25 November 2014

AMEC File: VM00276A.5

VIA EMAIL

Goldcorp Canada Ltd.
Equity Silver Mine
P.O. Box 1450
Houston, B.C.
Canada V0J 1Z0

Attention: Mr. Mike Aziz, Mine Manager

Dear Mr. Aziz,

Reference: **Dam Break and Inundation Assessments**
Equity Silver Mine, Houston, B.C.

Please find enclosed the above-noted report outlining the dam break and inundation assessments completed for Equity Silver Mine. Please contact the undersigned if you have any questions regarding our submission.

Sincerely,

AMEC Environment & Infrastructure,
a division of AMEC America Limited

Original signed by Andrew Witte, M.Eng., P.Eng.

Andrew Witte, M.Eng., P.Eng.
Project Manager

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DAM BREAK AND INUNDATION ASSESSMENTS
EQUITY SILVER MINE

Submitted to:

Goldcorp Canada Ltd.
Equity Silver Mine
P.O. Box 1450
Houston, B.C.
Canada V0J 1Z0

Submitted by:

AMEC Environment & Infrastructure,
a division of AMEC Americas Limited
Burnaby, BC

25 November 2014

AMEC File: VM00276A.5

EXECUTIVE SUMMARY

The Equity Silver Mine is located approximately 40 km southeast of Houston, British Columbia (BC). The mine is currently under the care and maintenance of Goldcorp Canada Ltd. (Goldcorp) due to long-term Acid Rock Drainage (ARD) management. AMEC Environment & Infrastructure (AMEC) was retained by Goldcorp to perform dam break and inundation assessments for the following eight dams at the Equity Silver Mine:

- Tailings Pond Dam No. 1 (Dam No. 1);
- Tailings Pond Dam No. 2 (Dam No. 2);
- Tailings Pond Diversion Dam (Diversion Dam);
- ARD Storage Pond South Dike;
- Bessemer Creek Silt Check Dam; and
- ARD Collection Pond Dams (No. 1 Sump, Main ARD Pond and ARD Surge Pond).

In 2010, AMEC conducted a Dam Safety Review (DSR) for the Equity Silver Mine which assigned consequence classifications to the dams within this study (AMEC 2011c) that ranged from “Significant” to “Very High”. Given the layout of these structures on the Equity Silver Mine site and the multiple watersheds involved, the dam break and inundation assessments were broken into six separate assessments using three different methodologies: detailed hydraulic modelling, desktop assessment and simplified methods.

This study does not include quantitative predictions of water quality impacts due to the dam break analyses and inundation modelling as this is not a typical requirement under the CDA guidelines pertaining to dam breach studies. However, as much of the water impounded within the dams of interest contains ARD, some qualitative discussion is provided on the potential extents of the inundation areas that could be impacted by contact with ARD discharges. Discussion on dilution potential throughout the flood path is also provided.

Detailed hydraulic modelling (using HEC-RAS) was developed to simulate the breaches of Dam No. 1 and Dam No. 2 for both sunny-day and flood-induced failures. The results of these models included peak flow, maximum depth, peak velocity and peak wave travel time. Beyond, the No. 1 Seepage Pond Dam, no significant structures have been identified along Foxy Creek downstream of the No. 1 Dam until the forestry bridge on Maxan Creek. At the outlet of Bulkley Lake, roughly 20 km downstream of Dam No. 1, there is a bridge crossing for CN Rail and several farms with houses and other buildings. Failure of Dam No. 1, would overwhelm and washout the No. 1 Seepage Pond Dam. The forestry bridge on Maxan Creek may be overwhelmed and washed out by both sunny-day and flood-induced failures of Dam No. 1. Despite potential attenuation in Bulkley Lake, the bridge crossing for CN Rail downstream of the lake may be overwhelmed and washed out by both sunny-day and flood-induced failures of Dam No. 1. In addition, the majority of the houses and other buildings on the farms downstream of Bulkley Lake will be within the floodplain of both the sunny-day and flood-induced failures of Dam No. 1. However, some of the flow may bypass the flat area leading to Bulkley Lake and head directly to the area downstream of the lake outlet resulting in lower flood attenuation and higher flows.

There are several significant structures downstream of Dam No. 2 including the site water treatment facilities, power substation, power lines, ARD pump houses and ARD Collection Ponds. A small cabin is also located just downstream of the Bessemer Creek Silt Check Dam. Downstream of Goosly Lake there is a forestry bridge crossing at Buck Creek Upper Falls, and ultimately the Town of Houston, BC roughly 40 km downstream of Dam No. 2. Both sunny-day and flood-induced failures of Dam No. 2 would inundate and washout the ARD Collection Ponds and the Bessemer Creek Silt Check Dam. The water treatment plant would not be within the floodplains of either of these failure scenarios. However, the substation (including some of the power lines) and the ARD pump houses will be in the floodplains of both the sunny-day and flood-induced failures of Dam No. 2. Both of these failures would also place the cabin just downstream of the Bessemer Creek Silt Check Dam in the floodplain. Goosly Lake will likely provide some attenuation of both sunny-day and flood-induced failures. However, both failure modes may overwhelm and washout the forestry bridge crossing at Buck Creek Upper Falls as well as impact the residences downstream of the falls. The incremental flooding effects of a sunny-day failure of Dam No. 2 upstream of Houston, BC are expected to be less than the flows associated with a 10 year return period rainstorm event.

In the case of a flood-induced failure, the water quality in the creeks downstream of Dam No. 1 and Dam No. 2 is expected to deteriorate, even in the absence of a dam failure. These creeks would experience large amounts of sediment and the worst impact on water quality. Depending on the time of the breach, the period these creeks would be affected after a sunny-day breach of these dams may extend until the creeks are flushed during the following freshet. The impact on water quality may extend due to the loss of ARD containment facilities until the system is restored. For a flood-induced failure, it was estimated that the tailings runout distance would be roughly 300 m and 500 m from the toes of Dam No. 1 and Dam No. 2, respectively. For a sunny-day failure, the tailings runout distance was estimated to be 850 m and 660 m from the toes of Dam No. 1 and Dam No. 2, respectively. The sunny-day tailings runout estimated for Dam No. 2 will likely go beyond the 660 m as the topography begins to steepen into the Bessemer Creek Valley. Based on this study, it is expected that the impacts on the water quality of Bulkley Lake and Goosly Lake due to the failure of Dam No. 1 and Dam No. 2, respectively, will be significant.

A desktop review of the existing site topography was carried out to determine the most likely potential path of a hypothetical dam breach of the Diversion Dam. The flow path would join that of Dam No. 1. However, the Treated Water and Emergency ARD Pond may provide some storage and attenuation for the water and tailings expected from a breach of the tailings impoundment. A hypothetical breach of Dam No. 1 and Dam No. 2 are considered to represent the more critical inundation limits and water quality scenarios for a breach of the tailings impoundment.

Due to their smaller size, simplified and conservative dam break assessment methods were used to simulate the breaches of the ARD Collection Pond Dams, ARD Storage Pond South Dike and Bessemer Creek Silt Check Dam. The flood wave parameters (water depth, flow and velocity) along typical creek sections downstream of the structures were estimated for a sunny-day dam failure. A sunny-day failure was assessed for these structures as this would be the worst case scenario for ARD impact to Bessemer Creek, Buck Creek and Goosly Lake as there would be limited dilution available in the creeks. As with the hypothetical breach of Dam No.2 the same significant structures exist downstream of these structures. A sunny-day failure of these dams would inundate and washout the Bessemer Creek Silt Check Dam. A sunny-day failure would also place the cabin just downstream of the Bessemer Creek Silt Check Dam in the floodplain as would a failure of this dam in conjunction with a cascade failure of the ARD Collection Pond Dams. The potential area for ARD contamination due to the sunny-day failure of these dams would be measurable and would reach Goosly Lake which would act as a sink for sediment, metals and pH.

This study improves the understanding of the potential impacts associated with the breach of a single facility at the Equity Silver Mine site and also provides insight into the interdependencies within the tailings and ARD management systems in the context of these dam breaches. Therefore, the consequence classification and design flood criteria from the 2010 DSR were re-evaluated based on the findings of this study. As such, consequence classifications of “Significant” to “Very High” have been determined and are summarised in the following table. These classifications are the same as the consequence classifications determined in the 2010 DSR except for the ARD Surge Pond and the Main ARD Pond which have increased from “Significant” to “High”.

Consequence Classifications for the Dams at the Equity Silver Mine Site within this Study

Dam	Consequence Classification
Tailings Pond Dam No. 1	Very High
Tailings Pond Dam No. 2	Very High
Tailings Pond Diversion Dam	Very High
ARD Storage Pond South Dike	High
ARD Surge Pond	High *
Main ARD Pond	High *
No. 1 Sump	Significant
Bessemer Creek Silt Check Dam	High

** Consequence classification has been increased from the 2010 DSR.*

Dam classification sets the stage for surveillance and emergency planning. The flood failure parameters determined in this study are essential for emergency preparedness planning (EPP) and for informing the Operation, Maintenance and Surveillance (OMS) Manual. An EPP and OMS manual were produced as part of an overall site risk assessment in December 2004 following the high flow events of 2002. The EPP and OMS manuals have been revised over the past several years and are currently being revised to reflect the results of this study as per the 2014 Ministerial orders.

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IMPORTANT NOTICE

1.0 INTRODUCTION

The Equity Silver Mine is located approximately 40 km southeast of Houston, British Columbia (BC) (Refer to **Figure 1.1**). The mine is currently under the care and maintenance of Goldcorp Canada Ltd. (Goldcorp) due to long-term Acid Rock Drainage (ARD) management.

AMEC Environment & Infrastructure (AMEC) was retained by Goldcorp to perform dam break and inundation assessments for the following eight dams at the Equity Silver Mine (Refer to **Figure 1.1**):

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- ARD Storage Pond South Dike;
- Bessemer Creek Silt Check Dam; and
- ARD Collection Pond Dams (No. 1 Sump, Main ARD Pond and ARD Surge Pond).

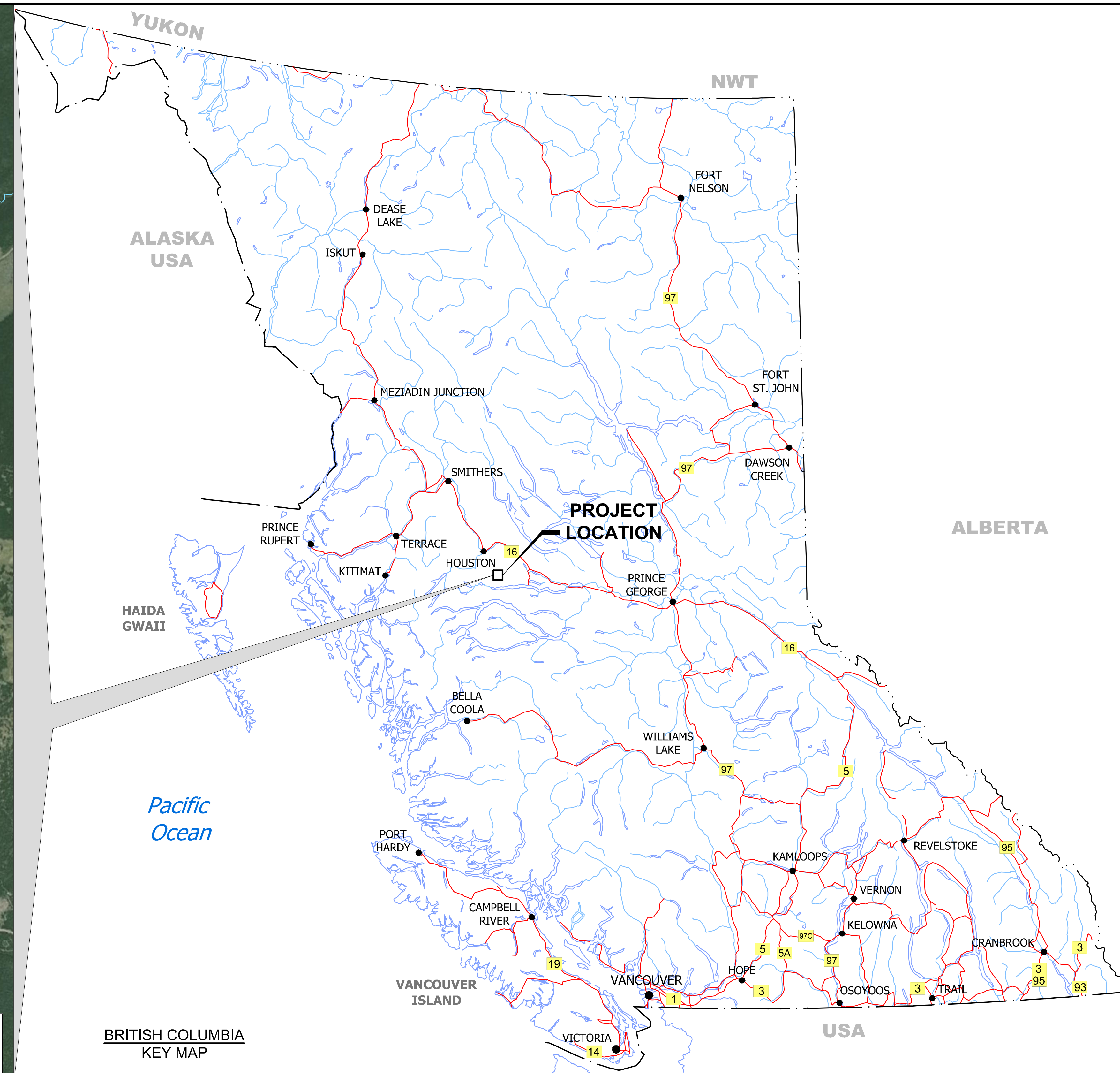
In 2010, the first formal Dam Safety Review (DSR) was performed by AMEC for the Equity Silver Mine site in accordance with the 2007 Canadian Dam Association (CDA) Dam Safety Guidelines. The 2010 DSR recommended that "dam break analyses be undertaken for all structures with an incremental consequence classification (ICC) level of high or higher." The 2010 DSR also recommended that although not rated as "High", a flood routing analysis from a cascade failure of the ARD Collection Pond Dams be performed. Based on the 2010 DSR and subsequent hydraulic structures analyses, the BC Ministry of Energy and Mines (MEM) issued orders requiring that Goldcorp provide dam break and inundation assessments for the dams at the Equity Silver Mine that fall within these criteria (MEM 2013). On August 18, 2014, the Chief Inspector's Office of MEM issued orders mandating that all BC tailings dams with a failure consequence classification of "High", "Very High" or "Extreme" must have a Dam Break Inundation Study completed, with a report submitted to the ministry, by 1 December 2014. This report presents the results of the dam break and inundation assessments for the dams listed above at the Equity Silver Mine which is intended to satisfy both the recommendations of the 2010 DSR as well as the 2013 and 2014 Ministerial orders.

When describing the structures and sites in this report, the standard orientation convention used in dam engineering was employed where the terminology "Left" and "Right" are used while looking in the downstream direction.

The scope of this report includes the following:

- Section 2.0: provides a brief review of the project and background as it relates to the dam break and inundation assessments;
- Section 3.0: outlines the objectives of this study;
- Section 4.0: describes the failure scenarios used as the basis for the assessments;

- Section 5.0: discusses the assessment methodologies employed;
- Section 6.0: summarizes the results of the assessments;
- Section 7.0: discusses the implications of this study to the current Dam Classifications;
- Section 8.0: presents the implications of the results of this study to the Emergency Preparedness Plan (EPP); and
- Section 9.0: provides conclusions and recommendations.



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AMEC Environment & Infrastructure Suite 600, 4445 Lougheed Highway Burnaby, BC, V5C 0E4 Tel. 604-294-3811 Fax 604-294-4664	DATUM: -- PROJECTION: -- SCALE: AS SHOWN	TITLE: KEY MAP AND PROJECT LOCATION PLAN	REV. NO: B FIGURE NO: 1.1

S:\PROJECTS\VM00276A – Equity Silver Mine\DRAWINGS\2014 DBA\VM00276A.5.4–FIGURE–1.1.dwg – FIGURE 1.1 – Nov. 19, 2014 12:58pm – tim.hawker

2.0 BACKGROUND

Open pit mining commenced at the Equity Silver Mine in 1980. Open pit mining and underground mining continued until 1994, when the mine was closed. The mine is currently under care and maintenance due to well-documented long-term ARD management.

The Equity Silver Mine includes a tailings impoundment consisting of the following main components (Refer to **Figure 2.1**):

- Dam No.1;
- Dam No.2;
- Diversion Dam; and
- Bessemer Creek and Berzelius Creek diversion canals that divert surface water around the tailings impoundment.

Runoff and seepage from the tailings impoundment and waste rock stockpile area are collected in various ditches, sumps and constructed ponds with containment dams and directed to the water treatment plant for immediate processing or held and treated at a later date before being discharged to the environment. The ARD collection system includes the following water control structures (Refer to **Figure 2.1**):

- No. 1 Dam Seepage Pond and Dam;
- Main ARD Pond and Dam;
- ARD Surge Pond and Dam;
- Getty Creek Pond and Dam;
- Dam No.3;
- ARD Storage Pond South Dike; and
- Emergency ARD Storage Pond and Splitter Dike.

In addition to the ARD collection system structures listed above, the Equity Silver Mine site also includes two freshwater management structures located outside of the ARD collection system and main mine site footprint:

- Bessemer Creek Silt Check Pond and Dam; and
- Lu Lake and Dams.

The tailings impoundment is enclosed by Dam No. 1 to the north, Dam No. 2 to the south, the Diversion Dam to the west, and high ground to the east (Refer to **Figure 2.1**). The tailings impoundment is located approximately on the divide between two watersheds: Foxy Creek and Bessemer Creek (Refer to **Figure 2.2**). The dams were designed with low permeability glacial till zones, transition and filter zones, and structural zones of compacted rockfill (Refer to

Figure 2.3). The geometry of the tailings dam includes an initial downstream constructed embankment composed of glacial till and coarse rockfill that transitions to a centerline constructed embankment that is laterally supported on the upstream side by the tailings and rockfill on the downstream.

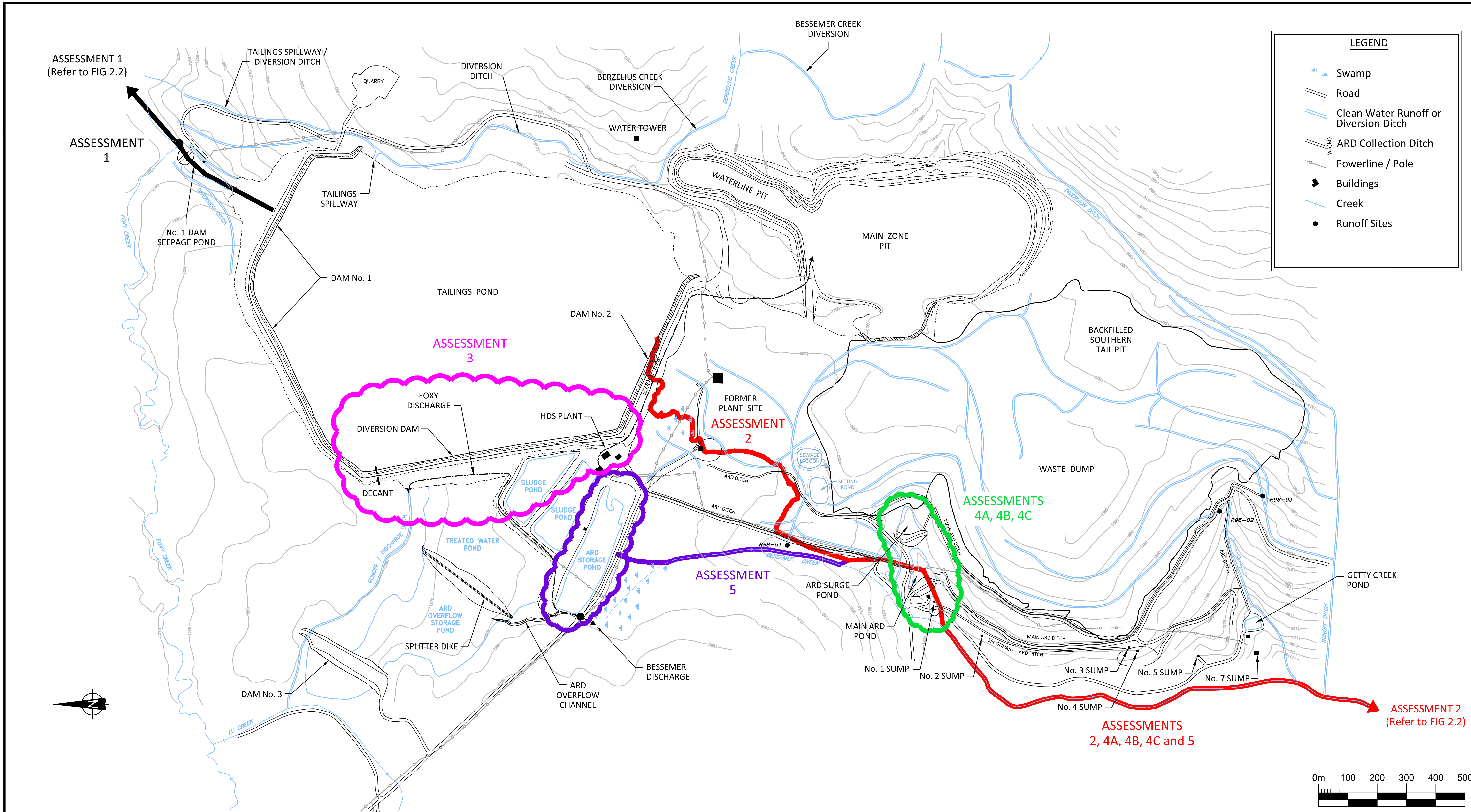
The tailings impoundment was decommissioned in 1994. A permanent, open channel spillway was constructed that year on the right (east) abutment of Dam No. 1, reporting to the Berzelius Creek Diversion Canal and then discharging into Foxy Creek. Clean, non-contact water is diverted around the impoundment via the Berzelius Creek Diversion located upstream of the impoundment. A water cover is maintained over the tailings to reduce the potential for oxidation of sulphide material in the tailings and subsequent ARD production (AMEC 2012). These dams are the tallest dams at the Equity Mine Site and they range in height from approximately 20 m (Dam No. 2) to 65 m (Dam No. 1) (KC 1996). The tailings impoundment provides containment for approximately 30 million m^3 of tailings solids and free water (Equity 1991). **Table 2.1** shows some of the key elevations and dimensions for the tailings impoundment.

Table 2.1: Key Elevation and Dimensions for the Tailings Impoundment

Dimension	Dam No. 1	Dam No. 2	Diversion Dam
Embankment length (m)	1430	885	600
Height of embankment (m)	65	20	35
Embankment crest elevation (m)	1294.0		
Spillway crest elevation (m)	1292.5		
Minimum elevation of the water surface (top of tailings) (m) [1]	1285.5		
Approximate bottom of centerline of compacted till zone (m) [2]	1278.0		

1. *This is not equivalent to the bottom of the tailings impoundment elevation.*
2. *Based on the cross-section for Dam No. 1 in **Figure 2.3**, elevation 1278 m has been assumed to be the maximum possible sunny-day failure depth for the tailings impoundment for derivation of the tailings release volume.*

The tailings impoundment spillway is a trapezoidal channel and has a width of approximately 5 m. The length of the spillway is approximately 35 m and has a flat slope. Riprap is used for erosion protection on the sides of the spillway inlet. The base of the spillway is founded in bedrock.



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DWN BY: TH
CHK'D BY: JW / AW
DATUM: MINE
PROJECTION: MINE
SCALE: AS SHOWN

PROJECT: EQUITY SILVER MINE DAM BREAK AND INUNDATION ASSESSMENTS

TITLE: MINE SITE OVERVIEW

DATE: NOVEMBER 2014
PROJECT NO: VM00276A.5.400
REV. NO: B
FIGURE NO: 2.1

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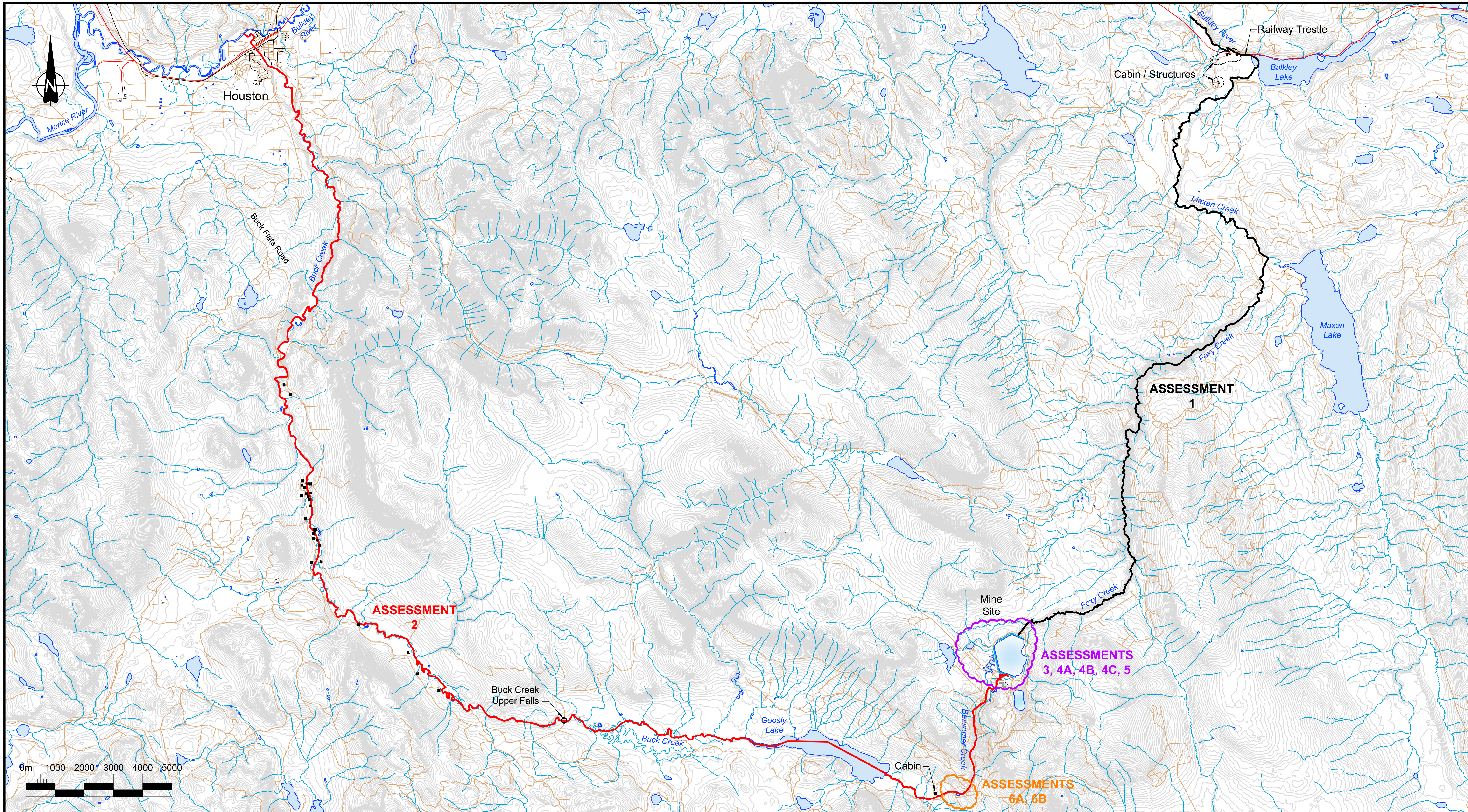

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DATA REFERENCES:
Base Planimetry - CANVEC, Natural Resources Canada (NRCAN), National Topographic Series: Mapsheets 93L01, 02, 07 and 08.
Roads - Digital Road Atlas (DRA), Province of British Columbia, GeoBC/DataBC, BC Geographic Warehouse

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DATUM:	NAD 83
PROJECTION:	UTM Zone 9
SCALE:	AS SHOWN

PROJECT: EQUITY SILVER MINE DAM BREAK AND INUNDATION ASSESSMENTS

TITLE: PROJECT WIDE OVERVIEW

DATE:	NOVEMBER 2014
PROJECT NO:	VA00276A.5.400
REV. NO:	A
FIGURE NO:	2.2

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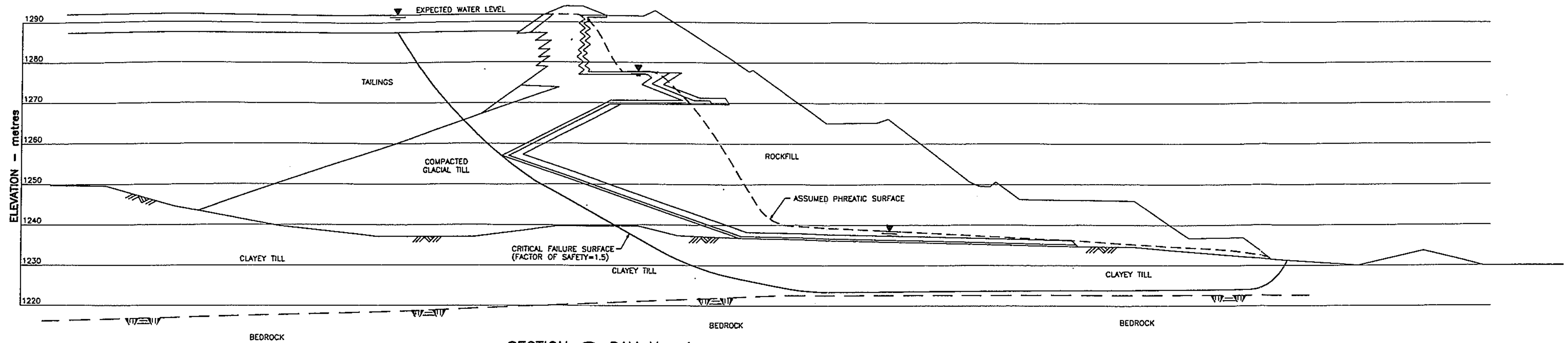
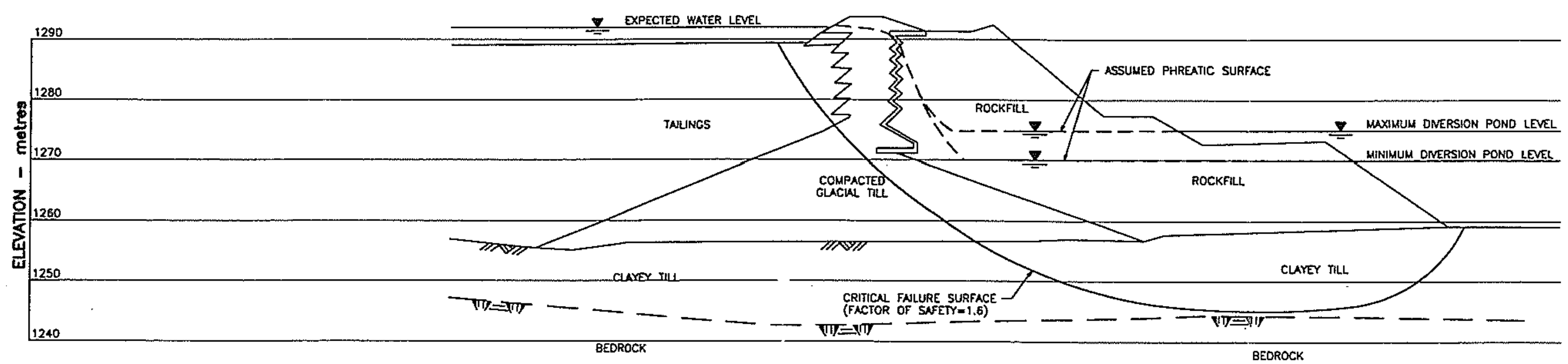
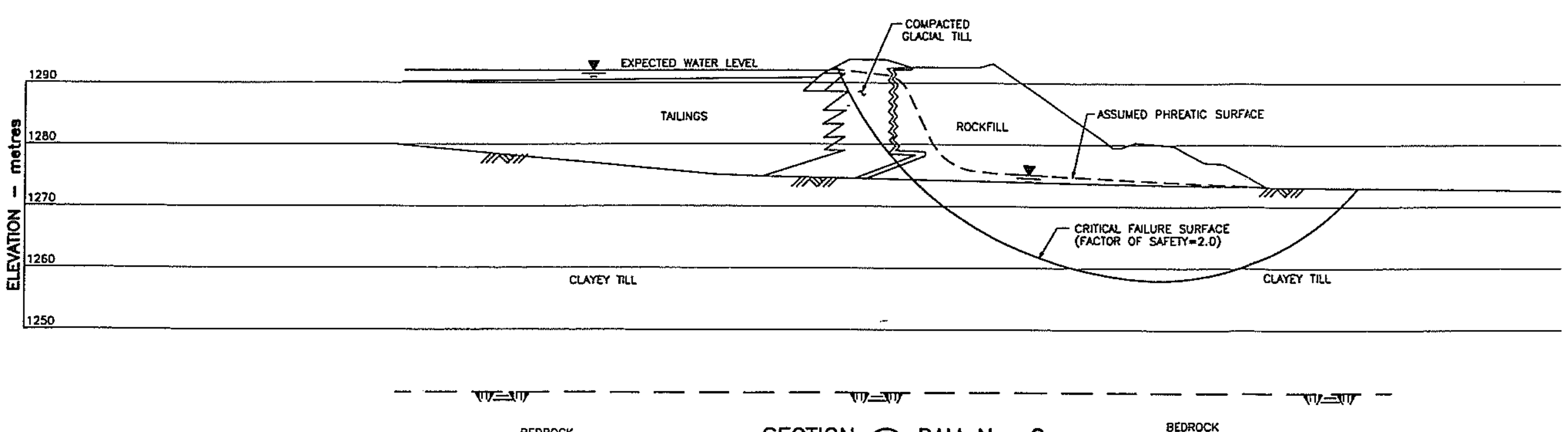


SECTION A/001 DAM No. 1



SECTION B/001 DIVERSION DAM



SECTION C/001 DAM No. 2

PARAMETER FOR STABILITY ANALYSIS

MATERIAL	UNIT WEIGHT (kN/m^3)	EFFECTIVE COHESION C' (kPa)	EFFECTIVE FRICTION ANGLE ø' (degrees)
TAILINGS	17.0	0	20
COMPACTED GLACIAL TILL	20.4	20	27
CLAYEY TILL	20.4	20	27
ROCKFILL	19.6	0	37.5

STABILITY ANALYSIS RESULTS FOR CRITICAL FAILURE SURFACES

MATERIAL	FACTOR OF SAFETY (BISHOP'S SIMPLIFIED)	
	STATIC	PSEUDOSTATIC (a=0.147g)
DAM No.1	1.5	1.07
DIVERSION DAM	1.6	1.14
DAM No.2	2.0	1.42

NOTES

1. AS-BUILT DAM SECTIONS PROVIDED BY EQUITY SILVER MINE.
2. STABILITY ANALYSES ASSUME STEADY STATE SEEPAGE.
3. STABILITY ANALYSES CARRIED OUT USING LIMIT EQUILIBRIUM COMPUTER PROGRAM SLOPE/W, USING BISHOP'S METHOD OF SOLUTION.
4. REVISION 1 FOR 1995 AUNUAL REVIEW.

NOTE:
THIS DRAWING SHOULD BE READ IN CONJUNCTION WITH THE AMEC ENVIRONMENT & INFRASTRUCTURE REPORT No. VM00276A.5.400 DATED NOVEMBER 2014.

DAM SECTIONS REFERENCE: *KLOHN-CRIPPEN, PROJECT PB2147 23, TAILINGS DISPOSAL: 'STABILITY ANALYSIS AS-BUILT DAM SECTIONS', DRAWING NO: D-23003 R1, DATED MARCH 25, 1996.*

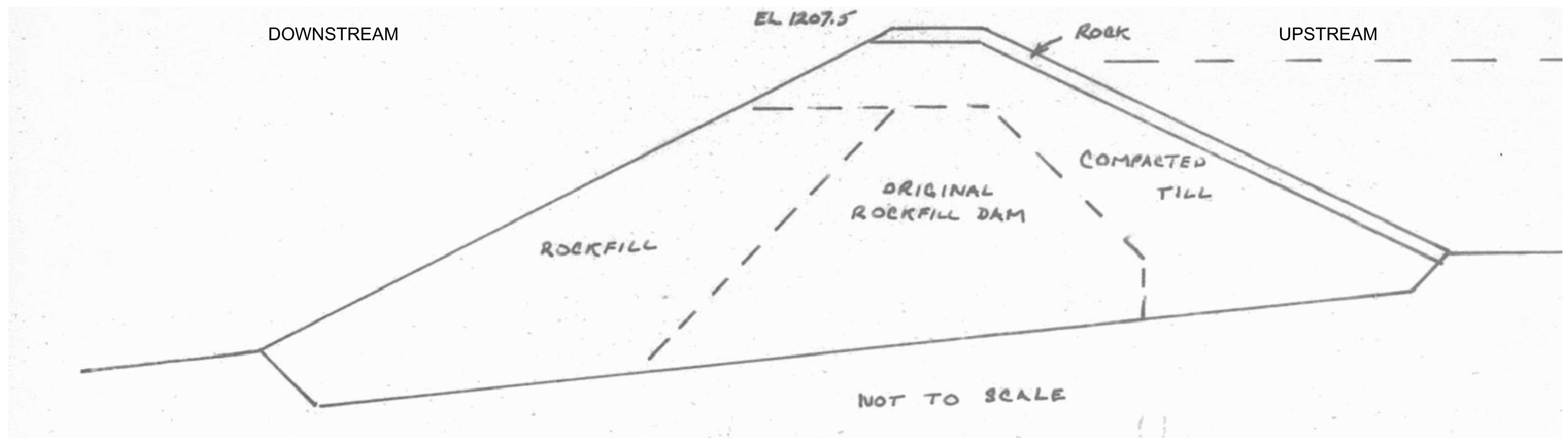
CLIENT: GOLDCORP CANADA LTD	DWN BY: YC	PROJECT: EQUITY SILVER MINE DAM BREAK AND INUNDATION ASSESSMENTS	DATE: NOVEMBER 2014
	CHK'D BY: AW		PROJECT NO: VM00276A.5.400
AMEC Environment & Infrastructure, Suite 600, 4445 Lougheed Highway, Burnaby, BC, V5C 0E4, Tel. 604-294-3811 Fax 604-294-4664	DATUM: --	TITLE: TAILINGS IMPOUNDMENT REPRESENTATIVE DAM SECTIONS	REV. NO: A
	PROJECTION: --		FIGURE NO: 2.3
	SCALE: Not to Scale		

The ARD Storage Pond South Dike forms the southern boundary of the ARD Storage Pond and is located next to the mine access road (Refer to **Figure 2.1**). This pond provides live storage for ARD pumped from the Main ARD Pond and the No. 1 Seepage Pond and is the primary ARD feed for the water treatment plant (AMEC, 2012). If the ARD pumping system has been transferring ARD from the Main ARD Pond to the ARD Storage Pond at a capacity in excess of the water treatment plant for an extended period of time and the ARD Storage Pond is full to capacity, ARD flows will be diverted into the Emergency ARD Pond via an overflow channel (AMEC, 2012). The ARD Storage Pond South Dike is constructed of a low permeability till zone separated from the road rockfill with a fine filter material (AMEC 2014b). This dike is approximately 7 m high and has a maximum storage volume of approximately 180,000 m^3 (AMEC 2012). Refer to **Figure 2.4** for a typical cross-section of the ARD Storage Pond South Dike.

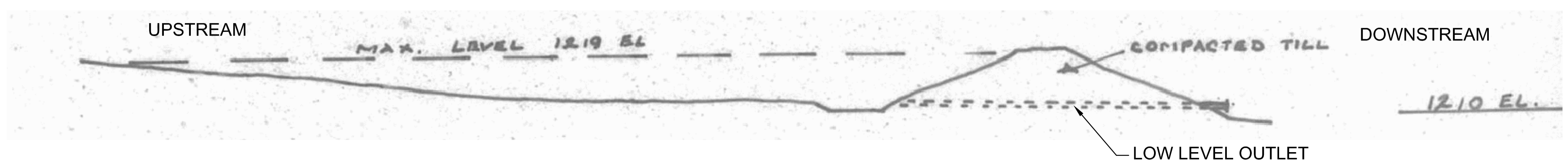
The No. 1 Sump is located to the west of the waste stockpile area and downstream of the Main ARD Pond (Refer to **Figure 2.1**). This is a minor structure with a small impoundment and an embankment created by an existing road. The No. 1 Sump collects drainage from the surrounding area, Sump No. 2 and the secondary ARD ditch. The water collected by this sump is pumped to the main ARD ditch and directed to the Main ARD Pond. Any spills from this sump will be directed to Bessemer Creek via an emergency pipe spillway (AMEC 2014b). The structure is a small earth dam (AMEC 2014b), is approximately 4 m high, and has a maximum storage volume of approximately 1,185m^3 (AMEC 2011b). A typical cross-section for the No. 1 Sump is not available.

The Main ARD Pond is located to the west of the waste stockpile area downstream of the ARD Surge Pond (Refer to **Figure 2.1**). The Main ARD Pond collects drainage from the surrounding area, flow from the ARD Surge Pond and pumped flows from the Getty Creek Sump and the No. 1 Sump. The water collected by this pond is pumped to the ARD Storage Pond and eventually is processed through the water treatment plant prior to discharge to the environment. The dam and reservoir are equipped with a single emergency spillway pipeline (AMEC 2014b). The structure is a small earthfill dam (AMEC 2014b) that is approximately 7.5 m high (AMEC 2012) and has a maximum storage volume of approximately 16,500 m^3 (AMEC 2014a). Refer to **Figure 2.4** for a typical cross-section of the Main ARD Pond.

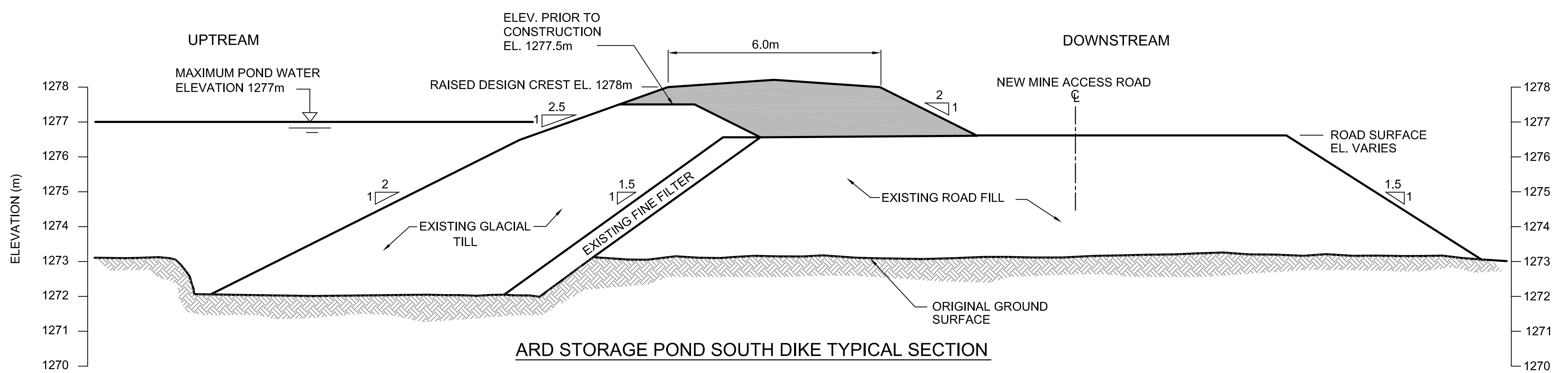
The ARD Surge Pond is located to the west of the waste stockpile area and upstream of the Main ARD Pond (Refer to **Figure 2.1**). The ARD Surge Pond collects drainage from the surrounding area and seepage from the waste stockpiles. The water collected by this pond is drained by gravity through a gated low level outlet to the Main ARD Pond. The dam and reservoir are equipped with an emergency spillway on the right dam abutment consisting of two pipes (AMEC 2014b). The dam was constructed of compacted earth fill (AMEC 2014b), is approximately 6 m high, and has a maximum storage volume of approximately 22,400 m^3 (AMEC 2014a). Refer to **Figure 2.4** for a typical cross-section of the ARD Surge Pond.



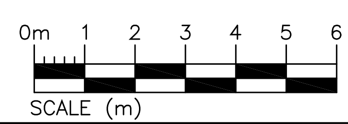
MAIN ARD POND DAM TYPICAL SECTION
NTS



ARD SURGE POND DAM TYPICAL SECTION
NTS



ARD STORAGE POND SOUTH DIKE TYPICAL SECTION



NOTE:
THIS DRAWING SHOULD BE READ IN CONJUNCTION WITH THE AMEC ENVIRONMENT & INFRASTRUCTURE REPORT No. VM00276A.5.400 DATED NOVEMBER 2014.

DAMS SECTIONS REFERENCE:
- MAIN ARD POND AND ARD SURGE POND DAMS- *"EQUITY SILVER MINES LTD. DECOMMISSIONING & CLOSURE PLAN" DATED APRIL 1991.*
- ARD STORAGE POND DAM- *AMEC, PROJECT VM00276-200, "2002 CONSTRUCTION SUMMARY REPORT, SOUTH DYKE, DAM NUMBERS 2 AND 3, EQUITY WATER MANAGEMENT PROJECT 2002" DRAWING 00276-5, DATED NOVEMBER 6 2002.*

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PROJECTION:	--
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PROJECT: EQUITY SILVER MINE DAM BREAK AND INUNDATION ASSESSMENTS

TITLE: ARD POND DAMS REPRESENTATIVE DAM SECTIONS

DATE:	NOVEMBER 2014
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FIGURE NO:	2.4

The Bessemer Creek Silt Check Dam is the final point of compliance on Bessemer Creek downstream of the Equity Silver Mine site (Refer to **Figure 2.2**). Sediment from Bessemer Creek and the diversions settles out into the pond and then the water is decanted over the spillway into the environment. The maximum storage elevation of the pond corresponds to the water level of the 200-year closure design storm event. (AMEC 2012) The dam was constructed of compacted earth fill, is approximately 8 m high (AMEC 2014b), and has a maximum storage volume of approximately 30,000 m^3 (AMEC 2012). Refer to **Figure 2.5** for details of the configuration of the Bessemer Creek Silt Check Dam following upgrades to the spillway in 2006.

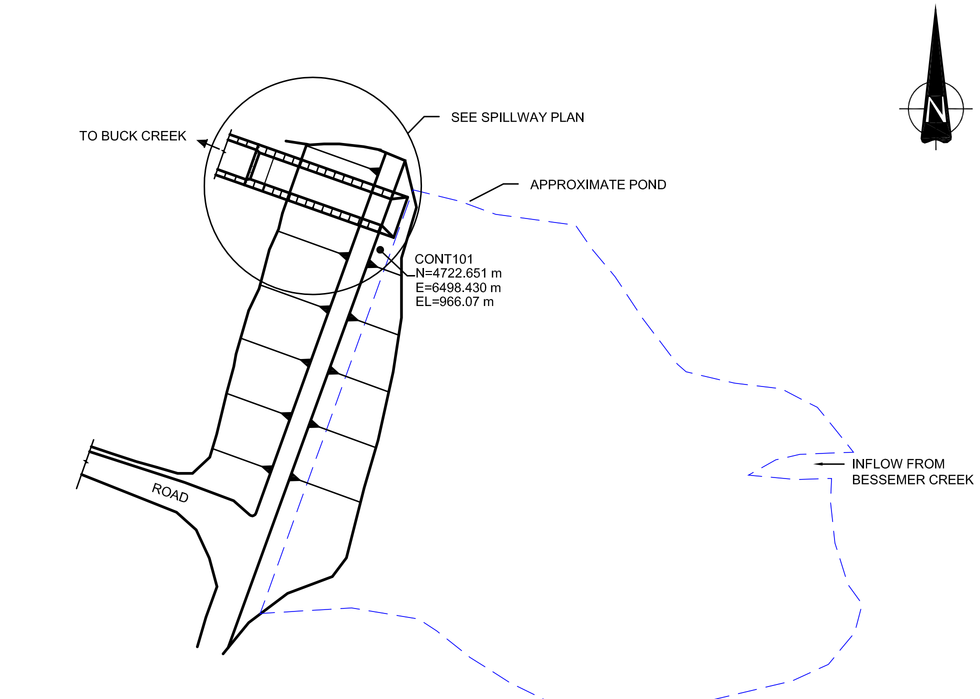
The consequence classification and design flood criteria following the 2010 DSR and used for the dam break and inundation assessments are summarized in **Table 2.2**.

Table 2.2: 2010 DSR Consequence Classifications for the Dams within this Study

Dam	Consequence Classification [1]	Recommended Inflow Design Flood per 2007 CDA Guidelines	Inflow Design Flood applied to Dam Breach
Tailings Pond Dam No. 1	Very High	2/3 between the 1/1000 and PMF	PMF [3]
Tailings Pond Dam No. 2	Very High	2/3 between the 1/1000 and PMF	PMF [3]
Tailings Pond Diversion Dam	Very High	2/3 between the 1/1000 and PMF	PMF [3]
ARD Storage Pond South Dike	High	1/3 between 1/1000 and PMF	N/A [4]
ARD Surge Pond	Significant [2]	Between 1/100 and 1/1000 year	N/A [4]
Main ARD Pond	Significant [2]	Between 1/100 and 1/1000 year	N/A [4]
No. 1 Sump	Significant	Between 1/100 and 1/1000 year	N/A [4]
Bessemer Creek Silt Check Dam	High	1/3 between 1/1000 and PMF	N/A [4]

1. *Consequence Classification per 2007 CDA Guidelines from the 2010 DSR (AMEC 2014b).*
2. *Based on Goldcorp's internal risk management the consequence classification for the ARD Surge Pond and the Main ARD Pond was increased from the "Significant" in the 2010 DSR (AMEC 2011b) to "High" (AMEC 2014a) for hydraulic structures reviews.*
3. *The design criterion of the Probable Maximum Flood (PMF) was selected as this facility contains approximately 30 million m^3 of tailings solids and free water and is upstream of a major fisheries resource for the region.*
4. *Simplified Assessments run for sunny-day failures (average year hydrology) only and do not include flooding scenarios.*

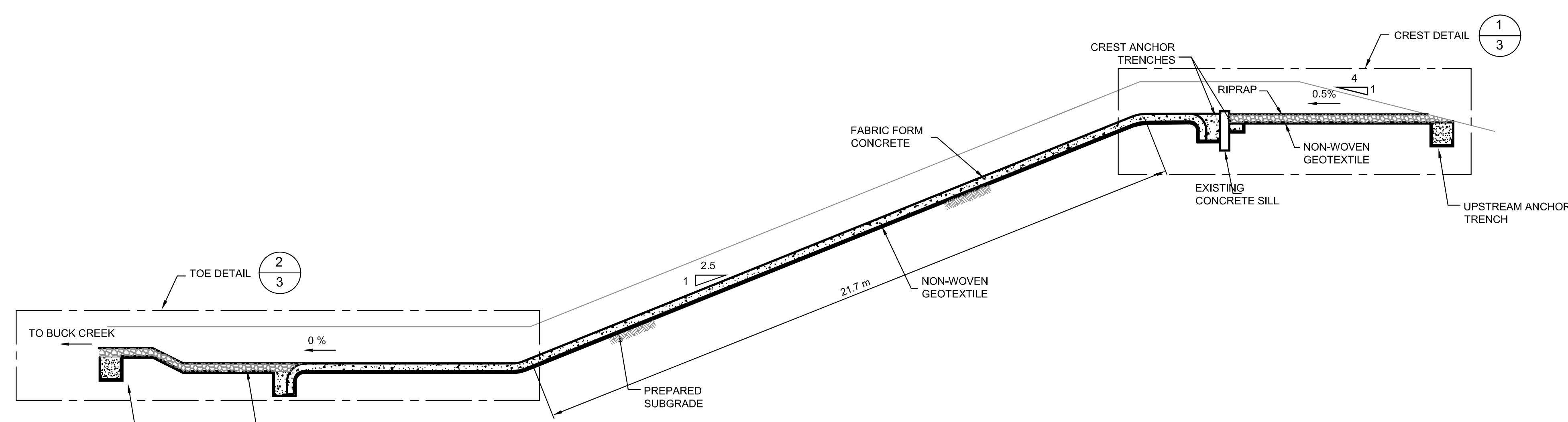
Refer to Appendix A for representative photographs of the above noted structures at the Equity Silver Mine site.



PLAN

0m 20 40 60 80

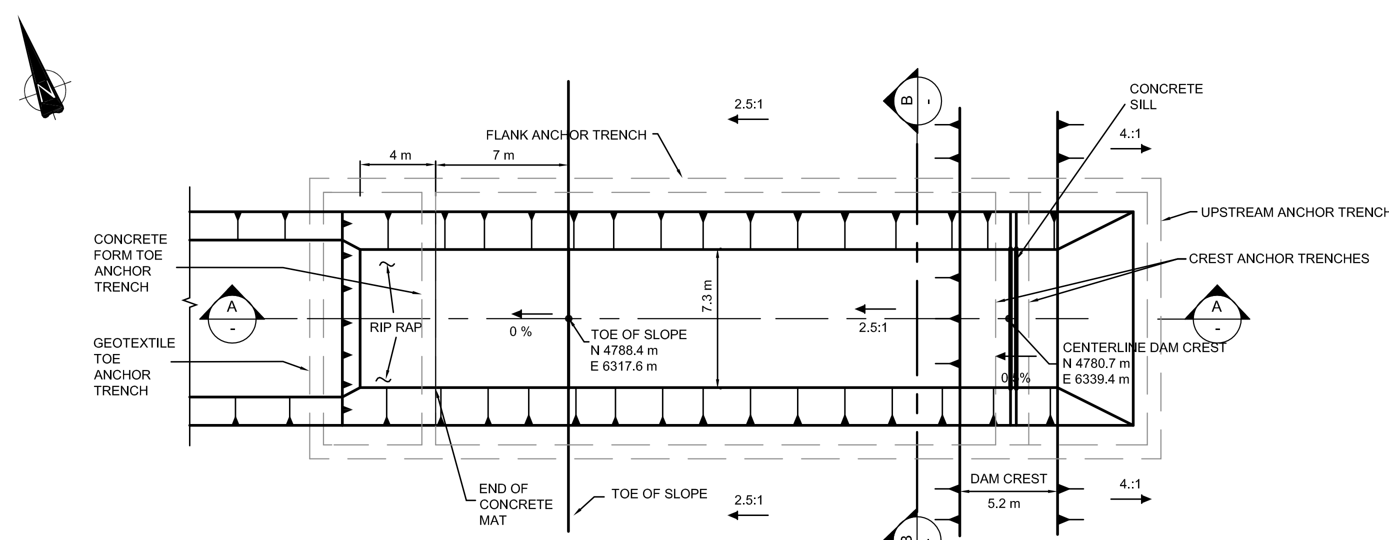
SCALE (m)



PROFILE A-A

0m 2 4 6 8

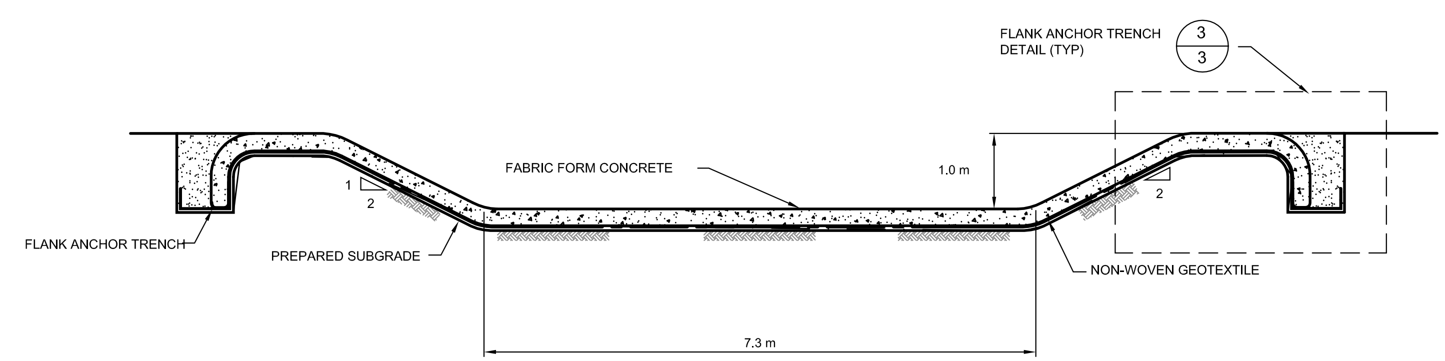
SCALE (m)



SPILLWAY PLAN

0m 4 8 12 16

SCALE (m)



CROSS-SECTION B-B

0m 1 2 3 4

SCALE (m)

NOTES:

COORDINATES FROM STEVE HOWARD SURVEY 'EQV0502' DATED AUGUST 23, 2005. TO BE CONFIRMED BEFORE CONSTRUCTION COMMENCES.

NOTE:

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DRAWING REFERENCE:

AMEC PROJECT VM00276.03 "EQUITY SILVER WATER MANAGEMENT PROJET, BESSEMER CREEK SILT CHECK DAM SPILLWAY RECONSTRUCTION", DRAWING 2, DATED OCTOBER 3, 2005.

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PROJECTION:	--
SCALE:	AS SHOWN

PROJECT: EQUITY SILVER MINE DAM BREAK AND INUNDATION ASSESSMENTS

TITLE: BESSEMER CREEK SILT CHECK DAM PLAN AND SECTIONS

DATE:	NOVEMBER 2014
PROJECT NO:	VM00276A.5.400
REV. NO:	A
FIGURE NO:	2.5

S:\PROJECTS\VM00276A – Equity Silver Mine\DRAWINGS\2014 DBA\VM00276A.5.4–FIGURE–2.5.dwg – Figure 2.3 – Nov. 19, 2014 1:11pm – yuan.chen

3.0 STUDY OBJECTIVES

The objectives of this study are to:

- Determine the potential effects of flows and water surface elevations in a hypothetical failure of the dams listed in **Section 1.0**;
- Increase the understanding of the interdependencies within the tailings impoundment and ARD management systems in the context of dam breaches. For example, the flood wave released from a hypothetical breach of Dam No. 2 might impact the Main ARD Pond and disrupt the ability to effectively collect and treat continued ARD seepage from the waste stockpile area; and
- Provide insight into, and potential enhancement of the existing emergency preparedness and response framework currently in place at the Equity Silver Mine site.

To achieve these objectives, given the layout of the various dams on the Equity Silver Mine site and the multiple watersheds involved, the dam break and inundation assessments were broken into six separate assessments using three different methodologies which are outlined in **Section 5.0**.

This study does not include quantitative predictions of water quality impacts due to the dam break analyses and inundation modelling as this is not a typical requirement under the CDA guidelines pertaining to dam breach studies. However, as much of the water impounded within the dams of interest contains ARD, some qualitative discussion will be provided on the potential extents of the inundation areas that could be impacted by contact with ARD discharges. Discussion on dilution potential throughout the flood path will also be considered.

4.0 FAILURE SCENARIOS

A dam break analysis is used to determine the ultimate discharge from a hypothetical breach of a facility as outlined in the 2007 CDA Dam Safety 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 are usually considered:

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 operations caused by internal erosion, piping, earthquakes, improper operation or another unanticipated event. It is assumed that mean annual flow conditions are occurring in all the catchments at the time of the breach.

4.2 Flood-Induced Failure

This failure mode simulates a dam breach resulting from a natural flood of a magnitude greater than the spillway can safely pass or in case of spillway blockage. A hypothetical peak water level is used to trigger this failure mode which would result in overtopping of the dam and subsequent breach of the facility. It is assumed that applicable Inflow Design Flood (IDF) conditions are occurring in all the catchments at the time of the breach.

5.0 ASSESSMENT METHODOLOGY

Dam break flood wave routing analysis (detailed or simplified) and inundation assessments in conjunction with the recommendations of the 2007 CDA guidelines have been performed for the dams outlined in **Section 1.0**. The 2007 CDA guidelines recommend that inundation studies provide the following information along the flood path:

- Peak flow;
- Maximum depth;
- Peak velocity; and
- Peak travel time.

The dam break and inundation assessments were broken into separate assessments using the methodologies outlined below.

5.1 Detailed HEC-RAS Modelling (Dam No. 1 and Dam No 2)

Dam No. 1 (Assessment 1) is located upstream of Foxy Creek (Refer to **Figure 2.1** and **Figure 2.2**). Foxy Creek discharges into Maxan Creek near Maxan Lake. Maxan Creek then discharges into Bulkley Lake and ultimately discharges into the Bulkley River which represents a major fisheries resource for the region. Beyond the No. 1 Seepage Pond Dam, no significant structures have been identified along Foxy Creek until the forestry bridge on Maxan Creek. At the outlet of Bulkley Lake there is a bridge crossing for CN Rail and several farms with houses and other buildings.

Dam No. 2 (Assessment 2) is located upstream of Bessemer Creek (Refer to **Figure 2.1** and **Figure 2.2**). Bessemer Creek discharges into Buck Creek. Buck Creek then discharges into Goosly Lake and ultimately discharges into the Bulkley River at Houston, BC. There are several significant structures downstream of Dam No. 2 including the site water treatment facilities, shop and office, power substation, power lines and ARD pump houses. A small cabin is also located just downstream of the Bessemer Creek Silt Check Dam. Downstream of Goosly Lake there is a forestry bridge crossing at Buck Creek Upper Falls. Downstream of the falls there are some residences and farms along Buck Creek and ultimately the Town of Houston, BC. The effects of the flood wave from a breach of Dam No. 2 on the ARD Collection Pond Dams and the Bessemer Creek Silt Check Dam were assessed as part of this study.

Due to the complex nature of the watersheds downstream of Dams No. 1 and No. 2, detailed hydraulic models have been developed using the Hydrologic Engineering Center River Analysis System (HEC-RAS).

HEC-RAS is a software package developed by the US Army Corps of Engineers (USACE) that allows performance of one-dimensional hydraulic analysis. The HEC-RAS system contains four components:

- Steady flow water surface profile computations;
- Unsteady flow simulation;
- Movable boundary sediment transport computations; and
- Water quality analysis.

A key element of the software is that all components use a common geometric data representation and also common geometric and hydraulic computation routines. In addition, the system contains several hydraulic design features that can be used once the basic water surface profiles have been determined.

In natural channels it is often difficult for the modeller to predict how the flow will react to channel bars, bends and sub-channels and the flow attenuation in the channel. To overcome this problem, the unsteady flow component was used for this assignment. Nevertheless, the current Version 4.1.0 can perform mixed flow regime (subcritical, supercritical, hydraulic jumps, and draw downs) calculations in the unsteady flow computations module. Some of the special features of the unsteady flow component include a dam break analysis (utilized herein).

The HEC-RAS model for Dam No. 1 extends from Dam No. 1 along Foxy Creek and Maxan Creek through Bulkley Lake and along the Bulkley River for approximately 3 km as shown on **Figure 2.2** (Assessment 1).

The HEC-RAS model for Dam No. 2 extends from Dam No. 2 along Bessemer Creek and Buck Creek through Goosly Lake to upstream of Houston, BC as shown on **Figure 2.2** (Assessment 2).

Both failure scenarios (sunny-day and flood-induced) have been assessed for Dam No. 1 (Assessment 1) and Dam No. 2 (Assessment 2). For a sunny-day failure the HEC-RAS model was run first without the breach for the mean annual flows to set the No Failure mode of the sunny-day dam breach. The breach was then superimposed on the No Failure mode to assess the incremental impact of the breach under average flow conditions throughout the watershed.
For a flood-induced failure the HEC-RAS model was first run without the dam breach to set the No Failure mode for the flood-induced dam breach. The breach was then superimposed on the No Failure mode to assess the incremental impact of the breach under the flood conditions throughout the watershed.

5.2 Desktop Assessment (Diversion Dam)

The Diversion Dam is located upstream of both Bessemer and Foxy creeks. Prior to mine development, Lu Creek flowed through the area currently occupied by the Emergency Pond, Diversion Pond and tailings Impoundment and into Foxy Creek. The Lu Creek Diversion now discharges directly into Foxy Creek as shown on **Figure 2.1**. It was unclear as to how a failure of the Diversion Dam would be routed through the Diversion and Emergency Ponds and whether the eventual flood wave would be attenuated by the Splitter Dike and Dam No. 3 or overtop the dams and reach the environment by way of Dam No. 3 or the ARD Storage Pond (Refer to **Figure 2.1**). Therefore, a desktop review (Assessment 3) of the existing site topography was performed to determine whether a failure of the Diversion Dam is most likely to impact Foxy Creek or Bessemer Creek and whether the potential impact necessitates a detailed HEC-RAS dam break and inundation assessment for the Diversion Dam.

5.3 Simplified Assessments (ARD Collection Pond Dams, ARD Storage Pond South Dike and Bessemer Creek Silt Check Dam)

The ARD Storage Pond South Dike, Bessemer Creek Silt Check Dam, and ARD Collection Pond Dams (No. 1 Sump, Main ARD Pond and ARD Surge Pond) are located adjacent to or along Bessemer Creek downstream of Dam No. 2 (Refer to **Figures 2.1** and **Figure 2.2**). The Bessemer Creek Silt Check Dam is located along Bessemer Creek approximately 1 km upstream of Buck Creek. The ARD Storage Pond South Dike and ARD Collection Pond Dams are located downstream of the junction between Dam No. 2 and the Diversion Dam. A failure of the ARD Storage Pond South Dike, Bessemer Creek Silt Check Dam and ARD Collection Pond Dams would impact Bessemer Creek and potentially Buck Creek. As with the hypothetical breach of Dam No. 2 the same significant structures exist downstream of the ARD Storage Pond South Dike, Bessemer Creek Silt Check Dam, and ARD Collection Pond Dams.

Due to their smaller size as compared to the tailings dams, simplified and conservative dam break assessments were used for these dams. Initially, the BC Hydro (BCH 1984) flood attenuation method in conjunction with simplified hydraulic calculations (FlowMaster) was carried out. From this initial work it was determined that additional steady state flow HEC-RAS modelling was required for these dams to check and increase the precision of these estimates. Due to their inherent simplicity, these results are more conservative that the detailed hydraulic analysis used for the dam breach assessments of Dam No. 1 and Dam No. 2.

Simplified dam break assessments for the ARD Collection Pond Dams (Assessment 4A, 4B and 4C), ARD Storage Pond South Dike (Assessment 5) and Bessemer Creek Silt Check Dam (Assessment 6A and 6B) were performed (Refer to **Figures 2.1** and **Figure 2.2**). The potential impact scenarios of these assessments are summarized in **Table 5.1.**

Table 5.1 Potential Impact Scenarios of the Simplified Dam Break Assessments

Assessment	Potential Impact Scenario
4A	Failure of the No. 1 Sump along Bessemer Creek to the Bessemer Creek Silt Check Dam.
4B	Cascade failure of the Main ARD Pond and the No. 1 Sump along Bessemer Creek to the Bessemer Creek Silt Check Dam.
4C	Cascade failure of the ARD Surge Pond, Main ARD Pond and the No. 1 Sump along Bessemer Creek to the Bessemer Creek Silt Check Dam (worst case scenario of 4A, 4B and 4C).
5	Failure of the ARD Storage Pond South Dike along Bessemer Creek, past the ARD Collection Pond Dams to the Bessemer Creek Silt Check Dam.
6A	Failure of the Bessemer Creek Silt Check Dam to Goosly Lake.
6B	Failure of the Bessemer Creek Silt Check Dam to Goosly Lake, including Assessment 4C.

Only the sunny-day failure scenarios were assessed for these structures as this is the worst case scenario for downstream structures, creeks and lakes as there would be no dilution of the ARD.

Estimated flood wave parameters (water depth, flow and velocity) along typical creek sections downstream of the structures are provided to indicate the potential impact of the dam break on the stream channel. Such information provides an estimate of the stream area (channel and bank area) that could be impacted by contact with ARD discharges from a single or collection storage pond failure.

6.0 DAM BREAK AND INUNDATION ASSESSMENTS

This section presents the dam break flood wave routing analyses (detailed and simplified) and inundation assessments for the dams listed in **Section 1.0** using the methodologies outlined in **Section 5.0**. The results are used for qualitative assessment of water quality downstream of the dams in **Section 6.4**. In addition, the results were also used to discuss the potential effects of hypothetical dam breaks and subsequent inundation on significant structures and crossings downstream of the dams in **Section 6.5**.

6.1 Dam No. 1 and Dam No.2

Detailed HEC-RAS modelling dam breach and inundation assessments of Dam No. 1 (Assessment 1) and Dam No. 2 (Assessment 2) were performed.

6.1.1 HEC-RAS Model Setup

Hydrology

The catchment areas contributing to Dam No. 1 (Assessment 1) and Dam No. 2 (Assessment 2) HEC-RAS model flows were evaluated based on the review of regional topography and are shown in **DWG01** and **DWG04**, respectively. The regional Water Survey of Canada (WSC) hydrometric stations in the proximity of the project were used for the estimation of the mean annual flows. **Table 6.1** provides a summary of the hydrometric stations.

Table 6.1 Summary of Regional Hydrometric Stations

ID	Station Name	Coordinates		Catchment Area (km^2)	Period of Record
		Latitude	Longitude		
08EE013	Buck Creek at the Mouth	54°23'52" N	126°39'4" W	565	1973 - 2012
08EE003	Bulkley River near Houston	54°23'45" N	126°42'30" W	2,370	1930 - 2013
08EE004	Bulkley River near Quick	54°37'5" N	126°53'55" W	7,340	1930 - 2012

An average unit flow rate of 0.013 $m^3/s/km^2$ was obtained from an analysis of the data from the above regional hydrometric stations. This value was used to estimate the mean annual flows of the local catchment areas for the sunny-day failure mode. **Table 6.2** presents the catchment areas and mean annual flows. For cross-section locations refer to **DWG02** and **DWG05**.

Table 6.2: Mean Annual Flows For Sunny-Day Failure

Description of Location	Catchment Area (km^2)	Mean Annual Flow (m^3/s)
		Based on Unit Discharge
Dam No. 1 to Downstream of Bulkley Lake (Assessment 1)		
Up to Bulkley Lake	382.7	5.0
Cross section 795 (Downstream of Bulkley Lake)	108.5	1.4
Total for Entire Model	491.1	6.5
Dam No. 2 to the Bulkley River at Houston, BC (Assessment 2)		
Goosly Lake Outlet	117.1	1.5
Cross Section 1700 (Upstream of Houston, BC)	452.1	6.0
Total for Entire Model	569.2	7.5

In order to determine the inflow hydrographs corresponding to flood-induced conditions (Refer to **Table 2.2**) throughout the watersheds, the hydrologic model developed by the Hydrologic Engineering Centers-Hydrologic Modeling System (HEC-HMS) was used. The HEC-HMS model is designed to simulate the precipitation-runoff processes of watershed systems using the Soil Conservation Service (SCS) methodology. Separate HEC-HMS models were created for Dam No. 1 (Assessment 1) and Dam No. 2 (Assessment 2).

Input parameters for the HEC-HMS models included the catchment area, lag time and curve number (CN). The time of concentration was estimated for the catchment areas using the Kirpich formula, assuming that the lag time is 0.6 times the time of concentration.

Flows determined from the BC Peak Flood Maps (Coulson & Obedkoff 1998) were used to calibrate the HEC-HMS models. Flows were estimated for 1 in 10 and 1 in 100 year return period events. The calibration of the models was based on the 1 in 100 year return period map for the applicable catchment area. A CN value of 50 was used in conjunction with a Type 1A storm distribution in the HEC-HMS models.

The short duration Intensity-Duration-Frequency rainfall depths have been previously estimated at the Equity Silver Mine site based on the AMEC 2011 hydrology and water management structures review (AMEC 2011b) and are summarized in **Table 6.3**.

Table 6.3: Short Duration Rainfall Frequency Depths for the Mine Site

Return	Rainfall Depth (mm) for Event Duration								
Period	5-min	10-min	15-min	30-min	1-hour	2-hour	6-hour	12-hour	24-hour
2	4	5	6	9	12	16	26	33	41
5	6	8	10	12	17	22	34	43	54
10	7	10	12	15	20	26	39	50	62
25	8	13	14	18	24	31	46	59	73
50	10	15	16	20	27	34	51	65	81
100	11	17	18	22	30	38	56	72	89
200	12	19	20	24	33	42	61	78	97
500	14	22	23	27	37	46	67	86	107
1000	15	24	25	29	40	50	72	93	115
PMP					78		193		251

The 24 hour rainfall depths in **Table 6.3** were used to estimate the IDF's where applicable in this dam break and inundation assessment (Refer to **Table 2.2**). A maximum snowmelt of 30 mm/day of snow water equivalent was assumed to account for snowmelt for inflow discharge calculations. The estimated Probable Maximum Precipitation (PMP) flood-induced hyetograph for Dam No. 1 (Assessment 1) and Dam No. 2 (Assessment 2), including snowmelt, is shown in **Figure 6.1**.

A 24-hour duration PMP storm event was routed through the watersheds to produce the resulting PMF inflow hydrographs for each of the catchments used in the dam breach models for Dam No. 1 and Dam No. 2. Longer duration events may produce greater overall flood volumes but do not have a significant impact of the dam breach peak flows or peak watershed response during flood routing. Thus, the application of a 24-hour duration storm event is considered appropriate. **Table 6.4** shows the PMF flood-induced peak inflows estimated at specific cross-section locations from HEC-HMS modelling for Dam No. 1 (Assessment 1) which were used in the dam breach HEC-RAS modelling assessment. The resulting PMF hydrographs for each catchment area in Assessment 1 are shown in **Figure 6.2**. **Table 6.5** shows the PMF flood-induced peak inflows estimated at specific cross-section locations from HEC-HMS modelling for Dam No. 2 (Assessment 2) which were used in the dam breach HEC-RAS modelling assessment. The resulting PMF hydrographs for each catchment area in Assessment 2 are shown in **Figure 6.3**.

Table 6.4: PMF Flood-Induced Peak Inflows Estimated from HEC-HMS Model for Dam No. 1 (Assessment 1)

Cross-Section ID (Location Description)	Catchment Area (km^2)	Flood-Induced Peak Inflows (m^3/s)
1000 (Dam No. 1 of Tailings Impoundment)	5.72	20.3
980 (Foxy Creek)	22.2	66.5
960 (Foxy Creek)	22.0	78.0
940 (Foxy Creek)	21.4	76.0
930 (Foxy Creek)	11.3	40.1
890 (Foxy Creek upstream of Maxan Creek)	11.1	33.5
880 (Maxan Creek downstream of Foxy Creek)	237.2	375.5
850 (Maxan Creek)	16.4	58.2
810 (Maxan Creek upstream of Bulkley Lake)	35.2	105.1
790 (Bulkley River downstream of Bulkley Lake)	264.2	268.7

Table 6.5: PMF Flood-Induced Peak Inflows Estimated from HEC-HMS Model for Dam No. 2 (Assessment 2)

Cross-Section ID (Location Description)	Catchment Area (km^2)	Flood-Induced Peak Inflows (m^3/s)
1960 (Bessemer Creek upstream of the Bessemer Creek Silt Check Dam)	9.6	34.0
1940 (Bessemer Creek downstream of the Bessemer Creek Silt Check Dam)	68.4	154.8
1905 (Downstream of Goosly Lake)	34.5	101.0
1790 (Buck Creek)	264.2	124.8
1720 (Buck Creek)	125.2	232.3

Figure 6.1: PMP Flood-Induced Hyetograph for Dam No. 1 (Assessment 1) and Dam No. 2 (Assessment 2)

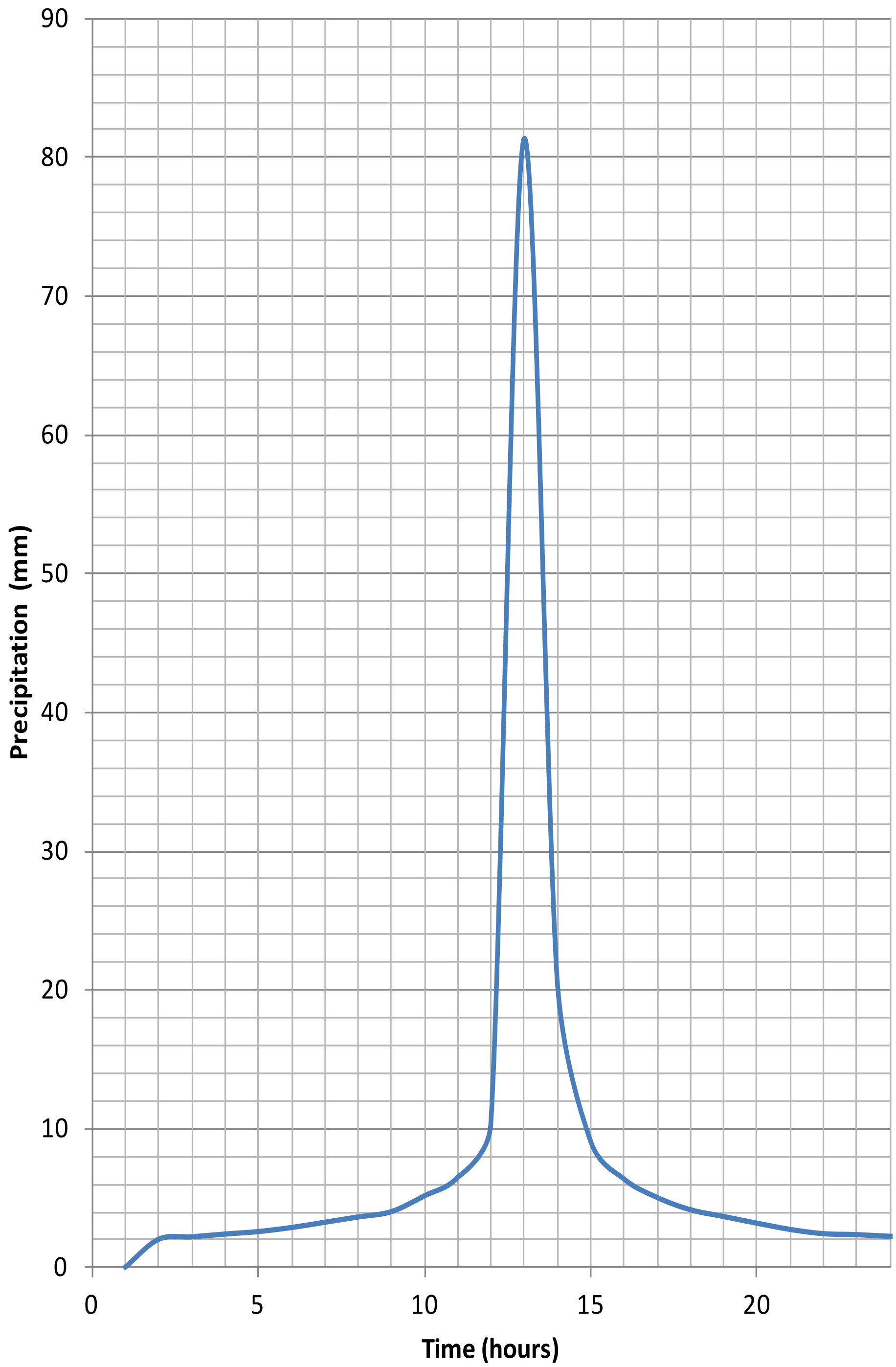


Figure 6.2: PMF Flood-Induced Inflow Hydrographs for Dam No. 1 (Assessment 1)

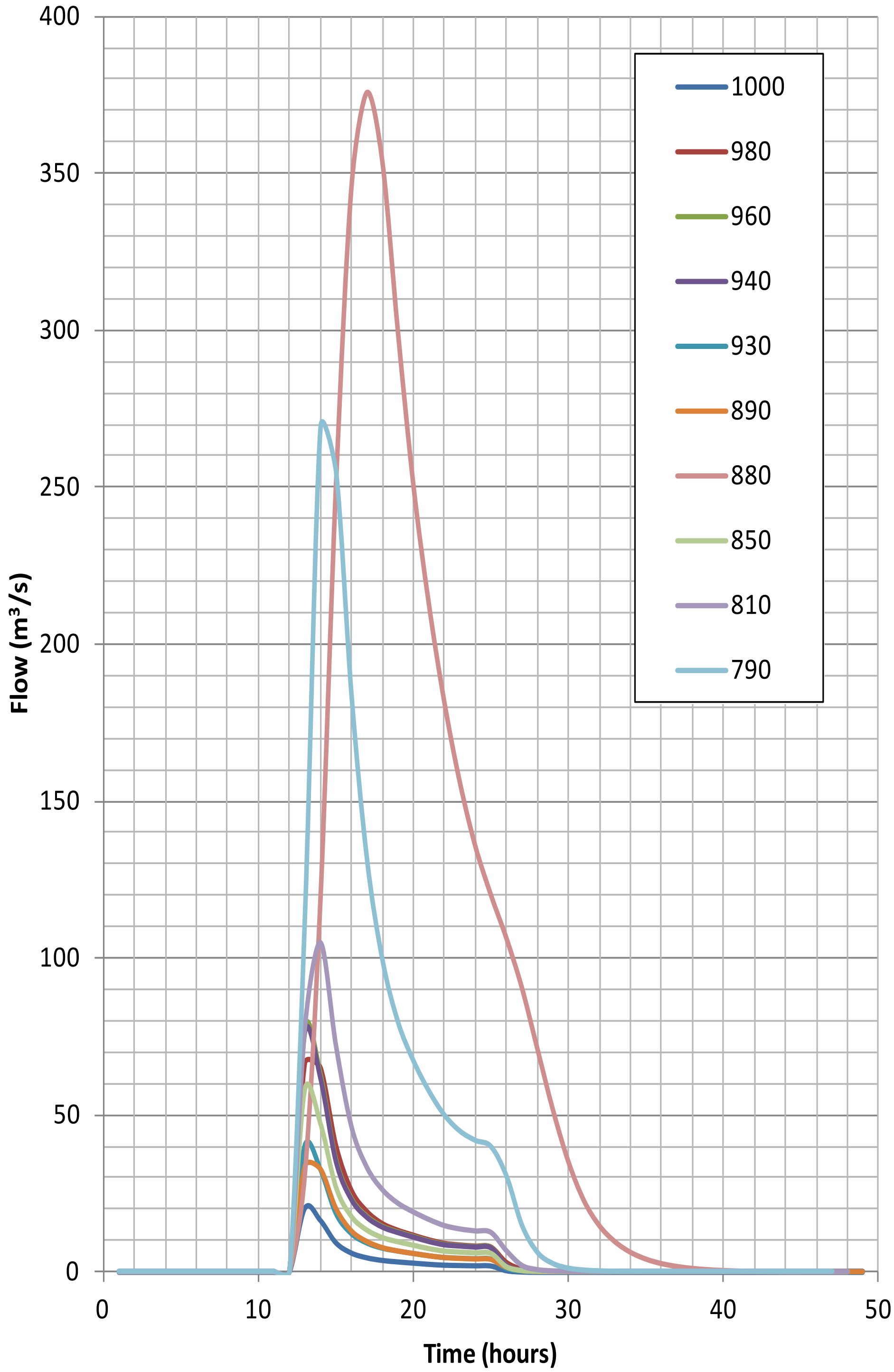
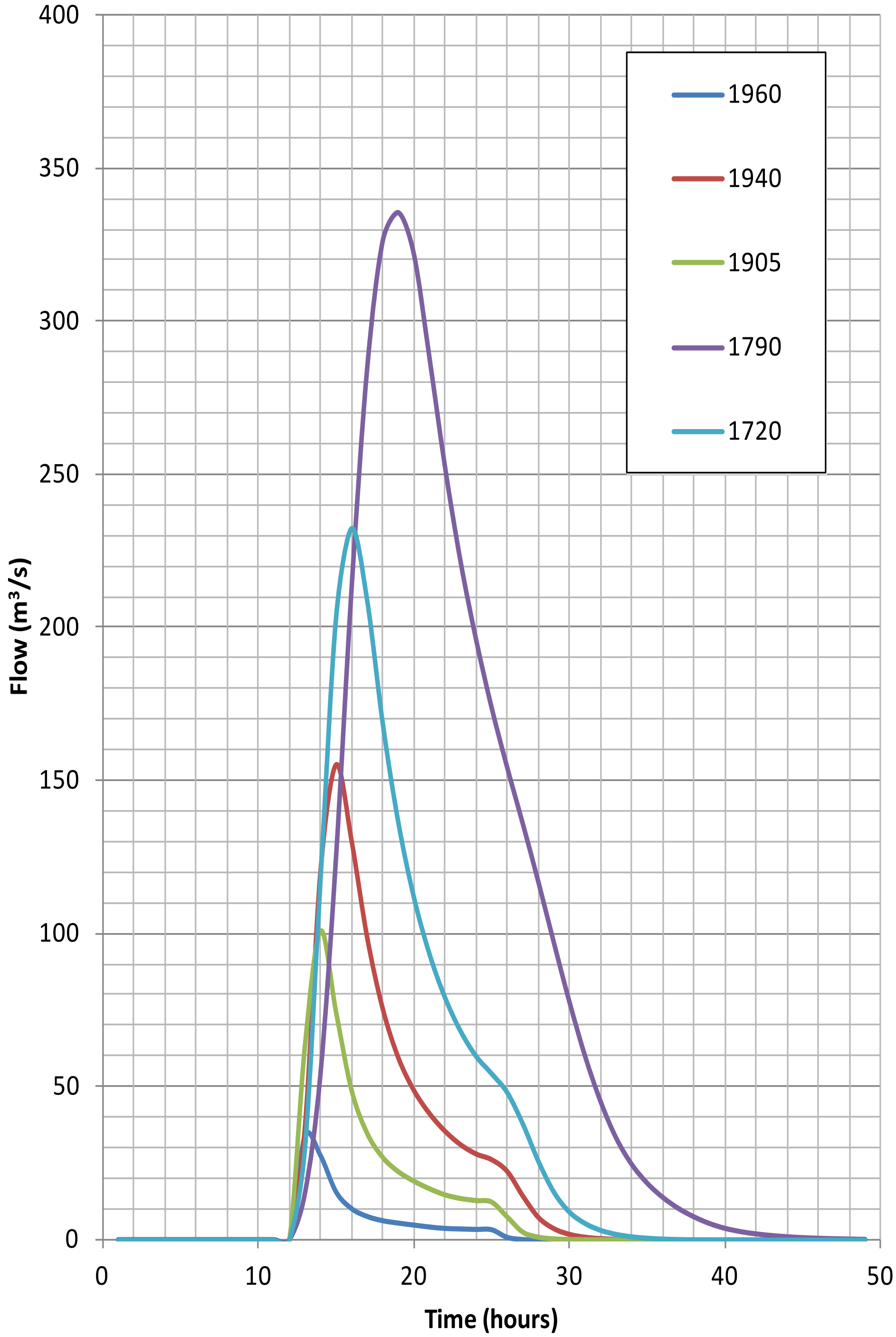


Figure 6.3: PMF Flood-Induced Inflow Hydrographs for Dam No. 2 (Assessment 2)



Geometry

The layouts of the HEC-RAS models for Dam No. 1 (Assessment 1) and Dam No. 2 (Assessment 2) are shown on **DWG02** and **DWG05**.

The Dam No. 1 (Assessment 1) HEC-RAS model extends from Dam No. 1 of the tailings impoundment to 3 km downstream of Bulkley Lake and includes the following key reaches:

- Tailings impoundment and Dam No. 1;
- Reach from Dam No 1 along Foxy Creek to Maxan Creek;
- Reach along Maxan Creek from Foxy Creek to Bulkley Lake;
- Through Bulkley Lake; and
- Reach along the Bulkley River from Bulkley Lake to 3 km downstream of the lake.

The Dam No. 2 (Assessment 2) HEC-RAS model extends from Dam No. 2 of the tailings impoundment to upstream of Houston, BC and includes the following key reaches:

- Tailings impoundment and Dam No. 2;
- Reach from Dam No 2 along Bessemer Creek to the Bessemer Creek Silt Check Dam (passes the ARD Collection Pond Dams);
- Reach along Bessemer Creek from the Bessemer Creek Silt Check Dam to Buck Creek;
- Reach along Buck Creek from Bessemer Creek to Goosly Lake;
- Through Goosly Lake;
- Reach along Buck Creek from Goosly Lake to the Upper Falls; and
- Reach along Buck Creek from the Upper Falls to upstream of Houston, BC.

All Dam No. 1 (Assessment 1) and Dam No. 2 (Assessment 2) HEC-RAS model cross-sections are shown on **DWG03 (5 Sheets)** and **DWG06 (6 Sheets)**, respectively. Detailed LIDAR topography was available for the mine site and short distances downstream of the site along Foxy and Bessemer creeks. However, outside of this area much less detailed topography available from the BC government had to be used. Therefore, the cross-sections use for HEC-RAS modelling and inundation limits used the topography available at that location.

Storage Areas

The tailings impoundment contained by Dam No. 1 (Assessment 1) to the north, the Diversion Dam to the west (Assessment 3) and Dam No. 2 (Assessment 2) to the south would act as a storage and routing area (Refer to **Figure 2.1**). The high inflows from the catchment to the east would be attenuated by this area (i.e., the large volumes of inflows would be stored and released over a longer period of time). The large surface area of the pond would absorb the inflows as it rises, temporarily storing the water before it is released through the outlet at a lower magnitude.

Section 6.1.2 summarizes the breach height and elevation parameters used for the sunny-day and flood-induced dam breach assessments. **Table 6.6** shows the storage – elevation relationship for the tailings impoundment.

Table 6.6: Tailings Impoundment. Storage-Elevation Relationship

Elevation (m)	Water Volume (m^3)	Tailings Volume (m^3)	Total Volume (m^3)
1285.5	0	0	0
1286.0	1,200	200	1,500
1286.5	20,800	4,300	25,100
1287.0	84,000	17,400	101,400
1287.5	209,200	43,300	252,500
1288.0	418,300	86,600	504,900
1288.5	708,100	146,600	854,700
1289.0	1,066,000	220,800	1,286,800
1289.5	1,488,000	308,200	1,796,200
1290.0	1,954,200	404,700	2,358,900
1290.5	2,450,000	507,400	2,957,400
1291.0	2,967,100	614,500	3,581,600
1291.5	3,502,300	725,300	4,227,600
1292.0	4,050,100	838,800	4,888,800
1292.5	4,612,500	955,200	5,567,700
1293.0	5,187,800	1,074,400	6,262,200
1293.5	5,772,200	1,195,400	6,967,600
1294.0	6,332,800	1,311,500	7,644,300

The Dam No. 1 (Assessment 1) HEC-RAS model passes through Bulkley Lake and the Dam No. 2 (Assessment 2) HEC-RAS model passes through Goosly Lake. Both Bulkley Lake and Goosly Lake have been assumed to act as storage and routing areas within their respective HEC-RAS models similar to the tailings impoundment described above. As there is no storage-elevation information available for either of these lakes, a more simplified approach was used in estimating storage by assuming a constant surface area that will rise and fall with the passage of the flood wave. For Dam No. 1 (Assessment 1) the storage in Bulkley Lake was estimated using an area of 2,330,000 m^2 and a minimum outflow elevation of 710 m. For Dam No. 2 (Assessment 2) the storage in Goosly Lake was estimated using an area of 2,440,000 m^2 and a minimum outflow elevation of 800 m.

Tailings Release Volume

The CDA documents do not provide explicit guidance regarding the treatment of tailings release from mining dams. Many of the previously published dam breach studies accounted only for water releases and did not take into account the relative contribution of tailings re-suspension to the flood wave. Nevertheless, release of tailings should be considered in a tailings dam break study as sediment transport processes have been shown to significantly contribute to the volume released. Review of the historical tailings dam failure databases indicate that the amount of tailings released following a dam failure can be quite variable, ranging from 1% to 100% of the impounded volume. The tailings release volume is dependent on many factors such as the pond water volume driving re-suspension, characteristics of the stored tailings, configuration of the impoundment, embankment geometry and materials as well as the breach formation parameters. On average, the total amount of tailings released during the breach is anticipated to be approximately one fifth (20%) of the total impounded tailings (Azam and Li 2010).

It is assumed that the entire free water pond (all water impounded within the reservoir depending on the breach scenario down to the top of the tailings surface at elevation 1285.5 m) will be released during the breach. In addition, it is assumed that the flood wave will entrain and carry a solids content of up to 35% by mass (approximately 20% solids by volume). During a dam breach, the volume of tailings that would mix with water was estimated at between 1.0 million m^3 and 1.3 million m^3 for the sunny day failure and the flood failure, respectively. The total tailings volume in the impoundment is approximately 25 million m^3 (i.e., 33 million tonnes at 1.3 tonnes/m^3). The mixture of tailings with water would represent 5% of the total impounded tailings volume. In addition, a much slower secondary flow of tailings following the initial flood wave would be released and deposited closer to the dam. As this release is much slower than the initial flood wave associated with the release of the water pond it does not contribute to the inundation limits and flow rates downstream developed based on routing of the peak flood wave.

As previously noted, the geometry of the tailings dam includes an initial downstream constructed embankment composed of glacial till and coarse rockfill that does not derive its strength from the impounded tailings. At approximately elevation 1278.0 m the dam geometry transitions to a centerline constructed embankment that is laterally supported on the upstream side by the tailings and rockfill on the downstream. During a flood-induced failure where the breach develops due to downcutting through the embankment crest, the breach is inferred to terminate at elevation 1285.5 m when the pond is empty. In a sunny-day failure such as an earthquake, widespread liquefaction of the tailings could destabilize the inside of the impoundment leading to an upstream failure of the centerline section into the pond and subsequent breach of the crest. Under these conditions the volume of impounded water may be lower than the flood-induced failure however the breach is anticipated to continue to the base of the centerline section at elevation 1278.0 m which could lead to an increased volume of tailings released in the secondary flow failure of up to about 1.0 Mm^3. This would create a total tailings release volume on the order of 10% of the total impounded tailings volume which compares well with the case histories when considering the specific geometry of the Equity tailings impoundment. Moreover, some additional tailings may continue to be released through the breach over time at a slower rate due to sedimentation processes. The modelled limits of tailings runout will be discussed and presented later.

6.1.2 Dam Breach Assessment Parameters

Dam breach assessments require that several parameters be estimated such as: breach height and elevation, breach sideslope ratio, breach width, breach formation time, initial conditions and boundary conditions. The parameters defining the configuration of Dam No. 1 and Dam No. 2 were estimated from available literature and experience on other projects for the failure mode (sunny-day or flood-induced) as discussed in the following sections. The parameters were assumed to be the same for the breach of both Dam No. 1 and Dam No. 2.

Breach Height and Elevation

The minimum elevation of the water surface (top of tailings) within the tailings impoundment is 1285.5 m which represents the depth of breach required to fully empty the impoundment of free water. The tailings impoundment crest elevation is 1294.0 m, therefore the maximum breach height would be 8.5 m for a flood-induced failure. The invert of the spillway on the tailings impoundment is 1292.5 m, therefore the maximum breach height for a sunny-day failure due to downcutting is 7.0 m. It is important to note that these breach heights are not the entire dam height. However, tailings runout for a sunny-day failure has been estimated based on the failure of the tailings impoundment at an elevation of 1278.0 m as previously described.

Breach Sideslope Ratio

The breach sideslope ratio for a flood-induced failure is estimated at 1H:1V (Froehlich 2008) based on downcutting of the flood wave through the compacted embankment fills. For other failure modes, the ratio could be as steep as 0.7H:1V which has been used for sunny-day failure.

Breach Width

Previous case studies (Harrington 2014) show that the ratio between the height of the breach (H) and the width of the breach varies from 0.5 H to 8 H depending on the impounded volume. Thus the estimated average breach width would range between 4.3 m and 68 m for a flood-induced breach height of 8.5 m and between 3.5 m and 56 m for a sunny-day breach height of 7.0 m.

The combined volume of water and entrained tailings that could be released during a flood-induced event from the tailings impoundment is estimated to be 7,644,000 m^3. The breach height formed by down cutting through the dam crest during a flood-induced event was assumed to be 8.5 m. Under these conditions, the estimated average breach width is 59.0 m for a flood-induced failure mode (Froehlich 2008). The corresponding bottom width would be 50.5 m.

The combined volume of water and entrained tailings that could be released during a sunny-day event from the tailings impoundment is estimated to be 5,567,000 m^3. The breach height formed by down cutting through the dam crest during a sunny-day event was assumed to be 7.0 m. Under these conditions, the estimated average breach width is 52.0 m for a sunny-day failure mode (Froehlich 2008). The corresponding bottom width would be 47.1 m.

Breach Formation Time

Previous case studies (Harrington 2014) show that breach formation time could range between 0.1 hour and 4 hours depending on impounded volume. The breach formation time was determined assuming a volume of 7,644,000 m^3 for flood-induced and a volume of 5,567,000 m^3 for the sunny-day failure modes with a breach height of 8.5 m and 7.0 m, respectively (Froehlich 2008). The estimated breach formation time is 1.8 hours for flood-induced and 1.9 hours for the sunny-day failure modes.

Initial Conditions

Initial water surface elevation and flow conditions are required to initiate a HEC-RAS model. **Table 6.7** includes the initial conditions for each failure scenario (flood-induced and sunny-day) used in the Dam No. 1 (Assessment 1) and Dam No. 2 (Assessment 2) HEC-RAS models.

Table 6.7: Dam No. 1 (Assessment 1) and Dam No. 2 (Assessment 2) HEC-RAS Models Initial Conditions

Parameter	Unit	Flood-Induced Failure	Sunny-Day Failure
Tailings Impoundment Water Surface Elevation	(m)	1294.0	1292.5
Initial Flow	(m^3/s)	1.0	1.0

The HEC-RAS models include an initial time step of 24 hours prior to the dam breach to develop computationally stable initial hydraulic conditions.

Boundary Conditions

The Dam No. 1 (Assessment 1) HEC-RAS model was constrained by the following boundary conditions:

- Upstream Flow Hydrograph (flow into the tailings impoundment);
- Lateral Flow Hydrographs (from the catchment areas downstream of the tailings impoundment along Foxy Creek and Maxan Creek); and

- Downstream Normal Depth Slope (on the Bulkley River, 3 km downstream of Bulkley Lake).

The boundary conditions were set for the flood-induced and sunny-day failure modes. The upstream and lateral hydrographs were estimated for Dam No. 1 in **Section 6.1.1** for the flood-induced failure mode. The mean annual flows were used for the sunny-day failure, which were determined in **Section 6.1.1**. The inflow hydrographs were applied to the cross sections for the assessment of Dam No. 1 as shown in **Table 6.8**.

Table 6.8: Inflow Hydrograph Locations for Dam No. 1 (Assessment 1)

HEC-RAS Model Section	Catchment Area (km^2)	Boundary Condition
980	22.2	Flow Hydrograph
960	22.0	Lateral Hydrograph
940	21.5	Lateral Hydrograph
930	11.3	Lateral Hydrograph
890	11.1	Lateral Hydrograph
880	237.2	Lateral Hydrograph
850	16.4	Lateral Hydrograph
815	35.2	Lateral Hydrograph
790	264.2	Lateral Hydrograph

The downstream normal slope on the Bulkley River, 3 km downstream of Bulkley Lake was set to 0.001 m/m.

The Dam No. 2 (Assessment 2) HEC-RAS model was constrained by the following boundary conditions:

- Upstream Flow Hydrograph (flow into the tailings impoundment);
- Lateral Flow Hydrographs (from the catchment areas downstream of the tailings impoundment along Bessemer Creek and Buck Creek); and
- Downstream Normal Depth Slope (Buck Creek at Houston, BC).

The boundary conditions were set for the flood-induced and sunny-day failure modes. The upstream and lateral hydrographs were estimated for Dam No. 2 in **Section 5.1.1** for the flood-induced failure mode. The mean annual flows were used for the sunny-day failure, which were determined in **Section 5.1.1**. The inflow hydrographs are applied to the cross sections for the assessment of Dam No. 2 as shown in **Table 6.9**.

Table 6.9: Inflow Hydrograph Locations for Dam No. 2 (Assessment 2)

HEC-RAS Model Section	Catchment Area (km^2)	Boundary Condition
1997	n/a	Flow Hydrograph
1996	2.1	Lateral Hydrograph
1960	9.6	Lateral Hydrograph
1940	68.4	Lateral Hydrograph
1905	34.4	Lateral Hydrograph
1792	264.2	Lateral Hydrograph
1780	n/a	Flow Hydrograph
1720	125.2	Lateral Hydrograph

The downstream normal slope on Buck Creek upstream of Houston, BC was set to 0.009 m/m.

Modelling Uncertainties

There are numerous uncertainties inherent in dam breach modelling and inundation mapping of extreme flows associated with dam breaches. For example:

- Breach parameters such as formation time, breach depth, width and side slopes are typically selected based on correlation with historical dam failures and require considerable judgement. Furthermore, the majority of the dam failure database used to make such correlations includes small dams, dikes and levees and do not include high consequence dams designed to modern standards (i.e., CDA, 2007).
- Most dam breach analysis methods have been developed for water-retaining structures (i.e., reservoirs and hydro-electric facilities) which have well defined geometries and structural elements. Tailings dams, by contrast, are often constructed throughout active mining operations in conjunction with active tailings deposition such that the effective limits of the upstream crest are difficult to define.
- Calibration of dam breach models to extreme flow scenarios is very difficult as the necessary extreme flow is often unavailable. To overcome this models are typically calibrated to available streamflow conditions and then statistically extrapolated to the design flows. This introduces uncertainty in calibration but at this time it is the only available tool.
- Manning's n is used to express the floodplain roughness. For model stability, n may be increased which could result in a wider floodplain, lower wave velocity and longer travel time. For emergency planning, notifications and evacuation, if required, should consider less available time than estimated by dam breach modelling.
- Detailed LIDAR topography was available for the mine site and short distances downstream of the site along Foxy and Bessemer creeks. However, outside of this area

much less detailed topography available from the BC government had to be used. More detailed topography facilitates more accurate floodplain/ARD inundation limits.

- Due to a limited topographical detail in the area of Bulkley Lake it is unknown if some of the flow may bypass the flat area leading to Bulkley Lake and head directly to the area downstream of the lake outlet resulting in lower flood attenuation and higher flows.

Given the above uncertainties, the flows and flood inundation limits produced from the dam breach analysis presented herein should be regarded as approximate. The modelling results presented in the following sections should be viewed in this context and consideration should be given to these uncertainties when developing and executing the Emergency Preparedness Plan (EPP) and any other manuals or procedures.

6.1.3 Dam Breach HEC-RAS Modeling Results

The HEC-RAS models for Dam No. 1 (Assessment 1) and Dam No. 2 (Assessment 2) were run for the flood-induced and sunny-day failure modes based on the inputs and geometry discussed in the preceding sections. The following model outputs are presented and discussed in the following sections:

- Peak flows;
- Maximum water surface levels;
- Maximum water depth;
- Peak velocities;
- Time to reach maximum water levels from the start of the breach; and
- Travel time for peak wave.

The HEC-RAS model outputs for Dam No. 1 (Assessment 1) and Dam No. 2 (Assessment 2) were used to create inundation maps **DWG02** and **DWG05**. The results can be used for emergency planning purposes. A discussion will be included on the potential extents of the tailings release from Dam No. 1 and Dam No. 2 on Foxy Creek and Bessemer Creek, respectively.

The HEC-RAS models were run for the failure modes explained in **Section 4.0**. “No Failure” runs were used to set the baseline conditions for assessing the incremental effects due to the dam breach. The incremental effects of flow and depth between the No Failure case and the Failure Mode are expected to decrease due to channel and floodplain routing as the flood wave travels downstream of the dam.

6.1.4 Dam No. 1 Modelling Results

Peak flow, maximum depth, maximum water surface elevation and peak velocity results of the HEC-RAS model runs for Dam No. 1 (Assessment 1) are summarized in **Table 6.10** with more results presented in Appendix B. These results give an overall view of the hydraulic conditions prior to dam breach and following a dam breach.

Table 6.10: Peak Flow, Maximum Depth, Maximum Water Surface Elevation and Peak Velocity Results for Dam No. 1 (Assessment 1)

Reach	River Station	Length Channel (m)	Station	Min. Channel Elevation (m)	Flood-Induced Failure								Sunny-Day Failure							
					Peak Flow (m^3/s)		Maximum Velocity (m/s)		Maximum Surface Water Level (m)		Depth (m)		Peak Flow (m^3/s)		Maximum Velocity (m/s)		Maximum Surface Water Level (m)		Depth (m)	
					No Failure	Failure Mode	No Failure	Failure Mode	No Failure	Failure Mode	No Failure	Failure Mode	No Failure	Failure Mode	No Failure	Failure Mode	No Failure	Failure Mode	No Failure	Failure Mode
Foxy Creek Downstream of Dam No.1	980	2639	34588	1173.5	67	1432	1.4	3.8	1174.7	1178.7	1.2	5.2	5.0	948.9	0.6	3.3	1173.9	1177.7	0.4	4.3
	970	1261	31949	1105.0	66	1372	2.1	5.0	1106.5	1110.9	1.5	5.9	5.0	937.8	1.0	4.5	1105.5	1110.0	0.5	5.0
	960	724	30688	1047.6	63	1358	1.0	4.2	1051.1	1057.0	3.5	9.4	5.0	934.7	0.8	3.9	1048.5	1055.5	0.9	7.9
	950	3010	29964	1034.7	137	1383	2.0	3.9	1037.2	1042.4	2.5	7.7	5.0	931.9	0.7	3.5	1035.2	1041.1	0.5	6.4
	940	2734	26954	980.4	136	1342	1.6	3.8	983.7	988.8	3.2	8.3	5.0	921.3	0.7	3.5	981.0	987.3	0.6	6.8
	930	2979	24220	924.1	200	1310	0.8	1.5	931.0	939.2	6.9	15.1	5.0	894.9	0.3	1.4	925.5	936.6	1.4	12.4
	920	1872	21241	862.0	226	1246	1.1	1.8	870.1	878.8	8.1	16.8	5.0	864.6	0.4	1.6	863.5	876.4	1.5	14.4
	910	1139	19369	834.9	223	1207	1.3	2.2	841.6	847.8	6.7	12.9	5.0	845.1	0.4	1.9	836.3	846.1	1.5	11.3
	900	779	18230	812.2	221	1187	0.5	0.9	815.1	818.2	2.9	6.0	5.0	835.0	0.2	0.8	812.9	817.3	0.7	5.1
	890	1311	17451	803.0	218	1164	0.6	0.9	805.7	808.4	2.7	5.4	5.0	814.4	0.2	0.8	803.5	807.7	0.5	4.7
Downstream of Maxan Lake	880	632	16140	784.3	223	1132	0.3	0.7	789.7	791.8	5.4	7.4	5.0	762.9	0.2	0.7	785.1	790.4	0.8	6.1
	870	1483	15508	778.7	580	1478	0.6	0.8	783.0	785.0	4.3	6.2	5.0	730.9	0.2	0.6	779.6	783.4	0.9	4.7
	860	2394	14025	767.7	576	1396	0.4	0.5	771.3	772.7	3.5	5.0	5.0	619.0	0.1	0.4	768.5	771.4	0.8	3.6
	850	1565	11631	755.1	554	1222	0.5	0.6	760.7	762.6	5.6	7.5	5.0	429.7	0.2	0.4	756.0	760.2	0.9	5.1
	840	2060	10066	748.0	557	1191	0.5	0.7	752.4	754.1	4.4	6.1	5.0	394.4	0.2	0.4	748.8	751.9	0.8	3.9
	830	2221	8006	735.3	548	1149	0.4	0.6	739.7	740.8	4.4	5.6	5.0	349.5	0.1	0.4	736.0	739.1	0.7	3.9
	820	837	5786	721.1	538	1091	0.4	0.5	726.3	727.5	5.3	6.4	5.0	296.8	0.1	0.3	722.3	725.6	1.2	4.5
Bulkley Lake	815	1807	4949	719.0	535	1071	0.6	0.8	722.1	722.8	3.0	3.8	5.0	289.7	0.3	0.5	719.7	721.6	0.7	2.6
	795	1079	3142	715.3	342	553	0.6	0.7	718.7	719.3	3.4	4.0	2.0	68.6	0.2	0.5	715.7	717.4	0.4	2.1
Downstream of Bulkley Lake	790	1163	2063	712.3	339	525	0.3	0.3	717.0	717.8	4.7	5.5	2.0	66.9	0.1	0.2	712.8	714.9	0.5	2.6
	780	500	900	710.3	355	552	0.3	0.4	715.2	716.1	4.9	5.7	2.0	65.9	0.1	0.2	711.2	713.4	0.9	3.0
	770	400	400	708.9	354	547	0.3	0.3	713.2	714.2	4.3	5.4	2.0	65.1	0.1	0.2	709.5	711.3	0.6	2.4
	760	0	0	706.6	353	546	0.2	0.2	711.9	713.1	5.3	6.5	2.0	64.1	0.1	0.1	707.1	710.7	0.5	4.0

Flood-Induced Failure Results

For the flood-induced failure mode, the peak flow will be attenuated from 1,432 m^3/s at Dam No. 1 (Assessment 1) to 1,071 m^3/s at Bulkley Lake. Once the flood wave passes through Bulkley Lake the peak flow under a flood-induced failure will have reduced to 525 m^3/s compared to a peak flow of 339 m^3/s in a flood event at the same location with no dam failure. However, due to the coarse resolution of the topography in this area it is unknown if some of the flow may bypass the flat area leading to Bulkley Lake and head directly to the area downstream of the lake outlet resulting in lower flood attenuation and higher flows.

For the flood-induced failure mode, the water depth at Dam No. 1 (Assessment 1) will be 5.2 m. As the flood wave progresses downstream the water depth will be 3.8 m upstream of Bulkley Lake and 5.5 m downstream of Bulkley Lake compared to a water depth of 3.0 m and 4.7 m in a flood event at the same location with no dam failure, respectively.

For the flood-induced failure mode, the peak velocity at Dam No. 1 (Assessment 1) will be 3.8 m/s. As the flood wave progresses downstream the peak velocity will be 0.8 m/s upstream of Bulkley Lake and 0.3 m/s downstream of Bulkley Lake compared to a peak velocity of 0.6 m/s and 0.3 m/s in a flood event at the same location with no dam failure, respectively.

Sunny-Day Failure Results

For the sunny-day failure mode, the peak flow will be attenuated from 949 m^3/s at Dam No. 1 (Assessment 1) to 290 m^3/s at Bulkley Lake. Once the flood wave passes through Bulkley Lake the peak flow under a sunny-day failure will be reduced to 67 m^3/s compared to a peak flow of 2.0 m^3/s in a sunny-day event at the same location with no dam failure. However, as described above, some of the flow may bypass the flat area leading to Bulkley Lake and head directly the area downstream of the lake outlet resulting in lower flood attenuation and higher flows.

For the sunny-day failure mode, the water depth at Dam No. 1 (Assessment 1) will be 4.3 m. As the flood wave progress downstream the water depth will be 2.6 m upstream of Bulkley Lake and 2.6 m downstream of Bulkley Lake compared to a water depth of 0.7 m and 0.5 m in a sunny-day event at the same location with no dam failure, respectively.

For the sunny-day failure mode, the peak velocity at Dam No. 1 (Assessment 1) will be 3.3 m/s. As the flood wave progresses downstream the peak velocity will be 0.5 m/s upstream of Bulkley Lake and 0.2 m/s downstream of Bulkley Lake compared to a peak velocity of 0.3 m/s and 0.1 m/s in a sunny-day event at the same location with no dam failure, respectively.

6.1.5 Dam No.2 Modelling Results

Peak flow, maximum depth, maximum water surface elevation and peak velocity depth results of the HEC-RAS model runs for Dam No. 2 (Assessment 2) are summarized in **Table 6.11** with more results presented in Appendix C. These results give an overall view of the hydraulic conditions prior to dam breach and following a dam breach.

Table 6.11: Peak Flow, Maximum Depth, Maximum Water Surface Elevation and Peak Velocity Results for Dam No. 2 (Assessment 2)

Reach	River Station	Length Channel (m)	Station	Min. Channel Elevation (m)	Flood-Induced Failure								Sunny-Day Failure							
					Peak Flow (m^3/s)		Maximum Velocity (m/s)		Maximum Surface Water Level (m)		Depth (m)		Peak Flow (m^3/s)		Maximum Velocity (m/s)		Maximum Surface Water Level (m)		Depth (m)	
					No Failure	Failure Mode	No Failure	Failure Mode	No Failure	Failure Mode	No Failure	Failure Mode	No Failure	Failure Mode	No Failure	Failure Mode	No Failure	Failure Mode	No Failure	Failure Mode
Bessemer Creek Downstream of Dam No. 2	1997	200	39928	1273.9	30	1417	0.1	0.4	1277.0	1278.7	3.1	4.8	1.0	943.0	0.1	0.3	1274.3	1277.9	0.4	3.9
Bessemer Creek Downstream of ARD Storage Pond	1996	451	39728	1269.6	33	1421	0.4	0.4	1271.1	1277.7	1.5	8.1	1.0	936.6	0.2	0.3	1272.4	1276.7	2.8	7.1
	1995	195	39277	1244.7	31	1409	0.3	0.7	1247.6	1255.7	3.0	11.0	1.0	929.0	0.1	0.6	1245.9	1254.1	1.3	9.4
	1994	241	39082	1236.8	31	1405	0.4	1.0	1238.6	1244.7	1.8	8.0	1.0	928.1	0.2	0.9	1237.2	1243.6	0.4	6.8
	1993	145	38841	1210.1	31	1402	1.2	1.8	1211.9	1219.3	1.8	9.2	1.0	927.4	0.4	1.6	1210.4	1218.3	0.3	8.2
	1992	86	38696	1197.9	31	1401	1.0	2.4	1200.8	1208.4	2.9	10.5	1.0	927.1	0.4	2.2	1198.7	1207.3	0.8	9.4
Bessemer Creek Downstream of ARD Collection Ponds	1991	311	38610	1192.3	31	1401	1.0	2.2	1195.4	1201.7	3.1	9.4	1.0	927.0	0.5	2.0	1193.2	1200.6	0.9	8.3
	1990	986	38299	1169.1	31	1399	1.1	2.7	1171.5	1180.4	2.5	11.4	1.0	926.6	0.4	2.4	1169.8	1179.0	0.7	9.9
Bessemer Creek through the Bessemer Creek Silt Check Dam	1980	1023	37313	1094.1	31	1393	1.1	2.4	1097.4	1107.8	3.3	13.7	1.0	924.6	0.4	2.2	1094.9	1106.1	0.8	12.0
	1970	622	36290	1042.6	31	1387	0.6	2.2	1043.8	1050.3	1.2	7.8	1.0	922.0	0.2	1.9	1042.9	1048.9	0.4	6.3
	1960	1230	35668	1009.3	30	1381	0.6	2.0	1012.6	1023.6	3.3	14.4	1.0	920.3	0.3	1.8	1010.1	1021.4	0.8	12.1
	1950	933	34438	957.7	63	1376	0.6	1.0	961.1	969.8	3.4	12.1	1.0	914.6	0.2	1.0	958.4	967.9	0.7	10.3
Bessemer Creek and Buck Creek Confluence	1940	1195	33504	923.7	52	1272	0.0	0.3	929.0	933.2	5.3	9.5	1.0	843.6	0.1	0.3	924.6	931.6	0.9	7.9
	1930	958	32310	918.2	197	1252	0.2	0.4	922.8	926.2	4.6	8.0	1.0	706.2	0.1	0.3	918.8	924.7	0.7	6.6
Goosly Lake	1920	0	31352	914.9	58	271	0.0	0.1	919.3	921.7	4.4	6.8	1.0	80.6	0.0	0.0	917.2	919.6	2.3	4.7
	1905	476	31352	916.1	57	268	0.1	0.2	919.3	921.7	3.2	5.6	4.0	78.9	0.1	0.2	917.2	919.6	1.1	3.5
Buck Creek Downstream of Goosly Lake	1900	649	30877	913.7	79	288	0.4	0.6	916.8	918.6	3.1	4.9	4.0	78.8	0.2	0.4	914.7	916.8	1.0	3.1
	1890	1000	30228	908.9	75	288	0.3	0.4	911.2	912.5	2.3	3.5	4.0	78.6	0.1	0.3	909.7	911.2	0.8	2.3
	1880	2301	29228	901.5	71	287	0.2	0.2	903.6	904.7	2.2	3.2	4.0	78.3	0.1	0.2	902.3	903.7	0.8	2.2
	1870	1754	26927	889.2	59	265	0.1	0.1	891.7	893.4	2.5	4.2	4.0	75.2	0.1	0.1	890.2	891.9	1.0	2.7
Buck Creek Upper Falls	1860	847	25173	885.8	58	253	0.6	0.6	887.6	889.3	1.8	3.5	4.0	72.5	0.3	0.6	886.3	887.8	0.5	2.0

Reach	River Station	Length Channel (m)	Station	Min. Channel Elevation (m)	Flood-Induced Failure								Sunny-Day Failure							
					Peak Flow (m^3/s)		Maximum Velocity (m/s)		Maximum Surface Water Level (m)		Depth (m)		Peak Flow (m^3/s)		Maximum Velocity (m/s)		Maximum Surface Water Level (m)		Depth (m)	
					No Failure	Failure Mode	No Failure	Failure Mode	No Failure	Failure Mode	No Failure	Failure Mode	No Failure	Failure Mode	No Failure	Failure Mode	No Failure	Failure Mode	No Failure	Failure Mode
Buck Creek heading towards Houston, BC	1850	2523	24326	866.3	58	259	0.7	1.1	870.7	874.0	4.4	7.6	4.0	72.1	0.2	0.7	868.3	871.1	1.9	4.7
	1840	1879	21803	841.5	58	248	0.3	0.4	844.0	845.5	2.5	4.0	4.0	71.1	0.3	0.3	842.2	844.1	0.6	2.6
	1830	1205	19924	834.0	57	236	0.1	0.2	836.9	838.9	2.9	4.8	4.0	62.0	0.1	0.1	834.8	837.0	0.8	3.0
	1820	664	18719	829.9	60	234	0.3	0.4	833.7	835.7	3.8	5.9	4.0	67.9	0.3	0.3	830.8	833.9	1.0	4.0
	1810	1207	18055	828.0	7	225	0.0	0.2	832.0	833.8	4.0	5.8	4.0	66.6	0.1	0.2	829.1	831.9	1.1	3.9
	1800	838	16848	825.9	6	222	0.0	0.1	832.0	833.1	6.1	7.2	4.0	60.9	0.0	0.1	827.6	830.4	1.7	4.6
	1790	10	16010	825.5	291	299	0.8	0.8	831.1	831.2	5.7	5.7	4.0	60.8	0.2	0.5	826.5	828.4	1.1	2.9
	1780	2000	16000	802.5	291	299	0.5	0.5	807.5	807.5	4.9	5.0	4.0	60.1	0.3	0.3	803.4	805.6	0.9	3.0
	1770	2000	14000	786.4	290	298	0.4	0.6	791.7	791.7	5.3	5.3	4.0	58.9	0.2	0.3	787.6	790.0	1.2	3.6
	1760	2000	12000	774.2	286	293	0.380	0.380	780.4	780.4	6.2	6.3	4.0	61.7	0.2	0.4	774.9	777.1	0.7	3.0
	1750	2000	10000	759.6	285	292	0.910	0.910	767.8	767.8	8.2	8.3	4.0	61.4	0.2	0.5	761.5	764.4	1.9	4.8
	1740	2000	8000	749.2	279	286	0.340	0.340	755.5	755.5	6.2	6.3	4.0	59.9	0.2	0.3	750.4	752.7	1.2	3.5
	1730	2000	6000	732.0	278	285	1.570	1.570	738.9	739.0	6.9	7.0	4.0	59.7	0.5	1.0	733.2	735.6	1.2	3.5
	1720	2000	4000	661.2	278	285	1.270	1.270	668.1	668.2	6.9	6.9	4.0	59.7	0.6	0.8	661.9	664.6	0.7	3.4
	1710	2000	2000	637.0	329	334	0.400	0.400	641.9	642.2	4.9	5.2	4.0	58.5	0.1	0.3	637.6	639.4	0.6	2.4
Buck Creek Upstream of Houston, BC	1700	0	0	623.6	328	337	0.500	0.500	628.7	628.7	5.1	5.1	4.0	58.3	0.2	0.4	624.5	626.6	1.0	3.0

Flood-Induced Failure Results

For the flood-induced failure mode, the peak flow will attenuate from 1,417 m^3/s at Dam No. 2 (Assessment 2) to 1,401 m^3/s at the ARD Collection Ponds, to 1,272 m^3/s at the confluence of Buck Creek, to 268 m^3/s at Goosly Lake, and to 253 m^3/s at Buck Creek Upper Falls. Once the flood wave reaches Houston, BC the peak flow under a flood-induced failure will be 337 m^3/s compared to a peak flow of 328 m^3/s in a flood event at the same location with no dam failure. The effect of a flood-induced failure may not be observed at Houston as the change in flow is negligible.

Table 6.12 summarizes the estimated natural peak flood flows expected in Bessemer Creek and Buck Creek based on BC Peak Flood Maps (Coulson & Obedkoff 1998).

Table 6.12: Bessemer Creek and Buck Creek Natural Peak Flood Flows

Location	Catchment Area (km^2)	Return Period Peak Flood Flows (m^3/s)		
		10-year	200-year	1000-year
Bessemer Creek from the Tailings Impoundment to the Bessemer Creek Silt Check Dam	9.6	2.38	3.02	3.43
Along Bessemer Creek and Buck Creek from the Tailings Impoundment to Goosly Lake	78	12.3	15.6	17.8
Buck Creek at Houston, BC	580	59.6	75.6	85.9

For a flood-induced failure of Dam No. 2, the peak outflows expected in Bessemer Creek, Buck Creek and upstream of Houston, BC are larger than the 1 in 1000 year peak flood flows that this same system could naturally expect in **Table 6.12**. In 1985, the BC Ministry of Environment Water Management Branch conducted a floodplain study of the Bulkley River at Houston including Buck Creek. This study estimated that 1 in 200 year peak flood flow at the mouth of Buck Creek to be 91.5 m^3/s.

For the flood-induced failure mode, the water depth at Dam No. 2 (Assessment 2) will be 4.8 m. As the flood wave progress downstream the water depth will be 9.4 m at the ARD Collection Ponds, 9.5 m at the confluence of Buck Creek, 5.6 m at Goosly Lake, and 3.5 m at Buck Creek Upper Falls. Once the flood wave reaches upstream of Houston, BC the water depth for a flood-induced failure will be 5.1 m compared to a water depth of 5.1 m in a flood event at the same location with no dam failure.

For the flood-induced failure mode, the peak velocity at Dam No. 2 (Assessment 2) will be 0.4 m/s. As the flood wave progresses downstream the peak velocity will be 2.2 m/s at the ARD Collection Ponds, 0.3 m/s at the confluence of Buck Creek, 0.2 m/s at Goosly Lake, and 0.6 m/s at Buck Creek Upper Falls. Once the flood wave reaches the area upstream of Houston, BC the peak velocity for a flood-induced failure will be 0.5 m/s compared to a peak velocity of 0.5 m/s in a flood event at the same location with no dam failure.

Sunny-Day Failure Results

For the sunny-day failure mode, the peak flow will attenuate from 943 m^3/s at Dam No. 2 (Assessment 2) to 927 m^3/s at the ARD Collection Ponds, to 844 m^3/s at the confluence of Buck Creek, to 79 m^3/s at Goosly Lake, and to 73 m^3/s at Buck Creek Upper Falls. Once the flood wave reaches upstream of Houston, BC the peak flow under a sunny-day failure will be 58 m^3/s compared to a peak flow of 4 m^3/s in a sunny-day event at the same location with no dam failure.

For a sunny-day failure of Dam No. 2, the peak outflows expected in Bessemer Creek, through Goosly Lake and in Buck Creek are larger than the 1 in 1000 year peak flood flows that this same system could naturally expect in **Table 6.12**. Once the sunny-day failure peak outflow from Dam No. 2 has reached upstream of Houston, BC it will be close to a 1 in 10 year peak flood that this area could naturally expect.

For the sunny-day failure mode, the water depth at Dam No. 2 (Assessment 2) will be 3.9 m. As the flood wave progresses downstream the water depth will be 8.3 m at the ARD Collection Ponds, 7.9 m at the confluence of Buck Creek, 3.5 m at Goosly Lake, and 2.0 m at Buck Creek Upper Falls. Once the flood wave reaches upstream of Houston, BC the water depth for a sunny-day failure will be 3.0 m compared to a water depth of 1.0 m in a sunny-day at the same location with no dam failure.

For the sunny-day failure mode, the peak velocity at Dam No. 2 (Assessment 2) will be 0.3 m/s. As the flood wave progresses downstream the peak velocity will be 2.0 m/s at the ARD Collection Ponds, 0.3 m/s at the confluence of Buck Creek, 0.2 m/s at Goosly Lake, and 0.6 m/s at Buck Creek Upper Falls. Once the flood wave reaches upstream of Houston, BC the peak velocity for a sunny-day failure will be 0.4 m/s compared to a peak velocity of 0.2 m/s in a sunny-day event at the same location with no dam failure.

6.1.6 Peak Travel Time

The time to reach the maximum water level and the peak wave travel time from Dam No. 1 (Assessment 1) and Dam No. 2 (Assessment 2) were estimated. The results are shown in **Table 6.13** and **Table 6.14** for Dam No. 1 and Dam No. 2, respectively. The time to reach the maximum water level immediately downstream of the dams is close to the dam breach full formation time (i.e. the peak flow occurs when the maximum breach is reached).

Table 6.13: Peak Wave Travel Time for Dam No. 1 (Assessment 1)

Reach	River Station	Flood-Induced Failure		Sunny-Day Failure	
		Time to Reach Max. Water Level since the Start of the Breach (hours)	Peak Wave Travel Time from the Dam (hours)	Time to Reach Max. Water Level since the Start of the Breach (hours)	Peak Wave Travel Time from the Dam (hours)
Foxy Creek Downstream of Dam No. 1	980	1.4	0.0	2.0	0.0
	890	3.1	1.7	4.7	2.7
Upstream of Bulkley Lake	815	7.5	6.1	12.3	10.3
Downstream of Bulkley Lake	795	14.0	12.6	21.0	19.0
	760	16.0	14.6	25.8	23.8

For the flood-induced failure mode, the peak wave travel time from Dam No. 1 (Assessment 1) to Bulkley Lake is approximately 6 hours. It would take approximately 7 hours for the flood wave to travel through Bulkley Lake as the flood wave would reach downstream of Bulkley Lake after approximately 13 hours from the start of the dam breach. The peak wave travel time may be reduced if the flow bypasses Bulkley Lake.

For the sunny-day failure mode, the peak wave travel time from Dam No. 1 (Assessment 1) to Bulkley Lake is approximately 10 hours. It would take approximately 9 hours for the flood wave to travel through Bulkley Lake as the flood wave would reach downstream of Bulkley Lake after approximately 19 hours from the start of the dam breach. The peak wave travel time may be reduced if the flow bypasses Bulkley Lake.

Table 6.14: Peak Wave Travel Time for Dam No. 2 (Assessment 2)

Reach	River Station	Flood-Induced Failure		Sunny-Day Failure	
		Time to Reach Max. Water Level since the Start of the Breach (hours)	Peak Wave Travel Time from the Dam (hours)	Time to Reach Max. Water Level since the Start of the Breach (hours)	Peak Wave Travel Time from the Dam (hours)
Bessemer Creek Downstream of Dam No. 2	1997	1.9	0.0	2.0	0
Bessemer Creek Downstream of ARD Collection Ponds	1991	2.8	0.9	2.3	0.3
Bessemer Creek and Buck Creek Confluence	1940	6.2	4.2	2.9	0.9
Goosley Lake	1905	7.7	5.7	7.8	5.8
Buck Creek heading towards Houston, BC	1790	9.2	7.2	15.1	13.1
Buck Creek Upstream of Houston, BC	1700	14.4	12.5	22.6	20.6

For the flood-induced failure mode, the peak wave travel time from Dam No. 2 (Assessment 2) to the ARD Collection Ponds is approximately 0.9 hours. The flood wave would reach Goosly Lake after approximately 6 hours from the start of the dam breach. The flood wave would reach upstream of Houston, BC after approximately 13 hours from the start of the dam breach.

For the sunny-day failure mode, the peak wave travel time from Dam No. 2 (Assessment 2) to the ARD Collection Ponds is approximately 0.3 hours. The flood wave would reach Goosly Lake after approximately 6 hours from the start of the dam breach. The flood wave would reach upstream of Houston, BC after approximately 21 hours from the start of the dam breach.

The flood attenuation in the lakes and the floodplain roughness may affect the peak wave velocity and travel time. For emergency planning, it should be assumed that shorter time may be required for notification and evacuation of residents.

6.1.7 Tailings Release from the Tailings Impoundment

There are two mechanisms for tailings release. First, the flood wave will entrain tailings solids during the breach and carry them in suspension as it travels downstream of a dam. It is assumed that the flood wave can carry a solids content of up to 35%, as previously discussed. 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 and flow as a debris flow (liquefied mass) down the shell of a dam.

Following the initial release of the flood wave induced by a dam failure, a small portion of the tailings local to the point of breach could mobilize and flow out of the impoundment. The release volume is approximated by the volume above a planar surface extending back from the bottom of the breach. The portion of the dam and tailings above the failure plane is assumed to mobilize and exit the reservoir forming the tailings runout downstream of the dam toe. During the breach the flood wave will carry a portion of the tailings as suspended sediment while the mobilized tailings flow downstream until they achieve a slope of approximately 20H:1V. Although, there is uncertainty regarding the terminal slope of the tailings runout it is typically approximated as the residual shear strength of the tailings deposit. Based on review of available case studies this has been assumed at about 3° or 5% (Blight and Fourie, 2003) which is equal to 20H:1V. The same slope (20H:1V) was adopted for the backslope within Dam No. 1, Dam No. 2 and the tailings impoundment.

For a flood-induced failure, the tailings runout distance was estimated to be roughly 300 m and 500 m from the toes of Dam No. 1 and Dam No. 2, respectively. For a sunny-day failure, the tailings runout distance was estimated to be 850 m and 660 m from the toes of Dam No. 1 and Dam No. 2, respectively. The sunny-day tailings runout estimated for Dam No. 2 will likely go beyond the 660 m as the topography begins to steepen into the Bessemer Creek Valley. Due to the uncertainty inherent in the simplified tailings flow modeling employed it is not possible to predict the tailings runout behavior beyond this point with sufficient confidence. Additional detailed debris flow modelling would be required which is beyond the scope of this study. The extension of the cut and fill of the runout tailings for Dam No 1 and Dam No.2 are shown on **DWG02** and **DWG05**, respectively. As can be seen on these drawings, the tailings runout areas are larger for a sunny-day failure than a flood-induced failure. This is due to the fact that more of the dam is assumed to fail in a sunny-day scenario than a flood-induced scenario, as has been previously discussed. It should be noted that the runout area shown represents all the area that is at risk from runout tailings. In the case of an actual dam breach, the area will be limited to the location of the breach.

6.2 Diversion Dam

A desktop review was performed of existing site topographic data in the vicinity of the Diversion Dam to determine whether it is more likely that a hypothetical breach of this dam would impact Foxy Creek or Bessemer Creek (Refer to **Figure 2.1**). The desktop review concluded that it is more likely that a hypothetical breach of the Diversion Dam would impact Foxy Creek (Refer to **DWG07**). The potential flow paths plotted on **DWG07** (Inset 1) show that a hypothetical breach of the Diversion Dam would likely flow towards Dam No. 3 through the Treated Water Pond and the ARD Emergency Pond. The Splitter Dike between the Treated Water and the ARD Emergency Ponds would likely fail and Dam No. 3 would also likely fail due to the large magnitude of flow (water and tailings) expected from a breach of the tailings impoundment. However, the Treated Water and the Emergency ARD Ponds would provide some storage and attenuation for the water and tailings expected from the breach of the tailings impoundment. If these ponds are empty at the time of a breach they could provide approximately up to 1,800,000 m^3 of storage (AMEC 2009). The volume of water and tailings that could be released from the tailings impoundment during a flood-induced failure and a sunny-day failure is estimated to be 7,644,000 m^3 and 5,567,000 m^3, respectively. At this time a detailed assessment of the inundation limits corresponding to a hypothetical breach of this dam is not considered to be necessary as breaches of Dam No.1 and Dam No.2 are considered to represent the more critical scenarios for breach of the tailings impoundment.

6.3 ARD Collection Pond Dams (No.1 Sump, Main ARD Pond and ARD Surge Pond), ARD Storage Pond South Dike and Bessemer Creek Silt Check Dam

Simplified dam break assessments were performed for the ARD Collection Pond Dams (No. 1 Sump, Main ARD Pond and ARD Surge Pond) (Assessments 4A, 4B and 4C), ARD Storage Pond South Dike (Assessment 5) and Bessemer Creek Silt Check Dam (Assessments 6A and 6B).

6.3.1 Dam Breach Peak Outflows

The peak outflows expected from a sunny-day failure of the ARD Collection Pond Dams, ARD Storage Pond South Dike and Bessemer Creek Silt Check Dam were estimated using graphical methods based on historical data that relate peak outflow to dam, reservoir or breach characteristics (DSO 1998) and Froehlich's (1995) equation. The graphical methods resulted in a wide range of peak outflow values, while the peak outflows from Froehlich's equation fell within the lower portion of this range. As these dams are small in height, it was determined based on professional judgement that the peak outflows from Froehlich's equation seemed the most realistic in relation to the peak outflows expected from a breach of the tailings impoundment. Froehlich's equation uses height of water and storage volume to predict peak outflows from dam breaches and takes the following form:

$$Q_p = 0.607\ (V_w^{0.295} \times H_w^{1.24})$$

where: Q_p = peak outflow (m^3/s
V_w = storage volume (m^3)
H_w = height of water (m)

Table 6.15 summarizes the peak dam breach outflows estimated for the ARD Collection Pond Dams, ARD Storage Pond South Dike and Bessemer Creek Silt Check Dam along with the height of water and storage information used for these predictions. The assessments are described in **Table 5.1**.

Table 6.15: Sunny-Day Peak Dam Breach Outflows Estimated for the ARD Collection Pond Dams (Assessments 4A, 4B and 4C), ARD Storage Pond South Dike (Assessment 5) and Bessemer Creek Silt Check Dam (Assessments 6A and 6B)

Assessment	Description of Assessment	Storage Volume (m^3)	Height of Water (m)	Sunny-Day Peak Dam Breach Flow (m^3/s)
4A	ARD Collection Pond Dam – No. 1 Sump	1,185	4.0	27
4B	ARD Collection Pond Dam – Main	16,500	7.5	157
4C	ARD Collection Pond Dam – Surge	22,400	6.0	264
5	ARD Storage Pond South Dike [1]	38,600	1.3	19
6A	Bessemer Silt Check Dam	30,000	8.0	167
6B	Bessemer Silt Check Dam	30,000	8.0	454

1. *The ARD Storage Pond South Dike is built as part of the mine access road (Refer to **Figure 2.4**). It is highly unlikely that the existing road would fail. Therefore, for the dam breach analysis of the ARD Storage Pond South Dike, it has been assumed that only the top portion of the dam from the crest to the top of the road would fail. Therefore the storage volume and height of water in this table are considerably less than for the entire structure as outlined in **Section 2.0**.*

The Bessemer Check Silt Check Dam spillway can pass a 1 in 200 year peak flood of 12 m^3/s with acceptable freeboard (AMEC 2011a). This flood is less that all of the sunny-day peak dam breach flows summarized in **Table 6.15.** Therefore, failures of the dams in Assessment 4A, 4B, 4C and 5 would overwhelm and likely washout the Bessemer Creek Silt Check Dam.

Failures of ARD Collection Pond Dams, ARD Storage Pond South Dike and Bessemer Creek Silt Check Dam would impact Bessemer Creek and Buck Creek. **Table 6.12** summarizes the estimated natural peak flood flows expected in Bessemer Creek based on BC Peak Flood Maps (Coulson & Obedkoff 1998). All of the sunny-day peak dam breach outflows in **Table 6.15** are larger than the 1 in 1000 year peak flood flows that Bessemer Creek and Buck Creek could naturally expect in **Table 6.12**.

6.3.2 Simplified Assessment and HEC-RAS Modelling

Simplified dam breach assessments were used to estimate the flood wave geometries expected from failures of the ARD Collection Pond Dams (No. 1 Sump, Main ARD Pond and ARD Surge Pond), ARD Storage Pond South Dike and Bessemer Creek Silt Check Dam. Initially, the attenuation of the flows in **Table 6.15** from the dams to the downstream extents (either the Bessemer Creek Silt Check Dam or Goosly Lake) was estimated using an attenuation rate method from BC Hydro (1984). Using the computer program FlowMaster, these flows were applied to the cross-sectional geometry to estimate maximum water depth, top width and velocity expected from a sunny-day dam breach failure. However, after the above initial assessment it was necessary to create HEC-RAS models for each of these dams to check the precision and accuracy of the initial estimates. Therefore, a steady state flow HEC-RAS model was created for Bessemer Creek for the potential failures of the ARD Collection Pond Dams, ARD Storage Pond South Dike and Bessemer Creek Silt Check Dam using the sunny-day peak outflows in **Table 6.15**. These HEC-RAS models were used to estimate the maximum water depth, top width and velocity expected from a sunny-day failure downstream of these dams. The cross-sections used for the assessment of these dams can be seen on **DWG07** and **DWG08 (4 Sheets)** in plan and profile, respectively.

6.3.3 Estimated Flood Wave Geometries

The maximum water depth, top width and velocity expected from a sunny-day dam breach failure of the ARD Collection Pond Dams (Assessments 4A, 4B and 4C), ARD Storage Pond South Dike (Assessment 5) and Bessemer Creek Silt Check Dam (Assessments 6A and 6B) are summarized in **Table 6.16** through **Table 6.21**.

Table 6.16: Maximum Depth, Top Width and Velocity Results for the No. 1 Sump (Assessment 4A)

Section	Methodology	BCH	BCH / FlowMaster	HEC-RAS Steady Flow	BCH / FlowMaster	HEC-RAS Steady Flow	BCH / FlowMaster	HEC-RAS Steady Flow
	Distance (km)	Attenuated Peak Flow (m^3/s)	Maximum Water Depth (m)		Top Width (m)		Velocity (m/s)	
1992	0.0	27.0	1.0	0.9	28.7	23.6	1.8	2.3
1990	0.2	26.9	1.5	1.7	14.3	15.1	2.3	2.0
1989	0.7	26.7	1.6	1.5	10.5	9.81	2.6	3.0
1985	1.0	26.6	1.5	1.7	11.9	13.0	2.5	2.1
1980	1.2	26.5	1.8	1.7	9.6	8.80	2.6	3.1
1977	1.6	26.4	1.4	1.7	19.1	20.6	1.8	1.4
1975	1.9	26.3	0.8	0.8	30.4	30.8	1.5	1.5
1970	2.2	26.1	0.7	0.7	51.1	49.0	1.3	1.6

Section	Methodology	BCH	BCH / FlowMaster	HEC-RAS Steady Flow	BCH / FlowMaster	HEC-RAS Steady Flow	BCH / FlowMaster	HEC-RAS Steady Flow
	Distance (km)	Attenuated Peak Flow (m^3/s)	Maximum Water Depth (m)		Top Width (m)		Velocity (m/s)	
1965	2.5	26.0	1.0	1.1	28.2	30.0	1.6	1.4
1960	2.8	25.9	1.6	1.6	15.3	15.2	2.1	2.2
1957	3.4	25.7	1.0	1.0	30.9	31.5	1.6	1.6

Table 6.17: Maximum Depth, Top Width and Velocity Results for the Main ARD Pond (Assessment 4B) – Includes the No. 1 Sump

Section	Methodology	BCH	BCH / FlowMaster	HEC-RAS Steady Flow	BCH / FlowMaster	HEC-RAS Steady Flow	BCH / FlowMaster	HEC-RAS Steady Flow
	Distance (km)	Attenuated Peak Flow (m^3/s)	Maximum Water Depth (m)		Top Width (m)		Velocity (m/s)	
1992	0.0	157.0	2.0	1.9	49.3	47.3	2.9	3.2
1990	0.2	156.6	3.1	3.3	24.2	25.5	3.8	3.4
1989	0.7	155.4	3.4	3.3	18.1	17.8	4.2	4.4
1985	1.0	154.7	3.1	3.4	20.7	21.9	4.0	3.5
1980	1.2	154.3	3.9	3.7	19.7	18.6	3.9	4.4
1977	1.6	153.5	2.9	3.3	37.9	39.7	2.8	2.2
1975	1.9	152.7	1.9	2.0	48.9	49.6	2.5	2.4
1970	2.2	152.1	1.4	1.3	63.9	62.0	2.4	2.9
1965	2.5	151.4	2.1	2.4	51.0	55.8	2.6	2.2
1960	2.8	150.7	3.1	3.0	28.3	27.9	3.3	3.5
1957	3.4	149.6	1.8	1.9	61.3	61.9	2.5	2.5

Table 6.18: Maximum Depth, Top Width and Velocity Results for the ARD Surge Pond (Assessment 4C) – Includes the Main ARD Pond and the No. 1 Sump

Section	Methodology	BCH	BCH / FlowMaster	HEC-RAS Steady Flow	BCH / FlowMaster	HEC-RAS Steady Flow	BCH / FlowMaster	HEC-RAS Steady Flow
	Distance (km)	Attenuated Peak Flow (m^3/s)	Maximum Water Depth (m)		Top Width (m)		Velocity (m/s)	
1992	0.0	264.0	2.4	2.4	61.7	61.2	3.3	3.4
1990	0.2	263.3	3.8	4.0	28.5	29.7	4.4	4.0

Section	Methodology	BCH	BCH / FlowMaster	HEC-RAS Steady Flow	BCH / FlowMaster	HEC-RAS Steady Flow	BCH / FlowMaster	HEC-RAS Steady Flow
	Distance (km)	Attenuated Peak Flow (m^3/s)	Maximum Water Depth (m)		Top Width (m)		Velocity (m/s)	
1989	0.7	261.3	4.3	4.2	20.9	20.6	4.9	5.0
1985	1.0	260.1	3.9	4.2	23.7	24.9	4.7	4.1
1980	1.2	259.4	4.8	4.6	25.5	24.1	4.4	4.8
1977	1.6	258.1	3.5	4.0	40.5	42.6	3.3	2.7
1975	1.9	256.8	2.4	2.5	54.7	55.1	2.9	2.9
1970	2.2	255.7	1.8	1.7	68.3	66.5	2.9	3.4
1965	2.5	254.6	2.6	2.9	61.0	66.3	3.0	2.5
1960	2.8	253.5	3.8	3.7	32.7	32.2	3.8	4.1
1957	3.4	251.5	2.2	2.3	68.9	69.7	2.9	3.0

Table 6.19: Maximum Depth, Top Width and Velocity Results for the ARD Storage Pond South Dike (Assessment 5) – Assumes a Partial Loss of the Dike [1]

Section	Methodology	BCH	BCH / FlowMaster	HEC-RAS Steady Flow	BCH / FlowMaster	HEC-RAS Steady Flow	BCH / FlowMaster	HEC-RAS Steady Flow
	Distance (km)	Attenuated Peak Flow (m^3/s)	Maximum Water Depth (m)		Top Width (m)		Velocity (m/s)	
1997	0.0	19.0	0.3	0.3	109.6	95.7	0.8	1.2
1995	0.6	18.8	1.4	1.5	40.2	45.0	1.2	0.9
1994	0.7	18.8	1.0	0.9	17.4	16.0	1.9	2.3
1993	1.0	18.7	1.0	1.1	15.5	18.0	2.1	1.7
1992	1.3	18.7	0.8	0.8	20.8	20.1	1.8	2.1
1990	1.5	18.6	1.3	1.5	13.3	14.0	2.1	1.8
1989	2.0	18.5	1.4	1.3	9.31	8.82	2.4	2.8
1985	2.3	18.4	1.3	1.4	10.6	11.6	2.3	1.9
1980	2.5	18.3	1.6	1.4	8.40	7.81	2.3	2.9
1977	2.9	18.2	1.3	1.5	17.2	19.2	1.6	1.3
1975	3.2	18.1	0.7	0.7	27.7	28.2	1.3	1.3
1970	3.5	18.1	0.6	0.6	47.4	45.8	1.2	1.4
1965	3.8	18.0	0.9	1.0	25.5	27.1	1.5	1.3
1960	4.1	17.9	1.4	1.4	13.4	13.4	1.9	2.0

Section	Methodology	BCH	BCH / FlowMaster	HEC-RAS Steady Flow	BCH / FlowMaster	HEC-RAS Steady Flow	BCH / FlowMaster	HEC-RAS Steady Flow
	Distance (km)	Attenuated Peak Flow (m^3/s)	Maximum Water Depth (m)		Top Width (m)		Velocity (m/s)	
1957	4.7	17.8	0.9	0.9	26.9	27.5	1.5	1.5

1. *The ARD Storage Pond South Dike is built as part of the mine access road (Refer to **Figure 2.4**). It is highly unlikely that the existing road would fail. Therefore, for the dam breach analysis of the ARD Storage Pond South Dike, it has been assumed that only the top portion of the dam from the crest to the top of the road would fail. Therefore the outflow is considerably less than for the entire structure.*

Table 6.20: Maximum Depth, Top Width and Velocity Results for the Bessemer Silt Check Dam (Assessment 6A)

Section	Methodology	BCH	BCH / FlowMaster	HEC-RAS Steady Flow	BCH / FlowMaster	HEC-RAS Steady Flow	BCH / FlowMaster	HEC-RAS Steady Flow
	Distance (km)	Attenuated Peak Flow (m^3/s)	Maximum Water Depth (m)		Top Width (m)		Velocity (m/s)	
1955	0.00	167.0	2.0	1.9	46.5	44.2	2.9	3.4
1950	0.14	166.7	2.4	3.5	43.1	54.7	2.8	1.5
1945	1.00	164.6	1.8	0.9	95.6	105.2	1.6	2.5
1940	1.34	163.8	3.6	4.0	72.5	81.4	1.2	1.0
1930	2.30	161.6	2.7	2.5	224	203	0.8	1.2
1920	2.88	160.3	1.3	1.1	335	328	0.6	0.8
1915	3.30	159.3	0.7	0.7	759	760	0.3	0.3

Table 6.21: Maximum Depth, Top Width and Velocity Results for the Bessemer Silt Check Dam (Assessment 6B) – Includes a Cascade Failure of the ARD Collection Ponds

Section	Methodology	BCH	BCH / FlowMaster	HEC-RAS Steady Flow	BCH / FlowMaster	HEC-RAS Steady Flow	BCH / FlowMaster	HEC-RAS Steady Flow
	Distance (km)	Attenuated Peak Flow (m^3/s)	Maximum Water Depth (m)		Top Width (m)		Velocity (m/s)	
1955	0.00	454.0	3.1	3.0	63.2	61.0	3.9	4.4
1950	0.14	453.1	3.7	3.6	57.0	56.6	3.7	3.8
1945	1.00	447.5	3.4	3.4	173	173	1.9	1.9
1940	1.34	445.4	4.2	4.6	480	651	0.8	0.9
1930	2.30	439.3	3.3	3.2	267	266	1.3	1.7
1920	2.88	435.7	1.8	1.6	749	746	0.6	1.0

Section	Methodology	BCH	BCH / FlowMaster	HEC-RAS Steady Flow	BCH / FlowMaster	HEC-RAS Steady Flow	BCH / FlowMaster	HEC-RAS Steady Flow
	Distance (km)	Attenuated Peak Flow (m^3/s)	Maximum Water Depth (m)		Top Width (m)		Velocity (m/s)	
1915	3.30	433.1	1.2	1.2	778	779	0.5	0.5

Using the flood wave geometry data presented in **Table 6.16** to **Table 6.21**, the potential ARD impact areas of the dam breaks on Bessemer Creek and Buck Creek down to Goosly Lake are shown on **DWG07** and **GWG08**. These drawings show the estimated stream area (channel and bank area) that could be impacted by contact with ARD discharges from failures of the ARD Collection Ponds (No. 1 Sump, Main ARD Pond and ARD Surge Pond), ARD Storage Pond South Dike and the Bessemer Creek Silt Check Dam.

6.4 Qualitative Assessment of Water Quality

A qualitative assessment of water quality considering the effects of dilution on pH, suspended solids or turbidity only was performed to provide initial expectations of the changes of water quality in the event of a dam breach. The following factors would affect water quality:

- Mode of failure (flood-induced or sunny-day);
- The location of the breach (Dam No. 1, Dam No. 2, Diversion Dam, ARD Collection Ponds, ARD Storage Pond South Dike and the Bessemer Creek Silt Check Dam);
- Distance downstream from the dams (dilution); and
- Month of dam failure (mean monthly flow in the reaches downstream of the dams would affect water quality for sunny-day failure).

In general, water quality would be improving further away from the dams. The water quality will change over the reaches downstream of the dams due to the contribution of additional lateral flow from side catchments. The immediate area downstream of the dams will be impacted by the deposition of the mobilized tailings flow. Bulkley Lake downstream of Dam No. 1 and Goosly Lake Downstream of Dam No. 2 are anticipated to act like settling ponds that would reduce the solids content and also attenuate the flow.

The approach to assess water quality was based on comparing the water quality following dam failure with a baseline condition where the dam does not fail. This incremental effect would be the basis for investigating the consequence of dam failure on water quality. As dilution is a major factor that affects water quality, the flow conditions for flood-induced and sunny-day failures should be considered separately.

In the case of the flood-induced failure, the water quality in the creeks downstream of Dam No. 1 and Dam No. 2 are expected to deteriorate due to high flows and sediment transport, even in the absence of a dam failure. The creeks downstream of these dams would experience large amounts of sediment. The peak flows that these creeks would carry are included in **Table 6.10** and **Table 6.11** for Dam No. 1 and Dam No. 2, respectively. The flow at Bulkley Lake (downstream of Dam No. 1) without dam failure is estimated to be 535 m^3/s. In the case of a dam breach during a flood, the flow is estimated to increase to 1,071 m^3/s. This increase of 536 m^3/s is equivalent to 50 %, thus the effect on water quality at Bulkley Lake due to a Dam No. 1 breach during the PMF would likely be significant. The reach of Foxy Creek immediately downstream of Dam No. 1 is likely to experience the worst impact on water quality.

The flow at Goosly Lake (downstream of Dam No. 2) without dam failure is estimated to be 58 m^3/s. In the case of a dam breach during a flood, the flow is estimated to increase to 271 m^3/s. This increase of 213 m^3/s is equivalent to 79 % hence the effect on water quality at Goosly Lake due to a Dam No. 2 breach during the PMF would likely be significant. The reach of Bessemer Creek immediately downstream from Dam No. 2 to Goosly Lake is likely to experience the worst impact on water quality.

The conditions of the dam failure due to sunny-day failure are different from the flood-induced failure conditions. Although the released flows during the sunny-day failure are lower than the flood-induced flows, the incremental effects on the flow, depth and water quality are interpreted to be higher. In addition, the baseline flows, which are assumed to be the mean monthly and annual flows, are much lower than the resulting dam breach outflows.

In the case of a sunny-day failure, noticeable incremental changes in the flows and water quality could be observed between Dam No. 1 and Bulkley Lake. The mean annual flow at Bulkley Lake without dam failure is estimated to be 5 m^3/s. In case of a sunny-day breach of Dam No. 1, the flow is estimated to increase to 290 m^3/s. This increase of 285 m^3/s is equivalent to 99 %. Hence, the effect on water quality at Bulkley Lake due to sunny-day dam breach of Dam No. 1 would be significant.

In the case of a sunny-day failure, noticeable incremental changes in the flows and water quality could be observed between Dam No. 2 and Goosly Lake. The mean annual flow at Goosly Lake without dam failure is estimated to be 1 m^3/s. In case of a sunny-day breach of Dam No. 2, the flow is estimated to increase to 81 m^3/s. This increase of 80 m^3/s is equivalent to 99 %. Hence, the effect on water quality at Goosly Lake due to sunny-day dam breach of Dam No. 2 would be significant. Depending on the time of the breach, the period the creeks downstream of Dam No. 1 and Dam No. 2 would be affected after a sunny-day breach of these dams may extend until the creeks are flushed during freshet.

A sunny-day failure was assessed for the ARD Collection Ponds (No. 1 Sump, Main ARD Pond and ARD Surge Pond), ARD Storage Pond South Dike and the Bessemer Creek Silt Check Dam. This would be the worst case scenario for ARD impact to Bessemer Creek, Buck Creek and Goosly Lake as there would be limited to little dilution available in the creeks. As can be seen from **Table 6.16** to **Table 6.21** and in **DWG07**, the potential area for ARD contamination due to the sunny-day failure of these dams would be measurable and would reach Goosly Lake.

Once the ARD contamination from a failure of these dams reaches Goosly Lake, the lake would act as a sink for sediment, metals and pH.

A potential failure of the Diversion Dam would likely impact Foxy Creek. However, the Treated Water and the ARD Overflow Storage Ponds would provide some storage and attenuation for the water and tailings expected from a breach of the tailings impoundment. Therefore, at this time a hypothetical breach of Dam No.1 and Dam No.2 are considered to represent the more critical water quality scenarios for a breach of the tailings impoundment.

6.5 Assessment of Significant Structures and Crossings

Dam No. 1 is located upstream of Foxy Creek. Foxy Creek discharges into Maxan Creek which discharges into Bulkley Lake and ultimately discharges into the Bulkley River which represents a major fisheries resource for the region. Beyond the No. 1 Seepage Pond Dam, no significant structures have been identified along Foxy until the forestry bridge on Maxan Creek. At the outlet of Bulkley Lake there is a bridge crossing for CN Rail, several farms with houses and other buildings.

Failure of Dam No. 1, would overwhelm and washout the No. 1 Seepage Pond Dam. **DWG02** shows that forestry bridge on Maxan Creek will be overwhelmed and washed out by sunny-day and flood-induced failures of Dam No. 1. Despite potential attenuation in Bulkley Lake, **DWG02** shows that the bridge crossing for CN Rail downstream of the lake might be overwhelmed and washed out by sunny-day and flood-induced failures of Dam No. 1. In addition, the majority of the houses and other buildings on the farms downstream of Bulkley Lake will be within the floodplain of both the sunny-day and flood-induced failures of Dam No. 1. No detailed topography was available in the area of Bulkley Lake and therefore it was difficult to ascertain if the potential flood waves from the failure of Dam No. 1 would enter Bulkley Lake or actually bypass it. Without attenuation in Bulkley Lake the potential impacts downstream of Bulkley Lake from the sunny-day and flood-induced failures would be greater.

Dam No. 2 is located upstream of Bessemer Creek. Bessemer Creek discharges into Buck Creek which discharges into Goosly Lake and ultimately discharges into the Bulkley River at Houston, BC. There are several significant structures downstream of Dam No. 2 including the site water treatment facilities, power substation, power lines and ARD pump houses and ARD Collection Ponds. There is a small cabin located just downstream of the Bessemer Creek Silt Check Dam. Downstream of Goosly Lake there is a forestry bridge crossing at Buck Creek Upper Falls. Downstream of the falls there are a few residences and farms along Buck Creek and ultimately the Town of Houston, BC.

DWG05 shows that both a sunny-day and flood-induced failure of Dam No. 2 would inundate and washout the ARD Collection Ponds and the Bessemer Creek Silt Check Dam. The water treatment plant would not be within the floodplains of either of these failure scenarios. However, the substation (including some of the power lines) and ARD pump houses will also be in the floodplains of sunny-day and flood-induced failure of Dam No. 2. Both of these failures would also place the cabin just downstream of the Bessemer Creek Silt Check Dam in the floodplain. **DWG05** shows that Goosly Lake will likely provide attenuation of both a sunny-day and flood-induced failures. However, both failure modes might overwhelm and washout the forestry bridge crossing at Buck Creek Upper Falls as well as impact the residences downstream of the falls. For a flood-induced failure of Dam No. 2, the peak outflows expected upstream of Houston, BC are larger than the 1 in 1000 year peak flood flows that this same system could naturally expect. However, for a sunny-day failure of Dam No. 2, the peak outflows expected upstream of Houston, BC will be close to a 1 in 10 year peak flood that this area could naturally expect. The incremental flooding effects of a sunny-day failure of Dam No. 2 upstream of Houston, BC are expected to be less than the flows associated with a 10 year return period rainstorm event.

The ARD Storage Pond South Dike, Bessemer Creek Silt Check Dam, and ARD Collection Pond Dams are located adjacent to or along Bessemer Creek downstream of Dam No. 2. The Bessemer Creek Silt Check Dam is located approximately 1 km upstream of the confluence with Buck Creek. The ARD Storage Pond South Dike and ARD Collection Pond Dams are located downstream of the junction between Dam No. 2 and the Diversion Dam. A failure of the ARD Storage Pond South Dike, Bessemer Creek Silt Check Dam and ARD Collection Pond Dams would impact Bessemer Creek. As with the hypothetical breach of Dam No.2 the same significant structures exist downstream of these structures. **DWG08** shows that a sunny-day failure of these dams would inundate and washout the Bessemer Creek Silt Check Dam. A sunny-day failure would also place the cabin just downstream of the Bessemer Creek Silt Check Dam in the floodplain as would a failure of this dam in conjunction with a cascade failure of the ARD Collection Pond Dams.

7.0 DAM CLASSIFICATION

7.1 2007 CDA Guidelines

Dam classification sets the stage for surveillance and emergency planning. A summary of the 2007 CDA Guidelines regarding dam classification is presented in **Table 7.1**. A dam structure can be classified as one of the five consequence categories shown in **Table 7.1**. The following definitions and concepts are used for the dam classification:

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: 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 loss of life. 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.

Table 7.1: 2007 CDA Dam Classification Guidelines

Dam Class	PAR	Incremental Losses		
		Loss of Life	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 (e.g., 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 (e.g., hospital, major industrial complex, major storage facilities for dangerous substances)

***Note 1**: Definition for population at risk:*
***None** – There is no identifiable population at risk, 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 (e.g., seasonal cottage use, passing through on transportation routes, participating in recreational activities). **Permanent** – The population at risk is ordinarily located in the dam-breach inundation zone (e.g., as permanent residents); three consequence classes (high, very high, extreme) are proposed to allow for more detailed estimates of potential loss of life (to assist in decision-making if the appropriate analysis is carried out).*
***Note 2**: Implications for loss of life:*
***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.*

7.2 Consequence Classification for Equity Silver Mine Dams

Re-evaluation of the consequence classification of the following eight dams at the Equity Silver Mine has been undertaken according to the 2007 CDA Guidelines:

- Tailings Pond Dam No. 1 (Dam No. 1);
- Tailings Pond Dam No. 2 (Dam No. 2);
- Tailings Pond Diversion Dam (Diversion Dam);
- ARD Storage Pond South Dike;
- Bessemer Creek Silt Check Dam; and
- ARD Collection Pond Dams (No. 1 Sump, Main ARD Pond and ARD Surge Pond).

Based on the evaluation outlined below, consequence classifications of “Significant” to “Very High” have been determined. These classifications are the same as the consequence classification presented in **Table 2.2** in **Section 2.0**, except for those for the Main ARD Pond and ARD Surge Pond which have been increased to “High”. Comments for each consequence category are discussed below and summarized in **Table 7.2**.

7.3 Closure Implications

The Equity Silver Mine dam classifications outlined above have been prepared for the current operational conditions of the dams and mine site. Closure of the mine, changes in water quality, roads and the downstream water use may have implications on the classification of these dams.

Table 7.2: Consequence Classification of Equity Silver Mine Dams (CDA 2007)

Dam	Population at Risk	Incremental Losses			Classification (Consequence Category – CDA 2007)	Effects on Goldcorp
		Loss of Life	Environmental and Cultural Values	Infrastructure and Economics		
Dam No. 1	**Failure Effect:** Water mixed with tailings would be running into Foxy Creek. The flood wave would travel further to Bulkley Lake and down the Bulkley River. The incremental effects from the sunny day failure are higher than the flood failure. Failure of the Dam No. 1 would also cause failure of the No. 1 Dam Seepage Pond which would add any contained ARD to the flood wave down Foxy Creek with contamination expected to Bulkley Lake affecting local drinking water supplies. In addition, the following infrastructure could be damaged: gravel roads and bridges used for logging along Foxy Creek, the CN Rail crossing on the Bulkley Lake outlet and the low lying residences on the west side of Bulkley Lake.					
	Permanent	10 or fewer **High**	Significant loss or deterioration of critical fish habitat would be expected. Restoration or compensation in kind is possible but impractical. **Very High**	High economic losses affecting infrastructure, public transportation, and commercial facilities. **High**	**VERY HIGH**	Regulatory fines. Extensive environmental cleanup and repair costs associated with the breach. Also, reputation would be severely affected.
Dam No. 2	**Failure Effect:** Water mixed with tailings would be running into Bessemer Creek. The flood wave would travel further to Goosly Lake and down Buck Creek to the Town of Houston, BC. The incremental effects from the sunny day failure are higher than the flood failure. Failure of the Dam No. 2 would also cause failure of the ARD Collection Ponds and the Bessemer Creek Silt Check Dam which would add any contained ARD and sediments to the flood wave down Bessemer Creek with contamination expected to Goosly Lake affecting local drinking water supplies. ARD containment would be lost until the facilities can be restored. In addition, the following infrastructure could be damaged: site treatment facilities, pumphouses and pipelines, power lines and substation, gravel roads and bridges used for logging along Bessemer/Buck Creek, the cabin below Bessemer Creek Silt Check and the residences on Buck Creek below the upper falls.					
	Permanent	10 or fewer **High**	Significant loss or deterioration of critical fish habitat would be expected. Restoration or compensation in kind is possible but impractical. **Very High**	High economic losses affecting infrastructure, public transportation, and commercial facilities. **High**	**VERY HIGH**	Regulatory fines. Extensive environmental cleanup and repair costs associated with the breach. Also, reputation would be severely affected.
Diversion Dam	**Failure Effect:** Failure of Diversion dam would mimic that of Dam No. 1 with water mixed with tailings running into Foxy Creek. However the effects would be slightly muted by the attenuation of the flood wave within the Treated Water Pond and Emergency Pond prior to discharging into Foxy Creek. In addition, the following infrastructure could be damaged: sludge and treatment ponds, site access road and power lines.					
	Permanent	10 or fewer **High**	Significant loss or deterioration of critical fish habitat would be expected. Restoration or compensation in kind is possible but impractical. **Very High**	High economic losses affecting infrastructure, public transportation, and commercial facilities. **High**	**VERY HIGH**	Regulatory fines. Extensive environmental cleanup and repair costs associated with the breach. Also, reputation would be severely affected.

Dam	Population at Risk	Incremental Losses			Classification (Consequence Category – CDA 2007)	Effects on Goldcorp
		Loss of Life	Environmental and Cultural Values	Infrastructure and Economics		
No. 1 Sump	**Failure Effect:** Failure of the No. 1 Sump would release a limited amount of ARD contaminated water into Bessemer Creek.					
	Temporary Only	Unspecified **Significant**	No significant loss or deterioration of fish or wildlife habitat. Loss of marginal habitat only. Restoration or compensation in kind highly possible. **Significant**	Losses to recreational facilities, seasonal workplaces, and infrequently used transportation routes **Significant**	**SIGNIFICANT**	Regulatory fines. Reputation would be negatively affected.
Main ARD Pond	**Failure Effect:** Failure of the Main ARD Pond Dam would overwhelm and breach the No. 1 Sump releasing ARD contaminated water into Bessemer Creek potentially overtopping and breaching the Bessemer Creek Silt Check Dam adding the accumulated sediment within the Silt Check to the flood wave. Contaminated water would be expected to Goosly Lake affecting habitat and local drinking water supplies. ARD containment would be lost until the facilities can be restored. The Cabin below the silt check would be inundated and potentially destroyed.					
	Temporary Only	Unspecified **Significant**	Significant loss or deterioration of important fish habitat would be expected. Restoration or compensation in kind is highly possible. **High**	Losses to recreational facilities, seasonal workplaces, and infrequently used transportation routes **Significant**	**HIGH**	Regulatory fines. Moderate environmental cleanup and repair costs associated with the breach. Also, reputation would be severely affected.
ARD Surge Pond	**Failure Effect:** Failure of the ARD Surge Pond Dam would overwhelm and breach the Main ARD Pond Dam and No. 1 Sump releasing ARD contaminated water into Bessemer Creek potentially overtopping and breaching the Bessemer Creek Silt Check Dam adding the accumulated sediment within the Silt Check to the flood wave. Contaminated water would be expected to Goosly Lake affecting habitat and local drinking water supplies. ARD containment would be lost until the facilities can be restored. The Cabin below the silt check would be inundated and potentially destroyed.					
	Temporary Only	Unspecified **Significant**	Significant loss or deterioration of important fish habitat would be expected. Restoration or compensation in kind is highly possible. **High**	Losses to recreational facilities, seasonal workplaces, and infrequently used transportation routes **Significant**	**HIGH**	Regulatory fines. Moderate environmental cleanup and repair costs associated with the breach. Also, reputation would be severely affected.

<table>
<tr><th rowspan="2">Dam</th><th rowspan="2">Population at Risk</th><th colspan="3">Incremental Losses</th><th rowspan="2">Classification (Consequence Category – CDA 2007)</th><th rowspan="2">Effects on Goldcorp</th></tr>
<tr><th>Loss of Life</th><th>Environmental and Cultural Values</th><th>Infrastructure and Economics</th></tr>
<tr><td rowspan="2">ARD Storage Pond</td><td colspan="6">Failure Effect: Failure of the ARD Storage Pond would release ARD contaminated water into Bessemer Creek. ARD containment would be lost until the facilities can be restored.</td></tr>
<tr><td>Temporary Only</td><td>Unspecified

Significant</td><td>Significant loss or deterioration of important fish habitat would be expected.

Restoration or compensation in kind is highly possible.

High</td><td>Losses to recreational facilities, seasonal workplaces, and infrequently used transportation routes

Significant</td><td>HIGH</td><td>Regulatory fines.

Moderate environmental cleanup and repair costs associated with the breach.

Also, reputation would be severely affected.</td></tr>
<tr><td rowspan="2">Bessemer Creek Silt Check</td><td colspan="6">Failure Effect: Failure of Bessemer Creek Silt Check Dam Diversion dam would release a mixture of impounded sediments and water into Bessemer Creek. Turbid water would be expected to Goosly Lake affecting habitat. The Cabin below the silt check would be inundated and potentially destroyed.</td></tr>
<tr><td>Temporary Only</td><td>Unspecified

Significant</td><td>Significant loss or deterioration of important fish habitat would be expected.

Restoration or compensation in kind is highly possible.

High</td><td>Losses to recreational facilities, seasonal workplaces, and infrequently used transportation routes

Significant</td><td>HIGH</td><td>Regulatory fines.

Moderate environmental cleanup and repair costs associated with the breach.

Also, reputation would be severely affected.</td></tr>
</table>

8.0 EMERGENCY PREPAREDNESS PLAN (EPP)

The dam break and inundation assessments completed for Equity Silver Mine are intended to support the development of an EPP. The EPP should be prepared in accordance with the specifications provided in the 2007 CDA Dam Safety Guidelines.

An EPP and OMS manual were produced as part of an overall site risk assessment in December 2004 following the high flow events of 2002. The EPP and OMS manual have been revised over the past several years and are currently being revised to reflect the results of this study as per the 2014 Ministerial orders.

9.0 CONCLUSIONS AND RECOMMEDATIONS

AMEC performed dam break and inundation assessments for the following eight dams at the Equity Silver Mine:

- Tailings Pond Dam No. 1 (Dam No. 1);
- Tailings Pond Dam No. 2 (Dam No. 2);
- Tailings Pond Diversion Dam (Diversion Dam);
- ARD Storage Pond South Dike;
- Bessemer Creek Silt Check Dam; and
- ARD Collection Pond Dams (No. 1 Sump, Main ARD Pond and ARD Surge Pond).

Detailed hydraulic modelling (using HEC-RAS) was developed to simulate the breaches of Dam No. 1 and Dam No. 2 for both sunny-day and flood-induced failures. The results of these models included peak flow, maximum depth, peak velocity and peak wave travel time and are presented in **DWG02** and **DWG05**.

Beyond, the No. 1 Seepage Pond Dam, no significant structures have been identified along Foxy Creek downstream of Dam No. 1 until the forestry bridge on Maxan Creek. At the outlet of Bulkley Lake there is a bridge crossing for CN Rail and several farms with houses and other buildings. Failure of Dam No. 1 would overwhelm and washout the No. 1 Seepage Pond Dam. **DWG02** shows that the forestry bridge on Maxan Creek may be overwhelmed and washed out by sunny-day and flood-induced failures of Dam No. 1. Despite potential attenuation in Bulkley Lake, **DWG02** shows that the bridge crossing for CN Rail downstream of the lake may be overwhelmed and washed out by sunny-day and flood-induced failures of Dam No. 1. In addition, the majority of the houses and other buildings on the farms downstream of Bulkley Lake will be within the floodplain of both the sunny-day and flood-induced failures of Dam No. 1. However, some of the flow may bypass the flat area leading to Bulkley Lake and head directly to the area downstream of the lake outlet resulting in lower flood attenuation and higher flows.

There are several significant structures downstream of Dam No. 2 including the site water treatment facilities, power substation, power lines and ARD pump houses and ARD Collection

Ponds. There is also a small cabin located just downstream of the Bessemer Creek Silt Check Dam. Downstream of Goosly Lake there is a forestry bridge crossing at Buck Creek Upper Falls, and ultimately the Town of Houston, BC. **DWG05** shows that both a sunny-day and flood-induced failure of Dam No. 2 would inundate and washout the ARD Collection Ponds and the Bessemer Creek Silt Check Dam. The water treatment plant would not be within the floodplains of either of these failure scenarios. However, the substation (including some of the power lines) and ARD pump houses will also be in the floodplains of sunny-day and flood-induced failure of Dam No. 2. Both of these failures would also place the cabin just downstream of the Bessemer Creek Silt Check Dam in the floodplain. **DWG05** shows that Goosly Lake will likely provide attenuation of both a sunny-day and a flood-induced failure. However, both failure modes may overwhelm and washout the forestry bridge crossing at Buck Creek Upper Falls as well as impact the residences downstream of the falls. The incremental flooding effects of a sunny-day failure of Dam No. 2 upstream of Houston, BC are expected to be less than the flows associated with a 10 year return period rainstorm event.

In the case of the flood-induced failure mode, the water quality in the creeks downstream of Dam No. 1 and Dam No. 2 is expected to deteriorate, even in the absence of a dam failure. The creeks downstream of these dams would experience large amounts of sediment. Based on this study it is expected that the impacts on the water quality of Bulkley Lake and Goosly Lake downstream due to the failure of Dam No. 1 and Dam No. 2, respectively will be significant. The reaches of Foxy Creek and Bessemer Creek immediately downstream of Dam No. 1 and Dam No. 2, respectively are likely to experience the worst impact on water quality. Depending on the time of the breach, the period the creeks downstream of Dam No. 1 and Dam No. 2 would be affected after a sunny-day breach of these dams may extend until the creeks are flushed during freshet. The impact on water quality may extend due to the loss of ARD containment facilities until the system is restored.

A desktop review of the existing site topography was carried out to determine the most likely potential path of a hypothetical dam break for the Diversion Dam. The flow path would join Dam No.1. However, the Treated Water and the Emergency ARD Pond would provide some storage and attenuation for the water and tailings expected from a breach of the tailings impoundment. Therefore, at this time a hypothetical breach of Dam No.1 and Dam No.2 are considered to represent the more critical inundation limits and water quality scenarios for a breach of the tailings impoundment.

Due to their smaller size, simplified and conservative dam break assessment methods were used to simulate the breaches of the ARD Collection Pond Dams, ARD Storage Pond South Dike and Bessemer Creek Silt Check Dam. Estimated flood wave geometries (water depth, flow and velocity) along typical creek sections downstream of the structures are presented in **DWG08**. As with the hypothetical breach of Dam No.2 the same significant structures exist downstream of the ARD Storage Pond South Dike, Bessemer Creek Silt Check Dam, and ARD Collection Pond Dams. **DWG08** shows that a sunny-day failure of these dams would inundate and washout the Bessemer Creek Silt Check Dam. A sunny-day failure would also place the cabin just downstream of the Bessemer Creek Silt Check Dam in the floodplain as would a failure of this dam in conjunction with a cascade failure of the ARD Collection Pond Dams. A sunny-day failure was assessed for these structures as this would be the worst case scenario for ARD impact to Bessemer Creek, Buck Creek and Goosly Lake as there would be limited to little dilution available in the creeks. The potential area for ARD contamination due to the sunny-day failure of these dams would be measurable and would reach Goosly Lake. Once the ARD contamination from a failure of these dams reaches Goosly Lake, the lake would act as a sink for sediment, metals and pH.

Dam classification sets the stage for surveillance and emergency planning. As part of this study, the consequence classification and design flood criteria from the 2010 DSR and subsequent hydraulic structures reviews were evaluated based on the findings of this study.
Based on this study, consequence classifications of “Significant” to “Very High” have been determined and are summarised in **Table 9.1**. These classifications are the same as the consequence classification determined from the 2010 DSR except for the ARD Surge Pond and the Main ARD Pond which have increased from “Significant” to “High”.

Table 9.1: Consequence Classifications for the Dams at the Equity Silver Mine Site within this Study

Dam	Consequence Classification
Tailings Pond Dam No. 1	Very High
Tailings Pond Dam No. 2	Very High
Tailings Pond Diversion Dam	Very High
ARD Storage Pond South Dike	High
ARD Surge Pond	High *
Main ARD Pond	High *
No. 1 Sump	Significant
Bessemer Creek Silt Check Dam	High

** Consequence classification has been increased from the 2010 DSR.*

The results of this dam break and inundation assessment are intended to support the development of an EPP. The EPP should be prepared in accordance with the specifications provided in the 2007 CDA Dam Safety Guidelines. An EPP and OMS manual were produced as part of an overall site risk assessment in December 2004 following the high flow events of 2002. The EPP and OMS manual have been revised over the past several years and are currently being revised to reflect the results of this study as per the 2014 Ministerial orders.

10.0 CLOSING REMARKS AND LIMITATIONS

The conclusions presented herein are based on a technical evaluation of the findings of the work noted. If conditions other than those reported are noted during subsequent phases of the project, AMEC should be notified and be given the opportunity to review and revise the current conclusions, if necessary.

This report has been prepared for the exclusive use of Goldcorp Canada Ltd. for specific application to the area within this report. Any use which a third party makes of this report, or any reliance on or decisions made based on it, are the responsibility of such third parties. AMEC accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report. It has been prepared in accordance with generally accepted water resources engineering practices. No other warranty, expressed or implied, is made.

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Respectfully submitted,

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REFERENCES

AMEC Environment & Infrastructure (AMEC 2014a). Addendum to the 2010 Hydrology Update and Hydraulic Structures Review, Equity Silver Mine (Revision 1). Letter dated 7 March 2014 (Original date 27 June 3013).

AMEC Environment & Infrastructure (AMEC 2014b). Equity Silver Mine Tailings Impoundment and Water Management Structures 2013 Annual Review. Report dated 28 February 2014.

AMEC Environment & Infrastructure (AMEC 2012). Equity Silver Mine Tailings Impoundment and Water Management Structures Operation, Maintenance and Surveillance Manual (Revision 2). Report dated 17 July 2012.

AMEC Earth & Environmental Ltd. (AMEC 2011a). Assessment of Bessemer Silt Check Spillway, Equity Silver Mine. Letter dated 17 August 2011.

AMEC Earth & Environmental Ltd. (AMEC 2011b). Hydrology Update and Hydraulic Structures Review, Equity Silver Mine. Letter dated 11 March 2011.

AMEC Earth & Environmental Ltd. (AMEC 2011c). Equity Silver Mine 2010 Dam Safety Review Report - Draft. Email 18 January 2011.

AMEC Earth & Environmental Ltd. (AMEC 2009). 2002 Equity Silver Mine Diversion Pond Splitter Dike As-Built Report. Report dated March 2009.

AMEC Earth & Environmental Ltd. (AMEC 2003). 2002 Construction Summary Report South Dyke, Dam Nos. 2 and 3, Equity Water Management Project 2002. Report dated 12 February 2003.

Azam, Shahid and Li, Qiren. (2010). "Tailings Dam Failures – A Review of the Past One Hundred Years.

BC Hydro (BCH 1984). "Modelling Procedures for Dam Breach Inundation Studies". Hydroelectric Generation Projects Division. April 1984.

BC Ministry of Environment Water Management Branch (1985). "Report on the Floodplain Mapping Study Bulkley River at Houston (Including Buck Creek)". November 1985.

Blight G.E. and Fourie. (2003). "A Review of Catastrophic Flow Failures of Deposits of Mine Waste and Municipal Release".

Canadian Dam Association (CDA 2007). Dam Safety Guidelines and Technical Bulletin: Hydrotechnical Considerations for Dam Safety.

Coulson, C.H. and Obedkoff (1998). “British Columbia Streamflow Inventory Report”. March 1998.

Dam Safety Office (DSO 1998). “Prediction of Embankment Dam Breach Parameters – A Literature Review and Needs Assessment”. July 1998.

Equity Silver Mine Ltd. (Equity 1991). Equity Silver Mine Decommissioning & Closure Plan. Report dated April 1991.

Froehlich, D. C. (2008). “Embankment Dam Breach Parameters and Their Uncertainties”. *Journal of Hydraulic Engineering* , Vol. 134, No. 12, Pages 1708-1721.

Froehlich, D. C. (1995). “Peak Outflow from Breached Embankment Dam”. *Journal of Water Resources Planning and Management*, Vol. 121, No. 1, Pages 90-97.

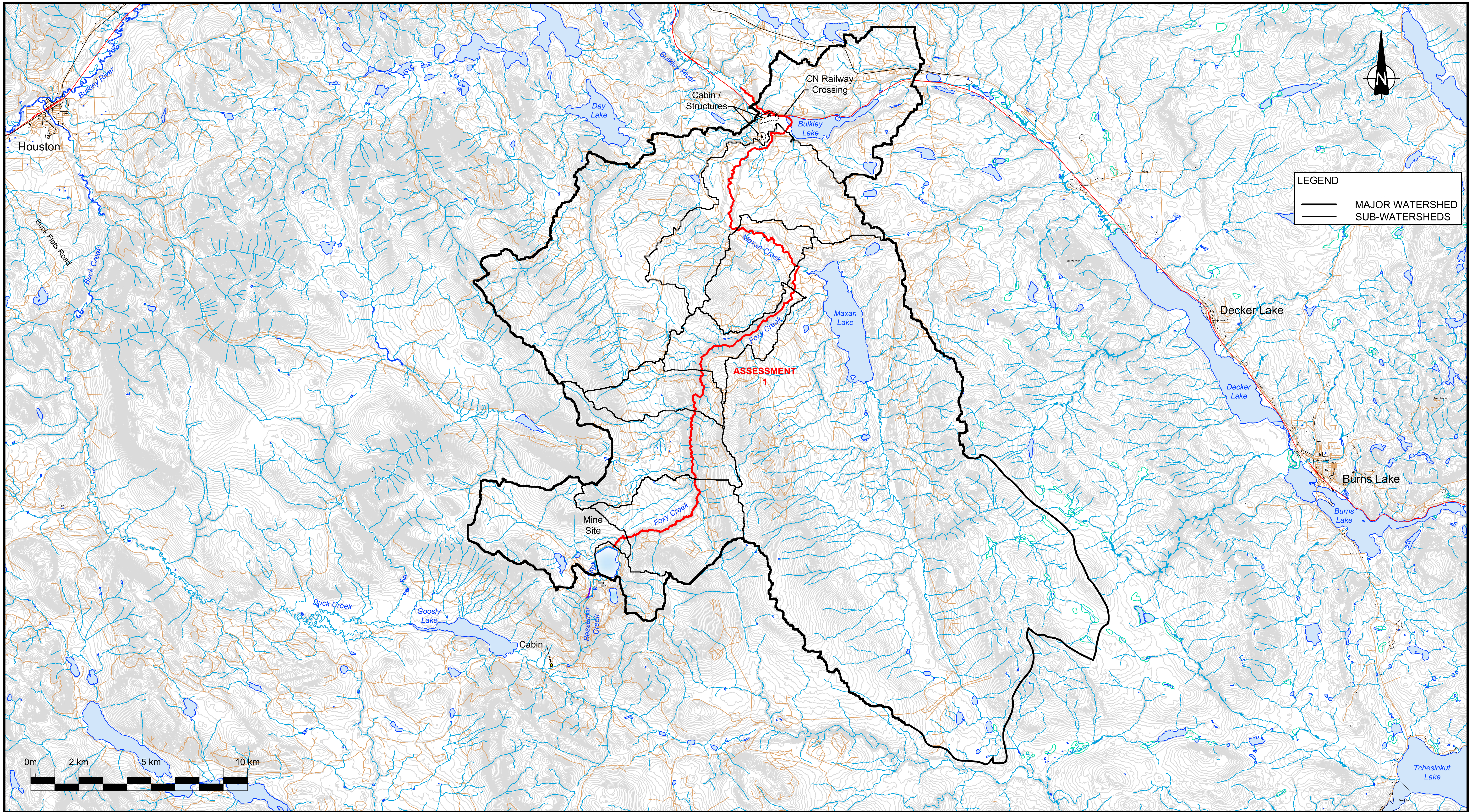
Harrington, Bruce W. (2014) “Hazard Classifications & Danger Reach Studies for Dams”. MD Department of the Environment, Dam Safety Division. Obtained from website 2014 http://www.mde.state.md.us/programs/Water/DamSafety/TechnicalReferences/Documents/www.mde.state.md.us/assets/document/damsafety/DambreakGuidelines/Documents/Hazard_Classification_Guidelines_Revised.pdf.

Hay & Company Consultants Inc. (Hay 1996). “Shallow Water Covers – Equity Silver Base Information on Physical Variables” (MEND Project 2.11.5ab). Report dated 26 April 1996.

Klohn-Crippen (KC 1996). Equity Silver Mine Tailings Storage Facility 1995 Annual Report. Report dated 25 March 1996.

BC Ministry of Energy and Mines (MEM 2013). Report of the Geotechnical Inspector – July 3, 2013, Equity Silver Mine.

DRAWINGS



NOTE:
THIS DRAWING SHOULD BE READ IN CONJUNCTION WITH THE AMEC ENVIRONMENT & INFRASTRUCTURE REPORT No. VM00276A.5.400 DATED NOVEMBER 2014.

DATA REFERENCES:
Base Planimetry - CANVEC, Natural Resources Canada (NRCAN), National Topographic Series: Mapsheets 93L01, 02, 07 and 08.
Roads - Digital Road Atlas (DRA), Province of British Columbia, GeoBC/DataBC, BC Geographic Warehouse

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CHK'D BY:	JW / AF
DATUM:	NAD 83
PROJECTION:	UTM Zone 9
SCALE:	AS SHOWN

PROJECT: EQUITY SILVER MINE DAM BREAK AND INUNDATION ASSESSMENTS

TITLE: HEC-HMS MODEL CATCHMENT AREA DAM No. 1 (ASSESSMENT 1)

DATE:	NOVEMBER 2014
PROJECT NO:	VA00276A.5.400
REV. NO:	B
DRAWING NO:	DWG01

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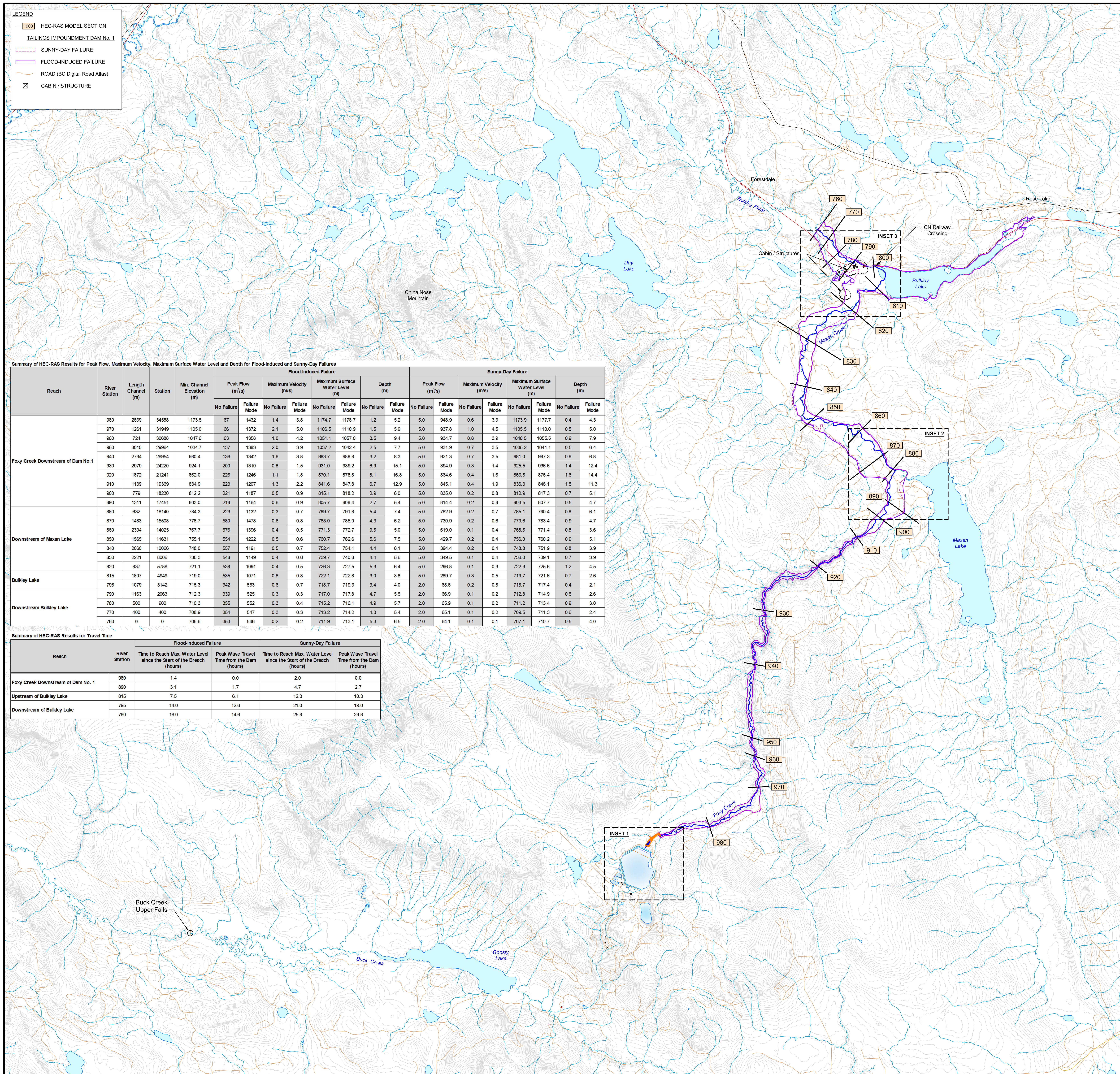

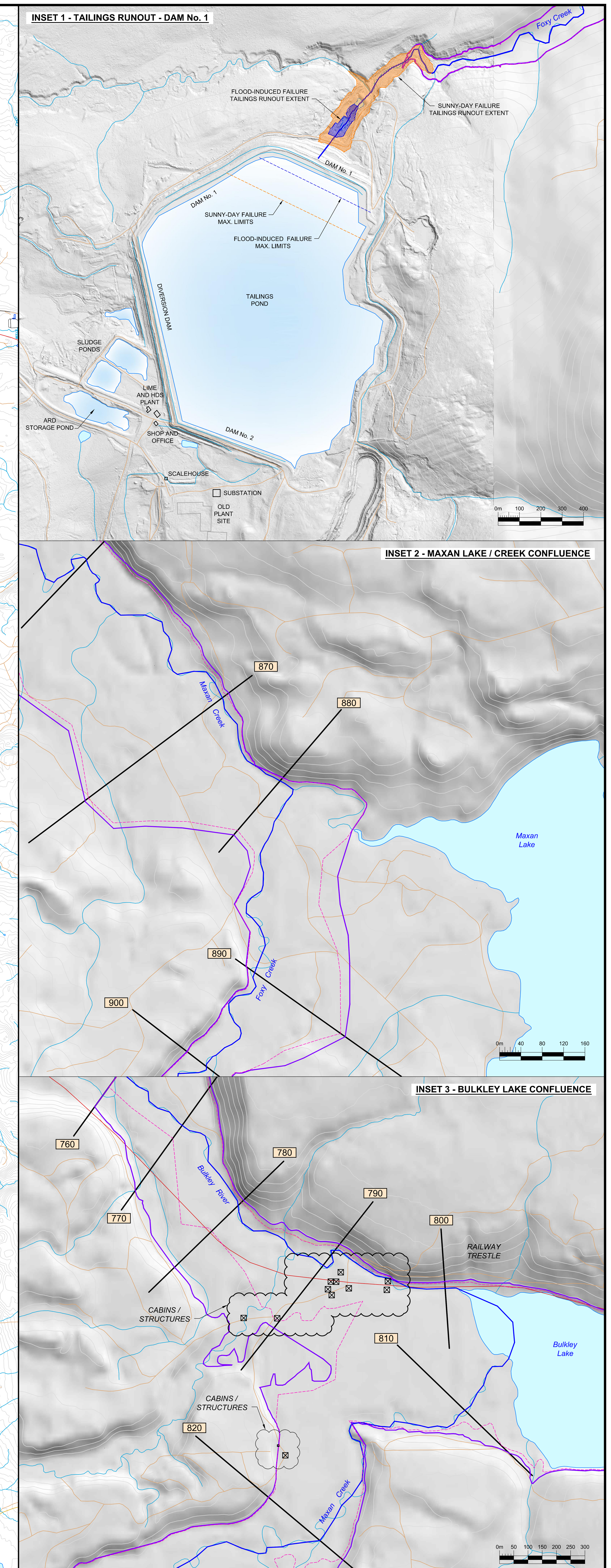

Summary of HEC-RAS Results for Peak Flow, Maximum Velocity, Maximum Surface Water Level and Depth for Flood-Induced and Sunny-Day Failures

Reach	River Station	Length Channel (m)	Station	Min. Channel Elevation (m)	Flood-Induced Failure: Peak Flow (m^3/s) – No Failure	Flood-Induced Failure: Peak Flow (m^3/s) – Failure Mode	Flood-Induced Failure: Maximum Velocity (m/s) – No Failure	Flood-Induced Failure: Maximum Velocity (m/s) – Failure Mode	Flood-Induced Failure: Maximum Surface Water Level (m) – No Failure	Flood-Induced Failure: Maximum Surface Water Level (m) – Failure Mode	Flood-Induced Failure: Depth (m) – No Failure	Flood-Induced Failure: Depth (m) – Failure Mode	Sunny-Day Failure: Peak Flow (m^3/s) – No Failure	Sunny-Day Failure: Peak Flow (m^3/s) – Failure Mode	Sunny-Day Failure: Maximum Velocity (m/s) – No Failure	Sunny-Day Failure: Maximum Velocity (m/s) – Failure Mode	Sunny-Day Failure: Maximum Surface Water Level (m) – No Failure	Sunny-Day Failure: Maximum Surface Water Level (m) – Failure Mode	Sunny-Day Failure: Depth (m) – No Failure	Sunny-Day Failure: Depth (m) – Failure Mode
Foxy Creek Downstream of Dam No.1	980	2639	34588	1173.5	67	1432	1.4	3.8	1174.7	1178.7	1.2	5.2	5.0	948.9	0.6	3.3	1173.9	1177.7	0.4	4.3
	970	1261	31949	1105.0	66	1372	2.1	5.0	1106.5	1110.9	1.5	5.9	5.0	937.8	1.0	4.5	1105.5	1110.0	0.5	5.0
	960	724	30688	1047.6	63	1358	1.0	4.2	1051.1	1057.0	3.5	9.4	5.0	934.7	0.8	3.9	1048.5	1055.5	0.9	7.9
	950	3010	29964	1034.7	137	1383	2.0	3.9	1037.2	1042.4	2.5	7.7	5.0	931.9	0.7	3.5	1035.2	1041.1	0.5	6.4
	940	2734	26954	980.4	136	1342	1.6	3.8	983.7	988.8	3.2	8.3	5.0	921.3	0.7	3.5	981.0	987.3	0.6	6.8
	930	2979	24220	924.1	200	1310	0.8	1.5	931.0	939.2	6.9	15.1	5.0	894.9	0.3	1.4	925.5	936.6	1.4	12.4
	920	1872	21241	862.0	226	1246	1.1	1.8	870.1	878.8	8.1	16.8	5.0	864.6	0.4	1.6	863.5	876.4	1.5	14.4
	910	1139	19369	834.9	223	1207	1.3	2.2	841.6	847.8	6.7	12.9	5.0	845.1	0.4	1.9	836.3	846.1	1.5	11.3
	900	779	18230	812.2	221	1187	0.5	0.9	815.1	818.2	2.9	6.0	5.0	835.0	0.2	0.8	812.9	817.3	0.7	5.1
	890	1311	17451	803.0	218	1164	0.6	0.9	805.7	808.4	2.7	5.4	5.0	814.4	0.2	0.8	803.5	807.7	0.5	4.7
Downstream of Maxan Lake	880	632	16140	784.3	223	1132	0.3	0.7	789.7	791.8	5.4	7.4	5.0	762.9	0.2	0.7	785.1	790.4	0.8	6.1
	870	1483	15508	778.7	580	1478	0.6	0.8	783.0	785.0	4.3	6.2	5.0	730.9	0.2	0.6	779.6	783.4	0.9	4.7
	860	2394	14025	767.7	576	1396	0.4	0.5	771.3	772.7	3.5	5.0	5.0	619.0	0.1	0.4	768.5	771.4	0.8	3.6
	850	1565	11631	755.1	554	1222	0.5	0.6	760.7	762.6	5.6	7.5	5.0	429.7	0.2	0.4	756.0	760.2	0.9	5.1
	840	2060	10066	748.0	557	1191	0.5	0.7	752.4	754.1	4.4	6.1	5.0	394.4	0.2	0.4	748.8	751.9	0.8	3.9
	830	2221	8006	735.3	548	1149	0.4	0.6	739.7	740.8	4.4	5.6	5.0	349.5	0.1	0.4	736.0	739.1	0.7	3.9
	820	837	5786	721.1	538	1091	0.4	0.5	726.3	727.5	5.3	6.4	5.0	296.8	0.1	0.3	722.3	725.6	1.2	4.5
Bulkley Lake	815	1807	4949	719.0	535	1071	0.6	0.8	722.1	722.8	3.0	3.8	5.0	289.7	0.3	0.5	719.7	721.6	0.7	2.6
	795	1079	3142	715.3	342	553	0.6	0.7	718.7	719.3	3.4	4.0	2.0	68.6	0.2	0.5	715.7	717.4	0.4	2.1
Downstream Bulkley Lake	790	1163	2063	712.3	339	525	0.3	0.3	717.0	717.8	4.7	5.5	2.0	66.9	0.1	0.2	712.8	714.9	0.5	2.6
	780	500	900	710.3	355	552	0.3	0.4	715.2	716.1	4.9	5.7	2.0	65.9	0.1	0.2	711.2	713.4	0.9	3.0
	770	400	400	708.9	354	547	0.3	0.3	713.2	714.2	4.3	5.4	2.0	65.1	0.1	0.2	709.5	711.3	0.6	2.4
	760	0	0	706.6	353	546	0.2	0.2	711.9	713.1	5.3	6.5	2.0	64.1	0.1	0.1	707.1	710.7	0.5	4.0

Summary of HEC-RAS Results for Travel Time

Reach	River Station	Flood-Induced Failure: Time to Reach Max. Water Level since the Start of the Breach (hours)	Flood-Induced Failure: Peak Wave Travel Time from the Dam (hours)	Sunny-Day Failure: Time to Reach Max. Water Level since the Start of the Breach (hours)	Sunny-Day Failure: Peak Wave Travel Time from the Dam (hours)
Foxy Creek Downstream of Dam No. 1	980	1.4	0.0	2.0	0.0
	890	3.1	1.7	4.7	2.7
Upstream of Bulkley Lake	815	7.5	6.1	12.3	10.3
Downstream of Bulkley Lake	795	14.0	12.6	21.0	19.0
	760	16.0	14.6	25.8	23.8

NOTES:

1. MODEL DESIGN SURFACES BASED ON A COMPOSITE OF THE LIDAR SURVEY 2008, AND NATIONAL CDED (CANADIAN DIGITAL ELEVATION DATA) MODEL, NATURAL RESOURCES CANADA.
2. THIS DRAWING SHOULD BE READ IN CONJUNCTION WITH THE AMEC ENVIRONMENT & INFRASTRUCTURE REPORT No. VM00276A.5.400 DATED NOVEMBER 2014.

REV	D	M	Y	ISSUE / REVISION DESCRIPTION	ENG.	APPR.
5						
4						
3						
2						
1						
B	21	11	14	ISSUED WITH FINAL REPORT	JW/AF	AW
A	14	11	14	ISSUED WITH DRAFT REPORT	JW/AF	AW

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DESIGNED BY: AF / DA
DRAWN BY: TH
CHECKED BY: AF
APPROVED BY: AW
SCALE: AS SHOWN

PROJECT: EQUITY SILVER MINE DAM BREAK AND INUNDATION ASSESSMENTS

TITLE: HEC-RAS MODEL FOR DAM No. 1 (ASSESSMENT 1)

PROJECT NO: VM00276A.5.400
REVISION NO: B
DATE: NOVEMBER 2014
DRAWING NO: DWG02

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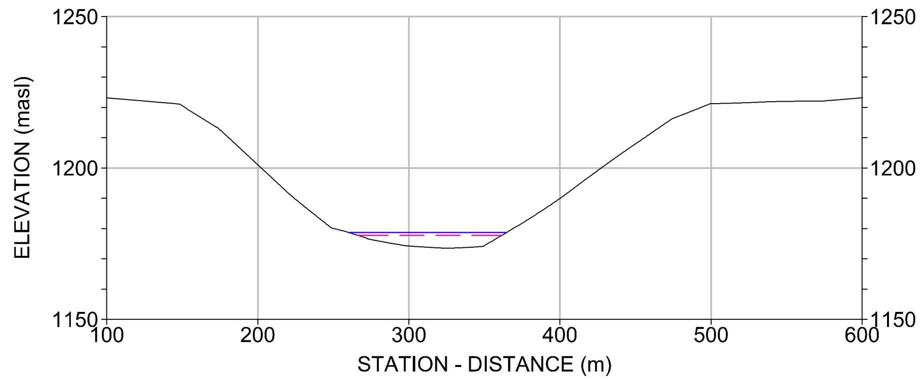

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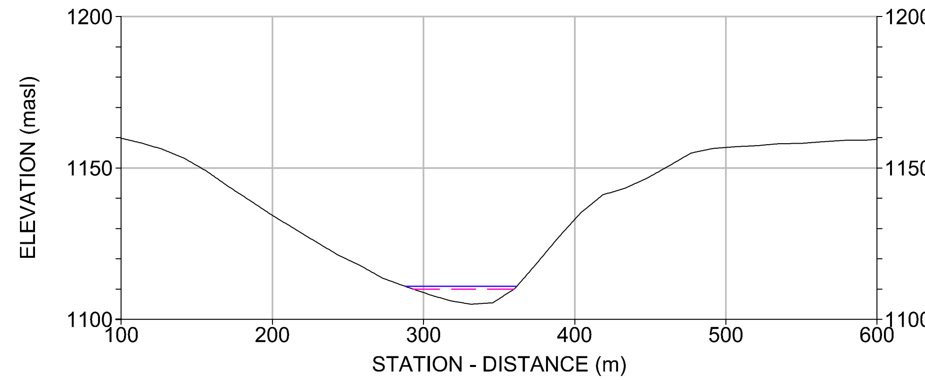

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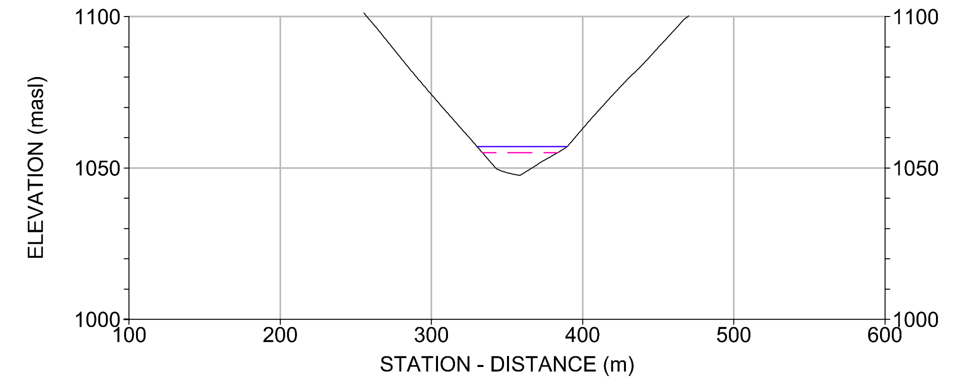

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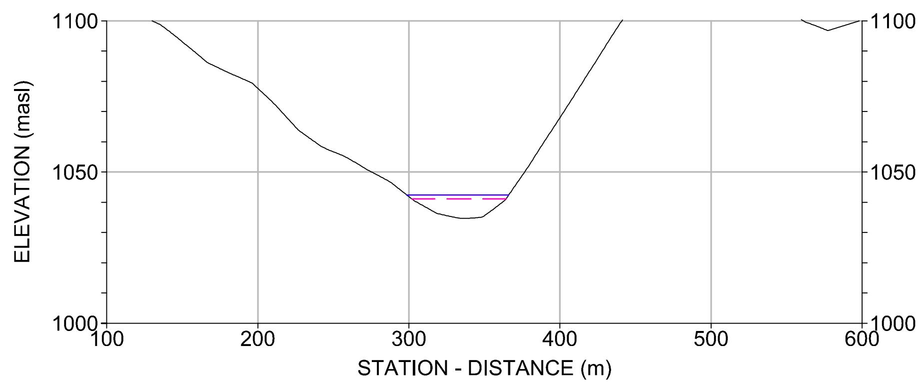

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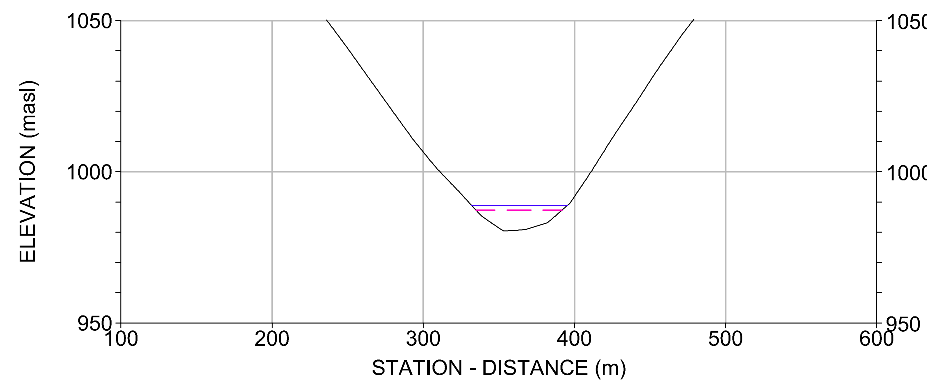

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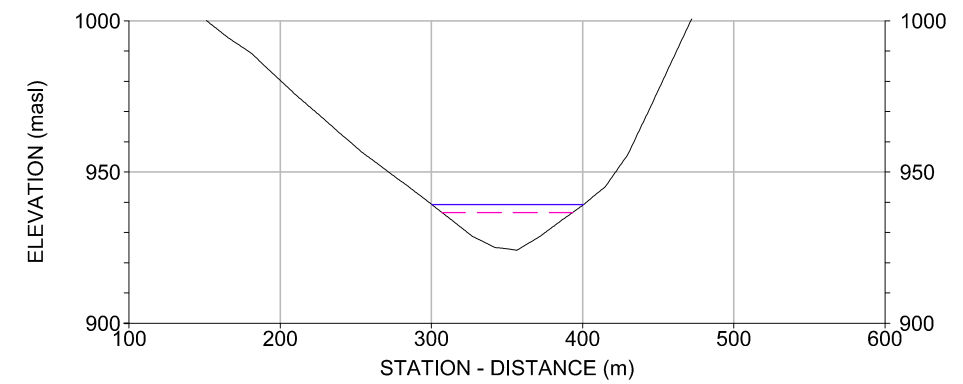

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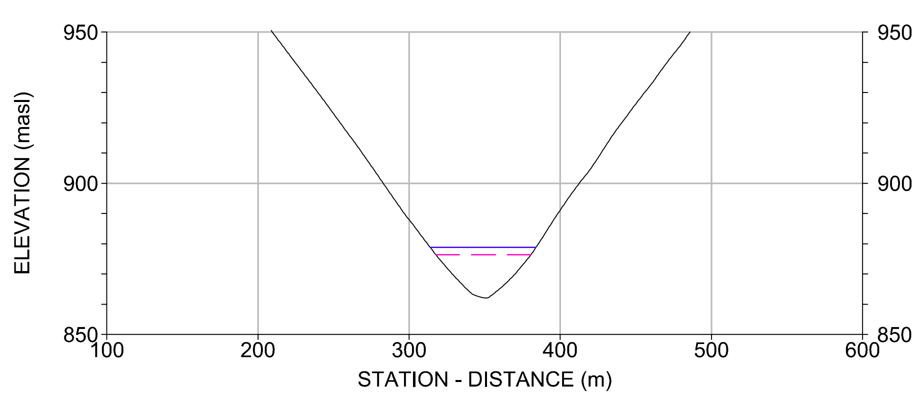

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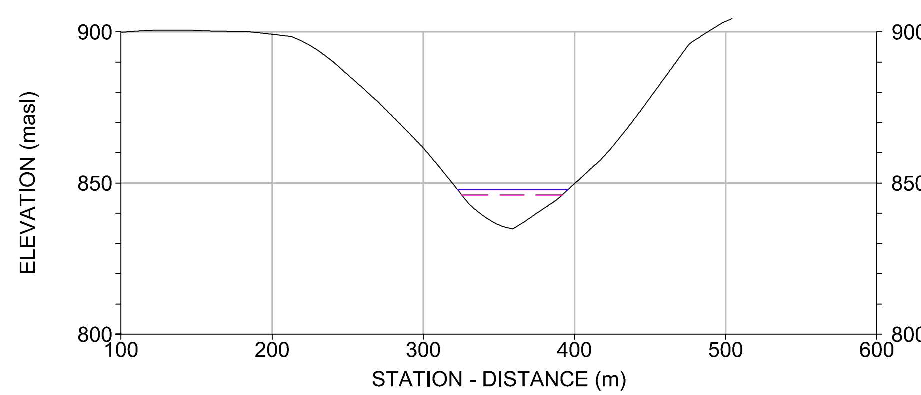

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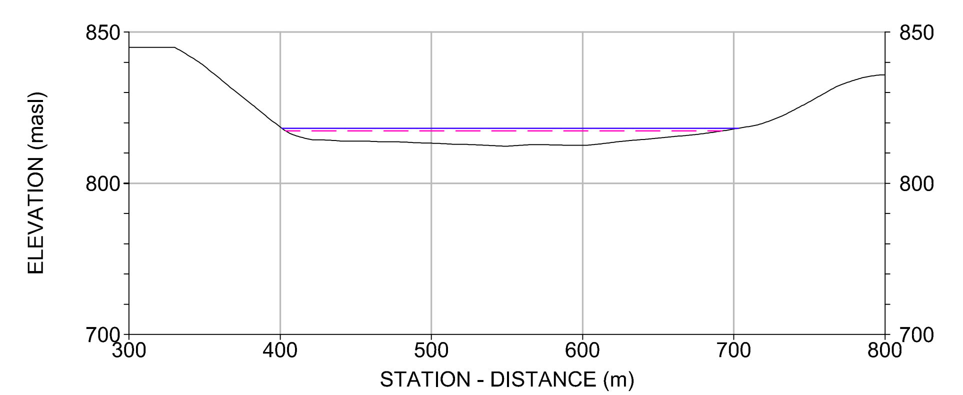

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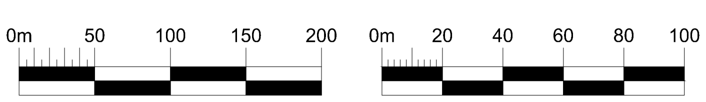
NOTE:
THIS DRAWING SHOULD BE READ IN CONJUNCTION WITH THE AMEC ENVIRONMENT & INFRASTRUCTURE REPORT No. VM00276A.5.400 DATED NOVEMBER 2014.



LEGEND:
DAM FAILURE MODEL
FLOOD-INDUCED
SUNNY-DAY

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DWN BY: TH	PROJECT: EQUITY SILVER MINE DAM BREAK AND INUNDATION ASSESSMENTS	DATE: NOVEMBER 2014
DESIGN BY: AF / DA		PROJECT NO: VM00276A.5.400
CHECK BY: AF	TITLE: HEC-RAS MODEL DAM No.1 (ASSESSMENT 1) CROSS SECTIONS - SHEET 1	REV. NO: B
APPR'D BY: AW		DRAWING NO:
SCALE: AS SHOWN		DWG03-1

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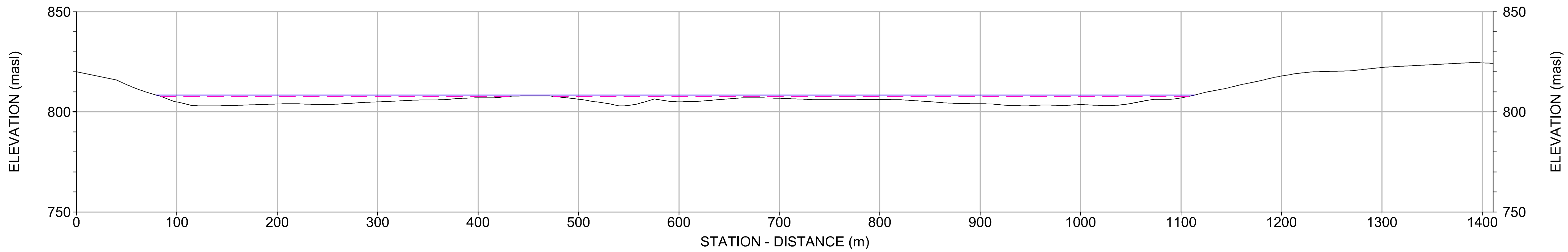

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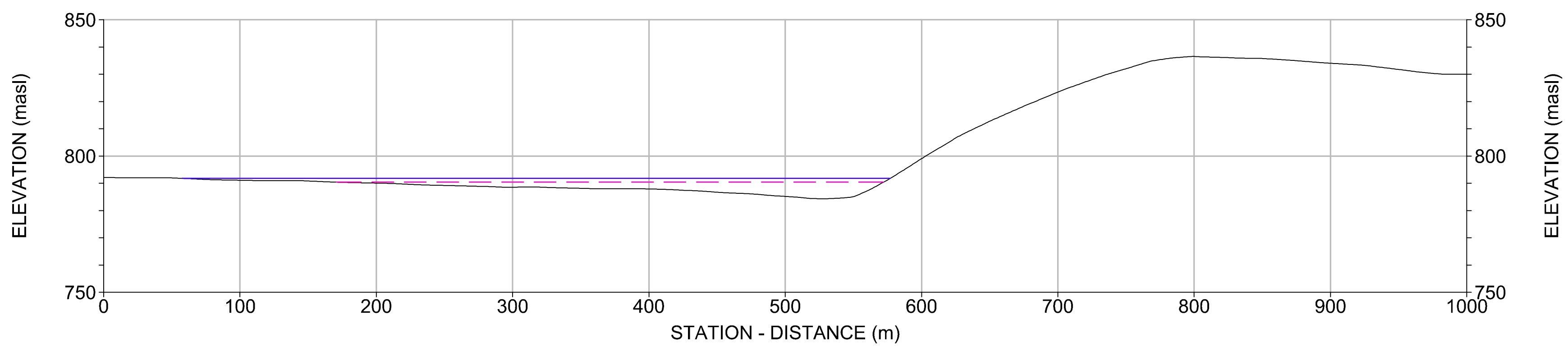

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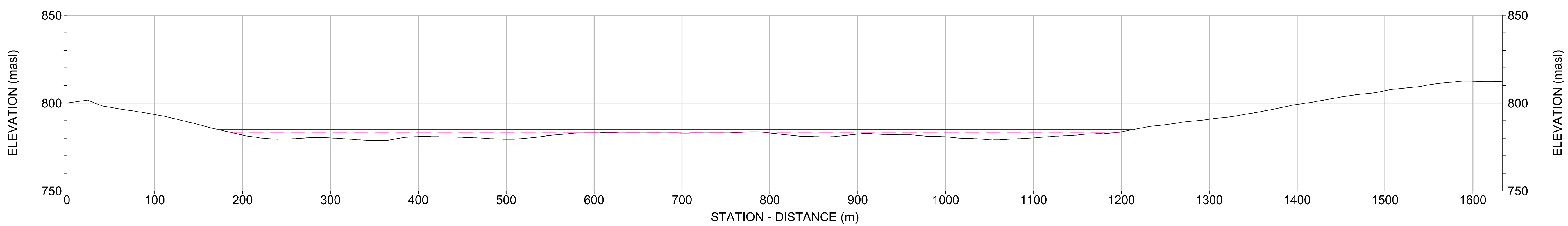

SECTION 870

NOTE:
THIS DRAWING SHOULD BE READ IN CONJUNCTION WITH THE AMEC ENVIRONMENT & INFRASTRUCTURE REPORT No. VM00276A.5.400 DATED NOVEMBER 2014.

Horizontal: 0m 50 100 150 200

Vertical: 0m 20 40 60 80 100

LEGEND:
DAM FAILURE MODEL
FLOOD-INDUCED
SUNNY-DAY

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DWN BY:	TH
DESIGN BY:	AF / DA
CHECK BY:	AF
APPR'D BY:	AW
SCALE:	AS SHOWN

PROJECT:
EQUITY SILVER MINE
DAM BREAK AND INUNDATION ASSESSMENTS

TITLE:
HEC-RAS MODEL DAM No.1 (ASSESSMENT 1)
CROSS SECTIONS - SHEET 2

DATE:	NOVEMBER 2014
PROJECT NO:	VM00276A.5.400
REV. NO:	B
DRAWING NO:	DWG03-2

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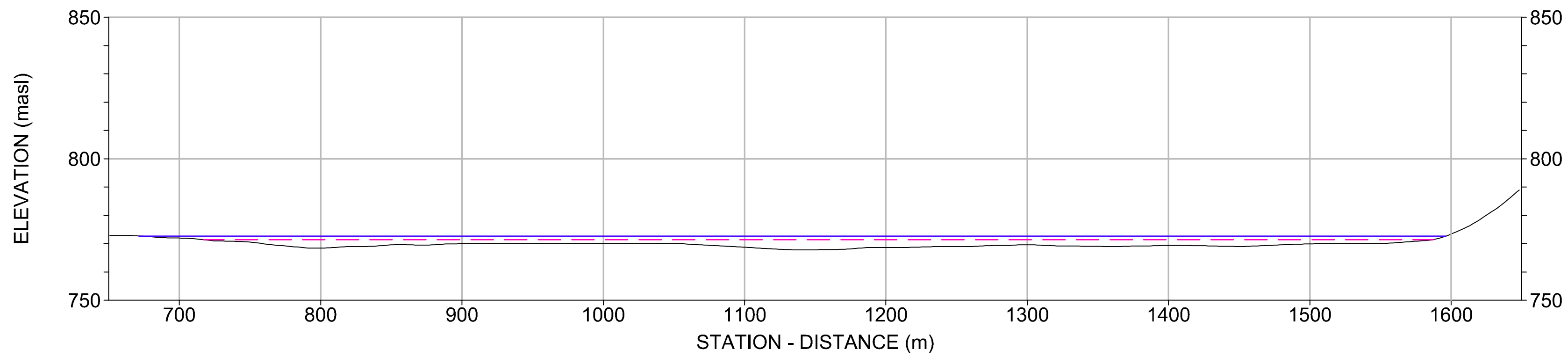

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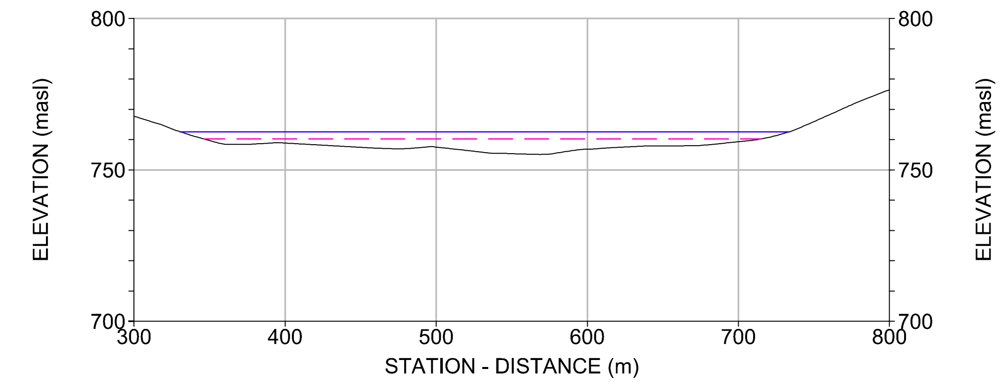

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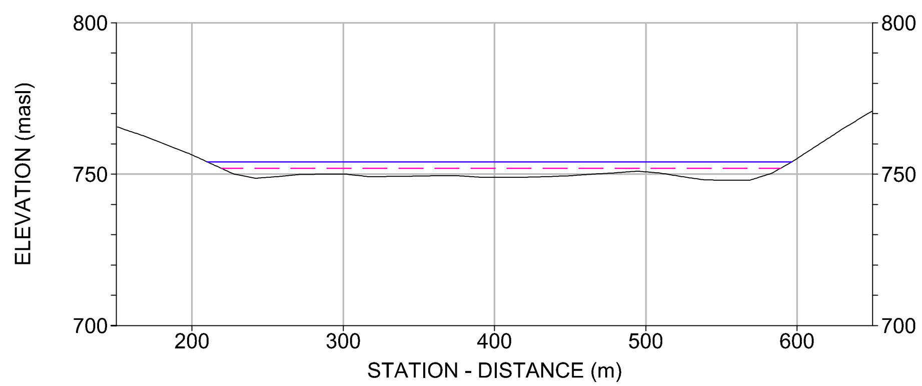

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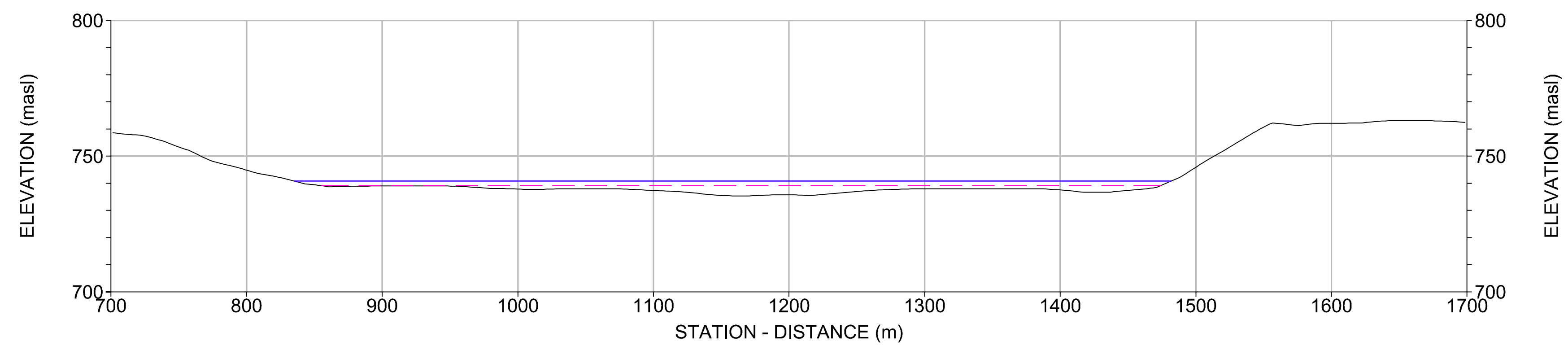

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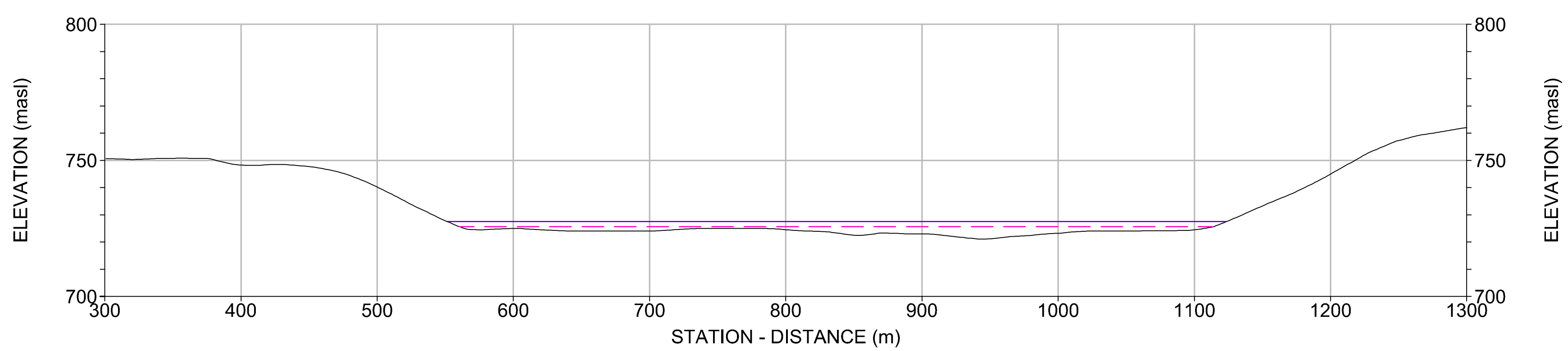

SECTION 820

NOTE:
THIS DRAWING SHOULD BE READ IN CONJUNCTION WITH THE AMEC ENVIRONMENT & INFRASTRUCTURE REPORT No. VM00276A.5.400 DATED NOVEMBER 2014.

LEGEND:
DAM FAILURE MODEL
FLOOD-INDUCED
SUNNY-DAY

0m 50 100 150 200
Horizontal

0m 20 40 60 80 100
Vertical

CLIENT:
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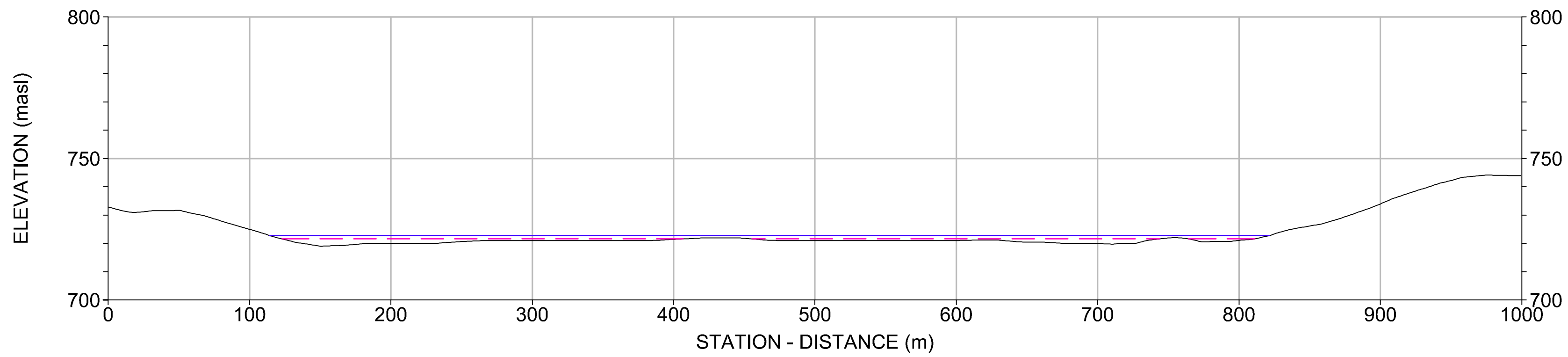
DWN BY:	TH
DESIGN BY:	AF / DA
CHECK BY:	AF
APPR'D BY:	AW
SCALE:	AS SHOWN

PROJECT:
EQUITY SILVER MINE
DAM BREAK AND INUNDATION ASSESSMENTS

TITLE:
HEC-RAS MODEL DAM No.1 (ASSESSMENT 1)
CROSS SECTIONS - SHEET 3

DATE:	NOVEMBER 2014
PROJECT NO:	VM00276A.5.400
REV. NO:	B
DRAWING NO:	DWG03-3



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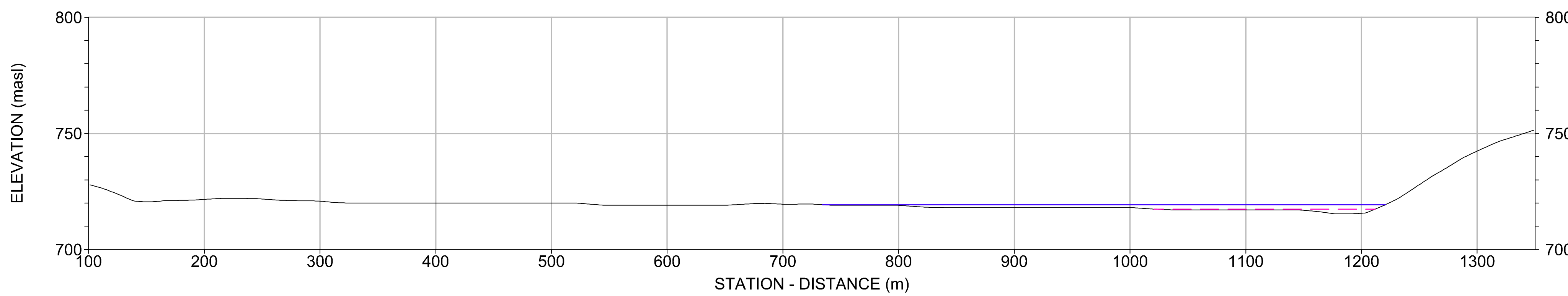
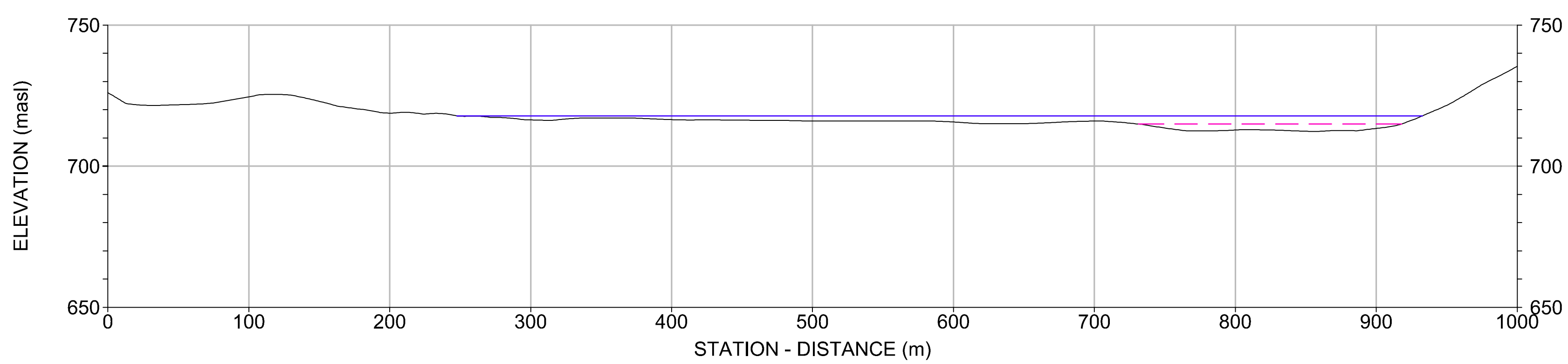


SECTION 795



SECTION 790

NOTE:
THIS DRAWING SHOULD BE READ IN CONJUNCTION WITH THE AMEC ENVIRONMENT & INFRASTRUCTURE REPORT No. VM00276A.5.400 DATED NOVEMBER 2014.

0m 50 100 150 200 Horizontal

0m 20 40 60 80 100 Vertical

LEGEND:
DAM FAILURE MODEL

- FLOOD-INDUCED
- SUNNY-DAY

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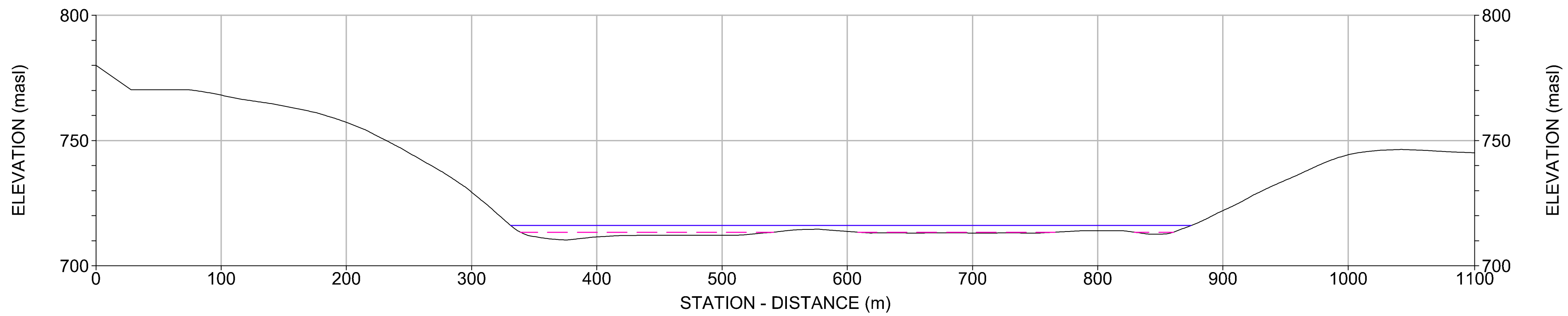
DESIGN BY:	AF / DA
CHECK BY:	AF
APPR'D BY:	AW
SCALE:	AS SHOWN

PROJECT:
EQUITY SILVER MINE
DAM BREAK AND INUNDATION ASSESSMENTS

TITLE:
HEC-RAS MODEL DAM No.1 (ASSESSMENT 1)
CROSS SECTIONS - SHEET 4

DATE:	NOVEMBER 2014
PROJECT NO:	VM00276A.5.400
REV. NO:	B
DRAWING NO:	DWG03-4



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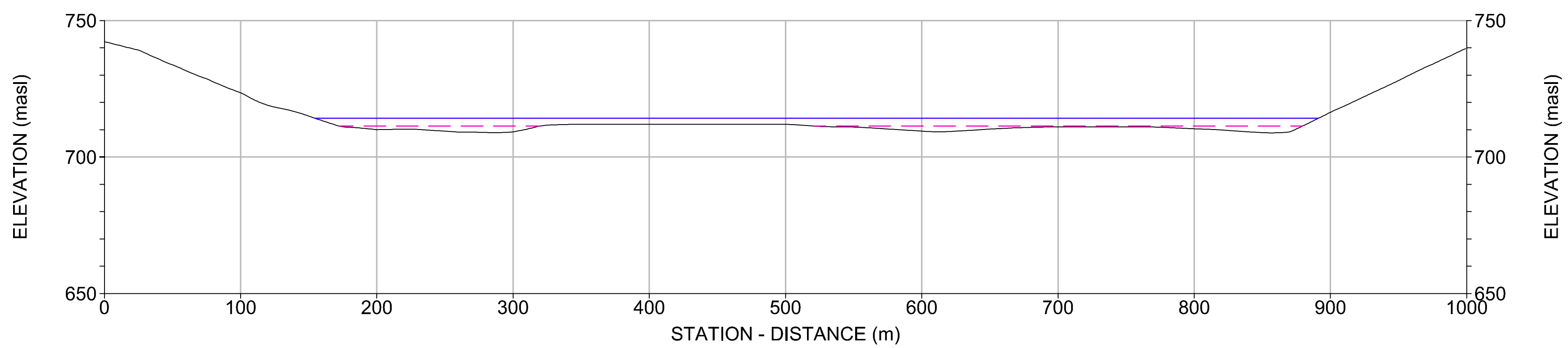

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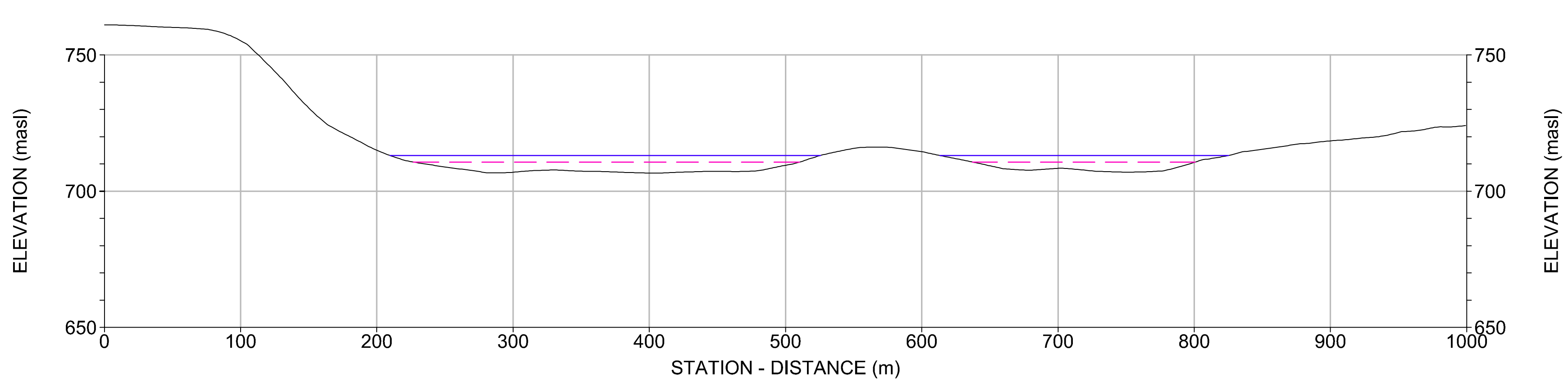

SECTION 760

NOTE:
THIS DRAWING SHOULD BE READ IN CONJUNCTION WITH THE AMEC ENVIRONMENT & INFRASTRUCTURE REPORT No. VM00276A.5.400 DATED NOVEMBER 2014.

Horizontal: 0m 50 100 150 200
Vertical: 0m 20 40 60 80 100

LEGEND:
DAM FAILURE MODEL
FLOOD-INDUCED
SUNNY-DAY

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DESIGN BY:	AF / DA
CHECK BY:	AF
APPR'D BY:	AW
SCALE:	AS SHOWN

PROJECT:
EQUITY SILVER MINE
DAM BREAK AND INUNDATION ASSESSMENTS

TITLE:
HEC-RAS MODEL DAM No.1 (ASSESSMENT 1)
CROSS SECTIONS - SHEET 5

DATE:	NOVEMBER 2014
PROJECT NO:	VM00276A.5.400
REV. NO:	B
DRAWING NO:	DWG03-5

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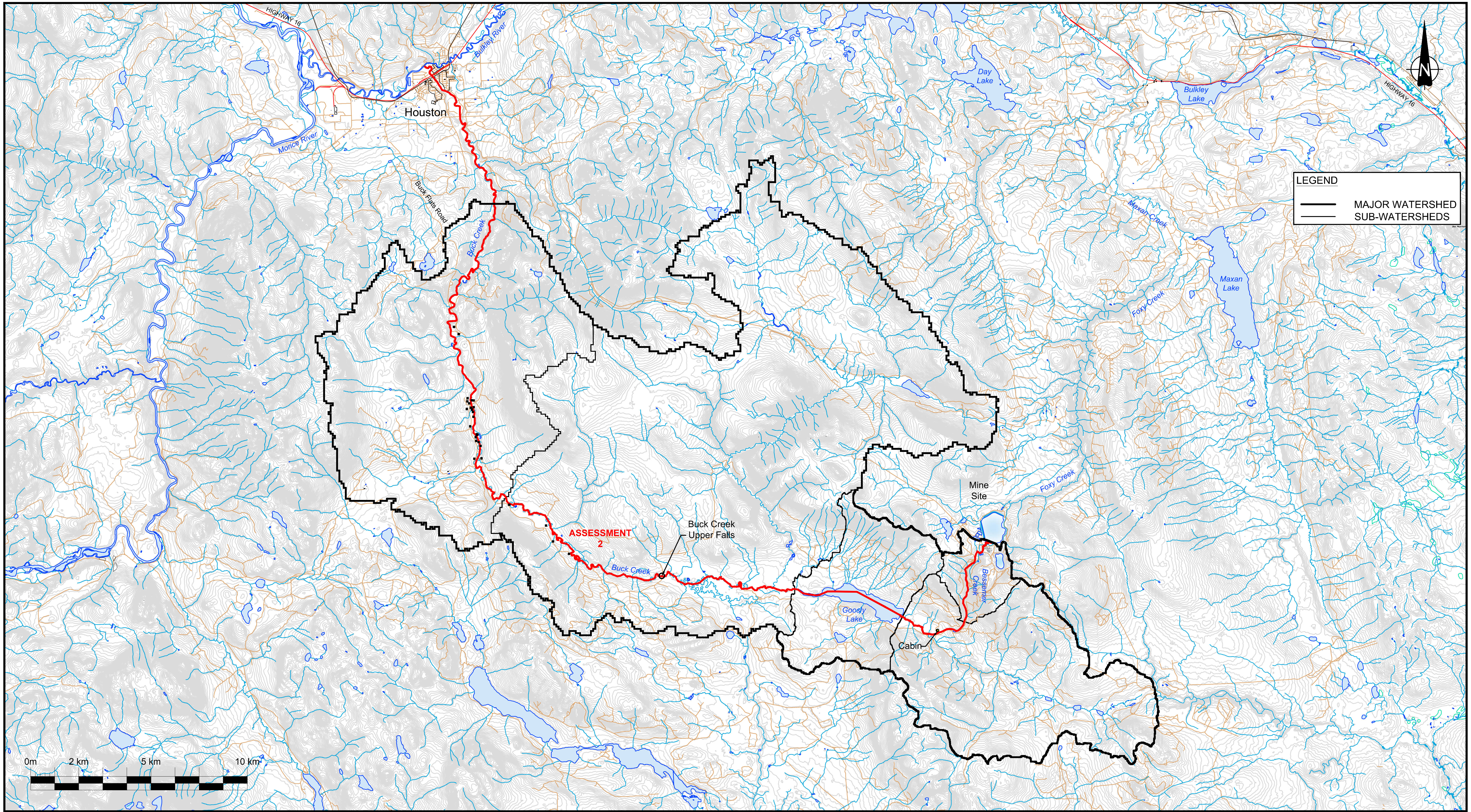

NOTE:
THIS DRAWING SHOULD BE READ IN CONJUNCTION WITH THE AMEC ENVIRONMENT & INFRASTRUCTURE REPORT No. VM00276A.5.400 DATED NOVEMBER 2014.

DATA REFERENCES:
Base Planimetry - CANVEC, Natural Resources Canada (NRCAN), National Topographic Series: Mapsheets 93L01, 02, 07 and 08.
Roads - Digital Road Atlas (DRA), Province of British Columbia, GeoBC/DataBC, BC Geographic Warehouse

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DWN BY: TH
CHK'D BY: JW / AF
DATUM: NAD 83
PROJECTION: UTM Zone 9
SCALE: AS SHOWN

PROJECT:
EQUITY SILVER MINE
DAM BREAK AND INUNDATION ASSESSMENTS

TITLE:
HEC-HMS MODEL CATCHMENT AREA DAM No. 2
(ASSESSMENT 2)

DATE: NOVEMBER 2014
PROJECT NO: VA00276A.5.400
REV. NO: B
DRAWING NO: DWG04

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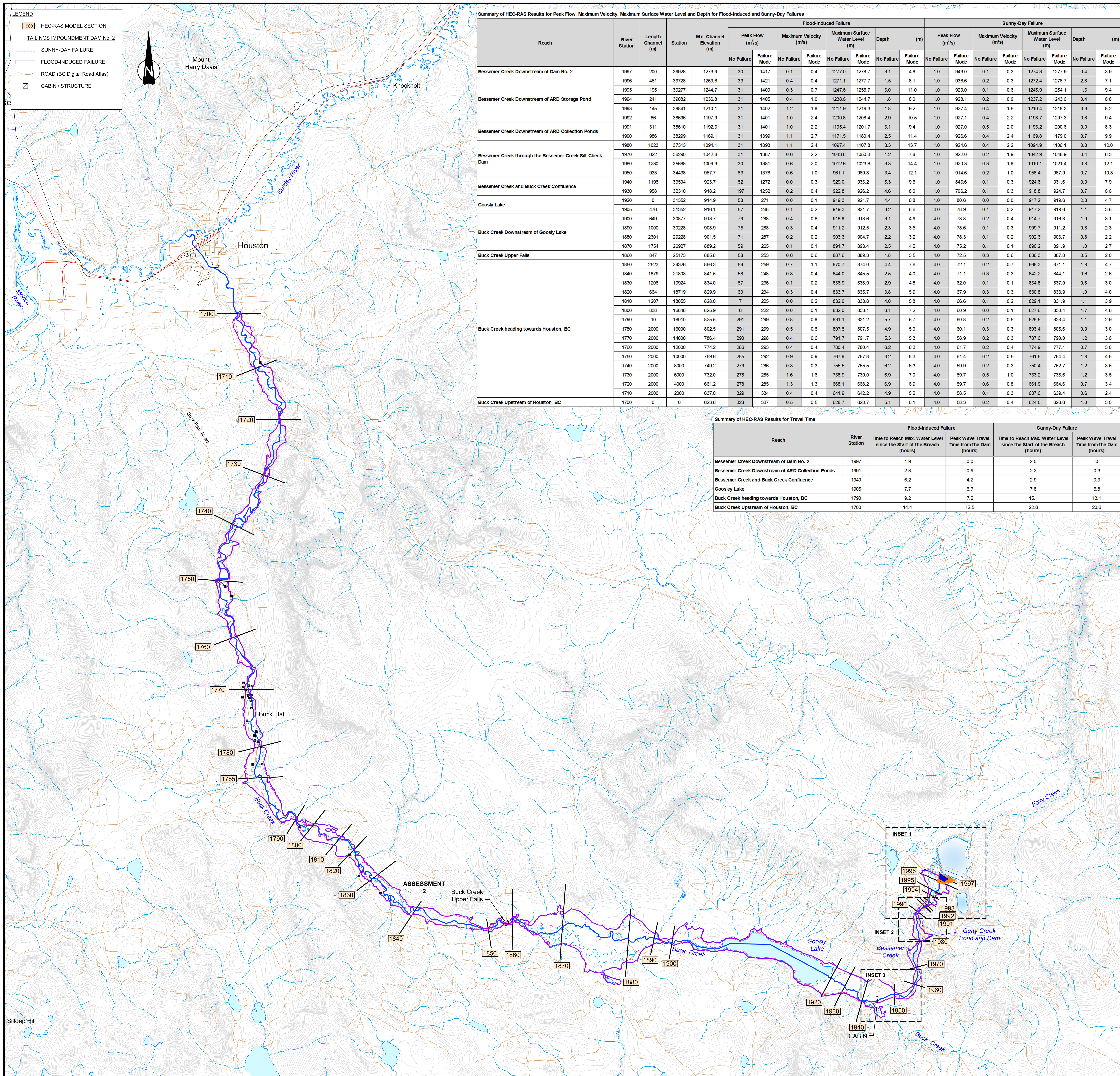
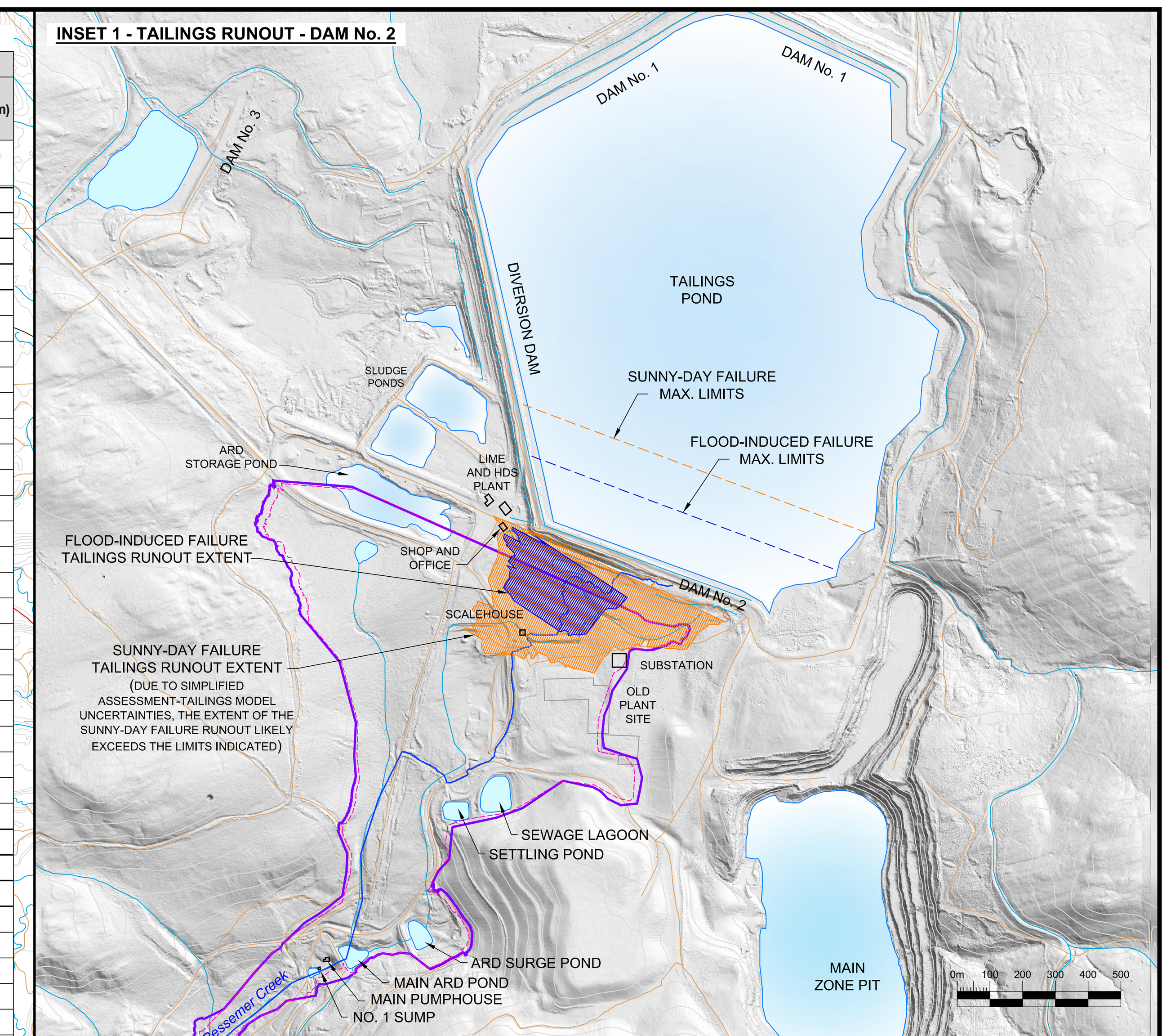


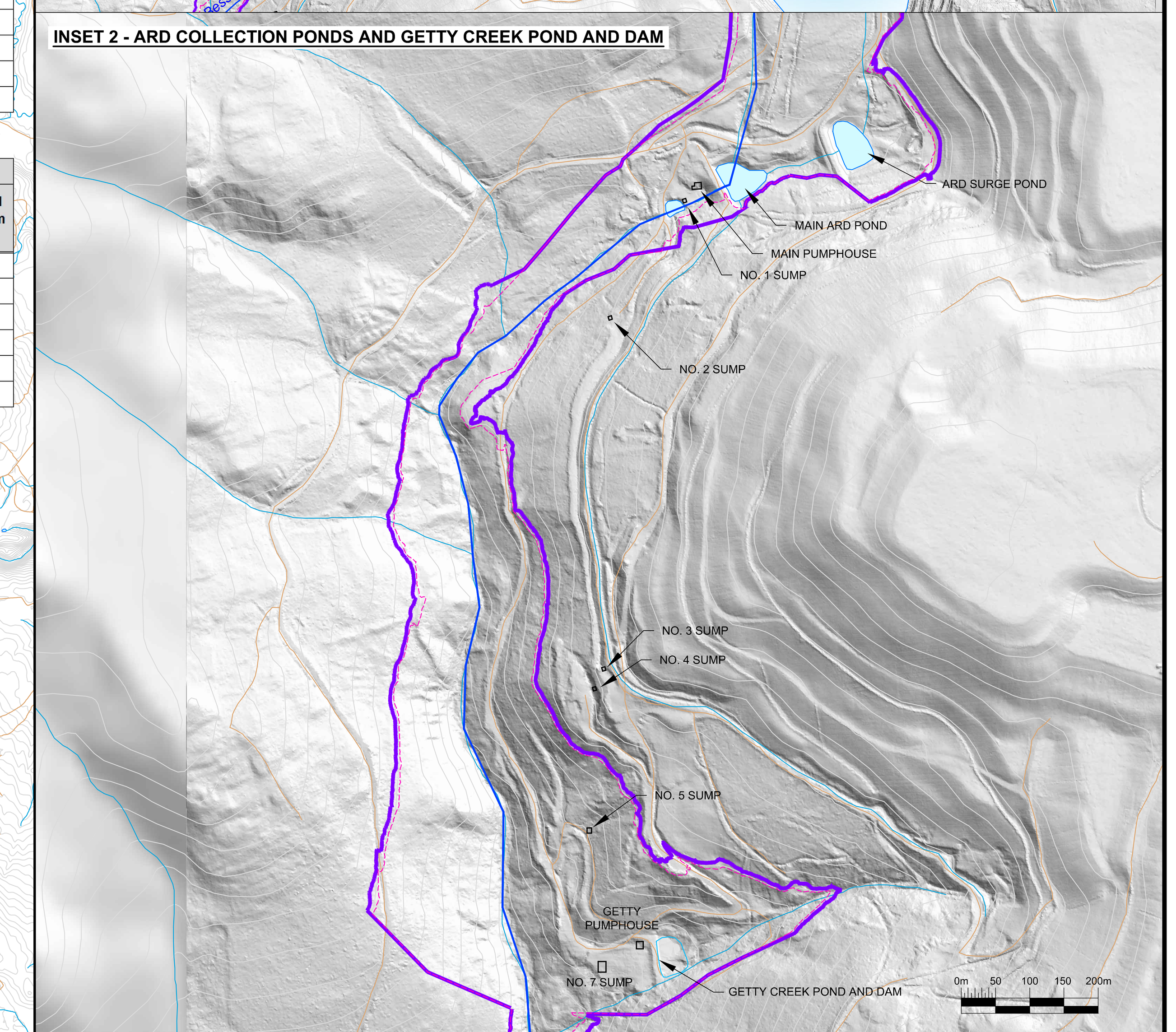
Summary of HEC-RAS Results for Peak Flow, Maximum Velocity, Maximum Surface Water Level and Depth for Flood-Induced and Sunny-Day Failures

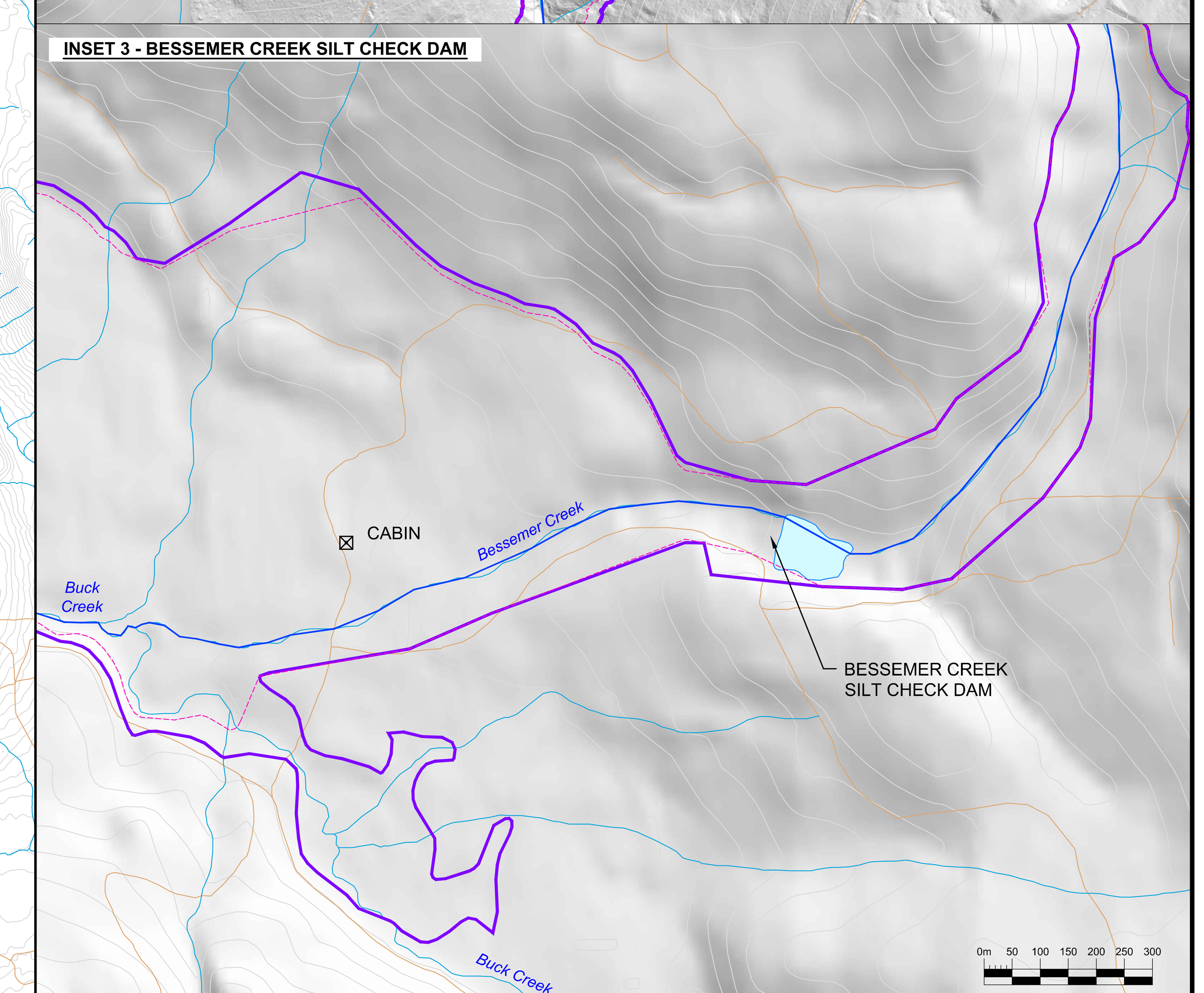
Reach	River Station	Length Channel (m)	Station	Min. Channel Elevation (m)	Flood-Induced Failure: Peak Flow (m^3/s)		Maximum Velocity (m/s)		Maximum Surface Water Level (m)		Depth (m)		Sunny-Day Failure: Peak Flow (m^3/s)		Maximum Velocity (m/s)		Maximum Surface Water Level (m)		Depth (m)	
					No Failure	Failure Mode	No Failure	Failure Mode	No Failure	Failure Mode	No Failure	Failure Mode	No Failure	Failure Mode	No Failure	Failure Mode	No Failure	Failure Mode	No Failure	Failure Mode
Bessemer Creek Downstream of Dam No. 2	1997	200	39928	1273.9	30	1417	0.1	0.4	1277.0	1278.7	3.1	4.8	1.0	943.0	0.1	0.3	1274.3	1277.9	0.4	3.9
Bessemer Creek Downstream of ARD Storage Pond	1996	451	39728	1269.6	33	1421	0.4	0.4	1271.1	1277.7	1.5	8.1	1.0	936.6	0.2	0.3	1272.4	1276.7	2.8	7.1
	1995	195	39277	1244.7	31	1409	0.3	0.7	1247.6	1255.7	3.0	11.0	1.0	929.0	0.1	0.6	1245.9	1254.1	1.3	9.4
	1994	241	39082	1236.8	31	1405	0.4	1.0	1238.6	1244.7	1.8	8.0	1.0	928.1	0.2	0.9	1237.2	1243.6	0.4	6.8
	1993	145	38841	1210.1	31	1402	1.2	1.8	1211.9	1219.3	1.8	9.2	1.0	927.4	0.4	1.6	1210.4	1218.3	0.3	8.2
	1992	86	38696	1197.9	31	1401	1.0	2.4	1200.8	1208.4	2.9	10.5	1.0	927.1	0.4	2.2	1198.7	1207.3	0.8	9.4
Bessemer Creek Downstream of ARD Collection Ponds	1991	311	38610	1192.3	31	1401	1.0	2.2	1195.4	1201.7	3.1	9.4	1.0	927.0	0.5	2.0	1193.2	1200.6	0.9	8.3
	1990	986	38299	1169.1	31	1399	1.1	2.7	1171.5	1180.4	2.5	11.4	1.0	926.6	0.4	2.4	1169.8	1179.0	0.7	9.9
Bessemer Creek through the Bessemer Creek Silt Check Dam	1980	1023	37313	1094.1	31	1393	1.1	2.4	1097.4	1107.8	3.3	13.7	1.0	924.6	0.4	2.2	1094.9	1106.1	0.8	12.0
	1970	622	36290	1042.6	31	1387	0.6	2.2	1043.8	1050.3	1.2	7.8	1.0	922.0	0.2	1.9	1042.9	1048.9	0.4	6.3
	1960	1230	35668	1009.3	30	1381	0.6	2.0	1012.6	1023.6	3.3	14.4	1.0	920.3	0.3	1.8	1010.1	1021.4	0.8	12.1
	1950	933	34438	957.7	63	1376	0.6	1.0	961.1	969.8	3.4	12.1	1.0	914.6	0.2	1.0	958.4	967.9	0.7	10.3
Bessemer Creek and Buck Creek Confluence	1940	1195	33504	923.7	52	1272	0.0	0.3	929.0	933.2	5.3	9.5	1.0	843.6	0.1	0.3	924.6	931.6	0.9	7.9
	1930	958	32310	918.2	197	1252	0.2	0.4	922.8	926.2	4.6	8.0	1.0	706.2	0.1	0.3	918.8	924.7	0.7	6.6
Goosly Lake	1920	0	31352	914.9	58	271	0.0	0.1	919.3	921.7	4.4	6.8	1.0	80.6	0.0	0.0	917.2	919.6	2.3	4.7
	1905	476	31352	916.1	57	268	0.1	0.2	919.3	921.7	3.2	5.6	4.0	78.9	0.1	0.2	917.2	919.6	1.1	3.5
Buck Creek Downstream of Goosly Lake	1900	649	30877	913.7	79	288	0.4	0.6	916.8	918.6	3.1	4.9	4.0	78.8	0.2	0.4	914.7	916.8	1.0	3.1
	1890	1000	30228	908.9	75	288	0.3	0.4	911.2	912.5	2.3	3.5	4.0	78.6	0.1	0.3	909.7	911.2	0.8	2.3
	1880	2301	29228	901.5	71	287	0.2	0.2	903.6	904.7	2.2	3.2	4.0	78.3	0.1	0.2	902.3	903.7	0.8	2.2
	1870	1754	26927	889.2	59	265	0.1	0.1	891.7	893.4	2.5	4.2	4.0	75.2	0.1	0.1	890.2	891.9	1.0	2.7
Buck Creek Upper Falls	1860	847	25173	885.8	58	253	0.6	0.6	887.6	889.3	1.8	3.5	4.0	72.5	0.3	0.6	886.3	887.8	0.5	2.0
Buck Creek heading towards Houston, BC	1850	2523	24326	866.3	58	259	0.7	1.1	870.7	874.0	4.4	7.6	4.0	72.1	0.2	0.7	868.3	871.1	1.9	4.7
	1840	1879	21803	841.5	58	248	0.3	0.4	844.0	845.5	2.5	4.0	4.0	71.1	0.3	0.3	842.2	844.1	0.6	2.6
	1830	1205	19924	834.0	57	236	0.1	0.2	836.9	838.9	2.9	4.8	4.0	62.0	0.1	0.1	834.8	837.0	0.8	3.0
	1820	664	18719	829.9	60	234	0.3	0.4	833.7	835.7	3.8	5.9	4.0	67.9	0.3	0.3	830.8	833.9	1.0	4.0
	1810	1207	18055	828.0	7	225	0.0	0.2	832.0	833.8	4.0	5.8	4.0	66.6	0.1	0.2	829.1	831.9	1.1	3.9
	1800	838	16848	825.9	6	222	0.0	0.1	832.0	833.1	6.1	7.2	4.0	60.9	0.0	0.1	827.6	830.4	1.7	4.6
	1790	10	16010	825.5	291	299	0.8	0.8	831.1	831.2	5.7	5.7	4.0	60.8	0.2	0.5	826.5	828.4	1.1	2.9
	1780	2000	16000	802.5	291	299	0.5	0.5	807.5	807.5	4.9	5.0	4.0	60.1	0.3	0.3	803.4	805.6	0.9	3.0
	1770	2000	14000	786.4	290	298	0.4	0.6	791.7	791.7	5.3	5.3	4.0	58.9	0.2	0.3	787.6	790.0	1.2	3.6
	1760	2000	12000	774.2	286	293	0.4	0.4	780.4	780.4	6.2	6.3	4.0	61.7	0.2	0.4	774.9	777.1	0.7	3.0
	1750	2000	10000	759.6	285	292	0.9	0.9	767.8	767.8	8.2	8.3	4.0	61.4	0.2	0.5	761.5	764.4	1.9	4.8
	1740	2000	8000	749.2	279	286	0.3	0.3	755.5	755.5	6.2	6.3	4.0	59.9	0.2	0.3	750.4	752.7	1.2	3.5
	1730	2000	6000	732.0	278	285	1.6	1.6	738.9	739.0	6.9	7.0	4.0	59.7	0.5	1.0	733.2	735.6	1.2	3.5
	1720	2000	4000	661.2	278	285	1.3	1.3	668.1	668.2	6.9	6.9	4.0	59.7	0.6	0.8	661.9	664.6	0.7	3.4
	1710	2000	2000	637.0	329	334	0.4	0.4	641.9	642.2	4.9	5.2	4.0	58.5	0.1	0.3	637.6	639.4	0.6	2.4
Buck Creek Upstream of Houston, BC	1700	0	0	623.6	328	337	0.5	0.5	628.7	628.7	5.1	5.1	4.0	58.3	0.2	0.4	624.5	626.6	1.0	3.0

Summary of HEC-RAS Results for Travel Time

Reach	River Station	Flood-Induced Failure: Time to Reach Max. Water Level since the Start of the Breach (hours)	Flood-Induced Failure: Peak Wave Travel Time from the Dam (hours)	Sunny-Day Failure: Time to Reach Max. Water Level since the Start of the Breach (hours)	Sunny-Day Failure: Peak Wave Travel Time from the Dam (hours)
Bessemer Creek Downstream of Dam No. 2	1997	1.9	0.0	2.0	0
Bessemer Creek Downstream of ARD Collection Ponds	1991	2.8	0.9	2.3	0.3
Bessemer Creek and Buck Creek Confluence	1940	6.2	4.2	2.9	0.9
Goosley Lake	1905	7.7	5.7	7.8	5.8
Buck Creek heading towards Houston, BC	1790	9.2	7.2	15.1	13.1
Buck Creek Upstream of Houston, BC	1700	14.4	12.5	22.6	20.6







NOTES:

1. MODEL DESIGN SURFACES BASED ON A COMPOSITE OF THE LIDAR SURVEY 2008, AND NATIONAL CDED (CANADIAN DIGITAL ELEVATION DATA) MODEL, NATURAL RESOURCES CANADA.
2. THIS DRAWING SHOULD BE READ IN CONJUNCTION WITH THE AMEC ENVIRONMENT & INFRASTRUCTURE REPORT No. VM00276A.5.400 DATED NOVEMBER 2014.

0m 500 1000 1500 2000

REV	D	M	Y	ISSUE / REVISION DESCRIPTION	ENG.	APPR.
5						
4						
3						
2						
1						
B	21	11	14	ISSUED WITH FINAL REPORT	JW/AF	AW
A	14	11	14	ISSUED WITH DRAFT REPORT	JW/AF	AW

AMEC Environment & Infrastructure
4445 Lougheed Highway, Suite 600
Burnaby, BC, V5C 0E4
Tel. 604-294-3811 Fax 604-294-4664

CLIENT: GOLDCORP CANADA LTD

DESIGNED BY: AF / DA
DRAWN BY: TH
CHECKED BY: AF
APPROVED BY: AW
SCALE: AS SHOWN

PROJECT: EQUITY SILVER MINE
DAM BREAK AND INUNDATION ASSESSMENTS

TITLE: HEC-RAS MODEL FOR DAM No. 2 (ASSESSMENT 2)

PROJECT NO: VM00276A.5.400
REVISION NO: B
DATE: NOVEMBER 2014
DRAWING NO: DWG05

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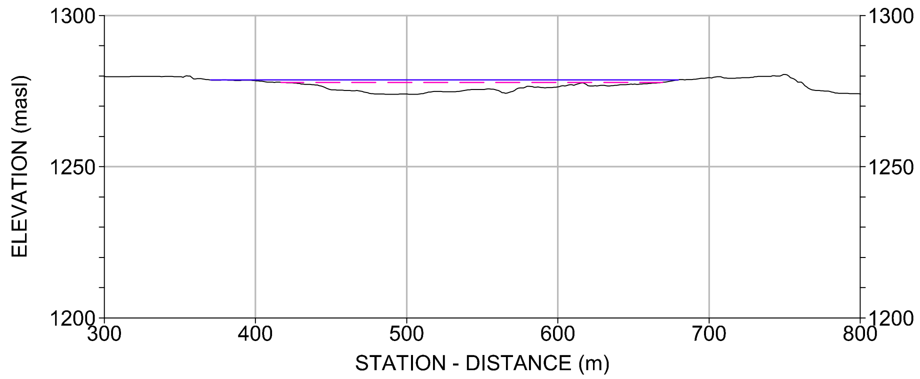

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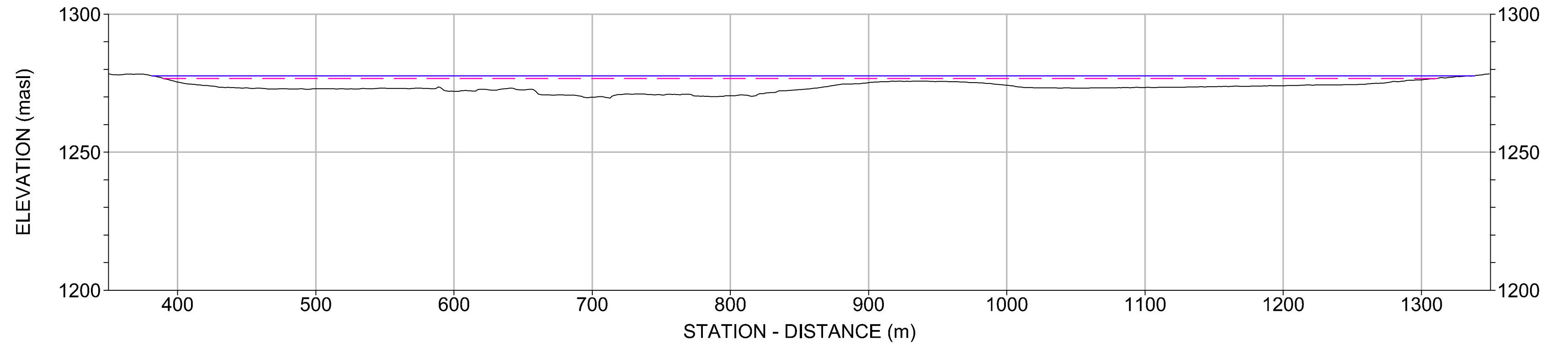

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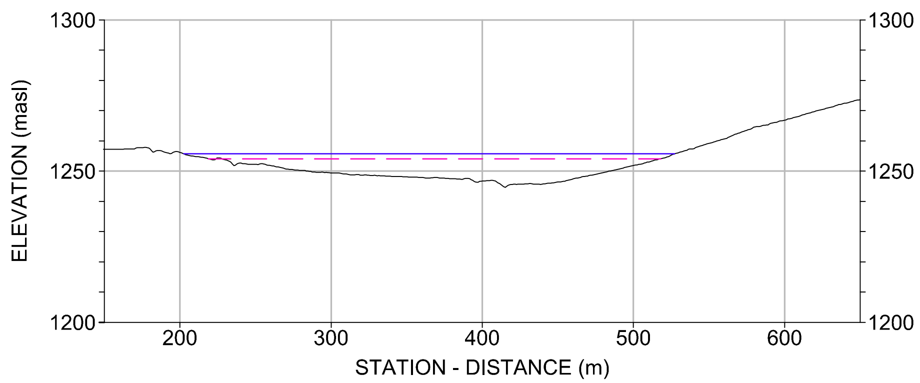

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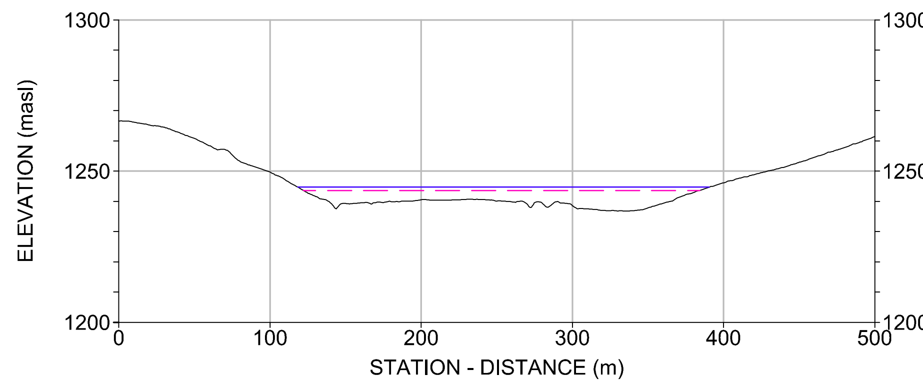

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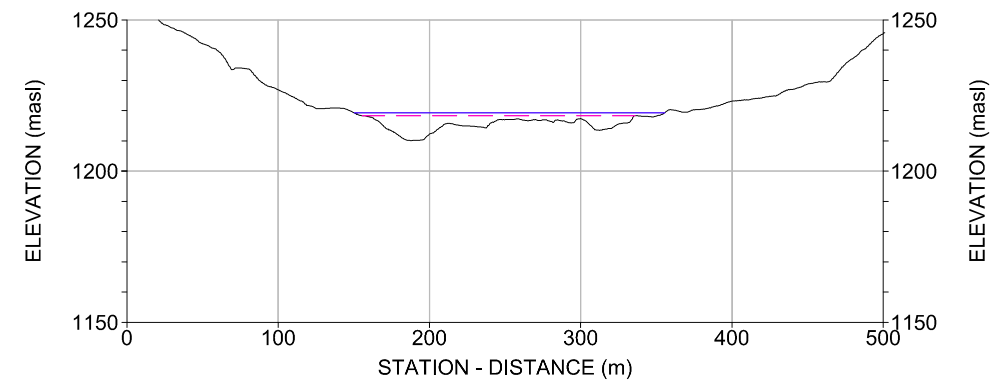

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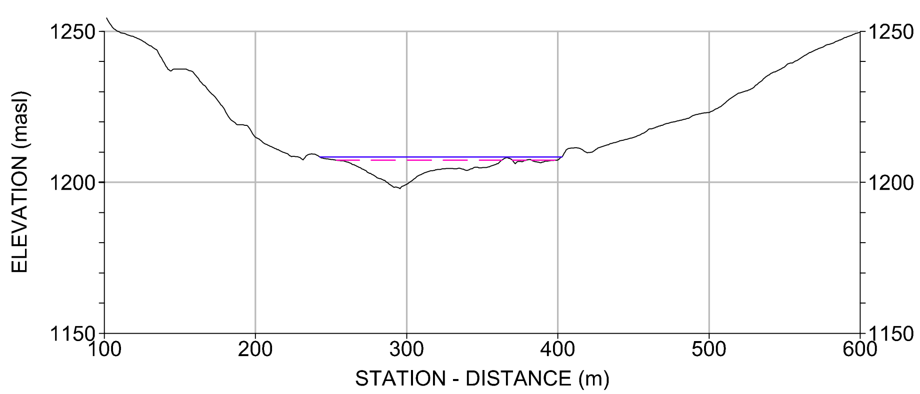

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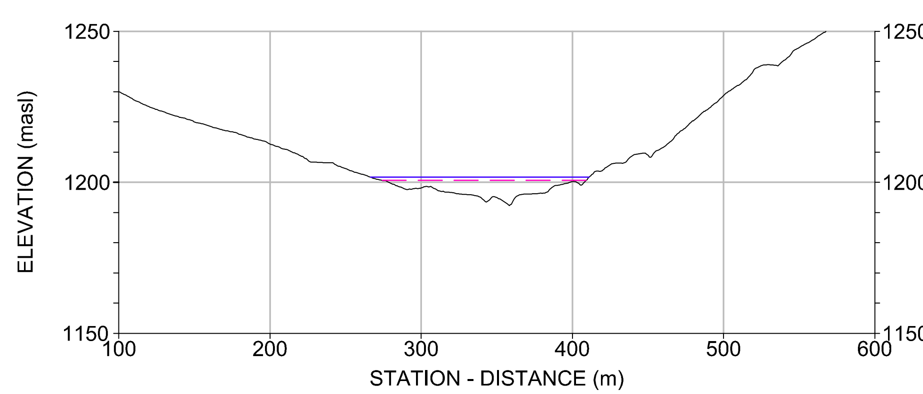

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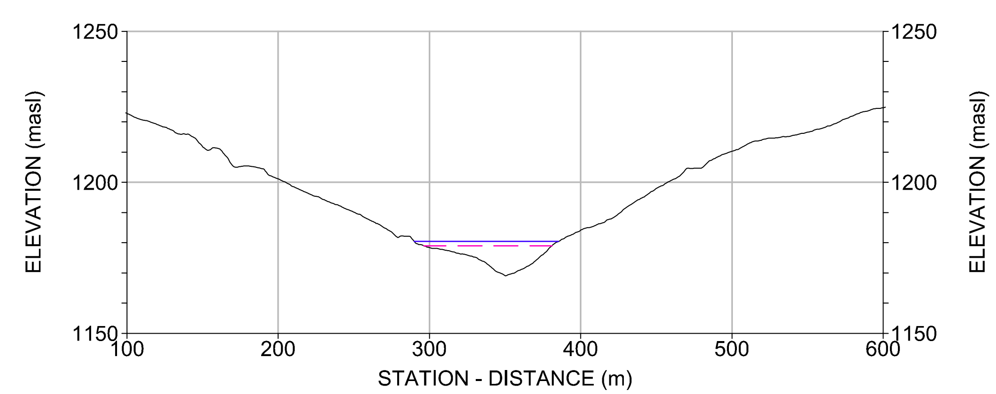

SECTION 1990

NOTE: SECTIONS HAVE BEEN VERTICALLY EXAGGERATED AND TRUNCATED FOR PRESENTATION CLARITY, AND WILL NOT REFLECT THE EXACT SECTION LIMITS DISPLAYED IN DRAWING 005.

NOTE:
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0m 50 100 150 200 — Horizontal
0m 20 40 60 80 100 — Vertical

LEGEND:
DAM FAILURE MODEL
FLOOD-INDUCED
SUNNY-DAY

CLIENT:
GOLDCORP
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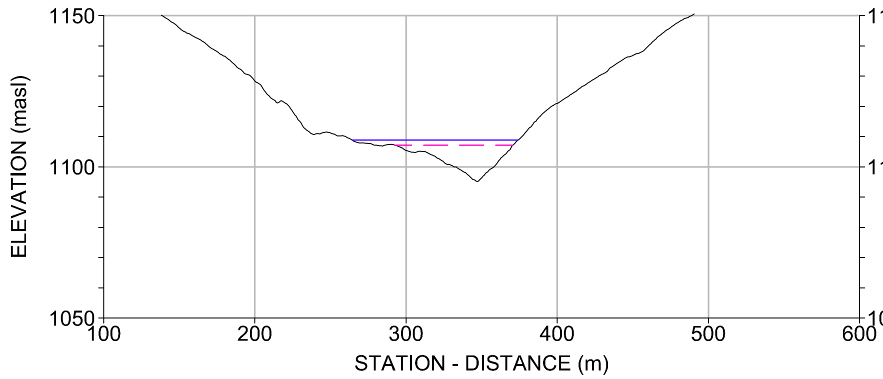
Burnaby, BC V5C 0E4
Tel. 604-294-3811 Fax 604-294-4664

DWN BY:	TH
DESIGN BY:	AF / DA
CHECK BY:	AF
APPR'D BY:	AW
SCALE:	AS SHOWN

PROJECT:
EQUITY SILVER MINE
DAM BREAK AND INUNDATION ASSESSMENTS

TITLE:
HEC-RAS MODEL DAM No.2 (ASSESSMENT 2)
CROSS SECTIONS - SHEET 1

DATE:	NOVEMBER 2014
PROJECT NO:	VM00276A.5.400
REV. NO:	B
DRAWING NO:	DWG06-1



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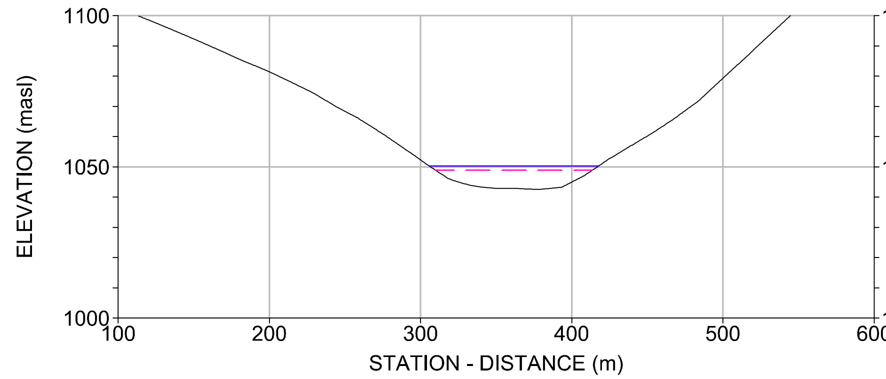

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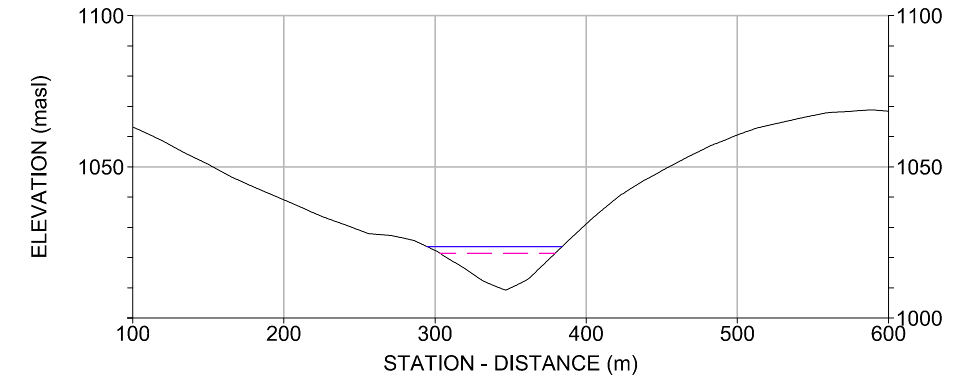

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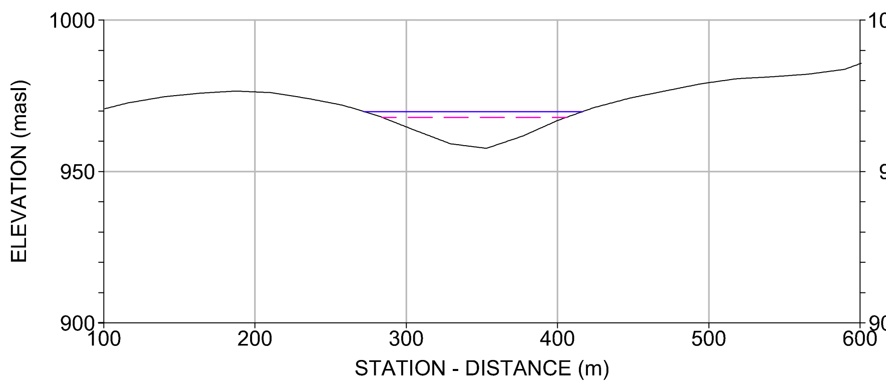

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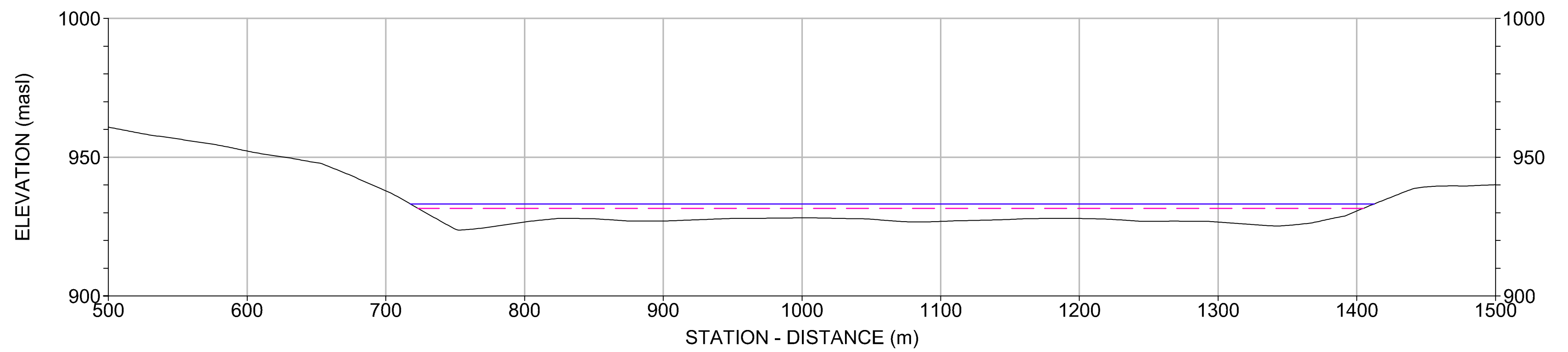

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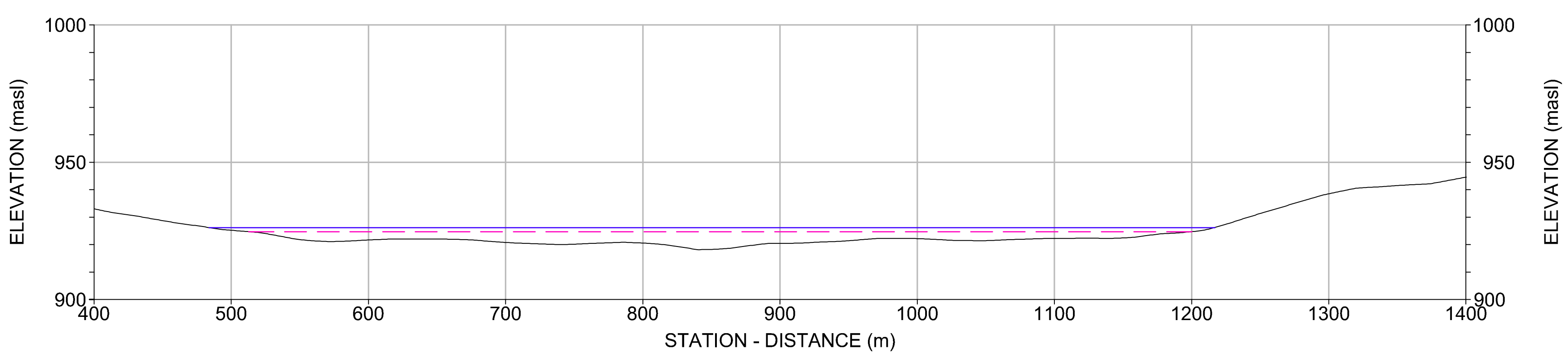

SECTION 1930

NOTE: SECTIONS HAVE BEEN VERTICALLY EXAGGERATED AND TRUNCATED FOR PRESENTATION CLARITY, AND WILL NOT REFLECT THE EXACT SECTION LIMITS DISPLAYED IN DRAWING 005.

NOTE:
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0m 50 100 150 200 Horizontal

0m 20 40 60 80 100 Vertical

LEGEND:
DAM FAILURE MODEL
FLOOD-INDUCED
SUNNY-DAY

CLIENT:
GOLDCORP
GOLDCORP CANADA LTD

AMEC Environment & Infrastructure
4445 Lougheed Highway, Suite 600
Burnaby, BC V5C 0E4
Tel. 604-294-3811 Fax 604-294-4664

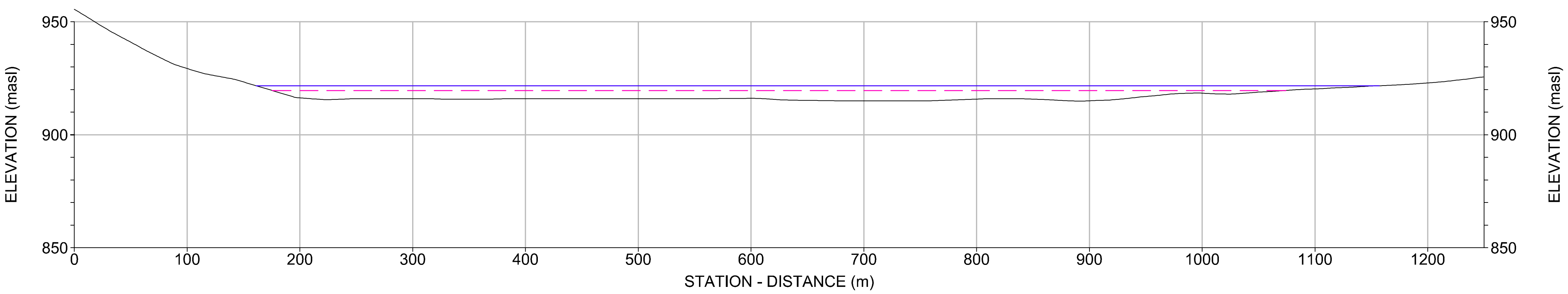
DWN BY:	TH
DESIGN BY:	AF / DA
CHECK BY:	AF
APPR'D BY:	AW
SCALE:	AS SHOWN

PROJECT:
EQUITY SILVER MINE
DAM BREAK AND INUNDATION ASSESSMENTS

TITLE:
HEC-RAS MODEL DAM No.2 (ASSESSMENT 2)
CROSS SECTIONS - SHEET 2

DATE:	NOVEMBER 2014
PROJECT NO:	VM00276A.5.400
REV. NO:	B
DRAWING NO:	DWG06-2

S:\PROJECTS\VM00276A - Equity Silver Mine\DRAWINGS\2014 DBA\VM00276A.5.4-DWG06.dwg - DWG06-2 - Nov. 24, 2014 10:18am - tim.hawker



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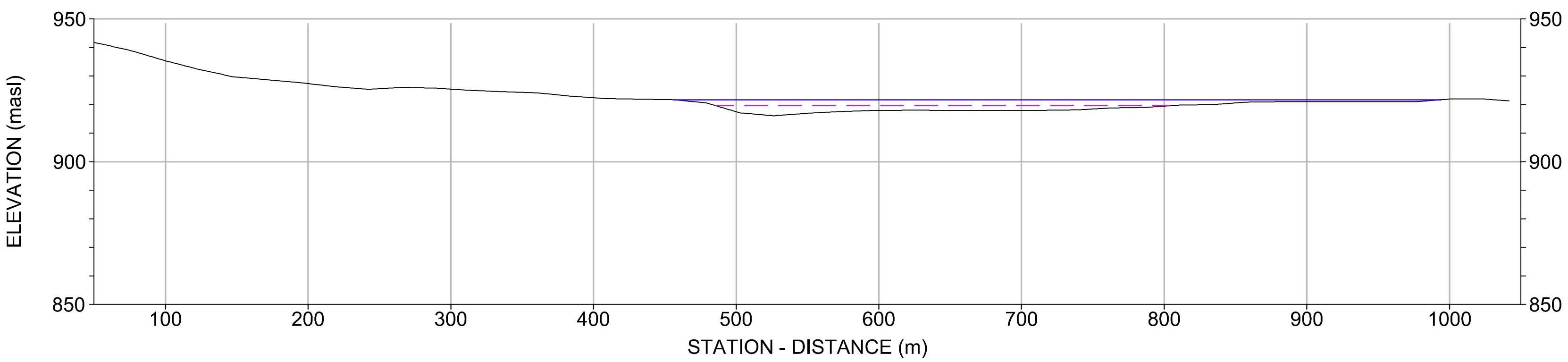

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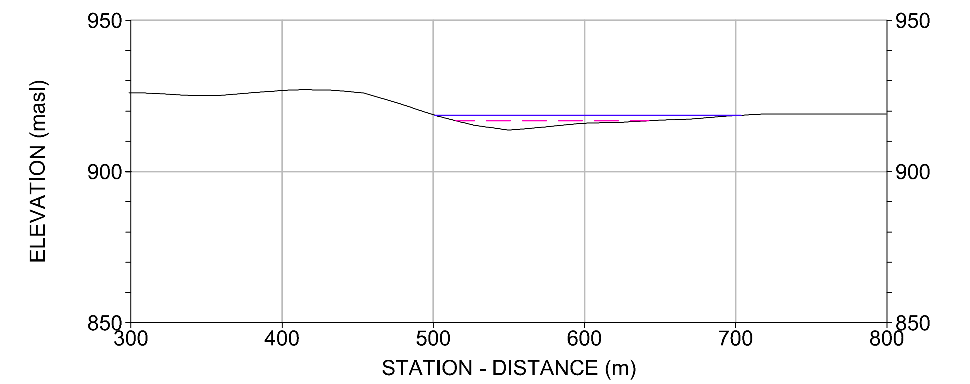

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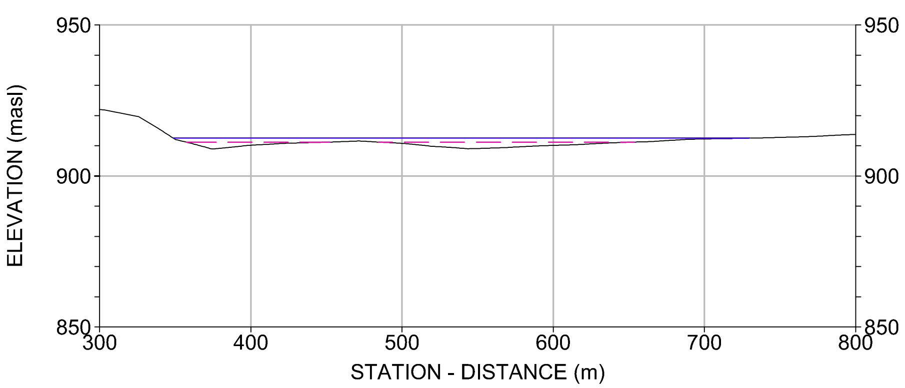

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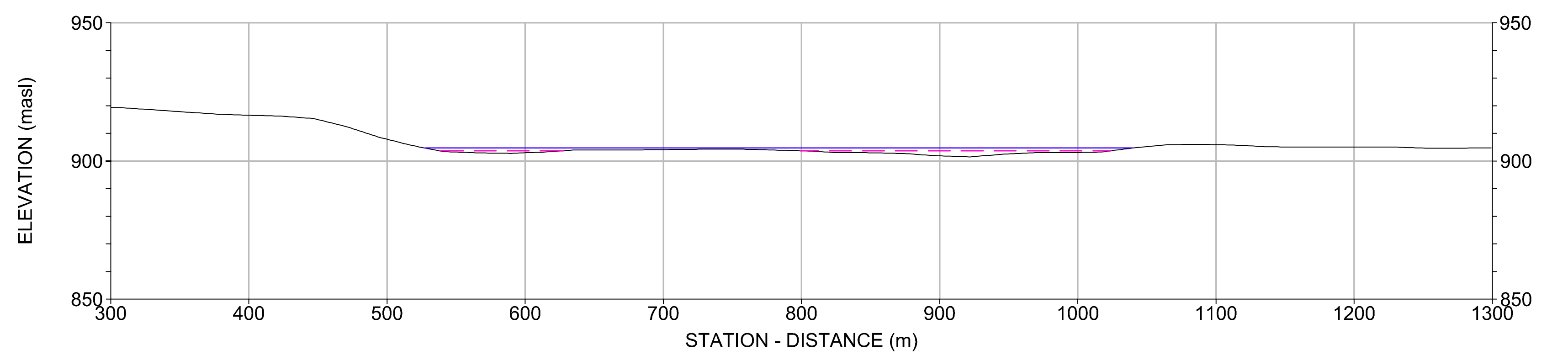

SECTION 1880

NOTE: SECTIONS HAVE BEEN VERTICALLY EXAGGERATED AND TRUNCATED FOR PRESENTATION CLARITY, AND WILL NOT REFLECT THE EXACT SECTION LIMITS DISPLAYED IN DRAWING 005.

NOTE:
THIS DRAWING SHOULD BE READ IN CONJUNCTION WITH THE AMEC ENVIRONMENT & INFRASTRUCTURE REPORT No. VM00276A.5.400 DATED NOVEMBER 2014.

0m 50 100 150 200
Horizontal

0m 20 40 60 80 100
Vertical

LEGEND:
DAM FAILURE MODEL
FLOOD-INDUCED
SUNNY-DAY

CLIENT:
GOLDCORP
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4445 Lougheed Highway, Suite 600
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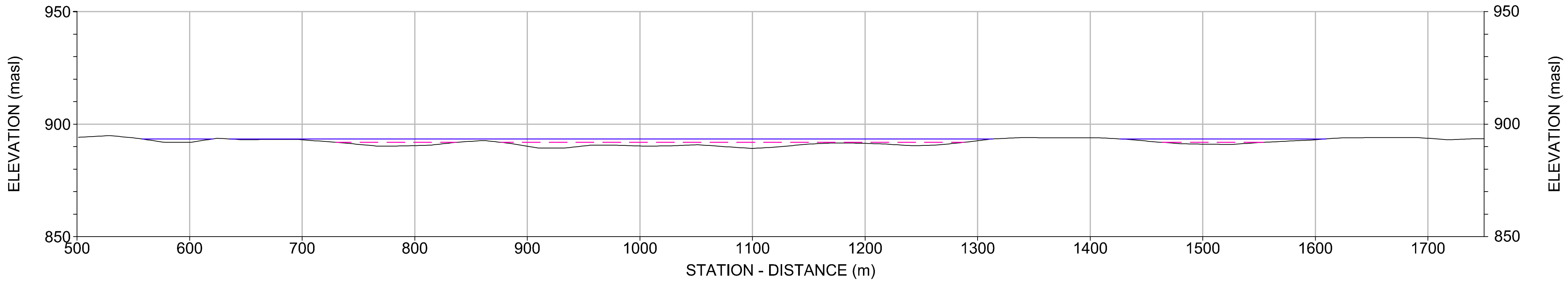
CHECK BY:	AF
APPR'D BY:	AW
SCALE:	AS SHOWN

PROJECT:
EQUITY SILVER MINE
DAM BREAK AND INUNDATION ASSESSMENTS

TITLE:
HEC-RAS MODEL DAM No.2 (ASSESSMENT 2)
CROSS SECTIONS - SHEET 3

DATE:	NOVEMBER 2014
PROJECT NO:	VM00276A.5.400
REV. NO:	B
DRAWING NO:	DWG06-3



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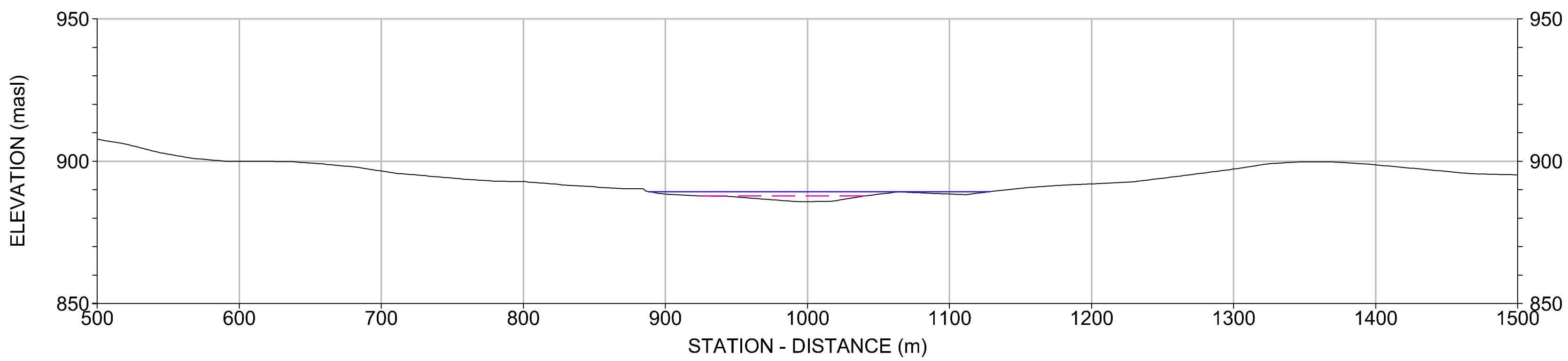

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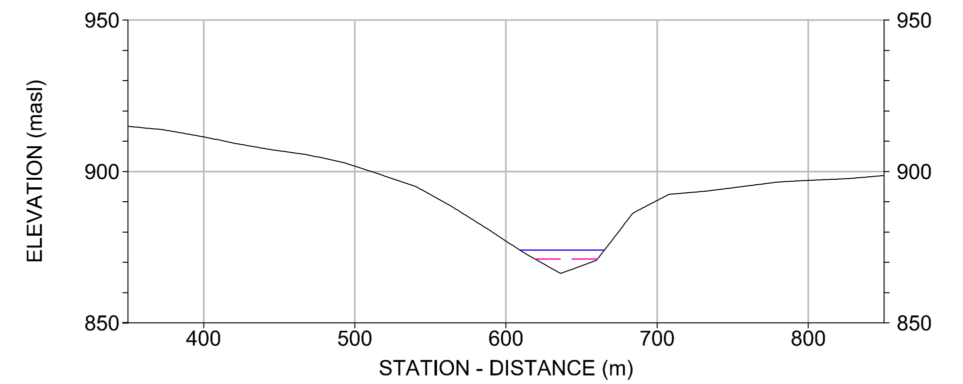

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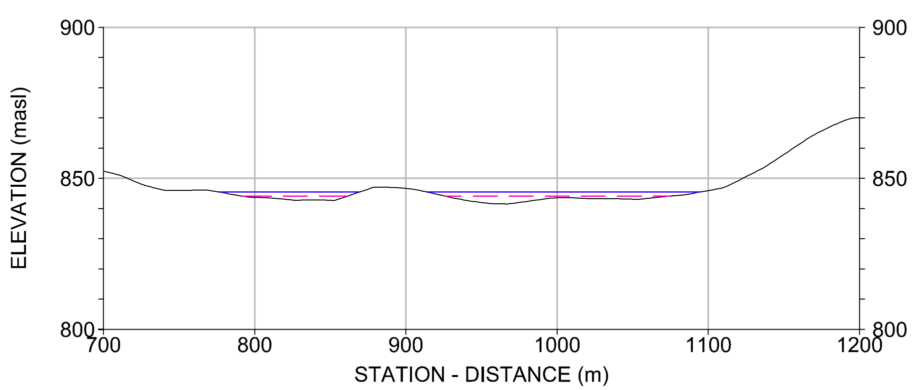

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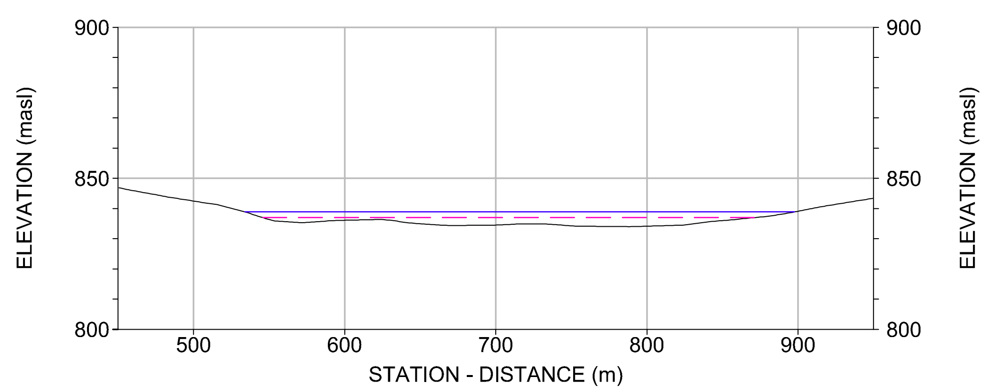

SECTION 1830

NOTE: SECTIONS HAVE BEEN VERTICALLY EXAGGERATED AND TRUNCATED FOR PRESENTATION CLARITY, AND WILL NOT REFLECT THE EXACT SECTION LIMITS DISPLAYED IN DRAWING 005.

NOTE:
THIS DRAWING SHOULD BE READ IN CONJUNCTION WITH THE AMEC ENVIRONMENT & INFRASTRUCTURE REPORT No. VM00276A.5.400 DATED NOVEMBER 2014.

0m 50 100 150 200
Horizontal

0m 20 40 60 80 100
Vertical

LEGEND:
DAM FAILURE MODEL
FLOOD-INDUCED
SUNNY-DAY

CLIENT:
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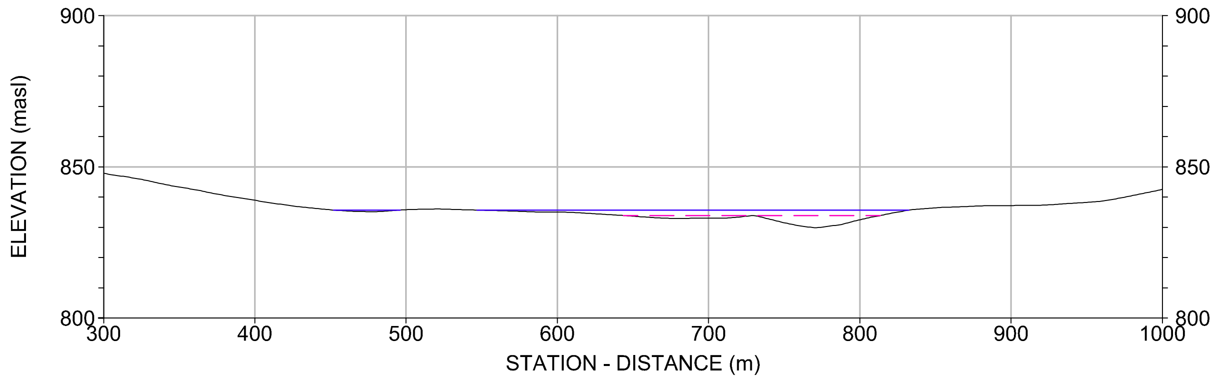
CHECK BY:	AF
APPR'D BY:	AW
SCALE:	AS SHOWN
PROJECT:	EQUITY SILVER MINE DAM BREAK AND INUNDATION ASSESSMENTS
TITLE:	HEC-RAS MODEL DAM No.2 (ASSESSMENT 2) CROSS SECTIONS - SHEET 4
DATE:	NOVEMBER 2014
PROJECT NO:	VM00276A.5.400
REV. NO:	B
DRAWING NO:	DWG06-4



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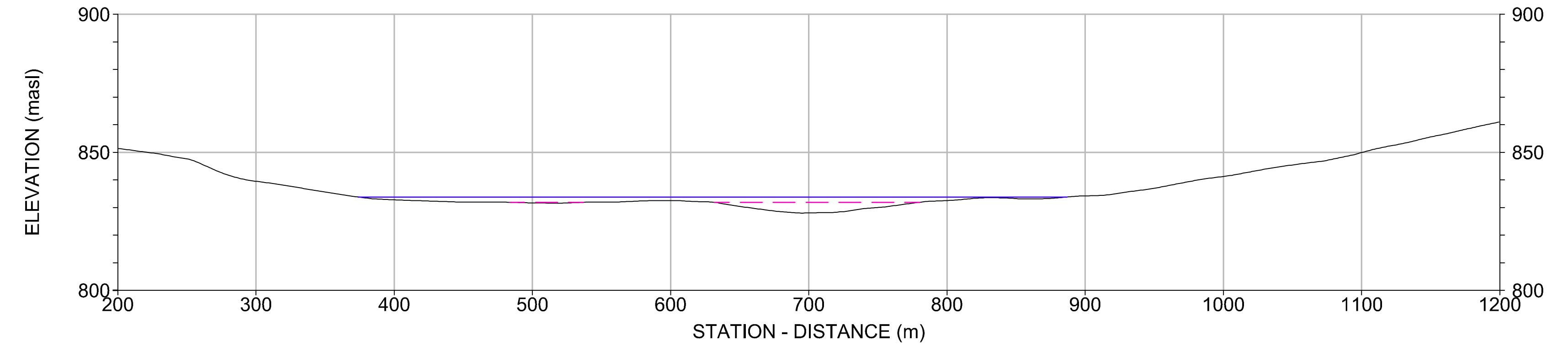

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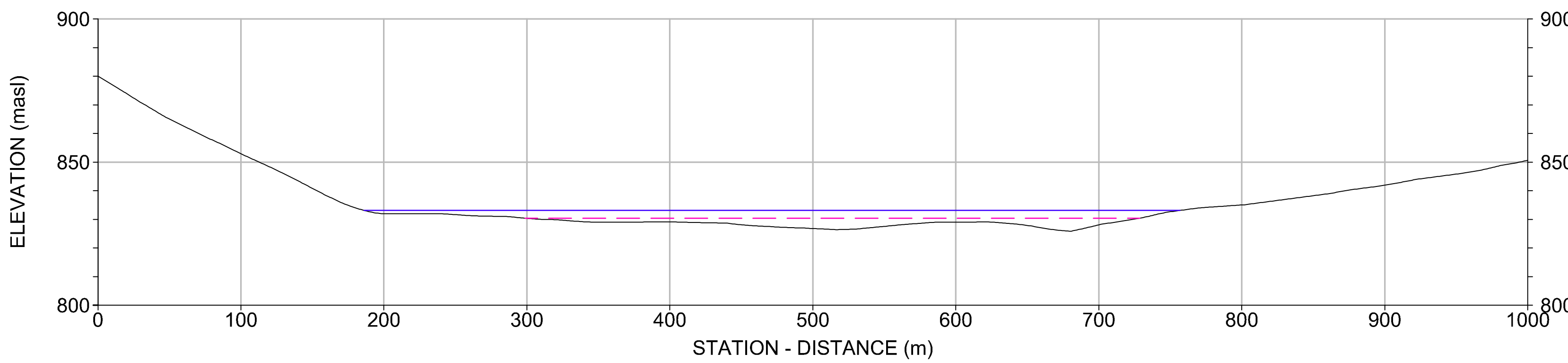

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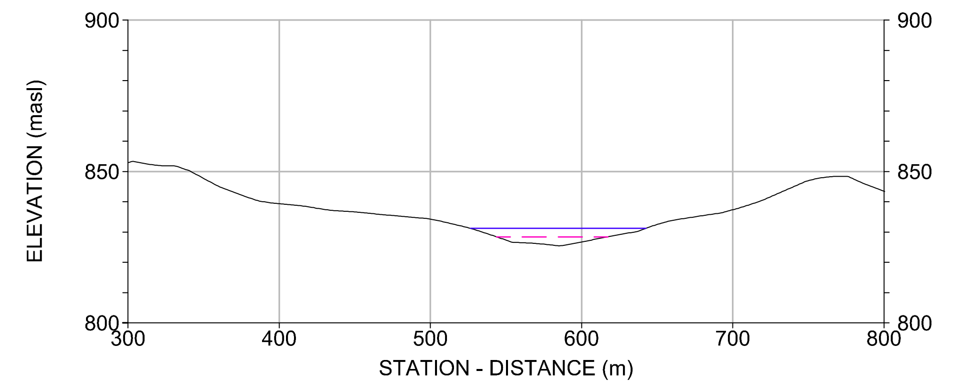

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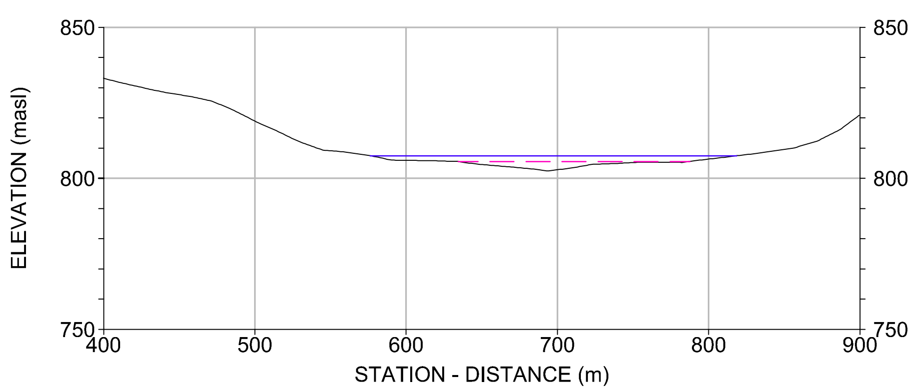

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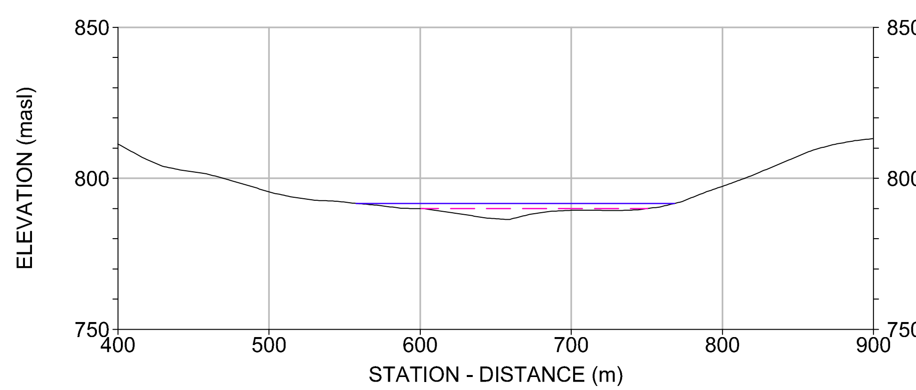

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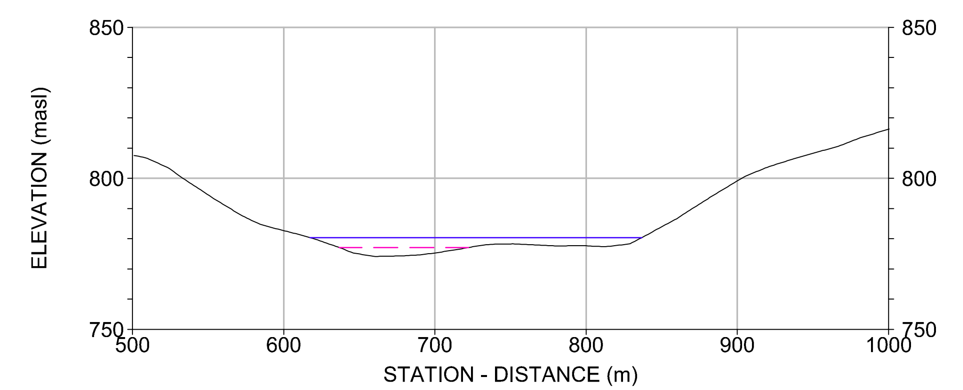

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NOTE: SECTIONS HAVE BEEN VERTICALLY EXAGGERATED AND TRUNCATED FOR PRESENTATION CLARITY, AND WILL NOT REFLECT THE EXACT SECTION LIMITS DISPLAYED IN DRAWING 005.

NOTE:
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0m 50 100 150 200
Horizontal

0m 20 40 60 80 100
Vertical

LEGEND:
DAM FAILURE MODEL
FLOOD-INDUCED
SUNNY-DAY

CLIENT:
GOLDCORP
GOLDCORP CANADA LTD

AMEC Environment & Infrastructure
4445 Lougheed Highway, Suite 600
Burnaby, BC V5C 0E4
Tel. 604-294-3811 Fax 604-294-4664

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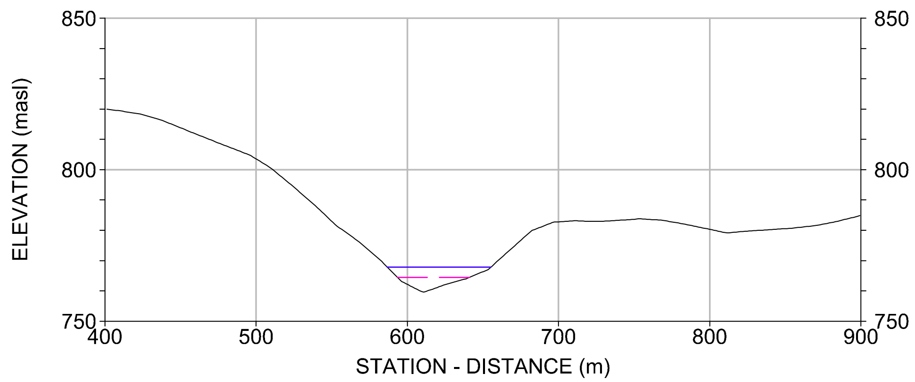
DESIGN BY:	AF / DA
CHECK BY:	AF
APPR'D BY:	AW
SCALE:	AS SHOWN

PROJECT:
EQUITY SILVER MINE
DAM BREAK AND INUNDATION ASSESSMENTS

TITLE:
HEC-RAS MODEL DAM No.2 (ASSESSMENT 2)
CROSS SECTIONS - SHEET 5

DATE:	NOVEMBER 2014
PROJECT NO:	VM00276A.5.400
REV. NO:	B
DRAWING NO:	DWG06-5

S:\PROJECTS\VM00276A - Equity Silver Mine\DRAWINGS\2014 DBA\VM00276A.5.4-DWG06.dwg - DWG06-5 - Nov. 24, 2014 10:18am - tim.hawker



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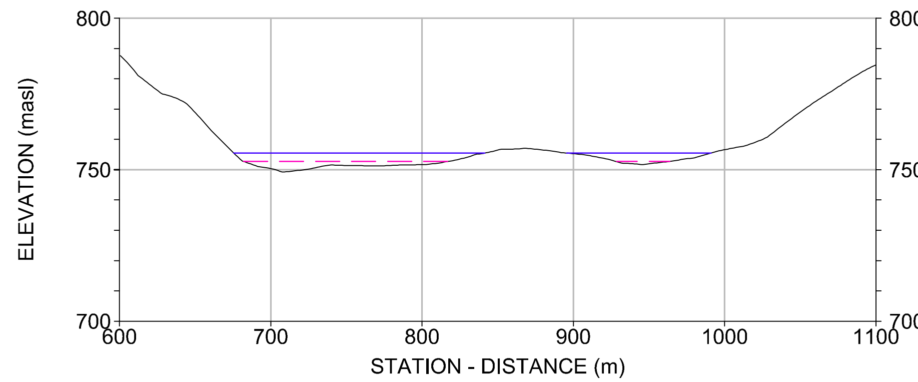

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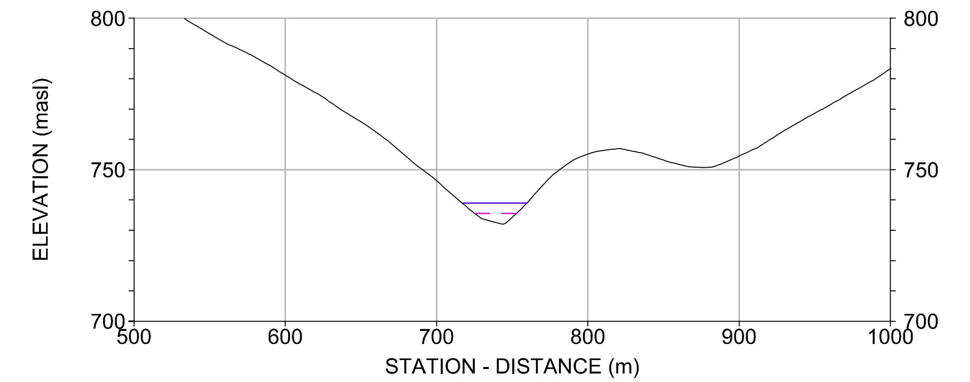

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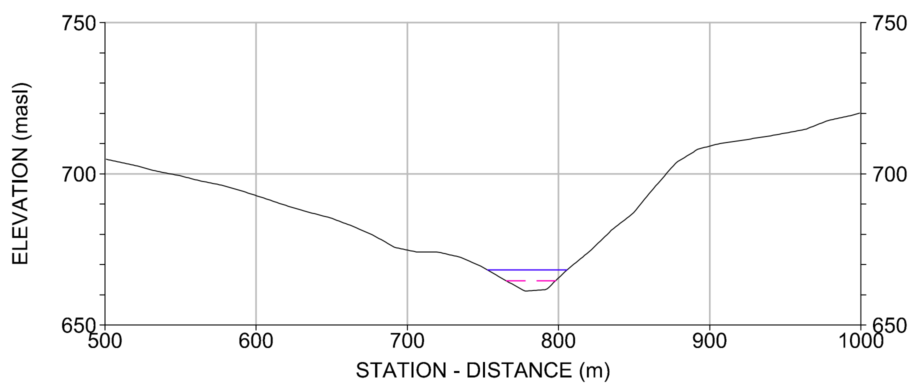

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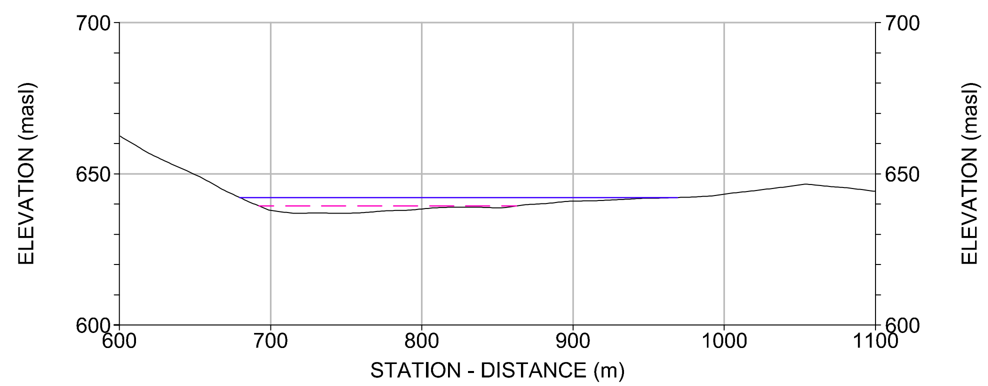

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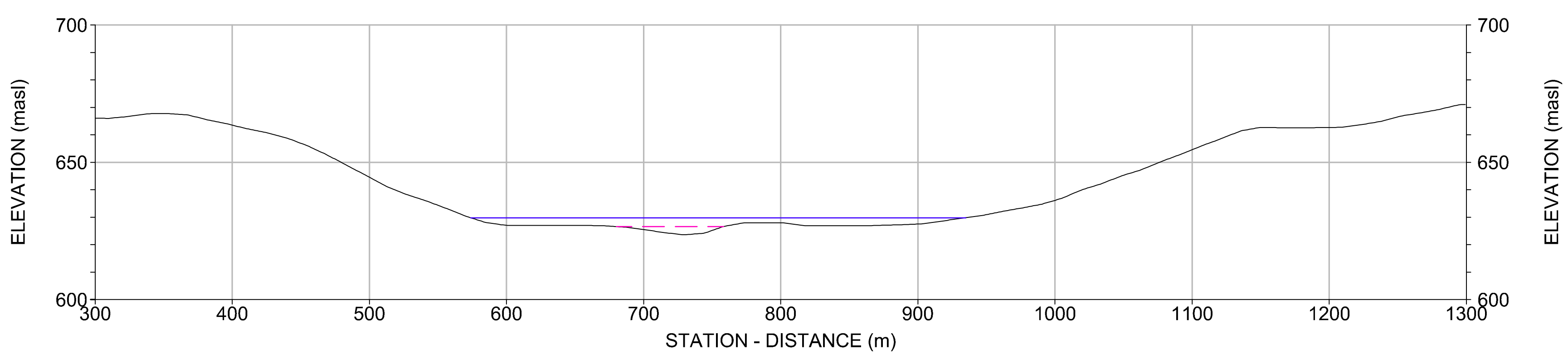

SECTION 1700

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NOTE:
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0m 50 100 150 200 Horizontal

0m 20 40 60 80 100 Vertical

LEGEND:
DAM FAILURE MODEL
FLOOD-INDUCED
SUNNY-DAY

CLIENT: GOLDCORP

GOLDCORP CANADA LTD

AMEC Environment & Infrastructure
4445 Lougheed Highway, Suite 600
Burnaby, BC V5C 0E4
Tel. 604-294-3811 Fax 604-294-4664

amec

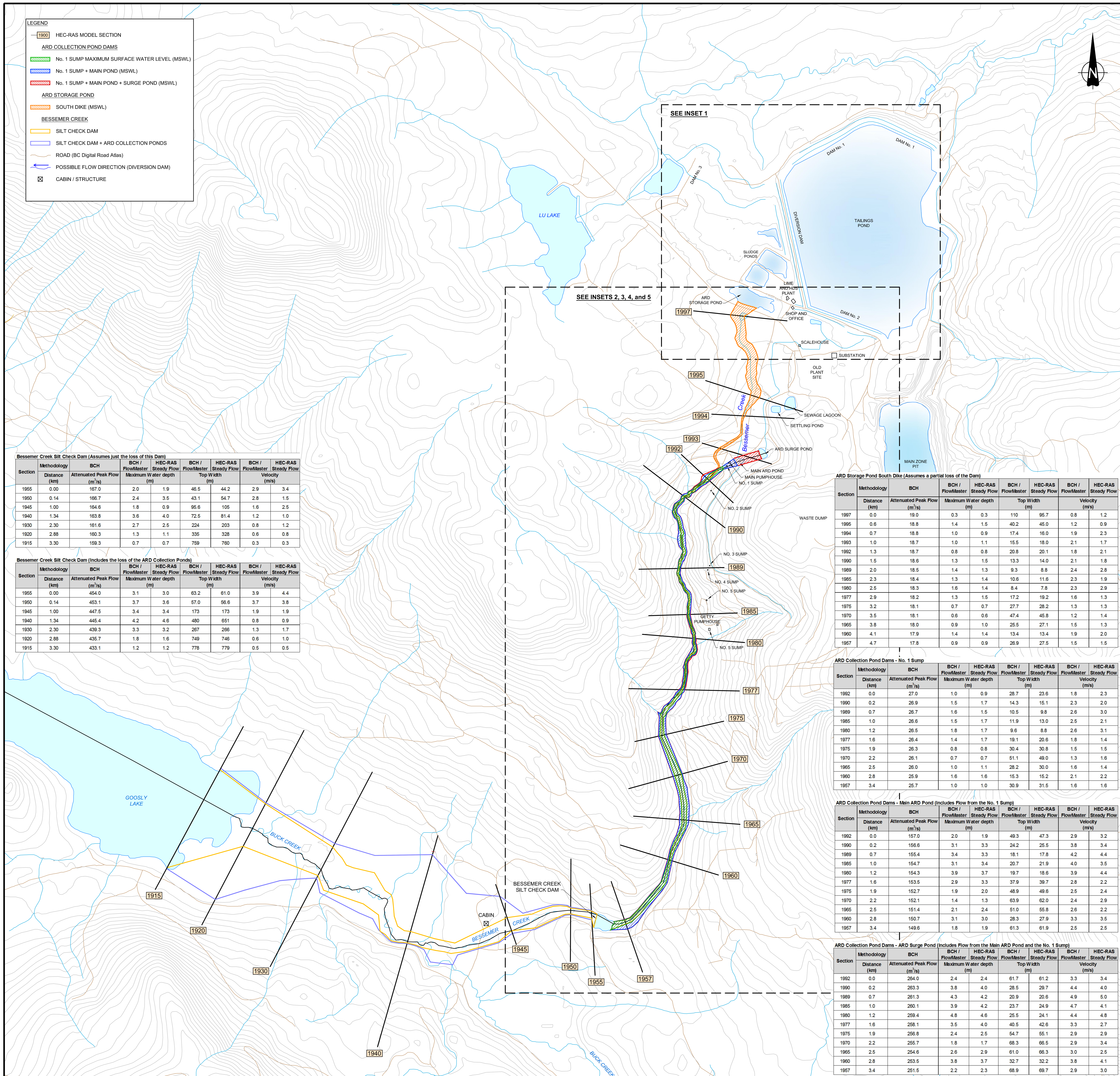
DWN BY:	TH
DESIGN BY:	AF / DA
CHECK BY:	AF
APPR'D BY:	AW
SCALE:	AS SHOWN

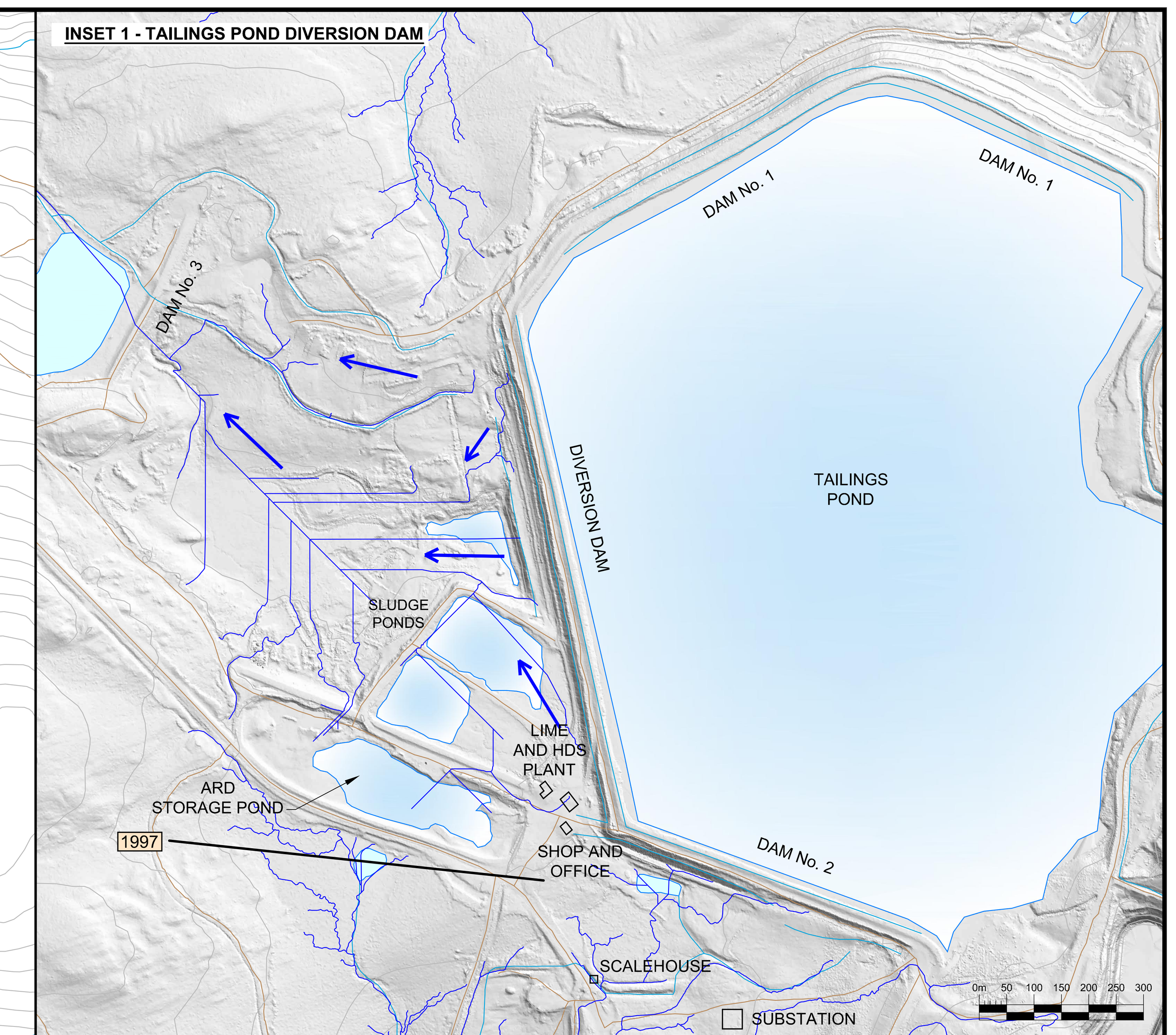
PROJECT: EQUITY SILVER MINE DAM BREAK AND INUNDATION ASSESSMENTS

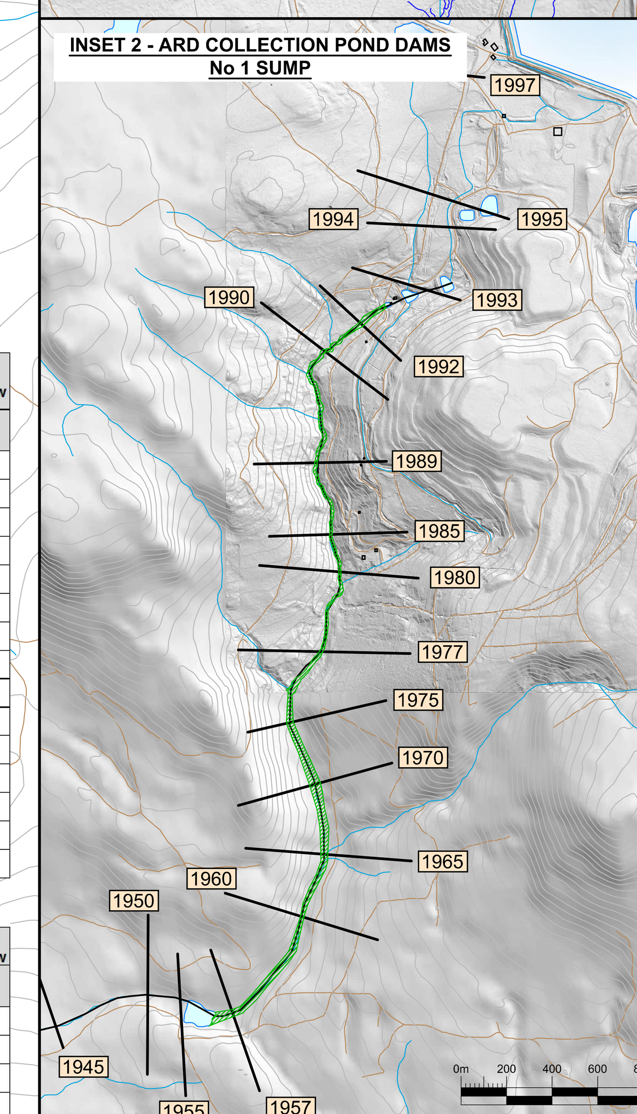
TITLE: HEC-RAS MODEL DAM No.2 (ASSESSMENT 2) CROSS SECTIONS - SHEET 6

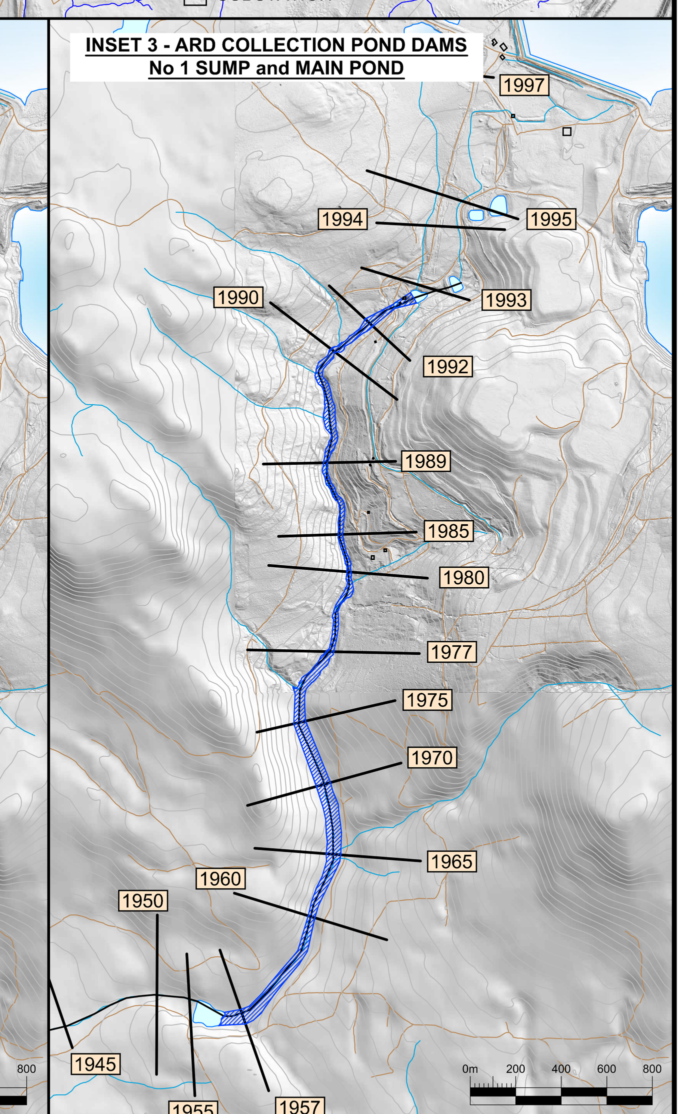
DATE:	NOVEMBER 2014
PROJECT NO:	VM00276A.5.400
REV. NO:	B
DRAWING NO:	DWG06-6

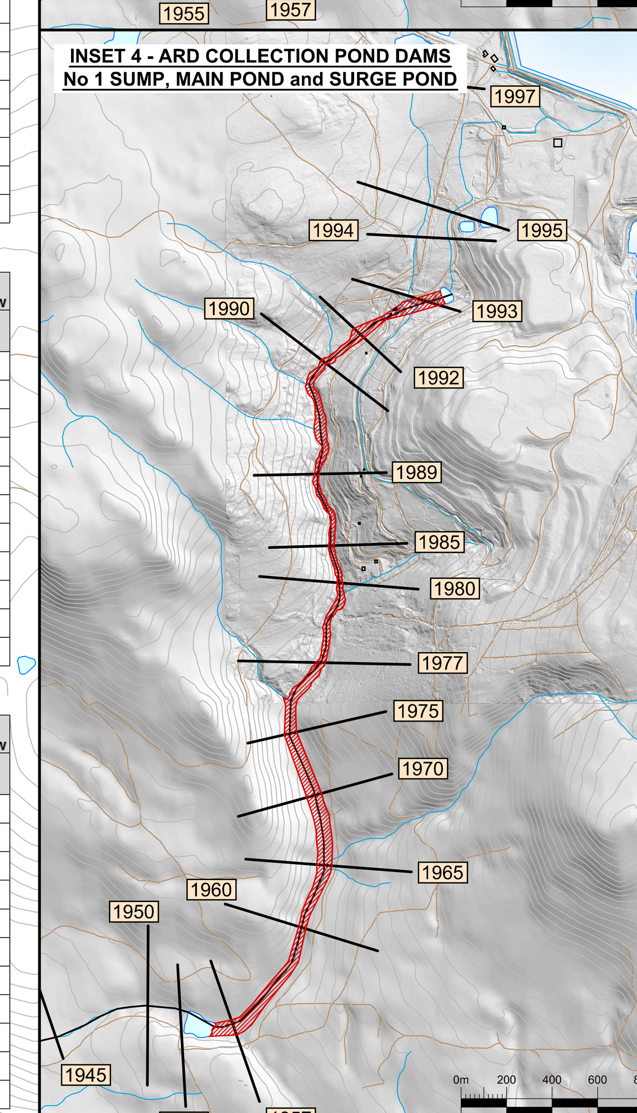
S:\PROJECTS\VM00276A – Equity Silver Mine\DRAWINGS\2014 DBA\VM00276A.5.4-DWG06.dwg – DWG06-6 – Nov. 24, 2014 10:18am – tim.hawker

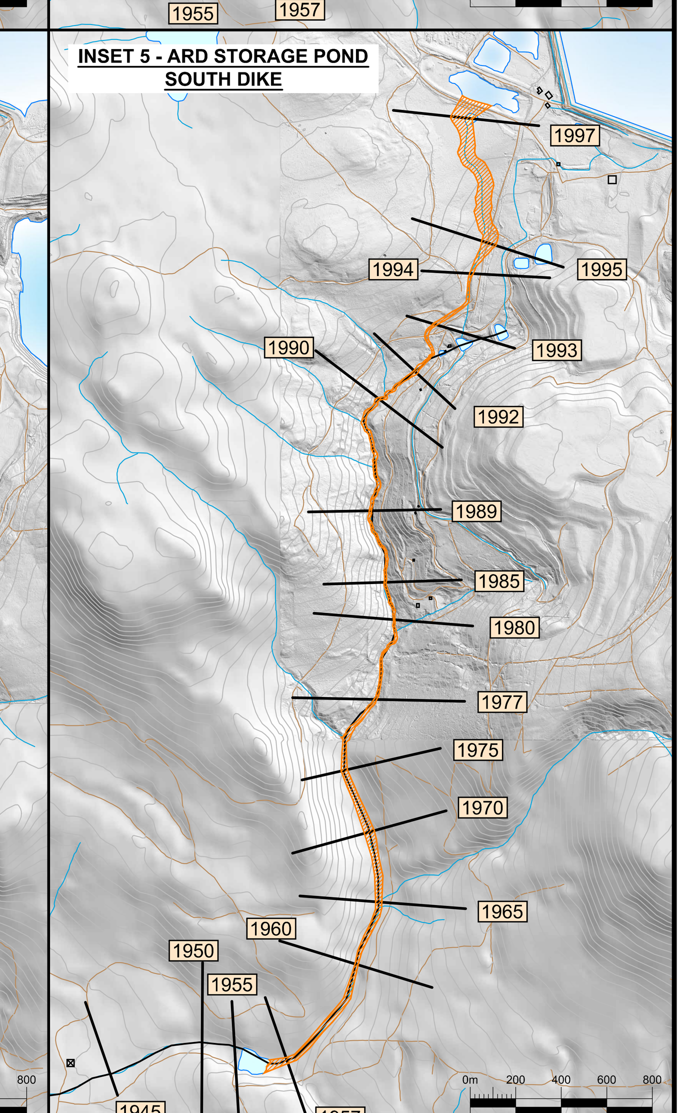












Bessemer Creek Silt Check Dam (Assumes just the loss of this Dam)

Section	Methodology	BCH	BCH / FlowMaster	HEC-RAS Steady Flow	BCH / FlowMaster	HEC-RAS Steady Flow	BCH / FlowMaster	HEC-RAS Steady Flow
	Distance (km)	Attenuated Peak Flow (m^3/s)	Maximum Water depth (m)		Top Width (m)		Velocity (m/s)	
1955	0.00	167.0	2.0	1.9	46.5	44.2	2.9	3.4
1950	0.14	166.7	2.4	3.5	43.1	54.7	2.8	1.5
1945	1.00	164.6	1.8	0.9	95.6	105	1.6	2.5
1940	1.34	163.8	3.6	4.0	72.5	81.4	1.2	1.0
1930	2.30	161.6	2.7	2.5	224	203	0.8	1.2
1920	2.88	160.3	1.3	1.1	335	328	0.6	0.8
1915	3.30	159.3	0.7	0.7	759	760	0.3	0.3

Bessemer Creek Silt Check Dam (Includes the loss of the ARD Collection Ponds)

Section	Methodology	BCH	BCH / FlowMaster	HEC-RAS Steady Flow	BCH / FlowMaster	HEC-RAS Steady Flow	BCH / FlowMaster	HEC-RAS Steady Flow
	Distance (km)	Attenuated Peak Flow (m^3/s)	Maximum Water depth (m)		Top Width (m)		Velocity (m/s)	
1955	0.00	454.0	3.1	3.0	63.2	61.0	3.9	4.4
1950	0.14	453.1	3.7	3.6	57.0	56.6	3.7	3.8
1945	1.00	447.5	3.4	3.4	173	173	1.9	1.9
1940	1.34	445.4	4.2	4.6	480	651	0.8	0.9
1930	2.30	439.3	3.3	3.2	267	266	1.3	1.7
1920	2.88	435.7	1.8	1.6	749	746	0.6	1.0
1915	3.30	433.1	1.2	1.2	778	779	0.5	0.5

ARD Storage Pond South Dike (Assumes a partial loss of the Dam)

Section	Methodology	BCH	BCH / FlowMaster	HEC-RAS Steady Flow	BCH / FlowMaster	HEC-RAS Steady Flow	BCH / FlowMaster	HEC-RAS Steady Flow
	Distance (km)	Attenuated Peak Flow (m^3/s)	Maximum Water depth (m)		Top Width (m)		Velocity (m/s)	
1997	0.0	19.0	0.3	0.3	110	95.7	0.8	1.2
1995	0.6	18.8	1.4	1.5	40.2	45.0	1.2	0.9
1994	0.7	18.8	1.0	0.9	17.4	16.0	1.9	2.3
1993	1.0	18.7	1.0	1.1	15.5	18.0	2.1	1.7
1992	1.3	18.7	0.8	0.8	20.8	20.1	1.8	2.1
1990	1.5	18.6	1.3	1.5	13.3	14.0	2.1	1.8
1989	2.0	18.5	1.4	1.3	9.3	8.8	2.4	2.8
1985	2.3	18.4	1.3	1.4	10.6	11.6	2.3	1.9
1980	2.5	18.3	1.6	1.4	8.4	7.8	2.3	2.9
1977	2.9	18.2	1.3	1.5	17.2	19.2	1.6	1.3
1975	3.2	18.1	0.7	0.7	27.7	28.2	1.3	1.3
1970	3.5	18.1	0.6	0.6	47.4	45.8	1.2	1.4
1965	3.8	18.0	0.9	1.0	25.5	27.1	1.5	1.3
1960	4.1	17.9	1.4	1.4	13.4	13.4	1.9	2.0
1957	4.7	17.8	0.9	0.9	26.9	27.5	1.5	1.5

ARD Collection Pond Dams - No. 1 Sump

Section	Methodology	BCH	BCH / FlowMaster	HEC-RAS Steady Flow	BCH / FlowMaster	HEC-RAS Steady Flow	BCH / FlowMaster	HEC-RAS Steady Flow
	Distance (km)	Attenuated Peak Flow (m^3/s)	Maximum Water depth (m)		Top Width (m)		Velocity (m/s)	
1992	0.0	27.0	1.0	0.9	28.7	23.6	1.8	2.3
1990	0.2	26.9	1.5	1.7	14.3	15.1	2.3	2.0
1989	0.7	26.7	1.6	1.5	10.5	9.8	2.6	3.0
1985	1.0	26.6	1.5	1.7	11.9	13.0	2.5	2.1
1980	1.2	26.5	1.8	1.7	9.6	8.8	2.6	3.1
1977	1.6	26.4	1.4	1.7	19.1	20.6	1.8	1.4
1975	1.9	26.3	0.8	0.8	30.4	30.8	1.5	1.5
1970	2.2	26.1	0.7	0.7	51.1	49.0	1.3	1.6
1965	2.5	26.0	1.0	1.1	28.2	30.0	1.6	1.4
1960	2.8	25.9	1.6	1.6	15.3	15.2	2.1	2.2
1957	3.4	25.7	1.0	1.0	30.9	31.5	1.6	1.6

ARD Collection Pond Dams - Main ARD Pond (Includes Flow from the No. 1 Sump)

Section	Methodology	BCH	BCH / FlowMaster	HEC-RAS Steady Flow	BCH / FlowMaster	HEC-RAS Steady Flow	BCH / FlowMaster	HEC-RAS Steady Flow
	Distance (km)	Attenuated Peak Flow (m^3/s)	Maximum Water depth (m)		Top Width (m)		Velocity (m/s)	
1992	0.0	157.0	2.0	1.9	49.3	47.3	2.9	3.2
1990	0.2	156.6	3.1	3.3	24.2	25.5	3.8	3.4
1989	0.7	155.4	3.4	3.3	18.1	17.8	4.2	4.4
1985	1.0	154.7	3.1	3.4	20.7	21.9	4.0	3.5
1980	1.2	154.3	3.9	3.7	19.7	18.6	3.9	4.4
1977	1.6	153.5	2.9	3.3	37.9	39.7	2.8	2.2
1975	1.9	152.7	1.9	2.0	48.9	49.6	2.5	2.4
1970	2.2	152.1	1.4	1.3	63.9	62.0	2.4	2.9
1965	2.5	151.4	2.1	2.4	51.0	55.8	2.6	2.2
1960	2.8	150.7	3.1	3.0	28.3	27.9	3.3	3.5
1957	3.4	149.6	1.8	1.9	61.3	61.9	2.5	2.5

ARD Collection Pond Dams - ARD Surge Pond (Includes Flow from the Main ARD Pond and the No. 1 Sump)

Section	Methodology	BCH	BCH / FlowMaster	HEC-RAS Steady Flow	BCH / FlowMaster	HEC-RAS Steady Flow	BCH / FlowMaster	HEC-RAS Steady Flow
	Distance (km)	Attenuated Peak Flow (m^3/s)	Maximum Water depth (m)		Top Width (m)		Velocity (m/s)	
1992	0.0	264.0	2.4	2.4	61.7	61.2	3.3	3.4
1990	0.2	263.3	3.8	4.0	28.5	29.7	4.4	4.0
1989	0.7	261.3	4.3	4.2	20.9	20.6	4.9	5.0
1985	1.0	260.1	3.9	4.2	23.7	24.9	4.7	4.1
1980	1.2	259.4	4.8	4.6	25.5	24.1	4.4	4.8
1977	1.6	258.1	3.5	4.0	40.5	42.6	3.3	2.7
1975	1.9	256.8	2.4	2.5	54.7	55.1	2.9	2.9
1970	2.2	255.7	1.8	1.7	68.3	66.5	2.9	3.4
1965	2.5	254.6	2.6	2.9	61.0	66.3	3.0	2.5
1960	2.8	253.5	3.8	3.7	32.7	32.2	3.8	4.1
1957	3.4	251.5	2.2	2.3	68.9	69.7	2.9	3.0

NOTES:

1. MODEL DESIGN SURFACES BASED ON A COMPOSITE OF: LIDAR SURVEY 2008, AND NATIONAL CDED DTM TILES (CANADIAN DIGITAL ELEVATION DATA), NATURAL RESOURCES CANADA.
2. BCH STANDS FOR BC HYDRO FLOW ATTENTUATION RATE METHOD WHICH USES PEAK DISCHARGE FROM A DAM BREACH AND DISTANCE ALONG THE CHANNEL TO ESTIMATE ATTENUATED FLOW (1998).
3. THE HEC-RAS MODEL ASSUMES A STEADY PEAK FLOW AT THE DAM THAT IS NOT ATTENUATED.
4. ALL SIMPLIFIED ASSESSMENTS HAVE BEEN TIED INTO THEIR ASSOCIATED STRUCTURES. NO DETAILED MODELING WAS PERFORMED ON THE STRUCTURES.
5. THIS DRAWING SHOULD BE READ IN CONJUNCTION WITH THE AMEC ENVIRONMENT & INFRASTRUCTURE REPORT No.VM00276A.5.400 DATED NOVEMBER 2014.

REV	D	M	Y	ISSUE / REVISION DESCRIPTION	ENG.	APPR.
5						
4						
3						
2						
1						
B	21	11	14	ISSUED WITH FINAL REPORT	AF/JW	AW
A	14	11	14	ISSUED WITH DRAFT REPORT	AF/JW	AW

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CLIENT: GOLDCORP CANADA LTD

DESIGNED BY: JW / DA
DRAWN BY: TH
CHECKED BY: AF
APPROVED BY: AW
SCALE: AS SHOWN

PROJECT: EQUITY SILVER MINE DAM BREAK AND INUNDATION ASSESSMENTS

TITLE: ARD COLLECTION POND DAMS, ARD STORAGE POND SOUTH DIKE, BESSEMER CREEK SILT CHECK DAM AND TAILINGS POND DIVERSION DAM SIMPLIFIED INUNDATION ASSESSMENTS

PROJECT NO: VM00276A.5.400
REVISION NO: B
DATE: NOVEMBER 2014
DRAWING NO: DWG07

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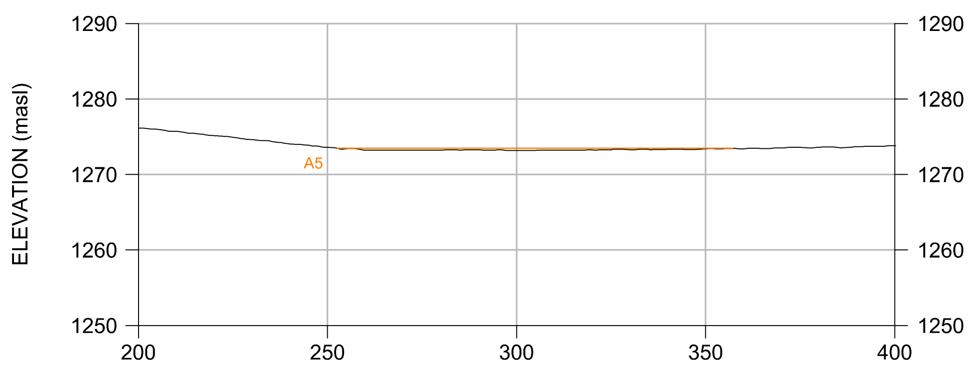

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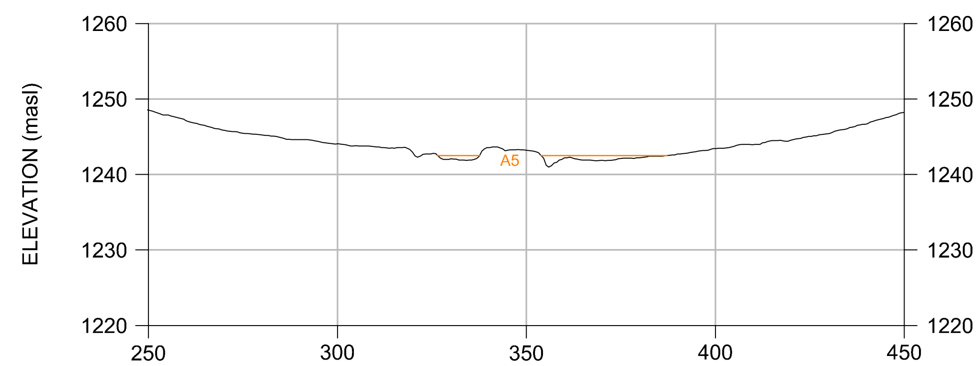

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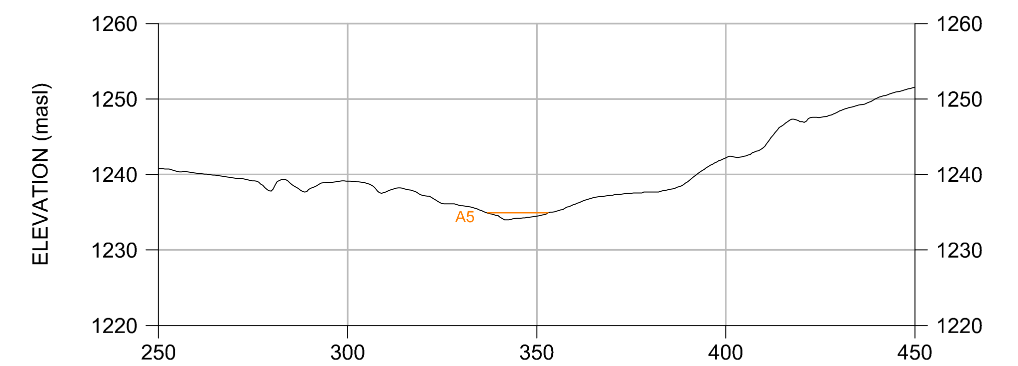

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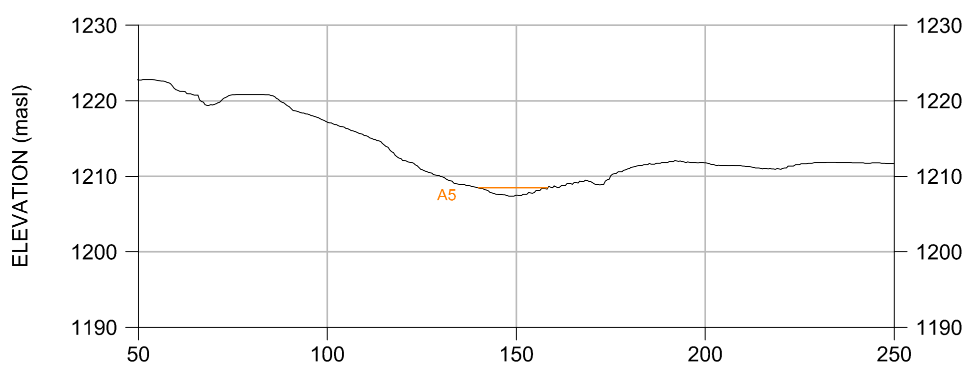

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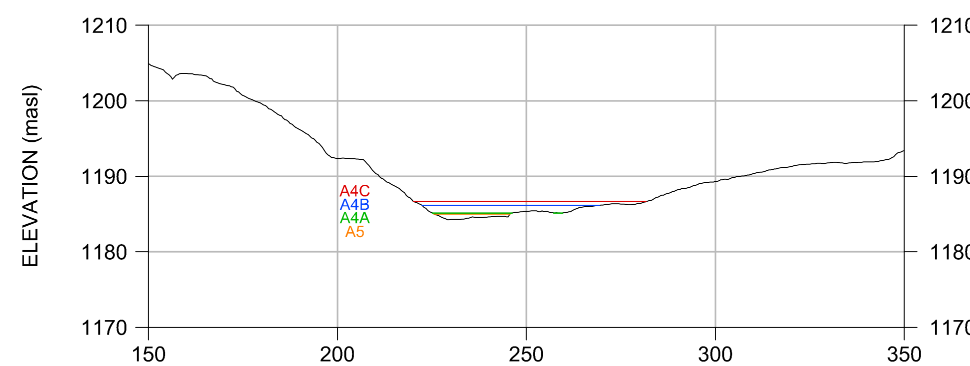

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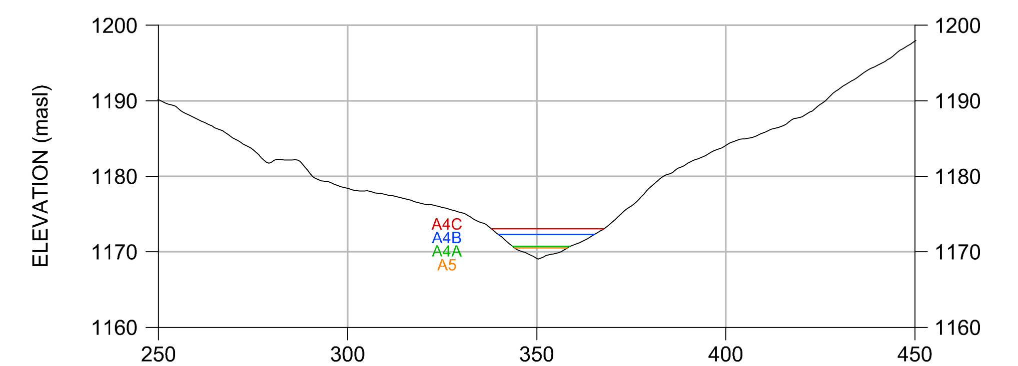

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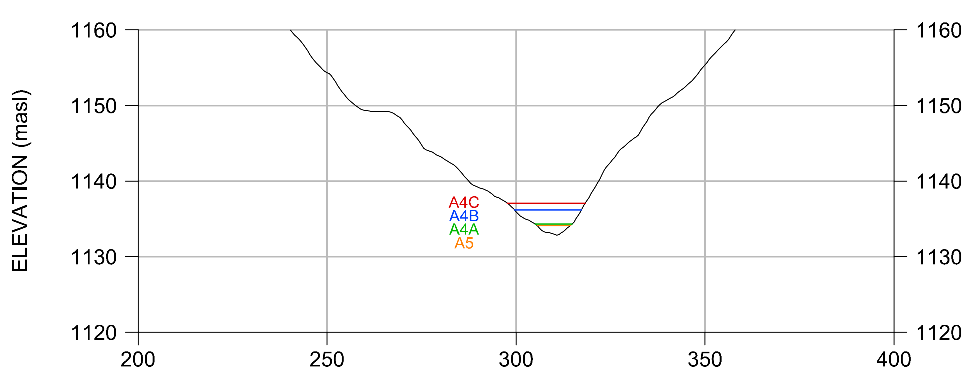

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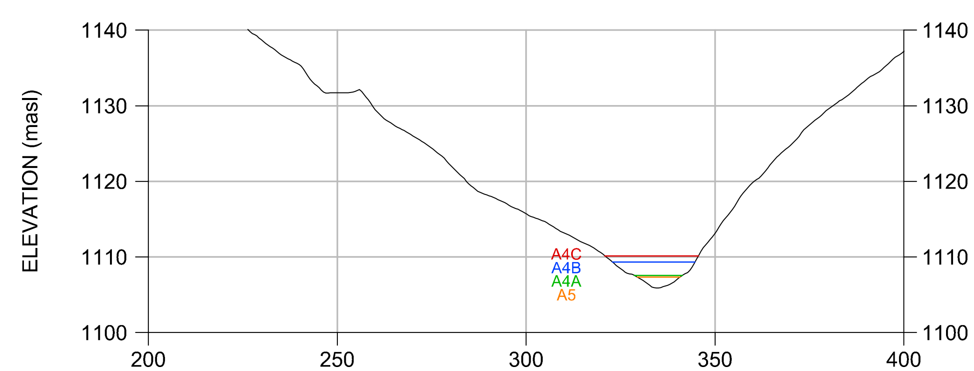

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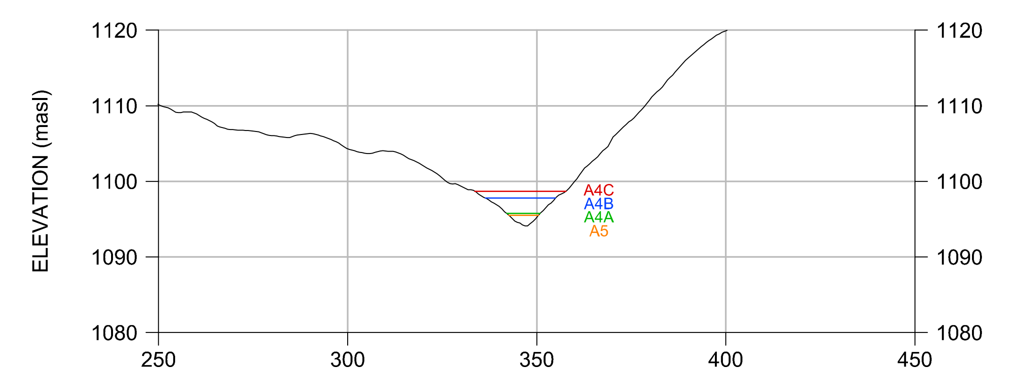

SECTION 1980

NOTE: SECTIONS HAVE BEEN VERTICALLY EXAGGERATED AND TRUNCATED FOR PRESENTATION CLARITY, AND WILL NOT REFLECT THE EXACT SECTION LIMITS DISPLAYED IN DRAWING 007.

NOTE:
THIS DRAWING SHOULD BE READ IN CONJUNCTION WITH THE AMEC ENVIRONMENT & INFRASTRUCTURE REPORT No. VM00276A.5.400 DATED NOVEMBER 2014.

0m 20 40 60 80 — Horizontal

0m 10 20 30 40 — Vertical

LEGEND:
High Water Levels
- ASSESSMENT 4A
- ASSESSMENT 4B
- ASSESSMENT 4C
- ASSESSMENT 5
- ASSESSMENT 6A
- ASSESSMENT 6B

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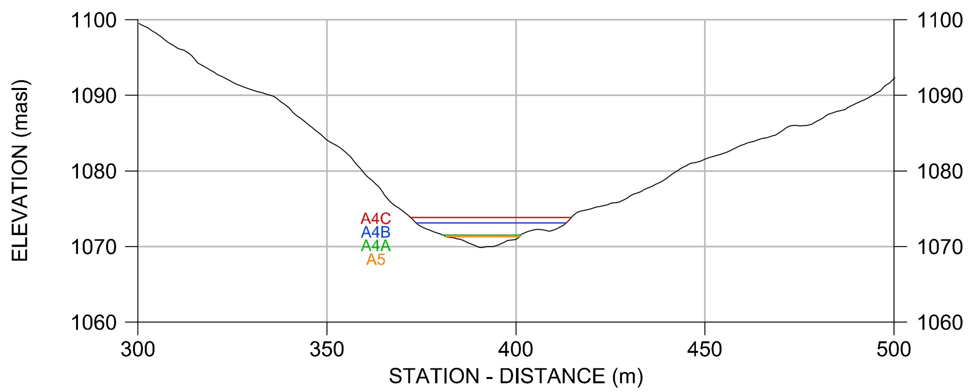
DWN BY:	TH
DESIGN BY:	JW / DA
CHECK BY:	AF
APPR'D BY:	AW
SCALE:	AS SHOWN
PROJECT:	EQUITY SILVER MINE DAM BREAK AND INUNDATION ASSESSMENTS
TITLE:	ARD COLLECTION POND DAMS (ASSESSMENTS 4ABC) ARD STORAGE POND SOUTH DIKE (ASSESSMENT 5) CROSS SECTIONS - SHEET 1
DATE:	NOVEMBER 2014
PROJECT NO:	VM00276A.5.400
REV. NO:	B
DRAWING NO:	DWG08-1



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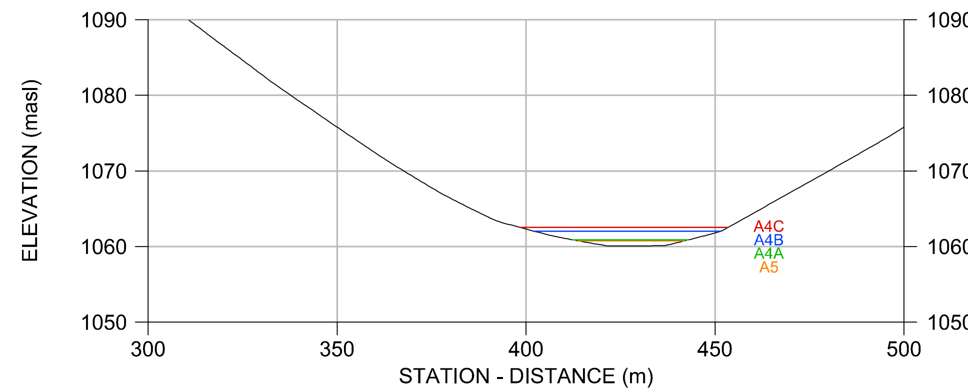

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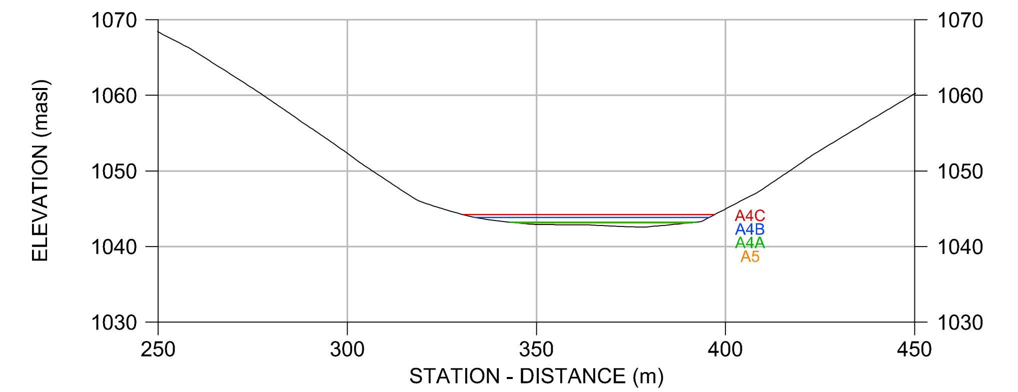

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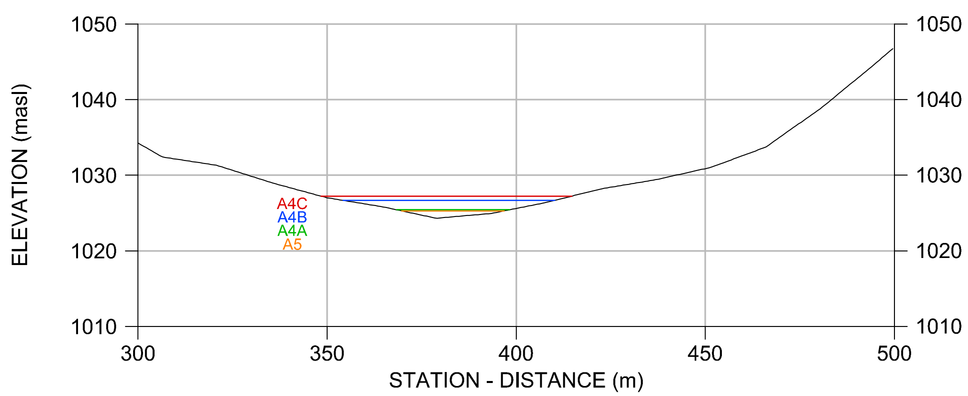

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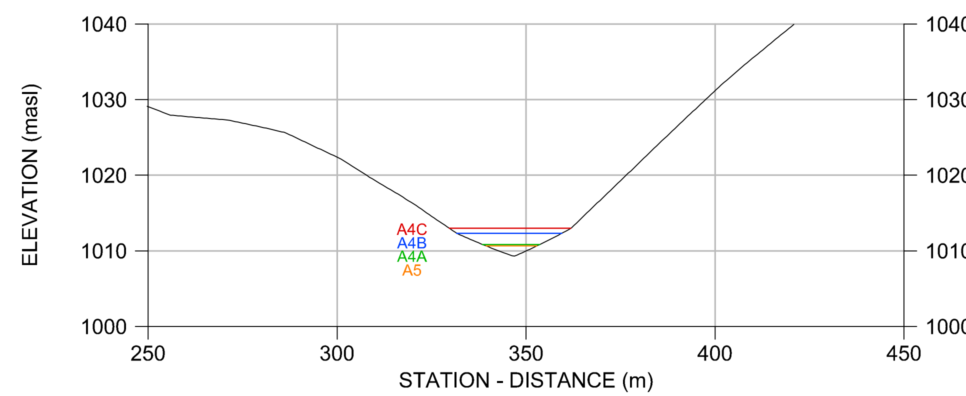

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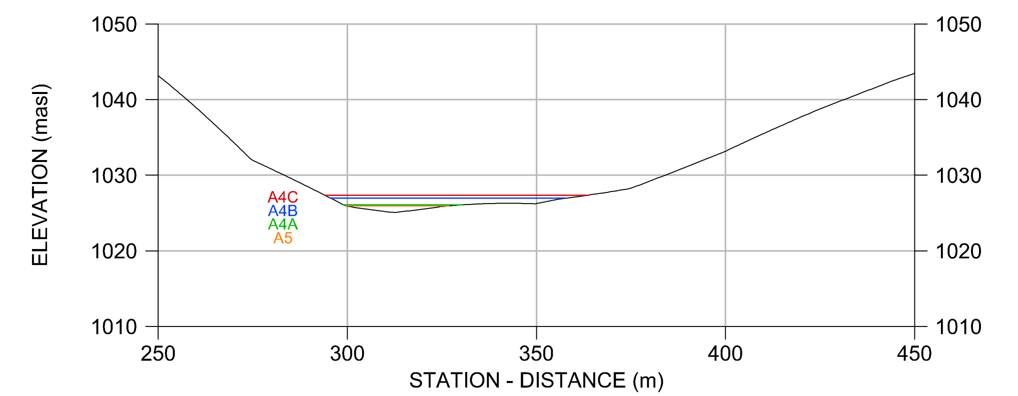

SECTION 1957

NOTE: SECTIONS HAVE BEEN VERTICALLY EXAGGERATED AND TRUNCATED FOR PRESENTATION CLARITY, AND WILL NOT REFLECT THE EXACT SECTION LIMITS DISPLAYED IN DRAWING 007.

NOTE:
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0m 20 40 60 80
Horizontal

0m 10 20 30 40
Vertical

LEGEND:
High Water Levels
- ASSESSMENT 4A
- ASSESSMENT 4B
- ASSESSMENT 4C
- ASSESSMENT 5
- ASSESSMENT 6A
- ASSESSMENT 6B

CLIENT:
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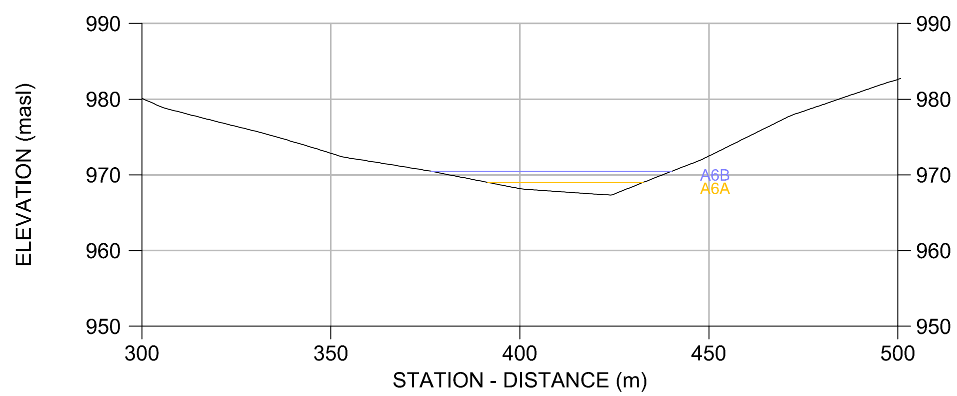
amec

DWN BY:	TH
DESIGN BY:	JW / DA
CHECK BY:	AF
APPR'D BY:	AW
SCALE:	AS SHOWN

PROJECT:
EQUITY SILVER MINE
DAM BREAK AND INUNDATION ASSESSMENTS

TITLE:
ARD COLLECTION POND DAMS (ASSESSMENTS 4ABC)
ARD STORAGE POND SOUTH DIKE (ASSESSMENT 5)
CROSS SECTIONS - SHEET 2

DATE:	NOVEMBER 2014
PROJECT NO:	VM00276A.5.400
REV. NO:	B
DRAWING NO:	DWG08-2



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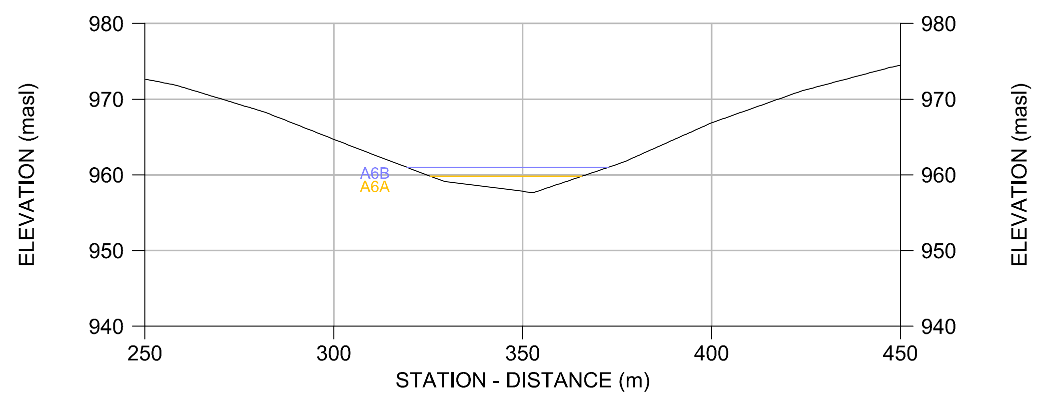

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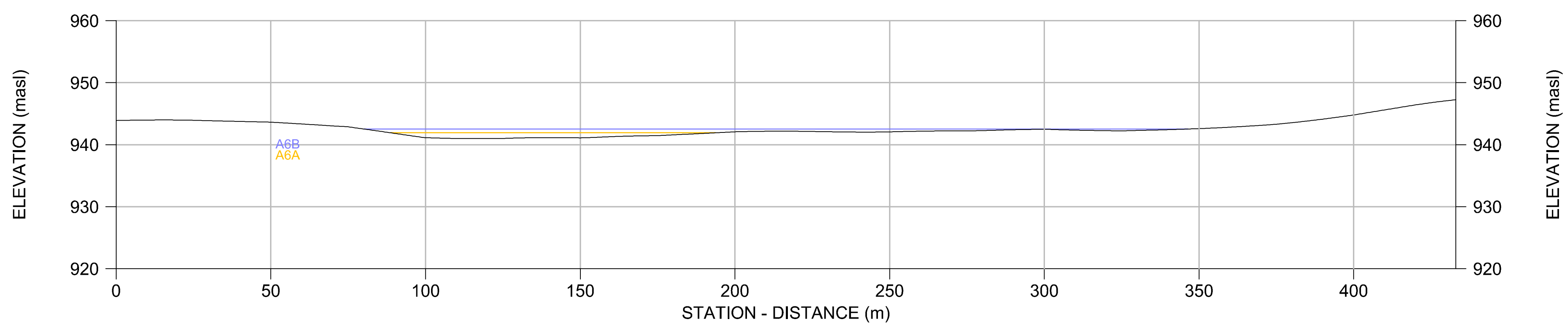

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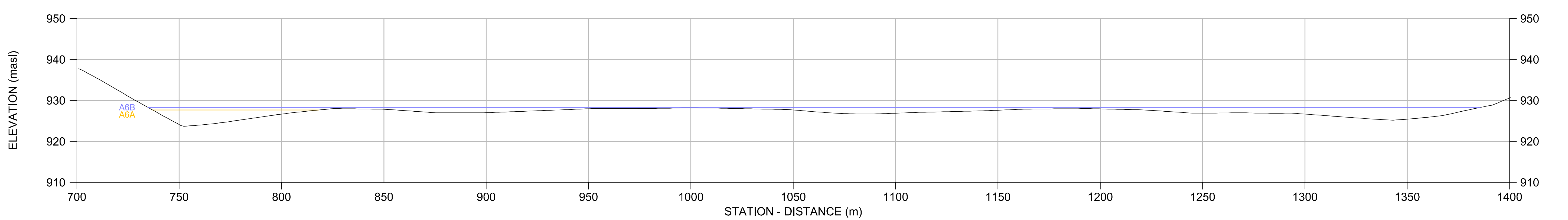

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NOTE: SECTIONS HAVE BEEN VERTICALLY EXAGGERATED AND TRUNCATED FOR PRESENTATION CLARITY, AND WILL NOT REFLECT THE EXACT SECTION LIMITS DISPLAYED IN DRAWING 007.

NOTE:
THIS DRAWING SHOULD BE READ IN CONJUNCTION WITH THE AMEC ENVIRONMENT & INFRASTRUCTURE REPORT No. VM00276A.5.400 DATED NOVEMBER 2014.

Horizontal: 0m 20 40 60 80

Vertical: 0m 10 20 30 40

LEGEND:
High Water Levels
- ASSESSMENT 4A
- ASSESSMENT 4B
- ASSESSMENT 4C
- ASSESSMENT 5
- ASSESSMENT 6A
- ASSESSMENT 6B

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DWN BY:	TH
DESIGN BY:	JW / DA
CHECK BY:	AF
APPR'D BY:	AW
SCALE:	AS SHOWN

PROJECT:
EQUITY SILVER MINE
DAM BREAK AND INUNDATION ASSESSMENTS

TITLE:
BESSEMER CREEK SILT CHECK DAM (ASSESSMENTS 6AB)
CROSS SECTIONS - SHEET 1

DATE:	NOVEMBER 2014
PROJECT NO:	VM00276A.5.400
REV. NO:	B
DRAWING NO:	DWG08-3

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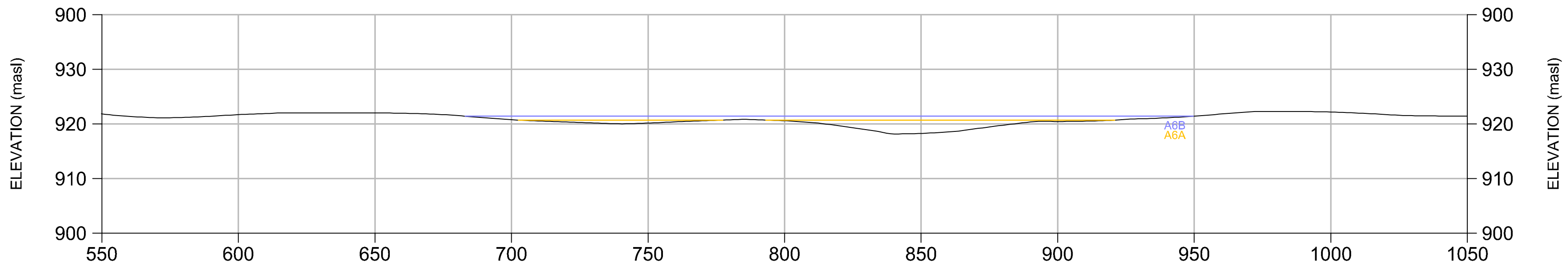

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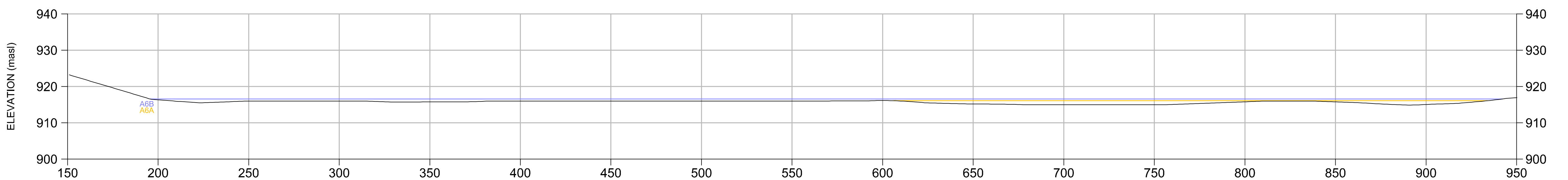

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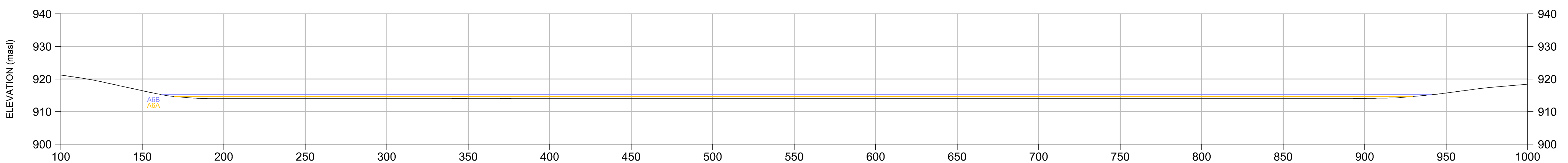

SECTION 1915

NOTE: SECTIONS HAVE BEEN VERTICALLY EXAGGERATED AND TRUNCATED FOR PRESENTATION CLARITY, AND WILL NOT REFLECT THE EXACT SECTION LIMITS DISPLAYED IN DRAWING 007.

NOTE:
THIS DRAWING SHOULD BE READ IN CONJUNCTION WITH THE AMEC ENVIRONMENT & INFRASTRUCTURE REPORT No. VM00276A.5.400 DATED NOVEMBER 2014.

0m 20 40 60 80 — Horizontal

0m 10 20 30 40 — Vertical

LEGEND:
High Water Levels
- ASSESSMENT 4A
- ASSESSMENT 4B
- ASSESSMENT 4C
- ASSESSMENT 5
- ASSESSMENT 6A
- ASSESSMENT 6B

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SCALE:	AS SHOWN

PROJECT:
EQUITY SILVER MINE
DAM BREAK AND INUNDATION ASSESSMENTS

TITLE:
BESSEMER CREEK SILT CHECK DAM (ASSESSMENTS 6AB)
CROSS SECTIONS - SHEET 2

DATE:	NOVEMBER 2014
PROJECT NO:	VM00276A.5.400
REV. NO:	B
DRAWING NO:	DWG08-4

APPENDIX A

Photos

Photo 1: Aerial photograph of the Tailings Pond Dam No. 1 with Seepage Pond in foreground and treatment facilities in the background. Taken 29 August 2006.

Photo 2: Aerial photograph of the Main Zone Pit and Tailings Pond Dam No. 2 with treatment facilities on the left of the photograph. Note electrical substation in open area directly downstream of Dam No. 2. Taken 29 August 2006.

Photo 3: Aerial photograph of the Tailings Pond Diversion Dam and downstream treatment facilities. Taken 29 August 2006.

Photo 4: Tailings Impoundment spillway channel and outlet into Berzelius Diversion Channel. Taken 18 September 2014.

Photo 5: Aerial photograph of the ARD Storage Pond, treatment facilities and offices, and Tailings Pond with Dam No. 2 in the background. Taken 29 August 2006.

Photo 6: ARD Storage Pond, view of the pond and upstream side of the dam, and the South Dam on the left hand side of the photo. Note low water level. Taken 29 August 2006.

Photo 7: Aerial photograph of the ARD Surge Pond and Main ARD Pond with associated infrastructure. Taken 29 August 2006.

Photo 8: ARD Surge Pond and Main ARD Pond, view from the waste dump above. Taken 18 September 2014.

Photo 9: ARD Surge Pond, view of upstream slope and spillway inlet pipes.
Taken 18 September 2014.

Photo 10: Main ARD Pond Dam, view of upstream side. Taken 18 September 2014.

Photo 11: No. 1 Sump Dam, view of upstream crest and road. Taken 18 September 2014.

Photo 12: Typical view of Bessemer Creek downstream of the ARD Collection Ponds.
Taken 18 September 2014.

Photo 13: Bessemer Creek Silt Check Dam, view of upstream face and pond from right abutment. Taken 18 September 2014.

Photo 14: Cabin located downstream of Bessemer Creek Silt Check Dam. Taken 18 September 2014.

Photo 15: Buck Creek looking downstream from the bridge crossing adjacent to the Bessemer Creek confluence. Taken 18 September 2014.

Photo 16: Buck Creek Upper Falls looking downstream.
Taken 18 September 2014.

Photo 17: Bridge on Foxy Creek downstream of the confluence with Maxan Lake outlet. Taken 18 September 2014.

Photo 18: Outlet of Bulkley Lake. Taken 18 September 2014.

Photo 19: Railway Crossing downstream of the Bulkley Lake outlet. Taken 18 September 2014.

Photo 20: Residences downstream of Bulkley Lake outlet. Taken 18 September 2014.

APPENDIX B

Dam No. 1 (Assessment 1) HEC-RAS Modelling Results

Figure B.1: Flood-Induced Failure Peak Flow for Dam No. 1 (Assessment 1)

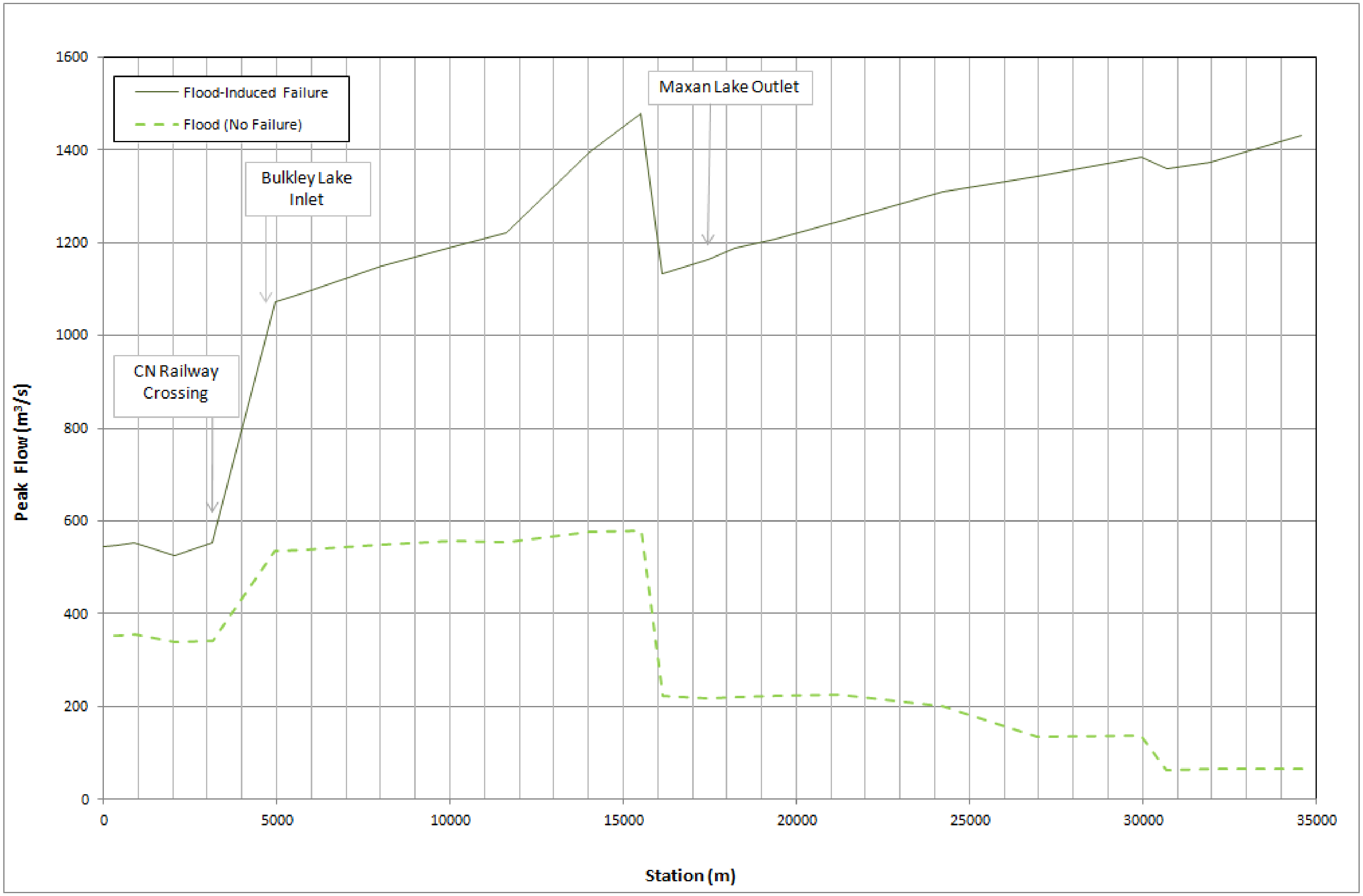


Figure B.2: Sunny-Day Failure Peak Flow for Dam No. 1 (Assessment 1)

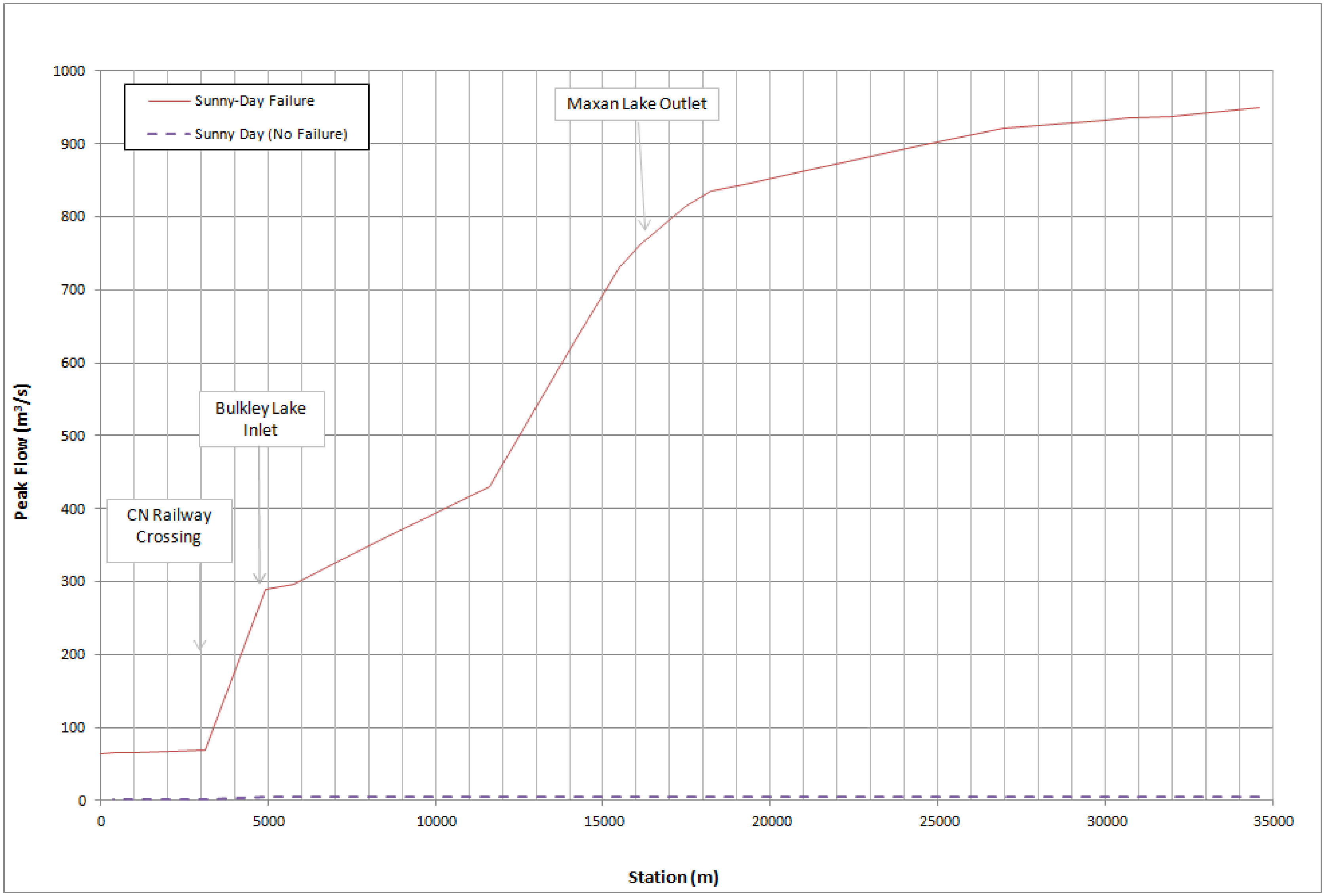


Figure B.3: Flood-Induced Failure Maximum Depth for Dam No. 1 (Assessment 1)

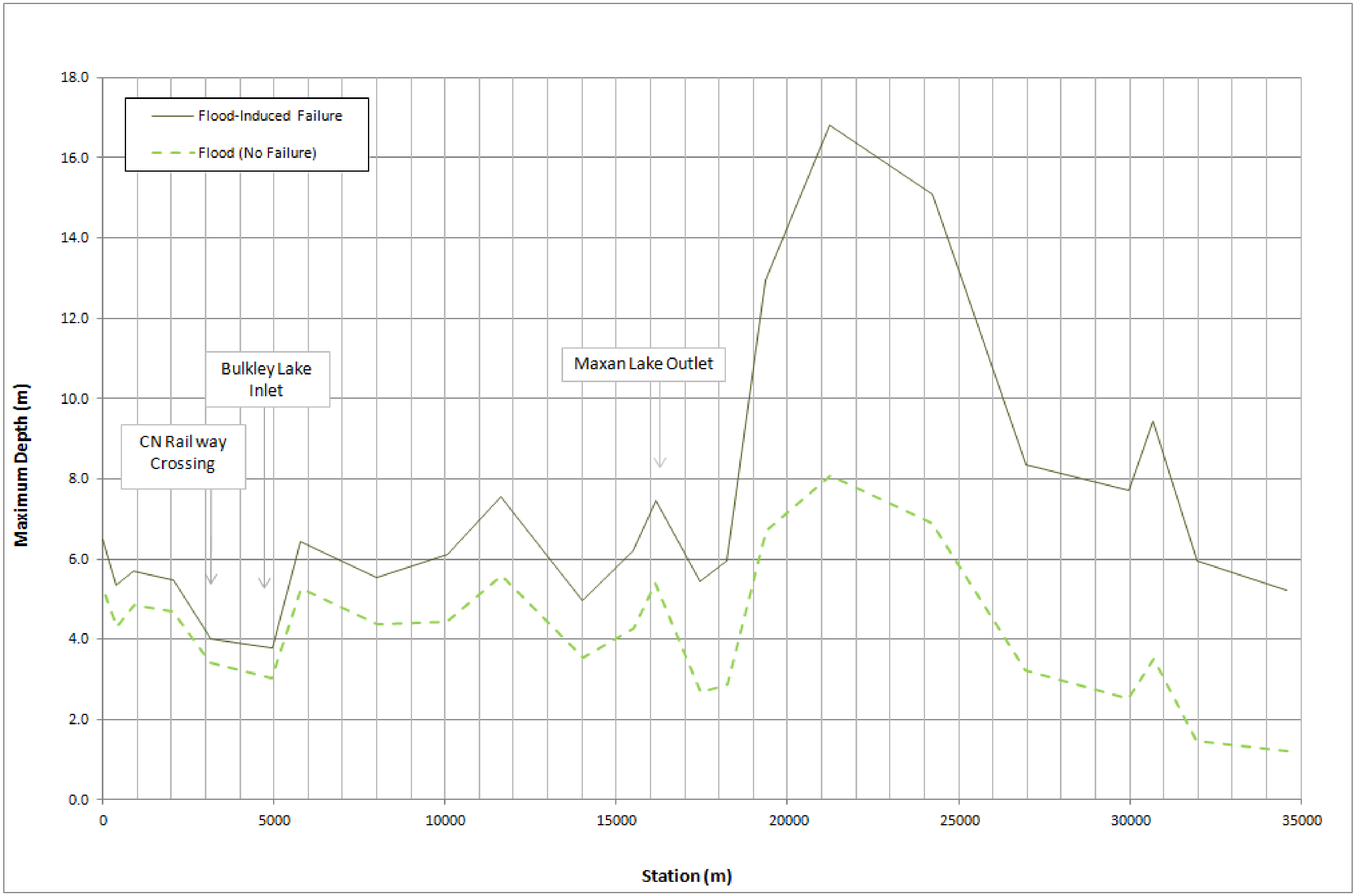


Figure B.4: Sunny-Day Failure Maximum Depth for Dam No. 1 (Assessment 1)

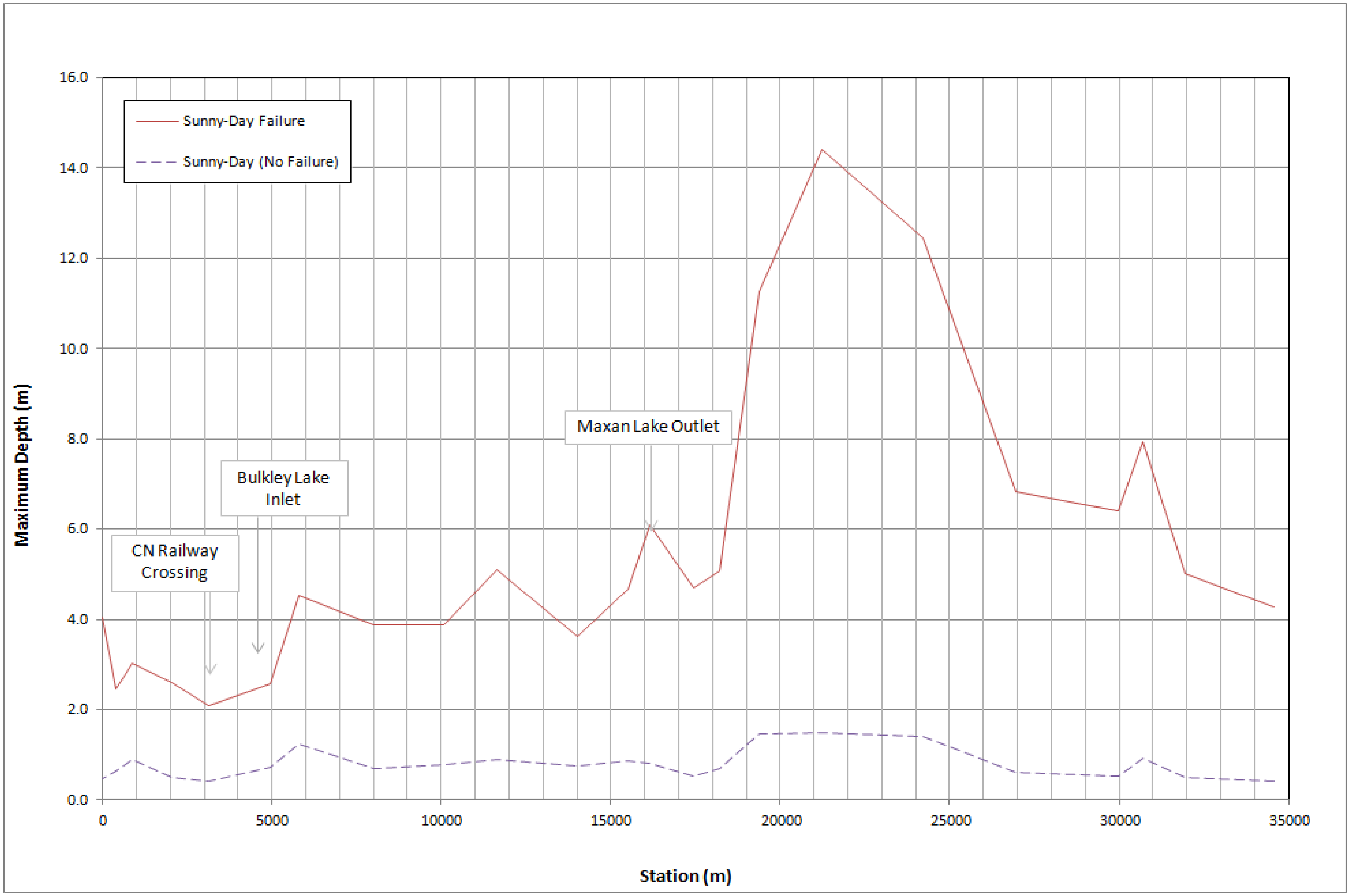
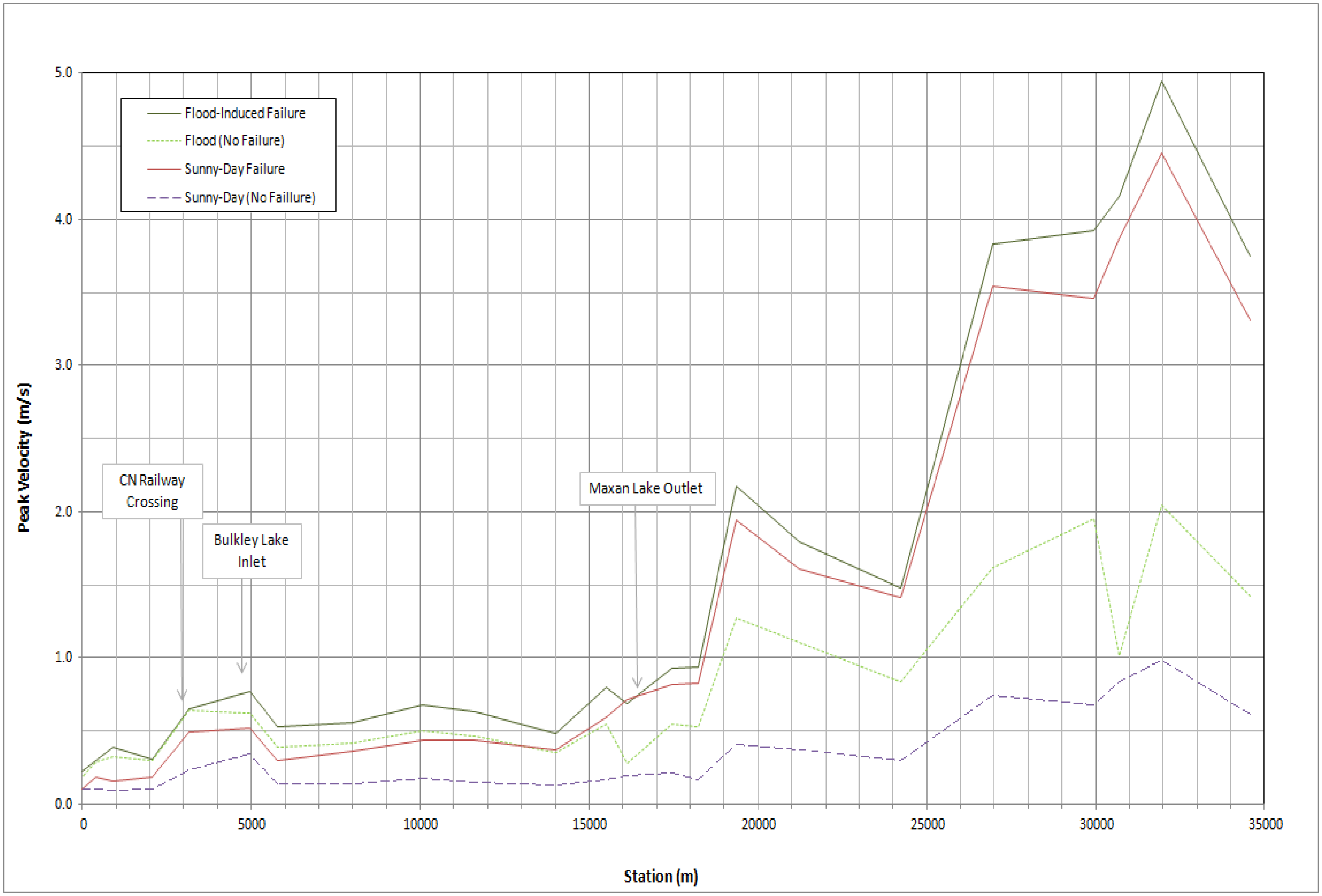


Figure B.5: Peak Velocity for Dam No. 1 (Assessment 1)



APPENDIX C

Dam No. 2 (Assessment 2) HEC-RAS Modelling Results

Figure C.1: Flood-Induced Failure Peak Flow for Dam No. 2 (Assessment 2)

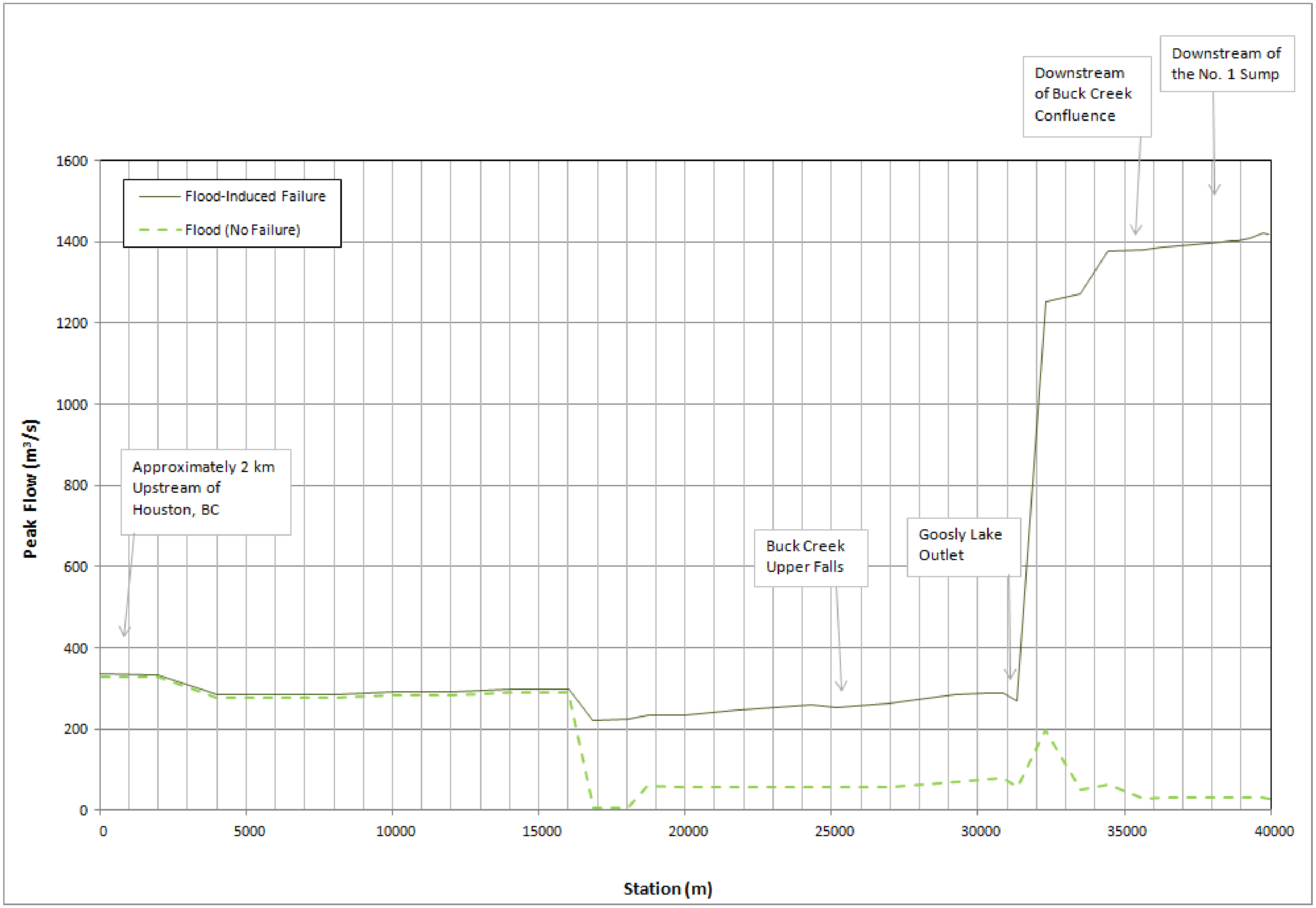


Figure C.2: Sunny-Day Failure Peak Flow for Dam No. 2 (Assessment 2)

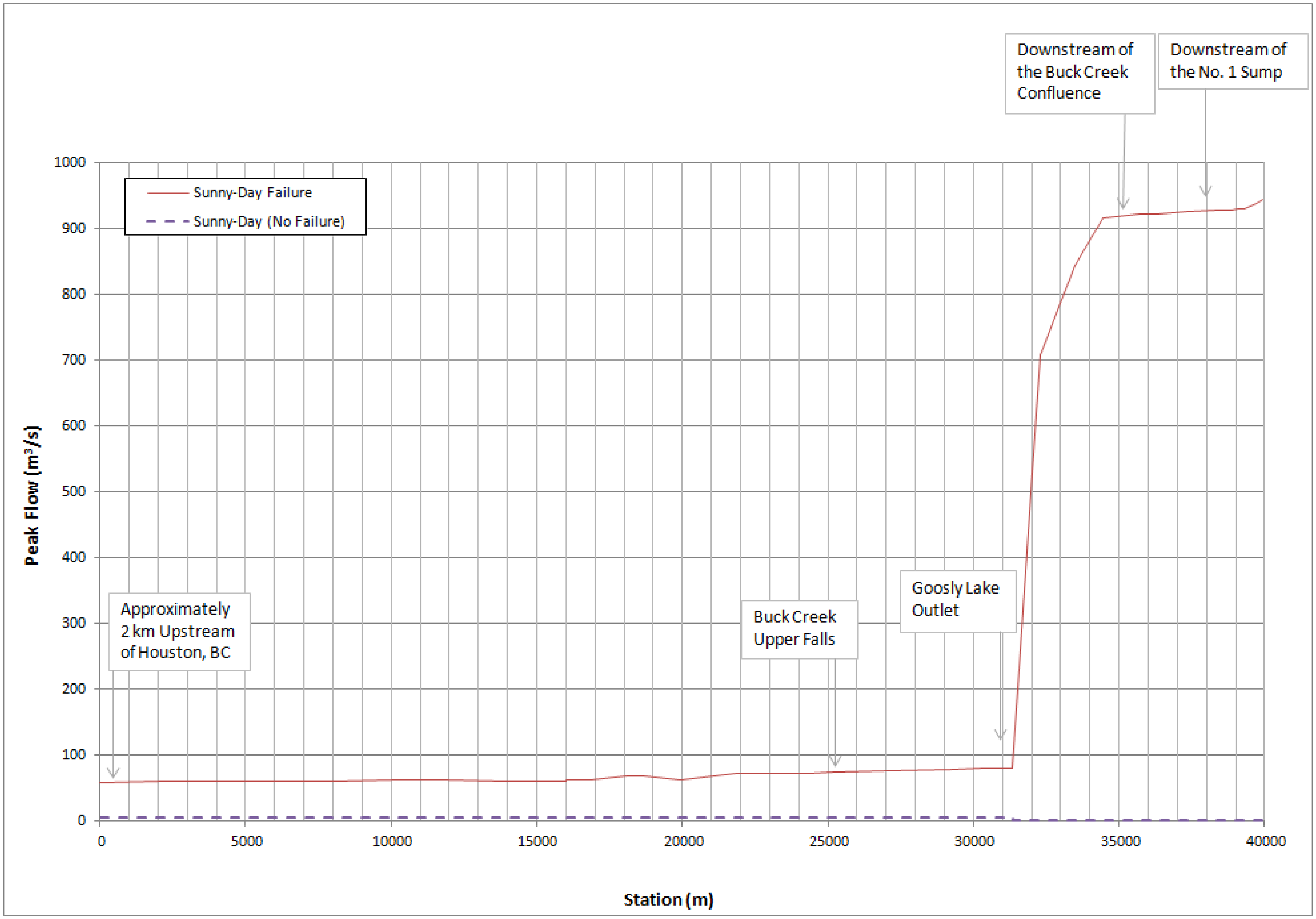


Figure C.3: Flood-Induced Failure Maximum Depth for Dam No. 2 (Assessment 2)

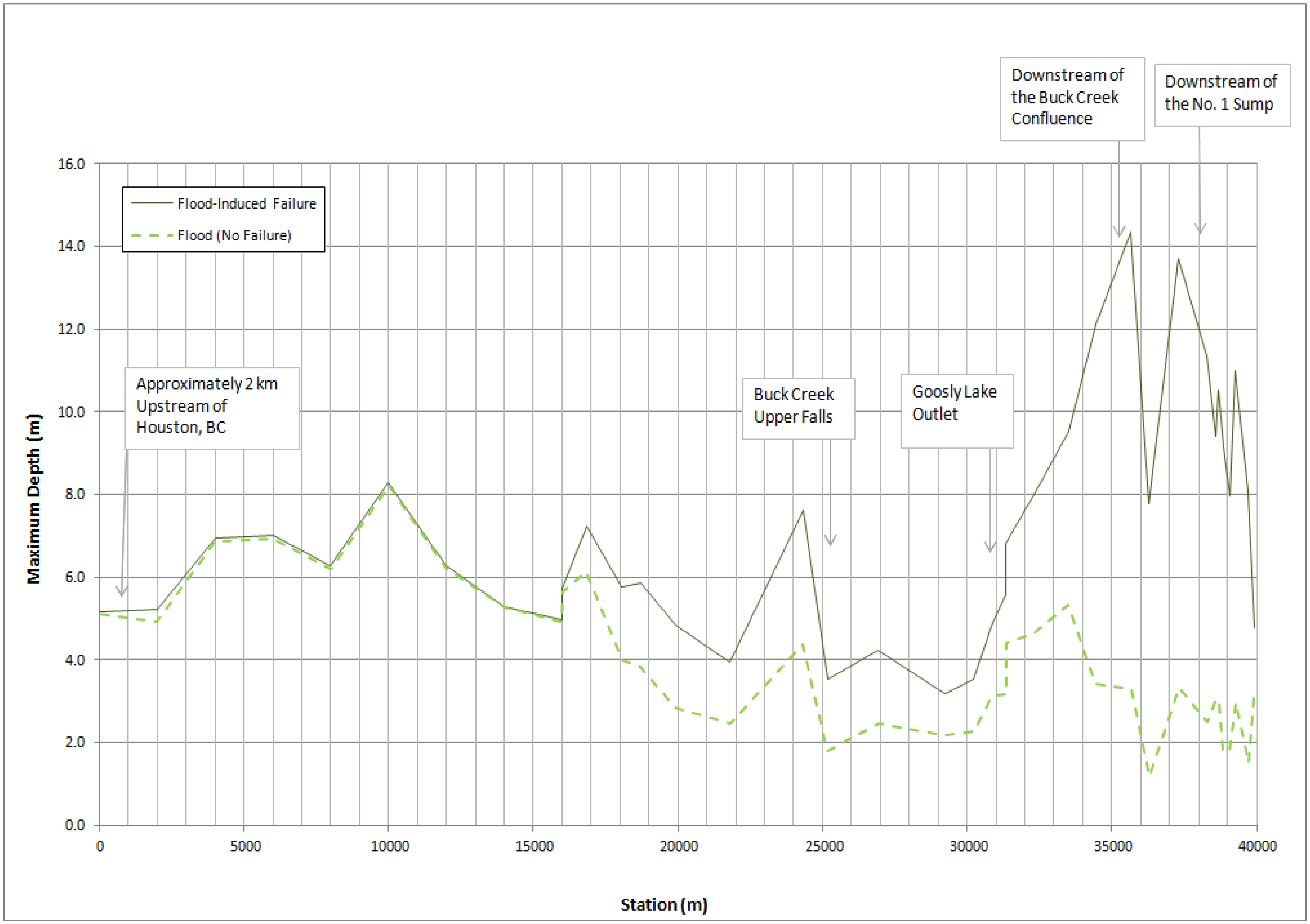


Figure C.4: Sunny-Day Failure Maximum Depth for Dam No. 2 (Assessment 2)

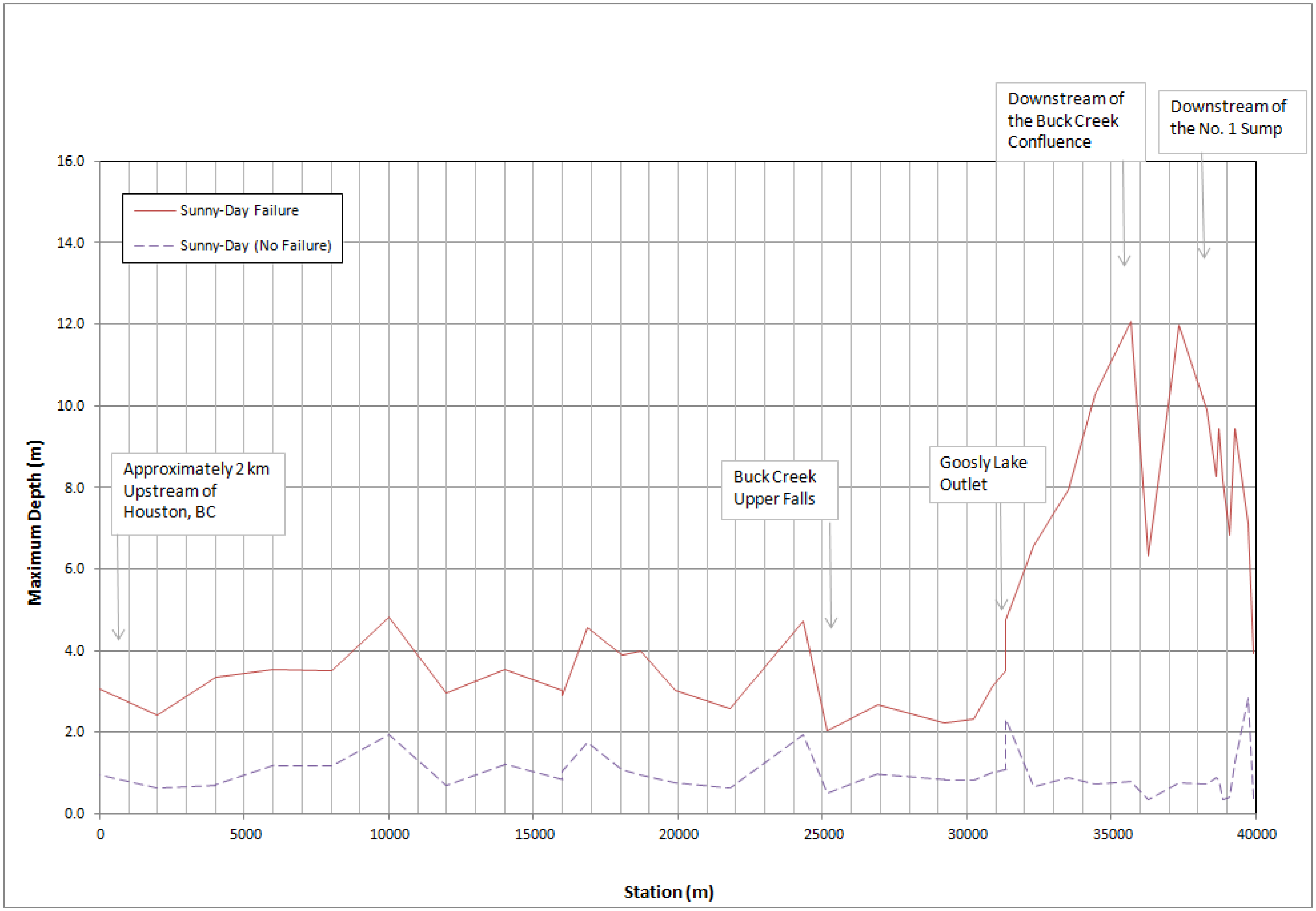


Figure C.5: Peak Velocity for Dam No. 2 (Assessment 2)