June 25, 2015

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

**Chris Fleming**
**Superintendent, Tailings and Water Management**

Dear Mr. Fleming:

**HVC Tailings Dams - Bethlehem Main (No. 1) Tailings Storage Facility**
**Response to MEM Memorandum - February 3, 2015**

## 1 INTRODUCTION

The Independent Expert Panel[1] (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 two dams forming the Bethlehem No. 1 Tailings Storage Facility (TSF) 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

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



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604.669.3800 t • 604.669.3835 f • www.klohn.com

surveillances, instrumentation monitoring, full time engineering staff on site and a thorough reporting plan which includes dam safety inspections and annual performance reports.

## 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 Bethlehem Main (Dam No. 1), and Bose Lake Dam which together impound the Bethlehem No. 1 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 MAIN (NO. 1) TSF OVERVIEW

Bethlehem Main (No. 1) TSF shown on the attached Figures 1 and 2, is an inactive tailings facility impounded by Bethlehem Dam No. 1 located at the western extent of the TSF and Bose Lake Dam located at the eastern extent. The closure spillway is located at Bose Lake Dam. No tailings have been deposited since 1989, and the closure spillway was added in 1995.

Dam No. 1 is a sand and rockfill dam with a rockfill downstream shell and upstream cycloned sand construction. The dam has a maximum height of 96 m and overall length of 1.9 km. The sandfill crest is nominally 3 m to 4 m higher than the rockfill. The dam was originally designed by Ingledow and Associates, with additional design and construction by Gepac and Fellhauer Consultants, with Klohn Leonoff Limited taking over in 1982. Construction began in 1963 with a 6 m high starter dam constructed of a short till dyke plus cycloned sand. The dam was raised in succeeding years by placing rockfill on the crest and on the downstream slope and placing spigotted or cycloned tailings on the upstream side. When the dam crest reached El. 1462.9 m, a 76 m wide rockfill toe berm to improve stability was added, with a crest width of about 15.24 m at El. 1429.4 m. The rockfill crest was raised to El. 1472 m in 1972. The dam was completed to El. 1476.9 m in 1983 by upstream construction with cycloned sand.

Bose Lake Dam is located in a saddle at the eastern extent of the TSF. The dam was originally designed by Gepac (1972). Fellhauer Consultants designed a 3 m raise (1981). Klohn Crippen Consultants Ltd designed the closure spillway (1994).The dam was constructed in stages with the last stage completed in 1981 to El. 1475.1 m or approximately 1.5 m lower than the Dam No. 1 crest. It is constructed of compacted, low hydraulic conductivity, glacial till with a rockfill downstream toe and filter drains to control seepage. The dam has a maximum height of 34 m and an overall length of 650 m.

There are ongoing investigations, monitoring and surveillance at the Bethlehem No. 1 TSF. Where ongoing activities relate to the MEM questions, we refer to 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 the dams at the Bethlehem TSF due to undrained shear failure of silt and clay foundation conditions similar to those found at Mount Polley. Silt and clay deposits are not noted in the foundation of Bose Dam. Two glacio-lacustrine clay layers are noted at Dam No. 1. Conservatively assuming continuous weak layers under the Dam No. 1, the dam will meet stability criteria. The available information is adequate to have confidence in this determination.

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

**Dam No. 1**
Two glacio-lacustrine clay layers in 4 boreholes were identified in the foundation footprint of Dam No. 1. The upper layer was approximately 1 m thick near the original ground surface upstream of the dam centerline in one borehole. The lower layer is approximately 0.5 m to 3 m thick, from 15 m to 17 m depth below the original ground surface under the downstream toe of the dam.

The clay layers are described as clay with silt and sand laminae, with relatively high moisture content which is similar to the Mount Polley glacio-lacustrine unit.

**Bose Lake Dam**
There is no evidence in the design reports or investigations of glacio-lacustrine or lacustrine soils. Bose Lake Dam is located on a bedrock saddle with till blanket where there is limited likelihood of lacustrine soils due to the shallow depth to bedrock.

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

There were 5 drill holes and 23 test pits at Dam No. 1 and 5 drill holes and 42 test pits at Bose Lake Dam. The average spacing for boreholes is about 300 m at Dam No. 1 and about 100 m for Bose Lake Dam. The number of borings at Dam No. 1 is adequate to confirm the presence of a clay layer, but insufficient to confirm the extent and properties of the clay layers.

The site investigation at Bose Lake Dam is considered sufficient to have confidence in the determination of no clay layers.

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

**Dam No. 1**

The dam design assumed a competent till foundation and did not initially allow for a soft surficial layer. During construction in the late 1960's, tension cracks and movement occurred on the main dam fill, because of weak surficial foundation soils. Where exposed, the surficial soils were removed and a rockfill toe berm was added to the dam in 1970 to 1971, buttressing the dam against these weak surficial foundation conditions. However, removal of the lower clay layer was not documented and we do not believe that it was removed.

Since there is currently no approved new construction, and there have been no tailings placed in the TSF since 1983, the only source of loading that could lead to undrained conditions are from seismic loading. There has been no significant movement or instability noted on the dam since end of operations in 1983 and any construction related pore pressures in the glacio-lacustrine soil would have since dissipated.

To assess the effects of the clay, we conducted a preliminary deformation analysis that assumes a continuous clay layer, 15 m below the base of the dam with assumed undrained strength similar to clay and silt elsewhere on site. We assumed that an undrained response would be triggered by an earthquake with a return period of 1:5,000 years (for a 'Very High' consequence dam as per CDA 2007 guidelines).

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.

This analysis indicated the minimum static FoS (drained) is 1.5, and the minimum post-earthquake FoS is 1.0 using undrained residual strengths. Although the (CDA 2007) target FoS of 1.5 is met for the static condition, the target FoS of 1.2 may not be met for the post-earthquake scenario, depending on the actual material properties, the extent of the clay layer, and whether or not the clay layer is susceptible to triggering an undrained response during the design earthquake.

Regardless, even in the event of the conservative assumptions noted above, the preliminary deformation analysis indicates a displacement (mean plus one standard deviation) of 1.45 m, which is acceptable given the design freeboard of 5 m from the spillway invert to the minimum dam crest.

**Bose Lake Dam**

As there is no indication of clay layers under the Bose Lake Dam, the design is considered appropriate. The dam is regularly inspected and there are no indications of stability issues.

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

**Dam No. 1**

The following gap has been identified for Dam No. 1:

- The overall extent and strength of the clay layers described above are unknown, including susceptibility to seismically induced triggering of undrained behaviour. The assessment of potential deformation following a seismically induced undrained response was based on conservative assumptions. Additional evaluation is warranted once site data is 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.
  - Stability and seismic displacement analyses are already planned to address this concern, as reported under previous recommendation DSI-BM-02 (2014), and will incorporate information from the additional drill hole and related lab testing. The analyses will assess potential for seismic undrained response of any discovered clay layers.

**Bose Lake Dam**

No gaps have been identified.

## 3.2 Task 2 - Water Balance Adequacy

The Bethlehem 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, at Bose Lake Dam abutment, with adequate freeboard to manage the design flood.

The ponded water in the Bethlehem No. 1 TSF forms two shallow pools in separate low spots on the tailings surface. The main pond is located near the middle of the TSF, and a second pond is located at a lower elevation next to Bose Lake Dam. The volume of these ponds combined is much smaller than the volume of the pond which existed during the tailings operation. Bose Lake Dam is about 1.8 m lower crest elevation than Dam No. 1, so there is no risk of overtopping of Dam No. 1 at the current crest elevations.

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

**Dam No. 1**

The volume of free water in the main pond closest to Dam No.1 on April 2, 2015 was 75,260 $m^3$ with the pond at El. 1468.7 m, giving a freeboard of 6.4 m (measured from pond level to the minimum crest of Bose Lake Dam (El. 1475.1 m). The spillway invert is at El. 1469.3 m and the Dam No. 1 crest is at El. 1476.9m. The maximum annual water levels, volumes, and freeboard for the past four years are:

| Year | Pond Elevation | Volume[1] | Freeboard[2] |
|---|---|---|---|
| 2014 | 1469.4 m | 203,000 $m^3$ | 5.7 m |
| 2013 | 1469.6 m | 253,000 $m^3$ | 5.5 m |
| 2012 | 1469.2 m | 153,000 $m^3$ | 5.9 m |
| 2011 | 1469.1 m | 128,000 $m^3$ | 6.0 m |

Note:

1. Pond volumes are estimated based on stage-storage curve provided by Teck (May 26, 2015).
2. Pond level to minimum dam crest at Bose Lake Dam El. 1475.1 m (KCB 2014b).
3. Pond elevations are based on survey water levels provided by Teck.

**Bose Lake Dam**

The volume of free water in the second small pool, closer to Bose Lake Dam on April 2, 2015 was 12,105 $m^3$ with a pond elevation of 1468.5 m giving a freeboard from the Bose pond to the Bose Lake Dam crest of 6.6 m. The spillway invert is at E. 1469.3 m, or 5.8 m below the Bose Lake Dam crest. The maximum water levels, volumes, and freeboard for the past four years are:

| Year | Pond Elevation | Volume[1] | Freeboard[2] |
|---|---|---|---|
| 2014 | 1468.7 m | 27,055 $m^3$ | 6.4 m |
| 2013 | 1469.0 m | 40,855 $m^3$ | 6.1 m |
| 2012 | 1468.5 m | 12,953 $m^3$ | 6.6 m |
| 2011 | 1468.4 m | 6,355 $m^3$ | 6.7 m |

Note:

1. Storage volume above El. 1469 m based on stage-storage curve provided by Teck, May 26, 2015 which uses 2014 LiDAR. No sounding data is available. Storage volume below El. 1469 m is based on an assumed pond bottom of El. 1468.3 m.
2. Pond level to minimum dam crest at Bose Lake Dam El. 1475.1 m (KCB 2014b).
3. Pond elevations are based on survey water levels provided by Teck.
4. 

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

In 2011 due to high precipitation runoff and inflows into the adjacent Bethlehem No. 2 (Trojan) TSF, a pumping system was established to move 500,000 $m^3$ of water from Bethlehem No. 2 TSF to Bethlehem No. 1 TSF. Pumping continued in 2012 with a further 250,000 $m^3$ of water transferred to Bethlehem No. 1 TSF. Pumping ceased in 2013, resulting in a decrease in the No. 1 pond water and an increase in freeboard.

No surplus mine water has been directed to this facility over the last five years. Inflows include: precipitation, runoff, and water pumped from Bethlehem No. 2 Pond as discussed above. Outflows include: deep seepage, seepage that reports to the seepage pond, evaporation, evapotranspiration, and release via spillway (though no release has been reported since the installation of the spillway). Since pumping from the Bethlehem No. 2 TSF ceased in 2013, the volume of outflows has exceeded the volume of inflows resulting in a net decrease in the pond volume.

***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 the Bethlehem No. 1 TSF.

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

**Dam No. 1**
The recommended minimum beach width during operations was specified as 122 m to 182 m from the dam crest (Fellhauer 1980). The mine has historically been able to maintain the required beach width. The current beach width is approximately 260 m.

**Bose Lake Dam**
The beach width is not specified for the Bose Lake Dam as Bose Lake Dam was designed as a water retaining dam (to impound the TSF decant water pond) and a beach is not required for safe operation of the dam. The closure emergency spillway is located on the left abutment of the Bose Lake Dam with the pond near the dam and 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)***

**Dam No. 1**
Based on the deformation analysis described in Section 3.1c above, the displacement of 1.45 m is acceptable given that the distance from the Dam No. 1 crest to the pond level is about 5.7 m.

**Bose Lake Dam**
Analyses (KCC 1996) predict potential deformations of Bose Lake Dam, under the design earthquake, of less than 0.1 m, which is acceptable.

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

The spillway is designed for the 24-hour Probable Maximum Precipitation (PMP) event, consequently the storm inflows would pass through the TSF spillway.

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

For Dam No. 1, we recommend reviewing the predicted potential deformation of Dam No. 1 crest from seismic loading, (as recommended under Item 1d above).

There are no gaps related to the water balance adequacy for Bose Lake Dam.

## 3.3 Task 3 - Filter Adequacy

The Bethlehem No. 1 TSF is at low risk of failure due to filter adequacy issues (piping). Filter specifications and as-built gradations are not available for Dam No. 1. However, potential for piping is reduced by maintaining low hydraulic gradients across the dam.

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

**Dam No. 1**

The original design of Dam No.1 did not provide for filter compatibility between tailings and dam fill materials, but rather relied on the large cycloned sand zone and long tailings beach to provide separation between the tailings pond and the dam rockfill. The design of the beach during operation required that the pond was kept a minimum of 122 m from the dam crest in order to maintain a low phreatic surface through the beach.

There is currently no active tailings deposition. There is a large beach with a small pond, resulting in a low hydraulic gradient between the pond and the dam fill. Seepage is monitored at the toe of Dam No.1 and runs clear with no evidence of sediment in the seepage, and therefore there is no indication of piping. Seepage monitoring has been ongoing for 43 years.

Therefore the current configuration and performance observations are consistent with the design requirements.

**Bose Lake Dam**

Bose Lake Dam is a glacial till embankment with a downstream filter zone, drain and rockfill zone.

Beach width is specified for Dam No. 1 but not for Bose Lake Dam. There is a design requirement for the pond to report to the spillway at the Bose Lake Dam left abutment.

We reviewed the design gradation specifications for filter stability outlined in (USACE 2004) for filter zones between the tailings and the downstream drains and filters. The dam zones met filter compatibility criteria with the following three exceptions:

1. The glacial till embankment is not filter compatible with the downstream filter layer except in the upper 3 m of the final dam raise. Below the upper 3 m, some of the filter may not be filter compatible with the glacial till embankment.
2. The Type B Rockfill and the Type D Drainage layer are not filter compatible.
3. The Type B Rockfill and the Type C Filter layer are not filter compatible.

However, a review of filter and drainage gradations indicates adequate internal stability of the filters using the method described by Kenney & Lau (Skempton & Brogan, 1994). Readings of 4 active piezometers indicate a very low hydraulic gradient through the dam such that even if the filter or drainage materials were considered "very unstable filter materials" they would not be expected to migrate (Skempton & Brogan, 1994).

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

**Dam No. 1**

The filter was constructed in accordance with the design with the following exceptions:

- During dam construction in 1966, 'some loads of overburden were placed in the rockfill zone'. but reportedly 'not enough to change their basic rockfill character' (Ingledow 1966b).

- Rockfill containing large amounts of fines, was dumped on both the upstream and downstream sides of the slope apparently during the winter of 1969/1970 (Ingledow 1970).
- During construction in 1970 some tailings flowed into the rockfill due to the fine tailings and slimes being placed in direct contact with the rockfill upstream slope without the prior deposit of coarser cycloned tailings on the upstream face. This situation was corrected by placing “de-slimed tailings” near the dam and spigotting the fines further upstream (Ingledow 1968).

**Bose Lake Dam**
The records are not sufficient to determine if the filter was constructed in accordance with the design. Specifications required one gradation analysis for every 10,000 cubic yards of glacial till and 1,000 cubic yards of filter and drainage material (Gepac 1972). However, most of the records were not available, and only one test gradation was located. The one available test gradation met the design specifications.

Although there is potential for locally higher gradients, the dam has a long performance record with no signs of piping such as sediment in the seepage or deformation of the glacial till embankment. These indications are signs of low risk of piping.

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

**Dam No. 1**
During the 2014 Dam Safety Inspection (KCB, 2014b), we recommended a review of instrumentation and a review of alert levels for piezometers in Dam No. 1. These recommendations, DSI-BTSF-04 (2014) and DSI-BTSF1-06 (2014) are underway and will provide information to review and monitor gradients across the dam core.

**Bose Lake Dam**
The same two recommendations from the 2014 DSI also apply to Bose Lake Dam, and include setting of piezometric alert levels, and a review of instrumentation to assess piezometric levels for stability and to assess the gradient across the dam. This work is also underway under DSI DSI-BTSF-04 (2014).

Based on our current estimates, the hydraulic gradient through the dam is low enough to maintain internal stability even if the as-built material gradations vary slightly from the design gradations. If the hydraulic gradient increases across the core or seepage observations indicate transport of material, then this condition will be reviewed.

# 4 SUMMARY OF GAPS AND SCHEDULE TO ADDRESS

The Bethlehem Dam No. 1 and the Bose Lake Dam are performing according to design. Based on ongoing monitoring, instrumentation, and surveillance activities, and the current small volume of free water, the dams are considered to be 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. There is limited information on material properties and extent of the clay layer identified at 15 to 17 m depth below Dam No. 1. We recommend a site investigation of (initially) one drill hole to sample and carry out laboratory testing on the layer. This will be completed by end of 2016.
2. Once the drill hole data is available and the properties of the glacio-lacustrine layer are better understood, the properties should be incorporated into the stability and seismic deformation review recommended in the KCB 2014 DSI (DSI-BM-02) This work has been initiated and will completed by end of 2016.
3. Update instrumentation alert levels at both dams as recommended in the KCB 2014 DSI (DSI-BTSF1-04 (2014), to be completed 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 2015 Bethlehem Main (No. 1) TSF MEM Memorandum Response. 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.

**KLOHN CRIPPEN BERGER LTD.**

Laura Barker, E.I.T.
Geotechnical Engineer

PROFESSIONAL ENGINEER — PROVINCE OF BRITISH COLUMBIA — D. A. WILLMS # 33062
June 25, 2015

David Willms, P.Eng., M.Eng.
Geological Engineer – Project Manager

June 25/15

Neil K. (Hemrajani) Singh, P.Eng., M.Eng.
Geotechnical Engineer – Project Director

LB/DW/NS:cd

Attachments: Figure 1 – Location Map for Tailings Dams and Water Retention Dams
Figure 2 – Bethlehem TSF No. 1 – Dam No. 1
Figure 3 - Bethlehem TSF No. 1 – Bose Lake Dam

## 6 REFERENCES

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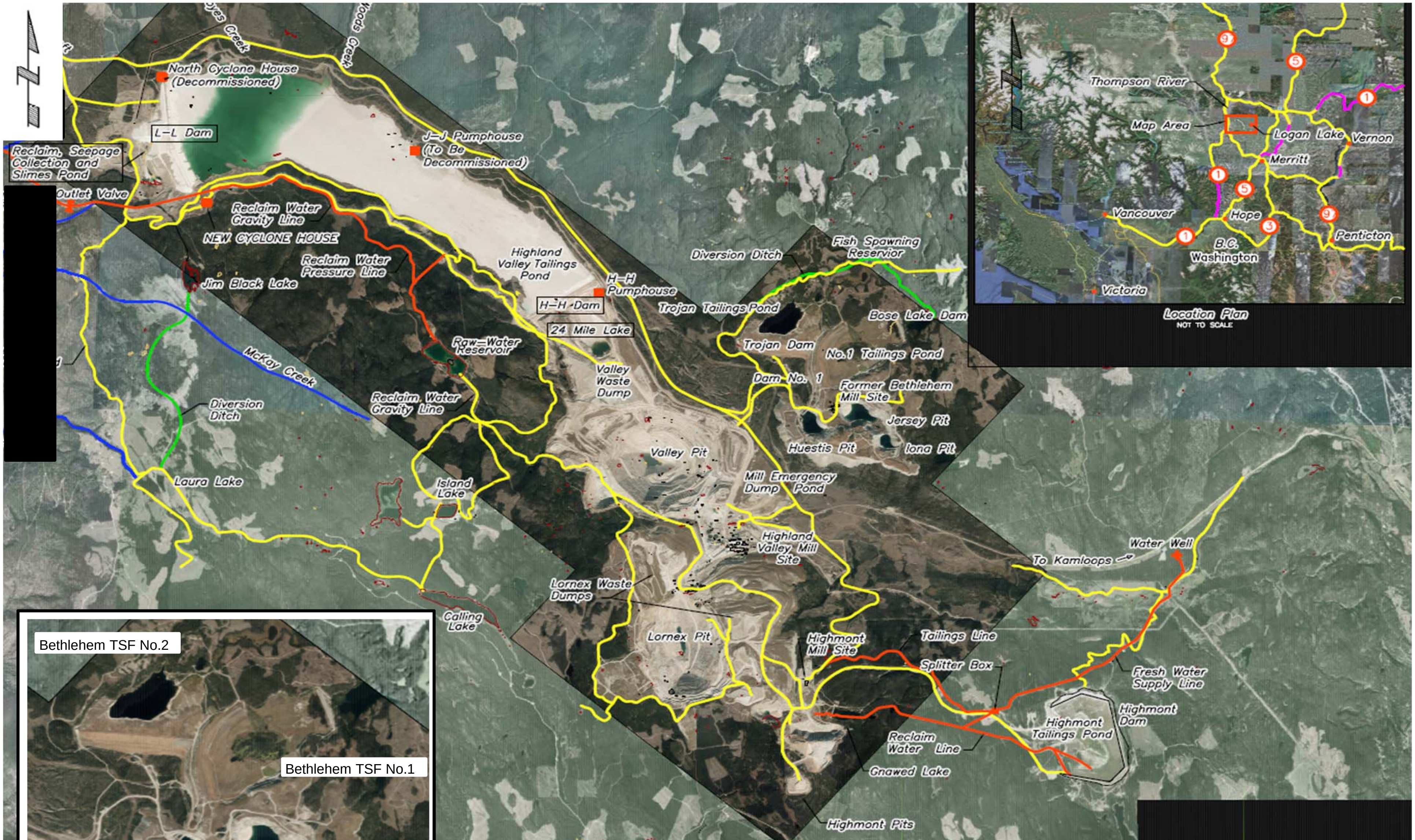
# FIGURES




Bethlehem Tailings Storage Facilities No.1 and No. 2

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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 11:58


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



| | |
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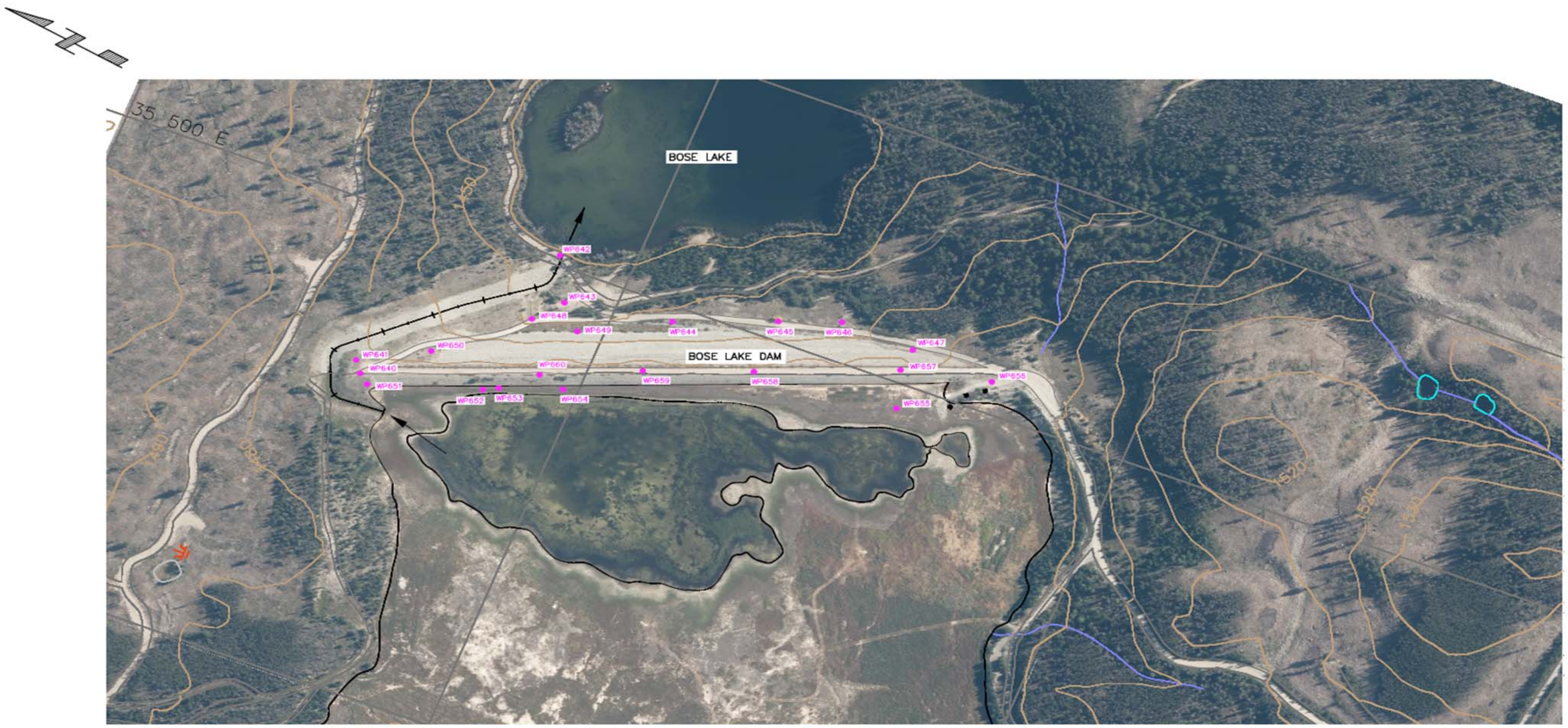
| CLIENT | TECK HIGHLAND VALLEY COPPER PARTNERSHIP |
| | Klohn Crippen Berger |
| PROJECT | HVC TAILINGS DAMS RESPONSE TO MEM MEMORANDUM |
| TITLE | BETHLEHEM TSF NO.1 DAM NO.1 |
| PROJECT No. | M02341A87 |
| No. | 2 |

Date & Time: 25/06/2015 11:58

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PROJECT
HVC TAILINGS DAMS
RESPONSE TO MEM MEMORANDUM

TITLE
BETHLEHEM TSF NO.1
BOSE LAKE DAM

PROJECT No. M02341A87

No. 3

Date & Time: 25/06/2015 11:58