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# BGC Project Memorandum

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| **To:** | **Town of Canmore** | **Doc. No.:** | **TC14-006** |
| **Attention:** | **Felix Camire** | **cc:** | **Andy Esarte** |
| **From:** | **Matthias Jakob** | **Date:** | **October 14, 2014** |
| **Subject:** | **Bow River – Cougar Creek Sedimentation Considerations** | | |
| **Project No.:** | **1261-012** | | |

## 1.0 INTRODUCTION

The Town of Canmore (ToC) is planning to construct a debris retention structure (the structure) upstream of the fan apex on Cougar Creek to protect the town from future debris floods and landslide dam outbreak floods. This structure will withhold sediment during debris floods, but allow bedload to pass the structure under average flood conditions. Following significant debris flood events, the sediment upstream of the structure would be excavated and transported to a specified disposal site.

The ToC wishes to understand the potential consequences of reduced sediment inputs from Cougar Creek to Bow River as a result of the structure. BGC Engineering Inc. (BGC) was requested by the ToC to comment on this issue. This memorandum describes qualitatively the potential consequences of reduced sediment supply, as well as options to document past and future morphologic changes and plan for adaptive measures should those be required.

## 2.0 FLUVIAL GEOMORPHOLOGY

### 2.1. Bow River

In the vicinity of Canmore, the Bow River has a wandering river morphology. This type of river is characterized by an irregularly sinuous channel, frequent wooded islands, and low-order braiding (Desloges and Church, 1989). These rivers typically have a network of perennial, seasonal and abandoned back-channels within the adjacent floodplain. Channel morphology in these rivers is dominated by the erosion, transport and deposition of coarser sediments (gravels and cobbles), which are deposited and stored locally within the channel (Ham and Church, 2002). Because the water must flow around the deposited sediments, the river current erodes adjacent banks to create flow conveyance. The end result is a moderate level of lateral instability. These types of rivers, or at least specific morphologically similar reaches, are typically aggrading or at least in equilibrium (where sediment transport in equals sediment transport out), otherwise the river would revert to a single-thread channel with a less complex morphology.

The wandering morphology appears to be sustained for the most part by sediment inputs upstream of Canmore, as the river has a multi-channel planform further upstream and tributary watersheds within the town boundaries, while prone to debris floods (e.g. Three Sisters Creek, Stoneworks Creek, Cougar Creek), are mostly disconnected from the main valley bottom. This disconnect is a result of a wide valley bottom that has allowed large alluvial fan complexes to build out onto the floodplain of the Bow River. Sediment transported on these tributaries preferentially deposits on the large alluvial fan complexes rather than passing through into the river itself, which has sufficient room to migrate laterally rather than erode into the fan deposits. Cougar Creek is a good example of this process, having built up a very large alluvial fan (3.1 $km^2$) since deglaciation of the area thousands of years ago.

## 2.2. Cougar Creek Confluence

The confluence of Cougar Creek with the Bow River occurs on an almost 1 km wide portion of the Bow River floodplain. Cougar Creek does not directly discharge into the main channel Bow River, but instead connects via side channels approximately 340 m north of the main river, and immediately downstream of the confluence with Policeman Creek (Figure 2-1). At this confluence, a small gravel bar has developed that demonstrates occasional gravel transport into this side channel.

During the 2013 debris flood on Cougar Creek, BGC (2014) estimated that approximately 90,000 $m^3$ of sediment was deposited on the fan complex. This volume estimate is based on a 2009-2013 comparison of LiDAR data. An additional amount of fine gravel and sand would have been deposited into the side channel and transported downstream; however, it is obvious from air photographs taken after the event that the proportion of bedload deposited into the Bow River was likely an order of magnitude less than what was deposited on the fan itself.

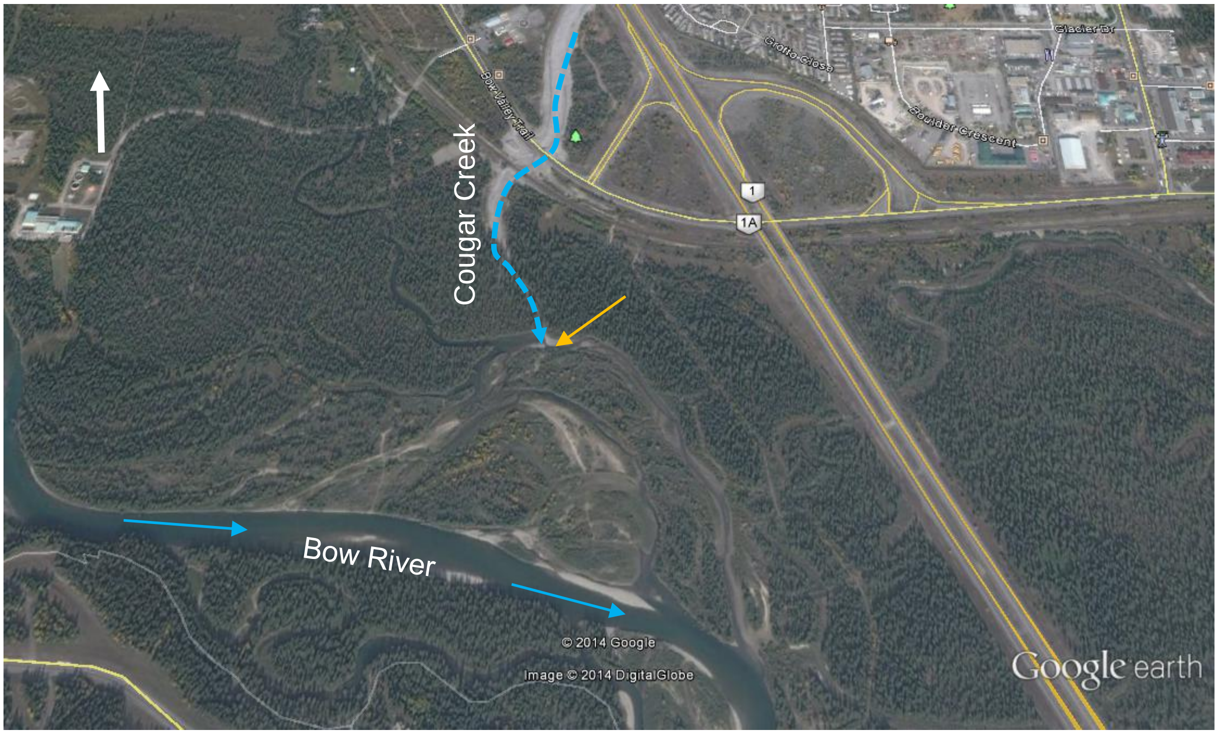


**Figure 2-1. Confluence of Cougar Creek with Bow River floodplain. The orange arrow shows the point of confluence. Image Google Earth.**

A field visit was conducted on October 7, 2014 by Dr. Matthias Jakob of BGC to view the confluence. Figure 2-2 shows a medial gravel bar on the south side of the side channel (continuation of Policeman Creek) that was deposited during the 2013 event (not visible on the 2008 orthophotos). This gravel bar has persisted to today. It is expected, however, that over time this gravel bar will be eroded during periods of high flow from Bow River and Policeman Creek.

Upstream of the confluence, the channel of Cougar Creek still shows significantly more sediment than visible on 2008 air photographs (Figure 2-3). This material, which is largely between 11 mm to 64 mm in diameter will be transported over time to Policeman Creek. However, upstream between the confluence and the CP Railway (CPR) tracks abundant loose sediment is still present in Cougar Creek, which would also be mobilized during high flows leading to further sedimentation.

**Figure 2-2. Gravel bar on the south side of Policeman Creek at the confluence with Cougar Creek which was likely deposited during the June 2013 debris flood. Photo looking west. BGC photograph of October 7, 2014.**


**Figure 2-3. Comparison of 2008 (left) and 2013 (right) orthophotos for the area near the confluence of Cougar Creek (coming in from the north) and Policeman Creek. The new gravel bar is shown by a red arrow.**

# 3.0 POTENTIAL SEDIMENT TRANSPORT IMPACTS

## 3.1. Assessment

The recommended debris barrier structure on Cougar Creek is designed to allow normal stream bedload to reach the Bow River. In extreme events, namely debris floods and landslide dam outbreak floods, coarse sediment and water (for landslide dam outbreak floods) would be stored. Water would be released through grillages and a water tunnel, while sediment upstream of the structure would need to be excavated following an extreme event. Coarse sediment (gravel to boulder size) passing the structure would continue to be deposited upstream of the Bow River – Cougar Creek confluence, while finer bedload would still be delivered to the Bow River floodplain on a regular basis during high flows irrespective of the structure in place. As a result, BGC does not expect significant changes in the sediment input to the Bow River.

## 3.2. Documentation

The potential concern with the structure in place is that the channel morphology of the Bow River would be simplified due to reduced sediment inputs. As an extreme case, if all Bow River tributaries were dammed and sediment delivery to the river cut off, the river would respond by downcutting into its alluvial gravel bed. This would, over time, lead to a change from a wandering channel with numerous channels to a single-thread channel and the development of river terraces, that, unlike floodplains would no longer be inundated during flood flow. Such river planform changes can have profound effects on local fish species, as gravel transport in general is beneficial to fish habitat, as it leads to the renewal and turnover of micro and macro habitats. As noted above, such drastic or even minor changes are not expected to occur on Bow River due to the construction of the structure near the fan apex of Cougar Creek.

Concerns about changes in channel morphology could be allayed by a historical air photo assessment. This method involves:

- acquiring air photographs for approximately every decade (many of which are already available), starting with the earliest known photographs in 1947;
- orthorectification of the air photographs; and
- mapping of the channel planform (i.e. gravel bars, islands, wetted channel) for each year.

Such an analysis would demonstrate how the Bow River morphology has changed over time. Rates of channel migration and gravel bar development can be estimated by overlaying the channel planforms in a GIS environment. It is also possible that black and white historical photographs from surveys in the late 1800s or historic ground surveys can be used to supplement the air photo record. Future channel changes could then be measured against the rates observed in the past. Such changes would be assessed every 10 years.

It should be noted, however, that the current Bow River channel morphology has been modified by past human disturbances. During the coal mining days, waste rock was directly dumped directly into the Bow River, as seen on the 1947 air photographs. The river is also dyked through the town centre, which may limit the natural lateral instability of the river. The interplay between channel disturbance and channel response is complex, and channel adjustments to disturbances can occur over many decades (e.g. Weatherly and Jakob, 2014). Therefore, an assessment of channel changes in the past century must consider these factors.

## 3.3. Potential Mitigation Options

The long-term monitoring of river planform changes, including the distal portions of Cougar Creek fan, can result in three possible outcomes: no discernable change, increased channel supply leading to more side channels and gravel bars, or decreased sediment loads leading to channel simplification.

In the case of no discernible change, human intervention is not warranted. An increase in sediment supply compared to pre-construction conditions is highly unlikely since it is expected that less material would be introduced during episodic extreme runoff events unless the CP rail culverts are replaced with a single span bridge. In that case, sediment may be washed into the lower reaches of Cougar Creek downstream of the railway tracks, necessitating less gravel removal. In the case of a simplified channel morphology that can be associated with reduced sediment supply from Cougar Creek, sediment could be reintroduced to the lower (downstream of the CPR tracks) channel reaches of the creek without dumping gravel directly into the Bow River. With this option, a portion of the sediment removed from the debris barrier could be trucked to the lower creek and reintroduced to the system. This approach would constitute an adaptive management strategy for the creek.

# 4.0 CLOSURE

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Yours sincerely,

**BGC ENGINEERING INC.**
**per:**

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APEGA Permit to Practice No.: P5366

HW/MJ/mp

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