UPPER MISSISSIPPI RIVER SYSTEM
ENVIRONMENTAL DESIGN HANDBOOK

CHAPTER 8

TRIBUTARY CHANNEL RESTORATION

Contents

Figures

Tables

Photographs

UPPER MISSISSIPPI RIVER SYSTEM ENVIRONMENTAL DESIGN HANDBOOK

CHAPTER 8

TRIBUTARY CHANNEL RESTORATION

8.1. Resource Problem

Large rivers, such as the Mississippi River and the Illinois River, are greatly influenced by their tributaries. Tributaries affect the hydrology, water quality, sediment characteristics, and physical configuration of the larger river that they enter.

In particular, sediment load from tributaries can have significant impacts to the ecology of the main stem river and backwater areas. “Sedimentation is among the most critical ecological problems of the Upper Mississippi River System (UMRS). The prediction that ecologically productive backwaters will fill and disappear in the next 50 to 100 years is alarming and clearly identifies sedimentation as a major concern of natural resource managers (USGS, Ecological Status and Trends, 1999).” Excessive suspended sediment can also be detrimental to aquatic organisms and plants.

Figure 8.1 showing a bed material (i.e. sand) budget for pools 1 through 10 of the UMRS illustrate the impacts of tributaries on coarse sediment transport. At each of the major sediment contributing tributaries in this reach (the Minnesota, Cannon, Chippewa, Zumbro, Root, Upper Iowa, and Wisconsin Rivers), there is a spike in the bed material on the UMR. The reaches that are labeled correspond to the geomorphic reaches identified in the Cumulative Effects Study (WEST Consultants, Inc., 2000). Reducing these sediment spikes could benefit not only the ecosystem, but also maintenance of the navigation channel.

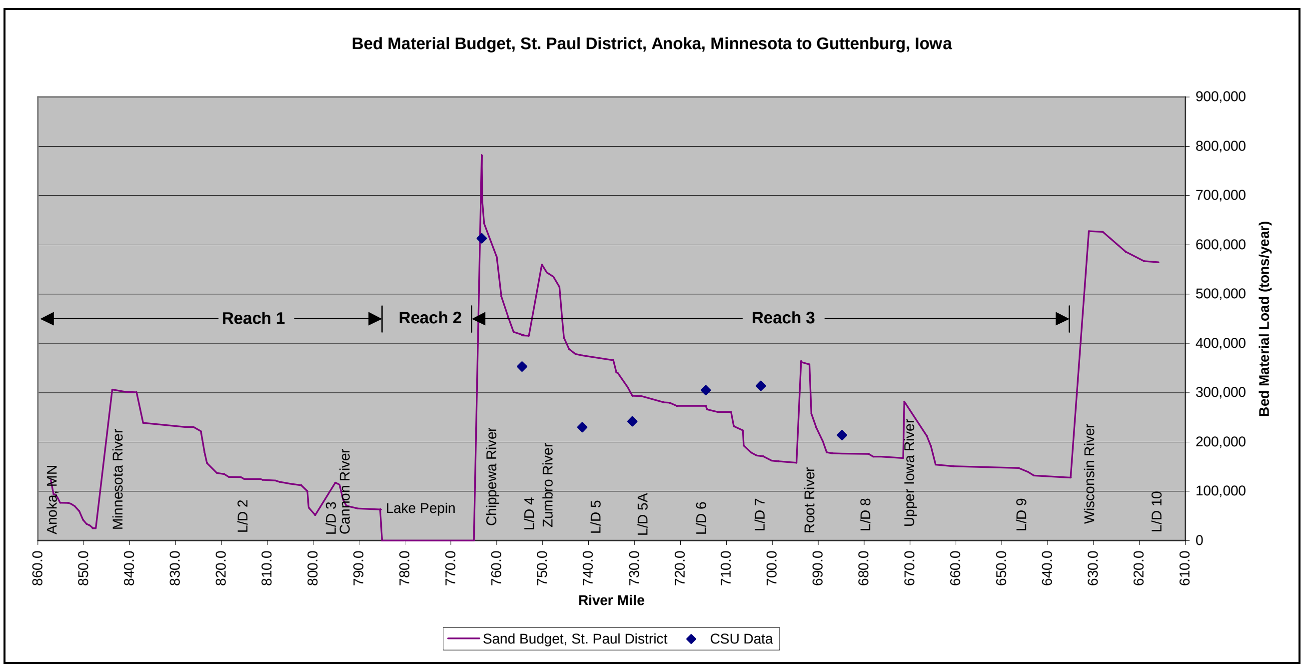

Figure 8.1. Bed Material Budget

Channelization of streams in the late 1800s and early 1900s involved straightening, deepening, and widening of existing channels as well as the headward extension of channel networks through the construction of numerous small artificial channels (Rhoads and Herricks, 1996). The channels were straightened to improve land drainage, lower flood stages, increase the acreage of farmable land, and reduce transit time for navigation. The channelization of tributary streams has contributed to the decline of suitable habitat and poor water quality. Channel modification or channelization activities are listed among the top 10 sources for non-point pollution impacts to rivers (U.S. Environmental Protection Agency, 1993). When a channel is straightened, the slope of the channel is increased, leading to higher velocities, increased erosion, and channel incision. This widespread erosion of sediment in the tributaries is carried to the main stem river.

A comparison of the bed material loads on the Black River which enters the UMRS in Pool 7 and the Upper Iowa River which enters in Pool 9 illustrate this concept.

Table 8.1. Comparison of Bed Load on Mississippi River Tributaries

	Tributary	
	Black River	**Upper Iowa River**
Drainage Area (square miles)	2,250	1,160
Bed material load entering the Mississippi Valley (tons per year)	220,000	115,000
Bed Material Load to Main Channel (tons per year)	0	115,000

The Black River, which was never significantly channelized, deposits its entire bed material load in a large delta that dominates the upper portion of pool 7. In the early 1990s, when the Corps and the Wisconsin DNR did a study of this area, three major and six minor distributary channels existed (Hendrickson, 1994). Sediment-laden Black River flow entered these distributary channels and eventually the entire bed material sediment load settled in some portion of the delta. A review of historic aerial photographs indicated that significant channel migration, with occasional avulsions, occurred on a decadal time scale. The resource managers involved with this study concluded that the dynamic conditions in the Black River delta resulted in excellent habitat and recommended that no efforts be pursued to manage this system.

The Upper Iowa River, on the other hand, was channelized in 1956, with dredged material placed in spoil banks on either side of the channel to further contain the river. Because of this, the entire bed material load of the Upper Iowa enters the main channel of the UMRS. This sediment affects habitat in downstream backwaters, and increases dredging in Pool 9. The following two photographs illustrate the difference between these two rivers.

Photograph 8.1. Black River

Photograph 8.2. Upper Iowa River

Tributaries not only contribute sediment to the system, but can also carry environmental contaminants. These contaminants include heavy metals, pesticides, synthetic organic compounds, and numerous other chemicals (USGS, Ecological Status and Trends, 1999).

Also, growth of deltas where tributary channels enter impounded areas of the navigation pools may result in a future river planform that resembles pre-impoundment conditions, with island- braided morphology, more tertiary channels, and fewer backwater areas than at present (USGS, Ecological Status and Trends, 1999).

Erosion in site-specific upland areas can have a significant effect on a project's floodplain and aquatic areas as the resultant sediment is deposited and accumulated in critical habitats. Yet, HREPs involving upland sediment control measures have not generally been pursued under the EMP. Upland sediment controls may be recommended for implementation if they are determined by an engineering analysis to be the most cost-effective way of preventing or reducing sedimentation in a project area that is within the UMRS floodplain (USACE, Report to Congress, 1997).

8.2. Tributary Channel Restoration

The topic of stream restoration is broad and encompasses many disciplines and design methodologies. Engineers, biologists, and geomorphologists may have very distinct ideas about what it means to "restore" a stream. An engineer may be concerned with flooding impacts or protecting infrastructure, a biologist may desire diverse habitat for fish and other aquatic organisms, and a geomorphologist may desire to return the stream to its "natural" planform and geometry. Product delivery teams should include all of these ideas while developing a stream restoration because streams are very complex and have multiple functions.

Restoration projects do not necessarily require returning a system to some predisturbance condition, as this is seldom feasible. The objective of a restoration project is then a partial recovery of the natural geomorphic, hydraulic, and ecological functions of the stream. It follows then that the design team requires expertise in the fields of geomorphology, hydraulics, and ecology (USACE, Hydraulic Design of Stream Restoration Projects, 2001).

Tributary restoration is a relatively new technique on the UMRS. Both the EMP and NESP programs offer the potential to consider tributary restoration, however, this will probably be limited to restoration of tributary channels where the tributary enters the Mississippi River Valley. While this may appear to be a limited approach, it could be very effective, as illustrated in the Black River and the Upper Iowa River example above. The Section 519 Program has been granted authority to construct projects in the Illinois River Basin, including tributaries. The Section 206 program may also provide the opportunity to construct stream restoration projects.

8.2.1. Design Methodology. The first step in a stream restoration project, as with any engineering project, is to clearly define project objectives in cooperation with stakeholders. In establishing objectives for a stream restoration project, it is advisable to assess at least the six following issues:

1. The existing condition of the stream and watershed.
2. The scale and severity of the resource loss or degradation due to stream instability.

3. Causal factors and controls that have resulted in the current stream condition. In this context it is useful to establish whether current instability in the channel is being driven by the current flow regime or is a product of past conditions.
4. The condition into which the channel is likely to evolve without a project. This often involves a strong reliance on geomorphic prediction coupled with engineering judgment.
5. The physical constraints on possible restoration measures such as water quality, available right-of-way or construction area, as well as budget constraints.
6. The range of alternative solutions that is both feasible and acceptable to the stakeholders (USACE, Hydraulic Design of Stream Restoration Projects, 2001).

In general, the engineering means to achieve the objective of stream restoration can be divided into three general categories based on the focus of the proposed solution: (A) hydrologic work, (B) habitat work, and (C) hydraulic work. Hydrologic work can be accomplished through the use of stormwater ponds or through the modification of reservoir release schedules to modify the runoff regime as necessary to meet project objectives. Habitat includes the construction of structures or features on the bed, bank, and/or riparian area to modify the biologic function of the stream. This can include measures that provide in-stream cover, low-flow channels, scour holes, riparian plantings, and substrate modification. Hydraulic work includes a variety of techniques that center on measures that affect the geomorphic characteristics of the channel. They can include measures to provide the channel dimensions and geometries required to produce a stable or regime condition, local works essential to supply the morphological diversity necessary to support a wide range of habitats, and the structures needed to hold the channel in its new alignment by preventing bank erosion (USACE, Hydraulic Design of Stream Restoration Projects, 2001).

Some disturbances to stream channels are so severe that restoration within a desired time frame requires total reconstruction of a new channel. If watershed land use changes or other factors have caused changes in sediment yield or hydrology, restoration to a historic channel condition is not recommended. In such cases, a new channel design is needed (FISRWG, Stream Corridor Restoration, 1998). In the case of tributary stream channelization in the Midwest, the hydrology, sediment yield, and land use have most likely been significantly altered by agricultural practices, so a new channel design may be required. If a new channel is not feasible or practical, other methods such as grade control, bank protection, or providing additional habitat structure could be implemented to provide habitat or reduce stream degradation.

The following simplified methodology for the design of a new stream channel is adapted and condensed from Stream Corridor Restoration: Principles, Practices, and Processes by the Federal Interagency Stream Restoration Working Group. A more comprehensive manual for detailed design of stream restoration projects is: Hydraulic Design of Stream Restoration Projects (USACE, ERDC/CHL TR-01-28). Both of these references further define the terms and the process for stream channel design.

Step 1. Describe physical aspects of the watershed and characterize its hydrologic response. This step should be based on data collected during the planning phase.

Step 2. Considering reach and associated constraints, select a preliminary right-of-way for the restored stream channel corridor and compute the valley length and valley slope.

Step 3. Determine the approximate bed material size distribution for the new channel.

Step 4. Conduct a hydrologic and hydraulic analysis to select a design discharge or range of discharges. The bankfull discharge is used by many designers, corresponding to approximately a 1 to 3 year recurrence interval flow. A sediment rating curve must be developed to integrate with the flow duration curve to determine the effective discharge. Incised streams are especially difficult to determine the bankfull discharge.

Step 5. Predict stable planform type. Stable channel bed slope is influenced by a number of factors, including sediment load and bank resistance to erosion. For the first iteration, restoration designers may assume a channel planform similar to stable reference channels in similar watersheds or undisturbed areas in the same watershed. By collecting data for stable channels and their valleys in reference reaches, insight can be gained on what the stable configuration would be for the restoration area. A designer could use aerial photographs or other historic information to gather insight about the stream prior to development or straightening. Also, the Rosgen classification system (figures 8.2 and 8.3) can be used to predict what a stable planform would be for the valley type, or topography of the area. A training module for using the Rosgen classification system is located at: http://www.fgmorph.com. Papers published by Rosgen about the classification system and natural channel design are available at http://www.wildlandhydrology.com/html/references_.html.

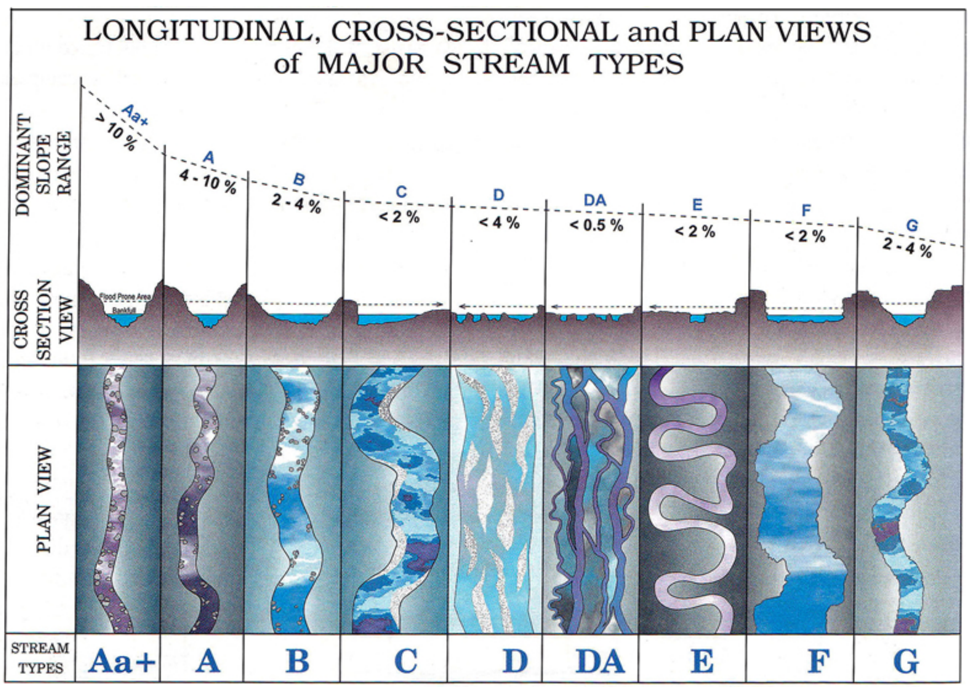

Figure 8.2. Rosgen Classification

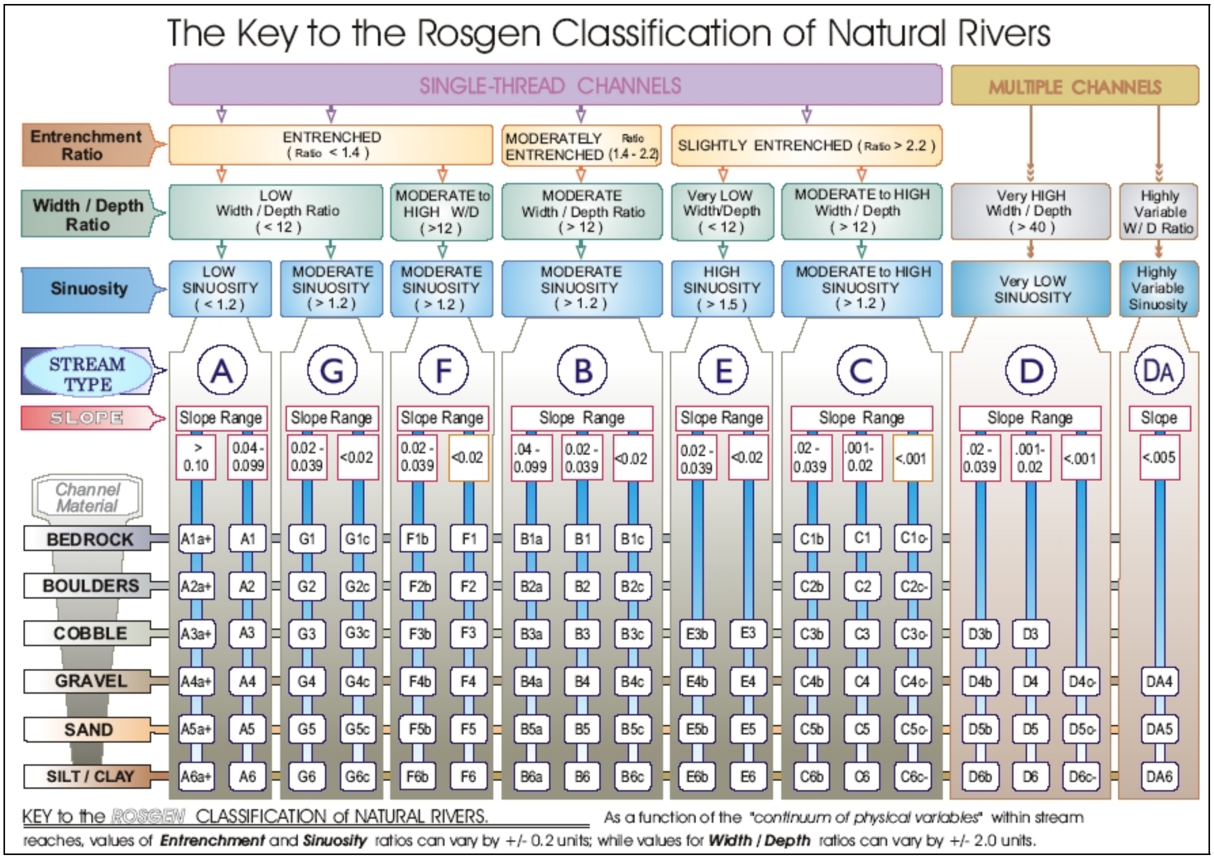

Figure 8.3. Rosgen Classification System

Once the stable planform type is established, the designer can proceed with the design. Three approaches are summarized in table 8.2 from the Stream Corridor Restoration Handbook.

> "There are three commonly applied approaches to natural channel design: analog, empirical, and analytical. Analog design replicates historic or adjacent channel characteristics and assumes equilibrium sediment and hydrologic conditions. Empirical design uses equations that relate various channel characteristics derived from regionalized or "universal" data sets, and also assumes equilibrium sediment and hydrologic conditions. Analytical design makes use of the continuity equation, roughness equations, hydraulic models, and a variety of sediment transport functions to derive equilibrium channel conditions, and thus is applicable to situations where historic or current channel conditions are not in equilibrium, or where applicable analogs or empirical equations are unavailable (Skidmore, Shields, Doyle, Miller, 2001)."

The analog approach includes the reference reach method, and the carbon copy approach. The reference reach method is used by Dave Rosgen, and described above. The reference reach method includes measurement and subsequent replication of a number of channel parameters, including width, depth, slope, bed material gradation, bankfull width, and sinuosity, among others. The carbon copy approach relies on replication of previous or historic channel characteristics (FISRWG, 1998). It is most commonly applied in the context of restoring meander planform in channels that have been straightened. Analog approaches are not valid if the sediment supply, hydrology, and boundary conditions are not similar for the analog and the design (Skidmore, Shields, Doyle, Miller, 2001).

"The empirical approach is referred to as the "Hydraulic Geometry Method" (FISRWG, 1998). Historic geomorphic studies of stable, natural channels resulted in "hydraulic geometry" formulas (Leopold and Maddock, 1953), which quantified attributes of channels in regime. These formulas generally relate dependant variables such as width, depth, or slope to independent variables such as discharge or bed material size, and are generated by a regression of large, regional data sets. Wharton (1995) states that the most significant problem in application of empirical relations is that they are only applicable over the range of conditions from which they were derived (Skidmore, Shields, Doyle, Miller, 2001)."

Analytical methods can be used to determine hydrologic and hydraulic design components, such as: water surface elevations, shear for bed and bank design, extent and duration of inundation, appropriate channel geometry, sizing bed material, and ensuring sediment continuity (Skidmore, Shields, Doyle, Miller, 2001). Programs used by the Corps of Engineers include HEC-6, SAM, HEC-RAS with the sediment option, and others.

Advantages and limitations of each approach should be carefully considered when applied to design of natural channels. The advantage of the analog and empirical approaches is the intuitive simplicity of replicating desired channel and habitat characteristics from stable systems. Analytical approaches are required when channel equilibrium is in question, and when no analog sites or empirical equations are applicable as a consequence of changing or differing hydrologic character and sediment inputs. The analytical approach often requires substantially more data, and more time than the other methods, and the reliability of the model is limited to the accuracy of the input variables and the applicability of the model to the design situation (Skidmore, Shields, Doyle, Miller, 2001).

Approach A		Approach B (Hey 1994)		Approach C (Fogg 1995)	
Task	**Tools**	**Task**	**Tools**	**Task**	**Tools**
Determine meander geometry and channel alignment[1].	Empirical formulas for meander wavelength, and adaptation of measurements from predisturbed conditions or nearly undisturbed reaches.	Determine bed material discharge to be carried by design channel at design discharge, compute bed material sediment concentration.	Analyze measured data or use appropriate sediment transport function[2] and hydraulic properties of reach upstream from design reach.	Compute mean flow, width, depth, and slope at design discharge.[4]	Regime or hydraulic geometry formulas with regional coefficients.
Compute sinuosity, channel length, and slope.	Channel length = sinuosity X valley length. Channel slope= valley slope/ sinuosity.	Compute mean flow, width, depth, and slope at design discharge.[4]	Regime or hydraulic geometry formulas with regional coefficients, or analytical methods (e.g. White, et.al., 1982, or Copeland, 1994)[3].	Compute or estimate flow resistance coefficient at design discharge.	Appropriate relationship between depth, bed sediment size, and resistance coefficient, modified based on expected sinuosity and bank/berm vegetation.
Compute mean flow width and depth at design discharge.[4]	Regime or hydraulic geometry formulas with regional coefficients, and resistance equations or analytical methods (e.g. tractive stress, Ikeda and Izumi, 1990, or Chang, 1988).	Compute sinuosity and channel length.	Sinuosity = valley slope/ channel slope. Channel length= sinuosity X valley length.	Compute mean channel slope and depth required to pass design discharge.	Uniform flow equation (e.g. Manning, Chezy) continuity equation, and design channel cross-sectional shape; numerical water surface profile models may be used instead of uniform flow equation.
Compute riffle spacing (if gravel bed), and add detail to design.	Empirical formulas, observation of similar streams, habitat criteria.	Determine meander geometry and channel alignment.	Lay out a piece of string scaled to channel length on a map (or equivalent procedure) such that meander arc lengths vary from 4 to 9 channel widths.	Compute velocity or boundary sheer stress at design discharge.	Allowable velocity or shear stress criteria based on channel boundary materials
Check channel stability and reiterate as needed.	Check stability.	Compute riffle spacing (if gravel bed), and add detail to design.	Empirical formulas, observation of similar streams, habitat criteria.	Compute sinuosity and channel length.	Sinuosity = valley slope/ channel slope. Channel length= sinuosity X valley length.
		Check channel stability and reiterate as needed.	Check stability.	Compute sinuosity and channel length.	Lay out a piece of string scaled to channel length on a map (or equivalent procedure) such that meander arc lengths vary from 4 to 9 channel widths.
				Check channel stability and reiterate as needed.	Check stability.

[1] Assumes meandering planform would be stable. Sinuosity and arc-length are known.
[2] Computation of sediment transport without calibration against measured data may give highly unreliable results for a specific channel (USACE, 1994, Kuhnle, et.al., 1989).
[3] The two methods listed assume a straight channel. Adjustments would be needed to allow for effects of bends.
[4] Mean flow width and depth at design discharge will give channel dimensions since design discharge is bankfull. In some situation channel may be increased to allow for freeboard. Regime and hydraulic geometry formulas should be examined to determine if they are mean width or top width.

Table 8.1 -- Three approaches to achieving final design. See text for first five common steps.
In Stream Corridor Restoration: Principles, Processes, and Practices, 10/98.
Interagency Stream Restoration Working Group (FISRWG)(15 Federal agencies of the US).

Table 8.2. Approaches to Natural Channel Design

8.2.2. Meander Design. Projects involving re-establishing meanders in a previously straightened reach, and other natural channel design projects, will require detailed design of meander geometry. "At this point, a word of caution is needed about re-establishing meanders in a previously straightened reach. While this is generally a commendable goal, and one that may be achievable in certain circumstances, it is usually not as straightforward as is often purported, particularly in large-scale projects, or where severe system instability exists or has existed in the past (Watson, Biedenharn, Scott, 1999).

Sinuosity is a commonly used parameter to describe the degree of meander activity in a stream. Sinuosity is defined as the ratio of the distance along the channel to the distance along the valley. Think of sinuosity as the ratio of the distance the fish swims to the distance the crow flies. A perfectly straight channel would have a sinuosity of 1.0, while a channel with a sinuosity of 3.0 or more would be characterized by tortuous meanders (Watson, Biedenharn, Scott, 1999). Figures 8.4 and 8.5 exhibit meander design criteria.

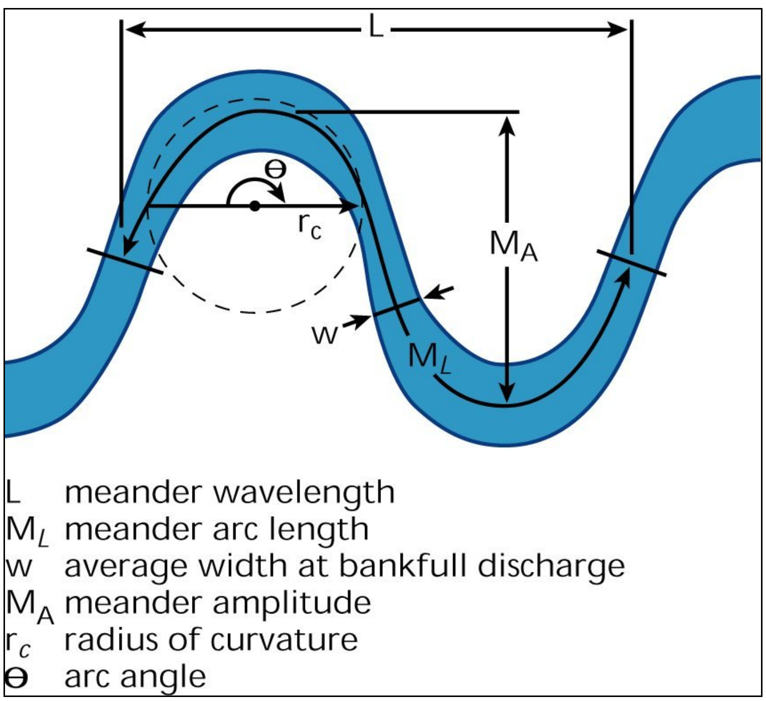

Figure 8.4. Typical Parameters used in Meander Design (FISWRG, 1998)

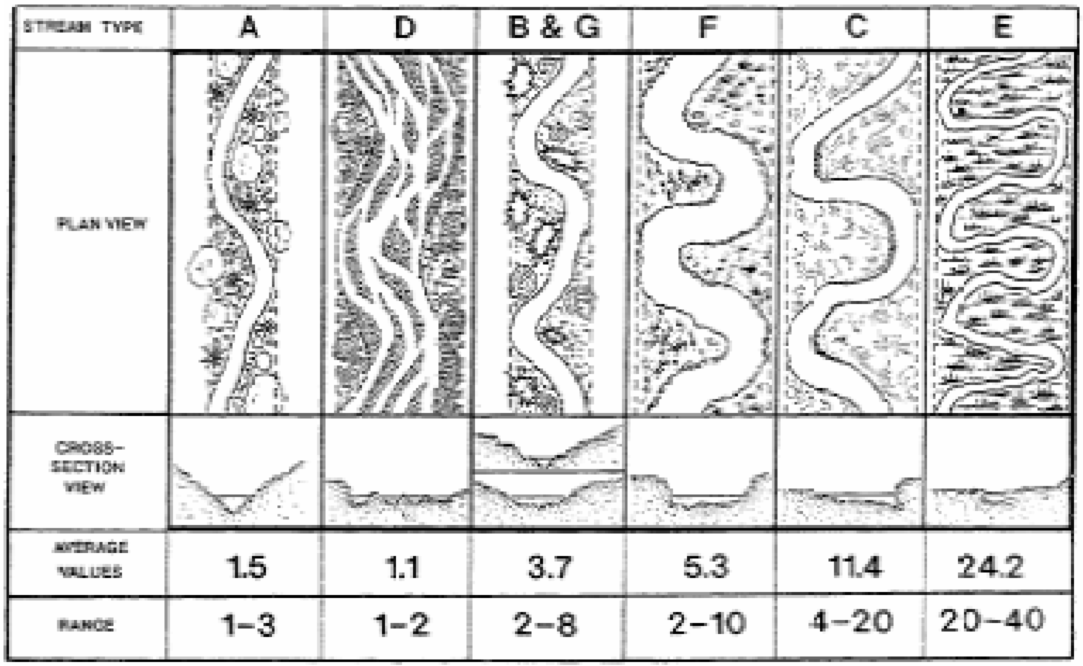

Figure 8.5. Meander Width Ratio (Belt width/Bankfull width) by Stream Type Categories (Rosgen, Catena, 1994)

There are five general approaches to meander design given in the Stream Corridor Restoration Handbook.

1. Replacement of meanders exactly as found before disturbance (carbon copy technique). This method is applicable if hydrology and bed materials are very similar or identical to pre-disturbance conditions.

2. Use of empirical relationships that allow computation of meander wavelength, L, and amplitude based on channel width or discharge.

3. Basin-wide analysis to determine fundamental wavelength, mean radius of curvature, and meander belt width in areas "reasonably free of geologic control."

4. Use of undisturbed reaches as design models.

5. Slope first. Meanders designed by first selecting a mean channel slope based on hydraulic geometry formulas.

8.2.3. Stream Restoration Structures. There are several structures that have been proven to be effective in creating in-stream habitat, reducing stream bank erosion, and creating a stable stream. These structures include rock vanes, J-hooks, hard points, and dikes. These structures are discussed in more detail in other sections of this Design Handbook.

8.2.4. Lessons Learned. Numerous stream restoration projects have been constructed through other programs and by other agencies. A designer should attempt to gather information about other projects that have been completed in the area, and discuss the lessons learned and performance of the project. As tributary restoration projects are constructed through the Section 519, Section 206, NESP, and/or the EMP program, it is anticipated that the Corps will have additional experience and lessons learned from tributary restoration projects.

8.2.5. Case Study - Chippewa River Sediment Dynamics

Chippewa River Sediment Dynamics. The Chippewa River enters the Mississippi River at river mile 763.4 in pool 4 just downstream of Lake Pepin. It is the major contributor of bed material sediment (i.e. sand size sediments) to the Mississippi River in the St. Paul District. Roughly 1/3 of the total dredging done in the St. Paul District is from lower pool 4.

On the Lower Chippewa River, bed and bank erosion accounts for the majority of the sediment being transported, and nearly 90-percent of this was delivered to the Mississippi River. This is based on USGS measurements of bed load and suspended sediment at gaging stations on the Chippewa River during water years 1976-83 (Rose, 1992). D. B Simons and Associates Inc. (1998) used this data to develop the sediment budget shown in figure 8.6. The sediment transport relationship for the Chippewa River at Durand was used to estimate the sediment contribution from the Red Cedar River. Between Carryville and Durand, the total sediment load increased almost an order of magnitude from 123,000 tons per year to 1,073,000 tons year. Bed and bank erosion in the 26 river miles between Carryville and Durand accounted for 82-percent of the total sediment load at Durand with the Red Cedar River adding only about 7-percent of the total. At Pepin near the mouth of the Chippewa River, the total sediment load had dropped to 940,000 tons per year, due to 133,000 tons per year of floodplain deposition on the Chippewa River.

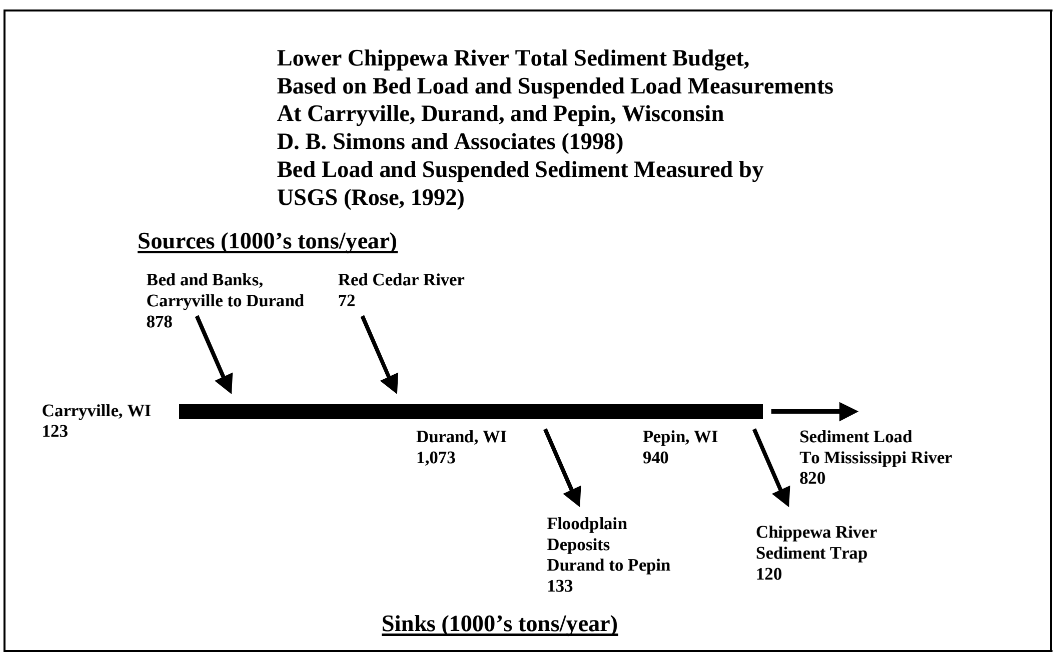

Figure 8.6. Lower Chippewa River Total Sediment Budget

Because the Chippewa River contributes so much sand to the Mississippi River, several projects have been done in this area to manage this sediment. These are summarized below.

Chippewa River Experimental Bank Stabilization Project, 1984. In the early 1980s, several techniques were used to stabilize the banks of the Chippewa River in the sediment producing reach from Carryville to Durand. One of the criteria for these techniques was that they had to be low cost (the cost of bank stabilization with riprap was already determined to be too expensive). Techniques involving geo-grids to reinforce the bank, vegetative stabilization, and others were tried. Later inspections indicated that none of these techniques was very successful and the project was not pursued further.

> **Lesson Learned.** Although, it is probably true that there aren't any cheap bank hardening techniques, at least not for a river as large as the Chippewa, the use of vanes should be considered for future use on tributaries like the Chippewa. Vanes, which redirect flow away from the bank were just being developed during the 1980s. They have been successfully used at dredged material placement sites on the UMRS , and are significantly cheaper than riprap.

Chippewa River Sediment Trap, 1984 to present. At the confluence of the Chippewa and Mississippi Rivers, a sediment trap has been maintained by the St. Paul District Corps of Engineers since 1984. Dredging of the trap averages 120,000 tons per year with the remaining 820,000 tons per year entering the Mississippi River.

> **Lessons Learned.** Because sediment traps tend to trap more sediment than the navigation channel, the overall dredging volumes in this reach of the river have increased since 1984. However, dredging of the trap resulted in significant decreases in dredging at the downstream Reads Landing and Crats Island dredge cuts (76-percent and 26-percent respectively). The reduction in dredging at Reads Landing has significance beyond the amount of material dredged. Prior to 1984, channel closures and emergency dredging were common occurrences at Reads Landing. This resulted in significant delays to the towing industry and environmental concerns regarding the emergency placement of the dredged material. This has been mostly eliminated through maintenance of the sediment trap.
>
> Although the Chippewa River sediment trap is maintained using O&M funds, it definitely reduces downstream sediment loads. Since sediment deposition is a major concern on the Mississippi River, the benefits the trap has in reducing the downstream sediment load and subsequent sediment transport to backwater areas is a positive impact. Sediment traps such as this could be considered at other tributaries.

Indian Slough Restoration Project, 1994. In 1994, over $500,000 was spent on the Indian Slough restoration project just downstream of the confluence of the Chippewa and Mississippi Rivers. The purpose of this project was to reduce the sediment load conveyed down Indian Slough into the Big Lake backwater and to reverse the effects of sediment deposition in Big Lake by dredging. This project successfully reduced the sediment load into Big Lake, however since Indian Slough is a major recreational route, a complete closure was not possible and sediment deposition continues to occur. Also, local anglers have reported the rock riffle pools (rock placed so as to change flow and create scour holes) and tree groins (log snags) at the Indian Slough, Wisconsin HREP are providing habitat for smallmouth bass and other game fish (Report to Congress, 2000).

8.2.6. References

FISRWG. 1998. *Stream Corridor Restoration: Principles, Processes, and Practices.* By the Federal Interagency Stream Restoration Working Group (FISRWG)(15 Federal agencies of the US government). Available at: http://www.nrcs.usda.gov/technical/stream_restoration/.

Hendrickson, J. S. and F. R. Haase. 1994. *Hydrodynamic Conditions in the Black River Delta/Lake Onalaska Area, Pool 7, Upper Mississippi River 1980-81 and 1991-92.* U. S. Army Corps of Engineers, St. Paul District.

Landwehr K, Rhoads BL. 2003. *Depositional Response of a Headwater Stream to Channelization, East Central Illinois, USA.* In *River Research and Applications*. Wiley: New York; 19: 77-100. Available at: http://www.environmental-center.com/magazine/wiley/1535-1459/pdf5.pdf.

Newbury, R.W. 2002. *Stream Restoration Hydraulic Design Short Course.* US Army Corps of Engineers, Rock Island, Illinois.

Rhoads BL, Herricks EE. 1996. *Naturalization of Headwater Streams In Illinois: Challenges and Possibilities.* In *River Channel Restoration: Guiding Principles for Sustainable Projects*, Brookes A, Shields Jr. FD (eds). Wiley: New York; 331-367.

Rosgen, D.L. *A Classification of Natural Rivers.* Catena, Vol. 22, 169-199. Elsevier Science, B.V. Amsterdam. Available at: http://www.wildlandhydrology.com/assets/CLASS_OF_NATURAL_RIVERS_300.PDF.

Rosgen, D.L. *The Reference Reach- A Blueprint for Natural Channel Design*. 1998. In *Proceedings ASCE Wetlands Engineering and River Restoration Conference*, Denver, CO, March 1998.

Skidmore, P. B., F. D. Shields, M. W. Doyle, and D. E. Miller. 2001. *A Categorization Of Approaches to Natural Channel Design.* Proceedings of the 2001 ASCE Wetlands Engineering and River Restoration Conference, Reno, Nevada. 12pp. Available at: http://www.blwi.com/SkidmorePB_NaturalChannelDesign_Approaches_2001.pdf.

Twain, Mark. *Life on the Mississippi.* Great Literature . 1997-2005 http://www.underthesun.cc/Classics/Twain/lifeonmississippi/ (26 Apr, 2005).

US Army Corps of Engineers. C*hannel Stability Assessment for Flood Control Projects.* EM 1110-2-1418. Washington D.C. 1994. Available at: http://www.usace.army.mil/inet/usace-docs/eng-manuals/em1110-2-1418/entire.pdf.

US Army Corps of Engineers. *Civil Works Ecosystem Restoration Policy.* ER 1165-2-1501. Washington D.C. 1999. Available at: http://www.usace.army.mil/inet/usace-docs/eng-regs/er1165-2-501/entire.pdf.

US Army Corps of Engineers. *Hydraulic Design of Flood Control Channels.* EM 1110-2-1601. Washington D.C. 1991. Available at: http://www.usace.army.mil/inet/usace-docs/eng-manuals/em1110-2-1601/entire.pdf.

US Army Corps of Engineers. *Hydraulic Design of Stream Restoration Projects.* ERDC/CHL TR-01-28. 2001. Available at: libweb.wes.army.mil/uhtbin/hyperion/CHL-TR-01-28.pdf.

US Army Corps of Engineers. *Report to Congress: An Evaluation of the Upper Mississippi River System Environmental Management Program.* 1997.

US Geological Survey. *Ecological Status and Trends of the Upper Mississippi River System 1998. A Report of the Long Term Resource Monitoring Program.* U.S. Geological Survey, Upper Midwest Environmental Sciences Center, La Crosse, Wisconsin. April 1999. LTRMP 99-T001. 236 pp. Available at: http://www.umesc.usgs.gov/reports_publications/status_and_trends.html.

Watson, C.C., D.S. Biedenharn, and S.H. Scott. 1999. *Channel Rehabilitation: Processes, Design, and Implementation*. Guidelines prepared for workshop presented by U.S. EPA. Available at: http://chl.erdc.usace.army.mil/Media/2/9/0/ChannelRehabilitation.pdf.

WEST Consultants, Inc. 2000. *Upper Mississippi River and Illinois Waterway Cumulative Effects Study*. Volume 2: Geomorphic Assessment Report to the U.S. Army Corps of Engineer District, Rock Island, IL. ENV Report 40-2.

8.3. Sediment Basins

A sediment basin consists of an earth embankment or a combination ridge and channel generally constructed across the slope and minor watercourse to form a sediment trap and a water detention basin. Sediment traps can be used to reduce watercourse and gully erosion, trap sediment, reduce and manage onsite and downstream runoff, and improve downstream water quality (NRCS, Code 638, 2001).

While not expressly precluded under the EMP authorization, Corps policy has generally regarded such features (upland sediment control) as beyond its purview and as the responsibility of other agencies. Nevertheless, two HREPs with upland features (Swan Lake and Batchtown) have been advanced as a result of specific Congressional directives. In both instances, the upland sediment control features were the most cost-effective way of protecting habitat in the project area. These features include hillside retention ponds, terracing, and other measures to reduce sediment delivery to the specific project area, but do not extend to land conservation practices throughout the watershed (USACE, EMP Report to Congress, 1997). Figure 8.7 shows an example of a detention basin.

8.3.1. Design Methodology . The Natural Resources Conservation Service (NRCS) has expertise in designing sediment basins, developed through years of helping farmers and landowners to reduce erosion of their land. The NRCS has published two Conservation Practice Standard documents (Code 638 and 350) on the design of Sediment Basins that were used as a reference for this design methodology. The following guidelines should be considered during the design of a sediment basin; site specific requirements or project features could be modified based on the site and desired goals for the project.

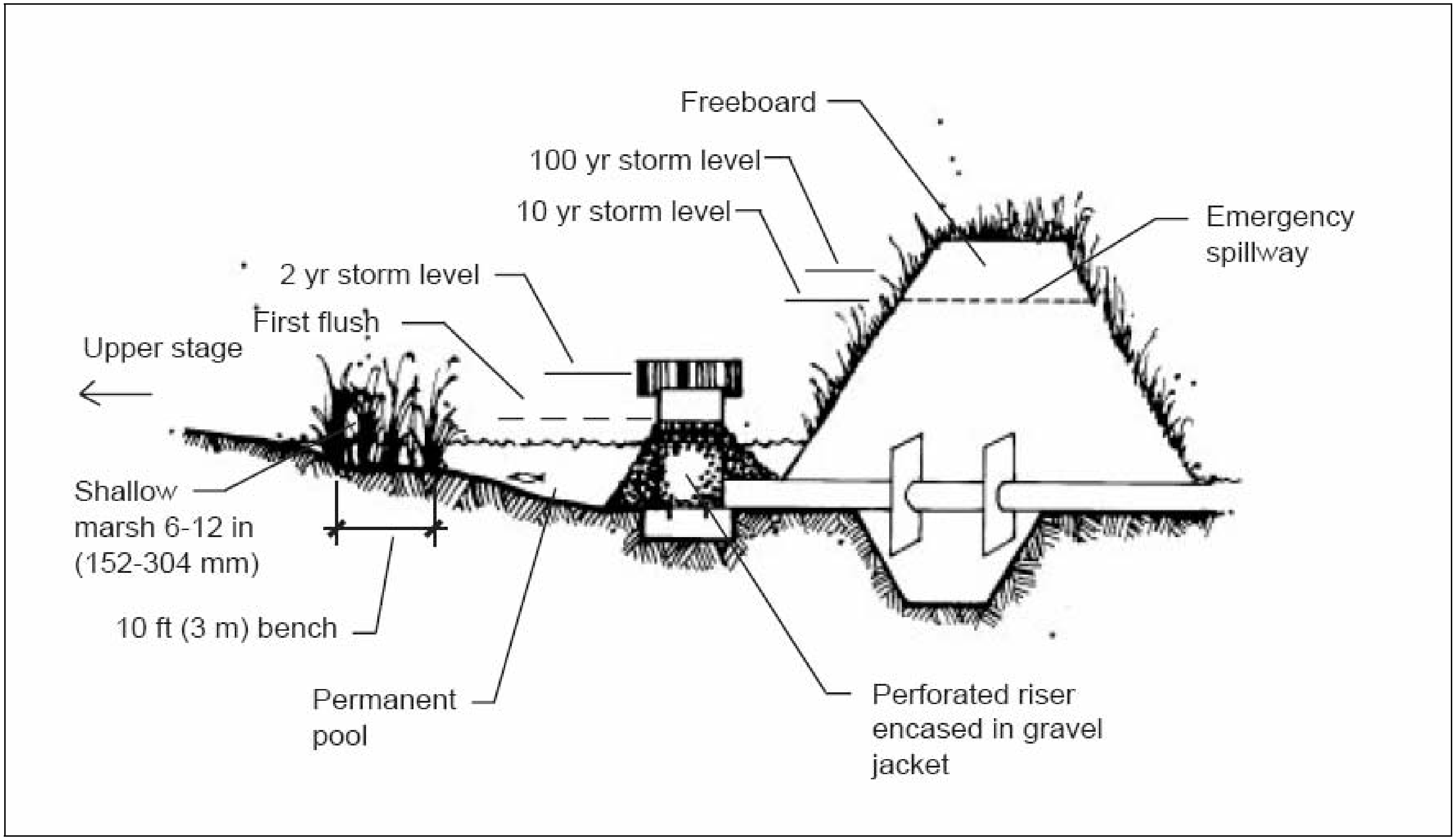

Figure 8.7. Detention Basin - Section View

8.3.1.1 Design Requirements. The following items should be included in the design of a sediment basin: Location and site map, soil type, drainage area and volume computations including sediment volume required, design cross sections, spacing, and outlet requirements.

8.2.1.2. Alignment. The embankment orientation and row direction shall be approximately perpendicular to the land slope to permit contouring.

8.3.1.3. Cross Section. The constructed elevation of the embankment shall be at least 5% greater than the design fill height to allow for settlement. The maximum design fill height shall be 15 feet. If the design fill height is less than 10 feet, the top width shall be 6 feet. If the fill height is between 10-15 feet, the top width shall be 8 feet. The slopes of the settled embankments shall be no less than 5H:1V, and no steeper than 2H:1V.

8.3.1.4. Capacity. The minimum basin design capacity shall be large enough to store the runoff from a 10-year frequency, 24-hour duration storm without overtopping. The basin shall also have the capacity to store 10 years of sediment accumulation unless provisions are made for periodic sediment removal from the basin to maintain the design capacity. The basin shall have the ends closed to the design elevation.

8.3.1.5. Outlets. Basins shall have underground outlets or soil infiltration outlets that meet the requirements of NRCS Code 600 and 620.

8.3.1.6. Vegetation. Slopes and disturbed areas shall be established to suitable erosion-resistant vegetation.

8.3.1.7. Requirements for Plans and Specifications. A location map, the profile along the centerline of the structure, cross section, outlet diameter, length, material, elevations, and seeding requirements should be included in the plans and specifications.

8.3.2. Lessons Learned. The following items are lessons learned from Swan Lake and Batchtown HREP projects.

- Baseline and Post Project Monitoring. Sediment control measures are currently not physically monitored after construction to measure effectiveness. Ideally, surveying the sedimentation trap impoundment prior to use and surveying periodically to measure the amount (tons) of sediment trapped would be desirable. The NRCS uses empirical formulas to determine the amount of sediment that will be prevented from entering a stream prior to construction based upon site conditions, but do not survey to verify their assumptions. The project sponsor (USFWS) states that they do not know if a significant amount of sediment is being reduced from entering their intended project after the investment in numerous sedimentation traps in the watershed, making it difficult to determine the cost effectiveness of the feature.

- The sediment control traps constructed in the watershed for both projects are on a volunteer basis. Farmers are approached by NRCS, but no control is used in getting a farmer to construct a trap on his property, even though his/her farm may be contributing significant amounts of sediment to the project. A systematic approach to determining the largest source of the sediment and then prioritizing and funding appropriately would be helpful. From a watershed perspective - did we put them in the right spot? Targeting the largest contributing sources is essential.

- Both projects have farmers that the NRCS has turned away in the project watershed, because of the limited project dollars. The program was slow to begin when the NRCS was first engaged on Swan Lake. At first, farmers were reluctant to build sediment traps out of the perception that the Government would be using their land. By the time the Batchtown project started, farmers were volunteering to build sedimentation traps after seeing how the program was administered across the Swan Lake watershed.

- The NRCS can build the sedimentation traps cheaper than the Corps because their construction contracting procedures are more flexible. The NRCS was a great partner.

8.3.3. References

Natural Resources Conservation Service. *NRCS Conservation Practice Standard. Code 350: Sediment Basin.* 2001.

Natural Resources Conservation Service. *NRCS Conservation Practice Standard. Code 638: Sediment Basin.* 2001.

U.S. Army Corps of Engineers. *Report to Congress: An Evaluation of the Upper Mississippi River System Environmental Management Program* 1997.

8.3.4. Case Studies. Upland sediment control measures have been implemented at the Swan Lake and Batchtown HREP projects.