Stantec

Memo

To:	John Menninger	From:	John Orwin
	Cincinnati, OH		Calgary, AB
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Reference: **110773396: Low Level Outlet Release Scenarios - Preliminary Identification of Erosion Potential and Contextual Regulatory Setting**

1. INTRODUCTION

The purpose of this memo is to provide a high level, preliminary understanding of the erosion potential under release rates from 0 m^3/s to 60 m^3/s from the Low Level Outlet (LLO) on the outlet channel (OC) and floodplain downstream of the Springbank Off-stream Reservoir (SR1) dam. The area focused on is between the toe of the SR1 dam and the confluence of the OC with the Elbow River. Actual sediment transport rates and associated dynamic changes in channel morphology are not assessed in this memo; nor is the effect of sustained release at the identified flow rates. Those will be addressed in the Environmental Impact Assessment.

The construction of the LLO will be covered under a provincial Water Act Approval for the SR1 project, as a whole. However, the operation of the LLO may be subject to further *Water Act* provisions as well as federal Fisheries Protection Provisions under the *Fisheries Act* dependent upon the selected operation regime and what may be deemed emergency or atypical, versus planned operation. A brief discussion of potential regulatory requirements and consideraitons for operation of the LLO is also presented to inform the selection of the outlet's design capacity. This discussion is not definitive as the SR1 project does not have a precedent and will likely require further consultation with regulators.

2. ENVIRONMENTAL SETTING

The OC currently has a meandering planform for the majority of its 1400 m length from the LLO to its confluence with the Elbow River, with an average gradient of 0.009 m/m (0.9%). Chainage for the OC has not yet been established. Flow is typically confined to a single channel although some branching is evident in the upper reaches. The OC is incised approximately 1.0 m in depth into glaciofluvial/glaciolacustrine material. Several areas of localized bank erosion resulting from undercutting are present along the OC, specifically in the lower reaches (Figure 2-1).

Current baseline flow in the OC is intermittent with flow occurring primarily during spring runoff. Flow also occurs in response to sustained wet periods (Figure 2-2). Baseflow water typically has an electrical conductivity in the range of 1600 µS/cm, suggesting a spring influence. Flow in the channel ceases or goes subsurface during dry periods. Flow data shows that the OC has a rapid response to precipitation input with steep ascending discharge limbs (Figure 2-2). Recession from flow peaks also show rapid declines.

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Figure 2-1 Outlet Channel – note bank collapse induced by toe cutting on true right bank. Locations of A and B are show in Figure 4-1

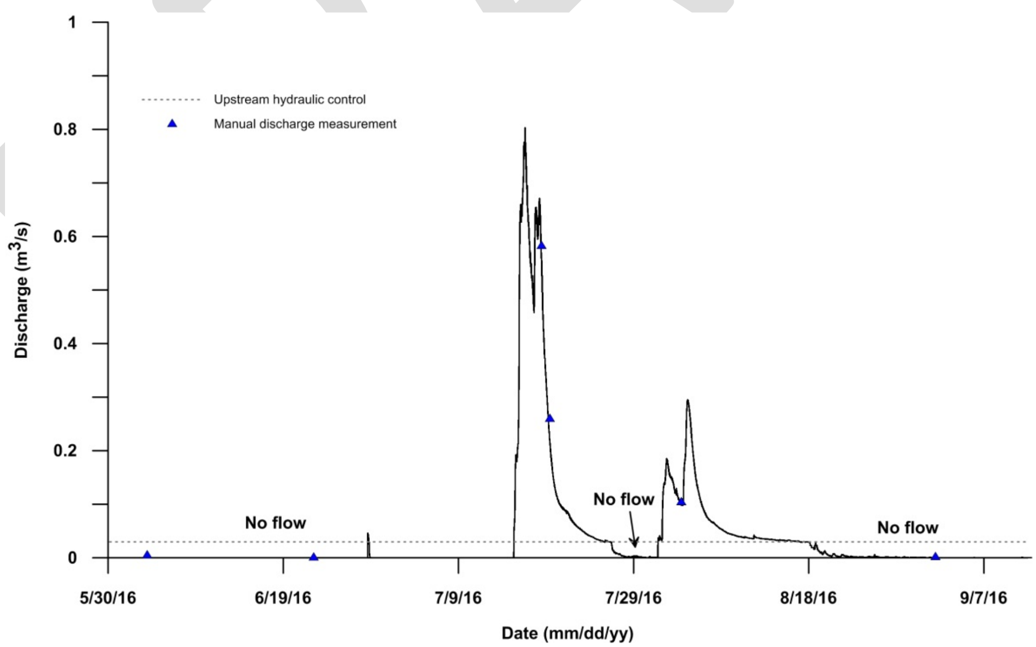

Figure 2-2 Outlet Channel Hydrograph recorded during 2016 at Location A in Figure 2-1.

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3. APPROACH AND DATA SOURCES

Pre- and post-2013 high flow event 1.0 m^2 grid LiDAR derived Digital Elevation Models (DEMs) were used as an initial screening tool to identify where erosion has historically occurred in the OC. Vertical accuracy is in the order of 0.3 m. The pre-2013 LiDAR was flown on May 15th 2007 and the post-2013, on November 1st, 2015. Given that the flow data indicates that the OC is likely dry during these periods and leaf cover would have been minimal, the LiDAR derived DEMs provide cross-sectional data for the actual channel, in addition to the floodplain.

Identifying erosional areas gives a benchmark to identify where further erosion may be expected under different release rates and to validate model output. To do this, a simple differencing between the two surfaces was calculated in ArcGIS 10.3.1. Given the resolution of each DEM, aggradational or degradational changes of less than approximately 0.3 m are unlikely to be captured. As a result, the differencing approach should indicate areas of change visible in imagery.

To understand where erosion may occur in the OC under different LLO discharge rates, the distribution of shear stress (N/m^2) was modeled under different discharge rates using HEC-RAS 5.01®. This US Army Corp of Engineering model allows the spatial distribution of boundary shear stresses to be mapped within the OC channel and floodplain. A critical shear stress of 48.5 N/m^2 was used as a potential mobilization threshold. Boundary shear stresses greater than this value indicate an increased likelihood of sediment mobilization. This threshold was based on an estimated sediment D_{50} (median particle size) of 50 mm (pebble) and application of the Shields equation (Knighton, 1998). The critical shear stress, τ_{CR} is calculated as:

$$\tau_{CR=970D_{50}}$$

Data on the shallow surficial geology from borehole logs near the LLO support the estimated D_{50} of 50 mm. The logs suggest that within 1 to 3 meters of the surface, the surficial geology consists of gravelly clay with sand. Cobbles and boulders are present at depths greater than 2.0 m. The presence of cobbles and boulders in the existing OC channel (Figure 3-1) and the borehole logs suggest that this material is likely a lag deposit derived from glaciofluvial deposition during the late phases of the Wisconsinan ice sheet retreat (Moran 1986). Although contemporary fluvial activity may remobilize some fractions of the lag deposit, widespread transport under current baseline conditions is unlikely. This assumption is based on a bankfull discharge in the OC of approximately 1.0 m^3/s, as estimated from monitoring data. Sufficient boundary shear stress is not able to exerted on the channel bed at this flow rate and depth to mobilize and transport larger cobble and boulder size sediment.

Discharge from the LLO was set at a constant rate. The discharge rates applied in the shear stress analysis were: 1; 5; 10; 15; 20; 25; 30 and 60 m^3/s. A discharge of 30 m^3/s represents the currently planned maximum discharge rate of the LLO. A release rate of 60 m^3/s is included for comparison. An unsteady flow solver was run for a minimum of 24 hours for each discharge rate using a 5 x 5 m computational grid for a total of 29,198 elements. Note that this analysis is a snapshot in time and sustained release over multiple days will likely result in channel morphology changes that will change the distribution of shear stresses.

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The post-2013 LiDAR DEM was used to delineate the OC and floodplain area. Vegetation was mapped based on 0.45 m resolution imagery and classified into five categories. For modeling, each of these vegetation categories as well as the OC was assigned a Manning's *n* value to represent roughness as based on the literature (Sturm, 2001). The values used are summarized in Table 3-1.

Table 3-1 Landcover category and associated Manning's n value

Category	Manning's n Value	Area (m^2)	Area (%)
Barren	0.11	5994	2
Grass	0.035	154,201	48
Shrub	0.07	69,000	21
Trees	0.1	95,114	29
Water/Wetland	0.05	117	< 1
Total	-	324,427	100

4. RESULTS AND DISCUSSION

4.1 OBSERVATION OF HISTORIC EVENT BASED EROSION

The DEM differencing between the pre- and post-2013 high flow event in the OC is shown in Figure 4-1. The differencing suggests that channel erosion during the 2013 high flow event was not widespread. Erosional zones identified in Figure 4-1 correlate well with the erosional features show in Figure 2-1. Examination of the 0.45 m resolutions also confirms zones of active erosion identified in the DEM differencing.

Figure 4-1 Locations of channel erosion on the OC as a result of the 2013 high flow event

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4.2 SHEAR STRESS MODELLING

The results from the HEC-RAS modeling of shear stresses under different flow rates are shown in Figure 4-2 to Figure 4-5. The shear stress value of 48.5 N/m^2 has been used as a threshold value in the mapping. Where shear stresses are below this value, the potential to mobilize a D_{50} of 50 mm is reduced and a result, is coded blue in the mapping. Shear stresses above threshold are divided into classes of 50 N/m^2 with the colour gradation indicating increasing shear stresses.

Based on this high-level analysis, boundary shear stresses theoretically capable of mobilizing particle sizes greater than 50 mm become more widespread with flow rates of approximately 15 m^3/s and higher. The results suggest that under a flow rate of 30 m^3/s, widespread bed mobilization is possible along the majority of the existing channel bed and banks. This mobilization would likely result in widespread channel and bank erosion along the majority of the current OC, with associated increases in suspended sediment as the bed and banks are actively mobilized. Given that the results presented are for an instantaneous moment in time, sustained release increases the likelihood of planform changes as the OC adjusts to a regime shift. Modeling the extent and type of planform change, for example, braiding is beyond the scope of this memo.

Although the HEC-RAS results provide a guide to the erosion potential along the OC under different flow rates, there are several caveats to interpreting the results. The modeling was done based on an assumption of uniformity in the D_{50} in the OC. Particle sizes will vary along the channel length and as a result the critical shear stress will change resulting in some zones being more resistant to erosion and others less resistant. This variability is not captured in the model results. The model was not run dynamically. As a result, the distribution of shear stresses and the morphological response to those shear stresses will change during release at any rate. These changes will result in shifts in the location of degradation and aggradation down the OC. As a result, the results presented here are a guide only to erosional potential in the OC and are not definitive.

Figure 4-2 Shear Stress Distribution under 1 m^3/s and 5 m^3/s

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Figure 4-3 Shear Stress Distribution under 10 m^3/s and 15 m^3/s

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Figure 4-4 Shear Stress Distribution under 20 m^3/s and 25 m^3/s

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Figure 4-5 Shear Stress Distribution under 30 m^3/s and 60 m^3/s

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5. REGULATORY SETTING

No recent regulatory precedent exists for the type of operation planned for the LLO (R Poon, Alberta Environment and Parks, pers. comm. 2016). As a result, the following discussion is preliminary and may not accurately reflect the ultimate regulatory requirements.

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The construction and operation of SR1 will be covered under one provincial Water Act approval that includes any activity in a water body that involves wetlands or re-alignment of streams. However, operation of SR1 and subsequent release into the OC will also require authorization from the Department of Fisheries and Oceans Canada (DFO) under the federal Fisheries Act. An authorization under the Fisheries Act is required when there is potential serious harm to fish or fish habitat that are part of, or support, a commercial, recreational and Aboriginal fishery. The Elbow River qualifies as this type of fishery. The OC , or at least portions of it, will also likely qualify as a fishery as it is a tributary of the Elbow River. The OC has not yet been assessed by a Qualified Aquatic Environmental Specialist (QAES) but it is likely that the OC, from a fish habitat perspective, is low quality habitat. Fish are present, at least seasonally, in the lower reaches of the OC and given the results of the HEC-RAS analysis, impact to fish habitat and increases in suspended sediment is likely during a release event. If this impact can be avoided or mitigated, then an authorization for operational release into the OC may not be required. The requirements for what constitutes mitigation for the SR1 project will need to be discussed with DFO.

If the mitigations applied do not fully mitigate the impact, the next criterion is determination of whether the residual impact will result in serious harm to fish. If this residual impact is unavoidable, then the harm to the fishery can be addressed by some form of offsetting. The form of offsetting required is case specific and will require consultation with DFO. If offsetting is applied, an offsetting plan will need to be submitted. A key component of this plan is that it must demonstrate that the offsetting measures will maintain or improve the productivity of fisheries. Public interest may also be taken into account where the project plays a role in the well-being of society at a given place and time. The weighting of the public interest factor is at the discretion of the Minister.

A further complication that will require consultation with regulators is the timing of releases from SR1 that could induce erosion of the OC and subsequently deposit sediment into the Elbow River. The Elbow River is subject to a Restricted Activity Period (RAP) from May 1st to July 15th and September 1st to April 15th under Water Act Code of Practice legislation to protect sensitive life stages of fish. During these periods, any instream activity that can result in increased levels of suspended sediment above CCME (Canadian Council of Ministers for the Environment) guidelines for protection of aquatic life are to be avoided. Release of water down the OC after a flood control event on the Elbow River is likely to occur during the RAP and will likely increase suspended sediment transport in the OC when flow rates approach the bankfull discharge. To obtain authorization to work (discharge) during a RAP will require a Water Act approval and must be prepared by a QAES. It is possible to request an amendment to work in a RAP on an existing Water Act approval.

In summary, the SR1 project, including the OC, will fall under the Fisheries Act and require an authorization. Further information is required from the Aquatics Team on fish presence and the quality of fish habitat before next steps can be recommended. These recommendations should come from a QAES. It is also highly unlikely that the OC will be considered in independence of the Elbow River by DFO or under the Water Act, given that the Elbow River is important fish habitat and the OC is a tributary.

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6. RECOMMENDATIONS

- Where possible, and as determined by the size of the flood event being diverted from the Elbow River, discharge from the LLO be maintained within a range to minimize erosion potential in the OC and the Elbow River.
- Regulatory strategy should be discussed with a QAES after a fisheries habitat assessment has been completed for the OC. This assessment is scheduled for the week of September 19th to 23rd, 2016.

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7. REFERENCES

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