Regional Sediment Management of Watersheds, Reservoirs, and Rivers

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ABSTRACT: The Regional Sediment Management (RSM) Program was started by the U.S. Army Corps of Engineers to facilitate a paradigm shift away from action-by-action or project-by-project sediment management, to a longer-term, regional approach across multiple projects and business lines. Cost savings, environmental benefits, and improved communication and collaboration are possible by managing sediment in a regional context. This paper summarizes three case studies demonstrating the benefits of regional sediment management of watersheds, rivers, and reservoirs.

1 INTRODUCTION

Historically, the engineering, operation, and maintenance of infrastructure has been narrowly focused, with an individual project intended to meet an individual, geographically-limited need. For example, in 1967, Hickahala Creek, a stream in northern Mississippi, USA, was straightened, cleared, and widened to increase flood conveyance. Immediately post-construction, the channel did exhibit decreased flood stages. However, these channel modifications lead to rapid headcutting up the main channel and tributaries. The resulting bank failures and field gullying introduced sediment at such an accelerated rate that the downstream channel aggraded 1.8 to 2.4 meters (m). The flood control benefits to a portion of the project were lost within three years. Clearly, sedimentation issues require a systems or regional approach.

In 1999, the U.S. Army Corps of Engineers (USACE) initiated the Regional Sediment Management (RSM) Program with the specific goal of facilitating a paradigm shift away from project-by-project or even action-by-action sediment management, to a longer-term, regional approach to improve the management and use of sediments across multiple projects and business lines while increasing benefits, reducing costs, and improving communication and collaboration. The RSM program encourages these efforts by funding projects at the district level and through a newly-established RSM Center of Expertise. Much of the work of the RSM program has been accomplished in coastal systems with a focus on using sediments dredged from navigation channels to reduce coastal shoreline erosion or for habitat creation (Rosati et. al, 2004). However, in recent years the focus has broadened to include watersheds, rivers, and reservoirs. The following are examples of RSM in these settings.

2 EXAMPLE- MISSOURI RIVER FLOOD RECOVERY

The Missouri River, a 4215 km sand-bed river that drains 1,371,010 km^2 in the central United States, experienced a historic flood in 2011. RSM principles incorporated after the flood aided in the post-flood rebuilding of infrastructure. These efforts included levee setbacks and creative use of dredge material to build riverine habitat and protect levees (Boyd, 2013). Two specific examples are discussed here.

The first example involved the creative use of dredging to both repair a levee and create shallow water habitat for endangered species at Hamburg Bend Chute in Southeastern Nebraska. At a large bend centered within the chute, significant erosion along the outer bank threatened a Federal levee which protects adjacent homes and farmland. The floodwaters eroded the toe of the levee causing considerable concern for its stability. In addition to the erosion on the outer bank, a point bar formed as the channel migrated. Figure 1 shows the design drawing for repairing the levee toe.

Sediment was needed to fill the scour hole between the riprap bank and the toe of the levee for stabilization. The volume required to fill the scour hole exceeded the material available in the point bar, which was to be dredged to provide fill and open up the chute channel. Therefore, an additional sediment source was required. Trucking and dredging were both considered, with dredging being the less costly and more timely option.

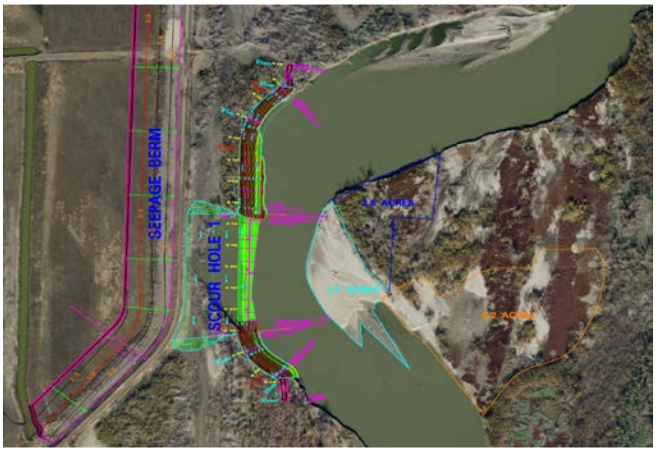

Figure 1. Hamburg Bend Chute Repair Plan

In the process of identifying a dredge material source, the design team consulted with engineers and biologists from the Missouri River Recovery Program (MRRP), who were tasked with designing and building appropriate habitat areas for the endangered Pallid Sturgeon. The MRRP team worked with the design team to set the location, shape, and depth of an area that would meet the volume needs of the construction project and create a backwater habitat area that qualified as appropriate water habitat. The project ultimately included adding seepage blankets in multiple areas along the landward side of the levee. At one site, less than 1 percent of the seepage blanket material was sourced from the dredging. However, at a second site just upstream, RSM principles were employed and coarse sediments deposited in the river channel provided approximately 50 percent of the fill material needed and were considerably less expense. This project was successful because of the effective communication between the Emergency Management team and the various engineering offices supporting the flood recovery effort.

The second Missouri River example occurred a few miles upstream of the first at the Decatur Bridge north of Omaha, NE. To address the need for large amounts of fill material required to rebuild the bridge abutment, the Iowa Department of Transportation worked with USACE and the Iowa Department of Natural Resources to source material that also benefitted habitat creation. A number of shallow wetland areas were filled during the flood and sandbar deposits in the Missouri River needed to be removed. Through a combination of excavation to deepen wetlands and dredging to remove sandbars, sufficient fill was sourced to build control structures and support bank stabilization on and around the bridge abutment. Figure 2 shows the completed project in the winter of 2011/2012. The entire project was completed in a matter of months to allow the highway to reopen.

Figure 2. Bridge Abutment Repair at Decatur Bridge

3 EXAMPLE- HICKAHALA CREEK

As mentioned in the introduction, flood conveyance benefits were lost on Hickahala Creek due to sediment accumulation. In 1993, Hickahala Creek was again modified to improve flood conveyance. This time, the project incorporated the principles of RSM (although the RSM program would not formally start for six years.) The watershed approach to sediment management was undertaken, including features for grade control, bank stabilization, and gully-prevention in the upstream channels and watershed (Figure 3). Two riprap bed sills on Hickahala and Senatobia Creeks played a crucial role in the stabilization of the upper watershed (Figure 4). These structures were originally built at the existing bed elevation with no drop across them. By 2003, a 1 m drop had developed across the structures, indicating that these structures had prevented the upward migration of a 1 m headcut. Bed lowering of 1 m in the upper watershed would have resulted in further bank erosion and gullying and significantly increased the sediment supply to the downstream channel. Figure 5 plots the minimum monthly gage readings on Senatobia Creek, a tributary to Hickahala Creek. As seen, significant channel aggradation followed the 1967 channel improvement work. On the other hand, following the 1993 channel improvement, which included the watershed sediment management features, the channel did not aggrade and overall sediment loads decreased by an estimated 64% (Biedenharn et. al, 2004). Hickahala Creek flows into Coldwater River just upstream of Arkabutla Reservoir, which continues to accumulate sediment.

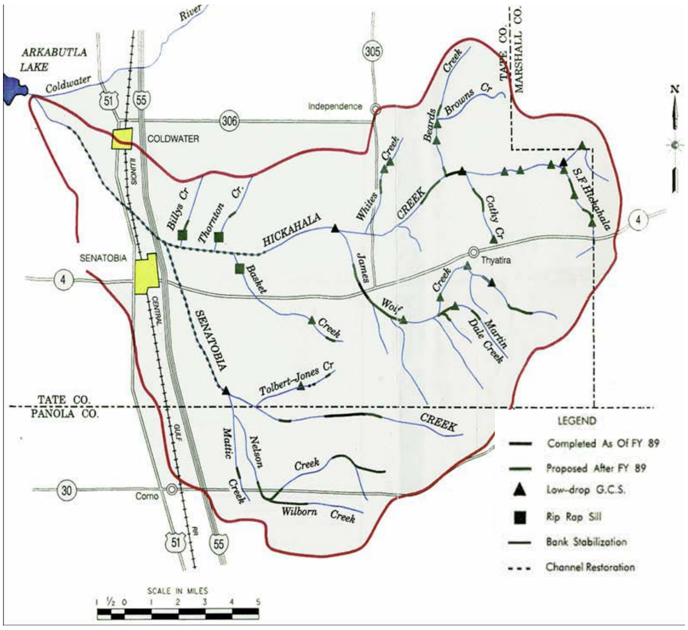

Figure 3. Stream and Watershed Treatments in the Hickahala Creek Watershed. From Biedenharn et. al, 2004.

Figure 4. Riprap sills post-construction (above) and during 2003 inspection (below). From Biedenharn et. al, 2004.

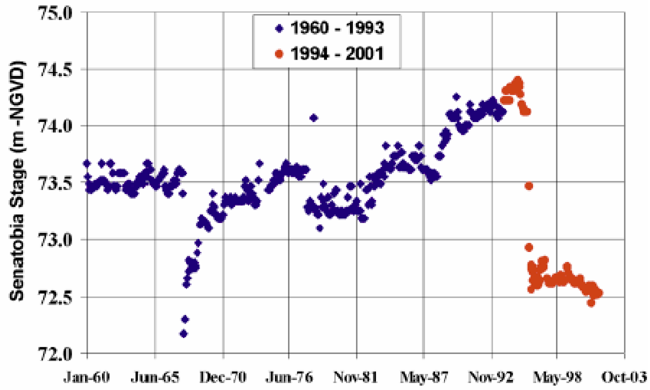

Figure 5. Minimum Monthly Elevation of Gage Readings on Senatobia Creek, Tributary to Hickahala Creek. From Biedenharn et. al, 2004.

Managing the sediment at a regional scale provided sustainable benefits and decreased the need for future dredging costs for this flood damage reduction project. In addition, RSM provided additional benefits in the form of bank protection and grade stabilization in the watershed.

4 EXAMPLE- TUTTLE CREEK LAKE

Sediment management to reduce sediment accumulation in Tuttle Creek Lake in Kansas, USA provides another example of effective regional sediment management. Like virtually all reservoirs, Tuttle Creek Lake is experiencing sediment accumulation and attendant loss of storage capacity. Sediment accumulates in the multipurpose pool at a rate of 5.8 million cubic yards per year. Costs to dredge this material and place it upland on adjacent fields would cost over $40 million / year. Sediment management at the watershed level offers a cost-effective means to reduce the rate of sediment accumulation and decrease maintenance costs. Aerial photography and field surveys identified the most erosional banks (erosional "hot-spots") in the watershed (USACE 2011). The State of Kansas estimated that stabilization of these sites was 21 times more cost-effective than reservoir dredging (Gnau 2013) and has since implemented bank stabilization on most of these bank erosion "hot spots." Common stabilization methods include bank shaping, longitudinal toe protection, and training structures (Figure 6).

These projects benefit the reservoir project by slowing the rate of storage depletion while also providing bank stabilization and water quality benefits to the upstream channels.

Figure 6. Erosional hotspot upstream of Tuttle Creek Lake before (above) and after (below) stabilization.

These efforts to date reduce storage depletion but do not solve the problem of sediment accumulation. The next step for Regional Sediment Management at Tuttle Creek Lake, as in many inland systems, is to reestablish sediment continuity from the uplands, through the reservoir, into the downstream channel (Shelley 2015). At Tuttle Creek Lake, these actions could cost significantly less than traditional dredging with upland placement of the material and would benefit turbidity-dependent fish species in the downstream channel (Shelley et. al, 2015). Similar economic and environmental benefits may be possible at reservoirs worldwide (Annandale 2013).

5 CONCLUSION/NEXT STEPS

RSM in the watershed, reservoir, and river environment is a developing concept, one that requires communication and sharing ideas across Federal agency, state, and local boundaries. This paper discussed RSM during post-flood recovery on the Missouri River, in conjunction with a flood conveyance improvements on Hickahala Creek, and to address storage loss in Tuttle Creek Lake. By incorporating the principles of RSM, these projects have been able to achieve multiple infrastructure and environmental objectives more effectively and at lower cost compared to a narrowly-focused view of sediment management.

The next steps for the USACE RSM program include such as activities as sponsoring workshops, technical training, and other outreach to stakeholder groups, documenting case studies, and overcoming policy and regulatory hurdles. Within USACE, a growing number of districts are embracing the RSM principles and integrating creative and beneficial uses of sediment to increase cost savings and improve communication while reducing flood risk, creating habitat, or benefitting a number of other purposes.

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