

June 25, 2015

Teck Highland Valley Copper Partnership
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Chris Fleming
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Dear Mr. Fleming:

**HVC Tailings Dams – Trojan Dam - Bethlehem No. 2 Tailings Storage Facility
Response to MEM Memorandum - February 3, 2015**

1 INTRODUCTION

The Independent Expert Panel¹ (Panel) appointed by Ministry of Energy and Mines, British Columbia (MEM) released their report on the Mount Polley tailings dam breach on January 30, 2015. Subsequent to the release of the Expert Panel report MEM issued a memorandum on February 3, 2015 (MEM memorandum), to all tailings dam owners in British Columbia to undertake a specific risk assessment of their tailing dams and report the results to MEM by June 30, 2015.

This report outlines KCB's assessment of conditions at the Trojan Dam of the Bethlehem No. 2 Tailings Storage Facility relative to the specific aspects raised by the MEM memorandum, based on a review of available documents to prepare a "summary of knowledge". This assessment has been sealed by a qualified professional engineer and complies with generally-accepted professional practice common to the local area.

The report format is based on the MEM wording and numbering system, as requested by MEM. MEM items are shown in blue italicized text; KCB's response is shown in normal black text.

We consider this assessment to represent the knowledge of the facility available to KCB at the time of writing. Operating, inactive and closed facilities are subject to physical and geochemical changes over time, including ongoing construction activities. It is essential that monitoring and assessment of the facilities continue through regular surveillance, dam safety inspections, dam safety reviews and other stewardship activities. Teck HVC has a very robust surveillance program as outlined in their Operations, Surveillance and Maintenance manual, involving regular inspections, weekly surveillances, instrumentation monitoring, full time engineering staff on site and a thorough reporting plan which includes dam safety inspections and annual performance reports.

¹ Independent Expert Engineering Investigation and Review Panel, 2015. *Report on Mount Polley Tailings Storage Facility Breach*. January 30.

1.1 Assessment Scope

The MEM memorandum asked that an assessment be undertaken to determine if the dams may be at risk due to the following three conditions:

1. Undrained shear failure of silt and clay foundation;
2. Water balance adequacy; and
3. Filter adequacy.

KCB reviewed available historical information on foundation characterization, design, construction, and operations records for the Trojan Dam of the Bethlehem No. 2 Tailings Storage Facility (TSF) to prepare responses for sub-items listed in the MEM memorandum. A summary of the documents reviewed is included in the reference list. Responses to the above three items are provided in Section 3, following the numbering system used in the MEM memorandum. Documents supporting this letter will be maintained on-site by Teck.

Our review included review of test pit and borehole logs from the original investigation and design to the present, with particular consideration of whether silt and clay soils are present.

2 BETHLEHEM NO. 2 TSF OVERVIEW

The Bethlehem No. 2 TSF shown on the attached Figures 1 and 2 is impounded by the Trojan Dam and is an inactive tailings facility. No tailings have been deposited since 1989, and a closure spillway was added in 1996.

The Trojan rockfill starter dam was constructed to El. 1414 m from 1973 to 1980 with coarser rock placed downstream of the dam axis, and finer rockfill upstream. A filter zone of pit run sand and gravel was placed to the same elevation as the rockfill dam portion, El. 1414 m, against the upstream fine rockfill zone as a filter between the tailings and the rockfill dam. Gepac, 1973 specified the use of “reasonably well graded” coarse sand and gravel from local borrows for this filter zone. No gradation specification was provided.

Additional layers which act as filters include:

- A transition zone along the upstream face of the dam, ~19 m wide at the toe of the dam, and 6 m wide at the top.
- A 1.5 m thick filter layer was placed over the upstream half of the dam foundation up to El. 1411 m.

Both the foundation filter and transition zone were composed of selected small rock fragments and stones (Gepac 1973).

A 610 mm diameter corrugated steel pipe culvert, within a narrow, ~1 m deep trench backfilled with compacted sand and gravel, was installed at the deepest section of the dam to divert Trojan Creek and Unnamed Creek before the starter dam construction. The first 15 m of the upstream end of this

culvert was filled with concrete in 1983. It is unknown whether the remainder of the culvert was backfilled.

In 1981/82 Klohn Leonoff (1982) reviewed the dam design and proposed an upstream raise using cycloned sand. The already placed rockfill would serve as a downstream buttress and toe drain. From 1982 to 1987 Trojan Dam was raised upstream from El. 1414 m to final El. 1441.5 m using tailings sand.

At the left abutment where Trojan Dam meets Dam No. 1, the rockfill embankment was flared to increase contact width between the two dams to a minimum of 150 m at the crest and correspondingly more at the base. Cycloned sand was placed to a minimum 240 m width at the left abutment.

There is ongoing monitoring and surveillance at the Bethlehem No. 2 TSF. Where ongoing activities relate to the MEM questions, we quote existing recommendations and tasks and their reference number.

3 RESPONSES TO MEM MEMORANDUM

3.1 Task 1 - Review of Foundation Conditions

Risk of Undrained shear failure of silt and clay foundations

There is low risk to Trojan Dam from undrained shear failure of silt and clay foundation conditions similar to those found at Mount Polley. A distinct sandy silt layer with some clay is noted at 30 m to 36 m depth in the Gepac design report. This layer is also noted in drill hole logs. The material is described as a sandy silt and gravel with some clay, boulders, stiff to very dense; however the descriptions in the logs are not detailed enough to preclude the presence of a potential glacio-lacustrine layer within the silt. At DH-1 (closest to the abutment with Dam No.1), the elevation of this layer is at approximately El. 1357.5 m (+/- 3 m), which is similar to the elevation of the lower interpreted glacio-lacustrine layer below Dam No. 1. The two silt or clay layers below the Bethlehem TSF No.1 are at approximately El. 1373 m and El. 1361 m (15 m to 17 m below Dam No.1 foundation level). This indicates the possibility of a silt or clay layer beneath Trojan Dam but we do not have a high level of confidence in the available information.

A stability analysis assuming continuous weak layers at elevations 1373 m and 1361 m has shown that even with silt or clay layers under the Trojan Dam, the dam will meet stability criteria.

a. Including a determination with respect to whether or not similar foundation conditions exist below the dams on your site

There is inconclusive evidence of glacio-lacustrine soils beneath the Trojan Dam.

Construction reports indicate that a shallow layer of forest mat and overburden was stripped from the foundation during construction, and that muskeg deposits in the area of two creeks were

removed. The foundation material is noted as dense glacial deposits over bedrock. The depth to bedrock increases from about 3 m at the right abutment to about 61 m in the mid-valley.

Two glacio-lacustrine layers have been identified nearby, beneath the adjacent Bethlehem TSF No.1. Trojan Dam abuts against Dam No. 1 (of Bethlehem TSF No.1). The extent of the glacio-lacustrine layers beneath Bethlehem TSF No. 1 is unknown, but elevations are approximately El. 1373 m and El. 1361 m (15 m to 17 m depth below original ground).

Although not shown on the Gepac drill logs, a comment in the Gepac report (1973) describes a distinct silt layer in DH-1 and DH-2 from approximately 30 m to 36 m depth. In DH-1, closest to the abutment with Dam No. 1, the silt layer is approximately at El. 1357.5 m (+/- 3 m) which is close to the elevation of the lower glacio-lacustrine layer noted at Bethlehem Dam No. 1. There are no other details on this layer.

b. Whether or not sufficient site investigation (drill holes, etc.) has been completed to have confidence in this determination

We reviewed logs from seven drill holes and 41 test pits (Gepac 1973, KCC 1994) which listed no glacio-lacustrine or lacustrine soils. However, the logs are not considered adequate to verify that there are no glacio-lacustrine or lacustrine soils - some of the drill holes near the center of the dam do not extend to bedrock, there is limited detail in these drill logs, and there is a comment in the Gepac report that indicates a distinct silt layer in two drill holes which is reflected on the drill hole logs but is not described in sufficient detail.

Thus, while the logs do not indicate a clay layer similar to that at Mount Polley, the descriptions are not sufficient to preclude the existence of a glacio-lacustrine layer within the silt.

c. If present, whether or not the dam design properly accounts for these materials

The design considered the foundation materials to be dense glacial till. The distinct silt layer noted in DH-1 and DH-2 may include an extension of the glacio-lacustrine layer from below Dam No. 1 to below Trojan Dam (although there is no direct evidence).

We therefore considered the effect on stability if there were two clay layers at elevations 1373 m and 1361 m (as estimated below Bethlehem TSF No.1). This analysis also took into account the current consequence classification ('Very High'). Our analysis used a peak frictional strength of 35° for the foundation till and a peak undrained shear strength/vertical effective stress ratio of 0.24 for the assumed glacio-lacustrine layers using laboratory testing results from glacio-lacustrine soil at L-L Dam.

Based on the assumed conditions, the minimum static Factor of Safety (FoS) (drained) was 1.5, the minimum post-earthquake FoS (undrained) was 1.3. The dam therefore meets design criteria under static and earthquake loading even under the conservative assumption of a continuous, weak clay layer in the foundation.

Based on a deformation analysis, we estimate a displacement (mean plus one standard deviation) of 0.5 m. Displacements under the design earthquake are acceptable given the design freeboard of 3 m.

The Trojan Dam has not had new tailings placed or a construction raise after 1989, and six survey monuments at the crest have recorded negligible movements of between 25 mm to 60 mm total, (KCB 2014).

d. If any gaps have been identified, a plan and schedule for additional sub-surface investigation

The following gap is identified:

- There is limited detail available from the original drill hole logs (1973) which do not fully describe the silt layer. A similar unit at 15 m to 17 m depth has been identified as glacio-lacustrine under the adjacent Bethlehem Dam No. 1. The overall extent and material properties of these silt and clay layers are unknown.
- The assessment of potential deformation following a seismically induced undrained response is based on conservative assumptions. Additional evaluation is warranted once site specific material properties are available.

The following plan is recommended to address this gap.

- Drill at least one hole to verify presence or absence of a silt or clay layer and collect undisturbed samples for laboratory strength testing.
- We are currently conducting seismic stability and deformation analyses for the new consequence classification for Trojan Dam (Teck HVC Task No. DSI-TD-08 (2014)). This will incorporate information from the proposed drilling. These analyses will include a review of whether higher pore water pressures (and undrained conditions) could be induced by seismic loading.

3.2 Task 2 - Water Balance Adequacy

The Bethlehem No. 2 TSF is at low risk of failure due to water balance issues since it does not receive water from the mining operations and there is a closure spillway in place with adequate freeboard to manage the design flood.

a. Including the total volume of surplus mine site water (if any) stored in the tailings storage facility

The volume of free water in Trojan Pond as of April 17, 2015 was approximately 1.9 Mm³ corresponding to a pond elevation of 1432.9 m giving a freeboard (measured from pond level to the minimum dam crest) of 8.2 m. The spillway invert is 5.6 m below the dam crest. The maximum annual pond elevations, estimated volumes, and freeboard for the past five years are:

Year	Pond Elevation	Volume ⁽¹⁾	Freeboard ⁽²⁾
2014	1432.9 m	1,857,878 m ³	8.2 m
2013	1434.2 m	2,376,548 m ³	6.9 m
2012	1434.7 m	2,592,872 m ³	6.4 m
2011	1434.4 m	2,452,952 m ³	6.7 m
2010	1435.2 m	2,880,574 m ³	5.9 m

Note:

- (1) Pond volumes are estimated based on a stage-storage curve provided by Teck, May 26, 2015.
- (2) Pond level to minimum dam crest El. 1441.1 m (KCB 2014).
- (3) Pond elevations are based on survey water levels provided by Teck.

b. The volume of surplus mine water that has been added to the facility over each of the past five years

No surplus mine water has been directed to this facility over the last five years. Pond inflows include: precipitation, runoff, controlled inflows from Trojan Creek and the Fish Spawning Reservoir. Outflows include: deep seepage, seepage that reports to the seepage pond, evaporation, evapotranspiration, release via spillway when applicable, pumping to Bethlehem No. 1 when applicable (last done in 2013). The volume of outflows has exceeded the volume of inflows resulting in a net decrease since 2012.

c. Any plans that are in place or that are under development to release surplus mine water to the environment

There are no plans in place to release water from Bethlehem No.2 TSF.

d. Recommended beach width(s), and the ability of the mine to maintain these widths

The recommended minimum operational and closure beach width for the TSF was specified as 150 m (KL 1987) The current beach width is approximately 210 m. The dam has a spillway designed to pass the PMF which is a passive system designed to operate independent of any action taken by HVC.

The mine is able to maintain these beach widths by use of a diversion channel on the northwest of the impoundment (updated in 2014) which reduces inflow, by pumping water to Pond No. 1, or by passing water if necessary through the spillway.

e. The ability of the TSF embankments to undergo deformation without the release of water (i.e. the adequacy of the recommended beach width

Previous (KCC, 1996) deformation analysis indicated an expected deformation of 0.5 m using a Newmark Analysis (with strength reduction). Preliminary deformation analysis using the upgraded consequence classification for Trojan Dam, and considering potential glacio-lacustrine layers is discussed under item 1c above and indicates about 0.5 m (mean plus one standard deviation) of deformation, indicating the dam has adequate freeboard. This preliminary analysis will be updated as part of ongoing recommendation DSI-TD-08 (2014).

f. Provisions and contingencies that are in place to account for wet years

The spillway capacity is based on the 24 hour Probable Maximum Precipitation event (PMP) to account for water management in wet years.

g. If any gaps have been identified, a plan and schedule for addressing these issues

There are no gaps identified with the water balance at Trojan Dam.

3.3 Task 3 - Filter Adequacy

The Bethlehem No. 2 TSF is at low risk of failure due to filter adequacy issues (piping). Filter specifications and as-built gradations are not available but are not relevant since the dam design now incorporates a large upstream cycloned sand raise, and a long tailings beach. The condition of the decommissioned culvert is unknown but is considered low risk due to the performance record.

a. Including the beach width and filter specifications necessary to prevent potential piping

Filter zones were constructed with the starter dam; however there are no design gradations for these filter zones. The design report specified the use of well graded filter materials along the upstream toe of the dam. The original diversion culvert has been buried and the upstream 15 m was backfilled with concrete. It is unknown whether the remainder of the culvert was backfilled. There was a sinkhole located above the upstream end of the culvert which occurred in 2003 and was backfilled in 2003 (KCC 2003). No re-activation of the sinkhole has been observed.

Above El. 1414 m, the Trojan Dam was built as an upstream dam with cycloned sand with a sand and gravel filter between the cycloned sand and the rockfill. The sand and gravel filter was designed to meet filter criteria with the cycloned sand and to be filter-compatible with the rockfill (KL, 1982).

The Trojan Pond is currently 210 m from the cycloned sand crest which is greater than the design width of 150 m.

b. Whether or not the filter has been constructed in accordance with the design

There were no filter design specifications available for the Gepac (1973) dam.

Prior to the 1982 to 1987 upstream dam raise, the exposed filter zone to El. 1414 m was appraised visually by Klohn Leonoff and appeared satisfactory (KL 1982). Gradations were not available for the upstream cycloned sand dam raise (1982 to 1987).

Piezometers monitor the piezometric level between the pond and the dam. Piezometric levels indicate low hydraulic gradients across the dam filter zones. The local hydraulic gradient is estimated to be about 0.5 which is less than the critical gradient of 0.7 for horizontal flow (reported in Skempton and Brogan, 1994 from Adel et al., 1988) and less than the critical gradient of 1.0 for upward vertical flow for a marginally stable sand and gravel material (Skempton and Brogan, 1994) and therefore there is low risk of piping.

Piezometer P85-2 shows a phreatic surface level about 27 m higher than adjacent piezometers P13-3 and P13-4 (near the dam center line). A performance review of instrumentation is ongoing to check the hydraulic gradient in this area – piezometer P85-2 is suspect, but the two newer piezometers (P13-3 and P13-4) are considered reliable.

The current configuration and performance observations of the dam are consistent with design requirements.

c. If any gaps have been identified, a plan and schedule for addressing these issues.

The following gaps have been identified:

- Design filter specifications are not available from the (Gepac 1973) design, and there are no available as-built gradations for installed filter materials. Therefore, filter compatibility cannot be verified;
- However, as the dam incorporates a large upstream cycloned sand raise, and a long tailings beach, potential for piping is reduced by maintaining low hydraulic gradients across the dam. Current average hydraulic gradients are low but local gradients are unknown. Anomalous readings from one piezometer are being reviewed – the piezometer is suspect and has been replaced with newer instruments; and
- The condition of the decommissioned culvert is unknown.

The following plan is underway to address these gaps:

- A performance review of instrumentation including updating alert levels at Trojan Dam is ongoing, per recommendations in KCB 2014 DSI-TD-05 (2014) and DSI-TD-06 (2014);
- A monitoring point for observations of seepage is being established at the downstream location of the decommissioned culvert, as per recommendation in KCB 2014 DSI-TD-12 (2014). This is planned for completion in 2016.

4 SUMMARY OF GAPS AND SCHEDULE TO ADDRESS

The Trojan Dam is performing according to design and is considered at low risk due to:

1. Undrained shear failure of silt and clay foundation;
2. Water balance adequacy; and
3. Filter adequacy.

However, there are some gaps in the knowledge base for the dams and we recommend the following:

1. Drill at least one hole to verify presence or absence of a silt or clay layer and collect undisturbed samples for laboratory strength testing. This is scheduled to be completed by end of 2016.

2. We are currently conducting seismic stability and deformation analyses for the new consequence classification for Trojan Dam (Teck HVC Task No. DSI-TD-08 (2014)) scheduled for completion in December 2015. This will later be modified to incorporate information from the proposed drilling (in 2016). These analyses will include a review of whether higher pore water pressures (and undrained conditions) could be induced by seismic loading.
3. A performance review of instrumentation including updating alert levels at Trojan Dam is ongoing, per recommendations in KCB 2014 DSI-TD-05 (2014), scheduled for completion in November 2016, and DSI-TD-06 (2014), scheduled for completion in December 2015;
4. A monitoring point for observations of seepage is being established at the downstream location of the decommissioned culvert, as per recommendation in KCB 2014 DSI-TD-12 (2014). This is planned for completion by end of 2016.


5 CLOSING

This report is an instrument of service of Klohn Crippen Berger Ltd. The report has been prepared for the exclusive use of Teck Highland Valley Copper Partnership (Teck) for the specific application to the Bethlehem No. 2 TSF MEM Response Project. The report's contents may not be relied upon by any other party without the express written permission of Klohn Crippen Berger. The review is based on available information at the time of writing. In this report, Klohn Crippen Berger has endeavoured to comply with generally-accepted professional practice common to the local area. Klohn Crippen Berger makes no warranty, express or implied.

Yours truly,
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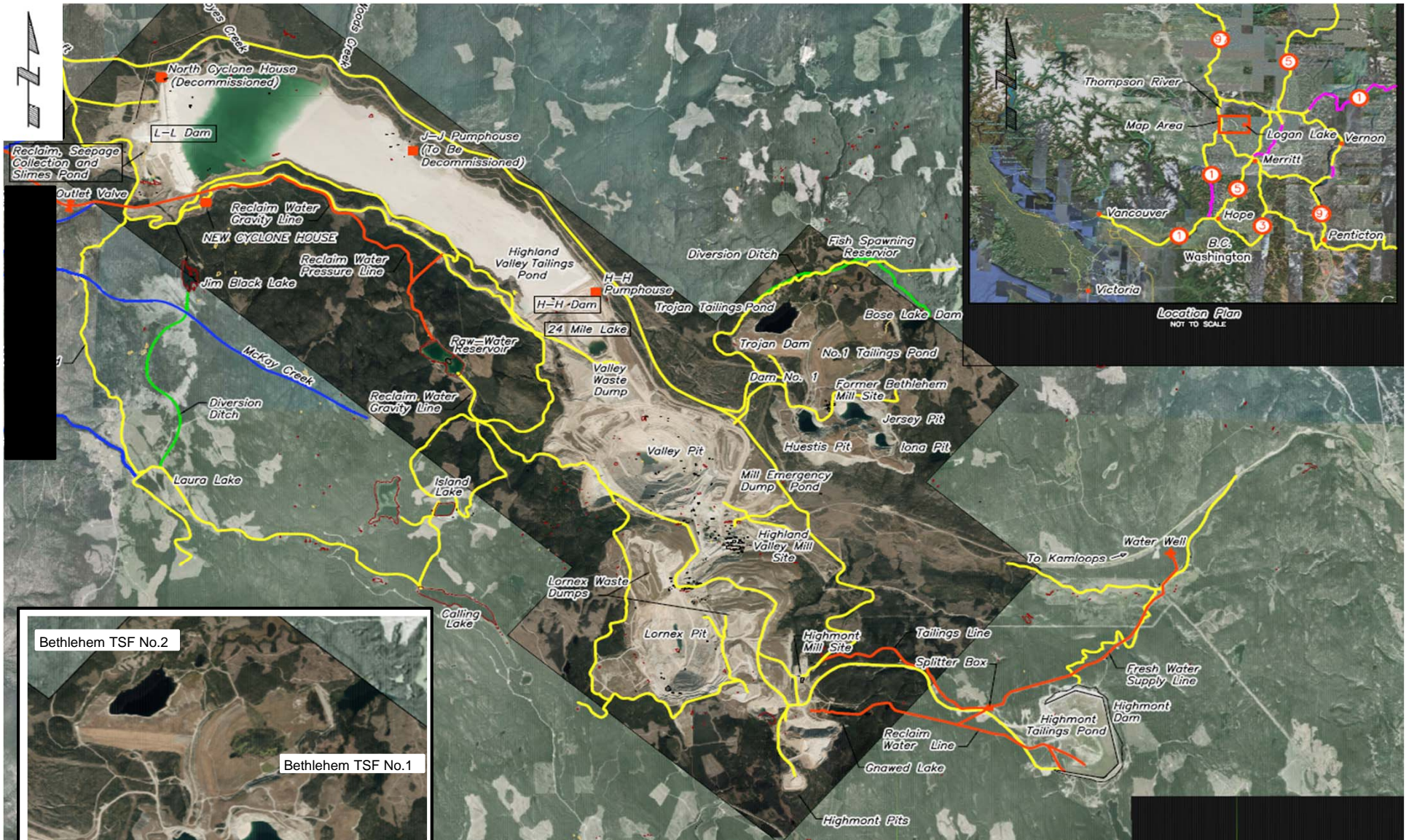
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Attachments: Figure 1 – Location Map for Tailings Dams and Water Retention Dams
Figure 2 – Bethlehem TSF No. 2 – Trojan Dam

REFERENCES

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FIGURES



Bethlehem TSF No.2

Bethlehem TSF No.1

Bethlehem Tailings Storage Facilities No.1 and No. 2

TO BE READ WITH KLOHN CRIPPEN BERGER REPORT DATED JUNE 25, 2015

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CLIENT
TECK HIGHLAND VALLEY COPPER PARTNERSHIP



PROJECT
 HVC TAILINGS DAMS
 RESPONSE TO MEM MEMORANDUM

TITLE
 LOCATION MAP FOR TAILINGS DAMS
 AND WATER RETENTION DAMS

PROJECT No. M02341A87

No. 1

DATE & TIME: 25/06/2015 12:03



TO BE READ WITH KLOHN CRIPPEN BERGER REPORT DATED JUNE 25, 2015

DATE & TIME: 25/06/2015 12:03

<p>AS A MUTUAL PROTECTION TO OUR CLIENT, THE PUBLIC AND OURSELVES, ALL REPORTS AND DRAWINGS ARE SUBMITTED FOR THE CONFIDENTIAL INFORMATION OF OUR CLIENT FOR A SPECIFIC PROJECT AND AUTHORIZATION FOR USE AND/OR PUBLICATION OF DATA, STATEMENTS, CONCLUSIONS OR ABSTRACTS FROM OR REGARDING OUR REPORTS AND DRAWINGS IS RESERVED PENDING OUR WRITTEN APPROVAL.</p>	<p>CLIENT TECK HIGHLAND VALLEY COPPER PARTNERSHIP</p>	<p>PROJECT HVC TAILINGS DAMS RESPONSE TO MEM MEMORANDUM</p>	
		<p>TITLE BETHLEHEM TSF NO.2 TROJAN DAM</p>	
		<p>PROJECT No. M02341A87</p>	<p>No. 2</p>