HIGHLAND VALLEY COPPER
DAM BREAK AND FLOOD INUNDATION STUDY
BETHLEHEM TAILINGS STORAGE FACILITY POND NO. 2 (TROJAN)

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

28 February 2014

TE1330191

Mr. Chris Fleming
Teck Highland Valley Copper Partnership
P.O. Box 1500
Logan Lake, BC V0K 1W0

Dear Mr. Fleming:

Re: Final Report - Trojan Dam Break and Inundation Study

Please find enclosed the above-noted final report outlining the dam break and inundation study completed for the Bethlehem Tailings Storage Facility (TSF) No. 2 Pond (Trojan).

The No. 2 Pond consists of an embankment dam (Trojan Dam) and impounded water and tailings (No. 2 Pond). The analysis has considered dam failure and release of both flood water and tailings. In the event of dam failure, there is expected to be some danger posed to workers in the Valley Open Pit downstream. There is also expected to be a temporary interruption of traffic on Highway 97C, and potential loss of important aquatic habitat in Witches Brook.

Dam classification according to the 2007 Canadian Dam Association (CDA) Guidelines has also been completed as part of this study, and a classification of "Very High" was determined for Trojan Dam.

Please contact the undersigned if you have any questions regarding our submission.

Sincerely,

AMEC Environment & Infrastructure,
a division of AMEC Americas Limited

Original hard copies signed by
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HX/cjy

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1.0 INTRODUCTION

This report documents the dam break and inundation study conducted for the Bethlehem No. 2 Tailings Pond (Trojan Pond) at the Highland Valley Copper (HVC) site in Logan Lake, British Columbia (BC). This report has been prepared by AMEC Environment & Infrastructure, a division of AMEC Americas Limited (AMEC). This study has been conducted as per our proposal submitted to HVC in August, 2013.

2.0 BACKGROUND

The HVC Mine is located near Logan Lake, approximately 50 kilometres (km) southwest of Kamloops, BC. A general site location plan is shown in Figure 2.1. Trojan Pond is part of the larger Bethlehem Tailings Storage Facility (TSF), which contains two ponds: Bethlehem No. 1 and No. 2 Tailings Ponds. A site plan of the Bethlehem TSF is shown in Figure 2.2.

The Bethlehem No. 2 Dam (Trojan Dam) is an earth embankment dam impounding both water and tailings of the Trojan Pond. Figures 2.3 and 2.4 show the plan view and cross section of Trojan Dam, respectively. Tailings disposal in the Trojan Pond ceased in 1989 and the facility is being operated in its current configuration indefinitely.

The Trojan Dam was constructed across the original Trojan Creek to form the Trojan Pond. A 610 millimetres (mm) diameter culvert was initially installed through the dam foundation at the dam section, which was used for passing Trojan Creek Flow. The culvert was blocked at its upstream end in October 1983. A permanent spillway with a rock control section was constructed in 1996 at the west abutment of the dam. Plan and section drawings of the Trojan Dam Spillway are presented in Figure 2.5.

Some of the key elevations and dimensions of Trojan Dam are as follows:

- embankment crest elevation = 1441.5 metres above sea level (masl);
- embankment length = 1.7 km;
- embankment toe elevation = 1390 masl;
- nominal height of embankment = 51.5 metres (m);
- spillway crest elevation = 1435.5 masl; and
- tailings beach elevation = 1441.5 masl.

A diversion ditch system exists upstream of No. 2 Pond and has been designed to convey flows around the Pond up to a 1 in 100-year return period event. However, for flow above that event, the water bypasses the diversion ditch and enters the No. 2 Pond.

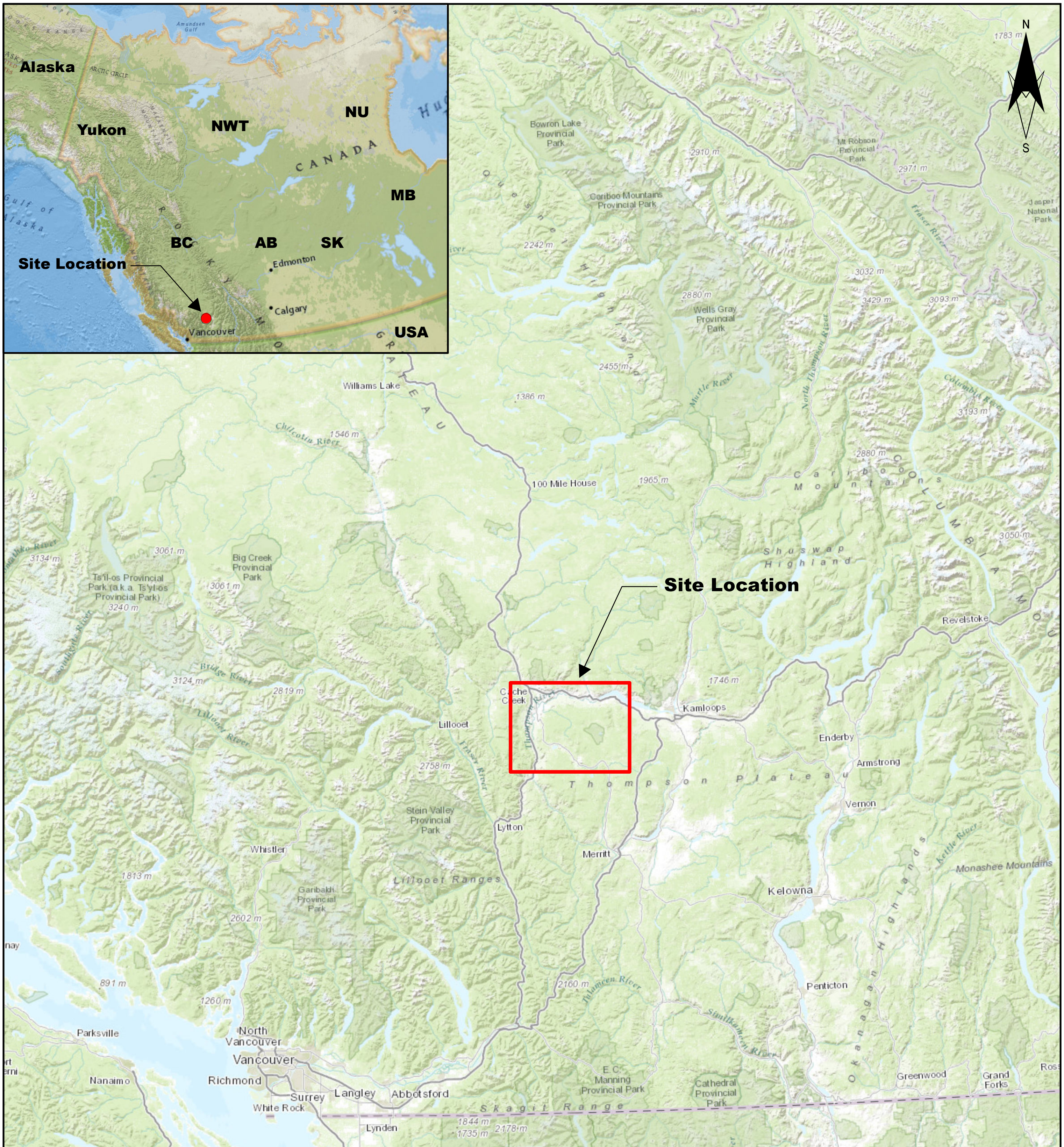
Since the construction of the spillway in 1996, the water level in the Bethlehem No. 2 Pond has varied between 1431.9 and 1435.2 masl. Inflow to the No. 2 Pond is generated by surface runoff from adjacent watersheds located primarily to the north of the facility. As a result, seasonal variations in pond levels are evident in the data. Pond elevation records show a slight increasing trend in water surface elevations since 2008, with a maximum pond level of 1435.21 masl recorded in June 2011.

Trojan Dam was previously classified as “High” in accordance with the 1999 Canadian Dam Association (CDA) Guidelines (Klohn Crippen Berger (KCB) 2003). The inflow design flood (IDF) for this classification would correspond to the 1:1000-year rainfall event under the updated CDA 2007 Guidance. However, the spillway that was installed in 1996 was designed to convey the probable maximum flood (PMF) (KCB, 1994).

Under flood conditions, it is possible that there will be an accumulation of flood water behind Trojan Dam. Breach of the dam under flood conditions would cause the release of flood water and tailings material. The flood water would potentially result in the flooding of downstream areas.

The area downstream of Trojan Dam contains BC Highway 97C, a provincial highway connecting the community of Logan Lake with the City of Merritt to the south, and the Village of Ashcroft to the west. There are also extensive mine workings downstream of the Trojan Dam; the Valley Open Pit is an active mining area with an estimated depth of approximately 430 m. HVC has indicated that there are workers present in the pit on a regular basis.

Witches Brook also lies in the downstream environment. It is believed that Witches Brook supports wild Rainbow Trout that spawn in the gravel deposits along Witches Brook. The coarse gravel substrate may also provide rearing habitat for Chinook Salmon and Coho Salmon. Recent efforts have been made by the BC Ministry of Forests, Lands and Natural Resources to promote passage of salmonids in Witches Brook.



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CLIENT: Highland Valley Copper Teck	SCALE: 0 25 50 100 Kilometres 1:40,000,000	PROJECT: DAM BREAK AND INUNDATION STUDY	DWN BY: TM CHK'D BY: JM
AMEC Environment & Infrastructure, a Division of AMEC Americas Limited Suite 1 - 495 Prospect Street Fredericton, NB E3B 9M4 Tel. 506-458-1000 Fax 506-450-0829 www.amec.com	DATUM: NAD 83 PROJECTION: UTM Zone 10 PROJECT NO: TE1330191.2000	TITLE: BETHLEHEM TAILINGS STORAGE FACILITY SITE LOCATION MAP	DATE: Nov 26, 2013 REV. NO: FIGURE NO: 2.1

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Legend

Former Witches Brook Location

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PROJECT No:	TE1330191
DATUM:	NAD 83
PROJECTION:	UTM Zone 10
SCALE:	500 250 0 500 Metres 1:25,000
PROJECT:	DAM BREAK AND INUNDATION STUDY
TITLE:	BETHLEHEM GENERAL SITE LOCATION
DWN BY:	TM
CHK'D BY:	JM
DATE:	Dec 3, 2013
REV NO:	1
FIGURE:	2-2

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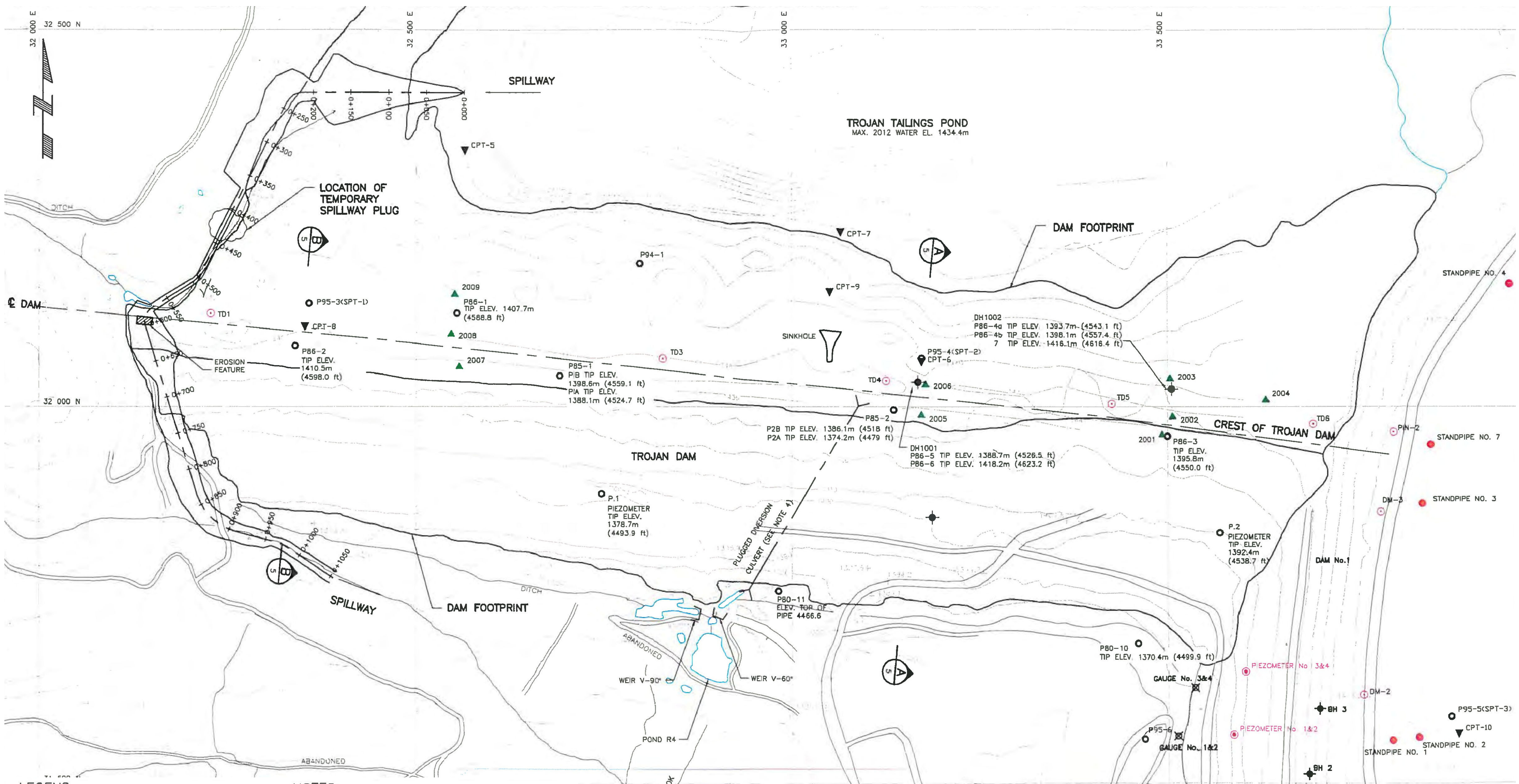
SOURCE: Teck Aerial Imagery 2012,2011



LEGEND

- ▲ 2004 — CONE PENETRATION TEST
- DH1001 — SAMPLED DRILL HOLE
- P95-1 — PIEZOMETER – 1995
- CPT-10 — CONE PENETRATION TEST – 1995
- TD-1 — SURVEY MONUMENTS
- PIEZOMETERS
- STANDPIPES
- GAUGING STATION

NOTES:

1. PLAN OF DAM INCLUDES RAISE: TO EL.4695' CONSTRUCTED OF CYCLONED SAND
2. DRAWING ADAPTED FROM DWG.D-2916-13 IN KLOHN LEONOFF REPORT DATED NOV 22, 1982
3. ELEVATIONS BASED ON BETHLEHEM DATUM
4. 24" DIA. CORRUGATED STEEL PIPE DIVERSION CULVERT UNDER ROCKFILL SECTION. UPSTREAM 50ft. OF CULVERT PLUGGED WITH CONCRETE IN OCT. 1983
5. ELEVATIONS LESS THAN 1500 ARE IN METRES.
6. ELEVATIONS GREATER THAN 4000 ARE IN FEET.

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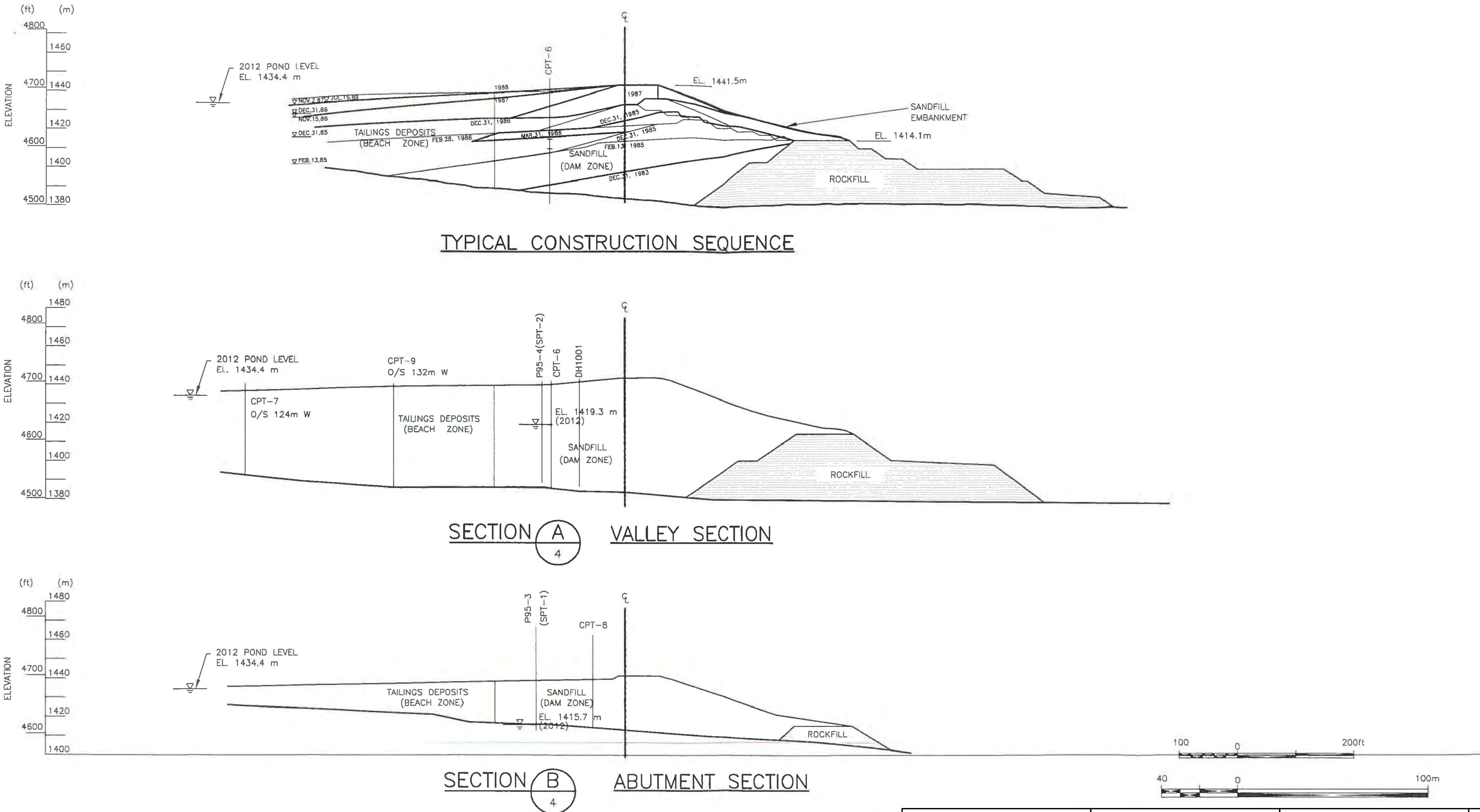
CLIENT: Highland Valley Copper Teck	PROJECT No: TE1330191 SOURCE: BASE PLAN TAKEN FROM PENCIL MANUSCRIPT SUPPLIED BY BETHLEHEM COPPER CORPORATION DWG 81-184M DATED JULY 17, 1981 KLOHN LEONOFF PROJECT NO. PB291618, DWG NO. D-2030 REV 1 DATED NOV 13, 1992 UPDATED IN KLOHN CRIPPEN PROJECT PM 291626, LONG TERM STABILITY ASSESSMENT DWG NO 8-23016 REV 09 DATED DEC 9, 1996	PROJECT: DAM BREAK AND INUNDATION STUDY	DWN BY: TM CHK'D BY: JM DATE: Dec 5, 2013
AMEC Environment & Infrastructure, a Division of AMEC Americas Ltd. 495 Prospect St., Suite 1 Fredericton, NB E3B 9M4 Tel. 506-458-1000 Fax 506-450-0829 www.amec.com		TITLE: PLAN TROJAN DAM	REV NO: FIGURE: 2-3

Path: G:\GIS\PROJECTS\TE133019_TECK_TrojanDam\MXD\20131220_JM_TrojanDam_Plan.mxd User: jonathan.thornton, Date: 20/12/2013

SOURCE: Teck Report - Bethlehem and Highmont Tailings Storage Facilities - 2012 Annual Review of Tailings Dam, August 2013



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Highland Valley Copper Teck	SOURCE: BASED ON KLOHN CRIPPEN DWG. B-23017 DEC 9, 1996, PROJECT M291623, REPORT - LONG TERM STABILITY ASSESSMENT	DAM BREAK AND INUNDATION STUDY	CHK'D BY: JM
			DATE: Dec 5, 2013
AMEC Environment & Infrastructure, a Division of AMEC Americas Ltd. 495 Prospect St., Suite 1 Fredericton, NB E3B 9M4 Tel, 506-458-1000 Fax 506-450-0829 www.amec.com		TITLE: TYPICAL SECTIONS TROJAN DAM	REV NO:
			FIGURE: 2-4

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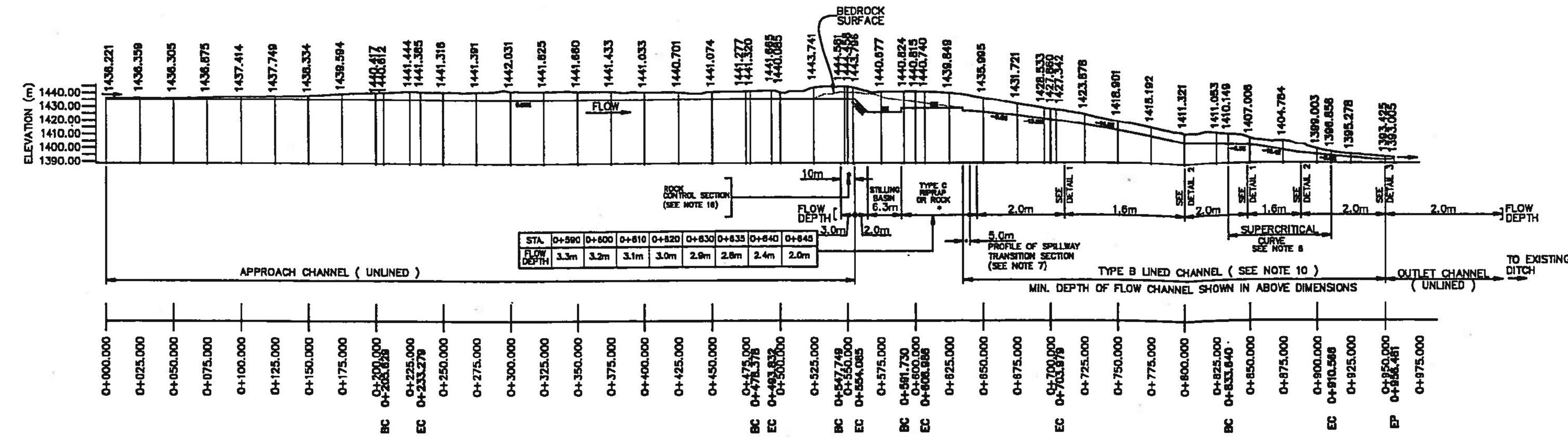
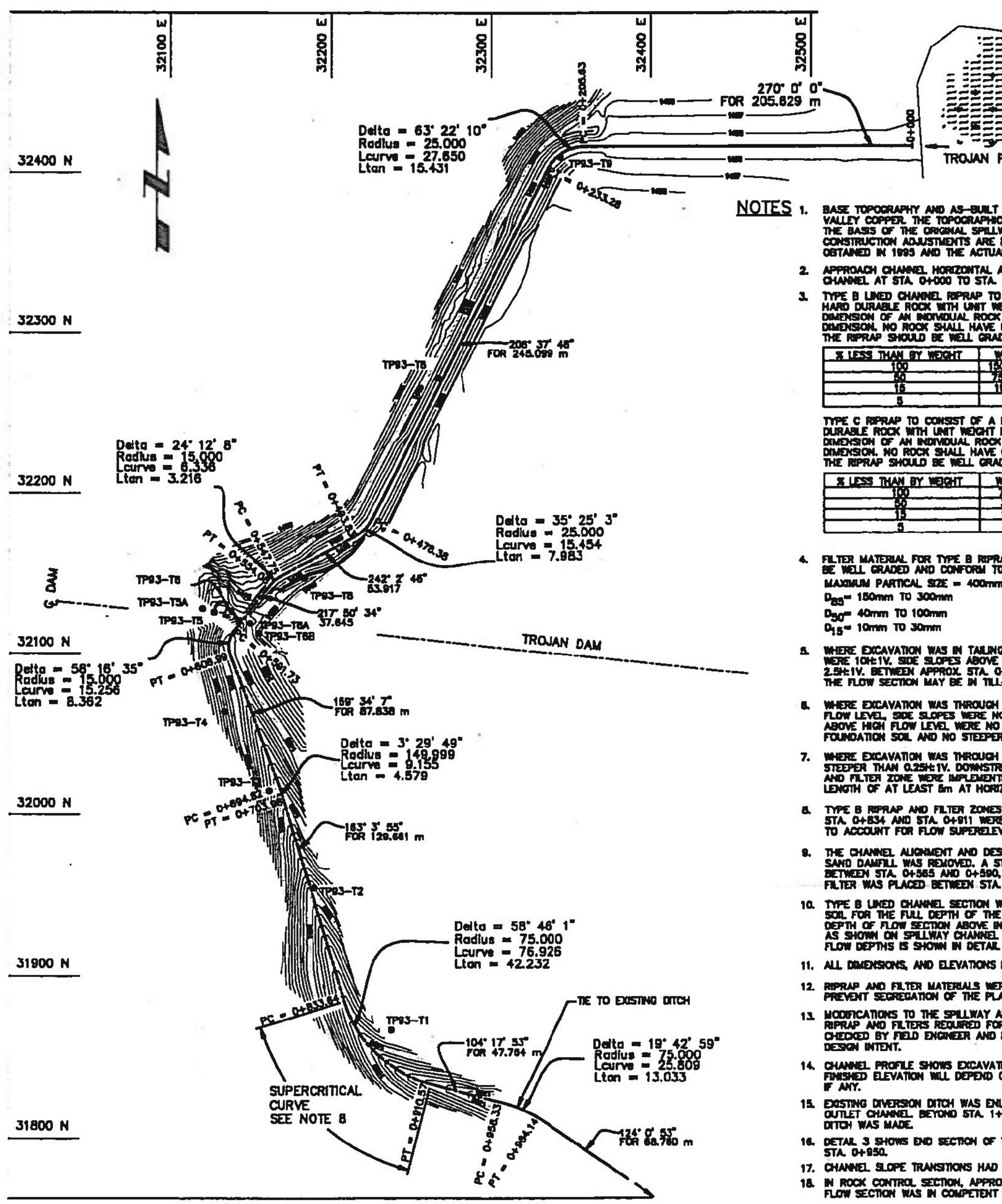
SOURCE: Teck Report - Bethlehem and Highmont Tailings Storage Facilities - 2012 Annual Review of Tailings Dam, August 2013



PROFILE ALONG SPILLWAY CHANNEL

(SEE NOTE 14)



GENERAL ARANGEMENT – PLAN

NOTES

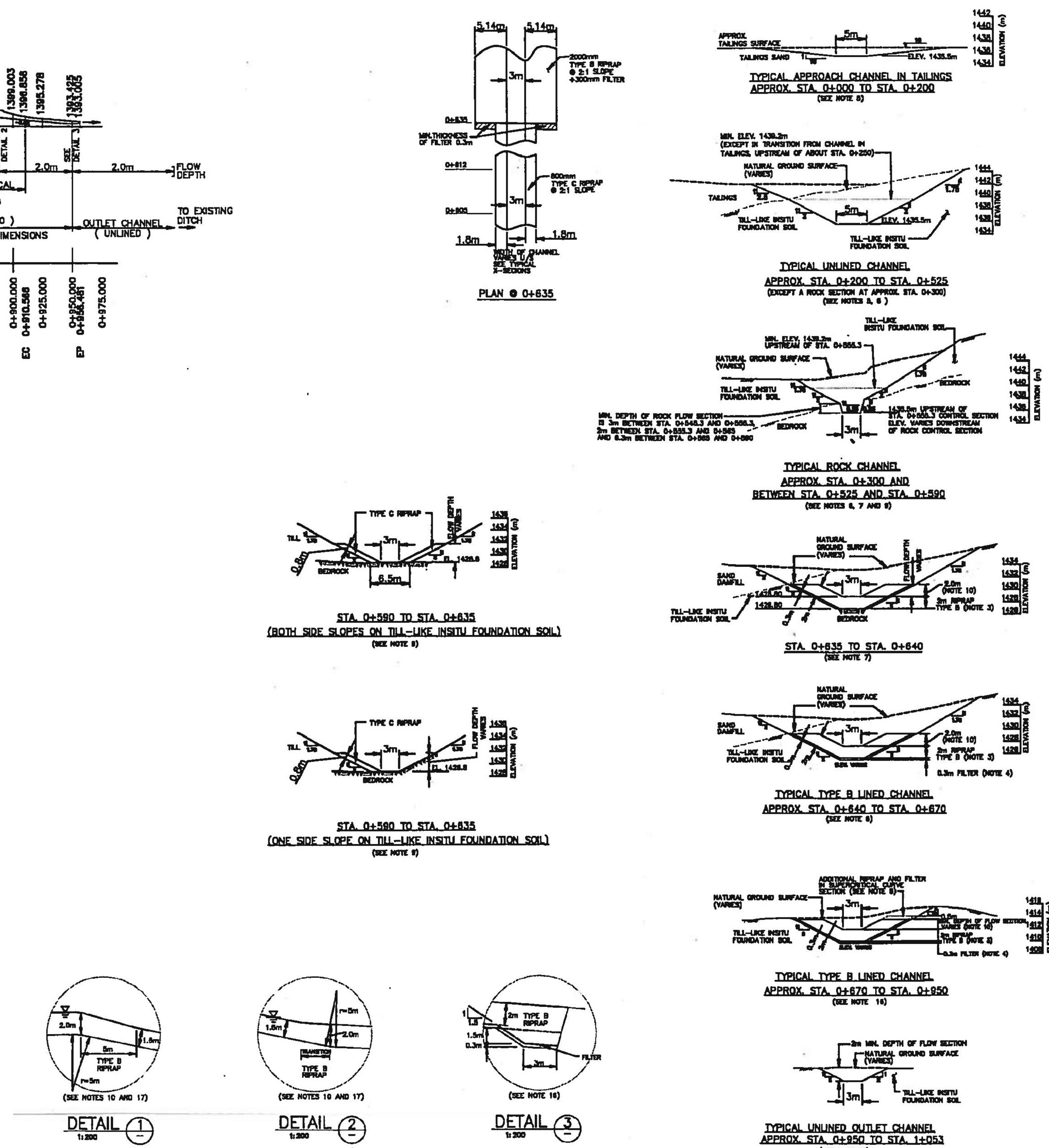
1. BASE TOPOGRAPHY AND AS-BUILT SURVEY WERE SUPPLIED BY HIGHLAND VALLEY COPPER. THE TOPOGRAPHIC MAP AND 1993 TEST PITTING DATA FORMED THE BASIS OF THE ORIGINAL SPILLWAY DESIGN. DESIGN MODIFICATIONS AND CONSTRUCTION ADJUSTMENTS ARE BASED ON ADDITIONAL TEST PITTING DATA OBTAINED IN 1995 AND THE ACTUAL GROUND CONDITIONS ENCOUNTERED.
2. APPROACH CHANNEL HORIZONTAL AT ELEV. 1435.5m FROM START OF TAILINGS CHANNEL AT STA. 0+000 TO STA. 0+555.3 IN ROCK CHANNEL.
3. TYPE B LINED CHANNEL RIPRAP TO CONSIST OF A 2000mm THICK LAYER OF HARD DURABLE ROCK WITH UNIT WEIGHT NOT LESS THAN 2400 kg/m^3. NO DIMENSION OF AN INDIVIDUAL ROCK SHOULD BE LESS THAN 1/3 OF LARGEST DIMENSION. NO ROCK SHALL HAVE OBVIOUS FRACTURE PLANES OR FISSURES. THE RIPRAP SHOULD BE WELL GRADED AND CONFORM TO THE FOLLOWING:

% LESS THAN BY WEIGHT	WEIGHT (kg)	DIA. (mm)
100	1500 TO 3000	1050 TO 1340
50	750 TO 1270	840 TO 1000
15	190 TO 630	530 TO 800
5	160	500

TYPE C RIPRAP TO CONSIST OF A 800mm THICK LAYER OF HARD DURABLE ROCK WITH UNIT WEIGHT NOT LESS THAN 2400 kg/m . NO DIMENSION OF AN INDIVIDUAL ROCK SHOULD BE LESS THAN 1/3 OF LARGEST DIMENSION. NO ROCK SHALL HAVE OBVIOUS FRACTURE PLANES OR FISSURES. THE RIPRAP SHOULD BE WELL GRADED AND CONFORM TO THE FOLLOWING:

% LESS THAN BY WEIGHT	WEIGHT (kg)	DIA. (mm)
100	70 TO 140	380 TO 480
50	35 TO 60	300 TO 380
15	10 TO 30	190 TO 290
5	9	180

4. FILTER MATERIAL FOR TYPE B RIPRAP ON TILL-LIKE FOUNDATION SOIL SHOULD BE WELL GRADED AND CONFORM TO THE FOLLOWING:
   MAXIMUM PARTICAL SIZE = 400mm
   D_{85}= 150mm TO 300mm
   D_{50}= 40mm TO 100mm
   D_{15}= 10mm TO 30mm
5. WHERE EXCAVATION WAS IN TAILINGS BELOW HIGH FLOW LEVEL, SIDE SLOPES WERE 10H:1V. SIDE SLOPES ABOVE HIGH FLOW LEVEL WERE NO STEEPER THAN 2.5H:1V. BETWEEN APPROX. STA. 0+200 AND 0+525, THE UPPER PORTION OF THE FLOW SECTION MAY BE IN TILL-COVERED TAILINGS-SAND SLOPE LOCALLY.
6. WHERE EXCAVATION WAS THROUGH TILL-LIKE FOUNDATION SOIL BELOW HIGH FLOW LEVEL, SIDE SLOPES WERE NO STEEPER THAN 2H:1V. SIDE SLOPES ABOVE HIGH FLOW LEVEL WERE NO STEEPER THAN 1.75H:1V IN TILL-LIKE FOUNDATION SOIL AND NO STEEPER THAN 2H:1V IN SAND DAMFILL.
7. WHERE EXCAVATION WAS THROUGH BEDROCK, SIDE SLOPES WERE NO STEEPER THAN 0.25H:1V. DOWNSTREAM OF STA. 0+635, TYPE B RIPRAP AND FILTER ZONE WERE IMPLEMENTED IN A TRANSITION SECTION FOR A LENGTH OF AT LEAST 5m AT HORIZONTAL GRADE.
8. TYPE B RIPRAP AND FILTER ZONES AT OUTER CHANNEL SLOPE BETWEEN STA. 0+834 AND STA. 0+911 WERE 0.5m ABOVE THE HIGH FLOW LEVEL TO ACCOUNT FOR FLOW SUPERELEVATION.
9. THE CHANNEL ALIGNMENT AND DESIGN WERE MODIFIED AFTER OVERLYING SAND DAMFILL WAS REMOVED. A STILLING BASIN WAS IMPLEMENTED BETWEEN STA. 0+565 AND 0+590, AND LIGHTER TYPE C RIPRAP WITH NO FILTER WAS PLACED BETWEEN STA. 0+590 AND 0+635.
10. TYPE B LINED CHANNEL SECTION WAS IN TILL-LIKE FOUNDATION SOIL FOR THE FULL DEPTH OF THE RIPRAP LINED SECTION. MINIMUM DEPTH OF FLOW SECTION ABOVE INVERT VARIES WITH CHANNEL SLOPE AS SHOWN ON SPILLWAY CHANNEL PROFILE. TRANSITION DETAIL BETWEEN FLOW DEPTHS IS SHOWN IN DETAIL 1 AND 2.
11. ALL DIMENSIONS, AND ELEVATIONS IN METRES.
12. RIPRAP AND FILTER MATERIALS WERE PLACED IN A MANNER TO PREVENT SEGREGATION OF THE PLACED MATERIALS.
13. MODIFICATIONS TO THE SPILLWAY AND CONSTRUCTION MATERIALS FOR RIPRAP AND FILTERS REQUIRED FOR LINING THE SPILLWAY CHANNEL WERE CHECKED BY FIELD ENGINEER AND DESIGNERS FOR COMPLIANCE WITH THE DESIGN INTENT.
14. CHANNEL PROFILE SHOWS EXCAVATION ELEVATION ALONG CENTRELINE. FINISHED ELEVATION WILL DEPEND ON LINING AND FILTER THICKNESS, IF ANY.
15. EXISTING DIVERSION DITCH WAS ENLARGED WITHIN THE SEGMENT OF OUTLET CHANNEL. BEYOND STA. 1+053, SMOOTH TRANSITION TO EXISTING DITCH WAS MADE.
16. DETAIL 3 SHOWS END SECTION OF TYPE B RIPRAP AND FILTER AT STA. 0+950.
17. CHANNEL SLOPE TRANSITIONS HAD A VERTICAL RADIUS OF 5m.
18. IN ROCK CONTROL SECTION, APPROX. 0+545.3 TO 0+555.3, ENTIRE FLOW SECTION WAS IN COMPETENT BEDROCK.
19. UNLINED OUTLET CHANNEL MAY REQUIRE RIPRAP PROTECTION IF EXCESSIVE EROSION DEVELOPS IN THE FUTURE.



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CLIENT:	Highland Valley Copper Teck
PROJECT No:	TE1330191
SOURCE:	BASED ON KLOHN CRIPPEN BERGER DWG NO. 114-BOB-201 AS-BUILT TROJAN DAM SPILLWAY PLAN, PROFILE & SECTIONS, JAN 12, 2002
PROJECT:	DAM BREAK AND INUNDATION STUDY
TITLE:	AS-BUILT TROJAN DAM SPILLWAY PLAN, PROFILE & SECTIONS
DWN BY:	TM
CHK'D BY:	JM
DATE:	Dec 5, 2013
REV NO:	
FIGURE:	2-5

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Path: G:\GIS\PROJECTS\TE133019_TECK_TrojanDam\MXD\20131220_JM_TrojanDam_Spillway_Plan_Profile_Sections.mxd User: jonathan.thornton, Date: 20/12/2013

SOURCE: Teck Memo Report - Bose Lake Dam and Trojan Dam As-Built Spillways, Jan 2002

3.0 STUDY OBJECTIVES

As part of HVC's commitment to responsible tailings management, HVC requested AMEC to conduct a dam break analysis for Trojan Dam. In the proposal issued to HVC in August 2013, the objectives of the study were identified as the following:

- to complete an inundation study for the dam;
- to estimate the deposited tailings in the event of dam breach; and
- to classify the dam in accordance with the 2007 CDA Guidelines (CDA 2007).

The following tasks were outlined in the August 2013 scope of work:

- hydrological modelling to estimate IDF hydrographs into the reservoir and at other locations of interest in the potentially affected area along the flood path;
- dam break analysis and inundation modelling to delineate flood zones in the areas of interest;
- delineation of potential areas of tailing deposit;
- dam classification, including evaluation of population at risk and incremental loss;
- reporting; and
- project management.

The area downstream of Trojan Dam consists primarily of undeveloped HVC property, BC Highway 97C, and the Valley Open Pit. The primary concern for flood inundation is interruption to traffic on Highway 97C and the mine workers in the Valley Open Pit. To assess flood inundation, detailed inundation mapping has not been prepared for this study. Rather, a hydraulic analysis has been completed to determine the flow depth over Highway 97C, and also to determine the fill rate and flood depth in the Valley Open Pit.

4.0 FAILURE SCENARIOS

Dam breach analysis is used to determine the ultimate discharge from a hypothetical break of the dam facility as outlined in the 2007 CDA Guidelines. The outcome of the analysis is a flood peak or flood wave generated immediately downstream of the dam which is routed through the topography downstream of the facility to a point where the effects are considered negligible. Two hypothetical failure scenarios have been considered for Trojan Dam:

1. sunny-day failure, and
2. flood-induced failure.

4.1 Sunny-Day Failure

This failure mode simulates a sudden dam breach that occurs during normal operation caused by internal erosion, piping, earthquakes, improper operation, or another unanticipated event. It is assumed that there is no precipitation in the catchments at the time of the breach. While the sunny-day failure may not result in the largest flood peak, this type of failure can occur suddenly and with little warning (such as an earthquake). For this reason, a sunny-day failure may result in a higher incremental consequence than a flood-induced failure.

4.2 Flood-Induced Failure

This failure mode simulates a dam breach resulting from a natural flood. As noted above, the spillway is designed to pass the PMF, hence the potential for overtopping is very low. To simulate the flood induced event, it is assumed that the failure of the dam could be triggered at the peak of the flood event resulting in the subsequent release of a flood wave. It is assumed that flow conditions associated with the flood event are occurring in the surrounding catchments at the time of the breach.

5.0 HYDROLOGY

The objective of the hydrological modelling is to generate hydrographs for the predetermined modelling scenarios at the location of interest downstream of the Trojan Dam. These hydrographs will subsequently be used as input in the inundation assessment.

The watersheds located upstream of the No. 2 Pond are comprised of undeveloped, mountainous terrain. A map of the drainage areas contributing to the No. 2 Pond, and near-by watercourses, is presented in Figure 5.1. A summary of these watersheds and respective drainage areas are presented in Table 5.1. During a storm event, inflow would be generated from these watersheds and migrate into the No. 2 Pond. As noted above, flows in excess of the 1 in 100-year event bypass the diversion ditch system and enters the No. 2 Pond.

Once the water elevation in the pond exceeds the spillway invert elevation, water will flow downstream through the spillway toward Highway 97C and ultimately to the Valley Open Pit. A portion of this discharge may bypass the pit and flow into Witches Brook located approximately 2 km east of the Valley Open Pit. However, for the hydrological assessment it will be assumed that all discharge enters the pit.

Table 5.1 Watershed Summary for Trojan Dam Hydrological Model

Watershed Name	Drainage Area Square Kilometres (km^2)
T1-U	7.26
T2-U	1.71
T3-U	0.99
T4-U	0.43
T5-U	4.18
T6-U	0.36
T7-U	1.20
T1-D	2.43

5.1 Design Rainfall Distribution

The following flood events were considered for the hydrological modelling:

- 1:100-year;
- 1:1000-year;
- 1/3 between 1:1000-year and the PMF;
- 2/3 between 1:1000-year and the PMF; and
- PMF.

Modelling for each scenario was completed using a 30-day duration.

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CLIENT: Highland Valley Copper / Teck	0 500 1,000 Meters	PROJECT: DAM BREAK AND INUNDATION STUDY	DWN BY: JT	DATE: Dec 5, 2013
	DATUM: NAD 83		CHK'D BY: JM	REV. NO:
AMEC Environment & Infrastructure, a Division of AMEC Americas Limited	PROJECTION: UTM Zone 10	TITLE: BETHLEHEM NO.2 POND CATCHMENT BOUNDARIES AND WATERCOURSES	SCALE: 1:30000	FIGURE NO: 5.1
Suite 1 - 495 Prospect Street, Fredericton, NB E3B 9M4, Tel. 506-458-1000 Fax 506-450-0829 Web www.amec.com	PROJECT NO: TE1330191			

Path: G:\GIS\PROJECTS\TE133019_TECK_TrojanDam\MXD\20131219_JM_Trojan_Dam_Catchment_Boundary_Fig_5_1.mxd User: jonathan.thornton Date: 20/12/2013

SOURCE: Bing Map - Aerial Photography, Data AMEC 2013

The probable maximum precipitation (PMP) was estimated in the early 1990s to support the spillway design for Trojan Dam (KCB 2002). That estimate was generated using a Hershfield probabilistic method for estimating PMP (KCB 1994). According to that study, the 24-hour PMP rainfall depth was estimated to be 260 mm, and was based on rainfall data for the Kamloops Airport and Mamit Lake weather stations; these stations are located approximately 20 and 50 km from the HVC site, respectively. The study notes that records from the Highland Valley Lornex station, which is closer to the site, were not used due to a relatively short record available at the time. The Highland Valley Lornex station is located approximately 5 km away from the No. 2 Pond.

Precipitation records at the Highland Valley BCCL Station ceased in 1989. However, precipitation records at the Highland Valley Lornex Station (#1123469) are available from 1967 to 2007 (40 years). These data have been used by the Hydrometeorology Division of the Canadian Climate Centre to estimate PMP values for a range of storm durations. The Canadian Climate Centre has generated a 24-hour PMP total rainfall depth of 182.2 mm. Given the proximity of the Highland Valley Lornex Station (5 km), it is now advisable that these updated PMP estimates developed by the Canadian Climate Centre be adopted for the HVC site.

Intensity-duration-frequency data for the Environment Canada weather station in Kamloops, BC (Station #1163780) were used to derive the incremental rainfall depth for the 1:100 year rainfall event. A 1:100-year design rainfall distribution was then generated using the Alternating Block method (Chow 1988). This rainfall distribution was then applied to the other rainfall events listed above.

Given the size of the drainage areas contributing to the Bethlehem No. 2 Pond (Table 5.1), it was determined that a 30-day composite design storm would be most suitable. The 30-day incremental rainfall depths were also derived using the Alternating Block method (Chow 1988). The 30-day, PMP rainfall distribution is shown in Figure 5.2, having a total rainfall depth of 556.5 mm (according to Canadian Climate Centre estimates). The 24-hour distribution was considered to be the wettest day and was embedded on the 16th day of the 30-day rainfall event. The 24-hour, PMP rainfall distribution is shown in Figure 5.3 having a total rainfall depth of 182.2 mm.

5.2 Hydrological Modelling

The hydrological modelling was completed using the US (United States) Army Corps of Engineers (ACE) software HEC-HMS (version 3.5) as the modelling platform. The model encompasses the watersheds draining into the No. 2 Pond, and watersheds upstream of Highway 97C. Initial modelling considered the pond under normal operating conditions (ie. no dam break) and accounted for discharge from the Trojan Dam Spillway only. This is considered to be the base case for the flood assessment.

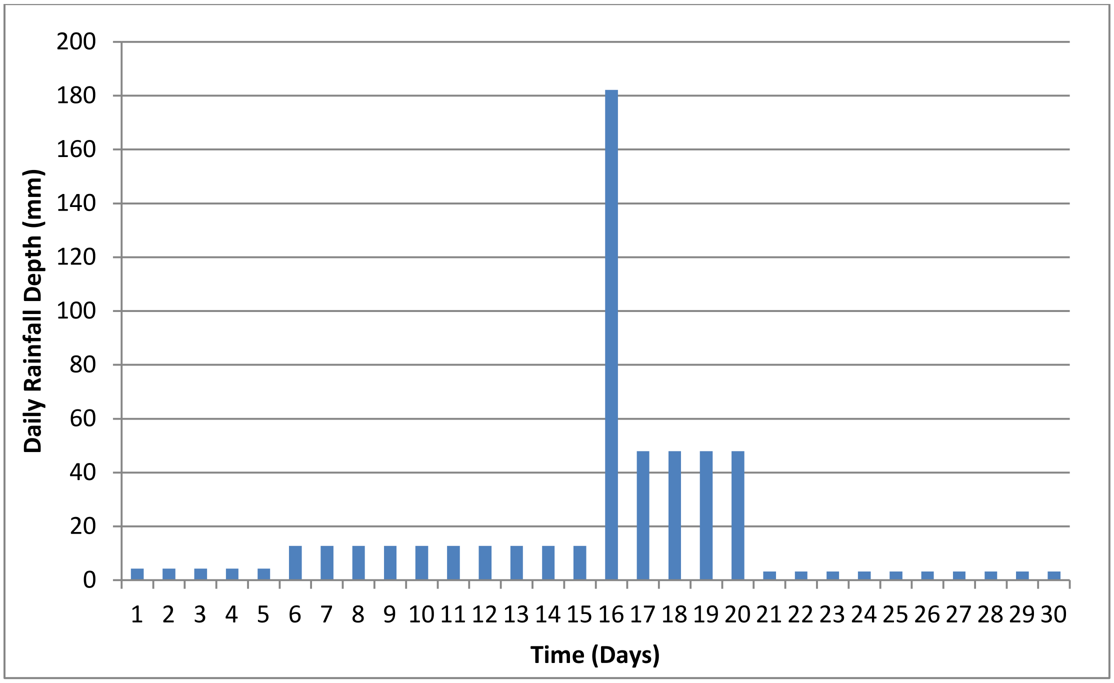


Figure 5.2 Rainfall Hyetograph for 24-hour, PMP Rainfall Event for the HVC Site

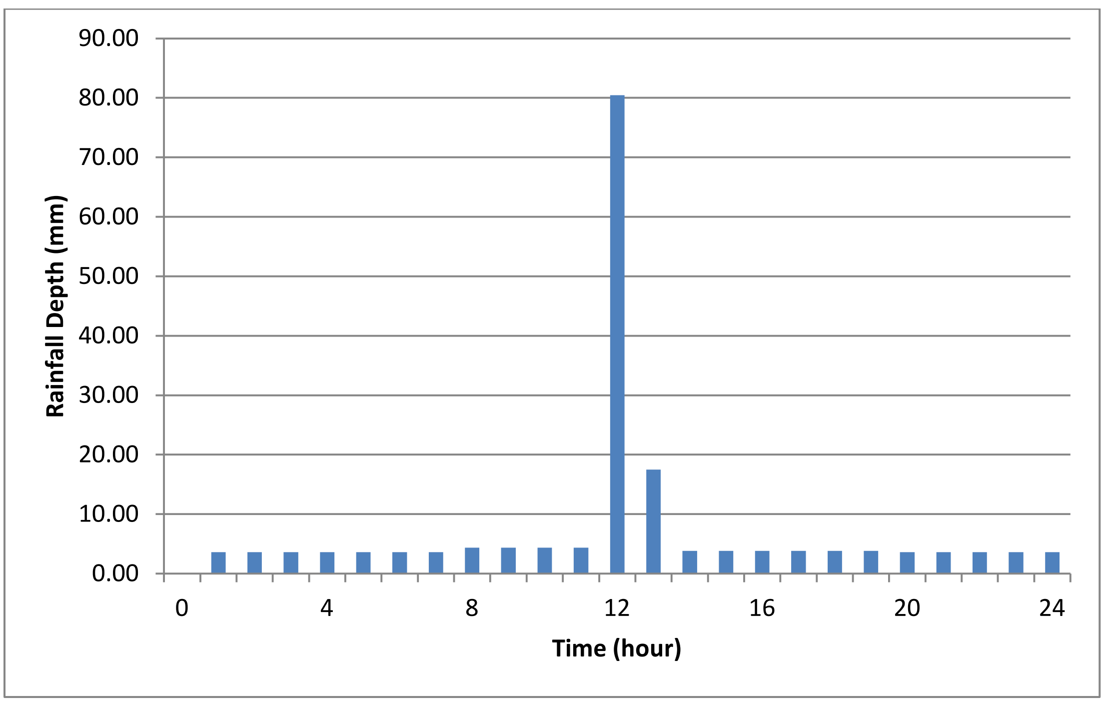


Figure 5.3 Rainfall Hyetograph for 24-hour, PMP Rainfall Event for the HVC Site

The US Soil Conservation Service (SCS) unit hydrograph method was used to model the rainfall runoff response within each watershed. The SCS unit hydrograph method has been derived for wide range of catchment sizes and types (Ponce 1989), and has been deemed appropriate for the drainage areas contributing to the Bethlehem No. 2 Pond.

The SCS runoff curve number method has been used to determine the amount of runoff generated for each watershed. According to Ponce (1989), a runoff curve number of 77 is suitable for a wooded drainage area for average antecedent rainfall conditions. This value represents the upper limit for undeveloped watersheds as there has been considerable logging activity (clear cutting) in the surrounding catchment area.

The design storms were modelled when the surrounding catchment is in a saturated state (high antecedent rainfall condition). Therefore, the runoff curve number has been adjusted to 90 to reflect a saturated catchment condition (Ponce 1989). The HEC-HMS model was run for the five rainfall events noted above. Specific parameters for each watershed have been summarized in Table 5.2 below. A percent impervious value of 100% has been used to simulate rainfall on the No. 2 Pond (T7-U). A 30% impervious value has also been assigned to T1-D to account for the mine workings located downstream of the dam (interpreted from aerial photography).

Table 5.2 Watershed Parameter Summary for Trojan Dam Hydrological Model

Watershed Name	Runoff Curve Number	% Impervious
T1-U	90	0
T2-U	90	0
T3-U	90	0
T4-U	90	0
T5-U	90	0
T6-U	90	0
T7-U	N/A	100
T1-D	90	30

Stage-storage data for the Bethlehem No. 2 Pond was obtained from KCB (1994) and the stage-storage curve is shown in Figure 5.4. Stage-storage data for the Valley Open Pit was derived from the 2012 LiDAR data provided by HVC. Geometry of the Trojan Dam Spillway has also been obtained from KCB (2002) and is included as Figure 2.5. It has been assumed that the water surface elevation in the No. 2 Pond was at the spillway invert elevation (1435.5 masl) prior to each design rainfall event.

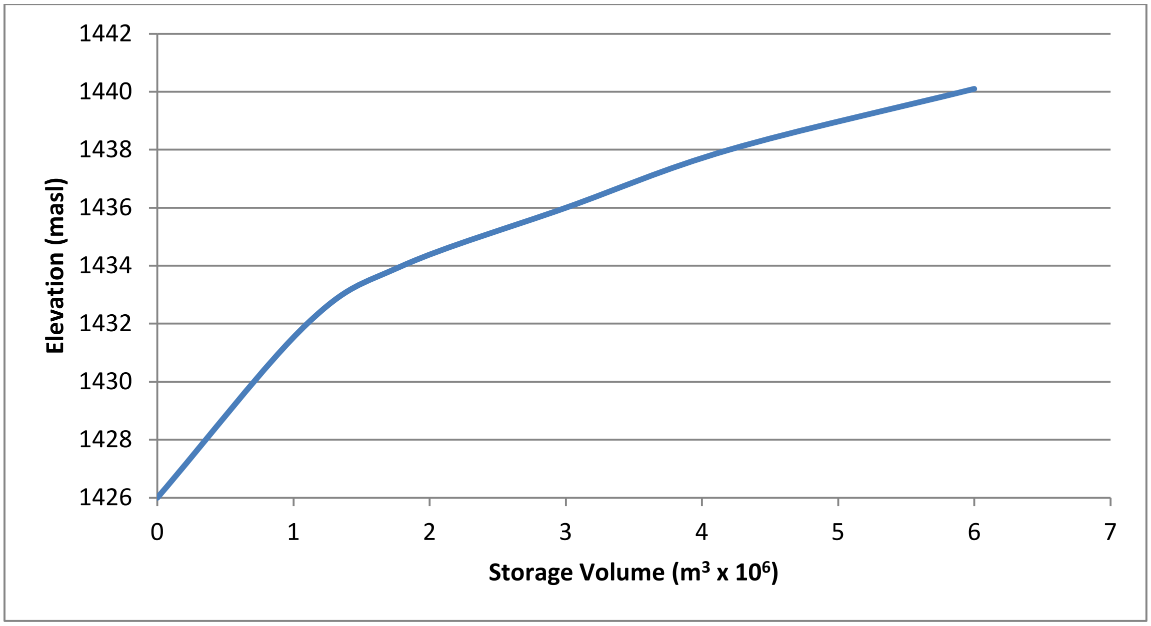


Figure 5.4 Stage-Storage for Bethlehem No. 2 Pond

5.3 Base Case Modelling Results

The base case conditions were modelled for the five rainfall events outlined in Section 5.1. The resulting inflow and outflow hydrograph for the No. 2 Pond during the 30-day, PMF design storm is shown below in Figure 5.5. Figure 5.5 shows a peak inflow to the No. 2 Pond of 133.2 cubic metres per second (m^3/s) for the PMF. The corresponding spillway outflow has a peak value of 26.1 m^3/s. The difference between the peak inflow and outflow values is due to attenuation of inflow by the pond prior to discharging through the spillway. A summary table of the HEC-HMS results is also presented in Table 5.3.

The Trojan Dam Spillway design described by KCB (1994) notes that the spillway was designed to safely pass the PMF. The PMF flow through the spillway was estimated by KCB (1994) to be in the order of 54 m^3/s. This is greater than the peak flow modelled as part of this assessment (26.1 m^3/s). The difference in peak flow can be attributed to the updated PMF rainfall depth used in this study, which is lower than that used for the KCB (1994) study.

As noted in Table 5.3, the peak water level in No. 2 Pond during the PMF event is estimated to be 1438.5 masl, which compares to the peak water level of 1439.0 masl estimated by KCB (1994).

The peak flow values modelled for each watershed contributing to Trojan Pond were also compared to regional equations developed for Agriculture and Agri-Foods Canada (Abrahamson and Pentland 2010). It was found that the modelled peak flows were generally in agreement with the regional equations for the BC Interior. The percent difference was found to range between 75 and 115%, depending on the watershed considered. Some variation between modelled flows and the regional equations is expected due to the inclusion of site specific hydrological parameters in the model. Overall, however, it was found that the modelled flows were generally in agreement with the regional equations.

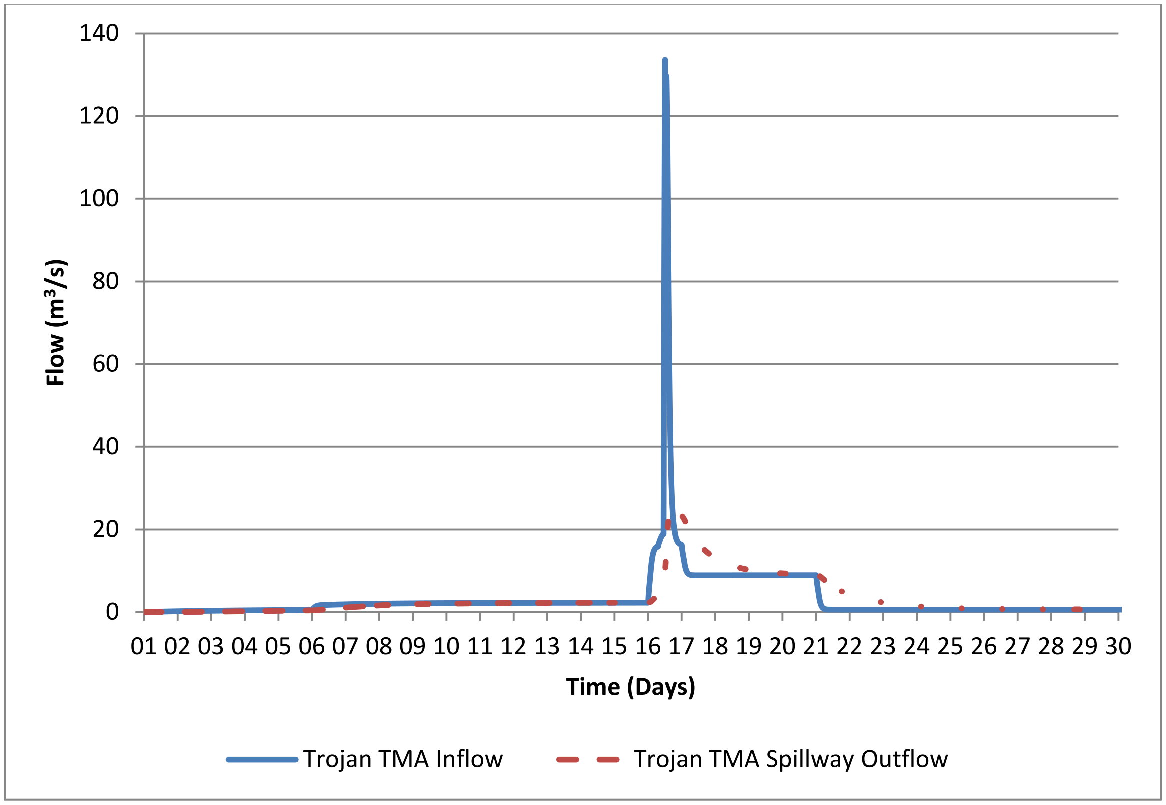


Figure 5.5 Hydrograph of Inflow to No. 2 Pond and Outflow (Spillway Only) during 30-day PMF Rainfall Event for the Base Case

Table 5.3 Summary of Hydrological Model Results for Base Case

Flood Event (Base Case - No Failure)	Peak Water Level (masl)	Peak Inflow to No. 2 Pond (m^3/s)	Peak Outflow (Spillway) (m^3/s)
l00-year return period	1436.5	35.7	5.1
l000-year return period	1436.8	54.0	7.7
1/3 between 1:1000 and PMF	1437.3	84.3	12.7
2/3 between 1:1000 and PMF	1438.0	119.0	20.2
PMF	1438.5	133.2	26.1

6.0 DAM BREAK ASSESSMENT

Two failure modes have been considered for this assessment: a flood-induced failure, and a sunny-day failure. A breach simulation was conducted for both a flood-induced and sunny-day failure.

For a flood-induced failure, overtopping of Trojan Dam is not expected under any of the flood events modeled since the peak water levels in the pond do not exceed the dam crest elevation of 1443 masl (refer to Table 5.3). Therefore, dam failure due to overtopping is considered unlikely. Another possible mode of failure is due to piping through the internal structure of the dam, but this is also very unlikely given that the pore pressures and seepage through the dam are low. While neither failure mode is considered likely, both have been considered for the Trojan Dam and are discussed below.

Dam overtopping failure occurs when water is able to flow over the dam crest, causing erosion of the dam crest material. This erosion results in the formation of a dam breach that expands progressively downward into the dam structure. It may be possible to force overtopping of Trojan Dam by introducing a blockage in the spillway. A complete blockage of the spillway is considered unlikely, but is still conceivable. Such a blockage may occur due to accumulation of debris or ice in the spillway.

Failure due to piping could be caused by seepage through the dam core. Seepage through the core may increase in velocity and quantity eroding the fine sediments from the dam core. When enough material erodes, a direct hydraulic connection is made between the impoundment reservoir and the downstream dam face (USACE 2010). Once such a connection is made, dam failure is imminent and a full breach of the dam is likely. It should be noted that the probability of a piping failure coinciding with flood conditions in the pond is considered extremely low.

The hydrological model discussed in Section 5.2 has been modified to include both a forced overtopping failure and piping failure of Trojan Dam. The timing of both failure modes has been set to coincide with the peak water level in the pond. This timing of dam failure allows for the greatest possible flood wave downstream.

6.1 Breach Parameters

The parameters defining the configuration of the dam breach were estimated from available literature and are discussed below. Froehlich (2008) provides methods to estimate breach parameters for both piping and overtopping failures. The peak water level for the PMF of 1438.5 masl, corresponding to an impoundment volume of 4.9 million cubic metres (Mm^3) was used to develop breach parameters for piping failure. For the overtopping failure scenario (with a blocked spillway), the peak water level for the PMF in the pond was modelled to be 1441.5 masl (at the dam crest elevation), corresponding to an impoundment volume of approximately 7.7 Mm^3. These flood conditions were used to develop the following breach parameters:

Breach Height and Elevation: The crest elevation of the Trojan Dam is 1441.5 masl. According to stage-storage information for No. 2 Pond, the elevation of the pond corresponding to zero storage is 1426 masl. Therefore the breach would have a maximum possible height of 15.5 m, and a minimum elevation of 1426 masl (bottom of pond). A breach height of 15.5 m was used for both overtopping and piping failures.

Breach Side Slope Ratio: The breach side slope ratio for an overtopping failure is estimated at 1H:1V (Froehlich 2008) based on down cutting of the flood wave through the compacted embankment fills. The side slope ratio for piping failure is assumed to be steeper and is estimated to be 0.7H:1V (Froehlich 2008).

Breach Width: The average dam breach width varies between 1 to 5 times the height of water against the dam at failure. According to methods outlined in Froehlich (2008), the dam breach width has been estimated to have a bottom width of 47 m for overtopping failure, and 31 m for piping failure.

Breach Development Time: Breach development time can range between 0.1 to 4 hours depending on the impoundment volume (Harrington 2012). The estimated breach time for overtopping has been estimated to be approximately 1.0 hour, and 0.8 hours for piping (Froehlich 2008).

6.2 Dam Break Modelling Results

The HEC-HMS model framework used to model base case conditions (no dam failure) was modified to include both an overtopping and piping dam failure. The dam failures were set to coincide with the peak water level in the pond, which resulted in the largest flood wave downstream. Modelling results for the dam failures are presented in Tables 6.1 and 6.2 for overtopping and piping failure, respectively. The No. 2 Pond inflow and outflow hydrographs for the PMF are presented in Figure 6.1 for overtopping and in Figure 6.2 for piping failure.

It can be seen in Tables 6.1 and 6.2 that the overtopping failure results in a considerably larger flood wave. This is due to the increased volume of water impounded against the dam as a result of the (hypothetically) blocked spillway. Since the overtopping failure results in the largest flood wave, these results have been carried forward and used for the inundation assessment to follow.

It should be noted that despite efforts to force an overtopping failure, only the PMF and the 2/3 between 1:1000-year and PMF storms resulted in a peak water level greater than the dam crest elevation, with a blocked spillway. For storms less than the 2/3 between 1:1000-year and PMF, overtopping of the dam crest is considered extremely low. Moreover, the probability of overtopping for any of the storm events is very remote, since a blockage of the spillway would have to happen simultaneously with the flood event. However, as noted above, these scenarios have been considered to investigate the maximum consequence associated with failure of the Trojan Dam.

The piping failure did not result in the largest flood wave and will not be considered further. However, as noted above, the probability of a piping failure occurring during a flood event is also extremely low.

Table 6.1 Summary of Hydrological Model Results for Overtopping Dam Failure

Flood Event (Overtopping Failure)	Peak Water Level (masl)	Peak Inflow to No. 2 Pond (m^3/s)	Peak Outflow (Breach) (m^3/s)
l00-year return period	1438.5	35.7	1739.1
l000-year return period	1439.5	54.0	1926.1
1/3 between 1:1000 and PMF	1440.1	84.3	2043.3
2/3 between 1:1000 and PMF	1441.5	119.0	2492.8
PMF	1441.5	133.2	3055.1
Sunny-Day Failure	N/A	N/A	N/A

Table 6.2 Summary of Hydrological Model Results for Piping Dam Failure

Flood Event (Piping Failure)	Peak Water Level (masl)	Peak Inflow to No. 2 Pond (m^3/s)	Peak Outflow (Spillway) (m^3/s)	Peak Outflow (Breach) (m^3/s)
l00-year return period	1436.5	35.7	5.1	953.6
l000-year return period	1436.8	54.0	7.6	1005.2
1/3 between 1:1000 and PMF	1437.3	84.3	12.7	1946.8
2/3 between 1:1000 and PMF	1438.0	119.0	20.2	2026.6
PMF	1438.5	133.2	26.1	2069.0
Sunny-Day Failure	1435.5	N/A	N/A	779.0

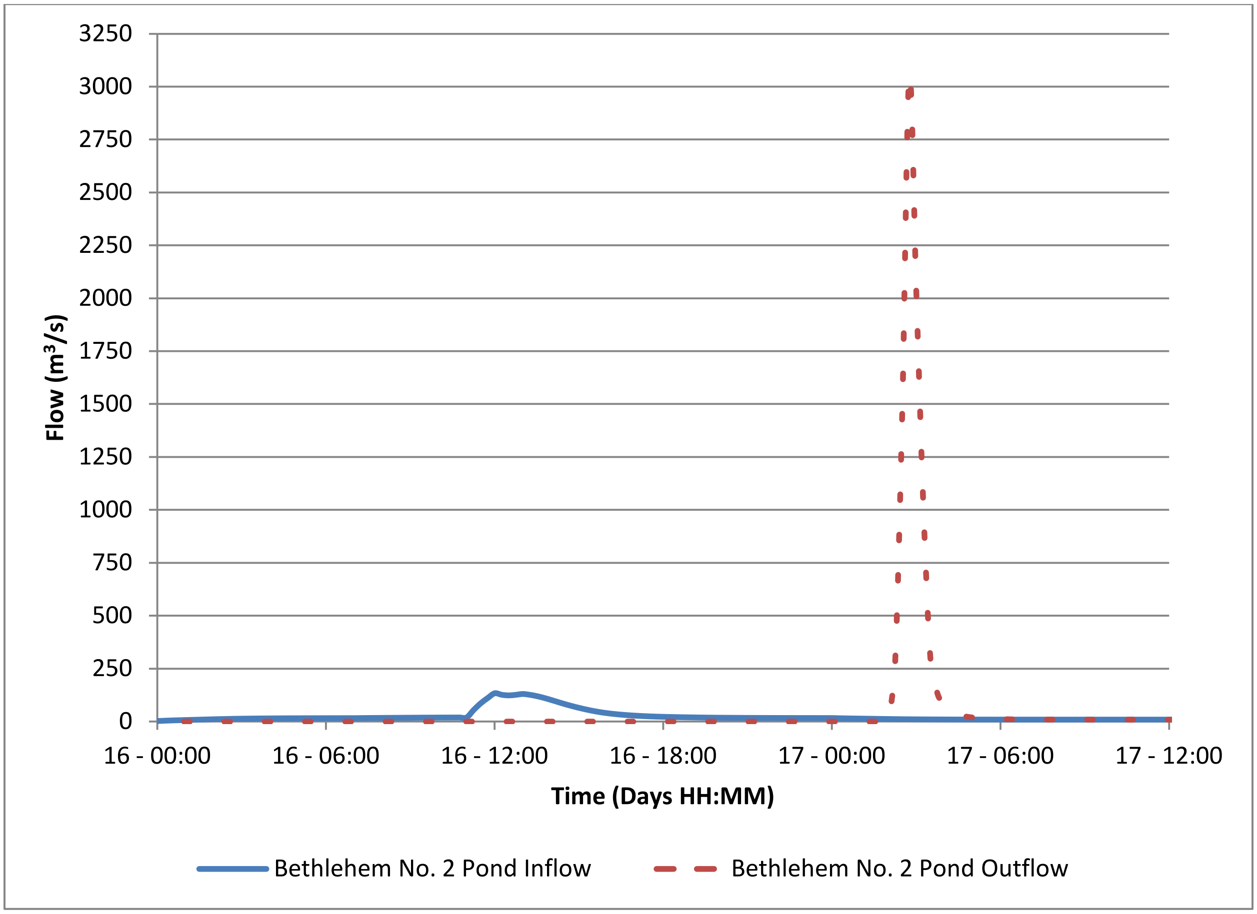


Figure 6.1 Hydrograph of No. 2 Pond Inflow and Outflow (Spillway and Breach) during 30-day PMF Rainfall Event for Overtopping Dam Failure

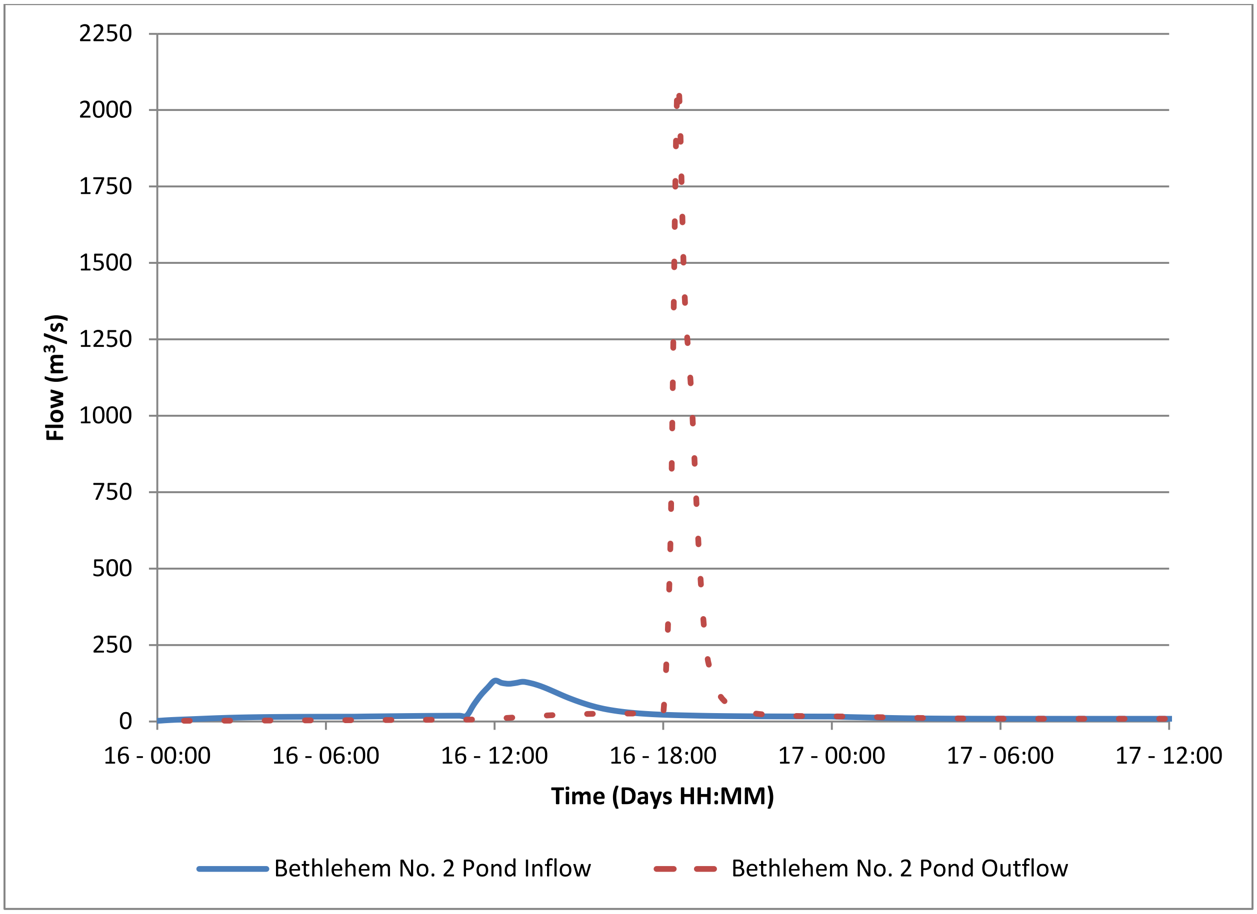


Figure 6.2 Hydrograph of No. 2 Pond Inflow and Outflow (Spillway and Breach) during 30-day PMF Rainfall Event for Piping Dam Failure

7.0 INUNDATION MODELLING

This section describes the inundation modelling conducted for the area downstream of the Trojan Dam for the overtopping failure hydrographs generated as part of the hydrological modelling. Inundation mapping is typically conducted for watercourses with existing development. During the extreme flood events with or without the dam failure, flood water released from the Trojan Dam will flow over the area between the Trojan Dam and Highway 97C. The flow path in this area is not defined and there is very limited development in this area. When the flood water reaches Highway 97C, a portion of the flood water will flow across Highway 97C through the existing culvert or over the top of the highway into the Valley Open Pit, depending on the peak flow rate. A portion of the flood water will flow along Highway 97C, crossing it at some point into Witches Brook. The following evaluates the inundation effect on Highway 97C, Valley Open Pit and Witches Brook respectively.

7.1 British Columbia Highway 97C

An estimated 6 m diameter corrugated steel culvert exists beneath Highway 97C. The capacity of this culvert has been determined to be sufficient under the base case for flows up to the PMF. However, in the case of a dam breach, the capacity of this culvert will be exceeded and overtopping of the highway is expected.

A hydraulic model was developed using the HY-8 software package by the US Federal Highway Administration. HY-8 is designed to model culvert hydraulics and is capable of estimating the flow depth over the road based on the culvert and roadway geometry. A model of the BC Highway 97C crossing downstream of the Trojan Dam suggests that overtopping of the highway will occur for all of the failure scenarios presented in Table 6.1. The overtopping depth is estimated to have a peak value of 2.3 m for the PMF event.

7.2 Valley Open Pit

Once the flood wave passes the highway, it will enter the Valley Open Pit a short distance further downstream. The pit is currently operational and work crews are routinely present in the pit. In the event of dam failure, there is a potential danger to those working in the pit.

After review of the 2012 LiDAR data, a stage-storage relationship for the pit has been developed. The LiDAR data began at elevation 776 masl and extends to elevation 1206 masl. It was assumed that the effective bottom of the pit lies at elevation 776 masl, suggesting a total pit depth of approximately 430 m.

Using the stage-storage data developed for Valley Open Pit, the volume of water and corresponding flood level in the pit has been modelled. Table 7.1 shows the final water surface elevation within the pit after each of the rainfall events considered for this study. This exercise was completed for both the base case and for overtopping failure. The fill rate is also presented in Figure 7.1 for both the PMF and 1:1000-year storm.

Table 7.1 Summary of Hydrological Model Results for Flood Level in Valley Open Pit

Inflow Design Flood	No Failure		Overtopping Failure	
	Flood Level in Valley Open Pit (masl)	Total Water Depth (m)	Flood Level in Valley Open Pit (masl)	Total Water Depth (m)
I00-year return period	800	24	814	38
I000-year return period	806	30	819	43
1/3 between 1:1000 and PMF	810	34	822	46
2/3 between 1:1000 and PMF	828	52	838	62
PMF	842	66	854	78
Sunny Day	N/A	N/A	804	28

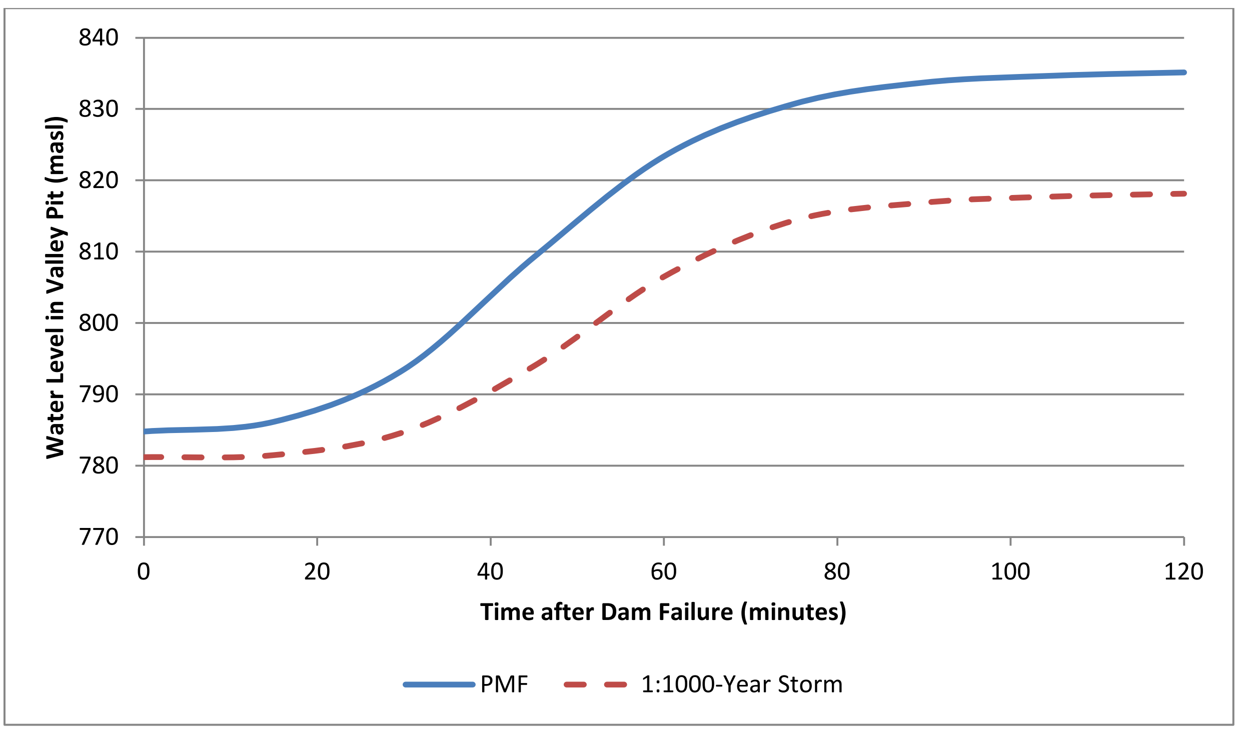


Figure 7.1 Water Level in Valley Open Pit after 1:1000-year Storm and PMF Failure Scenarios

HVC has indicated that the number of workers in the pit is generally in the order of 200 people. Generally, these workers are located above elevation 805 masl in the pit. Occasionally, smaller work crews (100 or fewer) may be present below elevation 805 masl.

It can be seen in Figure 7.1 that the water level would raise rapidly in the pit within the first two hours after failure. It should be noted that the fill depth exceeds elevation 805 masl within the first 40-60 minutes after dam failure. The information provided in Figure 7.1 should be used in the preparation of the Emergency Preparedness Plan (EPP), as it provides information regarding an acceptable evacuation time after dam failure.

7.3 Witches Brook

A portion of the flood water released from the Trojan Dam will flow along and across Highway 97C and eventually into Witches Brook. The proportion of the flood water entering Witches Brook is dependent on the localized topographic features and is difficult to determine. However, in order to enter Witches Brook, the flood flow must flow along Highway 97C for a distance where it will also be spilled into the Valley Open Pit, and then flow through an underpass. These features are expected to significantly limit flood flow entering Witches Brook. For the purpose of this project, the proportion of total volume of flood water entering Witches Brook is estimated to be less than one tenth of the total flood volume.

Water accumulating in Trojan Pond is not toxic to fish. However, flood water released during a dam break event may have elevated metal concentrations resulting from interaction between the flood water and tailings. The elevated metal concentrations may be harmful to fish. The water quality effect resulting from the dam breach events is beyond the scope of this study.

8.0 TAILINGS RUNOUT

The analysis in the previous section describes the flood wave caused by failure of the Trojan Dam. It is also expected that tailings will be released as a result of dam failure. There are two mechanisms for tailings release at Trojan Dam. First, the flood wave will entrain tailings solids during the breach and carry them in suspension as it travels downstream. It is assumed that the flood wave can carry a solids content of up to 35% and as the flood wave continues and the velocities reduce, the percentage of solids that can be retained in the flow will reduce and tailings solids will settle out. Secondly, following the initial release of the flood wave, a bulk mass of tailings may mobilize due to the loss of confinement and shear strength; it is expected that this release will be in the form of debris flow (liquefied mass).

The volume of tailings impounded in the No. 2 Pond has been estimated from the pond geometry presented by KCB (1994). Based on this information, the estimated total volume of impounded tailings within the Bethlehem No. 2 Pond is 51.9 Mm^3. This estimate was calculated using a top of tailings elevation of 1441.5 masl, tailings bottom elevation of 1388.2 masl, and a total surface area of 1.03 km^2.

Two scenarios have been considered for tailings runout: a flood-induced failure, and a sunny-day failure (such as an earthquake). Both scenarios are presented in the following sections.

8.1 Flood-Induced Failure

Using the methods outlined in Froehlich (2008), the breach geometry for tailings release was estimated. It should be noted that this estimate is intended for water and is therefore a rough approximation of the actual breach size. The breach geometry was calculated to have a bottom width of 68 m, and a total depth of 51.5 m (to bottom of dam). The development time for the breach was estimated to be 0.8 hours.

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 used in the course of this study (Blight 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 purposes of this study, the resting slope of tailings within the pond was assumed to be 3%. Using the estimated breach geometry, and a 3% resting slope, the volume of spilled tailings has been estimated to be roughly 13.9 Mm^3. This estimate assumes that the zone of mobilized tailings expands in a radial shape upstream from the breach, up to the top elevation of tailings. This total volume has been assumed to account for both entrained tailings released in the flood wave, and that released as a liquefied mass.

8.1.1 Effect on Highway 97C

A portion of the released tailings, especially the liquefied tailings mass, will be deposited on Highway 97C. This tailings deposition will cause interruption to traffic on this highway. Cleanup effort will be required to reopen the highway.

8.1.2 Effect on Valley Open Pit

It is assessed that a dominant portion of the spilled tailings will be deposited in the Valley Open Pit, causing additional water level rise. The flood levels in the Valley Open Pit (presented in Table 7.1) have been updated to include the spilled tailings component of the flood. It has been assumed for this analysis that once the pond water has evacuated through the breach, tailings will then begin to release. The final flood levels for all failure scenarios (including both water and tailings) are presented in Table 8.1.

Table 8.1 Flood Level in Valley Open Pit for both Water and Deposited Tailings

Inflow Design Flood	Flood Level in Valley Open Pit (masl)	Total Fill Depth (m)
l00-year return period	874	98
l000-year return period	876	100
1/3 between 1:1000 and PMF	878	102
2/3 between 1:1000 and PMF	887	111
PMF	897	121

As shown in Figure 7.1, it will take approximately two hours for the flood water to fill the pit. It is assumed that only after this time that any significant amount of tailings will begin to enter the pit. Therefore, it is believed that the flood water poses the most immediate risk to workers in the pit.

8.1.3 Effect on Witches Brook

It is unlikely that significant amount of the liquefied tailings mass will migrate into Witches Brook due to obstructions along this path. A portion of the entrained tailings may enter Witches Brook with the flow. The entrained tailings will deposit along Witches Brook, resulting in a deterioration of the gravel habitat conditions favored by the wild Rainbow Trout, Chinook Salmon and Coho Salmon. As indicated previously, the proportion of the flood flow entering Witches Brook will be limited.

8.2 Sunny-Day Failure

Only about 1.5% of historical embankment dam failures have been attributed to earthquakes (USBR 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 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, Dam No. 2 is partially a rockfill dam and will retain a portion of its containment ability even through the most severe earthquake. There is a potential for settlement of the rockfill during an earthquake which may cause the dam crest to drop. The dam would still continue to provide containment to the tailings storage behind the dam, although the containment would be reduced from its former capacity.

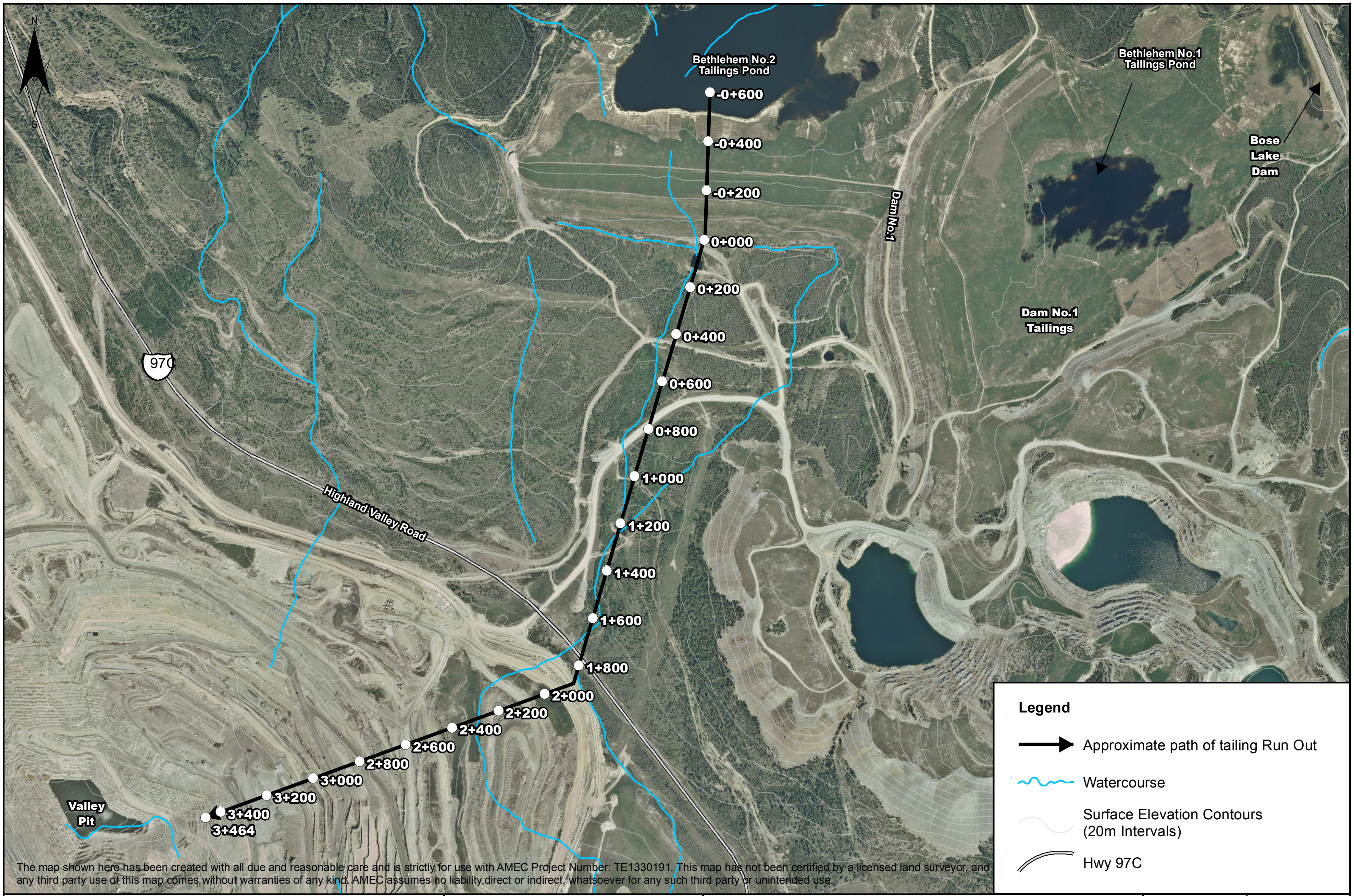
For the purposes of a dam break analysis, the CDA (2007) Guidelines state that a hypothetical dam breach should be considered. The probability of such a dam breach is not an explicit consideration. Hence, for this analysis, we assumed that a breach could hypothetically develop during a seismic event, despite the probability of this being very low.

The volume of tailings run out 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 run out 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. The migration of tailings run out will be governed by this terminal slope and will be limited.

In the case for Dam No. 2, the tailings run out is further compounded by the presence of significant volume of water in the Trojan Pond. The presence of this water will enhance the liquefied state of the tailings, causing it to migrate further and faster. This volume of water will also enhance and accelerate breach development.

An estimated path of tailings run out is shown in Figure 8.1. In the event of a dam breach and associated tailings run out, the terminal point of the tailings run out will be the Valley Open Pit.

There is uncertainty regarding the terminal slope of the tailings run out, and this slope is dependent on the liquid content of the tailings run out. Literature used in the course of this study (Blight 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 run out from the Dam No. 2 was estimated using a final slope of 3%, which was judged to be a conservative value.



CLIENT: Highland Valley Copper Teck	0 100 200 400 600 800 Meters DATUM: NAD83	PROJECT: **DAM BREAK AND INUNDATION STUDY BETHLEHEM DAM No.1**	DWN BY: JT	DATE: Feb 26, 2014
			CHK'D BY: HX	REV. NO:
AMEC Environment & Infrastructure, a Division of AMEC Americas Limited Suite 1 - 495 Prospect Street Fredericton, NB E3B 9M4 Tel. 506-458-1000 Fax 506-450-0829 www.amec.com	PROJECTION: UTM Zone 10 North PROJECT NO: TE1330191	TITLE: **APPROXIMATE PATH OF TAILINGS RUN OUT**	SCALE:	FIGURE NO: 8.1

Path: G:\GIS\PROJECTS\TE133019_TECK_TrojanDam\MXD\20140227_Trojan_No_1_Section.mxd User: jonathan.thornton Date: 27/02/2014

SOURCE: TECK LiDAR Ortho Photograpy 2012/2011

Figure 8.2 shows the existing profile along the path of the tailings run out. It also shows the assumed final slope of 3% at the end of the tailings run out. Based on a comparison of the two profiles, the volume of tailings to be released has been estimated to be 32 Mm^3. It is apparent that the topography downstream of the dam has a slope steeper than 3%. This suggests that the topography downstream of the dam is too steep for the released tailings to deposit, and a dominant portion of the released tailings will continue to migrate until it reaches the Valley Open Pit.

8.2.1 Effect on Highway 97C

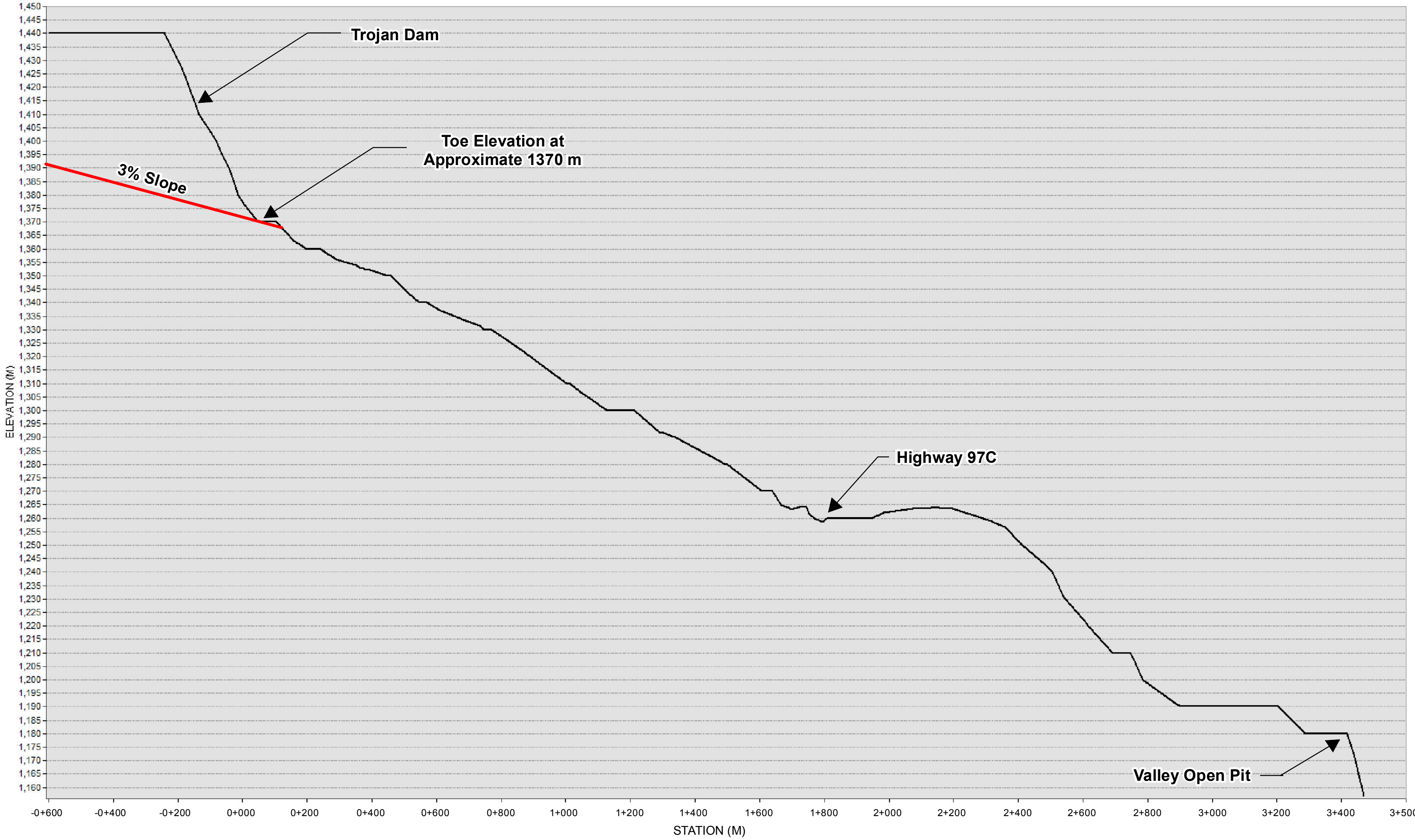
The effect of a sunny-day failure of Trojan Dam on Highway 97C is expected to be similar to that for a flood-induced failure.

8.2.2 Effect on Valley Open Pit

The inflows of water accumulated in the Trojan Pond and tailings run out will cause the Valley Open Pit to be infilled to an elevation exceeding elevation 900 m, jeopardizing people working in the Valley Open Pit.

8.2.3 Effect on Witches Brook

In a sunny day failure scenario, a portion of the water in Trojan Pond will find its way into Witches Brook with associated entrained tailings. The effect on Witches Brook is expected to be similar to that for a flood-induced failure, although the total volume of water entering Witches Brook will be substantially less.



CLIENT: Highland Valley Copper Teck		PROJECT: DAM BREAK AND INUNDATION STUDY BETHLEHEM DAM NO.2	DWN BY: JT	DATE: Feb 26, 2014
	DATUM: NAD83		CHK'D BY: HX	REV. NO:
AMEC Environment & Infrastructure, a Division of AMEC Americas Limited Suite 1 - 495 Prospect Street Fredericton, NB E3B 9M4 Tel. 506-458-1000 Fax 506-450-0829 www.amec.com	PROJECTION: UTM Zone 10 North	TITLE: PROFILES ALONG THE APPROXIMATE PATH OF TAILINGS RUN OUT	SCALE:	FIGURE NO: 8.2
	PROJECT NO: TE1330191			

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SOURCE: TECK LiDAR Ortho Photography 2012/2011

9.0 DAM CLASSIFICATION

9.1 2007 CDA Guidelines

For the Trojan Dam, a classification is required for determining the recommended IDF, freeboard requirements, seismic criteria, and surveillance program. A summary of the 2007 CDA Guidelines regarding dam classification is presented in Table 9.1. 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 Loss of Life (LOL): This is the potential life that may be lost as a consequence of the failure of the dam structure. CDA provides bench mark values for the incremental LOL. A dam may be classified up to extreme based on this consequence category.

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 determinant factor. A dam may be classified up to extreme based on this determinant factor.

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 determinant factor. A dam may be classified up to extreme based on this determinant factor.

9.2 Classification for Trojan Dam

Classification of Trojan Dam according to the 2007 CDA Guidelines has been undertaken. With respect to a flooding failure event, based on the evaluation outlined below, a Dam Classification of "Very High" has been assigned to Trojan Dam. This classification is higher than the previous dam classification based on the 1999 CDA Guidelines, which resulted in a classification of "High" (KCB 2003). Comments for each consequence category are discussed below and summarized in Table 9.2.

Table 9.1 2007 CDA Dam Classification Guidelines

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

Notes:

1: Definition for PAR:

None – There is no identifiable PAR, so there is no possibility of loss of life other than through unforeseeable misadventure.

Temporary – People are only temporarily in the dam-breach inundation zone (eg., seasonal cottage use, passing through on transportation routes, participating in recreational activities).

Permanent – The PAR is ordinarily located in the dam-breach inundation zone (eg., as permanent residents); three consequence classes (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: Implications for LOL:

Unspecified – The appropriate level of safety is required at a dam where people are temporality 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.

Table 9.2 Dam Classification of Trojan Dam (CDA 2007)

Consequence Category	Matching Description of 2007 CDA Guidelines	Rational	Consequence Category
Population at Risk	Permanent	There are workers in the Valley Open Pit on a regular basis.	High and Above
Incremental Loss of Life	100 or fewer	Loss of life is limited to workers below elevation 805 masl	Very High
Incremental Loss of Environmental and Cultural Values	Significant loss of important fish habitat	Loss of important habitat in Witches Brook and loss of recreational opportunities in Trojan Pond	Very High
Incremental Loss of Infrastructure and Economics	Disruption of public transportation	Temporary disruption of traffic on BC Highway 97C	High
Dam Classification			**Very High**
Effect on HVC	Dam repair, tailings and water removal from pit.		

PAR: The Valley Open Pit is located down gradient of Dam No. 2, and there are workers in the pit on a regular basis. These workers are therefore considered "permanent", and the dam classification for this consequence category is assessed to be "High and Above". There is also danger to the transient population present on BC Highway 97C.

Incremental LOL: There are often more than 100 workers in the Valley Open Pit. Deposition of water and tailings into the pit will cause infilling of the pit and cut-off of the escape route used by the workers. This may result in a potentially high fatality rate, however, it is understood that many of the workers would be able to exit the pit, and/or seek refuge in the event of dam failure. Therefore, the LOL is believed to be "100 or fewer", and the dam classification for this consequence category is assessed to be "Very High".

Incremental Loss of Environmental and Cultural Values: In the event of dam failure most of the flood wave and tailings are expected to enter the Valley Open Pit. However, it is likely that Witches Brook would receive some of the released material. Witches Brook is believed to support Rainbow Trout, and provide habitat for important species such as Chinock and Coho Salmon. It is expected that this habitat would be significantly deteriorated if a significant amount of tailings were deposited into Witches Brook. For these reasons, a consequence category of "Very High" has been assigned. Failure of the Trojan Dam will also cause the loss of Trojan Pond, which is used to support a triploid trout population for recreational purpose. This triploid trout population will be lost and associated recreation opportunities interrupted.

Incremental Loss of Infrastructure and Economics: The area immediately downstream of Trojan Dam consists primarily of HVC mine property. Public Highway 97C also passes through the downstream environment and is expected to be overtopped in the result of dam failure. However, overtopping of the highway is expected to be temporary and would only cause a short-term disruption to transportation along Highway 97C. Therefore, a consequence category of "High" has been assigned.

9.3 Potential Effects on HVC

The study demonstrates that there would be a temporary disruption to HVC operations in the Valley Open Pit if Trojan Dam were to fail. This disruption would occur for all of the failure scenarios considered for this study. After failure, HVC will be required to repair the dam and remove both water and deposited tailings from the Valley Open Pit before mining operations in the pit can resume. Habitat restoration and/or compensation would also be required if tailings are deposited into Witches Brook. These clean up and repair efforts would come at a significant cost to HVC.

9.4 Closure Implications

The dam classification outlined above has been prepared for the current operational condition of the dam and mine site. Closure of the mine will have implications on the classification of the Trojan Dam. In particular, the fate of the Valley Open Pit and the absence of workers within the pit will likely reduce the dam classification. However, the presence of aquatic habitat in Witches Brook is likely to maintain a dam classification category of at least “Very High”. It should be noted, however, that classification of the dam should be re-assessed once closure conditions become better defined.

10.0 EMERGENCY PREPAREDNESS PLAN

The dam break and inundation analysis for Trojan Dam is intended to support the development of an EPP. The EPP should be prepared in accordance with the specifications provided in the 2007 CDA Guidelines. This study suggests that particular emphasis should be placed on Highway 97C and the Valley Open Pit in the development of the EPP.

11.0 CONCLUSION AND RECOMMENDATIONS

A dam break assessment has been completed to estimate the resulting flood wave and inundation downstream of Trojan Dam. This assessment suggests that Highway 97C, located approximately 2 km downstream of Trojan Dam, will be overtopped by the flood wave. Moreover, the Valley Open Pit will be filled with flood water and tailings to an estimated elevation of 897 masl for the PMF, and 916 masl for a sunny-day failure. There is also some potential for tailings deposition in Witches Brook, and loss of important aquatic habitat downstream.

Classification of the Trojan Dam was also undertaken according to the 2007 CDA Guidelines. The dam classification was found to be “Very High” due to the risk posed to the permanent population working in the Valley Open Pit, and also the potential loss of important aquatic habitat in Witches Brook.

It is recommended that current mining practices within the Valley Open Pit be reviewed to develop an evacuation plan for the pit in the event of failure of the Trojan Dam. This may be addressed as part of the EPP to be developed for the HVC site. The temporary disruption of Highway 97C should also be addressed as part of the EPP.

12.0 CLOSING

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

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