HIGHLAND VALLEY COPPER
H-H DAM BREAK AND TAILINGS RUNOUT STUDY

FINAL REPORT

Submitted to:
Teck Highland Valley Copper Partnership
P.O. Box 1500
Logan Lake, British Columbia
V0K 1W0

Submitted by:
AMEC Environment & Infrastructure,
A Division of AMEC Americas Limited
Fredericton, New Brunswick

February 2014
TE1330191.1000
26 February 2014

TE1330191.1000

Mr. Chris Fleming
Superintendent Tailing and Water Management
Highland Valley Copper
P.O. Box 1500
Logan Lake, BC V0K 1W0

Dear Mr. Fleming:

Re: Final Report-H-H Dam Break and Tailings Runout Study

Please find enclosed the above-noted final report.

Please contact the undersigned if you have any questions regarding the enclosed.

Sincerely,

C.A. (Andy) Small, M.Sc., P. Eng
Project Manager
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CAS/cjy
1.0 INTRODUCTION

AMEC Environment & Infrastructure, a Division of AMEC Americas Limited (AMEC) was retained by Teck Highland Valley Copper Partnership (HVC) to conduct a dam breach and inundation study for a number of dams located on its property near Logan Lake, British Columbia. This report documents the study conducted for the H-H Dam. The study has been conducted as per our proposal submitted to HVC in August, 2013.

H-H Dam is a 1.5 kilometres (km) long earthfill embankment dam constructed across a valley. The location of the dam is shown in Figure 1.1. Together with the L-L dam constructed on the opposite end of the valley, it forms the Highland Tailings Storage Facility. It is the active tailings storage facility currently being used by HVC for its operations at the site. Tailings are discharged along the H-H Dam in the form of tailings slurry. The slurry flows toward the L-L dam, depositing the tailings along its path. A tailings beach is formed in the process sloping away from the H-H Dam. There is no water ponding against the H-H Dam during normal and flood conditions.

The 24 Mile Lake, which is used as an emergency water storage facility, is located downgradient and to the southeast of the H-H Dam along the valley (Figure 1.1). The top elevation of the lake is approximately 1220 metres (m) with a maximum storage of approximately 13.5 million cubic meters (m$^3$). The Valley Open Pit is located further south and approximately 3 km from the H-H Dam. In the event the H-H Dam becomes breached with an associated tailings release, there is a potential risk that the tailings runout will enter the 24 Mile Lake, displacing the water storage in the lake. The displaced water may potentially enter the Valley Open Pit and subject the workers in the pit to danger.

The objectives of this study consist of the following:

- to evaluate tailings runout, tailings deposition, and water displacement from the 24 Mile Lake in the event of a breach of the H-H Dam; and
- to recommend classification of the H-H Dam in accordance with the 2007 Canadian Dam Association (CDA) Guidelines.

Due to the absence of water behind the H-H Dam, an inundation study was not conducted for this dam.
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2.0 DESIGN OVERVIEW

The H-H Dam was constructed by the centerline method over competent glacial overburden foundation. The dam has an imperious central glacial till core and downstream earth and rockfill shell.

A plan view of the H-H Dam alignment is shown in Figure 2.1. A typical section showing the construction of the H-H Dam is shown in Figure 2.2.

The H-H Dam was constructed through a series of raises. The original ground at the dam site was at an elevation of approximately 1179.6 m. As of 2012, the dam was constructed to an elevation of 1264.4 m. The ultimate design elevation for the dam is at 1292.7 m, which will be reached in approximately 2028. The current height of the dam is approximately 84.8 m (El. 1264.4 – El. 1179.6). The final H-H Dam height at closure is estimated to be 113.1 m (El. 1292.7 – El. 1179.6) at its highest section.
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NOTES:
1. In 1993, downstream construction practices changed from the placement and mechanical compaction of natural borrow materials to the end dumping and haul truck compaction of pit waste rock.
2. The shaded area represents 1993-2012 fill zones.
3. Final minimum average downstream slope of 2.5H:1v will be constructed as a series of benches.

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SOURCE:
Based on KLOHN CRIPPEN BERGER M02341A3401, DWG A=21007 (r7)

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PROJECT:
HIGHLAND VALLEY COPPER
H-H DAM BREAK AND TAILINGS RUNOUT STUDY

TITLE:
H-H DAM TYPICAL SECTION

DATUM:
NAD 83

PROJECTION:
UTM Zone 10 North

SCALE:
1:150,000

SOURCE:
Based on KLOHN CRIPPEN BERGER M02341A3401, DWG A=21007 (r7)
3.0 TAILINGS RUNOUT EVALUATION

As indicated previously, there is no standing water ponding against the H-H Dam under normal and flood conditions, therefore, this dam is not susceptible to flood induced failure. However, this dam is potentially susceptible to earthquake induced failure or other unspecified failure mechanisms.

Only about 1.5 percent (%) of historical failures of embankment dams have been attributed to earthquakes (United States Department of the Interior, Bureau of Reclamation, 2012). The shaking motion during an earthquake could cause the earthfill material to liquefy and lose its shear strength. The reduction in shear strength may potentially cause the embankment slopes to deform, flatten, slide and fail. The crest elevation of the dam may drop, with large longitudinal cracks developing along the dam alignment. There may also be differential settlement along the dam alignment. Earthquake will significantly reduce the ability of the earthfill dams to contain its contents. In the most severe condition, the embankment dam may fail, causing the contents (tailings, water) behind the dam to be released.

An embankment dam may fail during an earthquake and release its contents. Under this scenario, there will be very little advanced warning for emergency measures to be implemented to reduce potential losses, particularly when the loss of life (LOL) may be expected. An embankment dam may also fail after the earthquake. Under this scenario, there will be time available to evacuate the potentially affected population or workers, as well as properties of significance.

An earthquake may potentially cause significant damage along the entire alignment of the dam. However, in the case of the H-H Dam, it is likely that the dam will retain a portion of its containment ability even through the most severe earthquake. For example, if the embankment slope on the downstream side fails, and the crest of the dam is dropped as a consequence, the lowered dam crest will continue to provide containment to the tailings storage behind the dam, although this containment will be a fraction of its former capacity prior to the earthquake.

AMEC (2012) conducted a dam safety review of H-H Dam and concluded that the dam would be stable under a 1 in 5,000 year return period seismic event with a peak ground acceleration (PGA) of 0.24 g (where g is the acceleration due to gravity). Hence, the likelihood of failure of H-H Dam through a seismic event is very low, but when conducting a dam break analysis, the CDA (2007) Guidelines state that a hypothetical dam breach should be considered. The probability of the dam breach is not an explicit consideration. Hence, for this analysis, we assumed that a breach could hypothetically develop during a seismic event, but it would have very low probability.

The volume of tailings runout is dependent on many complex factors, including the damaged condition of the dam and the liquefied state of the tailings after the earthquake. The tailings runout will form a beach downstream of the dam. The final slope of the beach will be such that the sliding force on the tailings mass resulting from the slope is balanced by the internal friction in the tailings mass. In the absence of water flow (other than the water that will flow with the
tailings as a liquefiable mass), the migration of the tailings runout will be governed by this
terminal slope and will be limited. For the purpose of this study, it is assumed that the breach
will occur along the entire alignment of the H-H Dam. This breach scenario is the most severe
and will result in the highest volume of tailings runout.

There is uncertainty regarding the terminal slope of the tailings runout, and this slope is
dependent on the liquid content of the tailings runout. Literature found in the course of this
study (Blight G.E. and Fourie, 2003) documented the final slopes resulting from flow failure
(liquefied failure) ranging from 2-4%. In a study for a similar facility (AMEC, 2013), AMEC
adopted a slope of 5%.

For the purpose of this study, tailings runout distance from the H-H Dam was estimated using a
final slope of 3%, which was judged to be a conservative value. The elevation of the 3% line is
placed such that the cut volume (indicating tailings runout from the impoundment) and fill
volume (indicating tailings deposition) are approximately balanced. The final slope and
elevation of the tailings runout is shown in section in Figure 3.1 and on plan view in Figure 3.2.

The findings from this study suggest that the tailings runout will approximately reach the
southern limit of the 24 Mile Lake and displace a portion of the water in the lake. The volume of
the water displacement is dependent on the breach dimension and configuration, the water level
at the time of the dam breach in 24 Mile Lake, and the height of the H-H Dam at the time of the
breach.

If the water level in the 24 Mile Lake is low at the time of the dam failure, the water displacement
may result in a water level rise; or if the water level is high, a spill into the Valley Open Pit may
result. HVC advised that the 24 Mile Lake was used as an emergency water dump, and as
such the water level in the lake was not controlled. Therefore, it is possible that at the time of
the dam failure, the storage in the lake could be at its maximum capacity. As indicated
previously, the top elevation of the 24 Mile Lake is approximately 1220 m. At this elevation, the
24 Mile Lake has a total storage capacity of approximately 13.5 million m³.

Under current conditions, assuming the lake is full at the time of the dam failure, the water
displacement volume will be approximately half of the total volume of the lake, or seven million
cubic meters. Nearly the entire content of the lake, or 13.5 million m³, may potentially be
displaced under the ultimate design elevation condition of the H-H Dam.

Figure 3.3 shows the elevation and storage curve for the Valley Open Pit. Under the current
configuration of H-H Dam, the water level in the Valley Open Pit may rise from 776 m to
elevation 829 m. Under the ultimate elevation condition of H-H Dam, the water level in the
Valley Open Pit may rise from 776 m to 856 m. However, the Valley Open Pit would also be
expanded at the same time that H-H Dam is being raised, so the actual water level rise under
the ultimate condition will be less than indicated above.
Figure 3.3
Maximum Fill Levels in Valley Open Pit

Potential flood level under ultimate condition
Potential flood level under existing condition
HVC advised that the workers in the Valley Open Pit typically work above elevation 805 m. The water level rise resulting from the displacement of the 24 Mile Lake may potentially exceed this elevation. The flood water will also cut off the escape route by the workers.

The H-H Dam and the tailings impoundment is an important operational asset to HVC. Breach of the dam will cause significant interruption to the mining and milling operations at the site. A pumping station downstream of H-H Dam could also be damaged.
4.0 DAM CLASSIFICATION

4.1 2007 CDA Guidelines

For the H-H Dam, a classification is required for determining the earthquake loading to be used in evaluating the design of the dam as well as inform the surveillance program. A summary of the 2007 CDA Guidelines regarding dam classification is presented in Table 4.1. Based on the 2007 CDA Guidelines, a dam structure is classified by considering the following four consequence categories:

**Population at Risk (PAR):** This considers if population exists in the potentially affected area resulting from the failure, and the permanent nature of the population. If permanent population is present in the potentially affected area, regardless of the size of the population, the dam must be classified as “High and Above”. It should be noted that, unlike the other consequence categories, PAR is determined based on the total population that may be affected, rather than the incremental population resulting from the failure of the dam.

**Incremental LOL:** This is the potential life that may be lost as a consequence of the failure of the dam structure. CDA provides benchmark values for the incremental LOL.

**Incremental Loss of Environmental and Culture Values:** This is the potential loss that may be incurred as a consequence of the failure of the dam structure. CDA provides qualitative descriptions for guiding the evaluation of this consequence category.

**Incremental Loss of Infrastructure and Economics:** This is the potential loss that may be incurred as a consequence of the failure of the dam structure. CDA provides qualitative descriptions for guiding the evaluation of this consequence category.

4.2 Classification for H-H Dam

**PAR:** The Valley Open Pit is located downgradient from the H-H Dam, and there are workers in the pit on a regular basis. Therefore, the PAR is assessed to be “Permanent”, and the dam classification for this consequence category is assessed to be “High and Above”.

**Incremental LOL:** There are often more than 100 workers in the Valley Open Pit. Displacement of water from the 24 Mile Lake may cause rapid water level rise and cut-off of the escape route by the workers. This may result in a potentially high fatality rate. However, given the number of workers in the Valley Open Pit, the total number of fatality is unlikely to exceed 100. Therefore, the dam classification for this consequence category is assessed to be “Very High”.

Table 4.1 CDA Dam Classification Guidelines

<table>
<thead>
<tr>
<th>Dam Class</th>
<th>PAR(^1)</th>
<th>Incremental Losses</th>
<th>Environmental and Cultural Values</th>
<th>Infrastructure and Economics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LOL(^2)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>None</td>
<td>0</td>
<td>• Minimal short-term</td>
<td>Low economic losses; area</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• No long term loss</td>
<td>contains limited infrastructure or services</td>
</tr>
<tr>
<td>Significant</td>
<td>Temporary only</td>
<td>Unspecified</td>
<td>• No significant loss or deterioration of fish or wildlife habitat</td>
<td>Losses to recreational facilities, seasonal workplaces, and infrequently used transportation routes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Loss of marginal habitat only</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Restoration or compensation in kind highly possible</td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>Permanent</td>
<td>10 or fewer</td>
<td>• Significant loss or deterioration of <em>important</em> fish or wildlife habitat</td>
<td>High economic losses affecting infrastructure, public transportation, and commercial facilities</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Restoration or compensation in kind is highly possible</td>
<td></td>
</tr>
<tr>
<td>Very high</td>
<td>Permanent</td>
<td>100 or fewer</td>
<td>• Significant loss or deterioration of <em>critical</em> fish or wildlife habitat</td>
<td>Very high economic losses affecting important infrastructure or services (e.g., highway, industrial facility, storage facilities, for dangerous substances)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Restoration or compensation in kind possible but impractical</td>
<td></td>
</tr>
<tr>
<td>Extreme</td>
<td>Permanent</td>
<td>More than 100</td>
<td>• Major loss of <em>critical</em> fish or wildlife habitat</td>
<td>Extreme losses affecting critical infrastructure or services, (e.g., hospital, major industrial complex, major storage facilities for dangerous substances)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Restoration or compensation in kind impossible</td>
<td></td>
</tr>
</tbody>
</table>

Notes:
1. Definitions for PAR:
   - **None** – there is no identifiable PAR, so there is no possibility of LOL other than through unforeseeable misadventure.
   - **Temporary** – People are only temporarily in dam-breach inundation zone (e.g., seasonal cottage use, passing through on transportation routes participating in recreational activities).
   - **Permanent** – The PAR is ordinarily located in the dam-breach inundation zone (e.g., as permanent residents); three consequence classed (high, very high, extreme) are proposed to allow for more detailed estimates of potential LOL (to assist in decision-making if the appropriate analysis is carried out).
2. Implication of LOL:
   - **Unspecified** – The appropriate level of safety required at a dam where people are temporarily at risk depends on the number of people, the exposure time, the nature of their activity, and other conditions. A higher class could be appropriate, depending on the requirements. However, the design flood requirement, for example, might not be higher if the temporary population is not likely to be present during the flood season.

Source: This table originates as Table 2.1 from the *2007 Dam Safety Guidelines* of the CDA.
**Incremental Loss of Environmental and Culture Values:** The 24 Mile Lake is not considered to have environmental and culture value. Therefore, failure of the H-H Dam and partial filling of the 24 Mile Lake with tailings will not result in a loss of environmental and culture values. Therefore, the dam classification for this consequence category is assessed to be “Low”.

**Incremental Loss of Infrastructure and Economics:** A dam breach would result in an HVC operation shutdown for an extended period of time. HVC advised that this shutdown could last longer than six months with major economic impacts to the region (employment, spin-off and associated businesses, etc.). Therefore, the incremental loss of infrastructure and economic loss is assessed to be “Very High”.

**Dam Classification:** A summary of the dam classification for each of the four consequence categories included in the 2007 CDA Guidelines is provided in Table 4.2. The highest classification for the H-H Dam is “Very High”, which is assessed for the consequence category of incremental LOL and incremental loss of infrastructure and economics. Therefore, the overall classification for the H-H Dam is evaluated to be “Very High”.

### Table 4.2 Summary of Dam Classification for H-H Dam

<table>
<thead>
<tr>
<th>Consequence Category</th>
<th>Matching Description of 2007 CDA Guidelines</th>
<th>Rational</th>
<th>Consequence Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>PAR</td>
<td>Permanent</td>
<td>There are workers in the Valley Open Pit on a regular basis.</td>
<td>High and Above</td>
</tr>
<tr>
<td>Incremental LOL</td>
<td>100 or fewer</td>
<td>The displaced water from the 24 Mile Lake may cause rapid water level rise in the Valley Open Pit. It will also cut off the escape route by the workers</td>
<td>Very High</td>
</tr>
<tr>
<td>Incremental Loss of Environmental and Culture Values</td>
<td>Minimum short-term loss, no long-term loss</td>
<td>The 24 Mile Lake has no environmental and culture values</td>
<td>Low</td>
</tr>
<tr>
<td>Incremental Loss of Infrastructure and Economics</td>
<td>Very high economic losses affecting important infrastructure or services</td>
<td>Major economic impacts to the region in terms of employment, spin-off and associated businesses, etc.</td>
<td>Very High</td>
</tr>
<tr>
<td>Dam</td>
<td></td>
<td></td>
<td>Very High</td>
</tr>
<tr>
<td>Effect on HVC</td>
<td>Potential loss of the pump house, significant interruption to mining and milling operations, and significant cost for repairing the H-H Dam, loss of other operational asset in the areas downstream of the H-H Dam</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
In a Dam Safety Review (DSR) completed by AMEC (2012), a “Very High” classification was assessed for the H-H Dam for consideration of the potential economic losses to the region in the event production in the Valley Open Pit is interrupted.

**Effects on HVC:** As noted above, breach of the dam will cause significant interruption to the mining and milling operations at the site. Significant cost will be incurred for repairing the dam. A pumphouse is located downstream of the H-H dam. This pumphouse is essential for HVC operations at the site. Breach of the dam may cause significant damage to the pumphouse and the other facilities in the areas downstream of the dam.
5.0 RECOMMENDATIONS

It is recommended that the operation of the 24 Mile Lake be reviewed and a maximum high operating water level be established based on the findings from this study to limit the volume of water spilled into the Valley Open Pit in the event of an earthquake induced failure of the H-H Dam. Modifications may be required to the 24 Mile Lake to handle the hypothetical failure of H-H Dam, such as raising the road on the south side of 24 Mile Lake.
6.0 CLOSING

This report was prepared for the exclusive use of HVC, for specific application to the subject Site. Any use which a third party makes of this report, or any reliance on or decisions to be made based on it, are the responsibility of the third party. Should additional parties require reliance on this report, written authorization from AMEC will be required. With respect to third parties, AMEC has no liability or responsibility for losses of any kind whatsoever, including direct or consequential financial effects on transactions or property values, or requirements for follow-up actions and costs.

We trust that our submission meets your requirements. Please do not hesitate to contact us if you have any questions regarding our report.

Sincerely,

AMEC Environment & Infrastructure,  
a Division of AMEC Americas Limited

Prepared by:                                   Reviewed by:

Hydrotechnical Engineer                       Project Manager
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Email: huixi.xie@amec.com                     Email: andy.small@amec.com
7.0 REFERENCES


