# Meredell Farm Stream Restoration Plan
# Randolph County, North Carolina

**Submitted to:**

**North Carolina Department of Environment and Natural Resources**
**Ecosystem Enhancement Program**

**Prepared by:**


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# Meredell Farms Stream Restoration Plan
# Randolph, North Carolina

Prepared for The North Carolina Ecosystem Enhancement Program

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# Executive Summary

The North Carolina Ecosystem Enhancement Program (EEP) proposes to conduct stream restoration activities at Meredell Farm, near the town of Liberty in Randolph County, North Carolina. The project will restore 3,865 linear feet, enhance 4,704 linear feet, and preserve 5,136 linear feet of stream in the Cape Fear River Basin. The project involves Sandy Creek and two of its unnamed tributary streams and is shown in Exhibit 1.1. The site lies in the Deep River watershed within North Carolina Division of Water Quality (NCDWQ) sub-basin 03-06-09 and United States Geologic Survey (USGS) hydrologic unit 03030003020010.

For analysis and design purposes, the on-site streams were divided into seven reaches. The reach locations are shown on Exhibit 1.2. The reaches were numbered sequentially moving from east to west with tributaries carrying a UT designation and main reaches an M designation. A ridge separates the project into two subwatersheds. UT1 and UT2 drain into the M1 subwatershed while UT3, UT4, and UT5 drain into the M2 subwatershed. UT1 begins off site, flows into the project area from the east, and ends at the confluence with UT2. UT2 begins on site at a farm pond outlet pipe, flows southwest to its confluence with UT1. M1 begins at the confluence of UT1 and UT2 and ends at its confluence with Sandy Creek. UT3 begins on the adjacent property and flows into the project area for a short distance from the northeast to the confluence with UT4 and then to the east to the confluence with UT5 and M2. UT4 begins on site, flows through the project from the east and ends at the confluence with UT3. UT5 flows through the project site from the north and ends at the confluence of UT3 and M2. M2 begins at the confluence with UT5 and UT3 and ends at the property boundary.

The design goals of the project include:

- Restore 3,865 LF of channel dimension, pattern and profile
- Enhance 4,704 LF of channel dimension and/or profile
- Preserve 5,136 LF of stream channel and riparian buffer
- Improve floodplain functionality by matching floodplain elevation with bankfull stage
- Establish native stream bank and floodplain vegetation in the permanent conservation easement
- Improve the water quality in the Upper Cape Fear River watershed by fencing cattle out of the stream and reducing bank erosion

**TABLE ES.1**
Restoration Overview
*Meredell Farms Restoration Plan*

| Project Feature | Existing Condition | Design Condition | Approach |
|---|---|---|---|
| UT1 | 1,621 LF | 1,880 LF | Priority 1 Restoration / Enhancement |
| UT2 | 1,006 LF | 1,095 LF | Priority 1 Restoration / Enhancement |
| M1 | 2,013 LF | 2,254 LF | Priority 1 Restoration |
| UT3 | 1,236 LF | 1,351 LF | Priority 1 Restoration / Enhancement |
| UT4 | 913 LF | 913 LF | Enhancement |
| UT5 | 1,075 LF | 1,075 LF | Enhancement |
| M2 | 1,398 LF | 1,398 LF | Preservation |
| Sandy Creek 1 | 1,033 LF | 1,033 LF | Preservation |
| Sandy Creek 2 | 801 LF | 801 LF | Preservation |
| Sandy Creek 3 | 1,902 LF | 1,902 LF | Preservation |

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# 1 Introduction and Background

## 1.1 Brief Project Description and Location

The North Carolina Ecosystem Enhancement Program (EEP) proposes to conduct stream restoration activities at Meredell Farm, near the town of Liberty in Randolph County, North Carolina. The project will restore 3,865 linear feet of stream, enhance 4,704 linear feet, and preserve 5,136 linear feet of stream in the Cape Fear River Basin. The project involves Sandy Creek and two of its unnamed tributary streams and is shown in Exhibit 1.1. The site lies in the Deep River watershed within North Carolina Division of Water Quality (NCDWQ) sub-basin 03-06-09 and United States Geologic Survey (USGS) hydrologic unit (HU) is 03030003020010.

For analysis and design purposes, the on-site streams were divided into seven reaches. The reach locations are shown on Exhibit 1.2. The reaches were numbered sequentially moving from east to west with tributaries carrying a "UT" designation and main reaches n "M" designation. A ridge separates the project into two subwatersheds. UT1 and UT2 drain into the M1 subwatershed while UT3, UT4, and UT5 drain into the M2 subwatershed. UT1 begins off site, flows into the project area from the east, and ends at the confluence with UT2. UT2 begins on-site at a farm pond outlet pipe, and flows southwest to its confluence with UT1. M1 begins at the confluence of UT1 and UT2 and ends at its confluence with Sandy Creek. UT3 begins on the adjacent property and flows into the project area for a short distance from the northeast to the confluence with UT4 and then to the east to the confluence with UT5 and M2. UT4 begins on-site, flows through the project from the east and ends at the confluence with UT3. UT5 flows through the project site from the north and ends at the confluence of UT3 and M2. M2 begins at the confluence with UT5 and UT3 and ends at the property boundary.

All of the unnamed tributary stream reaches, with the exception of UT4, are shown as intermittent blue-line streams on the USGS topographic quadrangle as shown in Exhibit 1.1. UT4 does not appear on the USGS quad, but appears to be spring fed. The total existing length of project stream reaches is approximately 13,000 ft.

## 1.2 Project Goals and Objectives

The design goal of the project is to restore and improve the stream channel and riparian buffer form and function on-site. To achieve this goal the following objectives have been identified:

- Restore 3,865 LF of channel dimension, pattern and profile
- Enhance 4,704 LF of channel dimension and/or profile
- Preserve 5,136 LF of stream channel and riparian buffer
- Improve floodplain functionality by matching floodplain elevation with bankfull stage
- Establish native stream bank and floodplain vegetation in the permanent conservation easement
- Improve the water quality in the Upper Cape Fear River watershed by fencing cattle out of the stream and reducing bank erosion

Portions of existing incised, eroding, and channelized streams will be filled, and new meandering channels will be constructed across the floodplain. Invasive vegetation will be removed and native vegetation will be re-established.

## 1.3 Report Overview

This report has the following organization. Section 2 provides new readers with a review of the background science and methodologies applied by Buck Engineering in the practice of natural channel design. It does not contain information specific to this project. Sections 3 through 6 of the report discuss site-specific project details. They cover watershed assessment findings, stream corridor assessment results, design criteria, and the restoration design, respectively. Section 7 presents the monitoring and evaluation plan for the post-implementation period. References are included in Section 8, and appendices are included that summarize cultural resources, correspondence, hazardous waste screening, a summary of existing site conditions, site photographs, and NCDWQ stream forms.

# 2 Background Science and Methods

## 2.1 Application of Fluvial Processes to Stream Restoration

A stream and its floodplain comprise a dynamic environment where the floodplain, channel, and bedform evolve through natural processes. Weather and hydraulic processes erode, transport, sort, and deposit alluvial materials throughout the riparian system. The size and flow of a stream are directly related to its watershed area. Other factors that affect channel size and stream flow are geology, land use, soil types, topography, and climate. The morphology, or size and shape, of the channel reflect all of these factors (Leopold et al., 1992; Knighton, 1998).

Streams operating under dynamic equilibrium maintain their dimension, pattern, and profile over time, and neither degrade nor aggrade. Land use changes in the watershed, including increases in impervious land cover and removal of riparian vegetation, can upset this balance. A new equilibrium may eventually be reached, but not before large adjustments in channel form can occur, such as extreme bank erosion or incision (Lane, 1955; Schumm, 1960). By understanding and applying natural stream processes to stream restoration projects, a self-sustaining stream can be designed and constructed that maximizes stream and biological potential (Leopold et al., 1992; Leopold, 1994; Rosgen, 1996).

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

### 2.1.1 Channel Forming Discharge

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

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

### 2.1.2 Bedform Diversity and Channel Substrate

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

#### *2.1.2.1 Step/Pool Streams*

A step/pool bed profile is characteristic of steep streams formed within colluvial valleys. Steep mountain streams demonstrate step/pool morphology as a result of episodic sediment transport mechanisms. Because of the high energy associated with the steep channel slope, the substrate in step/pool streams contains significantly larger particles than streams in flatter alluvial valleys. Steps form from accumulations of boulders and cobbles that span the channel, resulting in a backwater pool upstream and plunge pool downstream. Smaller particles collect in the interstices of steps creating stable, interlocking structures (Knighton, 1998).

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

#### *2.1.2.2 Gravel Bed Streams*

Meandering gravel bed streams in alluvial valleys have sequences of riffles and pools that maintain channel slope and bed stability. The riffle is a bed feature composed of gravel or larger size particles. During low flow periods, the water depth at a riffle is relatively shallow and the slope is steeper than the average slope of the channel. At low flows, water generates turbulence as it flows over riffles, providing oxygen to the stream. Riffles control the stream bed elevation and are usually found entering and exiting meander bends. The inside of the meander bend is a depositional feature called a point bar, which also helps maintain channel form (Knighton, 1998). Pools are typically located on the outside bends of meanders between riffles. Pools have a flat slope and are much deeper than the average depth of the channel. At low flows, pools are depositional features and riffles are scour features.

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

#### *2.1.2.3 Sand Bed Streams*

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

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

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

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

### 2.1.3 <u>Stream Classification</u>

The Rosgen stream classification system categorizes essentially all types of channels based on measured morphological features (Rosgen, 1994, 1996). The system (illustrated in Exhibit 2.1) presents several stream types based on a hierarchical scale. The first level of classification distinguishes between single- and multiple-thread channels. Streams are then separated based on degrees of entrenchment, width/depth ratio, and sinuosity. Slope range and channel materials are also used in the classification system. Stream types are further described according to average riparian vegetation, organic debris, blockages, flow regimes, stream size, depositional features, and meander pattern.

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

### 2.1.4 Stream Stability

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

### 2.1.5 Channel Evolution

A common sequence of physical adjustments has been observed in many streams following disturbance. This adjustment process is often referred to as channel evolution. Disturbance can result from channelization, increase in runoff due to build-out in the watershed, removal of streamside vegetation, and other changes that negatively affect stream stability. All of these disturbances occur in both urban and rural environments. Several models have been used to describe this process of physical adjustment for a stream. The Simon (1989) channel evolution model characterizes channel evolution in six classes, including:

- I Sinuous, pre-modified
- II Channelized
- III Degradation
- IV Degradation and widening
- V Aggradation and widening
- VI Quasi-equilibrium

Exhibit 2.3 illustrates the six classes of the Simon channel evolution model.

The channel evolution process is initiated when disturbance occurs in a stable, well-vegetated stream that interacts frequently with its floodplain. Disturbance commonly results in an increase in stream velocity or sediment load that causes degradation, often referred to as channel incision (Lane, 1955). Incision eventually leads to over-steepening of the banks and, when critical bank heights are exceeded, the banks begin to fail and mass wasting of soil and rock leads to channel widening. Incision and widening continue moving upstream in the form of a head-cut. Eventually the mass wasting slows and the stream begins to aggrade. A new low-flow channel begins to form in the sediment deposits. By the end of the evolutionary process, a stable stream with dimension, pattern, and profile similar to those of undisturbed channels forms in the deposited alluvium. The new channel is at a lower elevation than its original form with a new floodplain constructed of alluvial material (FISRWG, 1998).

### 2.1.6 Priority Levels of Restoring Incised Rivers

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

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

## 2.2 Natural Channel Design Overview

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

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

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

Once a dimension, pattern, and profile have been developed for the project reach, the design is tested to ensure that the new channel will not aggrade or degrade. A discussion of sediment transport methodology is provided in Section 2.6. After the sediment transport assessment, additional structural elements are then added to the design to provide grade control, protect stream banks, and enhance habitat. Section 2.7 describes these in-stream structures.

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

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

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

## 2.3 Geomorphic Characterization Methodology

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

### 2.3.1 Bankfull Identification

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

- Identify the most consistent bankfull indicators along the reach that were obviously formed by the stream, such as a point bar or lateral bar. Bankfull is usually the back of this feature, unless sediment supply is high. In that case, the bar may flatten and bankfull will be the front of the feature at the break in slope. The indicator is rarely the top of the bank or lowest scour mark.
- Measure the difference in height between the water surface and the bankfull indicator. For example, the indicator may be 2.2 feet above the water surface. Bankfull stage corresponds to a flow depth. It should not vary by more than a few tenths of a foot throughout the reach, unless a tributary enters the reach and increases the size of the drainage area.
- Go to a stable riffle. If a bankfull indicator is not present at this riffle, use the height measured in the previous step to establish the indicator. For example, measure 2.2 feet above water surface and place a flag in both the right and left bank.
- Measure the distance from the left bank to the right bank between the indicators. Calculate the cross-sectional area.
- Obtain the appropriate regional curve (e.g., rural Piedmont, urban Piedmont, Mountain, or Coastal Plain) and determine the cross-sectional area associated with the drainage area of the reach.
- Compare the measured cross-sectional area to the regional curve cross-sectional. If the measured cross-sectional area is not a close fit, look for other bankfull indicators and test them. If there are no other indicators, look for reasons to explain the difference between the two cross-sectional areas. For example, if the cross-sectional area of the stable riffle is lower than the regional curve area, look for upstream impoundments, wetlands, or a mature forested watershed. If the cross-sectional area is higher than the regional curve area, look for stormwater drains, parking lots, or signs of channelization.

It is important to perform the bankfull verification at a stable riffle using indicators from depositional features. The cross-sectional area will change with decreasing stability. In some streams, bankfull indicators will not be present due to incision or channelization. In such cases, it is important to verify bankfull through other means such as a gauge station survey or reference bankfull information that is specific to the geographic location. The gauge information can be used, along with regional curve information, to estimate bankfull elevation in parts of the project reach that lacks bankfull indicators.

### 2.3.2 Bed Material Characterization

Buck Engineering performs bed material characterization using a modified Wolman procedure (Wolman, 1954; Rosgen, 1996). A 100-count pebble count is performed in transects across the streambed, with the number of riffle and pool transects being proportional to the percentage of riffles and pools within the longitudinal distance of a given stream type. As stream type changes, a separate pebble count is performed. The median particle size of the modified Wolman procedure is known as the $d_{50}$. The $d_{50}$ describes the bed material classification for that reach. The bed material classification is shown on Exhibit 2.1 and ranges from a classification of 1 for a channel $d_{50}$ of bedrock to a classification of 6 for a channel $d_{50}$ with particle sizes in the silt/clay range.

### 2.3.3 Stream Classification

Cross-sections are surveyed along stable riffles for the purpose of stream classification. Relevant data includes entrenchment ratio (ER), width/depth ratio (w/d ratio), and sinuosity. The ER is calculated by dividing the flood-prone width (width measured at twice the maximum bankfull depth) by the bankfull width. The w/d ratio is calculated by dividing bankfull width by mean bankfull depth. Exhibit 2.5 shows examples of the channel dimension measurements used in the Rosgen stream classification system. Finally, the numbers that coincide with each bed material classification are to further classify the stream type. For example, a Rosgen E3 stream type is a narrow and deep cobble-dominated channel with access to a floodplain that is greater than two times its bankfull width.

## 2.4 Channel Stability Assessment Methodology

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

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

This field evaluation is followed by the evaluation of various channel dimension relationships. The evaluation of these categories and ratios leads to a determination of a channel's current state, potential for restoration, and appropriate methods that could be used during restoration activities. A description of each category is provided in the following sections.

### 2.4.1 Stream Channel Condition Observations

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

- Riparian vegetation – concentration, composition, and rooting depth and density;

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

These qualitative observations are useful in the assessment of channel stability. They provide a consistent method of documenting stream conditions that allows for comparisons across different sets of site conditions. They also help explain the quantitative measurements described below. Exhibit 2.5 illustrates some of these quantitative measurements.

### 2.4.2 Vertical Stability – Degradation/Aggradation

The bank height and entrenchment ratios are measured in the field to assess vertical stability. The bank height ratio is measured as the ratio of the lowest bank height divided by a maximum bankfull depth. Table 2.4.1 shows the relationship between bank height ratio (BHR) and vertical stability developed by Rosgen (2001a).

**Table 2.4.1**
**Conversion of Bank Height Ratio (Degree of Incision) to Adjective Rankings of Stability**

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

*Source: Rosgen, 2001a*

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

### 2.4.3 Lateral Stability

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

### 2.4.4 Channel Pattern

The channel pattern is assessed in the field by measuring the stream's plan features including radius of curvature, meander wavelength, meander belt width, stream length, and valley length. Results are used to compute the meander width ratio (described above), ratio of radius of curvature to bankfull width, sinuosity, and meander wavelength ratio (meander wavelength divided by bankfull width).

These ratios are compared to reference reach data for the same valley and stream type to determine if the whether channel pattern has been impacted.

### 2.4.5 River Profile and Bed Features

A longitudinal profile is created by measuring and plotting elevations of the channel bed, water surface, bankfull, and low bank height. Facet (e.g., riffle, run, pool) slopes of each individual feature are important for stability assessment and design. Profile points are surveyed periodically and at significant breaks in slope such as the head of a riffle or pool. This can be used to assess changes in river slope compared to valley slope, which affects sediment transport, stream competence, and the balance of energy. For example, the removal of large woody debris may increase the step/pool spacing and result in excess energy inputs and subsequent channel degradation.

### 2.4.6 Channel Dimension Relations

The bankfull width/depth ratio provides an indication of departure from reference reach conditions and describes channel instability. A greater width/depth ratio compared to reference conditions may indicate accelerated stream bank erosion, excessive sediment deposition, stream flow changes, and alteration of channel shape (e.g., from channelization). A smaller width/depth ratio compared to reference conditions may indicate channel incision and downcutting. Both increases and decreases in width/depth ratio can indicate evolutionary shifts in stream type (i.e., transition of one stream type to another). Table 2.4.2 shows the relationship between the degree of width/depth ratio increase and channel stability developed by Rosgen (2001a).

**Table 2.4.2**
**Conversion of Width/Depth Ratios to Adjective Ranking of Stability from Stability Conditions**

| Stability Rating | Ratio of Project to Reference Width/Depth |
|---|---|
| Very stable | 1.0 |
| Stable | 1.0 – 1.2 |
| Moderately unstable | 1.21 – 1.4 |
| Unstable | > 1.4 |

*Source: Rosgen, 2001a*

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

### 2.4.7 Channel Evolution

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

## 2.5 Design Parameter Selection Methodology

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

### 2.5.1 Upstream Reference Reaches

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

### 2.5.2 Reference Reach Searches

If a reference reach cannot be located upstream of the project reach, a review of a reference reach database is required. The search attempts to identify reference reaches near the project site. The search screens for streams with the same valley and stream type as those in the project area. If streams are found that meet these criteria, the reference reaches are field-surveyed for validation and comparison. This is done because the database values that may have been originally collected and provided by a third party. If a search of the database reveals no reference reaches that meet the appropriate criteria, a field search is performed locally to identify a stream that could be used as a reference reach.

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

### 2.5.3 Reference Reach Databases

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

### 2.5.4 Regime Equations

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

### 2.5.5 Comparison to Past Projects

It is very useful to compare these reference reaches with the results of past projects built under similar conditions. Ultimately, these sites provide the best pattern and profile ratios because they reflect site conditions after construction. While most reference reaches are in mature forests, restoration sites are generally in floodplains with little or no mature woody vegetation. The lack of this vegetation severely alters floodplain processes and stream bank conditions. If past ratios did not provide adequate stability or bedform diversity, they are not used. Conversely, if past project ratios created stable channels with optimal bedform diversity; they will be incorporated into the design.

Ultimately, the design criteria are selections of ratios and equations made after a thorough evaluation of the above parameters. Several approaches may be used to optimize the design. Section 5 discusses the process of selecting for this project.

## 2.6 Sediment Transport Competency and Capacity Methodology

Stream restoration designs must be tested to ensure that the new channel dimensions (in particular, the design bankfull mean depth) create a stream that has the ability to move its sediment load without aggrading or degrading over time. The ability of the stream to transport its total sediment load is quantified through two measures: sediment transport competency and sediment transport capacity. Competency is a stream's ability to move particles of a given size and is a measurement of force, often expressed as units of pounds per square foot (lbs/ft$^2$). Sediment transport capacity is a stream's ability to move a quantity of sediment and is a measurement of stream power, often expressed as units of watts/square meter. Sediment transport capacity is also calculated as a sediment transport rating curve, which provides an estimate of the quantity of total sediment load transported through a cross-section per unit time. The curve is provided as a sediment transport rate in pounds per second (lbs/sec) versus discharge or stream power.

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

### 2.6.1 Competency Analysis

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

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

a) Calculate the ratio d50/d^50

Where: d50 = median diameter of the riffle bed (from 100 count in the riffle or pavement sample)

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

If the ratio d50/d^50 is between the values of 3.0 and 7.0, then calculate the critical dimensionless shear stress using Equation 1.

$\tau$ *ci = 0.0834 (d50/d^50)–0.872 (Equation 1)

b) If the ratio d50/D^50 is not between the values of 3.0 and 7.0, then calculate the ratio of di/d50

Where: di = Largest particle from the bar sample (or subpavement)

d50 = median diameter of the riffle bed (from 100 count in the riffle or the pavement sample)

If the ratio di/d50 is between the values of 1.3 and 3.0, then calculate the critical dimensionless shear stress using Equation 2.

$\tau$ *ci = 0.0384 (di/d50)–0.887 (Equation 2)

### 2.6.2 Aggradational Analysis

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

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

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

Where: dr (ft) = Required bankfull mean depth

de (ft)= Design bankfull mean depth

1.65 = Sediment density (submerged specific weight)

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

t*ci = Critical dimensionless shear stress

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

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

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

The aggradation analysis is used to assess both existing and design conditions. For example, if the calculated value for the existing critical depth is significantly larger than the measured maximum bankfull depth, this indicates that the stream is aggrading. Alternately, if the proposed design depth significantly differs from the calculated critical depth and the analysis is deemed appropriate for the site conditions, the design dimensions should be revised accordingly.

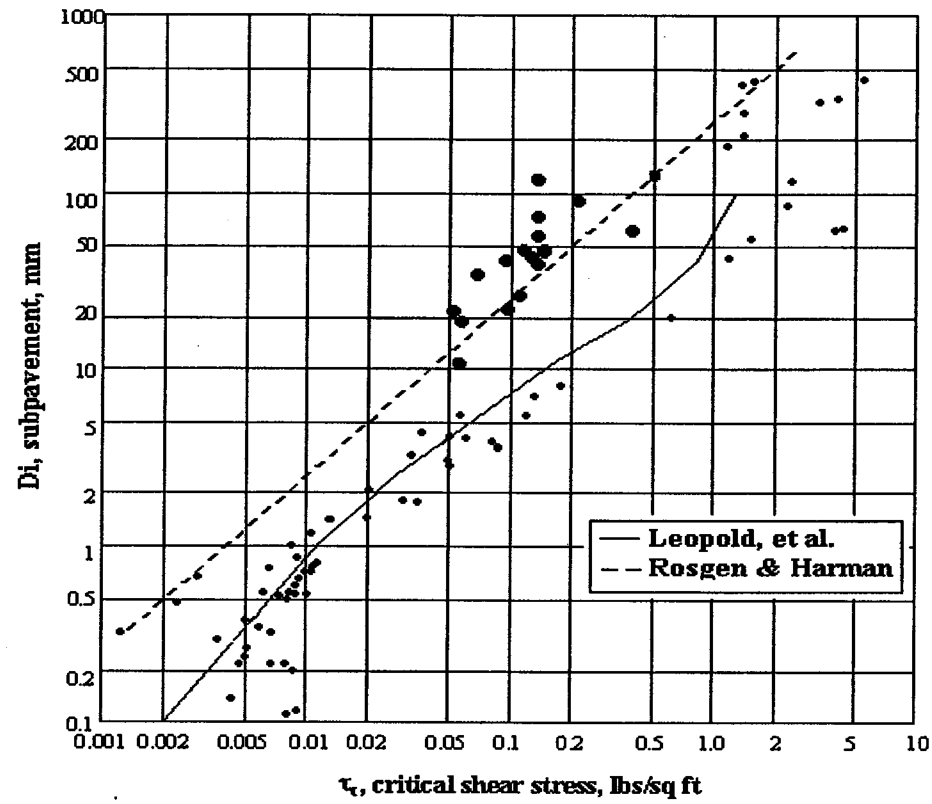
### 2.6.3 Competency Analysis using Shield's Curve

As a complement to the required depth and slope calculations, boundary shear stresses for a design riffle cross-section can be compared with a modified Shield's curve to predict sediment transport competency. The shear stress placed on the sediment particles is the force that entrains and moves the particles, given by:

$$\tau = \gamma R s$$ (Equation 5)

Where,
$\tau$ = shear stress (lb/ft$^2$)
$\gamma$ = specific gravity of water (62.4 lb/ft$^3$)
R = hydraulic radius (ft)
s = average channel slope (ft/ft)

The boundary shear stress can be estimated for the design cross-section and plotted on a modified Shield's curve, as shown in Figure 2.6.1. The particle size that Shield's curve predicts will be moved is compared to the $D_i$ of the site subpavement. Shield's curve predicts whether the design conditions will have enough shear stress to move a particle larger than the largest subpavement particle found in the creek and prevent aggradation.




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

*Figure 2.6.1 Modified Shield's Curve*

### 2.6.4 Sediment Transport Capacity

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

$w = \gamma QS/W_{bkf}$, where (Equation 6)

$w$ = mean stream power in W/m$^2$

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

Q = bankfull discharge in $m^3/s$

S = Design channel slope (meters per meter)

$W_{bkf}$ = Bankfull channel width in meters

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

Equation 6 does not provide a sediment transport rating curve; however, it does describe the stream's ability to accomplish work, i.e., move sediment. Calculated stream power values are compared to reference and published values. If deviations from known stable values for similar stream types and slopes are observed, the design should be reassessed to confirm that sediment will be adequately transported through the system without imparting excess energy to the channel.

## 2.7 In-Stream Structures

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

### 2.7.1 Grade Control

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

### 2.7.2 Bank Protection

Bank protection is critical during and after construction as bank and floodplain vegetation establishes a reinforcing root mass. It may take several years to completely establish floodplain vegetation, but significant bank protection is often observed after two to four growing seasons. Bank protection structures generally provide both reinforcement to the stream banks and re-direction of flow away from the banks and toward the center of the channel.

### 2.7.3 Habitat Enhancement

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

### 2.7.4 Selection of Structure Types

**Table 2.7.1 Functions of In-Stream Structures**

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

The selection of structure types and locations typically follows dimension, pattern, and profile design. In some situations, structures comprise the main, or possibly only stream improvement activity. More often, structures are used in conjunction with grading, realignment, and planting in an effort to improve channel stability and aquatic habitat. Table 2.7.1 summarizes the functions of several in-stream structures.

## 2.8 Vegetation

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

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

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

1. Channel bottom - extending up to the low flow stage. Emergent, aquatic plants dominate bank range, extending from the low flow stage to the bankfull stage;

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

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

### 2.8.1 Live Staking

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

### 2.8.2 Riparian Buffer Re-Vegetation

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

Buffers are most valuable and effective when comprised of a combination of trees, shrubs, and herbaceous plants. Although width generally increases the capacity of riparian buffers to improve water quality and provide greater habitat value, even buffers less than 85 feet wide have been shown to improve water quality and habitat (Budd et al., 1987). An estimated minimum width of 30 feet is required for creating beneficial forest structure and riparian habitat.

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

- Design for sheet flow into and across the riparian buffer area;
- If possible, the width of the riparian buffer area should be proportional to the watershed area, the slope of the terrain, and the velocity of the flow through the buffer;
- Forest structure should include understory and canopy species. Canopy species are particularly important adjacent to waterways to moderate stream temperatures and to create habitat; and

- Use native plants that are adapted to the site conditions (e.g., climate, soils, and hydrology). In suburban and urban settings riparian forested buffers may not need to resemble natural ecosystems to improve water quality and habitat.

## 2.9 Risk Recognition

It is important to recognize the risks inherent in the assessment, design, and construction of environmental restoration projects. Such endeavors involve the interpretation of existing conditions to deduce appropriate design criteria, the application of those criteria to design, and, most importantly, the execution of the construction phase. There are many factors that ultimately determine the success of these projects and many of the factors are beyond the influence of a designer. Restorations must use an approach based on sound field observations, accepted methodologies, and best professional judgment to address as many site-specific factors as possible. However, it is important to acknowledge that factors such as daily temperatures, the amount and frequency of rainfall during and following construction, subsurface conditions, and changes in watershed characteristics that are beyond the control of the designer.

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

# 3 Watershed Assessment Results

## 3.1 Watershed Delineation

The Meredell Farm site is located approximately three miles west of Liberty, in Randolph County NC (Exhibit 1.1) in the Upper Cape Fear River Basin. The site lies in the Deep River watershed within North Carolina Division of Water Quality (NCDWQ) sub-basin 03-06-09 and United States Geologic Survey (USGS) hydrologic unit 03030003020010. Exhibit 3.1 shows the watershed boundaries and drainage areas for the various project reaches.

## 3.2 Site Hydrology/Hydraulics

### 3.2.1 Surface Water Classification

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

The project reaches are unnamed tributaries to Sandy Creek, which is identified by NCDWQ index number 17-16-(1). Sandy Creek has been assigned a surface water classification of WS-III. The project reaches also have the WS-III classification. WS-III waters are used as sources of water supply for drinking, culinary, or food processing purposes where a more protective WS-I or WS-II classification is not feasible. WS-III waters are generally located within low to moderately developed watersheds. All WS-III waters are also protected for Class C uses. The project reaches are outside the critical area for the water supply and their drainages are therefore subject to the less restrictive development rules associated with the non-critical (balance) area of a WS-III watershed.

### 3.2.2 Site Hydrologic and Hydraulic Characteristics

The Federal Emergency Management Agency Flood Insurance Rate Map (FIRM) for Randolph County, NC (Community Number 370195) indicates that the there is no regulatory floodplain associated with the Meredell Farms project site. Prior to developing final design plans, existing and proposed HEC-RAS models will be developed from survey data in order to determine flooding impacts. Discharges will be estimated for the 5, 10, 25, 50, and 100 year flood.

## 3.3 Geology

The project area is in the northeast region of Randolph County, which is in the Piedmont Region of central North Carolina. The site is located within the Carolina Slate Belt and has a subsurface geology consisting of mafic metavolcanic rock. This rock is interbedded with mafic and intermediate metavolcanic rock, meta-argillite, and metamudstone. The site is located on rolling hills with well-defined stream valley's falling toward Sandy Creek. Sandy Creek is located within a wider, flatter valley bottom. The site has a moderately deep soil layer over rocky subsoil. Bedrock is exposed in many areas and the site is littered with large rocks and boulders, either encountered during tilling of the site, or exposed by erosion.

### 3.4 Soils

Soils at the site were determined using NRCS Soil Survey data for Randolph County (USDA-NRCS, 2002). A map depicting the boundaries of each soil type is presented in Exhibit 3.2. There are three general soil types found within the project boundaries. These soils will support stream restoration activities. A discussion of each soil type and its locations is presented in Table 3.4.1.

All of the stream reaches that were surveyed as part of this study are mapped as Mecklenburg Loam (Ma). Mecklenburg loam and Mecklenburg clay loam (Me) comprise the majority of the Meredell farm property. The Mecklenburg series is a very deep, well drained soil found on uplands in the Piedmont. They have formed in the residuum from mafic high-grade metamorphic or igneous rock. They have a loamy or loamy clayey surface layer and loamy and clayey subsoil. Permeability is slow. Depth to bedrock is more than 60 inches.

Sandy Creek is located in an area composed of a combination of Chewacla and Wehadkee soil series. The Chewacla series is commonly found in the Piedmont near streams and drainage ways on floodplains with relatively low slopes and frequent flooding. Chewacla typically has a very deep soil profile, somewhat poor drainage, moderate permeability, and a very shallow depth to the seasonal high water table. The surface layer and subsurface layers are loamy in texture with an increase in clay content starting at about three feet below the surface.

The Wehadkee series is commonly found in Piedmont river and stream valleys on floodplains with low slopes and frequent flooding. Wehadkee has a very deep soil profile, poor drainage, moderate permeability, and a very shallow depth to the seasonal high water table. The surface layer is silty, loamy in texture. The subsoil includes very fine sand, beginning at a depth of 25 inches.

Due to wetness and flooding, Chewacla and Wehadkee soils are often poorly suited for growing crops, pasture, or any kind of urban development. The Natural Resources Conservation Service considers the Chewacla series to be a hydric soil (NRCS, 1995) when frequently flooded, which is the case on Meredell Farm.

A small area of Wynott-Enon soils is present in the upper section of UT5 and along Sandy Creek on the east side of the property. The Wynott series is moderately deep, well drained and has moderately slow to slow permeability. The Enon series has a very deep soil profile. It is a well-drained soil with slow permeability.

**Table 3.4.1 Project Soil Types and Descriptions**

| Soil Name | Location | Description |
|---|---|---|
| Mecklenburg Loam | Throughout project area | very deep, well drained soils |
| Chewacla and Wehadkee | Within Sandy Creek floodplain | somewhat poorly drained soil on flood plains |
| Wynott-Enon | Upper section of UT5 and near Sandy creek on the East side of property | well drained soil |

*Source: Randolph County Soil Survey, USDA-NRCS, 2002.*

## 3.5 Land Use

All streams within the Meredell Farm Stream Restoration project drain surrounding agricultural, forested, and individual residences. Overall, the Upper Cape Fear River watershed is mostly rural with land uses that include agriculture, timber logging, forested area and some residential property (impervious surface less than 5 percent). The project is located on Meredell Farm, a small farm operation that includes a dairy operation and row crop production. The project includes headwater stream systems that discharge into Sandy Creek.

## 3.6 Endangered/Threatened Species

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

Species that the United States Fish and Wildlife Service (USFWS) and North Carolina Natural Heritage Program (NHP) list under federal protection for Randolph County as of April 30, 2004 are listed in Table 3.6.1. A brief description of the characteristics and habitat requirements of these species follow the table, along with a conclusion regarding potential project impact. In addition, Federal Species of Concern are listed in Table 3.6.2.

## Table 3.6.1 Species Under Federal Protection

| Scientific Name | Common Name | Federal Status | State Status | Habitat Present / Biological Conclusion |
|---|---|---|---|---|
| | | **Vertebrates** | | |
| *Notropis mekistocholas* | Cape Fear Shiner | E | E | No /No Affect |
| | | **Vascular Plants** | | |
| *Helianthus schweinitzii* | Schweinitz's sunflower | E | E | May Affect/ Not likely to adversely Affect |

Notes:

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

## Table 3.6.2 Federal Species of Concern in Randolph County

| Scientific Name | Common Name | Federal Status | State Status | Habitat Present? |
|---|---|---|---|---|
| | | **Invertebrates** | | |
| Alasmidonta varicose | Brook Floater | FSC | E | * No Habitat Present |
| Fusconaia masoni | Atlantic Pigtoe | FSC | E | * No Habitat Present |
| Lampsilis cariosa | Yellow Lampmussel | FSC | E | * No Habitat Present |
| Toxolasma pullus | Savannah Lilliput | FSC | E | * No Habitat Present |
| Villosa Vaughaniana | Carolina Creekshell | FSC | E | * No Habitat Present |

Notes:

FSC – do not require biological conclusion.

### 3.6.1 Federally Protected Species

#### *3.6.1.1 Vertebrates*

***Notropis mekistocholas*** **(Cape Fear Shiner)**
Federal Status: Endangered

Family: Cyprinidae

Federally Listed: September 26, 1987

The Cape Fear shiner is a small minnow, rarely exceeding 2.4 inches in length. It is a pale silvery yellow with a black stripe along each side. The fins are yellow and pointed, the upper lip is black, and the lower lip has a thin black bar along its edge.

Water willow (*Justicia americana*) beds in flowing areas of creeks and rivers appear to be an essential element of the species' habitat. Cape Fear Shiner are found in clean, rocky streams over gravel, cobble, and boulder substrate, and is known to inhabit pools, riffles, and slow runs. Juveniles are often found in slack water, among mid-stream rock outcrops, and in side channels and pools.

**Biological Conclusion: No Effect**
No suitable habitat exists for the Cape Fear shiner within the proposed restoration area. The streams proposed for restoration do not have water willow beds and have been too severely impacted to maintain populations of the Cape Fear shiner. Based upon the NHP's database, checked on April 30, 2004, no populations of this species have been reported in the project area. Therefore, the proposed project is not anticipated to result in an adverse impact to this species.

#### *3.6.1.2 Vascular Plants*

***Helianthus schweinitzii*** **(Schweinitz's sunflower)**

Federal Status: Endangered

Plant Family: Asteraceae

Federally Listed: May 7, 1991

Schweinitz's sunflower, usually 3 to 6 feet tall, is a perennial herb with one to several fuzzy purple stems growing from a cluster of carrot-like tuberous roots. Leaves are 2 to 7 inches long, 0.4 to 0.8 inches wide, lance-shaped, and usually opposite, with upper leaves alternate. Leaves feel like felt on the underside and rough, like sandpaper, on the upper surface. The edges of the leaves tend to curl under. Flowers are yellow composites, and generally smaller than other sunflowers in North America. Flowering and fruiting occur mid-September to frost. This plant grows in clearings and along the edges of upland woods, thickets, and pastures. It is also found along roadsides, powerline clearings, old pastures, and woodland openings. It prefers full sunlight or partial shade, but is intolerant of full shade.

**Biological Conclusion: May affect – not likely to adversely affect**

Small pockets of potential habitat for Schweinitz's sunflower occur along field edges throughout the project area. Field surveys within the potential habitat areas for plant individuals were performed on October 23, 2003. No populations were found within the area of potential impact. Based upon the NHP's database, checked on April 30, 2004, no populations of this species have been reported in the project area. Therefore, the proposed project is not anticipated to result in an adverse impact to this species.

3.6.2 Federal Species of Concern and State Status

Federal Species of Concern (FSC) are not legally protected under the ESA and are not subject to any of its provisions, including Section 7, until they are formally proposed or listed as Threatened or Endangered. Table 3.6.2 includes FSC species listed for Randolph County and their state classifications. Organisms that are listed as Endangered (E), Threatened (T), or Special Concern (SC) on the NHP list of Rare Plant and Animal Species are afforded State protection under the State Endangered Species Act and the North Carolina Plant Protection and Conservation Act of 1979.

## 3.7 Cultural Resources

Buck Engineering sent a letter on November 19, 2003, during the feasibility reporting phase, requesting that the North Carolina State Historic Preservation Office (NC SHPO) review the potential for cultural resources in the vicinity of the Meredell Farm property. A response was received December 16, 2003 (Appendix A). Only one archaeological resource, site 31RD965, was located within one mile of the proposed project area. This site will not be affected by the proposed mitigation activities. However, SHPO has requested that specific project plans be forwarded when they become available so that they may evaluate potential effects upon as yet unrecorded archaeological resources.

## 3.8 Potentially Hazardous Environmental Sites

Buck Engineering obtained an EDR Transaction Screen Map Report (Appendix B), during the feasibility reporting phase that identifies and maps real or potential hazardous environmental sites within the distance required by the American Society of Testing and Materials (ASTM) Transaction Screen Process (E 1528). The overall environmental risk for this site was determined to be low as there are no listed sites within ½ mile of a Superfund (National Priorities List, NPL); ½ mile of hazardous waste treatment, storage, or disposal facilities; ¼ mile of a Comprehensive Environmental Response, Compensation, and Liability Act Information System (CERCLIS) hazardous waste site; ¼ mile of suspect state hazardous waste site; ½ mile of solid waste or landfill facilities; or 1/8 mile of a leaking underground storage tank. Evidence of hazardous materials was not found during site investigations. Landowners interviewed by Buck Engineering were not aware of any hazardous materials issues.

## 3.9 Potential Constraints

Site constraints and potential fatal flaws have been examined. No fatal flaws were identified, although there are minor constraints that have been addressed during the design phase of the restoration planning. Constraints that were addressed during the design phase included the presence of bedrock, the potential for restoration versus enhancement on certain stream reaches, and farm operational needs. Constraints identified during the feasibility study phase, but not previously addressed, are discussed in this section.

3.9.1 Property Ownership and Boundary

The conservation easement has been signed based on a preliminary map outlining the easement boundaries. Once construction is complete, a recordable map will be produced to replace the preliminary map currently on file. Property owners are supportive of the project and have agreed to the establishment of permanent conservation easements. The signed conservation easement includes emergency watering areas for cattle; these areas will be located at stream crossings. The Piedmont Land Conservancy has coordinated easement negotiations with the property owners. The Piedmont Land Conservancy is also willing to assume long-term responsibility for the site.

### 3.9.2 Site Access

The best opportunity for construction access to the site is through the main entrance to Meredell Farm. Temporary easements are being negotiated to ensure access to the site for construction, as well as access to the site throughout the monitoring period. Access is currently being coordinated with the landowners and easement holders and will be finalized prior to construction. Unimproved farm roads along the edges of the row crop fields are currently providing access to the various reaches. These roads may need to be improved for construction and will likely need repair following construction.

### 3.9.3 Utilities

The farm has a buried irrigation line that crosses UT5. Additionally, UT2 begins as an outlet pipe from a farm pond. No other utilities are known to be located on the site where they would interfere with restoration efforts. The irrigation line and the outlet pipe can be avoided or protected during construction. If damage does occur, repair may be required.

### 3.9.4 Farm Operations

Meredell Farm is an operating dairy cattle and crop production facility. Therefore, the project must be supportive of the operational needs of the farm. The restoration design incorporates cattle crossings, fencing, and pasture access as identified by the site owner(s) (Exhibit 3.3). No constraints or fatal flaws have been associated with this aspect of the project.

# 4 Stream Corridor Assessment Results

## 4.1 Reach Identification

For analysis and design purposes, we divided on-site streams into seven reaches. The reach locations are shown on Exhibit 1.2. The reaches were numbered sequentially moving from east to west with tributaries carrying a "UT" designation and main reaches a "M" designation. A ridge separates the project into two subwatersheds. UT1 and UT2 drain into the M1 subwatershed while UT3, UT4 and UT5 drain into the M2 subwatershed. UT1 begins off site, flows into the project from the east, and ends at the confluence with UT2. UT2 begins on site at a farm pond outlet pipe, flows from the northeast, and ends at the confluence with UT1. M1 begins at the confluence of UT1 and UT2 and ends at the confluence of Sandy Creek. UT3 begins on the adjacent property and flows into the project area for a short distance from the northeast to the confluence with UT4 and then to the east to the confluence with UT5 and M2. UT5 flows through the project site from the north and ends at the confluence with UT3 and M2. M2 begins at the confluence of UT3 and UT5, and ends at the property boundary.

All of the unnamed tributary stream reaches, with the exception of UT4, are shown as intermittent blue-line streams on the USGS topographic quadrangle as shown in Exhibit 1.1. UT4 does not appear on the USGS quad, but appears to be spring fed. We completed Stream Classification Forms prepared by NCDWQ and aquatic life (fish, amphibians, crayfish, and/or macrobenthos) was noted in all of the reaches. All stream reaches have significant flow and are considered perennial based on field assessments (Appendix E).

## 4.2 Geomorphic Characterization and Channel Stability Assessment

NCDOT provided Buck Engineering with general topographic and planimetric surveying of the project site. Buck Engineering developed a contour map based on NCDOT survey data for the plan set basemapping. Buck Engineering performed cross-section surveys of stream reaches to assess the current condition and overall stability of the channels and added other significant planimetric features to the basemapping. The locations of cross-section surveys on the project reaches are shown on the design plan sheets. The following report sections summarize the survey results for all project reaches.

### 4.2.1 M1 Subwatershed

UT1, and UT2 drain into the M1 subwatershed as shown in Exhibit 3.1. Watershed sizes were calculated at the terminus of each reach as described in section 4.1 (Table 4.2.1). Appendix C contains summaries of existing condition parameters, cross section survey results, and a bed material distribution graph for all reaches.

**Table 4.2.1 M1 Subwatershed Reach Description**

| Reach | Reach Length (linear feet) | Watershed Size (acres) |
|---|---|---|
| UT1 | 1,621 | 64 |
| UT2 | 1,006 | 67 |
| M1 | 2,013 | 168 |

#### *4.2.1.1 UT1*

UT1 is broken into two subreaches, UT1a is in the upstream section of the reach in a more confined valley. UT1b starts where the valley becomes more open in the downstream section. Currently cattle have access to the stream and the stream classification is highly variable throughout the reach. The reach lacks bedform diversity and mostly consists of embedded riffle/ runs. Silt is prevalent in the few pools that exist within the reach. While the reach is generally unstable both vertically and laterally, areas of bedrock create some local stability.

UT1 is unstable with a stream type classification that changes several times throughout. The most upstream section classifies as a G4 (Rosgen, 1994). The stream is incised with a bank height ratio (BHR) of 4.1 indicating that the stream is highly unstable and vertical eroding banks are prevalent in this upper section. Moving downstream the reach becomes overly wide for a short section in which the stream changes to a F4 classification. The banks have been impacted by cattle traffic in this area and riffles present are embedded. The stream type changes to an E4 classification at a bedrock knickpoint. At this point, the stream becomes moderately stable for a short section of the reach due to low BHR and the presence of bedrock; however the banks have been impacted from cattle crossing the stream. In the lower section of the reach (near the confluence with M1) the stream classification remains an E4, however the stream becomes highly unstable and incised with a BHR of 3.8. The stream in this area appears to be in the process of creating a new floodplain at a lower elevation. Banks are severely eroded and trampled by cattle in this lower section.

Pebble counts using the modified Wolman procedure (Wolman, 1954) indicate the median particle size in the riffles is 11.2 mm. This particle size is representative of a gravel bed stream.

#### *4.2.1.2 UT2*

UT2 is broken into two subreaches at a change in valley type. The valley type for UT2a most closely resembles a V-type valley that is fairly confined and steep. In UT2b the valley opens up slightly and is more U-shaped. This is evidenced in the change in stream type that occurs in this area.

UT2a is classified as a Rosgen B5-1 stream type (Rosgen, 1994) in the upper section of the reach where the valley is confined and the slope is high. The valley opens up in UT2b and the stream type transitions to an E5-1 classification. The bed material is composed of bedrock and silt/sand. Bulk sampling procedure was used to characterize the mobile silt/sand particles in the bankfull channel bottom. The $D_{50}$ particle size of the bulk sample is representative of a sand bed stream.

UT2a is incised with bank height ratios ranging from 2.2 to 3.7 in the surveyed cross sections. These values fall into the highly unstable range in Rosgen's comparison of bank height ratio to vertical stability ranking. While the bank height ratios are high, the upper section is fairly stable due to the amount of bedrock in the channel. UT2b is more unstable and has down cut in some areas. Cattle crossings have impacted the banks, adding to the amount of lateral instability (especially in the lower section of the reach where the banks are higher and bank slumping has occurred). UT2b is at an early Stage IV in the Simon Evolution Model, which indicates that the channel is in the process of degrading and widening.

#### *4.2.1.3 M1*

M1 appears to have been channelized at some point in the past. The valley for M1 is U shaped with a somewhat confined floodplain in the upper half of the reach. The valley becomes wide and flat in the lower half of the reach near the confluence with Sandy Creek. M1 is classified as a straightened and incised G4c stream type (Rosgen, 1994). Pebble counts using the modified Wolman procedure (Wolman, 1954) indicate the median particle size in the riffles is 16.4 mm. This particle size is representative of a gravel bed stream. Aquatic habitat within most of the M1 watershed is poor. The stream lacks cover and bedform diversity, with embedded riffle/ runs and a few shallow silt dominated pools.

M1 has incised and has experienced some widening through bank erosion. Bank height ratios ranged from 2.1 to 3.4 in the surveyed cross sections. These values fall into the highly unstable range. The stream has downcut to bedrock in some areas adding some level of vertical stability. Meander width ratios are extremely low compared to stable stream types in North Carolina (NCDOT Reference Reach Database). This departure is indicative of a condition of lateral instability. Width to depth ratios ranged from 5.8 to 7.9 in the surveyed cross sections. This range of ratios compares well to the range of width to depth ratios in stable E stream types in North Carolina (NCDOT Reference Reach Database). Although width to depth ratios do not show a significant departure from reference conditions, evidence of moderate to high bank erosion and low meander width ratios indicate that this system is laterally unstable.

### 4.2.2 M2 Subwatershed

UT3, UT4 and UT5 drain into the M2 subwatershed as shown in Exhibit 3.1. Watershed sizes were calculated at the terminus of each reach as described in section 4.1 (Table 4.2.2). Appendix C contains summaries of existing condition parameters, cross section survey results, and a bed material distribution graph for all reaches.

**Table 4.2.2 M2 Subwatershed Reach Description**

| Reach | Reach Length (linear feet) | Watershed Size (acres) |
|---|---|---|
| UT3 | 1,236 | 148 |
| UT4 | 913 | 56 |
| UT5 | 1,075 | 59 |
| M2 | 1,398 | 265 |

#### *4.2.2.1 UT3*

UT3 is split into two subreaches at a change in stream type. UT3a is in the upper section and is incised with a high BHR (around 3.8) and occurs in a moderately steep valley. Though the BHR indicates that this section of stream is highly unstable, it has down cut to bedrock in many areas creating vertical stability with step pool features. UT3a classifies as a B4c stream type. Pebble counts using the modified Wolman procedure (Wolman, 1954) indicate the median particle size reach wide is 32.0 mm. This particle size is representative of a course gravel bed stream. Small areas of local erosion do exist along the upper section of this reach, however this section exhibits good in-stream cover, leaf packs and woody debris within the channel. Lateral stability is further enhanced by a woody buffer approximately 60 feet wide on the left bank.

In UT3b the valley widens out on the left bank and the stream is pushed against the toe of slope on the right side. The stream gradient is significantly reduced in this area and the bed material is predominantly sand. Bulk sampling procedure was used to characterize the mobile silt/sand particles in the bankfull channel bottom. The $D_{50}$ particle size of the bulk sample is representative of a course sand bed stream. This area of UT3 has experienced some aggradation, possibly from sediments derived upstream (outside of the project area where erosion may be more extensive). The cross section performed in this lower section of UT3b classifies the stream as a C5 with an entrenchment ratio of 2.5 and width to depth ratio of 37.3. The BHR is 1, indicating that the channel is relatively stable. However, due to the streams location within the valley, it is possible that the stream will move towards a more unstable state.

Reach UT3, as well as UT5, flows into an area that would meet the ACOE criteria for jurisdictional wetlands. As these reaches enter the stream/wetland complex the channels are not incised and become less defined with multiple, interconnected side channels. This system would be a DA stream type according to the Rosgen classification system. The system is stable due to cohesive bank materials with dense root mass and extensively developed wetland vegetation. It is proposed that UT3b transition into the main channel of the DA stream following restoration. This system has been designated M2 and continues down valley to Sandy Creek. Reach M2 will be preserved within a conservation easement as a component of the mitigation plan (see plan sheet 18).

*4.2.2.2 UT4*

UT4 is a small headwaters stream that originates on the property and is situated in a moderately steep, confined valley and has a small undeveloped buffer. The upper section of the stream classifies as an E5/C5 stream type with an entrenchment ratio of 7.7 and a width to depth ratio of 11.6. This section of the stream is currently stable. However the BHR (1.3), indicates that the stream bed is at risk for degradation as the existing head cuts move up the valley. Algae is also prevalent in this section of the stream, probably due to nutrient run off from adjacent agricultural fields and the dairy farm combined with an inadequate vegetative buffer around the stream.

Moving downstream through a series of head cuts the stream becomes incised and transitions into a G5 stream type with an entrenchment ratio of 1.6 and width to depth ratio of 7.8. The bank height ratio in the lower section is 2, which is considered highly unstable. This reach is considered to be in stage IV in the Simon Evolution Model, indicating that the channel is in the process degrading and widening. In-stream habitat is poor, as the reach lacks well-developed riffles and pools and exhibits areas of bank erosion throughout.

*4.2.2.3 UT5*

UT5 is a small stream; the channel itself begins off site but appears to be an intermittent/ephemeral channel in the upper section of the property becoming perennial through a series of head cuts. The stream is in a small, confined U-shaped valley. Riffles are not well developed and shallow pools occur mainly below head cuts.

UT5 is classified as a Rosgen E5 stream type (Rosgen, 1994). The upper section of the reach is relatively stable with a BHR of 1, an entrenchment ratio of 14.2 and width to depth ratio of 7.1. This is likely to change as head cuts move up the valley. The lower section of this reach becomes somewhat incised and BHR increases to 2 (highly unstable). The entrenchment ratio in this lower section of the reach ranges between 2.3-2.9 with a width to depth ratio of 5.2-7.4. The channel is actively degrading and falls into class III in the Simon Channel Evolution Model. The stream is experiencing localized areas of bank erosion but appears to be laterally stable at this time. The channel bed did have a few areas where cobble and boulders were present. However the majority of the channel consisted of sand and gravel, therefore bulk sampling procedures were used to characterize the mobile particles in the bankfull channel bottom. The $D_{50}$ particle size of the bulk sample is representative of a coarse sand bed stream.

As mentioned above in section 4.2.2.1, reach UT5 flows into a DA stream/wetland system. This system has been designated M2 and continues down valley to Sandy Creek. Reach M2 will be preserved within a conservation easement as a component of the mitigation plan (see plan sheet 18).

#### *4.2.2.4 M2*

M2 is currently in good condition. The riparian area is extensive and intact with large trees and dense shrubs present on both banks. The riparian buffer is in good condition and the floodplain is broad and flat. The stream was classified as a Rosgen E stream type (Rosgen; 1994). It has good pattern and is not incised with access to the floodplain during flows above bankfull. This reach is not in need of restoration and will be considered a preservation area, therefore topographic surveys were not conducted on this reach.

## 4.3 Bankfull Verification

The bankfull stage in all reaches on the Meredell Farm site was identified in the field using standard field indicators including: the top of bank, top of point bars, and/or an upper scour line. These indicators are consistent with other Piedmont streams. Cross-sectional area is plotted versus drainage area for all project reaches as shown on Figure 4.3. The cross-sectional areas for most of the project reaches fall well within the 95% confidence intervals of the rural Piedmont curve comparing cross sectional area to drainage area with the exception of UT4 and UT5. These reaches are very small and tend to have variable bankfull cross sectional areas. Furthermore, the two reaches fall in an area of the curve where data points for streams of similar sizes are not available.

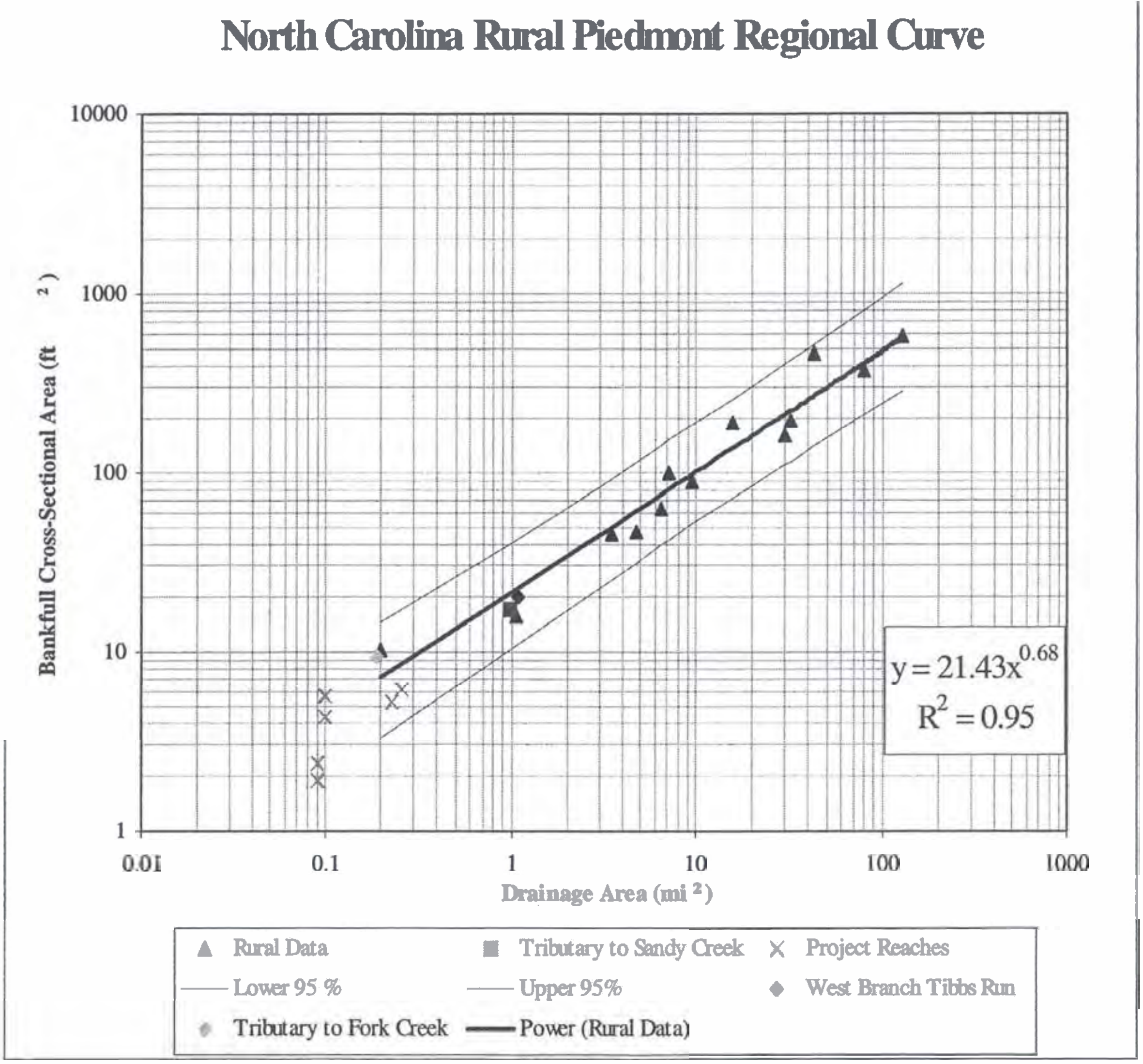



*Figure 4.3 Rural Piedmont Regional Curve with Surveyed Bankfull Cross-Section Areas for the Tributary to Fork Creek, Tributary to Sandy Creek, West Branch Tibbs Run and Project Reaches. (Project data points were not used in determining the regression line.) (Harman et al., 1999)*

In order to verify that the Piedmont regional curve is appropriate to use in this region, we compared data from three reference reaches in the NCDOT reference reach database. These three streams, Tributary to Fork Creek, Tributary to Sandy Creek, and West Tibbs Run, are all located in the Cape Fear River Basin within Randolph County. The reference reaches show additional points in the vicinity of the project area that were not used to determine the regression line. As indicated in Figure 4.3, each of the reference reaches falls within the 95 percent confidence interval. The Tick Creek gage station, surveyed for the rural piedmont regional curve regression line, is also located approximately 20 miles from the restoration site and agrees with the regional curves.

## 4.4 Vegetation

The riparian areas of Reaches UT1, UT2, and M1 have been cleared to expand grazing areas for cattle. Only a handful of trees are found along the stream banks, primarily black willow (<u>*Salix*</u>

*nigra*), sweetgum (*Liquidambar styraciflua*), and red maple (*Acer rubrum*). A stand of mature, large American beech (*Fagus grandifolia*) is located along UT1. All three of these reaches offer the opportunity for riparian buffer re-establishment.

Riparian vegetation along reaches UT3, UT4, and UT5 is limited and in poor condition. The buffer is often comprised of only a single row of trees or shrubs (five to ten feet in width on one or both of the banks). The vegetative assemblages within Reaches UT3, UT4, and UT5 most closely resemble the Basic Mesic Forest as classified by Schafale and Weakley (1990). Dominant species within these ecological communities include the following: tulip poplar (*Liriodendron tulipifera*), American beech, southern sugar maple (*Acer floridanum*), red oak (*Quercus rubra*), white oak (*Quercus alba*), loblolly pine (*Pinus taeda*), flowering dogwood (*Cornus florida*), ironwood (*Carpinus caroliniana*), hop hornbeam (*Ostrya virginiana*), black haw (*Viburnum prunifolium*), spicebush (*Lindera benzoin*), Christmas fern (*Polystichum acrostichoides*), and black cohosh (*Cimicifuga racemosa*). These ecological communities are uneven-aged, with only a few mature trees present. Scattered disturbed areas are present, allowing for pines, weedy hardwoods, and Japanese honeysuckle (*Lonicera japonica*) to invade in areas once dominated by shade-tolerant species.

Much of the vegetation found along Reaches UT3, UT4, and UT5 appears to be successional and/or exotic and, therefore, can be improved. These reaches offer opportunities for buffer enhancement through additional planting and invasive/exotic weed control. The riparian area for M2 and along Sandy Creek is in a more natural condition, with existing riparian vegetation along both banks. The vegetative assemblages within this section of M2 and Sandy Creek most closely resemble the Piedmont Alluvial Forest as classified by Schafale and Weakley (1990). Dominant species within these ecological communities include the following: tulip poplar, red maple, river birch (*Betula nigra*), cherry bark oak (*Quercus pagoda*), swamp chestnut oak (*Quercus michauxii*), American elm (*Ulmus americana*), flowering dogwood, ironwood, giant cane (*Arundinaria gigantea*), false nettle (*Boehmeria cylindrica*), sedge species (*Carex spp.*), and Virginia chain fern (*Woodwardia aureolata*). These ecological communities are uneven-aged, and are subject to long duration flood events.

Other than the riparian floodplain wetland beginning at the confluence at UT3 and UT5 and continuing along M2 and along Sandy Creek (see Section 4.2.2.1), no significant wetland areas occur within the project limits on Meredell Farm. Wetland vegetation exists along the fringe of the farm pond at the headwaters of Reach UT2. This pond will not be manipulated for the project and therefore the wetland community will remain. Much of the riparian floodplain area associated with Reach M2 and along Sandy Creek, which appears to be USACE jurisdictional wetlands, will be protected within a permanent conservation easement.

# 5 Selected Design Criteria

## 5.1 Potential for Restoration

The project is located in a rural watershed, with no plans indicating significant land use changes in the foreseeable future. The main constraint to restoration is the confined valley type in which many of the streams occur. In areas where stream reaches are confined, a meandering channel is not appropriate or attainable. In these areas in-stream structures and buffer establishment will be used to enhance stream stability and in-stream habitat. Other constraints are addressed in Section 3.9.

### 5.1.1 M1 Subwatershed Restoration Potential

The M1 mainstem channel and its two tributaries (UT1 and UT2) have been impacted by direct cattle access. The steeper, confined stream reaches in the upper sections of UT1 and UT2 exhibit some areas of stability where bedrock is present. Rosgen Priority III and IV enhancement approaches will be used to improve habitat features and bedform diversity in the upper portions of the reaches. Full restoration is not proposed due to the confined valley condition and the presence of only localized areas of instability. The remaining reaches of UT1, UT2 and M1 are incised and show a trend toward lateral migration. Without restoration, it is possible that incision would stabilize, but the redevelopment of meanders would continue through bank erosion. As a result, the majority of the restoration in the M1 subwatershed should attempt to speed up the evolutionary process already occurring. In these downstream sections, Rosgen B and C stream types will be constructed to provide access to the available floodplain areas.

### 5.1.2 M2 Subwatershed Restoration Potential

M2 and its tributaries are within an area utilized for crop production and therefore have not been impacted by recent cattle disturbance. The main restoration approaches used for the M2 watershed are Rosgen Priority III and IV enhancement techniques. In most areas, isolated sections of erosion will be stabilized through grading and stabilization of the streambanks. Structures will be placed in selected areas to improve bank stability and bed diversity. Between stations 16+50 and 21+20 on UT3, the stream pattern will be modified by using Rosgen Priority I and II approaches to restore a Rosgen C type channel. In this area, pattern adjustment was incorporated into the design to move the stream away from the toe of a steep hill. A Priority I/ II restoration approach will be used and a Rosgen C stream type will be constructed in this lower section of UT3. Invasive vegetative species removal efforts and native reforestation of the riparian buffer will further enhance restoration efforts within the watershed.

## 5.2 Design Criteria Selection

Selection of natural channel design criteria is based on a combination of approaches including review of reference reach databases, regime equations, and evaluation of results from past projects, as discussed in Section 2.5.

Selection of a general restoration approach was the first step in selecting design criteria for the streams on the Meredell Farms site. The approach was based on each reach's potential for restoration as determined during the site assessment. After selection of the general restoration approach, specific design criteria were developed so each reach's plan view layout, cross-section dimensions, and profile could be described for the purpose of developing construction documents.

Two separate stream and valley conditions are present on the project site. UT1a, UT2a and UT3a are considered to be high-slope colluvial systems. UT1b, UT2b, and UT3b as well as UT4, UT5 and M1 are all considered low-slope alluvial systems. These groups will be discussed below as opposed to individual reaches due to the fact that similar design criteria were selected for all reaches within each group.

### 5.2.1 Reference Reach Survey

A reference reach search was conducted in the area surrounding the site. The search of this area revealed no reference reaches of suitable quality for design use. General land use in the area surrounding the project site consists of low concentration residential and agricultural. Streams in the area have generally been straightened and channelized during the conversion of land to agriculture or the development of residential areas. This is believed to be the primary reason why no reference reach could be found near the site.

### 5.2.2 Reference Reach Database

A reference reach database, developed by the NCDOT, was consulted for design parameter selection. Three reference reach datasets were selected from the database. These datasets were selected for their proximity to the project as well as the stream types they represent. All three reference reaches are located in Randolph County and are classified as Rosgen E stream types. Though streams within the project were designed to be Rosgen C stream types with w/d ratios of 12, it is expected that some reaches will narrow to E channels over time. Designing for C streams helps reduce stress on newly constructed meander bends.

The West Branch to Tibbs Run has a drainage area of 1.08 $mi^2$ and is representative of an E5 stream type. A tributary to Sandy Creek and a tributary to Fork Creek were found that are representative of E4 stream types. These tributaries have drainage areas of 0.97 and 0.19 square miles respectively. Though these streams have larger drainage areas than the streams on Meredell Farm, they are still representative of smaller stream systems. Pattern data was available for West Branch of Tibbs Run and Tributary to Sandy Creek. The meander length ratio and radius of curvature ratio were within the ranges used in the design. The meander width ratio on both reference reaches were slightly higher then that used in the design. Using the meander width ratio from these reference reaches would place greater stress on the outside of newly constructed meander bends. This could lead to erosion and instability. In addition, the valley is too confined to use these ratios. Professional judgment and past experience was used to develop an appropriate ratio for this part of the design. Data from these three reference reaches, considered in the design criteria selection, are shown in Appendix C.

### 5.2.3 Design Criteria Selection Method

As described above, specific design parameters were developed using a combination of reference reach data, past project experiences, and best professional judgment. Dimensionless ratios from an internal reference reach database were also used to develop the design values. The design philosophy at the Meredell Farms site was to use average values for the selected stream types and to allow the extremes to form over time under the processes of flooding, re-colonization of vegetation, and geologic influences.

## 5.3 Design Criteria for the Meredell Farms Site

After examining the assessment data collected at the site and exploring the site's potential for restoration, an approach to the stream restoration was developed. First, an appropriate stream type for the valley type present at the site was selected. The design stream types were further refined based on the channel evolution sequence exhibited by the stream after examination of existing conditions survey data and other field observations, as well as conditions observed on reference streams under similar conditions. Available belt width and channel incision were considered, as well. The proposed stream types for the project are summarized in Table 5.3.1.

**Table 5.3.1 Project Design Stream Types**

| Reach | Proposed Stream Type | Rationale |
|---|---|---|
| UT1a | n/a | The stream bed lacks stability and bedform diversity. Enhancement of the reach will be accomplished by installing in-stream structures to improve habitat and protect against incision, and by establishing adequate vegetation in the stream side buffer zone. |
| UT1b | C | The reach is exhibiting an E-G-F-C-E evolution sequence. Priority I / Priority II restoration will return the reach to its original stream type with a functioning floodplain on the abandoned floodplain terrace. The Priority II section will be used to tie UT1a into the Priority I restoration downstream. |
| UT2a | n/a | The stream bed is moderately stable and bedform diversity is fair for a step pool type of stream. Enhancement of the reach will be accomplished by installing in-stream structures to improve habitat and protect against incision, and by establishing adequate vegetation in the stream side buffer zone. |
| UT2b | C | The reach is exhibiting an E-G-F-C-E evolution sequence. Priority I / Priority II restoration will return the reach to its original stream type with a functioning floodplain on the abandoned floodplain terrace. The Priority II section will be used to tie UT2a into the Priority I restoration downstream. |
| M1 | C | The reach is exhibiting an E-G-F-C-E evolution sequence. Priority I / Priority II restoration will return the reach to its original stream type with a functioning floodplain on the abandoned floodplain terrace. The Priority II section will be used to transition from the Priority I section upstream into Sandy Creek at the downstream end of the reach. |
| UT3a | n/a | The stream bed is moderately stable and bedform diversity is fair. Enhancement of the reach will be accomplished by establishing adequate vegetation in the stream side buffer zone. In the downstream portion of the reach, the stream bed is moderately stable and bedform diversity is fair. Enhancement of the reach will be accomplished by installing structures to stabilize eroding bank areas, and by establishing adequate vegetation in the stream side buffer zone. |
| UT3b | C | The reach is exhibiting an E-G-F-C-E evolution sequence. Priority I / Priority II restoration will return the reach to its original stream type with a functioning floodplain on the abandoned floodplain terrace. UT3b will transition into the main channel of the DA stream/wetland complex located at its confluence with UT5. |
| UT4 | n/a | In the upper portion of the reach, the stream bed is moderately stable and bedform diversity is fair. Enhancement of the reach will be accomplished by establishing adequate vegetation in the stream side buffer zone. In the lower portion of the reach, the stream is exhibiting a tendency to incise, moving toward a condition of decreasing stability. Grade control structures will be installed along the lower portion of the reach to protect against downcutting and adequate vegetation will be established in the stream side buffer zone. |
| UT5 | n/a | While the upper portions of the reach are moderately stable, the lower portions are exhibiting signs of incision. Grade control structures will be installed along the lower portions of the reach to protect against downcutting, and areas of active bank erosion stabilized. A stream site buffer zone will be established by establishing adequate vegetation. |
| M2 | n/a | Stream is in a stable condition with an adequate riparian buffer. Stream will be protected through a conservation easement. |

# 6 Restoration Design

## 6.1 Restoration Approach

The primary objective of the restoration design is to construct streams with a stable dimension, pattern, and profile that have access to their floodplain at bankfull flows. As discussed in the previous section, two separate stream and valley conditions are present on the project site. Reaches UT1b, the lower half of UT2a, UT2b, UT3, M1, and M2 are all considered relatively low slope alluvial systems. The upper half of UT2a and reaches UT3 and UT4 are considered to be higher slope colluvial systems. The reaches will be grouped for design criteria discussion based on these two conditions. The proposed design includes the following elements:

- Lower Slope Alluvial Reaches
  - UT1b – a Priority I/II restoration approach will be used to restore a C stream type below the valley constriction.
  - UT2b – the reach will be restored to a C stream type.
  - UT3b – the reach will be restored to a C stream type.
  - UT4 – a Priority IV enhancement approach will be used to enhance the stream.
  - UT5 – a Priority IV enhancement approach will be used to enhance the stream.
  - M1 – the reach will be restored to a C stream type.
  - M2 – the reach will be preserved.

- Higher Slope Colluvial Reaches
  - UT1a – a Priority IV enhancement approach will be used to enhance the stream.
  - UT2a – a Priority IV enhancement approach will be used to enhance the stream.
  - UT3a – a Priority IV enhancement approach will be used to enhance the stream.
  - Project-wide planting and preservation of the riparian zone. A conservation easement has been obtained to permanently protect the restoration area.

Preliminary plans for the Meredell Farm Stream Restoration project are attached. Details of the design are discussed in the following sections.

## 6.2 Water Quality Improvement Area

Reach UT2 captures runoff from the area of the farm where dairy cattle production is most intense. Runoff from this area, as well as some effluent from the cattle houses, is captured in a constructed farm pond. Reach UT2 begins as discharge from the outlet pipe of the farm pond. The nutrient and pollutant content of this water is of concern. Additionally, the pipe discharges the water at more than 10 feet in the air causing erosion of the area. Water quality can be improved if this discharge were to be retained, at least for a short period of time, and passed through a stand of wetland vegetation. It is proposed that a series of step-pools be constructed at the discharge location of the farm pond. These step-pools will create shallow pools of water that would support emergent wetland vegetation. The vegetation would slow the flow of water, trap sediment, and take up excess nutrients. The purpose of the step-pool system is to provide for an improvement in the water quality. The design calls for minor excavation of the area, working with the existing topography, to create low berms with rock spillways. The rock spillways prevent headcut, as well as a means of aerating the water as it flows over the rock. The final berm discharges the water onto a large, naturally occurring, bedrock outcropping.

## 6.3 Design Rationale (Channel Dimension, Pattern, and Profile)

### 6.3.1 Low Slope Alluvial Reaches

All the low slope alluvial reaches have very similar geomorphic conditions. Because the reaches are similar in terms of slope and valley type, similar design ratios will be used for all reaches.

The stream banks are unstable along sections of all project reaches because the channels are incising, riparian vegetation has been removed, and/or cattle have frequently trampled and eroded the banks. Stable cross-sections will be achieved by constructing channels with appropriate area and width/depth ratios based on reference reach information, regime equations, and past project experience. Sinuosity will be increased by adding meanders to lengthen the channel where appropriate. Grade control in the stream bed will be provided by in-stream structures such as constructed riffles and cross vanes. These in-stream structures will also help to improve bedform diversity.

#### *6.3.1.1 Dimension*

The existing channel dimensions are generally unstable throughout the project area due to excessive velocities and shear stresses in the channels. A lack of dense and deep root structure from an intact woody riparian buffer has also led to instability throughout the project. To address the erosion in project reaches, the stream cross-section (dimension) will be adjusted in order to reduce velocities and near-bank shear stress. Rosgen C stream types with w/d ratios of 12 will be created in the lower sections of UT1, UT2, UT3 and throughout M1. It is expected that some reaches will narrow to E channels over time. The ratio of low bank height to bank height (BHR) will be maintained at 1. In areas along the main channel where bank height might exceed bankfull stage because of localized topography or a low stream bed elevation, benches will be constructed at the bankfull stage. Once flood water rises above the bankfull stage, erosion-causing stress in the near bank region can be greatly reduced if the storm flow is able to spread out and slow down on a floodplain or a bench. Root wads, transplants, and log vanes will be used to provide bank protection at the outside of stream bends where necessary. Typical cross-sections are shown on the plan sheets and geomorphic design tables are provided in Appendix C.

#### *6.3.1.2 Pattern*

All existing channels through the Meredell Farm Stream Restoration are extremely straight ($k<1.1$). The proposed project will increase the sinuosity in all Priority I designed channels ($k\sim1.3$), adding hundreds of linear feet of stream in the process. Meander length ratios will range between 7 and 11 for all low slope alluvial streams. These more lengthy meanders will allow the channel to dissipate energy, thereby reducing erosion and increasing bedform diversity. Radius of curvature ratios will range from 2 to 3. Finally, the meander width ratio (MWR) of the stream will be increased as part of the restoration. Meander widths will be 3.5 to 8 times wider than bankfull width. Plan views of the main channel are shown on the plan sheets and geomorphic design parameters are provided in Appendix C.

#### *6.3.1.3 Profile/Bedform*

The existing channel profiles are generally unstable throughout. Several reaches are moderately to highly incised (UT1b, UT2b, UT4, UT5 and M1). There is very little diversity in the bedform of the existing channels – pools, riffles, glides, runs, etc. are nearly indistinguishable from each other in some sections. The stream restoration will include the construction of a riffle-pool stream bed, with additional habitat and diversity provided by constructed riffles, log-vanes and cross-vanes at certain locations. The in-stream structure locations are shown on the plan sheets.

### 6.3.2 High Slope Colluvial Reaches

All of the high slope, colluvial reaches are similar in terms of slope, valley type, geomorphic conditions. The stream banks on these reaches are unstable along sections and the channels are incising. Most of the vegetation has been removed from the riparian areas. Because of the confined valley types, restoration is not feasible and, therefore, enhancement approaches will be used for all of these reaches.

The existing channel dimensions are unstable in the high slope colluvial systems even though there is some dense and deep root structure from an intact woody riparian buffer on most stream sections. Bank height ratios are large enough (BHR>2.0) that stream banks are collapsing because of the excessive velocities generated during storm flows. To address the erosion and entrenchment in these reaches, steps and pools will be created by installing cross-vanes and log weirs. Constructed riffles will prevent headcut and root-wads will reduce bank erosion. All of these structures will also provide in-stream habitat. All high-slope colluvial streams are extremely straight (k~1.0). Stream pattern is used only to keep the channel in the low point of the valley. This configuration mimics the pattern of natural B stream types. The valley type for UT4 transitions several times along the reach between a Type II colluvial valley and Type VII alluvial valley. This variability in valley type is reflected in the proposed stream design. The proposed channel realignment varies between a low sinuosity, step pool system and a highly sinuous, alluvial stream using the same design ratios discussed for alluvial streams. The transitions between the two channel types follow the changes in valley type. Proposed plan views of all reaches are shown on the plan sheets.

The profiles of all high slope colluvial streams at the Meredell Farm Stream Restoration site are highly unstable due to the loss of riparian vegetation and cattle traffic. There is very little diversity in the existing channel bedforms – pools, riffles, glides, runs, etc. are nearly indistinguishable in most cases. An enhancement approach is provided with the incorporation of cross-vanes and constructed riffles to provide additional grade control and to improve bedform diversity. Structure locations are shown on the plan sheets.

## 6.4 Stream Preservation

### 6.4.1 Existing DA Stream/Wetland Preservation System

Reaches UT3 and UT5 flow into an area that would meet the ACOE criteria for jurisdictional wetlands. As these reaches enter the stream/wetland complex the channels are not incised and become less defined with multiple, interconnected side channels. This system would be a DA stream type according to the Rosgen classification system. The system is stable due to cohesive bank materials with dense root mass and extensively developed wetland vegetation. It is proposed that UT3b transition into the main channel of the DA stream following restoration. This system has been designated M2 and continues down valley to Sandy Creek. Reach M2 will be preserved within a conservation easement as a component of the mitigation plan, as shown on plan sheet 18.

### 6.4.2 Sandy Creek Preservation

There are three locations where Sandy Creek flows on the Meredell Farm project site. Each of these locations (SC1, SC2 and SC3 shown on Exhibit 3.1) will be preserved within a conservation easement as a component of the mitigation plan. Reach SC3 encompasses only one bank of Sandy Creek. Preservation reaches are shown on plan sheet 18

## 6.5 Sediment Transport

### 6.5.1 Capacity Analysis

The lower halves of UT2 ($D_{50}$=0.66 mm) and UT3b ($D_{50}$=1.0 mm) have median particle sizes that result in their classification as sand bed streams. Due to the need to transport this volume of material, sediment transport capacity is considered more important than competency for these reaches. Shear stress and stream power are calculated for these reaches and compared with average values for similar stream types (Nanson and Croke, 1992).

Sediment transport capacity, measured as unit stream power ($W/m^2$), was compared for the existing stream channel and the design conditions for the lower halves of UT2 and UT3b. Table 6.5.1 shows bankfull boundary shear stress and stream power values for existing and design conditions. Stream power values for the existing and design conditions all compare well to values for similar streams and valley types described in Nanson and Croke (1992). According to their classification system, all channels are classified as B3c valley types (sand, organic, and silt bed streams in wide alluvial valleys). The range of stream powers for the B3c valley type in the Nanson and Croke study is 10 to 60 $W/m^2$. Calculated stream power values for all project sandbed streams fall within this range.

**Table 6.5.1 Boundary Shear Stresses and Stream Power for Existing and Design Conditions for UT2 and UT3b**

| Parameter | Value (Existing/Design) | |
|---|---|---|
| | UT2 | UT3b |
| Bankfull Q (cfs) | 13.0 / 13.0 | 20.4 / 20.4 |
| Bankfull Area (sq ft) | 4.2 / 4.5 | 7.3 / 8.0 |
| Bankfull Width, W (ft) | 6.7 / 7.3 | 10.5 / 9.8 |
| Bankfull Mean Depth, D (ft) | 0.6 / 0.6 | 0.7 / 0.8 |
| Width to Depth Ratio, W/D (ft/ft) | 10.6 / 12.0 | 15 / 12.0 |
| Wetted Perimeter | 8.0 / 8.5 | 11.9 / 11.4 |
| Hydraulic Radius, R (ft) | 0.5 / 0.5 | 0.6 / 0.7 |
| Slope (ft/ft) | 0.0171 / 0.0134 | 0.0101 / 0.0081 |
| Boundary Shear Stress, $\tau$ ($lbs/ft^2$) | 0.565 / 0.439 | 0.403 / 0.336 |
| Stream Power ($W/m^2$) | 31.1 / 20.9 | 18.4 / 14.7 |

### 6.5.2 Competency Analysis

An evaluation of channel competency was performed for the lower half of UT1 and reach M1 using procedures outlined in Section 2.6.1. For each reach one pavement/subpavement sample and one 100-count sample were collected. Data presented in Appendix C were used to determine particle sizes for the various calculations. Values for both reaches are presented together in this section in the order of M1 and UT1. Critical dimensionless shear stress was calculated for the existing and design reaches as $t^*_{ci}$ = 0.0326 and 0.0170 respectively for the order of reaches listed above. These values of dimensionless shear stress are used in the aggradation analysis presented below.

Using existing slopes and the subpavement $D_{100}$ particle sizes, Equation 3 indicates a required depth of 0.7 and 0.2 feet, respectively. These required depth values are consistently lower than the actual depths of 1.0 and 0.6 feet, meaning that the existing depths are more than sufficient to transport the larger materials and prevent aggradation. Using design slopes and the subpavement $D_{100}$ particle sizes, Equation 3 indicates a required depth of 0.8 and 0.6 feet, respectively. These required depth values are equal to the design depths of 0.8 and 0.6 feet meaning that the design depths are sufficient to transport the larger materials and prevent aggradation.

The boundary shear stress and measured $D_{100}$ subpavement particle sizes were plotted on the Modified Shield's Curve (Figure 2.6.1) for existing and design conditions for both reaches. The shear stress value and the measured $D_{100}$ particle size for UT1 is within the range of values used to calculate the regression equation. The Shield's Curve analysis supports the critical depth based conclusion that the design cross-sections can move sediment competently and prevent aggradation. The shear stress values and the measured $D_{100}$ particle size for M1 plotted slightly below the range of values used to calculate the regression equation for the Modified Shields Curve, but fall between the modified and original curve.

The required slope was calculated using Equation 4 and compared to the design slope for both reaches. The required and design slopes were approximately equal for both reaches meaning that the design slopes are sufficient to transport the larger materials and prevent aggradation.
The calculated shear stress can be used to describe the upper competency limits for the design channel as discussed in Section 2.7.4. The estimated boundary shear stress was 0.54 lbs/ft$^2$, and 0.26 lbs/ft$^2$ respectively. Based on the Modified Shield's Curve (Figure 2.6.1), the shear stress value calculated for UT1 will move particles up to about 50 mm in size, which corresponds roughly to a particle size between the D84 and the D95 from the reach-wide pebble count sample. The shear stress value calculated for M1 will move particles up to about 130 mm in size. This value is slightly larger than the $D_{84}$ calculated from the reach wide pebble count; however, in-stream structures and will control grade throughout the reach. A summary of the existing condition and design competency values is shown in Table 6.5.2.

**Table 6.5.2 Existing Condition and Design Sediment Competency Values**

| Shear Stress Analysis | M1 Existing/Design | UT1 Existing/Design |
|---|---|---|
| Bankfull Xsec Area, Abkf (sq ft) | 6.3 / 8.6 | 5.9 / 4.5 |
| Bankfull Width, Wbkf (ft) | 6.4 / 10.2 | 10.6 / 7.3 |

**Table 6.5.2 Existing Condition and Design Sediment Competency Values**

| Shear Stress Analysis | M1 Existing/Design | UT1 Existing/Design |
|---|---|---|
| Bankfull Mean Depth, Dbkf (ft) | 1.0 / 0.8 | 0.6 / 0.6 |
| Wetted Perimeter, WP=W+2D (ft) | 8.4 / 11.8 | 11.8 / 8.5 |
| Hydraulic Radius, R (ft) | 0.8 / 0.7 | 0.5 / 0.5 |
| Schan (ft/ft) | 0.0130 / 0.0119 | .0258 / .0079 |
| Boundary/Bankfull Shear Stress, $\tau$ (lb/sq ft) | 0.61 / 0.54 | 0.81 / 0.26 |
| $D_{50}$ 100 ct/pavement (mm), $D_{50pve}$ | 20.59 | 19.98 |
| $D_{50}$ (mm) - bar sample/subpavement, $D_{50subpve}$ | 7.01 | 12.0 |
| ratio – $D_{50pve}$ / $D_{50subpve}$ | 2.94 | 1.67 |
| ratio – di/ $D_{50pve}$ | 2.53 | 2.50 |
| $\tau$ *ci | 0.0326 | 0.0170 |
| D100 subpavement (mm) | 52 | 50 |
| d bar large (ft) | 0.17 | 0.16 |
| Dcrit (ft) | 0.7 / 0.8 | 0.2 / 0.6 |
| Scrit | 0.0092 / 0.0115 | 0.0082 / 0.0077 |

## 6.6 In-Stream Structures

A variety of in-stream structures are proposed for the Meredell Farm Stream Restoration site. Structures such as root wads, constructed riffles, and log vanes will be used to stabilize the newly-restored stream. Table 6.6.1 summarizes the use of in-stream structures at the site.

**Table 6.6.1 In-Stream Structure Types and Locations**
***Meredell Farm Stream Restoration Plan***

| Structure Type | Location |
|---|---|
| Root Wad | UT1, UT2, UT3b, UT5, and M1 |
| Cross Vane | UT1, UT2, UT4, and M1 |
| Constructed Riffle | UT1, UT2, UT3b, and M1 |
| Log Vane | UT1, UT2, UT3b and M1 |
| Log Weir | UT3b, UT4 and UT5 |

### 6.6.1 Root Wad

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

### 6.6.2 Cross Vanes

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

### 6.6.3 Constructed Riffle

A constructed riffle consists of the placement of coarse bed material in the stream at the specific riffle locations along the profile. A buried log or rock weir at the upstream and downstream end of each riffle will control the slope through the riffle. The purpose of this structure is to provide grade control and improve riffle habitat. In the higher slope reaches, the constructed riffles and cross vanes are often intermixed to provide diversity of structure and in stream habitat.

### 6.6.4 Log Vane

A log vane is used to protect the stream bank and enhance aquatic habitat. The length of a single vane structure can span 50 to 70 percent the bankfull channel width. Vanes are located just downstream of the point where the stream flow intersects the bank at an acute angle in a meander bend. Log vanes will be placed in the larger, low slope channels on the project site.

### 6.6.5 Log Weir

A log weir consists of placing header and footer logs in the bed of the stream channel, perpendicular to the stream flow. The logs extend into the streambanks to prevent erosion and bypassing of the structure. The logs are flush with the channel bottom upstream of the log and designed to prevent pooling upstream. Footer logs are placed to the depth of scour to prevent undermining of the structure. Although a pool is often excavated during installation, they will typically form naturally downstream of the structure. Log weirs provide bed form diversity, maintain channel profile, and provide pool and cover habitat.

## 6.7 Vegetation

The vegetative components of this project include stream bank, floodplain, wetland (water quality improvement area), hillslope planting, and invasive species removal. In addition, any areas of the site that are disturbed, lack diversity, or might be adversely impacted by the construction process, will be replanted.

### 6.7.1 Stream Bank and Floodplain Re-Vegetation

The stream banks and the adjacent riparian area will be planted with both woody and herbaceous vegetation as shown on the attached plan sheets. Any stream banks with a slope of 2:1 or greater will be vegetated using live-stake or bare-root planting techniques. A buffer of woody and herbaceous species will be planted within the conservation easement limits. A schedule of plants for use on this project is shown in Table 6.7.1.

**Table 6.7.1 Plant Schedule**
*Meredell Farm Stream Restoration Plan*

| COMMON NAME | BOTANICAL NAME |
|---|---|
| **Riparian Buffer Plantings** | |
| **Trees** | |
| Sycamore | *Platanus occidentalis* |
| Willow oak | *Quercus phellos* |
| River birch | *Betula nigra* |
| Shagbark hickory | *Carya ovata* |
| Persimmon | *Diospyros virginiana* |
| **Shrubs/small trees** | |
| Pawpaw | *Asimina triloba* |
| Ironwood | *Carpinus caroliniana* |
| Witch-hazel | *Hamamelis virginiana* |
| Spicebush | *Lindera benzoin* |
| **Native Seed Mix for Stream Banks and Buffers** | |
| Fringed sedge | *Carex crinata* |
| River oats | *Chasmanthium latifolium* |
| Virginia wild rye | *Elymus virginicus* |
| Deertongue | *Panicum clandestinum* |
| **Woody Vegetation for Live Stakes** | |
| Silky willow | *Salix sericea* |
| Silky dogwood | *Cornus amomum* |
| Elderberry | *Sambucus canadensis* |

### 6.7.2 Invasive Species Removal

The stream reaches in subwatershed M1 have little or no riparian vegetation and invasive species do not present a problem along these reaches (UT1, UT2 and M1). The stream reaches in subwatershed M2 have moderately poor riparian buffers with little desirable riparian vegetation with invasive species presenting a significant problem (UT3, UT4, and UT5). Invasive species such as honeysuckle and privet are present in abundance. Mechanical, chemical, or hand removal of these invasive species will be a necessary part of the restoration effort. If these or other invasive species re-establish and persist more than three years after the stream restoration has been constructed, hand cutting and herbicide treatment will again be required.

# 7 Monitoring and Evaluation

Channel stability and vegetation survival will all be monitored on the project site. Post-restoration monitoring will be conducted for five years following the completion of construction to document project success.

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

## 7.1 Stream Monitoring

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

### 7.1.1 Cross-Sections

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

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

### 7.1.2 Pattern

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

### 7.1.3 Longitudinal Profile

A complete longitudinal profile will be completed during the first year and then every two years over the course of a five-year period (for a total of three times). Measurements will include average channel slope, pool slope, riffle slope, and pool-to-pool spacing. Survey points will include thalweg, water surface, inner berm, bankfull, and top of bank. Each of these survey points will be taken at prescribed intervals and at the head of each feature: riffle, run, pool, glide, and the maximum pool depth location. The survey will be tied to a permanent benchmark.

The longitudinal profile data should show that the bedform features are remaining stable, and are not aggrading or degrading. The pools should remain deep with flat water surface slopes and the riffles should remain steep and shallow.

### 7.1.4 Photo Reference Sites

Digital photographs will be used to evaluate restored sites. There will be one photo reference site per cross-section showing both banks and the stream channel. Several of the in-stream structures (e.g., rock vanes, cross vanes, and root wads) will also be photographed. After construction is complete, photo reference sites will be marked with wooden stakes.

The stream will be photographed longitudinally beginning at the downstream end of the restoration site and moving upstream to the end of the site. Photographs will be taken looking upstream at delineated locations. Reference photo locations will be marked and described for future reference. Points will be close enough together to provide an overall view of the reach. Shot angles will be selected to provide the best view. Angles will be noted and will be maintained over time to the extent possible. When modifications to photo position must be made due to obstructions or other reasons, the new position will be noted along with any landmarks needed to identify the location.

Reference photo transects will also be taken at each permanent cross-section. Photographs will be taken of both banks at each cross-section. A survey tape will be centered in the photographs of the bank. The water line will be located in the lower edge of the frame and as much of the bank as possible included in each photo. Photographers should make an effort to consistently maintain the same area in each photo over time. Photos will show distinct treatment areas; for example, unique images if two different types of erosion control material are used. The detailed photo log will allow for future comparisons.

Photographs will be used to qualitatively evaluate channel aggradation or degradation, bank erosion, success of riparian vegetation, and effectiveness of in-stream structures and erosion control measures. Longitudinal photos should indicate the absence of developing bars within the channel or an excessive increase in channel depth. Lateral photos should indicate stable banks over time. A series of photos over time should indicate successional maturation of riparian vegetation. Vegetative succession should include initial herbaceous growth, followed by increasing densities of woody vegetation, and then ultimately a mature overstory with herbaceous understory.

## 7.2 Vegetation Monitoring

All woody vegetation will be flagged and evaluated for at least five years to determine survival rates. At least two staked survival plots shall be evaluated. Plots should include both live staked and other planted areas. Plots will be 25 feet by 100 feet and all flagged stems will be counted in those plots. Success of woody vegetation plantings will be defined as 320 stems per acre after five years. When woody vegetation does not survive, a determination will be made as to the need for replacement; in general, if greater than 25 percent die, replacement will be required.

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

## 7.3 Maintenance Issues

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

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

Maintenance issues and recommended remediation measures will be detailed and documented in the as-built and monitoring reports. Factors which may have caused any maintenance needs, including any of the conditions listed above, shall be discussed.

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## Exhibits

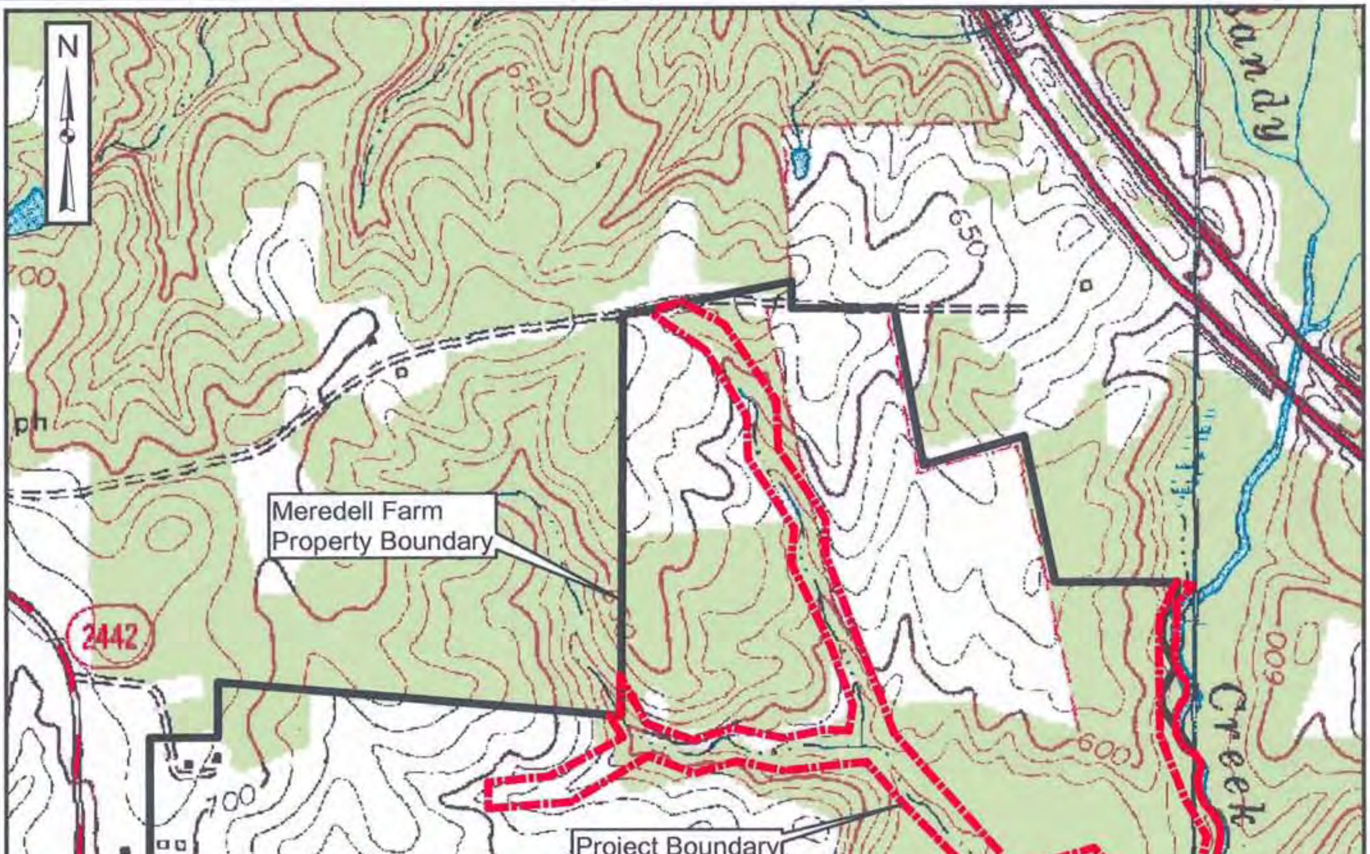



Exhibit 1.1. Project Vicinity Map

Ecosystem Enhancement Program

0 250 500 1,000 1,500 2,000 Feet

Randolph County

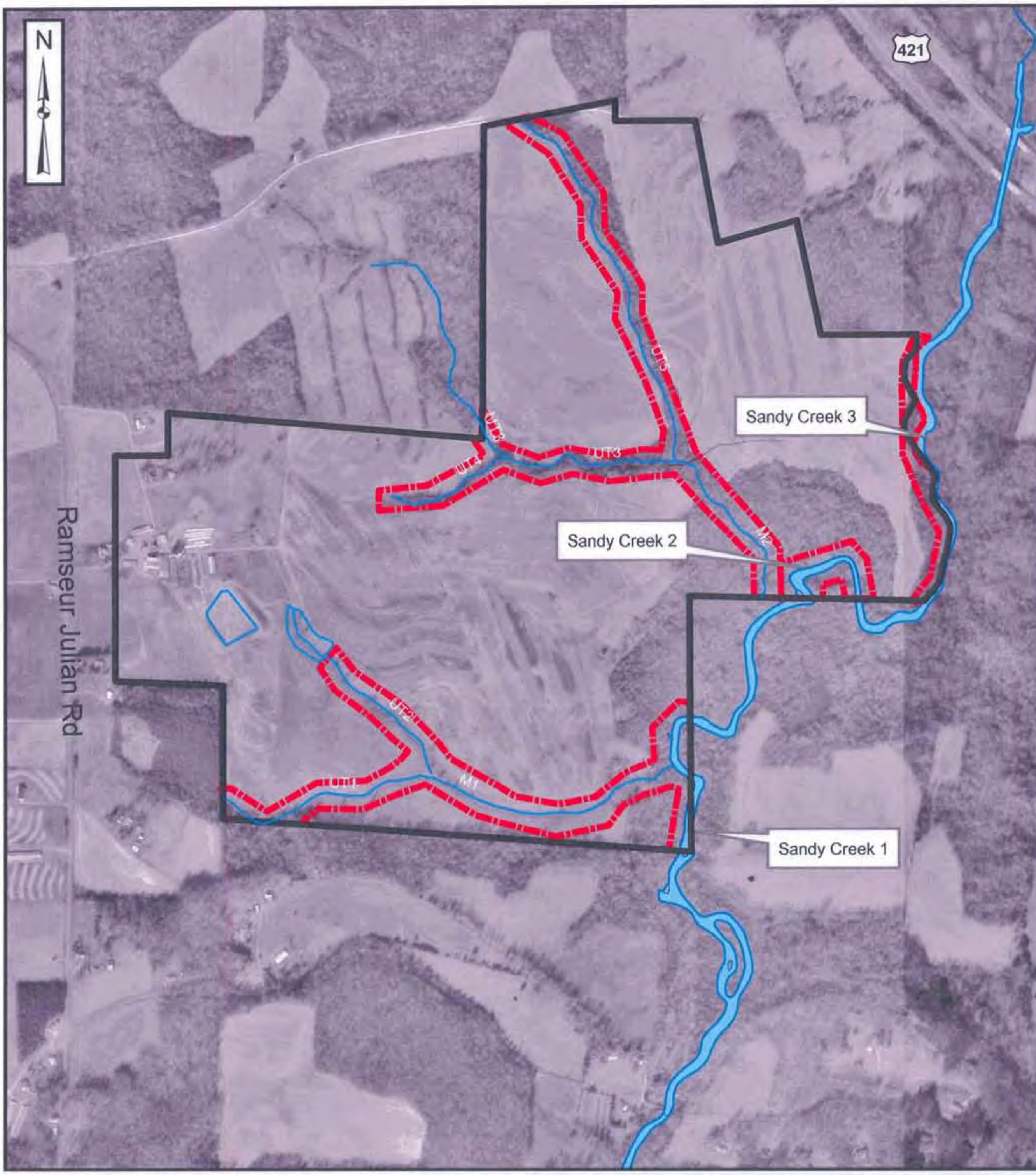


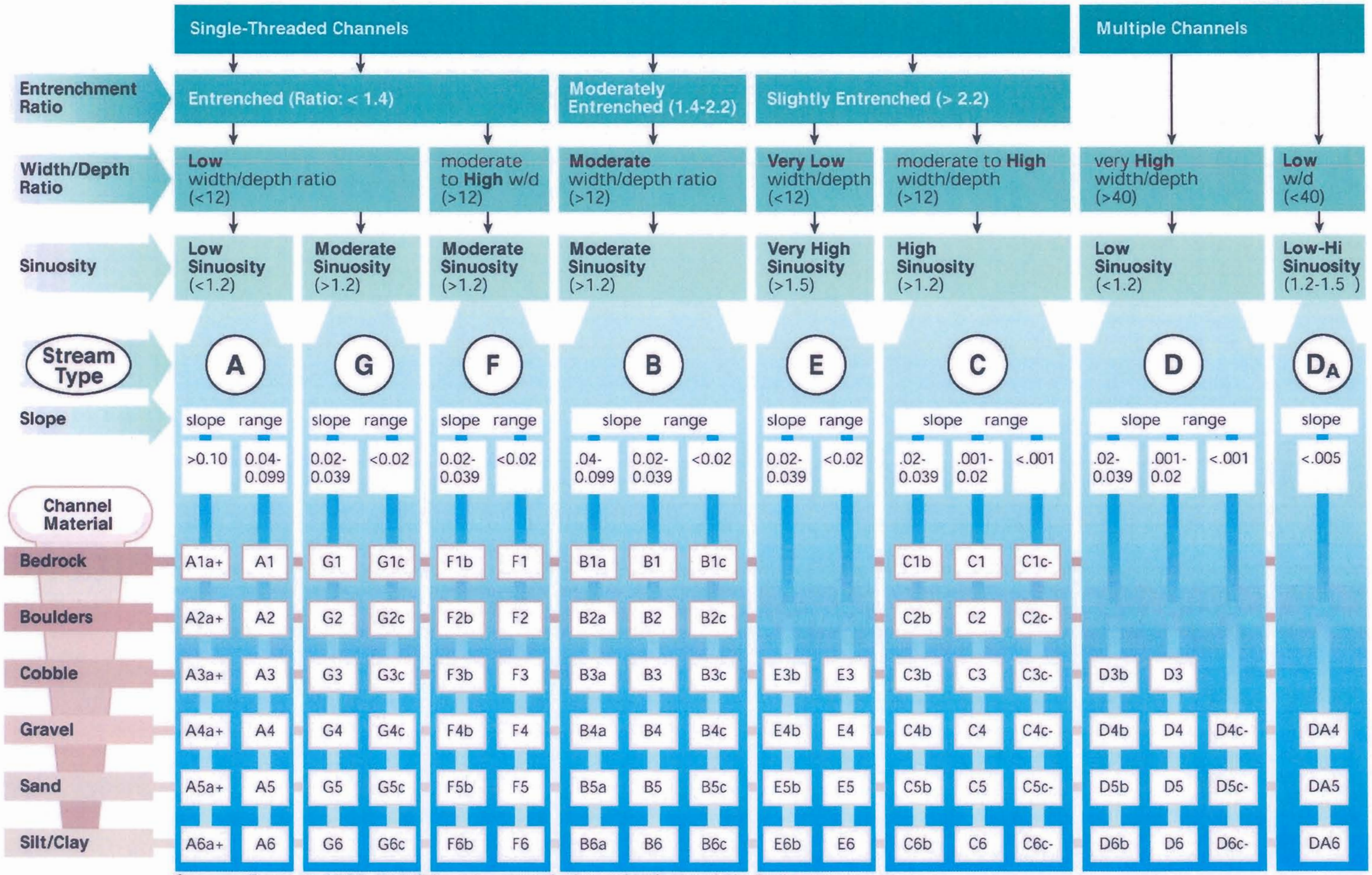

Exhibit 1.2. Site Hydrology

Ecosystem Enhancement Program

0 250 500 1,000 1,500 2,000 Feet

**Legend**

- Stream Reaches
- Property Boundary
- Easement Boundary

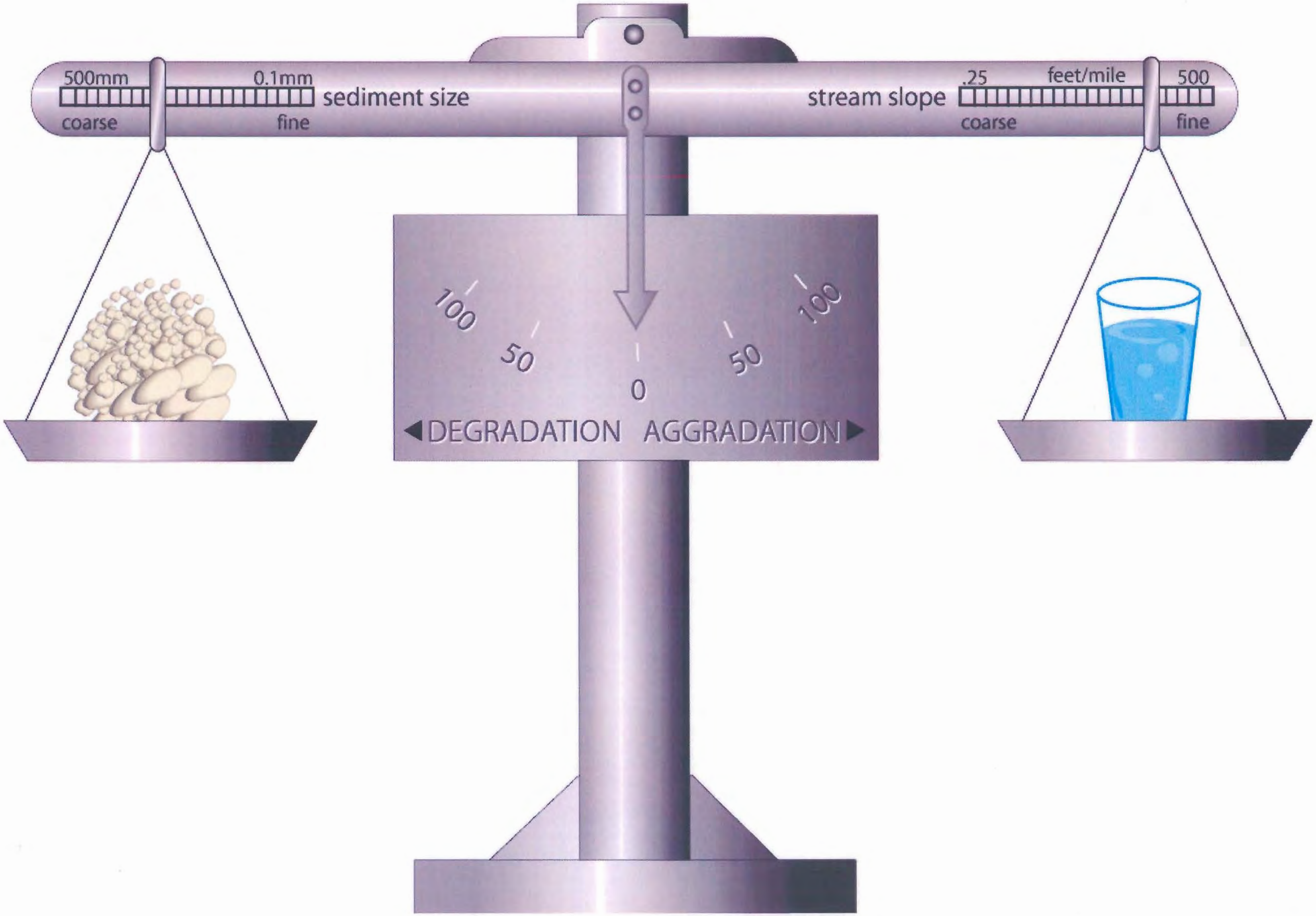



**Source: Rosgen 1996. Published by permission of Wildland Hydrology.**

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

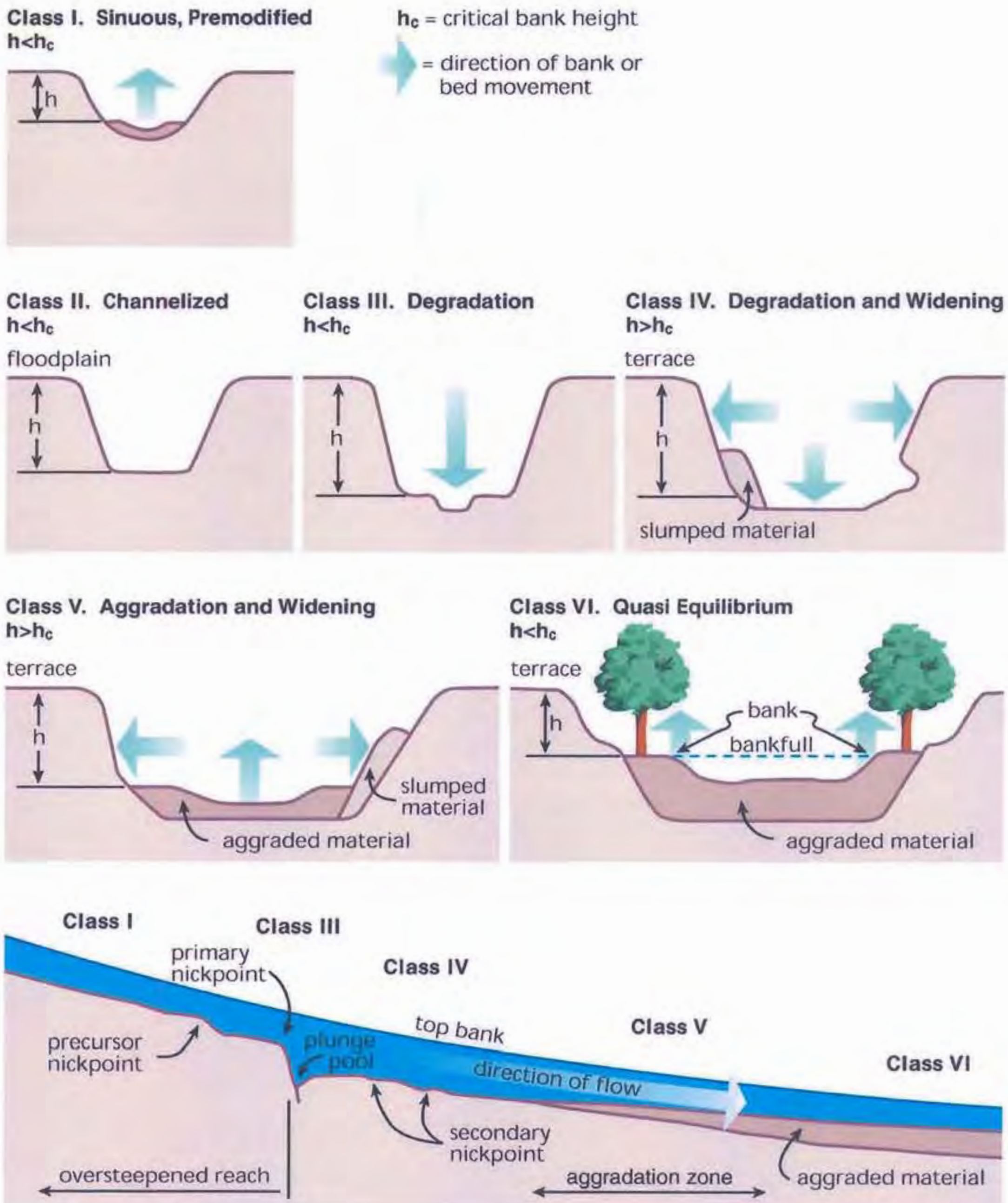
**Exhibit 2.1**
Rosgen Stream Classification
*Meredell Farm Restoration Plan*

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




After: Lane, 1955

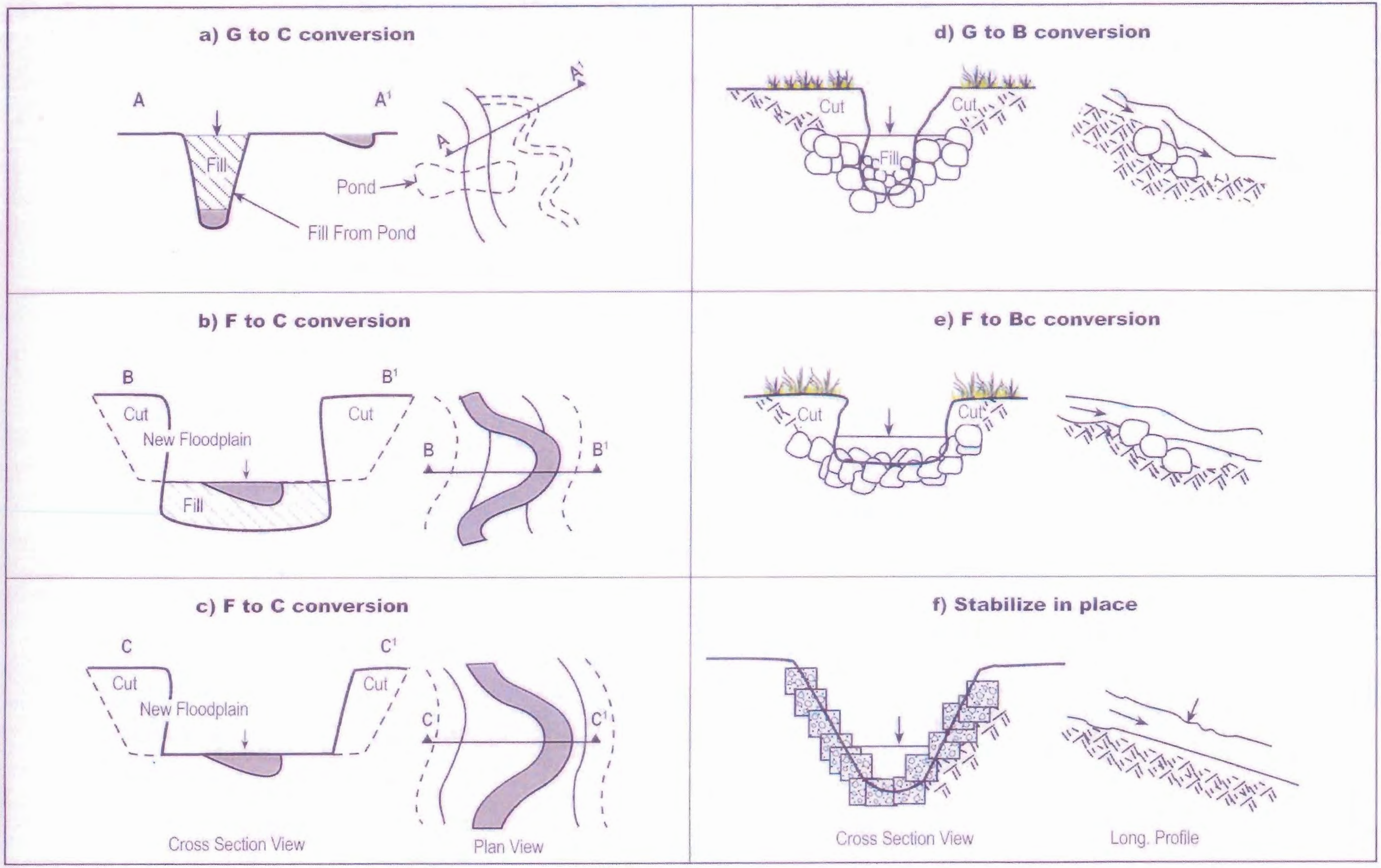
**Exhibit 2.2**
Factors Influencing Stream Stability
*Meredell Farm Restoration Plan*




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

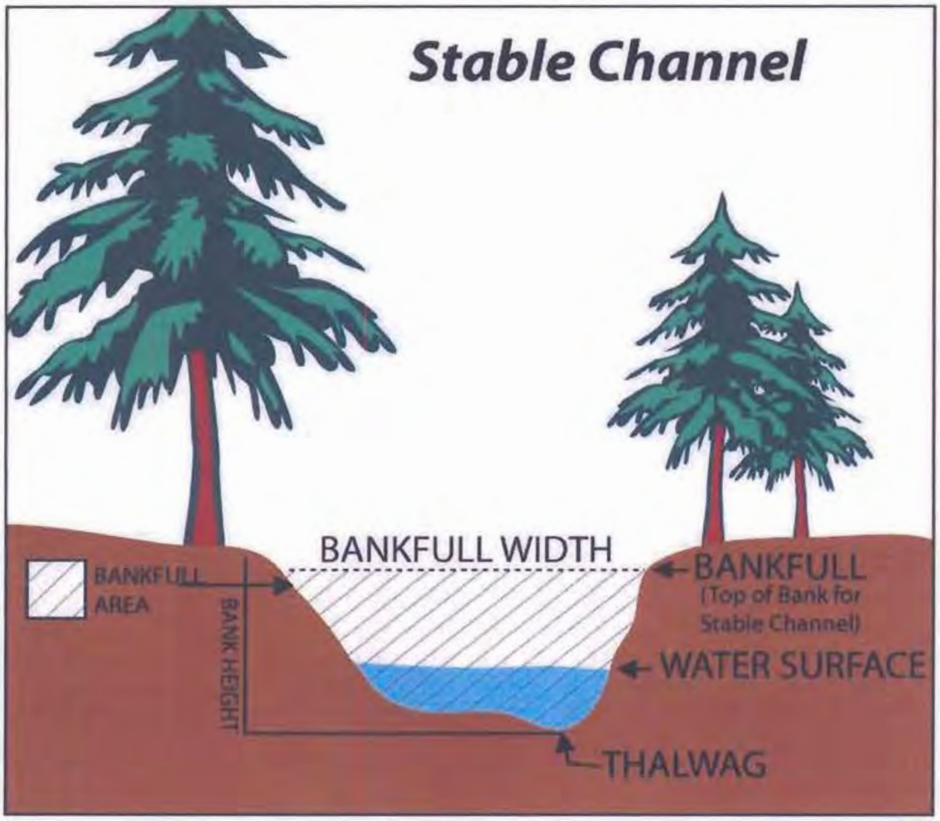
**Exhibit 2.3**
Simon Channel Evolution Model
*Meredell Farm Restoration Plan*

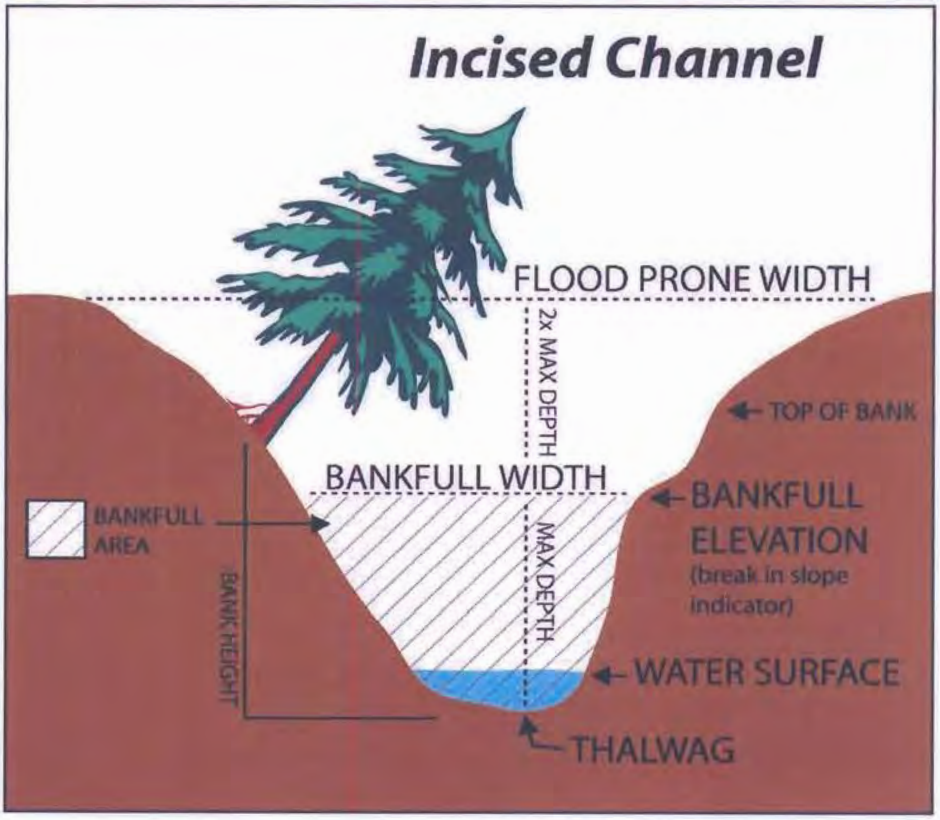
Source: Simon, 1989




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

**Exhibit 2.4**
Restoration Priorities for Incised Channels
*Meredell Farm Restoration Plan*




### *Channel Dimension Measurements*

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

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

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

Max depth (dmax): the deepest point within the cross-section measured to the bankfull elevation

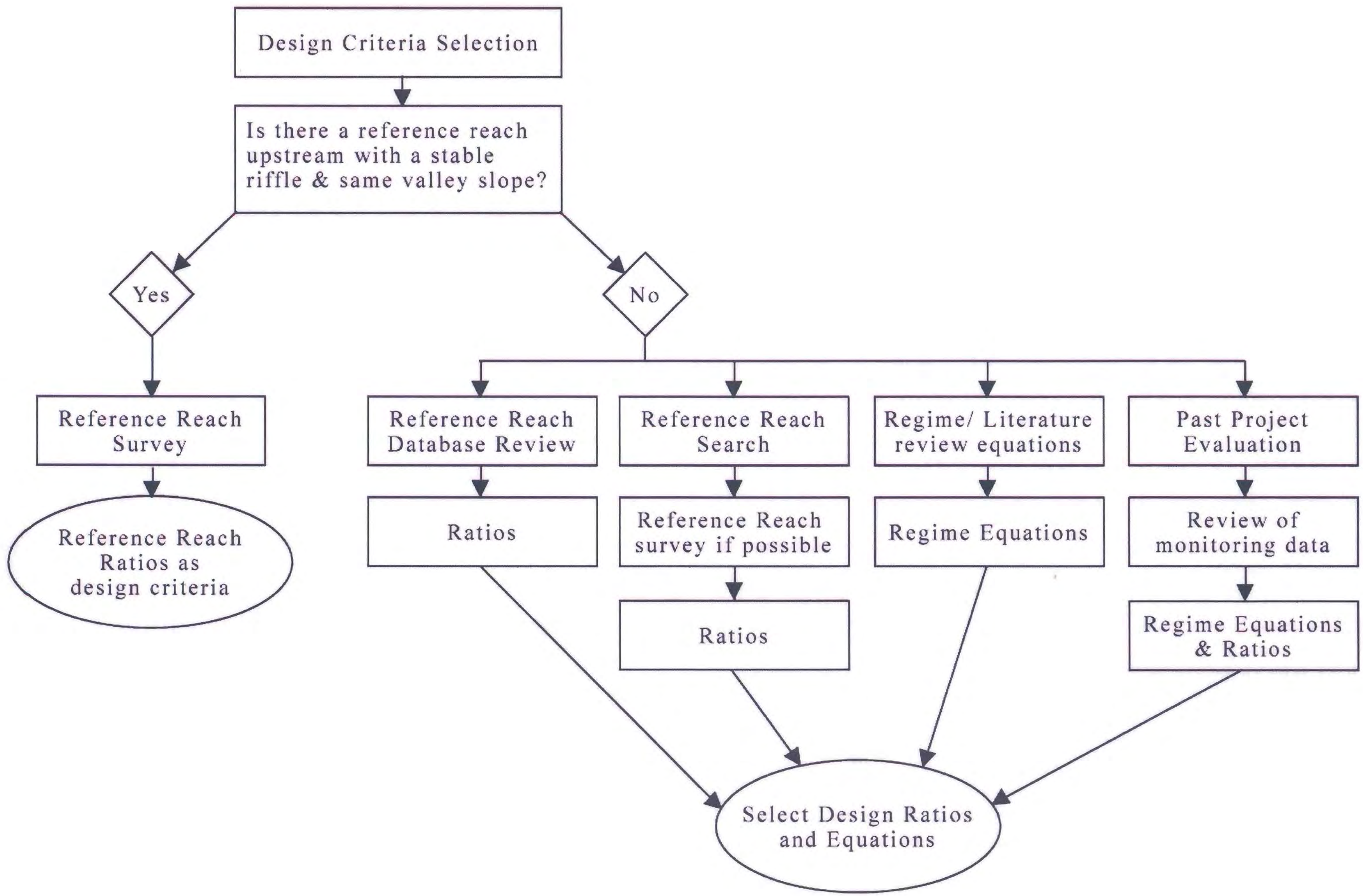
Width to Depth Ratio: Bankfull width ÷ Bankfull mean depth

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

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

Entrenchment Ratio: Floodprone width ÷ bankfull width

**Exhibit 2.5**
Channel Dimension Measurements
*Meredell Farm Restoration Plan*




BUCK ENGINEERING

**Exhibit 2.6**
Design Criteria Selection
*Meredell Farm Restoration Plan*

**Rootwads**

**Constructed Riffle**

**Rock Cross Vane**

**Exhibit 2.7**
Examples of Instream Structures
*Meredell Farm Restoration Plan*

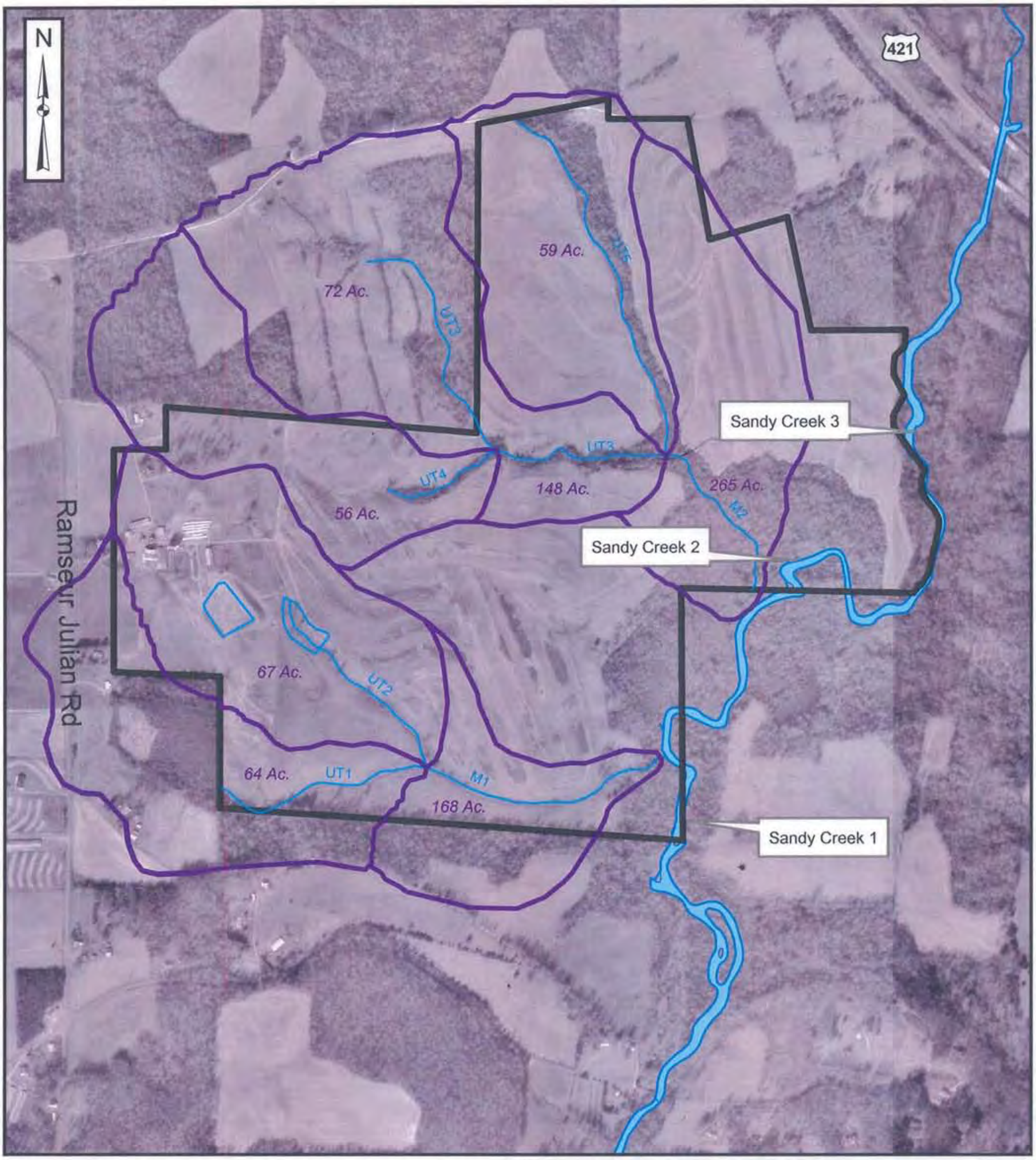



Exhibit 3.1. Watershed Boundaries

Ecosystem Enhancement Program

0 250 500 1,000 1,500 2,000 Feet

**Legend**

Stream Reaches

Watersheds

Property Boundary

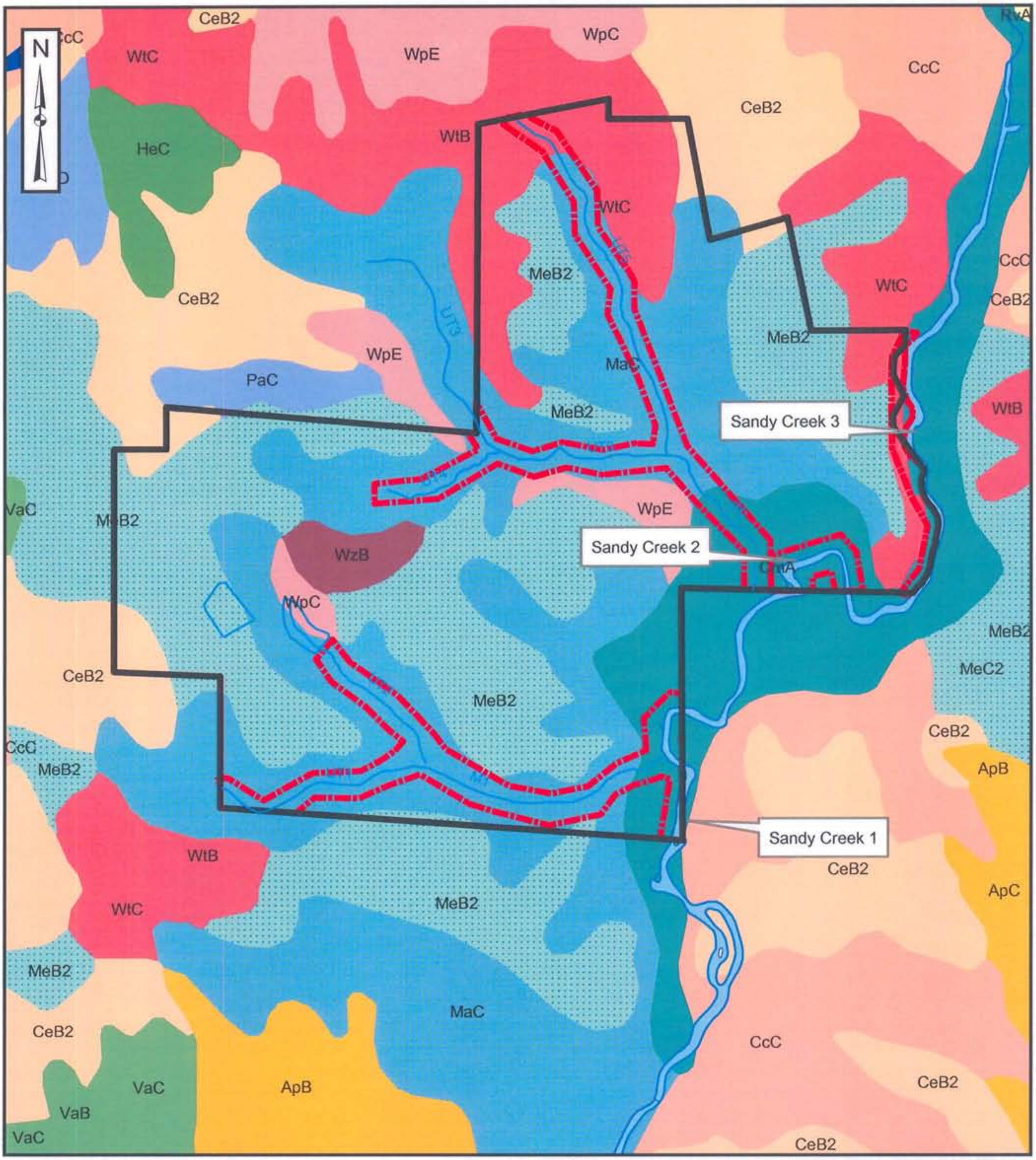



Exhibit 3.2. Project Soil Map

Ecosystem Enhancement Program

0 250 500 1,000 1,500 2,000 Feet

**Soil Name**

- Cecil Sandy Clay Loam (Me)-CeB2
- Cecil Sandy Loam-CcC
- Chewacla And Wehadkee (Ff)-CmA
- Helena Sandy Loam-HeC
- Mecklenburg Clay Loam-MeB2
- Mecklenburg Loam-MaC
- Water
- Pacolet Fine Sandy Loam-PaC
- Wilkes-Poindexter-Wynott-WpC,WpE
- Wynott-Enon-WtB,WtC
- Wynott-Wilkes-Poindexter-WzB
- Appling Sandy Loam-ApB,ApC
- Riverview Sandy Loam-RvA
- Vance Sandy Loam-VaB,VaC
- Easment Boundary
- Stream Reaches
- Property Boundary

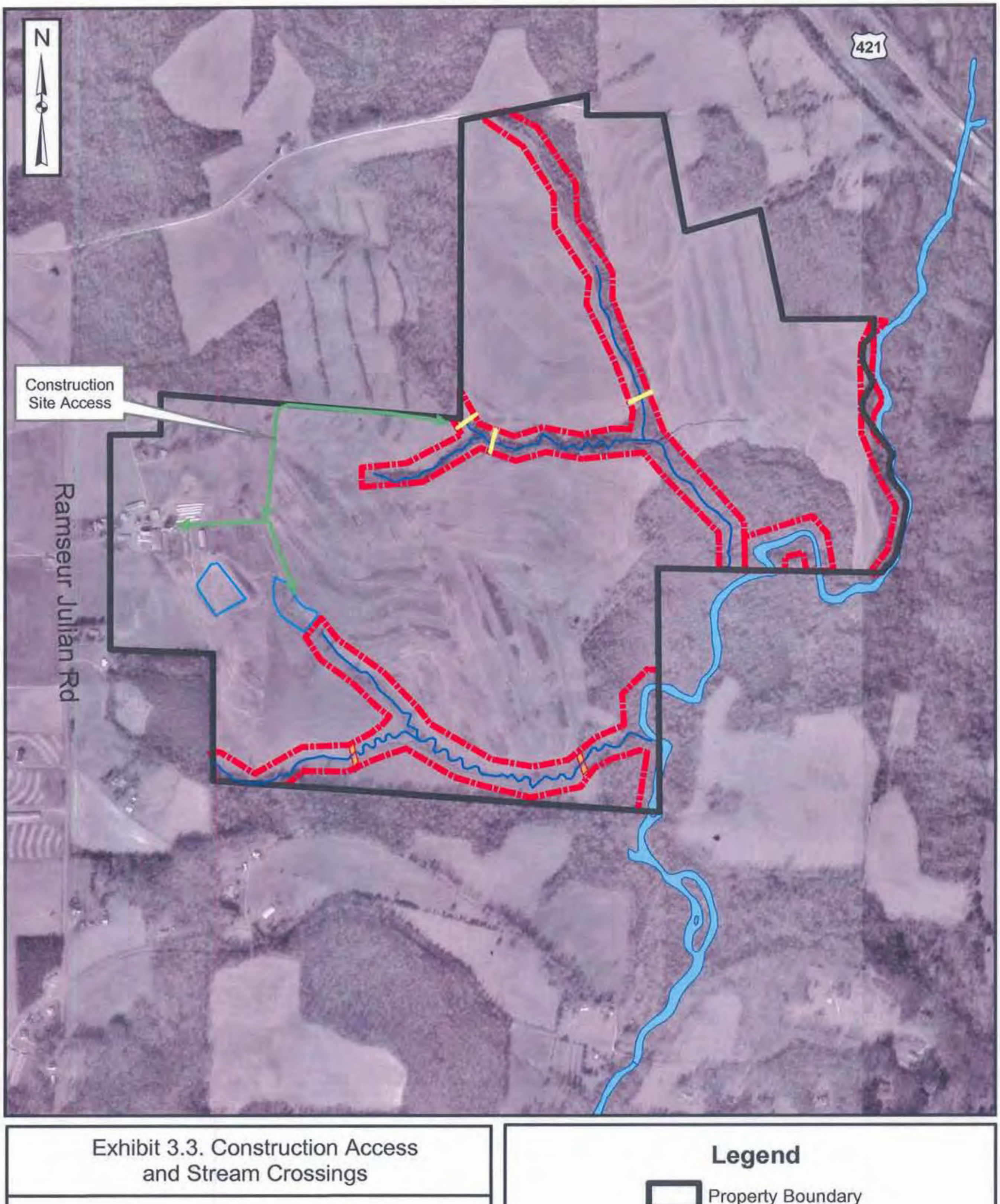



Exhibit 3.3. Construction Access and Stream Crossings

Ecosystem Enhancement Program

0 250 500 1,000 1,500 2,000 Feet

**Legend**

- Property Boundary
- Easement Boundary
- Proposed Ford Crossing
- Existing Culvert Crossing

# Appendix A

Cultural Resources Correspondence

History for All the People
1903 2003
North Carolina Office of Archives and History

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



Division of Historical Resources

December 16, 2003

Douglas Smith
Buck Engineering
8000 Regency Parkway, Suite 200
Cary, NC 27511

Re: Stream Restoration on Meredell Farm, Randolph County, ER03-3451

Dear Mr. Smith:

Thank you for your letter of November 19, 2003, concerning the above project.

With regard to archaeological resources, site 31RD965 is the only site located within 1 mile of the proposed project area. The National Register eligibility of this prehistoric site is unknown at present, but it is unlikely that this site will be affected by your undertaking.

Please forward specific project plans and a map indicating the area of potential effect (APE) for the stream restoration project when they are available so we may evaluate potential effects upon as yet unrecorded archaeological resources.

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

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

Sincerely,

Renee Gledhill-Earley
David Brook







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

## Appendix B

EDR Transaction Screen Map Report

# The EDR-Transaction Screen™ Map Report
## With Toxicheck/® Analysis

**Merdell Farms**
**Ramseur Julian Rd**
**Liberty, NC 27298**

**Inquiry Number: 01086101.1r**

**November 20, 2003**

Environmental Data Resources, Inc.

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

3530 Post Road
Southport, Connecticut 06890

**Nationwide Customer Service**

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

FORM-HOW

# TABLE OF CONTENTS

**SECTION** **PAGE**



**APPENDICES**



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

# TOXICHECK®

**Subject Property:** MERDELL FARMS
RAMSEUR JULIAN RD
LIBERTY, NC 27298

**Environmental Risk Code:** **LOW**

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

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

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

# EXECUTIVE SUMMARY

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

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

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

**QUESTION 21**

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

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

**QUESTION 22**

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

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

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

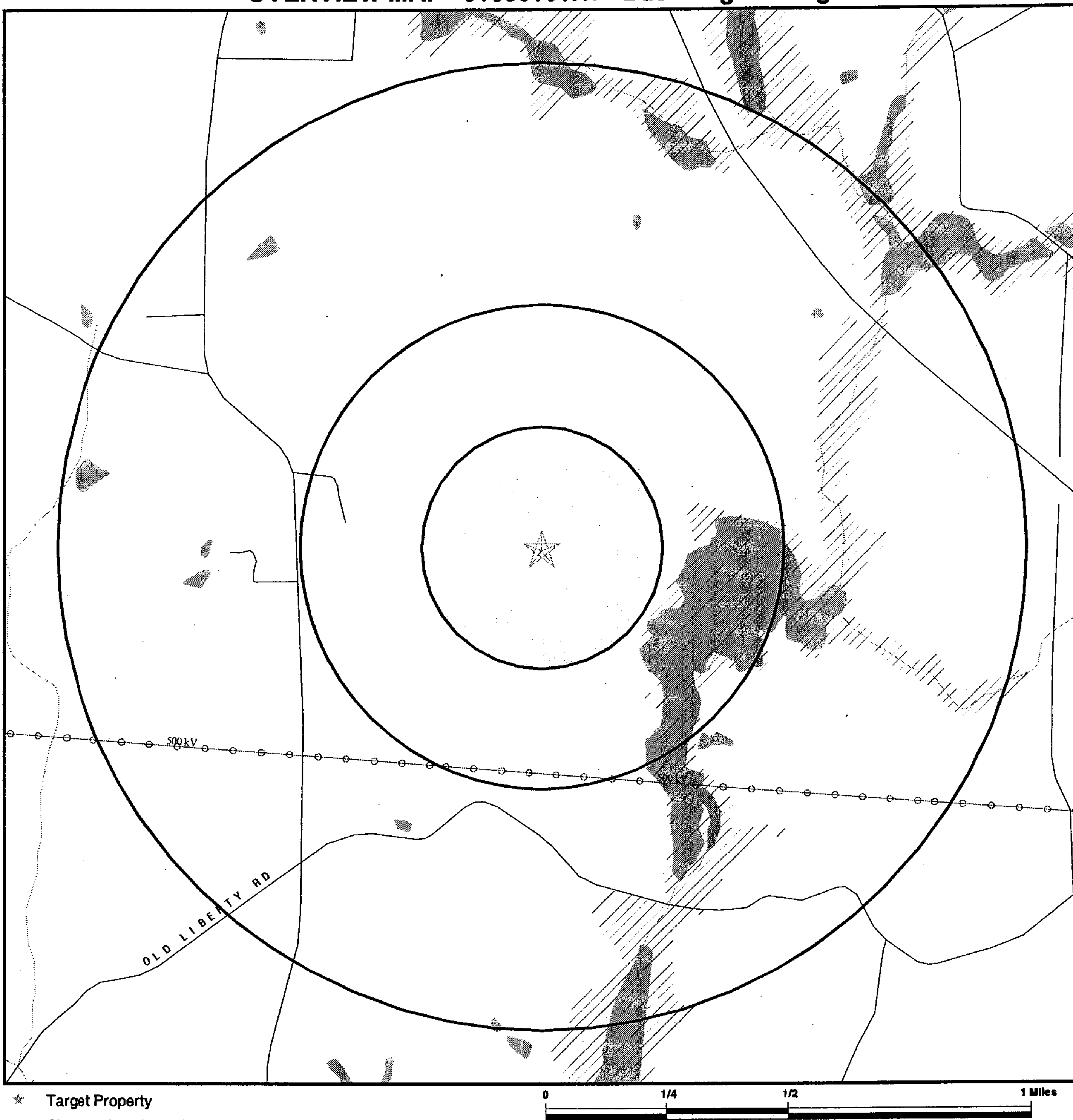
**Additional Research - ASTM Supplemental Government Databases**

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

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

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

# OVERVIEW MAP - 01086101.1r - Buck Engineering




- ☆ Target Property
- ▲ Sites at elevations higher than or equal to the target property
- ◆ Sites at elevations lower than the target property
- ▲ Coal Gasification Sites
- National Priority List Sites
- Landfill Sites
- Dept. Defense Sites
- Power transmission lines
- Oil & Gas pipelines
- 100-year flood zone
- 500-year flood zone
- Federal Wetlands
- Hazardous Substance Disposal Sites

| | | | |
|---|---|---|---|
| TARGET PROPERTY: | Merdell Farms | CUSTOMER: | Buck Engineering |
| ADDRESS: | Ramseur Julian Rd | CONTACT: | Jessica Rohrbach |
| CITY/STATE/ZIP: | Liberty NC 27298 | INQUIRY #: | 01086101.1r |
| LAT/LONG: | 35.8562 / 79.6353 | DATE: | November 20, 2003 1:32 pm |

# MAP FINDINGS SUMMARY

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

# MAP FINDINGS SUMMARY

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

NOTES:

TP = Target Property

NR = Not Requested at this Search Distance

Sites may be listed in more than one database

| Map ID<br>Direction<br>Distance<br>Distance (ft.)<br>Elevation | Site | Database(s) | EDR ID Number<br>EPA ID Number |
|---|---|---|---|

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

NO SITES FOUND

ORPHAN SUMMARY

| City | EDR ID | Site Name | Site Address | Zip | Database(s) |
|---|---|---|---|---|---|
| LIBERTY | U001198524 | WILLIAM KIVETT | SR 1006 S | 27298 | UST |
| LIBERTY | U003146928 | BOWMAN'S GROCERY (CLOSED) | ROUTE 2, BOX 34 | 27298 | UST |
| LIBERTY | S105896654 | LOWE & ROUTH OIL-HOME STAT. - B | SR 2261 | 27298 | LUST |
| LIBERTY | U001198208 | LIB VOR | S.R. 2459 | 27298 | UST |
| LIBERTY | S105485920 | LIBERTY DUMP | SR 2459, 4 MI SW OF TOWN | 27298 | OLI |
| LIBERTY | S102868518 | PUMP-N-PAK | 4994 HWY 49 S | 27298 | IMD, LUST |
| LIBERTY | S105897529 | ART'S TOWN AND COUNTRY | 6976 HWY 49 NORTH | 27298 | LUST |
| LIBERTY | U001189085 | ELLIOTT'S EXXON | HWY 49 | 27298 | UST |
| LIBERTY | U001198875 | FREEMAN FORD INC | HWY 49 SOUTH | 27298 | UST |
| LIBERTY | U003138280 | ARTS TOWN & COUNTRY | PO BOX 1266 - 6979 HWY 49 N | 27298 | UST |
| LIBERTY | S105897872 | SHOWFERY PROPERTY, MICHAEL & SUSAN DOWDY | 7228 NC HWY 49 NORTH | 27298 | LUST |
| LIBERTY | U001195053 | MARCO GAS | INTERSECT. OF SR 2261 & HWY 421 | 27298 | UST |
| LIBERTY | U001198033 | S & S AUTO SERV (FORMER TENAN | RT. L BOX 338A | 27298 | UST |
| LIBERTY | U001198088 | ALLEN HATCHERY | OLD US 421 | 27298 | UST |
| LIBERTY | U003142644 | JIM'S SELF SERV | OLD 49 WEST | 27298 | UST |
| LIBERTY | S101573925 | HOLTS EXXON - LIBERTY | 105 S. OLD GREENSBORO | 27298 | IMD, LUST |
| LIBERTY | U001205309 | KINRO INC | STATE ROAD 2427 | 27298 | UST |
| SILER CITY | U001187062 | PARNELL'S 66 | HWY 64 EAST | 27298 | IMD, UST |

# AREA RADON INFORMATION

No records reported for ZIP:27298 NC

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

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

- Federal Area Radon Information for Zip Code: 27298

Number of sites tested: 1

| Area | Average Activity | % <4 pCi/L | % 4-20 pCi/L | % >20 pCi/L |
|---|---|---|---|---|
| Living Area - 1st Floor | 0.200 pCi/L | 100% | 0% | 0% |
| Living Area - 2nd Floor | Not Reported | Not Reported | Not Reported | Not Reported |
| Basement | Not Reported | Not Reported | Not Reported | Not Reported |

- Federal Area Radon Information for RANDOLPH County, NC

Number of sites tested: 7

| Area | Average Activity | % <4 pCi/L | % 4-20 pCi/L | % >20 pCi/L |
|---|---|---|---|---|
| Living Area - 1st Floor | 0.443 pCi/L | 100% | 0% | 0% |
| Living Area - 2nd Floor | Not Reported | Not Reported | Not Reported | Not Reported |
| Basement | 0.400 pCi/L | 100% | 0% | 0% |

## GOVERNMENT RECORDS SEARCHED / DATA CURRENCY TRACKING

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

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

**FEDERAL ASTM STANDARD RECORDS**

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

Date of Government Version: 07/22/03
Date Made Active at EDR: 08/26/03
Database Release Frequency: Semi-Annually
Date of Data Arrival at EDR: 08/04/03
Elapsed ASTM days: 22
Date of Last EDR Contact: 08/04/03

**NPL Site Boundaries**

Sources:

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

EPA Region 1
Telephone 617-918-1143

EPA Region 3
Telephone 215-814-5418

EPA Region 4
Telephone 404-562-8033

EPA Region 6
Telephone: 214-655-6659

EPA Region 8
Telephone: 303-312-6774

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

Date of Government Version: 06/10/03
Date Made Active at EDR: 08/26/03
Database Release Frequency: Semi-Annually
Date of Data Arrival at EDR: 08/04/03
Elapsed ASTM days: 22
Date of Last EDR Contact: 08/04/03

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

Date of Government Version: 09/11/03
Date Made Active at EDR: 10/29/03
Database Release Frequency: Quarterly
Date of Data Arrival at EDR: 09/24/03
Elapsed ASTM days: 35
Date of Last EDR Contact: 09/24/03

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

Date of Government Version: 09/11/03
Date Made Active at EDR: 10/29/03
Database Release Frequency: Quarterly

Date of Data Arrival at EDR: 09/24/03
Elapsed ASTM days: 35
Date of Last EDR Contact: 09/24/03

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

Date of Government Version: 09/17/03
Date Made Active at EDR: 11/11/03
Database Release Frequency: Semi-Annually

Date of Data Arrival at EDR: 10/01/03
Elapsed ASTM days: 41
Date of Last EDR Contact: 09/08/03

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

Date of Government Version: 09/10/03
Date Made Active at EDR: 10/01/03
Database Release Frequency: Varies

Date of Data Arrival at EDR: 09/11/03
Elapsed ASTM days: 20
Date of Last EDR Contact: 09/11/03

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

Date of Government Version: 12/31/02
Date Made Active at EDR: 02/03/03
Database Release Frequency: Annually

Date of Data Arrival at EDR: 01/27/03
Elapsed ASTM days: 7
Date of Last EDR Contact: 10/27/03

**FEDERAL ASTM SUPPLEMENTAL RECORDS**

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

Date of Government Version: 12/01/01
Database Release Frequency: Biennially

Date of Last EDR Contact: 10/01/03
Date of Next Scheduled EDR Contact: 12/15/03

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

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

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

Date of Government Version: 07/25/03 — Date of Last EDR Contact: 10/07/03
Database Release Frequency: Quarterly — Date of Next Scheduled EDR Contact: 01/05/04

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

Date of Government Version: 03/31/03 — Date of Last EDR Contact: 10/23/03
Database Release Frequency: Annually — Date of Next Scheduled EDR Contact: 01/19/04

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

Date of Government Version: 07/16/03 — Date of Last EDR Contact: 10/07/03
Database Release Frequency: Quarterly — Date of Next Scheduled EDR Contact: 01/05/04

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

Date of Government Version: 08/27/03 — Date of Last EDR Contact: 10/01/03
Database Release Frequency: Semi-Annually — Date of Next Scheduled EDR Contact: 12/29/03

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

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

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

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

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

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

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

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

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

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

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

Date of Government Version: 12/31/01 — Date of Last EDR Contact: 09/23/03
Database Release Frequency: Annually — Date of Next Scheduled EDR Contact: 12/22/03

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

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

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

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

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

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

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

Date of Last EDR Contact: 10/20/03
Date of Next Scheduled EDR Contact: 01/19/04

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

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

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

## STATE OF NORTH CAROLINA ASTM STANDARD RECORDS

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

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

Date of Data Arrival at EDR: 07/22/03
Elapsed ASTM days: 27
Date of Last EDR Contact: 10/14/03

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

Date of Government Version: 10/27/03
Date Made Active at EDR: 11/14/03
Database Release Frequency: Semi-Annually

Date of Data Arrival at EDR: 10/27/03
Elapsed ASTM days: 18
Date of Last EDR Contact: 10/27/03

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

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

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

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

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

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

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

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

Date of Government Version: 10/17/03
Date Made Active at EDR: 11/10/03
Database Release Frequency: Semi-Annually
Date of Data Arrival at EDR: 10/17/03
Elapsed ASTM days: 24
Date of Last EDR Contact: 10/14/03

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

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

**STATE OF NORTH CAROLINA ASTM SUPPLEMENTAL RECORDS**

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

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

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

Date of Government Version: 06/05/03
Database Release Frequency: Semi-Annually
Date of Last EDR Contact: 10/20/03
Date of Next Scheduled EDR Contact: 01/19/04

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

Date of Government Version: 08/08/03
Database Release Frequency: Semi-Annually

Date of Last EDR Contact: 08/11/03
Date of Next Scheduled EDR Contact: 11/10/03

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

Date of Government Version: 10/15/03
Database Release Frequency: Quarterly

Date of Last EDR Contact: 10/27/03
Date of Next Scheduled EDR Contact: 01/26/04

**EDR PROPRIETARY HISTORICAL DATABASES**

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

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

**BROWNFIELDS DATABASES**

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

Date of Government Version: 12/31/02
Database Release Frequency: Varies

Date of Last EDR Contact: 08/18/03
Date of Next Scheduled EDR Contact: 11/03/03

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

Date of Government Version: 10/17/03
Database Release Frequency: Semi-Annually

Date of Last EDR Contact: 10/14/03
Date of Next Scheduled EDR Contact: 01/24/04

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

Date of Government Version: 10/17/03
Database Release Frequency: Quarterly

Date of Last EDR Contact: 10/14/03
Date of Next Scheduled EDR Contact: 01/12/04

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

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

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

**OTHER DATABASE(S)**

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

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

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

**STREET AND ADDRESS INFORMATION**

# Appendix C

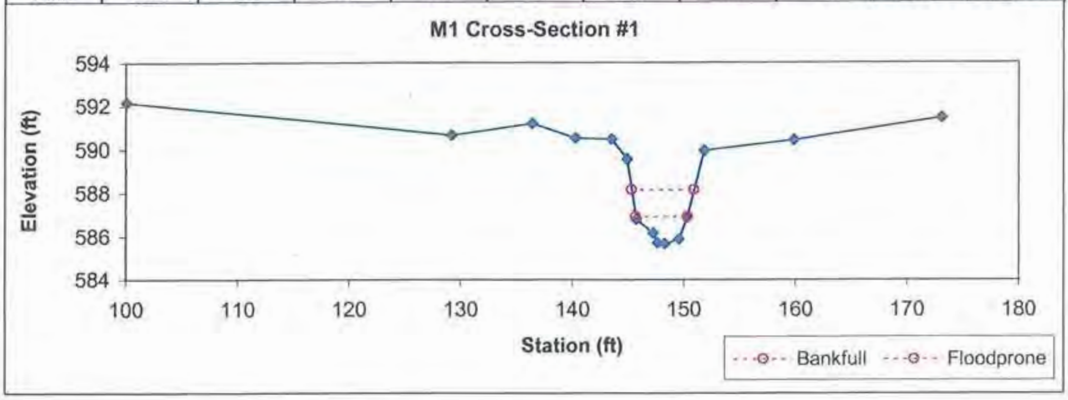
Existing Condition Data

## Cross-Section Data Summary Table

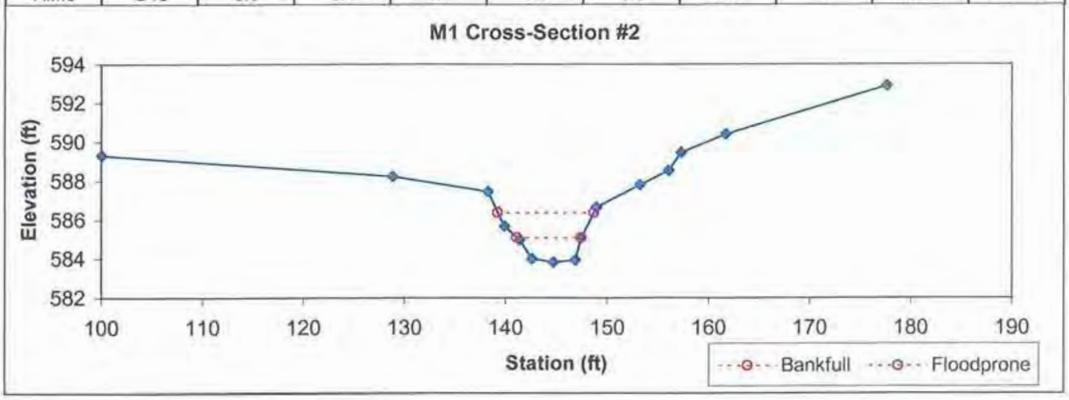
| Reach | M1 | M1 | M1 | M1 | M1 | UT1 | UT1 | UT1 | UT1 | UT1 | UT1 | UT1 | UT1 | UT1 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cross-section Descriptor | X1 | X2 | X3 | X4 | X5 | X1 | X2 | X3 | X4 | X5 | X6 | X7 | X8 | X9 |
| Feature | Riffle | Riffle | Pool | Riffle | Riffle | Riffle | Pool | Riffle | Pool | Riffle | Pool | Riffle | Riffle | Riffle |
| Rosgen Stream Type | G4c | G4c | --- | G4c | G4c | G4 | --- | F4b | --- | E4b | --- | C4b | E4b | E4b |
| Bankfull Width (ft) | 4.6 | 6.4 | 6.0 | 7.6 | 6.9 | 4.1 | 6.2 | 14.7 | 10.0 | 5.6 | 6.4 | 10.6 | 5.8 | 7.0 |
| Bankfull Mean Depth (ft) | 0.8 | 1.0 | 1.6 | 1.1 | 0.9 | 0.7 | 1.8 | 0.6 | 1.7 | 0.5 | 1.0 | 0.6 | 0.6 | 0.6 |
| Width/Depth Ratio | 5.8 | 6.5 | 3.8 | 6.9 | 7.9 | 5.7 | 3.5 | 26.2 | 5.8 | 11.7 | 6.1 | 19.0 | 9.5 | 11.9 |
| Bankfull Area (sq ft) | 3.7 | 6.3 | 9.4 | 8.4 | 6.0 | 2.9 | 11.1 | 8.3 | 17.5 | 2.6 | 6.6 | 5.9 | 3.5 | 4.1 |
| Bankfull Max Depth (ft) | 1.2 | 1.3 | 2.1 | 1.4 | 1.4 | 0.9 | 2.4 | 0.8 | 2.4 | 0.8 | 1.5 | 1.1 | 0.9 | 1.0 |
| Width of Floodprone Area (ft) | 6 | 10 | 13 | 11 | 13 | 6 | 9 | 19 | 50 | 15 | 13 | 59 | 40 | 14 |
| Entrenchment Ratio | 1.2 | 1.5 | 2.2 | 1.4 | 1.9 | 1.4 | 1.5 | 1.3 | 5.0 | 2.8 | 2.0 | 5.5 | 6.9 | 2.1 |
| Bank Height Ratio | 3.4 | 2.8 | 2.1 | 2.8 | 3.0 | 4.1 | 2.7 | 3.0 | 1.6 | 3.8 | 3.0 | 1.1 | 1.3 | 4.6 |

| Reach | UT2 | UT2 | UT2 | UT2 | UT2 | UT3 | UT3 | UT4 | UT4 | UT5 | UT5 | UT5 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cross-section Descriptor | X1 | X2 | X3 | X4 | X5 | X1 | X2 | X1 | X2 | X1 | X2 | X3 |
| Feature | Riffle | Pool | Riffle | Riffle | Riffle | Riffle | Riffle | Riffle | Riffle | Riffle | Riffle | Riffle |
| Rosgen Stream Type | B5-1 | --- | B5-1 | E5-1 | E5-1 | B4c | C5 | E5 | G5 | E5 | E5 | E5 |
| Bankfull Width (ft) | 6.7 | 6.1 | 6.8 | 4.9 | 8.1 | 7.7 | 15.4 | 4.7 | 4.7 | 2.9 | 3.9 | 3.1 |
| Bankfull Mean Depth (ft) | 0.5 | 0.6 | 0.4 | 0.5 | 0.8 | 0.5 | 0.4 | 0.4 | 0.6 | 0.4 | 0.5 | 0.6 |
| Width/Depth Ratio | 12.5 | 9.5 | 18.4 | 9.8 | 10.6 | 14.3 | 37.3 | 11.6 | 7.8 | 7.1 | 7.4 | 5.2 |
| Bankfull Area (sq ft) | 3.6 | 3.9 | 2.5 | 2.4 | 6.2 | 4.2 | 6.3 | 1.9 | 2.8 | 1.2 | 2.0 | 1.8 |
| Bankfull Max Depth (ft) | 1.0 | 1.0 | 0.8 | 1.0 | 1.2 | 1.0 | 0.9 | 0.7 | 0.9 | 0.7 | 0.9 | 1.0 |
| Width of Floodprone Area (ft) | 10 | 14 | 11 | 11 | 17 | 9 | 39 | 37 | 7 | 41 | 9 | 9 |
| Entrenchment Ratio | 1.6 | 2.2 | 1.7 | 2.3 | 2.1 | 1.2 | 2.5 | 7.7 | 1.6 | 14.2 | 2.3 | 2.9 |
| Bank Height Ratio | 2.3 | 1.7 | 2.2 | 3.7 | 2.3 | 3.8 | 1.0 | 1.3 | 2.0 | 1.0 | 2.0 | 1.9 |

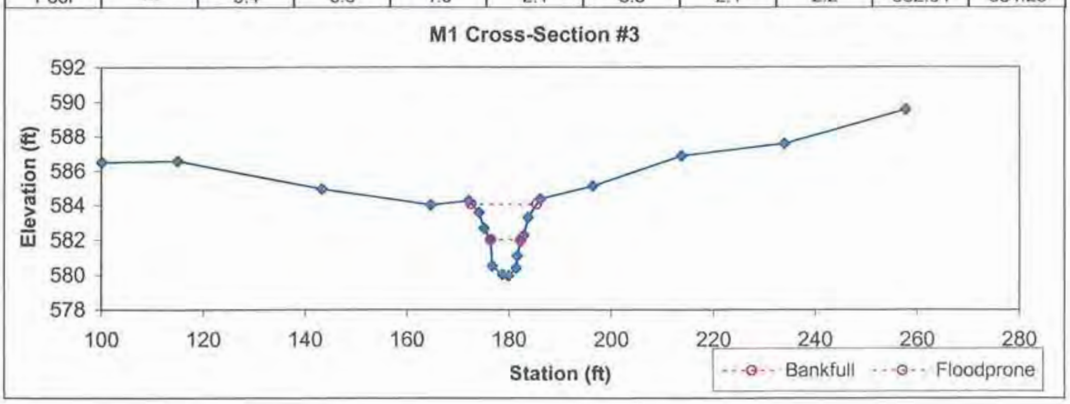
| Feature | Stream Type | BKF Area | BKF Width | BKF Depth | Max BKF Depth | W/D | BH Ratio | ER | BKF Elev | TOB Elev |
|---|---|---|---|---|---|---|---|---|---|---|
| Riffle | G4c | 3.7 | 4.6 | 0.8 | 1.2 | 5.8 | 3.4 | 1.2 | 586.92 | 589.95 |



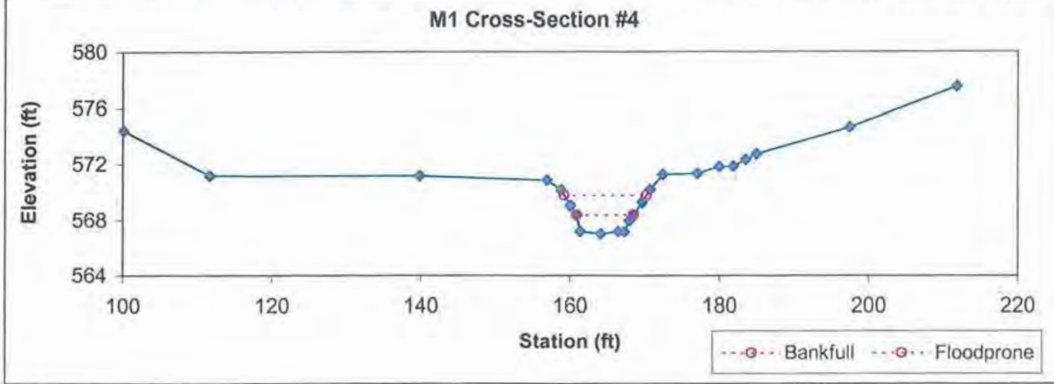

| Feature | Stream Type | BKF Area | BKF Width | BKF Depth | Max BKF Depth | W/D | BH Ratio | ER | BKF Elev | TOB Elev |
|---|---|---|---|---|---|---|---|---|---|---|
| Riffle | G4c | 6.3 | 6.4 | 1.0 | 1.3 | 6.5 | 2.8 | 1.5 | 585.14 | 587.48 |



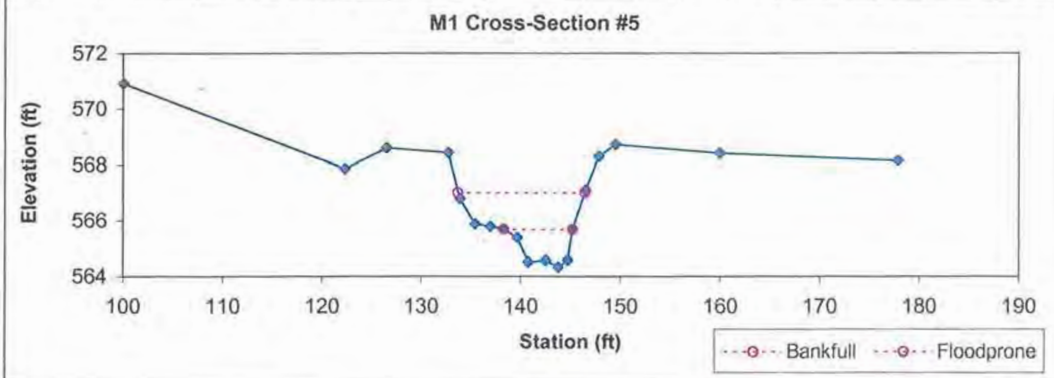

| Feature | Stream Type | BKF Area | BKF Width | BKF Depth | Max BKF Depth | W/D | BH Ratio | ER | BKF Elev | TOB Elev |
|---|---|---|---|---|---|---|---|---|---|---|
| Pool | --- | 9.4 | 6.0 | 1.6 | 2.1 | 3.8 | 2.1 | 2.2 | 582.04 | 584.28 |



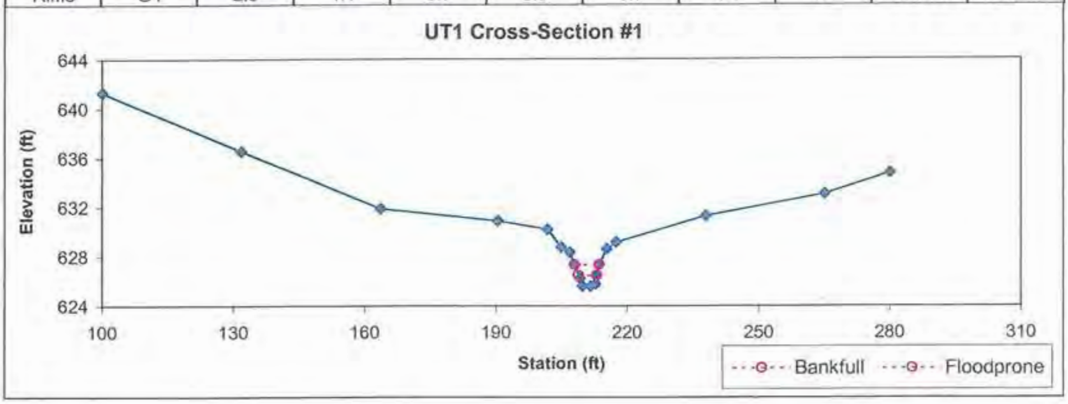
| Feature | Stream Type | BKF Area | BKF Width | BKF Depth | Max BKF Depth | W/D | BH Ratio | ER | BKF Elev | TOB Elev |
|---|---|---|---|---|---|---|---|---|---|---|
| Riffle | G4c | 8.4 | 7.6 | 1.1 | 1.4 | 6.9 | 2.8 | 1.4 | 568.39 | 570.84 |



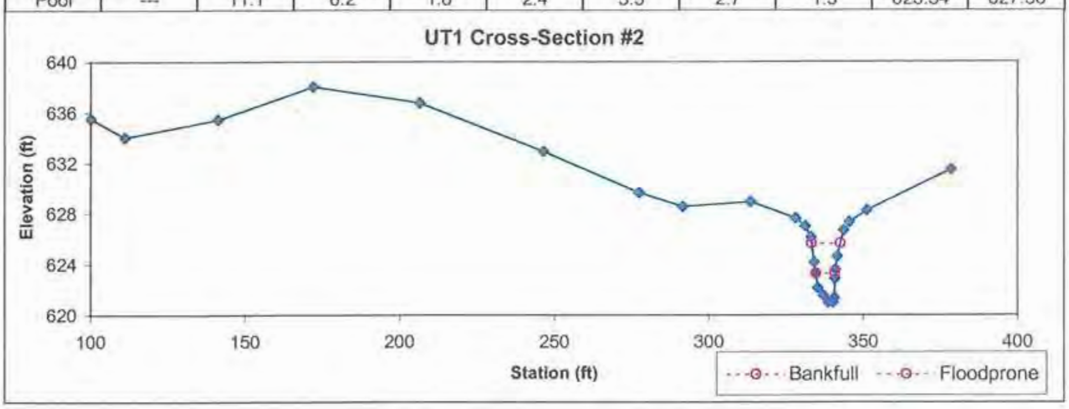

| Feature | Stream Type | BKF Area | BKF Width | BKF Depth | Max BKF Depth | W/D | BH Ratio | ER | BKF Elev | TOB Elev |
|---|---|---|---|---|---|---|---|---|---|---|
| Riffle | G4c | 6.0 | 6.9 | 0.9 | 1.4 | 7.9 | 3.0 | 1.9 | 565.7 | 568.45 |



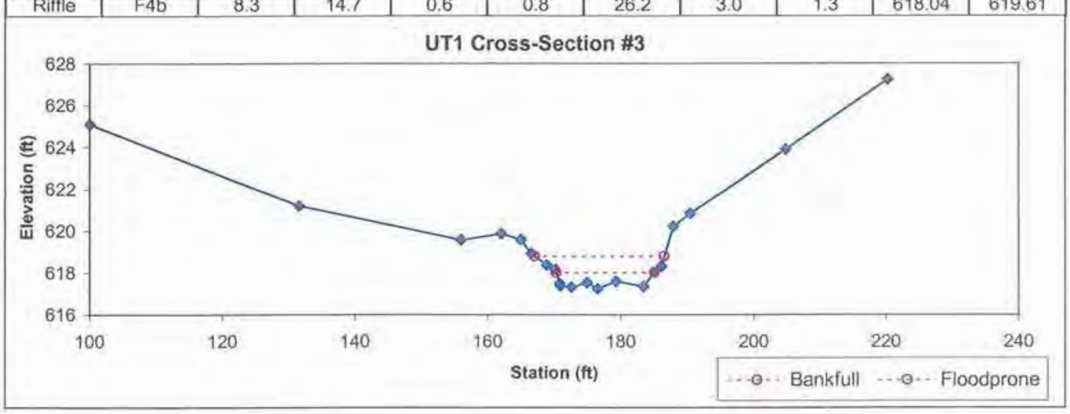
| Feature | Stream Type | BKF Area | BKF Width | BKF Depth | Max BKF Depth | W/D | BH Ratio | ER | BKF Elev | TOB Elev |
|---|---|---|---|---|---|---|---|---|---|---|
| Riffle | G4 | 2.9 | 4.1 | 0.7 | 0.9 | 5.7 | 4.1 | 1.4 | 626.48 | 629.19 |



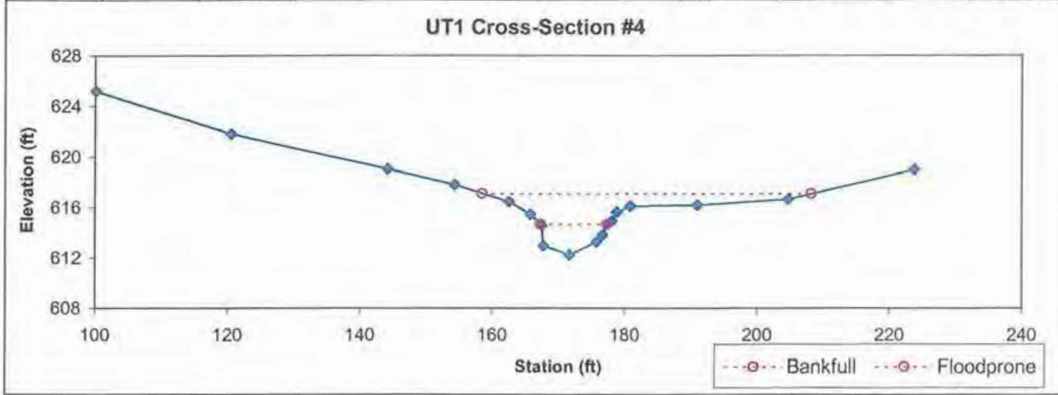

| Feature | Stream Type | BKF Area | BKF Width | BKF Depth | Max BKF Depth | W/D | BH Ratio | ER | BKF Elev | TOB Elev |
|---|---|---|---|---|---|---|---|---|---|---|
| Pool | --- | 11.1 | 6.2 | 1.8 | 2.4 | 3.5 | 2.7 | 1.5 | 623.34 | 627.36 |



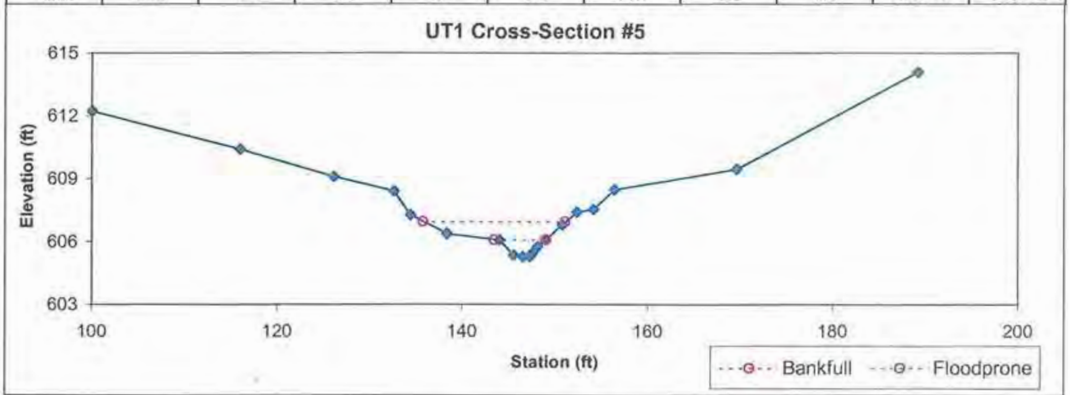

| Feature | Stream Type | BKF Area | BKF Width | BKF Depth | Max BKF Depth | W/D | BH Ratio | ER | BKF Elev | TOB Elev |
|---|---|---|---|---|---|---|---|---|---|---|
| Riffle | F4b | 8.3 | 14.7 | 0.6 | 0.8 | 26.2 | 3.0 | 1.3 | 618.04 | 619.61 |



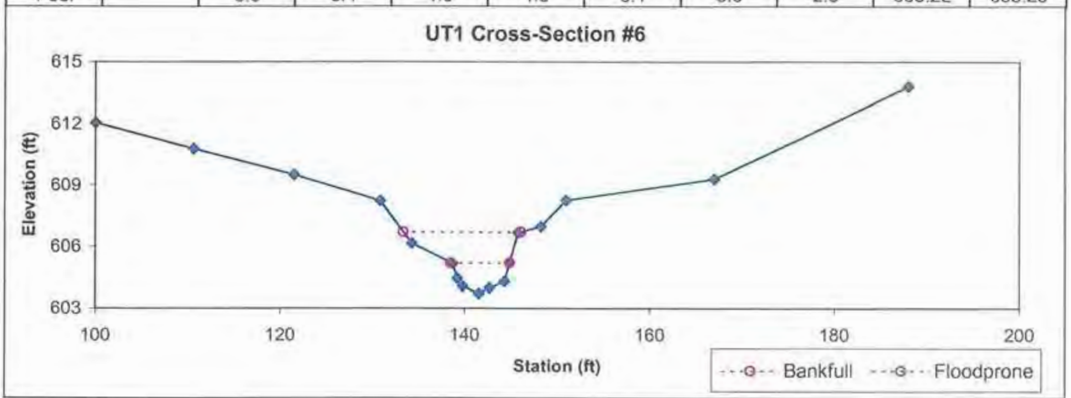
| Feature | Stream Type | BKF Area | BKF Width | BKF Depth | Max BKF Depth | W/D | BH Ratio | ER | BKF Elev | TOB Elev |
|---|---|---|---|---|---|---|---|---|---|---|
| Pool | --- | 17.5 | 10.0 | 1.7 | 2.4 | 5.8 | 1.6 | 5.0 | 614.68 | 616.11 |



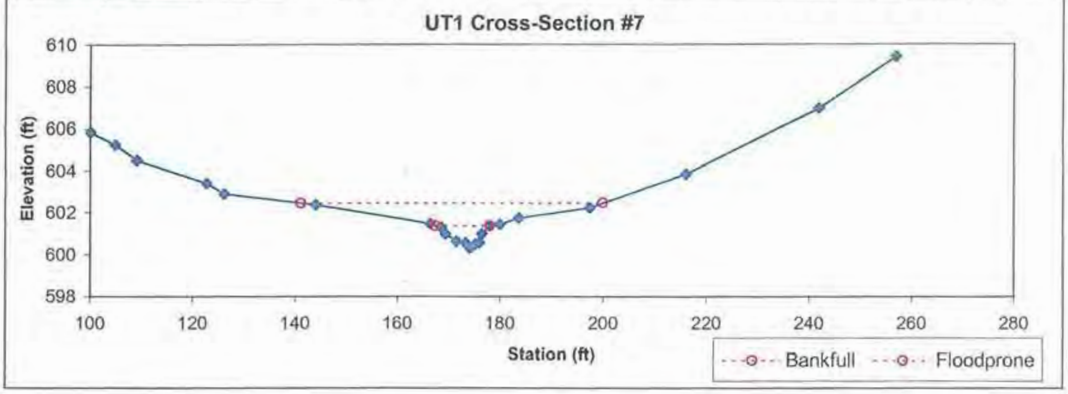

| Feature | Stream Type | BKF Area | BKF Width | BKF Depth | Max BKF Depth | W/D | BH Ratio | ER | BKF Elev | TOB Elev |
|---|---|---|---|---|---|---|---|---|---|---|
| Riffle | E4b | 2.6 | 5.6 | 0.5 | 0.8 | 11.7 | 3.8 | 2.8 | 606.12 | 608.42 |



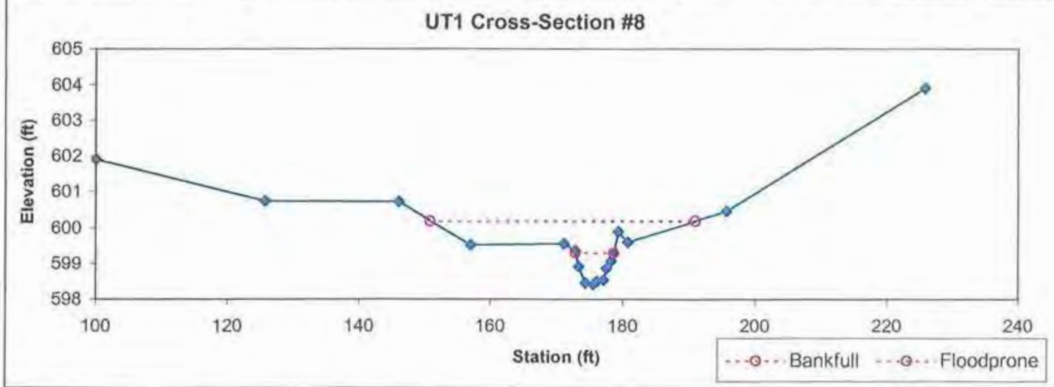

| Feature | Stream Type | BKF Area | BKF Width | BKF Depth | Max BKF Depth | W/D | BH Ratio | ER | BKF Elev | TOB Elev |
|---|---|---|---|---|---|---|---|---|---|---|
| Pool | --- | 6.6 | 6.4 | 1.0 | 1.5 | 6.1 | 3.0 | 2.0 | 605.22 | 608.23 |



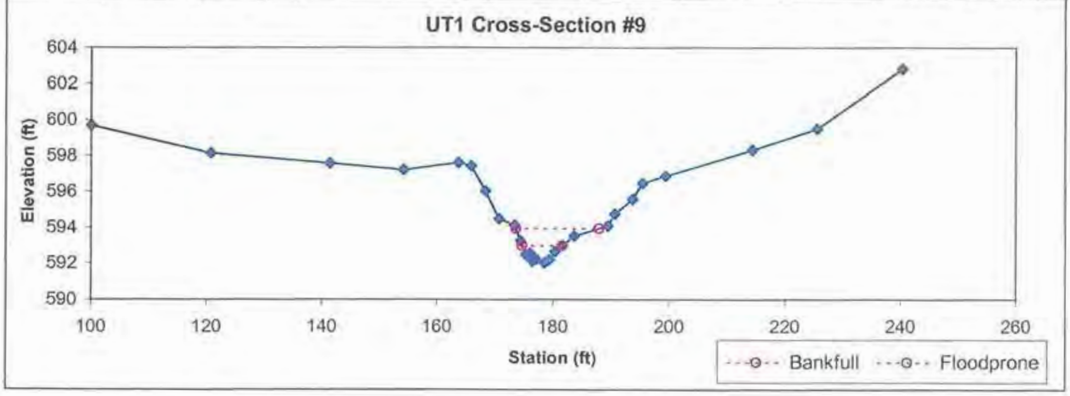
| Feature | Stream Type | BKF Area | BKF Width | BKF Depth | Max BKF Depth | W/D | BH Ratio | ER | BKF Elev | TOB Elev |
|---|---|---|---|---|---|---|---|---|---|---|
| Riffle | C4b | 5.9 | 10.6 | 0.6 | 1.1 | 19.0 | 1.1 | 5.5 | 601.39 | 601.47 |



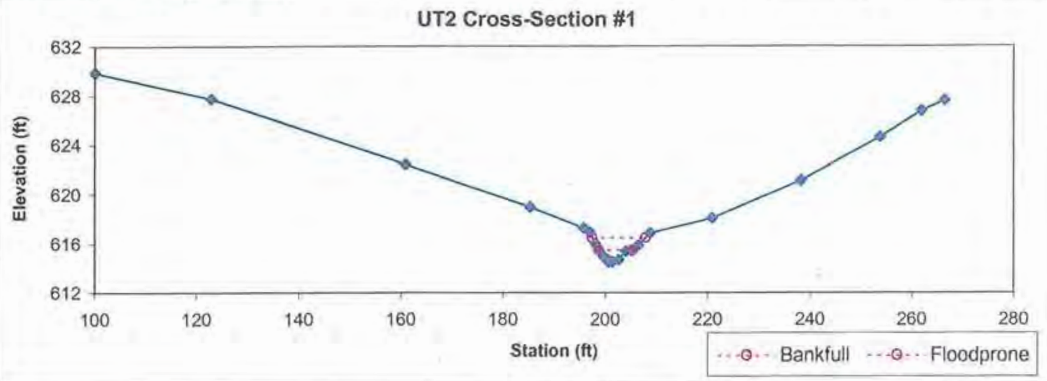

| Feature | Stream Type | BKF Area | BKF Width | BKF Depth | Max BKF Depth | W/D | BH Ratio | ER | BKF Elev | TOB Elev |
|---|---|---|---|---|---|---|---|---|---|---|
| Riffle | E4b | 3.5 | 5.8 | 0.6 | 0.9 | 9.5 | 1.3 | 6.9 | 599.32 | 599.58 |



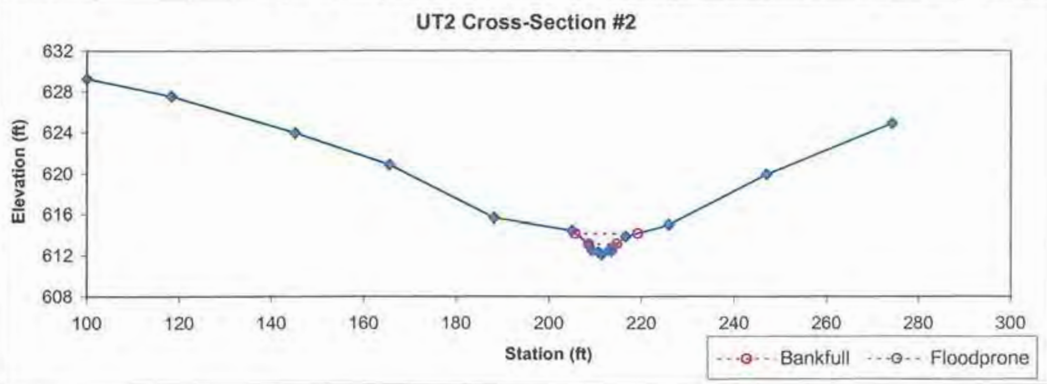

| Feature | Stream Type | BKF Area | BKF Width | BKF Depth | Max BKF Depth | W/D | BH Ratio | ER | BKF Elev | TOB Elev |
|---|---|---|---|---|---|---|---|---|---|---|
| Riffle | E4b | 4.1 | 7.0 | 0.6 | 1.0 | 11.9 | 4.6 | 2.1 | 593.00 | 596.48 |



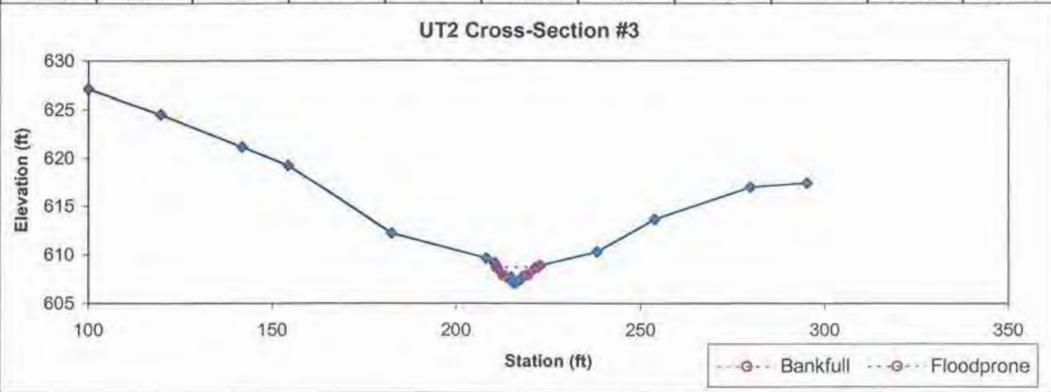
| Feature | Stream Type | BKF Area | BKF Width | BKF Depth | Max BKF Depth | W/D | BH Ratio | ER | BKF Elev | TOB Elev |
|---|---|---|---|---|---|---|---|---|---|---|
| Riffle | B5-1 | 3.6 | 6.7 | 0.5 | 1.0 | 12.5 | 2.3 | 1.6 | 615.53 | 616.9 |



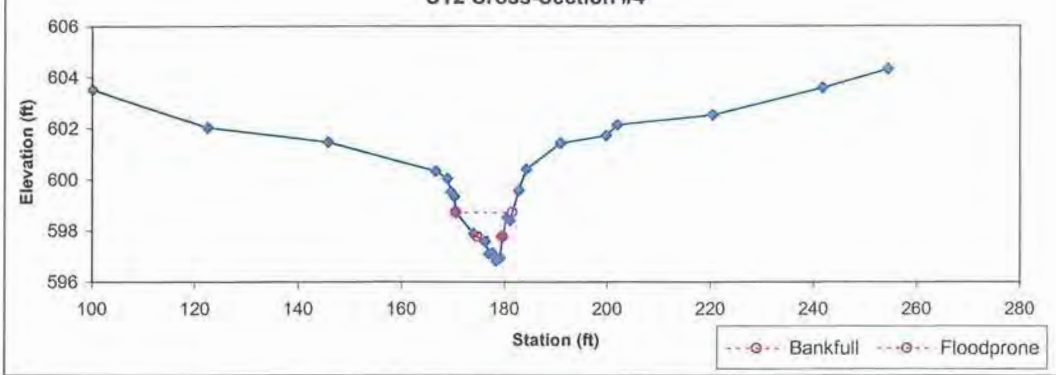

| Feature | Stream Type | BKF Area | BKF Width | BKF Depth | Max BKF Depth | W/D | BH Ratio | ER | BKF Elev | TOB Elev |
|---|---|---|---|---|---|---|---|---|---|---|
| Pool | --- | 3.9 | 6.1 | 0.6 | 1.0 | 9.5 | 1.7 | 2.2 | 613.19 | 613.91 |



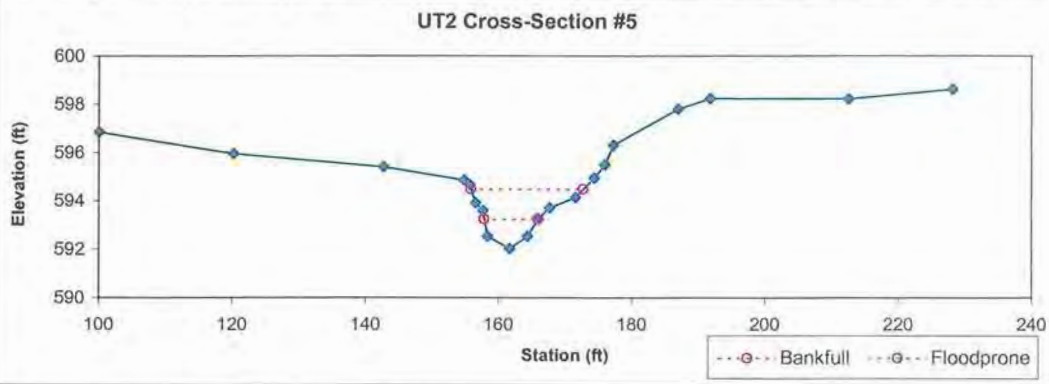

| Feature | Stream Type | BKF Area | BKF Width | BKF Depth | Max BKF Depth | W/D | BH Ratio | ER | BKF Elev | TOB Elev |
|---|---|---|---|---|---|---|---|---|---|---|
| Riffle | B5-1 | 2.5 | 6.8 | 0.4 | 0.8 | 18.4 | 2.2 | 1.7 | 607.97 | 608.93 |



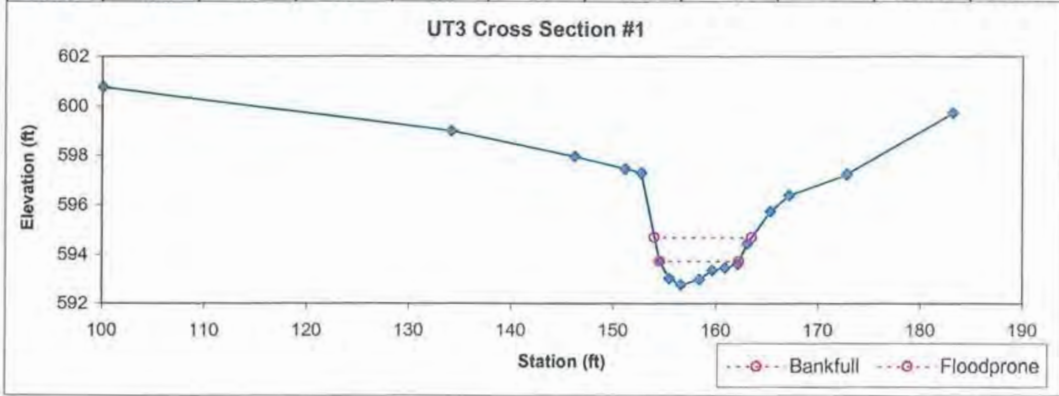
| Feature | Stream Type | BKF Area | BKF Width | BKF Depth | Max BKF Depth | W/D | BH Ratio | ER | BKF Elev | TOB Elev |
|---|---|---|---|---|---|---|---|---|---|---|
| Riffle | E5-1 | 2.4 | 4.9 | 0.5 | 1.0 | 9.8 | 3.7 | 2.3 | 597.79 | 600.35 |



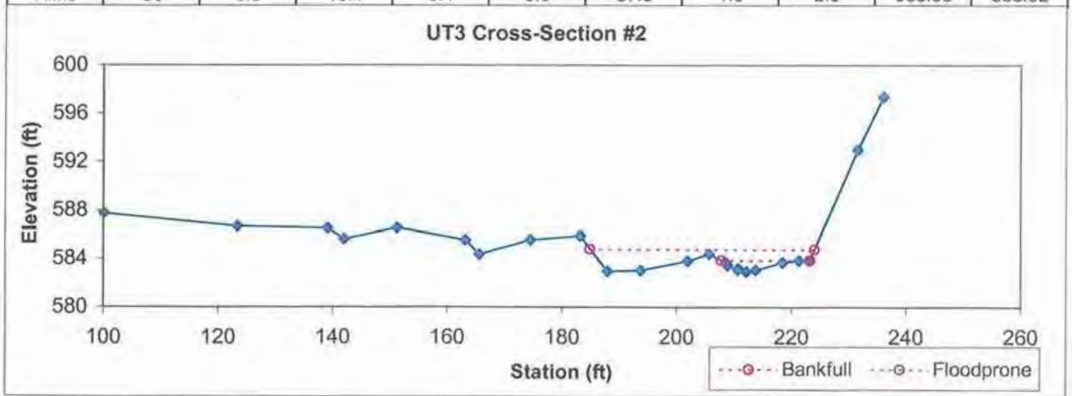

| Feature | Stream Type | BKF Area | BKF Width | BKF Depth | Max BKF Depth | W/D | BH Ratio | ER | BKF Elev | TOB Elev |
|---|---|---|---|---|---|---|---|---|---|---|
| Riffle | E5-1 | 6.2 | 8.1 | 0.8 | 1.2 | 10.6 | 2.3 | 2.1 | 593.27 | 594.87 |



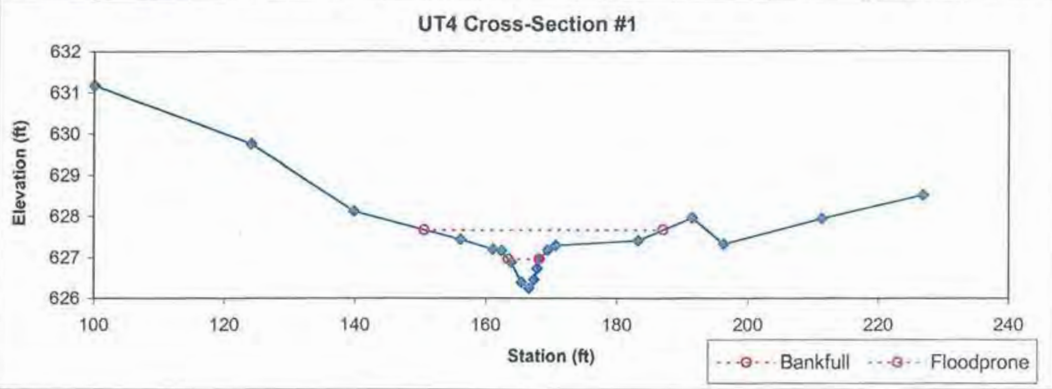
| Feature | Stream Type | BKF Area | BKF Width | BKF Depth | Max BKF Depth | W/D | BH Ratio | ER | BKF Elev | TOB Elev |
|---|---|---|---|---|---|---|---|---|---|---|
| Riffle | B4c | 4.2 | 7.7 | 0.5 | 1.0 | 14.3 | 3.8 | 1.2 | 593.75 | 596.40 |



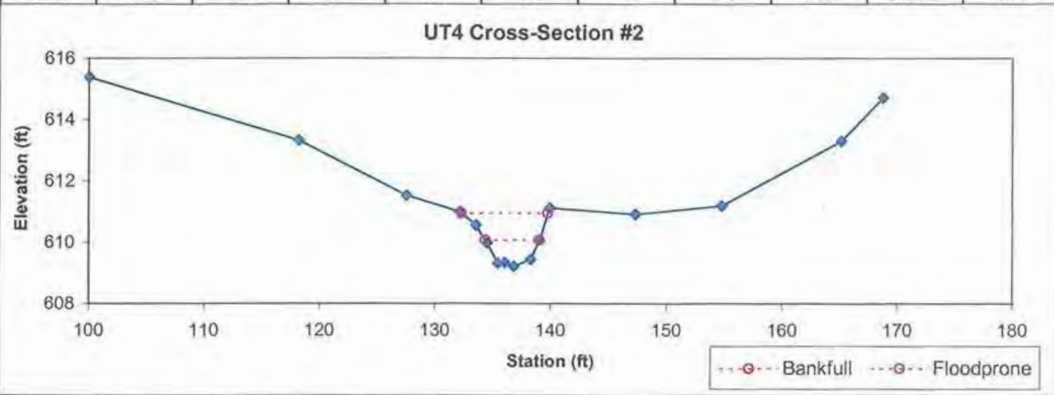

| Feature | Stream Type | BKF Area | BKF Width | BKF Depth | Max BKF Depth | W/D | BH Ratio | ER | BKF Elev | TOB Elev |
|---|---|---|---|---|---|---|---|---|---|---|
| Riffle | C5 | 6.3 | 15.4 | 0.4 | 0.9 | 37.3 | 1.0 | 2.5 | 583.93 | 583.92 |



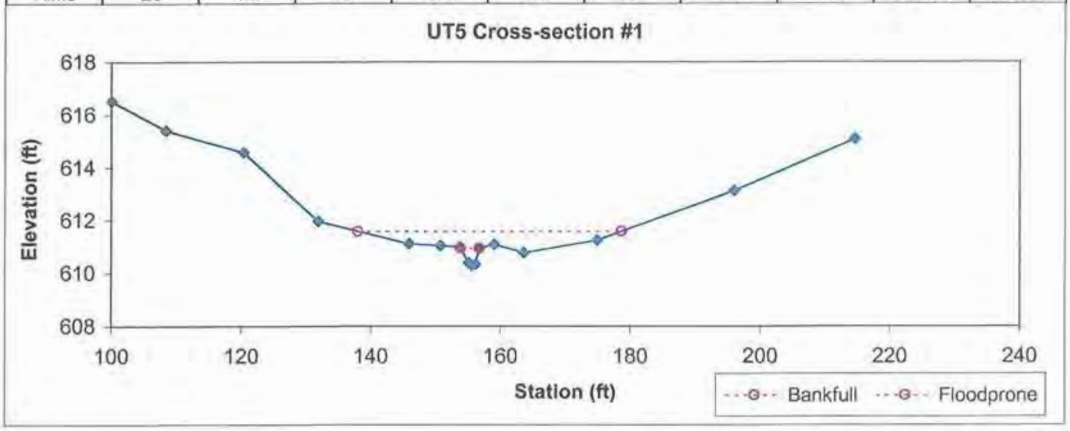
| Feature | Stream Type | BKF Area | BKF Width | BKF Depth | Max BKF Depth | W/D | BH Ratio | ER | BKF Elev | TOB Elev |
|---|---|---|---|---|---|---|---|---|---|---|
| Riffle | E5 | 1.9 | 4.7 | 0.4 | 0.7 | 11.6 | 1.3 | 7.7 | 626.96 | 627.2 |



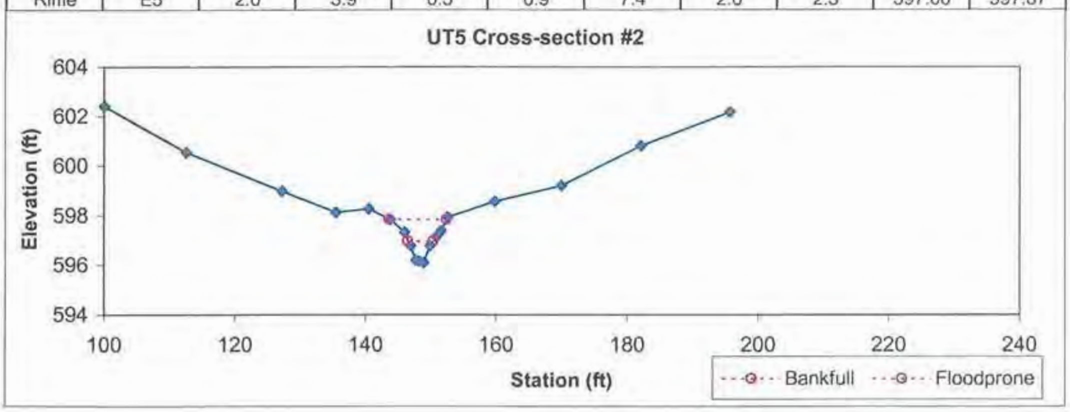

| Feature | Stream Type | BKF Area | BKF Width | BKF Depth | Max BKF Depth | W/D | BH Ratio | ER | BKF Elev | TOB Elev |
|---|---|---|---|---|---|---|---|---|---|---|
| Riffle | G5 | 2.8 | 4.7 | 0.6 | 0.9 | 7.8 | 2.0 | 1.6 | 610.09 | 611 |



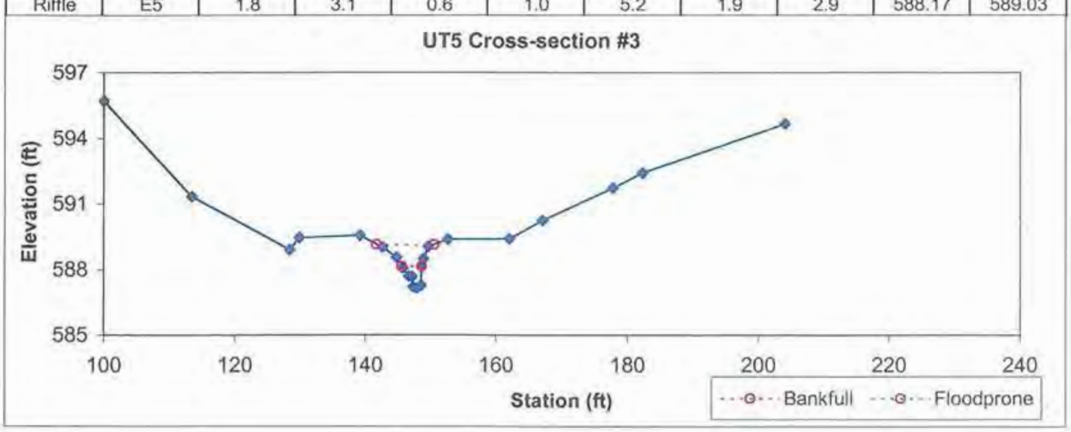
| Feature | Stream Type | BKF Area | BKF Width | BKF Depth | Max BKF Depth | W/D | BH Ratio | ER | BKF Elev | TOB Elev |
|---|---|---|---|---|---|---|---|---|---|---|
| Riffle | E5 | 1.2 | 2.9 | 0.4 | 0.7 | 7.1 | 1.0 | 14.2 | 610.95 | 610.95 |




| Feature | Stream Type | BKF Area | BKF Width | BKF Depth | Max BKF Depth | W/D | BH Ratio | ER | BKF Elev | TOB Elev |
|---|---|---|---|---|---|---|---|---|---|---|
| Riffle | E5 | 2.0 | 3.9 | 0.5 | 0.9 | 7.4 | 2.0 | 2.3 | 597.00 | 597.87 |




| Feature | Stream Type | BKF Area | BKF Width | BKF Depth | Max BKF Depth | W/D | BH Ratio | ER | BKF Elev | TOB Elev |
|---|---|---|---|---|---|---|---|---|---|---|
| Riffle | E5 | 1.8 | 3.1 | 0.6 | 1.0 | 5.2 | 1.9 | 2.9 | 588.17 | 589.03 |



| Meredell Farm Reach M1 | Existing Stream Values | |
|---|---|---|
| **Parameter** | **MIN** | **MAX** |
| Drainage Area, DA (sq mi) | 0.26 | |
| Stream Type (Rosgen) | G4c | G4c |
| Bankfull Riffle XSEC Area, Abkf (sq ft) | 3.7 | 8.4 |
| Bankfull Riffle Width, Wbkf (ft) | 4.6 | 7.6 |
| Bankfull Riffle Mean Depth, Dbkf (ft) | 0.8 | 1.1 |
| Width to Depth Ratio, W/D (ft/ft) | 5.8 | 7.9 |
| Width Floodprone Area, Wfpa (ft) | 6 | 13 |
| Entrenchment Ratio, Wfpa/Wbkf (ft/ft) | 1.2 | 1.9 |
| Riffle Max Depth @ bkf, Dmax (ft) | 1.2 | 1.4 |
| Riffle Max Depth Ratio, Dmax/Dbkf | 1.3 | 1.5 |
| Meander Length, Lm (ft) | 70 | 170 |
| Meander Length Ratio, Lm/Wbkf * | 11.0 | 26.6 |
| Radius of Curvature, Rc (ft) | 16 | 25 |
| Rc Ratio, Rc/Wbkf * | 2.5 | 3.9 |
| Belt Width, Wblt (ft) | 20 | 30 |
| Meander Width Ratio, Wblt/Wbkf * | 3.1 | 4.7 |
| Sinuosity, K | 1.08 | |
| Valley Slope, Sval (ft/ft) | 0.014 | |
| Channel Slope, Schan (ft/ft) | 0.0130 | |
| Pool Max Depth, Dmaxpool (ft) | 2.1 | |
| Pool Max Depth Ratio, Dmaxpool/Dbkf | 2.2 | |
| Pool Width, Wpool (ft) | 6.0 | |
| Pool Width Ratio, Wpool/Wbkf | 0.9 | |
| d16 (mm) | n/a | |
| d35 (mm) | 0.3 | |
| d50 (mm) | 16.5 | |
| d84 (mm) | 60.4 | |
| d95 (mm) | 128.0 | |

Note 1: This reach has a very low sinuosity and poor bedform diversity. Due to lack of pools in the reach, no pool cross sections were performed.

| Meredell Farm Reach UT1 | Existing Stream Values | |
|---|---|---|
| **Parameter** | **MIN** | **MAX** |
| Drainage Area, DA (sq mi) | 0.1 | |
| Stream Type (Rosgen) | G4, F4b, E4b, C4b | |
| Bankfull Riffle XSEC Area, Abkf (sq ft) | 2.6 | 8.3 |
| Bankfull Riffle Width, Wbkf (ft) | 4.1 | 14.7 |
| Bankfull Riffle Mean Depth, Dbkf (ft) | 0.5 | 0.7 |
| Width to Depth Ratio, W/D (ft/ft) | 5.7 | 26.2 |
| Width Floodprone Area, Wfpa (ft) | 6 | 59 |
| Entrenchment Ratio, Wfpa/Wbkf (ft/ft) | 1.3 | 6.9 |
| Riffle Max Depth @ bkf, Dmax (ft) | 0.8 | 1.1 |
| Riffle Max Depth Ratio, Dmax/Dbkf | 1.3 | 1.8 |
| Bank Height Ratio, Dtob/Dmax (ft/ft) | 1.1 | 4.6 |
| Meander Length, Lm (ft) | 80 | 400 |
| Meander Length Ratio, Lm/Wbkf * | 10.0 | 50.2 |
| Radius of Curvature, Rc (ft) | 13 | 45 |
| Rc Ratio, Rc/Wbkf * | 1.6 | 5.6 |
| Belt Width, Wblt (ft) | 10 | 140 |
| Meander Width Ratio, Wblt/Wbkf * | 1.2 | 17.5 |
| Sinuosity, K | 1.2 | |
| Valley Slope, Sval (ft/ft) | 0.031 | |
| Channel Slope, Schan (ft/ft) | 0.0258 | |
| Riffle Slope, Sriff (ft/ft) | 0.0933 | 0.0220 |
| Riffle Slope Ratio, Sriff/Schan | 3.62 | 0.85 |
| Pool Slope, Spool (ft/ft) | 0.0000 | 0.0091 |
| Pool Slope Ratio, Spool/Schan | 0.0000 | 0.35 |
| Pool Max Depth, Dmaxpool (ft) | 2.4 | |
| Pool Max Depth Ratio, Dmaxpool/Dbkf | 4.0 | |
| Pool Width, Wpool (ft) | 6.4 | 10.0 |
| Pool Width Ratio, Wpool/Wbkf | 0.8 | 1.3 |
| Pool-Pool Spacing, Lps (ft) | 18.0 | 171.0 |
| Pool-Pool Spacing Ratio, Lps/Wbkf | 2.3 | 21.4 |
| d16 (mm) | n/a | |
| d35 (mm) | 0.8 | |
| d50 (mm) | 11.2 | |
| d84 (mm) | 38.4 | |
| d95 (mm) | 63.2 | |

| Meredell Farm Reach UT2 | Existing Stream Values | |
|---|---|---|
| **Parameter** | **MIN** | **MAX** |
| Drainage Area, DA (sq mi) | 0.1 | |
| Stream Type (Rosgen) | B5 | E5 |
| Bankfull Riffle XSEC Area, Abkf (sq ft) | 2.4 | 6.2 |
| Bankfull Riffle Width, Wbkf (ft) | 4.9 | 8.1 |
| Bankfull Riffle Mean Depth, Dbkf (ft) | 0.4 | 0.8 |
| Width to Depth Ratio, W/D (ft/ft) | 9.8 | 18.4 |
| Width Floodprone Area, Wfpa (ft) | 11 | 17 |
| Entrenchment Ratio, Wfpa/Wbkf (ft/ft) | 1.6 | 2.3 |
| Riffle Max Depth @ bkf, Dmax (ft) | 0.8 | 1.2 |
| Riffle Max Depth Ratio, Dmax/Dbkf | 1.5 | 2.0 |
| Bank Height Ratio, Dtob/Dmax (ft/ft) | 2.2 | 3.7 |
| Meander Length, Lm (ft) | 60 | 95 |
| Meander Length Ratio, Lm/Wbkf * | 8.8 | 13.9 |
| Radius of Curvature, Rc (ft) | 3 | 13 |
| Rc Ratio, Rc/Wbkf * | 0.4 | 1.9 |
| Belt Width, Wblt (ft) | 15 | 15 |
| Meander Width Ratio, Wblt/Wbkf * | 2.2 | 2.2 |
| Sinuosity, K | 1.12 | |
| Valley Slope, Sval (ft/ft) | 0.036 | |
| Channel Slope, Schan (ft/ft) | 0.0321 | |
| Riffle Slope, Sriff (ft/ft) | 0.0088 | 0.2250 |
| Riffle Slope Ratio, Sriff/Schan | 0.27 | 7.01 |
| Pool Slope, Spool (ft/ft) | 0.0005 | 0.4000 |
| Pool Slope Ratio, Spool/Schan | 0.02 | 12.46 |
| Pool Max Depth, Dmaxpool (ft) | 1.0 | |
| Pool Max Depth Ratio, Dmaxpool/Dbkf | 1.7 | |
| Pool Width, Wpool (ft) | 6.1 | |
| Pool Width Ratio, Wpool/Wbkf | 0.9 | |
| Pool-Pool Spacing, Lps (ft) | 30.0 | 67.0 |
| Pool-Pool Spacing Ratio, Lps/Wbkf | 4.4 | 9.8 |
| d16 (mm) | 0.2 | |
| d35 (mm) | 0.4 | |
| d50 (mm) | 0.7 | |
| d84 (mm) | 9.8 | |
| d95 (mm) | 20.7 | |

Note 1: This reach has a very low sinuosity and poor bedform diversity. Due to lack of pools in the reach, no pool cross sections were performed.

| Meredell Farm Reach UT3 | Existing Stream Values | |
|---|---|---|
| **Parameter** | **MIN** | **MAX** |
| Drainage Area, DA (sq mi) | 0.23 | |
| Stream Type (Rosgen) | F4/1 | C4/1 |
| Bankfull Riffle XSEC Area, Abkf (sq ft) | 4.2 | 6.3 |
| Bankfull Riffle Width, Wbkf (ft) | 7.7 | 15.4 |
| Bankfull Riffle Mean Depth, Dbkf (ft) | 0.4 | 0.5 |
| Width to Depth Ratio, W/D (ft/ft) | 14.3 | 37.3 |
| Width Floodprone Area, Wfpa (ft) | 9 | 39 |
| Entrenchment Ratio, Wfpa/Wbkf (ft/ft) | 1.2 | 2.5 |
| Riffle Max Depth @ bkf, Dmax (ft) | 0.9 | 1.0 |
| Riffle Max Depth Ratio, Dmax/Dbkf | 1.8 | 2.2 |
| Bank Height Ratio, Dtob/Dmax (ft/ft) | 1.0 | 3.8 |
| Meander Length, Lm (ft) | 25 | 105 |
| Meander Length Ratio, Lm/Wbkf * | 2.2 | 9.1 |
| Radius of Curvature, Rc (ft) | 18 | 55 |
| Rc Ratio, Rc/Wbkf * | 11.6 | 4.8 |
| Belt Width, Wblt (ft) | 15 | 60 |
| Meander Width Ratio, Wblt/Wbkf * | 1.3 | 5.2 |
| Sinuosity, K | 1.2 | |
| Valley Slope, Sval (ft/ft) | 0.0126 | |
| Channel Slope, Schan (ft/ft) | 0.0105 | |
| d16 (mm) | 0.1 | 0.4 |
| d35 (mm) | 0.8 | 0.7 |
| d50 (mm) | 32.0 | 1.0 |
| d84 (mm) | 2628.5 | 6.8 |
| d95 (mm) | 3565.8 | 15.4 |
| | UT3a pebble count | UT3b bulk |

Note 1: This reach has a very low sinuosity and poor bedform diversity. Due to lack of pools in the reach, no pool cross sections were performed.

| Meredell Farm Reach UT4 | Existing Stream Values | |
|---|---|---|
| **Parameter** | **MIN** | **MAX** |
| Drainage Area, DA (sq mi) | 0.09 | |
| Stream Type (Rosgen) | E5 | G5 |
| Bankfull Riffle XSEC Area, Abkf (sq ft) | 1.9 | 2.8 |
| Bankfull Riffle Width, Wbkf (ft) | 4.7 | 4.7 |
| Bankfull Riffle Mean Depth, Dbkf (ft) | 0.4 | 0.6 |
| Width to Depth Ratio, W/D (ft/ft) | 7.8 | 11.6 |
| Width Floodprone Area, Wfpa (ft) | 8 | 37 |
| Entrenchment Ratio, Wfpa/Wbkf (ft/ft) | 1.6 | 7.7 |
| Riffle Max Depth @ bkf, Dmax (ft) | 0.7 | 0.9 |
| Riffle Max Depth Ratio, Dmax/Dbkf | 1.4 | 1.7 |
| Bank Height Ratio, Dtob/Dmax (ft/ft) | 1.3 | 2.0 |
| Meander Length, Lm (ft) | 80 | 220 |
| Meander Length Ratio, Lm/Wbkf * | 17.0 | 46.8 |
| Radius of Curvature, Rc (ft) | 13 | 70 |
| Rc Ratio, Rc/Wbkf * | 2.7 | 14.9 |
| Belt Width, Wblt (ft) | 10 | 35 |
| Meander Width Ratio, Wblt/Wbkf * | 2.1 | 7.4 |
| Sinuosity, K | 1.13 | |
| Valley Slope, Sval (ft/ft) | 0.0461 | |
| Channel Slope, Schan (ft/ft) | 0.0408 | |
| d16 (mm) | 0.3 | |
| d35 (mm) | 0.6 | |
| d50 (mm) | 0.9 | |
| d84 (mm) | 4.2 | |
| d95 (mm) | 12.0 | |

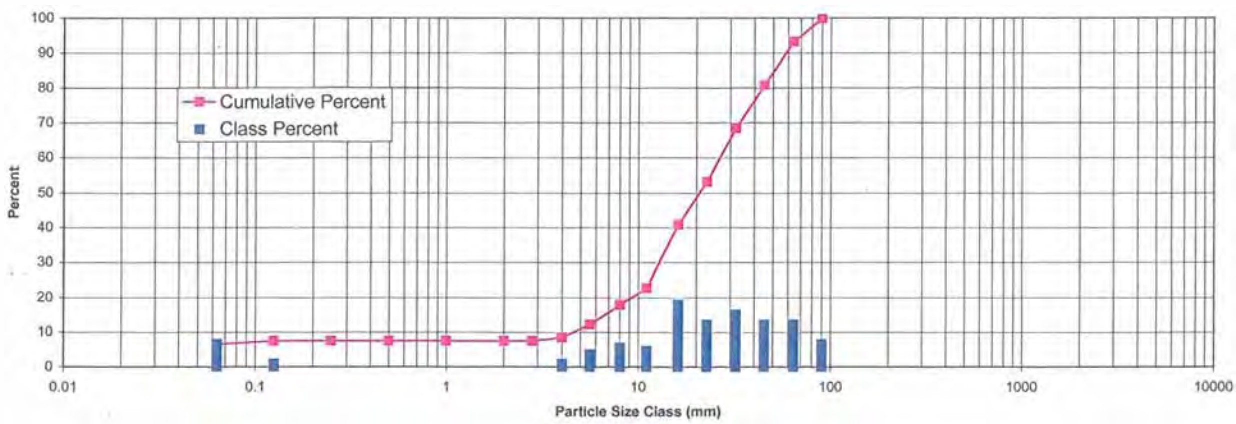
Note 1: This reach has a very low sinuosity and poor bedform diversity. Due to lack of pools in the reach, no pool cross sections were performed.

| Meredell Farm Reach UT5 | Existing Stream Values | |
|---|---|---|
| **Parameter** | **MIN** | **MAX** |
| Drainage Area, DA (sq mi) | 0.09 | |
| Stream Type (Rosgen) | | |
| Bankfull Riffle XSEC Area, Abkf (sq ft) | 1.2 | 1.8 |
| Bankfull Riffle Width, Wbkf (ft) | 2.9 | 3.1 |
| Bankfull Riffle Mean Depth, Dbkf (ft) | 0.4 | 0.6 |
| Width to Depth Ratio, W/D (ft/ft) | 5.2 | 7.1 |
| Width Floodprone Area, Wfpa (ft) | 6 | 41 |
| Entrenchment Ratio, Wfpa/Wbkf (ft/ft) | 2.1 | 14.2 |
| Riffle Max Depth @ bkf, Dmax (ft) | 0.7 | 1.0 |
| Riffle Max Depth Ratio, Dmax/Dbkf | 1.7 | 1.8 |
| Bank Height Ratio, Dtob/Dmax (ft/ft) | 1.1 | 2.6 |
| Meander Length, Lm (ft) | 50 | 120 |
| Meander Length Ratio, Lm/Wbkf * | 16.7 | 40.0 |
| Radius of Curvature, Rc (ft) | 20 | 62 |
| Rc Ratio, Rc/Wbkf * | 6.8 | 20.5 |
| Belt Width, Wblt (ft) | 15 | 35 |
| Meander Width Ratio, Wblt/Wbkf * | 5.0 | 11.7 |
| Sinuosity, K | 1.11 | |
| Valley Slope, Sval (ft/ft) | 0.0429 | |
| Channel Slope, Schan (ft/ft) | 0.0387 | |
| d16 (mm) | 0.3 | |
| d35 (mm) | 0.6 | |
| d50 (mm) | 1.0 | |
| d84 (mm) | 8.5 | |
| d95 (mm) | 23.7 | |

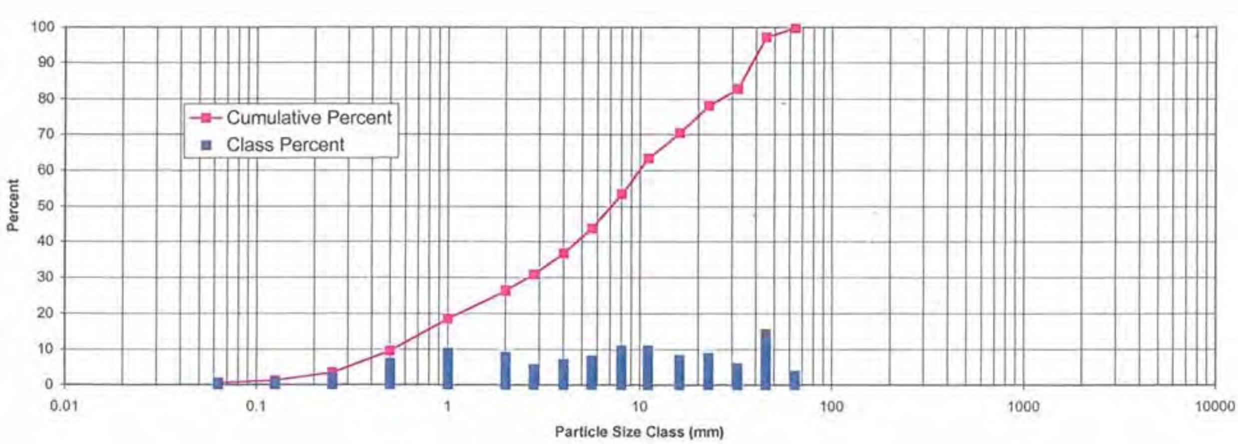
Note 1: This reach has a very low sinuosity and poor bedform diversity. Due to lack of pools in the reach, no pool cross sections were performed.

| Channel materials - M1 | | | |
|---|---|---|---|
| | Pavement | Pavement | Subpavement |
| $D_{16}$ = | 7.02 | 33.30 | 0.82 |
| $D_{35}$ = | 14.14 | 41.45 | 3.58 |
| $D_{50}$ = | 20.59 | 52.72 | 7.01 |
| $D_{84}$ = | 49.08 | 78.62 | 32.80 |
| $D_{95}$ = | 69.69 | 86.28 | 42.57 |
| User defined %: | | | |
| 99 | | | |
| D99 = | 85.51 | 89.24 | 56.04 |

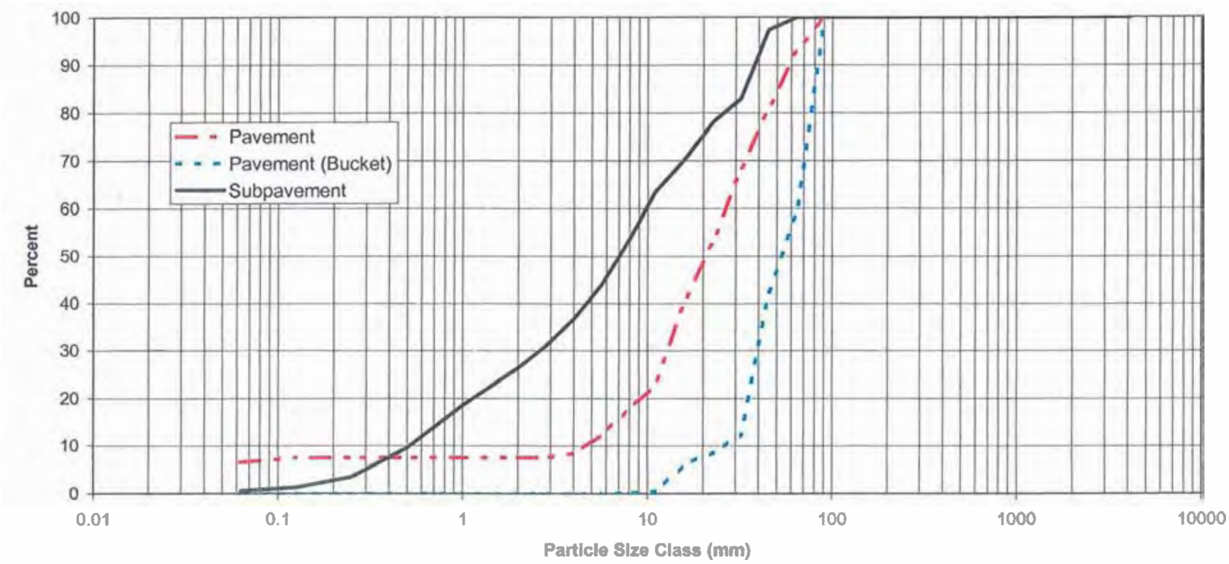
**M1 Pavement Sediment Distribution**




**M1 Subpavement Sediment Distribution**



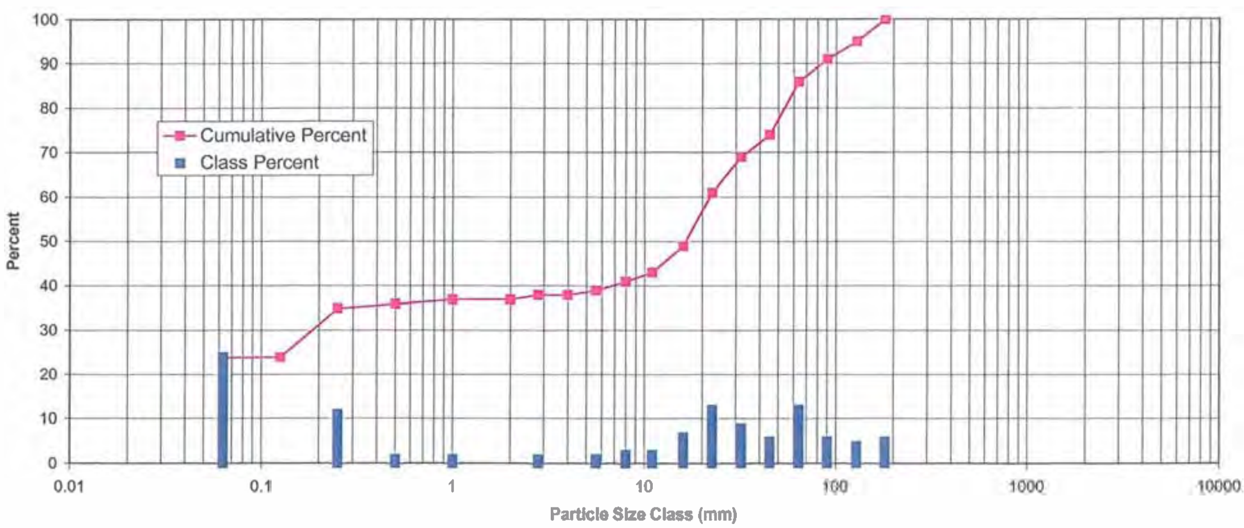
M1 Sediment Distribution by Layer



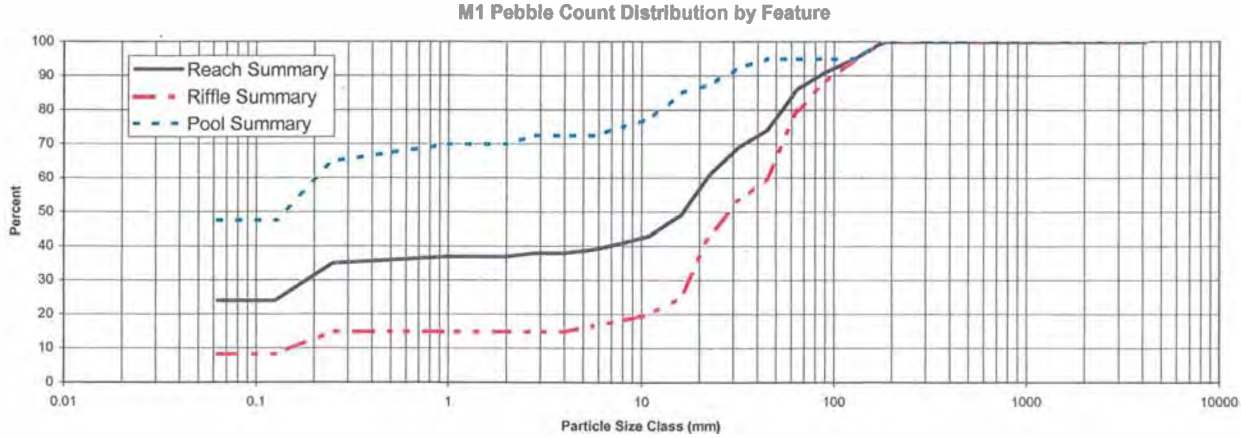
**M1 PEBBLE COUNT DATA**

| Cummulative | | Riffle | | Pool | |
|---|---|---|---|---|---|
| Channel materials | | Channel materials | | Channel materials | |
| $D_{16}$ = | #N/A | $D_{16}$ = | 4.89 | $D_{16}$ = | #N/A |
| $D_{35}$ = | 0.25 | $D_{35}$ = | 19.32 | $D_{35}$ = | #N/A |
| $D_{50}$ = | 16.47 | $D_{50}$ = | 28.50 | $D_{50}$ = | 0.14 |
| $D_{84}$ = | 60.35 | $D_{84}$ = | 75.38 | $D_{84}$ = | 15.22 |
| $D_{95}$ = | 128.00 | $D_{95}$ = | 128.00 | $D_{95}$ = | 128.00 |
| | | | | | |
| Percent: | [redacted]99[redacted] | Percent: | 99 | Percent: | 99 |
| D99 = | 168.14 | D99 = | 168.14 | D99 = | 168.14 |

**M1 Pebble Count Sediment Distribution**

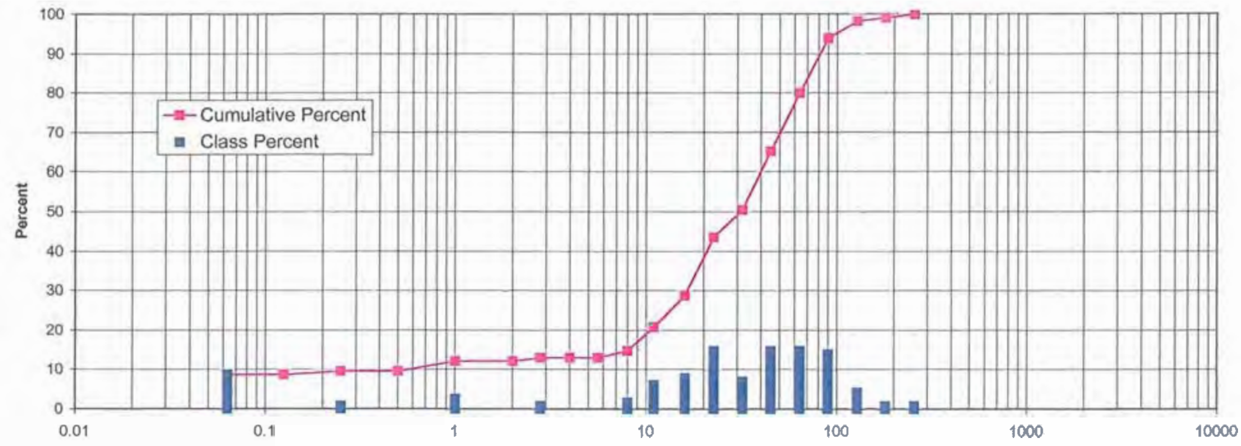



**M1 Pebble Count Distribution by Feature**

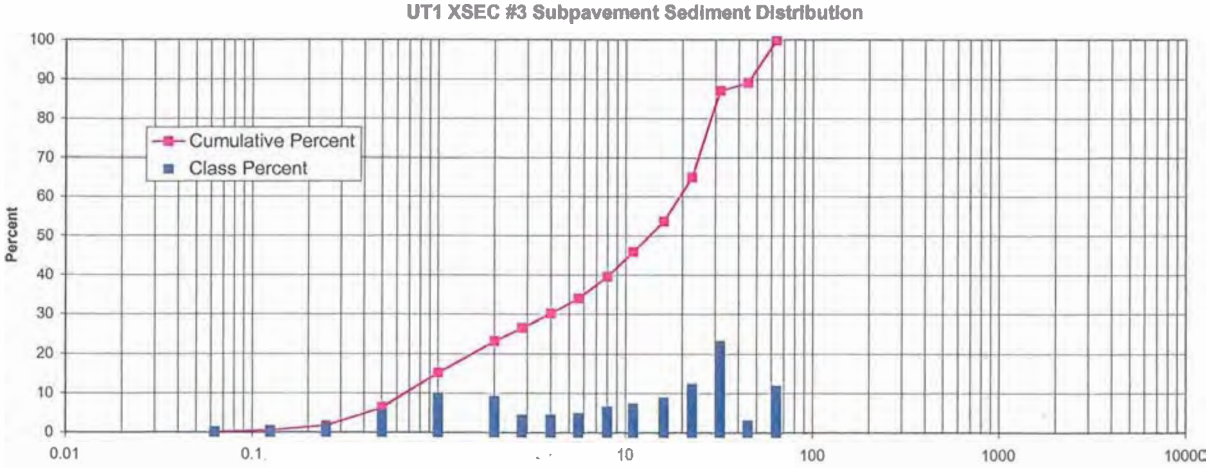


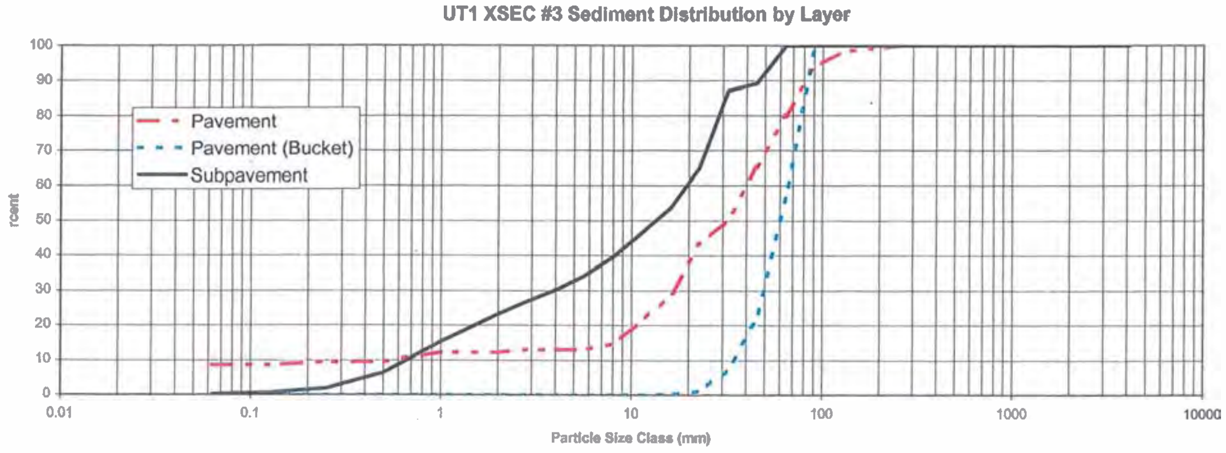
| Channel materials - UT1 XSEC#3 | | | |
|---|---|---|---|
| | Pavement | Pavement | Subpavement |
| $D_{16}$ = | 8.53 | 39.31 | 1.06 |
| $D_{35}$ = | 18.54 | 51.45 | 5.93 |
| $D_{50}$ = | 31.31 | 59.84 | 13.36 |
| $D_{84}$ = | 70.59 | 79.35 | 30.44 |
| $D_{95}$ = | 98.28 | 86.53 | 54.38 |
| User defined %: 99 | | | |
| D99 = | 171.03 | 89.29 | 61.95 |

UT1 XSEC #3 Pavement Sediment Distribution



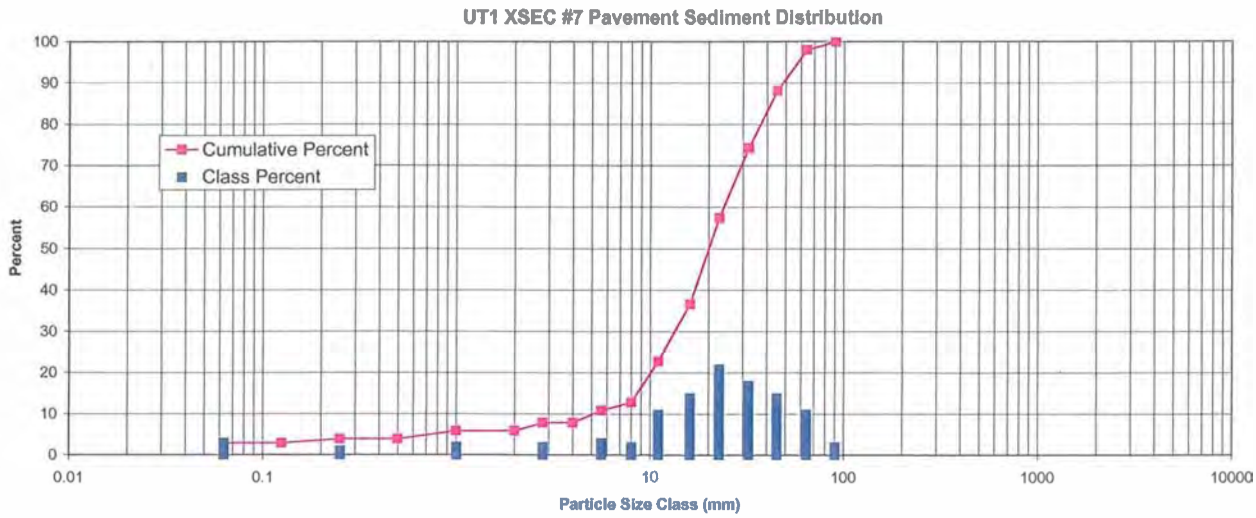

UT1 XSEC #3 Subpavement Sediment Distribution

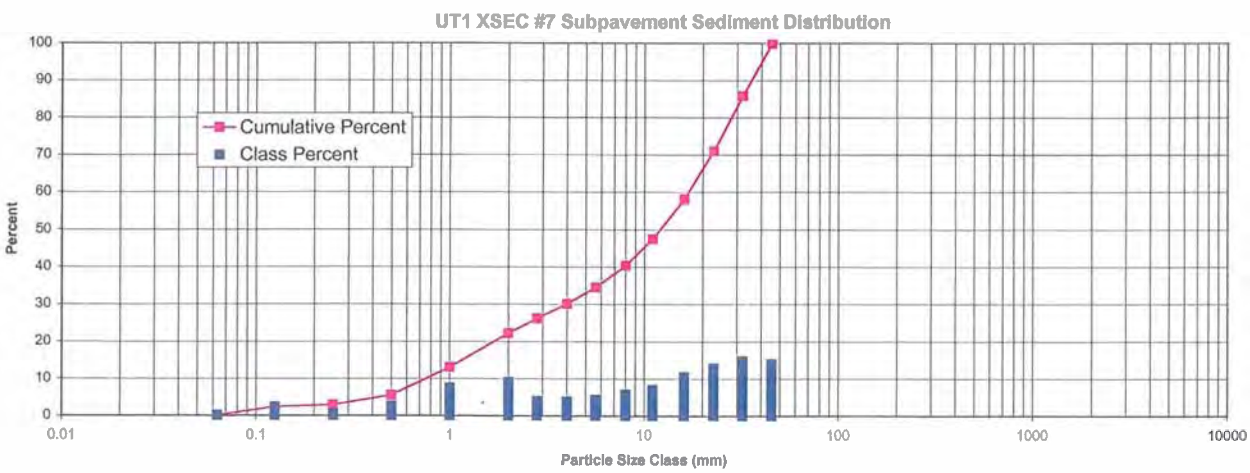


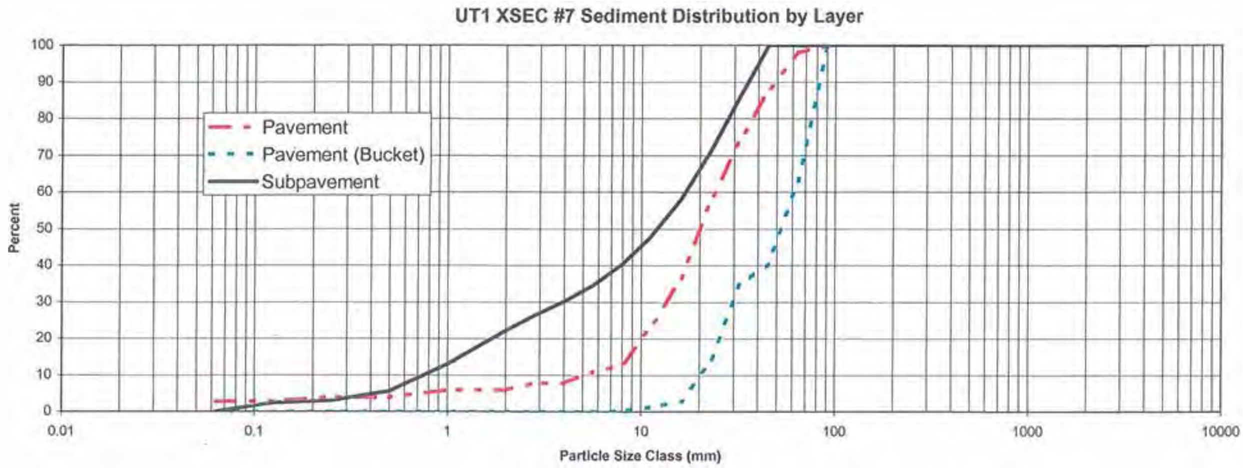


UT1 XSEC #3 Sediment Distribution by Layer
Pavement
Pavement (Bucket)
Subpavement
rcent
100
90
80
70
60
50
40
30
20
10
0
0.01
0.1
1
10
100
1000
10000
Particle Size Class (mm)

| Channel materials - UT1 XSEC #7 | | | |
|---|---|---|---|
| | Pavement | Pavement | Subpavement |
| $D_{16}$ = | 8.85 | 23.62 | 1.24 |
| $D_{35}$ = | 15.31 | 32.59 | 5.75 |
| $D_{50}$ = | 19.98 | 52.17 | 12.00 |
| $D_{84}$ = | 40.66 | 77.62 | 30.58 |
| $D_{95}$ = | 57.48 | 85.93 | 39.86 |
| User defined %: | | | |
| 99 | | | |
| D99 = | 75.77 | 89.17 | 43.92 |



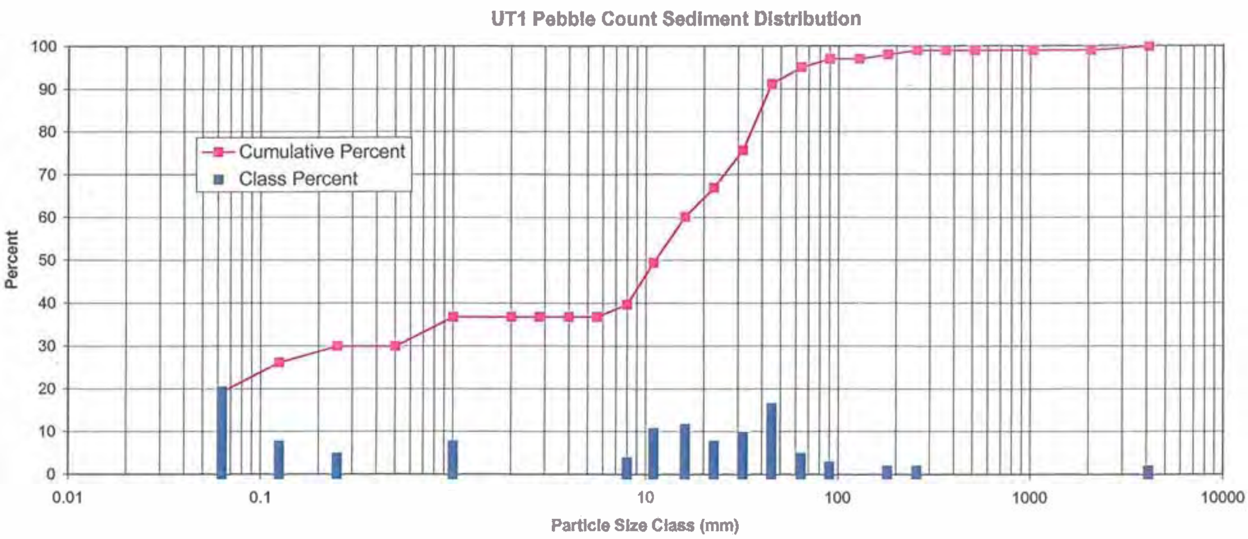



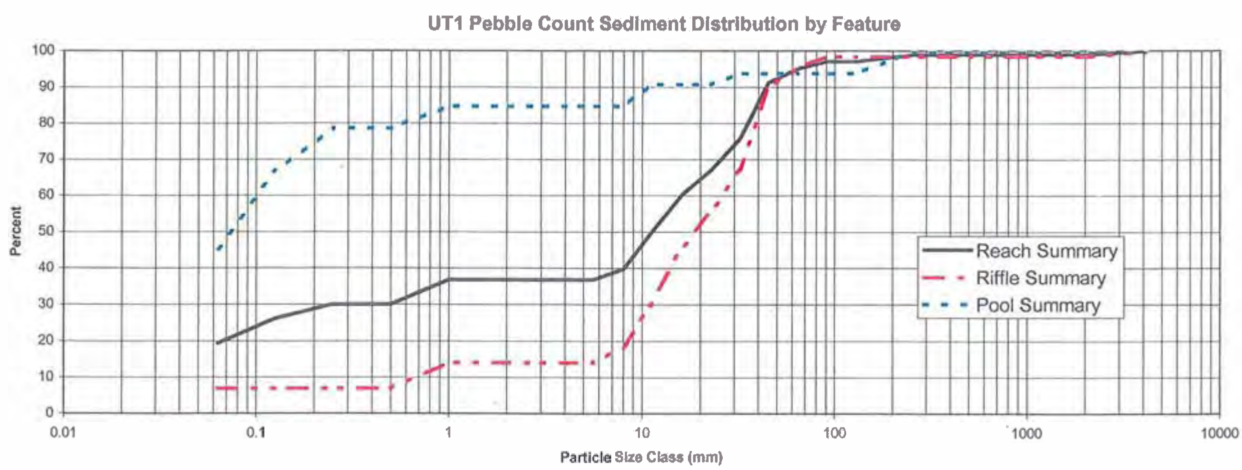


UT1 XSEC #7 Sediment Distribution by Layer
Percent
Particle Size Class (mm)
Pavement
Pavement (Bucket)
Subpavement
0.01
0.1
1
10
100
1000
10000

**UT1 PEBBLE COUNT**

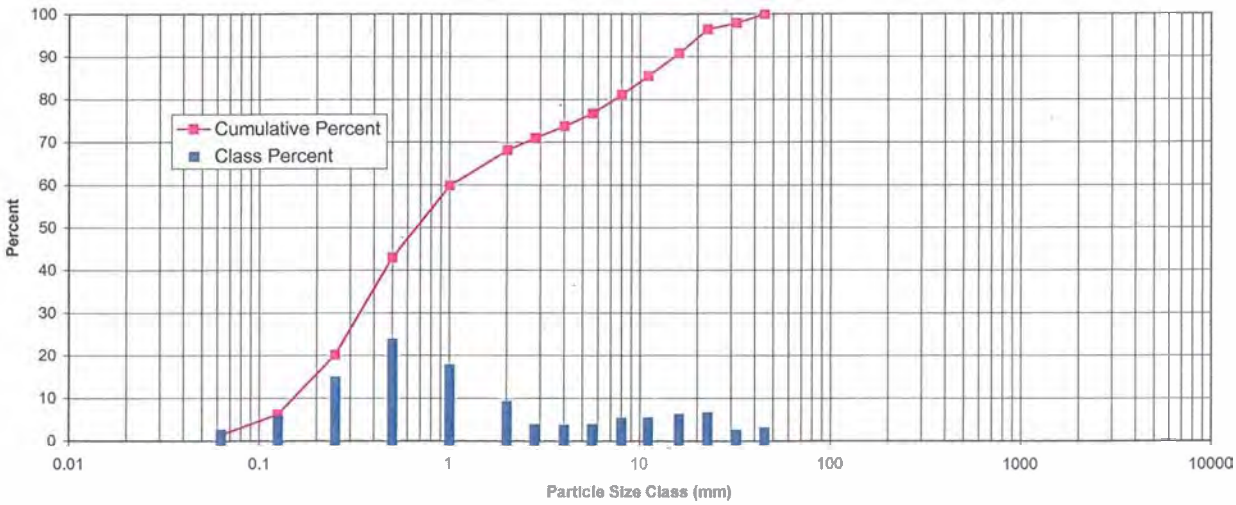
| Cummulative | | Riffle | | Pool | |
|---|---|---|---|---|---|
| Channel materials | | Channel materials | | Channel materials | |
| $D_{16}$ = | #N/A | $D_{16}$ = | 6.46 | $D_{16}$ = | #N/A |
| $D_{35}$ = | 0.82 | $D_{35}$ = | 12.39 | $D_{35}$ = | #N/A |
| $D_{50}$ = | 11.19 | $D_{50}$ = | 18.55 | $D_{50}$ = | 0.07 |
| $D_{84}$ = | 38.37 | $D_{84}$ = | 41.15 | $D_{84}$ = | 0.91 |
| $D_{95}$ = | 63.16 | $D_{95}$ = | 61.24 | $D_{95}$ = | 144.22 |
| | | | | | |
| Percent: | [redacted] | Percent: | 99 | Percent: | 99 |
| D99 = | 253.31 | D99 = | 2521.38 | D99 = | 227.91 |



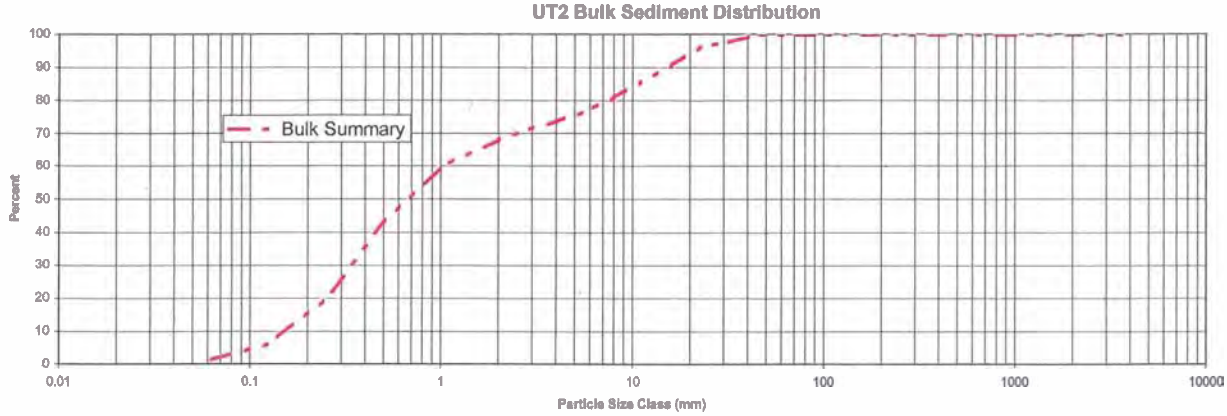



| Cummulative UT2 | |
|---|---|
| **Channel materials** | |
| $D_{16}$ = | 0.20 |
| $D_{35}$ = | 0.39 |
| $D_{50}$ = | 0.66 |
| $D_{84}$ = | 9.84 |
| $D_{95}$ = | 20.67 |
| | |
| Percent: | 99 |
| D99 = | 38.18 |

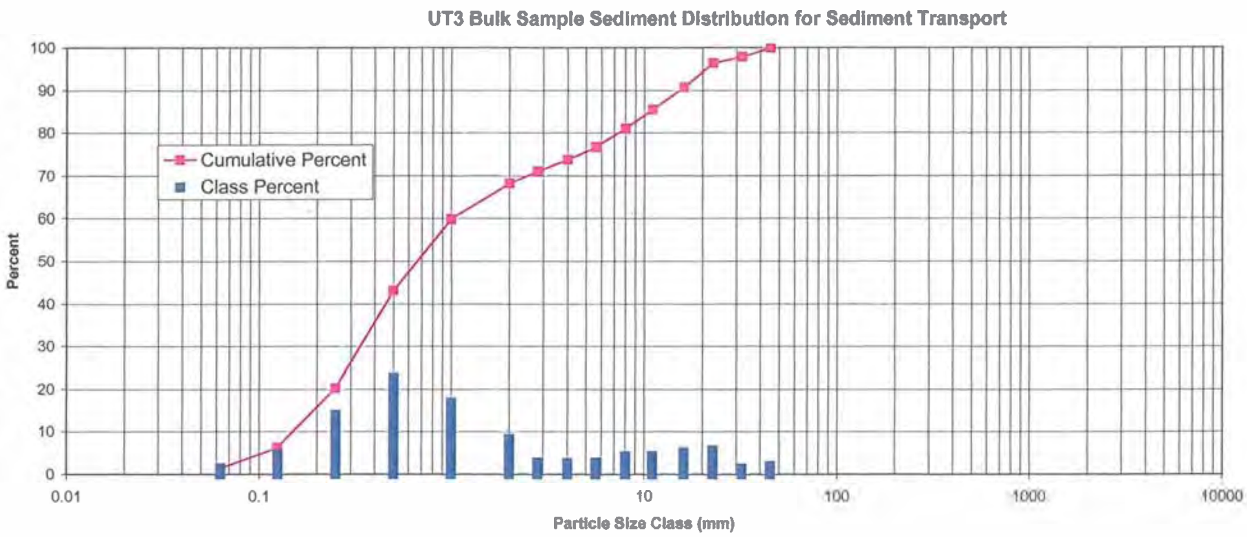
**UT2 Sand Bed/Bedrock Sediment Distribution - Bulk Sample**




**UT2 Bulk Sediment Distribution**

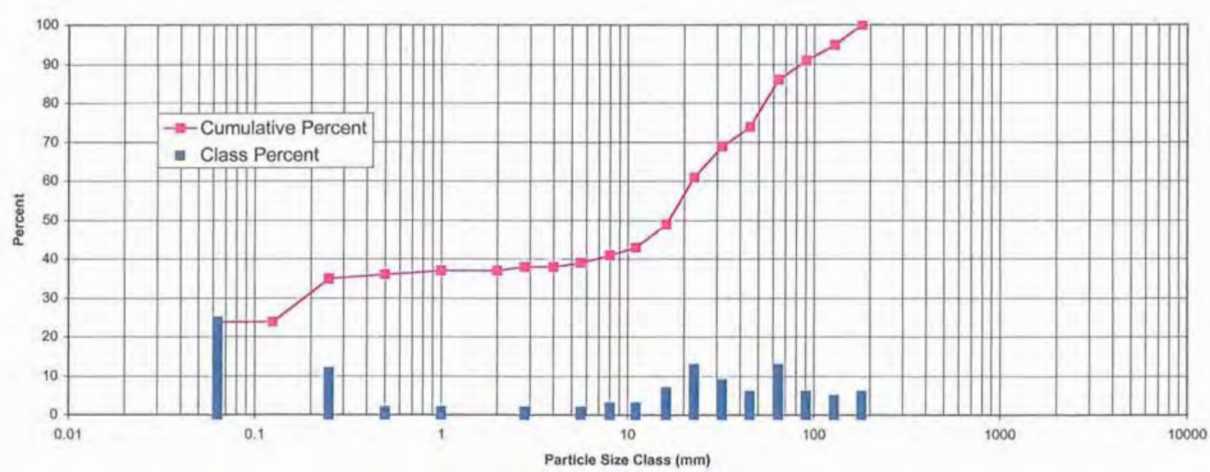


| Cummulative UT3 | |
|---|---|
| **Channel materials** | |
| $D_{16}$ = | 0.36 |
| $D_{35}$ = | 0.67 |
| $D_{50}$ = | 1.00 |
| $D_{84}$ = | 6.80 |
| $D_{95}$ = | 15.38 |
| | |
| Percent: | 99 |
| D99 = | 59.38 |

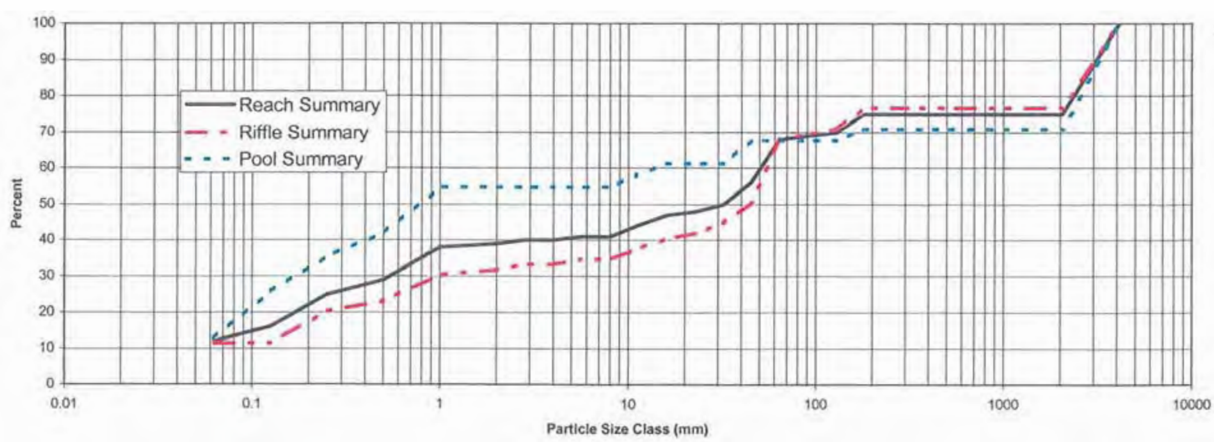


| Cummulative | | Riffle | | Pool | |
|---|---|---|---|---|---|
| Channel materials | | Channel materials | | Channel materials | |
| $D_{16}$ = | 0.13 | $D_{16}$ = | 0.18 | $D_{16}$ = | 0.07 |
| $D_{35}$ = | 0.79 | $D_{35}$ = | 8.19 | $D_{35}$ = | 0.24 |
| $D_{50}$ = | 32.00 | $D_{50}$ = | 43.12 | $D_{50}$ = | 0.77 |
| $D_{84}$ = | 2628.46 | $D_{84}$ = | 2538.92 | $D_{84}$ = | 2795.50 |
| $D_{95}$ = | 3565.78 | $D_{95}$ = | 3527.36 | $D_{95}$ = | 3635.10 |
| | | | | | |
| Percent: | [redacted] | Percent: | 99 | Percent: | 99 |
| D99 = | 3983.99 | D99 = | 3975.37 | D99 = | 3999.37 |

UT3b Pebble Count Sediment Distribution

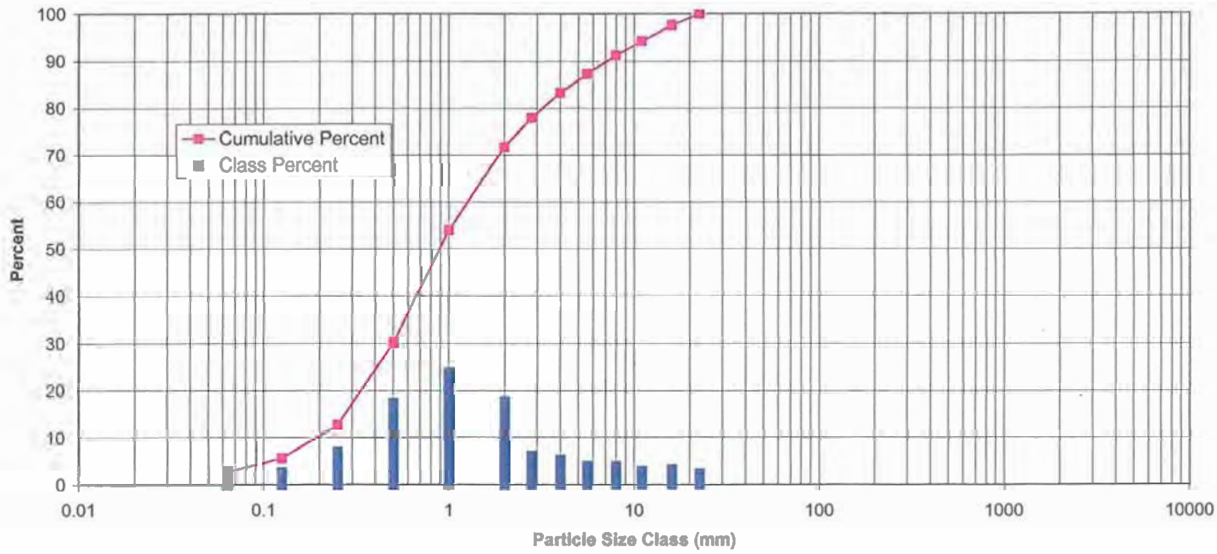



UT# Sediment Distribution by Feature



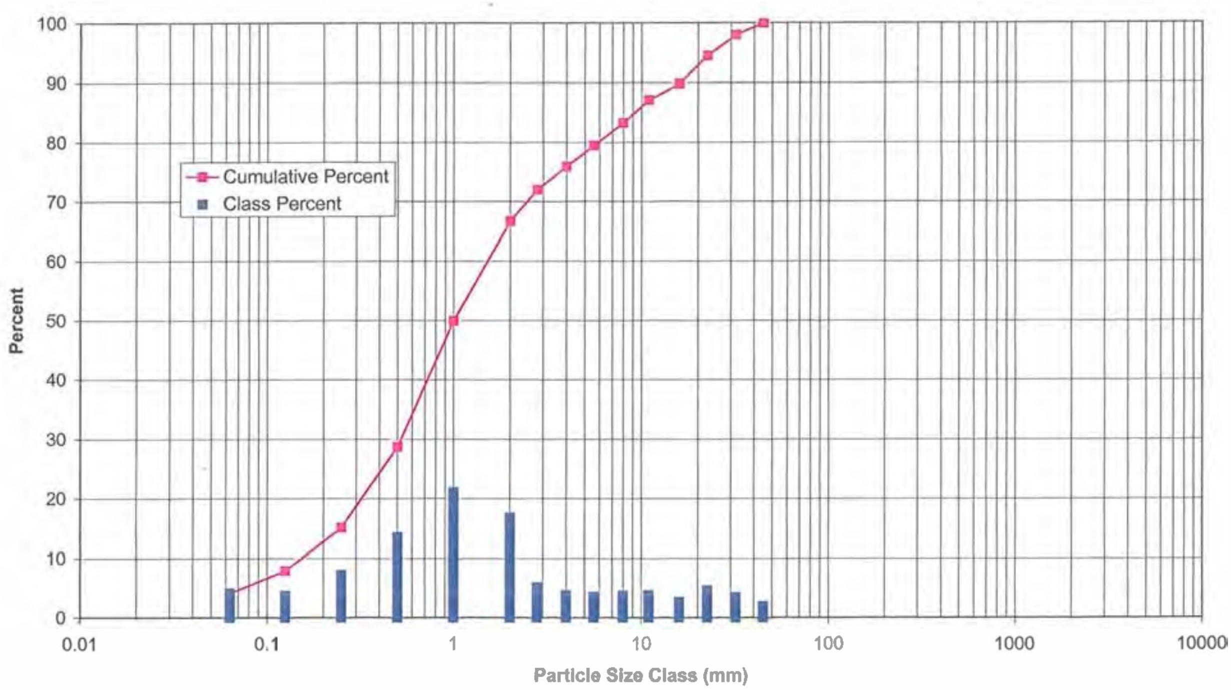
| Cummulative | |
|---|---|
| **Channel materials** | |
| $D_{16}$ = | 0.28 |
| $D_{35}$ = | 0.58 |
| $D_{50}$ = | 0.89 |
| $D_{84}$ = | 4.23 |
| $D_{95}$ = | 11.97 |
| | |
| Percent: | 99 |

**UT4 Bulk Sample Sediment Distribution**



| Cummulative | |
|---|---|
| Channel materials | |
| $D_{16}$ = | 0.26 |
| $D_{35}$ = | 0.61 |
| $D_{50}$ = | 1.00 |
| $D_{84}$ = | 8.49 |
| $D_{95}$ = | 23.73 |
| | |
| Percent: | [illegible] |
| D99 = | 37.83 |

**UT5 Bulk Sample Sediment Distribution**



# Appendix D

Site Photographs

# Meredell Farm Photo Log


Runoff from dairy enters UT1


M1-Typical Bank Erosion


M1-Location where cattle now cross


M1-Cattle have unrestricted access

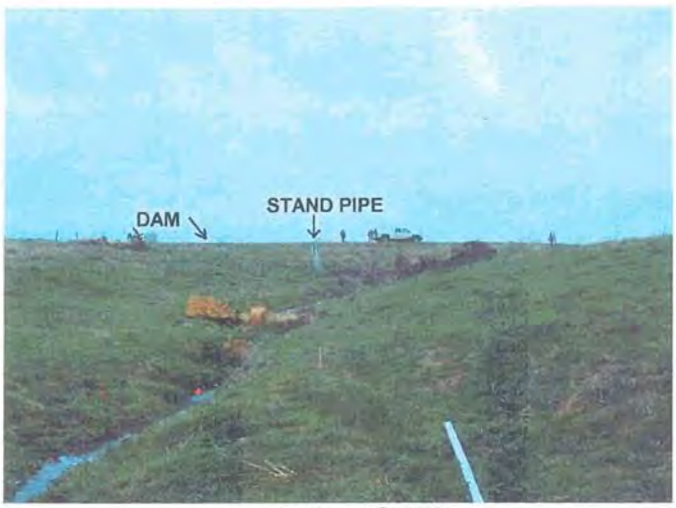

M1-Lower end near confluence with Sandy Creek


Begin UT1 - Headcut

# Meredell Farm Photo Log

UT1 - Approximate location to begin restoration

Lower end of UT1



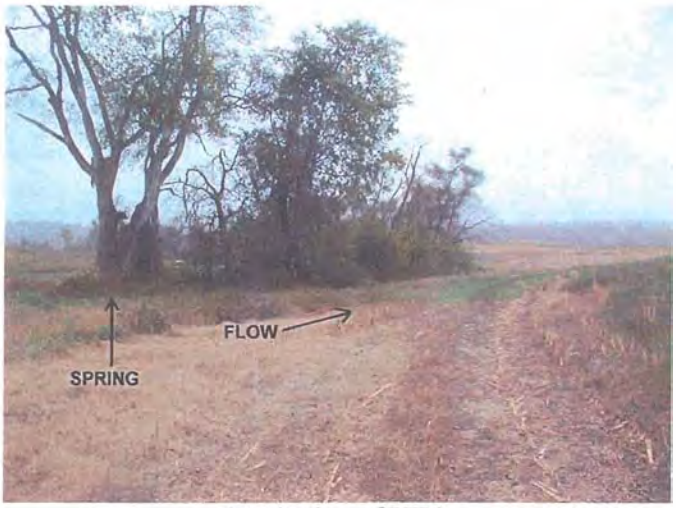

Beginning of UT2

UT2- Approximate location to begin restoration

Beginning of UT3

UT3b - Incised and eroding

# Meredell Farm Photo Log




Beginning of UT4

UT5 to be enhanced by preventing headcut and improving riparian buffer

Sandy Creek

## Appendix E

DWQ Stream Forms

## NCDWQ Stream Classification Form

Project Name: Meredell Farms – UT1 | River Basin: Cape Fear | County: Randolph | Evaluator: JR, SR
DWQ Project Number: | Nearest Named Stream: Sandy Creek | Latitude: | Signature:
Date: June 28, 2004 | USGS QUAD: | Longitude: | Location/Directions:

***PLEASE NOTE:** ***If evaluator and landowner agree that the feature is a man-made ditch, then use of this form is not necessary. Also, if in the best professional judgement of the evaluator, the feature is a man-made ditch and not a modified natural stream—this rating system should not be used****

### Primary Field Indicators: (Circle One Number Per Line)

| I. Geomorphology | Absent | Weak | Moderate | Strong |
|---|---|---|---|---|
| 1) Is There A Riffle-Pool Sequence? | 0 | 1 | 2 | **3** |
| 2) Is The USDA Texture In Streambed Different From Surrounding Terrain? | 0 | 1 | 2 | **3** |
| 3) Are Natural Levees Present? | **0** | 1 | 2 | 3 |
| 4) Is The Channel Sinuous? | 0 | **1** | 2 | 3 |
| 5) Is There An Active (Or Relic) Floodplain Present? | 0 | **1** | 2 | 3 |
| 6) Is The Channel Braided? | **0** | 1 | 2 | 3 |
| 7) Are Recent Alluvial Deposits Present? | 0 | **1** | 2 | 3 |
| 8) Is There A Bankfull Bench Present? | 0 | 1 | **2** | 3 |
| 9) Is A Continuous Bed & Bank Present? *(*NOTE: If Bed & Bank Caused By Ditching And WITHOUT Sinuosity Then Score=0*)* | 0 | 1 | 2 | **3** |
| 10) Is A 2nd Order Or Greater Channel (As Indicated On Topo Map *And/Or* In Field) Present? | | *Yes*=3 | *No*=**0** | |

*PRIMARY GEOMORPHOLOGY INDICATOR POINTS:* __14____

| II. Hydrology | Absent | Weak | Moderate | Strong |
|---|---|---|---|---|
| 1) Is There A Groundwater Flow/Discharge Present? | 0 | **1** | 2 | 3 |

***PRIMARY HYDROLOGY INDICATOR POINTS:*** __1____

| III. Biology | Absent | Weak | Moderate | Strong |
|---|---|---|---|---|
| 1) Are Fibrous Roots Present In Streambed? | 3 | **2** | 1 | 0 |
| 2) Are Rooted Plants Present In Streambed? | **3** | 2 | 1 | 0 |
| 3) Is Periphyton Present? | 0 | **1** | 2 | 3 |
| 4) Are Bivalves Present? | **0** | 1 | 2 | 3 |

***PRIMARY BIOLOGY INDICATOR POINTS:*** ___6____

### Secondary Field Indicators: *(Circle One Number Per Line)*

| I. Geomorphology | Absent | Weak | Moderate | Strong |
|---|---|---|---|---|
| 1) Is There A Head Cut Present In Channel? | 0 | **.5** | 1 | 1.5 |
| 2) Is There A Grade Control Point In Channel? | 0 | .5 | 1 | **1.5** |
| 3) Does Topography Indicate A Natural Drainage Way? | 0 | .5 | 1 | **1.5** |

*SECONDARY GEOMORPHOLOGY INDICATOR POINTS:* __3.5____

| II. Hydrology | Absent | Weak | Moderate | Strong |
|---|---|---|---|---|
| 1) Is This Year's (Or Last's) Leaflitter Present In Streambed? | **1.5** | 1 | .5 | 0 |
| 2) Is Sediment On Plants (Or Debris) Present? | 0 | **.5** | 1 | 1.5 |
| 3) Are Wrack Lines Present? | **0** | .5 | 1 | 1.5 |
| 4) Is Water In Channel *And* >48 Hrs. Since Last *Known* Rain? *(*NOTE: If Ditch Indicated In #9 Above Skip This Step And #5 Below*)* | 0 | .5 | 1 | **1.5** |
| 5) Is There Water In Channel During Dry Conditions *Or* In Growing Season)? | 0 | .5 | 1 | **1.5** |
| 6) Are Hydric Soils Present In Sides Of Channel (Or In Headcut)? | | *Yes*=*1.5* | *No*=**0** | |

*SECONDARY HYDROLOGY INDICATOR POINTS:* __5.0____

| III. Biology | Absent | Weak | Moderate | Strong |
|---|---|---|---|---|
| 1) Are Fish Present? | 0 | .5 | 1 | **1.5** |
| 2) Are Amphibians Present? | 0 | .5 | **1** | 1.5 |
| 3) Are AquaticTurtles Present? | **0** | .5 | 1 | 1.5 |
| 4) Are Crayfish Present? | **0** | .5 | 1 | 1.5 |
| 5) Are Macrobenthos Present? | 0 | .5 | **1** | 1.5 |
| 6) Are Iron Oxidizing Bacteria/Fungus Present? | **0** | .5 | 1 | 1.5 |
| 7) Is Filamentous Algae Present? | 0 | .5 | **1** | 1.5 |

| 8) Are Wetland Plants In Streambed? | SAV | Mostly OBL | Mostly FACW | Mostly FAC | Mostly FACU | Mostly UPL |
|---|---|---|---|---|---|---|
| *(* NOTE: If Total Absence Of All Plants In Streambed As Noted Above Skip This Step UNLESS SAV Present*).* | *2* | 1 | .75 | .5 | **0** | 0 |

*SECONDARY BIOLOGY INDICATOR POINTS:* __4.5____

**TOTAL POINTS (Primary + Secondary) =__34__**

**(If Greater Than Or Equal To 19 Points The Stream Is At Least Intermittent)**

# NCDWQ Stream Classification Form

| | | | |
|---|---|---|---|
| Project Name: Meredell Farms – UT2 | River Basin: Cape Fear | County: Randolph | Evaluator: JR, SR |
| DWQ Project Number: | Nearest Named Stream: Sandy Creek | Latitude: | Signature: |
| Date: June 28, 2004 | USGS QUAD: | Longitude: | Location/Directions: |

***PLEASE NOTE:** *If evaluator and landowner agree that the feature is a man-made ditch, then use of this form is not necessary. Also, if in the best professional judgement of the evaluator, the feature is a man-made ditch and not a modified natural stream—this rating system should not be used**

## Primary Field Indicators: (Circle One Number Per Line)

| I. Geomorphology | Absent | Weak | Moderate | Strong |
|---|---|---|---|---|
| 1) Is There A Riffle-Pool Sequence? | 0 | 1 | **2** | 3 |
| 2) Is The USDA Texture In Streambed Different From Surrounding Terrain? | 0 | 1 | **2** | 3 |
| 3) Are Natural Levees Present? | **0** | 1 | 2 | 3 |
| 4) Is The Channel Sinuous? | 0 | **1** | 2 | 3 |
| 5) Is There An Active (Or Relic) Floodplain Present? | 0 | **1** | 2 | 3 |
| 6) Is The Channel Braided? | **0** | 1 | 2 | 3 |
| 7) Are Recent Alluvial Deposits Present? | 0 | **1** | 2 | 3 |
| 8) Is There A Bankfull Bench Present? | 0 | 1 | **2** | 3 |
| 9) Is A Continuous Bed & Bank Present? | 0 | 1 | 2 | **3** |

*(*NOTE: If Bed & Bank Caused By Ditching And **WITHOUT** Sinuosity Then Score=0*)*

10) Is A 2nd Order Or Greater Channel (As Indicated On Topo Map ***And/Or*** In Field) Present? *Yes*=3 *No*=**0**

*PRIMARY GEOMORPHOLOGY INDICATOR POINTS:* __12____

| II. Hydrology | Absent | Weak | Moderate | Strong |
|---|---|---|---|---|
| 1) Is There A Groundwater Flow/Discharge Present? | 0 | **1** | 2 | 3 |

***PRIMARY HYDROLOGY INDICATOR POINTS:*** __1____

| III. Biology | Absent | Weak | Moderate | Strong |
|---|---|---|---|---|
| 1) Are Fibrous Roots Present In Streambed? | 3 | 2 | **1** | 0 |
| 2) Are Rooted Plants Present In Streambed? | **3** | 2 | 1 | 0 |
| 3) Is Periphyton Present? | 0 | 1 | **2** | 3 |
| 4) Are Bivalves Present? | **0** | 1 | 2 | 3 |

***PRIMARY BIOLOGY INDICATOR POINTS:*** ___6____

## Secondary Field Indicators: *(Circle One Number Per Line)*

| I. Geomorphology | Absent | Weak | Moderate | Strong |
|---|---|---|---|---|
| 1) Is There A Head Cut Present In Channel? | 0 | **.5** | 1 | 1.5 |
| 2) Is There A Grade Control Point In Channel? | 0 | .5 | 1 | **1.5** |
| 3) Does Topography Indicate A Natural Drainage Way? | 0 | .5 | 1 | **1.5** |

*SECONDARY GEOMORPHOLOGY INDICATOR POINTS:* __3.5____

| II. Hydrology | Absent | Weak | Moderate | Strong |
|---|---|---|---|---|
| 1) Is This Year's (Or Last's) Leaflitter Present In Streambed? | **1.5** | 1 | .5 | 0 |
| 2) Is Sediment On Plants (Or Debris) Present? | 0 | .5 | **1** | 1.5 |
| 3) Are Wrack Lines Present? | **0** | .5 | 1 | 1.5 |
| 4) Is Water In Channel ***And*** >48 Hrs. Since Last ***Known*** Rain? *(*NOTE: If Ditch Indicated In #9 Above Skip This Step And #5 Below*)* | 0 | .5 | 1 | **1.5** |
| 5) Is There Water In Channel During Dry Conditions ***Or*** In Growing Season)? | 0 | .5 | 1 | **1.5** |

6) Are Hydric Soils Present In Sides Of Channel (Or In Headcut)? *Yes=1.5* *No*=**0**

*SECONDARY HYDROLOGY INDICATOR POINTS:* __5.5___

| III. Biology | Absent | Weak | Moderate | Strong |
|---|---|---|---|---|
| 1) Are Fish Present? | **0** | .5 | 1 | 1.5 |
| 2) Are Amphibians Present? | 0 | .5 | **1** | 1.5 |
| 3) Are AquaticTurtles Present? | **0** | .5 | 1 | 1.5 |
| 4) Are Crayfish Present? | **0** | .5 | 1 | 1.5 |
| 5) Are Macrobenthos Present? | 0 | **.5** | 1 | 1.5 |
| 6) Are Iron Oxidizing Bacteria/Fungus Present? | 0 | **.5** | 1 | 1.5 |
| 7) Is Filamentous Algae Present? | 0 | .5 | 1 | **1.5** |

| 8) Are Wetland Plants In Streambed? | SAV | Mostly OBL | Mostly FACW | Mostly FAC | Mostly FACU | Mostly UPL |
|---|---|---|---|---|---|---|
| *(* **NOTE:** If Total Absence Of All Plants In Streambed As Noted Above Skip This Step UNLESS SAV Present*).* | 2 | 1 | .75 | **.5** | 0 | 0 |

*SECONDARY BIOLOGY INDICATOR POINTS:* __4.0____

**TOTAL POINTS (Primary + Secondary) =_32___**

**(If Greater Than Or Equal To 19 Points The Stream Is At Least Intermittent)**

## NCDWQ Stream Classification Form

Project Name: Meredell Farms – UT3 | River Basin: Cape Fear | County: Randolph | Evaluator: JR, SR
DWQ Project Number: | Nearest Named Stream: Sandy Creek | Latitude: | Signature:
Date: June 28, 2004 | USGS QUAD: | Longitude: | Location/Directions:

***PLEASE NOTE:** *If evaluator and landowner agree that the feature is a man-made ditch, then use of this form is not necessary. Also, if in the best professional judgement of the evaluator, the feature is a man-made ditch and not a modified natural stream—this rating system should not be used**

**Primary Field Indicators:** (Circle One Number Per Line)

| I. Geomorphology | Absent | Weak | Moderate | Strong |
|---|---|---|---|---|
| 1) Is There A Riffle-Pool Sequence? | 0 | 1 | 2 | **3** |
| 2) Is The USDA Texture In Streambed Different From Surrounding Terrain? | 0 | 1 | 2 | **3** |
| 3) Are Natural Levees Present? | **0** | 1 | 2 | 3 |
| 4) Is The Channel Sinuous? | 0 | **1** | 2 | 3 |
| 5) Is There An Active (Or Relic) Floodplain Present? | 0 | **1** | 2 | 3 |
| 6) Is The Channel Braided? | **0** | 1 | 2 | 3 |
| 7) Are Recent Alluvial Deposits Present? | 0 | **1** | 2 | 3 |
| 8) Is There A Bankfull Bench Present? | 0 | 1 | **2** | 3 |
| 9) Is A Continuous Bed & Bank Present? | 0 | 1 | 2 | **3** |

*(*NOTE: If Bed & Bank Caused By Ditching And **WITHOUT** Sinuosity Then Score=0*)*

10) Is A 2nd Order Or Greater Channel (As Indicated On Topo Map ***And/Or*** In Field) Present? *Yes*=3 *No*=**0**

*PRIMARY GEOMORPHOLOGY INDICATOR POINTS:* 14

| II. Hydrology | Absent | Weak | Moderate | Strong |
|---|---|---|---|---|
| 1) Is There A Groundwater Flow/Discharge Present? | 0 | **1** | 2 | 3 |

***PRIMARY HYDROLOGY INDICATOR POINTS:*** 1

| III. Biology | Absent | Weak | Moderate | Strong |
|---|---|---|---|---|
| 1) Are Fibrous Roots Present In Streambed? | 3 | **2** | 1 | 0 |
| 2) Are Rooted Plants Present In Streambed? | **3** | 2 | 1 | 0 |
| 3) Is Periphyton Present? | **0** | 1 | 2 | 3 |
| 4) Are Bivalves Present? | **0** | 1 | 2 | 3 |

***PRIMARY BIOLOGY INDICATOR POINTS:*** 5

**Secondary Field Indicators:** *(Circle One Number Per Line)*

| I. Geomorphology | Absent | Weak | Moderate | Strong |
|---|---|---|---|---|
| 1) Is There A Head Cut Present In Channel? | 0 | .5 | **1** | 1.5 |
| 2) Is There A Grade Control Point In Channel? | 0 | .5 | 1 | **1.5** |
| 3) Does Topography Indicate A Natural Drainage Way? | 0 | .5 | 1 | **1.5** |

*SECONDARY GEOMORPHOLOGY INDICATOR POINTS:* 4.0

| II. Hydrology | Absent | Weak | Moderate | Strong |
|---|---|---|---|---|
| 1) Is This Year's (Or Last's) Leaflitter Present In Streambed? | **1.5** | 1 | .5 | 0 |
| 2) Is Sediment On Plants (Or Debris) Present? | 0 | **.5** | 1 | 1.5 |
| 3) Are Wrack Lines Present? | 0 | .5 | 1 | 1.5 |
| 4) Is Water In Channel ***And*** >48 Hrs. Since Last ***Known*** Rain? *(*NOTE: If Ditch Indicated In #9 Above Skip This Step And #5 Below*)* | 0 | .5 | 1 | **1.5** |
| 5) Is There Water In Channel During Dry Conditions ***Or*** In Growing Season)? | 0 | .5 | 1 | **1.5** |

6) Are Hydric Soils Present In Sides Of Channel (Or In Headcut)? *Yes=1.5* *No*=**0**

*SECONDARY HYDROLOGY INDICATOR POINTS:* 5.0

| III. Biology | Absent | Weak | Moderate | Strong |
|---|---|---|---|---|
| 1) Are Fish Present? | **0** | .5 | 1 | 1.5 |
| 2) Are Amphibians Present? | 0 | .5 | **1** | 1.5 |
| 3) Are AquaticTurtles Present? | **0** | .5 | 1 | 1.5 |
| 4) Are Crayfish Present? | 0 | .5 | **1** | 1.5 |
| 5) Are Macrobenthos Present? | 0 | .5 | **1** | 1.5 |
| 6) Are Iron Oxidizing Bacteria/Fungus Present? | **0** | .5 | 1 | 1.5 |
| 7) Is Filamentous Algae Present? | **0** | .5 | 1 | 1.5 |

| 8) Are Wetland Plants In Streambed? | SAV | Mostly OBL | Mostly FACW | Mostly FAC | Mostly FACU | Mostly UPL |
|---|---|---|---|---|---|---|
| *(* NOTE: If Total Absence Of All Plants In Streambed As Noted Above Skip This Step **UNLESS** SAV Present*).* | 2 | 1 | .75 | **.5** | 0 | 0 |

*SECONDARY BIOLOGY INDICATOR POINTS:* 3.5

**TOTAL POINTS (Primary + Secondary) =32.5**

**(If Greater Than Or Equal To 19 Points The Stream Is At Least Intermittent)**

## NCDWQ Stream Classification Form

| | | | |
|---|---|---|---|
| Project Name: Meredell Farms – UT4 | River Basin: Cape Fear | County: Randolph | Evaluator: JR, SR |
| DWQ Project Number: | Nearest Named Stream: Sandy Creek | Latitude: | Signature: |
| Date: June 28, 2004 | USGS QUAD: | Longitude: | Location/Directions: |

***PLEASE NOTE:** *If evaluator and landowner agree that the feature is a man-made ditch, then use of this form is not necessary. Also, if in the best professional judgement of the evaluator, the feature is a man-made ditch and not a modified natural stream—this rating system should not be used**

**Primary Field Indicators:** (Circle One Number Per Line)

| I. Geomorphology | Absent | Weak | Moderate | Strong |
|---|---|---|---|---|
| 1) Is There A Riffle-Pool Sequence? | 0 | 1 | **2** | 3 |
| 2) Is The USDA Texture In Streambed Different From Surrounding Terrain? | 0 | 1 | **2** | 3 |
| 3) Are Natural Levees Present? | **0** | 1 | 2 | 3 |
| 4) Is The Channel Sinuous? | 0 | **1** | 2 | 3 |
| 5) Is There An Active (Or Relic) Floodplain Present? | 0 | **1** | 2 | 3 |
| 6) Is The Channel Braided? | **0** | 1 | 2 | 3 |
| 7) Are Recent Alluvial Deposits Present? | 0 | **1** | 2 | 3 |
| 8) Is There A Bankfull Bench Present? | 0 | 1 | **2** | 3 |
| 9) Is A Continuous Bed & Bank Present? | 0 | 1 | 2 | **3** |
| *(*NOTE: If Bed & Bank Caused By Ditching And **WITHOUT** Sinuosity Then Score=0*)* | | | | |
| 10) Is A 2nd Order Or Greater Channel (As Indicated On Topo Map *And/Or* In Field) Present? | | *Yes*=3 | *No*=**0** | |

*PRIMARY GEOMORPHOLOGY INDICATOR POINTS:* __12.0____

| II. Hydrology | Absent | Weak | Moderate | Strong |
|---|---|---|---|---|
| 1) Is There A Groundwater Flow/Discharge Present? | **0** | 1 | 2 | 3 |

***PRIMARY HYDROLOGY INDICATOR POINTS:*** ___0___

| III. Biology | Absent | Weak | Moderate | Strong |
|---|---|---|---|---|
| 1) Are Fibrous Roots Present In Streambed? | 3 | **2** | 1 | 0 |
| 2) Are Rooted Plants Present In Streambed? | 3 | **2** | 1 | 0 |
| 3) Is Periphyton Present? | **0** | 1 | 2 | 3 |
| 4) Are Bivalves Present? | **0** | 1 | 2 | 3 |

***PRIMARY BIOLOGY INDICATOR POINTS:*** ___4.0____

**Secondary Field Indicators:** *(Circle One Number Per Line)*

| I. Geomorphology | Absent | Weak | Moderate | Strong |
|---|---|---|---|---|
| 1) Is There A Head Cut Present In Channel? | 0 | .5 | **1** | 1.5 |
| 2) Is There A Grade Control Point In Channel? | 0 | **.5** | 1 | 1.5 |
| 3) Does Topography Indicate A Natural Drainage Way? | 0 | .5 | 1 | **1.5** |

*SECONDARY GEOMORPHOLOGY INDICATOR POINTS:* __3.0____

| II. Hydrology | Absent | Weak | Moderate | Strong |
|---|---|---|---|---|
| 1) Is This Year's (Or Last's) Leaflitter Present In Streambed? | 1.5 | **1** | .5 | 0 |
| 2) Is Sediment On Plants (Or Debris) Present? | 0 | **.5** | 1 | 1.5 |
| 3) Are Wrack Lines Present? | **0** | .5 | 1 | 1.5 |
| 4) Is Water In Channel *And* >48 Hrs. Since Last ***Known*** Rain? *(*NOTE: If Ditch Indicated In #9 Above Skip This Step And #5 Below*)* | 0 | .5 | 1 | **1.5** |
| 5) Is There Water In Channel During Dry Conditions *Or* In Growing Season)? | 0 | .5 | 1 | **1.5** |
| 6) Are Hydric Soils Present In Sides Of Channel (Or In Headcut)? | | *Yes=1.5* | *No*=**0** | |

*SECONDARY HYDROLOGY INDICATOR POINTS:* __4.5____

| III. Biology | Absent | Weak | Moderate | Strong |
|---|---|---|---|---|
| 1) Are Fish Present? | **0** | .5 | 1 | 1.5 |
| 2) Are Amphibians Present? | 0 | **.5** | 1 | 1.5 |
| 3) Are AquaticTurtles Present? | **0** | .5 | 1 | 1.5 |
| 4) Are Crayfish Present? | **0** | .5 | 1 | 1.5 |
| 5) Are Macrobenthos Present? | 0 | **.5** | 1 | 1.5 |
| 6) Are Iron Oxidizing Bacteria/Fungus Present? | **0** | .5 | 1 | 1.5 |
| 7) Is Filamentous Algae Present? | 0 | .5 | 1 | 1.5 |

| 8) Are Wetland Plants In Streambed? | SAV | Mostly OBL | Mostly FACW | Mostly FAC | Mostly FACU | Mostly UPL |
|---|---|---|---|---|---|---|
| *(* NOTE: If Total Absence Of All Plants In Streambed As Noted Above Skip This Step **UNLESS** SAV Present*).* | 2 | 1 | .75 | **.5** | 0 | 0 |

*SECONDARY BIOLOGY INDICATOR POINTS:* _3.0_____

**TOTAL POINTS (Primary + Secondary) =_26.5___**

**(If Greater Than Or Equal To 19 Points The Stream Is At Least Intermittent)**

## NCDWQ Stream Classification Form

| | | | |
|---|---|---|---|
| Project Name: Meredell Farms – UT5 | River Basin: Cape Fear | County: Randolph | Evaluator: JR, SR |
| DWQ Project Number: | Nearest Named Stream: Sandy Creek | Latitude: | Signature: |
| Date: June 28, 2004 | USGS QUAD: | Longitude: | Location/Directions: |

***PLEASE NOTE:** *If evaluator and landowner agree that the feature is a man-made ditch, then use of this form is not necessary. Also, if in the best professional judgement of the evaluator, the feature is a man-made ditch and not a modified natural stream—this rating system should not be used**

### Primary Field Indicators: (Circle One Number Per Line)

| I. Geomorphology | Absent | Weak | Moderate | Strong |
|---|---|---|---|---|
| 1) Is There A Riffle-Pool Sequence? | 0 | **1** | 2 | 3 |
| 2) Is The USDA Texture In Streambed Different From Surrounding Terrain? | 0 | 1 | **2** | 3 |
| 3) Are Natural Levees Present? | **0** | 1 | 2 | 3 |
| 4) Is The Channel Sinuous? | 0 | 1 | **2** | 3 |
| 5) Is There An Active (Or Relic) Floodplain Present? | 0 | 1 | **2** | 3 |
| 6) Is The Channel Braided? | **0** | 1 | 2 | 3 |
| 7) Are Recent Alluvial Deposits Present? | 0 | **1** | 2 | 3 |
| 8) Is There A Bankfull Bench Present? | 0 | 1 | **2** | 3 |
| 9) Is A Continuous Bed & Bank Present? *(*NOTE: If Bed & Bank Caused By Ditching And **WITHOUT** Sinuosity Then Score=0*)* | 0 | 1 | 2 | **3** |
| 10) Is A 2nd Order Or Greater Channel (As Indicated On Topo Map *And/Or* In Field) Present? | | *Yes*=3 | | *No*=**0** |

*PRIMARY GEOMORPHOLOGY INDICATOR POINTS:* __13____

| II. Hydrology | Absent | Weak | Moderate | Strong |
|---|---|---|---|---|
| 1) Is There A Groundwater Flow/Discharge Present? | 0 | **1** | 2 | 3 |

***PRIMARY HYDROLOGY INDICATOR POINTS:*** __1__

| III. Biology | Absent | Weak | Moderate | Strong |
|---|---|---|---|---|
| 1) Are Fibrous Roots Present In Streambed? | 3 | **2** | 1 | 0 |
| 2) Are Rooted Plants Present In Streambed? | 3 | **2** | 1 | 0 |
| 3) Is Periphyton Present? | **0** | 1 | 2 | 3 |
| 4) Are Bivalves Present? | **0** | 1 | 2 | 3 |

***PRIMARY BIOLOGY INDICATOR POINTS:*** __4_____

### Secondary Field Indicators: *(Circle One Number Per Line)*

| I. Geomorphology | Absent | Weak | Moderate | Strong |
|---|---|---|---|---|
| 1) Is There A Head Cut Present In Channel? | 0 | .5 | **1** | 1.5 |
| 2) Is There A Grade Control Point In Channel? | 0 | .5 | **1** | 1.5 |
| 3) Does Topography Indicate A Natural Drainage Way? | 0 | .5 | 1 | **1.5** |

*SECONDARY GEOMORPHOLOGY INDICATOR POINTS:* ___3.5___

| II. Hydrology | Absent | Weak | Moderate | Strong |
|---|---|---|---|---|
| 1) Is This Year's (Or Last's) Leaflitter Present In Streambed? | **1.5** | 1 | .5 | 0 |
| 2) Is Sediment On Plants (Or Debris) Present? | 0 | **.5** | 1 | 1.5 |
| 3) Are Wrack Lines Present? | 0 | .5 | 1 | **1.5** |
| 4) Is Water In Channel ***And*** >48 Hrs. Since Last ***Known*** Rain? *(*NOTE: If Ditch Indicated In #9 Above Skip This Step And #5 Below*)* | 0 | .5 | 1 | **1.5** |
| 5) Is There Water In Channel During Dry Conditions ***Or*** In Growing Season)? | 0 | .5 | 1 | **1.5** |
| 6) Are Hydric Soils Present In Sides Of Channel (Or In Headcut)? | | *Yes=1.5* | | *No=***0** |

*SECONDARY HYDROLOGY INDICATOR POINTS:* ___5.0___

| III. Biology | Absent | Weak | Moderate | Strong |
|---|---|---|---|---|
| 1) Are Fish Present? | **0** | .5 | 1 | 1.5 |
| 2) Are Amphibians Present? | 0 | .5 | **1** | 1.5 |
| 3) Are AquaticTurtles Present? | **0** | .5 | 1 | 1.5 |
| 4) Are Crayfish Present? | **0** | .5 | 1 | 1.5 |
| 5) Are Macrobenthos Present? | 0 | **.5** | 1 | 1.5 |
| 6) Are Iron Oxidizing Bacteria/Fungus Present? | **0** | .5 | 1 | 1.5 |
| 7) Is Filamentous Algae Present? | **0** | .5 | 1 | 1.5 |

| 8) Are Wetland Plants In Streambed? *(* NOTE: If Total Absence Of All Plants In Streambed As Noted Above Skip This Step **UNLESS** SAV Present*).* | SAV | Mostly OBL | Mostly FACW | Mostly FAC | Mostly FACU | Mostly UPL |
|---|---|---|---|---|---|---|
| | 2 | 1 | .75 | **.5** | 0 | 0 |

*SECONDARY BIOLOGY INDICATOR POINTS:* __2.0___

**TOTAL POINTS (Primary + Secondary) =_28.5___**

**(If Greater Than Or Equal To 19 Points The Stream Is At Least Intermittent)**

## NCDWQ Stream Classification Form

Project Name: Meredell Farms – M1 | River Basin: Cape Fear | County: Randolph | Evaluator: JR, SR
DWQ Project Number: | Nearest Named Stream: Sandy Creek | Latitude: | Signature:
Date: June 28, 2004 | USGS QUAD: | Longitude: | Location/Directions:

***PLEASE NOTE:** *If evaluator and landowner agree that the feature is a man-made ditch, then use of this form is not necessary. Also, if in the best professional judgement of the evaluator, the feature is a man-made ditch and not a modified natural stream—this rating system should not be used**

### Primary Field Indicators: (Circle One Number Per Line)

| I. Geomorphology | Absent | Weak | Moderate | Strong |
|---|---|---|---|---|
| 1) Is There A Riffle-Pool Sequence? | 0 | 1 | **2** | 3 |
| 2) Is The USDA Texture In Streambed Different From Surrounding Terrain? | 0 | 1 | **2** | 3 |
| 3) Are Natural Levees Present? | **0** | 1 | 2 | 3 |
| 4) Is The Channel Sinuous? | 0 | **1** | 2 | 3 |
| 5) Is There An Active (Or Relic) Floodplain Present? | 0 | 1 | **2** | 3 |
| 6) Is The Channel Braided? | **0** | 1 | 2 | 3 |
| 7) Are Recent Alluvial Deposits Present? | 0 | **1** | 2 | 3 |
| 8) Is There A Bankfull Bench Present? | 0 | 1 | **2** | 3 |
| 9) Is A Continuous Bed & Bank Present? | 0 | 1 | 2 | **3** |
| *(*NOTE: If Bed & Bank Caused By Ditching And **WITHOUT** Sinuosity Then Score=0*)* | | | | |
| 10) Is A 2nd Order Or Greater Channel (As Indicated On Topo Map ***And/Or*** In Field) Present? | *Yes*=**3** | | *No*=0 | |

*PRIMARY GEOMORPHOLOGY INDICATOR POINTS:* __16____

| II. Hydrology | Absent | Weak | Moderate | Strong |
|---|---|---|---|---|
| 1) Is There A Groundwater Flow/Discharge Present? | 0 | **1** | 2 | 3 |

***PRIMARY HYDROLOGY INDICATOR POINTS:*** ___1____

| III. Biology | Absent | Weak | Moderate | Strong |
|---|---|---|---|---|
| 1) Are Fibrous Roots Present In Streambed? | **3** | 2 | 1 | 0 |
| 2) Are Rooted Plants Present In Streambed? | **3** | 2 | 1 | 0 |
| 3) Is Periphyton Present? | 0 | **1** | 2 | 3 |
| 4) Are Bivalves Present? | **0** | 1 | 2 | 3 |

***PRIMARY BIOLOGY INDICATOR POINTS:*** ____7___

### Secondary Field Indicators: *(Circle One Number Per Line)*

| I. Geomorphology | Absent | Weak | Moderate | Strong |
|---|---|---|---|---|
| 1) Is There A Head Cut Present In Channel? | 0 | .5 | 1 | 1.5 |
| 2) Is There A Grade Control Point In Channel? | 0 | .5 | 1 | **1.5** |
| 3) Does Topography Indicate A Natural Drainage Way? | 0 | .5 | 1 | **1.5** |

*SECONDARY GEOMORPHOLOGY INDICATOR POINTS:* __3.0____

| II. Hydrology | Absent | Weak | Moderate | Strong |
|---|---|---|---|---|
| 1) Is This Year's (Or Last's) Leaflitter Present In Streambed? | **1.5** | 1 | .5 | 0 |
| 2) Is Sediment On Plants (Or Debris) Present? | 0 | **.5** | 1 | 1.5 |
| 3) Are Wrack Lines Present? | **0** | .5 | 1 | 1.5 |
| 4) Is Water In Channel ***And*** >48 Hrs. Since Last ***Known*** Rain? *(*NOTE: If Ditch Indicated In #9 Above Skip This Step And #5 Below*)* | 0 | .5 | 1 | **1.5** |
| 5) Is There Water In Channel During Dry Conditions ***Or*** In Growing Season)? | 0 | .5 | 1 | **1.5** |
| 6) Are Hydric Soils Present In Sides Of Channel (Or In Headcut)? | | *Yes=1.5* | *No*=**0** | |

*SECONDARY HYDROLOGY INDICATOR POINTS:* ___5.0___

| III. Biology | Absent | Weak | Moderate | Strong |
|---|---|---|---|---|
| 1) Are Fish Present? | 0 | .5 | **1** | 1.5 |
| 2) Are Amphibians Present? | 0 | .5 | **1** | 1.5 |
| 3) Are AquaticTurtles Present? | **0** | .5 | 1 | 1.5 |
| 4) Are Crayfish Present? | **0** | .5 | 1 | 1.5 |
| 5) Are Macrobenthos Present? | 0 | **.5** | 1 | 1.5 |
| 6) Are Iron Oxidizing Bacteria/Fungus Present? | 0 | **.5** | 1 | 1.5 |
| 7) Is Filamentous Algae Present? | 0 | .5 | **1** | 1.5 |

| 8) Are Wetland Plants In Streambed? | SAV | Mostly OBL | Mostly FACW | Mostly FAC | Mostly FACU | Mostly UPL |
|---|---|---|---|---|---|---|
| *(* **NOTE:** If Total Absence Of All Plants In Streambed As Noted Above Skip This Step **UNLESS** SAV Present*).* | 2 | 1 | .75 | .5 | **0** | 0 |

*SECONDARY BIOLOGY INDICATOR POINTS:* _4.0_____

**TOTAL POINTS (Primary + Secondary) =_36___**

**(If Greater Than Or Equal To 19 Points The Stream Is At Least Intermittent)**

# Appendix F

Design Parameters

Design Parameters from Database

| Parameter | West Branch of Tibbs Run MIN | West Branch of Tibbs Run MAX | Tributary To Sandy Creek MIN | Tributary To Sandy Creek MAX | Tributary To Fork Creek MIN | Tributary To Fork Creek MAX |
|---|---|---|---|---|---|---|
| Drainage Area, DA (sq mi) | 1.08 | | 0.97 | | 0.19 | |
| Stream Type (Rosgen) | E5 | | E4 | | E4 | |
| Bankfull Discharge, Qbkf (cfs) | 88 | | 70 | | 38 | |
| Bankfull Riffle XSEC Area, Abkf (sq ft) | 20.7 | | 17.4 | | 9.3 | 9.4 |
| Bankfull Mean Velocity, Vbkf (ft/s) | 4.3 | | 4 | | 4 | |
| Width to Depth Ratio, W/D (ft/ft) | 4.57 | | 8.57 | | 5.5 | 18.9 |
| Entrenchment Ratio, Wfpa/Wbkf (ft/ft) | 28.1 | | 6.67 | | 9.6 | 13.4 |
| Riffle Max Depth Ratio, Dmax/Dbkf | 1.1 | | 1.6 | | 1.3 | 2.3 |
| Bank Height Ratio, Dtob/Dmax (ft/ft) | 1.5 | | 1.2 | | 1.3 | 1.5 |
| Meander Length Ratio, Lm/Wbkf | 7.6 | | 7.23 | | | |
| Rc Ratio, Rc/Wbkf | 4.72 | | 2.5 | | | |
| Meander Width Ratio, Wblt/Wbkf | 7.29 | | 8.5 | | | |
| Sinuosity, K | 1.2 | | 1.80 | | 1.1 | |
| Valley Slope, Sval (ft/ft) | 0.0043 | | 0.0025 | | 0.0095 | |
| Channel Slope, Schan (ft/ft) | 0.0037 | | 0.0014 | | 0.0088 | |
| Riffle Slope Ratio, Srif/Schan | 2.03 | | 1.36 | | 2.85 | |
| Run Slope Ratio, Srun/Srif | | | | | | |
| Glide Slope Ratio, Sglide/Schan | | | | | | |
| Pool Slope Ratio, Spool/Schan | 0.11 | | 0.29 | | 0.12 | |
| Slope Run, Srun (ft/ft) | | | | | | |
| Run Slope Ratio, Srun/Schan | | | | | | |
| Slope Glide, Sglide (ft/ft) | | | | | | |
| Glide Slope Ratio, Sglide/Schan | | | | | 1.30 | 2.00 |
| Pool Max Depth Ratio, Dmaxpool/Dbkf | 1.19 | | 1.45 | | 1.6 | 2.1 |
| Pool Width Ratio, Wpool/Wbkf | 1.17 | | 1.1 | | 0.6 | 0.8 |
| Pool-Pool Spacing Ratio, Lps/Wbkf | 6.09 | | 5.25 | | | |
| d16 (mm) | 0.136 | | 0.21 | | 0.19 | |
| d35 (mm) | 0.24 | | 0.44 | | 6.72 | |
| d50 (mm) | 0.7 | | 2.7 | | 12.9 | |
| d84 (mm) | 12 | | 15.7 | | 49.8 | |
| d95 (mm) | 22 | | 38.6 | | 88.6 | |

Notes:

All slopes are water surface slopes.

| Meredell Farm M1 | Design Stream Values | | Rationale | Design Reference |
|---|---|---|---|---|
| **Parameter** | **MIN** | **MAX** | | |
| Drainage Area, DA (sq mi) | 0.26 | | | Final Design Report, Page 2-4 |
| Stream Type (Rosgen) | C | | Note 1 | |
| Bankfull Discharge, Qbkf (cfs) | | | Note 2 | Final Design Report, Page 4-6 |
| Bankfull Riffle XSEC Area, Abkf (sq ft) | 8.6 | 8.6 | Note 2 | Final Design Report, Page 4-6 |
| Bankfull Mean Velocity, Vbkf (ft/s) | 0.0 | 0.0 | V=Q/A | |
| Bankfull Riffle Width, Wbkf (ft) | 10.2 | 10.2 | $\sqrt{Abkf * W / D}$ | Rosgen Level 4 |
| Bankfull Riffle Mean Depth, Dbkf (ft) | 0.8 | 0.8 | d=A/W | |
| Width to Depth Ratio, W/D (ft/ft) | 12.0 | 12.0 | Note 3 | Reference Parameters |
| Width Floodprone Area, Wfpa (ft) | | | | Project Plan Map |
| Entrenchment Ratio, Wfpa/Wbkf (ft/ft) | 0.0 | 0.0 | Note 4 | |
| Riffle Max Depth @ bkf, Dmax (ft) | 1.0 | 1.3 | | |
| Riffle Max Depth Ratio, Dmax/Dbkf | 1.2 | 1.5 | Note 5 | Reference Parameters |
| Max Depth @ tob, Dmaxtob (ft) | 1.0 | 1.3 | | |
| Bank Height Ratio, Dtob/Dmax (ft/ft) | 1.0 | 1.0 | Note 6 | |
| Meander Length, Lm (ft) | 71 | 112 | | |
| Meander Length Ratio, Lm/Wbkf * | 7.0 | 11.0 | Note 7 | Reference Parameters |
| Radius of Curvature, Rc (ft) | 20 | 30 | | Reference Parameters |
| Rc Ratio, Rc/Wbkf * | 2.0 | 3.0 | Note 8 | |
| Belt Width, Wblt (ft) | 36 | 81 | | |
| Meander Width Ratio, Wblt/Wbkf * | 3.5 | 8.0 | Note 9 | Reference Parameters |
| Sinuosity, K | 1.38 | | TW length/Valley len | Project Plan Map |
| Valley Slope, Sval (ft/ft) | 0.0180 | | | |
| Channel Slope, Schan (ft/ft) | 0.0130 | | Sval / K | Rosgen Level 4 |
| Slope Riffle, Srif (ft/ft) | 0.0156 | 0.0260 | | |
| Riffle Slope Ratio, Srif/Schan | 1.2 | 2.0 | Note 10 | Reference Parameters |
| Slope Pool, Spool (ft/ft) | 0.0000 | 0.0007 | | |
| Pool Slope Ratio, Spool/Schan | 0.00 | 0.05 | Note 10 | |
| Pool Max Depth, Dmaxpool (ft) | 1.7 | 2.5 | | |
| Pool Max Depth Ratio, Dmaxpool/Dbkf | 2.0 | 3.0 | Note 11 | Reference Parameters |
| Pool Width, Wpool (ft) | 13.2 | 17.3 | | |
| Pool Width Ratio, Wpool/Wbkf | 1.3 | 1.7 | Note 12 | Reference Parameters |
| Pool-Pool Spacing, Lps (ft) | 20.3 | 50.8 | | |
| Pool-Pool Spacing Ratio, Lps/Wbkf | 2.0 | 5.0 | Note 13 | Reference Parameters |
| d16 (mm) | N/A | | | |
| d35 (mm) | 0.3 | | | |
| d50 (mm) | 16.5 | | | |
| d84 (mm) | 60.4 | | | |
| d95 (mm) | 128.0 | | | |

**Notes:**

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**Note 3**: A final W/D ratio was selected by reviewing the reference parameters and sediment transport competency information.

**Note 4**: Required for stream classification.

**Note 5**: The Reference Reaches did not list a ratio for this parameter. A ratio was selected from other reference reaches and past project experience.

**Note 6**: A bank height ratio of 1.0 ensures that all flows greater than bankfull will spread onto a floodplain. This minimizes shear stress in the channel and maximizes floodplain functionality resulting in lower risk of channel instability.

**Note 7**: The reference ratios were used as the low range. We increased the range to allow for a higher pool to pool spacing.

**Note 8**: The reference ratios were used for this ratio.

**Note 9**: The Oak Forest Branch ratio was not used for this parameter because it is too low. Low ratios increase shear stress in the channel and decrease bedform diversity. The tributary to Cane Creek was used as the upper range. The values shown are common throughout North Carolina, based on our experience. Generally, a higher value results in better bedform diversity. Max values are often not obtained due to site constraints. Belt width constraints for this site include hillslopes and pastureland.

**Note 10**: Profile slope ratios were taken from the Reference Reaches and evaluation of past projects.

**Note 11**: The Oak Forest Branch reference reach ratio was used as the low range for max pool depth. We increased the range to allow for better quality habitat.

**Note 12**: Based on previous project experience, the reference ratios for pool width were too low. It is more conservative to design a pool wider than the riffle. Over time, the pool width may narrow, which is a positive evolution.

**Note 13**: The pool to pool spacing range was taken from the Reference Reach data and past project experience.

| Meredell Farms Reach UT1b | Design Stream Values | | Rationale | Design Reference |
|---|---|---|---|---|
| **Parameter** | **MIN** | **MAX** | | |
| Drainage Area, DA (sq mi) | 0.1 | | | Final Design Report, Page 2-4 |
| Stream Type (Rosgen) | C | | Note 1 | |
| Bankfull Discharge, Qbkf (cfs) | | | Note 2 | Final Design Report, Page 4-6 |
| Bankfull Riffle XSEC Area, Abkf (sq ft) | 4.5 | 4.5 | Note 2 | Final Design Report, Page 4-6 |
| Bankfull Mean Velocity, Vbkf (ft/s) | 0.0 | 0.0 | V=Q/A | |
| Bankfull Riffle Width, Wbkf (ft) | 7.3 | 7.3 | $\sqrt{Abkf * W / D}$ | Rosgen Level 4 |
| Bankfull Riffle Mean Depth, Dbkf (ft) | 0.6 | 0.6 | d=A/W | |
| Width to Depth Ratio, W/D (ft/ft) | 12.0 | 12.0 | Note 3 | Reference Parameters |
| Width Floodprone Area, Wfpa (ft) | | | | Project Plan Map |
| Entrenchment Ratio, Wfpa/Wbkf (ft/ft) | 0.0 | 0.0 | Note 4 | |
| Riffle Max Depth @ bkf, Dmax (ft) | 0.7 | 0.9 | | |
| Riffle Max Depth Ratio, Dmax/Dbkf | 1.2 | 1.5 | Note 5 | Reference Parameters |
| Max Depth @ tob, Dmaxtob (ft) | 0.7 | 0.9 | | |
| Bank Height Ratio, Dtob/Dmax (ft/ft) | 1.0 | 1.0 | Note 6 | |
| Meander Length, Lm (ft) | 51 | 81 | | |
| Meander Length Ratio, Lm/Wbkf * | 7.0 | 11.0 | Note 7 | Reference Parameters |
| Radius of Curvature, Rc (ft) | 15 | 22 | | Reference Parameters |
| Rc Ratio, Rc/Wbkf * | 2.0 | 3.0 | Note 8 | |
| Belt Width, Wblt (ft) | 26 | 59 | | |
| Meander Width Ratio, Wblt/Wbkf * | 3.5 | 8.0 | Note 9 | Reference Parameters |
| Sinuosity, K | 1.40 | | TW length/Valley len | Project Plan Map |
| Valley Slope, Sval (ft/ft) | 0.0159 | | | |
| Channel Slope, Schan (ft/ft) | 0.0110 | | Sval / K | Rosgen Level 4 |
| Slope Riffle, Srif (ft/ft) | 0.0132 | 0.0220 | | |
| Riffle Slope Ratio, Srif/Schan | 1.2 | 2.0 | Note 10 | Reference Parameters |
| Slope Pool, Spool (ft/ft) | 0.0000 | 0.0006 | | |
| Pool Slope Ratio, Spool/Schan | 0.00 | 0.05 | Note 10 | |
| Pool Max Depth, Dmaxpool (ft) | 1.2 | 1.8 | | |
| Pool Max Depth Ratio, Dmaxpool/Dbkf | 2.0 | 3.0 | Note 11 | Reference Parameters |
| Pool Width, Wpool (ft) | 9.6 | 12.5 | | |
| Pool Width Ratio, Wpool/Wbkf | 1.3 | 1.7 | Note 12 | Reference Parameters |
| Pool-Pool Spacing, Lps (ft) | 14.7 | 36.7 | | |
| Pool-Pool Spacing Ratio, Lps/Wbkf | 2.0 | 5.0 | Note 13 | Reference Parameters |
| d16 (mm) | N/A | | | |
| d35 (mm) | 0.8 | | | |
| d50 (mm) | 11.2 | | | |
| d84 (mm) | 38.4 | | | |
| d95 (mm) | 63.2 | | | |

**Notes:**

**Note 1:** A C stream type is appropriate for a wide alluvial valley with a gravel streambed. A C was used rather than an E to prevent vertical streambanks and provide a more conservative design.

**Note 2:** The North Carolina Piedmont regional curve along with existing, stable cross sections were used for obtaining dimension information.

**Note 3:** A final W/D ratio was selected by reviewing the reference parameters and sediment transport competency information.

**Note 4:** Required for stream classification.

**Note 5:** The Reference Reaches did not list a ratio for this parameter. A ratio was selected from other reference reaches and past project experience.

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**Note 7**: The reference ratios were used as the low range. We increased the range to allow for a higher pool to pool spacing.

**Note 8**: The reference ratios were used for this ratio.

**Note 9**: The Oak Forest Branch ratio was not used for this parameter because it is too low. Low ratios increase shear stress in the channel and decrease bedform diversity. The tributary to Cane Creek was used as the upper range. The values shown are common throughout North Carolina, based on our experience. Generally, a higher value results in better bedform diversity. Max values are often not obtained due to site constraints. Belt width constraints for this site include hillslopes and pastureland.

**Note 10**: Profile slope ratios were taken from the Reference Reaches and evaluation of past projects.

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| Meredell Farm UT2b | Design Stream Values | | Rationale | Design Reference |
|---|---|---|---|---|
| **Parameter** | **MIN** | **MAX** | | |
| Drainage Area, DA (sq mi) | 0.1 | | | Final Design Report, Page 2-4 |
| Stream Type (Rosgen) | C | | Note 1 | |
| Bankfull Discharge, Qbkf (cfs) | | | Note 2 | Final Design Report, Page 4-6 |
| Bankfull Riffle XSEC Area, Abkf (sq ft) | 4.5 | 4.5 | Note 2 | Final Design Report, Page 4-6 |
| Bankfull Mean Velocity, Vbkf (ft/s) | 0.0 | 0.0 | V=Q/A | |
| Bankfull Riffle Width, Wbkf (ft) | 7.3 | 7.3 | $\sqrt{Abkf * W / D}$ | Rosgen Level 4 |
| Bankfull Riffle Mean Depth, Dbkf (ft) | 0.6 | 0.6 | d=A/W | |
| Width to Depth Ratio, W/D (ft/ft) | 12.0 | 12.0 | Note 3 | Reference Parameters |
| Width Floodprone Area, Wfpa (ft) | | | | Project Plan Map |
| Entrenchment Ratio, Wfpa/Wbkf (ft/ft) | 0.0 | 0.0 | Note 4 | |
| Riffle Max Depth @ bkf, Dmax (ft) | 0.7 | 0.9 | | |
| Riffle Max Depth Ratio, Dmax/Dbkf | 1.2 | 1.5 | Note 5 | Reference Parameters |
| Max Depth @ tob, Dmaxtob (ft) | 0.7 | 0.9 | | |
| Bank Height Ratio, Dtob/Dmax (ft/ft) | 1.0 | 1.0 | Note 6 | |
| Meander Length, Lm (ft) | 51 | 81 | | |
| Meander Length Ratio, Lm/Wbkf * | 7.0 | 11.0 | Note 7 | Reference Parameters |
| Radius of Curvature, Rc (ft) | 15 | 22 | | Reference Parameters |
| Rc Ratio, Rc/Wbkf * | 2.0 | 3.0 | Note 8 | |
| Belt Width, Wblt (ft) | 26 | 59 | | |
| Meander Width Ratio, Wblt/Wbkf * | 3.5 | 8.0 | Note 9 | Reference Parameters |
| Sinuosity, K | 1.2 | | TW length/Valley len | Project Plan Map |
| Valley Slope, Sval (ft/ft) | 0.0166 | | | |
| Channel Slope, Schan (ft/ft) | 0.0134 | | Sval / K | Rosgen Level 4 |
| Slope Riffle, Srif (ft/ft) | 0.0161 | 0.0268 | | |
| Riffle Slope Ratio, Srif/Schan | 1.2 | 2.0 | Note 10 | Reference Parameters |
| Slope Pool, Spool (ft/ft) | 0.0000 | 0.0007 | | |
| Pool Slope Ratio, Spool/Schan | 0.00 | 0.05 | Note 10 | |
| Pool Max Depth, Dmaxpool (ft) | 1.2 | 1.8 | | |
| Pool Max Depth Ratio, Dmaxpool/Dbkf | 2.0 | 3.0 | Note 11 | Reference Parameters |
| Pool Width, Wpool (ft) | 9.6 | 12.5 | | |
| Pool Width Ratio, Wpool/Wbkf | 1.3 | 1.7 | Note 12 | Reference Parameters |
| Pool-Pool Spacing, Lps (ft) | 14.7 | 36.7 | | |
| Pool-Pool Spacing Ratio, Lps/Wbkf | 2.0 | 5.0 | Note 13 | Reference Parameters |
| d16 (mm) | | | | |
| d35 (mm) | | | | |
| d50 (mm) | | | | |
| d84 (mm) | | | | |
| d95 (mm) | | | | |

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**Note 13**: The pool to pool spacing range was taken from the Reference Reach data and past project experience.

| Meredell Farm Reach UT3b | Design Stream Values | | Rationale | Design Reference |
|---|---|---|---|---|
| **Parameter** | **MIN** | **MAX** | | |
| Drainage Area, DA (sq mi) | 0.23 | | | Final Design Report, Page 2-4 |
| Stream Type (Rosgen) | C5 | | Note 1 | |
| Bankfull Discharge, Qbkf (cfs) | | | Note 2 | Final Design Report, Page 4-6 |
| Bankfull Riffle XSEC Area, Abkf (sq ft) | 8.0 | 8.0 | Note 2 | Final Design Report, Page 4-6 |
| Bankfull Mean Velocity, Vbkf (ft/s) | 0.0 | 0.0 | V=Q/A | |
| Bankfull Riffle Width, Wbkf (ft) | 9.8 | 9.8 | $\sqrt{Abkf * W / D}$ | Rosgen Level 4 |
| Bankfull Riffle Mean Depth, Dbkf (ft) | 0.8 | 0.8 | d=A/W | |
| Width to Depth Ratio, W/D (ft/ft) | 12.0 | 12.0 | Note 3 | Reference Parameters |
| Width Floodprone Area, Wfpa (ft) | | | | Project Plan Map |
| Entrenchment Ratio, Wfpa/Wbkf (ft/ft) | 0.0 | 0.0 | Note 4 | |
| Riffle Max Depth @ bkf, Dmax (ft) | 1.0 | 1.2 | | |
| Riffle Max Depth Ratio, Dmax/Dbkf | 1.2 | 1.5 | Note 5 | Reference Parameters |
| Max Depth @ tob, Dmaxtob (ft) | 1.0 | 1.2 | | |
| Bank Height Ratio, Dtob/Dmax (ft/ft) | 1.0 | 1.0 | Note 6 | |
| Meander Length, Lm (ft) | 69 | 108 | | |
| Meander Length Ratio, Lm/Wbkf * | 7.0 | 11.0 | Note 7 | Reference Parameters |
| Radius of Curvature, Rc (ft) | 20 | 29 | | Reference Parameters |
| Rc Ratio, Rc/Wbkf * | 2.0 | 3.0 | Note 8 | |
| Belt Width, Wblt (ft) | 34 | 78 | | |
| Meander Width Ratio, Wblt/Wbkf * | 3.5 | 8.0 | Note 9 | Reference Parameters |
| Sinuosity, K | 1.30 | 1.30 | TW length/Valley len | Project Plan Map |
| Valley Slope, Sval (ft/ft) | 0.0014 | | | |
| Channel Slope, Schan (ft/ft) | 0.0080 | | Sval / K | Rosgen Level 4 |
| Slope Riffle, Srif (ft/ft) | 0.0096 | 0.0000 | | |
| Riffle Slope Ratio, Srif/Schan | 1.2 | 2.0 | Note 10 | Reference Parameters |
| Slope Pool, Spool (ft/ft) | 0.0000 | 0.0000 | | |
| Pool Slope Ratio, Spool/Schan | 0.00 | 0.05 | Note 10 | |
| Pool Max Depth, Dmaxpool (ft) | 1.6 | 2.4 | | |
| Pool Max Depth Ratio, Dmaxpool/Dbkf | 2.0 | 3.0 | Note 11 | Reference Parameters |
| Pool Width, Wpool (ft) | 12.7 | 16.7 | | |
| Pool Width Ratio, Wpool/Wbkf | 1.3 | 1.7 | Note 12 | Reference Parameters |
| Pool-Pool Spacing, Lps (ft) | 19.6 | 49.0 | | |
| Pool-Pool Spacing Ratio, Lps/Wbkf | 2.0 | 5.0 | Note 13 | Reference Parameters |
| d16 (mm) | 0.1 | | | |
| d35 (mm) | 0.8 | | | |
| d50 (mm) | 32.0 | | | |
| d84 (mm) | >2048 | | | |
| d95 (mm) | >2048 | | | |

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