United States Department of the Interior

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November 19, 2012

Memorandum

To: Superintendent, Grand Teton National Park

Through: Gary Rosenlieb, Acting Chief, Water Resources Division (WRD

From: Mike Martin, Hydrologist (WRD), Gary Smillie, Hydrology Program Lead, (WRD)

Subject: Technical Memo describing issues associated with the loss or removal of a low head dam on the Gros Ventre River.

Purpose and Summary

The purpose of this memo is to present results of a recently completed scour analysis for a private bridge that crosses the Gros Ventre River in GRTE near the town of Kelly, Wyoming.

Problem Statement and Scope of Report

Park staff at GRTE requested assistance from WRD to evaluate the likely consequences of removing a diversion structure on the Gros Ventre River. This low-head dam structure (dam) is about five to six feet high and completely traverses the river channel, raising the river stage several feet to supply water to the Newbold Ditch. Since the ditch is no longer used, there is consideration to remove the dam and restore the natural functions of the river including unobstructed fish passage. However, the dam is currently in a state of imminent failure, so the consequences of loss of this structure have taken on a degree of urgency.

The primary complication with the loss or removal of the dam is the presence of a bridge about 650 feet upstream (Figure 1). This privately owned bridge, which provides access to residents on the left bank of the river, has one support pier in the approximate center of the channel that is buried to an unknown depth in the river bed. The two possible concerns from dam removal for the bridge pier are 1) a steepening of the river bed profile that would lead to increased velocities for some distance up stream, possibly inducing scour around the pier and, 2) loss of the sediment wedge that has accumulated behind the dam, which could possibly be supporting the pier.

This memo addresses the first effect of potential increase in stream velocity and subsequent scour through standard hydraulic analyses. The second concern, loss of the accumulated sediment and undermining of the pier is not investigated in this work because of insufficient information regarding the historic grade of the river and of the depth to which the pier is founded in the alluvium. Furthermore, the data that would be necessary to evaluate this possible impact is not easily obtained, and therefore, we are unable to make a reasonable prediction at this time.

Figure 1 - Google earth image showing both the diversion structure and the bridge in the vicinity of Kelly Wyoming.

Procedure and Results

Pier scour

To address the possibility of scour near the bridge after removal of the dam, WRD staff utilized HEC-RAS, the Army Corps of Engineers river analysis software, which includes a routine to calculate bridge scour under various hydraulic conditions. Nicholas Kraus of Quadrant Consulting, (consultant) Inc. supplied WRD with the basic HEC-RAS model of this reach of the Gros Ventre River, developed from survey data they collected in 2011. Their model contained complete stream channel cross sections from about 240 feet below the dam to just below the bridge. WRD staff supplemented this data set with bridge geometry data and two additional cross sections upstream of the bridge collected in September 2012, (Figure 2). To model the bridge removal scenario, we adjusted the geometry files of the stream channel to reflect loss of the sediment that has accumulated behind the dam (Figure 3).

The HEC-RAS routine has three parts to calculate total scour at a bridge site; contraction scour, pier scour, and abutment scour. In the case of this scenario, there are no bridge abutments in the flowfield so abutment scour does not apply. Furthermore, the channel geometry does not contract at the bridge crossing so contraction scour is unlikely, and in fact was not predicted by the model. The single pier is directly in the flowfield, and therefore, some degree of pier scour is likely.

While some scour may occur at lower, more frequent flows, the standard procedure is to evaluate higher magnitude flows like the 100-year flood to assess a worst case scenario (USACOE, 2010). We utilized a range of design flows provided to us by the consultant from the 2-year flood of 3280 cubic feet per second (cfs) to the 100-year flood of 5480 cfs. Furthermore, we estimated the predominant grain size of the bed material to range from about four to eight inch cobbles in the immediate vicinity of the bridge. Coarser alluvium, such as that present in this reach of the river, tends to reduce total depth of scour by “armoring” the channel and this effect is accounted for in the governing equations (USDOT-FHWA, 2012).

The results of the analysis indicate that this reach of the Gros Ventre river is subject to live (mobile) bed conditions and some pier scour even at relatively frequent flows. With the dam in place the transition from an immobile bed to a “live” bed occurs between 3000 and 4000 cfs. With the dam removed, this transition occurs in the lower flow range of between 2000 and 3000 cfs, reflecting the increased velocity associated with the slightly steeper channel. We analyzed the suite of design flows from the 2-year flood to the 100-year flood through both the existing conditions and the modeled streambed after dam removal and found that all flow velocities increased about 18 percent with the removal of the dam. This was an increase from about 1 foot per second (fps) to 1.4 fps for each flow. For instance, the estimated channel velocity immediately above the bridge for the 100-year flow increased from about 7.8 to 9.1 fps after “removal” of the dam.

The analyses suggest that pier scour occurs throughout the range of modeled flows with predictions ranging from about 2.8 to 3.3 feet of depth around the pier. These results were only slightly higher after dam removal as a result of the higher predicted velocities. These results are consistent with field observations where there is already evidence of roughly 1 – 1.5 feet of bed scour around the pier. Therefore, from this analysis we conclude that there will likely be some additional scour around the pier with higher flows and, if the dam is removed or fails on its own the total depth of scour will increase somewhat over existing conditions.

It is difficult to make an accurate prediction of the stability of the pier as it relates to the predicted depth of scour since the depth of the pier footer is presently unknown. We can however make a definitive determination that the threat to the bridge will only increase with removal of the dam and with the occurrence of higher magnitude, less frequent flows.

Loss of Sediment Wedge

As mentioned above, the condition of the dam has deteriorated significantly since May 2012, and this has happened during a very low runoff season. A large portion of the flow is now moving through or under the structure, a situation that will likely cause structural failure, possibly this winter and almost certainly, during high flow in the spring.

When failure (or removal) of the dam occurs, the sediment wedge will begin to degrade though upstream migration of a headcut. There is risk that this headcut could progress to the bridge pier and undermine the footer, possibly causing the bridge to fail. As mentioned, we do not know the depth of the sediment wedge in the vicinity of the bridge and such a determination would require a lengthy longitudinal survey of the river bed. But again, since we do not know the depth of the pier footer, acquiring an accurate estimate of the depth of aggradation around the pier would provide an indeterminate analysis of the threat to the bridge. It is difficult to predict the time it will take for the headcut to migrate the 600 or so feet to the bridge because of hydrologic uncertainty and other factors. However, we believe that during high flow the headcut may advance rapidly upstream leaving little time for protective actions.

Given these uncertainties and the potential risk involved to the bridge, we recommend the park anticipate dam failure and have a plan in-place to deal with potential erosion around the bridge pier. For example, it would be well advised to be prepared to place appropriately sized rip-rap near the bridge pier to forestall scour if it becomes apparent that the bridge is under imminent threat following failure of the downstream dam. Given the modeled velocities during the 100-year flood of about 13.6 fps, fairly large stone should be selected. If large blocks are not available or cost prohibitive, partially grouted rock of smaller size may be employed to provide flexible and permeable, yet stable protection (Pers. Comm., Scott Hogan, FHWA, 2012) . Actual placement of the pier protection should be planned and executed by an experienced bridge engineer to ensure stability and effectiveness of the placed rip-rap and reduce the potential negative consequences on the associated stream channel.

Summary

WRD performed a scour analysis for the bridge over the Gros Ventre River at Kelly, Wyoming. Due to the channel and bridge geometry, contraction and abutment scour are not likely. However, the single supporting pier is directly in the flowfield, and likely subject to scour.

Modeling results suggest that removal of the dam will result in somewhat higher flow velocities for a given discharge due to a steepening of the bed. Furthermore, entrainment of the bed material (live bed conditions) occurs at fairly frequent flows (around 3000-4000 cfs) under current conditions and this threshold will decrease to about 2000 to 3000 cfs with the removal of the dam.

Modeling results suggest that scour around the pier occurs at fairly frequent flows as well as more rare events like the 100-year flood. Model predictions indicate scour depths around the pier from about 2.8 to 3.3 feet. And these results are essentially the same with and without the dam.

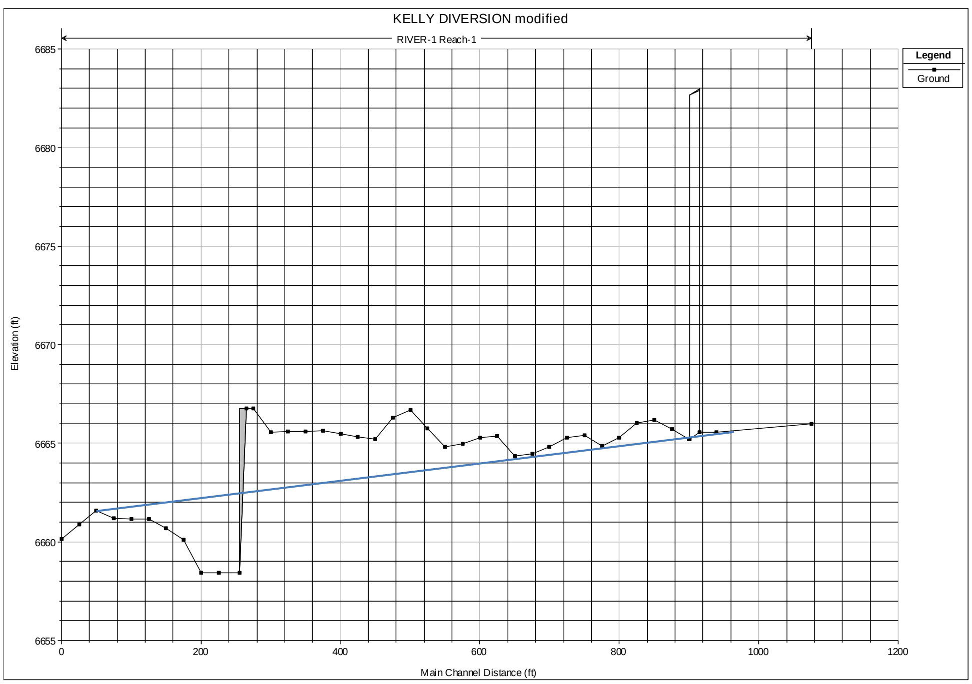

Figure 2 – Thalweg profile of Gros Ventre River encompassing the Newbold ditch diversion and the Kelly bridge. The dotted black line is from the 2010 survey and represents existing conditions. The solid blue line is the projected slope of the river bed after dam removal.

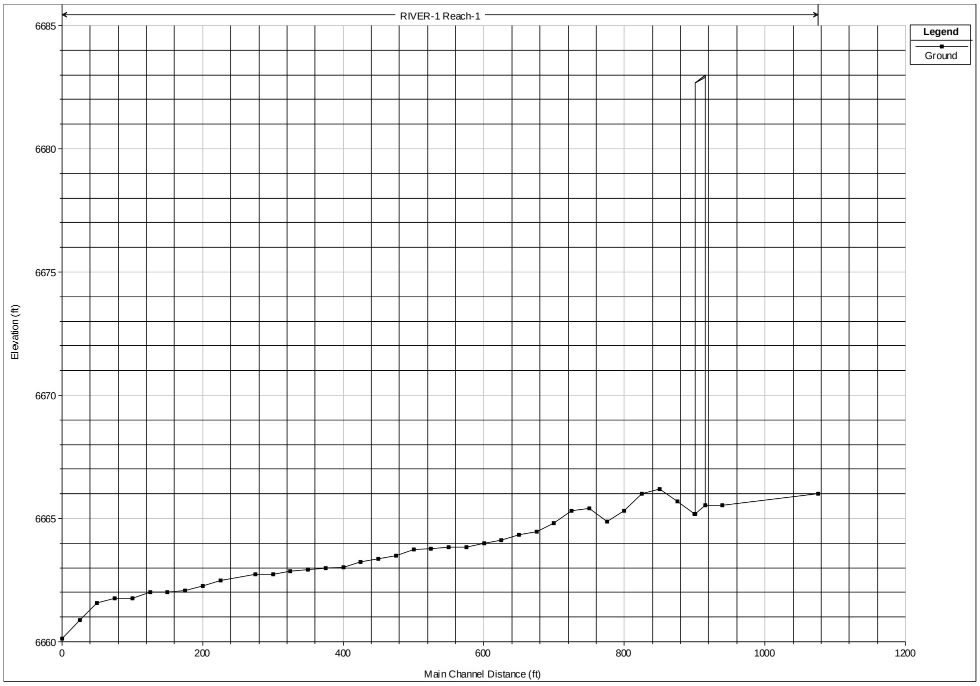

Figure 3 – Thalweg profile of the *modeled* streambed for Gros Ventre River in the vicinity of the Kelly Bridge after removal or loss of the dam.

References

USDOT-FHWA, 2012. Evaluating Scour at Bridges. Hydraulic Engineering Circular #18. Office of Bridge Technology, FHWA, Room e76-322, 1200 New Jersey Av. SE. Washington D.C. 20590.

USACOE, 2010. HEC-RAS, River Analysis System Hydraulic Reference Manual. U.S. Army Corps of Engineers Hydrologic Engineering Center, 609 Second Street, Davis, Ca. 95616.

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2380 – Rosnlieb, Hansen, Smillie
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