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COPPER MOUNTAIN MINE
TAILINGS MANAGEMENT FACILITY
DAM BREACH INUNDATION STUDY
REVISION 1

Submitted to:

Copper Mountain Mine (BC) Ltd.
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IMPORTANT NOTICE

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1.0 INTRODUCTION

AMEC Environment & Infrastructure, a division of AMEC Americas Limited (AMEC) was retained by Copper Mountain Mine (BC) Ltd. (CMML) to perform a Dam Breach Inundation Study for the Copper Mountain Mine (CMM) Tailings Management Facility (TMF). The TMF includes two dams, an East Dam and a West Dam. The objective of the study is to predict the potential effects of a worst case catastrophic failure in order to provide CMML, regulatory and public safety personnel with information to assist disaster scenario response planning. In order to achieve this objective, the study assesses the potential magnitude, extent, and impacts of an uncontrolled release of tailings and water resulting from a hypothetical breach of either of the two TMF tailings dams.

The two TMF dams have been designed to withstand the Maximum Credible Earthquake (MCE) as well as the Probable Maximum Flood (PMF), as documented in a previous AMEC report (AMEC 2011b). Those two design criteria represent the most extreme loadings used in dam design, i.e., greater loadings would be considered unreasonably excessive and without justifiable physical rationale. Failure of either the East Dam or West Dam is, therefore, considered extremely unlikely. Nevertheless, the consequences of a hypothetical dam breach have been assessed and reported, in order to meet regulatory requirements, and to provide input to emergency preparedness and response planning for the mine.

2.0 BACKGROUND

2.1 Project Description

The Copper Mountain Mine, operated by CMML, is located approximately 15 km southwest of Princeton, in south-central British Columbia. The project area is situated approximately 300 km from Vancouver, at Lat. 49° 20’ N, Long. 120° 31’ W. Elevations at the site range from 770 m to 1,300 m. The TMF is located in a valley, which trends east-west and is bounded by the Similkameen River Valley to the west and the Wolfe Creek Valley to the east (refer to **Figure 2.1**). Access to the Copper Mountain Mine area is from Princeton via an existing paved 20 km public access road, known locally as the Copper Mountain Mine Road.

Open pit production mining and use of the TMF commenced in 1972. The mine continued to operate until November 1996 at which time operations were suspended due to market conditions. The mine and the tailings area remained inactive until the mine was reopened in 2011.

The TMF is contained by two tailings dams located at the east and west ends of the valley (refer to **Figure 2.2** and **Figure 2.3**). Initially, the dams were constructed using the centerline method of construction, with the cycloned sands and talus materials mechanically placed and compacted downstream of centerline. From 1980 to 1996, the dams were raised using both centerline and upstream construction methods with the cycloned sand being placed by direct deposition (spigotting) without compaction. All total tailings and cyclone overflow were directed to the interior of the impoundment. Process water was reclaimed from the supernatant pond within the impoundment, which was located towards the East Dam.

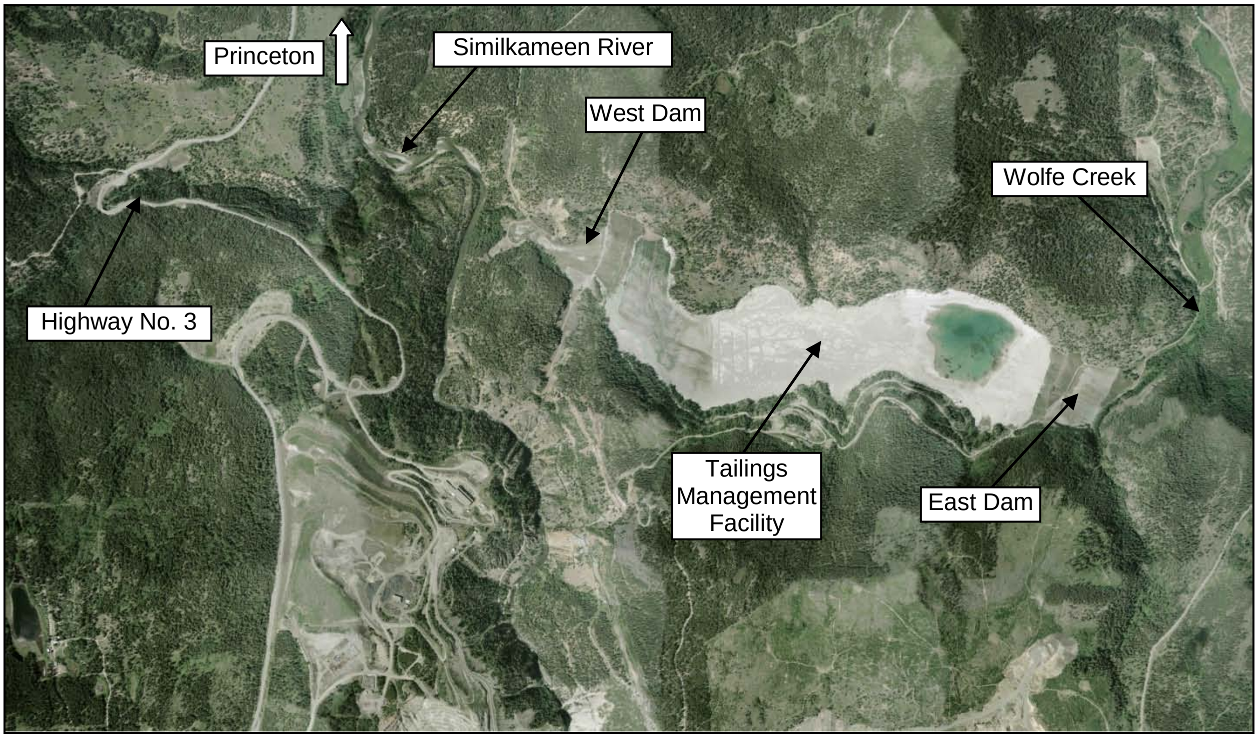


Figure 2.1: Aerial View of the TMF Prior to Reactivation

Figure 2.2: Aerial View of the East Dam Looking West (July 2012)

Figure 2.3: Aerial View of the West Dam Looking Northeast (July 2012)

2.2 TMF Dam Design Criteria

2.2.1 Consequence Classification per CDA Guidelines

The East Dam and the West Dam are designed in accordance with the *2007 Canadian Dam Association (CDA) Guidelines*. The *2007 CDA Guidelines* are based on classifying dams based on failure consequence categories. The failure consequence classification is then used to select appropriate hydrologic and seismic design criteria. The more severe the consequences of failure, the higher the applicable seismic and hydrologic design loadings.

On the basis of the consequence classification scheme per the current *2007 CDA Guidelines*, the hydrologic and seismic design criteria for each of the dams were established based on the following consequence classifications (AMEC 2011b):

East Dam	Very High
West Dam	Very High

2.2.2 Dam Stability

The dams are designed to satisfy minimum factor of safety (FoS) criteria, as per the *2007 CDA Guidelines*, for both short-term and long-term conditions based on two-dimensional limit equilibrium analysis. The minimum FoS for different loading conditions are as follows (AMEC 2011b):

Static loading, long term conditions:		> 1.5
Short term, construction conditions:		> 1.3
Design earthquake loading conditions:	- pseudostatic -	> 1.0
	- post-earthquake -	> 1.2

2.2.3 Seismic Loading

The *2007 CDA Guidelines* require that, for the "very high" consequence classification chosen for the two TMF dams, these dams be designed to accommodate the loading associated with a 1:5,000-year return period seismic event. In fact, the two dams were actually designed to accommodate a higher loading, associated with the Maximum Credible Earthquake (MCE), which has an approximate return period of 1:10,000-years[1]. The MCE design earthquake parameters for the project are as follows (AMEC 2011b):

Magnitude	7.0
PGA	0.38g

2.2.4 Hydrologic Loading

The *2007 CDA Guidelines* specify hydrologic loading in terms of the magnitude of the Inflow Design Flood (IDF). The IDF can be generated by either snowmelt or rainfall, or, more commonly, by some combination thereof. The critical IDF criteria for the Copper Mountain TMF depend on whether the mine is being operated or the mine has reached the end of its life and has been closed. The selection of the appropriate criteria is discussed in the Tailings Management Facility Final Design Report (AMEC 2011b). Relevant factors include the following:

- The TMF design does not incorporate an emergency spillway, thus all flood inflows must be capable of being safely contained within the facility. The key flood parameter is therefore the flood volume; the peak inflow rate is immaterial.
- Over time, stored flood water volume gradually declines due to the fact that the natural long term water balance of the TMF is negative - i.e., for average precipitation and runoff, annual outflows due to seepage and evaporation losses exceed annual inflows due to precipitation and runoff.

[1] The MCE is the design criterion typically required for an "extreme" consequence dam classification.

The adopted criteria are as follows:

- Closure Stage: The closure stage IDF is the total annual runoff volume resulting from the probable maximum snow accumulation (PMSA) spring snowmelt runoff plus the subsequent 1 in 100 wet year return period seasonal precipitation[2] runoff, representing a total annual inflow of 4.3 Mm^3.
- Operations Stage: The closure IDF volume of 4.3 Mm^3 enters the pond over the duration of the runoff season. If such an inflow were to occur during the operations stage, it is expected to be manageable by a combination of storage and the installed reclaim water pumping capacity of 3,200 m^3/hour, or 76,800 m^3/day. Thus, during operations, the more critical IDF is considered to be the runoff volume resulting from a shorter duration high intensity precipitation event. Accordingly, the 72-hour duration probable maximum precipitation was selected as the operations stage IDF, corresponding to a runoff volume of 2.5 Mm^3.

2.2.5 Freeboard

The freeboard allowance for the dams accommodates the stored inflow from the IDF plus an amount that accounts for wind set-up and wave run-up, as per *2007 CDA Guidelines*. For both the operations and closure stages, the design freeboard equals the increase in water level due to the IDF surcharge, plus a minimum additional amount of 2 m.

2.2.6 Beach Width

The reclaim water pond within the tailings impoundment is to be kept separated from the East Dam and the West Dam by an above-water tailings beach. The tailings beach is an important design component in the maintenance of a low phreatic surface (water table) through the cycloned sand dams, which in turn is important for the stability of the dams. During operations, the beach width naturally varies; however the target width is to be at least 100 m, but never less than 50 m. In practice, it should be possible to achieve greater beach widths, via management of tailings discharge locations and control of pond water levels (AMEC 2011a).

[2] The precipitation season covers the period April - October inclusive, and represents the balance of the runoff year subsequent to snowmelt, until freeze-up.

3.0 FAILURE SCENARIOS

3.1 General Considerations

The severity of a dam failure scenario is generally proportional to the height of the dam and the volume of tailings and water stored behind the dam. For a tailings dam which is continually raised in stages until mine closure, the most severe failure scenario is typically a failure that occurs after the maximum dam height and maximum pond level are reached, i.e. at or just prior to closure. Post-closure, the Copper Mountain TMF will drain downwards and de-saturate, becoming more stable and reducing the failure potential over time. Rather than analyzing a number of hypothetical failures for different dam heights, representing increasingly severe consequences during the operating life of the mine, it was decided to examine only ***the most severe failure scenario, which is failure at or just prior to closure.*** This scenario is defined for the purpose of this study as the ***"active closure" stage***. In that way there will only be one consistent definition of dam breach consequences, thus avoiding the need to update emergency response procedures and planning with every dam raise stage.

3.2 Active Closure Stage Failure Mode

The possible failure modes during the active closure stage are: (i) dam overtopping, (ii) piping, and (iii) seismic event (earthquake). Failure by overtopping can be set aside as there will be more than enough storage volume to accommodate the entire closure IDF. Piping failure is theoretically possible only when there is a significant volume of free water in the tailings pond, able to supply increasing amounts of seepage flow through the dam. Similarly, an earthquake failure mode resulting in an outflow from the dam requires a flowable mass, thus some free water, or at least saturated or near-saturated tailings. Of the latter two failure modes, the earthquake failure is considered the more severe as it causes a near-instantaneous breach and outflow, whereas the piping failure mode develops by internal erosion over time. An earthquake failure mode is therefore selected as the mode to be analyzed.

For the Copper Mountain TMF, once operations cease, drain-down of water from the deposited tailings will occur. i.e., the dams will largely de-saturate. Once de-saturation is substantially complete, a seismic event would no longer result in an outflow of fluid from the TMF. Detailed transient seepage analysis performed for the end of operations case (AMEC 2011b) indicated that the long-term drained (safe) condition is effectively reached in about six months after the end of tailings deposition, with substantial drain-down achieved after only 30 days. Thus, the period for which the dams are exposed to a potential failure triggered by a large seismic event post-closure is limited to roughly a six month window of time.

The volume of water associated with the failure window noted above is taken to equal the volume associated with the maximum operating pond water level of El. 987.0 m, i.e. a volume of 1.5 Mm^3. That volume could only be exceeded if a significant precipitation event was to occur within the indicated six month window. However, it is not reasonable to consider that an extreme precipitation event would occur at the same time as an earthquake in the MCE category.

The assumed failure mode of a seismic event occurring within six months of the end of operations represents the worst case scenario and is in accordance with the *2007 CDA Dam Safety Guidelines*.

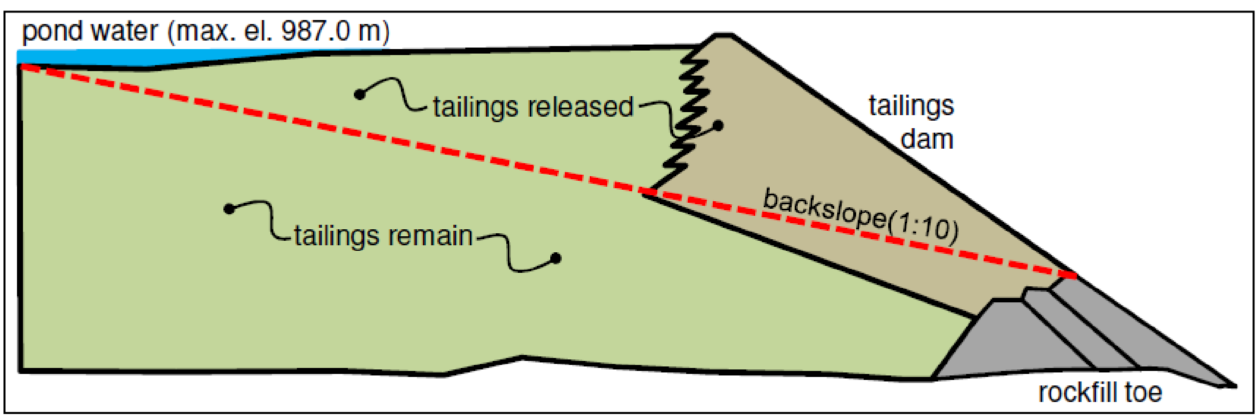
The seismic event is conservatively assumed to lead to an instantaneous failure of either the East Dam or the West Dam, or both. Each hypothetical dam failure results in the release of saturated tailings and of the free water ponded at the surface of the TMF.

3.3 East Dam Breach

Tailings Release: The hypothetical East Dam breach is assumed to involve an instantaneous failure of the entire East Dam above the rockfill toe (see **Figure 3.1**). The failure is followed by a release of saturated tailings into Wolfe Creek. The tailings runout extends into the Wolfe Creek Valley inundating the entire creek valley to some distance downstream of the toe such that the tailings achieve a stable profile. Based on case studies and the rheological properties of the tailings material, the runout profile was assessed to become stable at a slope of 10H:1V. The volume of tailings released is the volume located above this stable profile.

Water Release: At the time of failure, the free water pond at the surface of the TMF is assumed to be at the maximum level of 987 m. It is assumed that the water entrains tailings as it flows over the saturated mass, to a maximum of 30% tailings by volume, above which the mixture would no longer behave as a liquid. This entrainment increases the volume of the initial dam breach flood wave. The flood wave would travel downstream and progressively attenuate along Wolfe Creek through a series of small lakes (Lorne Lake, Issitz Lake, Wolfe Lake, and Jackson Lake) and then ultimately reach the Similkameen River approximately 20 km downstream of the East Dam.

Figure 3.1 below provides a conceptual schematic section of the dam, tailings, and pond water, showing the failure profile, and is representative of both the East and West Dams.



Note: Schematic is not to scale and is vertically exaggerated.

Figure 3.1: Dam Failure Schematic

3.4 West Dam Breach

Tailings Release: For the hypothetical West Dam breach, there is assumed to be a near instantaneous failure of the entire West Dam portion above the rockfill toe. The failure is followed by a release of saturated tailings into the Similkameen River. The tailings runout extends into the Similkameen Valley inundating the valley some distance downstream as well as upstream of the dam toe until the tailings achieve a stable profile and would temporarily block the flow of the river, as discussed in more detail below. Based on case studies and the rheological properties of the tailings material, the runout profile was assessed to become stable at a slope of 10H:1V. The volume of tailings released is the volume located above this stable profile.

Water Release: At the time of failure, the free water pond at the surface of the TMF is assumed to be at the maximum level of 987 m. As this water is released it is assumed to pick up tailings solids to a maximum of 30% by volume. This entrainment increases the volume of the initial dam breach flood wave. The flood wave would travel downstream and progressively attenuate along the Similkameen River to the town of Princeton.

3.5 Simultaneous Dam Failures

Given the assumed earthquake failure mode, it is possible that both the East Dam and West Dam could fail simultaneously. In such a case, the volume of tailings solids in the TMF is more than adequate to supply the estimated full release volumes for both dam failure scenarios, as the east and west tailings failure profiles do not intersect. However, the water release volume is limited; if both dams were to fail simultaneously, the available water release volume would be split between the two failures, however this would not be a worst case scenario as compared to failure of each dam as a single failure event and has therefore not been modelled.

3.6 Similkameen Valley Tailings Landslide Dam Failure

The hypothetical West Dam tailings runout is predicted to flow both downstream and upstream into the Similkameen River Valley. A wedge-like deposition surface would then form with a crest spanning the entire Similkameen River Valley at the toe of the West Dam. It is assumed that the tailings runout deposit develops sufficient shear strength to form what amounts to a landslide dam within the valley, blocking the flow of the Similkameen River. The Similkameen River flows would accumulate and form a large pond upstream of the tailings landslide dam. At some point, without prior remedial action, the tailings landslide dam would fail, releasing the ponded water in a second flood wave down the Similkameen River to Princeton. The volume of impounded water would be much larger than the volume of the TMF water pond, thus this second flood wave would be much larger than the first.

Failure of the tailings landslide dam was analyzed as an earthen dam breach. Two modes of failure were considered for this dam breach: an overtopping failure and a piping failure. Both failures were conservatively assumed to be instantaneous. Entrainment of solids is not typically considered significant for an earthen dam breach, as the volume of released water is typically orders of magnitude greater than the volume of solid material available for entrainment.

3.7 Wolfe Creek Tailings Landslide Dam

Wolfe Creek is not considered vulnerable to significant ponding by a tailings landslide dam. As part of closure, Wolfe Creek will be routed through a coarse rock drain, plus be provided with a raised overflow channel. Also, the Wolfe Creek valley is much steeper and narrower, with much less ponding potential. As a result, Wolfe Creek is expected to find a flow path through or along the toe of the runout deposit without significant secondary breach and flow release events.

3.8 Overview

An overview of the project area is provided on the attached **Map 1**. The map shows the TMF footprint bounded by the East Dam and West Dam, the expected flow paths along Wolfe Creek and the Similkameen River corresponding to the East Dam and West Dam failures, respectively, and the Similkameen Tailings Landslide Dam and ponding area.

4.0 METHODOLOGY

4.1 General

The hypothetical sudden failure of either the East Dam or West Dam would result in the release of a combination of saturated tailings and water. The tailings portion will run out to some distance downstream of the tailings impoundment and then come to rest when gravity forces become balanced by external and internal friction forces. The water flood wave (containing some entrained tailings) will continue to flow downstream, gradually decreasing in magnitude as the released water volume becomes distributed along the valley and channel in accordance with the valley geometry and river hydraulics. For this analysis, the tailings runout and water flood wave have been treated separately.

The tailings runout extent and configuration was determined by distributing the released volume along the valley topography downstream of the failed dam, with a surface slope of 10H:1V starting at the top of the rockfill toe, as indicted in **Figure 3.1** above.

Analysis of the flood wave produced by the water release involved two steps: (i) estimation of the peak outflow rate from the dam breach; and (ii) routing of the flood wave downstream. These steps were performed using empirical relationships based on data from actual dam breach events and dimensionless routing curves derived from analytical solutions of fluid flow. These methods include selecting parameter values and coefficients which represent the upper range of observed dam breach flood waves, and produce conservative results. This approach provides a level of analysis appropriate to support emergency response planning and emergency notifications of vulnerable infrastructure and downstream communities at risk.

4.2 Tailings Release

4.2.1 Tailings Release Volume

In the event of a dam failure, a portion of the tailings would mobilize and flow out of the impoundment and the rest would remain within the impoundment. The release volume is approximated by the volume above a plane surface at a slope of 10H:1V (the tailings release *backslope*) extending back from the top of the rockfill toe (see **Figure 3.1** above). The rockfill toe berm is assessed to remain stable under earthquake loading and is thus assumed to remain intact. The volume of tailings material above the backslope is computed to equal 50 Mm^3 for both the East Dam and West Dam failures.

4.2.2 Tailings Runout

East Dam Breach: For the hypothetical East Dam breach, the mobilized tailings exit the TMF and run into the Wolfe Creek valley downstream of the dam. To determine the area covered by the tailings runout, a plane surface at a 10H:1V slope was imposed along the valley. This surface was then adjusted vertically until the volume under the surface equalled the release volume of 50 Mm^3. The upstream limit of the tailings runout rests against the dam's rockfill toe. The intersection of the runout surface with the existing topography delineates the area covered by the tailings runout, and is illustrated in the attached **Map 1**.

West Dam Breach: For the hypothetical West Dam breach, the released tailings would enter the Similkameen River Valley almost at a right angle and then divide into two lobes, the major lobe travelling downstream and a second lobe moving upstream. The tailings come to rest with all surfaces at a 10H:1V slope. The resulting runout surface topography is characterized by a ridge across the Similkameen River Valley with slopes extending both upstream and downstream along the valley, similar to the surface that might be formed from a landslide coming from the valley side. The resulting surface was then adjusted vertically until the volume under the surface equalled the release volume of 50 Mm^3. The intersection of this surface with the existing topography delineates the area inundated by the tailings runout, and is illustrated in the attached **Map 1**. The height of the ridge across the Similkameen valley was computed to be at El. 845 m.

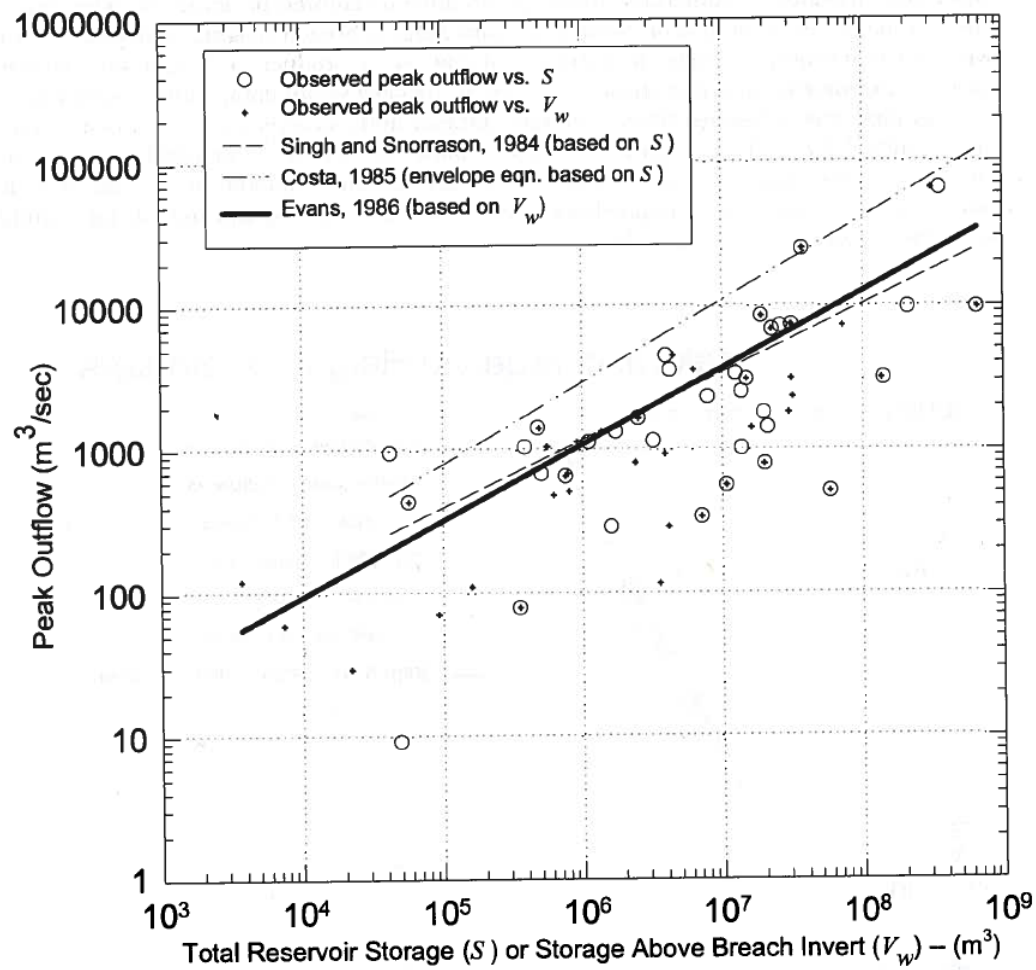
4.3 Water Release

4.3.1 East and West Tailings Dams

For both the hypothetical east and west tailings dam breaches, it was assumed that the full volume of the free water pond within the impoundment is released. The release volume was assumed to be that volume associated with the maximum water level at El. 987 m at the end of operations with the impoundment filled to its maximum design capacity, which equals 1.5 Mm^3. It is assumed that the water entrains tailings as it is released and progresses downstream. The maximum plausible volume of entrained tailings solids is approximately 30% by volume, which corresponds to an additional volume of about 0.5 Mm^3. Therefore, the *effective* volume of water released is 2.0 Mm^3. Note that the entrainment of 0.5 Mm^3 of tailings by the water release represents 1% of the volume of the tailings release; adjustment of the latter value in computing the runout footprint is therefore not justified.

The peak flood discharge was estimated on the basis of published relationships between peak reservoir discharge and total reservoir water storage, derived from observed dam breach events, as shown in **Figure 4.1** (Wahl, 1998). Using the total release volume of 2.0 Mm^3 and the relationship defined by the heavy black line in **Figure 4.1** (based on volume above the breach invert), the peak discharge rate is 1700 m^3/s. This value applies to both the East Dam and the West Dam.

Routing of the flood wave downstream for both dams was done using a graphical method developed by the US Army Corps of Engineers (1980). The method is based on application of the Saint-Venant flow equations to a prismatic channel with slope, hydraulic roughness and conveyance characteristics representative of the actual channel.



Note: Figure adapted from *Wahl "Prediction of Embankment Dam Breach Parameters, A Literature Review and Needs Assessment", US Department of the Interior, Bureau of Reclamation, Dam Safety Office, July 1998.*

Figure 4.1: Peak Outflow Discharge Rate vs Water Storage Volume

4.3.2 Landslide Dam Breach

The peak flood discharge for each of the two instantaneous breach scenarios for the landslide dam on the Similkameen River was estimated using the same procedure as described above, using **Figure 4.1**; the peak discharge values are reported below in **Section 5.2**.

Routing of the flood wave downstream was done using a graphical method developed by the US Army Corps of Engineers (1980). The method is based on application of the Saint-Venant flow equations to a prismatic channel with slope, hydraulic roughness and conveyance characteristics representative of the actual channel.

4.4 Model Limitations

Modelling of dam breach tailings runout, and flood peak discharges and flood routing involves adopting various assumptions and simplifications to make the analyses manageable. The objective is to do so in a way that tends to produce conservative results - i.e., the model results are more severe than they would likely be in reality.

For example, the approach taken to estimate the tailings runout footprint produced a runout surface with its upstream end at an elevation somewhat higher than that of the top of the dam's rockfill toe. In other words, the downstream topography is such that not all of the 50 Mm^3 of tailings volume located above the assumed backslope would actually be able to runout. Thus, the modelled tailings runout footprint would in reality not extend as far as modelled.

An additional conservative assumption was that the tailings runout into the Similkameen River Valley would be unaffected by contact with river water, which in reality can be expected to add mobility and flatten the runout surface somewhat, thus producing a lower ridge across the river valley and a corresponding lower volume of impounded river water, and thus a less severe subsequent dam overtopping flood wave.

A further conservative assumption with respect to failure of the landslide dam is that its failure (whether by piping or by overtopping) was assumed to be instantaneous. In reality, development of the breach through the very massive cross-section of the landslide dam would require some time, likely in the order of hours, and would take longer than most observed dam breach events forming the basis of **Figure 4.1**. Thus, in reality, the landslide dam breach flood wave would be expected to have a lower peak discharge, and to develop over a longer period of time, implying that the flood wave would take a longer time to arrive in Princeton and would be less deep.

The results of the current dam breach analyses, although approximate are, therefore, considered to be conservative.

5.0 RESULTS

5.1 Tailings Runout

5.1.1 East Dam Breach

Map 1 presents the results of the hypothetical East Dam breach tailings runout analysis. The area inundated by the tailings runout is indicated on the Map (referred to as “EAST RUNOUT INSET”). Approximately 100 hectares of creek valley are inundated by tailings and the runout extends approximately 1.5 km downstream of the dam. There are no standard methods available to determine the time it will take for the tailings runout to achieve the limits indicated on the figure. A conservative estimate is that the full extent of the runout is achieved within a few hours.

5.1.2 West Dam Breach

Map 1 illustrates the area inundated by the hypothetical West Dam breach tailings runout (referred to as “WEST RUNOUT INSET”). Approximately 120 hectares of river valley are inundated by tailings. The runout extends approximately 1.7 km downstream and 1.2 km upstream of the dam. There are no standard methods available to determine the time it will take for the tailings runout to achieve the limits indicated on **Map 1**. A conservative estimate is that the full extent of the runout is achieved within a few hours.

The tailings hypothetical runout would create a landslide dam across the Similkameen River Valley. The crest of this tailings landslide dam is at about elevation 845 m. The existing valley bottom at this point has an elevation of 735 m, thus the height of the landslide dam is 110 m. The area inundated by ponding of the Similkameen River behind this crest to elevation 845 m is shown on **Map 1**.

5.2 Water Release Volume and Peak Outflow

5.2.1 Tailings Dams Breaches

The water release volume and peak discharge are the same for the east and west tailings dams. The plane of the backslope of the tailings release is assumed to reach the water pond and permits the full volume of water to be released. The total volume of stored pond water corresponding to the maximum water surface elevation of 987 m is 1.5 Mm^3. As this water exits the tailings facility, it picks up wet tailings to a maximum concentration of 30% by volume. Therefore, the total effective water release volume is 2.0 Mm^3. As presented above in **Section 4.3**, the total release volume of 2.0 Mm^3 is estimated to produce a peak instantaneous discharge rate of 1,700 m^3/s.

To provide a context for the magnitude of the estimated dam breach peak discharge, it can be compared to natural flood discharges of varying magnitudes for Wolfe Creek and the

Similkameen River, as listed in **Table 5.1**, which shows that the dam breach peak discharges far exceed the 200-year flood peaks of the receiving streams. The West Dam breach peak is approximately 500 times the 200-year flood peak of Wolfe Creek, while the East Dam breach peak is 2.5 times the 200-year flood peak of the Similkameen River. Discussion of the flood wave properties (i.e. water level increase and travel time) is provided in Section 5.3.

Table 5.1: Flood Frequency Discharge Estimates

Return Period	Annual Instantaneous Peak Discharge (m^3/s)	
	Wolfe Creek	Similkameen River
10-year	1.6	397
100-year	2.8	580
200-year	3.5	633

5.2.2 Tailings Landslide Dam Breach

The hypothetical tailings landslide dam predicted to block the Similkameen River is estimated to form a crest at El. 845 m, or 110 m above the base level at El. 735 m. The flow of the Similkameen River would immediately begin to collect behind the dam, forming a pond with gradually increasing water level. At some point, without prior intervention, the dam would fail. Two modes of failure were evaluated:

- Ponding of water to the full 110 m height of the dam, followed by overtopping and instantaneous failure. This failure mode would release the largest flood volume and produce the most severe consequences.
- Ponding of water to some intermediate elevation, at which stage there would be an assumed instantaneous failure caused by seepage piping through the dam. This failure mode is not likely to occur until water has ponded to some significant depth; a pond water depth of 65 m was adopted for the piping failure mode.

Table 5.2 presents the total release volumes and peak outflow discharge rates for the two failure modes. The volumes were extracted from the topographic data for the ponded valley; the peak outflow values were derived from **Figure 4.1** above.

Table 5.2: Tailings Landslide Dam Water Release Volume and Peak Outflow

Failure Mode	Pond Water Elevation (m)	Release Volume (Million m^3)	Peak Outflow (m^3/s)
Overtopping Failure	845	77	10,000
Piping Failure	800	15	5,000

The times required to fill the pond to the indicated levels were estimated from average monthly flow data for the Similkameen River, using both the spring high flow season with an average discharge rate of 85 m^3/s, and the late summer through winter low flow season with an average discharge of 8 m^3/s. The results are summarized in **Table 5.3**.

Table 5.3: Days Required to Reach Failure Water Level for Mean Flows

Failure Mode	Pond Water Elevation at Failure (m)	Pond Volume (Million m^3)	May-June Season	Aug-Mar Season
Overtopping Failure	845	77	10	100
Piping Failure	800	15	2	20

The data in **Table 5.3** show that the less severe piping failure of the tailings landslide dam could occur as quickly as two days after the initial failure of the West Tailings Dam, while the more severe overtopping failure would take 10 days, if it were to occur in the May - June high flow season.

5.3 Flood Routing

5.3.1 General

Dimensionless curves developed by the US Army Corps of Engineers (1980) were used to route the estimated peak outflow downstream. These dimensionless curves were based on the results of numerical simulation experiments that solved a dimensionless form of the Saint-Venant equations. Application of the dimensionless curves allows for the determination of three flood wave parameters: time of arrival of the wave front; maximum flood depth above the existing water surface; and time of maximum flood depth.

5.3.2 Tailings Dams

5.3.2.1 Routing Parameters

Routing parameters required for application of the dimensionless routing curves were derived from the topography and geometry of the Wolfe Creek and Similkameen River valleys. **Table 5.4** presents a summary of the routing parameters.

Table 5.4: East and West Dam Breach Flood Routing Parameters

Parameter	East Breach	West Breach
Water depth at dam[1]	4.7 m	4.7 m
Valley bottom slope[2]	0.016 m/m	0.0073 m/m
Valley Mannings roughness, n	0.10	0.10
Valley cross section exponent[3]	0.5	0.5

1. *The water depth at dam was computed using Manning's equation and valley section properties.*
2. *The channel slope was calculated using the downstream valley topography.*
3. *The cross section exponent varies between 0 and 1, with 0 representing a rectangular cross section and 1 representing a triangular cross section; 0.5 was chosen based on the valley topography.*

5.3.2.2 East Dam Breach Flood Routing Results

The anticipated flow path for the hypothetical East Dam Breach is illustrated in **Map 1**. The kilometre markings shown in the figure refer to the distance downstream of the dam. **Table 5.5** summarizes the estimated flood wave properties for the east breach at points of interest along the flow path.

Table 5.5: Routing of East Dam Breach Flood Wave

Distance Downstream of Dam (km)	Location	Max WL (m)	Flood ΔT (hrs)	Max WL ΔT (hrs)	Remarks
0.5	Verde Creek confluence	1.8	0.05	0.07	Flood wave travels up Verde Creek.
1.5	-	1.3	0.2	0.3	
3.0	-	1.0	0.5	0.6	
6.0	-	0.7	1.3	1.4	
9.0	Road crossing	0.4	2.2	2.5	Low risk to bridge.
10.5	Lorne Lake	0.3	2.6	3.2	
13.0	Jackson Lake	0.1	3.5	4.5	
16.0	Issitz Lake	<0.1	4.5	6.3	
17.5	Road crossing	<0.1	5.1	7.3	Low risk to bridge.
18.0	Wolfe Lake	<0.1	5.3	7.6	
20.0	Hwy 3 crossing	<0.1	6.0	9.1	Low risk to bridge.
20.5	Similkameen R.	<0.1	6.2	9.5	

Max WL denotes maximum water level increase above initial water level.
Flood ΔT denotes arrival time of breach flood wave after initiation of breach.
Max WL ΔT denotes arrival time of maximum water level after initiation of breach.

The attenuation of the flood wave as it travels downstream is shown by the declining water levels in **Table 5.5**; the height of the flood wave declines to less than 0.1 m near kilometre 13 (~7 km upstream of the Similkameen River). The timing of the arrival of the start of the flood wave and the peak of the flood wave at the Similkameen River is approximately 6.2 hours and 9.5 hours, respectively.

5.3.2.3 West Dam Breach Flood Routing Results

The anticipated flow path for a West Breach Scenario is illustrated in Map **1**. A summary of the calculated flood wave properties is presented in **Table 5.6**.

Table 5.6: Routing of West Dam Breach Flood Wave

Distance Downstream of Dam (km)	Location	Max WL (m)	Flood ΔT (hrs)	Max WL ΔT (hrs)	Remarks
0.5	-	2.1	0.06	0.10	
1.0	Whipsaw Creek confluence	1.8	0.15	0.2	Flood wave travels upstream Whipsaw Creek.
3.0	-	1.4	0.6	0.7	
4.5	Stevenson Creek confluence	1.2	1.0	1.1	Flood wave travels upstream Stevenson Creek.
7.0	Bromley Creek confluence	1.0	1.8	1.9	Flood wave travels upstream Bromley Creek.
12.0	Upstream end of Princeton	0.7	3.6	3.9	Flooding of low-lying areas expected.
14.0	Highway 3 crossing	0.7	4.4	4.8	Low impact to bridge.
14.5	Downstream end of Princeton/ Tulameen River confluence	0.6	4.6	5.1	Flooding of low-lying areas expected.
15.5	Trailer Park	0.6	5.0	5.6	Moderate risk of inundation onto trailer park.
17.5	Golf Course and Allison Creek confluence	0.5	5.8	6.6	Moderate risk of inundation onto low elevation areas of the golf course on west side of property.
18.0	Allison Creek confluence	0.5	6.0	6.9	Flood wave travels upstream Allison Creek.
19.5	Shisler Creek confluence	0.4	6.7	7.8	Flood wave travels upstream Shisler Creek.

Max WL denotes maximum water level increase above initial water level.
Flood ΔT denotes arrival time of breach flood wave after initiation of breach.
Max WL ΔT denotes arrival time of maximum water level after initiation of breach.

The attenuation of the flood wave as it travels downstream is shown by the declining water levels in **Table 5.6**. By the time the flood wave reaches the town of Princeton, it has attenuated to 0.7 m. It would take 3.6 hrs after the breach for the flood wave front to reach Princeton. The peak flood wave height would follow closely at 3.9 hrs. The flood wave is not fully attenuated by the time it would reach Princeton and some flooding would be anticipated in low-lying areas.

5.3.3 Tailings Landslide Dam

5.3.3.1 Failure Scenarios

Two failure scenarios were considered: (1) a piping failure with the water at El. 800 m, corresponding to a depth of 65 m; and (2) an overtopping failure with the water at El. 845 m, corresponding to a depth of 110 m. Failure was conservatively assumed to be instantaneous and that no human intervention or remedial/preventative action was undertaken following the initial breach of the West Dam. The flow path for the tailings landslide dam breach for either failure mode would be the same as for the West Tailings Dam breach (refer to **Map 1**). The routing parameters would also be the same, except for the water depth which would be 65 m and 110 m, for the piping and overtopping failures, respectively.

Table 5.7 summarizes the computed flood wave properties for the two failure modes at points of interest along the flow path. A much larger flood wave is released and travels much faster than the tailings dam breach flood waves. Thus, the wave arrival times are expressed in minutes rather than hours in **Table 5.7**.

Table 5.7: Routing of Landslide Dam Breach Flood Wave

Distance Downstream of Dam (km)	Description	Piping Breach with Water Depth=65 m			Overtopping Breach with Water Depth=110 m			Remarks
		Max WL (m)	Flood ΔT (min)	Max WL ΔT (min)	Max WL (m)	Flood ΔT (min)	Max WL ΔT (min)	
0.5	-	36	0.4	1	62	0.3	1	Widespread flooding.
1.0	Whipsaw Creek confluence	36	1	3	61	1	2	Widespread flooding.
3.0	-	33	4	8	58	3	6	Widespread flooding.
4.5	Stevenson Creek confluence	31	7	12	56	4	9	Widespread flooding.
7.0	Bromley Creek confluence	29	11	19	53	8	15	Widespread flooding.
12.0	Upstream end of Princeton	26	23	34	49	15	25	Widespread flooding.
14.0	Highway 3 crossing	26	28	40	48	18	30	Bridge destroyed.
14.5	Princeton at Tulameen River confluence	25	29	41	47	19	31	Widespread flooding.
15.5	Trailer Park	25	32	44	47	21	33	Park flooded.
17.5	Golf Course / Allison Creek confluence	24	37	50	46	24	37	Golf course flooded.
18.0	Allison Creek confluence	24	38	52	46	25	38	Widespread flooding.
19.5	Shisler Creek confluence	24	43	57	45	28	42	Widespread flooding.

Max WL denotes maximum water level increase above initial water level.
Flood ΔT denotes arrival time of breach flood wave after initiation of breach.
Max WL ΔT denotes arrival time of maximum water level after initiation of breach.

The hypothetical landslide dam breach flood wave reaching Princeton is estimated to be 25 m to 50 m high, and would reach the town in only 15 to 30 minutes. This would result in widespread destructive flooding throughout Princeton. Inspection of available topographic mapping in the vicinity of the town suggests that water levels could reach as high as the 685 m elevation in the vicinity of the town. All major transportation routes and the majority of the town would be completely inundated. The methodology used for the flood routing analysis does not permit computation of flood flow velocities; however, they would be very high and cause significant destruction.

The flood wave would continue to travel far downstream of Princeton before it became attenuated to something approaching historical flood levels.

Prior to failure of the landslide dam, water could pond to as high as the dam crest, or to El. 845 m. The upstream valley of the Similkameen would thus be inundated to that elevation. Inspection of the available mapping does not indicate any infrastructure within the inundation zone. However, Highway 3 immediately upstream of the landslide dam appears to be situated at about El. 850 m, and should be considered vulnerable, given the uncertainties associated with this type of analysis.

5.3.3.2 Mitigative Actions

In the unlikely event that a catastrophic failure of the West Tailings Dam were to occur, there would be some time available to initiate mitigative actions to reduce the flood effects of the subsequent failure of the tailings landslide dam formed by the tailings runout across the Similkameen River Valley.

6.0 SUMMARY AND CONCLUSIONS

A catastrophic failure of either the East Dam or the West Dam of the Copper Mountain TMF is considered to be an extremely unlikely event. Nevertheless, such failures need to be considered at least theoretically, so that their consequences can be assessed and emergency response plans developed. This was the purpose of the current study.

This report presents analyses of the flooding and inundation consequences of hypothetical, near-instantaneous earthquake-induced failures of the TMF East and West Tailings Dams. The analyses considered tailings runout and water flood waves separately. Saturated tailings released by the dam breach would exit the TMF and runout to a final slope of 10H:1V. The water flood wave released by the breach would travel downstream through either Wolfe Creek (East Dam breach) or the Similkameen River (West Dam breach). The tailings runout from the West Dam breach would run into and block the Similkameen River valley, thus forming a landslide dam behind which river flows would pond until this dam too would breach. Failure of the West Dam would thus result in two sequential flood waves.

Routing of the flood waves was performed using conservative methods to estimate both the peak outflow discharge and the attenuation of the flood wave as it travels downstream. A breach of the East Dam would produce an instantaneous peak outflow at the dam toe with an estimated flow depth of 4.7 m. However, the flood wave would attenuate rapidly, becoming 1.8 m deep at 0.5 km from the dam, and less than 0.1 m approximately 7 km before it would reach the Similkameen River.

A breach of the West Dam would produce an instantaneous peak outflow at the dam with an estimated flow depth of 4.7 m. The flood wave would attenuate rapidly in the initial reach, becoming 2.1 m deep at 0.5 km from the dam, but would attenuate at a slower rate downstream. The flood depth at and through Princeton would still be about 0.7 m, and could thus be expected to inundate low-lying areas. The flood wave would require three to four hours to reach Princeton.

A breach of the tailings landslide dam formed as a consequence of the West Tailings Dam failure would result in a flood wave much more severe than that of the West Dam failure itself. The flood wave height at the Town of Princeton would be 25 m to 50 m high, depending on the mode of failure. This flood wave would reach the Town of Princeton in 15 to 30 minutes after failure of the landslide dam. However, there would be an additional time delay estimated to be at least 2 days, and possibly as much as 100 days, between the initial West Dam breach and the subsequent landslide dam breach, thus there should be adequate time for emergency response and evacuation.

The assumptions used in modelling the shape and elevation of the landslide dam, and assessing its failure, are considered conservative. Further, no allowance has been made in the analysis for reductions in the magnitude and impacts of the landslide dam breach flood wave that might be achievable by mitigative actions such as lowering the overflow elevation by water jets, blasting or conventional earth moving, lowering ponding levels by pumping and/or siphoning with large diameter pipes or by other means.

It is important to note, as well, that the exposure period for tailings dam failure triggered by a large seismic event, under the worst case (end of construction) conditions, as evaluated herein, is limited to a period at or just prior to closure and roughly a six month window of time thereafter. After this period the dam will de-saturate, subsequent to which the assumed tailings dam breach scenarios as well as the landslide dam breach will no longer be applicable.

Finally, when interpreting the results of a theoretical dam breach analysis as presented herein, it is important to keep in mind that simplifications and uncertainties are unavoidable. While conservative, the tailings runout and flood routing predictions should therefore be regarded as approximate. This context should be considered when developing and executing emergency preparedness and response plans.

7.0 CLOSURE

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 Copper Mountain Mine (BC) 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.

If you require further assistance please contact us at (780) 944-6370.

Respectfully submitted,

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MAPS

EAST DAM BREACH FLOOD WAVE

Distance Downstream of Dam (km)	Location	Max WL (m)	Flood T (hrs)	Max WL T (hrs)	Remarks
0.5	Verde Creek confluence	1.8	0.05	0.07	Flood wave travels up Verde Creek.
1.5	-	1.3	0.2	0.3	
3	-	1	0.5	0.6	
6	-	0.7	1.3	1.4	
9	Road crossing	0.4	2.2	2.5	Low risk to bridge.
10.5	Lorne Lake	0.3	2.6	3.2	
13	Jackson Lake	0.1	3.5	4.5	
16	Issitz Lake	<0.1	4.5	6.3	
17.5	Road crossing	<0.1	5.1	7.3	Low risk to bridge.
18	Wolfe Lake	<0.1	5.3	7.6	
20	Hwy 3 crossing	<0.1	6	9.1	Low risk to bridge.
20.5	Similkameen R.	<0.1	6.2	9.5	

WEST DAM BREACH FLOOD WAVE

Distance Down-stream of Dam (km)	Location	Max WL (m)	Flood T (hrs)	Max WL T (hrs)	Remarks
0.5	-	2.1	0.06	0.1	
1	Whipsaw Creek confluence	1.8	0.15	0.2	Flood wave travels upstream Whipsaw Creek.
3	-	1.4	0.6	0.7	
4.5	Stevenson Creek confluence	1.2	1	1.1	Flood wave travels upstream Stevenson Creek.
7	Bromley Creek confluence	1	1.8	1.9	Flood wave travels upstream Bromley Creek.
12	Upstream end of Princeton	0.7	3.6	3.9	Flooding of low-lying areas expected.
14	Highway 3 crossing	0.7	4.4	4.8	Low impact to bridge.
14.5	Downstream end of Princeton/ Tulameen River confluence	0.6	4.6	5.1	Flooding of low-lying areas expected.
15.5	Trailer Park	0.6	5	5.6	Moderate risk of inundation onto trailer park.
17.5	Golf Course and Allison Creek confluence	0.5	5.8	6.6	Moderate risk of inundation onto golf course.
18	Allison Creek confluence	0.5	6	6.9	Flood wave travels upstream Allison Creek.
19.5	Shisler Creek confluence	0.4	6.7	7.8	Flood wave travels upstream Shisler Creek.

LANDSLIDE DAM BREACH FLOOD WAVE

Distance Down-stream of Dam (km)	Description	Piping Breach with Water Depth=65 m			Overtopping Breach with Water Depth=110 m			Remarks
		Max WL (m)	Flood T (min)	Max WL T (min)	Max WL (m)	Flood T (min)	Max WL T (min)	
0.5	-	36	0.4	1	62	0.3	1	Widespread flooding.
1	Whipsaw Creek confluence	36	1	3	61	1	2	Widespread flooding.
3	-	33	4	8	58	3	6	Widespread flooding.
4.5	Stevenson Creek confluence	31	7	12	56	4	9	Widespread flooding.
7	Bromley Creek confluence	29	11	19	53	8	15	Widespread flooding.
12	Upstream end of Princeton	26	23	34	49	15	25	Widespread flooding.
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17.5	Golf Course / Allison Creek confluence	24	37	50	46	24	37	Golf course flooded.
18	Allison Creek confluence	24	38	52	46	25	38	Widespread flooding.
19.5	Shisler Creek confluence	24	43	57	45	28	42	Widespread flooding.

NOTE:

THIS DRAWING SHOULD BE READ IN CONJUNCTION WITH *COPPER MOUNTAIN MINE TAILINGS MANAGEMENT FACILITY, DAM BREACH INUNDATION STUDY, REVISION 1, OCT 2013*

CLIENT LOGO:

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DWN BY: DJH
CHK'D BY: N vd G
DATUM: NAD 83
PROJECTION: UTM Zone 10
SCALE: 1:50,000

PROJECT: COPPER MOUNTAIN MINE TALINGS MANAGEMENT FACILITY DAM BREACH INUNDATION STUDY

TITLE: DAM BREACH FLOOD WAVES FLOOD WATER DEPTHS AND ARRIVAL TIMES

DATE: OCT 2013
PROJECT NO: VM00482.B.3.300
REV No.: 2
DRAWING No.: MAP 1

Map Path: Path: P:\Water\PROJECT\VM\00482 Copper Mountain\April 2013\GIS\Map 2 Dam Breach Inundation Study.mxd