Evaluation of Shallow Water Habitat Construction Methods on the Missouri River

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Abstract:
The Missouri River Biological Opinion (2000) and the Amended Biological Opinion (2003) set forth the requirements for the creation of Missouri River shallow water habitat (SWH). The Omaha District Corps of Engineers has conducted significant SWH design, construction, and monitoring activities since 2004. A review of several specific projects including dike modifications, backwaters, and chutes are presented that discusses the physical habitat response to construction activities. Tools and analysis techniques developed to assist with bend evaluation are provided that evaluate bend physical and hydraulic flow parameters. Monitoring activities that illustrate the impact of sediment on project performance are also presented. Observations related to project performance with suggestions for improvement are provided.

INTRODUCTION

In 1989, The U.S. Army Corps of Engineers (Corps) initiated consultation with the U.S. Fish and Wildlife Service (Service) regarding operation of the Missouri River Main Stem Reservoir System. Consultation covered operation of the Missouri and Kansas Rivers as well as the Missouri River Bank stabilization and Navigation Project. The 2000 Biological Opinion found that the actions proposed by the Corps would jeopardize the Interior least tern, pallid sturgeon, and piping plover. With the intent of precluding jeopardy to the species, the Service provided a Reasonable and Prudent Alternative (RPA). The Corps requested re-initiation of formal consultation and an amended Biological Opinion was provided in 2003. The Missouri River Biological Opinion and the Amended Biological Opinion (USFWS, 2003) set forth the requirements for the creation of shallow water habitat. In conjunction with the biological opinion, an update to the master manual that provides for the operation of the Missouri River system was completed by the Corps in 2004 (USACE, 2004). The RPA consisted of numerous elements pertaining to flow management, habitat diversity, and habitat acres. The RPA performance standard for Missouri River shallow water habitat acres below Gavins Point Dam to St. Louis, a distance of 811 river miles, was established as 30 acres per mile. Since 2003, the Corps has completed construction of numerous projects intended to create shallow water habitat in this reach of the Missouri River. Following construction, monitoring activities have been conducted to evaluate the project performance. Activities have been conducted in both Omaha and Kansas City Corps of Engineers Districts. The Missouri River geometry and hydraulic characteristics change significantly between the two Corps Districts which results in major differences in project formulation. This paper focuses on project performance within the Omaha District and the portion of the channelized Missouri River between Ponca, NE, river mile 752, and Rulo, NE, at river mile 498.

Pallid Sturgeon Habitat: The pallid sturgeon is native to the Missouri and Mississippi Rivers and is adapted to the free flowing, warm water, and turbid habitats that are in a constant state of change. Floodplains, backwater, chutes, sloughs, islands, sandbars and main channel waters formed the large river ecosystem that provided habitat for all life stages of pallid sturgeon. Evidence of reproduction for wild origin pallid sturgeon is lacking. Destruction and alteration of big river ecological functions and habitat that was once provided by the Missouri and Mississippi

Rivers is believed to be the primary cause of declines in reproduction, growth, and survival of pallid sturgeon.

Shallow Water Habitat Definition: As set within the biological opinion, the parameters used to define shallow water habitat are Missouri River flow depths less than 5 feet (1.5M) and velocities less than 2 fps (0.6 m/s) (USFWS, 2003). For the purposes of assessing habitat creation, the effective discharge is defined as the 50% exceedance discharge from the August flow duration curve(s). Although the habitat accounting system is based on the effective discharge, data is also gathered and analyzed for a range of flows to provide a full impact assessment. Within the context of the RPA, defined shallow water habitat acreage refers to the following conditions:

- 50% exceedance August flow
- Flow depth less than 5 feet (1.5M)
- Flow velocity less than 2 ft/sec (0.6 m/s)

Construction Methods: Shallow water habitat is created using many different approaches that are classified according to the construction method and location. Some methods utilize the main channel while other methods utilize the adjacent floodplain. Habitat construction methods that have been used within the Omaha District include:

- Structure Notching (in-channel revetment and dikes)
- Dredging (off-channel)
- Pilot Channel (off-channel)
- Chute (off-channel)
- Major Dike Modification (in-channel dike lowering and chevron construction)

Plan view photos of typical construction projects are shown in Figure 1.

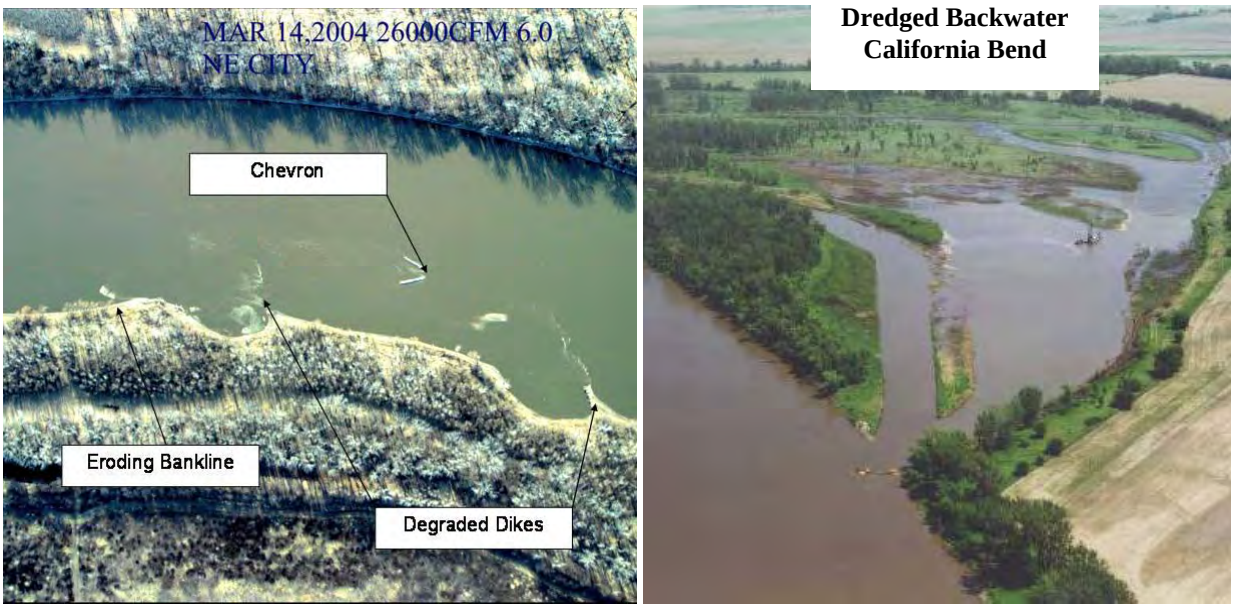

Figure 1. Typical Construction Projects.

Employment of the various methods is often limited by physical parameters, available real estate, and other factors. For instance, not all bends are suitable for the construction of an off channel chute. Dike modifications must consider real estate requirements and adjacent floodplain uses as channel widening is generally expected to occur. A summary of construction activities within the Omaha District, Missouri River mile 752 to 498, is shown in Table 1. Habitat acreage estimates are developed from analysis of collected data using developed procedures (USACE, 2007). A range of estimated acreage is presented that reflects the dynamic nature of constructed projects with both the initial acreage and the future projected growth acreage tabulated.

Table 1
Missouri River Construction Summary
Through 2008 - River Mile 752 to 498, Omaha District

Chutes			
	18 Chutes Constructed, 34.8 miles total length		
	* SWH acreage estimated range:	436	to 782
Backwaters			
	15 Backwater Areas		
	* SWH acreage estimated range:	367	to 483
Structure Modifications			
	565 Structure Modifications		
	* SWH acreage estimated range:	300	to 650
	All Construction Activities Total	**1,103**	**to 1915**

* Acreage values based on original construction and projected growth with future geometry growth and Missouri River dynamics

CONSTRUCTION PROJECT PERFORMANCE EVALUATION

Project Monitoring: Following habitat creation, monitoring is performed to evaluate the habitat formed in response to construction activities, to guide future habitat creation efforts, and to monitor impacts to other Missouri River authorized project purposes such as flood control, bank stabilization, and navigation. It is not practical, when considering cost and logistics, to conduct detailed data collection at every project. Therefore, data collection is performed at selected sites following an established monitoring program. Survey data at twenty bends has been collected between 2006 and 2009. A total length of nearly 42 river miles was surveyed each year. Data collection consists of hydrographic surveys, sediment samples, and ADCP depth-velocity data. Data was collected by different field teams following standard operating procedures (USACE, 2006). Data analysis is performed to evaluate river response and dynamics. A conceptual view of channel response to chevron construction, developed from analysis of collected data, is shown in Figure 2.

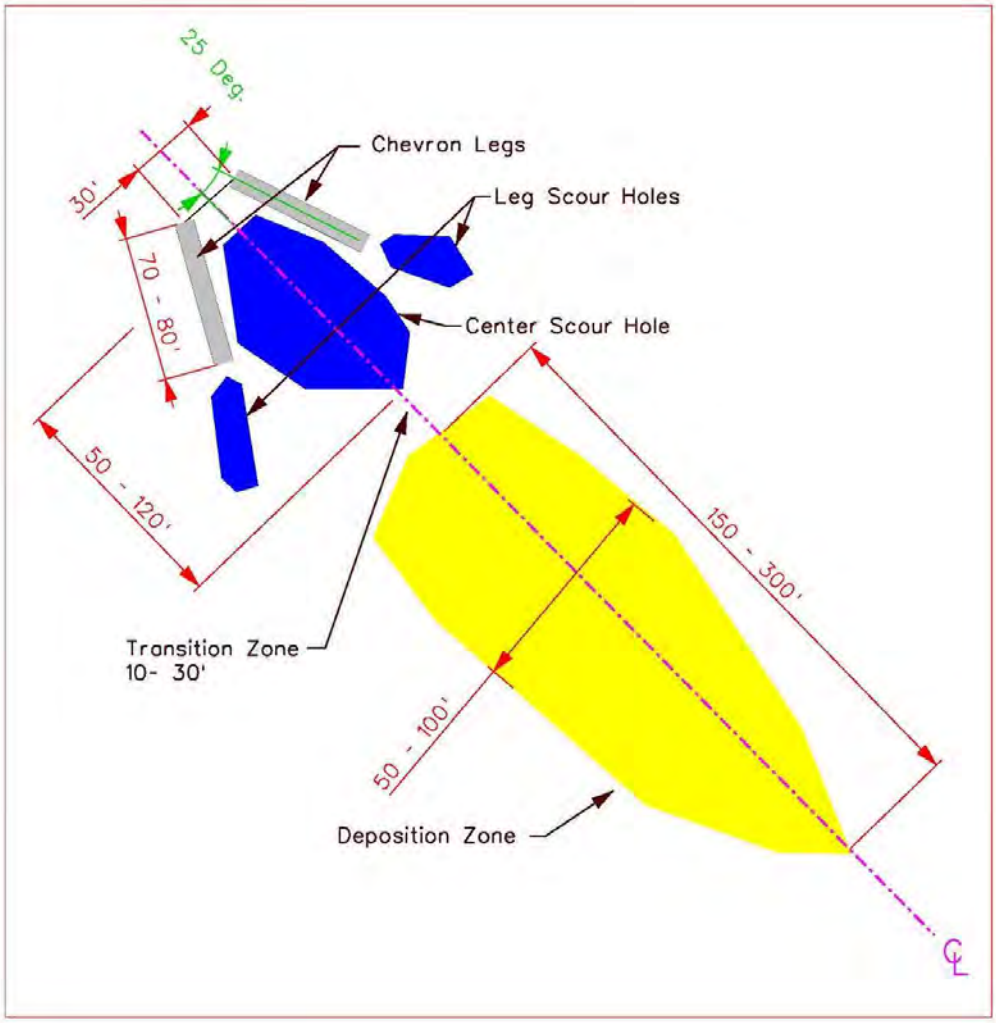

Figure 2. Conceptual View of River Response to Chevron Construction

Off Channel Chute Evaluation: Monitoring is also performed within off-channel chutes following construction. Many chutes were originally constructed at a minimal width sufficient for sustainability with the expectation of future growth in width to attain additional habitat benefit. Monitoring constructed chute projects has developed additional insight to chute dynamics. A few noteworthy examples are provided in the following sections:

Plattsmouth Chute: This project is located downstream of the Missouri - Platte River confluence. The Platte River is a large sediment contributor. Following initial construction, the Plattsmouth chute widened with increasing desirable habitat. In spring 2008, a major flood event on the Platte River resulted in the deposition of about 2-3 feet of sediment within the chute. Subsequent monitoring determined that normal flows removed the bulk of the deposited sediment.

- Chute had widened significantly following initial construction.
- Dynamic chute with natural variation and desirable habitat.
- Platte River 2008 flow event moved sandbar into the chute, deposited about 2-3 ft depth.

- Monitoring verified subsequent sediment removal over the following year, demonstrating chute sustainability.

Hamburg Chute: The Hamburg Bend chute was originally constructed in 1996 with a narrow 20 foot bottom width and several grade control structures to limit chute degradation. In 2008, severe shoaling occurred within the bend with notable impacts to other Missouri River project purposes including navigation. Chute surveys were conducted and ADCP flow measurements were performed that determined a chute flow that was about 18% of the total river flow. Surveys indicated that in addition to widening, significant chute degradation had also occurred between the grade control structures. As a result, the grade control structure has experienced higher flow velocity and turbulence more similar to a drop structure than a grade control structure.

HEC-RAS modeling was performed to determine a modification to the grade control structure to decrease the flows in the chute, allowing greater flows in the Missouri River. The grade control elevation was increased by 6 feet with a notch in the center to provide safe boat passage and to maintain flow connection during lower flow periods. An illustration of the modified control structure is provided in Figure 3.

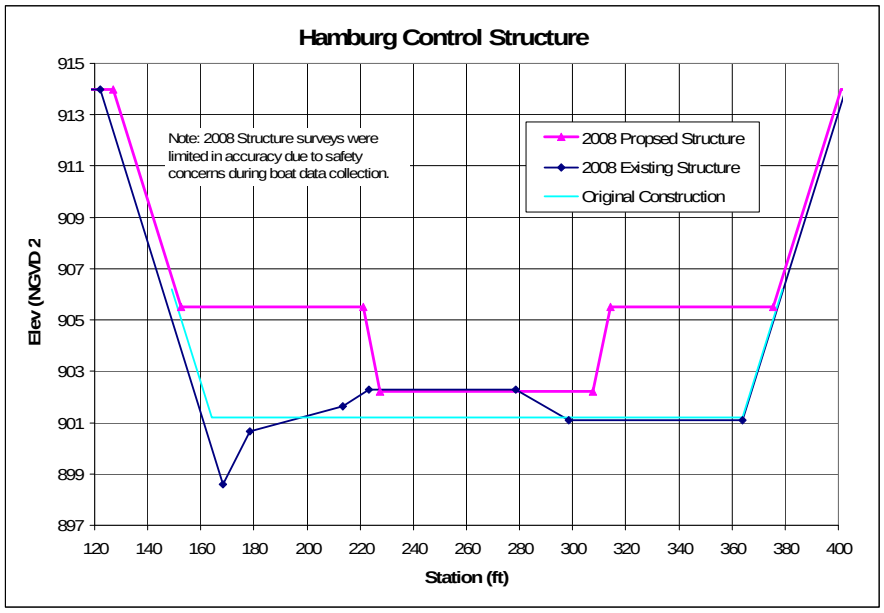

Figure 3. Hamburg Bend Chute Control Structure

Following grade control structure modification, additional surveys and Coast Guard provided information indicated that navigation issues did not occur within Hamburg Bend in 2009. However, post construction surveys show that the chute flow reduction is less than desired. Surveys indicate that the bottom of the notch in the grade control structure has already been eroded within the high flow velocity notch. Surveys also indicate that the energy loss through the structure was over-estimated by the HEC-RAS model. Subsequently, construction method modifications have been adopted to require original rock removal to increase new rock layer thickness and to increase the size of the rock within the grade control structure notch. Significant conclusions regarding chute grade control structure performance based on experiences at Hamburg Bend:

- Survey and Coast Guard information indicates that navigation issues did not occur within Hamburg Bend in 2009.
- Complete removal of all eroded/deteriorated riprap is necessary for structure stability.
- Increase riprap size and layer thickness within the notch to prevent erosion is recommended.
- Denser survey data downstream of the grade control structure would provide better rock quantity estimates.
- Post-construction surveys need to be completed immediately after construction including soundings and ADCP data.

Evaluation of constructed chutes has illustrated several critical factors that have been incorporated into future chute design as summarized below:

- Chutes have been successfully constructed with varying bottom width from a 10 foot pilot channel to full width (>100 ft).
- The HEC-RAS model should be carefully evaluated with observations that energy loss through the grade control structure was over estimated.
- Control structures are critical and should be designed to resemble more of a drop structure than simple grade control.
- The desired flow split between the chute and the main river is about 6-10% for a sustainable chute that does not impact the main channel.
- The most dynamic chutes with aggressive planform changes have an 80 – 85% (chute/main channel) length ratio.
- Chutes longer than channel will stay open but these chutes have limited dynamics with little change following construction.
- Chutes with multiple connections to the main river are feasible, maintain at least 1000 ft between connections for sustainability.

Backwater Area Evaluation: Numerous backwater areas have been constructed that consist of a single connection to the main river. Prior to project construction, the desirable backwater areas generally consist of old remnant chutes or cutoff bends that, while lower than surrounding areas, are no longer connected to the river. Due to the high Missouri River sediment load, deposition and associated degradation of backwater habitat quality has been a concern within constructed backwater areas. Field surveys from backwaters and an evaluation were conducted to evaluate backwater deposition rate and identify maintenance costs. Evaluation consisted of field surveys in fall 2008 that were compared to LiDAR surveys from 2006 and as-built surveys from the Contractor in 2004. This is a very short period to evaluate backwater deposition and caution should be used when evaluating results.

An example of a backwater area illustrating the entrance sediment deposition bar is included in Figure 4. The figure is taken at low winter flows and clearly illustrates the sediment bar formed at the entrance. Recent backwater construction has included a revised structure at the connection in an attempt to reduce the entrance deposition rate.

Figure 4. Typical Backwater at Low Winter Water Level Illustrating Entrance Sediment Bar

Conclusions of the evaluation are as follows:

- No determined difference in deposition rate due to backwater connection location (off chute or main channel, revetment or dike field).
- Deposition rate within different areas is highly variable with a wide range.
- Data is too limited and variable to reach conclusions regarding backwater life. Data indicates a likely backwater productive life of 15 to 30 years assuming a deposition depth of 3 feet.
- The connection zone, or first 100 - 150 feet from the river, aggrades faster with remedial action likely necessary in about 3 – 5 years.
- Recent backwater area construction methods have included a revised backwater river connection to reduce the sedimentation rate at the entrance.

Channel Widening Methods Evaluation: River structure modifications designed to promote channel widening were constructed at numerous bends. Observations have indicated a strong correlation between increasing river top width and shallow water habitat. River structure modifications are intended to create habitat both directly, by causing deposition within the structure vicinity, and indirectly, by redirecting currents in the near bank zone with a resulting increased bank erosion rate. The widening projects are designed to work with all authorized project purposes including navigation and flood control.

The predominant structures used with river structure modification projects consist of reverse sills, rootless dikes, dike notching, dike lowering, and chevrons. Quantitative assessments of each structure type were made using pre-and post construction surveys as shown in Figure 2. These evaluations indicate a typical habitat response of 0.2 to 1 acre for each individual structure. Depth diversity and bankline irregularity were increased over an area of roughly two acres per structure. A brief description of each structure is as follows:

Reverse Sill: The reverse sill consists of placing rock on an existing dike alignment riverward of the existing dike end. The reverse sill length varies from 50 to 100 feet and is usually built to an

elevation of 3 feet above normal navigation structure crown level. The higher elevation will maintain habitat at a full range of flows and also promotes structure visibility within the channel flow zone that enhances recreational boating safety. Reverse sill construction results in SWH creation in the structure vicinity, assists with maintenance of the channel thalweg location, and increases near bank flow.

Rootless Dike: Rootless dike geometry is similar to a reverse sill. The difference is that a rootless dike is not located on the alignment of an existing dike. Rootless dike length varies from 50 to 100 feet and is built to an elevation of -1 to 3 feet above normal structure levels. Rootless dike construction results in SWH creation in the structure vicinity, assists with maintenance of the channel thalweg location, and increases near bank flow.

Dike Notching: A dike notch consists of removing rock from an existing dike within the river and bank region. Phase 1 dike notching, referred to as a Type B notch, was constructed at numerous locations. The Type B notch included a 75 foot bottom width of which a portion was into the existing bank and was built with an invert 5 feet below normal structure crown elevation.

Phase 2 of the dike notching activities consists of further moving the notch into the bank to increase channel widening potential. Phase 2 of the dike notching also includes placing material within the notch to maintain a maximum notch width of 100 feet. Dike notch construction usually results in the increase of near bank flow velocity and some SWH associated with the structure. The main benefit of dike notching is to increase flow currents within the near bank vicinity and accelerate the widening process.

Dike Lowering: Dike lowering consists of removing rock from an existing dike within the river and into the bank. Lowering is performed from the riverward end of the dike for a variable distance that is generally on the order of 200 hundred feet.

Chevrons: The typical chevron employs two angled rock dikes located in the mid channel between the bank and the navigation channel. Chevrons are generally constructed in concert with dike lowering. The chevrons are constructed in between the existing dikes, usually between 50 and 150 feet from the bank. The riverside chevron dike directs flows to maintain the location of the navigation channel while the bank side chevron dike directs flow toward the near bank region. Observed variation in constructed chevron structures was noted in the length of the wings, angle between the wings, location/size of the scour hole, and the location/size of the deposition zone. Recent chevron modifications have been to fill the gap between the two dikes and to extend one or both of the wing dikes.

River structure modifications are likely to require several iterations to achieve optimum bend habitat. As the river responds to construction, the next phase of revisions is designed and implemented. An example of structure modifications with a second phase is illustrated in Figure 5. The photo illustrates a location where the chevron nose has bee modified and rootless dikes added in a second phase of structure modifications.

Figure 5. Modified Chevron with Nose, Wing, and Added Rootless Dike

A summary of notable channel widening project conclusions:

- Occurs in phases as the river responds to project construction.
- Dike removal or lowering is an essential component required to achieve channel widening.
- Modifications create new SWH within the near structure vicinity.
- Future SWH will occur with channel widening resulting from bank erosion.
- Ultimate channel widening sustainable width is expected in the range of 100 to 300 feet for an increase of 10 to 30 percent over the existing channel width.
- Bank erosion rate is highly variable and dependent upon many factors.
- Can be conducted while maintaining all authorized project purposes.
- Construction observations resulted in a revised rock specification and placement method to use rapid deployment rock placement to limit river bed erosion and reduce rock quantity.
- Channel widening rate has been less than optimal with likely causes including reduced flows and energy during the drought period and erosion resistant bank material.
- Will require construction in phases as the river responds to structure modifications.
- SWH is transitional and varies with flow level.
- The amount of SWH created by each structure is directly related to the perpendicular structure flow shadow. The reverse sill most efficient at creating SWH per structure length. However, other structures may have additional habitat benefits with increased depth and velocity diversity.

SUMMARY

The Omaha District Corps of Engineers has conducted significant SWH design, construction, and monitoring activities since 2004. A review of several specific projects including dike modifications, backwaters, and chutes were presented that discusses the physical habitat response to construction activities. Tools and analysis techniques have been developed to assist with bend evaluation were presented that evaluate bend physical and computed flow parameters. Monitoring activities that illustrate the impact of sediment on project performance were also presented. Significant observations regarding successful projects and modifications include:

- Chutes have been successfully constructed with varying bottom width from a 10 foot pilot channel to full width. The desired flow split between the chute and the main river is about 6-10% for a sustainable chute that does not impact the main channel.
- The most dynamic chutes with aggressive planform changes have an 80 – 85% (chute/main channel) length ratio. Longer chutes remain viable but are less active.
- Data indicates a likely backwater productive life of 15 – 30 years assuming a deposition depth of 3 feet.
- Channel widening to create SWH is feasible and will require several phases. An ultimate widening of 10 to 30% compared to the current top width is projected.

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