DEVELOPMENT OF A WATERSHED PLAN FOR THE SABOUGLA CREEK WATERSHED

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Abstract Through the Delta Headwaters Project (DHP), a methodology has been developed for the design of channel systems within a watershed context. Components of this approach have been used on various DHP watersheds, as well as on other watersheds throughout the U.S., but a comprehensive application of the methodology has yet to be implemented and evaluated. Using this methodology, a watershed plan was developed for the Sabougla Watershed, which is a tributary to the Yalobusha River in Mississippi. The methodology used included a comprehensive geomorphic assessment of the entire watershed, cross sectional surveys of the channel system, development of an existing conditions Sediment Impact Analysis Method (SIAM) model, identification and preliminary design of erosion control measures, and analysis of the impacts of the proposed measures on sediment yields from the watershed. The recommended plan for the Sabougla Creek Watershed includes a combination of grade control structures, bank stabilization, riser pipes for gully control, and land treatments. The existing conditions SIAM model was developed and calibrated based on observed channel morphology. The model was then modified to reflect the changes resulting from the implementation of the project features. With all the DHP features in place, the SIAM results indicated that there would be a reduction in fine sediment (silts, clay, and very fine sands) delivery at the mouth of Sabougla Creek of about 40%.

INTRODUCTION

The Delta Headwaters Project (DHP), formerly the Demonstration Erosion Control (DEC) Program, provides for the development of a system for control of sediment, erosion, and flooding in the hill areas of the Yazoo River Basin, Mississippi, and provides resources for technology transfer. The project was initiated in 1985 and continues today. A general overview of the DHP project is provided by Hudson (1997). Features that are being utilized to achieve the project goals include low drop and high drop grade control structures, bank-stabilization measures, minor grade control structures (also called pipe drops or riser pipes, floodwater retarding structures (dams), channel improvements (restoration), levees, and land treatment measures. The DHP is unique because it has provided a long term program that includes, planning, design, construction and monitoring. Through the monitoring program, many improvements to the design of individual features have been developed, as well as methodologies for the design of channel systems within a watershed context. Components of this approach have been used on various DHP watersheds, as well as on other watersheds throughout the U.S., but a comprehensive application of the methodology has yet to be implemented and evaluated. Using
this methodology, a watershed plan was developed for the Sabougla Watershed, which is a tributary to the Yalobusha River. This paper describes the methodologies utilized and the recommended plan for the watershed.

BACKGROUND

The Sabougla Creek watershed is located in the north-central Mississippi counties of Calhoun, Webster and Grenada. A location map of the watershed is shown in Figure 1. Sabougla Creek rises in north-central Webster county approximately 9 miles north of Eupora, MS, and flows in a general northwesterly direction to where it confluences with the Yalobusha River within the headwater area of Grenada Lake approximately 12 miles west of Calhoun City, MS. The lower portion of the watershed is heavily influenced by backwater from Grenada Lake.

A detailed field investigation and geomorphic analysis of the Sabougla Creek watershed was conducted in the spring of 2003 (Little and Biedenharn, 2003). Aerial and ground-based reconnaissance were utilized to inspect approximately 45 miles of channel and to document existing channel conditions and determine dominant geomorphic processes occurring within the basin. Documented information includes existing channel status, location and condition of existing structures, location of active bank erosion, knickpoints and knickzones, gullies and flooding, identification of type and extent of erosion processes, bed and bank material samples, channel plan form, vegetation patterns, sediment depths, and other significant morphological features. The locations of observed geomorphic features were incorporated in a GIS database. In general, the Sabougla Creek Watershed is experiencing severe channel incision, bank erosion and gully advancement in the upper portion of the basin. These sediment sources are contributing
to the channel and overbank sediment deposition problems in the lower reaches of the watershed. Typical erosion and sedimentation problems encountered in the Sabougla Creek Watershed are shown in Figure 2. Bed and bank material samples collected during the investigation were analyzed in the laboratory by mechanical sieve analysis, and the resulting gradation curves are presented. The data collected during the field investigation were used to determine a preliminary channel stability assessment for the watershed. This preliminary assessment classifies the stability of each stream on a reach-by-reach basis, and identifies reaches of active channel incision, bank erosion, gulley formation, and flooding. The assessment serves as a basis for additional technical analyses required for the planning and design of rehabilitative measures within the watershed.

Figure 3 Erosion and sedimentation problems in the Sabougla Watershed.

Because five years had elapsed since the 2003 study, it was determined that some supplemental field investigations would be required to update this study. This involved an aerial reconnaissance using geo-referenced photography technology, and ground based field investigations. These investigations, accomplished in the spring of 2008, identified areas where changes had occurred since the 2003 study.
CHANNELS SURVEYS

A primary objective of the Sabougla planning task was to develop a more economical procedure for acquiring the baseline channel surveys, which are a critical necessity for the development of watershed plans. Often, lack of sufficient watershed planning funds are problematic. For this reason, an innovative approach to obtaining channel surveys was developed and applied to the Sabougla Creek Watershed. The primary use of channel surveys at the watershed plan development stage is in the development of hydrologic and sediment transport models that are adequate for planning grade control, bank stabilization and other erosion and sediment control features. Historically, these surveys consisted of a detailed thalweg survey (thalweg points spaced about every 100 feet or so), and cross section surveys spaced at regular interval of between about 1,000 and 2,500 feet. For a 126 square mile watershed such as Sabougla, this level of survey detail could cost between about $100,000 and $200,000. For this reason, a different surveying approach was applied to the Sabougla Watershed. Using the knowledge gained from the field and geomorphic analyses, channel cross sections were located only at points where they were needed to capture the general geometry and slope of the channel. For instance, in the lower reaches of Sabougla where the channel was relatively stable, and there were no observed significant breaks in grade, cross sections may have been spaced over a mile apart or even more. In areas where knickpoints were present, a cross section was located at the downstream end of the knickzone and then another was placed at the upstream end. Although the details of the individual knickpoints was not captured by this method as it would with a traditional thalweg survey, the general slope and cross sectional geometry through the degradational reach could be obtained. By applying this method, 39 locations were identified where cross sections would be needed (Figure 3). By adopting this method, the cost of the surveys was only about $23,000. Although this was a reduced scope survey, it was did provide sufficient information to develop the overall watershed plans including the locations of all grade control, bank stabilization, and other erosion and sediment control features.

SEDIMENT IMPACT ANALYSIS METHOD (SIAM) MODELING

As water resource projects become more complex, there is a growing emphasis on the ability to implement effective regional sediment management. A common goal of many regional sediment management projects is the reduction of sediment loading from the watershed. This is often accomplished with rehabilitation features such as grade control structures, bank stabilization, drop pipes, dams, and land treatments. While these features are often implemented to reduce sediment yields to downstream areas, the spatial and temporal impacts of these features on the sediment regime of the system are far from straightforward, and often result in unexpected morphologic changes in the channel system. Therefore, the challenge in regional sediment management projects is to select the appropriate sediment management features that produce the desired reductions in sediment delivery while minimizing the disruption to the stability of the channel systems. To facilitate this decision-making process, the Sediment Impact Analysis Method (SIAM) model has been developed to provide for rapid assessment of the impact of sediment management activities on sedimentation trends. SIAM is viewed as a screening tool for the assessment of multiple rehabilitation alternatives, particularly in the reconnaissance and feasibility phases of a project. It provides a framework to combine sediment sources and computed sediment transport capacities into a model that can evaluate sediment imbalances and
downstream sediment yields for different alternatives. The development of SIAM includes the incorporation of the model into the “Hydraulic Design” module of the Hydrologic Engineering Center’s River Analysis System (HEC-RAS), which is an on-going task at the time of this writing. The SIAM model was selected as the appropriate tool for the Sabougla Creek Watershed. A summary of SIAM capabilities, applications, and limitations is provided in these proceedings by Jonas and Little (2010).

Figure 3 Cross section locations in Sabougla Creek Watershed.

**SIAM Inputs for the Sabougla Creek Watershed.** Data collected during the field investigations and geomorphic analysis was used to populate the SIAM Model for the Sabougla Creek Watershed. The following sections describe the data input for the model.

**Hydrology and Hydraulics.** Unfortunately, there are no hydrologic or sediment measurement gages maintained within the Sabougla Creek Watershed. For this reason it was necessary to scale the hydrology from the adjacent Yalobusha Watershed to the Sabougla Creek Watershed. Flow duration data that had been developed for the Yalobusha Watershed were transposed to the Sabougla Watershed based on a non-dimensional index procedure developed by Watson et al (1997). A HEC-RAS model was set up for the streams in the Sabougla Creek Watershed. The flows that were used to populate this model were transposed from the Yalobusha Creek Watershed.

**Bed and Bank Material Data.** Bed and bank material samples were collected throughout the watershed as part of the 2003 field investigation study. The 2008 field study confirmed that these data were still representative of the watershed, and therefore, were used as the data input to SIAM. The bed material gradations were used as basic input to the SIAM model.
**Sediment Supply.** SIAM requires the user to input estimates of all sediment supply from any sources in the watershed. The principle sources in the Sabougla Watershed were the streambanks, gullies, and from overland flow from the fields. Areas where significant bank erosion was occurring were identified from the field investigation and aerial reconnaissance. Estimates of bank erosion rates were transposed from the Yalobusha Watershed where a detailed study of erosion rates had been conducted. The bank material gradation data were used to provide an estimate of the supply of sediment from the banks by grain size. Gully locations were identified from the aerial reconnaissance. An estimate of the annual supply of sediment from these gullies was based on estimates developed for the Yalobusha Watershed. This annual supply was input to the model by grain size using the bank material gradations. Estimates of watershed sediment delivery were transposed from the Yalobusha Watershed.

**SIAM reaches.** The Sabougla Watershed streams that were to be modeled were divided into reaches based on the field investigations and geomorphic analysis. Factors that were considered in the selection of these reaches included, tributary locations, breaks in grade, changes in planform, geologic controls, significant sediment inputs, structure locations, and significant erosion or depositional areas. The location of the SIAM reaches is shown in Figure 4.

![Figure 4 Location of SIAM Reaches for the Sabougla Creek Watershed. The red circles represent the upstream and downstream ends of each reach.](image-url)
PLAN DEVELOPMENT

The recommended plan for the Sabougla Creek Watershed includes a combination of grade control structures, bank stabilization, riser pipes, and land treatments. A brief description of each of these follows.

**Grade Control Structures.** Channel degradation is a serious problem in the Sabougla Creek Watershed. Because of this, one of the most important features of the recommended plan is a series of grade control structures. Degradational reaches were identified from the SIAM model. These reaches were then checked against the field investigations to verify that the SIAM results were correct. A series of grade control structures were then placed in the SIAM model and the model was run to determine the impact of the structures. In some cases, the SIAM model indicated that some downstream areas that were stable in the pre-project runs became degradational as a result of the hydraulic impact of the upstream structures. In these cases, additional grade control structures were needed. Two different grade control plans were developed. Alternative 1 was a series of 3.3 foot (1 meter) low drop structures. A total of 50 structures were identified under the Alternative 1 plan. For each structure in the plan, the weir crest elevation, and latitude and longitude of the structures was identified. All the structures in this plan have drop heights of 3.3 feet, except for the one high drop structure on Lindsey Creek. Although this high drop is shown as part of the plan, it is considered to be a low priority because it is located on an extremely erosion resistant clay material and has been stable in this location for many years. A typical plan and profile of structures for one of the streams is shown in Figures 5 and 6. The Alternative 2 plan was similar to the first plan, but some of the 3.3 foot structures were replaced by 5 foot structures in Horse Pen, Bellefontaine, and Little Creeks. A total of 42 structures were identified under the Alternative 2 plan. The locations and crest elevations in these plans should be considered preliminary since detailed analysis at the design stage may alter the location or crest elevations of some of these structures. Changes in the layout may be caused by a number of local factors such as channel alignment, tributary locations, geologic controls, man-made structures, flood control impacts, access, etc. The design details of the structures will be determined by the design engineer. These could be the typical ARS type structures that have been used successfully for many years in the DHP streams a series of sloping loose rock structures.

**Bank Stabilization Plan** Areas where significant bank erosion was occurring were identified from the field investigations, aerial reconnaissance and close examination of the aerial videos. After a thorough analysis, the location and approximate length of streambanks to be protected was identified. The total length of bank erosion in the watershed where bank protection could be applied was determined to be about 22,200 feet.

**Minor Grade Control Structures (Riser Pipes)** Gully locations in the Sabougla Creek Watershed were identified from field investigations, aerial reconnaissance and close examination of the aerial videos. Thirty two gullies were identified that were candidates for stabilization with riser pipes.
**Land Treatment Measures** Since land treatment measures have historically been developed by the NRCS, no attempt was made to identify these features. For modeling purposes, it was assumed that land treatment would result in a reduction in sediment delivery of about 25% from the overland sources to the stream.

![Figure 5 Alternative 1 grade control layout for Lindsey Creek. All structures have 3.3 feet drop heights except No. L2 which has a 12 foot drop.](image)
Figure 6 Alternative 1 grade control reach of Lindsey Creek showing locations of nine grade control structures. All structures have drop heights of 3.3 feet except structure number 2 which has 12 feet.

IMPACTS OF RECOMMENDED PLAN

The existing conditions SIAM model was developed and calibrated based on observed channel morphology. The model was then modified to reflect the changes resulting from the implementation of the project features. With all the DHP features in place, the SIAM results indicated that there would be a reduction in fine sediment (silts, clay, and very fine sands) delivery at the mouth of Sabougla Creek of about 40%. The reduction in fine sediment delivery is expected to occur within a relatively short period following construction. It is difficult to quantify this time period but the reductions would probably be realized within a time of about 1 to 5 years. However, there are other, long term impacts that SIAM is not capable of predicting. Many of the recommended DHP features will reduce the delivery of coarse sediments (medium sands and greater) to the channel system. However, the time required for the impacts of these upstream coarse sediment reductions to be realized at the mouth may be measured in decades. In many instances, the time frame may be 50 to 100 years or longer. Therefore, the 40% reductions indicated by the SIAM model reflect the short term response, and it should be recognized that the long term reduction in sediment supply could be much greater.

REFERENCES