Klohn Crippen Berger

November 28, 2014

FortyTwo Metals Inc.
490 – 1122 Mainland Street
Vancouver, British Columbia
V6B 5L1

Mr. Scott Broughton, P.Eng.
Mine Manager

Dear Mr. Broughton:

MAX Molybdenum Mine
Tailings Storage Facility Dam Breach and Inundation Study

1 INTRODUCTION

Klohn Crippen Berger Ltd. (KCB) was retained by FortyTwo Metals Inc. (client) to undertake a preliminary dam breach and inundation study for the MAX Molybdenum Mine Tailings Storage Facility (TSF). The TSF is retained by two dams (Northwest and Southeast) as shown in Figure 1. The TSF is currently inactive and under care and maintenance. The purpose of this study is to estimate the extent of inundation that could occur as a result of a dam breach.

The dam breach analyses presented herein are based on hypothetical failure scenarios, and the results of such analyses in no way reflect upon the structural integrity or safety of the dam.

This dam breach and inundation study evaluates the consequences of Northwest Dam and Southeast Dam breach separately. It is a preliminary assessment based on empirical relationships, available topography and simplified assumptions. The results of this study give a qualitative indication of the extent of inundation resulting from a theoretical dam breach. The following theoretical dam breach scenarios were assessed for the TSF, which are consistent with the 2007 CDA guidelines:

- rainy-day dam failure (flood-induced dam failure):

  A rainy-day dam failure or overtopping type failure typically occurs during large flood inflow conditions where the pond water level rises high enough to breach or overtop the dam.

- sunny-day dam failure (piping, earthquake):

  A sunny-day dam failure or piping type failure is normally assumed to occur when the pond is at its normal operating level. Examples of sunny-day dam failures include the slope failure (slumping) of the dam due to static or earthquake loading, or the failure of the dam caused by piping (internal erosion).

Klohn Crippen Berger Ltd. • 500 - 2955 Virtual Way • Vancouver BC V5M 4X6 • CANADA
604.669.3800 t • 604.669.3835 f • www.klohn.com

2 PROJECT SETTING

2.1 Tailings Storage Facility

MAX Molybdenum Mine is located approximately 60 km south of Revelstoke and 3 km west of the Village of Trout Lake, in southeast British Columbia. MAX Mine is an underground molybdenum mine with a production rate of 500 tpd. Ore is processed in the mill onsite and concentrate is shipped by truck. The mine began commercial production in April 2008. The mine ceased operation in October 2011 and is currently under care and maintenance.

The TSF is located in a small drainage basin about 1 km northeast of the mill and is formed by two dams: Southeast Dam and Northwest Dam. Diversion ditches are located along both sides of the impoundment and a temporary spillway is located in the Southeast Dam.

In 2010, the Northwest Dam was raised to El. 785.7 m and the Southeast Dam was raised to El. 785.9 m. Current dam heights are 16.8 m (Northwest Dam) and 18.6 m (Southeast Dam) at their deepest sections. The supernatant pond, located in the center of the impoundment, covers a majority of the tailings and is approximately 0.2 Mm^3 (reported by the client) at the maximum allowable elevation during normal conditions (El. 784.5 m, 0.8 m below the temporary spillway). The volume of the total tailings stored in the facility was calculated from the original ground topography and the most recent tailings bathymetric survey, and is estimated to be approximately 250,000 m^3.

The dam hazard classification for both the dams is “high” (KCB 2014).

2.2 The Study Area and Downstream Drainage Network

Flood routing for dam breach inundation mapping is usually carried to a point beyond which flooding would no longer constitute a hazard to life and/or property. The location where this occurs for the MAX Mine dam breach and inundation analysis is at inlet to Trout Lake, at a bridge location (shown in Figure 1).

The study area is predominately located within the sub-arctic or cold, snowy forest climate zone with dense forests and meandering rivers along wide and narrow valley bottoms. The Village of Trout Lake is the only populated centre within the selected study area. A recreational campground at the north end of Trout Lake is usually occupied during the summer months.

2.2.1 Northwest Dam

The flood route downstream of Northwest Dam consists of the following:

- 750 m along Shrub Creek to Wilkie Creek (lower portion); and
- 3750 m along the lower portion of Wilkie Creek, which discharges into Trout Lake.

Shrub Creek has a gradient of approximately 6%. The average channel cross section has approximately 2.5H:1V side slopes on both sides with 3 m wide channel bottom. The lower portion of

Wilkie Creek is relatively flat with a gradient of approximately 0.5% and the channel meanders along the valley bottom up to 800 m wide.

2.2.2 Southeast Dam

The flood route downstream of Southwest Dam consists of the following:

- 550 m along Shrub Creek to its confluence with Edward Creek;
- 950 m along Wilkie Inlet downstream of the confluence of Shrub Creek and Allan Creek; and
- 900 m along Lower Wilkie Creek, which discharges into Trout Lake.

Shrub Creek has a gradient of approximately 2.5%. The average channel cross section has an approximately 3.5H:1V side slope on southern bank and 4H:1V side slope on northern bank with 13 m wide channel bottom. Lower Wilkie Creek is relatively flat with a gradient of approximately 0.3% close to Trout Lake and the channel meanders along the flood plain up to 720 m wide.

3 DAM BREACH METHODOLOGY AND ASSUMPTIONS

3.1 General

The primary goal of this study is to estimate the potential inundation area resulting from a theoretical dam breach. To do this, it is necessary to predict the potential inundation areas with and without the dam breach. Two scenarios were included in this study: rainy-day and sunny-day. The dam breach scenarios that were considered are summarized in Table 3.1.

Table 3.1 Dam Breach and Inundation Scenarios

Scenario	TSF Condition / Failure Mode	Natural Catchment Conditions
Rainy-day	No Failure	1/3 between 1000 year and PMF
	Overtopping ▪ Assumed the spillway blocked ▪ Pond elevation at 0.3 m above the dam crest elevation	1/3 between 1000 year and PMF
Sunny-day	No Failure	Mean Annual Flow (MAF)
	Piping ▪ Pond elevation at maximum allowable elevation (784.5 m)	Mean Annual Flow (MAF)

The peak discharge from the theoretical dam breach was estimated using empirical equations and charts (described in Section 3.3). A hydraulic model (described in Section 3.4) was used to estimate the flood water levels assuming constant flow equal to peak discharge plus natural flows (described in Section 3.2). The water levels from the hydraulic model cross-sections were used to interpolate the flood inundation extents based on the topography and judgment.

3.2 Natural Creek Flows

No streamflow data is available for the study area; therefore, the flows in the creeks downstream of the dams were estimated for mean annual and floods.

3.2.1 Rainy-Day Failure

The CDA Guidelines recommend an inflow design flood of 1/3 between 1000 year storm and Probable Maximum Precipitation (PMP) for dams classified as “high” (CDA 2007). The 1000 year 24 hour storm event depth is estimated to be 70 mm and was extrapolated using the data provided in Rainfall Frequency Atlas for Canada (Environment Canada 1985). The PMP is 170 mm for 24 hour storm duration (FortyTwo Metals, 2005).

Flood peak flows were estimated in HEC-HMS using SCS Type II Storm curve (USDA 1986). The estimated naturally occurring flows during rainy-day failures are summarized in Table 3.2. Though the land cover of the catchments can be identified as wooded area, the SCS Curve Number of 90 used for this analysis is higher than usual to account for pre-saturated ground condition prior to the storm event. A variety of lag time calculation methods were used to determine a lag time for the catchments. An average of all methods is used in the model as a representative value.

Table 3.2 Estimated Naturally Occurring Flows (for the 1/3 between the 1000 year and the PMP storm event)

Streams	Catchment (km^2)	Flow (m^3/s)
Northwest Dam		
Shrub Creek	0.8	15
Wilkie Creek Upstream	85	440
Inlet to Trout Lake	111	600
Southeast Dam		
Shrub Creek	0.2	3
Wilkie Creek Upstream	85	440
Inlet to Trout Lake	111	600

3.2.2 Sunny-Day Failure

The Mean Annual Flows (MAFs) estimated in the 2005 MAX Molybdenum Project Small Mine Application (FortyTwo Metals 2005) were scaled based on catchment area to determine the naturally occurring flows during sunny-day dam failures. The estimated naturally occurring flows during sunny-day dam failures are summarized in Table 3.3.

Table 3.3 Estimated Naturally Occurring Flows (for MAF)

Streams	Catchment (km^2)	Flow (m^3/s)
Northwest Dam		
Shrub Creek	0.8	0.03
Wilkie Creek Upstream	85	3
Inlet to Trout Lake	111	4
Southeast Dam		
Shrub Creek	0.2	0.03
Wilkie Creek Upstream	85	3
Inlet to Trout Lake	111	4

3.3 Released Volumes and Peak Flows

Based on the TSF geometry, the assumed outflow volumes of tailings and water for both the rainy-day and the sunny-day failure scenarios are summarized in Table 3.4.

Table 3.4 Assumed Tailings and Water Outflow Volumes for Dam Breach Analyses

Item	Volume (Mm^3)
Tailings	0.25
Pond water at maximum allowable pond level [1]	0.21
Flood water (required to overtop the dam)[2]	0.13
Total Breach Volume for sunny-day (piping) dam failure[3]	0.46
Total Breach Volume for rainy-day (overtopping) dam failure[3]	0.59

NOTES:
1. Pond water volume is calculated as the volume of water between the tailings and the maximum allowable pond level (El. 784.5 m).
2. Flood water volume is calculated as the volume water between the maximum allowable pond level (El. 784.5 m) and 0.3 m above the dam crest (786 m + 0.3 m = El. 786.3 m). This assumes the spillway (at El. 785.3 m) is blocked.
3. Assuming all of the tailings are released.

For the purpose of the dam failure assessment, it has been assumed that all of the stored water and tailings would be released. Although this assumption may be conservative for the total breach volume parameter, variations to this assumption do not have a large impact on the estimated peak discharge (based on the empirical equations described below).

Empirical equations and charts from MacDonald and Landridge-Monopilis (1984), Wahl (1998), Rico et al. (2008) and Fread (1981) were used to estimate the breach formation time and peak outflows from the hypothetical breach events. By assuming that the dam would breach to the base of the dam, it was conservatively estimated that a total of 0.46 Mm^3 and 0.59 Mm^3 of tailings and water would be released in a sunny-day (piping) and rainy-day (overtopping) failures, respectively. The Breach Formation Time (BFT) was estimated to be between 45 minutes to 1 hour. Based on a number of the empirical equations and charts, the peak breach discharge was estimated to be 300 m^3/s to 500 m^3/s

for both the sunny-day (piping) and rainy-day (overtopping) failures. The peak breach discharge of 400 m^3/s was used in the HEC-RAS model.

The peak breach discharge from the dam break will attenuate as the flood wave flows down the creek. Based on a USBR equation for peak flow attenuation (USBR 1982), the peak flow will dissipate by less than 5% before it reaches the equivalent distance of Trout Lake. For this study, no flow attenuation was assumed.

3.4 Hydraulic Model

3.4.1 HEC-RAS Computer Model

HEC-RAS model was used for the dam breach and inundation analysis for MAX Mine TSF. HEC-RAS is a one-dimensional hydraulic model developed by the US Army Corps of Engineers (USACE). It is capable of steady and unsteady flow simulations in river channels. Steady flow simulations were used for this study to calculate the flow along the channel downstream of the dam, with and without the dam breach. The limitation of HEC-RAS is that it cannot model two-dimensional flow; for example as a flood from a well-defined creek flows into a flood plain.

3.4.2 Model Geometry

Detailed 2 m contours near the TSF were provided by the client and cover the majority of the creeks; 20 m contours BC TRIM data were used in the northern portion of the lower Wilkie Creek. The cross-sections and their spacing along the river determine the geometric and hydraulic parameterization of the numerical model. Roughly 35 cross-sections were sampled across the model domain.

3.5 Model Uncertainties

There are a number of uncertainties inherent to dam breach and flood routing models. Some of the uncertainties for the MAX Mine TSF Dam Breach and Inundation Study are:

- Topography – Extents of inundation, especially in gently sloping valley bottoms, are sensitive to the topography; inaccurate topography can result in errors in inundation extents.
- Dam breach parameters – Breach formation time, depth, width and side slopes, are usually selected based on historical data and require a fair amount of judgment.
- Tailings dams vs. water dams – Most methodologies for estimating the dam breach parameters were developed for water-retaining dams, and they are applied to tailings dams with simplifying assumptions.
- Estimation of flow/ lack of calibration of model – Measured water level versus discharge data from a streamflow station are required to calibrate the model. Such data is often not available and, even if it is available, the data would cover only the range of flows recorded during the life of the station and not the extreme flood flows expected due a dam failure.

- Steady state vs. transient model – For simplification the model was run as steady state system. Dam breaches are transient and the resulting inundation area may change if the model was run transient.
- Selection of flow modeling software - HEC-RAS is one-dimensional; it cannot model two-dimensional flow, which may be required to more accurately determine the flood extents as the flood enters Wilkie Creek flood plain from Shrub Creek.

4 FLOOD INUNDATION RESULTS AND DICUSSION

The estimated sunny-day failure flood inundation areas for breaches at the Northwest and Southeast Dam are shown in Figure 1 and Figure 2, respectively. Mapping of the rainy-day failure flood inundation is not included due to the scale of the maps and the level of accuracy of the available topographic data.

4.1 Northwest Dam

The following key locations along the flood route were selected for the presentation of the model results:

- at the Northwest Dam;
- at the confluence of Shrub Creek and Wilkie Creek; and
- at the inlet of Trout Lake.

The above locations are shown in Figure 1. The preliminary dam break inundation water levels are summarized in Table 4.1.

Table 4.1 Northwest Dam Preliminary Dam Break Flows and Flood Depths

Scenarios	Locations of Interest	Natural Flow			Natural Flow and Dam Break Flow		
		Peak Flow (m^3/s)	Flow Depth (m)	Flow Elevation (m)	Peak Flow (m^3/s)	Flood Depth (m)	Flood Elevation (m)
Rainy Day Failure	At the Northwest Dam	15	2.1	774.1	415	8.1	780.1
	Confluence of Shrub Creek and Wilkie Creek	440	1.0	728.9	840	1.0	728.9
	Inlet of Trout Lake	600	2.1	715.7	1000	2.6	716.3
Sunny Day Failure	At the Northwest Dam	0.03	0.3	772.3	400	8.0	780.0
	Confluence of Shrub Creek and Wilkie Creek	3	0.3	728.3	403	0.7	728.7
	Inlet of Trout Lake	4	0.1	713.8	404	1.6	715.3

4.2 Southeast Dam

The following key locations along the flood route were selected for the presentation of the model results:

- at the Southeast Dam;
- at the confluence of Wilkie Inlet and Wilkie Creek; and
- at the inlet of Trout Lake.

The above locations are shown in Figure 2. The preliminary dam break impact is summarized in Table 4.2.

Table 4.2 Southeast Dam Preliminary Dam Break Flows and Flood Depths

Scenarios	Locations of Interest	Natural Flow			Natural Flow and Dam Break Flow		
		Peak Flow (m^3/s)	Flood Depth (m)	Flood Elevation (m)	Peak Flow (m^3/s)	Flood Depth (m)	Flood Elevation (m)
Rainy Day Failure	At the Southeast Dam	3	0.1	768.1	403	5.2	773.2
	Confluence of Shrub Creek and Wilkie Creek	550	1.6	717.2	950	2.3	717.9
	Inlet of Trout Lake	600	2.1	715.7	1000	2.6	716.3
Sunny Day Failure	At the Southeast Dam	0.03	0.02	768.0	400	5.2	773.2
	Confluence of Shrub Creek and Wilkie Creek	3	0.5	716.1	403	1.5	717.1
	Inlet of Trout Lake	4	0.1	713.8	404	1.6	715.3

5 CONCLUSIONS

The dam breach and inundation analyses completed for MAX Mine TSF are based on hypothetical modes of failure under extreme or highly unlikely events. For example, for a dam to be overtopped, not only would the flood storage capacity in the TSF have to be used up, but the freeboard would also have to be occupied. Given that this is study is based on hypothetical dam failures, the results of the analyses presented herein in no way reflect upon the structural integrity or safety of the dam.

The preliminary inundation study indicates that both the sunny-day (piping) failure and rainy-day (overtopping) failure would inundate the lower reaches of Wilkie Creek.

A bridge is located at the Wilkie Creek outlet to Trout Lake; however, the minimum elevation of the bridge has not been confirmed. The mean annual water elevation under the bridge is estimated to be 713.8 m. During a sunny-day dam failure the water level is expected to rise 1.5 m. During a rainy-day dam failure the water level is expected to rise 2.5 m from the mean annual water elevation. It is recommended that an assessment of clearance under the bridge, be completed to determine if there is sufficient capacity to convey the flows.

The inundation mapping, shown in Figure 1 and Figure 2, indicates that the theoretical flooding will not overtop the ridge between Wilkie Creek and the Village of Trout Lake. However, some areas along the banks of Trout Lake may be inundated.

6 RECOMMENDATIONS

The results of the theoretical dam breach and inundation study are based on the data available to KCB at the time of writing. If greater accuracy of flood inundation extents is required, we recommend the following steps be taken:

- Natural average and flood flows in the area should be confirmed with stream flow measurements or a regional analysis.
- Lower Wilkie Creek is wide and flat, accurate flood extents in this area are difficult to predict. More detailed topography is needed to more accurately estimate the flood extents.
- Due to the two-dimensional nature of the Shrub Creek and Wilkie Creek confluence, it is recommended that two-dimensional transient hydraulic modeling software be used to estimate more accurate flood extents.
- Depending on the flow conditions, the entrained tailings would either continue to travel downstream or deposit in the stream channel and on the floodplains as the flood recedes, which could lead to environmental and economic impacts. It is recommended to conduct detailed tailings run-out analysis to estimate the distances for tailings and water released from TSF.

7 CLARIFICATION REGARDING THIS LETTER

This letter is an instrument of service of Klohn Crippen Berger Ltd. The letter has been prepared for the exclusive use of FortyTwo Metals Inc. (Client) for the specific application to the MAX Molybdenum Mine. The letter's contents may not be relied upon by any other party without the express written permission of Klohn Crippen Berger. In this letter, Klohn Crippen Berger has endeavoured to comply with generally-accepted professional practice common to the local area. Klohn Crippen Berger makes no warranty, express or implied.

Yours truly,

KLOHN CRIPPEN BERGER LTD.

Y. J. Katty Wang, P.Eng.
Water Resources Engineer

Kate Patterson, M.Eng., P.Eng.
Water Resources Engineer

Terrence Jibiki, P.Eng.
Project Manager

KW/KP:dl

Attachments: Figure 1 – Northwest Dam Flood Inundation Mapping
Figure 2 – Southeast Dam Flood Inundation Mapping

REFERENCES

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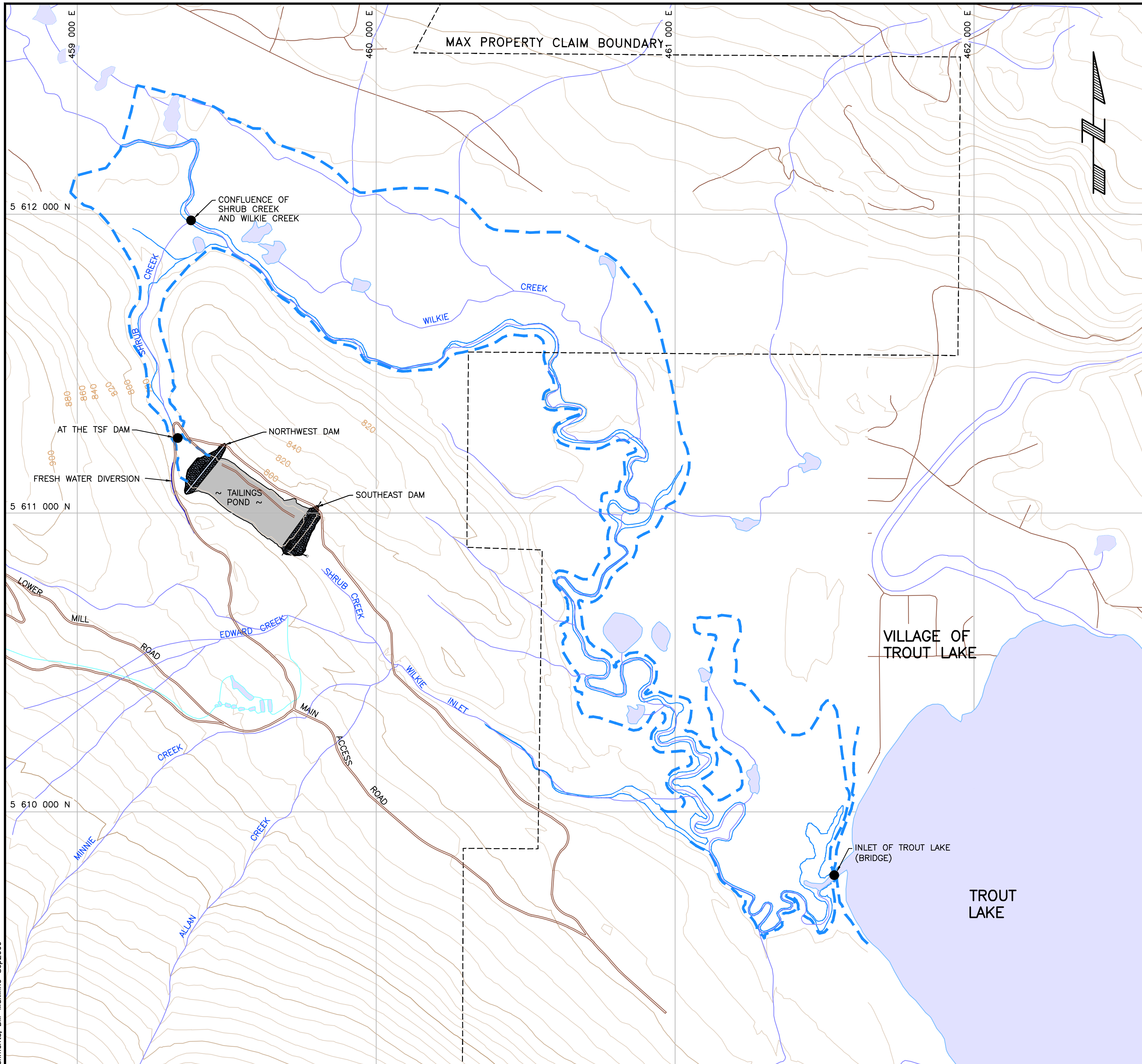
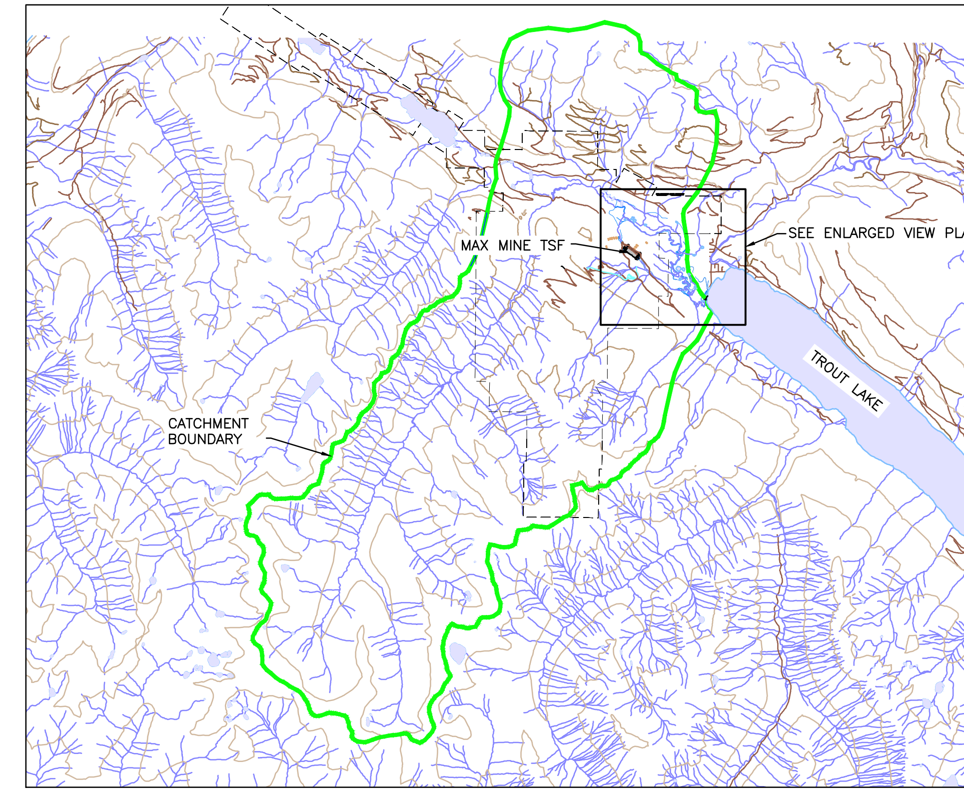
FIGURES



PLAN
SCALE A



LOCATION AND CATCHMENT PLAN
SCALE B

LEGEND

- DAM BREACH INUNDATION EXTENT (SUNNY–DAY DAM FAILURE)
- NATURAL CREEK FLOW
- CATCHMENT BOUNDARY
- ROAD
- STREAMS
- POINTS OF INTEREST

NOTES:

1. BASE DATA INCLUDING TOPOGRAPHIC CONTOURS, RIVERS AND LAND COVER IS DERIVED FROM THE BC TRIM II DATA SET (082K.063 & 063), CONTOURS: 20 METERS, PROJECTION: UTM NAD83 – ZONE 11
2. TAILINGS DAM BASE TOPOGRAPHY SUPPLIED BY FORTYTWO METALS INC., NOV. 2008.

SCALE A 0 250 m
SCALE B 0 5 km

NOT FOR CONSTRUCTION

To be read with Klohn Crippen Berger letter dated 2014–11–28

CLIENT

Forty Two Metals Inc.
(a wholly-owned subsidiary of Roca Mines Inc.)
490-1122 Mainland St.
Vancouver, B.C.
V6B 5L1
Tel 604.684.2900
Fax 604.684.2902
www.rocamines.com

Klohn Crippen Berger

PROJECT
MAX MOLYBDENUM MINE TAILINGS STORAGE FACILITY
DAM BREACH AND INUNDATION STUDY

TITLE
NORTHWEST DAM
FLOOD INUNDATION MAPPING

SCALE	PROJECT No.	FIG. No.
AS SHOWN	M09508A07	1

KCB–FIG–D–L

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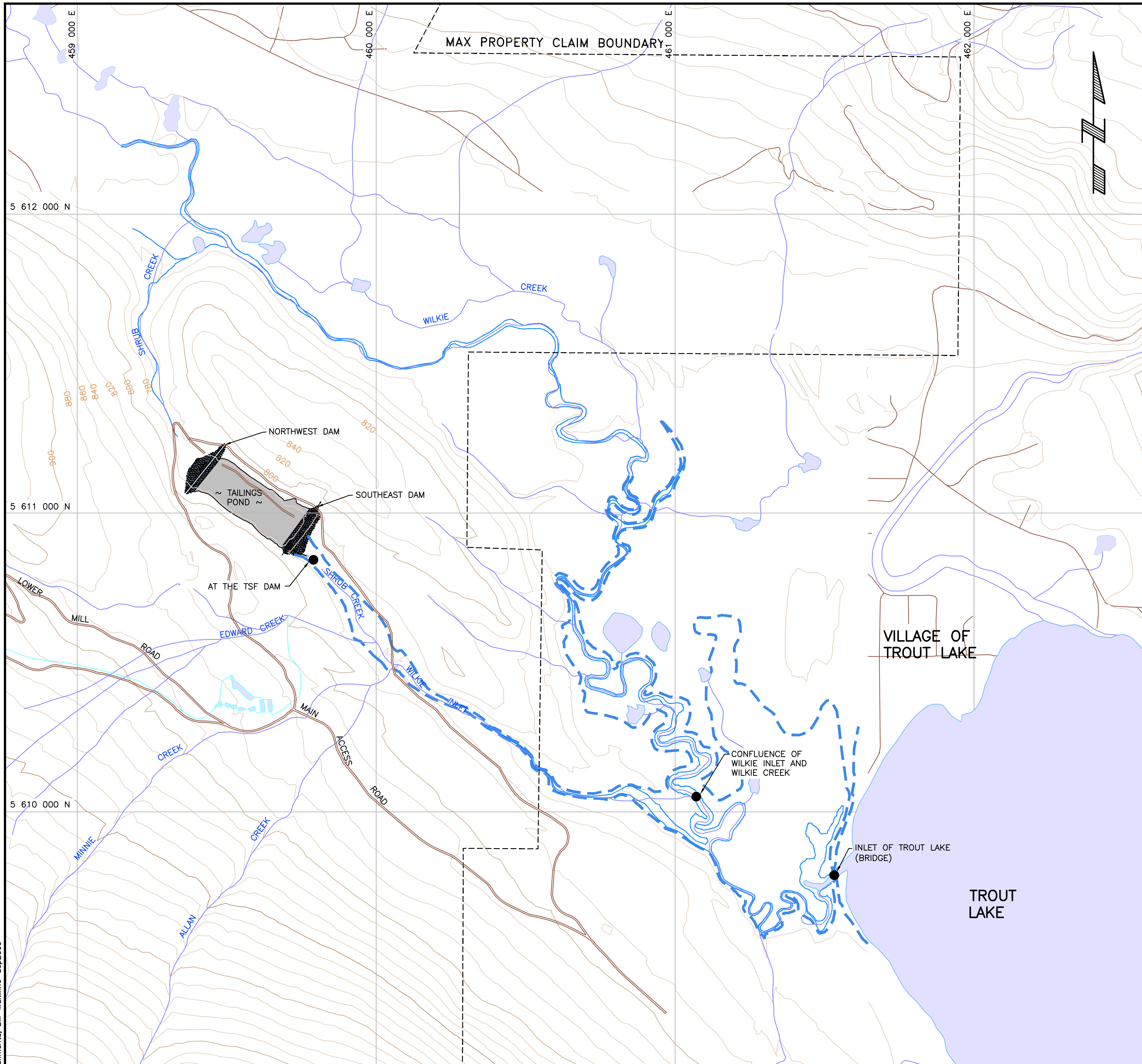
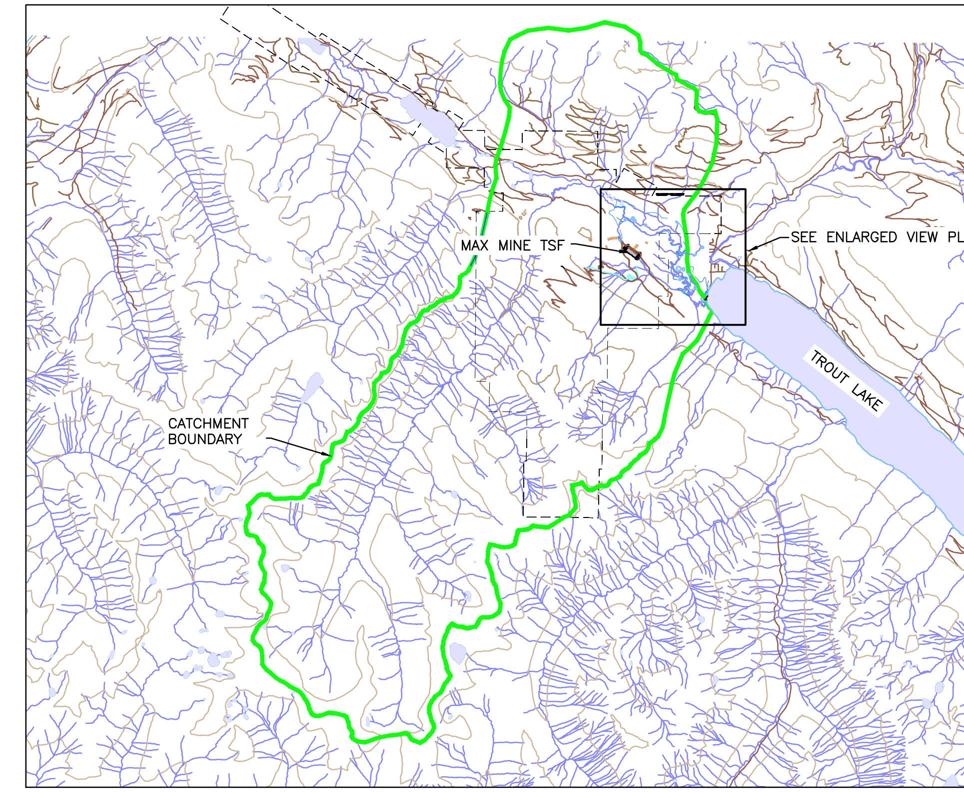


PLAN
SCALE A



LOCATION AND CATCHMENT PLAN
SCALE B

LEGEND

- DAM BREACH INUNDATION EXTENT (SUNNY-DAY DAM FAILURE)
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SCALE A 0 250 m
SCALE B 0 5 km

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CLIENT

Forty Two Metals Inc.
(a wholly-owned subsidiary of Roca Mines Inc.)
490-1122 Mainland St.
Vancouver, B.C.
V6B 5L1
Tel 604.684.2900
Fax 604.684.2902
www.rocamines.com

Klohn Crippen Berger

PROJECT
MAX MOLYBDENUM MINE TAILINGS STORAGE FACILITY
DAM BREACH AND INUNDATION STUDY

TITLE
SOUTHEAST DAM
FLOOD INUNDATION MAPPING

SCALE	PROJECT No.	FIG. No.
AS SHOWN	M09508A07	2

KCB-FIG-D-L

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