Evaluation of Fish Bypass Channel Velocity and Depth Pertaining to Meeting Biological Criteria

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Abstract

The Lower Yellowstone Project is a U.S. Bureau of Reclamation (Reclamation) irrigation project located in eastern Montana and Western North Dakota. The project consists of a diversion dam, a headworks structure, canals and pumps. Entrainment of fish into the main canal, along with lack of fish passage, specifically for the Endangered Species Act (ESA) listed Pallid sturgeon, led the U.S. Army Corps of Engineers (USACE), in collaboration with Reclamation, to design and construct a screened intake structure, bypass channel and new weir.

The screened intake structure was completed in 2012. The new weir and bypass channel were completed in 2022. Bathymetric surveys and velocity and discharge measurements were conducted five times between May and August 2022. Additionally, fish tracking via radio-telemetry was completed by Montana Fish, Wildlife & Parks throughout the year.

This extended abstract will focus on changes to the bypass channel cross section due to scour of erodible materials, deposition of material in the bypass entrance and the impact to the biological criteria set to maximize the attraction to and use of the bypass channel by Pallid sturgeon and all aquatic species of the Yellowstone River.

This extended abstract is a follow up to that presented during the 2015 SEDHYD conference, “Sediment Modeling on the Lower Yellowstone River at Intake Dam, Montana”, which presented modeling of the bypass channel during the design phase.

Background

The 2.1 mile long bypass channel was completed in April 2022. Design features include natural channel cross sections (variable side slopes), hardened entrance and exit structures, grade control structures, revetments at outside bends, and an armor layer on the invert composed of natural cobble material obtained by selective screening during excavation of the channel. The remainder of the bypass channel excavation extents were vegetated without additional engineered stabilization. This selective hardening was intentional to allow some movement of the bypass channel to better simulate a natural side channel. A plan view of the bypass channel is shown in Figure 1.

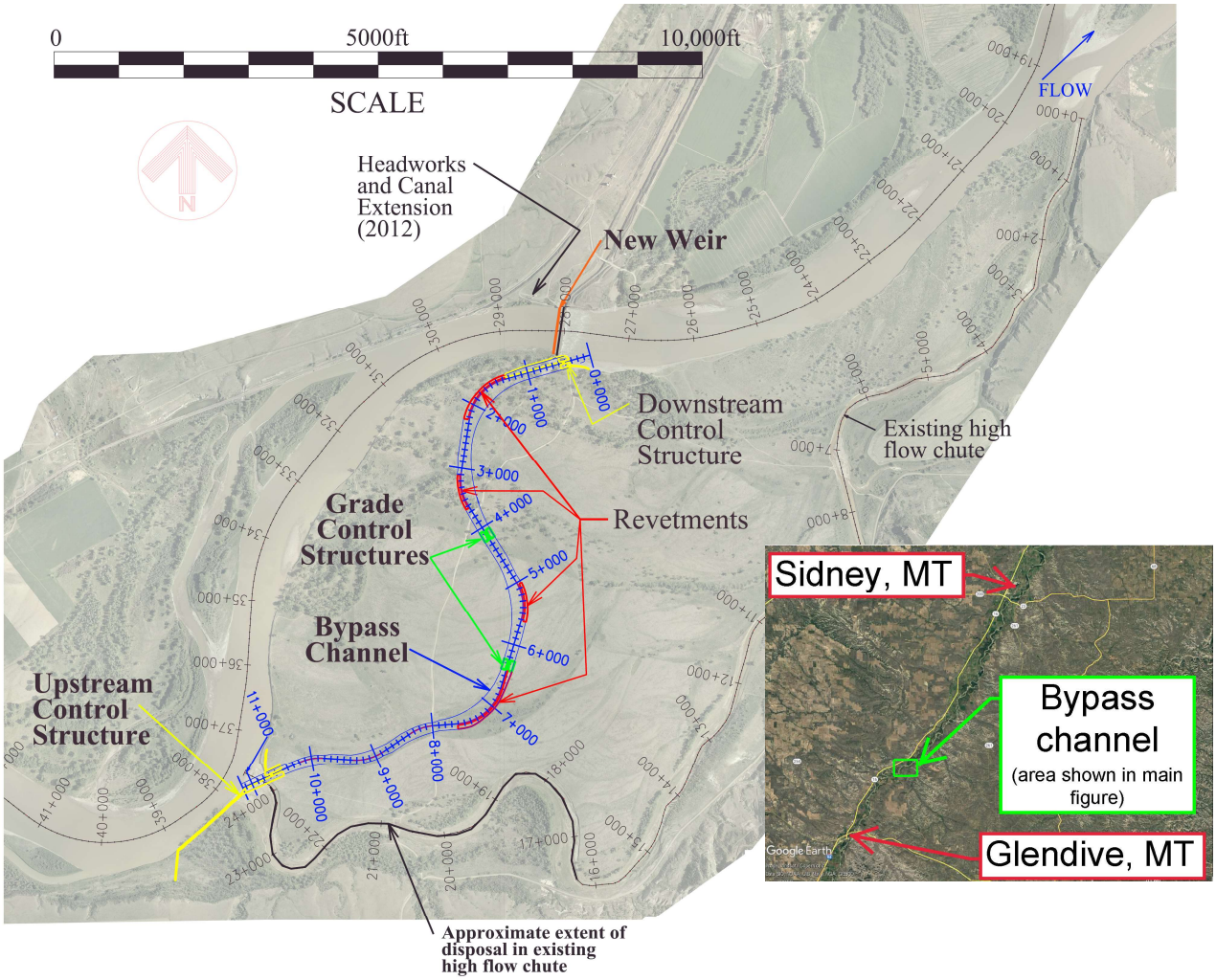

Figure 1. General overview of bypass channel

Bypass Channel Monitoring

During the design phase, the multi-agency project delivery team (PDT), composed of engineers, scientists, biologists, planners and other disciplines, developed what is referred to as biological criteria for the bypass channel. The criteria are intended to provide a set of measurable parameters that, if met in the bypass channel, would maximize attraction of fish to the entrance (downstream end) of the bypass as well as allow passage through the entire channel. The design criteria are shown in Table 1 (USBR 2021).

Table 1. Biological criteria used in design

Discharge at Sidney, Montana USGS Gage	7,000 – 14,999 ft^3/s	15,000 – 63,000 ft^3/s
Bypass Channel Flow Split	≥ 12%	13% to ≥15%
Bypass Channel Cross-section Velocities (measured as mean column velocity)	2.0 – 6.0 ft/s	2.4 – 6.0 ft/s
Bypass Channel Depth (minimum cross-sectional depth for 30 contiguous feet)	≥ 4.0 ft	≥ 6.0 ft
Bypass Channel Fish Entrance (measured as mean column velocity)	2.0 – 6.0 ft/s	2.4 – 6.0 ft/s
Bypass Channel Fish Exit (measured as mean column velocity)	≤ 6.0 ft/s	≤ 6.0 ft/s

Monitoring of the bypass channel physical characteristics was completed by the U.S. Geological Survey (USGS). The USGS measured depth, velocity and discharge at 19 cross sections within the bypass channel and discharge only at one cross section in the main channel of the Yellowstone River upstream from the bypass channel. These measurements were conducted five times between May 2022 and August 2022 over a range of discharges. Table 2 summarizes results of the measurements (USGS 2023).

Table 2. Measured data

	Survey Date (2022)				
	11-May	24-May	1-Jun	24-Jun	11-Aug
Measured data					
Yellowstone River discharge (cfs)	10,400	14,170	27,500	55,800	6,670
Bypass discharge - average (cfs)	1,886	2,373	4,345	8,766	1,059
Percent of total flow in bypass	18%	17%	16%	16%	16%
Average velocity in bypass (ft/s)	4.0	4.3	5.0	6.1	2.9
Average depth (ft)	5.6	5.9	7.9	10.6	4.0

As shown in Table 2, the bypass channel meets the biological criteria, on average, for all measured discharges. However, several individual cross sections did not meet depth and/or velocity criteria for the 24-Jun and 11-Aug measurements. Further evaluation of the cross sections not meeting the criteria indicates that lateral erosion experienced during relatively high flows in June 2022 resulted in widening of the channel in some areas outside of the hardened sections. While some erosion and deposition is desirable for natural channel dynamics, the condition of the bypass channel was evaluated under adaptive management and repairs were completed in March 2023.

References

U.S. Department of the Interior, Bureau of Reclamation (USBR). 2021. "Lower Yellowstone Intake Diversion Dam Fish Passage Project. Adaptive Management and Monitoring Plan."

U.S. Geological Survey (USGS). 2023. "Yellowstone River Fish Bypass Channel Physical and Hydraulic Monitoring." [In review].