FINAL DESIGN REPORT

BATTLE BRANCH STREAM REHABILITATION PROJECT

DELAWARE COUNTY OKLAHOMA

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OBJECTIVES

The objective of this report is to present the final design for proposed stream rehabilitation on Battle Branch, a tributary to Flint Creek in Delaware County, Oklahoma. The site is located on property owned by Mark Hayes in Section 18, Township 20 North, Range 25 East of the Indian Meridian. The report includes a brief description of the existing site and detailed plans of the proposed modifications.

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I. INTRODUCTION

This report presents the final design for proposed stream rehabilitation on Battle Branch in Delaware County, Oklahoma. The site is located in Section 18, Township 20 North, Range 25 East of the Indian Meridian, on property owned by Mark Hayes. Figure 1 shows the approximate location of the Hayes' ranch.

II. SITE DESCRIPTION

Battle Branch is a tributary to Flint Creek with a drainage area of 8 square miles. The confluence of Battle Branch and Flint Creek is located at mile 4.25 of Flint Creek. The drainage area of Flint Creek above the confluence is 99.5 square miles. The valley type for Battle Branch is predominately Type VI, moderately steep, fault controlled valleys. Figure 2 shows the locations of the two watersheds.

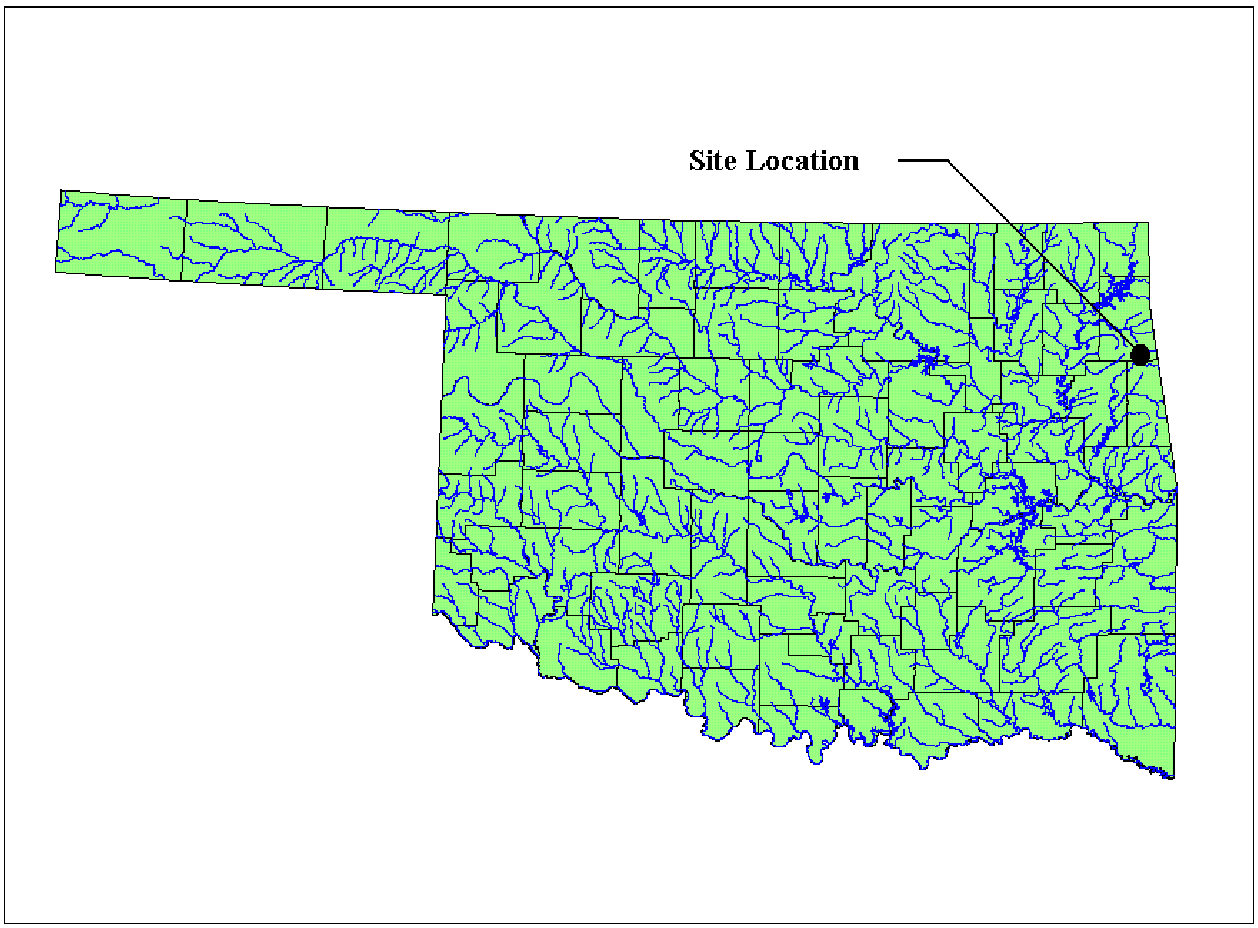

Figure 1: Location of the Hayes' ranch.

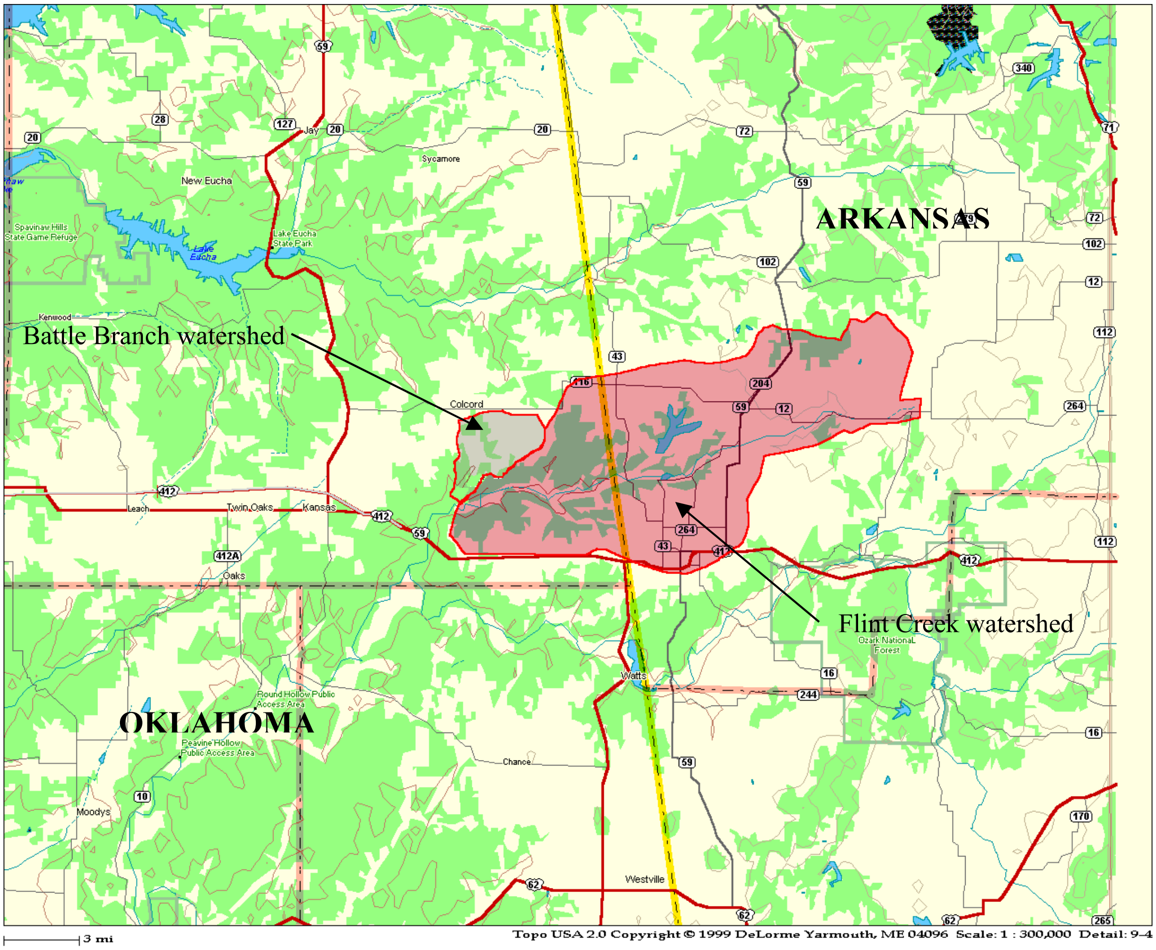

Figure 2: Location of the Battle Branch and Flint Creek watersheds.

The project site is located on Battle Branch in the vicinity of a stream crossing point (or ford). The crossing has destabilized the creek resulting in a tendency toward channel braiding. The result is a wider and shallower stream channel with depleted aquatic habitat and adverse impacts to the riparian wetland adjacent to the channel.

A fluvial geomorphologic analysis conducted at the site indicates that Battle Branch is a type "B4c" stream according to Rosgen's classification method (Rosgen, 1996). A summary of the geomorphic survey data is presented in Table 1. However, the channel appears to be overly wide with increased aggradation present and is therefore tending towards a "D4." Considering the evolutionary stage of the channel one would characterize it as being at Stage V (Simon, 1994) although strictly speaking the channel is not evolving from a degraded state.

The proposed rehabilitation project will reconfigure the channel utilizing geomorphological techniques and improve the riparian wetland at the site. A new channel will be constructed as a stable "B4c" thus accelerating the evolution of the channel to a quasi equilibrium condition (Stage VI). Mimicking more robust features observed at other sites riparian wetland area along the channel will enhance the riparian wetland area adjacent to the channel at the project site.

Table 1. Geomorphic Survey Data Summary.

	Battle Branch
B/F Width (ft)	65.13
B/F Mean Depth (ft)	1.69
B/F Max Depth (ft)	3.07
W/D =	38.6
Entrenchment =	1.9
Slope =	0.0053
Sinuosity =	?
Material:	Gravel
Stream Type:	B4c

III. BACKGROUND

The techniques to be employed in this project were developed utilizing the principals of fluvial geomorphology. Much of the design concept was based on techniques and an approach to restoring natural stream channels developed by Dave Rosgen (1996) who was expanding upon the work of Langbein and Leopold (1966), Leopold, Wolman and Miller (1964), Wolman (1954), and others who have come before him. The approach taken in this project used fluvial geomorphology to assess the channel characteristics of battle Branch in order to determine the "stream type" of the creek and the best design configuration to use to accomplish the stated objectives. A fluvial geomorphic approach was used to design the stream channel geometry proposed in the project. A brief background on fluvial geomorphology (as used in this project) will therefore be presented before presenting the proposed design.

A. Fluvial Geomorphology

The morphology of a stream or river is influenced by eight major variables including the channel slope, width, depth, discharge, velocity, the roughness of the channel materials, the sediment load and the sediment size (Leopold, et al. 1964). A change in any one of these variables sets up a series of channel adjustments which lead to a change in the others, resulting in channel pattern alterations (Rosgen, 1996).

B. Stream Classification

Rosgen (1994) has developed a stream classification system based on the eight variables presented above. The classification system organizes the morphological variables into characteristics commonly observed so that several "stream types" are identified (Figures 3 and 4). Descriptions of each of the morphological variables contained in the classification system are addressed below.

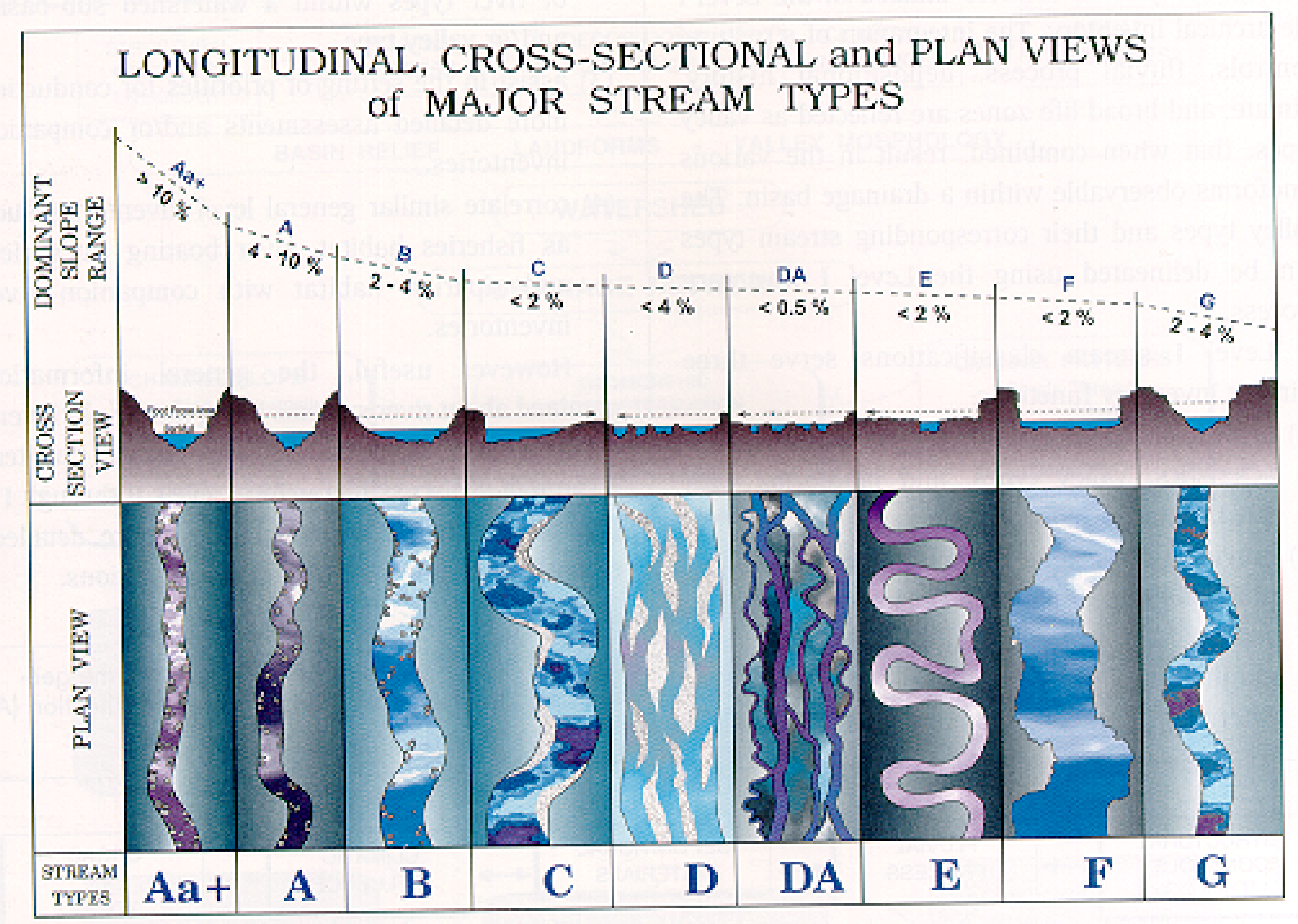

Figure 3: Longitudinal, cross-sectional and plan views of major stream types (from Rosgen, 1996).

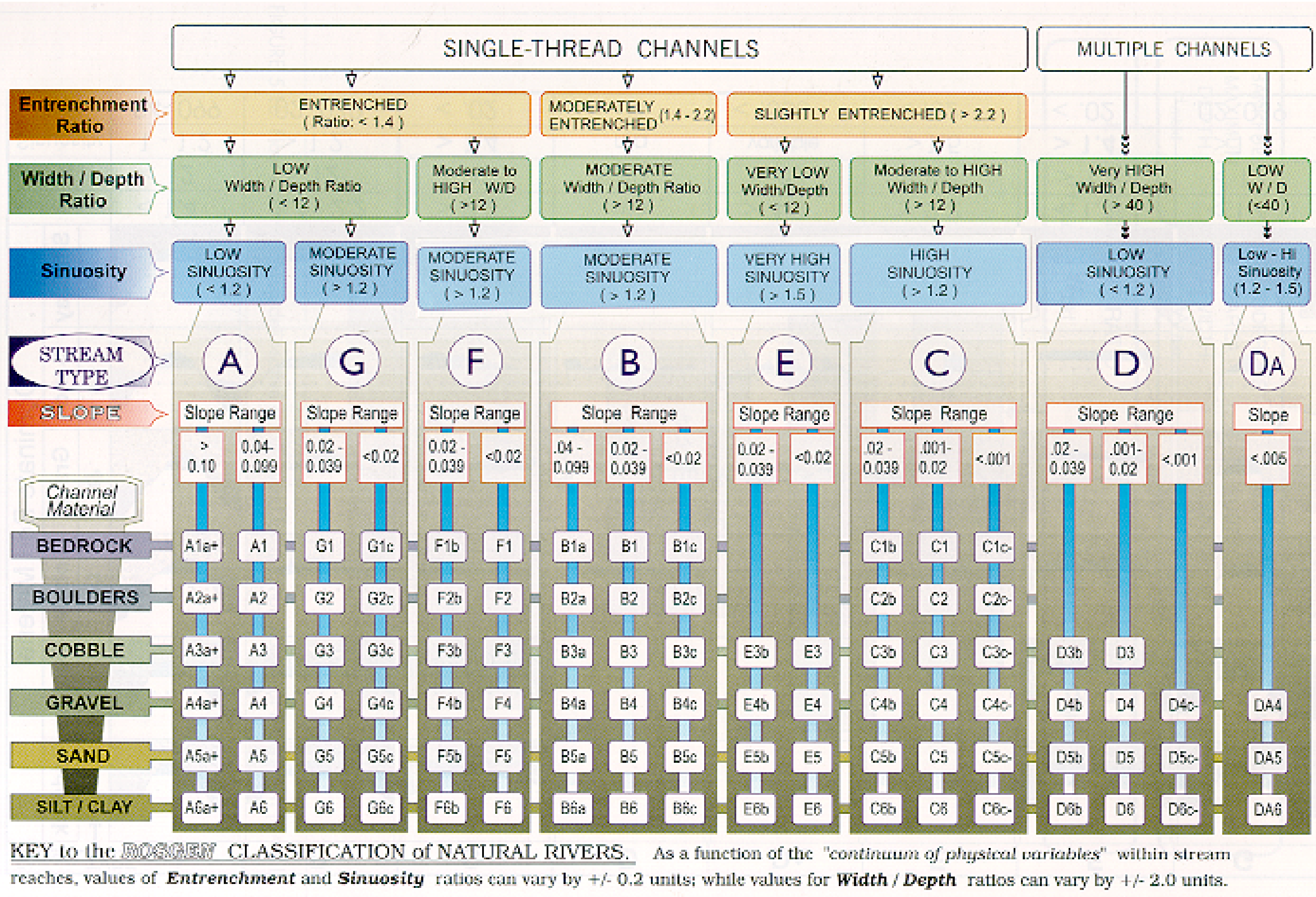

Figure 4: Longitudinal, cross-sectional and plan views of major stream types (from Rosgen, 1996).

1. ***Bankfull Discharge***

The bankfull discharge is defined as the instantaneous peak discharge that occurs a few days a year and is often related to the 1.5-year recurrence interval. It is perhaps the most important variable in the classification system as some of the other variables are dependent on it. Determination of the bankfull discharge is critical for proper application of the classification system. Discussions of bankfull discharge indicators and significance are presented by Leopold et al. (1964), Dunne and Leopold (1978), Andrews (1980), Rosgen (1996), and Leopold (1994).

2. ***Width/Depth Ratio***

The width/depth ratio is defined as the ratio of the bankfull channel width to the bankfull mean depth. The bankfull channel width and bankfull mean depth are the channel width and mean depth associated with the bankfull discharge.

3. ***Entrenchment Ratio***

The entrenchment ratio describes the vertical containment of the stream, or river, and the degree to which it is incised in the valley floor (Kellerhals et al., 1972). The entrenchment ratio is defined as the ratio of the width of the "flood-prone area" to the bankfull width of the channel. The **flood-prone area** is defined as the width of the channel at an elevation determined at twice the bank-full depth (Rosgen, 1996).

4. ***Sinuosity***

Sinuosity is a parameter describing the meander pattern of a stream or river. It is defined as the ratio of channel length to valley length. It can also be described as the ratio of the valley slope to the channel slope (Rosgen, 1996). Two additional parameters closely related to sinuosity are the **meander length** and the **radius of curvature**, as shown in Figure 5.

Langbein and Leopold (1966) developed the following relationship between these parameters:

$$R_c = \frac{L_m K^{1.5}}{13(K-1)^{0.5}} \qquad \text{(Eq. 1)}$$

where; R_c = Radius of bend curvature
K = Channel sinuosity
L_m = Meander length

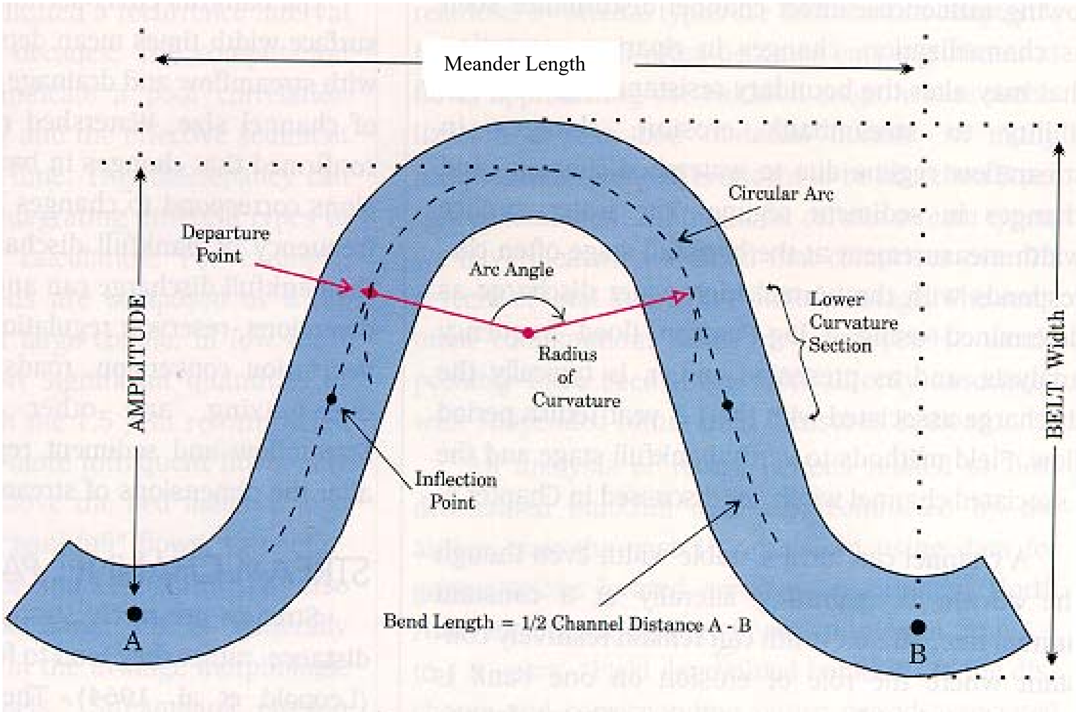

Figure 5: Plan-view of idealized river meander (Rosgen, 1996).

5. *Slope*

The slope of a stream channel is the final parameter used in the stream classification system presented by Rosgen. The slope of the channel is important in stream hydraulics. It provides the hydraulic energy to a stream system and is an important factor in sediment transfer and channel morphology. The slope is typically measured over at least 10 channel widths or one meander wavelength and preferably over 20 channel widths or two meander wavelengths.

6. *Channel Bed Materials*

The bed material of the channel is important in stream hydrology in that different materials provide varying resistance to flow and require different energy levels to transport. This in turn influences the ultimate shape of the channel. Thus channel bed material is an important characteristic of streams and is a logical component for an effective stream classification system. Field determination of the channel materials is accomplished using the "pebble count" method presented by Wolman (1954).

7. *Meander Width Ratio*

The meander width ratio is defined as the ratio of the belt width to the bankfull width of the channel. A significant result of Rosgen's classification system is the fact that the meander width ratio is linked to stream type. Thus, if the stream type is known the most probable state of channel pattern may be determined and used in stream restoration efforts.

The Rosgen stream classification system as detailed above provides fluvial geomorphologists, engineers, biologists and others working with streams and rivers a common means of communication. A "C4" stream for example in Maryland would have similar characteristics to a "C4" stream in Colorado or Oklahoma. Also, using the system requires the user to look at stream features and characteristics that perhaps they had never observed before. This may give them insight into the fluvial processes inherent in stream systems and benefit them in their work with streams be it for flood control, bridge design or improving fish habitat.

The greatest benefit of the stream classification system is that it allows one to determine the naturally stable configuration for a given stream and to use this knowledge in stream channel rehabilitation projects. Bank stabilization and flood control may be accomplished by utilizing the natural processes inherent in stream systems to dictate the most probable channel shape and pattern instead of forcing rivers into submission with concrete and rip-rap. The remainder of this report will detail the process as applied to the Battle Branch stream rehabilitation project.

IV. FIELD MEASUREMENTS FOR BATTLE BRANCH CLASSIFICATION

The first thing that needs to be done prior to implementing a stream rehabilitation project utilizing the techniques used in this project is to assess the stream system and classify it using Rosgen's stream classification system. In so doing, the natural state of the stream system can be determined. Efforts can then be undertaken to modify a disturbed section of stream back to its natural state.

A geomorphic survey of Battle Branch was conducted on July 10, 2001 utilizing a laser level and tape measure. A more extensive survey with a total station was conducted on January 15-16, 2003. A summary of the results of that survey was presented in Table 1. The plan view, longitudinal profile, and cross-sections are provided in the plans given in the appendix.

A pebble count analysis as described above was also conducted. The D16, D35, D50, D84 and D95 were found to be 12 mm, 18 mm, 26 mm, 56 mm and 128 mm, respectively.

In addition to the pebble count, a bar sample was also collected at the site and analyzed at the University of Oklahoma. The D16, D35, D50, D84 and D95 of the bar sample were determined to be 4 mm, 12 mm, 17 mm, 31 mm and 75 mm, respectively. The largest dominant particle size on the bar was observed to be 97 mm.

The results of the survey therefore indicate that Battle Branch at the proposed rehabilitation site is a braiding type "B4c" channel as described above. This is indicative of an unstable system. The cause of this instability is not positively known although it is most likely due to the impact of the stream crossing and possibly to changing land use practices and destruction of riparian areas in the watershed resulting in an increased sediment load that the channel is adjusting to.

V. BANK FULL DISCHARGE DETERMINATION

Unfortunately, there is not a U.S.G.S. gauging station located on Battle Branch to allow easy determination of the bankfull discharge. It was therefore necessary to use regression equations to estimate an appropriate bankfull discharge for the channel. Two types of regression equations were used, resistance equations and a "Regional Curve."

Resistance equations used included Manning's Equation with relationships presented by Rosgen (1998) and Cowan (1954) to determine appropriate n-values, and equations developed by Leopold, Wolman and Miller (1964), Limerinos (1970), Bray (1979) and Griffiths (1981) all of which use elements of channel size and bed material to determine an appropriate friction factor (*f*) for use in the Darcy-Weisbach Equation.

Regional curves relate hydraulic geometry parameters such as bankfull discharge, bankfull area, bankfull depth and bankfull width to the drainage area for a given hydro-geographic province. The regional curve utilized for this project was developed by Dutnell (2000) from data obtained at several U.S.G.S. gauge stations in the Central Irregular Plains ecoregion as defined by (Omernik, 1987).

The average discharge value determined using the six resistance equations named above was 677 cfs. The value obtained using the regional curve was 609 cfs. These values utilizing vastly different methods are in relatively good agreement. The bankfull discharge used in the design of this project was therefore 650 cfs.

VI. SEDIMENT TRANSPORT

Engineers have long treated streams and rivers as if they had only one function, moving water. However, streams have many functions, some physical, some biological and some chemical. The three are all connected as we are learning. From a physical perspective the main neglected element has been sediment transport although it is as an important function of rivers and streams as is water transport. In fact, it may be argued that is more important as it is what shapes the channel.

The channel-forming discharge, dominant discharge, effective discharge and bankfull discharge are essentially he same thing and were described by Wolman and Miller (1960) as being the flow that performs the most work, where work was defined as the product of the sediment transport rate and the frequency of occurrence. The recurrence interval of the bankfull discharge is reported to be between 1 and 2 years (Wolman and Leopold, 1957), with several researchers reporting values near the 1.5 year mark (Dunne and Leopold, 1978; Rosgen, 1996; Dutnell, 2000).

Flowing water exerts a shear stress on the bed and bank materials through which it is flowing and is proportional to the product of depth and slope. Critical shear stress is defined as the stress that initiates motion in the bed material. Larger materials require a larger stress to initiate motion and therefore have a larger shear stress than smaller particles. If the shear stress in the channel is not sufficient to mobilize the dominant particle size found in the bed material (i.e., it is less than the critical shear stress) the material will not be transported and the bed will aggrade. Similarly, if the shear stress is too large, the channel will degrade. A stable channel will have a shear stress approximately equal to the critical shear stress at the bankfull discharge.

Rosgen (1993) has shown that the particle size that the channel needs to move can be found by looking at the downstream third of point bars mid-way between the thalweg and the bankfull level and searching for the dominant large particle. In Battle Branch this particle size was determined to be approximately 97 mm. The dimensions of the proposed channel were therefore determined by balancing the shear stress in the channel at the bankfull discharge with the shear stress required to move a particle size of 97 mm.

VII. CHANNEL GEOMETRY DETERMINATION

Channel geometry includes the channel width, the channel depth, the slope of the channel, and the sinuosity of the channel. In a natural channel these variables are dependent on one another as well as on the dominant discharge, the bed material of the channel and the characteristics of the valley through which the stream flows.

When attempting to design a "natural" channel the first thing that the designer must know is the bankfull discharge of the channel as previously discussed. Next, the designer must specify the stream type that they are going to design. Specifying the stream type to be designed gives the designer several important parameters on which to base the design. These parameters include the entrenchment ratio, the width/depth ratio, the channel slope and the sinuosity of the channel.

A. Stream Type of Design Channel

Battle Branch was previously determined to be primarily a type "B4c" channel using the Rosgen classification system (Rosgen, 1996). However, in many places the channel has begun to exhibit braiding characteristics typical of a "D4" channel. "D" channels are not stable and are indicators of a system in dis-equilibrium. "D" channels may evolve from "B" channels in valleys subject to increased sediment loading and destruction of the riparian area. The combination of increased sediment load and unstable banks results in widening of the channel and an inability of the channel to pass the sediment that is delivered to it. As a result the channel begins to aggrade and eventually forms multiple channels where there had previously been only one. The objective of this project is to design a naturally stable "B4c" channel for battle Branch.

B. Channel Width and Channel Depth

Given that the stream type for which the South Llano River should be designed is a "B4c" and that the width/depth ratio for "B" channels is greater than 12, the width/depth ratio of the design channel should be 12 or greater. Knowing that the design discharge determined for Battle Branch is 650 cfs the objective then becomes to design a channel that will move the water and sediment load delivered to it while maintaining a width/depth ratio of greater than 12.

The width and depth required to move a particle size of 97 mm at the design discharge of 650 cfs were determined to be 62 feet and 2.5 feet respectively. This compares to the mean width and depth in the existing channel of 65.1 feet and 1.69 feet, respectively. Thus the design channel will be narrower and deeper than the existing channel and therefore should be capable of moving the sediment through the system.

C. Channel Meander Length and Radius of Curvature

The meander length and radius of curvature may be determined in a number of ways. For this project they were determined using the relationship developed by Leopold given above. The resulting meander length was determined to be approximately 704 feet. The radius of curvature was determined to be approximately 166 feet.

VIII. PROPOSED DESIGN

The first task accomplished in preparing the plans was to plot the existing conditions. This was accomplished using Autodesk Landdesktop 3. The existing plan view, cross-sections and longitudinal profile were all developed using Autodesk Landdesktop 3.

The design channel including the plan view, cross-sections and longitudinal profile was then plotted over the existing conditions using the dimensions calculated above. Locations of proposed structures, including cross-vanes and J-hooks were included on the plan view. The plans also include typical riffle and pool cross-sections and details for the cross-vanes and J-hooks. A complete set of the plans is included in the appendix.

A. Length of Disturbance

The length of disturbance in the channel bed and banks will extend a distance of approximately 1,200 feet.

B. Cut-Fill Material

Cut-fill calculations were made utilizing the cross-sections developed in the field surveys. It was determined that an estimated 1,988 cubic yards of material will be cut and an estimated 1,977 cubic yards of material will be filled. Of this, approximately 700 cubic yards is below the ordinary high water mark of the stream. There will be approximately

11 cubic yards of excess material, which will be spread on-site in an appropriate location above the bankfull level.

In addition, approximately 200 cubic yards of boulders will be used to construct cross-vanes J-hooks. Approximately 100 cubic yards of this will be installed below the ordinary high water mark of the stream.

IX. CONSTRUCTION

It is estimated that construction will take 7 to 10 days to complete. Equipment will likely include a large trackhoe (John Deer 892D-LC, or equivalent) equipped with a live thumb, a dozer (Cat D7 wide-track, or equivalent), and a front-end loader (JD544E, or equivalent). Dump trucks and/or semi-sized rock haulers will be required to transport boulders to the site. Construction is currently planned for August, 2003 during low flow conditions, pending receipt of the required 404 permit.

Construction will involve shaping the new channel to the dimensions and configuration shown in the plans provided in the appendix, using the trackhoe and dozer. Much of this work will necessitate operating equipment within the active channel, which is the primary reason that construction must be accomplished under low flow conditions. In discussions with Rosgen, he states that this is the most efficient method of construction and the least harmful to the environment. The reasoning is that accomplishing this type of work inevitably results in increased turbidity in the stream during construction but upon completion of construction the banks will be stable so that the sediment load to the stream will be reduced. Use of silt fencing and/or stream diversions extends the time it takes to complete the project, are relatively ineffectual in this application, and actually result in more sedimentation entering the stream during construction. According to Rosgen the best approach is to initiate construction at low flow conditions and complete the construction in as short amount of time as possible. This is the approach to be used in this project.

Excavation will be accomplished in such a manner so as to save as much existing vegetation as possible. Where it is necessary to remove vegetation all attempts will be made to save it by digging it up and moving it to a side location to be replanted following construction.

After the channel is shaped, 2 cross-vanes and 6 J-hooks will be installed using the trackhoe equipped with a live thumb, as detailed in the plans provided in the appendix. Cross-vanes are installed in the riffle sections of the stream and are used to control the grade in the channel to prevent the channel from degrading. J-hooks are installed in the pools or bends of the river and are designed to deflect water away from the outside banks. They are also effective at improving fish habitat as has been demonstrated in past ecperience on the Illinois River and Spring Creek. Approximately 440 tons of boulders, roughly 2’ x 3’ x 4’ in dimension will be used to create the cross-vanes and J-hooks proposed for this project.

X. ADVERSE IMPACTS

The adverse impacts of the project are minimal. There will be no loss of acres of waters of the U.S. and there should be no trees lost. There will be minimal adverse impact on aquatic organisms during construction due to increased turbidity and suspended solids but this will be more than offset by the improved habitat conditions that will exist after construction is complete.

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APPENDIX

DESIGN PLANS FOR BATTLE BRANCH

STREAM HABILITATION PROJECT