STABILIZATION OPTIONS FOR DESOTO COUNTY STREAM SYSTEMS, MS

Appendix B. Memphis Metropolitan Stormwater – North DeSoto County Feasibility Study

INTRODUCTION:

The summary report is developed to provide background information regarding the Memphis District-USACE study of the DeSoto County watersheds. To explain the geomorphic processes occurring within the watersheds, pictures were taken during field site analysis to provide direct links to channel and floodplain morphology. The pictures illustrate their corresponding forms within Schumm, Harvey, and Watson's (1984) qualitative 5-stage Channel Evolution Model (CEM).

Furthermore, this report describes, and outlines restoration alternatives based on the limited field site investigations (Horn Lake, Johnson, and Nolehoe Creeks) and FluvialGeomorph (FG) assessments. The assessments provided background for developing the watersheds stabilization plans and for developing and extrapolating stabilization alternatives for the additional 8 study watersheds within DeSoto County. The plans are developed in two phases, Phase I-Stabilization Alternatives and Phase II-Adaptive Management options for further bank stabilization and habitat enhancements.

BACKGROUND:

The Channel Evolution Model (CEM) is a conceptual model used to descriptively analyze the physical conditions of a stream reach or the network of streams within a watershed. Geomorphologists, engineers, and others who are familiar with the system can discuss model stages and relay physical channel characteristics to other disciplines. For example, stage IV is typical of aggrading reaches while II are degrading zones. By having knowledge of the CEM, practitioners have a good idea on what the state of channel stability and sediment transport is for that specific area of the stream or watershed. The CEM is a very useful tool in watershed and stream analysis.

Channel Evolution Model

The Channel Evolution Model (Schumm et al., 1984) was developed in the early to mid-eighties in the Yazoo River Basin in northwestern Mississippi. The Yazoo basin was characterized by a series of channelization projects throughout much of the region. The model provides background into the physical processes occurring due to channel instability. Channel instability progresses through as multiple channelization events occur has a definite and predictable pattern. The CEM is based on the natural progression of stages (stages I thru V, See Figure 1) the channel goes through as it tries to re-establish a new equilibrium. Various factors affect the progression through the stages such as the cohesion of bed and bank materials, new friction slope, precipitation rates, geotechnical bank properties, changes to discharge, and others.

Watershed development in De Soto County is a mix of rural and urban watersheds, with large increases in urbanization over the past 15 years. Because of the increase in recent urbanization, the following impacts due to the increased watershed development are:

- increased runoff from paved surfaces
- decrease in soil infiltration rates
- decreased time of concentration due to more effective conveyance system
- decreased sediment supply from a stabilized watershed.

It is common for urban watersheds to have reaches which have been channelized for agriculture and flood control, resulting in a lowered base level at the upstream end of the channelized reach.

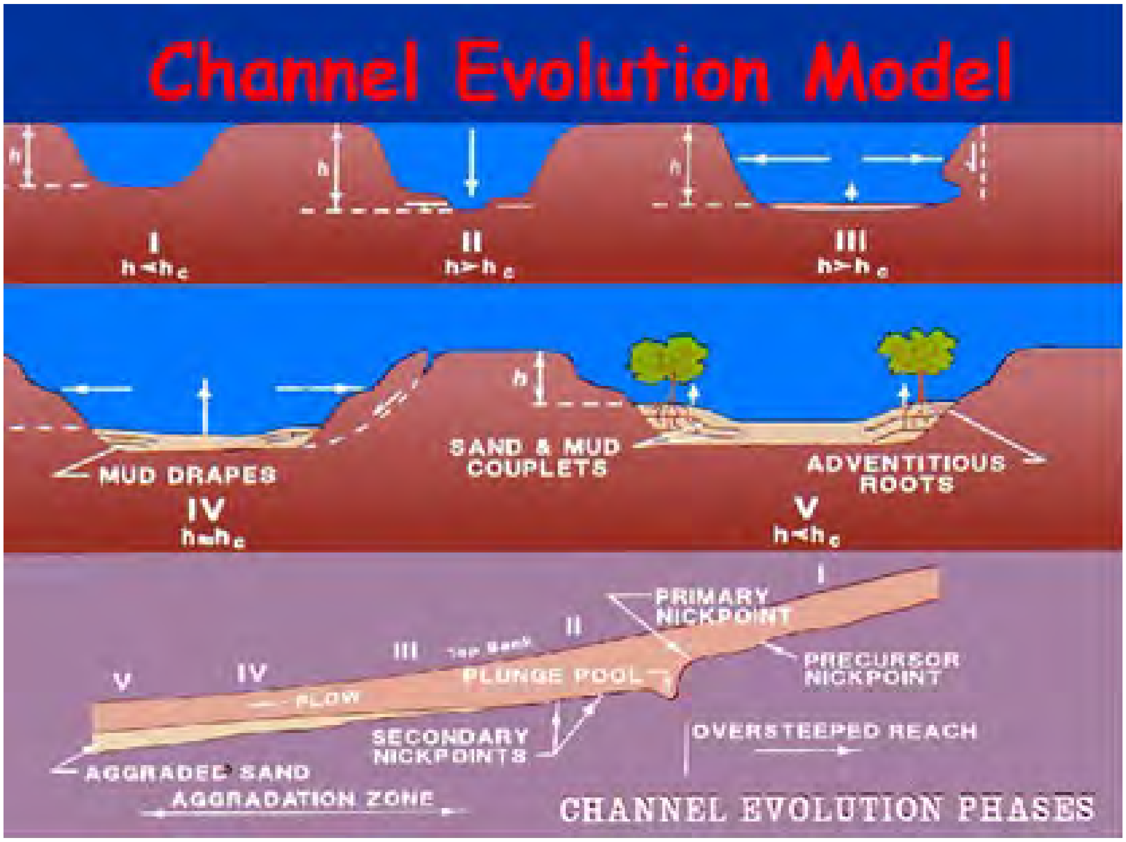

Figure 1. Channel Evolution Model (CEM)

CEM Type I: The first stage of the CEM is the stable pre-modified channel in a natural unaltered condition. The stream is connected to a floodplain with a recurrence interval in the one to three-year ranges. This range is consistent with the natural range Leopold, Wolman, and Miller concluded in their 1964 publication “Fluvial Processes in Geomorphology”. Type I streams have characteristic bank heights that are less than the critical bank height for failure (h < hc). Type I is also upstream of the active incision. Some examples of the Type I CEM are in Figures below:

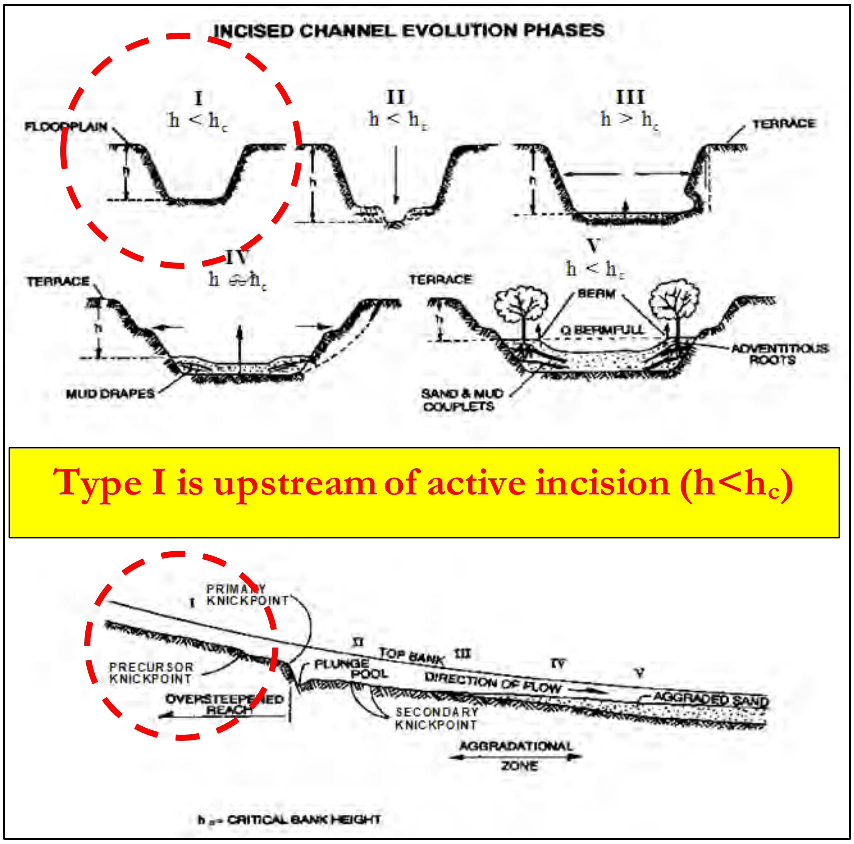

Figure 2. CEM Stage I

Figure 3. Example CEM Stage I immediately upstream of Stage II, Middle Johnson Creek Tributary

CEM Type II: The Type II stage is exemplified by active incision. The incision may be natural or could be man-made from channelization or other watershed activities. The stream is in a state of becoming disconnected to a floodplain which puts more pressure on the stream banks. Type II streams have characteristic bank heights less than the critical bank height (h < hc). They are however rapidly approaching the point where hc > h as the reach progresses towards Stage III. Some examples of the Type II CEM are in the pictures below:

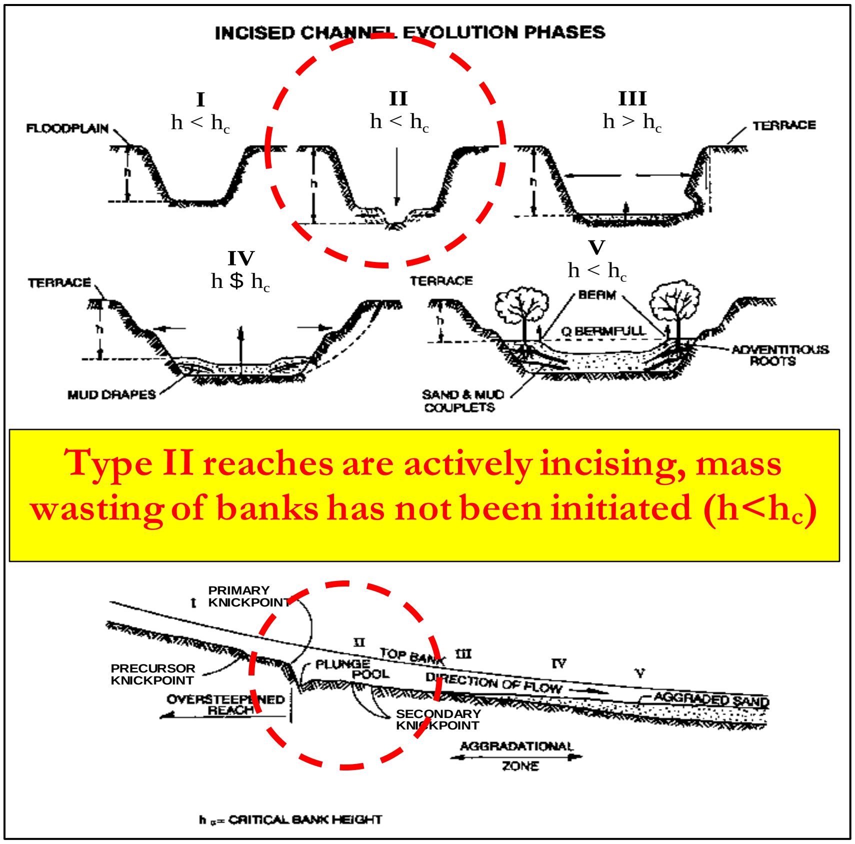


Figure 5. Example CEM Stage II, Middle Johnson Creek

CEM Type III: The Type III areas are downstream of the active incision. In Stage III the stream is now totally disconnected from the floodplain and the natural stream forming discharges; which put more pressure on the stream banks. Type III streams have characteristic bank failure with bank heights greater than the critical bank height ($h > hc$). Mass wasting of the banks and rapid channel widening are the dominant processes. The widening will continue as the system attempts to re-establish a new equilibrium and a new floodplain. Examples of the Type III CEM are in the pictures below:

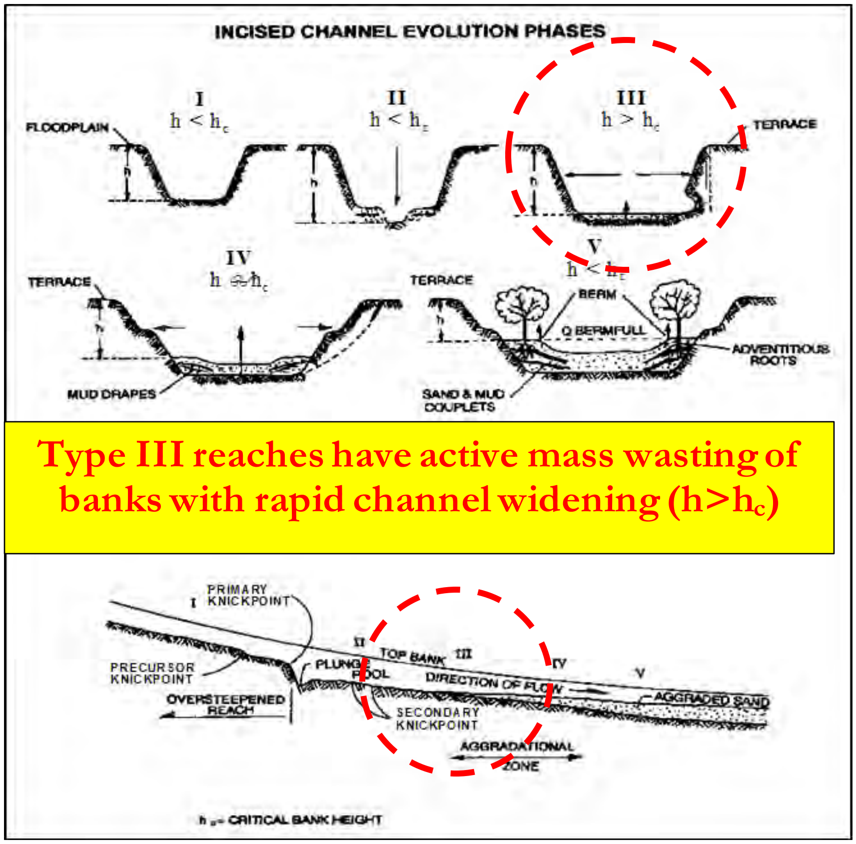

Figure 6. CEM Stage III

Figure 7. Example CEM Stage III, Middle Johnson Creek

CEM Stage IV: In Stage IV, the channel widening continues but at a much-reduced rate. Stage IV areas are downstream of the active incision and show the first stages of the channel reaching a new equilibrium. Stage IV is re-establishing a new floodplain within the old channel banks and at a lower base level. Type IV streams have very little bank failure with bank heights less than the critical bank height (h < hc). There is a new terrace forming on both sides of the stream and a new meandering pattern. Some examples of the Type IV CEM are in the pictures below:

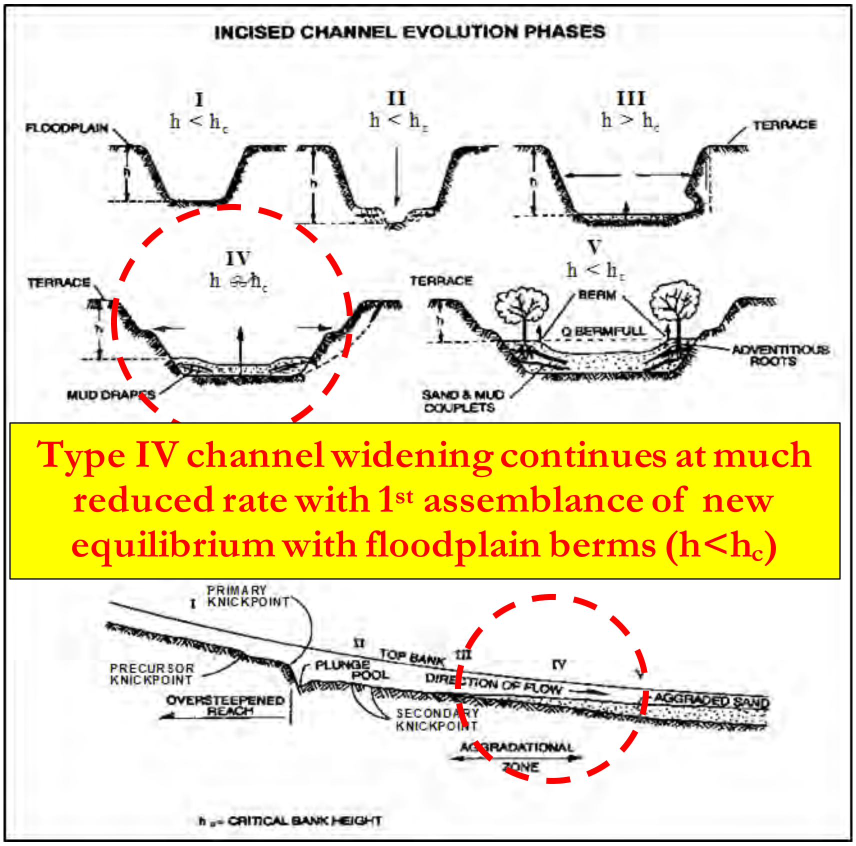

Figure 8. CEM Stage IV

Figure 9. Example CEM Stage IV, Lower Nolehoe Creek

CEM Stage V: The last stage of the CEM has a stable re-adjusted channel. The Stage V stream has a newly developed meandering pattern, which is once again connected to a floodplain with a recurrence interval in the one to three-year ranges. Type V streams have characteristic bank heights that are less than the critical bank height for failure (h < hc). Type V reaches represent a state of dynamic equilibrium with a balance between sediment supply and sediment transport capacity. Some examples of the Type I CEM are in the pictures below:

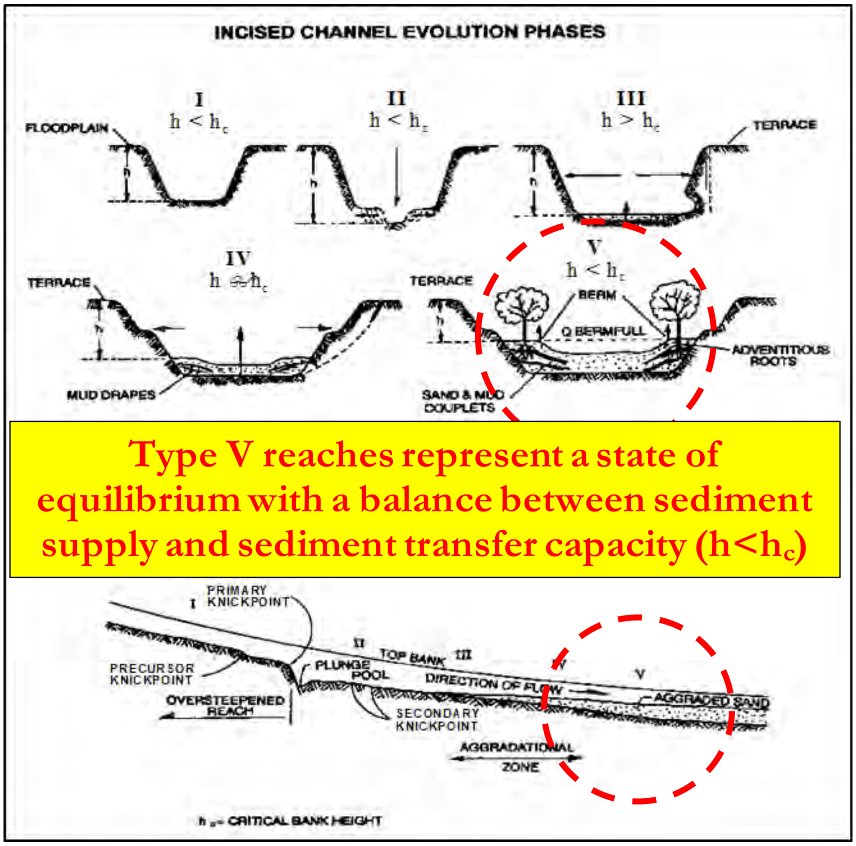

Figure 10. CEM Stage V

Figure 11. Example CEM Stage V, Lower Johnson Creek

Stream Stabilization and Restoration Techniques based on CEM Stage

Once an understanding of channel processes is completed for the study areas, identified CEM stages can be used from a reconnaissance level of detail to assist in determining what stabilization techniques will be appropriate. For example, constructing bank protection upstream of an actively degrading downstream reach (CEM stage II) will lead to project failure. This is recognized by understanding the underlying principles and processes that stream channels progress through as degradation occurs. Figure 12 provides some background into the possible stabilization techniques that would be advisable depending on the CEM stage. The structural practices that are identified are not the only practices available but provide a general background into the type of practice that is appropriate. There are other factors that ultimately weigh in on the final stabilization measures chosen. Some of the factors include geomorphic and engineering parameters such as Radius-of-curvature to bankfull width (Rc/Bw), meandering patterns, channel slopes, velocity and shear stress on bed and banks, presence of cohesive or non-cohesive soils, presence of incised channels with no access to floodplains, geotechnical properties of beds and banks, location of infrastructure, rate of land use change, and others.

In September of 2017, USACE Headquarters published new guidance that stated all projects within the USACE portfolio are required to consider Engineering With Nature (EWN) type of practices. (USACE Memo, 2017). Engineering With Nature-Natural and Nature Based Features (EWN-NNBF) seeks to merge standard engineering practices to achieve more resilient and sustainable designs. EWN is defined as the intentional alignment of engineering and natural processes to efficiently and sustainably deliver economic, environmental, and social benefits through collaboration (King et al. 2020). EWN type practices will be considered in all stabilization and restoration plans for the DeSoto County watersheds.

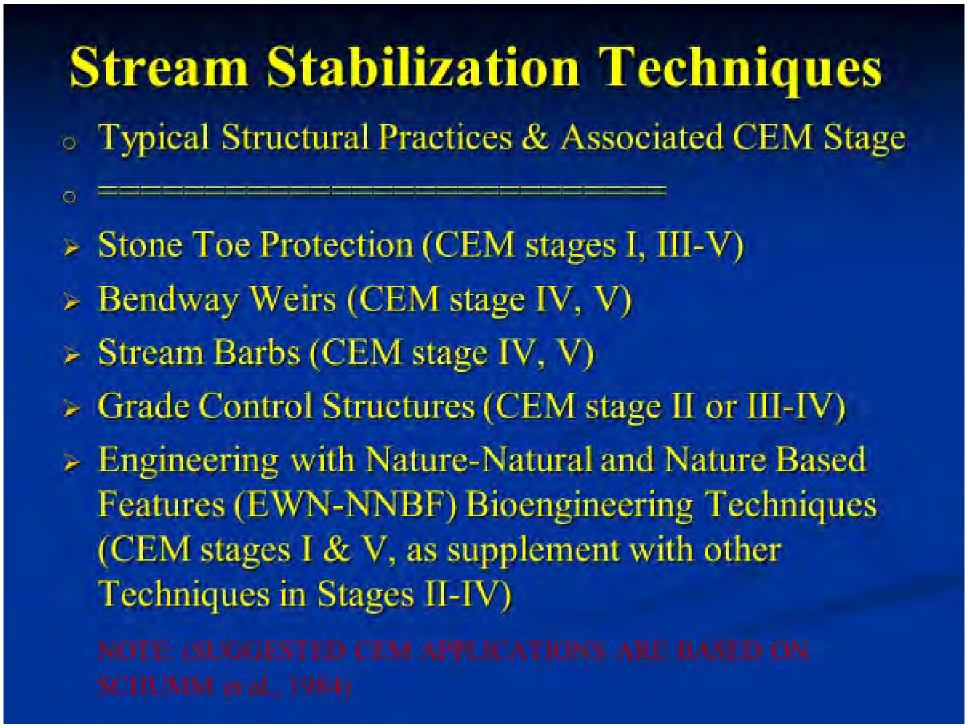

Figure 12. Common Stabilization Techniques and associated CEM Stage

The next section describes the proposed construction phases outlined in the preliminary geomorphic assessments and FG toolkit assessments.

Phase I: Johnson, Horn Lake, and Nolehoe assessments provide the basis for the defined stabilization and restoration plans. The overarching issues within the watersheds are channel degradation with varying degrees of channel instability located throughout the reaches. Johnson and Nolehoe Creek have limited existing grade control structures in place that will require a series of new structures to be constructed in addition to bank protection. Horn Lake Creek has many existing structures that can be further assessed and likely enhanced with the addition of a few more structures to stabilize the channel bed. This would require adding bank protection to stabilize additional areas within the reaches.

Primary Stabilization Focus: <u>The primary focus of Phase I is to stabilize the channel by providing the required bed protection measures to offset new and continued channel degradation trends</u>. This will likely require bank protection in areas upstream and downstream of the structures to provide further planform stability. The loose rock riffle grade control structures provide direct EWN benefits. NNBF are a natural part of the grade control structures function and design by reintroducing natural channel morphology. Figure 13 illustrates a non-NNBF type low drop grade control structure on Long Creek that does not allow for fish passage.

Figure 13. Long Creek-Low Drop Grade Control Structure

The loose rock riffle grade control structures provide the following structural, ecological, and biological habitat enhancements.

1) Reduce sediment delivery by stabilizing the channel bed and banks upstream of structures. Figure 14 illustrates a 62-percent reduction in sediment delivered due to grade control structures from projects in other northern-Mississippi stream systems (Delta Headwaters Program-DHP)

Bank Stability Impacts With Grade Control

Watershed	Sediment Delivered to Channel Without Grade Control (m3)	Sediment Delivered to Channel With Grade Control (m3)	Percent Reduction Sediment Delivered Due to Grade Control
Yalobusha	66,149,110	25,575,450	60%
Batupan Bogue	91,058,830	33,211,140	64%
Hickahala	34,921,210	5,658,480	84%
Long	63,506,510	16,261,300	74%
Hotopha	6,339,460	2,344,070	63%
Black	67,205,250	48,101,910	28%
		Average	62%

Figure 14. Delta Headwaters Program-Percent Reduction Delivered Due to GCS

2) Reintroduces pool and riffle sequences. Provides for flow energy dissipation with controlled elevation drops in a series of structures.
3) Form floodplain berms and benches to provide further stability to over-steepened streambanks and provides new channel margins for the recruitment of woody species riparian corridors to re-establish providing stable terrestrial and aquatic margin habitat (Figure 15).

Figure 15. Sinsinawa River, Northern Illinois; Loose Rock Riffle Grade Control with downstream right bank LPSTP, notice floodplain bench forming upstream of bridge

4) The stable floodplain berms and benches provide increased resistance slowing flows and depositing sediment and nutrients for sequestration.
5) When appropriate, the structures can be constructed to re-connect floodplains which provides dissipation of flow energy across the floodplain. The re-establishment of natural floodplain interactions with sediment depositing and nutrient recycling. Some aquatic species also benefit from having access to seasonal floodplains.
6) Provide fish passage with a 5-percent design slope, see typical in Figure 16 (20:1 backslope)

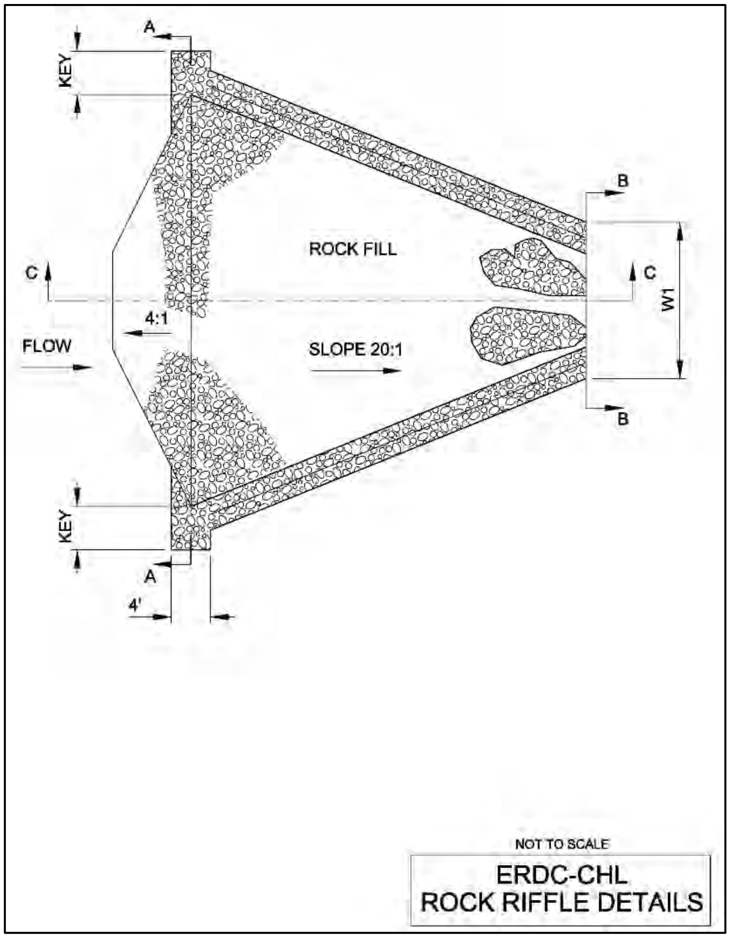

Figure 16. Typical Loose Rock Riffle Grade Control Design Plans

7) Provide fish spawning areas (constructed gravels) on the upstream front slope (typically 4:1 front slope but can be variable).
8) Provides stable substrate for macro-invertebrates, fish species (darter, others) and other aquatic species to colonize. Typically, if a stream has appropriate insect populations then the fisheries will recover with the renewed forage provided.
9) Increased channel roughness across the stable riffle increases oxygen uptake into the water for aquatic organisms.
10) Can be used in combination with other stabilization measures to provide a system approach to restoring stream stability and ecology.

Secondary Stabilization Focus: The secondary focus of Phase I is provide critical bank protection at locations throughout the reaches. This would likely be a form of toe protection to stabilize the base of the slope and either replant or let nature naturally recolonize the mid and upper banks. Longitudinal Peaked Stone Toe Protection (LPSTP) is considered an EWN option for stabilization because the mid and upper banks can incorporate natural bank protection with the toe of the eroding streambank stabilized. The EWN benefits for LPSTP includes using a more limited amount of material (riprap) to stabilize the eroding toe instead of previous engineering practices of sloping the bank back on a 3:1 slope and rocking the entire bank. EWN-NNBF focuses on limiting disturbance to the system (limited bank disturbance), incorporation of natural vegetation (vegetation planted or allowed to come in naturally), and providing ecological benefits with riparian development (vegetation for aquatic and terrestrial species enhancement), all which show the value with comparisons between the highly engineered rock lined bank revetments and the limited lower bank protection completed using LPSTP. However, there may be locations where total bank protection is needed, for example, to protect a road or bridge.

The LPSTP provide the following structural, ecological, and biological habitat enhancements.

1) Reduces sediment delivery to downstream reaches by providing bank stabilization.
2) Resilient design that provides a stable base for the bank to re-stabilize for riparian corridor re-establishment.

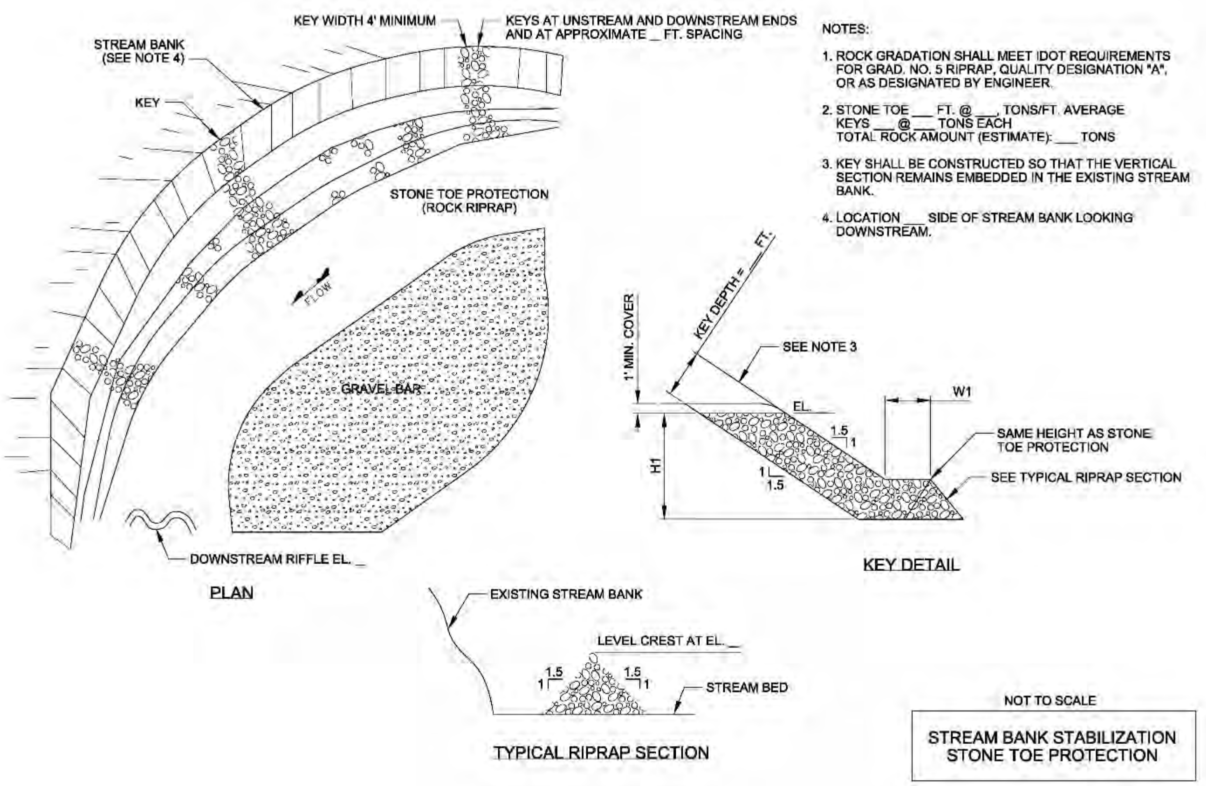

Figure 17. Typical Longitudinal Peaked Stone Toe Protection (LPSTP) Plans

3) Promotes aquatic benefits by re-establishing stable vegetation that in turn provides shade (reducing water temperatures), increase aquatic-terrestrial habitat for insects (fisheries/birds), and provides interstitial spaces for macro-invertebrates and fish to colonize below the water.
4) Can be used in combination with rootwads or other enhancements locked into the LPSTP to increase the habitat benefits (Figure 17).

Figure 17. Black Walnut Creek-North-central Illinois, Rootwads with LPSTP imbedded in bank.

5) Can be used to realign unstable meander bends to provide more stable planform (Figure 18).
6) Catches sediment and stabilizes the material in and behind the riprap toe (Figure 18).
7) Can be used in combination with other stabilization measures (re-directive measures, grade control structures, etc.) to provide more structure and ecological benefits.

Figure 18. Little Bogue, Northern Mississippi, LPSTP-notice alignment was moved from eroding bank to provide better planform alignment and a new floodplain is forming between the previously eroding terrace and new LPSTP alignment.

8) Can be used as a Reactive bank stabilization measure to reduce nutrient delivery to the stream. (Test site-Little Bogue Figure 18 and depiction in Figure 19)

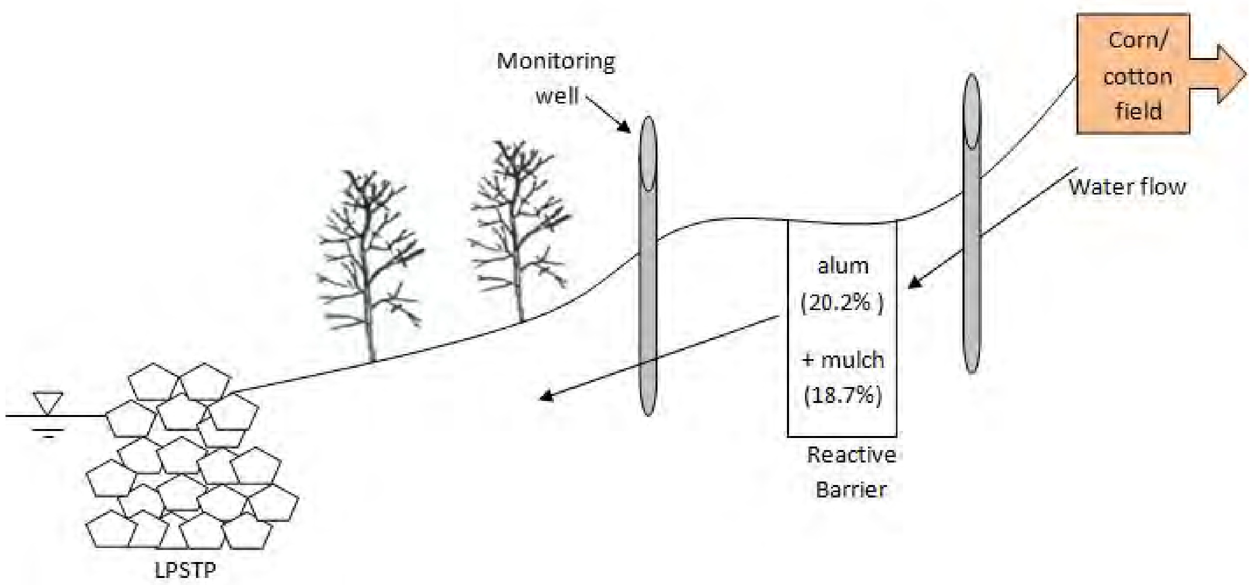

Figure 19. Little Bogue, Northern Mississippi, LPSTP-depiction of reactive measures added in trench behind riprap windrow and the terrace slope.

Third Stabilization Focus: Overland erosion and sediment is a major concern for stabilizing the stream systems in DeSoto County. The erosion caused from base-level lowing of the main-stream networks is typical. Erosion control measures in the upland areas adjacent to the stream corridors will be addressed as part of the system approach to stabilizing the watersheds. The upland stabilization measures include water and sediment control basins (WASCOB, Figure 20) with pipe outlets that take water from the terrace levels down to a stable outlet elevation near stream level. These are typical Natural Resources Conservation Service (NRCS) structures for agricultural erosion control. The Vicksburg District has been constructing these types of structures within the DHP for the past 30-years so there is plenty of examples of these structures within the northern Mississippi area watersheds.

Figure 20. Northern Mississippi-Chicken Spit Creek, Water & Sediment Control Basin

Phase II: Once Phase I work has been completed, that included stabilizing degradational channels with grade control structures, providing critical bank protection, and constructing WASCOB's; then adaptive management measures can occur to further enhance the channel restoration and ecological benefits. Recent USACE projects that are ongoing use a project construction extension a couple of years into the future to provide a mechanism for adjustments to the project (LRB-Cuyahoga River). Adaptive Management options for further bank stabilization and habitat enhancements may include additional bank protection and ecological focused structures. Some of those measures include:

1) Addition of LPSTP to critical bank erosion sites

2) Enhance LPSTP with Cedar Tree Revetments (CTR) for mid bank protection-trap sediment behind LPSTP
3) Enhance LPSTP with Rootwads for additional aquatic habitat
4) Standalone habitat enhancements where channels have stabilized (CTR, Rootwads, other bioengineering methods).
5) Add additional structure to streams with riprap structures between the grade control structures for aquatic habitat diversity (K-Logs, J-hooks, weirs, barbs, etc.)

DeSoto County Stabilization and Restoration Plans: Plans developed for this study were based on limited field site visits to Horn Lake, Johnson and Nolehoe Creeks in early November 2020. HLC had several existing grade control structures present, Johnson Creek had relatively no stabilization measures, while Nolehoe Creek had some culverts and erosion resistant bed materials that provided each watershed with a unique set of existing conditions. The Phase I and II plans were developed based on the limited field site and FluvialGeomorph assessments for the three watersheds. The 3-watersheds were used to infer similar channel stability conditions to the non-field site visited watersheds (9 additional) and develop stabilization plans for each. The analysis was completed in this way as a reasonable approach to expedite the planning schedule.

Study and data uncertainties: Uncertainties exist in any method when developing stabilization plans in fluvial systems for a number of reasons. Below is a list of potential uncertainties based on the data available for this study.

- Fluvial systems are not static but dynamic in nature so existing conditions can change in a short period of time. For example, the PDT could decide to gather detailed channel survey data in June and within a few days after data collection, flow events may change the channel conditions and local morphology, possibly making the channel survey data obsolete.
- Existing LiDAR data used for the analysis is approximately 10 years old and may not accurately reflect existing conditions. The data was used to identity channel stability issues and locations within the watershed where those issues are occurring. The channel stability issues were qualitatively field-identified on the 3 watersheds with no new channel survey data collected. However, the specific locations of these trends have likely changed since the LiDAR data was collected and will continue to change until construction of stabilization measures are complete.
- Grade control structures were located based on channel slopes (determined from LiDAR) and the locations will need to be adjusted in the field prior to final designs.

Additional key points and recommendations are listed below that should be accounted for in the next phase of the project development.

- Additional field site visits are required to identify channel stability issues within the watersheds. This will take a significant amount of time to complete and should be completed in phases. For example, concentration on collecting more detailed information on a group of priority watersheds (HLC-Johnson-Nolehoe) is recommended. From a construction perspective, all 12 watersheds will not be constructed at once, so concentrating on 3 or 4 priority watersheds first, then working on additional data collection needs with another set and then a final set would provide a sound approach to completing the project and overcoming dynamic conditions of change that channels typically exert (see study and data uncertainties).

- Phase I: Grade control structure locations will require adjustment based on:
  - H&H modeling efforts, no-rise to 100-year flood profiles
  - Adjustments in HLC with FRM considerations
  - Structure locations should not be in meander bends but in cross-over locations
  - Structure locations can be adjusted to address tributary channel stability
  - Structure locations require adjustments based on floodplain and terrace locations
  - Structure locations may be adjusted to protect pipeline, other utility crossings, bridges and roadways.
  - Structures may be designed at differing heights to assist with H&H no-rise conditions and site-specific habitat development areas (Nolehoe-Reach 2).
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- Phase II: Stabilization and restoration enhancements will need to be adjusted based on the following:
  - Additional field reconnaissance is required to identify and determine specific locations for bank protection and specific locations for habitat enhancements
  - Specific types of alternatives can be chosen based on conditions after GCS have been installed and the channels have had time to adjust. For example, some meander bends may require additional hard-structural bank protection (riprap) while others may only require a soft-structural bank protection (woody material with limited riprap).
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- There is a high level of professional judgment that has been used to develop the watershed plans. However, this is based on many years of developing similar stabilization and restoration plans with similarly limited data. There are uncertainties built into any method, especially working in a fluvial system. ERDC-CHL used the new geomorphic assessment toolbox FluvialGeomorph, existing empirical data developed from the DHP in northern Mississippi and best professional judgement to assist MVM in developing the DeSoto County watershed stabilization and restoration plans.