cross-sections Facing the Downstream Direction.
2. Bankfull represents elevation at station point along best fit line drawn through bankfull elevation points for stream profile.
3. Cross-section stationing represents approximate field locations.




EcoScience Corporation
Raleigh, North Carolina

REVISIONS

Client:
NCDOT

Project:
UT to DUTCH BUFFALO CREEK
DETAILED MITIGATION STUDIES
ROWAN COUNTY, NORTH CAROLINA

Title:
EXISTING PLAN VIEW AND CROSS-SECTIONS

| Dwn By: MAF | Date: NOV 2002 |
|---|---|
| Ckd By: WGL | Scale: As Shown |

ESC Project No.: 00-046.26

FIGURE
12

**Table 3A**
**Stream Geometry and Classification**
**UT to Dutch Buffalo Creek Mitigation Site**
(See Figure12 for existing stream-type locations)

| Dimension | | | | | | |
|---|---|---|---|---|---|---|
| | Existing conditions (G-type) | | Upstream Existing Conditions (E-type) | | Downstream Existing Conditions | |
| Attribute | Median | Range | Median | Range | Median | Range |
| DA | 0.5 | 0.5 - 0.6 | 0.5 | 0.5 – 0.6 | 0.5 | 0.5 - 0.6 |
| $A_{bkf}$ | 13 | 13 | 14.3 | 14.2 – 14.3 | 14.4 | 14.2 - 14.6 |
| $W_{bkf}$ (riffle) | 10.0 | 9.4 - 10.5 | 11.2 | 10.0 – 12.4 | 10.9 | 9.7 - 12.0 |
| $D_{bkf}$ (riffle) | 1.3 | 1.2 - 1.4 | 1.3 | 1.2 – 1.4 | 1.4 | 1.2 - 1.5 |
| $D_{max}$ (riffle) | 1.8 | 1.7 - 1.8 | 2.7 | 2.6 – 2.7 | 2.4 | 2.2 - 2.6 |
| FPA (riffle) | 16 | 16 | 195 | 190 – 200 | 220 | 220 - 265 |
| $W_{pool}$ | 13.4 | NA | 13.4 | NA | 11.6 | NA |
| $D_{max}$ (pool) | 2.3 | NA | 2.3 | NA | 2.6 | NA |
| $L_{pool}$ | NA | NA | NA | NA | NA | NA |
| LBH | 3.5 | 3.5 | 4.0 | 3.8 – 4.2 | 3.2 | 2.9 – 3.5 |

| Pattern | | | | | | |
|---|---|---|---|---|---|---|
| | Upstream Existing Conditions (G-type) | | Upstream Existing Conditions (E-type) | | Downstream Existing Conditions | |
| Attribute | Median | Range | Median | Range | Median | Range |
| $W_{belt}$ | No distinct repetitive pattern of riffles and pools within the degraded channel | | No distinct repetitive pattern of riffles and pools within the degraded channel | | No distinct repetitive pattern of riffles and pools within the degraded channel | |
| $L_m$ | | | | | | |
| $R_c$ | | | | | | |
| $L_{p-p}$ | | | | | | |
| Sin | 1.0 | NA | 1.0 | NA | 1.0 | NA |

| Profile | | | | | | |
|---|---|---|---|---|---|---|
| | Upstream Existing Conditions (G-type) | | Upstream Existing Conditions (E-type) | | Downstream Existing Conditions | |
| Attribute | Median | Range | Median | Range | Median | Range |
| $S_{sw}$ | 0.0076 | NA | 0.0076 | NA | 0.0025 | NA |
| $S_{valley}$ | 0.0076 | NA | 0.0076 | NA | 0.0056 | NA |
| $S_{riffle}$ | No distinct repetitive pattern of riffles and pools | | No distinct repetitive pattern of riffles and pools | | No distinct repetitive pattern of riffles and pools | |
| $S_{pool}$ | | | | | | |

| Stream Type | G 5/4 | E 5/4 | E 5/4 |
|---|---|---|---|

| | |
|---|---|
| DA | Drainage Basin Area (sq. mi.) |
| $A_{bkf}$ | Bankfull cross-sectional area (riffle) ($ft^2$) |
| $W_{bkf}$ | Bankfull width (ft) |
| $D_{bkf}$ | Average bankfull depth (ft) |
| $D_{max}$ | Maximum depth (ft) |
| FPA | Floodprone Area (ft) |
| $W_{pool}$ | Channel width at a pool (ft) |
| $L_{pool}$ | Individual pool length (ft) |
| LBH | Low bank height (distance from thalweg to the top of low bank) (ft) |
| $W_{belt}$ | Belt width (ft) |
| $L_m$ | Meander wavelength (ft) |
| $R_c$ | Radius of Curvature (ft) |
| $L_{p-p}$ | Length from pool to pool (ft) |
| Sin | Sinuosity (thalweg dist/straight-line dist.) |
| $S_{ws}$ | Slope of the water surface (rise/run) |
| $S_{valley}$ | Slope of the valley (rise/run) |
| $S_{riffle}$ | Slope of the riffle (rise/run) |
| $S_{pool}$ | Slope of the pool (rise/run) |

## Table 3B
## Stream Geometry and Classification Ratios
## UT to Dutch Buffalo Creek Mitigation Site
(See Figure12 for existing stream-type locations)

**Dimension Ratios**

| Attribute | Upstream Existing Conditions (G-type) | | Upstream Existing Conditions (E-type) | | Downstream Existing Conditions | |
|---|---|---|---|---|---|---|
| | Median | Range | Median | Range | Median | Range |
| DA | 0.5 | 0.5 - 0.6 | 0.5 | 0.5 – 0.6 | 0.5 | 0.5 - 0.6 |
| ENT | 1.6 | 1.5 - 1.7 | 18 | 15 – 20 | 22.8 | 18.4 - 27.2 |
| $W_{bkf}/D_{bkf}$ | 7.5 | 7 - 8 | 9 | 7 – 11 | 9 | 7 - 10 |
| BHR | 2.0 | 1.9 - 2.1 | 1.5 | 1.4 – 1.6 | 1.3 | NA |
| $D_{max}$ (riffle) / $D_{ave}$ (riffle) | 1.4 | 1.3 - 1.4 | 2.1 | 1.9 – 2.3 | 1.8 | 1.7 – 1.8 |
| $D_{max}$ (pool) / $D_{ave}$ (riffle) | 1.8 | NA | 1.8 | NA | 1.6 | 1.5 – 1.9 |
| $W_{pool}$ / $W_{bkf}$ (riffle) | 1.3 | NA | 1.3 | NA | 1.2 | 1.1 - 1.4 |

**Pattern Ratios**

| Attribute | Upstream Existing Conditions (G-type) | | Upstream Existing Conditions (E-type) | | Downstream Existing Conditions | |
|---|---|---|---|---|---|---|
| | Median | Range | Median | Range | Median | Range |
| $W_{belt}/W_{bkf}$ | No distinct repetitive pattern of riffles and pools within the degraded channel | | No distinct repetitive pattern of riffles and pools within the degraded channel | | No distinct repetitive pattern of riffles and pools within the degraded channel | |
| $L_m/W_{bkf}$ | | | | | | |
| $R_c/W_{bkf}$ | | | | | | |
| $L_{p-p}/W_{bkf}$ | | | | | | |

**Profile Ratios**

| Attribute | Upstream Existing Conditions (G-type) | | Upstream Existing Conditions (E-type) | | Downstream Existing Conditions | |
|---|---|---|---|---|---|---|
| | Median | Range | Median | Range | Median | Range |
| $S_{valley}/S_{ws}$ | 1.0 | NA | 1.0 | NA | *2.2 | NA |
| $S_{riffle}/S_{ws}$ | No distinct repetitive pattern of riffles and pools | | No distinct repetitive pattern of riffles and pools | | No distinct repetitive pattern of riffles and pools | |
| $S_{pool}/S_{ws}$ | | | | | | |

| | |
|---|---|
| DA | Drainage Basin Area (sq. mi.) |
| ENT | Entrenchment ratio (FPA/$W_{bkf}$) |
| $W_{bkf}$ | Bankfull width (ft) |
| $D_{bkf}$ | Average bankfull depth (ft) |
| BHR | Bank height ratio [low bank height/$D_{max}$ (riffle)] |
| $D_{max}$ | Maximum depth (ft) |
| FPA | Floodprone area (ft) |
| | Channel width at a pool (ft) |
| $L_{pool}$ | Individual pool length (ft) |
| LBH | Low bank height (distance from thalweg to the top of low bank) (ft) |
| $W_{belt}$ | Belt width (ft) |
| $L_m$ | Meander wavelength (ft) |
| $R_c$ | Radius of Curvature (ft) |
| $L_{p-p}$ | Length from pool to pool (ft) |
| Sin | Sinuosity (thalweg dist/straight-line dist.) |
| $S_{ws}$ | Slope of the water surface (rise/run) |
| $S_{valley}$ | Slope of the valley (rise/run) |
| $S_{riffle}$ | Slope of the riffle (rise/run) |
| $S_{pool}$ | Slope of the pool (rise/run) |

* Ratio of valley slope to water surface slope is high due to beaver activity causing aggradation of the stream channel. Actual sinuosities appear to be approximately 1.0 - 1.1 (thalweg distance / straight-line distance) as calculated using in-field measurements.

Beaver activity on Dutch Buffalo Creek has greatly influenced downstream channel morphology. Slackwater conditions caused by beavers, coupled with a decreasing valley slope and excessive upstream bank collapse/sediment load, have resulted in particulate matter deposition and channel aggredation. Thus, the downstream portion of the channel supports characteristics of an E-type stream. The downstream reach supports a flood-prone area ranging from 220 to 265 feet in length with an entrenchment ratio ranging from 18 to 27.

Detailed pebble counts were conducted on the existing channel. These data (see Appendix C) show the majority of substrate to be fine sand. This indicates that bank collapse and channel erosion are supplying the on-site stream with an above-average sediment load of fine-textured material. Restoration efforts are designed to reduce bank collapse, channel erosion, and particulate material suspension/deposition.

### 3.6 Jurisdictional Wetlands

Jurisdictional wetland limits are defined using criteria set forth in the U.S. Army Corps of Engineers (COE) Wetlands Delineation Manual (DOA 1987). As stipulated in this manual, the presence of three clearly defined parameters (hydrophytic vegetation, hydric soils, and evidence of wetland hydrology) are required for a wetland jurisdictional determination.

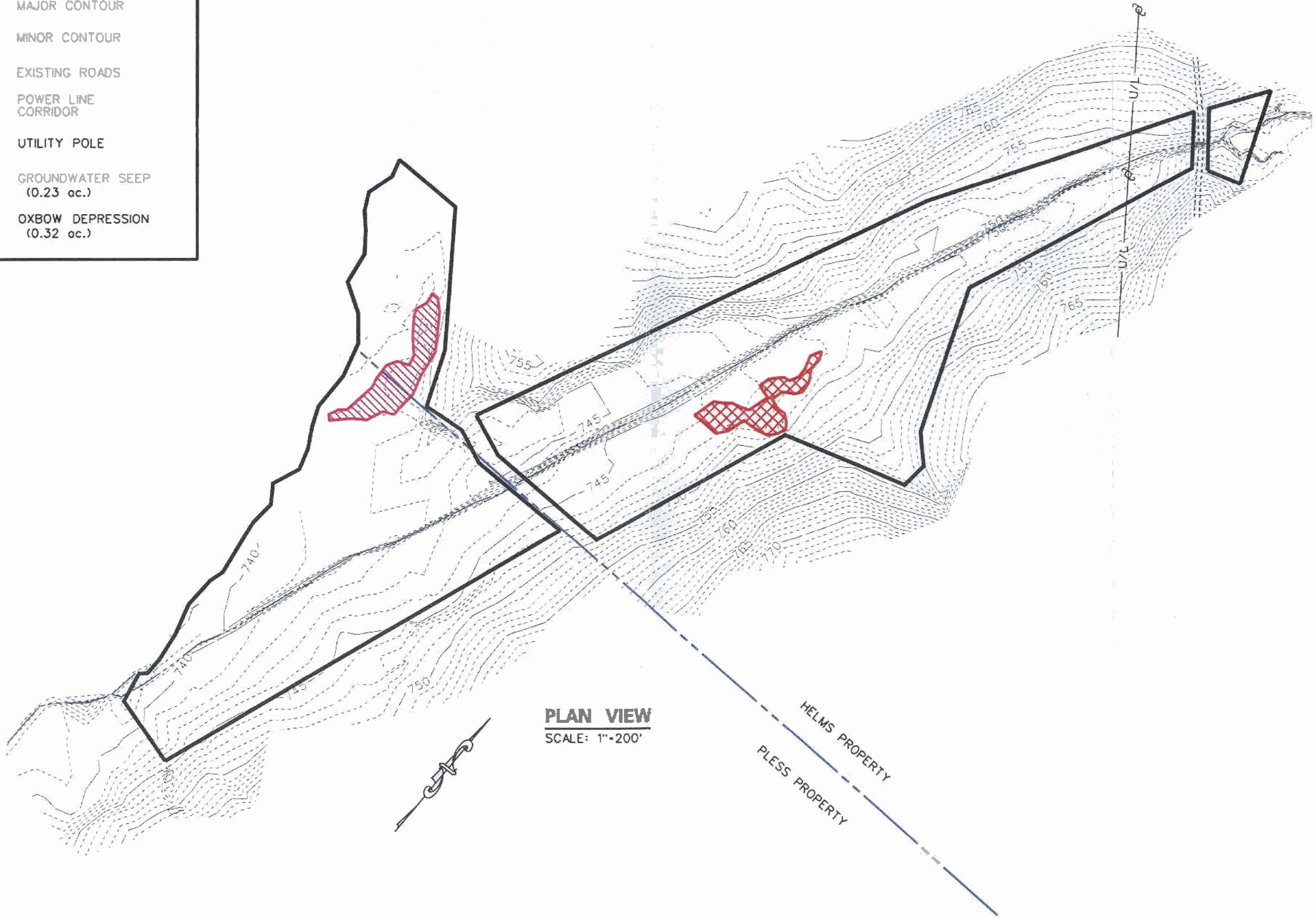
Jurisdictional wetland limits were delineated, flagged, and mapped in the field utilizing Global Positioning System (GPS) technology on September 2002. The jurisdictional delineation was field verified by Mr. John Thomas of the COE on March 4, 2003. Based on field assessment, jurisdictional wetlands exist as two individual pockets and occupy a total of 0.55 acre of the Site, as depicted in Figure 14.

The pocket located on the eastern floodplain periphery is the result of a draw that collects groundwater. Although this area is maintained by bush hogging and regular grazing, the groundwater draw is underlain by slightly gleyed soils, indicating consistent hydrologic input and poor drainage. Due to increased saturation, this area should exhibit a higher organic concentration and nutrient filtration abilities. Groundwater gauge data collected from a period of early March 2003 to May 2003 indicate that this portion of the site is subject to frequent water table drawdown events and may benefit from proposed surface water modifications, floodplain scarification, and planting.

The pocket on the western floodplain periphery is an oxbow depressional storage feature which was recently in pasture; however, cattle have been fenced out of this area. This oxbow is underlain by layered, alluvial deposits and unconsolidated gravel was found at depths of 40 inches, indicating the presence of a relict stream bed. This area is expected to eventually fill in with alluvial sediments and organic peats. Primary mesophytic successional species, such as rushes, sedges, tearthumb, swamp smartweed, and false nettle, have colonized the oxbow depression after fencing. This depressional wetland functions for flood storage, pollutant removal, and groundwater recharge. In an attempt to remove surface water, a ditch has been excavated which

## LEGEND

| | |
|---|---|
| (solid heavy line) | SITE BOUNDARY |
| (dashed line) | PROPERTY LINE |
| —120— | MAJOR CONTOUR |
| (dotted line) | MINOR CONTOUR |
| (dashed double line) | EXISTING ROADS |
| —U/L— | POWER LINE CORRIDOR |
| (symbol) | UTILITY POLE |
| (cross-hatch) | GROUNDWATER SEEP (0.23 ac.) |
| (diagonal hatch) | OXBOW DEPRESSION (0.32 ac.) |




**PLAN VIEW**
SCALE: 1"-200'

EcoScience Corporation
Raleigh, North Carolina

REVISIONS

Client: **NCDOT**

Project: **UT to DUTCH BUFFALO CREEK**

**DETAILED MITIGATION STUDIES**

ROWAN COUNTY, NORTH CAROLINA

Title: **JURISDICTIONAL WETLANDS**

| Dwn By: MAF | Date: NOV 2002 |
|---|---|
| Ckd By: WGL | Scale: 1"- 200' |

ESC Project No.: 00-046.26

FIGURE

**14**

connects the oxbow depression to the on-site channel. Groundwater gauge data indicate that this wetland pocket is currently jurisdictional; however, the excavated ditch is expected to be backfilled under proposed mitigation activities.

# 4.0 REFERENCE STUDIES

A fundamental concept of this stream classification entails the development and application of regional reference curves to stream reconstruction and enhancement. Regional reference curves can be utilized to predict bankfull stream geometry, discharge, and other parameters in altered systems. Development of regional reference curves for North Carolina was initiated in 1995. The curves characterize a broad range of streams within the Piedmont physiographic province. Small watersheds or deviations in valley slope, land use, or geologic substrates may not be accurately described by the curves; therefore, verification of individual watersheds may be necessary. Reference sites have been utilized in conjunction with regional curves for detailed planning and characterization of this mitigation project.

In order to develop proposed geometric parameters for the on-site, degraded channel, three nearby streams were measured for reference (Appendix D). The primary reference reaches for the upstream portion of the on-site channel are located 1) immediately upstream from the Site and 2) approximately 22 miles southwest of the Site on an unnamed tributary to Reedy Creek. These reference streams occur in the same USGS sub-basin as the Site (03040105) and are characterized by G-type and E-type channels. While ideal in location, the upstream G-type reference reach is not considered dimensionally stable. Pattern and profile characteristics however, appear to have not been degraded, allowing for limited assistance with channel design.

The primary reference reach for the downstream portion of the on-site channel is located approximately 11 miles northeast of the Site on an unnamed tributary to Crane Creek (Appendix D). This reference stream is located in an adjacent USGS sub-basin (03040103) and is characterized as an E-type channel.

Tables 4A and 4B provide a summary of the three reference streams utilized to establish reconstruction parameters. Data utilized to assemble Tables 4A and 4B are provided in Appendix D. These tables include reference stream geometry measurements as well as ratios of geometry relative to bankfull width, bankfull depth, and bankfull slope. Because the stream channels at these sites could not be adequately viewed from available aerial photography, plan views were developed through the use of laser technology. Subsequently, channel cross-sections were measured at systematic locations and stream profiles were developed via laser level. Stream substrates were quantified through systematic pebble counts along the reference reaches. In-field measurements of channel geometry were also performed along stream wavelengths located outside of the plan view area.

## 4.1 Reference Channel

Initially, reference streams in the region were visited and classified by stream type (Rosgen 1996). This classification stratifies streams into comparable groups based on

## Table 4A
## Reference Stream Geometry and Classification
## UT to Dutch Buffalo Creek Mitigation Site

**Dimension**

| Attribute | *UT to Dutch Buffalo Median | *UT to Dutch Buffalo Range | UT to Reedy Creek Median | UT to Reedy Creek Range | UT to Crane Creek Median | UT to Crane Creek Range |
|---|---|---|---|---|---|---|
| DA | 0.4 | 0.38 - 0.44 | 0.4 | 0.4 - 0.5 | 1.5 | 1.4 – 1.6 |
| $A_{bkf}$ | 11.1 | 10.2 - 11.7 | 15.5 | 11.8 - 17.1 | 20.5 | 19.3 – 25.0 |
| $W_{bkf(}$ (riffle) | 10.0 | 9.7 - 11.5 | 10.4 | 9.6 – 11.2 | 10.1 | 9.5 – 11.9 |
| $D_{bkf}$ (riffle) | 1.1 | 1.0 - 1.1 | 1.4 | 1.2 - 1.6 | 2.0 | 1.9 – 2.1 |
| $D_{max}$ (riffle) | 1.4 | 1.4 - 1.6 | 2.2 | 1.8 – 2.2 | 2.6 | 2.5 – 2.9 |
| FPA (riffle) | 17.5 | 16.0 – 18.5 | 58 | 42 – 71 | 237 | 232 – 345 |
| $W_{pool}$ | 10.6 | 8.8 – 12.4 | 14.2 | 13.7 – 14.7 | 11.1 | 10.5 – 11.7 |
| $D_{max}$ (pool) | 2.1 | 2.0 - 2.2 | 2.3 | 2.2 – 2.3 | 2.9 | 2.8 – 3.0 |
| $L_{pool}$ | 22 | 15 - 30 | 33 | 23 - 37 | 32 | 13 - 48 |
| LBH | 3.3 | 3.2 – 3.8 | 2.0 | 1.8 – 2.6 | 3.1 | 2.9 – 3.2 |

**Pattern**

| Attribute | *UT to Dutch Buffalo Median | *UT to Dutch Buffalo Range | UT to Reedy Creek Median | UT to Reedy Creek Range | UT to Crane Creek Median | UT to Crane Creek Range |
|---|---|---|---|---|---|---|
| $W_{belt}$ | 52.3 | 42.3 – 60.4 | 76.1 | 68.0 – 84.0 | 86.1 | 74.3 – 101.3 |
| $L_m$ | 80 | 58 – 111 | 102 | 81 – 137 | 73 | 61 – 115 |
| $R_c$ | 26.6 | 12.1 – 57.0 | 27.6 | 17.1 – 42.0 | 25.3 | 18.6 – 30.4 |
| $L_{p-p}$ | 55 | 34 – 90 | 84 | 13 – 112 | 53 | 26 – 114 |
| Sin | 1.4 | 1.3 - 1.5 | 1.55 | 1.4 – 1.6 | 1.8 | 1.7 – 1.9 |

**Profile**

| Attribute | *UT to Dutch Buffalo Median | *UT to Dutch Buffalo Range | UT to Reedy Creek Median | UT to Reedy Creek Range | UT to Crane Creek Median | UT to Crane Creek Range |
|---|---|---|---|---|---|---|
| $S_{sw}$ | 0.0062 | 0.0059-0.0069 | 0.0111 | 0.0105-0.0112 | 0.0014 | 0.0012-0.0016 |
| $S_{valley}$ | 0.0086 | NA | 0.0172 | NA | 0.0025 | NA |
| $S_{riffle}$ | 0.0091 | 0.0050-0.0159 | 0.0140 | 0.0105-0.0221 | 0.0019 | 0.0006-0.0033 |
| $S_{pool}$ | 0.0019 | 0.0005-0.0052 | 0.0069 | 0.0016-0.0182 | 0.0004 | 0.0000-0.0006 |

| Stream Type | *G 5 | E 5/4 | E 4/5 |
|---|---|---|---|

| | |
|---|---|
| DA | Drainage Basin Area (sq. mi.) |
| $A_{bkf}$ | Bankfull cross-sectional area (riffle) ($ft^2$) |
| $W_{bkf}$ | Bankfull width (ft) |
| $D_{bkf}$ | Average bankfull depth (ft) |
| $D_{max}$ | Maximum depth (ft) |
| FPA | Floodprone Area (ft) |
| $W_{pool}$ | Channel width at a pool (ft) |
| $L_{pool}$ | Individual pool length (ft) |
| LBH | Low bank height (distance from thalweg to the top of low bank) (ft) |
| $W_{belt}$ | Belt width (ft) |
| $L_m$ | Meander wavelength (ft) |
| $R_c$ | Radius of Curvature (ft) |
| $L_{p-p}$ | Length from pool to pool (ft) |
| Sin | Sinuosity (thalweg dist/straight-line dist.) |
| $S_{ws}$ | Slope of the water surface (rise/run) |
| $S_{valley}$ | Slope of the valley (rise/run) |
| $S_{riffle}$ | Slope of the riffle (rise/run) |
| $S_{pool}$ | Slope of the pool (rise/run) |

* Reference stream is immediately upstream from project site. This stream is characterized as a G-type (Gully) stream and is not considered stable; however, pattern and profile characteristics may be consulted during channel design.

## Table 4B
## Reference Stream Geometry and Classification Ratios
## UT to Dutch Buffalo Creek Mitigation Site

### Dimension Ratios

| Attribute | *UT to Dutch Buffalo Median | *UT to Dutch Buffalo Range | UT to Reedy Creek Median | UT to Reedy Creek Range | UT to Crane Creek Median | UT to Crane Creek Range |
|---|---|---|---|---|---|---|
| DA | 0.4 | 0.38 - 0.44 | 0.4 | 0.4 - 0.5 | 1.5 | 1.4 – 1.6 |
| ENT | 1.8 | 1.4 - 1.9 | 5.6 | 3.7 – 7.4 | 25.0 | 20.0 – 34.5 |
| $W_{bkf}/D_{bkf}$ | 9.1 | 9.0 – 11.4 | 7.8 | 6.4 – 8.1 | 5.1 | 4.5 – 5.7 |
| BHR | 2.4 | 2.3 – 2.4 | 1.0 | 1.0 – 1.2 | 1.2 | 1.1 – 1.2 |
| $D_{max}$ (riffle) / $D_{ave}$ (riffle) | 1.4 | 1.3 – 1.5 | 1.5 | 1.4 – 1.6 | 1.3 | 1.2 – 1.4 |
| $D_{max}$ (pool) / $D_{ave}$ (riffle) | 1.9 | 1.8 – 2.0 | 1.6 | 1.57 – 1.64 | 1.5 | 1.4 – 1.5 |
| $W_{pool}$ / $W_{bkf}$ (riffle) | 1.1 | 0.9 – 1.1 | 1.4 | 1.3 – 1.4 | 1.1 | 1.0 – 1.2 |

### Pattern Ratios

| Attribute | *UT to Dutch Buffalo Median | *UT to Dutch Buffalo Range | UT to Reedy Creek Median | UT to Reedy Creek Range | UT to Crane Creek Median | UT to Crane Creek Range |
|---|---|---|---|---|---|---|
| $W_{belt}/W_{bkf}$ | 5.2 | 4.2 – 6.0 | 7.3 | 6.5 – 8.1 | 8.5 | 7.4 – 10.0 |
| $L_m/W_{bkf}$ | 8 | 5.8 – 11.1 | 9.8 | 7.8 – 13.2 | 7.2 | 6.0 – 11.4 |
| $R_c/W_{bkf}$ | 2.7 | 1.2 – 5.7 | 2.7 | 1.6 – 4.0 | 2.5 | 1.8 – 3.0 |
| $L_{p-p}/W_{bkf}$ | 5.5 | 3.4 – 9.0 | 8.1 | 1.3 – 10.8 | 5.2 | 2.6 – 11.3 |

### Profile Ratios

| Attribute | *UT to Dutch Buffalo Median | *UT to Dutch Buffalo Range | UT to Reedy Creek Median | UT to Reedy Creek Range | UT to Crane Creek Median | UT to Crane Creek Range |
|---|---|---|---|---|---|---|
| $S_{valley}/S_{ws}$ | 1.4 | NA | 1.55 | NA | 1.8 | NA |
| $S_{riffle}/S_{ws}$ | 1.5 | 0.8 – 2.6 | 1.3 | 0.9 – 2.0 | 1.4 | 0.4 – 2.4 |
| $S_{pool}/S_{ws}$ | 0.3 | 0.1 – 0.8 | 0.6 | 0.1 – 1.6 | 0.3 | 0.0 – 0.4 |

DA Drainage Basin Area (sq. mi.)
ENT Entrenchment ratio ($FPA/W_{bkf}$)
$W_{bkf}$ Bankfull width (ft)
$D_{bkf}$ Average bankfull depth (ft)
BHR Bank height ratio [low bank height/$D_{max}$ (riffle)]
$D_{max}$ Maximum depth (ft)
FPA Floodprone area (ft)
$W_{pool}$ Channel width at a pool (ft)
$L_{pool}$ Individual pool length (ft)
LBH Low bank height (distance from thalweg to the top of low bank) (ft)

$W_{belt}$ Belt width (ft)
$L_m$ Meander wavelength (ft)
$R_c$ Radius of Curvature (ft)
$L_{p-p}$ Length from pool to pool (ft)
Sin Sinuosity (thalweg dist/straight-line dist.)
$S_{ws}$ Slope of the water surface (rise/run)
$S_{valley}$ Slope of the valley (rise/run)
$S_{riffle}$ Slope of the riffle (rise/run)
$S_{pool}$ Slope of the pool (rise/run)

* Reference stream is immediately upstream from project site. This stream is characterized as a G-type (Gully) stream and is not considered stable; however, pattern and profile characteristics may be consulted during channel design.

geometric characteristics. Reference reaches identified in the vicinity were characterized primarily as E-type (highly sinuous) channels with sand or gravel substrate. E-type streams are slightly entrenched, highly sinuous (>1.5) channels which exhibit high meander width ratios (belt width/bankfull width). In North Carolina, E-type streams occur in narrow to wide valleys with well-developed alluvial floodplains (Valley Type VIII). These streams exhibit a sequence of riffles and pools associated with a sinuous flow pattern.

Dimension

Field indicators measured at the UT to Reedy Creek indicate a bankfull cross-sectional area ranging from 11.8 to 17.1 square feet, including widths of 9.6 to 11.2 feet, average depths of 1.2 to 1.6 feet, and width/depth ratios of 6 to 8. Regional curves predict that the stream should exhibit a bankfull cross-sectional area of approximately 12 square feet, within the range displayed by the reach.

Data collected at UT to Crane Creek indicate a bankfull cross-sectional area ranging from 19.3 to 25.0 square feet, with bankfull widths of 9.5 to 11.9 feet, average depths of 1.9 to 2.1 feet, and width/depth ratios of 5 to 7. Regional curves predict that the stream should exhibit a bankfull cross-sectional area of approximately 28 square feet, slightly above the range displayed by the reach.

Pattern

Based on field surveys, the UT to Reedy Creek demonstrates an average sinuosity of 1.55 (Table 4A). This sinuosity supports a belt width which ranges between 68 and 84 feet, an average meander wavelength of 102 feet, and a radius of curvature ranging from 17 to 42 feet. Pattern values for this reference reach appear suitable for E-type streams in the vicinity.

In-field measurements of the UT to Crane Creek have yielded an average sinuosity of 1.8 (Table 4A). Accompanying this sinuosity is a belt width which ranges between 74 and 101 feet, an average meander wavelength of 88 feet, and a radius of curvature ranging between 19 and 30 feet. Meander geometry values for this reference reach are acceptable for an E-type streams in the region.

Field surveys of the reference portion of the UT to Dutch Buffalo Creek have delivered an average sinuosity of 1.4 (Table 4A). Associated with this sinuosity is a belt width ranging from 42 to 60 feet, and average meander wavelength of 80 feet, and a radius of curvature ranging between 12 and 57 feet. Pattern values for this reference reach are acceptable for E-type stream in the Piedmont.

Profile

Based on elevational profile surveys, the reference reach at the UT to Reedy Creek is characterized by a relatively steep valley slope (0.017 rise/run); however, this was expected because this reach is located relatively far upstream, away from the influence of Reëdy Creek and its associated floodplain. Typically, gradient decreases in a downstream direction as the watershed increases in size. This is evidenced by the valley slope of the UT to Crane Creek which is relatively flat (0.0025 rise/run). This reference reach was surveyed farther down valley and the comparatively flat valley slope was anticipated. The valley slope on the reference portion of the UT to Dutch Buffalo Creek is moderately steep (0.0086 rise/run). However, this tributary flows through a progressively flattening valley (the mitigation channel experiences valley slopes that range from 0.0076 to 0.0056 rise/run); therefore, geometric attributes have been modeled primarily after the two off-site reference reaches. The pool slopes ($S_{pool}$) and riffle slopes ($S_{riffle}$) of all three reference reaches reside, on average, within the range indicative of a stable stream system.

### 4.2 Reference Forest Ecosystems

According to Mitigation Site Classification (MiST) guidelines (EPA 1990), Reference Forest Ecosystems (RFEs) must be established for mitigation sites. RFEs are forested areas on which to model restoration efforts of the mitigation site in relation to soils, hydrology, and vegetation. RFEs should be ecologically stable climax communities and should represent believed historical (pre-disturbance) conditions of the mitigation site. Quantitative data describing plant community composition and structure are collected at the RFEs and subsequently applied as reference data for design of the mitigation site planting scheme.

Two RFE areas were chosen to guide plant community restoration along the on-site channel. The RFEs are both found within the Southern Outer Piedmont Ecoregion, one southwest and one northeast of the Site. Both RFEs support plant community, landform, and hydrological characteristics that restoration efforts will attempt to emulate. Circular, 0.1-acre plots were randomly established within the selected RFEs. Data collected within each plot include 1) tree, shrub, and herb species composition; 2) number of stems for each tree and shrub species; and 3) diameter at breast height (DBH) for each tree and shrub species. Field data (Table 5A and 5B) indicate importance values (IV) of dominant tree species calculated based on relative density, dominance, and frequency of tree species composition (Smith 1980). Hydrology, surface topography, and habitat features were also evaluated.

The southwestern RFE is located in the floodplain of Reedy Creek in Mecklenburg County, North Carolina. Within the RFE, vegetative sampling at four 0.1-acre plots indicate that forest tree vegetation was dominated by tulip poplar (IV=0.12), American elm (IV=0.10), northern red oak (*Quercus rubra*) (IV=0.08), and black walnut (*Juglans nigra*) (IV=0.07) (Table 5A). Other, less dominant tree species within the sample plots were green ash (*Fraxinus pennsylvanica*), boxelder, and American sycamore (*Platanus occidentalis*).

The northeastern RFE is located in the floodplain of the UT to Crane Creek in Rowan County, North Carolina. Three 0.1-acre plots were established which best characterize expected steady-state forest composition. Forest vegetation was dominated by swamp chestnut oak (*Quercus michauxii*) (IV=0.17), green ash (IV=0.13), American elm (IV=0.10), and shagbark hickory (IV=0.09) (Table 5B). Portions of the canopy were also

## Table 5A

Reference Forest Plot Summary
Bottomland Hardwood Forest (Canopy Species)
UT to Crane Creek Floodplain

| Tree Species | Number of Individuals[1] | Relative Density (%) | Frequency[1] (%) | Relative Frequency (%) | Basal Area ($ft^2$ / acre) | Relative Basal Area (%) | Importance Value |
|---|---|---|---|---|---|---|---|
| Acer negundo | 3 | 7.9 | 67 | 8.7 | 2.3 | 5.9 | 0.07 |
| Acer rubrum | 3 | 7.9 | 67 | 8.7 | 4.2 | 10.6 | 0.09 |
| Carya ovata | 5 | 13.2 | 67 | 8.7 | 2.5 | 6.3 | 0.09 |
| Cary tomentosa | 1 | 2.6 | 33 | 4.3 | 0.1 | 0.2 | 0.02 |
| Fagus grandiflora | 1 | 2.6 | 33 | 4.3 | 2.0 | 5.2 | 0.04 |
| Fraxinus americana | 1 | 2.6 | 33 | 4.3 | 1.3 | 3.3 | 0.03 |
| Fraxinus pennsylvanica | 6 | 15.8 | 100 | 13.0 | 3.5 | 8.8 | 0.13 |
| Juniperus virginica | 1 | 2.6 | 33 | 4.3 | 0.4 | 0.9 | 0.03 |
| Liquidambar styraciflua | 1 | 2.6 | 33 | 4.3 | 0.1 | 0.3 | 0.02 |
| Liriodendron tulipifera | 3 | 7.9 | 67 | 8.7 | 2.7 | 6.7 | 0.08 |
| Nyssa sylvatica | 1 | 2.6 | 33 | 4.3 | 0.1 | 0.2 | 0.02 |
| Quercus falcata | 1 | 2.6 | 33 | 4.3 | 2.9 | 7.3 | 0.05 |
| Quercus michauxii | 3 | 7.9 | 67 | 8.7 | 13.3 | 33.6 | 0.17 |
| Quercus phellos | 2 | 5.3 | 33 | 4.3 | 2.3 | 5.8 | 0.05 |
| Ulmus americana | 6 | 15.8 | 67 | 8.7 | 1.9 | 4.9 | 0.10 |
| **TOTALS** | 38 | 100 | 767 | 100 | 40 | 100 | 1 |

[1] Summary of three 0.1-acre plots

## Table 5B

Reference Forest Plot Summary
Bottomland Hardwood Forest (Canopy Species)
UT to Reedy Creek Floodplain

| Tree Species | Number of Individuals[1] | Relative Density (%) | Frequency[1] (%) | Relative Frequency (%) | Basal Area ($ft^2$ / acre) | Relative Basal Area (%) | Importance Value |
|---|---|---|---|---|---|---|---|
| Acer negundo | 6 | 7.8 | 50 | 5.3 | 1.9 | 2.6 | 0.05 |
| Acer rubrum | 2 | 2.6 | 50 | 5.3 | 0.6 | 0.8 | 0.03 |
| Carpinus caroliniana | 7 | 9.1 | 50 | 5.3 | 1.2 | 1.7 | 0.05 |
| Carya ovata | 2 | 2.6 | 50 | 5.3 | 5.4 | 7.3 | 0.05 |
| Celtis laevigata | 6 | 7.8 | 50 | 5.3 | 3.1 | 4.2 | 0.06 |
| Fagus grandiflora | 2 | 2.6 | 50 | 5.3 | 6.5 | 8.8 | 0.06 |
| Fraxinus pennsylvanica | 1 | 1.3 | 25 | 2.6 | 0.4 | 0.5 | 0.01 |
| Juglans nigra | 4 | 5.2 | 75 | 7.9 | 5.2 | 7.0 | 0.07 |
| Liquidambar styraciflua | 7 | 9.1 | 75 | 7.9 | 6.6 | 8.9 | 0.09 |
| Liriodendron tulipifera | 5 | 6.5 | 75 | 7.9 | 15.9 | 21.5 | 0.12 |
| Morus rubra | 8 | 10.4 | 75 | 7.9 | 4.0 | 5.4 | 0.08 |
| Nyssa sylvatica | 3 | 3.9 | 75 | 7.9 | 3.0 | 4.0 | 0.05 |
| Platanus occidentalis | 2 | 2.6 | 25 | 2.6 | 6.5 | 8.8 | 0.05 |
| Quercus alba | 2 | 2.6 | 25 | 2.6 | 1.7 | 2.2 | 0.02 |
| Quercus michauxii | 1 | 1.3 | 25 | 2.6 | 0.5 | 0.7 | 0.02 |
| Quercus phellos | 1 | 1.3 | 25 | 2.6 | 1.6 | 2.2 | 0.02 |
| Quercus rubra | 7 | 9.1 | 50 | 5.3 | 7.2 | 9.8 | 0.08 |
| Ulmus americana | 11 | 14.3 | 100 | 10.5 | 3.0 | 4.0 | 0.10 |
| **TOTALS** | 77 | 100 | 950 | 100 | 74 | 100 | 1 |

[1] Summary of four 0.1-acre plots

dominated by willow oak (*Quercus phellos*), boxelder, tulip-poplar, black tupelo (*Nyssa sylvatica*), and red maple (*Acer rubrum*).

## 5.0 RESTORATION PLAN

The primary goals of this restoration plan include 1) construction of a stable, riffle-pool stream channel; 2) enhancement of water quality functions in the on-site, upstream, and downstream segments of the channel; 3) creation of a natural vegetation buffer along restored stream channels; 4) maximization of the area returned to historic wetland function; and 5) restoration of wildlife functions associated with a riparian corridor/stable stream. The complete mitigation plan is depicted in Figure 15. Components of this plan may be modified based on construction or access constraints.

Primary activities designed to restore the complex include 1) stream restoration, 2) wetland enhancement, 3) soil scarification, and 4) plant community restoration. Subsequently, a monitoring plan and contingency plans are outlined in Section 6 of this document.

### 5.1 Stream Restoration

This stream restoration effort is designed to restore a stable, meandering stream that approximates hydrodynamics, stream geometry, and local microtopography relative to reference conditions. This effort consists primarily of stream reconstruction on new location. Geometric attributes for the existing, degraded channel and the proposed, stable channel are listed in Tables 6A, 6B, 6C, and 6D.

An erosion control plan and construction/transportation plan will be developed. Erosion control will be performed locally throughout the Site and will be incorporated into the construction sequencing. Exposed surficial soils at the Site are unconsolidated, alluvial sediments which do not re-vegetate rapidly after disturbance; therefore, seeding with appropriate grasses and immediate planting with disturbance-adapted shrubs will be employed following the earth-moving process. In addition, on-site root mats (seed banks) and vegetation will be stockpiled and redistributed after disturbance.

A transportation plan, including the location of access routes and staging areas, will be designed to avoid impacts to the existing wetland pockets and proposed design channel corridor. In addition, the transportation plan and all construction activities will minimize disturbance to existing vegetation and soils to the extent feasible. The number of transportation access points into the floodplain will be maximized to avoid traversing long distances through the Site interior.

#### 5.1.1 Reconstruction on New Location

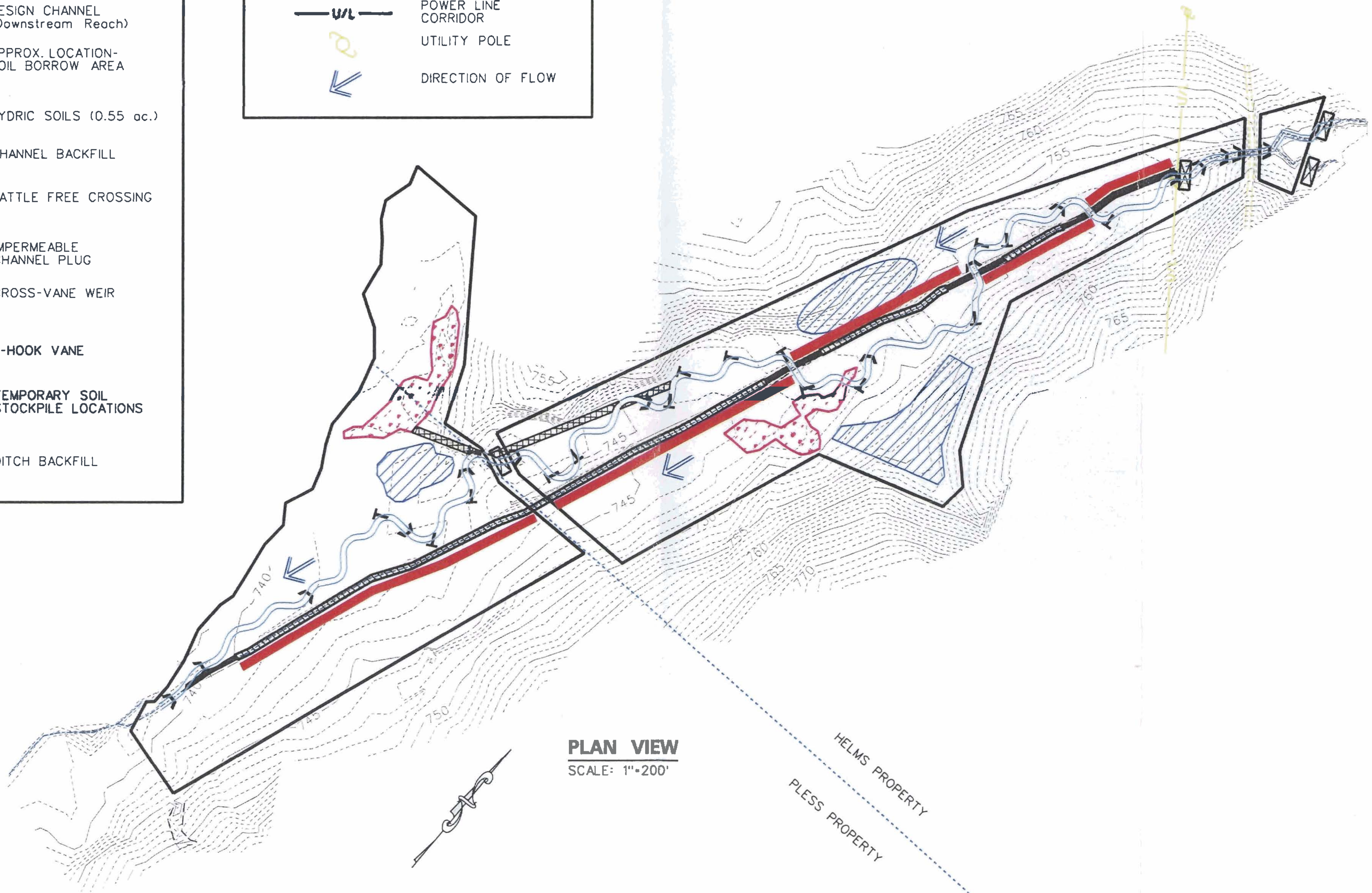
The Site is characterized by an adjacent floodplain that is suitable for design channel excavation. Primary activities designed to restore the channel on new location include 1) beltwidth preparation and grading, 2) channel excavation, 3) installation of channel plugs, and 4) backfilling of the abandoned channel.

## MITIGATION LEGEND

| | |
|---|---|
| | SITE BOUNDARY |
| | HELMS PROPERTY: 9.6 ac.<br>PLESS PROPERTY: 5.5 ac.<br>Total 15.1 ac. |
| | DESIGN CHANNEL (Upstream Reach) |
| | DESIGN CHANNEL (Downstream Reach) |
| | APPROX. LOCATION- SOIL BORROW AREA |
| | HYDRIC SOILS (0.55 ac.) |
| | CHANNEL BACKFILL |
| | CATTLE FREE CROSSING |
| | IMPERMEABLE CHANNEL PLUG |
| | CROSS-VANE WEIR |
| | J-HOOK VANE |
| | TEMPORARY SOIL STOCKPILE LOCATIONS |
| | DITCH BACKFILL |

## GENERAL LEGEND

| | |
|---|---|
| | PROPERTY LINE |
| 120 | MAJOR CONTOUR |
| | MINOR CONTOUR |
| | EXISTING ROADS |
| U/L | POWER LINE CORRIDOR |
| | UTILITY POLE |
| | DIRECTION OF FLOW |




**PLAN VIEW**
SCALE: 1"=200'

EcoScience Corporation
Raleigh, North Carolina

REVISIONS

Client: NCDOT

Project: UT to DUTCH BUFFALO CREEK

DETAILED MITIGATION STUDIES

ROWAN COUNTY, NORTH CAROLINA

Title: MITIGATION PLAN

| Dwn By: MAF | Date: NOV 2002 |
|---|---|
| Ckd By: WGL | Scale: 1"= 200' |

ESC Project No.: 00-046.26

FIGURE 15

## Table 6A
## Stream Geometry and Classification
## UT to Dutch Buffalo Creek Mitigation Site
(Upstream Reach [see Figure12 for existing stream-type locations])

### Dimension

| Attribute | Existing conditions (G-type) | | Existing Conditions (E-type) | | Proposed Conditions | |
|---|---|---|---|---|---|---|
| | Median | Range | Median | Range | Median | Range |
| DA | 0.5 | 0.5 - 0.6 | 0.5 | 0.5 – 0.6 | 0.5 | 0.5 – 0.6 |
| $A_{bkf}$ | 13 | 13 | 14.3 | 14.2 – 14.3 | 13.0 | 13.0 – 14.3 |
| $W_{bkf}$ (riffle) | 10.0 | 9.4 - 10.5 | 11.2 | 10.0 – 12.4 | 10.2 | 9.5 – 10.8 |
| $D_{bkf}$ (riffle) | 1.3 | 1.2 - 1.4 | 1.3 | 1.2 – 1.4 | 1.3 | 1.2 – 1.4 |
| $D_{max}$ (riffle) | 1.8 | 1.7 - 1.8 | 2.7 | 2.6 – 2.7 | 1.8 | 1.7 – 2.0 |
| FPA (riffle) | 16 | 16 | 195 | 190 – 200 | 164 | 125 – 200 |
| $W_{pool}$ | 13.4 | NA | 13.4 | NA | 13.3 | 12.2 – 14.3 |
| $D_{max}$ (pool) | 2.3 | NA | 2.3 | NA | 2.6 | 2.0 – 3.3 |
| $L_{pool}$ | NA | NA | NA | NA | 28 | 16 – 42 |
| LBH | 3.5 | 3.5 | 4.0 | 3.8 – 4.2 | 1.8 | 1.7 – 2.0 |

### Pattern

| Attribute | Existing Conditions (G-type) | | Existing Conditions (E-type) | | Proposed Conditions | |
|---|---|---|---|---|---|---|
| | Median | Range | Median | Range | Median | Range |
| $W_{belt}$ | No distinct repetitive pattern of riffles and pools within the degraded channel | | No distinct repetitive pattern of riffles and pools within the degraded channel | | 115 | 60 – 161 |
| $L_m$ | | | | | 95 | 71 – 127 |
| $R_c$ | | | | | 24.7 | 20.4 – 39.9 |
| $L_{p-p}$ | | | | | 60 | 40 – 107 |
| Sin | 1.0 | NA | 1.0 | NA | 1.37 | NA |

### Profile

| Attribute | Existing Conditions (G-type) | | Existing Conditions (E-type) | | Proposed Conditions | |
|---|---|---|---|---|---|---|
| | Median | Range | Median | Range | Median | Range |
| $S_{sw}$ | 0.0076 | NA | 0.0076 | NA | 0.0057 | 0.0051-0.0064 |
| $S_{valley}$ | 0.0076 | NA | 0.0076 | NA | 0.0076 | NA |
| $S_{riffle}$ | No distinct repetitive patter of riffles and pools | | No distinct repetitive patter of riffles and pools | | 0.0074 | 0.004-0.0125 |
| $S_{pool}$ | | | | | 0.0023 | 0.0006-0.0057 |

| Stream Type | G 5/4 | E 5/4 | E 5/4 |
|---|---|---|---|

| | |
|---|---|
| DA | Drainage Basin Area (sq. mi.) |
| $A_{bkf}$ | Bankfull cross-sectional area (riffle) ($ft^2$) |
| $W_{bkf}$ | Bankfull width (ft) |
| $D_{bkf}$ | Average bankfull depth (ft) |
| $D_{max}$ | Maximum depth (ft) |
| FPA | Floodprone Area (ft) |
| $W_{pool}$ | Channel width at a pool (ft) |
| $L_{pool}$ | Individual pool length (ft) |
| LBH | Low bank height (distance from thalweg to the top of low bank) (ft) |
| $W_{belt}$ | Belt width (ft) |
| $L_m$ | Meander wavelength (ft) |
| $R_c$ | Radius of Curvature (ft) |
| $L_{p-p}$ | Length from pool to pool (ft) |
| Sin | Sinuosity (thalweg dist/straight-line dist.) |
| $S_{ws}$ | Slope of the water surface (rise/run) |
| $S_{valley}$ | Slope of the valley (rise/run) |
| $S_{riffle}$ | Slope of the riffle (rise/run) |
| $S_{pool}$ | Slope of the pool (rise/run) |

## Table 6B
## Stream Geometry and Classification Ratios
## UT to Dutch Buffalo Creek Mitigation Site
(Upstream Reach [see Figure12 for existing stream-type locations])

### Dimension Ratios

| Attribute | Existing Conditions (G-type) Median | Existing Conditions (G-type) Range | Existing Conditions (E-type) Median | Existing Conditions (E-type) Range | Proposed Conditions Median | Proposed Conditions Range |
|---|---|---|---|---|---|---|
| DA | 0.5 | 0.5 - 0.6 | 0.5 | 0.5 – 0.6 | 0.5 | 0.5 – 0.6 |
| ENT | 1.6 | 1.5 - 1.7 | 18 | 15 – 20 | 16 | 12 – 20 |
| $W_{bkf}/D_{bkf}$ | 7.5 | 7 - 8 | 9 | 7 – 11 | 8 | 7 – 9 |
| BHR | 2.0 | 1.9 - 2.1 | 1.5 | 1.4 – 1.6 | 1.0 | 1.0 – 1.2 |
| $D_{max}$ (riffle) / $D_{ave}$ (riffle) | 1.4 | 1.3 - 1.4 | 2.1 | 1.9 – 2.3 | 1.4 | 1.3 – 1.5 |
| $D_{max}$ (pool) / $D_{ave}$ (riffle) | 1.8 | NA | 1.8 | NA | 2 | 1.5 – 2.5 |
| $W_{pool}$ / $W_{bkf}$ (riffle) | 1.3 | NA | 1.3 | NA | 1.3 | 1.2 – 1.4 |

### Pattern Ratios

| Attribute | Existing Conditions (G-type) Median | Existing Conditions (G-type) Range | Existing Conditions (E-type) Median | Existing Conditions (E-type) Range | Proposed Conditions Median | Proposed Conditions Range |
|---|---|---|---|---|---|---|
| $W_{belt}/W_{bkf}$ | No distinct repetitive pattern of riffles and pools within the degraded channel | | No distinct repetitive pattern of riffles and pools within the degraded channel | | 11.3 | 6 – 16 |
| $L_m/W_{bkf}$ | | | | | 9.3 | 7.0 – 12.5 |
| $R_c/W_{bkf}$ | | | | | 2.4 | 2.0 – 3.9 |
| $L_{p-p}/W_{bkf}$ | | | | | 5.9 | 3.9 – 10.5 |

### Profile Ratios

| Attribute | Existing Conditions (G-type) Median | Existing Conditions (G-type) Range | Existing Conditions (E-type) Median | Existing Conditions (E-type) Range | Proposed Conditions Median | Proposed Conditions Range |
|---|---|---|---|---|---|---|
| $S_{valley}/S_{ws}$ | 1.0 | NA | 1.0 | NA | 1.3 | NA |
| $S_{riffle}/S_{ws}$ | No distinct repetitive pattern of riffles and pools | | No distinct repetitive pattern of riffles and pools | | 1.3 | 0.7 – 2.2 |
| $S_{pool}/S_{ws}$ | | | | | 0.4 | 0.1 – 1.0 |

| | |
|---|---|
| DA | Drainage Basin Area (sq. mi.) |
| ENT | Entrenchment ratio ($FPA/W_{bkf}$) |
| $W_{bkf}$ | Bankfull width (ft) |
| $D_{bkf}$ | Average bankfull depth (ft) |
| BHR | Bank height ratio [low bank height/$D_{max}$ (riffle)] |
| $D_{max}$ | Maximum depth (ft) |
| FPA | Floodprone area (ft) |
| $W_{pool}$ | Channel width at a pool (ft) |
| $L_{pool}$ | Individual pool length (ft) |
| LBH | Low bank height (distance from thalweg to the top of low bank) (ft) |
| $W_{belt}$ | Belt width (ft) |
| $L_m$ | Meander wavelength (ft) |
| $R_c$ | Radius of Curvature (ft) |
| $L_{p-p}$ | Length from pool to pool (ft) |
| Sin | Sinuosity (thalweg dist/straight-line dist.) |
| $S_{ws}$ | Slope of the water surface (rise/run) |
| $S_{valley}$ | Slope of the valley (rise/run) |
| $S_{riffle}$ | Slope of the riffle (rise/run) |
| $S_{pool}$ | Slope of the pool (rise/run) |

**Table 6C**
**Stream Geometry and Classification**
**UT to Dutch Buffalo Creek Mitigation Site**
(Downstream Reach)

| Dimension | | | | |
|---|---|---|---|---|
| | Existing conditions | | Proposed Conditions | |
| Attribute | Median | Range | Median | Range |
| DA | 0.5 | 0.5 - 0.6 | 0.5 | 0.5 – 0.6 |
| $A_{bkf}$ | 14.4 | 14.2 - 14.6 | 14.4 | 14.4 – 15.2 |
| $W_{bkf(}$ (riffle) | 10.9 | 9.7 - 12.0 | 9.3 | 9.3 – 10.0 |
| $D_{bkf}$ (riffle) | 1.4 | 1.2 - 1.5 | 1.6 | 1.4 – 1.6 |
| $D_{max}$ (riffle) | 2.4 | 2.2 - 2.6 | 2.1 | 1.9 – 2.2 |
| FPA (riffle) | 220 | 220 - 265 | 243 | 220 - 265 |
| $W_{pool}$ | 11.6 | NA | 11.2 | 9.4 – 13.0 |
| $D_{max}$ (pool) | 2.6 | NA | 3.2 | 2.4 – 4.0 |
| $L_{pool}$ | NA | NA | 27 | 17 – 40 |
| LBH | 3.2 | 2.9 – 3.5 | 2.1 | 1.9 – 2.2 |

| Pattern | | | | |
|---|---|---|---|---|
| | Existing Conditions | | Proposed Conditions | |
| Attribute | Median | Range | Median | Range |
| $W_{belt}$ | No distinct repetitive pattern of riffles and pools within the degraded channel | | 68 | 56 – 83 |
| $L_m$ | | | 93 | 77 - 107 |
| $R_c$ | | | 24.1 | 19.8 – 35.8 |
| $L_{p-p}$ | | | 60 | 40 - 107 |
| Sin | 1.0 | NA | 1.35 | NA |

| Profile | | | | |
|---|---|---|---|---|
| | Existing Conditions | | Proposed Conditions | |
| Attribute | Median | Range | Median | Range |
| $S_{sw}$ | 0.0025 | NA | 0.0042 | 0.0037 - 0.0052 |
| $S_{valley}$ | 0.0056 | NA | 0.0056 | 0.0056 |
| $S_{riffle}$ | No distinct repetitive patter of riffles and pools | | 0.0055 | 0.0029 – 0.0092 |
| $S_{pool}$ | | | 0.0017 | 0.0004 – 0.0042 |

| | | |
|---|---|---|
| Stream Type | E 5/4 | E 5/4 |

| | | | |
|---|---|---|---|
| DA | Drainage Basin Area (sq. mi.) | $W_{belt}$ | Belt width (ft) |
| $A_{bkf}$ | Bankfull cross-sectional area (riffle) ($ft^2$) | $L_m$ | Meander wavelength (ft) |
| $W_{bkf}$ | Bankfull width (ft) | $R_c$ | Radius of Curvature (ft) |
| $D_{bkf}$ | Average bankfull depth (ft) | $L_{p-p}$ | Length from pool to pool (ft) |
| $D_{max}$ | Maximum depth (ft) | Sin | Sinuosity (thalweg dist/straight-line dist.) |
| FPA | Floodprone Area (ft) | $S_{ws}$ | Slope of the water surface (rise/run) |
| $W_{pool}$ | Channel width at a pool (ft) | $S_{valley}$ | Slope of the valley (rise/run) |
| $L_{pool}$ | Individual pool length (ft) | $S_{riffle}$ | Slope of the riffle (rise/run) |
| LBH | Low bank height (distance from thalweg to the top of low bank) (ft) | $S_{pool}$ | Slope of the pool (rise/run) |

**Table 6D**
**Stream Geometry and Classification Ratios**
**UT to Dutch Buffalo Creek Mitigation Site**
(Downstream Reach)

| Dimension Ratios | | | | |
|---|---|---|---|---|
| | Existing Conditions | | Proposed Conditions | |
| Attribute | Median | Range | Median | Range |
| DA | 0.5 | 0.5 - 0.6 | 0.5 | 0.5 – 0.6 |
| ENT | 22.8 | 18.4 - 27.2 | 26 | 24 - 29 |
| $W_{bkf}/D_{bkf}$ | 9 | 7 - 10 | 6 | 6 – 7 |
| BHR | 1.3 | NA | 1.0 | 1.0 – 1.2 |
| $D_{max}$ (riffle) / $D_{ave}$ (riffle) | 1.8 | 1.7 – 1.8 | 1.3 | 1.2 – 1.4 |
| $D_{max}$ (pool) / $D_{ave}$ (riffle) | 1.6 | 1.5 – 1.9 | 2.0 | 1.5 – 2.5 |
| $W_{pool}$ / $W_{bkf}$ (riffle) | 1.2 | 1.1 - 1.4 | 1.2 | 1.0 – 1.4 |

| Pattern Ratios | | | | |
|---|---|---|---|---|
| | Existing Conditions | | Proposed Conditions | |
| Attribute | Median | Range | Median | Range |
| $W_{belt}/W_{bkf}$ | No distinct repetitive pattern of riffles and pools within the degraded channel | | 7.3 | 6.0 – 8.9 |
| $L_m/W_{bkf}$ | | | 10.0 | 8.3 – 11.5 |
| $R_c/W_{bkf}$ | | | 2.6 | 2.1 – 3.8 |
| $L_{p-p}/W_{bkf}$ | | | 6.5 | 4.3 – 11.5 |

| Profile Ratios | | | | |
|---|---|---|---|---|
| | Existing Conditions | | Proposed Conditions | |
| Attribute | Median | Range | Median | Range |
| $S_{valley}/S_{ws}$ | *2.2 | NA | 1.3 | NA |
| $S_{riffle}/S_{ws}$ | No distinct repetitive pattern of riffles and pools | | 1.3 | 0.7 – 2.2 |
| $S_{pool}/S_{ws}$ | | | 0.4 | 0.1 – 1.0 |

| | | | |
|---|---|---|---|
| DA | Drainage Basin Area (sq. mi.) | $W_{belt}$ | Belt width (ft) |
| ENT | Entrenchment ratio (FPA/$W_{bkf}$) | $L_m$ | Meander wavelength (ft) |
| $W_{bkf}$ | Bankfull width (ft) | $R_c$ | Radius of Curvature (ft) |
| $D_{bkf}$ | Average bankfull depth (ft) | $L_{p-p}$ | Length from pool to pool (ft) |
| BHR | Bank height ratio [low bank height/$D_{max}$ (riffle)] | Sin | Sinuosity (thalweg dist/straight-line dist.) |
| $D_{max}$ | Maximum depth (ft) | $S_{ws}$ | Slope of the water surface (rise/run) |
| FPA | Floodprone area (ft) | $S_{valley}$ | Slope of the valley (rise/run) |
| $W_{pool}$ | Channel width at a pool (ft) | $S_{riffle}$ | Slope of the riffle (rise/run) |
| $L_{pool}$ | Individual pool length (ft) | $S_{pool}$ | Slope of the pool (rise/run) |
| LBH | Low bank height (distance from thalweg to the top of low bank) (ft) | | |

* Ratio of valley slope to water surface slope is high due to beaver activity causing aggradation of the stream channel. Actual sinuosities appear to be approximately 1.0 – 1.1 (thalweg distance / straight-line distance) as calculated using in-field measurements.

1) Beltwidth Preparation and Grading

The stream beltwidth corridor will be cleared to allow survey and equipment access. Care will be taken to avoid the removal of existing, deeply rooted vegetation within the beltwidth corridor which may provide design channel stability. Material excavated during grading will be stockpiled immediately adjacent to the channel segments to be abandoned and backfilled. These segments will be backfilled after stream diversion is completed. The preliminary grading plan depicted in Figure 16 summarizes activities involved in beltwidth preparation, floodplain grading, and channel backfilling.

Spoil material may be placed to stabilize temporary access roads and to minimize compaction of the underlying floodplain. However, all spoil will be removed from floodplain surfaces upon completion of construction activities.

After preparation of the corridor, the design channel and updated profile survey will be developed and the location of each meander wavelength plotted and staked along the profile. Riffle locations and relative frequency will be staked according to parameters outlined in Figure 16. These configurations may be modified in the field based on local variations in the floodplain profile. The stakes will be marked to denote the appropriate cross-section shape conceptually depicted in Figure 17 (riffle or pool).

2) Channel Excavation

The channel will be constructed within the range of values depicted in Tables 6A, 6B, 6C, and 6D. The cross-sectional area will be approximately 13 to 15 square feet, with a bankfull width ranging between 9 and 12 feet, and an average bankfull depth ranging between 1.2 to 1.4 feet in the upstream reach and 1.9 to 2.2 feet in the downstream reach.

Figure 16 provides a plan form and riffle elevations for the constructed channel. Riffle elevations refer to channel bed surface elevations at the specified location (top of riffle or bottom of riffle). Elevations depicted for top of riffles are approximately equivalent to the previous bottom of riffle, allowing for a flat water surface in all pools under normal flow conditions. A conceptual view of the proposed profile and plan view of the constructed channel is depicted in Figure 18.

The stream banks and local belt width area of constructed channels will be immediately planted with shrub and herbaceous vegetation. Shrubs such as tag alder and black willow may be purchased and planted, or removed from the banks of the abandoned channel and stockpiled during clearing, and placed into the stream construction area. Deposition of shrub and woody debris into and/or overhanging the constructed channel is encouraged. Root mats may also be selectively removed from adjacent areas and placed as erosion control features on channel banks.

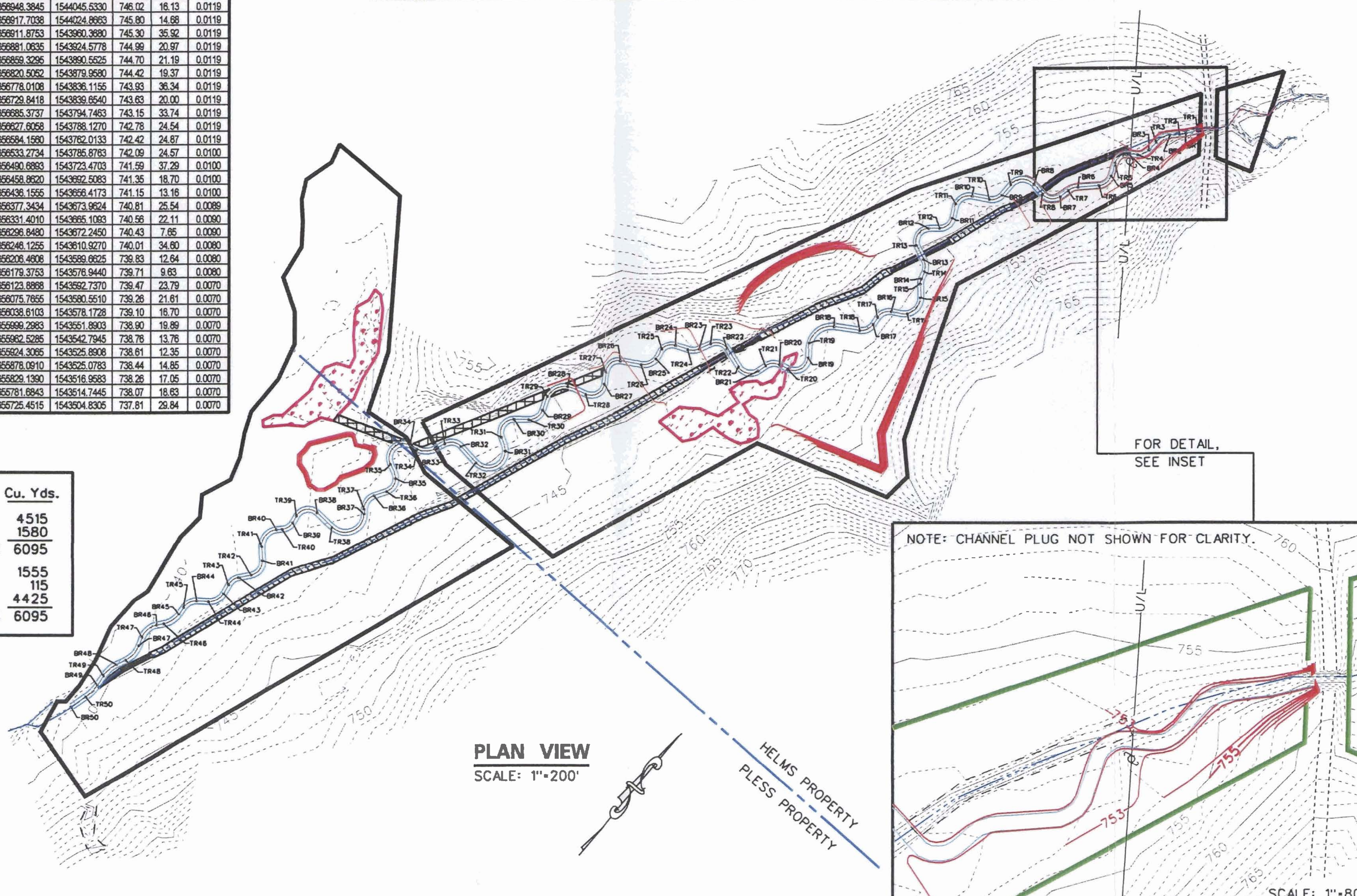
Particular attention will be directed toward providing vegetative cover and root growth along the outer bends of each stream meander. Live willow stake revetments will be constructed as conceptually depicted in Figure 19. Available root mats or biodegradable, coir fiber matting may be embedded into the break-in-slope to promote

| Top of Riffle ID | Northing | Easting | Elevation | Bottom of Riffle ID | Northing | Easting | Elevatio n | Riffle Length | Riffle Slope |
|---|---|---|---|---|---|---|---|---|---|
| TR1 | 657712.8128 | 1544329.6818 | 751.78 | BR1 | 657696.0668 | 1544317.2973 | 751.51 | 28.38 | 0.0095 |
| TR2 | 657688.0358 | 1544310.0233 | 751.49 | BR2 | 657676.6783 | 1544298.8500 | 751.34 | 15.93 | 0.0095 |
| TR3 | 657651.9740 | 1544288.3745 | 751.29 | BR3 | 657633.5708 | 1544287.9168 | 751.11 | 18.41 | 0.0095 |
| TR4 | 657615.3768 | 1544278.4913 | 751.07 | BR4 | 657606.0940 | 1544266.0158 | 750.92 | 15.55 | 0.0095 |
| TR5 | 657579.5568 | 1544258.7725 | 750.87 | BR5 | 657558.9063 | 1544267.3308 | 750.66 | 22.35 | 0.0095 |
| TR6 | 657532.7225 | 1544261.9125 | 750.61 | BR6 | 657507.6948 | 1544236.0135 | 750.27 | 36.01 | 0.0095 |
| TR7 | 657492.2413 | 1544227.1558 | 750.23 | BR7 | 657476.1970 | 1544223.2560 | 750.07 | 16.51 | 0.0095 |
| TR8 | 657458.7940 | 1544197.4793 | 750.01 | BR8 | 657461.8938 | 1544176.5270 | 749.81 | 21.18 | 0.0095 |
| TR9 | 657435.9920 | 1544146.3915 | 749.72 | BR9 | 657413.0470 | 1544146.3493 | 749.51 | 22.95 | 0.0095 |
| TR10 | 657393.5095 | 1544135.0370 | 749.46 | BR10 | 657378.6485 | 1544109.2598 | 749.18 | 29.75 | 0.0095 |
| TR11 | 657350.7959 | 1544096.8443 | 749.12 | BR11 | 657328.7918 | 1544107.5935 | 748.88 | 24.57 | 0.0095 |
| TR12 | 657301.0875 | 1544102.7478 | 748.83 | BR12 | 657288.6433 | 1544088.7310 | 748.64 | 18.74 | 0.0098 |
| TR13 | 657252.9140 | 1544091.5985 | 748.56 | BR13 | 657242.9325 | 1544115.7045 | 748.30 | 26.09 | 0.0100 |
| TR14 | 657228.1108 | 1544130.6738 | 748.26 | BR14 | 657216.1748 | 1544134.3488 | 748.14 | 12.49 | 0.0100 |
| TR15 | 657207.9350 | 1544138.9163 | 748.12 | BR15 | 657190.7128 | 1544153.9368 | 747.87 | 22.85 | 0.0110 |
| TR16 | 657155.3749 | 1544155.1343 | 747.80 | BR16 | 657140.1038 | 1544132.0418 | 747.49 | 27.93 | 0.0110 |
| TR17 | 657117.3353 | 1544120.3968 | 747.44 | BR17 | 657103.8105 | 1544122.2660 | 747.28 | 13.65 | 0.0119 |
| TR18 | 657080.8680 | 1544111.5925 | 747.23 | BR18 | 657057.1873 | 1544074.1248 | 746.70 | 44.32 | 0.0119 |
| TR19 | 657008.9184 | 1544059.4983 | 746.60 | BR19 | 656988.9535 | 1544073.9135 | 746.30 | 24.72 | 0.0119 |
| TR20 | 656952.0670 | 1544061.2405 | 746.21 | BR20 | 656948.3845 | 1544045.5330 | 746.02 | 16.13 | 0.0119 |
| TR21 | 656931.9028 | 1544028.5988 | 745.97 | BR21 | 656917.7038 | 1544024.8663 | 745.80 | 14.68 | 0.0119 |
| TR22 | 656901.0343 | 1543994.6093 | 745.73 | BR22 | 656911.8753 | 1543960.3680 | 745.30 | 35.92 | 0.0119 |
| TR23 | 656900.0660 | 1543933.4573 | 745.24 | BR23 | 656881.0635 | 1543924.5778 | 744.99 | 20.97 | 0.0119 |
| TR24 | 656867.3445 | 1543910.1668 | 744.95 | BR24 | 656859.3295 | 1543890.5525 | 744.70 | 21.19 | 0.0119 |
| TR25 | 656839.5147 | 1543876.7270 | 744.65 | BR25 | 656820.5052 | 1543879.9580 | 744.42 | 19.37 | 0.0119 |
| TR26 | 656796.7483 | 1543867.2548 | 744.37 | BR26 | 656778.0108 | 1543836.1155 | 743.93 | 36.34 | 0.0119 |
| TR27 | 656746.6658 | 1543828.8473 | 743.87 | BR27 | 656729.8418 | 1543839.6540 | 743.63 | 20.00 | 0.0119 |
| TR28 | 656695.8285 | 1543826.7155 | 743.55 | BR28 | 656685.3737 | 1543794.7463 | 743.15 | 33.74 | 0.0119 |
| TR29 | 656650.5449 | 1543779.5120 | 743.07 | BR29 | 656627.6058 | 1543788.1270 | 742.78 | 24.54 | 0.0119 |
| TR30 | 656599.9855 | 1543781.1973 | 742.72 | BR30 | 656584.1560 | 1543762.0133 | 742.42 | 24.87 | 0.0119 |
| TR31 | 656546.5990 | 1543765.4233 | 742.34 | BR31 | 656533.2734 | 1543785.8763 | 742.09 | 24.57 | 0.0100 |
| TR32 | 656485.9225 | 1543760.4523 | 741.96 | BR32 | 656490.6893 | 1543723.4703 | 741.59 | 37.29 | 0.0100 |
| TR33 | 656476.2895 | 1543699.2863 | 741.53 | BR33 | 656458.8620 | 1543692.5083 | 741.35 | 18.70 | 0.0100 |
| TR34 | 656438.9815 | 1543669.2705 | 741.29 | BR34 | 656436.1555 | 1543656.4173 | 741.15 | 13.16 | 0.0100 |
| TR35 | 656389.4908 | 1543651.7320 | 741.04 | BR35 | 656377.3434 | 1543673.9624 | 740.81 | 25.54 | 0.0089 |
| TR36 | 656350.3915 | 1543676.4260 | 740.76 | BR36 | 656331.4010 | 1543665.1093 | 740.56 | 22.11 | 0.0090 |
| TR37 | 656302.7298 | 1543667.3538 | 740.50 | BR37 | 656296.8480 | 1543672.2450 | 740.43 | 7.65 | 0.0090 |
| TR38 | 656244.0090 | 1543645.4605 | 740.29 | BR38 | 656246.1255 | 1543610.9270 | 740.01 | 34.60 | 0.0080 |
| TR39 | 656218.8534 | 1543587.1640 | 739.93 | BR39 | 656206.4608 | 1543589.6625 | 739.83 | 12.64 | 0.0080 |
| TR40 | 656186.2510 | 1543583.6895 | 739.79 | BR40 | 656179.3753 | 1543576.9440 | 739.71 | 9.63 | 0.0080 |
| TR41 | 656141.2585 | 1543576.4790 | 739.64 | BR41 | 656123.8868 | 1543592.7370 | 739.47 | 23.79 | 0.0070 |
| TR42 | 656092.6790 | 1543593.9960 | 739.41 | BR42 | 656075.7655 | 1543580.5510 | 739.26 | 21.61 | 0.0070 |
| TR43 | 656055.0578 | 1543575.2865 | 739.22 | BR43 | 656038.6103 | 1543578.1728 | 739.10 | 16.70 | 0.0070 |
| TR44 | 656011.4470 | 1543567.6375 | 739.04 | BR44 | 655999.2983 | 1543551.8903 | 738.90 | 19.89 | 0.0070 |
| TR45 | 655976.2445 | 1543541.6885 | 738.85 | BR45 | 655962.5285 | 1543542.7945 | 738.76 | 13.76 | 0.0070 |
| TR46 | 655933.8248 | 1543533.7558 | 738.70 | BR46 | 655924.3065 | 1543525.8908 | 738.61 | 12.35 | 0.0070 |
| TR47 | 655892.0984 | 1543520.1390 | 738.55 | BR47 | 655878.0910 | 1543525.0783 | 738.44 | 14.85 | 0.0070 |
| TR48 | 655844.7625 | 1543523.7953 | 738.38 | BR48 | 655829.1390 | 1543516.9583 | 738.26 | 17.05 | 0.0070 |
| TR49 | 655800.1945 | 1543512.6305 | 738.20 | BR49 | 655781.6843 | 1543514.7445 | 738.07 | 18.63 | 0.0070 |
| TR50 | 655754.2445 | 1543512.6468 | 738.02 | BR50 | 655725.4515 | 1543504.8305 | 737.81 | 29.84 | 0.0070 |

## LEGEND

- SITE BOUNDARY
- HELMS PROPERTY: 9.6 ac.
- PLESS PROPERTY: 5.5 ac.
- Total 15.1 ac.
- PROPERTY LINE
- 120 MAJOR CONTOUR
- MINOR CONTOUR
- PROPOSED CONTOUR
- EXISTING ROADS
- U/L POWER LINE CORRIDOR
- DESIGN CHANNEL (Upstream Reach)
- DESIGN CHANNEL (Downstream Reach)
- CHANNEL BACKFILL
- DITCH BACKFILL
- IMPERMEABLE CHANNEL PLUG
- UTILITY POLE
- TR9 TOP OF RIFFLE
- BR9 BOTTOM OF RIFFLE

| ESTIMATED FILL: | Cu. Yds. |
|---|---|
| EXISTING CHANNEL BACKFILL | 4515 |
| DITCH BACKFILL | 1580 |
| Total | 6095 |
| **ESTIMATED CUT:** | |
| CHANNEL EXCAVATION | 1555 |
| FLOOD PLAIN GRADING | 115 |
| SOIL BORROW AREAS | 4425 |
| Total | 6095 |




**PLAN VIEW**
SCALE: 1"=200'

EcoScience Corporation
Raleigh, North Carolina

REVISIONS

Client: NCDOT

Project: UT to DUTCH BUFFALO CREEK

DETAILED MITIGATION STUDIES

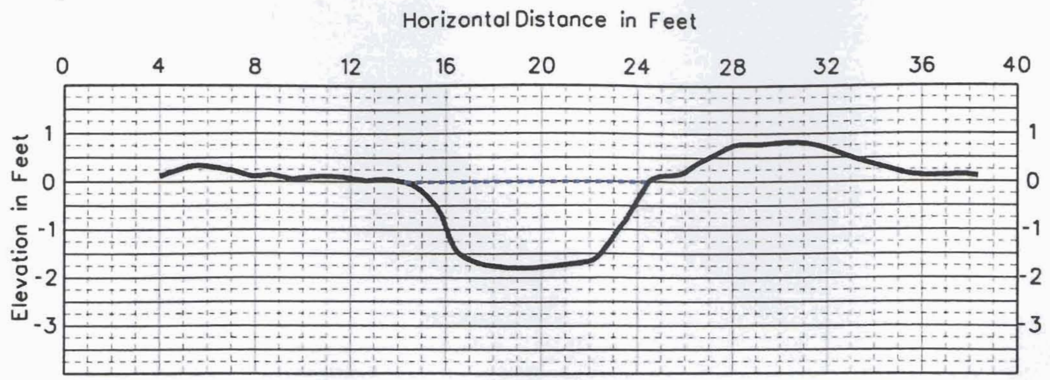
ROWAN COUNTY, NORTH CAROLINA

Title: GRADING PLAN

| Dwn By: MAF | Date: NOV 2002 |
|---|---|
| Ckd By: WGL | Scale: 1"= 200' |
| ESC Project No.: 00-046.26 | |

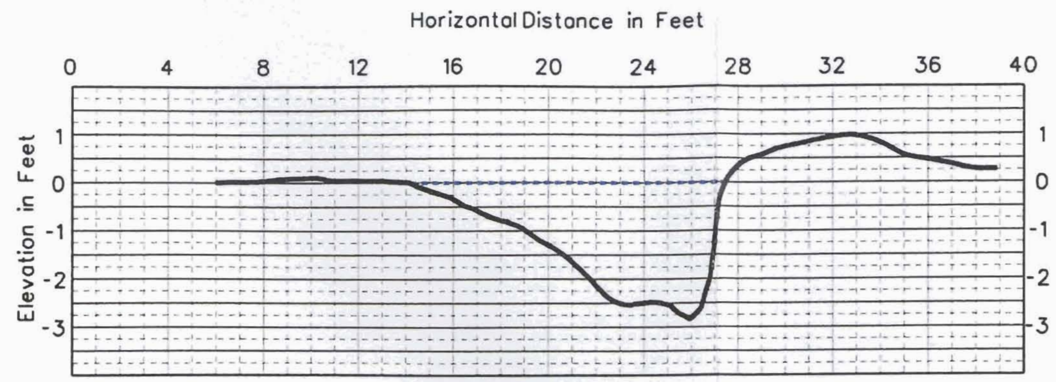
FIGURE 16

## UPSTREAM REACH



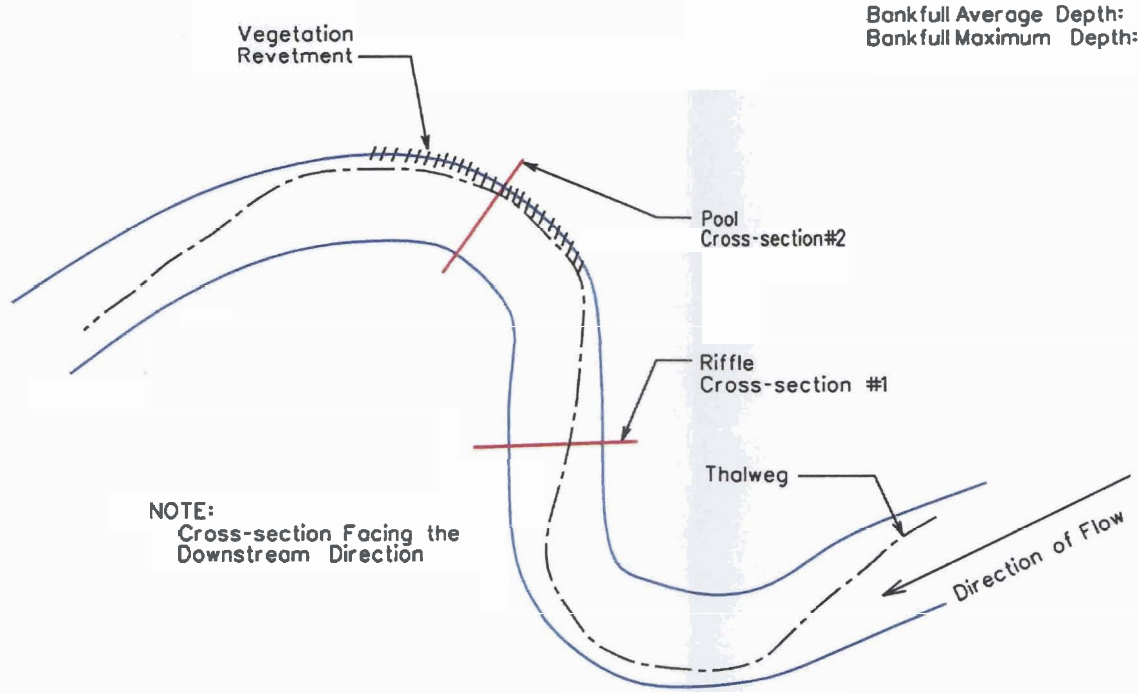

Cross-section
Riffle

Bankfull Cross-sectional Area: 13.0 ft.sq.
Bankfull Width: 10.2'
Bankfull Average Depth: 1.3'
Bankfull Maximum Depth: 1.8'



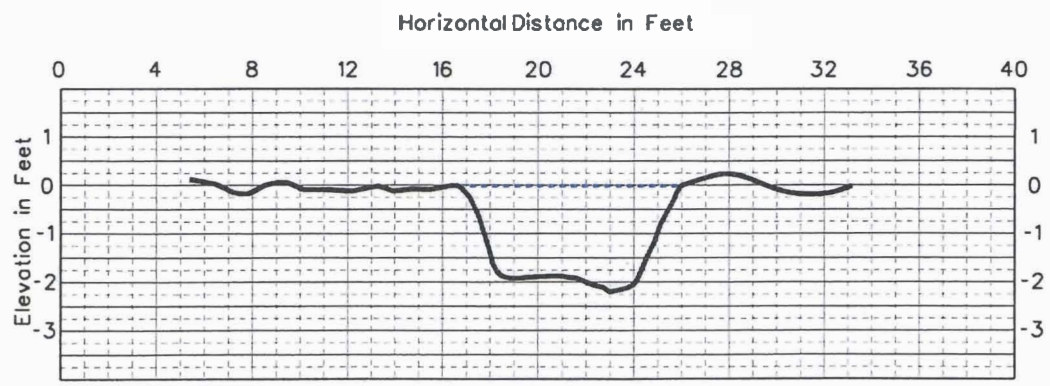

Cross-section 2
Pool

Bankfull Cross-sectional Area: 19.4 ft.sq.
Bankfull Width: 13.3'
Bankfull Average Depth: 1.5'
Bankfull Maximum Depth: 2.6'



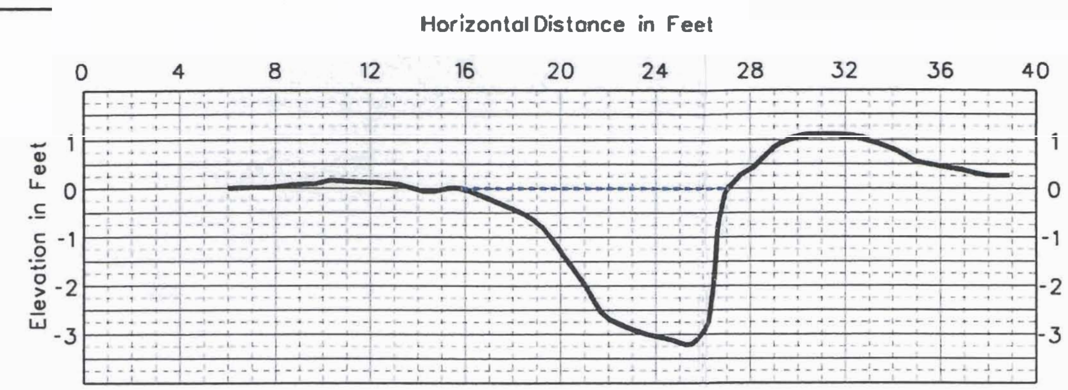

NOTE:
Cross-section Facing the Downstream Direction

## DOWNSTREAM REACH




Cross-section
Riffle

Bankfull Cross-sectional Area: 14.4 ft.sq.
Bankfull Width: 9.3'
Bankfull Average Depth: 1.6'
Bankfull Maximum Depth: 2.1'




Cross-section 2
Pool

Bankfull Cross-sectional Area: 19.5 ft.sq.
Bankfull Width: 11.2'
Bankfull Average Depth: 1.7'
Bankfull Maximum Depth: 3.2'

EcoScience Corporation
Raleigh, North Carolina

REVISIONS

Client:
NCDOT

Project:
UT to DUTCH BUFFALO CREEK
DETAILED MITIGATION STUDIES
ROWAN COUNTY, NORTH CAROLINA

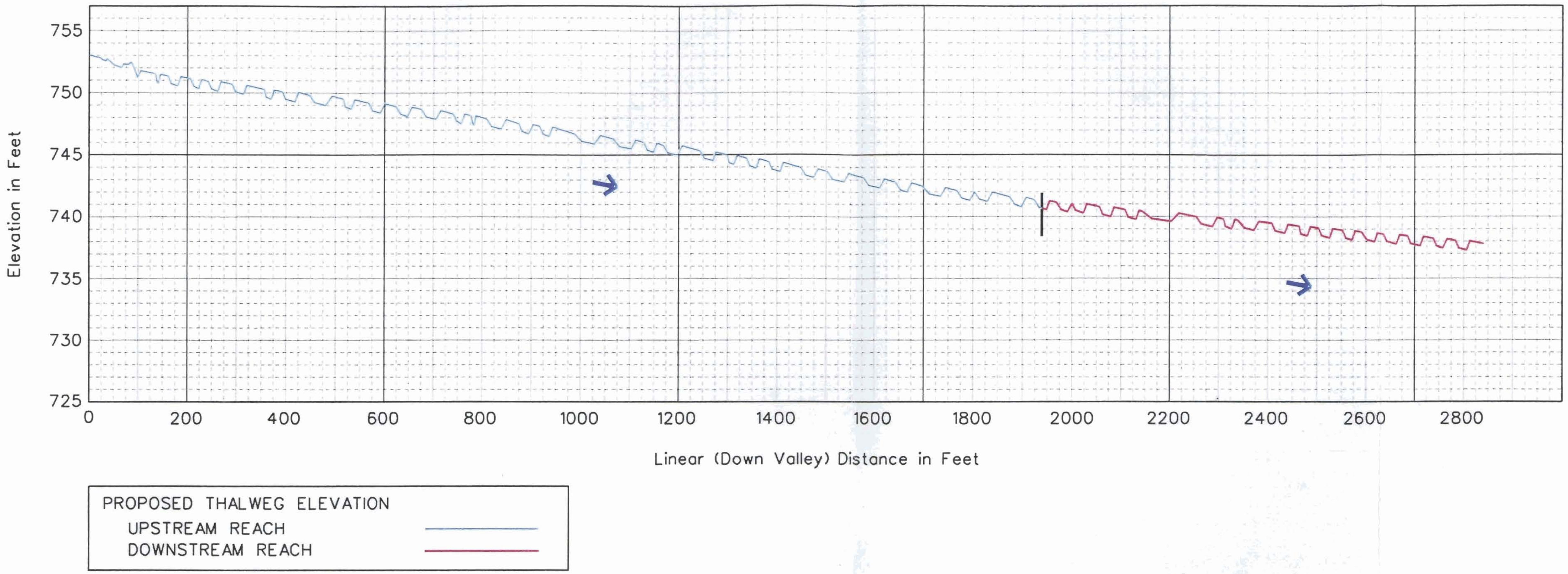
Title:
PROPOSED CROSS-SECTIONS

| Dwn By: MAF | Date: NOV 2002 |
|---|---|
| Ckd By: WGL | Scale: AS SHOWN |

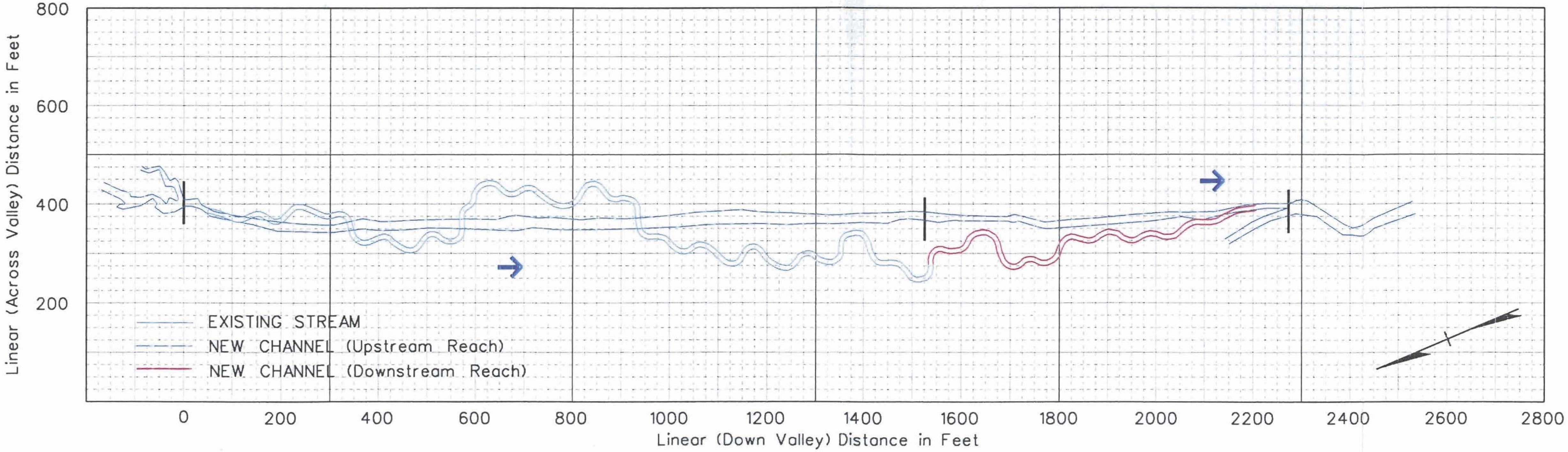
ESC Project No.: 00-046.26

FIGURE
17

## PROFILE




## PLAN VIEW




EcoScience Corporation
Raleigh, North Carolina

REVISIONS

Client: NCDOT

Project: UT to DUTCH BUFFALO CREEK

DETAILED MITIGATION STUDIES

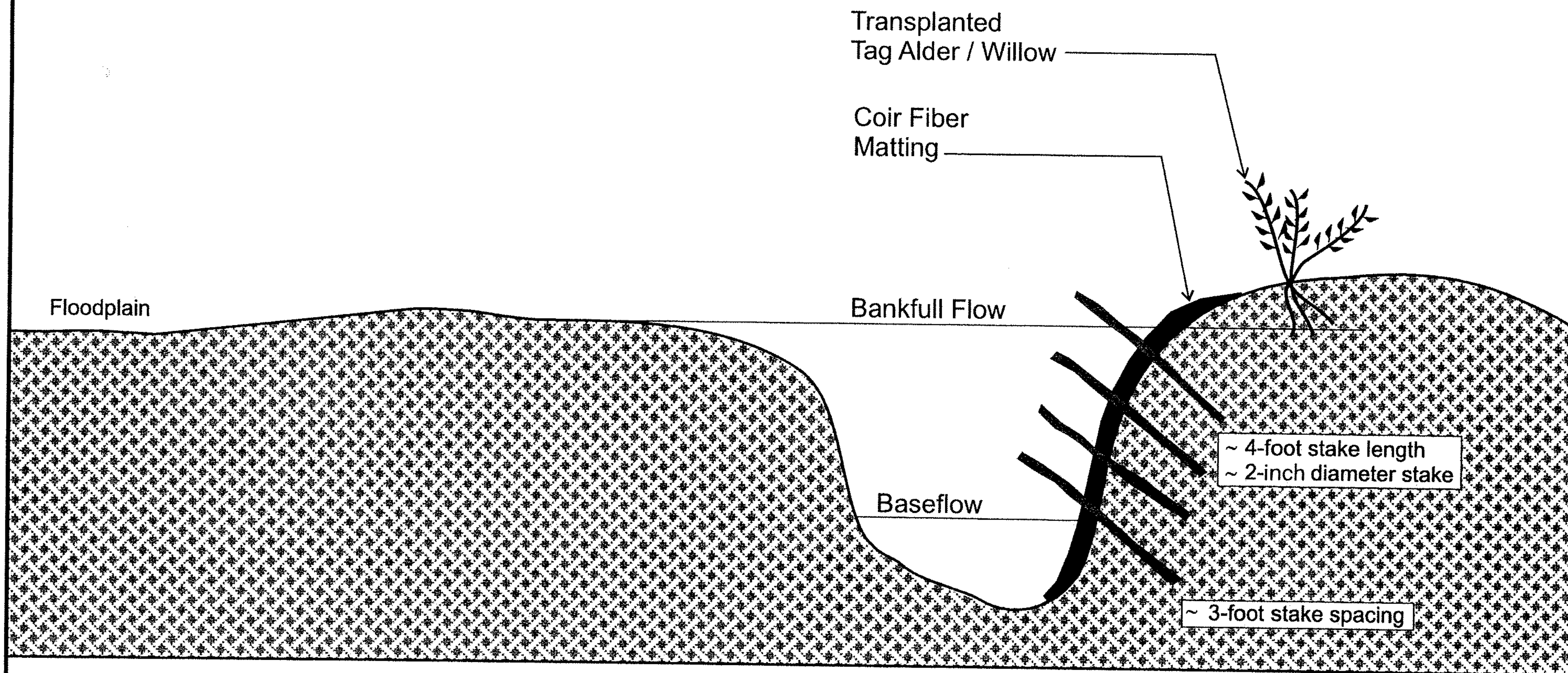
ROWAN COUNTY, NORTH CAROLINA

Title: PROPOSED PLAN VIEW AND PROFILE

| Dwn By: MAF | Date: NOV 2002 |
|---|---|
| Ckd By: WGL | Scale: As Shown |

ESC Project No.: 00-046.26

FIGURE 18




Not To Scale

EcoScience Corporation

**Live Willow Stake Embankment with Erosion Control Matting**
**UT to Dutch Buffalo Creek**
**DETAILED MITIGATION STUDIES**
Rowan County, North Carolina

| | |
|---|---|
| Figure: | 19 |
| Project: | 00-046.26 |
| Date: | NOV 2002 |

more rapid development of an overhanging bank. Willow stakes will be obtained and inserted through the coir fiber mat into the underlying soil.

4) Channel Plugs

Impermeable plugs will be installed along abandoned channel segments at locations identified in Figure 16. The plugs will consist of low-permeability materials or hardened structures designed to be of sufficient strength to withstand the erosive energy of surface flow events across the Site. Dense clays may be imported from off-site or existing material, compacted within the channel, may be suitable for plug construction. The plug will be sufficiently wide and deep to form an imbedded overlap in the existing banks and channel bed.

The plug situated at the upstream terminus of the design channel, located below the stream diversion point, may sustain high-energy flows. Therefore, a hardened structure or additional armoring (Section 5.1.1.1) may be considered at this location.

5) Channel Backfilling

After impermeable plugs are installed, the abandoned channel will be back-filled. Backfilling will be performed primarily by pushing stockpiled materials into the channel. Based on initial grading plan estimates (Figure 16), sufficient backfill material is expected from channel excavation, floodplain grading, and soil borrow areas. The channel will be filled to the extent that on-site material is available and compacted to maximize microtopographic variability, including ruts, ephemeral pools, and hummocks in the vicinity of the backfilled channel.

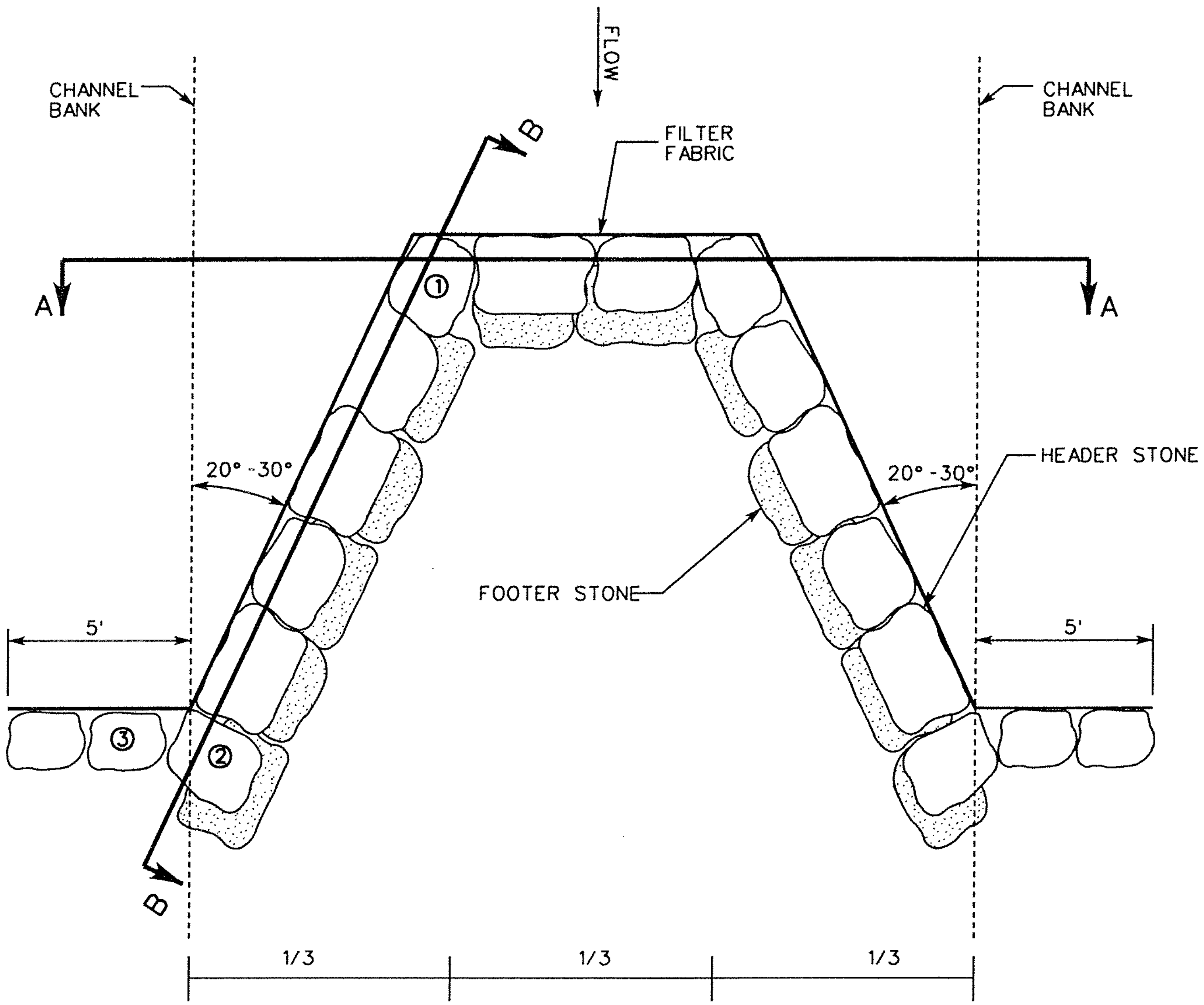
A deficit of fill material for channel back-fill may occur. If so, a series of closed, linear depressions may be left along confined channel segments. Additional fill material for critical areas may be obtained by excavating shallow depressions along the banks of these planned, open-channel segments. These excavated areas will represent closed linear, elliptical, or oval depressions. In essence, the channel may be converted to a sequence of shallow, ephemeral pools adjacent to effectively plugged and back-filled channel sections. These pools would be expected to stabilize and fill in with organic material over time. Vegetation debris (root mats, top soils, shrubs, woody debris, *etc.*) will be redistributed across the backfill area upon completion.

### 5.1.1.1 In-Stream Structures

Stream restoration under natural stream design techniques normally involves the use of in-stream structures for bank stabilization, grade control, and habitat improvement. Primary activities designed to achieve these objectives may include 1) installation of cross-vane weirs and/or 2) installation of J-hook vanes.

1) Cross-vane Weirs

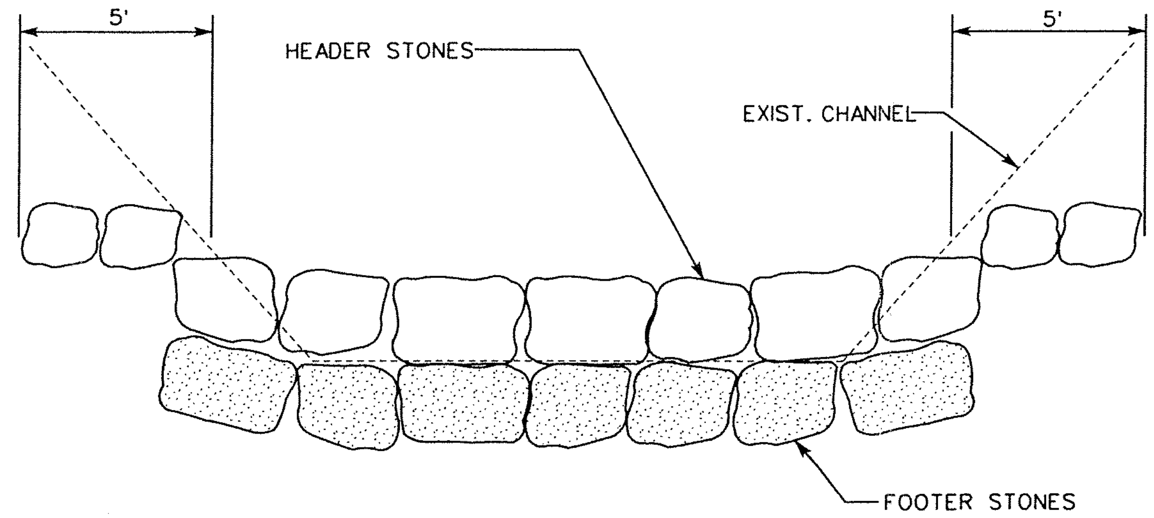
Cross-vane weirs may be installed in the channel as conceptually depicted in Figure 20. The purpose of the vane is to 1) sustain bank stability, 2) direct high velocity flows during bankfull events toward the center of the channel, 3) maintain average pool depth




## PLAN VIEW

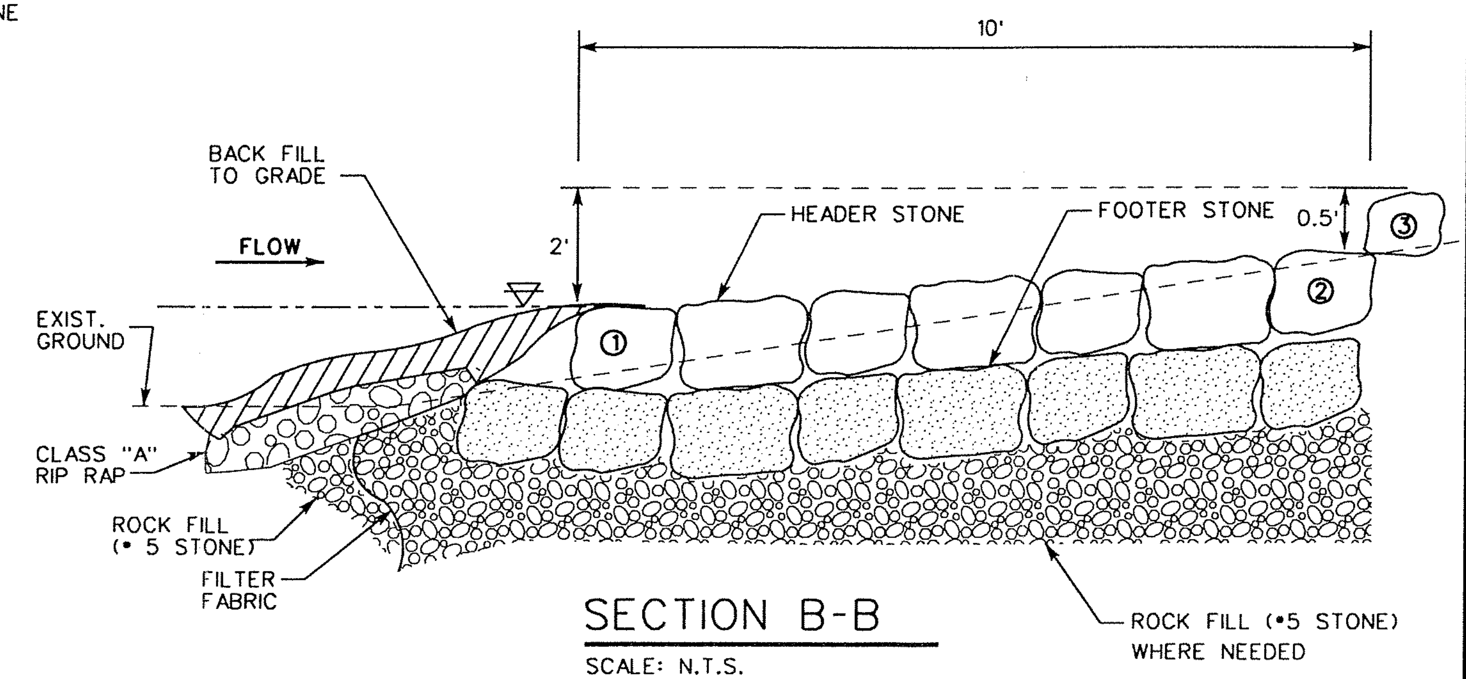
SCALE: N.T.S.

NOTE: HEADER AND FOOTER STONES ARE LARGE BOULDERS APPROXIMATELY 36" IN DIAMETER




## SECTION A-A

SCALE: N.T.S.




## SECTION B-B

SCALE: N.T.S.

EcoScience Corporation
Raleigh, North Carolina

REVISIONS

Client:
**NCDOT**

Project:
**UT to DUTCH BUFFALO CREEK**

**DETAILED MITIGATION STUDIES**

ROWAN COUNTY, NORTH CAROLINA

Title:
**CROSS-VANE WEIR**

| Dwn By: MAF | Date: NOV 2002 |
|---|---|
| Ckd By: WGL | Scale: As Shown |

ESC Project No.: 00-046.26

FIGURE
**20**

throughout the reach, 4) preserve water surface elevations and reconnect the adjacent floodplain to flooding dynamics from the stream, and 5) modify energy distributions through increases in channel roughness and local energy slopes during peak flows.

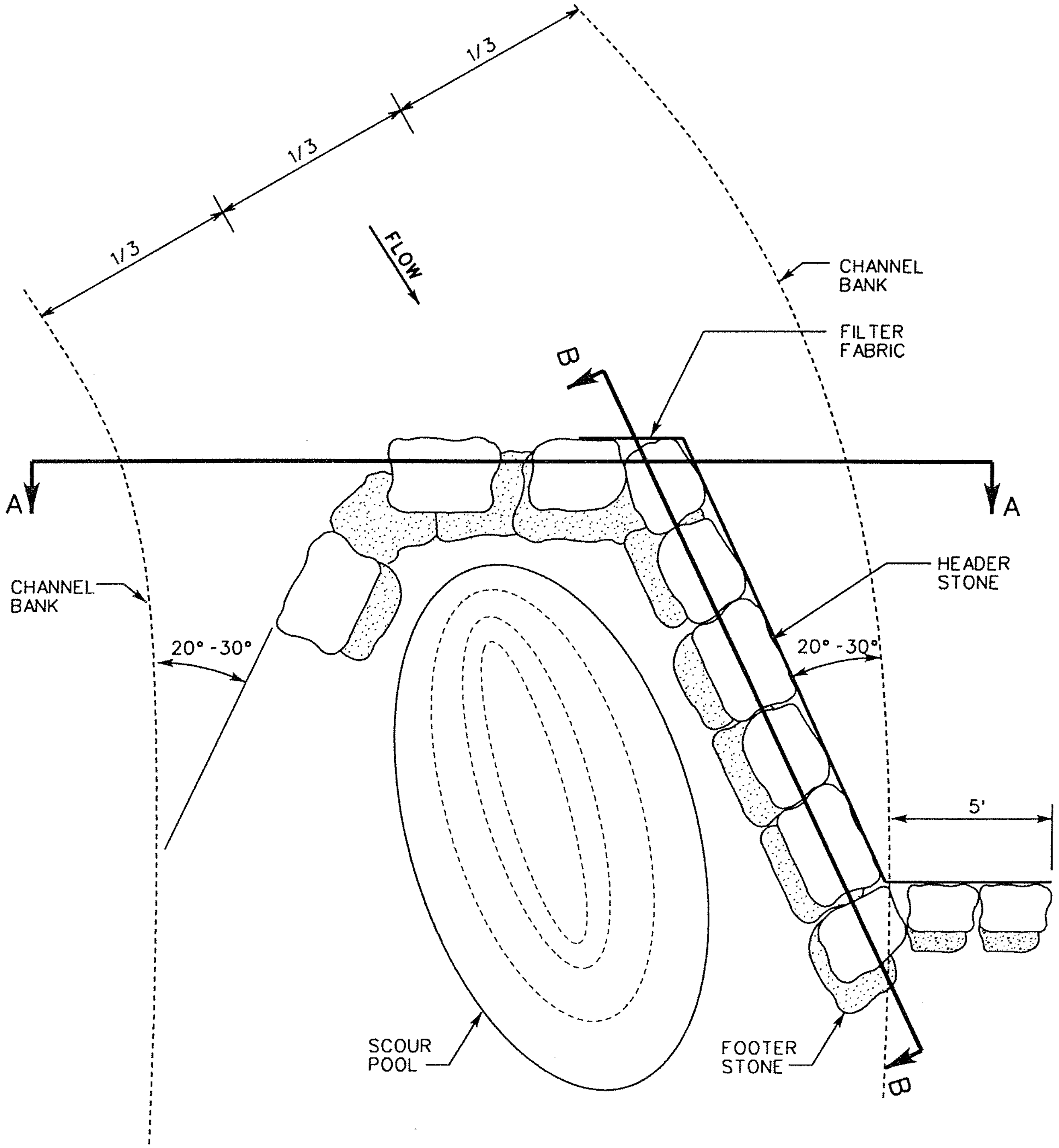
Cross-vane weirs will be constructed of boulders approximately 18 inches in minimum width. Cross-vane weir construction will be initiated by imbedding footer rocks into the stream bed for stability and to prevent undercutting of the structure. Header rocks will then be placed atop the footer rocks at the design elevation. Footer and header rocks create an arm that slopes from the center of the channel upward at approximately 10 to 15 degrees, tying in at the bankfull floodplain elevation. The cross-vane arms at both banks will be tied into the bank with a sill to eliminate the possibility of water diverting around the structure. Once the header and footer stones are in place, filter fabric will be buried into a trench excavated around the upstream side of the vane arms. The filter fabric is then draped over the header rocks to force water over the vane. The upstream side of the structure can then be backfilled with suitable material to the elevation of the header stones. Approximately 15 of these structures are anticipated at appropriate locations to maintain bank stability and surface-water elevations along the reach. The approximate location of each structure is depicted in Figure 15. Modifications to the location and elevation of each structure may be necessary during construction activities.

<u>2)</u> <u>J-hook vanes</u>
J-hook vane weirs may be installed in the channel as conceptually depicted in Figure 21. The primary purpose of the vane is to direct high-velocity flows during bankfull events towards the center of the channel. J-hook vanes will be constructed using the same type and size of rock used to construct cross-vane weirs. Similar to a cross vane, the arm of the J-hook vane must slope from the center of the channel upward at approximately 10 to 15 degrees, tying in at the bankfull floodplain elevation. Once the vane is in place, filter fabric is toed into a trench on the upstream side of the vane and draped over the structure to force water over the vane. The upstream side of the structure is then backfilled with suitable material.

## 5.2 Wetland Enhancement

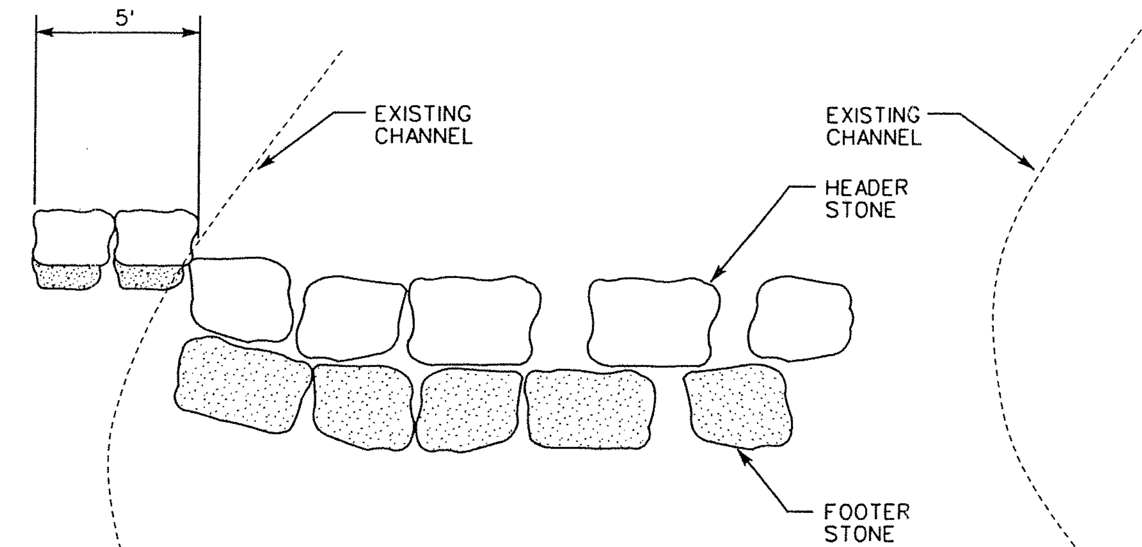
Site alterations designed to enhance characteristic groundwater wetland hydrology and characteristic wetland vegetation include 1) ditch cleaning prior to backfill, 2) ditch backfilling, 3) reestablishing hydrophytic vegetation, and 4) cattle exclusionary measures.

<u>1)</u> <u>Ditch Cleaning Prior to Backfill</u>
Ditches identified for backfilling in Figure 15 will be cleaned, as needed, to remove unconsolidated sediments within the ditches. Accumulated sediment within the ditches represents highly permeable material that may act as a conduit for continued drainage after enhancement. The unconsolidated sediments will be lifted from the channel to expose the underlying, relatively impermeable clay substrate along the ditch invert. The sediment will be temporarily placed on adjacent surfaces during ditch backfilling. Subsequently, the unconsolidated sediment will be incorporated into top soils and used



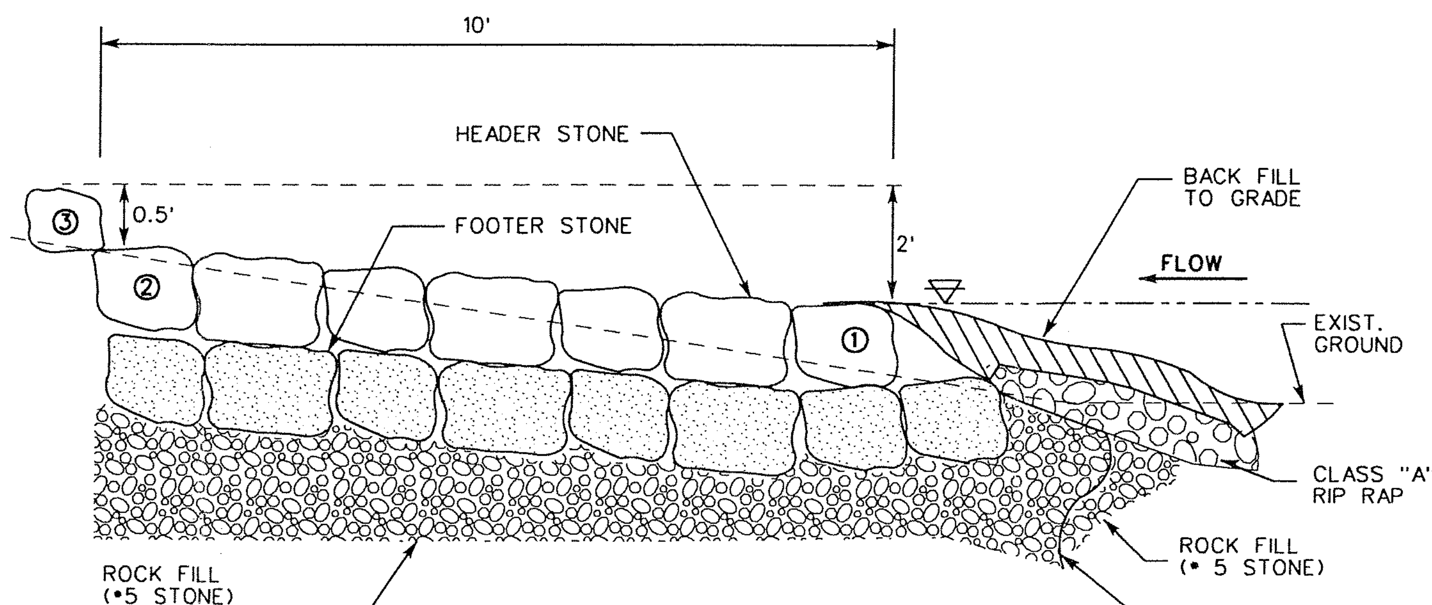

**PLAN VIEW**

SCALE: N.T.S.




**SECTION A–A**

SCALE: N.T.S.




**SECTION B–B**

SCALE: N.T.S.

NOTE: HEADER AND FOOTER STONES ARE LARGE BOULDERS APPROXIMATELY 36" IN DIAMETER

EcoScience Corporation
Raleigh, North Carolina

REVISIONS

Client: **NCDOT**

Project: **UT to DUTCH BUFFALO CREEK**

**DETAILED MITIGATION STUDIES**

ROWAN COUNTY, NORTH CAROLINA

Title: **TYPICAL J–HOOK VANE**

| | |
|---|---|
| Dwn By: MAF | Date: NOV 2002 |
| Ckd By: WGL | Scale: As Shown |
| ESC Project No.: 00-046.26 | |

FIGURE

**21**

throughout the Site for channel backfill and areas impacted by grading or other mitigation activities.

2) Ditch Backfilling

Ditches targeted for backfilling will be backfilled with clay-based material excavated from the depressions. Approximately 530 feet of ditches will be filled, graded, and compacted to the approximate elevation of the adjacent wetland surface.

3) Hydrophytic Vegetation

The wetland areas currently promote the growth of hydrophytic vegetation; however, this community has endured significant disturbance due to grazing activities and anthropogenic maintenance. Wetland areas will be planted with native vegetation typical of a wetland forested community. Emphasis has been focused on developing a diverse plant assemblage. Sections 5.4 (Plant Community Restoration) and 5.4.1 (Planting Plan) will provide detailed information concerning community species associations.

4) Cattle Exclusion

Measures will be taken to insure that grazing activities cease in wetland areas. The entire easement boundary will be fenced so that cattle will no longer be able to access the Site for grazing. Wetlands within the proposed easement should be protected from cattle intrusion.

## 5.3 Floodplain Soil Scarification

Microtopography and differential drainage rates within localized floodplain areas represent important components of floodplain functions. Reference forests in the region exhibit complex surface microtopography. Small concavities, swales, exposed root systems, seasonal pools, oxbows, and hummocks associated with vegetative growth and hydrological patterns are scattered throughout these systems. As discussed in the stream reconstruction section, efforts to advance the development of characteristic surface microtopography will be implemented.

In areas where soil surfaces have been compacted, ripping or scarification will be performed. Mixing of vegetation debris in surface soils and tip mounds will also promote future complexity across the landscape. After construction, the soil surface should exhibit complex microtopography ranging to 1 foot in vertical asymmetry across local reaches of the landscape. Subsequently, community restoration will be initiated on complex floodplain surfaces.

## 5.4 Plant Community Restoration

Restoration of floodplain forest and stream-side habitat allows for development and expansion of characteristic species across the landscape. Ecotonal changes between community types contribute to diversity and provide secondary benefits, such as enhanced feeding and nesting opportunities for mammals, birds, amphibians, and other wildlife.

RFE data, on-site observations, and community descriptions from *Classification of the Natural Communities of North Carolina* (Schafale and Weakley 1990) were used to develop the primary plant community associations that will be promoted during community restoration activities. These community associations include 1) Piedmont/Mountain bottomland forest, 2) stream-side assemblage, 3) Piedmon/low mountain alluvial forest, and 4) slope forest (Figure 22). Figure 23 identifies the location, based on elevation and position relative to the restored stream, of each target community to be planted. Planting elements within each map unit are listed below.

**Piedmont/Mountain Bottomland Forest**

1. Green Ash (*Fraxinus pennsylvanica*)
2. Swamp Chestnut Oak (*Quercus michauxii*)
3. American Sycamore (*Platanus occidentalis*)
4. Willow Oak (*Quercus phellos*)
5. Black Gum (*Nyssa sylvatica*)
6. Black Walnut (*Juglans nigra*)

**Stream-Side Forest Assemblage**

1. Black Willow (*Salix nigra*)
2. River Birch (*Betula nigra*)
3. American Sycamore (*Platanus occidentalis*)
3. Green Ash (*Fraxinus pennsylvanica*)

**Stream-Side Shrub Assemblage**

1. Tag Alder (*Alnus serrulata*)
2. Buttonbush (*Cephalanthus occidentalis*)
3. Elderberry (*Sambucus canadensis*)
4. Black Willow (*Salix nigra*)
5. Silky Dogwood (*Cornus amomum*)

**Piedmont/Low Mountain Alluvial Forest**

1. River Birch (*Betula nigra*)
2. American Sycamore (*Platanus occidentalis*)
3. Swamp Chestnut Oak (*Quercus michauxii*)
4. Spicebush (*Lindera benzoin*)
5. Button Bush (*Cephalanthus occidentalis*)
6. Elderberry (*Sambucus Canadensis*)

**Slope Forest**

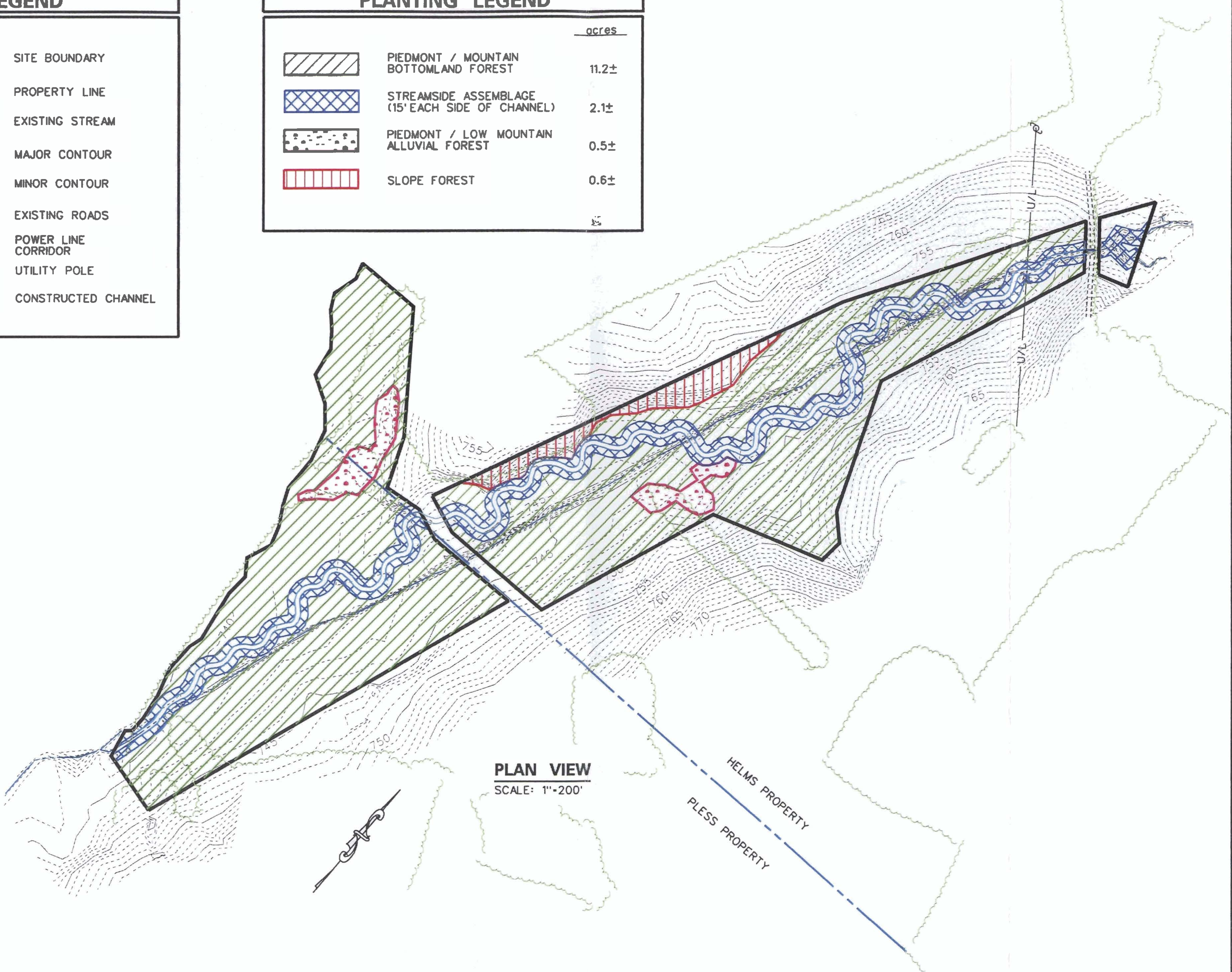
1. White Oak (*Quercus alba*)
2. Southern Red Oak (*Quercus falcata*)
3. Willow Oak (*Quercus phellos*)
4. Black Cherry (*Prunus serotina*)

## LEGEND

- SITE BOUNDARY
- PROPERTY LINE
- EXISTING STREAM
- 120 MAJOR CONTOUR
- MINOR CONTOUR
- EXISTING ROADS
- U/L POWER LINE CORRIDOR
- UTILITY POLE
- CONSTRUCTED CHANNEL

## PLANTING LEGEND

| | acres |
|---|---|
| PIEDMONT / MOUNTAIN BOTTOMLAND FOREST | 11.2± |
| STREAMSIDE ASSEMBLAGE (15' EACH SIDE OF CHANNEL) | 2.1± |
| PIEDMONT / LOW MOUNTAIN ALLUVIAL FOREST | 0.5± |
| SLOPE FOREST | 0.6± |




**PLAN VIEW**
SCALE: 1"=200'

EcoScience Corporation
Raleigh, North Carolina

REVISIONS

Client:
NCDOT

Project:
UT to DUTCH BUFFALO CREEK
DETAILED MITIGATION STUDIES
ROWAN COUNTY, NORTH CAROLINA

Title:
PLANTING PLAN

| Dwn By: MAF | Date: NOV 2002 |
|---|---|
| Ckd By: | Scale: 1"= 200' |

ESC Project No.: 00-046.26

FIGURE
22

| COMMUNITY ASSEMBLAGE | SLOPE FOREST | STREAMSIDE ASSEMBLAGE | PIEDMONT/ MOUNTAIN FLOODPLAIN FOREST | PIEDMONT/ LOW MOUNTAIN ALLUVIAL FOREST |
|---|---|---|---|---|
| CANOPY VEGETATION | White Oak<br>Southern Red Oak<br>Willow Oak<br>Black Cherry | **Streamside Forest**<br>Black Willow<br>River Birch<br>American Sycamore<br>Green Ash<br><br>**Streamside Shrub**<br>Tag Alder<br>Buttonbush<br>Elderberry<br>Black Willow<br>Silky Dogwood | Green Ash<br>Swamp Chestnut Oak<br>American Sycamore<br>Willow Oak<br>Black Gum<br>Black Walnut | Swamp Chestnut Oak<br>River Birch<br>American Sycamore<br>Spice Bush<br>Button Bush<br>Elderberry |
| LAND FORM | Floodplain Slopes | Stream Banks and Adjacent Flood Plain | Floodplain | Floodplain Depressions |


EcoScience Corporation
Raleigh, North Carolina 27605


Client: NCDOT

Project: UT to DUTCH BUFFALO CREEK

DETAILED MITIGATION STUDIES

ROWAN COUNTY, NORTH CAROLINA

Title: CONCEPTUAL MODEL OF TARGET COMMUNITY PATTERNS

| | |
|---|---|
| Dwn By: MAF | Date: NOV 2002 |
| Ckd By: WGL | Scale: As Shown |
| ESC Project No.: 00-046.26 | |

FIGURE 23

The stream-side trees and shrubs include species with high value for sediment stabilization, rapid growth rate, and the ability to withstand hydraulic forces associated with bankfull flow and overbank flood events. Stream-side trees will be planted within 10 to 15 feet of the channel throughout the meander belt width. Shrub elements will be planted along the banks of the reconstructed stream, concentrated along outer bends. Piedmont/Mountain bottomland hardwood forests are targeted for outer portions of the floodplain. Piedmont/low mountain alluvial forest will be planted in the relict oxbow and the side slope seep area containing hydric soils. Slope forests are intended for slopes adjacent to the floodplain.

Certain opportunistic species which may dominate the early successional forests have been excluded from community restoration efforts. Opportunistic species consist primarily of red maple, tulip tree, and sweetgum. These species should also be considered important components of bottomland forests where species diversity has not been jeopardized.

The following planting plan is the blueprint for community restoration. The anticipated results stated in the Success Criteria (Section 6.6) are expected to reflect potential vegetative conditions achieved after steady-state conditions prevail over time.

### 5.4.1 Planting Plan

The purpose of a planting plan is to re-establish vegetative community patterns across the landscape. The plan consists of 1) acquisition of available plant species, 2) implementation of proposed Site preparation, and 3) planting of selected species.

Species selected for planting will be dependent upon availability of local seedling sources. Advance notification to nurseries (1 year) will facilitate availability of various non-commercial elements.

Bare-root seedlings of tree species will be planted within specified map areas at a density of 680 stems per acre on 8-foot centers. Shrub species within streambank areas will be planted at a density of 2722 stems per acre on 4-foot centers. Table 7 depicts the total number of stems and species distribution within each vegetation association. Planting will be performed between Novernber 15 and March 15 to allow plants to stabilize during the dormant period and set root during the spring season. A total of 12,149 diagnostic tree and shrub seedlings will be planted during restoration (Table 7).

**TABLE 7**
**Planting Plan**
**Unnamed Tributary to Dutch Buffalo Creek Mitigation Site**

| **Vegetation Association (Planting Area)** | **Piedmont/Mountain Bottomland Hardwood Forest** | **Stream-Side Forest Assemblage** | **Stream-Side Shrub Assemblage** | **Piedmont/Low Mountain Alluvial Forest** | **Slope Forest** | **TOTAL** |
|---|---|---|---|---|---|---|
| **Area (acres)** | 11.2 | 1.6 | 0.5 | 0.5 | 0.6 | 14.4 |
| **SPECIES**[1] | # planted[2] | # planted[2] | # planted[2] | # planted[2] | # planted[2] | # planted[2] |
| Green Ash | 1523 | 272 | | | | 1795 |
| Swamp Chestnut Oak | 1523 | | | 110 | | 1633 |
| American Sycamore | 1523 | 272 | | 110 | | 1905 |
| Willow Oak | 1523 | | | | 102 | 1625 |
| Black Gum | 760 | | | | | 760 |
| Black Walnut | 760 | | | | | 760 |
| Black Willow | | 272 | 340 | | | 612 |
| River Birch | | 272 | | 110 | | 382 |
| Tag Alder | | | 340 | | | 340 |
| Buttonbush | | | 136 | 450 | | 586 |
| Elderberry | | | 340 | 450 | | 790 |
| Silky Dogwood | | | 205 | | | 205 |
| Spicebush | | | | 450 | | 450 |
| White Oak | | | | | 102 | 102 |
| Southern Red Oak | | | | | 102 | 102 |
| Black Cherry | | | | | 102 | 102 |
| **TOTAL** | 7612 | 1088 | 1361 | 1680 | 408 | 12149 |

[1] Scientific names for each species, required for nursery inventory, are listed in the mitigation plan.

[2] Planting densities comprise 680 trees and 2722 shrubs per acre within each specified planting area.

## 6.0 MONITORING PLAN

### 6.1 Site Monitoring

The NCDOT will provide an "as-built" plan of the stream reach within 90 days after construction has been completed. The as-built plan will include profile and plan view of the completed stream project. The as-built plan will serve as the baseline during the monitoring period. The as-built will consist of "red line" design plans, which will also include the location of permanent photo points and vegetation plots.

The mitigation project will be monitored biannually for three years. The NCDOT recommends this "preventive" review in order to identify development of potential problem areas along the stream reach. As part of the biannual review, the entire stream reach will be visually monitored for stability and vegetation establishment. The NCDOT believes the walkthrough will ensure that the entire stream reach is in good condition and again provide a through preventative review of the stream. Permanent photographic reference points along the stream will be established for the biannual monitoring.

During the biannual review of the stream, the entire stream reach will be evaluated for any potential problem areas such as stream bank instability, in-stream structure failure or unsuccessful vegetation establishment. Photographs of the good, stable sections of the stream, as well as potential problem areas, will be taken to document the stability of the stream and the severity of the potential problem area(s) encountered.

An annual report documenting the two yearly visits to the stream mitigation will be prepared. The report will contain photographs and documentation of the stream during the monitoring period.

If, during the biannual review of the stream reach, a failure is noted, the area will be evaluated to determine the corrective actions that will be required to resolve the problem. The NCDOT will measure cross sections in these areas where failure is occurring. These cross sections will be compared to the as-built. If remediation of an area is required, a proposal will be submitted for the needed work. Remedial actions will be undertaken considering any seasonal limitations at the Site.

The NCDOT recommends taking cross sections under this scenario in order to prevent unnecessary survey work of areas which are not failing. The NCDOT believes surveying cross sections and reviewing them in the office will not yield conclusive results about where sections of the stream may be failing. A field visit would have to occur in order to resolve whether the stream is actually failing.

Upon completion of monitoring the Site for three successful growing seasons, a final report will be prepared and presented to the resource agencies prior to a "Final Review" of the project. If remedial actions to the stream have been required during the monitoring period, an updated "as-built" will be attached to the report. The stream mitigation site will be reviewed with the resource agencies for final acceptance of the stream reach. If the resource agencies require additional work to the stream, then the work will be performed considering the seasonal limitations of the Site.

### 6.2 Hydrology Monitoring

While hydrological modifications are being performed on the Site, surficial monitoring wells will be designed and placed in accordance with specifications in the COE's *Installing Monitoring Wells/Piezometers in Wetlands* (WRP Technical Note HY-IA-3.1, August 1993). Monitoring wells will be set to a depth immediately above the top of the clay subsurface layer (range: 24 to 40 inches below the surface).

Five monitoring wells will be placed within the Site to provide representative coverage within each of the identified mitigation design units (Figure 24). Hydrological sampling will be performed throughout the growing season at intervals necessary to satisfy the hydrology success criteria within each design unit (EPA 1990).

Target hydrological characteristics include saturation or inundation for at least 12.5 percent of the growing season at lower landscape positions, during average climatic conditions. Upper landscape reaches may exhibit surface saturation/inundation between 5 percent and 12.5 percent of the growing season based on well data. These 5 - 12.5 percent areas are expected to support hydrophytic vegetation. If wetland parameters are marginal as indicated by vegetation and hydrology monitoring, a jurisdictional determination will be performed in the questionable area.


EcoScience Corporation
Raleigh, North Carolina

REVISIONS

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Client:
**NCDOT**

Project:
**UT to DUTCH BUFFALO CREEK**

**DETAILED MITIGATION STUDIES**

ROWAN COUNTY, NORTH CAROLINA

Title:
**MONITORING PLAN**

| Dwn By: MAF | Date: NOV 2002 |
|---|---|
| Ckd By: WGL | Scale: 1"= 200' |

ESC Project No.: 00-046.26

FIGURE
**24**

## 7.0 FINAL DISPENSATION OF THE PROPERTY

NCDOT will maintain the Site conservation easement until all mitigation activities are completed and the Site is determined to be successful. Mr. Helms and Mr. Pless are expected to retain ownership of their respective parcels. The conservation easement is expected to be transferred perpetually with property upon sale of the property. Covenants and/or restrictions on the deed will be included that will ensure adequate management and protection of the Site in perpetuity.

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# APPENDIX A
STREAM GAUGE DATA

# Peak Streamflow

## Norwood Creek Near Troutman, NC

**USGS Station #0214253830**
**Drainage Area 7.18 square miles**

| | Water Year | Discharge (cfs) | Exceedance Probability | Exceedance Probability % | Return Interval (years) |
|---|---|---|---|---|---|
| 1 | 1984 | 1480 | 0.05 | 5 | 19.0 |
| 2 | 1985 | 1320 | 0.11 | 11 | 9.5 |
| 3 | 1986 | 1320 | 0.16 | 16 | 6.3 |
| 4 | 1987 | 1200 | 0.21 | 21 | 4.8 |
| 5 | 1988 | 1050 | 0.26 | 26 | 3.8 |
| 6 | 1989 | 978 | 0.32 | 32 | 3.2 |
| 7 | 1990 | 690 | 0.37 | 37 | 2.7 |
| 8 | 1991 | 567 | 0.42 | 42 | 2.4 |
| 9 | 1992 | 470 | 0.47 | 47 | 2.1 |
| 10 | 1993 | 447 | 0.53 | 53 | 1.9 |
| 11 | 1994 | 394 | 0.58 | 58 | 1.7 |
| 12 | 1995 | 333 | 0.63 | 63 | 1.6 |
| 13 | 1996 | 314 | 0.68 | 68 | 1.5 |
| 14 | 1997 | 271 | 0.74 | 74 | 1.4 |
| 15 | 1998 | 263 | 0.79 | 79 | 1.3 |
| 16 | 1999 | 243 | 0.84 | 84 | 1.2 |
| 17 | 2000 | 191 | 0.89 | 89 | 1.1 |
| 18 | 2001 | 123 | 0.95 | 95 | 1.1 |

nkfull

365 cfs → Regional Curve accurately predicted bankfull

Discharge according to Regional Curve (Harman et. al. 1999)

$y = 89.039 x^{0.7223}$; where $y$ = discharge (cfs)
$x$ = Watershed Area (sq. mi)

# Peak Streamflow

## Dutchmans Creek Near Uwharrie, NC

**USGS Station #02123567**

**Drainage Area 3.44 square miles**

| | Water Year | Discharge (cfs) | Exceedance Probability | Exceedance Probability % | Return Interval (years) |
|---|---|---|---|---|---|
| 1 | 1982 | 1560 | 0.06 | 6 | 18.0 |
| 2 | 1983 | 1040 | 0.11 | 11 | 9.0 |
| 3 | 1986 | 791 | 0.17 | 17 | 6.0 |
| 4 | 1987 | 739 | 0.22 | 22 | 4.5 |
| 5 | 1988 | 690 | 0.28 | 28 | 3.6 |
| 6 | 1989 | 660 | 0.33 | 33 | 3.0 |
| 7 | 1990 | 471 | 0.39 | 39 | 2.6 |
| 8 | 1991 | 445 | 0.44 | 44 | 2.3 |
| 9 | 1992 | 405 | 0.50 | 50 | 2.0 |
| 10 | 1993 | 394 | 0.56 | 56 | 1.8 |
| 11 | 1994 | 376 | 0.61 | 61 | 1.6 |
| 12 | 1995 | 309 | 0.67 | 67 | 1.5 |
| 13 | 1997 | 298 | 0.72 | 72 | 1.4 |
| 14 | 1998 | 215 | 0.78 | 78 | 1.3 |
| 15 | 1999 | 171 | 0.83 | 83 | 1.2 |
| 16 | 2000 | 161 | 0.89 | 89 | 1.1 |
| 17 | 2001 | 90 | 0.94 | 94 | 1.1 |

unkfull

277 cfs → Regional Curve accurately predicted bankfull

Discharge according to Regional Curve (Harman et. al. 1999)

$y = 89.039\, x^{0.7223}$; where $y$ = Discharge (cfs)

$x$ = Watershed Area (sq. mi.)

# Peak Streamflow

## Big Bear Creek Near Richfield, NC

**USGS Station #02125000**
**Drainage Area 55.60 square miles**

| | Water Year | Discharge (cfs) | Exceedance Probability | Exceedance Probability % | Return Interval (years) |
|---|---|---|---|---|---|
| 1 | 1955 | 11400 | 0.02 | 2 | 48.0 |
| 2 | 1956 | 11100 | 0.04 | 4 | 24.0 |
| 3 | 1957 | 10100 | 0.06 | 6 | 16.0 |
| 4 | 1958 | 9700 | 0.08 | 8 | 12.0 |
| 5 | 1959 | 9700 | 0.10 | 10 | 9.6 |
| 6 | 1960 | 8410 | 0.13 | 13 | 8.0 |
| 7 | 1961 | 8270 | 0.15 | 15 | 6.9 |
| 8 | 1962 | 8030 | 0.17 | 17 | 6.0 |
| 9 | 1963 | 7770 | 0.19 | 19 | 5.3 |
| 10 | 1964 | 7520 | 0.21 | 21 | 4.8 |
| 11 | 1965 | 7460 | 0.23 | 23 | 4.4 |
| 12 | 1966 | 6690 | 0.25 | 25 | 4.0 |
| 13 | 1967 | 6600 | 0.27 | 27 | 3.7 |
| 14 | 1968 | 6590 | 0.29 | 29 | 3.4 |
| 15 | 1969 | 6110 | 0.31 | 31 | 3.2 |
| 16 | 1970 | 5830 | 0.33 | 33 | 3.0 |
| 17 | 1971 | 5610 | 0.35 | 35 | 2.8 |
| 18 | 1972 | 5400 | 0.38 | 38 | 2.7 |
| 19 | 1973 | 4900 | 0.40 | 40 | 2.5 |
| 20 | 1974 | 4880 | 0.42 | 42 | 2.4 |
| 21 | 1975 | 4880 | 0.44 | 44 | 2.3 |
| 22 | 1976 | 4880 | 0.46 | 46 | 2.2 |
| 23 | 1977 | 4850 | 0.48 | 48 | 2.1 |
| 24 | 1978 | 4820 | 0.50 | 50 | 2.0 |
| 25 | 1979 | 4700 | 0.52 | 52 | 1.9 |
| 26 | 1980 | 4550 | 0.54 | 54 | 1.8 |
| 27 | 1981 | 4370 | 0.56 | 56 | 1.8 |
| 28 | 1982 | 4200 | 0.58 | 58 | 1.7 |
| 29 | 1983 | 4150 | 0.60 | 60 | 1.7 |
| 30 | 1984 | 4140 | 0.63 | 63 | 1.6 |
| 31 | 1985 | 4040 | 0.65 | 65 | 1.5 |
| 32 | 1986 | 3990 | 0.67 | 67 | 1.5 |
| 33 | 1987 | 3720 | 0.69 | 69 | 1.5 |
| 34 | 1988 | 3620 | 0.71 | 71 | 1.4 |
| 35 | 1989 | 3440 | 0.73 | 73 | 1.4 |
| 36 | 1990 | 3440 | 0.75 | 75 | 1.3 |
| 37 | 1991 | 3410 | 0.77 | 77 | 1.3 |
| 38 | 1992 | 3360 | 0.79 | 79 | 1.3 |
| 39 | 1993 | 3290 | 0.81 | 81 | 1.2 |
| 40 | 1994 | 3020 | 0.83 | 83 | 1.2 |
| 41 | 1995 | 2850 | 0.85 | 85 | 1.2 |
| 42 | 1996 | 2740 | 0.88 | 88 | 1.1 |
| 43 | 1997 | 2030 | 0.90 | 90 | 1.1 |
| 44 | 1998 | 1960 | 0.92 | 92 | 1.1 |
| 45 | 1999 | 1730 | 0.94 | 94 | 1.1 |
| 46 | 2000 | 1610 | 0.96 | 96 | 1.0 |
| 47 | 2001 | 1520 | 0.98 | 98 | 1.0 |

ıkfull

Discharge according to Regional Curve (Harman et. al 1999)

$$y = 89.039\,x^{0.7223};$$

Where $y$ = discharge (cfs)
$x$ = Watershed Area (sq. Mi.)

1622 cfs → Regional Curve underestimated bankfull

# APPENDIX B
## SHEAR STRESS, STREAM POWER, AND SEDIMENT TRANSPORT DATA

**Design Channel**

**Upstream Reach**

useing eigth iteration

| | slope | D50 bed | D50bar | Largest Bar Sample | bar sample mm | Critical Shear str. | required Dbkf | required Slope |
|---|---|---|---|---|---|---|---|---|
| average | 0.0057 | 15 | 6 | 0.125 | 38 | 0.0375 | 1.35 | 0.0059 |
| min | 0.0051 | 15 | 6 | 0.125 | 38 | 0.0375 | 1.51 | 0.0059 |
| max | 0.0064 | 15 | 6 | 0.125 | 38 | 0.0375 | 1.20 | 0.0059 |

**Downstream Reach**

useing eigth iteration

| | slope | D50 bed | D50bar | Largest Bar Sample | bar sample mm | Critical Shear str. | required Dbkf | required Slope |
|---|---|---|---|---|---|---|---|---|
| average | 0.0042 | 15 | 6 | 0.125 | 38 | 0.0375 | 1.84 | 0.0048 |
| min | 0.0037 | 15 | 6 | 0.125 | 38 | 0.0375 | 2.08 | 0.0048 |
| max | 0.0052 | 15 | 6 | 0.125 | 38 | 0.0375 | 1.48 | 0.0048 |

**Existing Conditions**

**Upstream**

| slope | D50 bed | D50bar | Largest Bar Sample | bar sample mm | Critical Shear str. | required Dbkf | required Slope |
|---|---|---|---|---|---|---|---|
| 0.0076 | 15 | 6 | 0.125 | 38 | 0.0375 | 1.01 | 0.0059 |

**Downstream**

| slope | D50 bed | D50bar | Largest Bar Sample | bar sample mm | Critical Shear str. | required Dbkf | required Slope |
|---|---|---|---|---|---|---|---|
| 0.0025 | 15 | 6 | 0.125 | 38 | 0.0375 | 3.08 | 0.0059 |

# Entrainment Calculation Form

| | | | |
|---|---|---|---|
| Stream: | UT to Dutch Buffalo Creek | Reach: | Reference (Pavement/SubPav) |
| Date: | 8/15/2002 | Observers: | Grant, Joe, Ben |

## Critical Dimensionless Shear Stress:

$$\tau_{ci} = 0.0834(d_i/d_{50})^{-0.872}$$

| Value | Variable | Definition |
|---|---|---|
| 15 | $d_i$ (mm) | D50 Bed Material (D50 from riffle pebble count) |
| 6 | $d_{50}$ (mm) | Bar Sample D50 or Sub-pavement D50 |
| **0.038** | $\tau_{ci}$ | **Critical Dimensionless Shear Stress** |

### Bankfull Mean Depth Required for Entrainment of Largest Particle in Bar Sample:

$$d_r = (\tau_{ci} * 1.65 * D_i)/S_e$$

1.65 = submerged specific weight of sediment

| Value | Variable | Definition |
|---|---|---|
| 0.038 | $\tau_{ci}$ | Critical Dimensionless Shear Stress |
| 0.125 | $D_i$ (feet) | Largest particle from bar sample |
| 0.0062 | $S_e$ (ft/ft) | Existing Bankfull Water Surface Slope |
| **1.26** | **$d_r$ (ft)** | **Bankfull Mean Depth Required** |
| **1.1** | **$d_e$ (ft)** | **Existing Bankfull Mean Depth (from riffle cross section)** |
| Circle: | Stable ($d_e/d_r$ =1) | Aggrading ($d_e/d_r$ <1) Degrading ($d_e/d_r$ >1) |

### Bankfull Water Surface Slope Required for Entrainment of Largest Particle in Bar Sample:

$$S_r = (\tau_{ci} * 1.65 * D_i)/d_e$$

1.65 = submerged specific weight of sediment

| Value | Variable | Definition |
|---|---|---|
| 0.038 | $\tau_{ci}$ | Critical Dimensionless Shear Stress |
| 0.125 | $D_i$ (feet) | Largest particle from bar sample |
| 1.1 | $d_e$ (ft) | Existing Bankfull Mean Depth (from riffle cross section) |
| **0.0071** | $S_r$ (ft/ft) | Bankfull Water Surface Slope Required |
| Circle: | Stable ($S_e/S_r$ =1) | Aggrading ($S_e/S_r$ <1) Degrading ($S_e/S_r$ >1) |

## Sediment Transport Validation

| | |
|---|---|
| 38 | Largest Particle in Bar Sample $D_i$ (mm) |
| 0.35 | Bankfull Shear Stress $\tau_c = \gamma RS$ (lb/ft$^2$) |
| 64 | Moveable particle size (mm) at bankfull shear stress (predicted by the Shields Diagram: Blue field book:p238, Red field book: p190) |
| 0.16 | Predicted shear stress required to initiate movement of $D_i$ (mm) (see Shields Diagram: Blue field book:p238, Red field book: p190) |

**Reference Pavement/Sub-Pavement**

| slope | D50 pavement | D50 sub-pavement | Largest Sub-Pavement | Sub-Pavement mm | Critical Shear str. | required Dbkf | required Slope |
|---|---|---|---|---|---|---|---|
| 0.0045 | 15 | 6 | 0.125 | 38 | 0.0375 | 1.71 | 0.0073 |
| 0.0047 | 15 | 6 | 0.125 | 38 | 0.0375 | 1.64 | 0.0073 |
| 0.005 | 15 | 6 | 0.125 | 38 | 0.0375 | 1.54 | 0.0073 |
| 0.0055 | 15 | 6 | 0.125 | 38 | 0.0375 | 1.40 | 0.0073 |
| 0.006 | 15 | 6 | 0.125 | 38 | 0.0375 | 1.29 | 0.0073 |
| 0.0062 | 15 | 6 | 0.125 | 38 | 0.0375 | 1.24 | 0.0073 |
| 0.0065 | 15 | 6 | 0.125 | 38 | 0.0375 | 1.19 | 0.0073 |
| 0.0068 | 15 | 6 | 0.125 | 38 | 0.0375 | 1.13 | 0.0073 |
| 0.007 | 15 | 6 | 0.125 | 38 | 0.0375 | 1.10 | 0.0073 |
| 0.0075 | 15 | 6 | 0.125 | 38 | 0.0375 | 1.03 | 0.0073 |
| | | | | | | | |
| 0.0062 | 15 | 6 | 0.092 | 28 | 0.0375 | 0.92 | 0.0054 |
| 0.0062 | 15 | 6 | 0.098 | 30 | 0.0375 | 0.98 | 0.0058 |
| 0.0062 | 15 | 6 | 0.105 | 32 | 0.0375 | 1.05 | 0.0062 |
| 0.0062 | 15 | 6 | 0.111 | 34 | 0.0375 | 1.11 | 0.0066 |
| 0.0062 | 15 | 6 | 0.118 | 36 | 0.0375 | 1.18 | 0.0070 |
| 0.0062 | 15 | 6 | 0.125 | 38 | 0.0375 | 1.24 | 0.0073 |
| 0.0062 | 15 | 6 | 0.131 | 40 | 0.0375 | 1.31 | 0.0077 |
| 0.0062 | 15 | 6 | 0.138 | 42 | 0.0375 | 1.37 | 0.0081 |
| 0.0062 | 15 | 6 | 0.144 | 44 | 0.0375 | 1.44 | 0.0085 |
| 0.0062 | 15 | 6 | 0.151 | 46 | 0.0375 | 1.51 | 0.0089 |
| 0.0062 | 15 | 6 | 0.157 | 48 | 0.0375 | 1.57 | 0.0093 |
| 0.0062 | 15 | 6 | 0.164 | 50 | 0.0375 | 1.64 | 0.0097 |
| | | | | | | | |
| 0.0062 | 15 | 2 | 0.125 | 38 | 0.0144 | 0.48 | 0.0028 |
| 0.0062 | 15 | 3 | 0.125 | 38 | 0.0205 | 0.68 | 0.0040 |
| 0.0062 | 15 | 4 | 0.125 | 38 | 0.0263 | 0.87 | 0.0052 |
| 0.0062 | 15 | 5 | 0.125 | 38 | 0.0320 | 1.06 | 0.0063 |
| 0.0062 | 15 | 6 | 0.125 | 38 | 0.0375 | 1.24 | 0.0073 |
| 0.0062 | 15 | 7 | 0.125 | 38 | 0.0429 | 1.42 | 0.0084 |
| 0.0062 | 15 | 8 | 0.125 | 38 | 0.0482 | 1.60 | 0.0094 |
| 0.0062 | 15 | 9 | 0.125 | 38 | 0.0534 | 1.77 | 0.0105 |
| 0.0062 | 15 | 10 | 0.125 | 38 | 0.0586 | 1.94 | 0.0115 |
| 0.0062 | 15 | 11 | 0.125 | 38 | 0.0636 | 2.11 | 0.0125 |
| | | | | | | | |
| 0.0062 | 12 | 6 | 0.125 | 38 | 0.0456 | 1.51 | 0.0089 |
| 0.0062 | 13 | 6 | 0.125 | 38 | 0.0425 | 1.41 | 0.0083 |
| 0.0062 | 14 | 6 | 0.125 | 38 | 0.0398 | 1.32 | 0.0078 |
| 0.0062 | 15 | 6 | 0.125 | 38 | 0.0375 | 1.24 | 0.0073 |
| 0.0062 | 16 | 6 | 0.125 | 38 | 0.0355 | 1.18 | 0.0069 |
| 0.0062 | 17 | 6 | 0.125 | 38 | 0.0336 | 1.12 | 0.0066 |
| 0.0062 | 18 | 6 | 0.125 | 38 | 0.0320 | 1.06 | 0.0063 |
| 0.0062 | 19 | 6 | 0.125 | 38 | 0.0305 | 1.01 | 0.0060 |
| 0.0062 | 20 | 6 | 0.125 | 38 | 0.0292 | 0.97 | 0.0057 |

# Entrainment Calculation Form

| | |
|---|---|
| Stream: UT to Dutch Buffalo Creek | Reach: Reference (Point Bar 7b) |
| Date: 8/15/2002 | Observers: Grant, Joe, Ben |

## Critical Dimensionless Shear Stress:

$$\tau_{ci} = 0.0834(d_i/d_{50})^{-0.872}$$

| Value | Variable | Definition |
|---|---|---|
| 15 | $d_i$ (mm) | D50 Bed Material (D50 from riffle pebble count) |
| 6 | $d_{50}$ (mm) | Bar Sample D50 or Sub-pavement D50 |
| **0.038** | $\tau_{ci}$ | **Critical Dimensionless Shear Stress** |

**Bankfull Mean Depth Required for Entrainment of Largest Particle in Bar Sample:**

$$d_r = (\tau_{ci}*1.65*D_i)/S_e$$

1.65 = submerged specific weight of sediment

| Value | Variable | Definition |
|---|---|---|
| 0.038 | $\tau_{ci}$ | Critical Dimensionless Shear Stress |
| 0.131 | $D_i$ (feet) | Largest particle from bar sample |
| 0.0062 | $S_e$ (ft/ft) | Existing Bankfull Water Surface Slope |
| **1.32** | **$d_r$ (ft)** | **Bankfull Mean Depth Required** |
| **1** | **$d_e$ (ft)** | **Existing Bankfull Mean Depth (from riffle cross section)** |
| Circle: | Stable ($d_e/d_r$ =1) | Aggrading ($d_e/d_r$ <1) Degrading ($d_e/d_r$ >1) |

**Bankfull Water Surface Slope Required for Entrainment of Largest Particle in Bar Sample:**

$$S_r = (\tau_{ci}*1.65*D_i)/d_e$$

1.65 = submerged specific weight of sediment

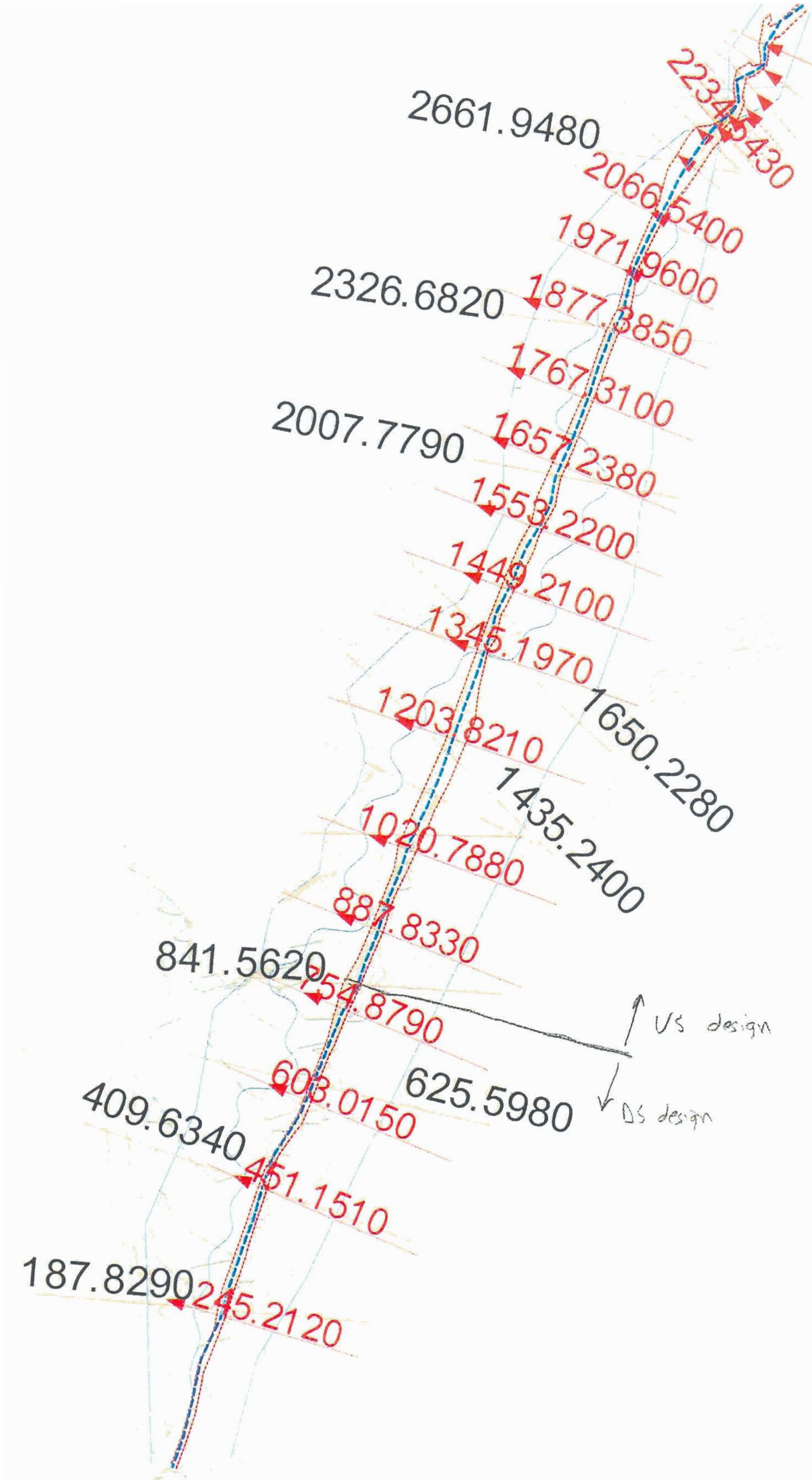
| Value | Variable | Definition |
|---|---|---|
| 0.038 | $\tau_{ci}$ | Critical Dimensionless Shear Stress |
| 0.131 | $D_i$ (feet) | Largest particle from bar sample |
| 1 | $d_e$ (ft) | Existing Bankfull Mean Depth (from riffle cross section) |
| **0.0082** | $S_r$ (ft/ft) | Bankfull Water Surface Slope Required |
| Circle: | Stable ($S_e/S_r$ =1) | Aggrading ($S_e/S_r$ <1) Degrading ($S_e/S_r$ >1) |

## Sediment Transport Validation

| | |
|---|---|
| 40 | Largest Particle in Bar Sample $D_i$ (mm) |
| 0.34 | Bankfull Shear Stress $\tau_c=\gamma RS$ (lb/ft$^2$) |
| 60 | Moveable particle size (mm) at bankfull shear stress (predicted by the Shields Diagram: Blue field book:p238, Red field book: p190) |
| 0.18 | Predicted shear stress required to initiate movement of $D_i$ (mm) (see Shields Diagram: Blue field book:p238, Red field book: p190) |

**Reference Top Riffle 7b**

| slope | D50 bed | D50bar | Largest Bar Sample | bar sample mm | Critical Shear str. | required Dbkf | required Slope |
|---|---|---|---|---|---|---|---|
| 0.0034 | 15 | 6 | 0.131 | 40 | 0.0375 | 2.39 | 0.0074 |
| 0.0045 | 15 | 6 | 0.131 | 40 | 0.0375 | 1.80 | 0.0074 |
| 0.0047 | 15 | 6 | 0.131 | 40 | 0.0375 | 1.73 | 0.0074 |
| 0.005 | 15 | 6 | 0.131 | 40 | 0.0375 | 1.62 | 0.0074 |
| 0.0055 | 15 | 6 | 0.131 | 40 | 0.0375 | 1.48 | 0.0074 |
| 0.006 | 15 | 6 | 0.131 | 40 | 0.0375 | 1.35 | 0.0074 |
| 0.0062 | 15 | 6 | 0.131 | 40 | 0.0375 | 1.31 | 0.0074 |
| 0.0065 | 15 | 6 | 0.131 | 40 | 0.0375 | 1.25 | 0.0074 |
| 0.0068 | 15 | 6 | 0.131 | 40 | 0.0375 | 1.19 | 0.0074 |
| 0.007 | 15 | 6 | 0.131 | 40 | 0.0375 | 1.16 | 0.0074 |
| 0.0075 | 15 | 6 | 0.131 | 40 | 0.0375 | 1.08 | 0.0074 |
| | | | | | | | |
| 0.0062 | 15 | 6 | 0.092 | 28 | 0.0375 | 0.92 | 0.0052 |
| 0.0062 | 15 | 6 | 0.098 | 30 | 0.0375 | 0.98 | 0.0055 |
| 0.0062 | 15 | 6 | 0.105 | 32 | 0.0375 | 1.05 | 0.0059 |
| 0.0062 | 15 | 6 | 0.111 | 34 | 0.0375 | 1.11 | 0.0063 |
| 0.0062 | 15 | 6 | 0.118 | 36 | 0.0375 | 1.18 | 0.0066 |
| 0.0062 | 15 | 6 | 0.125 | 38 | 0.0375 | 1.24 | 0.0070 |
| 0.0062 | 15 | 6 | 0.131 | 40 | 0.0375 | 1.31 | 0.0074 |
| 0.0062 | 15 | 6 | 0.138 | 42 | 0.0375 | 1.37 | 0.0077 |
| 0.0062 | 15 | 6 | 0.144 | 44 | 0.0375 | 1.44 | 0.0081 |
| 0.0062 | 15 | 6 | 0.151 | 46 | 0.0375 | 1.51 | 0.0085 |
| 0.0062 | 15 | 6 | 0.157 | 48 | 0.0375 | 1.57 | 0.0089 |
| 0.0062 | 15 | 6 | 0.164 | 50 | 0.0375 | 1.64 | 0.0092 |
| | | | | | | | |
| 0.0062 | 15 | 2 | 0.131 | 40 | 0.0144 | 0.50 | 0.0028 |
| 0.0062 | 15 | 3 | 0.131 | 40 | 0.0205 | 0.72 | 0.0040 |
| 0.0062 | 15 | 4 | 0.131 | 40 | 0.0263 | 0.92 | 0.0052 |
| 0.0062 | 15 | 5 | 0.131 | 40 | 0.0320 | 1.12 | 0.0063 |
| 0.0062 | 15 | 6 | 0.131 | 40 | 0.0375 | 1.31 | 0.0074 |
| 0.0062 | 15 | 7 | 0.131 | 40 | 0.0429 | 1.50 | 0.0084 |
| 0.0062 | 15 | 8 | 0.131 | 40 | 0.0482 | 1.68 | 0.0095 |
| 0.0062 | 15 | 9 | 0.131 | 40 | 0.0534 | 1.86 | 0.0105 |
| 0.0062 | 15 | 10 | 0.131 | 40 | 0.0586 | 2.04 | 0.0115 |
| 0.0062 | 15 | 11 | 0.131 | 40 | 0.0636 | 2.22 | 0.0125 |
| | | | | | | | |
| 0.0062 | 11 | 6 | 0.131 | 40 | 0.0492 | 1.72 | 0.0097 |
| 0.0062 | 12 | 6 | 0.131 | 40 | 0.0456 | 1.59 | 0.0090 |
| 0.0062 | 13 | 6 | 0.131 | 40 | 0.0425 | 1.48 | 0.0084 |
| 0.0062 | 14 | 6 | 0.131 | 40 | 0.0398 | 1.39 | 0.0078 |
| 0.0062 | 15 | 6 | 0.131 | 40 | 0.0375 | 1.31 | 0.0074 |
| 0.0062 | 16 | 6 | 0.131 | 40 | 0.0355 | 1.24 | 0.0070 |
| 0.0062 | 17 | 6 | 0.131 | 40 | 0.0336 | 1.17 | 0.0066 |
| 0.0062 | 18 | 6 | 0.131 | 40 | 0.0320 | 1.12 | 0.0063 |
| 0.0062 | 19 | 6 | 0.131 | 40 | 0.0305 | 1.07 | 0.0060 |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DS design
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## Helms Property Mitigation
## HEC-RAS Results

| HEC-RAS Plan: Design River: Design Reach: main | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Reach | River Sta | Profile | 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 | Conv. Total | Shear Chan | Shear LOB | Shear ROB | Power Total | Critical Depth |
| | | | (cfs) | (ft) | (ft) | (ft) | (ft) | (ft/ft) | (ft/s) | (sq ft) | (ft) | | (cfs) | (lb/sq ft) | (lb/sq ft) | (lb/sq ft) | (lb/ft s) | (ft) |
| main | 2898.914 | 1 yr | 65 | 753 | 755.53 | 754.48 | 755.6 | 0.001592 | 2.23 | 29.51 | 22.36 | 0.31 | 1629.2 | 0.15 | 0.01 | 0.01 | 0.28 | 1.48 |
| main | 2898.914 | 2 yr | 94 | 753 | 755.53 | 754.77 | 755.69 | 0.0033 | 3.22 | 29.6 | 22.45 | 0.45 | 1636.4 | 0.31 | 0.02 | 0.03 | 0.83 | 1.77 |
| main | 2898.914 | 10 yr | 238 | 753 | 758.12 | 755.74 | 758.15 | 0.00028 | 1.79 | 259.91 | 145.85 | 0.15 | 14222.9 | 0.07 | 0.03 | 0.02 | 0.03 | 2.74 |
| main | 2898.914 | 25 yr | 342 | 753 | 758.8 | 756.29 | 758.83 | 0.000262 | 1.92 | 365.03 | 167.49 | 0.15 | 21129.9 | 0.08 | 0.04 | 0.02 | 0.03 | 3.29 |
| main | 2898.914 | 50 yr | 435 | 753 | 759.22 | 756.78 | 759.25 | 0.000277 | 2.08 | 436.53 | 174.21 | 0.16 | 26137.8 | 0.09 | 0.05 | 0.03 | 0.04 | 3.78 |
| main | 2898.914 | 100 yr | 541.5 | 753 | 759.57 | 757.05 | 759.61 | 0.000309 | 2.29 | 498.03 | 176.45 | 0.17 | 30829.8 | 0.1 | 0.06 | 0.04 | 0.06 | 4.05 |
| | | | | | | | | | | | | | | | | | | |
| main | 2828.912 | 1 yr | 65 | 752.77 | 755.39 | 754.29 | 755.48 | 0.002179 | 2.36 | 27.53 | 37.7 | 0.36 | 1392.4 | 0.18 | | | 0.42 | 1.52 |
| main | 2828.912 | 2 yr | 94 | 752.77 | 755.12 | 754.59 | 755.38 | 0.00613 | 4.11 | 22.86 | 29.85 | 0.6 | 1200.6 | 0.53 | | | 2.16 | 1.82 |
| main | 2828.912 | 10 yr | 238 | 752.77 | 758.12 | 755.81 | 758.13 | 0.000137 | 1.13 | 368.89 | 166.49 | 0.11 | 20325.3 | 0.03 | 0.02 | 0.01 | 0.01 | 3.04 |
| main | 2828.912 | 25 yr | 342 | 752.77 | 758.8 | 755.86 | 758.81 | 0.000134 | 1.26 | 486.6 | 181.62 | 0.11 | 29581.5 | 0.03 | 0.02 | 0.02 | 0.02 | 3.09 |
| main | 2828.912 | 50 yr | 435 | 752.77 | 759.22 | 756.09 | 759.23 | 0.000146 | 1.39 | 562.87 | 186.5 | 0.11 | 36056.7 | 0.04 | 0.03 | 0.02 | 0.02 | 3.32 |
| main | 2828.912 | 100 yr | 541.5 | 752.77 | 759.57 | 756.32 | 759.59 | 0.000166 | 1.56 | 628.93 | 190.63 | 0.12 | 42011.7 | 0.05 | 0.03 | 0.03 | 0.03 | 3.55 |
| | | | | | | | | | | | | | | | | | | |
| main | 2769.599 | 1 yr | 65 | 752.31 | 755.34 | 753.55 | 755.38 | 0.000414 | 1.66 | 41.54 | 41.68 | 0.18 | 3192.8 | 0.07 | 0.05 | | 0.1 | 1.24 |
| main | 2769.599 | 2 yr | 94 | 752.31 | 754.97 | 753.82 | 755.08 | 0.001442 | 2.8 | 35.52 | 37.2 | 0.32 | 2475.5 | 0.21 | 0.13 | | 0.51 | 1.51 |
| main | 2769.599 | 10 yr | 238 | 752.31 | 757.95 | 754.72 | 758.08 | 0.00054 | 2.98 | 84.45 | 106.58 | 0.23 | 10242.2 | 0.18 | 0.15 | | 0.48 | 2.41 |
| main | 2769.599 | 25 yr | 342 | 752.31 | 758.58 | 755.23 | 758.75 | 0.000964 | 3.54 | 149.4 | 118.46 | 0.3 | 11016.8 | 0.26 | 0.05 | 0.03 | 0.17 | 2.92 |
| main | 2769.599 | 50 yr | 435 | 752.31 | 758.99 | 755.67 | 759.17 | 0.000985 | 3.79 | 197.01 | 125.89 | 0.3 | 13862.1 | 0.3 | 0.07 | 0.06 | 0.21 | 3.36 |
| main | 2769.599 | 100 yr | 541.5 | 752.31 | 759.31 | 756.11 | 759.51 | 0.001069 | 4.12 | 238.1 | 133.27 | 0.32 | 16565.3 | 0.34 | 0.08 | 0.08 | 0.27 | 3.8 |
| | | | | | | | | | | | | | | | | | | |
| main | 2750.8 | | Bridge | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | |
| main | 2737.042 | 1 yr | 65 | 750.48 | 753.48 | 752.04 | 753.56 | 0.001415 | 2.27 | 28.68 | 15.14 | 0.29 | 1728 | 0.15 | | | 0.34 | 1.56 |
| main | 2737.042 | 2 yr | 94 | 750.48 | 753.79 | 752.41 | 753.91 | 0.001938 | 2.82 | 33.39 | 16.05 | 0.34 | 2135.1 | 0.22 | | | 0.63 | 1.93 |
| main | 2737.042 | 10 yr | 238 | 750.48 | 754.5 | 753.58 | 754.91 | 0.005173 | 5.17 | 47.95 | 26.4 | 0.58 | 3309 | 0.71 | 0.1 | | 2.74 | 3.1 |
| main | 2737.042 | 25 yr | 342 | 750.48 | 754.81 | 754.21 | 755.45 | 0.007366 | 6.49 | 56.51 | 31.22 | 0.7 | 3984.9 | 1.09 | 0.25 | | 4.99 | 3.73 |
| main | 2737.042 | 50 yr | 435 | 750.48 | 755.02 | 754.77 | 755.87 | 0.009007 | 7.54 | 62.9 | 34.78 | 0.78 | 4583.6 | 1.44 | 0.42 | 0.07 | 7.19 | 4.29 |
| main | 2737.042 | 100 yr | 541.5 | 750.48 | 755.21 | 755.17 | 756.33 | 0.011076 | 8.71 | 68.82 | 37.88 | 0.87 | 5145.3 | 1.88 | 0.64 | 0.18 | 10.72 | 4.69 |
| | | | | | | | | | | | | | | | | | | |
| main | 2710.24 | 1 yr | 65 | 750.93 | 753.46 | 752.12 | 753.52 | 0.001137 | 1.81 | 35.98 | 19.54 | 0.23 | 1927.4 | 0.12 | | | 0.22 | 1.19 |
| main | 2710.24 | 2 yr | 94 | 750.93 | 753.76 | 752.36 | 753.84 | 0.001531 | 2.24 | 41.94 | 20.5 | 0.28 | 2402.5 | 0.18 | | | 0.41 | 1.43 |
| main | 2710.24 | 10 yr | 238 | 750.93 | 754.45 | 753.27 | 754.72 | 0.003726 | 4.18 | 59.68 | 34.13 | 0.45 | 3899.1 | 0.58 | 0.06 | 0.06 | 1.55 | 2.34 |
| main | 2710.24 | 25 yr | 342 | 750.93 | 754.75 | 753.77 | 755.17 | 0.00518 | 5.29 | 71.2 | 42.49 | 0.54 | 4751.9 | 0.9 | 0.12 | 0.14 | 2.51 | 2.84 |
| main | 2710.24 | 50 yr | 435 | 750.93 | 754.96 | 754.18 | 755.52 | 0.006394 | 6.15 | 80.83 | 48.33 | 0.61 | 5440.1 | 1.19 | 0.19 | 0.21 | 3.48 | 3.25 |
| main | 2710.24 | 100 yr | 541.5 | 750.93 | 755.15 | 754.71 | 755.88 | 0.007783 | 7.06 | 90.63 | 53.49 | 0.68 | 6138.1 | 1.54 | 0.28 | 0.3 | 4.78 | 3.78 |
| | | | | | | | | | | | | | | | | | | |
| main | 2661.948 | 1 yr | 65 | 750.56 | 753.29 | 752.43 | 753.42 | 0.003756 | 2.91 | 23.62 | 33.65 | 0.41 | 1060.6 | 0.34 | 0.02 | 0.02 | 0.44 | 1.87 |
| main | 2661.948 | 2 yr | 94 | 750.56 | 753.57 | 752.77 | 753.73 | 0.003981 | 3.34 | 35.17 | 50.42 | 0.44 | 1489.9 | 0.42 | 0.07 | 0.04 | 0.45 | 2.21 |
| main | 2661.948 | 10 yr | 238 | 750.56 | 754.25 | 753.92 | 754.5 | 0.00518 | 4.71 | 77.41 | 71.56 | 0.52 | 3306.8 | 0.76 | 0.29 | 0.17 | 1.06 | 3.36 |
| main | 2661.948 | 25 yr | 342 | 750.56 | 754.56 | 754.24 | 754.87 | 0.005785 | 5.38 | 100.97 | 78.67 | 0.56 | 4496.6 | 0.95 | 0.42 | 0.25 | 1.55 | 3.68 |
| main | 2661.948 | 50 yr | 435 | 750.56 | 754.8 | 754.44 | 755.15 | 0.00611 | 5.84 | 120.67 | 84.16 | 0.59 | 5564.9 | 1.09 | 0.53 | 0.32 | 1.94 | 3.88 |
| main | 2661.948 | 100 yr | 541.5 | 750.56 | 755.03 | 754.66 | 755.42 | 0.006548 | 6.34 | 140.37 | 89.31 | 0.62 | 6691.8 | 1.25 | 0.64 | 0.4 | 2.44 | 4.1 |
| | | | | | | | | | | | | | | | | | | |
| main | 2326.682 | 1 yr | 65 | 749.37 | 751.55 | 751.02 | 751.76 | 0.007197 | 3.73 | 18.7 | 38.35 | 0.56 | 766.2 | 0.58 | 0.03 | 0.02 | 0.74 | 1.65 |
| main | 2326.682 | 2 yr | 94 | 749.37 | 751.8 | 751.35 | 752.03 | 0.00703 | 4.12 | 32.74 | 77.6 | 0.57 | 1121.1 | 0.67 | 0.09 | 0.07 | 0.53 | 1.98 |
| main | 2326.682 | 10 yr | 238 | 749.37 | 752.37 | 752.27 | 752.62 | 0.007051 | 5.05 | 94.29 | 121.49 | 0.6 | 2834.4 | 0.91 | 0.29 | 0.2 | 0.86 | 2.9 |
| main | 2326.682 | 25 yr | 342 | 749.37 | 752.64 | 752.48 | 752.9 | 0.007022 | 5.44 | 128.64 | 131.32 | 0.61 | 4081.2 | 1.01 | 0.39 | 0.27 | 1.13 | 3.11 |
| main | 2326.682 | 50 yr | 435 | 749.37 | 752.85 | 752.63 | 753.11 | 0.007043 | 5.75 | 156.04 | 138.66 | 0.62 | 5183.4 | 1.1 | 0.47 | 0.31 | 1.37 | 3.26 |
| main | 2326.682 | 100 yr | 541.5 | 749.37 | 753.06 | 752.77 | 753.33 | 0.006901 | 5.99 | 186.84 | 146.37 | 0.62 | 6518.5 | 1.16 | 0.54 | 0.36 | 1.58 | 3.4 |

## Helms Property Mitigation
## HEC-RAS Results

| HEC-RAS Plan: Design River: Design Reach: main | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Reach | River Sta | Profile | 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 | Conv. Total | Shear Chan | Shear LOB | Shear ROB | Power Total | Critical Depth |
| | | | (cfs) | (ft) | (ft) | (ft) | (ft) | (ft/ft) | (ft/s) | (sq ft) | (ft) | | (cfs) | (lb/sq ft) | (lb/sq ft) | (lb/sq ft) | (lb/ft s) | (ft) |
| main | 2007.779 | 1 yr | 65 | 747.11 | 750.11 | 749.05 | 750.2 | 0.002385 | 2.53 | 27.57 | 26 | 0.34 | 1330.9 | 0.24 | 0.03 | 0.03 | 0.36 | 1.94 |
| main | 2007.779 | 2 yr | 94 | 747.11 | 750.44 | 749.38 | 750.55 | 0.002338 | 2.81 | 48.7 | 116.16 | 0.34 | 1943.9 | 0.29 | 0.05 | 0.02 | 0.12 | 2.27 |
| main | 2007.779 | 10 yr | 238 | 747.11 | 751.08 | 750.7 | 751.2 | 0.002581 | 3.53 | 145.03 | 165.05 | 0.38 | 4685 | 0.41 | 0.09 | 0.12 | 0.23 | 3.59 |
| main | 2007.779 | 25 yr | 342 | 747.11 | 751.38 | 750.93 | 751.51 | 0.002647 | 3.83 | 196.08 | 172.14 | 0.39 | 6646.8 | 0.47 | 0.13 | 0.17 | 0.33 | 3.82 |
| main | 2007.779 | 50 yr | 435 | 747.11 | 751.62 | 751.08 | 751.74 | 0.002673 | 4.04 | 236.65 | 176.63 | 0.39 | 8413.8 | 0.51 | 0.16 | 0.2 | 0.41 | 3.97 |
| main | 2007.779 | 100 yr | 541.5 | 747.11 | 751.86 | 751.22 | 751.99 | 0.002654 | 4.23 | 280.36 | 180.39 | 0.4 | 10510.3 | 0.54 | 0.2 | 0.24 | 0.49 | 4.11 |
| | | | | | | | | | | | | | | | | | | |
| main | 1905.694 | 1 yr | 65 | 746.51 | 748.72 | 748.18 | 748.92 | 0.006846 | 3.64 | 17.93 | 14.73 | 0.55 | 785.6 | 0.55 | 0.02 | 0.02 | 1.78 | 1.67 |
| main | 1905.694 | 2 yr | 94 | 746.51 | 749.04 | 748.51 | 749.31 | 0.0068 | 4.18 | 25.25 | 60.16 | 0.57 | 1139.9 | 0.68 | 0.09 | 0.02 | 0.65 | 2 |
| main | 1905.694 | 10 yr | 238 | 746.51 | 749.85 | 749.64 | 750.08 | 0.005203 | 4.74 | 95.09 | 104.71 | 0.53 | 3299.5 | 0.76 | 0.14 | 0.24 | 0.73 | 3.13 |
| main | 1905.694 | 25 yr | 342 | 746.51 | 750.2 | 749.9 | 750.43 | 0.004856 | 5 | 133.78 | 113.74 | 0.52 | 4907.6 | 0.81 | 0.19 | 0.32 | 0.9 | 3.39 |
| main | 1905.694 | 50 yr | 435 | 746.51 | 750.46 | 750.08 | 750.69 | 0.004749 | 5.24 | 163.77 | 119.75 | 0.52 | 6312.3 | 0.87 | 0.24 | 0.38 | 1.07 | 3.57 |
| main | 1905.694 | 100 yr | 541.5 | 746.51 | 750.71 | 750.25 | 750.95 | 0.004721 | 5.5 | 194.72 | 125.83 | 0.53 | 7881 | 0.93 | 0.28 | 0.44 | 1.26 | 3.74 |
| | | | | | | | | | | | | | | | | | | |
| main | 1699.305 | 1 yr | 65 | 745.2 | 748.13 | 746.65 | 748.15 | 0.000424 | 1.35 | 63.62 | 43 | 0.15 | 3156.1 | 0.06 | 0.02 | 0.03 | 0.04 | 1.45 |
| main | 1699.305 | 2 yr | 94 | 745.2 | 748.5 | 746.91 | 748.52 | 0.000468 | 1.56 | 82.47 | 84.36 | 0.17 | 4347.2 | 0.08 | 0.01 | 0.03 | 0.03 | 1.71 |
| main | 1699.305 | 10 yr | 238 | 745.2 | 749.47 | 747.67 | 749.5 | 0.000485 | 1.94 | 208.14 | 152.42 | 0.18 | 10808.5 | 0.11 | 0.03 | 0.04 | 0.05 | 2.47 |
| main | 1699.305 | 25 yr | 342 | 745.2 | 749.85 | 748.01 | 749.88 | 0.000535 | 2.17 | 268.6 | 166.07 | 0.19 | 14783 | 0.13 | 0.04 | 0.05 | 0.07 | 2.81 |
| main | 1699.305 | 50 yr | 435 | 745.2 | 750.11 | 748.29 | 750.16 | 0.000582 | 2.36 | 313.86 | 176.53 | 0.2 | 18038.4 | 0.16 | 0.05 | 0.06 | 0.09 | 3.09 |
| main | 1699.305 | 100 yr | 541.5 | 745.2 | 750.37 | 748.8 | 750.42 | 0.00063 | 2.55 | 360.19 | 187.4 | 0.21 | 21577.1 | 0.18 | 0.06 | 0.07 | 0.11 | 3.6 |
| | | | | | | | | | | | | | | | | | | |
| main | 1650.228 | 1 yr | 65 | 744.86 | 747.32 | 746.46 | 747.41 | 0.002585 | 2.6 | 28.58 | 22.95 | 0.35 | 1278.4 | 0.26 | | 0.1 | 0.44 | 1.6 |
| main | 1650.228 | 2 yr | 94 | 744.86 | 747.56 | 746.75 | 747.7 | 0.003396 | 3.19 | 34.38 | 25.23 | 0.41 | 1613.1 | 0.38 | | 0.16 | 0.76 | 1.89 |
| main | 1650.228 | 10 yr | 238 | 744.86 | 748.25 | 747.7 | 748.61 | 0.006559 | 5.25 | 62.02 | 134.42 | 0.59 | 2938.7 | 0.94 | 0.03 | 0.18 | 0.72 | 2.84 |
| main | 1650.228 | 25 yr | 342 | 744.86 | 748.53 | 748.5 | 748.92 | 0.007268 | 5.93 | 103.94 | 160.06 | 0.63 | 4011.6 | 1.16 | 0.15 | 0.27 | 0.96 | 3.64 |
| main | 1650.228 | 50 yr | 435 | 744.86 | 748.71 | 748.69 | 749.12 | 0.007684 | 6.37 | 134.31 | 168.3 | 0.66 | 4962.3 | 1.31 | 0.24 | 0.35 | 1.23 | 3.83 |
| main | 1650.228 | 100 yr | 541.5 | 744.86 | 748.9 | 748.86 | 749.32 | 0.007837 | 6.71 | 167.29 | 176.82 | 0.67 | 6116.7 | 1.43 | 0.32 | 0.43 | 1.49 | 4 |
| | | | | | | | | | | | | | | | | | | |
| main | 1435.24 | 1 yr | 65 | 744.16 | 746.53 | 745.85 | 746.69 | 0.004919 | 3.25 | 23.6 | 63.32 | 0.47 | 926.8 | 0.43 | 0.03 | 0.03 | 0.31 | 1.69 |
| main | 1435.24 | 2 yr | 94 | 744.16 | 746.74 | 746.19 | 746.89 | 0.004579 | 3.42 | 41.87 | 112.15 | 0.46 | 1389.2 | 0.45 | 0.06 | 0.05 | 0.24 | 2.03 |
| main | 1435.24 | 10 yr | 238 | 744.16 | 747.05 | 747.05 | 747.24 | 0.006502 | 4.57 | 98.81 | 227.21 | 0.57 | 2951.5 | 0.77 | 0.13 | 0.15 | 0.42 | 2.89 |
| main | 1435.24 | 25 yr | 342 | 744.16 | 747.17 | 747.17 | 747.38 | 0.007714 | 5.17 | 126.02 | 241.5 | 0.62 | 3893.9 | 0.96 | 0.2 | 0.23 | 0.68 | 3.01 |
| main | 1435.24 | 50 yr | 435 | 744.16 | 747.26 | 747.26 | 747.49 | 0.008501 | 5.57 | 147.1 | 246.3 | 0.66 | 4717.9 | 1.1 | 0.26 | 0.29 | 0.93 | 3.1 |
| main | 1435.24 | 100 yr | 541.5 | 744.16 | 747.33 | 747.33 | 747.6 | 0.009537 | 6.04 | 166.31 | 249.03 | 0.7 | 5544.7 | 1.28 | 0.34 | 0.37 | 1.29 | 3.17 |
| | | | | | | | | | | | | | | | | | | |
| main | 1320.59* | 1 yr | 65 | 743.53 | 745.73 | 745.24 | 745.97 | 0.008213 | 3.95 | 17.09 | 40.54 | 0.59 | 717.2 | 0.65 | 0.01 | 0.01 | 0.8 | 1.71 |
| main | 1320.59* | 2 yr | 94 | 743.53 | 745.88 | 745.59 | 746.2 | 0.010532 | 4.78 | 27.41 | 94.92 | 0.68 | 916 | 0.92 | 0.08 | 0.06 | 0.64 | 2.06 |
| main | 1320.59* | 10 yr | 238 | 743.53 | 746.29 | 746.34 | 746.57 | 0.010318 | 5.56 | 85.98 | 186.76 | 0.71 | 2343 | 1.15 | 0.22 | 0.28 | 0.82 | 2.81 |
| main | 1320.59* | 25 yr | 342 | 743.53 | 746.44 | 746.48 | 746.73 | 0.011063 | 6.05 | 115.89 | 208.85 | 0.74 | 3251.6 | 1.33 | 0.3 | 0.38 | 1.13 | 2.95 |
| main | 1320.59* | 50 yr | 435 | 743.53 | 746.59 | 746.58 | 746.84 | 0.00981 | 5.97 | 148.68 | 221.08 | 0.7 | 4391.9 | 1.27 | 0.34 | 0.42 | 1.2 | 3.05 |
| main | 1320.59* | 100 yr | 541.5 | 743.53 | 746.72 | 746.68 | 746.97 | 0.009506 | 6.11 | 178.1 | 227.06 | 0.7 | 5554 | 1.3 | 0.4 | 0.47 | 1.41 | 3.15 |
| | | | | | | | | | | | | | | | | | | |
| main | 1205.941 | 1 yr | 65 | 742.89 | 745.03 | 744.58 | 745.18 | 0.005538 | 3.41 | 30.36 | 85.9 | 0.5 | 873.4 | 0.47 | 0.06 | 0.08 | 0.26 | 1.69 |
| main | 1205.941 | 2 yr | 94 | 742.89 | 745.32 | 745.1 | 745.42 | 0.003658 | 3.12 | 59.34 | 123.57 | 0.42 | 1554.3 | 0.37 | 0.07 | 0.11 | 0.17 | 2.21 |
| main | 1205.941 | 10 yr | 238 | 742.89 | 745.73 | 745.54 | 745.88 | 0.005555 | 4.43 | 121.78 | 180.13 | 0.53 | 3193.3 | 0.7 | 0.18 | 0.29 | 0.46 | 2.65 |
| main | 1205.941 | 25 yr | 342 | 742.89 | 745.92 | 745.72 | 746.1 | 0.006433 | 5.04 | 158.88 | 204.92 | 0.58 | 4263.9 | 0.88 | 0.26 | 0.39 | 0.67 | 2.83 |
| main | 1205.941 | 50 yr | 435 | 742.89 | 746.06 | 745.85 | 746.25 | 0.007011 | 5.47 | 188.23 | 214.33 | 0.61 | 5195.2 | 1.02 | 0.32 | 0.48 | 0.88 | 2.96 |
| main | 1205.941 | 100 yr | 541.5 | 742.89 | 746.2 | 745.99 | 746.41 | 0.007453 | 5.85 | 219.44 | 218.94 | 0.64 | 6272.6 | 1.15 | 0.4 | 0.56 | 1.15 | 3.1 |

## Helms Property Mitigation
## HEC-RAS Results

| HEC-RAS Plan: Design River: Design Reach: main | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Reach | River Sta | Profile | 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 | Conv. Total | Shear Chan | Shear LOB | Shear ROB | Power Total | Critical Depth |
| | | | (cfs) | (ft) | (ft) | (ft) | (ft) | (ft/ft) | (ft/s) | (sq ft) | (ft) | | (cfs) | (lb/sq ft) | (lb/sq ft) | (lb/sq ft) | (lb/ft s) | (ft) |
| main | 841.562 | 1 yr | 65 | 741.03 | 743.56 | 742.8 | 743.67 | 0.00312 | 2.83 | 39.02 | 143.11 | 0.38 | 1163.7 | 0.31 | 0.02 | 0.05 | 0.09 | 1.77 |
| main | 841.562 | 2 yr | 94 | 741.03 | 743.55 | 743.15 | 743.79 | 0.007011 | 4.21 | 36.95 | 141.75 | 0.57 | 1122.6 | 0.69 | 0.04 | 0.11 | 0.29 | 2.12 |
| main | 841.562 | 10 yr | 238 | 741.03 | 743.96 | 743.91 | 744.12 | 0.005934 | 4.47 | 102.39 | 179.77 | 0.54 | 3089.6 | 0.72 | 0.16 | 0.22 | 0.49 | 2.88 |
| main | 841.562 | 25 yr | 342 | 741.03 | 744.16 | 744.03 | 744.31 | 0.00542 | 4.53 | 140.24 | 198.47 | 0.52 | 4645.5 | 0.72 | 0.19 | 0.26 | 0.58 | 3 |
| main | 841.562 | 50 yr | 435 | 741.03 | 744.31 | 744.12 | 744.46 | 0.005053 | 4.57 | 172.13 | 212.95 | 0.51 | 6119.2 | 0.72 | 0.21 | 0.28 | 0.64 | 3.09 |
| main | 841.562 | 100 yr | 541.5 | 741.03 | 744.47 | 744.22 | 744.62 | 0.004747 | 4.61 | 206.76 | 227.64 | 0.5 | 7859.4 | 0.72 | 0.23 | 0.29 | 0.7 | 3.19 |
| | | | | | | | | | | | | | | | | | | |
| main | 659.631 | 1 yr | 65 | 739.77 | 742.64 | 741.92 | 742.81 | 0.005493 | 3.31 | 19.62 | 194.76 | 0.49 | 877 | 0.45 | | | 1.5 | 2.15 |
| main | 659.631 | 2 yr | 94 | 739.77 | 742.97 | 742.27 | 742.98 | 0.000611 | 1.24 | 194.7 | 344.7 | 0.17 | 3801.3 | 0.06 | 0 | 0.02 | 0.01 | 2.5 |
| main | 659.631 | 10 yr | 238 | 739.77 | 743.45 | 742.85 | 743.46 | 0.000676 | 1.54 | 372 | 390.8 | 0.18 | 9156.2 | 0.08 | 0.02 | 0.04 | 0.03 | 3.08 |
| main | 659.631 | 25 yr | 342 | 739.77 | 743.7 | 742.86 | 743.71 | 0.000688 | 1.66 | 470.49 | 410.82 | 0.19 | 13034.5 | 0.1 | 0.03 | 0.06 | 0.04 | 3.09 |
| main | 659.631 | 50 yr | 435 | 739.77 | 743.88 | 742.93 | 743.9 | 0.000692 | 1.75 | 548.23 | 422.94 | 0.19 | 16537.8 | 0.1 | 0.03 | 0.06 | 0.04 | 3.16 |
| main | 659.631 | 100 yr | 541.5 | 739.77 | 744.07 | 743.03 | 744.08 | 0.000699 | 1.84 | 628.1 | 434.36 | 0.19 | 20487.5 | 0.11 | 0.04 | 0.07 | 0.05 | 3.26 |
| | | | | | | | | | | | | | | | | | | |
| main | 409.634 | 1 yr | 65 | 738.69 | 741.76 | 740.86 | 741.89 | 0.003754 | 2.91 | 25.16 | 143.68 | 0.41 | 1060.9 | 0.34 | 0.01 | 0 | 0.11 | 2.17 |
| main | 409.634 | 2 yr | 94 | 738.69 | 741.97 | 741.2 | 742.08 | 0.003427 | 3.01 | 67.96 | 231.32 | 0.4 | 1605.8 | 0.35 | 0.04 | 0.04 | 0.09 | 2.51 |
| main | 409.634 | 10 yr | 238 | 738.69 | 742.5 | 742.22 | 742.57 | 0.002484 | 3.06 | 209.6 | 286.98 | 0.35 | 4774.9 | 0.33 | 0.09 | 0.11 | 0.13 | 3.53 |
| main | 409.634 | 25 yr | 342 | 738.69 | 742.77 | 742.35 | 742.83 | 0.002271 | 3.14 | 288.54 | 306.85 | 0.34 | 7176.3 | 0.34 | 0.11 | 0.13 | 0.16 | 3.66 |
| main | 409.634 | 50 yr | 435 | 738.69 | 742.97 | 742.45 | 743.03 | 0.002163 | 3.22 | 351.99 | 321.87 | 0.34 | 9352.9 | 0.34 | 0.12 | 0.14 | 0.18 | 3.76 |
| main | 409.634 | 100 yr | 541.5 | 738.69 | 743.18 | 742.54 | 743.23 | 0.002055 | 3.3 | 419.92 | 333.65 | 0.34 | 11945.3 | 0.35 | 0.14 | 0.16 | 0.21 | 3.85 |
| | | | | | | | | | | | | | | | | | | |
| main | 187.829 | 1 yr | 65 | 737.89 | 741.03 | 740.04 | 741.14 | 0.003001 | 2.68 | 30.45 | 87.84 | 0.37 | 1186.5 | 0.28 | 0.02 | 0.02 | 0.14 | 2.15 |
| main | 187.829 | 2 yr | 94 | 737.89 | 741.26 | 740.39 | 741.37 | 0.003002 | 2.92 | 53.76 | 113.74 | 0.38 | 1715.8 | 0.32 | 0.05 | 0.05 | 0.15 | 2.5 |
| main | 187.829 | 10 yr | 238 | 737.89 | 741.87 | 741.52 | 741.98 | 0.003 | 3.52 | 147.5 | 179.92 | 0.39 | 4345.1 | 0.43 | 0.11 | 0.15 | 0.25 | 3.63 |
| main | 187.829 | 25 yr | 342 | 737.89 | 742.15 | 741.73 | 742.26 | 0.003 | 3.79 | 201.11 | 194.92 | 0.4 | 6243.7 | 0.48 | 0.16 | 0.19 | 0.33 | 3.84 |
| main | 187.829 | 50 yr | 435 | 737.89 | 742.37 | 741.86 | 742.48 | 0.003004 | 3.99 | 244.28 | 206.42 | 0.41 | 7936.2 | 0.51 | 0.19 | 0.22 | 0.39 | 3.97 |
| main | 187.829 | 100 yr | 541.5 | 737.89 | 742.59 | 742 | 742.7 | 0.003002 | 4.18 | 290.59 | 218.1 | 0.41 | 9883.8 | 0.55 | 0.21 | 0.24 | 0.46 | 4.11 |
| main | 187.829 | 100 yr | 541.5 | 737.89 | 742.59 | 742 | 742.7 | 0.003002 | 4.18 | 290.59 | 218.1 | 0.41 | 9883.8 | 0.55 | 0.21 | 0.24 | 0.46 | 4.11 |

## Stream Power

**Existing Conditions Upstream (G-type)**

| Specific Weight of Water | Discharge | Slope | Channel Width | stream power |
|---|---|---|---|---|
| 62.4 | 58 | 0.0076 | 10 | 2.75 |

**Existing Conditions Upstream (E-type)**

| Specific Weight of Water | Discharge | Slope | Channel Width | stream power |
|---|---|---|---|---|
| 62.4 | 58 | 0.0076 | 11.2 | 2.46 |

**Existing Conditions Downstream**

| Specific Weight of Water | Discharge | Slope | Channel Width | stream power |
|---|---|---|---|---|
| 62.4 | 62 | 0.0025 | 10.9 | 0.89 |

**Proposed Conditions (Upstream) (using eigth iteration)**

| | Specific Weight of Water | Discharge | Slope | Channel Width | stream power |
|---|---|---|---|---|---|
| average | 62.4 | 58 | 0.0057 | 10.2 | 2.02 |
| min | 62.4 | 58 | 0.0051 | 10.2 | 1.81 |
| max | 62.4 | 58 | 0.0064 | 10.2 | 2.27 |

**Proposed Conditions (Downstream) (using eigth iteration)**

| | Specific Weight of Water | Discharge | Slope | Channel Width | stream power |
|---|---|---|---|---|---|
| average | 62.4 | 62 | 0.0042 | 9.3 | 1.75 |
| min | 62.4 | 62 | 0.0037 | 9.3 | 1.54 |
| max | 62.4 | 62 | 0.0052 | 9.3 | 2.16 |

**Helms Reference**

| Specific Weight of Water | Discharge | Slope | Channel Width | stream power |
|---|---|---|---|---|
| 62.4 | 50 | 0.0062 | 10 | 1.93 |

**Dan Nicholas Reference**

| Specific Weight of Water | Discharge | Slope | Channel Width | stream power |
|---|---|---|---|---|
| 62.4 | 117 | 0.0014 | 10.1 | 1.01 |

**Reedy Creek Reference**

| Specific Weight of Water | Discharge | Slope | Channel Width | stream power |
|---|---|---|---|---|
| 62.4 | 17 | 0.0111 | 10.4 | 1.13 |

**Helms Reference**

| Specific Weight of Water | Discharge | Slope | Channel Width | stream power | |
|---|---|---|---|---|---|
| 62.4 | 50 | 0.0062 | 10 | 1.93 | slope we are using (TR7b - TR1) |
| 62.4 | 50 | 0.0054 | 10 | 1.68 | slope from BR7b - BR1 |
| 62.4 | 50 | 0.0069 | 10 | 2.15 | slope from max |
| 62.4 | 50 | 0.0052 | 10 | 1.62 | slope from min |
| 62.4 | 50 | 0.0057 | 10 | 1.78 | slope from iteration average |
| 62.4 | 50 | 0.0056 | 10 | 1.75 | slope from sigma plot |

# APPENDIX C
EXISTING CONDITIONS DATA

# Table A
## MORPHOLOGICAL MEASUREMENT TABLE

| Variables | Existing Conditions | | | Reference Conditions | | | Proposed Conditions | |
|---|---|---|---|---|---|---|---|---|
| | Upstream (G-type) | Upstream (E-type) | Downstream | UT to Dutch Buffalo Creek | UT to Reedy Creek | UT to Crane Creek | Upstream | Downstream |
| 1 Stream type (Rosgen) | G 5/4 | E 5/4 | E 5/4 | G 5 | E 5/4 | E 4/5 | E 5/4 | E 5/4 |
| 2 Drainage area (square miles) | 0.5 | 0.5 | 0.5 | 0.4 | 0.4 | 1.5 | 0.5 | 0.5 |
| 3 Bankfull width ($W_{bkf}$) (feet) | 10.0 | 11.2 | 10.9 | 10.0 | 10.4 | 10.1 | 10.2 | 9.3 |
| 4 Bankfull mean depth ($D_{bkf}$) (feet) | 1.3 | 1.3 | 1.4 | 1.1 | 1.4 | 2.0 | 1.3 | 1.6 |
| 5 Width/depth ratio ($W_{bkf}/D_{bkf}$) | 7.5 | 9 | 9 | 9.1 | 7.8 | 5.1 | 8 | 6 |
| 6 Bankfull cross-sectional area ($A_{bkf}$) (square feet) | 13.0 | 14.3 | 14.4 | 11.1 | 15.5 | 20.5 | 13.0 | 14.4 |
| 7 Bankfull mean velocity (feet / second) | 4.0 | 3.7 | 3.7 | 4.1 | 2.9 | 5.8 | 4.0 | 3.7 |
| 8 Bankfull discharge (cubic feet / second) | 52 | 52 | 52 | 44 | 44 | 119 | 52 | 52 |
| 9 Bankfull max depth ($D_{mbkf}$) (feet) | 1.8 | 2.7 | 2.4 | 1.4 | 2.2 | 2.6 | 1.8 | 2.1 |
| 10 Width of floodprone area ($W_{FPA}$) (feet) | 16 | 195 | 220 | 17.5 | 58 | 237 | 164 | 243 |
| 11 Entrenchment ratio (ER) | 1.6 | 18 | 22.8 | 1.8 | 5.6 | 25 | 16 | 26 |
| 12 Meander length ($L_m$) (feet) | ---- | ---- | ---- | 80 | 102 | 73 | 95 | 93 |
| 13 Meander length ratio ($L_m/W_{bkf}$) | ---- | ---- | ---- | 8 | 9.8 | 7.2 | 9.3 | 10.0 |
| 14 Radius of curvature ($R_c$) (feet) | ---- | ---- | ---- | 26.6 | 27.6 | 25.3 | 24.7 | 24.1 |
| 15 Ratio of radius of curvature to bankfull width ($R_c/W_{bkf}$) | ---- | ---- | ---- | 2.7 | 2.7 | 2.5 | 2.4 | 2.6 |
| 16 Belt width ($W_{blt}$) (feet) | ---- | ---- | ---- | 52.3 | 76.1 | 86.1 | 115.0 | 68.0 |
| 17 Belt width ratio ($W_{blt}/W_{bkf}$) | ---- | ---- | ---- | 5.2 | 7.3 | 8.5 | 11.3 | 7.3 |
| 18 Sinuosity (stream length/valley length) | 1.0 | 1.0 | 1.0 | 1.4 | 1.55 | 1.8 | 1.37 | 1.35 |
| 19 Valley Slope | 0.0076 | 0.0076 | 0.0056 | 0.0086 | 0.0172 | 0.0025 | 0.0076 | 0.0056 |
| 20 Average water surface slope | 0.0076 | 0.0076 | 0.0025 | 0.0062 | 0.0111 | 0.0014 | 0.0054 | 0.0035 |
| 21 Riffle slope | ---- | ---- | ---- | 0.0091 | 0.0140 | 0.0019 | 0.0068 | 0.0068 |
| 22 Ratio of riffle slope to water surface slope | ---- | ---- | ---- | 1.5 | 1.3 | 1.4 | 1.3 | 1.9 |
| 23 Pool slope | ---- | ---- | ---- | 0.0019 | 0.0069 | 0.0004 | 0.0022 | 0.0021 |
| 24 Ratio of pool slope to water surface slope | ---- | ---- | ---- | 0.3 | 0.6 | 0.3 | 0.4 | 0.6 |
| 25 Maximum pool depth ($D_{pmax}$) (feet) | 2.3 | 2.3 | 2.6 | 2.1 | 2.3 | 2.9 | 2.6 | 3.2 |
| 26 Ratio of pool depth to average bankfull depth ($D_{pool}/D_{bkf}$) | 1.8 | 1.8 | 1.6 | 1.9 | 1.6 | 1.5 | 2.0 | 2.0 |
| 27 Pool width ($W_{pool}$) (feet) | 13.4 | 13.4 | 11.6 | 10.6 | 14.2 | 11.1 | 13.3 | 11.2 |
| 28 Ratio of pool width to bankfull width ($W_{pool}/W_{bkf}$) | 1.3 | 1.3 | 1.2 | 1.1 | 1.4 | 1.1 | 1.3 | 1.2 |
| 29 Pool to pool spacing ($L_{p-p}$) (feet) | ---- | ---- | ---- | 55 | 84 | 53 | 60 | 60 |
| 30 Ratio of pool to pool spacing to bankfull width ($L_{p-p}/W_{bkf}$) | ---- | ---- | ---- | 5.5 | 8.1 | 5.2 | 5.9 | 6.5 |
| 31 Ratio of low bank height to bankfull max depth (BHR) | 2.0 | 1.5 | 1.3 | 2.4 | 1.0 | 1.2 | 1.0 | 1.0 |

# Helms Existing Conditions - Dimension

* upper reach = P1 - P35 (design)
  lower reach = P36 - P51 (design)

## Riffles - upper reach

| X-sect # | A-bkfl | W-bkfl | Dave | Dmax | W/D | FPA | Ent Ratio | LB height | BHR | Dmax/Dave | Stream Type |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 13.0 | 9.4 | 1.4 | 1.8 | 7 | 16 | 1.7 | 3.5 | 1.9 | 1.3 | G |
| 2 | 13.0 | 10.5 | 1.2 | 1.7 | 8 | 16 | 1.5 | 3.5 | 2.1 | 1.4 | G |
| 4 | 14.3 | 12.4 | 1.2 | 2.7 | 11 | 190 | 15.3 | 3.8 | 1.4 | 2.3 | E |
| 5 | 14.2 | 10.0 | 1.4 | 2.6 | 7 | 200 | 20.0 | 4.2 | 1.6 | 1.9 | E |
| **Average** | **13.6** | **10.6** | **1.3** | **2.2** | **8** | **106** | **9.6** | **3.8** | **1.8** | **1.7** | **G/E** |
| **Median** | **14.2** | **10.5** | **1.4** | **2.6** | **8** | **190** | **15.3** | **3.8** | **1.9** | **1.9** | |

## Riffles - lower reach

| X-sect # | A-bkfl | W-bkfl | Dave | Dmax | W/D | FPA | Ent Ratio | LB height | BHR | Dmax/Dave | Stream Type |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 14.2 | 9.7 | 1.5 | 2.6 | 7 | 265 | 27.2 | 3.5 | 1.3 | 1.7 | E |
| 8 | 14.6 | 12 | 1.2 | 2.2 | 10 | 220 | 18.4 | 2.9 | 1.3 | 1.8 | E |
| **Average** | **14.4** | **10.9** | **1.4** | **2.4** | **9** | **243** | **22.8** | **3.2** | **1.3** | **1.8** | **E** |

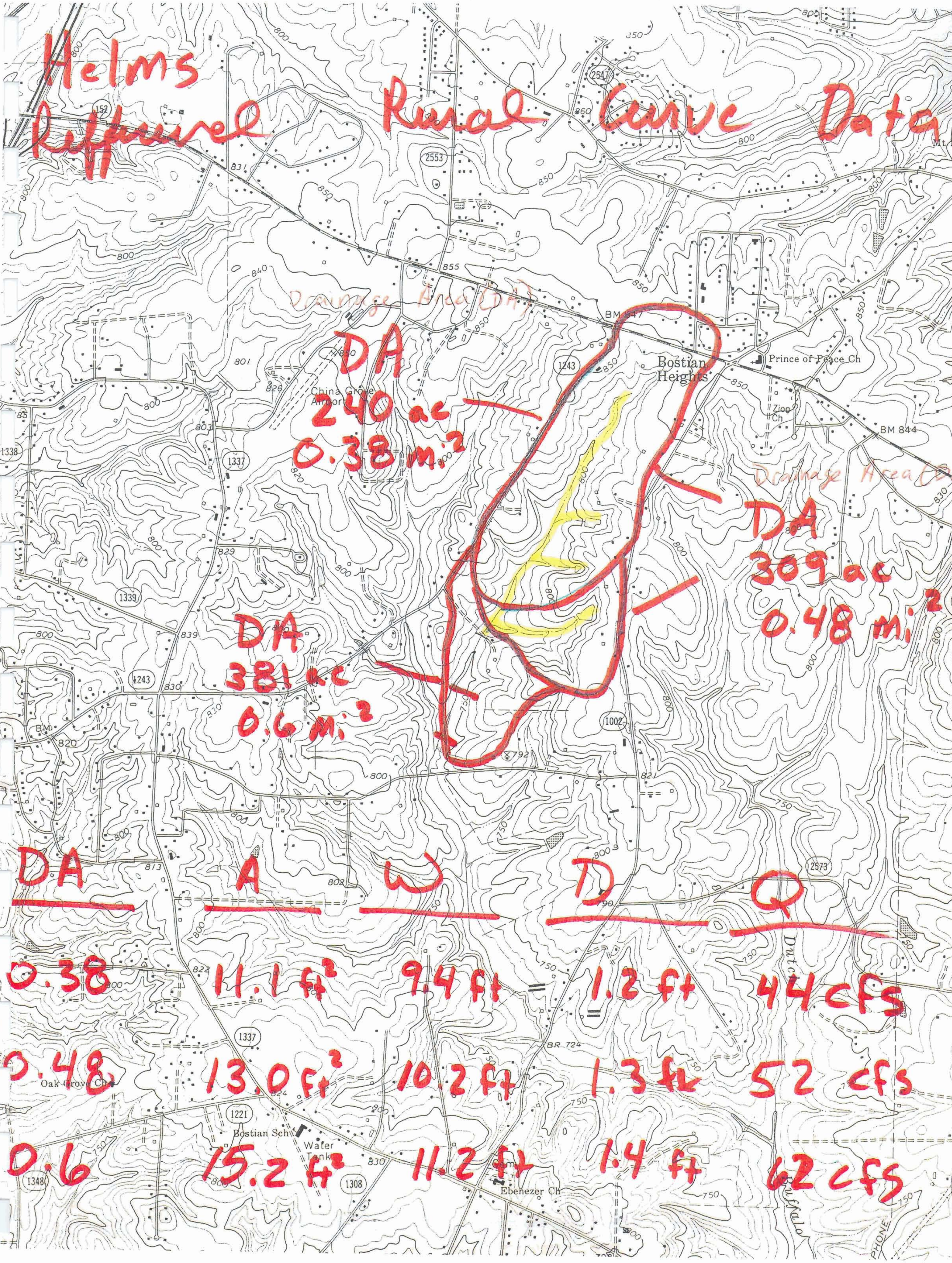
## Pools - upper reach

| X-sect # | A-bkfl | W-bkfl | Dave | Dmax | LB height | BHR | Dmax/Dave |
|---|---|---|---|---|---|---|---|
| 3 | 20.5 | 13.4 | 1.5 | 2.3 | 3.4 | 1.5 | 1.5 |

## Pools - lower reach

| X-sect # | A-bkfl | W-bkfl | Dave | Dmax | LB height | BHR | Dmax/Dave |
|---|---|---|---|---|---|---|---|
| 7 | 17.8 | 11.6 | 1.5 | 2.6 | 3.1 | 1.2 | 1.7 |

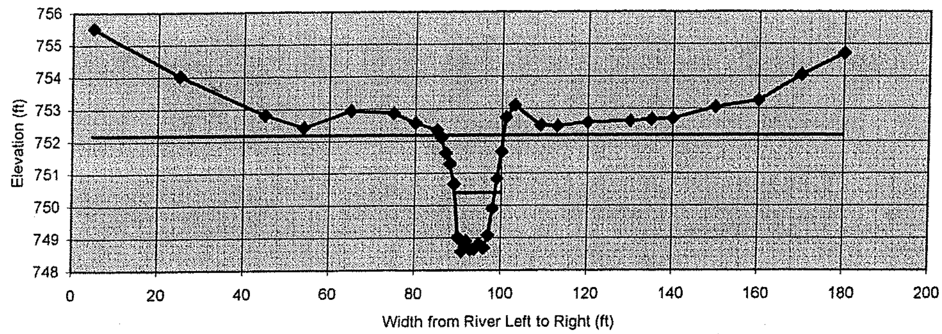
Helms Refferel Rural Curve Data




| DA | A | W | D | Q |
|---|---|---|---|---|
| 0.38 | 11.1 ft² | 9.4 ft | 1.2 ft | 44 cfs |
| 0.48 | 13.0 ft² | 10.2 ft | 1.3 ft | 52 cfs |
| 0.6 | 15.2 ft² | 11.2 ft | 1.4 ft | 62 cfs |

x-section 1 @ 350'

FP = 125




| | |
|---|---|
| section: | |
| | Riffle |
| | --- |
| | --- |
| description: | |
| height of instrument (ft): | 758.51 |

| notes | omit pt. | distance (ft) | FS (ft) | elevation |
|---|---|---|---|---|
| | ☑ | 5 | 2.99 | 755.52 |
| | ☑ | 25 | 4.48 | 754.03 |
| | ☑ | 45 | 5.69 | 752.82 |
| | ☑ | 54 | 6.09 | 752.42 |
| | ☑ | 65 | 5.57 | 752.94 |
| | ☑ | 75 | 5.64 | 752.87 |
| | ☑ | 80 | 5.95 | 752.56 |
| | ☑ | 85 | 6.17 | 752.34 |
| TOB | ☑ | 86 | 6.39 | 752.12 |
| | ☑ | 87 | 6.89 | 751.62 |
| | ☑ | 88 | 7.22 | 751.29 |
| | ☐ | 89 | 7.85 | 750.66 |
| | ☐ | 90 | 9.49 | 749.02 |
| | ☐ | 91 | 9.92 | 748.59 |
| | ☐ | 92 | 9.61 | 748.9 |
| | ☐ | 93 | 9.86 | 748.65 |
| | ☐ | 94 | 9.85 | 748.66 |
| | ☐ | 95 | 9.69 | 748.82 |
| | ☐ | 96 | 9.82 | 748.69 |
| | ☐ | 97 | 9.43 | 749.08 |
| | ☐ | 98 | 8.6 | 749.91 |
| | ☐ | 99 | 7.68 | 750.83 |
| | ☐ | 100 | 6.85 | 751.66 |
| TOB | ☑ | 101 | 5.78 | 752.73 |
| | ☑ | 103 | 5.4 | 753.11 |
| | ☑ | 109 | 6.02 | 752.49 |
| | ☑ | 113 | 6.05 | 752.46 |
| | ☑ | 120 | 5.93 | 752.58 |
| | ☑ | 130 | 5.89 | 752.62 |
| | ☑ | 135 | 5.85 | 752.66 |
| | ☑ | 140 | 5.82 | 752.69 |
| | ☑ | 150 | 5.46 | 753.05 |
| | ☑ | 160 | 5.26 | 753.25 |
| | ☑ | 170 | 4.47 | 754.04 |
| | ☑ | 180 | 3.8 | 754.71 |

| FS bankfull | FS top of bank | W fpa (ft) | channel slope (%) | Manning's "n" |
|---|---|---|---|---|
| 8.12 | 6.39 | 16.0 | | |
| 750.39 | 752.12 | | | |

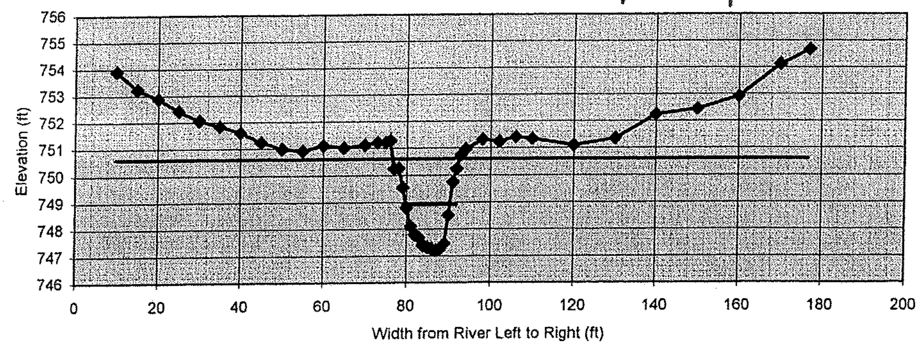
| dimensions | | | |
|---|---|---|---|
| 13.0 | x-section area | 1.4 | d mean |
| 9.4 | width | 10.9 | wet P |
| 1.8 | d max | 1.2 | hyd radi |
| 3.5 | bank ht | 6.8 | w/d ratio |
| 16.0 | W flood prone area | 1.7 | ent ratio |

| hydraulics | |
|---|---|
| 0.0 | velocity (ft/sec) |
| 0.0 | discharge rate, Q (cfs) |
| 0.00 | shear stress ((lbs/ft sq) |
| 0.00 | shear velocity (ft/sec) |
| 0.000 | unit stream power (lbs/ft/sec) |
| 0.00 | Froude number |
| 0.0 | friction factor u/u* |
| 0.0 | threshold grain size (mm) |

| check from channel material | | | |
|---|---|---|---|
| 7 | measured D84 (mm) | | |
| 56.9 | relative roughness | 12.8 | fric. factor |
| 0.000 | Manning's n from channel material | | |

x-section 2 @ 502'

FP= 140




| section: | |
|---|---|
| | Riffle<br>---<br>--- |
| description: | |
| height of instrument (ft): | 757.28 |

| notes | omit pt. | distance (ft) | FS (ft) | elevation |
|---|---|---|---|---|
| fence @ 0 | ☑ | 10 | 3.36 | 753.92 |
| | ☑ | 15 | 4.05 | 753.23 |
| | ☑ | 20 | 4.38 | 752.9 |
| | ☑ | 25 | 4.86 | 752.42 |
| | ☑ | 30 | 5.21 | 752.07 |
| | ☑ | 35 | 5.43 | 751.85 |
| | ☑ | 40 | 5.66 | 751.62 |
| | ☑ | 45 | 6.03 | 751.25 |
| | ☑ | 50 | 6.28 | 751 |
| | ☑ | 55 | 6.36 | 750.92 |
| | ☑ | 60 | 6.17 | 751.11 |
| | ☑ | 65 | 6.25 | 751.03 |
| | ☑ | 70 | 6.15 | 751.13 |
| | ☑ | 73 | 6.06 | 751.22 |
| | ☑ | 75 | 6.06 | 751.22 |
| TOB | ☑ | 76 | 5.98 | 751.3 |
| | ☑ | 77 | 7.03 | 750.25 |
| | ☑ | 78 | 7.02 | 750.26 |
| | ☐ | 79 | 7.73 | 749.55 |
| | ☐ | 80 | 8.49 | 748.79 |
| | ☐ | 81 | 9.17 | 748.11 |
| | ☐ | 82 | 9.49 | 747.79 |
| | ☐ | 83 | 9.6 | 747.68 |
| | ☐ | 84 | 9.89 | 747.39 |
| | ☐ | 85 | 9.96 | 747.32 |
| | ☐ | 86 | 10.01 | 747.27 |
| thalweg | ☐ | 87 | 10.07 | 747.21 |
| | ☐ | 88 | 10.02 | 747.26 |
| | ☐ | 89 | 9.82 | 747.46 |
| | ☐ | 90 | 8.77 | 748.51 |
| | ☐ | 91 | 7.54 | 749.74 |
| | ☐ | 92 | 7.04 | 750.24 |
| TOB | ☑ | 93 | 6.53 | 750.75 |
| | ☑ | 94 | 6.32 | 750.96 |
| | ☑ | 98 | 5.95 | 751.33 |
| | ☑ | 102 | 6.03 | 751.25 |
| | ☑ | 106 | 5.86 | 751.42 |
| | ☑ | 110 | 5.94 | 751.34 |
| | ☑ | 120 | 6.18 | 751.1 |
| | ☑ | 130 | 5.92 | 751.36 |
| | ☑ | 140 | 5.03 | 752.25 |
| | ☑ | 150 | 4.83 | 752.45 |
| | ☑ | 160 | 4.36 | 752.92 |
| | ☑ | 170 | 3.16 | 754.12 |
| relic fence | ☑ | 177 | 2.6 | 754.68 |
| | ☐ | | | |
| | ☐ | | | |
| | ☐ | | | |
| | ☐ | | | |
| | ☐ | | | |
| | ☐ | | | |
| | ☐ | | | |
| | ☐ | | | |
| | ☐ | | | |
| | ☐ | | | |
| | ☐ | | | |

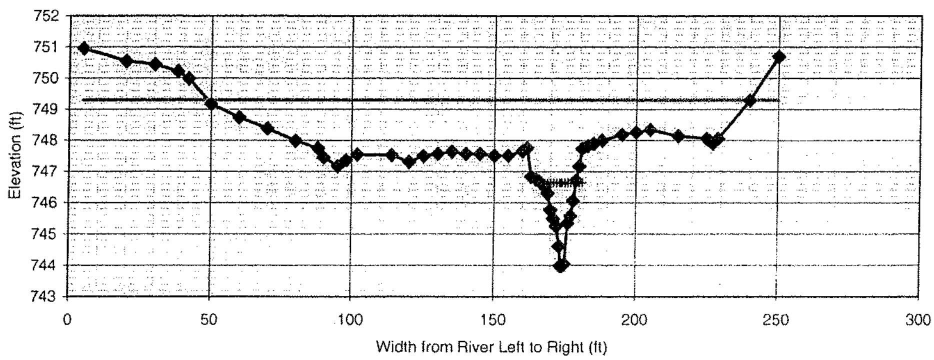
| FS bankfull | FS top of bank | W fpa (ft) | channel slope (%) | Manning's "n" |
|---|---|---|---|---|
| 8.37 | 6.53 | 16.0 | | |
| 748.91 | 750.75 | | | |

| dimensions | | | |
|---|---|---|---|
| 13.0 | x-section area | 1.2 | d mean |
| 10.5 | width | 11.5 | wet P |
| 1.7 | d max | 1.1 | hyd radi |
| 3.5 | bank ht | 8.4 | w/d ratio |
| 16.0 | W flood prone area | 1.5 | ent ratio |

| hydraulics | |
|---|---|
| 0.0 | velocity (ft/sec) |
| 0.0 | discharge rate, Q (cfs) |
| 0.00 | shear stress ((lbs/ft sq) |
| 0.00 | shear velocity (ft/sec) |
| 0.000 | unit stream power (lbs/ft/sec) |
| 0.00 | Froude number |
| 0.0 | friction factor u/u* |
| 0.0 | threshold grain size (mm) |

| check from channel material | | | |
|---|---|---|---|
| 7 | measured D84 (mm) | | |
| 51.1 | relative roughness | 12.6 | fric. factor |
| 0.000 | Manning's n from channel material | | |

x-section 4 @ 1023'




| section: | |
|---|---|
| | Riffle |
| | --- |
| | --- |
| description: | |
| height of instrument (ft): | 753.64 |

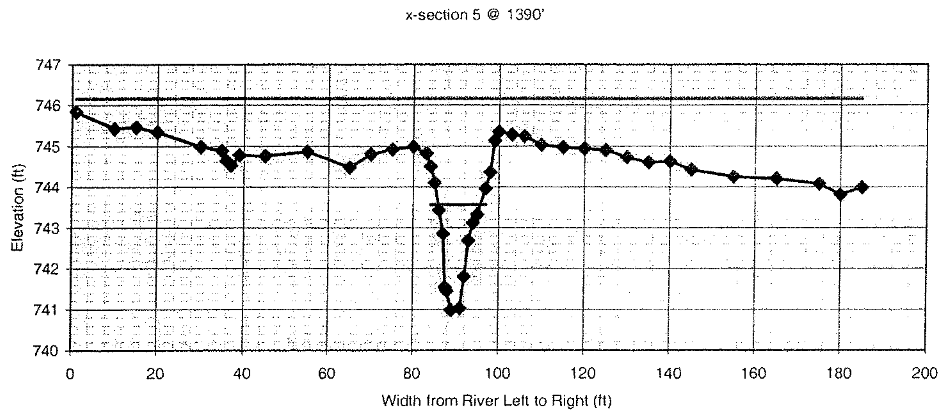
| notes | omit pt. | distance (ft) | FS (ft) | elevation | |
|---|---|---|---|---|---|
| fence @ 0 | ☑ | 5 | 2.69 | 750.95 | |
| | ☑ | 20 | 3.09 | 750.55 | |
| | ☑ | 30 | 3.2 | 750.44 | |
| | ☑ | 38 | 3.42 | 750.22 | |
| | ☑ | 42 | 3.65 | 749.99 | |
| | ☑ | 50 | 4.47 | 749.17 | |
| | ☑ | 60 | 4.9 | 748.74 | |
| | ☑ | 70 | 5.26 | 748.38 | |
| | ☑ | 80 | 5.65 | 747.99 | |
| | ☑ | 88 | 5.9 | 747.74 | |
| | ☑ | 90 | 6.19 | 747.45 | |
| | ☑ | 95 | 6.47 | 747.17 | |
| | ☑ | 98 | 6.28 | 747.36 | |
| | ☑ | 102 | 6.09 | 747.55 | |
| | ☑ | 114 | 6.11 | 747.53 | |
| | ☑ | 120 | 6.33 | 747.31 | |
| | ☑ | 125 | 6.14 | 747.5 | |
| | ☑ | 130 | 6.07 | 747.57 | |
| | ☑ | 135 | 6 | 747.64 | |
| | ☑ | 140 | 6.07 | 747.57 | |
| | ☑ | 145 | 6.07 | 747.57 | |
| | ☑ | 150 | 6.13 | 747.51 | |
| | ☑ | 155 | 6.13 | 747.51 | |
| | ☑ | 160 | 5.99 | 747.65 | |
| TOB | ☑ | 161.5 | 5.89 | 747.75 | |
| | ☑ | 163 | 6.81 | 746.83 | |
| | ☑ | 165 | 6.9 | 746.74 | |
| | ☐ | 166 | 6.95 | 746.69 | |
| | ☐ | 167 | 7.05 | 746.59 | |
| | ☐ | 168 | 7.13 | 746.51 | |
| | ☐ | 169 | 7.34 | 746.3 | |
| | ☐ | 170 | 7.88 | 745.76 | |
| | ☐ | 171 | 8.16 | 745.48 | |
| | ☐ | 172 | 8.39 | 745.25 | |
| | ☐ | 173 | 9.03 | 744.61 | |
| | ☐ | 173.5 | 9.66 | 743.98 | |
| | ☐ | 174 | 9.66 | 743.98 | |
| | ☐ | 175 | 9.6 | 744.04 | |
| | ☐ | 176 | 8.3 | 745.34 | |
| | ☐ | 177 | 8.06 | 745.58 | |
| | ☐ | 178 | 7.58 | 746.06 | |
| | ☐ | 179 | 6.92 | 746.72 | |
| | ☐ | 180 | 6.47 | 747.17 | |
| TOB | ☐ | 181 | 5.91 | 747.73 | |
| | ☑ | 183 | 5.82 | 747.82 | |
| | ☑ | 185 | 5.74 | 747.9 | |
| | ☑ | 188 | 5.64 | 748 | |
| | ☑ | 195 | 5.45 | 748.19 | |
| | ☑ | 200 | 5.38 | 748.26 | — 110 |
| | ☑ | 205 | 5.3 | 748.34 | |
| | ☑ | 215 | 5.5 | 748.14 | |
| | ☑ | 225 | 5.58 | 748.06 | |
| | ☑ | 227 | 5.73 | 747.91 | |

| FS bankfull | FS top of bank | W fpa (ft) | channel slope (%) | Manning's "n" |
|---|---|---|---|---|
| 7 | 5.91 | 190.0 | 0.0029 | 0.034 |
| 746.64 | 747.73 | | | |

| dimensions | | | |
|---|---|---|---|
| 14.3 | x-section area | 1.2 | d mean |
| 12.4 | width | 14.1 | wet P |
| 2.7 | d max | 1.0 | hyd radi |
| 3.8 | bank ht | 10.7 | w/d ratio |
| 190.0 | W flood prone area | 15.3 | ent ratio |

| hydraulics | |
|---|---|
| 0.2 | velocity (ft/sec) |
| 3.4 | discharge rate, Q (cfs) |
| 0.00 | shear stress ((lbs/ft sq) |
| 0.03 | shear velocity (ft/sec) |
| 0.000 | unit stream power (lbs/ft/sec) |
| 0.00 | Froude number |
| 7.7 | friction factor u/u* |
| ~~0.1~~ | threshold grain size (mm) |

| check from channel material | | | |
|---|---|---|---|
| 8 | measured D84 (mm) | | |
| 41.7 | relative roughness | 12.1 | fric. factor |
| 0.022 | Manning's n from channel material | | |




| | |
|---|---|
| section: | Riffle |
| | --- |
| | --- |
| description: | |
| height of instrument (ft): | 750.62 |

| notes | omit pt. | distance (ft) | FS (ft) | elevation |
|---|---|---|---|---|
| fence @ -6 | ☑# | 1 | 4.78 | 745.84 |
| | ☑# | 10 | 5.19 | 745.43 |
| | ☑# | 15 | 5.16 | 745.46 |
| | ☑# | 20 | 5.28 | 745.34 |
| | ☑# | 30 | 5.64 | 744.98 |
| | ☑# | 35 | 5.73 | 744.89 |
| | ☑# | 36 | 5.98 | 744.64 |
| | ☑# | 37 | 6.09 | 744.53 |
| | ☑# | 39 | 5.84 | 744.78 |
| | ☑# | 45 | 5.86 | 744.76 |
| helms 2 | ☑# | 55 | 5.76 | 744.86 |
| | ☑# | 65 | 6.14 | 744.48 |
| | ☑# | 70 | 5.82 | 744.8 |
| | ☑# | 75 | 5.7 | 744.92 |
| | ☑# | 80 | 5.63 | 744.99 |
| TOB | ☑# | 83 | 5.8 | 744.82 |
| | ☐# | 84 | 6.12 | 744.5 |
| | ☐# | 85 | 6.52 | 744.1 |
| | ☐# | 86 | 7.19 | 743.43 |
| | ☐# | 87 | 7.77 | 742.85 |
| | ☐# | 87.5 | 9.08 | 741.54 |
| | ☐# | 88 | 9.17 | 741.45 |
| | ☐# | 89 | 9.64 | 740.98 |
| | ☐# | 91 | 9.59 | 741.03 |
| | ☐# | 92 | 8.82 | 741.8 |
| | ☐# | 93 | 7.93 | 742.69 |
| | ☐# | 94 | 7.5 | 743.12 |
| | ☐# | 95 | 7.3 | 743.32 |
| | ☐# | 97 | 6.66 | 743.96 |
| | ☑# | 98 | 6.26 | 744.36 |
| TOB | ☑# | 99 | 5.49 | 745.13 |
| | ☑# | 100 | 5.27 | 745.35 |
| | ☑# | 103 | 5.34 | 745.28 |
| | ☑# | 106 | 5.38 | 745.24 |
| | ☑# | 110 | 5.59 | 745.03 |
| | ☑# | 115 | 5.65 | 744.97 |
| | ☑# | 120 | 5.68 | 744.94 |
| | ☑# | 125 | 5.72 | 744.9 |
| | ☑# | 130 | 5.89 | 744.73 |
| | ☑# | 135 | 6.02 | 744.6 |
| | ☑# | 140 | 5.99 | 744.63 |
| | ☑# | 145 | 6.2 | 744.42 |
| | ☑# | 155 | 6.37 | 744.25 |
| | ☑# | 165 | 6.42 | 744.2 |
| | ☑# | 175 | 6.54 | 744.08 |
| | ☑# | 180 | 6.81 | 743.81 |
| | ☑# | 185 | 6.63 | 743.99 |
| up steep | ☐# | | | |
| | ☐# | | | |
| | ☐# | | | |
| | ☐# | | | |
| | ☐# | | | |
| | ☐# | | | |

10
15

| FS bankfull | FS top of bank | W fpa (ft) | channel slope (%) | Manning's "n" |
|---|---|---|---|---|
| 7.05 | 5.49 | 200.0 | | |
| 743.57 | 745.13 | | | |

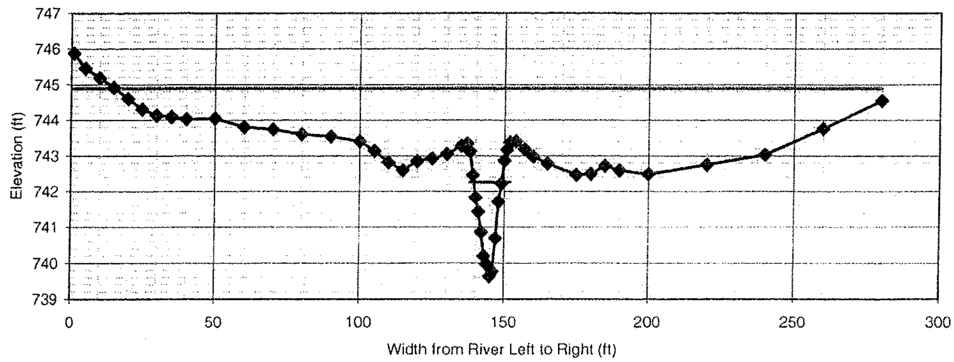
| dimensions | | | |
|---|---|---|---|
| 14.2 | x-section area | 1.4 | d mean |
| 10.0 | width | 12.0 | wet P |
| 2.6 | d max | 1.2 | hyd radi |
| 4.2 | bank ht | 7.0 | w/d ratio |
| 200.0 | W flood prone area | 20.0 | ent ratio |

| hydraulics | |
|---|---|
| 0.0 | velocity (ft/sec) |
| 0.0 | discharge rate, Q (cfs) |
| 0.00 | shear stress ((lbs/ft sq) |
| 0.00 | shear velocity (ft/sec) |
| 0.000 | unit stream power (lbs/ft/sec) |
| 0.00 | Froude number |
| 0.0 | friction factor u/u* |
| 0.0 | threshold grain size (mm) |

| check from channel material | | | |
|---|---|---|---|
| 8 | measured D84 (mm) | | |
| 51.5 | relative roughness | 12.6 | fric. factor |
| 0.000 | Manning's n from channel material | | |

83

x-section 6 @ 1688'




section:

Riffle

---

---

description:

height of instrument (ft): 749.46

| notes | omit pt. | distance (ft) | FS (ft) | elevation | |
|---|---|---|---|---|---|
| FP edge | #☑# | 1 | 3.58 | 745.88 | |
| | #☑# | 5 | 4 | 745.46 | |
| | #☑# | 10 | 4.27 | 745.19 | |
| | #☑# | 15 | 4.54 | 744.92 | |
| | #☑# | 20 | 4.86 | 744.6 | |
| | #☑# | 25 | 5.15 | 744.31 | |
| | #☑# | 30 | 5.32 | 744.14 | |
| | #☑# | 35 | 5.37 | 744.09 | |
| | #☑# | 40 | 5.43 | 744.03 | |
| | #☑# | 50 | 5.41 | 744.05 | |
| | #☑# | 60 | 5.66 | 743.8 | |
| | #☑# | 70 | 5.72 | 743.74 | |
| | #☑# | 80 | 5.85 | 743.61 | |
| | #☑# | 90 | 5.92 | 743.54 | |
| | #☑# | 100 | 6.05 | 743.41 | |
| | #☑# | 105 | 6.32 | 743.14 | |
| | #☑# | 110 | 6.64 | 742.82 | |
| | #☑# | 115 | 6.87 | 742.59 | |
| | #☑# | 120 | 6.61 | 742.85 | 0 |
| | #☑# | 125 | 6.54 | 742.92 | |
| | #☑# | 130 | 6.41 | 743.05 | 16 |
| | #☑# | 135 | 6.18 | 743.28 | |
| TOB | #☑# | 137 | 6.11 | 743.35 | - |
| | #☐# | 138 | 6.34 | 743.12 | |
| | #☐# | 139 | 7 | 742.46 | |
| | #☐# | 140 | 7.63 | 741.83 | |
| | #☐# | 141 | 8.03 | 741.43 | |
| | #☐# | 142 | 8.6 | 740.86 | |
| | #☐# | 143 | 9.27 | 740.19 | |
| | #☐# | 144 | 9.49 | 739.97 | |
| Bed | #☐# | 145 | 9.83 | 739.63 | |
| | #☐# | 146 | 9.69 | 739.77 | |
| | #☐# | 147 | 8.77 | 740.69 | |
| | #☐# | 148 | 7.75 | 741.71 | |
| | #☐# | 149 | 7.24 | 742.22 | |
| | #☐# | 150 | 6.6 | 742.86 | |
| TOB | #☐# | 151 | 6.29 | 743.17 | |
| | #☐# | 152 | 6.09 | 743.37 | |
| | #☑# | 154 | 6.05 | 743.41 | |
| | #☑# | 157 | 6.28 | 743.18 | |
| | #☑# | 160 | 6.48 | 742.98 | |
| | #☑# | 165 | 6.68 | 742.78 | |
| | #☑# | 175 | 6.99 | 742.47 | |
| | #☑# | 180 | 6.97 | 742.49 | |
| | #☑# | 185 | 6.74 | 742.72 | |
| | #☑# | 190 | 6.87 | 742.59 | |
| | #☑# | 200 | 6.98 | 742.48 | |
| | #☑# | 220 | 6.71 | 742.75 | |
| | #☑# | 240 | 6.43 | 743.03 | |
| | #☑# | 260 | 5.7 | 743.76 | |
| | #☑# | 280 | 4.91 | 744.55 | |
| | #☐# | | | | |
| | #☐# | | | | |

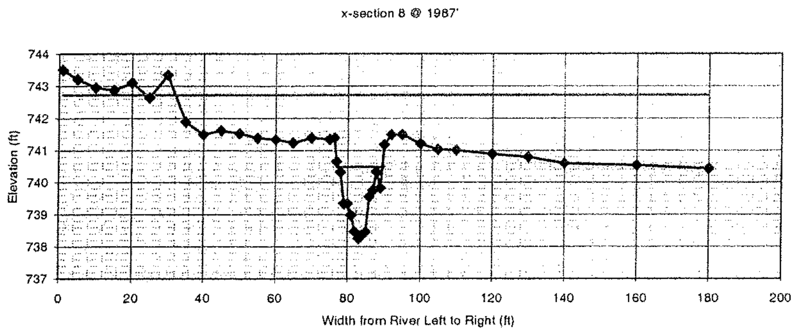
| FS bankfull | FS top of bank | W fpa (ft) | channel slope (%) | Manning's "n" |
|---|---|---|---|---|
| 7.2 | 6.29 | 265.0 | | |
| 742.26 | 743.17 | | | |

| dimensions | | | |
|---|---|---|---|
| 14.2 | x-section area | 1.5 | d mean |
| 9.7 | width | 11.3 | wet P |
| 2.6 | d max | 1.3 | hyd radi |
| 3.5 | bank ht | 6.7 | w/d ratio |
| 265.0 | W flood prone area | 27.2 | ent ratio |

| hydraulics | |
|---|---|
| 0.0 | velocity (ft/sec) |
| 0.0 | discharge rate, Q (cfs) |
| 0.00 | shear stress ((lbs/ft sq) |
| 0.00 | shear velocity (ft/sec) |
| 0.000 | unit stream power (lbs/ft/sec) |
| 0.00 | Froude number |
| 0.0 | friction factor u/u* |
| ~~0.0~~ | threshold grain size (mm) |

| check from channel material | | | |
|---|---|---|---|
| 8 | measured D84 (mm) | | |
| 52.7 | relative roughness | 12.6 | fric. factor |
| 0.000 | Manning's n from channel material | | |

## Cross Section




| | section: |
|---|---|
| . | Riffle<br>---<br>--- |
| description: | |
| height of instrument (ft): | 746.85 |

| notes | omit pt. | distance (ft) | FS (ft) | elevation |
|---|---|---|---|---|
| | #☑# | 1 | 3.35 | 743.5 |
| | #☑# | 5 | 3.64 | 743.21 |
| | #☑# | 10 | 3.9 | 742.95 |
| | #☑# | 15 | 3.98 | 742.87 |
| | #☑# | 20 | 3.75 | 743.1 |
| | #☑# | 25 | 4.21 | 742.64 |
| | #☑# | 30 | 3.51 | 743.34 |
| | #☑# | 35 | 4.96 | 741.89 |
| | #☑# | 40 | 5.35 | 741.5 |
| | #☑# | 45 | 5.23 | 741.62 |
| | #☑# | 50 | 5.32 | 741.53 |
| | #☑# | 55 | 5.46 | 741.39 |
| | #☑# | 60 | 5.51 | 741.34 |
| | #☑# | 65 | 5.61 | 741.24 |
| | #☑# | 70 | 5.46 | 741.39 |
| | #☑# | 75 | 5.5 | 741.35 |
| TOB | #☑# | 75.33 | 5.46 | 741.39 |
| | #☐# | 77 | 6.19 | 740.66 |
| | #☐# | 78 | 6.53 | 740.32 |
| | #☐# | 79 | 7.51 | 739.34 |
| | #☐# | 80 | 7.51 | 739.34 |
| | #☐# | 81 | 7.87 | 738.98 |
| Bed | #☐# | 82 | 8.38 | 738.47 |
| Thalweg | #☐# | 83 | 8.6 | 738.25 |
| Bed | #☐# | 84 | 8.49 | 738.36 |
| | #☐# | 85 | 8.39 | 738.46 |
| | #☐# | 86 | 7.3 | 739.55 |
| MB | #☐# | 87 | 7.11 | 739.74 |
| | #☐# | 88 | 6.53 | 740.32 |
| | #☐# | 89 | 7.02 | 739.83 |
| TOB | #☐# | 90 | 5.67 | 741.18 |
| | #☑# | 92 | 5.36 | 741.49 |
| | #☑# | 95 | 5.35 | 741.5 |
| | #☑# | 100 | 5.64 | 741.21 |
| | #☑# | 105 | 5.81 | 741.04 |
| | #☑# | 110 | 5.84 | 741.01 |
| | #☑# | 120 | 5.96 | 740.89 |
| | #☑# | 130 | 6.05 | 740.8 |
| | #☑# | 140 | 6.25 | 740.6 |
| | #☑# | 160 | 6.31 | 740.54 |
| | #☑# | 180 | 6.43 | 740.42 |
| fence @ 2( | #☐# | | | |

☐

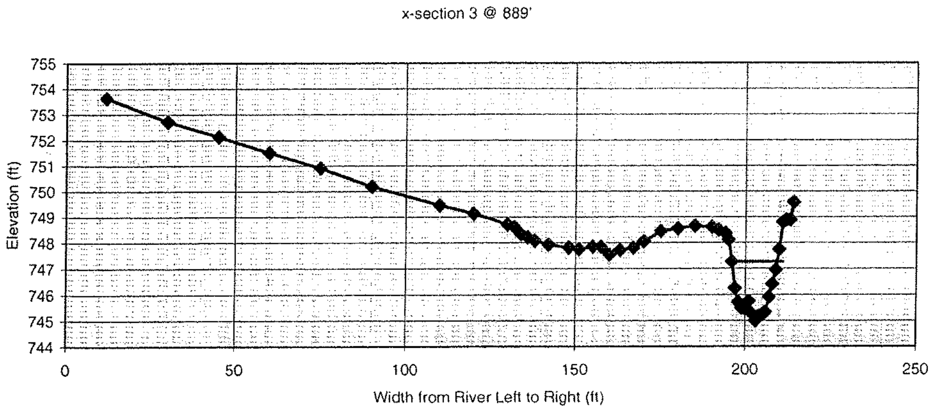
60

| FS bankfull | FS top of bank | W fpa (ft) | channel slope (%) | Manning's "n" |
|---|---|---|---|---|
| 6.365 | 5.67 | 220.0 | | |
| 740.485 | 741.18 | | | |

| dimensions | | | |
|---|---|---|---|
| 14.6 | x-section area | 1.2 | d mean |
| 12.0 | width | 13.7 | wet P |
| 2.2 | d max | 1.1 | hyd radi |
| 2.9 | bank ht | 9.8 | w/d ratio |
| 220.0 | W flood prone area | 18.4 | ent ratio |

| hydraulics | |
|---|---|
| 0.0 | velocity (ft/sec) |
| 0.0 | discharge rate, Q (cfs) |
| 0.00 | shear stress ((lbs/ft sq) |
| 0.00 | shear velocity (ft/sec) |
| 0.000 | unit stream power (lbs/ft/sec) |
| 0.00 | Froude number |
| 0.0 | friction factor u/u* |
| 0.0 | threshold grain size (mm) |

| check from channel material | | | |
|---|---|---|---|
| 8 | measured D84 (mm) | | |
| 44.2 | relative roughness | 12.2 | fric. factor |
| 0.000 | Manning's n from channel material | | |




| | |
|---|---|
| section: | |
| | Pool<br>---<br>--- |
| description: | |
| height of instrument (ft): | 754.39 |

| notes | omit pt. | distance (ft) | FS (ft) | elevation |
|---|---|---|---|---|
| fence @ 0 | #☑# | 12 | 0.75 | 753.64 |
| | #☑# | 30 | 1.67 | 752.72 |
| | #☑# | 45 | 2.26 | 752.13 |
| | #☑# | 60 | 2.88 | 751.51 |
| | #☑# | 75 | 3.48 | 750.91 |
| | #☑# | 90 | 4.2 | 750.19 |
| | #☑# | 110 | 4.93 | 749.46 |
| | #☑# | 120 | 5.25 | 749.14 |
| | #☑# | 130 | 5.67 | 748.72 |
| | #☑# | 132 | 5.78 | 748.61 |
| | #☑# | 134 | 6.05 | 748.34 |
| | #☑# | 136 | 6.18 | 748.21 |
| | #☑# | 138 | 6.31 | 748.08 |
| | #☑# | 142 | 6.46 | 747.93 |
| | #☑# | 148 | 6.57 | 747.82 |
| | #☑# | 151 | 6.64 | 747.75 |
| | #☑# | 155 | 6.54 | 747.85 |
| | #☑# | 157.5 | 6.55 | 747.84 |
| | #☑# | 160 | 6.85 | 747.54 |
| | #☑# | 163 | 6.67 | 747.72 |
| | #☑# | 167 | 6.59 | 747.8 |
| | #☑# | 170 | 6.34 | 748.05 |
| | #☑# | 175 | 5.94 | 748.45 |
| | #☑# | 180 | 5.84 | 748.55 |
| | #☑# | 185 | 5.74 | 748.65 |
| | #☑# | 190 | 5.78 | 748.61 |
| | #☑# | 192 | 5.89 | 748.5 |
| TOB | #☑# | 194 | 6.01 | 748.38 |
| | #☐# | 195 | 6.28 | 748.11 |
| | #☐# | 196 | 7.12 | 747.27 |
| | #☐# | 197 | 8.14 | 746.25 |
| | #☐# | 198 | 8.68 | 745.71 |
| | #☐# | 199 | 8.9 | 745.49 |
| | #☐# | 200 | 8.93 | 745.46 |
| | #☐# | 201 | 8.65 | 745.74 |
| | #☐# | 202 | 9.13 | 745.26 |
| thalweg | #☐# | 203 | 9.39 | 745 |
| | #☐# | 204 | 9.22 | 745.17 |
| | #☐# | 205 | 9.16 | 745.23 |
| | #☐# | 206 | 9.05 | 745.34 |
| | #☐# | 207 | 8.48 | 745.91 |
| | #☐# | 208 | 7.98 | 746.41 |
| | #☐# | 209 | 7.43 | 746.96 |
| | #☐# | 210 | 6.65 | 747.74 |
| | #☐# | 211 | 5.6 | 748.79 |
| | #☑# | 212 | 5.5 | 748.89 |
| | #☑# | 213 | 5.5 | 748.89 |
| | #☑# | 214 | 4.81 | 749.58 |
| up steep | #☐# | | | |
| | #☐# | | | |
| | #☐# | | | |
| | #☐# | | | |
| | #☐# | | | |

| FS bankfull | FS top of bank | W fpa (ft) | channel slope (%) | Manning's "n" |
|---|---|---|---|---|
| 7.12 | 6.01 | | | |
| 747.27 | 748.38 | | | |

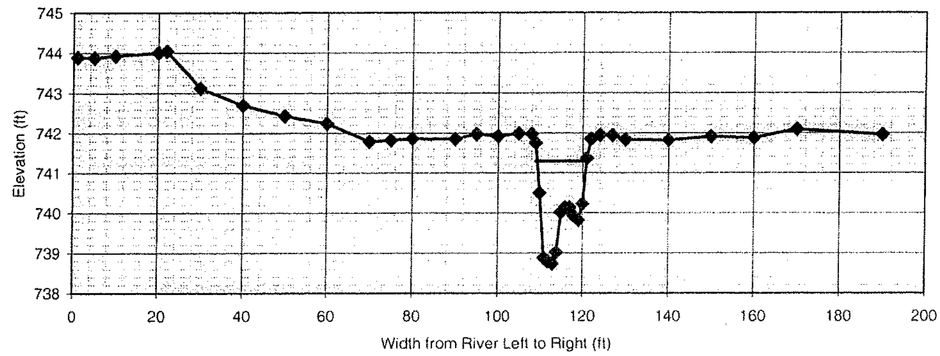
| dimensions | | | |
|---|---|---|---|
| 20.5 | x-section area | 1.5 | d mean |
| 13.4 | width | 14.7 | wet P |
| 2.3 | d max | 1.4 | hyd radi |
| 3.4 | bank ht | ~~8.8~~ | w/d ratio |
| ~~0.0~~ | W flood prone area | ~~0.0~~ | ent ratio |

| hydraulics | |
|---|---|
| ~~0.0~~ | velocity (ft/sec) |
| ~~0.0~~ | discharge rate, Q (cfs) |
| 0.00 | shear stress ((lbs/ft sq) |
| 0.00 | shear velocity (ft/sec) |
| ~~0.000~~ | unit stream power (lbs/ft/sec) |
| ~~0.00~~ | Froude number |
| ~~0.0~~ | friction factor u/u* |
| ~~0.0~~ | threshold grain size (mm) |

| check from channel material | | | |
|---|---|---|---|
| 8 | measured D84 (mm) | | |
| ~~55.2~~ | relative roughness | ~~12.8~~ | fric. factor |
| ~~0.000~~ | Manning's n from channel material | | |

#8
194

x-section 7 @ 1845'




| | |
|---|---|
| section: | |
| | Pool.<br>---<br>--- |
| description: | |
| height of Instrument (ft): | 747.66 |

| notes | omit pt. | distance (ft) | FS (ft) | elevation |
|---|---|---|---|---|
| | #☑# | 1 | 3.77 | 743.89 |
| | #☑# | 5 | 3.78 | 743.88 |
| | #☑# | 10 | 3.73 | 743.93 |
| | #☑# | 20 | 3.66 | 744 |
| | #☑# | 22 | 3.62 | 744.04 |
| | #☑# | 30 | 4.54 | 743.12 |
| | #☑# | 40 | 4.97 | 742.69 |
| | #☑# | 50 | 5.23 | 742.43 |
| | #☑# | 60 | 5.42 | 742.24 |
| | #☑# | 70 | 5.87 | 741.79 |
| | #☑# | 75 | 5.84 | 741.82 |
| | #☑# | 80 | 5.8 | 741.86 |
| | #☑# | 90 | 5.81 | 741.85 |
| | #☑# | 95 | 5.69 | 741.97 |
| | #☑# | 100 | 5.74 | 741.92 |
| | #☑# | 105 | 5.67 | 741.99 |
| TOB | #☑# | 108 | 5.69 | 741.97 |
| | #☐# | 109 | 5.91 | 741.75 |
| MB | #☐# | 110 | 7.16 | 740.5 |
| Bed | #☐# | 111 | 8.78 | 738.88 |
| | #☐# | 112 | 8.87 | 738.79 |
| Thalweg | #☐# | 113 | 8.92 | 738.74 |
| | #☐# | 114 | 8.64 | 739.02 |
| | #☐# | 115 | 7.64 | 740.02 |
| | #☐# | 116 | 7.52 | 740.14 |
| | #☐# | 117 | 7.52 | 740.14 |
| | #☐# | 118 | 7.74 | 739.92 |
| | #☐# | 119 | 7.83 | 739.83 |
| MB | #☐# | 120 | 7.43 | 740.23 |
| | #☐# | 121 | 6.3 | 741.36 |
| TOB | #☑# | 122 | 5.81 | 741.85 |
| | #☑# | 124 | 5.71 | 741.95 |
| | #☑# | 127 | 5.72 | 741.94 |
| | #☑# | 130 | 5.82 | 741.84 |
| | #☑# | 140 | 5.84 | 741.82 |
| | #☑# | 150 | 5.75 | 741.91 |
| | #☑# | 160 | 5.78 | 741.88 |
| | #☑# | 170 | 5.57 | 742.09 |
| | #☑# | 190 | 5.7 | 741.96 |
| fence @ 3 | #☐# | | | |

| FS bankfull | FS top of bank | W fpa (ft) | channel slope (%) | Manning's "n" |
|---|---|---|---|---|
| 6.37 | 5.81 | | | |
| 741.29 | 741.85 | | | |

| dimensions | | | |
|---|---|---|---|
| 17.8 | x-section area | 1.5 | d mean |
| 11.6 | width | 13.9 | wet P |
| 2.5 | d max | 1.3 | hyd radi |
| 3.1 | bank ht | ~~7.5~~ | w/d ratio |
| ~~0.0~~ | W flood prone area | ~~0.0~~ | ent ratio |

| hydraulics | |
|---|---|
| ~~0.0~~ | velocity (ft/sec) |
| ~~0.0~~ | discharge rate, Q (cfs) |
| 0.00 | shear stress ((lbs/ft sq) |
| 0.00 | shear velocity (ft/sec) |
| ~~0.000~~ | unit stream power (lbs/ft/sec) |
| ~~0.00~~ | Froude number |
| ~~0.0~~ | friction factor u/u* |
| ~~0.0~~ | threshold grain size (mm) |

| check from channel material | | | |
|---|---|---|---|
| 8 | measured D84 (mm) | | |
| ~~55.6~~ | relative roughness | ~~12.8~~ | fric. factor |
| ~~0.000~~ | Manning's n from channel material | | |

83

## Weighted Pebble Count

| | | | |
|---|---|---|---|
| Percent Riffle: | 60 | Percent Run: | 0 |
| Percent Pool: | 40 | Percent Glide: | 0 |

Pebble Count,

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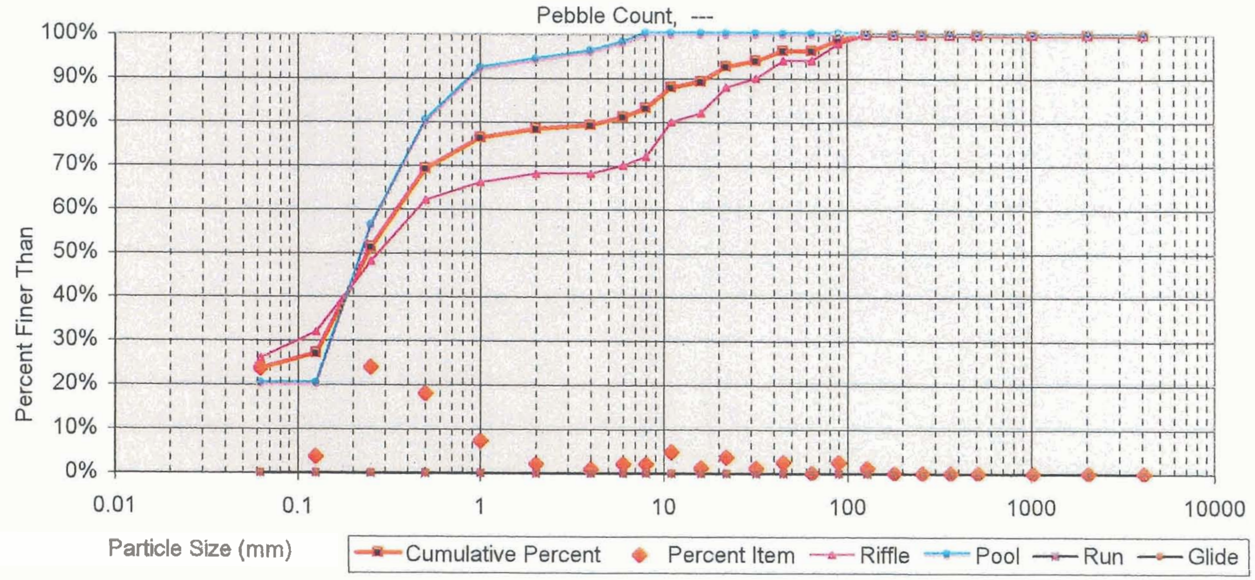
Note: **Existing Conditions Pebble Count**

| Material | Size Range (mm) | | Total # | |
|---|---|---|---|---|
| silt/clay | 0 | 0.062 | 23.6 | # # |
| very fine sand | 0.062 | 0.13 | 3.6 | # # |
| fine sand | 0.13 | 0.25 | 24.0 | # # |
| medium sand | 0.25 | 0.5 | 18.0 | # # |
| coarse sand | 0.5 | 1 | 7.2 | # # |
| very coarse sand | 1 | 2 | 2.0 | # # |
| very fine gravel | 2 | 4 | 0.8 | # # |
| fine gravel | 4 | 6 | 2.0 | # # |
| fine gravel | 6 | 8 | 2.0 | # # |
| medium gravel | 8 | 11 | 4.8 | # # |
| medium gravel | 11 | 16 | 1.2 | # # |
| coarse gravel | 16 | 22 | 3.6 | # # |
| coarse gravel | 22 | 32 | 1.2 | # # |
| very coarse gravel | 32 | 45 | 2.4 | # # |
| very coarse gravel | 45 | 64 | 0.0 | # # |
| small cobble | 64 | 90 | 2.4 | # # |
| medium cobble | 90 | 128 | 1.2 | # # |
| large cobble | 128 | 180 | 0.0 | # # |
| very large cobble | 180 | 256 | 0.0 | # # |
| small boulder | 256 | 362 | 0.0 | # # |
| small boulder | 362 | 512 | 0.0 | # # |
| medium boulder | 512 | 1024 | 0.0 | # # |
| large boulder | 1024 | 2048 | 0.0 | # # |
| very large boulder | 2048 | 4096 | 0.0 | # # |
| bedrock | | | 0.0 | # |
| Weighted Count: | | | 100 | |
| True Total Particle Count: | | | 100 | |




| Size percent less than (mm) | | | | |
|---|---|---|---|---|
| D16 | D35 | D50 | D84 | D95 |
| #N/A | 0.16 | 0.2 | 8 | 37 |

| Percent by substrate type | | | | | |
|---|---|---|---|---|---|
| silt/clay | sand | gravel | cobble | boulder | bedrock |
| 24% | 55% | 18% | 4% | 0% | 0% |

~~Pool Pebble Count~~

~~Pool Pebble Count~~

| Material | Size Range (mm) | | Count | |
|---|---|---|---|---|
| silt/clay | 0 | 0.062 | **10** | # # |
| very fine sand | 0.062 | 0.13 | **0** | # # |
| fine sand | 0.13 | 0.25 | **18** | # # |
| medium sand | 0.25 | 0.5 | **12** | # # |
| coarse sand | 0.5 | 1 | **6** | # # |
| very coarse sand | 1 | 2 | **1** | # # |
| very fine gravel | 2 | 4 | **1** | # # |
| fine gravel | 4 | 6 | **1** | # # |
| fine gravel | 6 | 8 | **1** | # # |
| medium gravel | 8 | 11 | | # # |
| medium gravel | 11 | 16 | | # # |
| coarse gravel | 16 | 22 | | # # |
| coarse gravel | 22 | 32 | | # # |
| very coarse gravel | 32 | 45 | | # # |
| very coarse gravel | 45 | 64 | | # # |
| small cobble | 64 | 90 | | # # |
| medium cobble | 90 | 128 | | # # |
| large cobble | 128 | 180 | | # # |
| very large cobble | 180 | 256 | | # # |
| small boulder | 256 | 362 | | # # |
| small boulder | 362 | 512 | | # # |
| medium boulder | 512 | 1024 | | # # |
| large boulder | 1024 | 2048 | | # # |
| very large boulder | 2048 | 4096 | | # # |
| bedrock | | | | # |
| | Total Particle Count: | | 50 | |

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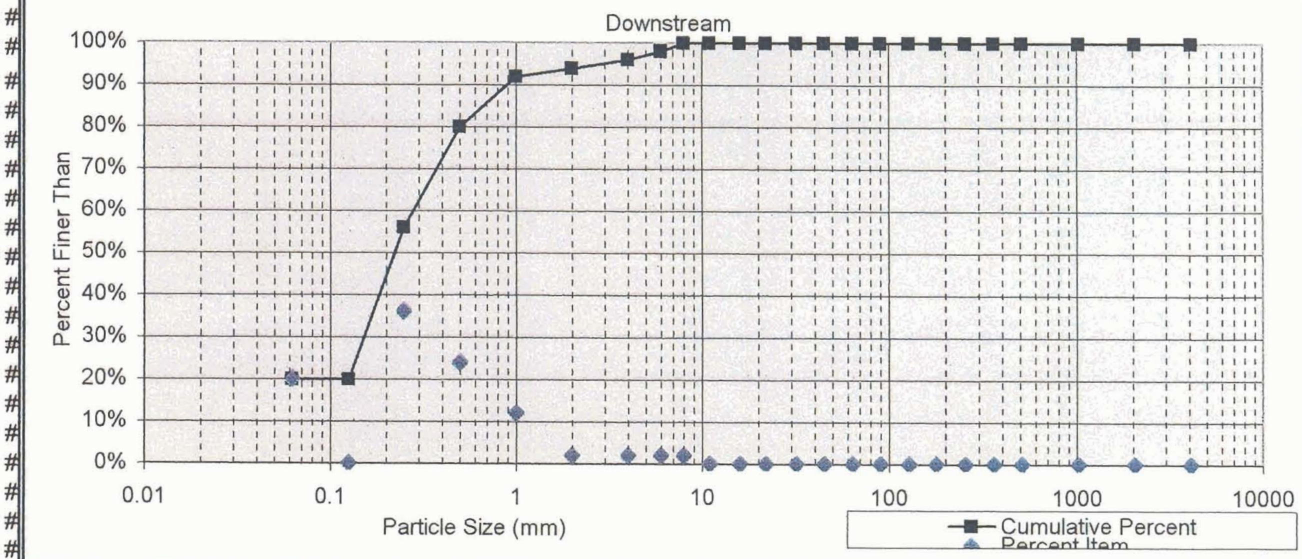
Note: **No Discernable Riffles/Pools so 50 taken upstream & 50 taken downstream**




| Size percent less than (mm) | | | | |
|---|---|---|---|---|
| D16 | D35 | D50 | D84 | D95 |
| #N/A | 0.17 | 0.2 | 1 | 3 |

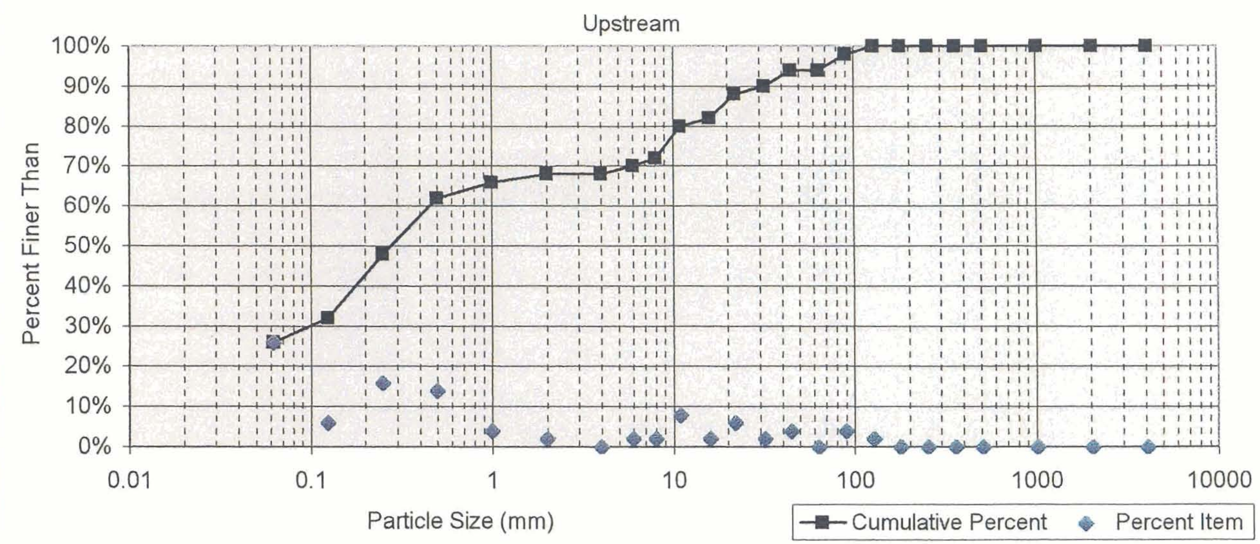
| Percent by substrate type | | | | | |
|---|---|---|---|---|---|
| silt/clay | sand | gravel | cobble | boulder | bedrock |
| 20% | 74% | 6% | 0% | 0% | 0% |

~~iffle Pebble Count~~

~~Riffle Pebble Count~~,

| Material | Size Range (mm) | | Count | |
|---|---|---|---|---|
| silt/clay | 0 | 0.062 | **13** | # # |
| very fine sand | 0.062 | 0.13 | **3** | # # |
| fine sand | 0.13 | 0.25 | **8** | # # |
| medium sand | 0.25 | 0.5 | **7** | # # |
| coarse sand | 0.5 | 1 | **2** | # # |
| very coarse sand | 1 | 2 | **1** | # # |
| very fine gravel | 2 | 4 | **0** | # # |
| fine gravel | 4 | 6 | **1** | # # |
| fine gravel | 6 | 8 | **1** | # # |
| medium gravel | 8 | 11 | **4** | # # |
| medium gravel | 11 | 16 | **1** | # # |
| coarse gravel | 16 | 22 | **3** | # # |
| coarse gravel | 22 | 32 | **1** | # # |
| very coarse gravel | 32 | 45 | **2** | # # |
| very coarse gravel | 45 | 64 | **0** | # # |
| small cobble | 64 | 90 | **2** | # # |
| medium cobble | 90 | 128 | **1** | # # |
| large cobble | 128 | 180 | | # # |
| very large cobble | 180 | 256 | | # # |
| small boulder | 256 | 362 | | # # |
| small boulder | 362 | 512 | | # # |
| medium boulder | 512 | 1024 | | # # |
| large boulder | 1024 | 2048 | | # # |
| very large boulder | 2048 | 4096 | | # # |
| bedrock | | | | # |
| | Total Particle Count: | | 50 | |

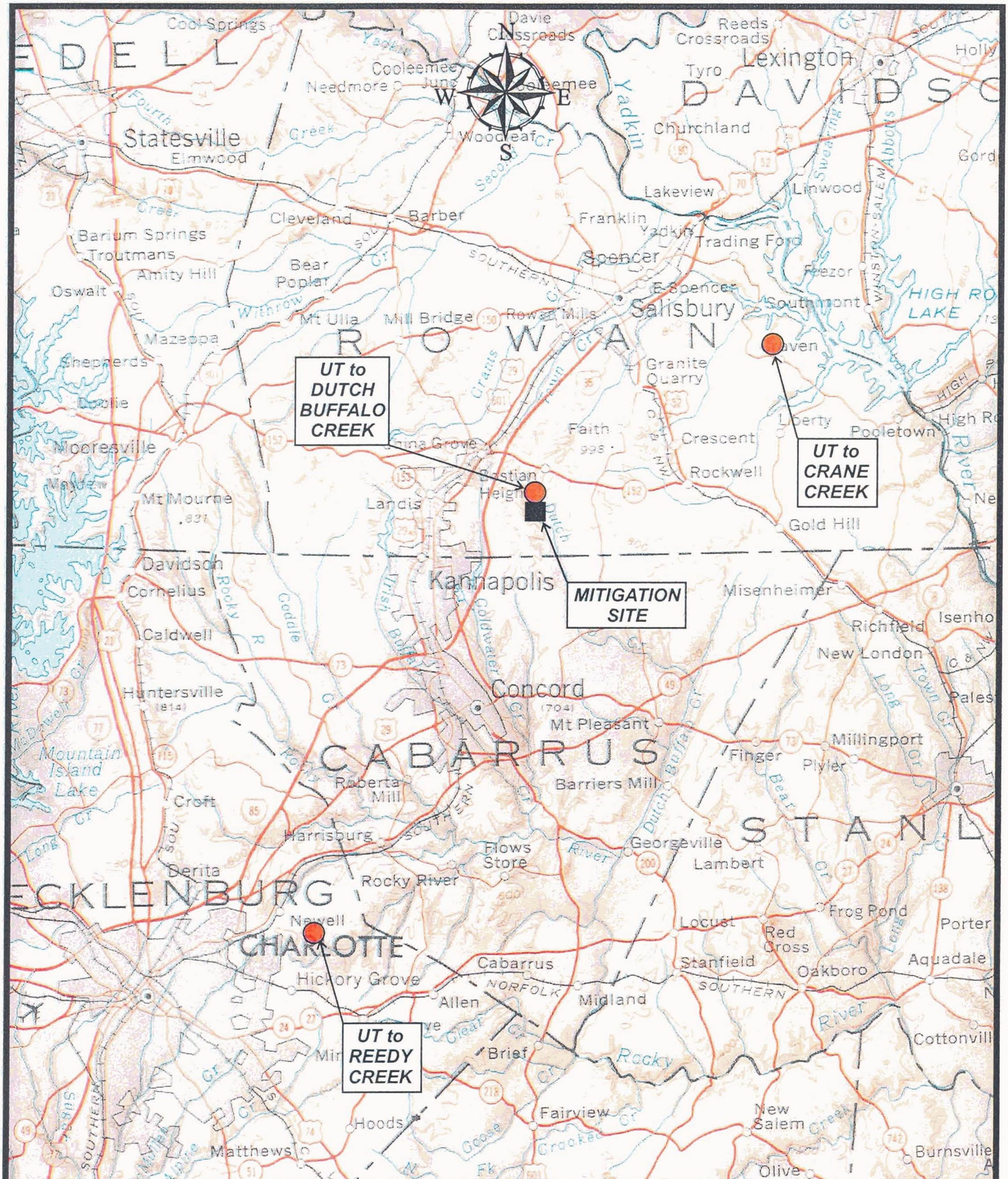
| | |
|---|---|
| | --- |
| | --- |
| | --- |
| Note: | **No Discernable Riffles/Pools so 50 taken upstream & 50 taken downstream** |




| Size percent less than (mm) | | | | |
|---|---|---|---|---|
| D16 | D35 | D50 | D84 | D95 |
| #N/A | 0.14 | 0.3 | 18 | 70 |

| Percent by substrate type | | | | | |
|---|---|---|---|---|---|
| silt/clay | sand | gravel | cobble | boulder | bedrock |
| 26% | 42% | 26% | 6% | 0% | 0% |

# APPENDIX D
REFERENCE DATA

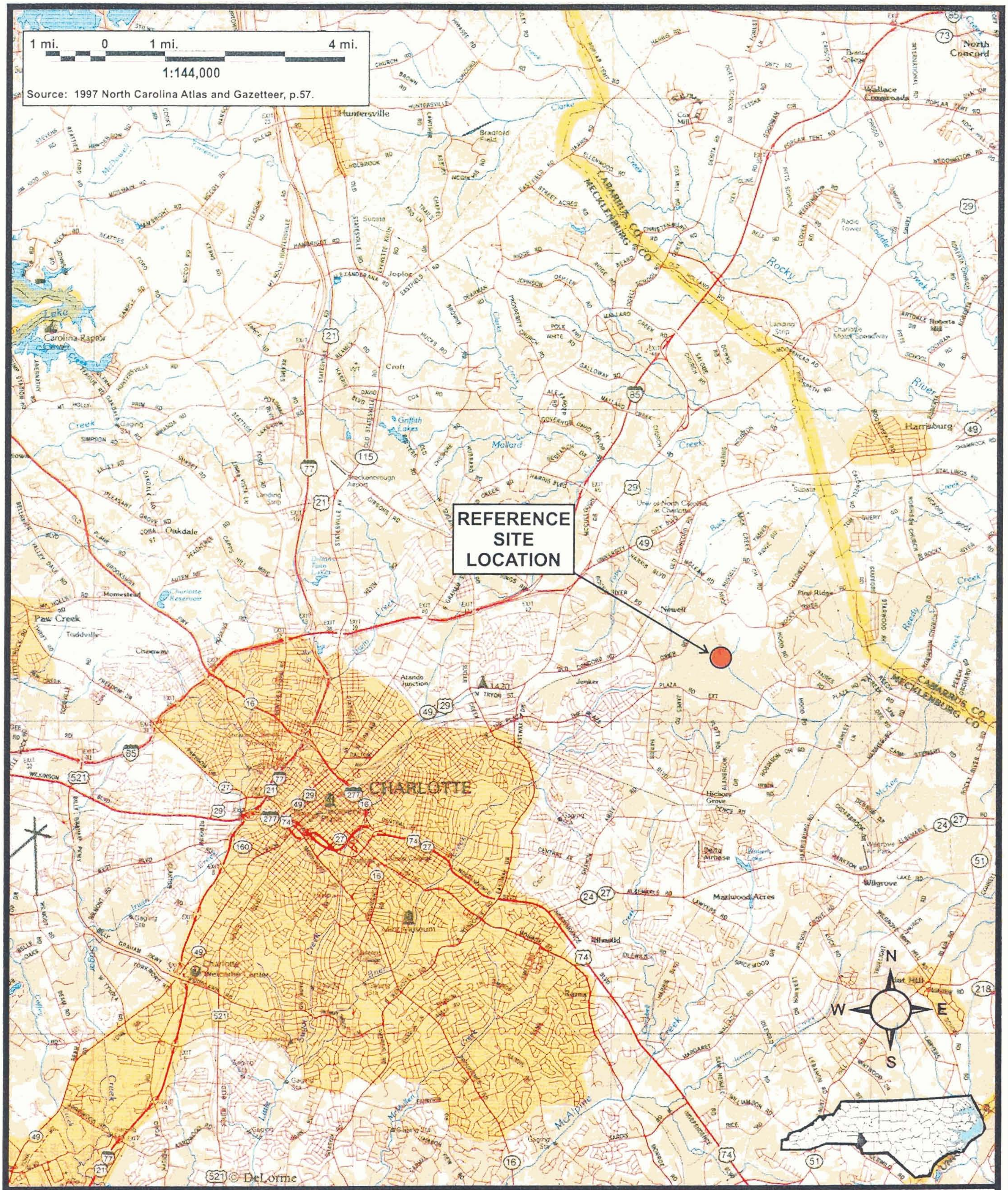



EcoScience Corporation
Raleigh, North Carolina

**REFERENCE SITE LOCATIONS**
**UT to Dutch Buffalo Creek**
**DETAILED MITIGATION STUDIES**
Rowan County, North Carolina

| | |
|---|---|
| Dwn. by: | MAF |
| Ckd by: | WGL |
| Date: | NOV 2002 |
| Project: | 00-046.26 |

APPENDIX D
Figure
1




EcoScience Corporation
Raleigh, North Carolina

**UT to REEDY CREEK**
**Reference Site**
Mecklenburg County, North Carolina

| | |
|---|---|
| Dwn. by: | MAF |
| Ckd by: | WGL |
| Date: | NOV 2002 |
| Project: | 00-046.26 |

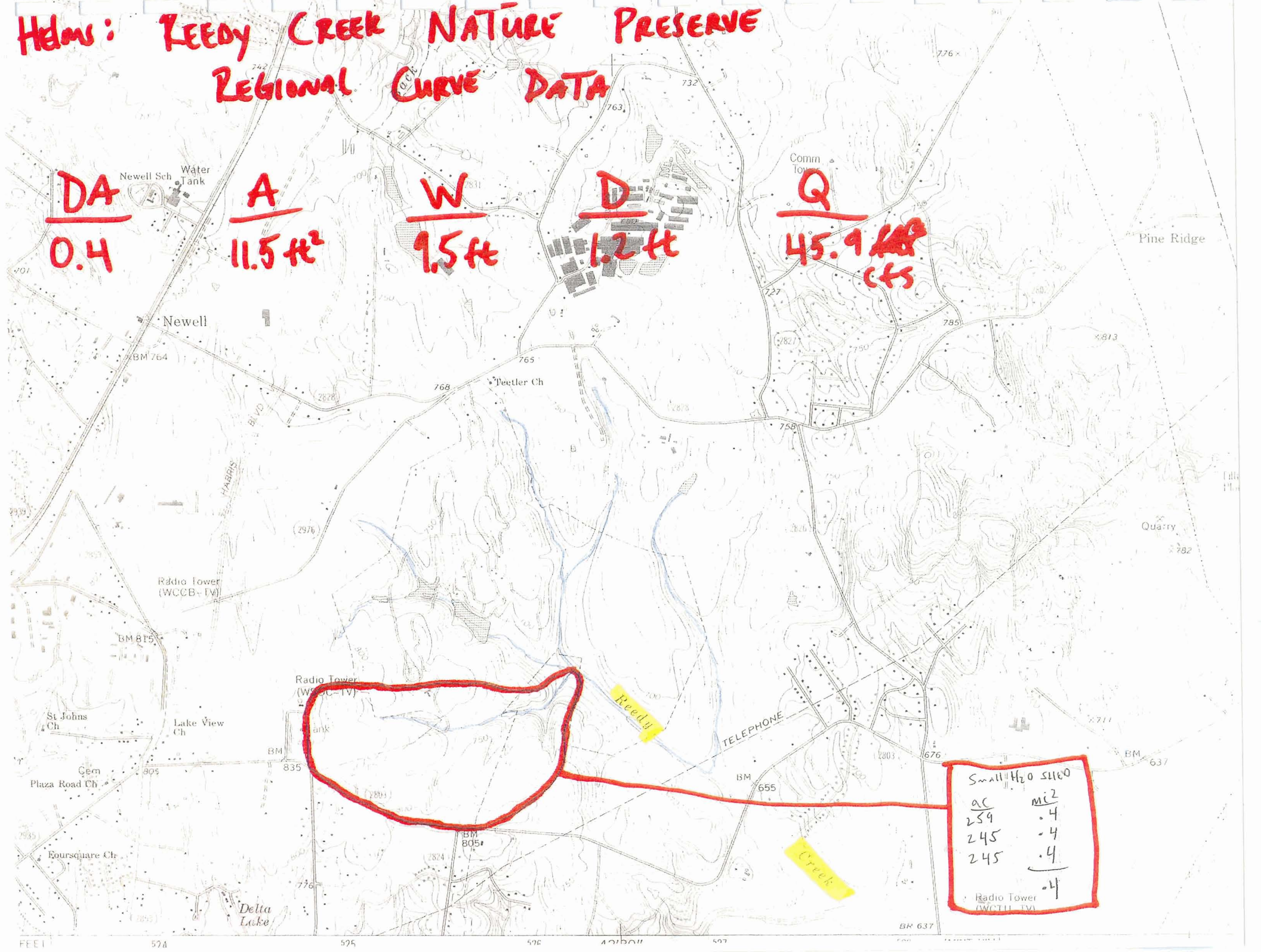
APPENDIX D
Figure
2A

Helms: Reedy Creek Nature Preserve Regional Curve Data

| DA | A | W | D | Q |
|---|---|---|---|---|
| 0.4 | 11.5 $ft^2$ | 9.5 ft | 1.2 ft | 45.9 cfs |

Small $H_2O$ SHED

| ac | $mi^2$ |
|---|---|
| 259 | .4 |
| 245 | .4 |
| 245 | .4 |
| | .4 |



# Helms! Reedy Creek Nature Park
# Reference Dimension

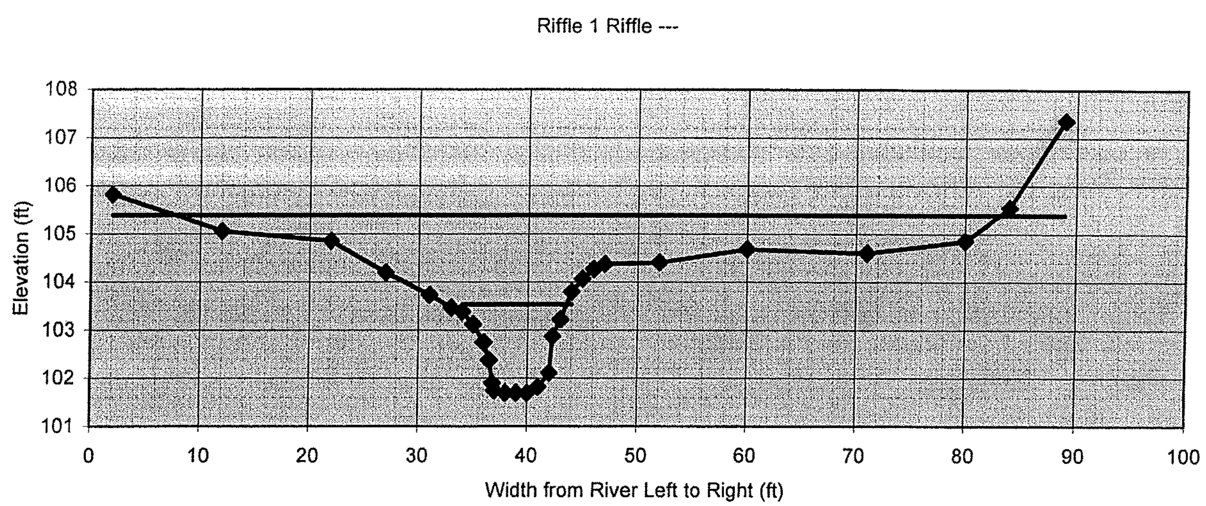
## Riffles

| X-Sect # | A Bkf | W Bkf | D Ave | D max | W/D | FPA | Ent. Ratio | LBH | BHR | Dmax/Dave | Stream Type |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 11.8 | 9.6 | 1.2 | 1.8 | 8 | 70.5 | 7.4 | 1.8 | 1.0 | 1.8 | E |
| 2 | 17.1 | 10.4 | 1.6 | 2.2 | 6 | 58 | 5.6 | 2.6 | 1.2 | 1.4 | E |
| 3 | 15.5 | 11.2 | 1.4 | 2.2 | 8 | 42 | 3.7 | 2.0 | 1.0 | 1.6 | E |
| Ave | 14.8 | 10.4 | 1.4 | 2.1 | 7 | 56.8 | 5.6 | 2.1 | 1.1 | 1.4 | |
| Median | 15.5 | 10.4 | 1.4 | 2.2 | 8 | 58 | 5.6 | 2.0 | 1.0 | 1.4 | |

## Pools

| X-Sect | A | W | D ave | D max | LBH | BHR |
|---|---|---|---|---|---|---|
| 2 | 17.1 | 14.7 | 1.2 | 2.3 | 2.3 | 1.0 |
| 4 | 18.8 | 13.7 | 1.4 | 2.2 | 2.3 | 1.0 |
| Ave | 18.0 | 14.2 | 1.3 | 2.3 | 2.3 | 1.0 |

## Cross Section




| | |
|---|---|
| section: | **Riffle 1** |
| | Riffle<br>---<br>--- |
| description: | Reedy Creek |
| height of instrument (ft): | **110.44** |

| notes | omit pt. | distance (ft) | FS (ft) | elevation |
|---|---|---|---|---|
| | ☑ | 2 | 4.62 | 105.82 |
| | ☑ | 12 | 5.38 | 105.06 |
| | ☑ | 22 | 5.58 | 104.86 |
| | ☑ | 27 | 6.24 | 104.2 |
| | ☑ | 31 | 6.71 | 103.73 |
| | ☑ | 33 | 6.97 | 103.47 |
| | ☐ | 34 | 7.06 | 103.38 |
| | ☐ | 35 | 7.32 | 103.12 |
| | ☐ | 36 | 7.69 | 102.75 |
| | ☐ | 36.5 | 8.06 | 102.38 |
| | ☐ | 36.8 | 8.54 | 101.9 |
| | ☐ | 37 | 8.69 | 101.75 |
| | ☐ | 38 | 8.74 | 101.7 |
| | ☐ | 39 | 8.74 | 101.7 |
| | ☐ | 40 | 8.75 | 101.69 |
| | ☐ | 41 | 8.62 | 101.82 |
| | ☐ | 42 | 8.33 | 102.11 |
| | ☐ | 42.3 | 7.57 | 102.87 |
| | ☐ | 43 | 7.22 | 103.22 |
| | ☐ | 44 | 6.64 | 103.8 |
| | ☑ | 45 | 6.37 | 104.07 |
| | ☑ | 46 | 6.17 | 104.27 |
| | ☑ | 47 | 6.06 | 104.38 |
| | ☑ | 52 | 6.03 | 104.41 |
| | ☑ | 60 | 5.75 | 104.69 |
| | ☑ | 71 | 5.83 | 104.61 |
| | ☑ | 80 | 5.58 | 104.86 |
| | ☑ | 84 | 4.9 | 105.54 |
| | ☑ | 89 | 3.08 | 107.36 |

| FS bankfull | FS top of bank | W fpa (ft) | channel slope (%) | Manning's "n" |
|---|---|---|---|---|
| 6.9 | 6.9 | 70.5 | | |
| 103.54 | 103.54 | | | |

**dimensions**

| | | | |
|---|---|---|---|
| 11.8 | x-section area | 1.2 | d mean |
| 9.6 | width | 10.8 | wet P |
| 1.8 | d max | 1.1 | hyd radi |
| 1.9 | bank ht | 7.8 | w/d ratio |
| 70.5 | W flood prone area | 7.4 | ent ratio |

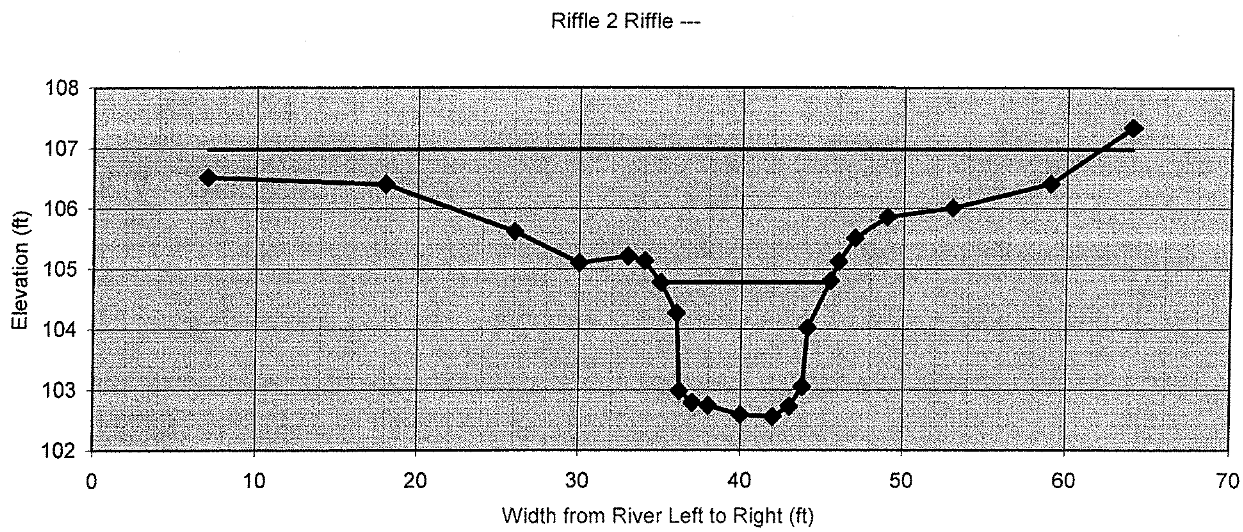
**hydraulics**

| | |
|---|---|
| 0.0 | velocity (ft/sec) |
| 0.0 | discharge rate, Q (cfs) |
| 0.00 | shear stress ((lbs/ft sq) |
| 0.00 | shear velocity (ft/sec) |
| 0.000 | unit stream power (lbs/ft/sec) |
| 0.00 | Froude number |
| 0.0 | friction factor u/u* |
| ~~0.0~~ | threshold grain size (mm) |

**check from channel material**

| | | | |
|---|---|---|---|
| 12 | measured D84 (mm) | | |
| 30.2 | relative roughness | 11.3 | fric. factor |
| 0.000 | Manning's n from channel material | | |

## Cross Section




| | |
|---|---|
| section: | **Riffle 2** |
| | Riffle<br>---<br>--- |
| description: | |
| height of instrument (ft): | **111.72** |

| notes | omit pt. | distance (ft) | FS (ft) | elevation |
|---|---|---|---|---|
| | ✓ | 7 | 5.2 | 106.52 |
| | ✓ | 18 | 5.32 | 106.4 |
| | ✓ | 26 | 6.1 | 105.62 |
| | ✓ | 30 | 6.62 | 105.1 |
| | ✓ | 33 | 6.51 | 105.21 |
| | ✓ | 34 | 6.59 | 105.13 |
| | | 35 | 6.95 | 104.77 |
| | | 36 | 7.45 | 104.27 |
| | | 36.2 | 8.74 | 102.98 |
| | | 37 | 8.93 | 102.79 |
| | | 38 | 8.98 | 102.74 |
| | | 40 | 9.13 | 102.59 |
| | | 42 | 9.16 | 102.56 |
| | | 43 | 8.99 | 102.73 |
| | | 43.8 | 8.67 | 103.05 |
| | | 44.1 | 7.7 | 104.02 |
| | | 45.5 | 6.92 | 104.8 |
| | ✓ | 46 | 6.6 | 105.12 |
| | ✓ | 47 | 6.21 | 105.51 |
| | ✓ | 49 | 5.86 | 105.86 |
| | ✓ | 53 | 5.71 | 106.01 |
| | ✓ | 59 | 5.31 | 106.41 |
| | ✓ | 64 | 4.38 | 107.34 |
| | | | | |
| | | | | |

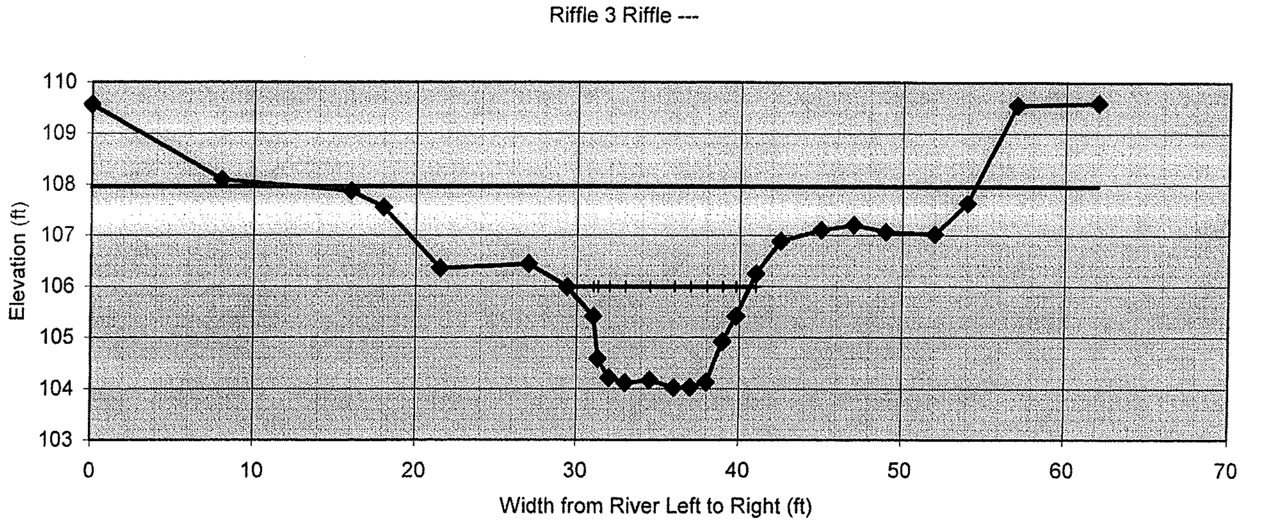
| FS bankfull | FS top of bank | W fpa (ft) | channel slope (%) | Manning's "n" |
|---|---|---|---|---|
| 6.95 | 6.59 | 58.0 | | |
| 104.77 | 105.13 | | | |

| dimensions | | | |
|---|---|---|---|
| 17.1 | x-section area | 1.6 | d mean |
| 10.4 | width | 12.7 | wet P |
| 2.2 | d max | 1.3 | hyd radi |
| 2.6 | bank ht | 6.4 | w/d ratio |
| 58.0 | W flood prone area | 5.6 | ent ratio |

| hydraulics | |
|---|---|
| 0.0 | velocity (ft/sec) |
| 0.0 | discharge rate, Q (cfs) |
| 0.00 | shear stress ((lbs/ft sq) |
| 0.00 | shear velocity (ft/sec) |
| 0.000 | unit stream power (lbs/ft/sec) |
| 0.00 | Froude number |
| 0.0 | friction factor u/u* |
| 0.0 | threshold grain size (mm) |

| check from channel material | | | |
|---|---|---|---|
| 12 | measured D84 (mm) | | |
| 40.2 | relative roughness | 12.0 | fric. factor |
| 0.000 | Manning's n from channel material | | |

## Cross Section




| | |
|---|---|
| section: | Riffle 3 |
| | Riffle<br>---<br>--- |
| description: | |
| height of instrument (ft): | 112.42 |

| notes | omit pt. | distance (ft) | FS (ft) | elevation |
|---|---|---|---|---|
| | ✓ | 0 | 2.85 | 109.57 |
| | ✓ | 8 | 4.32 | 108.1 |
| | ✓ | 16 | 4.55 | 107.87 |
| | ✓ | 18 | 4.87 | 107.55 |
| | ✓ | 21.5 | 6.06 | 106.36 |
| | ✓ | 27 | 5.98 | 106.44 |
| | ☐ | 29.4 | 6.43 | 105.99 |
| | ☐ | 31 | 7.01 | 105.41 |
| | ☐ | 31.3 | 7.83 | 104.59 |
| | ☐ | 32 | 8.21 | 104.21 |
| | ☐ | 33 | 8.3 | 104.12 |
| | ☐ | 34.5 | 8.25 | 104.17 |
| | ☐ | 36 | 8.4 | 104.02 |
| | ☐ | 37 | 8.39 | 104.03 |
| | ☐ | 38 | 8.29 | 104.13 |
| | ☐ | 39 | 7.5 | 104.92 |
| | ☐ | 39.8 | 7 | 105.42 |
| | ☐ | 41 | 6.17 | 106.25 |
| | ✓ | 42.5 | 5.53 | 106.89 |
| | ✓ | 45 | 5.31 | 107.11 |
| | ✓ | 47 | 5.21 | 107.21 |
| | ✓ | 49 | 5.35 | 107.07 |
| | ✓ | 52 | 5.39 | 107.03 |
| | ✓ | 54 | 4.79 | 107.63 |
| | ✓ | 57 | 2.86 | 109.56 |
| | ✓ | 62 | 2.82 | 109.6 |
| | ☐ | | | |

| FS bankfull | FS top of bank | W fpa (ft) | channel slope (%) | Manning's "n" |
|---|---|---|---|---|
| 6.43 | 6.43 | 42.0 | 0.0029 | 0.034 |
| 105.99 | 105.99 | | | |

### dimensions

| | | | |
|---|---|---|---|
| 15.5 | x-section area | 1.4 | d mean |
| 11.2 | width | 12.6 | wet P |
| 2.0 | d max | 1.2 | hyd radi |
| 2.0 | bank ht | 8.1 | w/d ratio |
| 42.0 | W flood prone area | 3.7 | ent ratio |

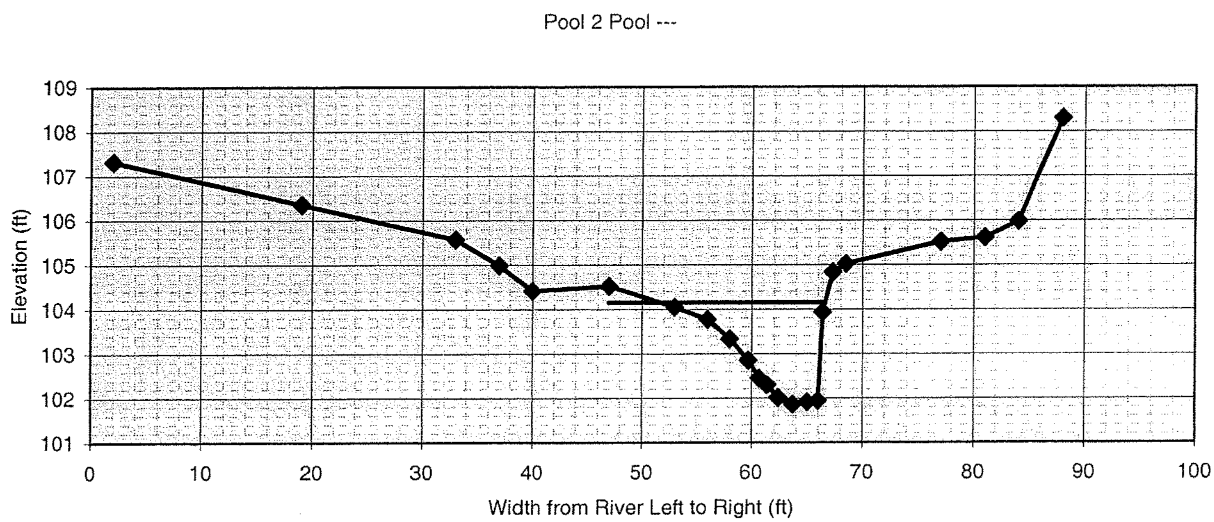
### hydraulics

| | |
|---|---|
| 0.3 | velocity (ft/sec) |
| 4.2 | discharge rate, Q (cfs) |
| 0.00 | shear stress ((lbs/ft sq) |
| 0.03 | shear velocity (ft/sec) |
| 0.001 | unit stream power (lbs/ft/sec) |
| 0.00 | Froude number |
| 8.0 | friction factor u/u* |
| 0.1 | threshold grain size (mm) |

### check from channel material

| | | | |
|---|---|---|---|
| 12 | measured D84 (mm) | | |
| 34.0 | relative roughness | 11.6 | fric. factor |
| 0.024 | Manning's n from channel material | | |

## Cross Section




| | |
|---|---|
| section: | **Pool 2** |
| | Pool<br>---<br>--- |
| description: | |
| height of instrument (ft): | **111.05** |

| notes | omit pt. | distance (ft) | FS (ft) | elevation |
|---|---|---|---|---|
| | # ☑ # | 2 | 3.73 | 107.32 |
| | # ☑ # | 19 | 4.69 | 106.36 |
| | # ☑ # | 33 | 5.48 | 105.57 |
| | # ☑ # | 37 | 6.07 | 104.98 |
| | # ☑ # | 40 | 6.64 | 104.41 |
| | # ☐ # | 47 | 6.53 | 104.52 |
| | # ☐ # | 53 | 7 | 104.05 |
| | # ☐ # | 56 | 7.28 | 103.77 |
| | # ☐ # | 58 | 7.72 | 103.33 |
| | # ☐ # | 59.7 | 8.2 | 102.85 |
| | # ☐ # | 60.7 | 8.6 | 102.45 |
| | # ☐ # | 61.4 | 8.75 | 102.3 |
| | # ☐ # | 62.4 | 9.04 | 102.01 |
| | # ☐ # | 63.7 | 9.19 | 101.86 |
| | # ☐ # | 65 | 9.14 | 101.91 |
| | # ☐ # | 66 | 9.11 | 101.94 |
| | # ☐ # | 66.4 | 7.12 | 103.93 |
| | # ☑ # | 67.3 | 6.22 | 104.83 |
| | # ☑ # | 68.5 | 6.03 | 105.02 |
| | # ☑ # | 77 | 5.53 | 105.52 |
| | # ☑ # | 81 | 5.44 | 105.61 |
| | # ☑ # | 84 | 5.07 | 105.98 |
| | # ☑ # | 88 | 2.75 | 108.3 |
| | # ☐ # | | | |

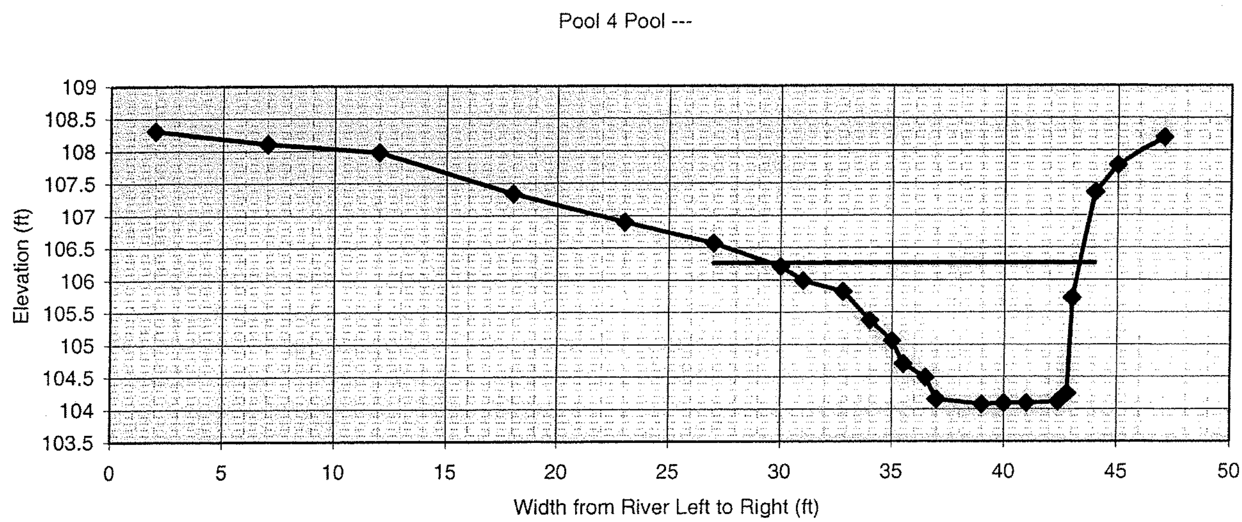
| FS bankfull | FS top of bank | W fpa (ft) | channel slope (%) | Manning's "n" |
|---|---|---|---|---|
| 6.9 | 6.9 | | | |
| 104.15 | 104.15 | | | |

| dimensions | | | |
|---|---|---|---|
| 17.1 | x-section area | 1.2 | d mean |
| 14.7 | width | 16.6 | wet P |
| 2.3 | d max | 1.0 | hyd radi |
| 2.3 | bank ht | ~~12.6~~ | w/d ratio |
| ~~0.0~~ | W flood prone area | ~~0.0~~ | ent ratio |

| hydraulics | |
|---|---|
| ~~0.0~~ | velocity (ft/sec) |
| ~~0.0~~ | discharge rate, Q (cfs) |
| 0.00 | shear stress ((lbs/ft sq) |
| 0.00 | shear velocity (ft/sec) |
| ~~0.000~~ | unit stream power (lbs/ft/sec) |
| ~~0.00~~ | Froude number |
| ~~0.0~~ | friction factor u/u* |
| ~~0.0~~ | threshold grain size (mm) |

| check from channel material | | | |
|---|---|---|---|
| ~~12~~ | measured D84 (mm) | | |
| ~~28.6~~ | relative roughness | ~~11.1~~ | fric. factor |
| ~~0.000~~ | Manning's n from channel material | | |

## Cross Section




section: **Pool 4**

Pool
---
---

description:

height of instrument (ft): **113.51**

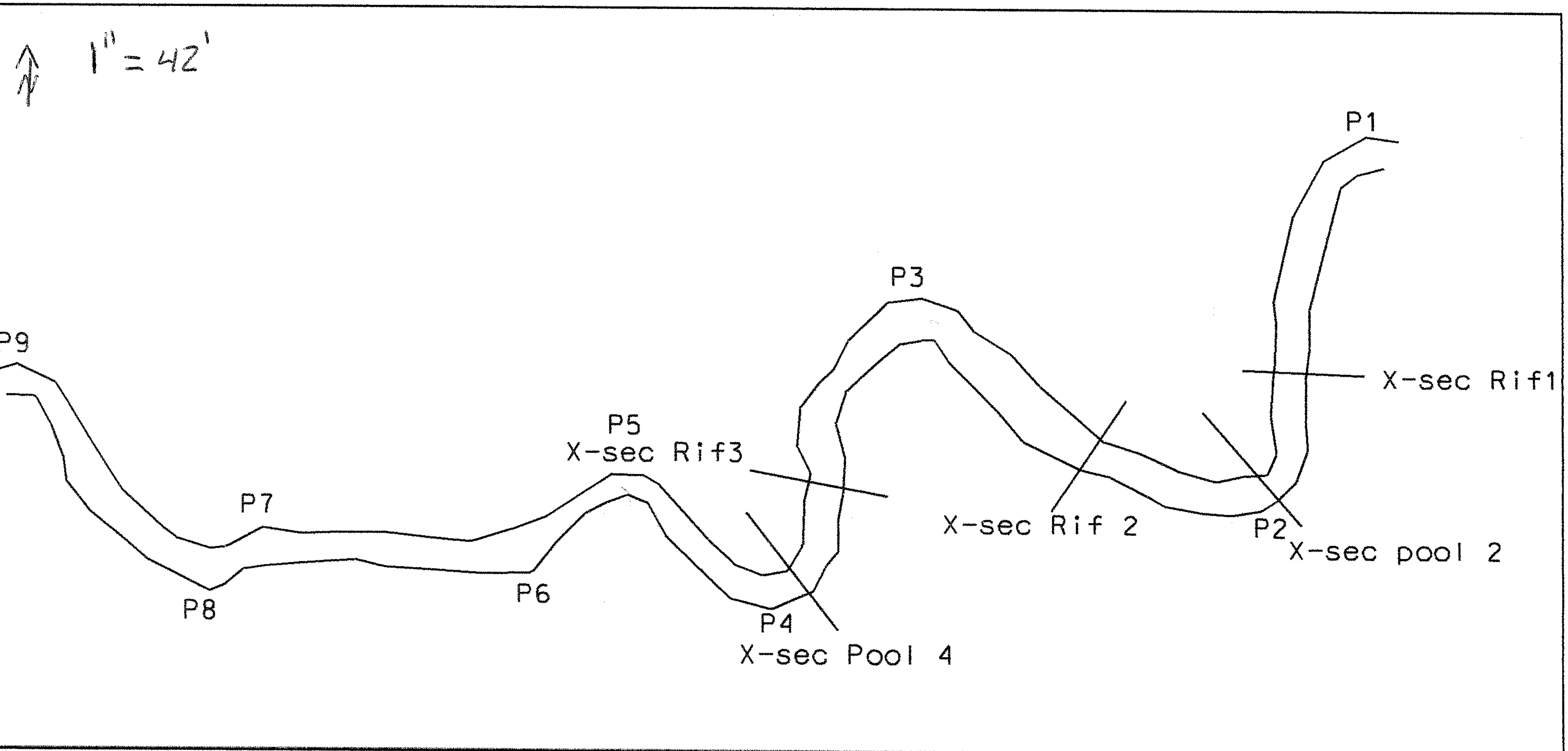
| notes | omit pt. | distance (ft) | FS (ft) | elevation |
|---|---|---|---|---|
| | ☑ | 2 | 5.2 | 108.31 |
| | ☑ | 7 | 5.4 | 108.11 |
| | ☑ | 12 | 5.53 | 107.98 |
| | ☑ | 18 | 6.17 | 107.34 |
| | ☑ | 23 | 6.61 | 106.9 |
| | ☐ | 27 | 6.94 | 106.57 |
| | ☐ | 30 | 7.3 | 106.21 |
| | ☐ | 31 | 7.52 | 105.99 |
| | ☐ | 32.8 | 7.69 | 105.82 |
| | ☐ | 34 | 8.14 | 105.37 |
| | ☐ | 35 | 8.45 | 105.06 |
| | ☐ | 35.5 | 8.81 | 104.7 |
| | ☐ | 36.5 | 9.02 | 104.49 |
| | ☐ | 37 | 9.36 | 104.15 |
| | ☐ | 39 | 9.44 | 104.07 |
| | ☐ | 40 | 9.42 | 104.09 |
| | ☐ | 41 | 9.42 | 104.09 |
| | ☐ | 42.4 | 9.4 | 104.11 |
| | ☐ | 42.8 | 9.27 | 104.24 |
| | ☐ | 43 | 7.79 | 105.72 |
| | ☐ | 44 | 6.16 | 107.35 |
| | ☑ | 45 | 5.74 | 107.77 |
| | ☑ | 47 | 5.31 | 108.2 |
| | ☐ | | | |

| FS bankfull | FS top of bank | W fpa (ft) | channel slope (%) | Manning's "n" |
|---|---|---|---|---|
| 7.25 | 6.16 | | | |
| 106.26 | 107.35 | | | |

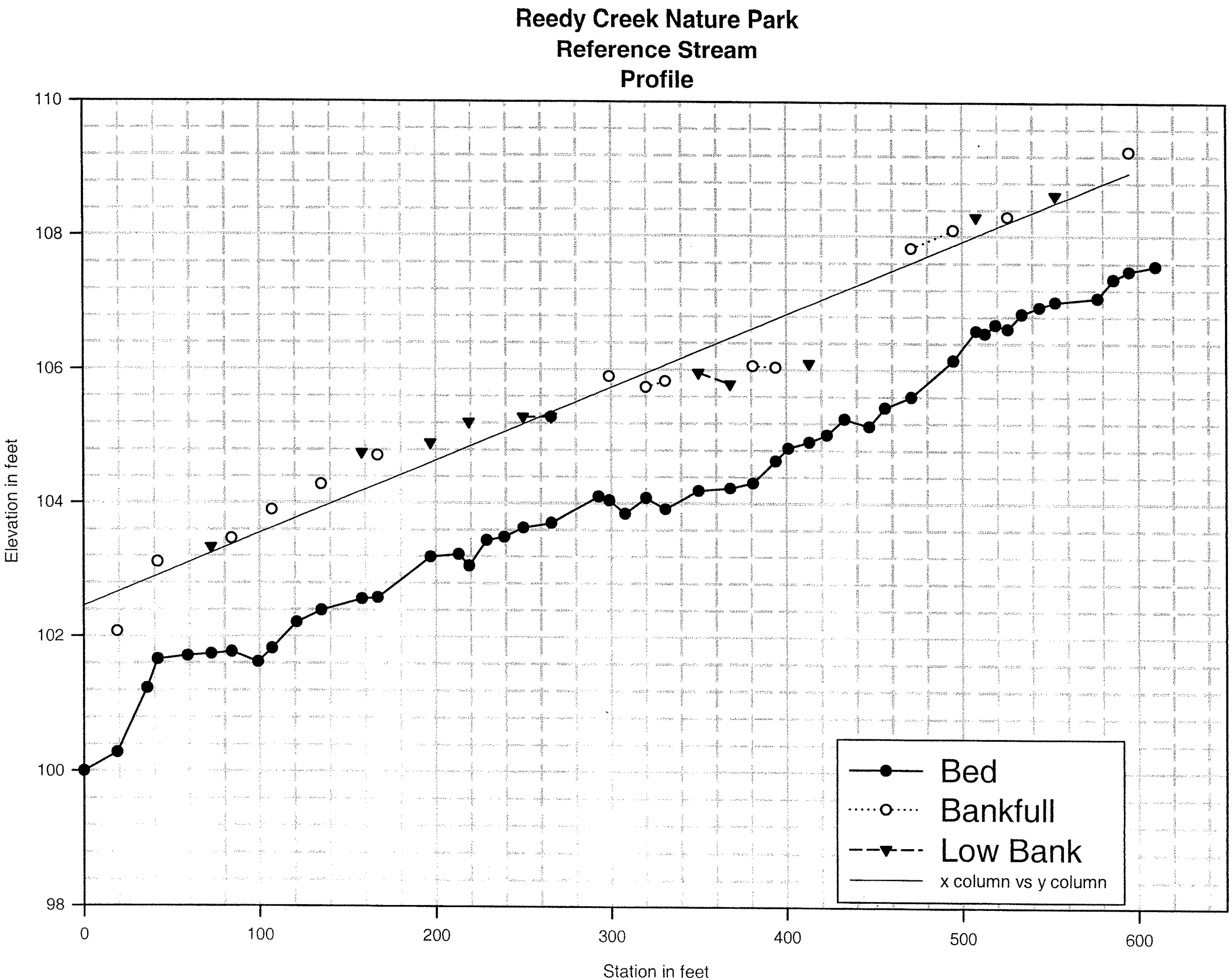
| dimensions | | | |
|---|---|---|---|
| 18.8 | x-section area | 1.4 | d mean |
| 13.7 | width | 15.8 | wet P |
| 2.2 | d max | 1.2 | hyd radi |
| 3.3 | bank ht | ~~10.0~~ | w/d ratio |
| ~~0.0~~ | W flood prone area | ~~0.0~~ | ent ratio |

| hydraulics | |
|---|---|
| ~~0.0~~ | velocity (ft/sec) |
| ~~0.0~~ | discharge rate, Q (cfs) |
| 0.00 | shear stress ((lbs/ft sq) |
| 0.00 | shear velocity (ft/sec) |
| ~~0.000~~ | unit stream power (lbs/ft/sec) |
| ~~0.00~~ | Froude number |
| ~~0.0~~ | friction factor u/u* |
| ~~0.0~~ | threshold grain size (mm) |

| check from channel material | | | |
|---|---|---|---|
| ~~12~~ | measured D84 (mm) | | |
| ~~33.7~~ | relative roughness | ~~11.5~~ | fric. factor |
| ~~0.000~~ | Manning's n from channel material | | |




\gps\reference\reedref.dgn Sep. 11, 2002 08:59:13



Reedy Creek Nature Park
Reference Stream
Profile
Elevation in feet
Station in feet
110
108
106
104
102
100
98
0
100
200
300
400
500
600
Bed
Bankfull
Low Bank
x column vs y column

## Weighted Pebble Count

| | | | |
|---|---|---|---|
| Percent Riffle: | 60 | Percent Run: | 0 |
| Percent Pool: | 40 | Percent Glide: | 0 |

Pebble Count,

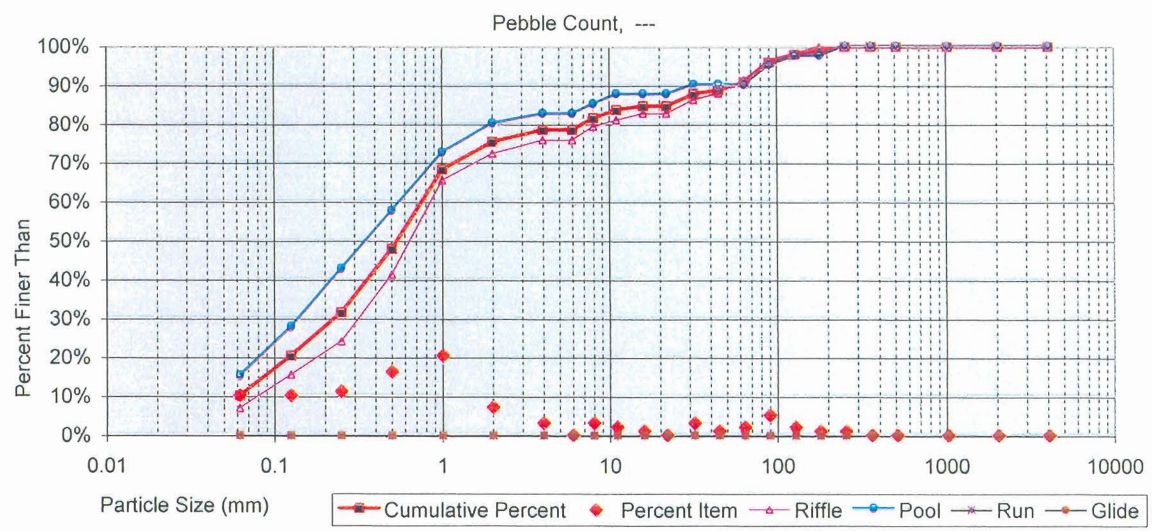
---

---

---

Note: **Reedy Creek Composite Pebble Count**

| Material | Size Range (mm) | | Total # | |
|---|---|---|---|---|
| silt/clay | 0 | 0.062 | 10.0 | # # |
| very fine sand | 0.062 | 0.13 | 10.0 | # # |
| fine sand | 0.13 | 0.25 | 11.0 | # # |
| medium sand | 0.25 | 0.5 | 16.0 | # # |
| coarse sand | 0.5 | 1 | 20.0 | # # |
| very coarse sand | 1 | 2 | 7.0 | # # |
| very fine gravel | 2 | 4 | 3.0 | # # |
| fine gravel | 4 | 6 | 0.0 | # # |
| fine gravel | 6 | 8 | 3.0 | # # |
| medium gravel | 8 | 11 | 2.0 | # # |
| medium gravel | 11 | 16 | 1.0 | # # |
| coarse gravel | 16 | 22 | 0.0 | # # |
| coarse gravel | 22 | 32 | 3.0 | # # |
| very coarse gravel | 32 | 45 | 1.0 | # # |
| very coarse gravel | 45 | 64 | 2.0 | # # |
| small cobble | 64 | 90 | 5.0 | # # |
| medium cobble | 90 | 128 | 2.0 | # # |
| large cobble | 128 | 180 | 1.0 | # # |
| very large cobble | 180 | 256 | 1.0 | # # |
| small boulder | 256 | 362 | 0.0 | # # |
| small boulder | 362 | 512 | 0.0 | # # |
| medium boulder | 512 | 1024 | 0.0 | # # |
| large boulder | 1024 | 2048 | 0.0 | # # |
| very large boulder | 2048 | 4096 | 0.0 | # # |
| bedrock | | | 2.0 | # |
| Weighted Count: | | | 100 | |
| True Total Particle Count: | | | 100 | |




| Size percent less than (mm) | | | | |
|---|---|---|---|---|
| D16 | D35 | D50 | D84 | D95 |
| 0.092 | 0.29 | 0.5 | 12 | 85 |

| Percent by substrate type | | | | | |
|---|---|---|---|---|---|
| silt/clay | sand | gravel | cobble | boulder | bedrock |
| 10% | 64% | 15% | 9% | 0% | 2% |

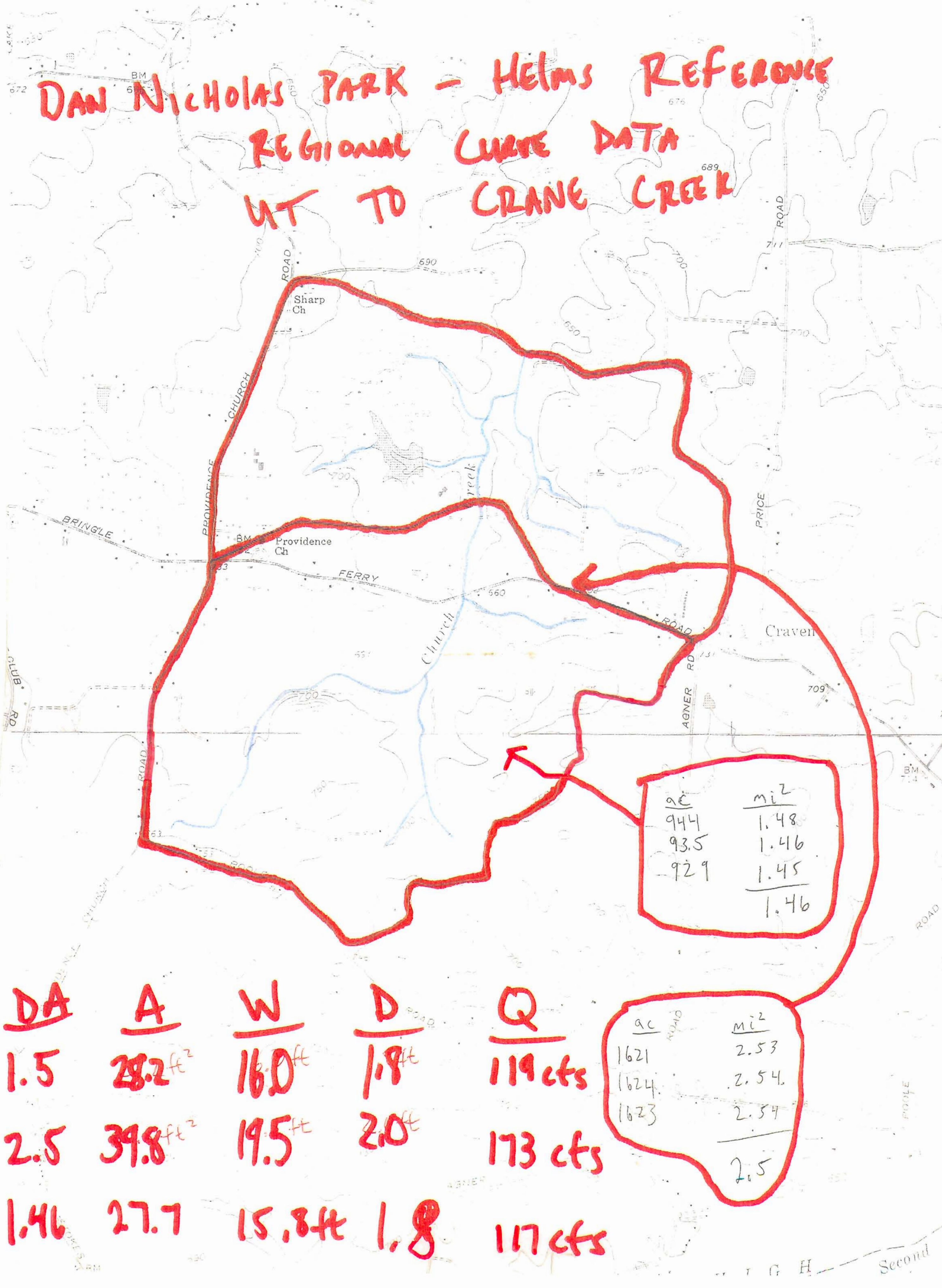

EcoScience Corporation
Raleigh, North Carolina

**UT to CRANE CREEK**
**Reference Site**
Rowan County, North Carolina

| | |
|---|---|
| Dwn. by: | MAF |
| Ckd by: | WGL |
| Date: | NOV 2002 |
| Project: | 00-046.26 |

APPENDIX D
Figure
2B

# DAN NICHOLAS PARK – HELMS REFERENCE REGIONAL CURVE DATA UT TO CRANE CREEK




| DA | A | W | D | Q |
|---|---|---|---|---|
| 1.5 | 28.2 ft² | 16.0 ft | 1.8 ft | 119 cfs |
| 2.5 | 39.8 ft² | 19.5 ft | 2.0 ft | 173 cfs |
| 1.46 | 27.7 | 15.8 ft | 1.8 | 117 cfs |

# HELMS: DAN NICHOLAS PARK (UT TO CRANE CR.)

## REFERENCE DIMENSION

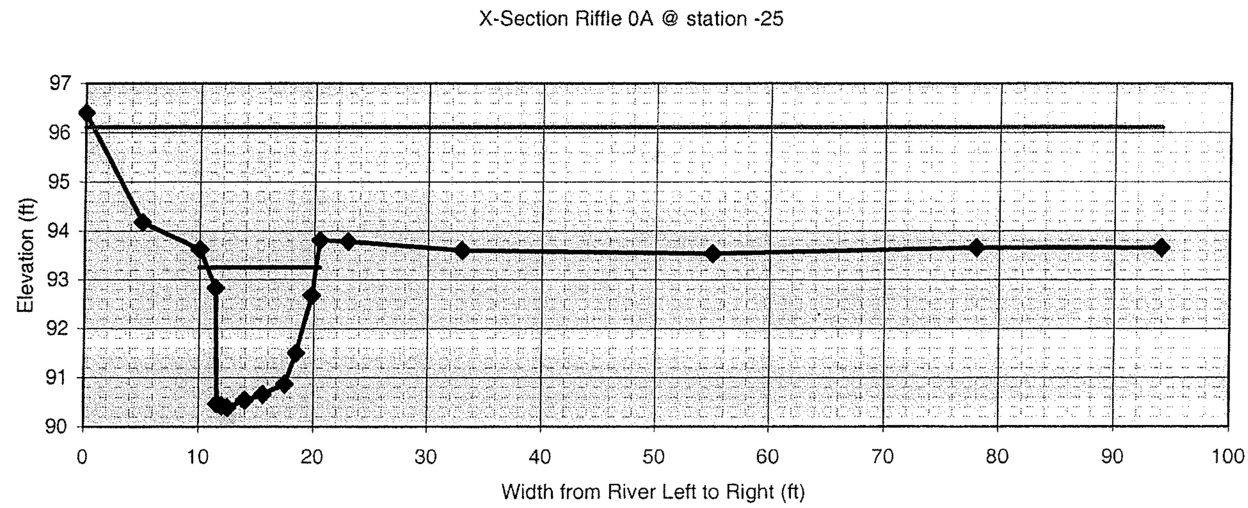
### Riffles

| X SECT # | A BKFL | W BKFL | DAVE | DMAX | W/D | FPA | ENT RATIO | Low Bank Height | Bank Height Ratio | DMAX/DAVE | STREAM TYPE |
|---|---|---|---|---|---|---|---|---|---|---|---|
| A | 19.8 | 9.5 | 2.1 | 2.9 | 4.5 | 237 | 25.0 | 3.2 | 1.1 | 1.4 | E |
| B | 25.0 | 11.9 | 2.1 | 2.6 | 5.7 | 237 | 20.0 | 3.1 | 1.2 | 1.2 | E |
| C | 20.5 | 10.1 | 2.0 | 2.5 | 5.1 | 232 | 23.0 | 2.9 | 1.2 | 1.3 | E |
| D | 19.3 | 10.0 | 1.9 | 2.5 | 5.3 | 345 | 34.5 | 3.1 | 1.2 | 1.3 | E |
| ve | 21.2 | 10.4 | 2.0 | 2.6 | 5.2 | 263 | 25.6 | 3.1 | 1.2 | 1.3 | |
| an | 20.5 | 10.1 | 2.0 | 2.6 | 5.1 | 237 | 25.0 | 3.1 | 1.2 | 1.3 | E |
| e | 19.3-25.0 | 9.5-11.9 | 1.9-2.1 | 2.5-2.9 | 4.5-5.7 | 232-345 | 20.0-34.5 | 2.9-3.2 | 1.1-1.2 | 1.2-1.4 | |

### Pools

| X-SECT # | A BKFL | W BKFL | DAVE | DMAX | LBH | BHR | DMAX/DAVE | LPOOL |
|---|---|---|---|---|---|---|---|---|
| [illegible] | 20.6 | 11.7 | 1.8 | 2.8 | 3.3 | 1.2 | 1.6 | |
| 3 | 19.5 | 10.5 | 1.9 | 3.0 | 4.0 | 1.3 | 1.6 | |
| IVE | 20.1 | 11.1 | 1.9 | 2.9 | 3.7 | 1.3 | 1.6 | |
| IAN | 19.5 | 11.7 | 1.9 | 3.0 | 4.0 | 1.7 | 1.6 | |

## Cross Section




section: **X-Section Riffle 0A**

Riffle
---
---

description:

height of instrument (ft): 99.76

| notes | omit pt. | distance (ft) | FS (ft) | elevation |
|---|---|---|---|---|
| FP extends | ☑ | 0 | 3.36 | 96.4 |
| | ☑ | 5 | 5.58 | 94.18 |
| TOB | ☐ | 10 | 6.14 | 93.62 |
| | ☐ | 11.4 | 6.93 | 92.83 |
| | ☐ | 11.6 | 9.29 | 90.47 |
| | ☐ | 12 | 9.33 | 90.43 |
| thalweg | ☐ | 12.5 | 9.37 | 90.39 |
| | ☐ | 14 | 9.22 | 90.54 |
| water eleva | ☐ | 15.6 | 9.1 | 90.66 |
| | ☐ | 17.5 | 8.89 | 90.87 |
| | ☐ | 18.5 | 8.26 | 91.5 |
| | ☐ | 19.8 | 7.08 | 92.68 |
| TOB | ☐ | 20.5 | 5.95 | 93.81 |
| | ☑ | 23 | 5.98 | 93.78 |
| | ☑ | 33 | 6.16 | 93.6 |
| | ☑ | 55 | 6.23 | 93.53 |
| | ☑ | 78 | 6.1 | 93.66 |
| | ☑ | 94 | 6.1 | 93.66 |
| up steepish | ☐ | | | |
| | ☐ | | | |
| stk: 3.95 | ☐ | | | |
| | ☐ | | | |
| | ☐ | | | |
| | ☐ | | | |
| | ☐ | | | |
| | ☐ | | | |
| | ☐ | | | |

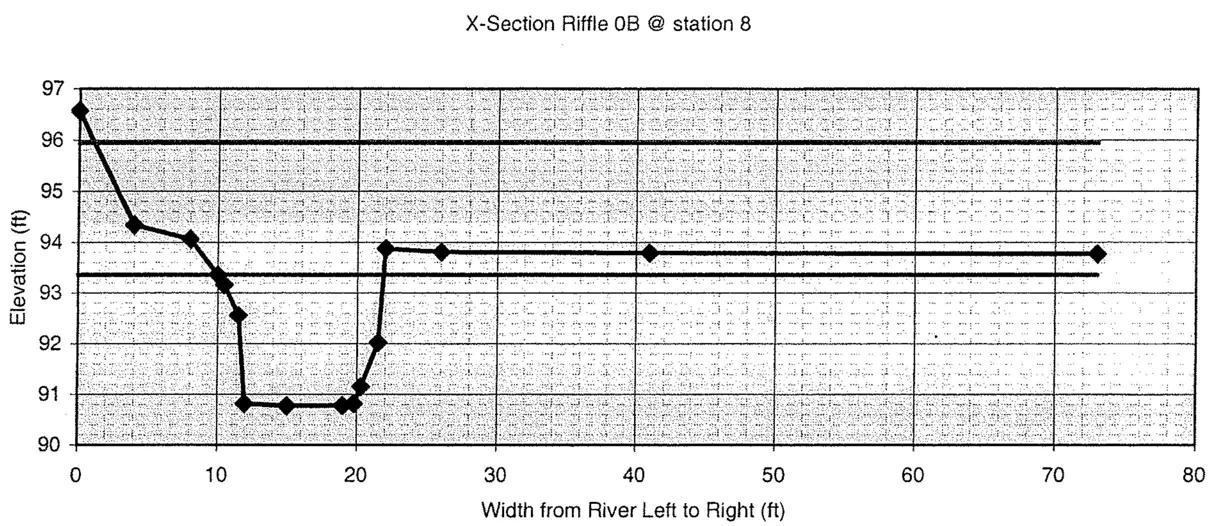
| FS bankfull | FS top of bank | W fpa (ft) | channel slope (%) | Manning's "n" |
|---|---|---|---|---|
| 6.51 | 6.14 | 16.0 | | |
| 93.25 | 93.62 | | | |

| dimensions | | | |
|---|---|---|---|
| 19.8 | x-section area | 2.1 | d mean |
| 9.5 | width | 12.8 | wet P |
| 2.9 | d max | 1.6 | hyd radi |
| 3.2 | bank ht | 4.5 | w/d ratio |
| ~~16.0~~ 237 | W flood prone area | ~~1.7~~ 25 | ent ratio |

| hydraulics | |
|---|---|
| 0.0 | velocity (ft/sec) |
| 0.0 | discharge rate, Q (cfs) |
| 0.00 | shear stress ((lbs/ft sq) |
| 0.00 | shear velocity (ft/sec) |
| 0.000 | unit stream power (lbs/ft/sec) |
| 0.00 | Froude number |
| 0.0 | friction factor u/u* |
| ~~0.0~~ | threshold grain size (mm) |

| check from channel material | | | |
|---|---|---|---|
| 0 | measured D84 (mm) | | |
| 0.0 | relative roughness | 0.0 | fric. factor |
| 0.000 | Manning's n from channel material | | |

## Cross Section




section: **X-Section Riffle 0B**

Riffle
---
---

description:

height of instrument (ft): **99.77**

| notes | omit pt. | distance (ft) | FS (ft) | elevation |
|---|---|---|---|---|
| up steep | # ☐ # | 0 | 3.2 | 96.57 |
| | # ☐ # | 4 | 5.43 | 94.34 |
| | # ☐ # | 8 | 5.71 | 94.06 |
| bankfull | # ☐ # | 10 | 6.41 | 93.36 |
| | # ☐ # | 10.5 | 6.61 | 93.16 |
| | # ☐ # | 11.5 | 7.21 | 92.56 |
| | # ☐ # | 12 | 8.95 | 90.82 |
| | # ☐ # | 15 | 9 | 90.77 |
| water dept | # ☐ # | 19 | 8.99 | 90.78 |
| water edge | # ☐ # | 19.8 | 8.95 | 90.82 |
| | # ☐ # | 20.3 | 8.62 | 91.15 |
| | # ☐ # | 21.5 | 7.75 | 92.02 |
| TOB | # ☐ # | 22 | 5.9 | 93.87 |
| | # ☐ # | 26 | 5.96 | 93.81 |
| | # ☐ # | 41 | 5.98 | 93.79 |
| | # ☐ # | 73 | 6 | 93.77 |
| | # ☐ # | | | |
| stk: 3.94 | # ☐ # | | | |
| | # ☐ # | | | |
| | # ☐ # | | | |
| | # ☐ # | | | |
| | # ☐ # | | | |
| | # ☐ # | | | |
| | # ☐ # | | | |
| | # ☐ # | | | |
| | # ☐ # | | | |
| | # ☐ # | | | |

| FS bankfull | FS top of bank | W fpa (ft) | channel slope (%) | Manning's "n" |
|---|---|---|---|---|
| 6.41 | 5.9 | | | |
| 93.36 | 93.87 | | | |

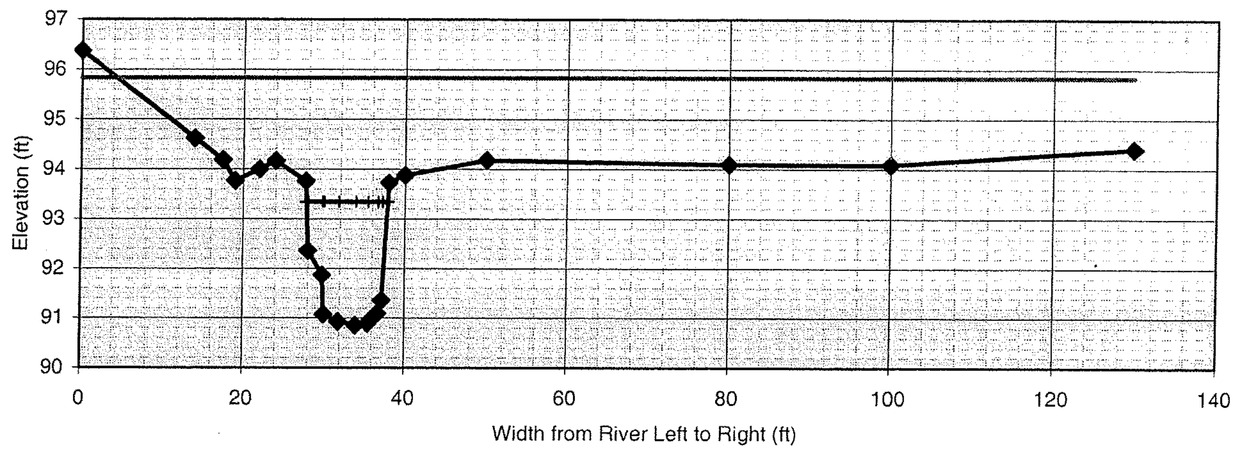
| dimensions | | | |
|---|---|---|---|
| 25.0 | x-section area | 2.1 | d mean |
| 11.9 | width | 14.8 | wet P |
| 2.6 | d max | 1.7 | hyd radi |
| 3.1 | bank ht | 5.6 | w/d ratio |
| ~~0.0~~ 237 | W flood prone area | ~~0.0~~ 20.0 | ent ratio |

| hydraulics | |
|---|---|
| 0.0 | velocity (ft/sec) |
| 0.0 | discharge rate, Q (cfs) |
| 0.00 | shear stress ((lbs/ft sq) |
| 0.00 | shear velocity (ft/sec) |
| 0.000 | unit stream power (lbs/ft/sec) |
| 0.00 | Froude number |
| 0.0 | friction factor u/u* |
| ~~0.0~~ | threshold grain size (mm) |

| check from channel material | | | |
|---|---|---|---|
| 0 | measured D84 (mm) | | |
| 0.0 | relative roughness | 0.0 | fric. factor |
| 0.000 | Manning's n from channel material | | |

## Cross Section

X-Section Riffle 3 @ station 219




| | |
|---|---|
| section: | X-Section Riffle 3 |
| | Riffle<br>---<br>--- |
| description: | [illegible] |
| height of instrument (ft): | 100.14 |

| notes | omit pt. | distance (ft) | FS (ft) | elevation |
|---|---|---|---|---|
| up steep | # ✓ # | 0 | 3.77 | 96.37 |
| | # ✓ # | 14 | 5.52 | 94.62 |
| | # ✓ # | 17.5 | 5.95 | 94.19 |
| | # ✓ # | 19 | 6.37 | 93.77 |
| | # ✓ # | 22 | 6.14 | 94 |
| | # ✓ # | 24 | 5.97 | 94.17 |
| TOB | # # | 27.7 | 6.38 | 93.76 |
| MB | # # | 28 | 7.78 | 92.36 |
| MB | # # | 29.8 | 8.27 | 91.87 |
| | # # | 30 | 9.07 | 91.07 |
| EOW | # # | 31.8 | 9.21 | 90.93 |
| thawleg | # # | 34 | 9.29 | 90.85 |
| | # # | 35.5 | 9.25 | 90.89 |
| | # # | 36.7 | 9.05 | 91.09 |
| MB | # # | 37.2 | 8.78 | 91.36 |
| TOB | # # | 38 | 6.42 | 93.72 |
| | # ✓ # | 40 | 6.26 | 93.88 |
| | # ✓ # | 50 | 5.96 | 94.18 |
| | # ✓ # | 80 | 6.04 | 94.1 |
| | # ✓ # | 100 | 6.05 | 94.09 |
| | # ✓ # | 130 | 5.73 | 94.41 |
| FP extends | # # | | | |
| | # # | | | |
| stk: 4.30 | # # | | | |
| | # # | | | |
| | # # | | | |
| | # # | | | |

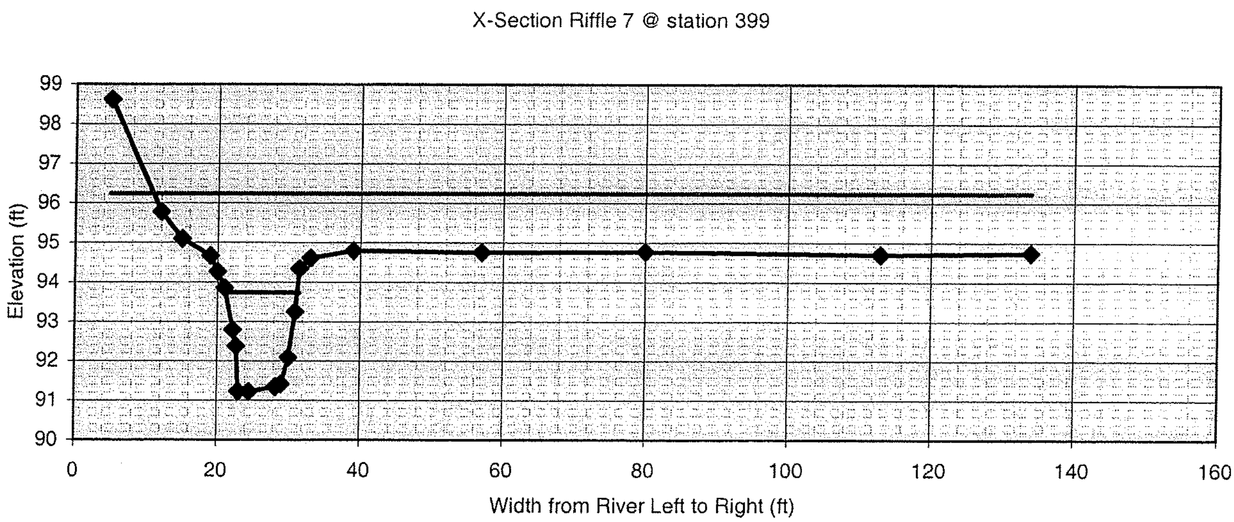
| FS bankfull | FS top of bank | W fpa (ft) | channel slope (%) | Manning's "n" |
|---|---|---|---|---|
| 6.8 | 6.42 | 150.0 | | 0.034 |
| 93.34 | 93.72 | | | |

| dimensions | | | |
|---|---|---|---|
| 20.5 | x-section area | 2.0 | d mean |
| 10.1 | width | 13.1 | wet P |
| 2.5 | d max | 1.6 | hyd radi |
| 2.9 | bank ht | 5.0 | w/d ratio |
| ~~150.0~~ 232.0 | W flood prone area | ~~14.9~~ 23.0 | ent ratio |

| hydraulics | |
|---|---|
| 0.0 | velocity (ft/sec) |
| 0.0 | discharge rate, Q (cfs) |
| 0.00 | shear stress ((lbs/ft sq) |
| 0.00 | shear velocity (ft/sec) |
| 0.000 | unit stream power (lbs/ft/sec) |
| 0.00 | Froude number |
| 0.0 | friction factor u/u* |
| ~~0.0~~ | threshold grain size (mm) |

| check from channel material | | | |
|---|---|---|---|
| 0 | measured D84 (mm) | | |
| 0.0 | relative roughness | 0.0 | fric. factor |
| 0.000 | Manning's n from channel material | | |

## Cross Section




| | |
|---|---|
| section: | X-Section Riffle 7 |
| | Riffle |
| | --- |
| | --- |
| description: | |
| height of instrument (ft): | 100.76 |

| notes | omit pt. | distance (ft) | FS (ft) | elevation |
|---|---|---|---|---|
| up steep | ✓ | 5 | 2.14 | 98.62 |
| | ✓ | 12 | 4.98 | 95.78 |
| | ✓ | 15 | 5.66 | 95.1 |
| | ✓ | 19 | 6.09 | 94.67 |
| | ✓ | 20 | 6.49 | 94.27 |
| | | 21 | 6.91 | 93.85 |
| | | 22.2 | 7.97 | 92.79 |
| | | 22.7 | 8.38 | 92.38 |
| EOW; depl | | 23 | 9.53 | 91.23 |
| | | 24.5 | 9.54 | 91.22 |
| EOW | | 28.2 | 9.42 | 91.34 |
| | | 29 | 9.34 | 91.42 |
| MB | | 30 | 8.67 | 92.09 |
| MB | | 30.9 | 7.51 | 93.25 |
| TOB | | 31.5 | 6.42 | 94.34 |
| | ✓ | 33 | 6.15 | 94.61 |
| | ✓ | 39 | 5.96 | 94.8 |
| | ✓ | 57 | 6 | 94.76 |
| | ✓ | 80 | 5.99 | 94.77 |
| | ✓ | 113 | 6.06 | 94.7 |
| | ✓ | 134 | 6.02 | 94.74 |
| | | | | |
| stk: 3.99 | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |

| FS bankfull | FS top of bank | W fpa (ft) | channel slope (%) | Manning's "n" |
|---|---|---|---|---|
| 7.03 | 6.42 | 18.5 | | |
| 93.73 | 94.34 | | | |

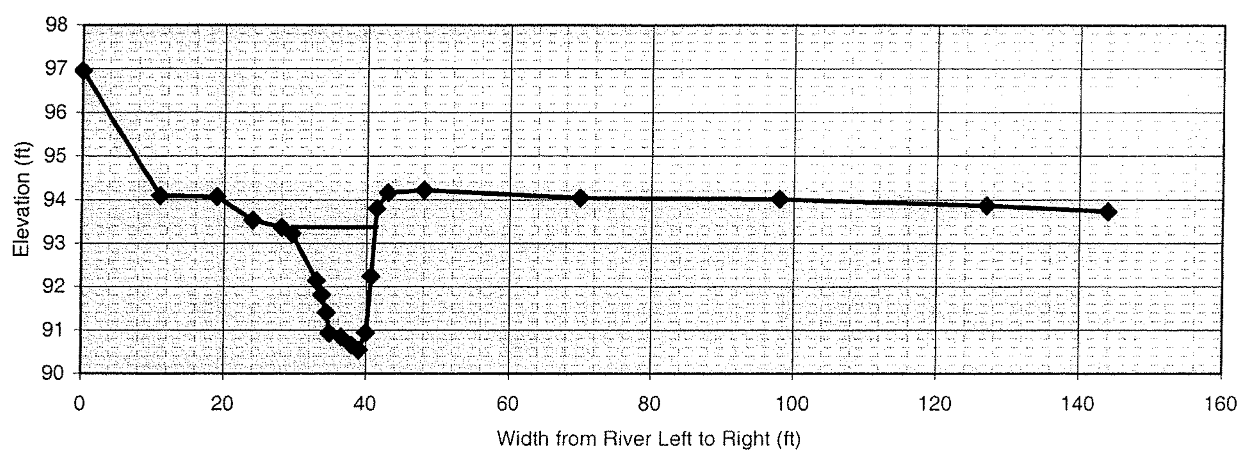
| dimensions | | | |
|---|---|---|---|
| 19.3 | x-section area | 1.9 | d mean |
| 10.0 | width | 12.5 | wet P |
| 2.5 | d max | 1.5 | hyd radi |
| 3.1 | bank ht | 5.2 | w/d ratio |
| ~~18.5~~ 345.0 | W flood prone area | ~~1.8~~ | ent ratio |

| hydraulics | |
|---|---|
| 0.0 | velocity (ft/sec) |
| 0.0 | discharge rate, Q (cfs) |
| 0.00 | shear stress ((lbs/ft sq) |
| 0.00 | shear velocity (ft/sec) |
| 0.000 | unit stream power (lbs/ft/sec) |
| 0.00 | Froude number |
| 0.0 | friction factor u/u* |
| ~~0.0~~ | threshold grain size (mm) |

| check from channel material | | | |
|---|---|---|---|
| 0 | measured D84 (mm) | | |
| 0.0 | relative roughness | 0.0 | fric. factor |
| 0.000 | Manning's n from channel material | | |

## Cross Section

X-Section Pool 3 @ station 162.5




| | |
|---|---|
| section: | Pool<br>---<br>--- |
| description: | |
| height of instrument (ft): | 100.17 |

| notes | omit pt. | distance (ft) | FS (ft) | elevation |
|---|---|---|---|---|
| up steep | ☑ | 0 | 3.22 | 96.95 |
| | ☑ | 11 | 6.08 | 94.09 |
| | ☑ | 19 | 6.1 | 94.07 |
| | ☑ | 24 | 6.64 | 93.53 |
| | ☑ | 28 | 6.8 | 93.37 |
| | ☐ | 29.5 | 6.95 | 93.22 |
| | ☐ | 33 | 8.03 | 92.14 |
| | ☐ | 33.7 | 8.35 | 91.82 |
| | ☐ | 34.4 | 8.77 | 91.4 |
| EOW | ☐ | 34.8 | 9.24 | 90.93 |
| | ☐ | 36.5 | 9.33 | 90.84 |
| | ☐ | 38 | 9.51 | 90.66 |
| thalweg | ☐ | 39 | 9.63 | 90.54 |
| EOW | ☐ | 40 | 9.23 | 90.94 |
| | ☐ | 40.7 | 7.93 | 92.24 |
| TOB | ☐ | 41.4 | 6.37 | 93.8 |
| | ☑ | 43 | 6.01 | 94.16 |
| | ☑ | 48 | 5.95 | 94.22 |
| | ☑ | 70 | 6.13 | 94.04 |
| | ☑ | 98 | 6.16 | 94.01 |
| | ☑ | 127 | 6.31 | 93.86 |
| | ☑ | 144 | 6.44 | 93.73 |
| | ☐ | | | |
| stk: 5.99 | ☐ | | | |

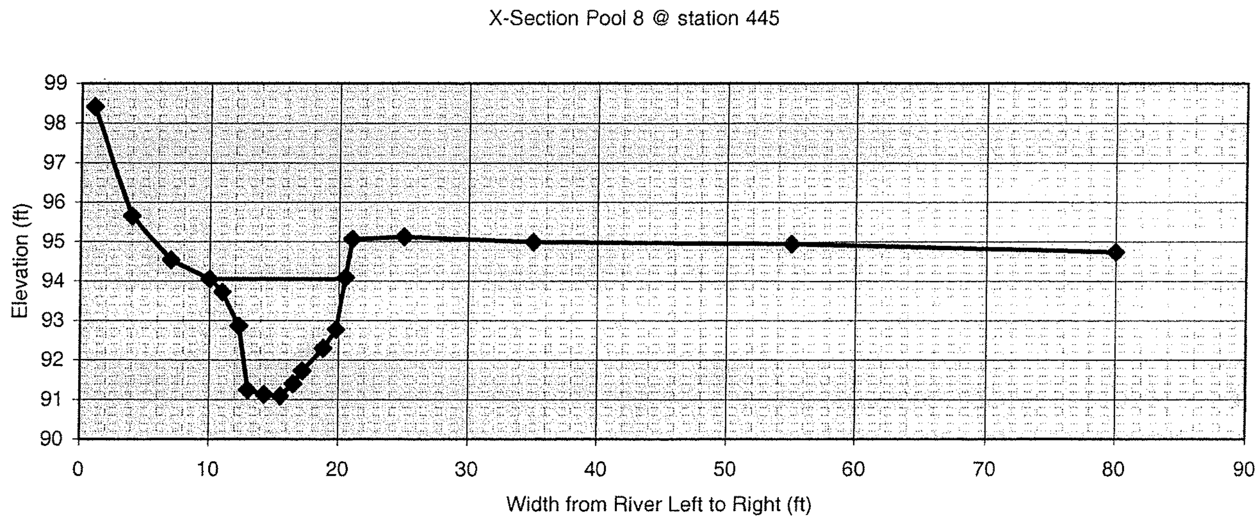
| FS bankfull | FS top of bank | W fpa (ft) | channel slope (%) | Manning's "n" |
|---|---|---|---|---|
| 6.8 | 6.37 | | | |
| 93.37 | 93.8 | | | |

| dimensions | | | |
|---|---|---|---|
| 20.6 | x-section area | 1.8 | d mean |
| 11.7 | width | 13.9 | wet P |
| 2.8 | d max | 1.5 | hyd radi |
| 3.3 | bank ht | ~~6.7~~ | w/d ratio |
| ~~0.0~~ | W flood prone area | ~~0.0~~ | ent ratio |

| hydraulics | |
|---|---|
| ~~0.0~~ | velocity (ft/sec) |
| ~~0.0~~ | discharge rate, Q (cfs) |
| 0.00 | shear stress ((lbs/ft sq) |
| 0.00 | shear velocity (ft/sec) |
| ~~0.000~~ | unit stream power (lbs/ft/sec) |
| ~~0.00~~ | Froude number |
| ~~0.0~~ | friction factor u/u* |
| ~~0.0~~ | threshold grain size (mm) |

| check from channel material | | | |
|---|---|---|---|
| ~~12~~ | measured D84 (mm) | | |
| ~~46.2~~ | relative roughness | ~~12.3~~ | fric. factor |
| ~~0.000~~ | Manning's n from channel material | | |

## Cross Section




| | |
|---|---|
| section: | Pool |
| | --- |
| | --- |
| description: | |
| height of instrument (ft): | 101.02 |

| notes | omit pt. | distance (ft) | FS (ft) | elevation |
|---|---|---|---|---|
| up steep | ☑ | 1 | 2.61 | 98.41 |
| | ☑ | 4 | 5.37 | 95.65 |
| | ☑ | 7 | 6.48 | 94.54 |
| | ☐ | 10 | 6.97 | 94.05 |
| | ☐ | 11 | 7.3 | 93.72 |
| | ☐ | 12.3 | 8.16 | 92.86 |
| EOW: depl | ☐ | 13 | 9.77 | 91.25 |
| | ☐ | 14.3 | 9.89 | 91.13 |
| | ☐ | 15.5 | 9.93 | 91.09 |
| EOW | ☐ | 16.5 | 9.62 | 91.4 |
| | ☐ | 17.2 | 9.29 | 91.73 |
| | ☐ | 18.8 | 8.72 | 92.3 |
| MB | ☐ | 19.8 | 8.25 | 92.77 |
| MB | ☐ | 20.5 | 6.93 | 94.09 |
| TOB | ☑ | 21 | 5.95 | 95.07 |
| | ☑ | 25 | 5.9 | 95.12 |
| | ☑ | 35 | 6.03 | 94.99 |
| | ☑ | 55 | 6.08 | 94.94 |
| | ☑ | 80 | 6.28 | 94.74 |
| | ☐ | | | |
| stk: 3.78 | ☐ | | | |

| FS bankfull | FS top of bank | W fpa (ft) | channel slope (%) | Manning's "n" |
|---|---|---|---|---|
| 6.97 | 5.95 | | | |
| 94.05 | 95.07 | | | |

### dimensions

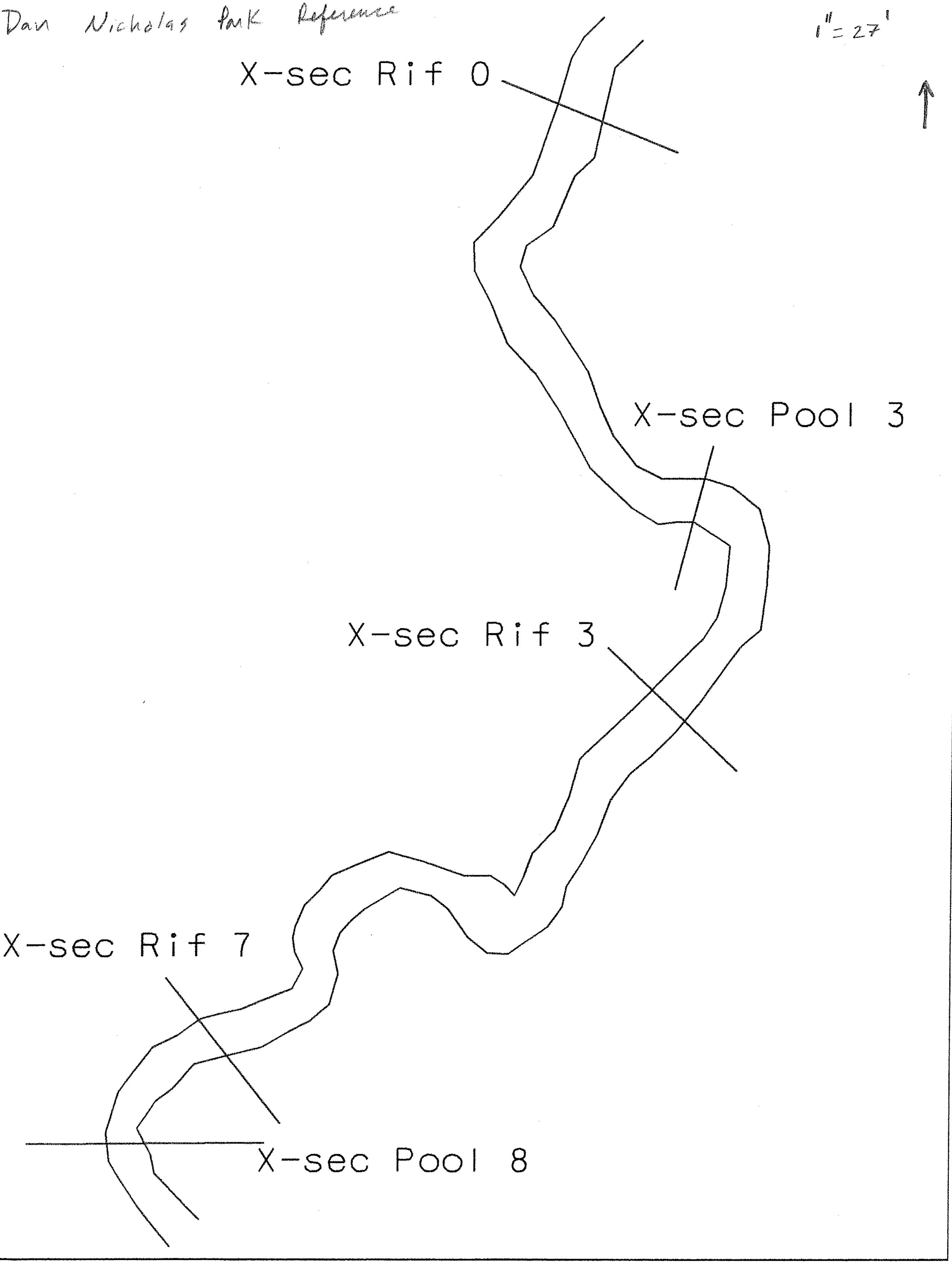
| | | | |
|---|---|---|---|
| 19.5 | x-section area | 1.9 | d mean |
| 10.5 | width | 12.9 | wet P |
| 3.0 | d max | 1.5 | hyd radi |
| 4.0 | bank ht | ~~5.6~~ | w/d ratio |
| ~~0.0~~ | W flood prone area | ~~0.0~~ | ent ratio |

### hydraulics

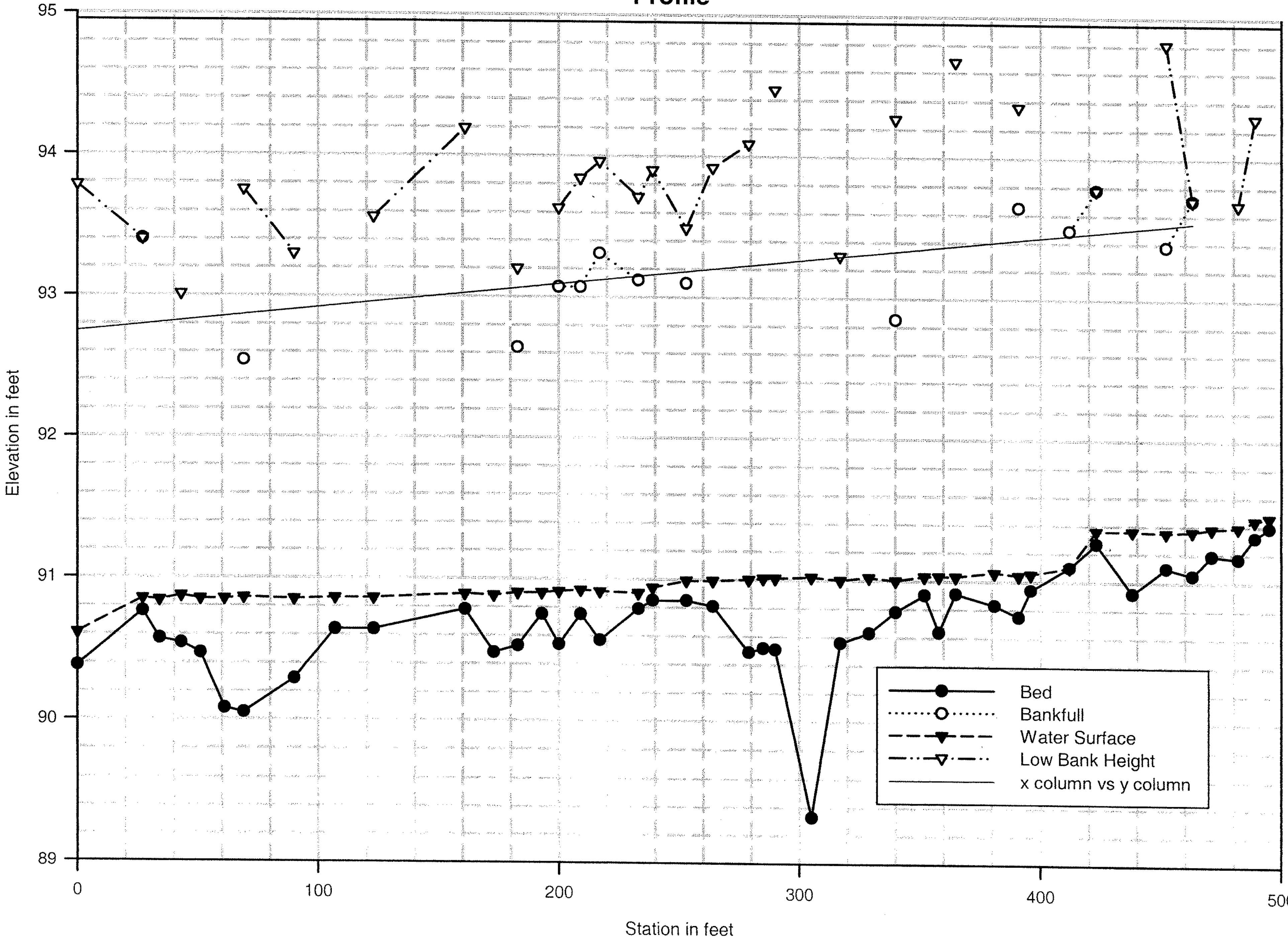
| | |
|---|---|
| ~~0.0~~ | velocity (ft/sec) |
| ~~0.0~~ | discharge rate, Q (cfs) |
| 0.00 | shear stress ((lbs/ft sq) |
| 0.00 | shear velocity (ft/sec) |
| ~~0.000~~ | unit stream power (lbs/ft/sec) |
| ~~0.00~~ | Froude number |
| ~~0.0~~ | friction factor u/u* |
| ~~0.0~~ | threshold grain size (mm) |

### check from channel material

Dan Nicholas Park Reference



Dan Nicholas Park
Reference Stream
Profile



## Weighted Pebble Count

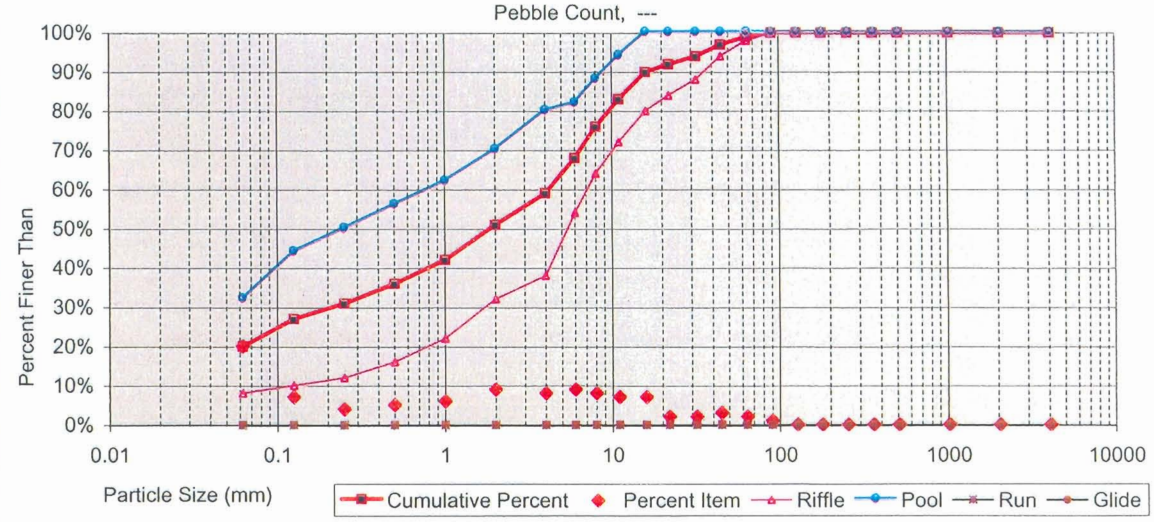
| | | | |
|---|---|---|---|
| Percent Riffle: | 50 | Percent Run: | 0 |
| Percent Pool: | 50 | Percent Glide: | 0 |

Pebble Count,

---
---
---

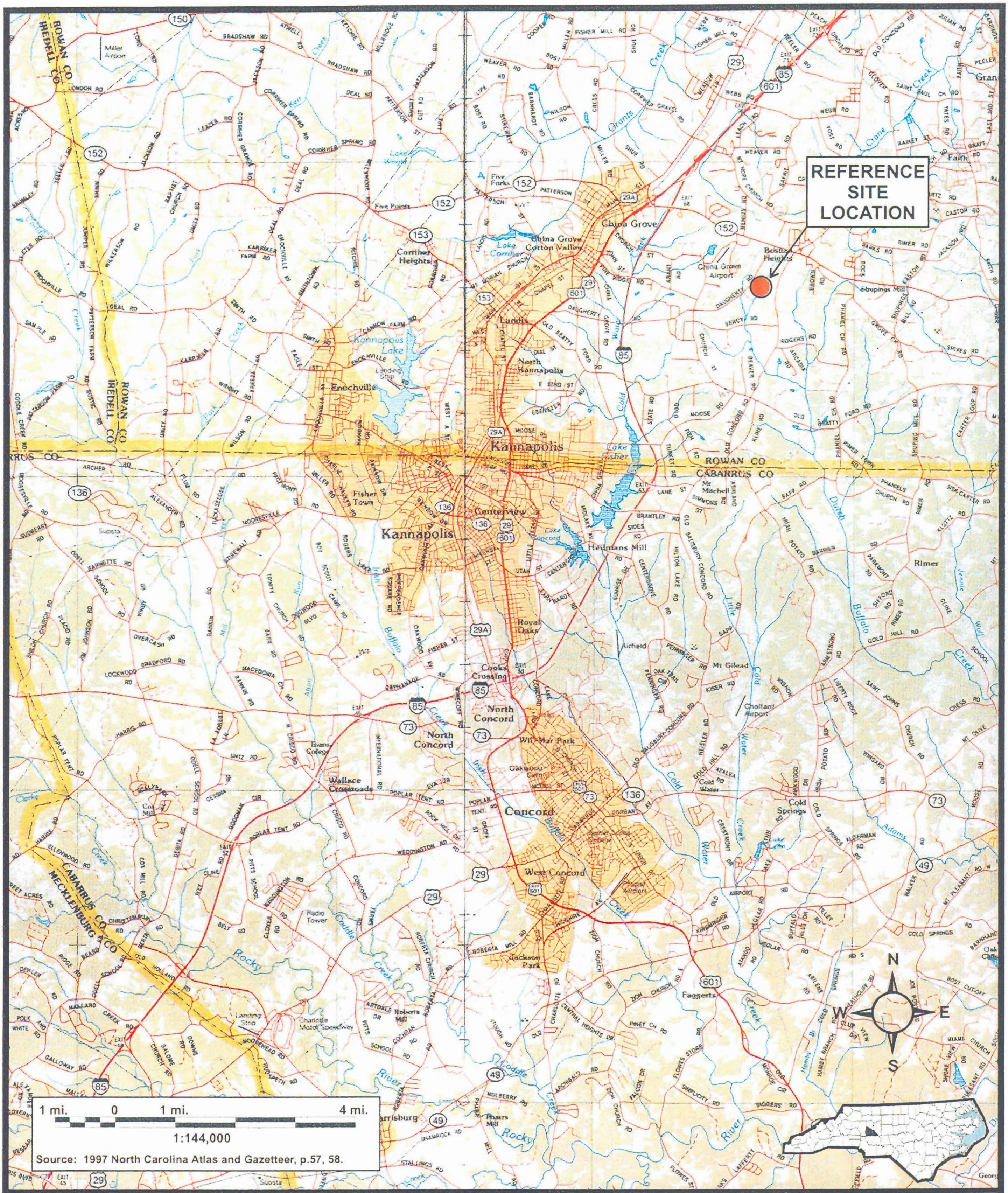
Note: **Dan Nicholas Weighted**

| Material | Size Range (mm) | | Total # | |
|---|---|---|---|---|
| silt/clay | 0 | 0.062 | 20.0 | # # |
| very fine sand | 0.062 | 0.13 | 7.0 | # # |
| fine sand | 0.13 | 0.25 | 4.0 | # # |
| medium sand | 0.25 | 0.5 | 5.0 | # # |
| coarse sand | 0.5 | 1 | 6.0 | # # |
| very coarse sand | 1 | 2 | 9.0 | # # |
| very fine gravel | 2 | 4 | 8.0 | # # |
| fine gravel | 4 | 6 | 9.0 | # # |
| fine gravel | 6 | 8 | 8.0 | # # |
| medium gravel | 8 | 11 | 7.0 | # # |
| medium gravel | 11 | 16 | 7.0 | # # |
| coarse gravel | 16 | 22 | 2.0 | # # |
| coarse gravel | 22 | 32 | 2.0 | # # |
| very coarse gravel | 32 | 45 | 3.0 | # # |
| very coarse gravel | 45 | 64 | 2.0 | # # |
| small cobble | 64 | 90 | 1.0 | # # |
| medium cobble | 90 | 128 | 0.0 | # # |
| large cobble | 128 | 180 | 0.0 | # # |
| very large cobble | 180 | 256 | 0.0 | # # |
| small boulder | 256 | 362 | 0.0 | # # |
| small boulder | 362 | 512 | 0.0 | # # |
| medium boulder | 512 | 1024 | 0.0 | # # |
| large boulder | 1024 | 2048 | 0.0 | # # |
| very large boulder | 2048 | 4096 | 0.0 | # # |
| bedrock | | | 0.0 | # |
| Weighted Count: | | | 100 | |
| True Total Particle Count: | | | 100 | |




| Size percent less than (mm) | | | | |
|---|---|---|---|---|
| D16 | D35 | D50 | D84 | D95 |
| #N/A | 0.44 | 1.9 | 12 | 36 |

| Percent by substrate type | | | | | |
|---|---|---|---|---|---|
| silt/clay | sand | gravel | cobble | boulder | bedrock |
| 20% | 31% | 48% | 1% | 0% | 0% |

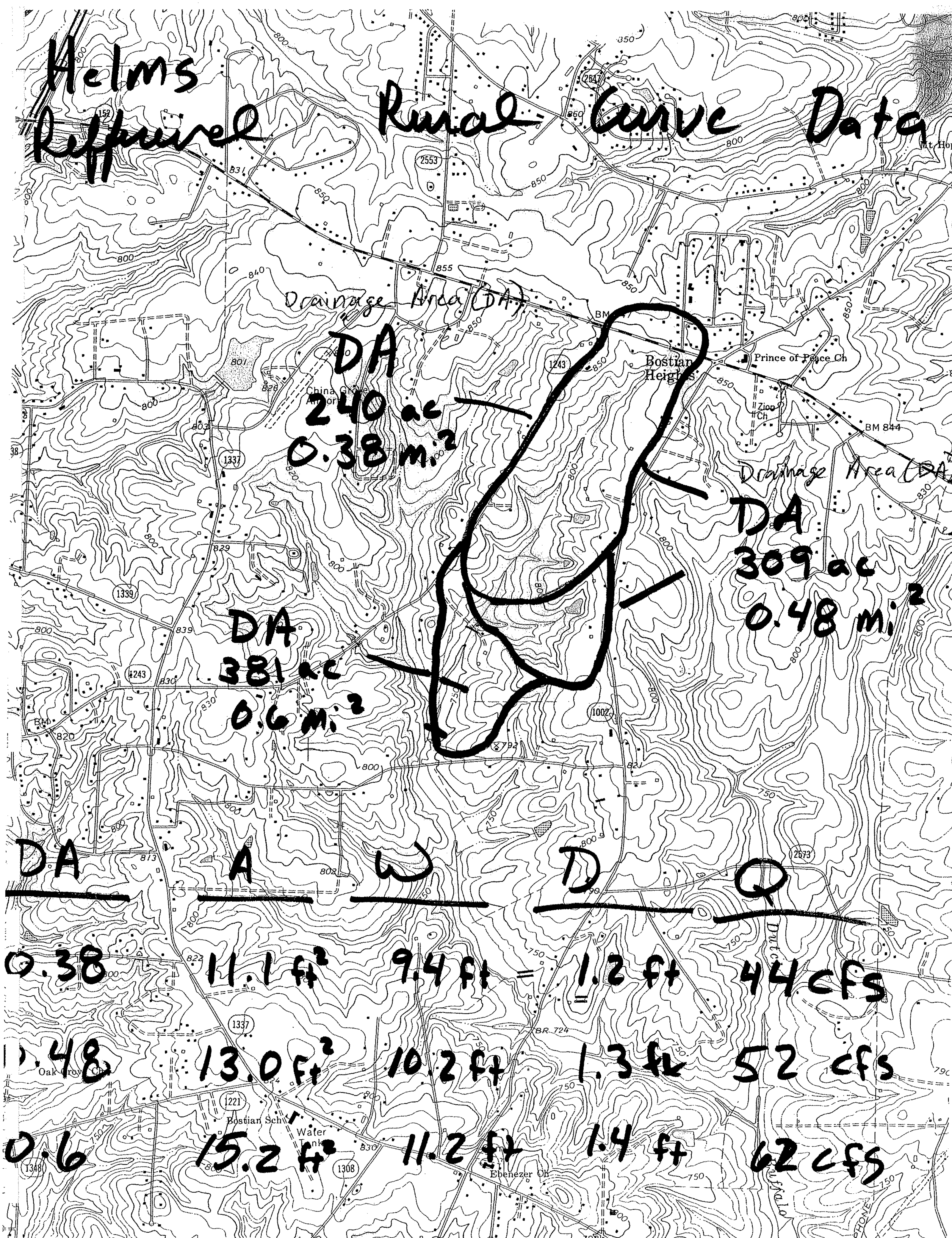



EcoScience Corporation
Raleigh, North Carolina

## UT to DUTCH BUFFALO CREEK
### Reference Site
Rowan County, North Carolina

| | | |
|---|---|---|
| Dwn. by: | MAF | APPENDIX D |
| Ckd by: | WGL | |
| Date: | NOV 2002 | Figure |
| Project: | 00-046.26 | 2C |

Helms Reffuivel Rural Curve Data




| DA | A | W | D | Q |
|---|---|---|---|---|
| 0.38 | 11.1 ft$^2$ | 9.4 ft | 1.2 ft | 44 cfs |
| 0.48 | 13.0 ft$^2$ | 10.2 ft | 1.3 ft | 52 cfs |
| 0.6 | 15.2 ft$^2$ | 11.2 ft | 1.4 ft | 62 cfs |

# Helms Upstream

# Reference Dimension

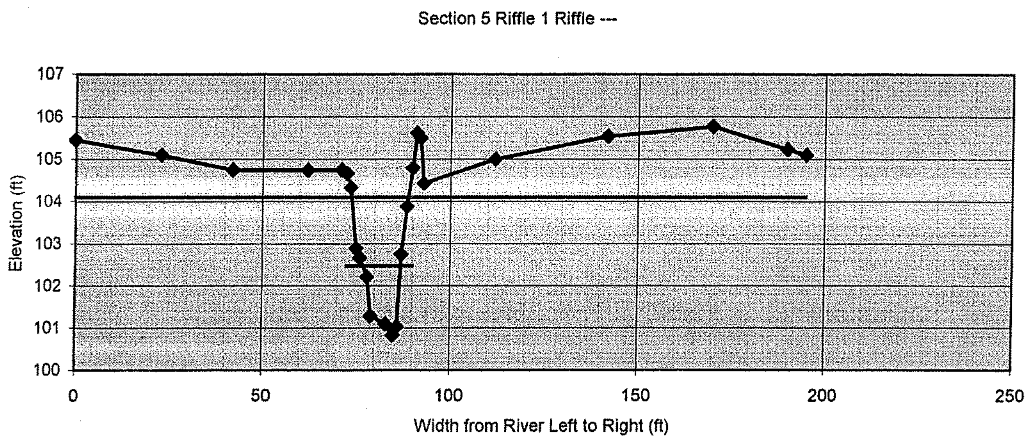
FFLES

| X-SECT # | A BKFL | W BKFL | DAVE | DMAX | W/D | FPA | ENT RATIO | LOW BANK HEIGHT | BANK HEIGHT RATIO | DMAX/DAVE | STREAM TYPE |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 11.7 | 11.5 | 1.0 | 1.4 | 11.4 | 16.0 | 1.4 | 3.2 | 2.3 | 1.4 | G ~~B~~ |
| 3 | 10.2 | 9.7 | 1.1 | 1.4 | 9.1 | 17.5 | 1.8 | 3.3 | 2.4 | 1.3 | ~~B~~ G |
| 5 | 11.1 | 10.0 | 1.1 | 1.6 | 9.0 | 18.5 | ~~1.9~~ 1.9 | 3.8 | 2.4 | 1.5 | ~~B~~ G |
| | 11.0 | 10.4 | 1.1 | 1.5 | 9.8 | 17.3 | 1.7 | 3.4 | 2.4 | 1.4 | |
| AN | 11.1 | 10.0 | 1.1 | 1.4 | 9.1 | 17.5 | 1.8 | 3.3 | 2.4 | 1.4 | G |
| ANGE | 10.2-11.7 | 9.7-11.5 | 1.0-1.1 | 1.4-1.6 | 9.0-11.4 | 16.0-18.5 | 1.4-1.9 | 3.2-3.8 | 2.3-2.4 | 1.3-1.5 | |

ols

| ECT | A BKFL | W BKFL | DAVE | DMAX | ~~W/D~~ | ~~FPA~~ | ~~ENT RATIO~~ | LOW BANK HEIGHT | BANK HEIGHT RATIO | DMAX/DAVE | L POOL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 10.9 | 8.8 | 1.2 | 2.0 | | | | 3.3 | 1.7 | 1.7 | 12 |
| | 12.0 | 12.4 | 1.0 | 2.2 | | | | 3.9 | 1.8 | 2.2 | 15 |
| E | 11.5 | 10.6 | 1.1 | 2.1 | | | | 3.6 | 1.8 | 2.0 | 13.5 |

## Cross Section




| | |
|---|---|
| section | **Section 5 Riffle 1** |
| | Riffle |
| | --- |
| | --- |
| description | |
| height of instrument (ft) | **110.07** |

| notes | omit pt | distance (ft) | FS (ft) | elevation |
|---|---|---|---|---|
| | ✓ | 0 | 4.61 | 105.46 |
| | ✓ | 23 | 4.97 | 105.1 |
| | ✓ | 42 | 5.32 | 104.75 |
| | ✓ | 62 | 5.33 | 104.74 |
| | ✓ | 71 | 5.32 | 104.75 |
| TOB | | 72.5 | 5.4 | 104.67 |
| | | 73.5 | 5.74 | 104.33 |
| | | 75 | 7.18 | 102.89 |
| | | 76 | 7.41 | 102.66 |
| | | 78 | 7.86 | 102.21 |
| | | 79 | 8.79 | 101.28 |
| | | 83 | 8.97 | 101.1 |
| thalweg | | 85 | 9.24 | 100.83 |
| | | 86 | 9.04 | 101.03 |
| | | 87 | 7.32 | 102.75 |
| | | 88.5 | 6.19 | 103.88 |
| TOB | | 90 | 5.27 | 104.8 |
| levee | ✓ | 91 | 4.45 | 105.62 |
| levee | ✓ | 92 | 4.57 | 105.5 |
| FP | ✓ | 93 | 5.64 | 104.43 |
| | ✓ | 112 | 5.07 | 105 |
| | ✓ | 142 | 4.53 | 105.54 |
| | ✓ | 170 | 4.3 | 105.77 |
| | ✓ | 190 | 4.84 | 105.23 |
| | ✓ | 195 | 4.97 | 105.1 |
| FP edge u\| | ✓ | | | |

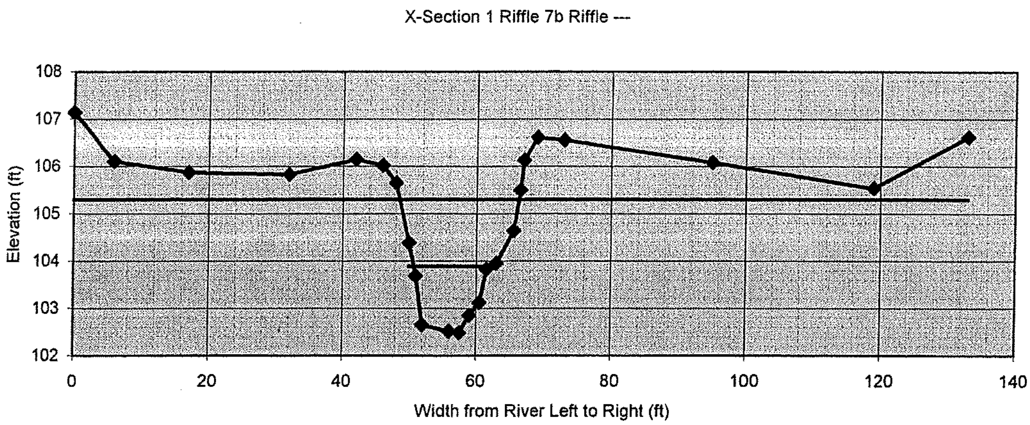
| FS bankfull | FS top of bank | W fpa (ft) | channel slope (%) | Manning's "n" |
|---|---|---|---|---|
| 7.6 | 5.4 | 18.5 | | |
| 102.47 | 104.67 | | | |

| dimensions | | | |
|---|---|---|---|
| 11.1 | x-section area | 1.1 | d mean |
| 10.0 | width | 11.3 | wet P |
| 1.6 | d max | 1.0 | hyd radi |
| 3.8 | bank ht | 9.0 | w/d ratio |
| 18.5 | W flood prone area | 1.9 | ent ratio |

| hydraulics | |
|---|---|
| 0.0 | velocity (ft/sec) |
| 0.0 | discharge rate, Q (cfs) |
| 0.00 | shear stress ((lbs/ft sq) |
| 0.00 | shear velocity (ft/sec) |
| 0.000 | unit stream power (lbs/ft/sec) |
| 0.00 | Froude number |
| 0.0 | friction factor u/u* |
| 0.0 | threshold grain size (mm) |

| check from channel material | | | |
|---|---|---|---|
| 0 | measured D84 (mm) | | |
| 0.0 | relative roughness | 0.0 | fric. factor |
| 0.000 | Manning's n from channel material | | |

**Cross Section**




| | |
|---|---|
| section: | X-Section 1 Riffle 7b |
| | Riffle |
| | --- |
| | --- |
| description: | |
| height of instrument (ft): | 111.49 |

| notes | omit pt. | distance (ft) | FS (ft) | elevation |
|---|---|---|---|---|
| up steep | ✓ | 0 | 4.35 | 107.14 |
| | ✓ | 6 | 5.38 | 106.11 |
| | ✓ | 17 | 5.62 | 105.87 |
| | ✓ | 32 | 5.66 | 105.83 |
| | ✓ | 42 | 5.35 | 106.14 |
| | ✓ | 46 | 5.47 | 106.02 |
| TOB | ✓ | 48 | 5.84 | 105.65 |
| MB | | 50 | 7.1 | 104.39 |
| MB | | 51 | 7.8 | 103.69 |
| | | 52 | 8.84 | 102.65 |
| | | 56 | 8.97 | 102.52 |
| thalweg | | 57.5 | 9.01 | 102.48 |
| | | 59 | 8.64 | 102.85 |
| | | 60.5 | 8.37 | 103.12 |
| | | 61.5 | 7.66 | 103.83 |
| | | 63 | 7.54 | 103.95 |
| | ✓ | 65.5 | 6.85 | 104.64 |
| MB | ✓ | 66.5 | 5.99 | 105.5 |
| | ✓ | 67 | 5.36 | 106.13 |
| TOB | ✓ | 69 | 4.88 | 106.61 |
| | ✓ | 73 | 4.93 | 106.56 |
| | ✓ | 95 | 5.41 | 106.08 |
| | ✓ | 119 | 5.95 | 105.54 |
| FP up shal | ✓ | 133 | 4.87 | 106.62 |

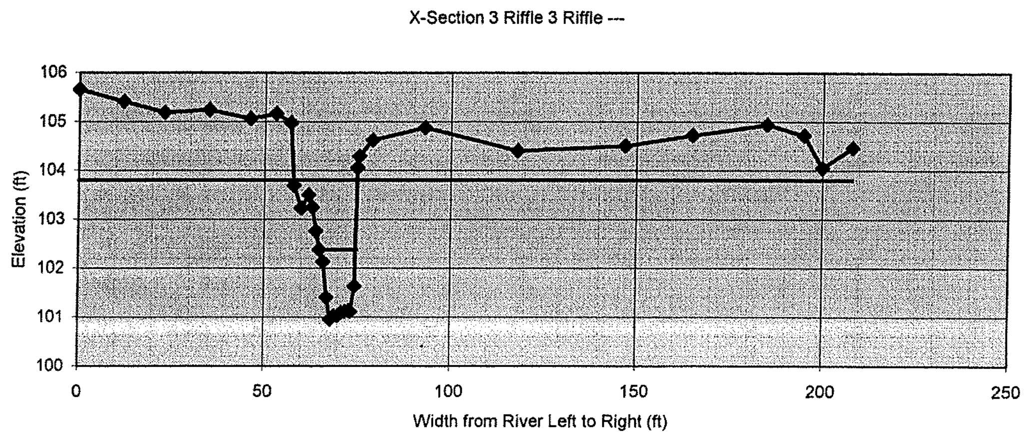
| FS bankfull | FS top of bank | W fpa (ft) | channel slope (%) | Manning's "n" |
|---|---|---|---|---|
| 7.6 | 5.84 | 16.0 | | |
| 103.89 | 105.65 | | | |

| dimensions | | | |
|---|---|---|---|
| 11.7 | x-section area | 1.0 | d mean |
| 11.5 | width | 12.3 | wet P |
| 1.4 | d max | 0.9 | hyd radi |
| 3.2 | bank ht | 11.4 | w/d ratio |
| 16.0 | W flood prone area | 1.4 | ent ratio |

| hydraulics | |
|---|---|
| 0.0 | velocity (ft/sec) |
| 0.0 | discharge rate, Q (cfs) |
| 0.00 | shear stress ((lbs/ft sq) |
| 0.00 | shear velocity (ft/sec) |
| 0.000 | unit stream power (lbs/ft/sec) |
| 0.00 | Froude number |
| 0.0 | friction factor u/u* |
| 0.0 | threshold grain size (mm) |

| check from channel material | | | |
|---|---|---|---|
| 0 | measured D84 (mm) | | |
| 0.0 | relative roughness | 0.0 | fric. factor |
| 0.000 | Manning's n from channel material | | |

## Cross Section




| | |
|---|---|
| section: | X-Section 3 Riffle 3 |
| | Riffle<br>---<br>--- |
| description: | |
| height of instrument (ft): | 110.38 |

| notes | omit pt. | distance (ft) | FS (ft) | elevation |
|---|---|---|---|---|
| FP+60 | ☑ | 0 | 4.72 | 105.66 |
| | ☑ | 12 | 4.97 | 105.41 |
| | ☑ | 23 | 5.19 | 105.19 |
| | ☑ | 35 | 5.14 | 105.24 |
| | ☑ | 46 | 5.32 | 105.06 |
| | ☑ | 53 | 5.21 | 105.17 |
| | ☑ | 57 | 5.4 | 104.98 |
| | ☑ | 58 | 6.69 | 103.69 |
| | ☑ | 60 | 7.15 | 103.23 |
| | ☑ | 62 | 6.88 | 103.5 |
| | ☑ | 63 | 7.13 | 103.25 |
| | ☑ | 64 | 7.62 | 102.76 |
| | ☐ | 65 | 8 | 102.38 |
| | ☐ | 66 | 8.25 | 102.13 |
| | ☐ | 67 | 8.98 | 101.4 |
| thalweg | ☐ | 68 | 9.42 | 100.96 |
| Bed | ☐ | 69 | 9.36 | 101.02 |
| Bed | ☐ | 70 | 9.35 | 101.03 |
| Bed | ☐ | 71 | 9.29 | 101.09 |
| Bed | ☐ | 72 | 9.27 | 101.11 |
| Bed | ☐ | 73 | 9.25 | 101.13 |
| Bed | ☐ | 73.5 | 9.27 | 101.11 |
| MB | ☐ | 74.5 | 8.75 | 101.63 |
| | ☐ | 75 | 6.33 | 104.05 |
| TOB | ☑ | 75.5 | 6.09 | 104.29 |
| | ☑ | 79 | 5.76 | 104.62 |
| | ☑ | 93 | 5.5 | 104.88 |
| | ☑ | 118 | 5.98 | 104.4 |
| | ☑ | 147 | 5.87 | 104.51 |
| | ☑ | 165 | 5.66 | 104.72 |
| | ☑ | 185 | 5.44 | 104.94 |
| | ☑ | 195 | 5.66 | 104.72 |
| slough | ☑ | 200 | 6.33 | 104.05 |
| | ☑ | 208 | 5.92 | 104.46 |
| FP up stee | ☐ | | | |
| | ☐ | | | |
| | ☐ | | | |
| | ☐ | | | |

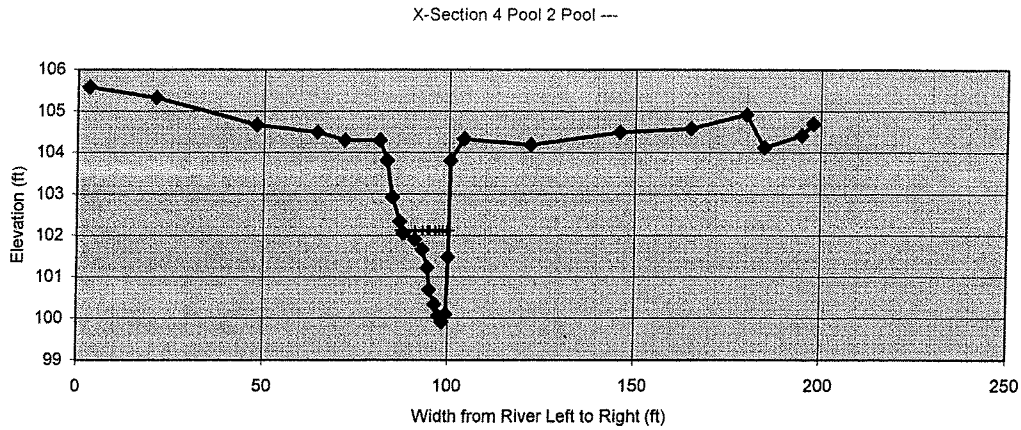
| FS bankfull | FS top of bank | W fpa (ft) | channel slope (%) | Manning's "n" |
|---|---|---|---|---|
| 8 | 6.09 | 17.5 | | |
| 102.38 | 104.29 | | | |

| dimensions | | | |
|---|---|---|---|
| 10.2 | x-section area | 1.1 | d mean |
| 9.7 | width | 10.8 | wet P |
| 1.4 | d max | 1.0 | hyd radi |
| 3.3 | bank ht | 9.1 | w/d ratio |
| 17.5 | W flood prone area | 1.8 | ent ratio |

| hydraulics | |
|---|---|
| 0.0 | velocity (ft/sec) |
| 0.0 | discharge rate, Q (cfs) |
| 0.00 | shear stress ((lbs/ft sq) |
| 0.00 | shear velocity (ft/sec) |
| 0.000 | unit stream power (lbs/ft/sec) |
| 0.00 | Froude number |
| 0.0 | friction factor u/u* |
| 0.0 | threshold grain size (mm) |

| check from channel material | | | |
|---|---|---|---|
| 0 | measured D84 (mm) | | |
| 0.0 | relative roughness | 0.0 | fric. factor |
| 0.000 | Manning's n from channel material | | |

## Cross Section




| | |
|---|---|
| section: | X-Section 4 Pool 2 |
| | Pool<br>---<br>--- |
| description: | |
| height of instrument (ft): | 109.84 |

| notes | omit pt. | distance (ft) | FS (ft) | elevation |
|---|---|---|---|---|
| up shallow | ☑ | 3 | 4.26 | 105.58 |
| | ☑ | 21 | 4.52 | 105.32 |
| | ☑ | 48 | 5.17 | 104.67 |
| | ☑ | 64.5 | 5.35 | 104.49 |
| | ☑ | 72 | 5.54 | 104.3 |
| TOB | ☑ | 81.5 | 5.54 | 104.3 |
| | ☑ | 83.5 | 6.03 | 103.81 |
| | ☑ | 85 | 6.91 | 102.93 |
| | ☐ | 87 | 7.5 | 102.34 |
| | ☐ | 88 | 7.79 | 102.05 |
| | ☐ | 91 | 7.94 | 101.9 |
| | ☐ | 93 | 8.18 | 101.66 |
| | ☐ | 94.5 | 8.62 | 101.22 |
| | ☐ | 95 | 9.15 | 100.69 |
| | ☐ | 96.5 | 9.5 | 100.34 |
| | ☐ | 97.5 | 9.78 | 100.06 |
| | ☐ | 98.5 | 9.93 | 99.91 |
| | ☐ | 99.5 | 9.74 | 100.1 |
| MB | ☐ | 100 | 8.36 | 101.48 |
| TOB | ☐ | 100.5 | 6.04 | 103.8 |
| | ☑ | 104 | 5.51 | 104.33 |
| | ☑ | 122 | 5.65 | 104.19 |
| | ☑ | 146 | 5.35 | 104.49 |
| | ☑ | 165 | 5.26 | 104.58 |
| | ☑ | 180 | 4.93 | 104.91 |
| slough | ☑ | 185 | 5.72 | 104.12 |
| | ☑ | 195 | 5.43 | 104.41 |
| | ☑ | 198 | 5.15 | 104.69 |
| FP edge u | ☑ | | | |
| | ☐ | | | |
| | ☐ | | | |
| | ☐ | | | |
| | ☐ | | | |
| | ☐ | | | |
| | ☐ | | | |
| | ☐ | | | |
| | ☐ | | | |
| | ☐ | | | |
| | ☐ | | | |

| FS bankfull | FS top of bank | [illegible] | channel slope (%) | [illegible] |
|---|---|---|---|---|
| 7.72 | 6.04 | 150.0 | | [illegible] |
| 102.12 | 103.8 | | | |

**dimensions**

| | | | |
|---|---|---|---|
| 12.0 | x-section area | 1.0 | d mean |
| 12.4 | width | 14.3 | wet P |
| 2.2 | d max | 0.8 | hyd radi |
| 3.9 | bank ht | 12.8 | w/d ratio |
| 150.0 | W flood prone area | 12.1 | ent ratio |

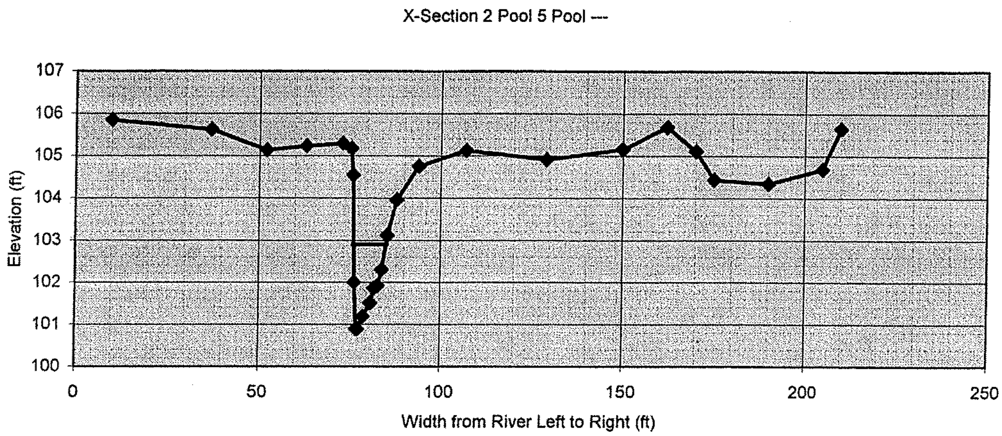
**hydraulics**

| | |
|---|---|
| 0.0 | velocity (ft/sec) |
| 0.0 | discharge rate, Q (cfs) |
| 0.00 | shear stress ((lbs/ft sq) |
| 0.00 | shear velocity (ft/sec) |
| 0.000 | unit stream power (lbs/ft/sec) |
| 0.00 | Froude number |
| 0.0 | friction factor u/u* |
| 0.0 | threshold grain size (mm) |

**[illegible]**

| | | | |
|---|---|---|---|
| 0 | measured D84 (mm) | | |
| 0.0 | relative roughness | 0.0 | fric. factor |
| 0.000 | Manning's n from channel material | | |

## Cross Section




| | |
|---|---|
| section: | X-Section 2 Pool 5 |
| | Pool |
| | --- |
| | --- |
| description: | |
| height of instrument (ft): | 110.76 |

| notes | omit pt | distance (ft) | FS (ft) | elevation |
|---|---|---|---|---|
| FP edge, u | ✓ | 10 | 4.9 | 105.86 |
| | ✓ | 37 | 5.13 | 105.63 |
| | ✓ | 52 | 5.62 | 105.14 |
| | ✓ | 63 | 5.52 | 105.24 |
| | ✓ | 73 | 5.46 | 105.3 |
| TOB | ✓ | 75.5 | 5.58 | 105.18 |
| | | 76 | 6.21 | 104.55 |
| MB | | 76.5 | 8.76 | 102 |
| | | 77.2 | 9.87 | 100.89 |
| thalweg | | 77.5 | 9.87 | 100.89 |
| | | 79 | 9.57 | 101.19 |
| | | 81 | 9.25 | 101.51 |
| | | 82 | 8.9 | 101.86 |
| | | 83 | 8.84 | 101.92 |
| | | 84 | 8.46 | 102.3 |
| | | 85.5 | 7.64 | 103.12 |
| | ✓ | 88 | 6.8 | 103.96 |
| | ✓ | 94 | 6 | 104.76 |
| | ✓ | 107 | 5.63 | 105.13 |
| | ✓ | 129 | 5.84 | 104.92 |
| | ✓ | 150 | 5.6 | 105.16 |
| | ✓ | 162 | 5.08 | 105.68 |
| | ✓ | 170 | 5.64 | 105.12 |
| depression | ✓ | 175 | 6.32 | 104.44 |
| depression | ✓ | 190 | 6.41 | 104.35 |
| thalweg | ✓ | 205 | 6.07 | 104.69 |
| | ✓ | 210 | 5.11 | 105.65 |
| FP edge, u | ✓ | | | |

| FS bankfull | FS top of bank | W fpa (ft) | channel slope (%) | Manning's "n" |
|---|---|---|---|---|
| 7.86 | 6.53 | | | |
| 102.9 | 104.23 | | | |

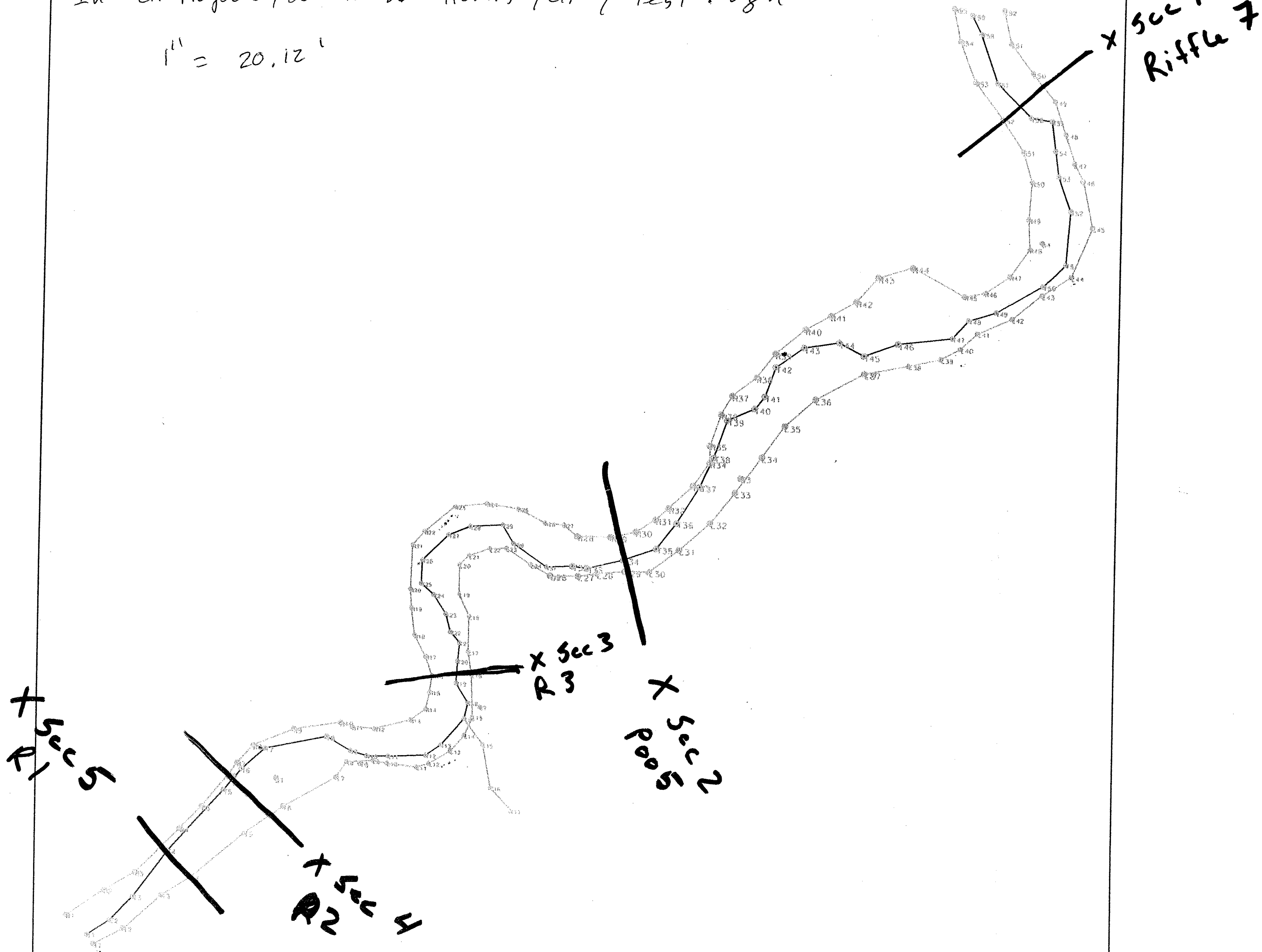
| dimensions | | | |
|---|---|---|---|
| 10.9 | x-section area | 1.2 | d mean |
| 8.8 | width | 10.5 | wet P |
| 2.0 | d max | 1.0 | hyd radi |
| 3.3 | bank ht | 7.0 | w/d ratio |
| 0.0 | W flood prone area | 0.0 | ent ratio |

| hydraulics | |
|---|---|
| 0.0 | velocity (ft/sec) |
| 0.0 | discharge rate, Q (cfs) |
| 0.00 | shear stress ((lbs/ft sq) |
| 0.00 | shear velocity (ft/sec) |
| 0.000 | unit stream power (lbs/ft/sec) |
| 0.00 | Froude number |
| 0.0 | friction factor u/u* |
| 0.0 | threshold grain size (mm) |

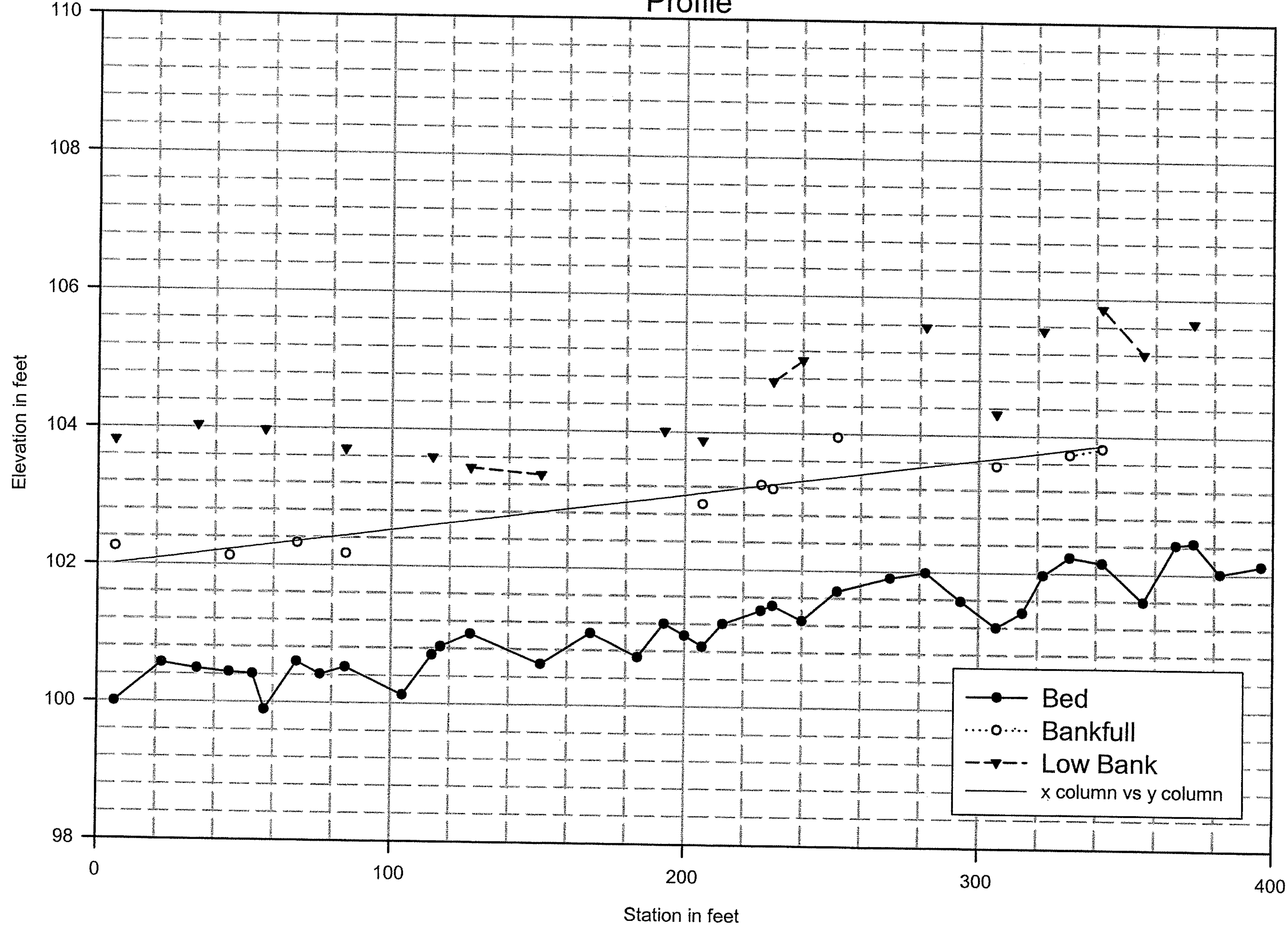
| check from channel material | | | |
|---|---|---|---|
| 0 | measured D84 (mm) | | |
| 0.0 | relative roughness | 0.0 | fric. factor |
| 0.000 | Manning's n from channel material | | |

In G: Projects/00-046.26 Helms/GPS/Test.dgn

1" = 20.12'



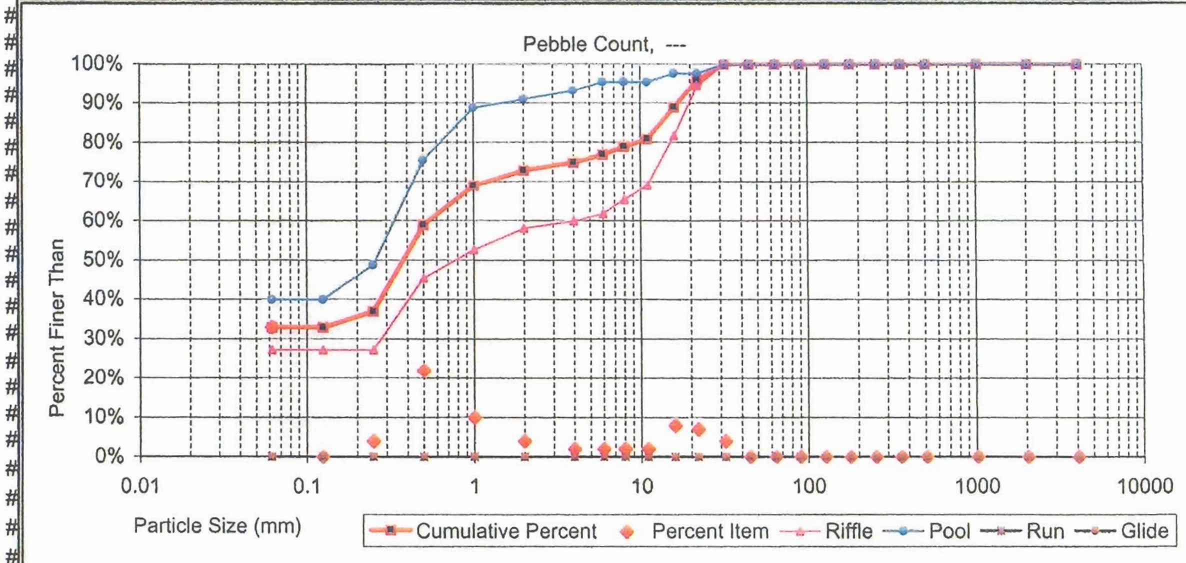
# UT to Dutch Buffalo Creek
# Reference Stream
# Profile



| Weighted Pebble Count | | | | |
|---|---|---|---|---|
| Percent Riffle: | 55 | Percent Run: | 0 | |
| Percent Pool: | 45 | Percent Glide: | 0 | Pebble Count, |

| | |
|---|---|
| | --- |
| | --- |
| | --- |
| Note: | **Helms Upstream Weighted** |

| Material | Size Range (mm) | | Total # | |
|---|---|---|---|---|
| silt/clay | 0 | 0.062 | 33.0 | # # |
| very fine sand | 0.062 | 0.13 | 0.0 | # # |
| fine sand | 0.13 | 0.25 | 4.0 | # # |
| medium sand | 0.25 | 0.5 | 22.0 | # # |
| coarse sand | 0.5 | 1 | 10.0 | # # |
| very coarse sand | 1 | 2 | 4.0 | # # |
| very fine gravel | 2 | 4 | 2.0 | # # |
| fine gravel | 4 | 6 | 2.0 | # # |
| fine gravel | 6 | 8 | 2.0 | # # |
| medium gravel | 8 | 11 | 2.0 | # # |
| medium gravel | 11 | 16 | 8.0 | # # |
| coarse gravel | 16 | 22 | 7.0 | # # |
| coarse gravel | 22 | 32 | 4.0 | # # |
| very coarse gravel | 32 | 45 | 0.0 | # # |
| very coarse gravel | 45 | 64 | 0.0 | # # |
| small cobble | 64 | 90 | 0.0 | # # |
| medium cobble | 90 | 128 | 0.0 | # # |
| large cobble | 128 | 180 | 0.0 | # # |
| very large cobble | 180 | 256 | 0.0 | # # |
| small boulder | 256 | 362 | 0.0 | # # |
| small boulder | 362 | 512 | 0.0 | # # |
| medium boulder | 512 | 1024 | 0.0 | # # |
| large boulder | 1024 | 2048 | 0.0 | # # |
| very large boulder | 2048 | 4096 | 0.0 | # # |
| bedrock | | | 0.0 | # |
| Weighted Count: | | | 100 | |
| True Total Particle Count: | | | 100 | |




| Size percent less than (mm) | | | | | Percent by substrate type | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| D16 | D35 | D50 | D84 | D95 | silt/clay | sand | gravel | cobble | boulder | bedrock |
| #N/A | 0.18 | 0.4 | 13 | 21 | 33% | 40% | 27% | 0% | 0% | 0% |