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A Methodology for Predicting Channel Form in Coastal Plain Headwater Systems

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Introduction

In 2007, an information paper was issued by the US Army Corps of Engineers (USACE) and the North Carolina Division of Water Quality (NCDWQ) that allowed for the restoration of Coastal Plain riparian headwater wetland valleys to provide compensatory stream mitigation. This information paper recognizes that in the Coastal Plain many headwater stream systems have been ditched and channelized to improve drainage. In their pre-disturbance condition, it is unlikely that these systems would have had defined channels; therefore, a restoration approach seeking to construct a meandering channel would not be appropriate.

Since few restoration projects have been implemented to date that make use of this information paper, technical design information for these systems is very limited. To provide additional design data, a study of Coastal Plain headwater reference sites was initiated with the following goals:

1) Identify reference sites that represent intact, functional systems
2) Describe the formation of channel features in headwater stream systems
3) Develop design guidance for determining when it is and is not appropriate to restore a defined stream channel.

The methods used to evaluate each goal are described in the sections that follow.

Identification of Reference Sites

Because headwater sites in the Coastal Plain are small and easily manipulated, it is difficult to locate systems that have not been altered or impacted by human activities. Searches were aimed at identifying small catchments (< 300 acres in size) with a wooded canopy and no apparent artificial drainage affecting the reference areas. Assessments would then be conducted at the most upstream point that showed a defined valley with periodic surface flow, and continuing downstream until a perennial flow feature was identified. Data collected from these assessments would then used to determine the points at which headwater valleys form channel and fluvial features.

An extensive search was conducted in an attempt to locate reference stream systems. Numerous potential sites were identified; however, the majority of these sites had been drained for agricultural purposes or local topography had been modified through forestry practices in the past. Initially, four reference reaches along two headwater drainages were identified in close proximity to Aurora, NC. To provide additional data, eight reference reaches were identified

along three headwater drainages within the Croatan National Forest, south of New Bern, NC. These reference sites are summarized as follows.

UT to Bailey Creek: Two reference reaches were surveyed on an unnamed tributary to Bailey Creek. Drainage areas for the upstream and downstream reaches are 88 and 94 acres, respectively. The upstream reach (UTBA-1A) exhibits wrack lines, scour features, and a somewhat braided flow pattern. In some locations, flow is confined but the channel is not well defined. Further downstream, the valley slope increases and the stream flow becomes confined to a single thread, meandering channel. This area was surveyed as the downstream reference reach (UTBA-1B). Channel dimension is relatively consistent, with riffle and pools formed by both channel meanders and woody debris.

UT to South Creek: Two reference reaches were surveyed on an unnamed tributary to South Creek. Drainage areas for the upstream and downstream reaches are 215 and 250 acres, respectively. The upstream reach (UTSC-1A) was surveyed approximately 600 feet downstream of NC Route 306. Along this upstream reach, flow patterns are diffuse and braided, with a considerable amount of subsurface flow during field surveys. Further downstream, the valley slope increases and the stream flow becomes confined to a single thread, meandering channel. This area was surveyed as the downstream reference reach (UTSC-1B), and is located approximately 400 feet downstream from UTSC-1A, and 400 feet upstream of a powerline transmission corridor. Channel dimension along this downstream reach is relatively consistent, with riffle and pools formed by both channel meanders and woody debris.

UTs to Brice Creek: Eight reference reach sites were identified along three separate headwater tributaries to Brice Creek in the Croatan National Forest, south of New Bern. These sites were identified as potential reference reaches through the help of NCDWQ staff who had reviewed the sites in the past. The three tributary drainages were labeled Sites 1, 2, and 3; Site 1 was the northern most site and Site 3 was the southern most site.

Three reference reaches were identified and surveyed along Site 1. Drainage areas for the three reaches from upstream to downstream (UTBR-1A, UTBR-1B, and UTBR-1C) are 96, 160, and 230 acres, respectively. UTBR-1A is the most upstream reach and exhibits diffuse flow patterns across a wetland floodplain, with few distinct channel features. UTBR-1B is the middle reach within the drainage and exhibits a more braided flow pattern with some sections of defined channel bed and banks. UTBR-1C is the further reach downstream and was located in an area where overall valley slope increases. The reach exists as a single thread, meandering stream channel with well defined bed and banks and a relatively constant channel dimension.

Three reference reaches were also identified along Site 2. Drainage areas were smaller than those identified for Site 1. Drainage areas for the three reaches from upstream to downstream (UTBR-2A, UTBR-2B, and UTBR-2C) are 25, 42, and 61 acres, respectively. The flow characteristics for each reach were similar to Site 1, with the most upstream reach (UTBR-2A) exhibiting diffuse flow with poorly defined channel features, the middle reach (UTBR-2B) exhibiting braided flows, and the downstream reach (UTBR-2C) exhibiting a single thread, meandering channel form.

Two reference reaches were identified along Site 3, which is a separate drainage just to the south of Site 2. Drainage areas for the two reaches from upstream to downstream (UTBR-3A and UTBR-3B) are 45 and 58 acres, respectively. The most upstream reach (UTBR-3A) exhibiting braided and diffuse flow with some channel features that were not consistent and were not well

defined along the reach length. The downstream reach (UTBR-3B) exhibiting a single thread, meandering channel form with well defined bed and banks.

Determining the Factors Affecting Channel Formation

Most stream restoration projects that have been completed in the Coastal Plain have involved the construction of a single-thread, meandering stream channel. As discussed in *Information Regarding Stream Restoration with Emphasis on the Coastal Plain* (2007), restoration of a single-thread channel is likely not appropriate for many headwater systems. In some situations, formation of a wetland valley with braided, diffuse flow will be more appropriate. By performing assessments on a range of reference sites (i.e. varying drainage areas, valley slopes, and channel definition), our goal was to determine the conditions under which different channel features (or no channel features at all) are formed. This understanding would allow for predicting the conditions under which various channel forms are developed, which could then be applied to future stream restoration projects in Coastal Plain headwater streams.

As discussed previously, we identified several reference sites that began as defined valleys with indications of periodic surface flows, and developed into more defined stream systems down valley as drainage area increased. Once these drainages were identified, specific reference reaches were delineated along the fall of the valley and survey were conducted to document channel form (or lack of channel form). Reference reaches were divided into three categories based on visible channel form:

Poorly Defined Channel - These systems exhibit a defined valley and evidence of periodic surface flow, but lack defined channel features. Channel bed and bank features cannot be identified, or if they can be identified, are poorly defined and only evident for short distances before their definition is lost. These reaches were commonly found at the upper most portions of the headwater drainage where flow events are not frequent and do not have sufficient energy to form channel features.

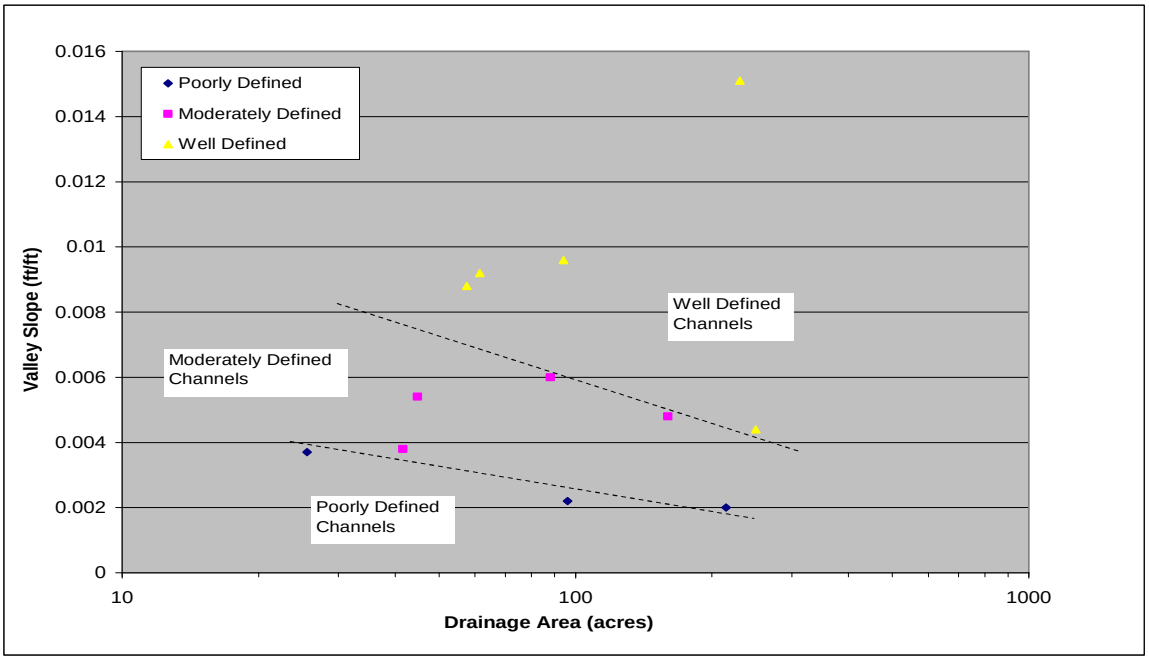
Moderately Defined Channel – These systems exhibit relatively constant bed and bank features, but the channel dimensions (cross-sectional area and shape) are highly variable. Flows are confined to one variable size channel in some areas, and multiple thread channels in other areas. Channel form appears to be defined mostly through localized scour, small debris jams, and vegetation.

Well Defined Channel – These systems can be considered typical, single-thread reference reach quality channels. Channel banks are obvious and constant, and sandy bed material is common. Channel dimension is relatively constant, with alternating riffle and pool areas. Some pools are formed by stream meanders while others are formed by scour from woody debris. Channel form is defined primarily through fluvial processes.

Each identified reference reach was surveyed along approximately 200 feet of its length. Cross-sections were surveyed at representative locations to document the dimension of any channel features, the width of the valley, and the general topography of the valley bottom. A longitudinal profile was also surveyed along the apparent center of the flow pathway, to determine overall slope, depth of a pools and riffles (if present), and variations in topography. Along reference reaches that exhibited well defined channels, surveys methods followed those used for traditional reference reach stream surveys that document channel dimension, pattern, and profile.

In simplest terms, the energy of flowing water is determined by its velocity and depth. Formation of a defined stream channel begins when flowing water has sufficient energy to begin the processes of scour, headcutting, and sediment transport. We used valley slope as a surrogate for flow velocity: the higher the valley slope, the higher the velocity of flowing water in the stream system during storm events. We used drainage area as a surrogate for flow depth and quantity: the higher the drainage area, the higher the volume of water (and depth of flowing water) for a given storm event. Each surveyed reference reach was classified as either a poorly defined, moderately defined, or well defined channel, based on visual observations during field surveys. Valley slope and drainage area data for each surveyed reference reach is provided in Chart 1 below.

Chart 1. Headwater reference reach data relating channel formation to drainage area and slope.



The collected data indicate that channel form can be predicted by measurements of valley slope and drainage area. As valley slope and drainage area increase, the energy of flowing water also increases and tends to form more defined stream channels. While boundaries have been placed on the graph to illustrate approximate ranges for each channel type, these boundaries should not be considered as distinct thresholds that trigger a change from one channel form to another. The data should be used to indicate ranges in which a particular channel form is likely to develop. In fact, reference sites that fell near the boundary of two channel forms were often difficult to classify distinctly as one of the three defined channel forms based on visual observations. For example, a reference site that plots near the boundary between a well defined and a moderately defined channel will usually display some characteristics of both.

Other results that were derived from this analysis are summarized below:

- Drainage area alone is not a good predictor of channel form. For example, at a drainage area of approximately 100 acres, all three defined channel forms were identified on reference sites.

- The document *Information Regarding Stream Restoration with Emphasis on the Coastal Plain* (2007) states that "… According to data being assembled by NCDWQ (Periann Russell, DWQ, personal communication) watershed less than 25 acres in size will not support a headwater system." Our data agree with this assessment. All identified reference sites were based on the presence of a defined valley and upstream drainage area, and evidence of periodic surface flow. The smallest drainage area of our evaluated reference sites was approximately 25 acres.
- The document *Information Regarding Stream Restoration with Emphasis on the Coastal Plain* (2007) also states that "… Typically, sites with watersheds less than 100 acres would not support a stream with defined bed and bank." Our data do not support this assessment. We identified two separate reference sites with drainage areas of 57 and 61 acres that displayed consistent bed and bank features, and well as fluvial bedform features. These sites were located within relatively steep valleys, where the small headwater valley transitioned into a deeper valley of a larger stream system.

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References

US Army Corps of Engineers and North Carolina Division of Water Quality. April 4, 2007. *Information Regarding Stream Restoration with Emphasis on the Coastal Plain*.