TETRA TECH EBA

TECHNICAL MEMO

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To:	Erik Pit A / Senior Project Manager	**Date:**	March 31, 2016
c:		**Memo No.:**	001
From:	Justin Pigage, P.Eng.	**File:**	ENG.WARC03039-01.006
Subject:	Fish Passage Memo Clinton Creek Mine Site, YT		

1.0 INTRODUCTION

Government of Yukon, Assessment and Abandoned Mines (AAM) have retained Tetra Tech EBA Inc. (Tetra Tech EBA) to assist with the summary and evaluation of geotechnical information related to closure of the abandoned Clinton Creek asbestos mine near Dawson City, Yukon. This memo presents proposed engineering mitigations to the closure options being considered to improve fish passage in Clinton and Wolverine creeks. The closure options being considered were evaluated from a fish passage perspective in the "Clinton Creek Site: Fish Utilization and Passage" report submitted in draft by AvF R&D in March 2016 (AvF 2016). The report summarizes current fish passage in Clinton and Wolverine creeks, and evaluates anticipated fish passage conditions for the closure options being considered.

2.0 CLOSURE OPTIONS

Project parties are considering several closure options for remediation of the Clinton Creek and Wolverine Creek valleys.

2.1 Clinton Creek

The proposed closure options currently being considered for the Clinton Creek valley are summarized below in Table 2.0. These are presented in more detail in the Life Cycle Cost Analysis for Remediation Options report prepared by Worley Parsons (Worley 2014).

Table 2.0 – Clinton Creek Valley Closure Option Summary

Closure Options	Clinton Creek Channel	Clinton Creek Waste Rock Dump	Hudgeon Lake
C3	Armour channel with riprap	No remediation	No remediation
D3	Armour channel with riprap	Stabilize waste rock dump	No remediation
E3	Lower channel and armour with riprap	Stabilize waste rock dump	Lower lake water level
F	Restore channel to valley floor	Remove waste rock to open pits, exposing valley floor	Fully drain lake
I2	Construct armoured channel south of existing channel over waste rock	Stabilize waste rock dump	No remediation

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2.2 Wolverine Creek

The project parties have not yet agreed on a set of closure options to consider further for the Wolverine Creek valley, but for the purpose of fish passage evaluation this is not considered necessary as fish travel above the existing rock weir on Wolverine Creek is not likely in any of the available options due to steep channel grades and low flows. General mitigations presented below apply to fish passage in Wolverine Creek but discussion of specific closure options is not included for the reasons stated above.

3.0 FISH PASSAGE

The draft report prepared by AvF R&D details the pre-mining aquatic baseline conditions, current fish passage conditions in the Clinton and Wolverine creeks, assesses the effects of Hudgeon Lake on downstream aquatic life, and evaluates the anticipated fish passage conditions for the closure options being considered by the project parties. The following sections (3.1 through 3.4) summarize the findings that are presented in greater detail in the draft AvF Fish Utilization and Passage report.

3.1 Pre-mining Aquatic Baseline Conditions

The Clinton Creek site was developed prior to regulatory requirements to collect aquatic baseline information. The most reliable source of information for pre-development aquatic conditions are historic air photos. Clinton Creek had a relatively low and constant gradient. Wolverine Creek had a low gradient near the confluence with Clinton Creek but ascended much more quickly into the upper watershed.

AvF concluded “The same fish species use Clinton Creek today as would have used Clinton and [Wolverine] Creeks prior to mine development, and in much the same manner.”

3.2 Current Fish Passage

Fish passage above the drop structures in Clinton Creek is not currently possible because summer flows do not provide a deep enough channel for fish movement.

Fish passage in Wolverine Creek is not currently possible because of the access road culvert at the confluence with Clinton Creek. It is anticipated that without the culvert, fish passage up to the first tributary entering from the east would be possible, but the rock weir structure and creek gradients would prevent fish passage in upper Wolverine Creek.

3.3 Effects of Hudgeon Lake

Hudgeon Lake collects significant solar energy. This energy, combined with the water quality of the lake has resulted in a large volume of nutrients in its thermally heterogeneous outflow, allowing for a large crop of algae to grow downstream of the lake. The algae serves to increase the growth rate of invertebrates, and this abundance of invertebrates support the fish population.

There is a risk of a large-scale release of water from Hudgeon Lake. If this release were to occur it would likely displace fish downstream and/or destroy fish habitat in Clinton Creek. The effects of the release would be present for years to decades until the creek reaches another equilibrium state.

3.4 Anticipated Fish Passage

AvF anticipates that the majority of closure options for Clinton Creek will allow fish passage into Hudgeon Lake immediately following construction but cautions that sustained access will not be possible in most cases without proper channel maintenance due to anticipated blockages from beaver activity:

- Option F will allow the greatest access for fish upstream in Clinton Creek. The manufactured channel is designed to mimic a natural channel, with a gradient of approximately 1% and a channel bottom of material similar to that found in natural channels.
- Options C3, D3, and E3 will allow fish passage upstream in Clinton Creek. The manufactured channel will have a gradient of approximately 4.5% and will be lined with armouring riprap with a median diameter of 500 mm.
- Option I2 will not allow fish passage into Hudgeon Lake because a portion of the manufactured channel has an 8% gradient, which is too steep for fish passage.

4.0 MITIGATIONS TO IMPROVE FISH PASSAGE

Through discussions with the project parties and the project biologist during a fish passage meeting hosted by AAM on March 9, 2016, several mitigations to improve fish passage for the closure options being considered were identified. These mitigations range from general design modifications proposed for all of the considered closure options to specific design modifications explicit to individual closure options. Proposed mitigations to increase fish passage that should be considered further during the future phases of closure option selection and design to increase fish passage are summarized in the following sections.

4.1 Channel Maintenance

The following Table 4.0 summarizes the inspection schedule proposed by Worley Parsons in the Life Cycle Cost Analysis for Remediation Options report (Worley 2014) for each of the closure options being considered and the anticipated maintenance requirements.

Table 4.0 – Clinton Creek Closure Option Inspection Schedule and Maintenance Requirements

Closure Options	Description of Activity
C3	The riprap channel and waste rock pile would require annual visual inspections. It is estimated that the creeping waste rock pile will necessitate replacing the channel approximately every 45 years if movement continues.
D3	The riprap channel and waste rock pile would require annual visual inspections. Regular maintenance of the channel is not anticipated if the channel is properly constructed and the waste rock pile is properly stabilized.
E3	The riprap channel and waste rock pile would require annual visual inspections. Regular maintenance of the channel is not anticipated if the channel is properly constructed and the waste rock pile is properly stabilized.
F	The waste rock pile and the Clinton Creek channel would require visual inspections every two years for approximately 10 years post-construction to ensure the structures are operating as expected.
I2	The riprap channel and waste rock pile would require annual visual inspections. Regular maintenance of the channel is not anticipated if the channel is properly constructed and the waste rock pile is properly stabilized.

All five short listed closure options require annual inspections (every two years for Option F) for at least the first ten years after construction. The inspections and subsequent maintenance recommendations should incorporate fish passage considerations. This will likely be limited to recommendations to remove dams constructed by beavers

but could extend to channel reconstruction works if extreme flood events negatively impact fish passage by displacing instream channel features. Channel inspection and maintenance will promote fish passage in the longer term by ensuring the channel is operating as the design intends.

4.2 Channel Shape

Current conceptual designs feature a flat bottomed manufactured Clinton Creek channel armoured against erosion with riprap. To accommodate freshet and design precipitation events the bottom of the manufactured channel measures 7.0 m across. Flows in Clinton Creek vary considerably from season to season and will likely not be high enough to sustain fish passage with such a wide channel bottom. Additional consideration should be given to incorporating a composite channel in place of the current flat bottom channel. Composite channels feature a smaller channel notched into the base of a larger channel. The notched channel maintains flow sufficient for fish access during low flow seasons while the larger channel provides capacity for design flood events. A comparison of the current flat bottomed channel cross section and proposed composite channel cross section is shown in the following Figure 4.1

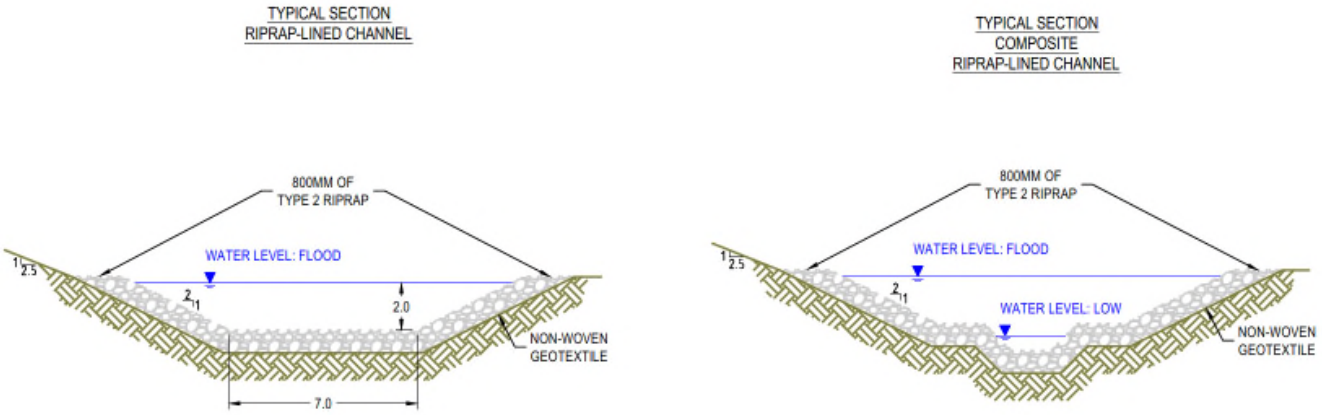

Figure 4.1: Flat bottom (left) and composite channel (right) conceptual cross sections

4.3 Channel Features

Current conceptual designs for the manufactured Clinton Creek channel are lined with a uniform layer of riprap for erosion protection. Incorporating riffle-pool sequence features more prominent in natural channels by implementing directional changes and placing larger boulders and other natural obstructions would enhance fish passage and provide over wintering habitat. Riffle-pool sequence channel features to promote fish passage should be incorporated in subsequent phases of design. A meandering channel with riffle-pool sequence features is likely more achievable under Closure Option F where a wide valley floor is available for channel construction. We acknowledge it may not be possible to incorporate a meandering channel with riffle-pool sequence features in other more spatially restricted closure options but have included this as a general recommendation as some of the techniques, such as boulder placement, can be incorporated into channel design regardless of closure option selection. A schematic diagram of a meandering stream channel showing a typical riffle-pool sequence design is shown in the following Figure 4.2

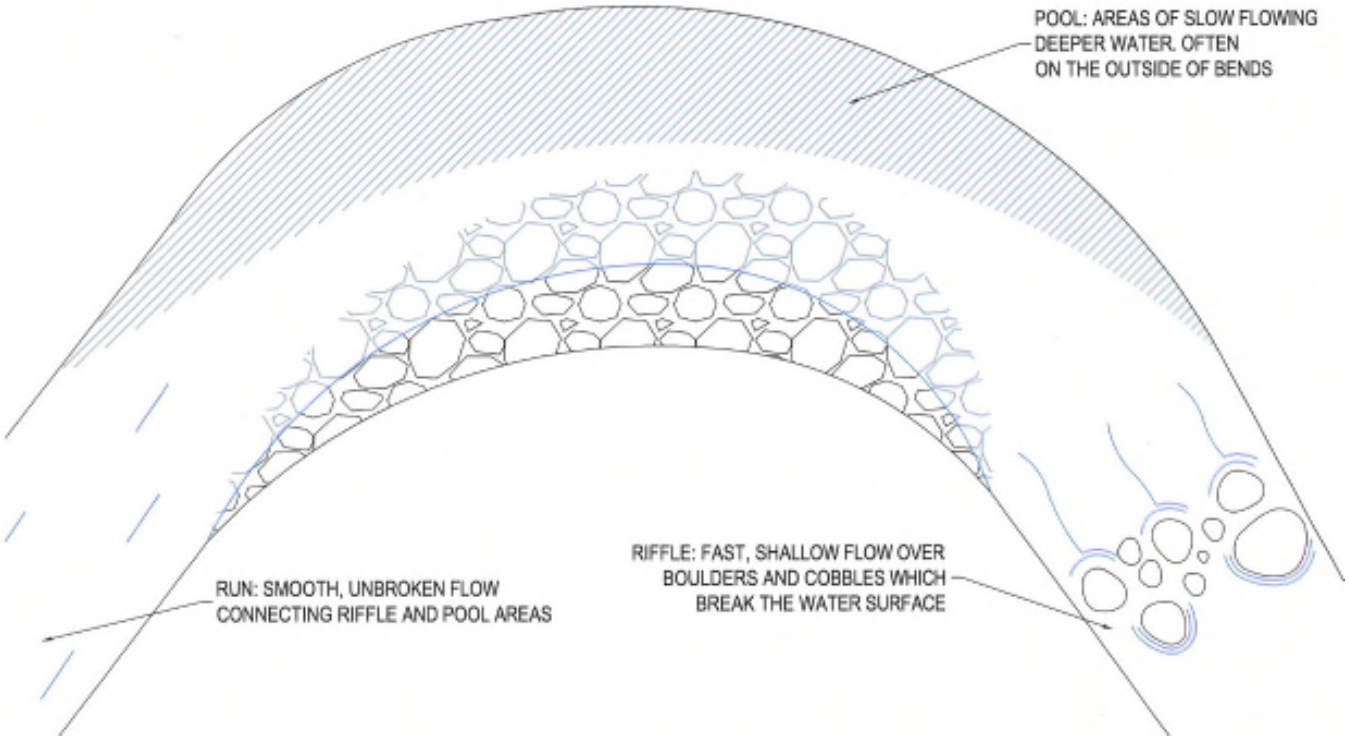

Figure 4.2: Riffle-pool sequence channel feature

4.4 Closure Option I2 – Channel Grade Modification

Closure option I2 relocates the centreline of the manufactured Clinton Creek channel about 50 m south to allow for the placement of waste rock in the existing Clinton Creek channel in an effort to provide toe resistance to arrest the continued movement of the Clinton Creek waste rock pile. The proposed channel alignment is 700 m long and is graded at 2% except for a 300 m section that is graded at 8%. As previously discussed, 8% is too steep to allow fish passage.

Consideration should be given to designing a longer manufactured channel to allow for a reduction of grade within the 8% section. Reducing the grade within that section from 8% to 4.5% (a grade more reasonable for promoting fish passage) would increase the overall channel length by about 250 m (950 m overall manufactured channel length). The manufactured channel would meet the existing Clinton Creek channel at station 1+030.

More favourable conditions for fish passage could also be achieved by designing a manufactured channel with an overall grade steeper than the proposed 2%. Increasing the overall grade to 4.5% would result in a channel approximately the same length as presently designed (710 m overall manufactured channel length).

It should be noted that both of the above proposed mitigations will significantly increase the volume of material to be excavated from the waste rock pile as the current I2 Closure Option more closely follows the elevation profile of the existing waste rock pile. Additionally, removing more waste rock from the toe region of the pile will decrease overall pile stability (typically mass at the toe of a structure provides resistance to failure). Determining the viability of such modifications to the I2 closure option design is beyond the scope of this memo.

5.0 CLOSURE

We trust this technical memo meets your present requirements. If you have any questions or comments, please contact the undersigned.

Respectfully submitted,
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REFERENCES

AvF R&D (2016). “Draft - Clinton Creek Site: Fish Utilization and Passage”.

Worley Parsons Group (2014). “Clinton Creek Site Lifecycle Cost Analysis for Remediation Options”.