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KUDZ ZE KAYAH PROJECT

LIFE OF MINE WATER BALANCE MODEL REPORT

Rev	Description	Date
0	Issued in Final	October 10, 2018

Knight Piésold CONSULTING

EXECUTIVE SUMMARY

BMC Minerals (No.1) Ltd. (BMC) is proposing to develop the Kudz Ze Kayah Mine Project (the Project) in south east Yukon. The proposed Project is currently undergoing a Screening Assessment by the Yukon Environmental and Socioeconomic Assessment Board's (YESAB) Executive Committee, under the *Yukon Environmental and Socio-economic Assessment Act* (*YESAA*). As part of this Assessment, YESAB requested that BMC update the water balance and water quality models, prior to YESAB preparing the draft Screening Report (YESAB, 2018). The updated water balance modelling completed by Knight Piésold Ltd. (KP) is presented in this report. The key objective of the updated water balance model (referred herein as the Life-of Mine Water Balance Model) was to develop surface water and groundwater flow estimates for use as inputs to the updated water quality model.

A Life-of-Mine (LOM) Water Balance Model simulates water management flows, surface water, and groundwater flows using one continuous model that is built out through the entire life cycle of the proposed Project.

The model was developed by modifying the Baseline Watershed Model developed for the Project by KP (2018b) to include sub-catchments representing proposed mine infrastructure and surface water diversions. The Baseline Watershed Model was calibrated to measured streamflow at seven Project gauging stations.

The LOM Water Balance Model is based on mean monthly climate inputs developed from the Project synthetic climate record extending from 1972 to 2017. This 46 year record has a mean annual precipitation of 520 mm.

In addition to modelling surface water runoff and groundwater recharge within the existing natural catchment areas, key mine facilities and water management processes are represented in the model in order to simulate mine site and receiving environment water flows from baseline to post-closure conditions. Water flow through the following Project facilities was explicitly modelled: Process Plant, Class A, B, and C Storage Facilities, Open Pit, Overburden Stockpile, Low Grade Ore Stockpile and Run of Mine Pad, Water Treatment Plant, collection ponds, collection channels, and diversion ditches. The LOM model simulated water management flows, surface water, and groundwater flows during the following phases of mine development:

- Baseline
- Construction (Year -2 and -1)
- Operations (Year 1 to 10)
- Active Closure (Year 11 to 13)
- Transitional Closure (Year 14 to 25), when water discharges naturally via the ABM Pit Lake spillway), and
- Post-Closure (from end of Transitional Closure to the end of model, Year 41).

Activities during the life cycle of the Project are expected to affect stream flows in Geona Creek, Finlayson Creek and South Creek, and these effects diminish with distance from the proposed mine footprint.

In Geona and Finlayson Creek:

- During Construction and Operations, decreased streamflows are primarily attributed to the Fault Creek Diversion, and dewatering of the Open Pit. The average annual decrease in streamflows is predicted to be the greatest immediately downstream of the Project at KZ-9, prior to discharge of mine site water from the Lower Water Management Pond (LWMP). Discharge of mine site water immediately downstream of KZ-9 and at KZ-15 decrease the magnitude of flow reductions compared to KZ-9.
- During Active and Transitional Closure, flows downstream of KZ-9 are lower in Active and Transitional Closure than during Operations, this is attributed to the cessation of pit dewatering and these flows no longer being discharged to Geona Creek.
- During Post-Closure, average annual streamflows display a minor increase in flow (2 L/s) relative to Baseline conditions attributed to inter-basin groundwater flows from the South Creek catchment to the Geona Creek catchment.

In South Creek:

- During Construction and Operations, predicted flows increase approximately 50% (35 L/s) on an average annual basis due to the Fault Creek Diversion and diversions around the Open Pit into the South Creek Drainage.
- During Active through Post-Closure, flows are predicted to be less than baseline flows by 5 L/s (6%) due to the influence of the Open Pit on groundwater flows.

LOM Water Balance Model results suggest that water may need to be held in the LWMP during the low flow winter period, particularly during mine years with higher dewatering requirements (i.e., Years 3 to 6). The largest modelled pond volume that develops using mean monthly climate inputs is 200,000 m^3. In all modelled years that a pond develops, the pond is able to be completely emptied again during freshet.

Streamflow results were provided to Alexco Environmental Group (AEG) to input to the water quality model (AEG, 2018).

<u>Sensitivity Scenarios and Climate Variability</u>

Sensitivity scenarios were developed using the water balance model to assess the sensitivity of simulated flows under wet and dry climates and different proportions of runoff generated from project facilities.

- A wet climate condition (1:50 year return period wet climate) and a dry climate condition (1:10 year return period dry climate) was placed into the climate string during each Project phase, resulting in twelve sensitivity scenarios. Results of the sensitivity case simulations were provided as inputs to the water quality model.
- Runoff sensitivity scenarios were developed to simulate a 10% decrease and 10% increase in runoff from key mine facilities. Results of the sensitivity scenarios indicate that the volume of water stored in the LWMP was not sensitive to the proportion of runoff from the facilities. The water treatment plant (WTP) treatment rates are sensitive to an increase in runoff percentage, however all predicted treatment rates remained below the design maximum treatment rate.

A Variable Climate Case (VCC) model was developed using the LOM Water Balance Model to assess potential effects of climate variability on surface and groundwater flows and mine water management. The VCC model is comprised of 46 separate model iterations. Separate models were generated by iteratively stepping the long-term climate record through the LOM Water Balance Model. The VCC Model was used to assess potential variability of pond volumes and water treatment plant influent rates. Results of the VCC Model indicate that water may need to be held in the LWMP during mine years with lower winter flows in the receiving environment. Years 3 through 6 are predicted to have higher dewatering flows from the Open Pit and underground and model results indicate water storage in the LWMP during these years is likely, even when winter flows are relatively high. All VCC Model iterations predicted that the maximum volume of water held in the LWMP would be less than the design pond volume.

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ABBREVIATIONS

Kudz Ze Kayah Project .... the Project
Alexco Environmental Group .... AEG
BMC Minerals (No.1) Ltd. .... BMC
high density polyethylene .... HDPE
Knight Piésold Ltd. .... KP
Kudz Ze Kayah .... KZK
litre L
Low Grade Ore .... LGO
Life of Mine .... LOM
Lower Water Management Pond .... LWMP
Potentially Acid Generating .... PAG
Run of Mine .... ROM
Upper Water Management Pond .... UWMP
tonnes per day .... tpd
Water Treatment Plant .... WTP
year .... yr
Yukon Environmental and Socio-economic Assessment Act .... YESAA
Yukon Environmental and Socio-economic Assessment Board .... YESAB

GLOSSARY

Baseflow: the portion of streamflow that comes from the sum of deep subsurface flow and delayed shallow subsurface flow.

Discharge: the volume of water flowing in a channel defined at a given location or cross section of the channel.

Discretization: the spatial representation of a modelled area into discrete zones.

Evapotranspiration: the process by which water is transferred from the land to the atmosphere by evaporation from land and water surfaces and by transpiration from plants.

Hydrometeorology/Hydrometeorological: pertaining to the transfer of water and energy from the atmosphere to the land surface, encompassing meteorology and hydrology.

Mean Annual Precipitation: the average amount of precipitation, expressed in mm, which will fall on a specified area in a single year.

Orographic Effects: An increase in precipitation with elevation attributed to an air mass cooling and losing moisture carrying capacity as it rises over topographic relief.

Project (the Project): mining activities proposed to be carried out at Kudz Ze Kayah by BMC Minerals (No.1) Ltd. Regional Analysis: the examination of data collected throughout a region to estimate the conditions of a specific location.

Runoff and Surface Runoff: the amount of water flowing in a channel or past a specific point or channel cross section, typically expressed in mm, on the surface of the land (visible water).

Sublimation: a physical process where a solid turns into a gas without going through a liquid stage. In this document, sublimation refers to the process of snow and ice changing into water vapor in the air without first melting into water.

Yukon Environmental and Socio-economic Assessment Board: an independent body, responsible for implementation of the assessment responsibilities under the Yukon Environmental and Socio-economic Assessment Act.

1.0 INTRODUCTION

1.1 SCOPE OF REPORT

The Kudz Ze Kayah (KZK) Project (the Project), is a proposed copper-zinc-lead mine owned by BMC Minerals (No.1) Ltd. (BMC). The KZK Project Proposal is currently undergoing a Screening Assessment by the Yukon Environmental and Socio-economic Assessment Board's (YESAB) Executive Committee, under the *Yukon Environmental and Socio-economic Assessment Act* (*YESAA*). As part of this Assessment, YESAB requested that BMC update the water balance and water quality models, prior to YESAB preparing the draft Screening Report (YESAB, 2018). The water balance model presented herein has been developed to support the YESAB request and updates to the water quality model.

Watershed and site-wide baseline and operational water balance modelling was previously completed to support the YESAB Project Proposal by Alexco Environmental Group (AEG, 2017; Appendix D-6 of the Project Proposal). This earlier watershed model was based on hydrometeorological data collected at site in 2015 and 2016 and incorporated a water balance of operational flows (Knight Piésold, 2016) as well as results of numerical groundwater modelling for the proposed open pit (Tetra Tech EBA, 2016; Appendix D-4 of the Project Proposal). BMC retained Knight Piésold Ltd. (KP) to update the watershed and site-wide baseline and operational water balance modelling and incorporate the following:

- Hydrometeorological data collected in 2017 (AEG, 2018a)
- An updated understanding of Project climate and hydrologic flow conditions based on the additional year of data collection (KP, 2018a), and
- Updates from the numerical groundwater model (Tetra Tech EBA, 2018).

KP developed the Life-of-Mine (LOM) Water Balance Model based on the above input. The LOM Water Balance Model simulates water management flows, surface water, and groundwater flows during all phases of mine development using one continuous model. Simulated surface water and groundwater flow results from the LOM Water Balance Model were provided as inputs to the updated water quality model (AEG, 2018b).

Sensitivity scenarios were evaluated to address YESAB's Information Request IR3-1c (*The updated water balance model should include a sensitivity analysis;* YESAB, 2018). Sensitivity scenarios were developed to assess the sensitivity of simulated flows under wet and dry climates and different proportions of runoff generated from project facilities.

A Variable Case Climate (VCC) model was developed using the LOM Water Balance Model to assess potential effects of climate variability on surface and groundwater flows and mine water management. The VCC model is comprised of 46 separate model iterations. Separate models were generated by iteratively stepping the long-term climate record through the LOM Water Balance Model. The VCC Model was used to assess potential variability of pond volumes and water treatment plant influent rates.

1.2 PROJECT DESCRIPTION

The Project is located in the Saint Cyr Range area of the Pelly Mountains approximately 250 km northeast of Whitehorse, Yukon Territory, Canada. Development of the Project is proposed to include open pit and underground mining methods at a processing throughput rate of approximately 5,500 tonnes per day (tpd) over a mine life of approximately 10 years. The Project will produce the following waste materials:

- Class A material – Filtered tailings and strongly potentially acid generating (PAG) and high potential for metal leaching waste rock
- Class B material – Mildly PAG and moderate potential for metal leaching waste rock
- Class C material – Non PAG and low potential for metal leaching waste rock, and
- Overburden and Topsoil material – Surficial material removed from the open pit area and beneath key infrastructure.

Key Project facilities and infrastructure include the Open Pit and underground workings, Class A, B, and C Storage Facilities, Overburden Stockpile, Low Grade Ore (LGO) Stockpile and Run of Mine (ROM) Pad, process plant, water treatment plant (WTP), water management ponds, diversion channels, and collection ditches.

Proposed mine facilities will be located in the Geona Creek catchment at the headwaters of Finlayson Creek. The ABM Deposit is located adjacent to the catchment divide between Geona Creek and South Creek catchments. Fault Creek flows through the ABM Deposit area and feeds into Geona Creek. The Fault Creek drainage will be diverted to South Creek to facilitate development of the Open Pit.

Water management flow diagrams showing the water management and key facilities during each Project phase are presented in Appendix A (Figures A.1 through A.7).

1.3 KEY REVISIONS TO THE WATER BALANCE MODEL

Changes incorporated into the LOM Water Balance Model compared to the Receiving Environment Water Balance presented in Appendix D-6 of the Project Proposal (AEG, 2017) are discussed below.

1.3.1 REVISIONS TO MODEL METHODOLOGY

Key changes to the model methodology include:

- The water balance model presented in the Project Proposal consisted of a series of six separate 'snapshot' models that represented the key phases of mine development from Baseline to Post-Closure. A snapshot model means that the mine footprint represented in the model is static (unchanging), and therefore a separate model is used to represent each phase of mine development. Mine site flows incorporated in these snapshot models were obtained from an external Mine Water Balance Model (KP, 2016). The updated LOM Water Balance Model presented herein represents all phases of mine development (Baseline to Post-Closure) using a single continuous model built-out using monthly time steps. Mine site flows in the LOM Water Balance Model are calculated within the model.
- The water balance model presented in the Project Proposal and based on the KP Mine Water Balance Model (KP, 2016) used runoff coefficients to estimate the amount of runoff generated within the mine site area, including the natural ground and facilities. The LOM Water Balance Model proportions precipitation onto a stockpile into runoff or infiltration, with infiltration further proportioned into water

held in storage or released from storage. The storage function permits water to be released from storage in a stockpile during the months following a precipitation event.

- The LOM Water Balance Model calculates the time for the ABM Pit Lake to fill and water to discharge via the spillway. The time for the pit to fill adopted in the previous water balance model was not calculated by the model but based on the results of three-dimensional groundwater modelling by Tetra Tech EBA (2016; Appendix D-4 of the Project Proposal).

1.3.2 REVISIONS TO SITE FACILITIES AND PROCESSES

The LOM Water Balance Model included the following revisions or additional detail compared to the Receiving Environment Water Balance presented in the Project Proposal (AEG, 2017; Appendix D-6 of the Project Proposal):

- Footprint areas for the Class A, B, and C Storage Facilities, Overburden Stockpile, LGO Stockpile, and Open Pit grow on a monthly basis as the Project develops.
- The seepage rate leaving the Class A and Class B Storage Facilities is based on a calculation of potential leakage through the composite liner. Leakage at a rate of 0.007 L/s is estimated to leak through the basal liner of each facility and contribute to Geona Creek at full build-out.
- Seepage is generated from the Class C Storage Facility, Overburden Stockpile, LGO Stockpile, and ABM Pit Lake and contributes to the receiving environment.
- Dewatering rates for the Open Pit and underground works and groundwater inflows and outflows from the ABM Pit Lake are revised to updated results from numerical modelling by Tetra Tech (2018).

2.0 METHODS

2.1 OVERVIEW

The LOM Water Balance Model simulates mine site flows and flows within the downstream receiving environment in one continuous model through the life of the mine. The model builds upon the Baseline Watershed Model developed for the Project (KP, 2018b and reproduced in Appendix B), which was modified to include representation of key mine facilities, mineral processing, and water management processes. The water balance model is developed using the GoldSim modelling platform and uses a monthly time step.

Key steps to develop the LOM Water Balance Model included:

- Reproduce the Baseline Watershed Model using the Goldsim modelling platform. The Baseline Watershed Model was originally created using Microsoft Excel.
- Divide baseline sub-catchments in the mine site area into smaller sub-catchments that allow mine infrastructure and surface water diversions to be represented in the model.
- Build key mine infrastructure, mineral processing, and surface water diversions into the model during all phases of mining.

Additional detail on the water balance model background and methodology is provided below.

2.2 WATERSHED MODEL METHODOLOGY

2.2.1 WATERSHED MODEL METHODOLOGY

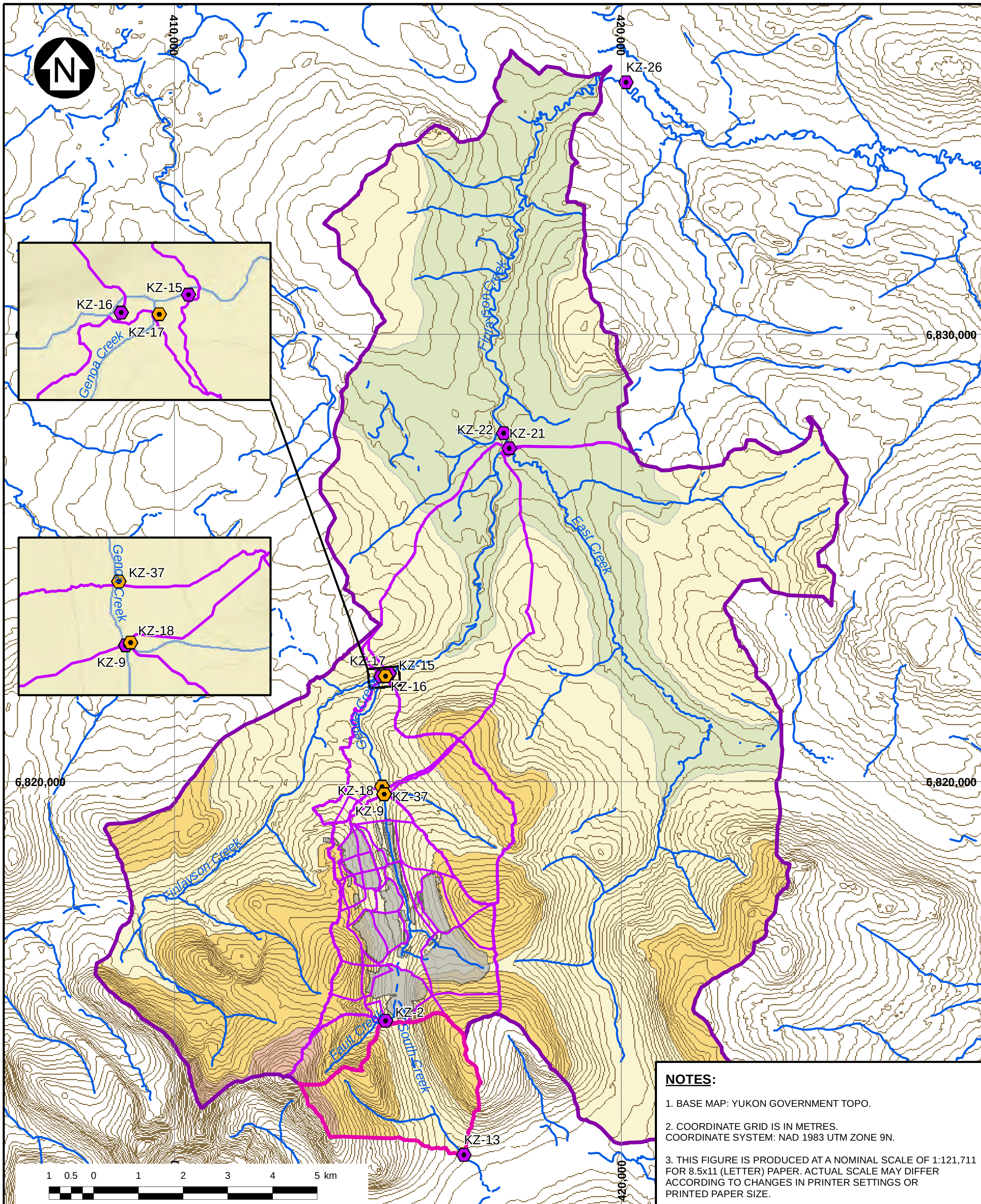
The LOM Water Balance Model is based on the Baseline Watershed Model provided in Appendix B. The watershed model framework is a semi-distributed parameter model that was developed as a spreadsheet-based model using Microsoft Excel. Climate input to the model is varied spatially based on differences in elevation, and the study area is divided into sub-catchments within which groundwater and surface water flows are modelled. Calculations in the model determine how precipitation is proportioned into different components of the hydrologic cycle, including rain or snow, snow pack accumulation, sublimation, snowmelt, evapotranspiration, and storage as soil moisture. The climate calculations determine the amount of water available for infiltration to groundwater and surface water storage and runoff. This available water is then either stored in reservoirs that represent surface water or groundwater storage in each sub-catchment or contribute to surface water or groundwater flows that leave the sub-catchment. Adjacent sub-catchments are linked together in the model to allow surface and groundwater flows to be routed to downstream sub-catchments. Detailed calculations to determine the climate components, groundwater infiltration, storage, and discharge, and surface water storage and discharge are described in Section 2 of the Baseline Watershed Model Report (Appendix B).

The Baseline Watershed Model was calibrated to measured streamflow at seven Project gauging stations. Parameter values that control surface water runoff and groundwater recharge and discharge were varied during the calibration process to obtain good agreement between measured and simulated streamflows. Parameter values assigned in the LOM Water Balance Model are consistent with values assigned in the calibrated Baseline Watershed Model. Results of the Baseline Model calibration and values assigned to model parameters are provided in the Baseline Watershed Model Report and are not reproduced here.

2.2.2 DEVELOP BASELINE CONDITION IN LOM MODEL

The mine site area of the LOM Water Balance Model was divided into smaller sub-catchments as shown on Figure 2.1 in order to represent hydrologic flows associated with proposed mine infrastructure and surface water diversions in the model. The majority of the mine site is located within the KZ-9 sub-catchment, with minor footprints extending into the KZ-17 and KZ-37 sub-catchments as shown on Figure 2.2. The remaining eight sub-catchment areas (KZ-2, KZ-18, KZ-16, KZ-15, KZ-21, KZ-22, KZ-26 and KZ-13) are unchanged from the Baseline Watershed Model. The LOM Water Balance Model uses 35 areas to represent the developing mine site area, including 33 areas in the KZ-9 sub-catchment and an additional area in each of the KZ-17 and KZ-37 sub-catchments.

Baseline flows were generated using the GoldSim LOM Water Balance Model once the mine site area was discretized (divided) into the smaller sub-catchment areas as described above. Mean monthly baseline streamflows predicted using the LOM Water Balance Model are shown in plots provided in Appendix C. The LOM Water Balance Model flows are shown in Appendix C along with streamflows predicted using the initial Excel-based Baseline Watershed Model. Comparison of the streamflows indicate the LOM Water Balance Model that is discretized into smaller sub-catchments in the mine site area simulates streamflows that are consistent with the Baseline Watershed Model (Appendix B).



NOTES:

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LEGEND:

- 10 M CONTOUR
- ACTIVE HYDROLOGY STATION & WATERSHED MODEL NODE
- WATERSHED MODEL NODE
- SUB-CATCHMENTS
- FINLYASON CREEK CATCHMENT
- SOUTH CREEK CATCHMENT
- PROJECT FACILITIES

ELEVATION BANDS (masl)

- 900 - 1,200
- 1,200 - 1,500
- 1,500 - 1,800
- 1,800 - 2,100

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	REVIEWED
0	09OCT'18	ISSUED WITH REPORT	KK	KK	CAS

BMC MINERALS (NO. 1) LTD

KUDZ ZE KAYAH PROJECT

LOM WATER BALANCE MODEL DISCRETIZATION

Knight Piésold CONSULTING

P/A NO.	REF NO.	
VA101-640/06	3	
FIGURE 2.1		REV 0

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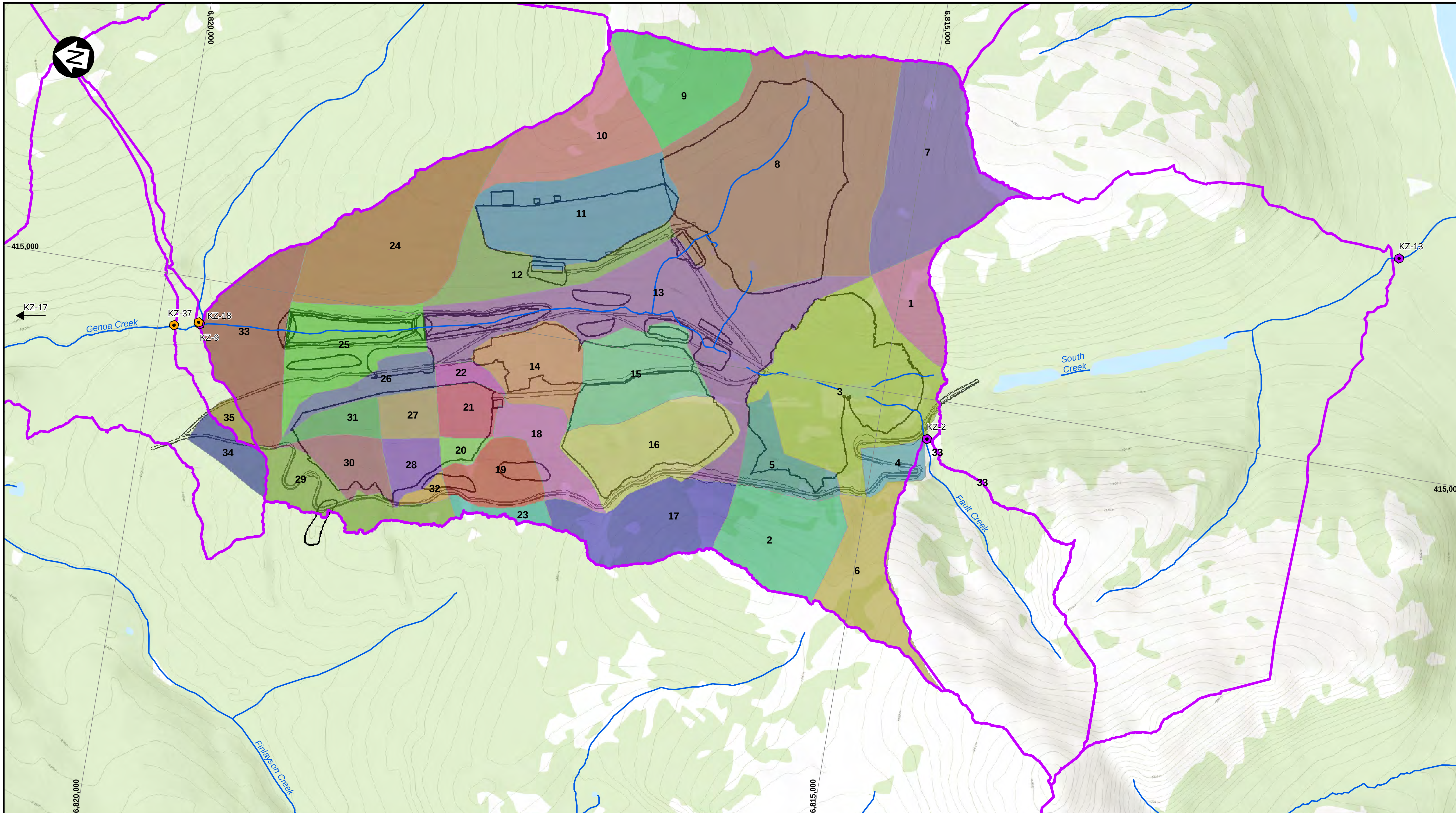

LEGEND:

- ACTIVE HYDROLOGY STATION & WATERSHED MODEL NODE
- WATERSHED MODEL NODE
- CREEK
- CATCHMENTS
- PROPOSED FACILITIES

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4. FOOTPRINTS OF MINE FACILITIES ARE SNOWN FOR ULTIMATE BUILD-OUT AT END OF OPERATIONS.

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	REVIEWED
0	09OCT'18	ISSUED WITH REPORT	KK	KK	CAS

BMC MINERALS (NO. 1) LTD.

KUDZ ZE KAYAH PROJECT

LOM WATER BALANCE MODEL
MINE SITE AREA DISCRETIZATION

Knight Piésold CONSULTING

P/A NO.	REF NO.
VA101-640/06	3

FIGURE 2.2 REV 0

2.3 MINE SITE FLOWS

Mine site flows are explicitly modelled in the LOM Water Balance Model, including flows associated with the following key mine facilities and processes:

- Process Plant
- Open Pit and Pit Rim Pond
- Class A, B, and C Storage Facilities and Collection Ponds
- Overburden Stockpile and Collection Pond
- Run of Mine (ROM) Pad, Low Grade Ore (LGO) Stockpile, and Sump
- Water Treatment Plant (WTP)
- Upper Water Management Pond (UWMP) and Lower Water Management Pond (LWMP)
- Surface water diversions (e.g., ditches and diversions), and
- Site water transfers (e.g., dust suppression, potable water, water pumped from one location to another).

Precipitation on a stockpile or storage facility is proportioned as either runoff or infiltration into the facility. Water that infiltrates into a facility is further separated into water held in storage or water released from storage as either seepage from the toe of the facility (toe discharge) or seepage to the underlying groundwater system. Calculations distributing water between runoff and infiltration into a facility use the same formula as for groundwater recharge to natural catchments described in Section 2.5.1 of the Baseline Watershed Model Report provided in Appendix B. Each modelled stockpile facility was assigned parameter values (i.e., K1, K2, and unit discharge) that best provided the anticipated proportions of runoff, infiltration, and seepage to groundwater.

Incorporation of hydrologic flows associated with the proposed mine facilities and proposed water management strategies are described in Section 4. Diagrams showing the water management plan for each Project phase are provided in Appendix A.

2.4 CLIMATE

Climate inputs to the LOM Water Balance Model consist of mean monthly precipitation and temperature values averaged from the long-term synthetic climate record extending from 1972 to 2017. The site-specific synthetic climate record was developed for the Project based on a correlation with regional climate data. Development of the long-term synthetic climate string is reported in the Hydrometeorology Analysis Report (KP, 2018a). The 46 year climate record is the same period of record incorporated into the Baseline Watershed Model (Appendix B) and has a mean annual precipitation of 520 mm.

2.5 EXTENT OF MODEL

The LOM Water Balance Model is constructed to represent Mine Year -2 to Year 41. The model also includes three years of baseline conditions prior to the start of Construction in Mine Year -2.

3.0 MINE DEVELOPMENT SEQUENCE

The LOM Water Balance Model simulates water management flows, surface water, and groundwater flows during all phases of mine development using one continuous model. The key phases of the mine life are summarized as:

- Baseline
- Construction (Year -2 and -1)
- Operations (Year 1 to 10)
- Active Closure (Year 11 to 13)
- Transitional Closure (Year 14 to 25, when water discharges naturally via the ABM Pit Lake spillway), and
- Post-Closure (from end of Transitional Closure into perpetuity).

The mine development schedule was based on the Open Pit and ore processing schedule presented in the Project Proposal submitted to YESAB (BMC, 2017). The mine plan is based on a nominal processing rate of 5,500 tpd.

Activities related to water management are listed below by phase and detailed by facility in Section 4. Diagrams showing the water management plan during each mine phase are presented in Appendix A. Flow schematics showing water pathways to and from each facility during each mine phase are provided in Appendix D (D.1 to D.7).

3.1 CONSTRUCTION

The Project begins with two years of construction prior to mine operation. Flow schematics for the two years of Construction are provided on Figure D.1 and Figure D.2 in Appendix D. The following general and water management activities occur during the construction phase and are represented in the model (more detailed information regarding each of the proposed construction and water management activities was previously described in the Project Proposal):

- Dewatering of overburden in the open pit area occurs during the 18 months prior to Operations facilitated by trenches. Overburden dewatering is pumped to the Pit Rim Pond prior to discharge to Geona Creek.
- Pre-stripping of overburden at the Open Pit begins in Year –1 and is stored in the Overburden Stockpile.
- The Class A Facility buttress is constructed in Year -1.
- Sediment ponds to collect and remove sediment from runoff leaving the Class C Storage Facility and Overburden Stockpile are constructed and operational in Year -1. Runoff from both sediment ponds is directed to Geona Creek.
- Diversion channels to direct non-contact water around Project facilities are constructed.
    - Diversions are constructed in Year -2 to direct runoff around the open pit area, including the Fault Creek Diversion Channel, Open Pit South Diversion Channel, Open Pit North Diversion Channel, and Geona Creek Diversion Channel.
    - Diversion channels are constructed in Year -1 to direct runoff around the Class A, B, and C Storage Facilities, including the East Diversion Channel and the Tote Road Diversion Channel.

- The Class A and B Collection Ponds, UWMP, and LWMP are constructed in Year -1 and are operated as flow-through ponds that do not retain water.

3.2 OPERATIONS

Operations consists of 10 years of ore processing. Flow schematics representing the Operations phase are provided on Figures D.3 and D.4 in Appendix D. The following facilities will be progressively built-out during Operations:

- Open Pit
- Class A Buttress
- Class A, B, and C Storage Facilities
- Overburden Stockpile, and
- ROM and LGO Pad.

The following water management activities occur during the Operations phase and are represented in the model:

- Processing of ore at Process Plant.
- Runoff from the Process Plant and associated sump.
- Water collected in the Class A and B Collection Ponds, Pit Rim Pond, ROM/LGO Sump, and Process Plant Sump is treated at the water treatment plant along with process water from the Process Plant. Treated water is sent to the Process Plant and the surplus is discharged to the LWMP.
- The Tote Road Diversion Channel, Geona Creek Diversion Channel, Open Pit North Diversion Channel and Open Pit South Diversion Channel are replaced by the North and South Upper Access Road Diversion Channel in Year 3.
- Diversion berms are progressively developed around the Class A and B Storage Facilities to divert surface runoff below the Diversion Channels around these facilities.
- Surplus from the UWMP is pumped to the LWMP for discharge starting in Year 1.
- Surplus from the LWMP is released to Geona Creek at two discharge locations (KZ-9 and KZ-15).

3.3 ACTIVE CLOSURE

Active Closure occurs from the end of ore processing (Year 11) to the end of reclamation of the diversions and storage facilities. The length of time to compete reclamation activities and develop operational closure covers is estimated at 3 years (Year 13). Diversions around the mine site will be decommissioned, allowing watercourses to return to their current direction. The following activities will occur during Active Closure and are included in the water balance model (Figure D.5):

- The Open Pit begins to fill from surface runoff and groundwater inflows.
- The Class A and B Collection Ponds remain operational, and water continues to be pumped from the collection ponds for treatment at the WTP.
- Final reclamation of the Class A, B, and C Storage Facilities begins in Active Closure; however, the closure cover is assumed not to be operational and does not affect the water balance of the facilities until the end of Active Closure.

- Diversion berms are maintained around the Class A and B Storage Facilities to divert surface runoff around these facilities.
- The Overburden Stockpile is used as reclamation material and removed at the start of Active Closure.
- ROM and LGO material are removed by the start of Active Closure. The cover over the Class B Storage Facility is extended over the ROM/LGO pad during Active Closure; however, the closure cover is not considered operational until the end of this phase.
- The Pit Rim Pond, Overburden Stockpile Sediment Pond, UWMP, LWMP and associated ditching and pumping systems are removed. The Class C Sediment Pond continues to operate.
- The Fault Creek Diversion Channel is decommissioned. Fault Creek returns to its existing drainage channel, which flows to the Open Pit and contributes to filling the ABM Pit Lake.
- The Upper Access Road Diversion Channels, East Diversion Channel, and South Diversion Channel are decommissioned.

3.4 TRANSITIONAL CLOSURE

Transitional Closure starts once the storage facilities are reclaimed with a cover and vegetation and is complete when the ABM Pit Lake fills. All diversion channels, collection ditches, and collection ponds will be removed, and no water retaining structures will remain on site. The open pit continues to flood and the water treatment plant continues to operate. The following activities will occur during Transitional Closure and are included in the water balance model (Figure D.6):

- Construction of covers on the Class A, B, and C Storage Facilities are complete and functioning at the start of Transitional Closure.
- The Class A, B, and C Collection Ponds are decommissioned. Runoff from the covers of the Class A, B, and C Storage Facilities is directed to Geona Creek.
- The WTP continues to treat water removed from within the Class A and B Storage Facilities via each facility’s seepage collection system.
- Construction of the North and South Wetlands in Geona Creek begins during Transitional Closure, but the wetlands do not influence the water balance.

3.5 POST-CLOSURE

Post-Closure starts when the ABM Pit Lake fills and begins to spill water to Geona Creek via the spillway. The water treatment plant is decommissioned. The following activities will occur (Figure D.7):

- The North and South Wetlands will be fully functioning by the start of Post-Closure to provide passive treatment of seepage from the Class A, B and C Storage Facilities and flow from the Open Pit.
- The diversion berms above the Class A and B Storage Facilities will remain to direct water around these facilities.

4.0 MODELLED WATER MANAGEMENT PROCESSES

The methodology used to represent each of the major mine facilities in the LOM Water Balance Model is discussed below, including a summary of the sources and losses of water at each facility and any key assumptions. Flow schematics showing water pathways to and from each facility during each mine phase are provided in Appendix D.

4.1 SUMMARY OF FACILITY WATER BALANCES

The water balance of each stockpile facility includes net precipitation on the facility, runoff, infiltration, seepage to groundwater, and water held in storage. The proportion of modelled runoff and infiltration to each of the facilities is summarized along with the net precipitation in Table 4.1. Net precipitation to each facility is expected to decrease once the facility is reclaimed due to an increase in evapotranspiration on the vegetated surface. Estimated rates of seepage to groundwater from each facility are summarized in Table 4.2.

Table 4.1 Runoff and Infiltration from Facilities

Facility	Mine Phase	Net Precipitation (m/yr)	Runoff %	Infiltration %
Class A Storage Facility	Operations & Active Closure[1]	0.29	20	80
	Transitional & Post Closure[2]	0.22	50	50[1]
Class B Storage Facility	Operations & Active Closure	0.32	20	80
	Transitional & Post Closure	0.25	50	50[1]
Class C Storage Facility	Operations & Active Closure	0.32	10	90
	Transitional & Post Closure	0.26	20	80
Overburden Stockpile	Operations	0.30	20	80
ROM/LGO	Operations & Active Closure	0.29	10	90
	Transitional & Post Closure	0.22	50	50
Class A Buttress	Operations & Active Closure	0.29	10	90
	Transitional & Post Closure	0.22	20	80

NOTES:

1. FACILIITES IN OPERATIONS AND ACTIVE CLOSURE ARE REPRESENTED AS FULLY UNRECLAIMED IN THE MODEL ALTHOUGH PROGRESSIVE RECLAMATION IS PROPOSED FOR THE CLASS A AND B STORAGE FACILITIES DURING THIS PERIOD.
2. FACILITIES IN TRANSITIONAL CLOSURE AND POST-CLOSURE ARE REPRESENTED AS RECLAIMED IN THE MODEL.
3. INFILTRATION TO THE CLASS A AND B STORAGE FACILITIES ONCE RECLAIMED IN TRANSITIONAL AND POST-CLOSURE REPRESENTS WATER THAT INFILTRATES INTO THE ROCK AND SOIL COVER ABOVE THE GEOMEMBRANE LINER. THE MAJORITY OF THIS INFILTRATED WATER DISCHARGES FROM THE COVER MATERIAL AND CONTRIBUTES TO GEONA CREEK OVER A SLOWER PERIOD THAN SURFACE RUNOFF. A PORTION OF WATER IS ASSUMED TO LEAK PAST THE GEOMEMBRANE LINER AND INTO THE FACILITY AT A RATE EQUAL TO THE RATE OF LEAKAGE OUT OF THE FACILITY (TABLE 4.2).

Table 4.2 Seepage Rates from Facilities

Facility	Mine Phase	Seepage[1] (L/s)
Class A Storage Facility	Operations to Post-Closure	0.007
Class B Storage Facility	Operations to Post-Closure	0.007
Class C Storage Facility	Operations & Active Closure	4.9
	Transitional & Post-Closure (Reclaimed)	3.3
Overburden Stockpile	Operations	1.8
ROM/LGO	Operations & Active Closure [2]	0.002
Class A Buttress	Operations & Active Closure	0.45
	Transitional & Post-Closure (Reclaimed)	0.36
ABM Pit Lake	Post-Closure	2.3

NOTES:

1. ESTIMATED SEEPAGE RATE AT MAXIMUM FACILITY FOOTPRINT.
2. THE ROM PAD AND LGO MATERIAL IS REMOVED AT THE END OF OPERATIONS. SEEPAGE TO GROUNDWATER IS ASSUMED TO BE GENERATED FROM THE FOOTPRINT AREA OF THE ROM PAD UNTIL THE CLOSURE COVER IS FULLY IN PLACE AND OPERATIONAL AT THE END OF ACTIVE CLOSURE.

4.2 OPEN PIT AND PIT RIM POND

Stripping and preliminary excavation at the Open Pit begins during Construction. The area of the Open Pit was linearly interpolated between the available pit phase plans from Year 1 to the end of Operations.

Sources of water to the Open Pit and ABM Pit Lake include:

- Surface water runoff from undiverted upslope catchment area (Year -1 onwards)
- Direct precipitation on the pit walls (Year -1 onwards) and ABM Pit Lake (Year 11 onwards)
- Groundwater dewatering (Year -1.5 through Year 10), and
- Groundwater inflows during Closure (Year 11 onwards).

Losses of water from the Open Pit and ABM Pit Lake include:

- Evaporation from the ABM Pit Lake
- Surface water discharge via a constructed channel to the South Wetland once the ABM Pit Lake reaches its maximum elevation during Post-Closure, and
- Groundwater outflow at a rate of 1.7 L/s in Post-Closure, assigned based on the results of 3-dimensional numerical groundwater modelling (Tetra Tech EBA, 2018).

The Pit Rim Pond will temporarily store runoff and groundwater that is pumped from the Open Pit and underground. Water from the Pit Rim Pond will be used in the paste plant or pumped to the WTP during Operations. The Pit Rim Pond will be decommissioned during Active Closure.

Groundwater flow to the Open Pit and underground workings was estimated using three-dimensional groundwater modelling conducted by Tetra Tech EBA (2018). Groundwater flow to the Open Pit includes the following details in the water balance model:

- Dewatering of the Open Pit and underground workings occurs through Construction and Operations, with dewatering flows directed to the Pit Rim Pond. Groundwater dewatering rates for each mine year were assigned as a constant value in the model equal to the average annual dewatering rate, calculated using rates for the first and last month of each year during Construction and Operations provided by Tetra Tech EBA (2018). Groundwater dewatering rates assigned in the LOM Water Balance Model are provided in Table 4.3.
- Open Pit dewatering ends at the end of Operations and groundwater flows into the Open Pit, contributing to the ABM Pit Lake. Groundwater inflows to the Open Pit during Closure are based on rates provided by Tetra Tech EBA (2018) and were assigned in the water balance model according to the elevation of the ABM Pit Lake. The relationship between groundwater inflows and Pit Lake elevation is presented in Table 4.4; inflows for intermediate elevations were linearly interpolated.
- The groundwater drawdown zone surrounding the Open Pit is predicted to extend into the South Creek (KZ-13) catchment as the Open Pit is advanced, causing groundwater from the South Creek catchment to flow to the Open Pit. The rate of groundwater flow between the South Creek and Geona Creek catchments is provided in Table 4.3 and Table 4.4 for Operations and Closure, respectively. During Baseline conditions, groundwater is predicted to flow from the Geona Creek catchment to the South Creek catchment at a rate of 400 m^3/d (4.6 L/s; Tetra Tech EBA, 2018). During Post-Closure, groundwater is predicted to flow from the South Creek catchment to Geona Creek catchment at a rate of 40 m^3/d (0.5 L/s).
- Groundwater seepage from the ABM Pit Lake is specified at 150 m^3/d (1.7 L/s) towards Geona Creek based on the results of 3-dimensional numerical modelling (Tetra Tech EBA, 2018). The water balance model assumes seepage from the ABM Pit Lake begins once the Pit Lake water surface reaches its maximum elevation.

Table 4.3 Open Pit and Underground Dewatering Rates (Construction and Operations)

Year	Open Pit Dewatering Rate (m^3/day)	Underground Dewatering Rate (m^3/day)	Flow from South Creek Catchment (m^3/day)
Baseline	-	-	-400[1,2]
Year -2 (last 6 mo)	5,150	0	200
Year -1	2,200	0	240
Year 1	1,200	0	25
Year 2	1,900	0	-165
Year 3	2,425	3,400	55
Year 4	1,560	2,950	250
Year 5	1,260	1,850	285
Year 6	1,365	1,700	285
Year 7	1,010	1,700	280
Year 8	1,060	1,700	275
Year 9	1,010	1,650	225

NOTES:

1. POSITIVE VALUES INDICATE GROUNDWATER FLOWS FROM SOUTH CREEK CATCHMENT AND CONTRIBUTES TO THE OPEN PIT AND UNDERGROUND WORKS. NEGATIVE VALUES INDICATE INTER-BASIN GROUNDWATER FLOW FROM GEONA CREEK CATCHMENT TO SOUTH CREEK CATCHMENT.
2. GROUNDWATER IS PREDICTED TO FLOW AT A RATE OF 400 m^3/d FROM THE GEONA CREEK CATCHMENT TO THE SOUTH CREEK CATCHMENT IN BASELINE CONDITIONS (TETRA TECH EBA, 2018).
3. THE INITIAL SIX MONTHS OF CONSTRUCTION ARE ASSIGNED A HIGHER DEWATERING RATE.

Table 4.4 Groundwater Inflows to the ABM Pit Lake based on Elevation

Pit Lake Elevation (masl)	Groundwater Inflow (m^3/day)[1]	Groundwater Flow from South Creek (m^3/day)[2]
1,250	1,520	190
1,279	1,680	140
1,290	1,720	130
1,301	1,720	130
1,309	1,720	130
1,319	1,700	120
1,327	1,680	120
1,335	1,660	120
1,342	1,640	120
1,346	1,620	120
1,352	1,610	120
1,357	1,570	110
1,362	1,520	110
1,367	1,480	110
1,371	1,350	100
1,375	1,310	80
1,380[3]	1,240	30
1,380[4]	1,410	40

NOTES:

1. GROUNDWATER INFLOW VALUES ARE FOR ACTIVE AND TRANSITIONAL CLOSURE AND ARE BASED ON RESULTS OF TETRA TECH EBA (2018).
2. VALUES INDICATE RATE OF GROUNDWATER FLOW FROM SOUTH CREEK CATCHMENT CONTRIBUTING TO THE ABM PIT LAKE.
3. VALUES ASSIGNED IN THE MODEL DURING THE FIRST YEAR THE PIT LAKE ELEVATION REACHES ITS MAXIMUM (1,380 masl) ELEVATION.
4. VALUES ASSIGNED IN THE MODEL IN SUBSEQUENT YEARS AFTER THE PIT LAKE REACHES ITS MAXIMUM ELEVATION.

4.3 PROCESS PLANT

The Process Plant is located on the western hillside of Geona Creek between the Class A and Class B Storage Facilities. The Process Plant Site consists of a lower pad for the WTP and Process Plant, and and an upper pad for the tailings filtration facility.

Precipitation on the Process Plant Site is proportioned into runoff and groundwater recharge. Surface runoff is collected in the Process Plant Site Sump and pumped to the WTP. Groundwater recharge flows to Geona Creek.

Sources of water to the Process Plant include:

- Reclaim water from the LWMP

- Process water from the WTP, and
- Water content in the ore.

Losses of water from the Process Plant include:

- Water in the filtered tailings reporting to the Class A Facility
- Water in concentrates
- Potable water, and
- Process water sent to the WTP.

Flow rates and assumptions for tailings and ore properties are listed in Table 4.5.

Table 4.5 Material Processing Assumptions

Parameter	Units	Value[1]
Dry Ore Production	tpd	5,500
Tailings Dry Density	t/m^3	1.80
Water in Ore	m^3/hr	12.9
Water in Tailings	m^3/hr	30.0
Reclaim Water from LWMP to Process Plant	m^3/hr	20.8
Process Water from WTP to Process Plant	m^3/hr	71.1
Process Water to WTP	m^3/hr	65.3
Water in Concentrates	m^3/hr	4.5
Water to Potable Water Treatment	m^3/hr	5.0

NOTES:

1. ALL VALUES PROVIDED BY BMC (GEORGE SMITH, PERSONAL COMMUNICATION, APRIL 24, 2018).

4.4 CLASS A AND B STORAGE FACILITIES AND INFRASTRUCTURE

4.4.1 CLASS A AND B STORAGE FACILITIES

Filtered tailings and Class A waste rock will be co-disposed in the Class A Storage Facility and Class B waste rock will be placed in the Class B Storage Facility. Both facilities are located on the western hillside of Geona Creek. Each facility footprint area is linearly interpolated between the beginning of Year 1 and the end of operations to determine the monthly footprint. Both facilities reach their maximum footprint area at the end of Operations.

The following water management strategies will be in place at the two storage facilities:

- Non-contact runoff will be directed around the facilities and to Geona Creek by diversion berms that are progressively advanced upslope as each facility grows.
- Both the Class A and B Storage Facilities will have a basin liner and closure cover consisting of a composite liner constructed of a high-density polyethylene (HDPE) geomembrane and a compacted glacial till layer.

Sources of water to the Class A and B Storage Facilities include net precipitation on the facility. Losses of water from the storage facilities occurs as runoff, water pumped from the facility via the seepage collection system, and as leakage through defects in the liner. Proportions of runoff, infiltration, and leakage from the facilities is specified in Table 4.1. The water balance of the Class A and B Storage Facilities consists of the following:

- Runoff from each storage facility will be directed to the respective facility's collection pond in Operations and Active Closure. Runoff from the reclaimed facilities in Transitional and Post-Closure contributes to Geona Creek.
- Net precipitation that does not runoff of the facility infiltrates material in the facility and is either held in storage or released from storage. Water released from storage in each facility will be collected in drains and sumps comprising the seepage collection system and is pumped to the respective facility's collection pond in Operations and Active Closure. Collection ponds will be decommissioned at the start of Transitional Closure and any water released from storage will be collected by the facility's seepage collection system and pumped directly to the WTP. The period of time water will be released from storage in the encapsulated facility is specified to be complete in the model at the end of Transitional Closure.
- Seepage to groundwater from the Class A and B Storage facilities was estimated by assuming defects exist in the composite liner (Appendix E). Results of the leakage calculation estimate a unit leakage rate from the storage facilities of $1x10^{-8}$ L/s/m^2, which corresponds to a leakage rate from each storage facility of 0.007 L/s at maximum build-out. The water balance assumes liner leakage starts in Year 1 and continues through Post-Closure at a rate that increases as the facility footprint increases. Leakage from both facilities is specified to discharge to Geona Creek downstream of the LWMP in the KZ-9 sub-catchment. Details of the liner leakage calculation are presented in the memo titled *Feasibility Study Estimate of Liner Leakage in Class A and Class B Storage Facilities* provided in Appendix E.

Reclamation of the storage facilities is complete at the end of Active Closure. Reclamation will include placement of a closure cover consisting of a composite liner overlain by drainage material, a layer of Class C material, overburden, topsoil, and a vegetated surface. The mine plan includes progressive reclamation of portions of the storage facilities as they fill. The water balance model does not include progressive reclamation and placement of the closure cover is instead specified at the end of Active Closure.

4.4.2 CLASS A STORAGE FACILITY BUTTRESS

A buttress for the Class A Storage Facility will be constructed from Class C material along the downslope edge of the facility. Construction of the buttress begins in Year -1 and reaches its maximum footprint area in Year 1. The monthly buttress footprint area in the model is linearly interpolated between Year -1 and Year 1.

Direct precipitation is the only source of water to the buttress within the LOM model. The estimated proportions of runoff and infiltration to the buttress are provided in Table 4.1. Seepage to groundwater beneath the buttress is specified to occur at a rate equivalent to the baseline rate of recharge in the undisturbed catchment once the facility is reclaimed, and at a rate that is 1.25 times higher than the baseline rate when unreclaimed.

Reclamation of the Class A Buttress is modelled to be complete at the end of Active Closure, even though progressive reclamation of the buttress is proposed during Operations. Modelling full reclamation of the buttress at the end of Active Closure is consistent with the modelled timing of reclamation of the storage facilities. Reclamation of the buttress includes placement of topsoil and a developing a vegetated surface.

4.4.3 CLASS A AND B COLLECTION PONDS

Collection Ponds located downstream of the Class A and B Storage Facilities will capture runoff along with water pumped from each facility's seepage collection system. Water held in the collection ponds will be pumped to the WTP for treatment. The Class A and Class B Collection Ponds will be lined with an HDPE geomembrane sitting on compacted till and will be operated as close to empty as practicable. The collection ponds will be decommissioned when the storage facility closure covers are operating effectively at the end of Active Closure.

Sources of water to the Class A and B Collection Ponds include precipitation on the ponds and runoff from undiverted contributing areas along with runoff and pumped releases from the seepage collection systems from each facility and runoff and toe discharge from the Class A Buttress.

4.5 CLASS C STORAGE FACILITY AND COLLECTION POND

Class C material will be stored in the Class C Storage Facility. The Class C Storage Facility is located on the east side of Geona Creek. The facility footprint area is linearly interpolated between the beginning of Year 1 and the end of operations to determine the monthly footprint. The Class C facility reaches its maximum footprint area at the end of Operations and remains that size through the closure phases even though material is removed for reclamation of other facilities.

Sources of water to the Class C Storage Facility include net precipitation on the facility during Operations and runoff from the undiverted upslope catchment in Closure. Losses of water from the Class C Storage Facility include runoff from the surface of the facility, seepage from the toe of the facility (toe discharge), and seepage to groundwater from the base of the facility. The proportion of net precipitation estimated as runoff and infiltration from the Class C Storage Facility through the mine life is provided in Table 4.1.

Reclamation of the Class C Storage Facility will be complete by the start of Transitional Closure. Reclamation includes placement of a soil cover and vegetated surface. Net precipitation to the facility is expected to decrease once the facility is reclaimed attributed to an increase in evapotranspiration.

Groundwater seepage from the Class C Storage Facility was estimated based on the rate of groundwater recharge to the undisturbed (baseline) catchment. Groundwater seepage from the Class C Storage Facility was assumed to be 1.5 times the baseline recharge rate during Operations and equal to the baseline recharge rate of 82 mm/yr once the facility is reclaimed at the start of Transitional Closure. Seepage rates are equal to 4.9 L/s from the unreclaimed facility and 3.3 L/s from the reclaimed facility when expressed as equivalent seepage rates from the facility at maximum footprint build-out.

The Class C Storage Facility runoff and toe discharge is collected in the Class C Collection Pond, which drains via a collection ditch to Geona Creek. The pond and the collection ditch are unlined and are assumed to be 80% efficient at conveying flows from the facility. The remaining 20% of bypass flows or channel losses infiltrates the ground and contributes to the groundwater system. The pond is modelled as a sediment pond that maintains a specified volume, with water in excess of this volume discharged via a collection ditch to Geona Creek. The Class C Collection Pond is decommissioned at the start of Transitional Closure, after which runoff and toe discharge from the storage facility contribute directly to Geona Creek.

4.6 OVERBURDEN STOCKPILE AND COLLECTION POND

The Overburden Stockpile will be used to manage the overburden material removed from the Open Pit area. The stockpile is located on the east side of Geona Creek to the north of the Class C Storage Facility. The facility footprint area is linearly interpolated between the beginning of Year -1 and Year 3 to determine the monthly footprint. The Overburden Stockpile reaches its maximum footprint area in Year 3 and is removed at the beginning of Active Closure when material is removed for reclamation of other facilities.

Sources of water to the Overburden Stockpile are limited to net precipitation on the facility. Runoff from undiverted areas of natural catchment downslope of the facility also contribute to the Overburden Collection Pond. Losses of water from the Overburden Stockpile include runoff from the surface of the facility, toe discharge, and seepage to groundwater. Runoff and infiltration into the Overburden Stockpile are estimated to be 20% and 80% of net precipitation, respectively (Table 4.1). Seepage to groundwater beneath the facility is estimated to be 1.5 times the rate of groundwater recharge in the undisturbed catchment (equal to 123 mm) calculated using the Baseline Watershed Model (Appendix B). This equals a seepage rate of 1.8 L/s from the facility at the full footprint extent.

All surface runoff from the facility will be routed to the Overburden Collection Pond via appropriate grading of the Overburden Stockpile and collection ditches. Flow from the Overburden Collection Pond will be conveyed to Geona Creek by gravity through a collection ditch. The pond and the collection ditch are unlined and are assumed to be 80% efficient at conveying flows from the facility. The remaining 20% of bypass flows or channel losses infiltrates the ground and contribute to the groundwater system. The pond is modelled as a sediment pond that maintains a specified volume, with water in excess of this volume discharged via a collection ditch to Geona Creek. The Overburden Collection Pond is decommissioned at the start of Active Closure, and runoff and toe discharge from the storage facility contribute directly to Geona Creek.

4.7 RUN OF MINE PAD AND LOW GRADE ORE STOCKPILE

The ROM Pad and LGO Stockpile are located at the base of the Class B Storage Facility, adjacent to the Process Plant. The facility footprint area is linearly interpolated between the beginning of Year 1 and Year 3 to determine the monthly footprint. The facility reaches its maximum footprint area in Year 3. The ROM pad and LGO stockpile will sit on a compacted, low permeability fill pad that overlies a pad of Class B or C rock. The basin liner of the Class B Facility extends beneath the LGO stockpile and ROM Pad, and includes a compacted glacial till and HDPE liner.

Runoff and infiltration into the LGO Stockpile are estimated to be 10% and 90% of net precipitation, respectively (Table 4.1). All surface runoff and toe discharge from the ROM Pad and LGO Stockpile will be collected in a sump and pumped to the WTP. Seepage to groundwater beneath the facility is estimated to occur as leakage through defects in the underlying HDPE geomembrane liner. Leakage through the HDPE liner is estimated at the same unit leakage rate as the Class A and B facilities ($1x10^{-8}$ L/s/m^2), resulting in a predicted leakage of 0.002 L/s when the facility is at maximum footprint.

The ROM and LGO material will be removed by the start of Active Closure and the pad will be covered with an extension of the Class B Storage Facility HDPE liner and cover. Reclamation of the pad is complete at the end of Active Closure and seepage to groundwater no longer occurs from the pad.

4.8 UPPER WATER MANAGEMENT POND (UWMP)

The UWMP is located in Geona Creek downgradient of the Process Plant. The UWMP is constructed in Year -1 and decommissioned at the start of Active Closure. Site contact water is routed to the UWMP for settling of sediments and is then pumped to the LWMP for additional storage prior to discharge. The UWMP is modelled as a water retaining pond with a specified minimum volume to facilitate settling of sediments; volumes in excess of the minimum volume are pumped to the LWMP.

A foundation drainage system will be constructed to convey groundwater flow beneath the UWMP and LWMP to Geona Creek. The UWMP will be lined with an HDPE geomembrane overlying compacted till. The lined facility is assumed to be 100% effective at retaining water. The 100% efficiency was assumed for modelling simplicity, since any leakage through the liner of the pond would flow downgradient and contribute to Geona Creek at approximately the same location that water pumped from the LWMP is released. In addition, defects in the pond geomembrane and the associated leakage are expected to be small given the short operational life of the pond (10 years) and the absence of vehicular traffic over the liner.

Sources of water to the UWMP include:

- Direct precipitation
- Non-contact runoff from diverted areas
- Non-contact runoff from undiverted areas, and
- A portion (30%) of the losses from the Class C Collection Pond and Collection Ditch. This portion was estimated based on the length of Collection Ditch located up-catchment of the UWMP and expected to contribute flow to the drainage upstream and flowing into the UWMP. The remainder of the seepage from the Class C Collection Pond and Collection Ditch contributes directly to Geona Creek.

Losses of water from the UWMP include evaporation from the pond and water pumped to the LWMP.

4.9 LOWER WATER MANAGEMENT POND (LWMP)

The LWMP is located in Geona Creek downstream of the UWMP. The LWMP is constructed in Year -1 and decommissioned at the start of Active Closure. The LWMP is modelled as a flow through pond, with water discharge to the downstream environment at KZ-15 and immediately downstream of KZ-9 based on the natural hydrograph. The LWMP is operated empty when there is sufficient capacity to discharge downstream.

A foundation drainage system will be constructed to convey groundwater flow beneath the LWMP to Geona Creek. The UWMP will be lined with an HDPE geomembrane overlying compacted till. The lined facility is assumed to be 100% effective at retaining water, based on the same rationale as the UWMP.

Sources of water to the LWMP include:

- Direct precipitation on the pond
- Runoff from undiverted areas

- Water pumped from the UWMP, and
- Discharge from the WTP.

Losses of water from the LWMP include:

- Evaporation
- Reclaim water for the Process Plant as required (see Section 4.2)
- Water required for dust suppression at a rate of 30 m^3/hr for 10 hours per day during the summer season from May through September, and
- Water discharged to Geona Creek immediately downstream of KZ-9 and Finlayson Creek at KZ-15. Discharge locations are shown on Figure 2.1. Discharge from the LWMP is constrained to the following ratios of natural streamflow to discharge flow:
  - KZ-37:
    - January to April: 2.3:1, and
    - May to December: 2:1.
  - KZ-15:
    - January to April: 4:1, and
    - May to December: 3:1.

Discharge from the LWMP is constrained to these ratios in order to minimize change in streamflow from baseline conditions at downstream locations and to minimize impact to receiving environment water quality. Water in excess of these ratios is held in the pond until the next month.

4.10 WATER TREATMENT PLANT (WTP)

The WTP starts to treat contact water at the start of Operations. The WTP is designed to treat runoff from the following sources, to a maximum treatment rate indicated in brackets (BQE Water, 2018):

- Class A Facility Collection Pond (287 m^3/hr)
- Process Water (68 m^3/hr), and
- Class B Facility Collection Pond, ROM pad and LGO stockpile sump, Pit Rim Pond, and Process Plant Sump (852 m^3/hr).

The Class A and B Collection Ponds will be decommissioned at the end of Active Closure and water will be pumped directly from the seepage collection systems in the Class A and B Storage Facilities to the WTP.

The WTP will be decommissioned when water treatment on-site is no longer necessary to meet water quality objectives in the receiving environment. The length of time treatment is required is partly dependent on the length of time drain-down (the release of water held in storage in material in the storage facilities) takes to complete. The drain-down period in the water balance model is specified to continue until the end of Transitional Closure. During Transitional Closure, water released from storage in the Class A and B Storage Facilities is collected by the facility's seepage collection system and pumped to the WTP. The WTP is decommissioned at the end of Transitional Closure in the model.

Treated flows from the WTP are discharged to the LWMP in Operations and to Geona Creek upstream of KZ-9 in Active and Transitional Closure.

4.11 NORTH AND SOUTH WETLANDS

The North and South Wetlands will be located within the Geona Creek drainage at the locations shown on Figure A.7. The North and South Wetlands are constructed and fully functioning by the start of Post-Closure to provide passive treatment of seepage from the Class A and B Storage Facilities and flow from the Open Pit. Surface flow from the ABM Pit Lake spillway is directed to the South Wetland. Water from the South Wetland flows to Geona Creek and into the North Wetland along with runoff from the covered Class A, B, and C Storage Facilities. Water from the North Wetland flows to Geona Creek.

4.12 DIVERSION CHANNELS

Diversion channels are used to capture and convey non-contact runoff around site infrastructure. Diversions are constructed by the start of Mine Year -1 with the exception of the Upper Access Road Diversions, which are constructed in Year 3. All diversion channels are decommissioned at the start of Active Closure.

The following Project diversion channels are incorporated in the model:

- East Diversion Channel: Directs non-contact runoff generated upslope of the Class C Storage Facility and Overburden Stockpile northward to Geona Creek.
- South Diversion Channel: Directs non-contact runoff generated upslope of the Class C Storage Facility and the Open Pit southward into South Creek.
- Fault Creek Diversion Channel: Diverts Fault Creek into South Creek to reduce flows toward the Open Pit.
- Open Pit Diversion Channels: Diversion channels along the west side of the Open Pit will function as the primary non-contact diversion channels in Years 1 and 2.
  - The Open Pit North Diversion Channel diverts water northward to the Geona Creek Diversion Channel and on to the UWMP.
  - The Open Pit South Diversion Channel diverts water southward to the Fault Creek Diversion Channel and on to South Creek.
- Tote Road Diversion Channels: Diversion channels along the main access road to the open pit area (Tote Road) will function as the primary non-contact diversion channel along the west side of the Class A and B Storage Facilities in Years 1 and 2.
  - The section of channel upslope of the Class A Storage Facility diverts water northward to Geona Creek.
  - The section of channel upslope of the Class B Storage Facility merges with the Open Pit North Channel and becomes the Geona Creek Diversion Channel, which routes water to the UWMP.
- Upper Access Road Diversion Channels: The Upper Access Road and Diversion Channels will be implemented in Year 3 to replace the Tote Road and Open Pit Diversion Channels as the primary diversion and to provide road access to the Paste Plant.
  - The section of channel upslope of the Class A and B Storage Facilities diverts water northward to Geona Creek.
  - The section of channel upslope of the Open Pit and the south portion of the Class B Storage Facility diverts water southward to the Fault Creek Diversion Channel and on to South Creek.

The Fault Creek Diversion Channel will be lined with an HDPE geomembrane and is assumed to be 100% efficient at conveying water. All other diversion channels are unlined and specified to be 50% efficient at conveying water. The 50% bypass or losses from the diversions infiltrates groundwater in the sub-catchment area directly downslope of the channel.

4.13 COLLECTION DITCHES

Collection ditches are used to collect runoff from disturbed areas for conveyance to collection points (e.g., collection ponds). Collection ditches downstream of the Overburden Stockpile and the Class A, B, and C Storage Facilities direct water to their respective collection ponds. Collection ditches are removed at the same time as their respective collection ponds.

Collection ditches around the Class A and B Storage Facilities will be lined and are assumed to be 100% efficient at conveying water.

5.0 RESULTS

5.1 STREAMFLOW RESULTS

A discussion on predicted streamflow changes in each catchment through the life of mine is provided below. Time series plots of simulated mean monthly flows at each of the water balance model nodes are presented in Appendix F. Predicted mean monthly streamflows at each model node during each mine phase and the calculated change in monthly flow from Baseline (in L/s and as % change) is presented in tables in Appendix G. Results in Appendix G are presented for the following mine years:

- Construction (Year -1)
- Early Operations (Year 2)
- Late Operations (Year 9)
- Active Closure (Year 12)
- Transitional Closure (Year 23), and
- Post-Closure (Year 38).

5.1.1 GEONA CREEK

Streamflow along Geona Creek and tributaries to Geona Creek during each phase of mine development is predicted to change as follows:

KZ-2 (Fault Creek):

- Flows at KZ-2 (Fault Creek) are directed to South Creek via the Fault Creek Diversion Channel in Construction and Operations.
- Surface flows at KZ-2 in Construction and Early Operations remain consistent with baseline flows.
- Mean monthly surface flows in Late Operations through Transitional Closure are predicted to decrease slightly (1 to 3 L/s) attributed to a decrease in groundwater discharge to the drainage under the influence of the groundwater drawdown zone of the Open Pit.
- Average annual and mean monthly streamflows at KZ-2 are within 1 L/s of baseline flows in Post-Closure. The minor decrease is due to the drawdown zone created along the high-wall side of the Open Pit, which causes a portion of the groundwater that would discharge to Fault Creek in Baseline conditions to instead flow to the Pit Lake.

KZ-9 (Geona Creek):

- The majority of the mine site area is located in the KZ-9 catchment, and average annual flows at KZ-9 are predicted to be less than baseline flows in Construction through Transitional Closure (Figures 5.1 and 5.2).
- Flows at KZ-9 are predicted to decrease the most in Operations due to active dewatering of the Open Pit and underground workings and capture of flows from Project facilities for treatment and release from the LWMP into Geona Creek immediately downstream of KZ-9 and on Finlayson Creek at KZ-15.
- Average annual streamflow increases in Active Closure relative to Operations due to the decommissioning of the UWMP and LWMP, which results in increased runoff in the Project area reaching KZ-9, and due to discharge of water from the WTP directly to Geona Creek upstream of KZ-9.

- Annual average streamflows in Post-Closure are slightly higher (2 L/s) than in Baseline. The increase is due to the inter-basin groundwater flow from the South Creek catchment to the ABM Pit Lake in the Geona Creek catchment. Monthly mean flows differ between Post-Closure and Baseline due to differences in drainage of water through the storage facilities and evaporation from the ABM Pit Lake.

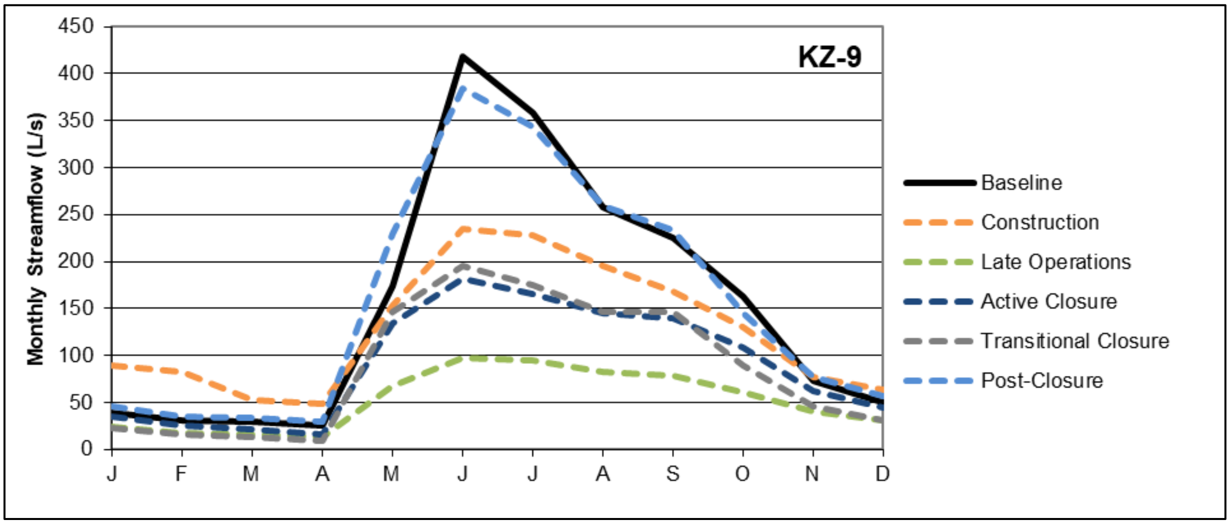

Figure 5.1 Predicted Flow at KZ-9 by Project Phase

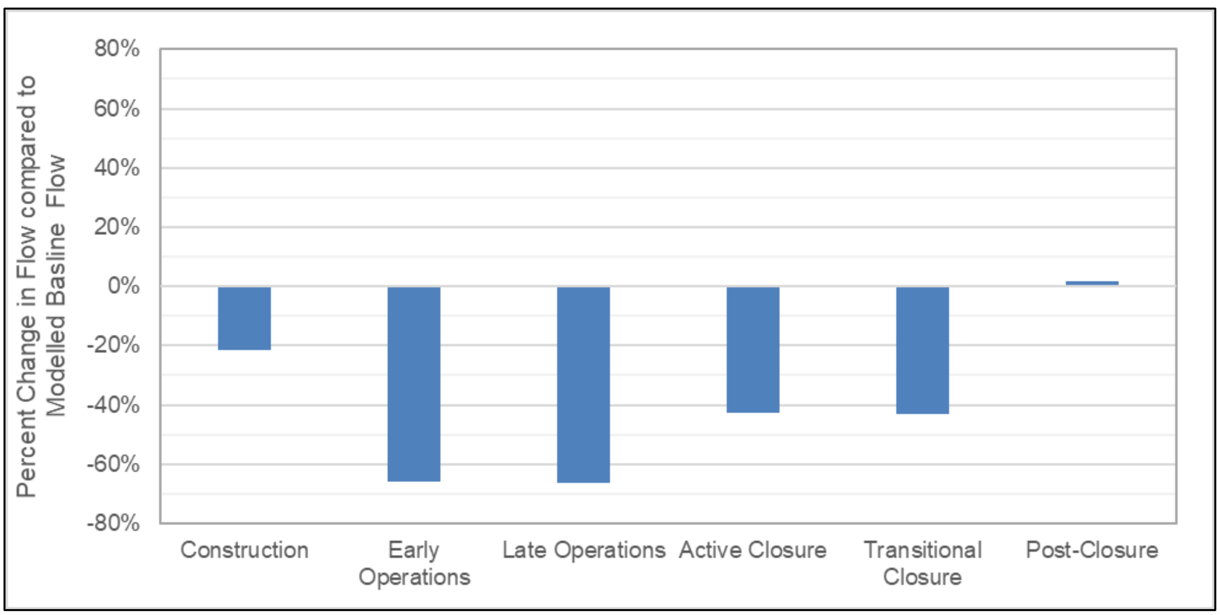

Figure 5.2 Predicted Percent Change in Flow at KZ-9

KZ-18 (Tributary of Geona Creek):

- The tributary to Geona Creek that flows to KZ-18 is unaffected by mine development. Predicted streamflows at KZ-18 remain unchanged through all phases of mine life.

KZ-37 (Geona Creek):

- Streamflows at KZ-37 are predicted to be lower than baseline flows during Construction through Transitional Closure (Figures 5.3 and 5.4). The magnitude decrease in streamflows at KZ-37 is less than at KZ-9 because of the water discharged to Geona Creek immediately downstream of KZ-9 from the LWMP (Table G.1 and G.2).
- Once mine site discharge immediately downstream of KZ-9 ceases in Active Closure, the magnitude decrease in flow (in L/s; Table G.2) relative to baseline flows at KZ-37 is consistent with KZ-9.
- Flows depart the most from baseline flows during Active and Transitional Closure when dewatering of the Open Pit is discontinued and groundwater and surface water flows fill the ABM Pit Lake.
- Annual average streamflows in Post-Closure are 2 L/s (1 %) higher than in Baseline, and exhibit similar monthly mean changes as flows at KZ-9.

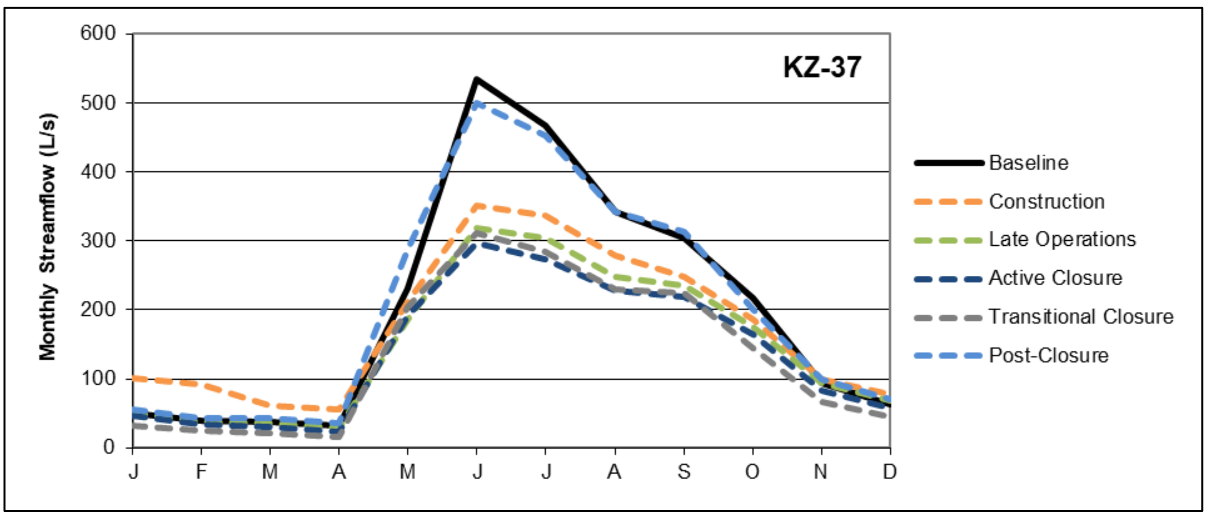

Figure 5.3 Predicted Flow at KZ-37 by Project Phase

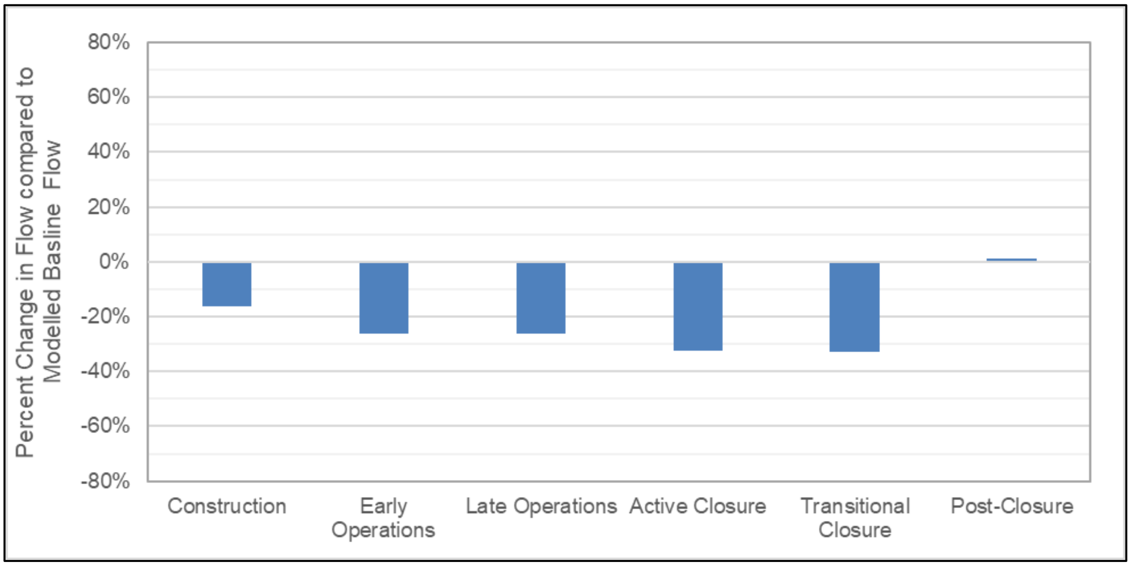

Figure 5.4 Predicted Percent Change in Flow at KZ-37

KZ-17 (Geona Creek):

- Streamflows at node KZ-17 display the same magnitude change in flow (in L/s) as KZ-37 (Table G.2).

5.1.2 EAST CREEK

KZ-21:

- East Creek is unaffected by mine development. Predicted streamflows at node KZ-21 remain unchanged through all phases of mine life (Table G.2).

5.1.3 FINLAYSON CREEK

KZ-16:

- The upper reach of Finlayson Creek that flows to KZ-16 is unaffected by mine development. Predicted streamflows at node KZ-16 remain unchanged through all phases of mine life (Table G.3).

KZ-15:

- Streamflows at the discharge location KZ-15 are predicted to be lower than baseline flows in Construction through Transitional Closure (Figures 5.5 and 5.6).
- The magnitude decrease in flow (L/s) during Operations is less than at upstream locations KZ-9 and KZ-37 due to the discharge of water from the LWMP at KZ-15. The decrease in flow during Construction and Operations is estimated to be 6 to 7% on an average annual basis.
- Annual average flows in Active and Transitional Closure are predicted to decrease by 65 to 66 L/s (12%) from baseline flows (Table G.3), consistent with flow predictions at the upstream Geona Creek locations, due to groundwater and surface water flows filling the ABM Pit Lake.

- Winter flows in Construction and Operations are slightly higher than in Baseline attributed to discharge of the dewatering flows from the Open Pit and underground. Once dewatering ceases, streamflows in winter months are predicted to be lower than baseline flows.
- Annual average streamflows in Post-Closure are predicted to be 2 L/s higher than baseline flows, which is equal to a 0% change in flow (Figure 5.6).

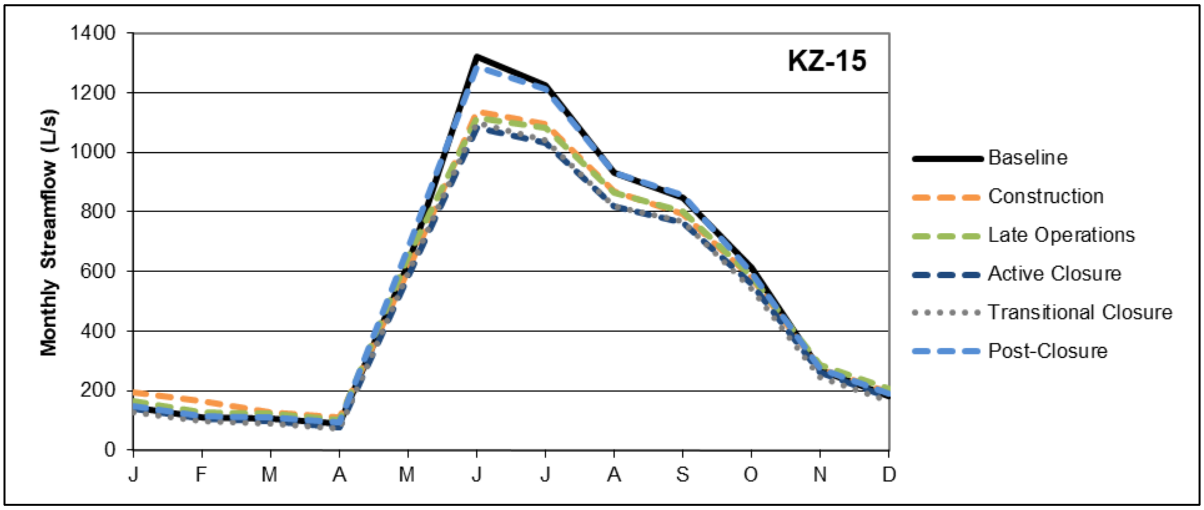

Figure 5.5 Predicted Flow at KZ-15 by Project Phase

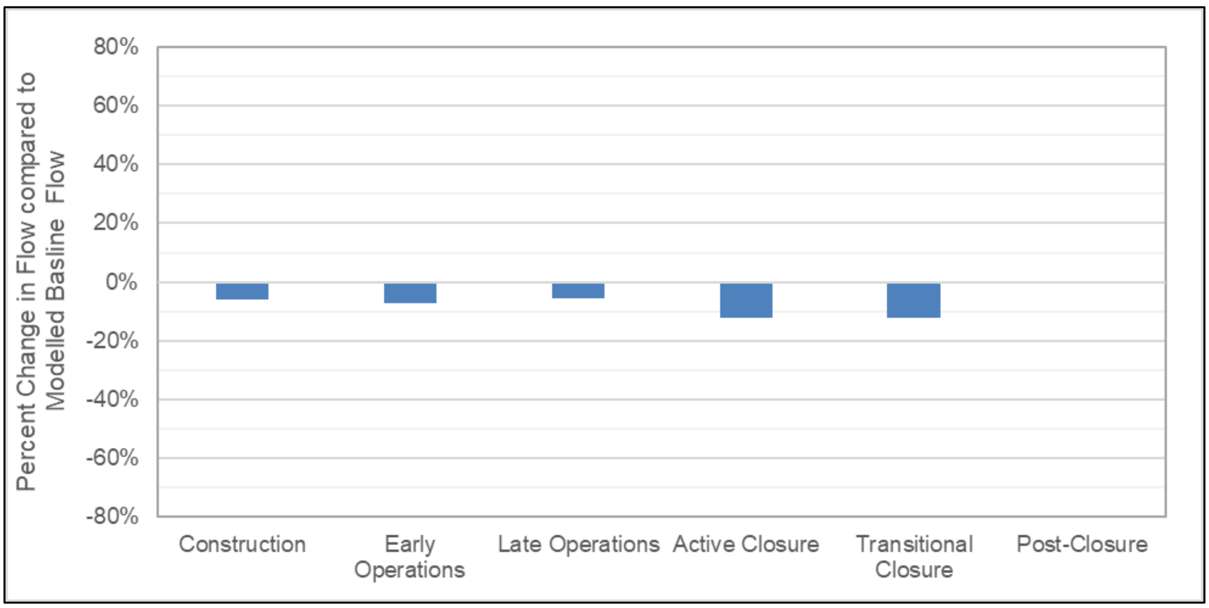

Figure 5.6 Predicted Percent Change in Flow at KZ-15

KZ-22 and KZ-26:

- The magnitude change in flow (L/s) at the two downstream-most nodes along Finlayson Creek are predicted to be consistent with change in flow at KZ-15 (Table G.3). Flows at KZ-26 during each mine phase are shown on Figure 5.7. Change in flow at KZ-26 on an annual average basis is predicted to vary by 5% or less from baseline flows during the life of the mine (Figure 5.8) and be the same as baseline flows in Post-Closure.

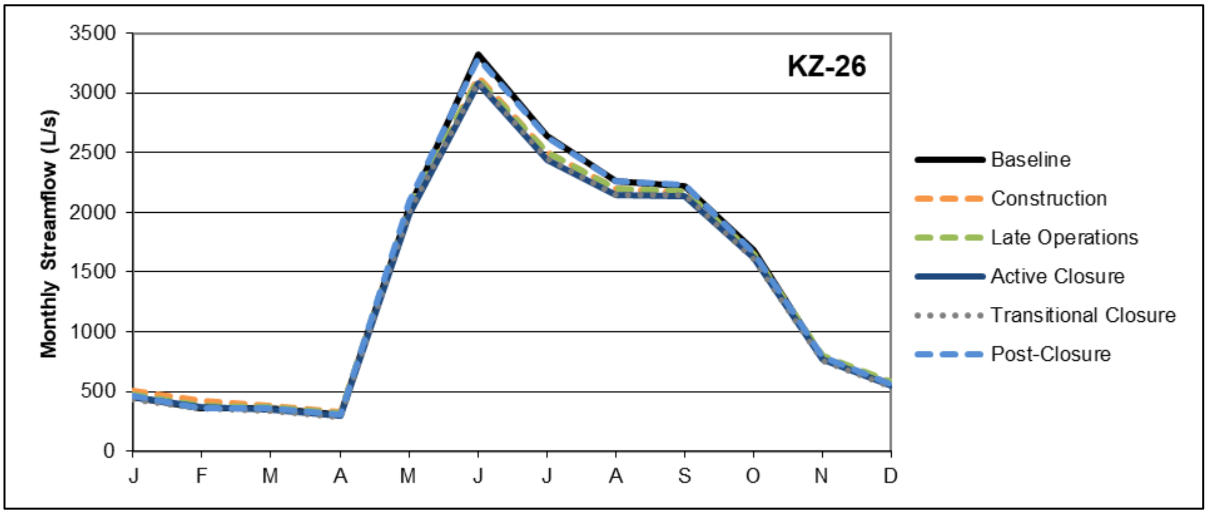

Figure 5.7 Predicted Flow at KZ-26 by Project Phase

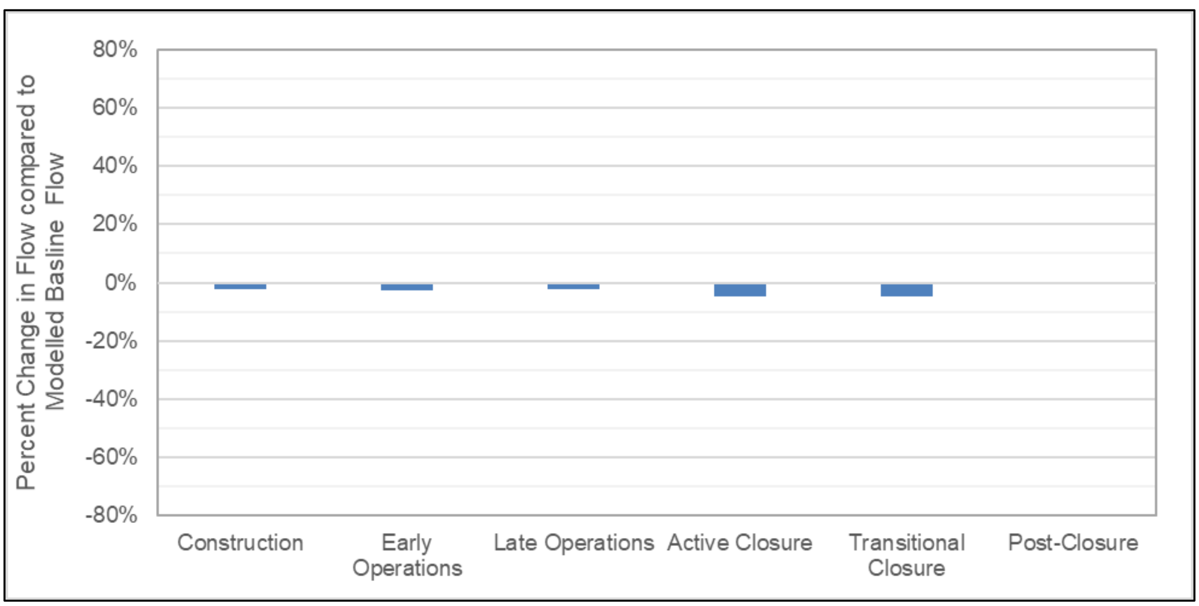

Figure 5.8 Predicted Percent Change in Flow at KZ-26

5.1.4 SOUTH CREEK

KZ-13:

- Predicted flows in South Creek at KZ-13 increase during Construction and Operations due to the runoff directed to this drainage via the Fault Creek Diversion and Open Pit diversions (Figures 5.9 and 5.10).
- South Creek flows are predicted to be less than baseline flows once the surface water diversions are removed in Active Closure. This decrease is attributed to the Open Pit serving as a groundwater sink, which causes groundwater to flow from the South Creek catchment to the Open Pit.
- Once the ABM Pit Lake fills in Post-Closure, South Creek streamflows are predicted to remain below baseline flows by 5 L/s (6%) on an average annual basis due to influences of the Open Pit on the groundwater flow regime (Table G.1). The predicted percent reduction in flow is larger during winter baseflow months and smaller during freshet flow months.

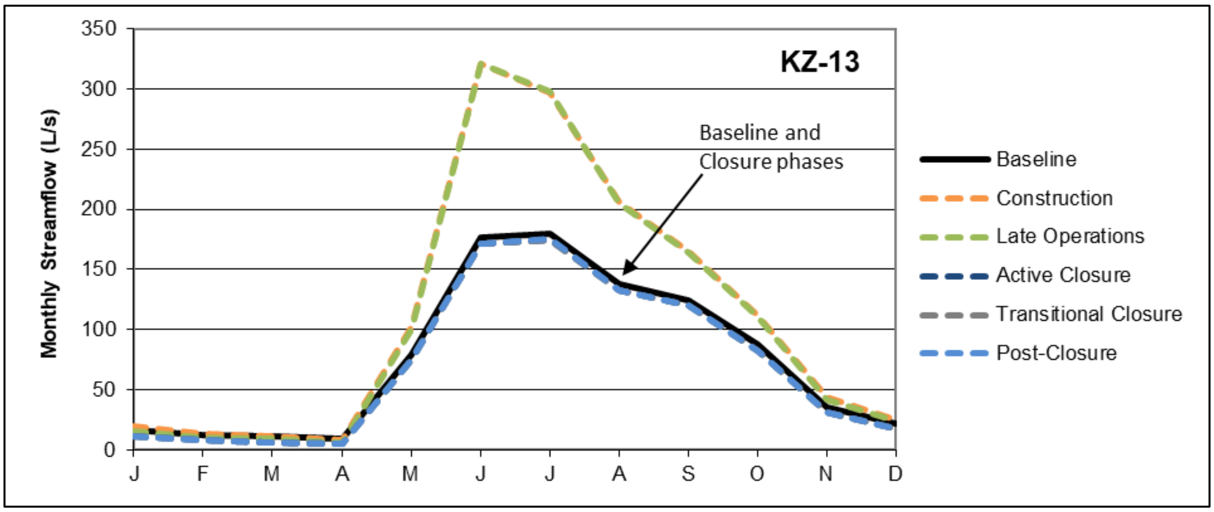

Figure 5.9 Predicted Flow at KZ-13 by Project Phase

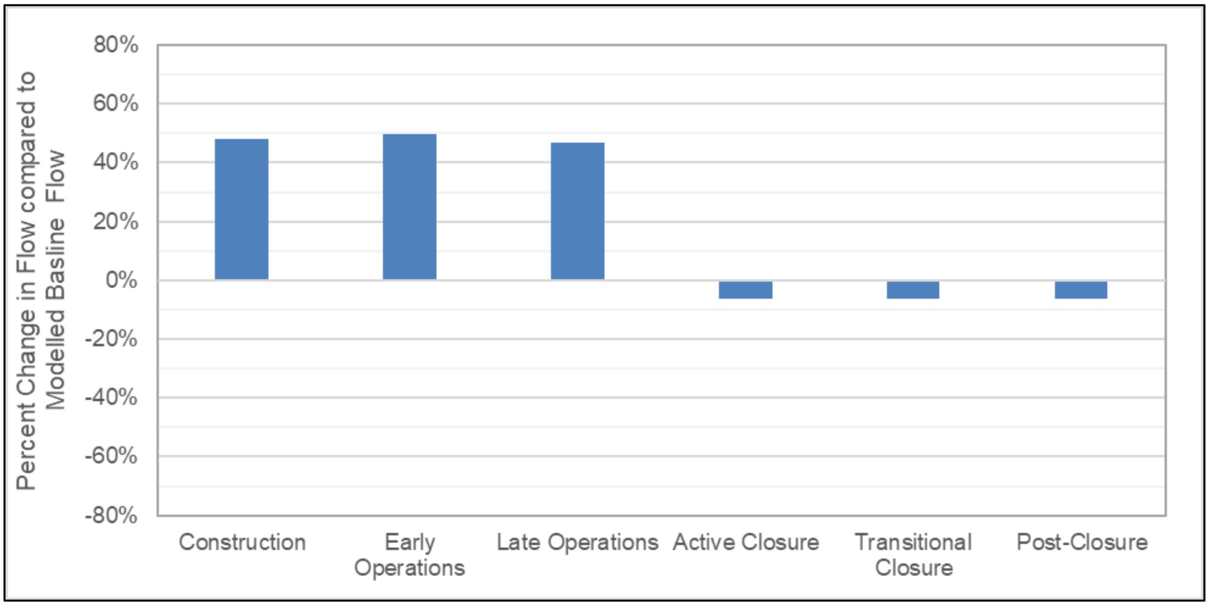

Figure 5.10 Predicted Percent Change in Flow at KZ-13

5.2 ACTIVE WATER MANAGEMENT

5.2.1 DISCHARGE OF WATER FROM LWMP

Water in the LWMP is discharged to the receiving environment immediately downstream of KZ-9 and at KZ-15 based on the following ratios of natural streamflow to discharge flow as discussed in Section 4.9:

- KZ-37:
  - January to April: 2.3:1, and
  - May to December: 2:1.
- KZ-15:
  - January to April: 4:1, and
  - May to December: 3:1.

The discharge strategy allows the volume of discharged water to match the streamflow hydrograph. Model results indicate there is capacity at these locations to discharge all water stored in the LWMP each month except during mid to late winter months (January to April) in Years 3 through 6. Dewatering of the underground starts in Year 3, and as a result, Years 3 through 6 have the highest open pit and underground dewatering requirements during the life of the Project (Tetra Tech EBA, 2018). Under mean monthly conditions, some water accumulation in the LWMP is expected for a period spanning between one to four consecutive months during these four years as shown in Figure 5.11.

Model results suggest that water may need to be held in the LWMP during the low flow winter period, particularly during mine years with higher dewatering requirements. The monthly volume of water directed to the LWMP and available for discharge during the winter months of years with higher dewatering flows is predicted to range from 75,000 to 130,000 m^3. At a design volume of 500,000 m^3 (reported in the Project

Proposal; BMC, 2017), the LWMP has sufficient storage capacity to hold water for several consecutive winter months and release the stored volume of water during freshet when flows are higher.

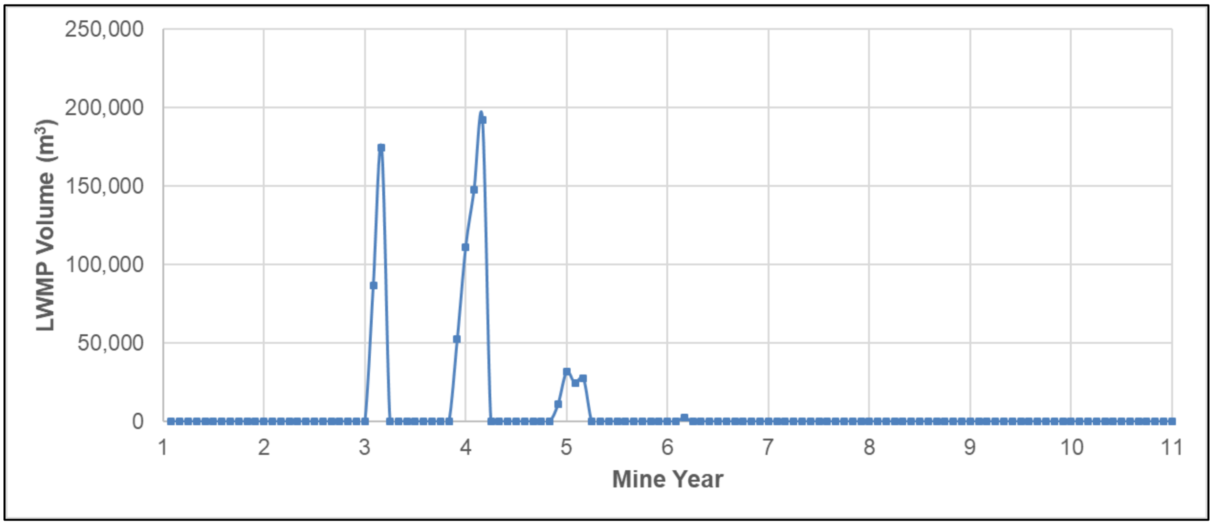

Figure 5.11 Simulated LWMP Volume

5.2.2 WATER TREATMENT PLANT

Mean monthly rates of treatment of the three water sources that feed into the WTP are shown on Figure 5.12. The rate of treatment of the Class A Facility Collection Pond is predicted to increase through the mine life as the facility footprint grows. The rate of treatment of the reclaim water remains a constant throughout the mine life. The rate of treatment of water from the Class B Storage Facility, ROM/LGO, Open Pit and Process Plant Sump is predicted to be the highest in Year 3 when the dewatering rate of the Open Pit and underground is the highest. The total annual volume of water treated by the WTP under average climatic conditions varies from 18 Mm^3 (Year 1) to 41 Mm^3 (Year 3) through Operations and Active Closure. All treatment rates are below the maximum design treatment rates for each influent stream specified in Section 4.10.

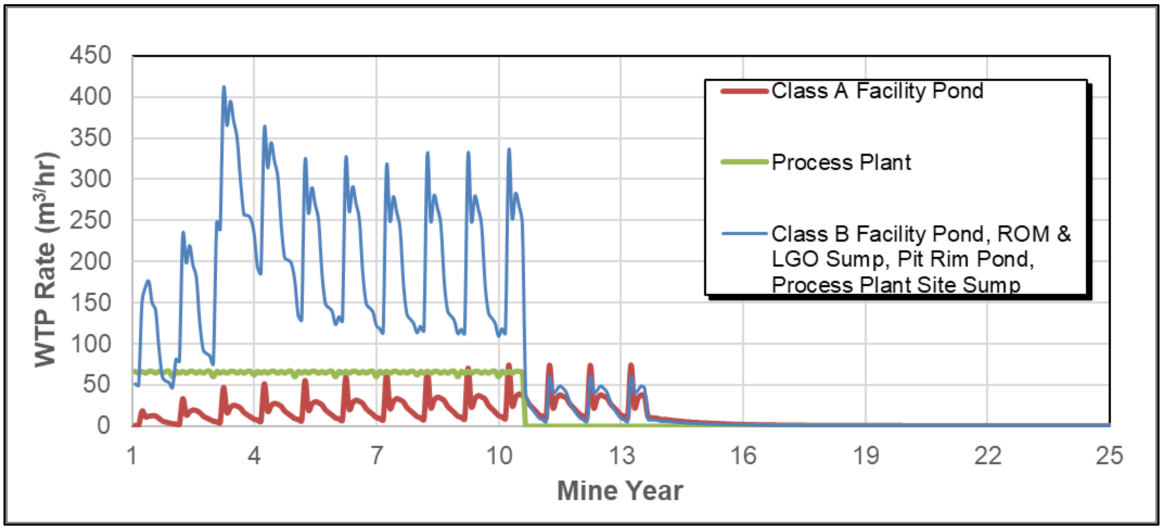

Figure 5.12 Simulated Water Treatment Rates

5.2.3 ABM PIT LAKE VOLUME

Results of the LOM Water Balance Model suggest the ABM Pit Lake will fill 15 years after dewatering is ceased at the end of Operations (i.e., in Year 25). A combination of groundwater inflows and surface water runoff fill the ABM Pit Lake in Active Closure and Transitional Closure. The simulated ABM Pit Lake surface water elevation over time is shown on Figure 5.13. The estimate of 15 years for the pit to fill compares well with the estimate of 16 years provided by Tetra Tech using a 3-dimensional groundwater model (Tetra Tech EBA, 2018).

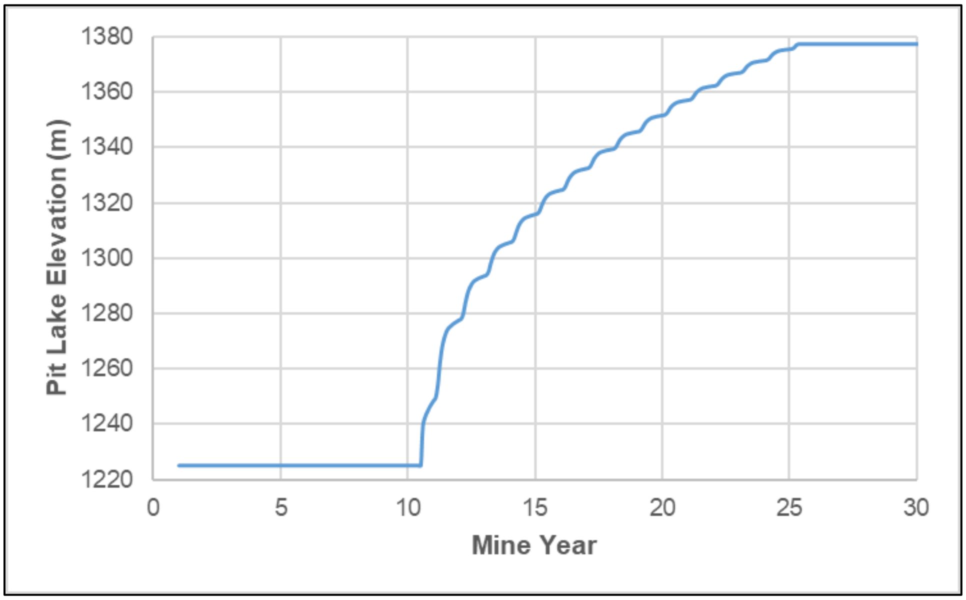

Figure 5.13 Simulated ABM Pit Lake Elevation

6.0 SENSITIVITY SCENARIOS

6.1 GENERAL

Sensitivity scenarios were evaluated to address YESAB's Information Request IR3-1c (*The updated water balance model should include a sensitivity analysis;* YESAB, 2018). The following sensitivity scenarios were developed:

- Climate sensitivity scenarios were developed by applying wet or dry climates to specific model years, and
- Runoff sensitivity scenarios were developed by varying the proportion of runoff from modelled facilities relative to the proportion of infiltration.

Additional detail for each sensitivity scenario is provided below.

6.2 CLIMATE SENSITIVITY SCENARIOS

6.2.1 METHOD

Climate sensitivity scenarios were developed in order to assess the influence of climate assigned in the model on water quality model results. The objective of the climate sensitivity cases was to create scenarios that test the sensitivity of the modelled water quality results. The following sensitivity cases were generated with the LOM Water Balance Model:

- W1 to W6 – Wet climate condition (1:50 year return period wet climate) during each phase of mine development, and
- D1 to D6 – Dry climate condition (1:10 year return period dry climate) during each phase of mine development.

A wet and dry year was generated in the sensitivity case by applying an annual precipitation to a model year that is equal to the estimated 1:50 year wet or 1:10 dry annual precipitation. Estimates of wet and dry year annual precipitation are presented in the Hydrometeorology Analysis Report (KP, 2018a) and are 722 mm for a 1:50 wet year and 394 mm for a 1:10 dry year. The wet and dry years were simulated by distributing the total annual year precipitation according to the mean annual distribution pattern. Monthly precipitation representing wet and dry years are shown in Table 6.1.

Table 6.1 Wet and Dry Year Monthly Precipitation

Month	1:50 Wet (mm)	Mean Monthly (mm)	1:10 Dry (mm)
January	40	28	22
February	27	20	15
March	30	22	17
April	19	13	10
May	52	37	28
June	93	66	51
July	127	91	70
August	114	82	63
September	83	59	46
October	57	40	31
November	40	28	22
December	40	29	22
Annual	722	516	394

NOTES:
1. VALUES CALCULATED BY DISTRIBUTING THE TOTAL ANNUAL WET AND DRY PRECIPITATION ACCORDING TO THE MEAN ANNUAL DISTRIBUTION.

The mine years assigned as the sensitivity cases were the same for the wet and dry scenarios and were selected so that they generally represented one of the last years of the respective mine phase. The wet/dry years were placed into the climate string as hydrologic years (spanning from October to September of the next year) so that the hydrologic year ends in the following mine years:

- W1/D1 (wet/dry) = Mine Year -1 (Construction)
- W2/D2 = Mine Year 2 (Early Operations)
- W3/D3 = Mine Year 9 (Late Operations)
- W4/D4 = Mine Year 12 (Active Closure)
- W5/D5 = Mine Year 20 (Transitional Closure), and
- W6/D6 = Mine Year 38 (Post-Closure).

6.2.2 RESULTS

Simulated mine site flows, streamflows, and groundwater flows from the sensitivity cases were provided as inputs to the water quality model (AEG, 2018b).

Predicted streamflows in the downstream receiving environment for the climate sensitivity cases are provided in plots comparing them against baseline streamflows in Appendix H. Wet or dry climate conditions during Active Closure or Transitional Closure (W4, D4, W5, and D5 scenarios) have an impact on the month or year the pit fills. A wet climate condition during Active or Transitional Closure (W4 and W5 scenarios) predicts the pit will fill almost one year earlier than the base case. A single dry climate year during Active or Transitional Closure (D4 and D5 scenarios) predicts the pit will fill one month later than the base case.

6.3 RUNOFF SENSITIVITY SCENARIOS

6.3.1 METHOD

Runoff sensitivity scenarios were developed to specifically address YESAB's Information Request IR3-1c (*The updated water balance model should include a sensitivity analysis for run-off coefficients).* Sensitivity scenarios were developed that simulate decreased and increased runoff from key mine facilities as follows:

- Decreased runoff scenario – runoff from key mine facilities was decreased by 10% from the base case value. Runoff was specified to be 5% in the decreased scenario if the base case runoff was 10%, and
- Increased runoff scenario – runoff from key mine facilities was increased by 10% from the base case value for all facilities.

Runoff was varied on the facilities specified in Table 6.2 by the percentage indicated in the table.

6.3.2 RESULTS

Water treatment plant influent rates and operational pond volumes are the key water management activities that may be influenced by a change in runoff proportion from Project facilities. The predicted influent rates to the WTP and LWMP operational volumes are shown in plots in Appendix I for the runoff sensitivity scenarios.

Mean monthly rates of treatment of the three treatment circuits that feed into the WTP are shown on Figure I.1 in Appendix I. Results of the runoff sensitivity scenarios display the following characteristics for the three WTP treatment circuits:

- Class A Treatment Circuit – Increased runoff causes the peak influent rate of water from the Class A Collection Pond to increase to 83 m^3/hr (from a base case value of 74 m^3/hr), while the decreased runoff scenario has a peak influent rate of 53 m^3/hr. The higher peak rates in the increased runoff scenario are associated with lower winter influent rates since a smaller proportion of the net precipitation is available to infiltrate the Class A Storage Facility and be released from storage over time. The peak treatment rate under the increased runoff case is about 30% of the maximum treatment capacity of Class A Treatment Circuit.
- Process Water Treatment Circuit – The rate of treatment of the reclaim water is unchanged by varying the modelled runoff on facilities.

- Class B, ROM/LGO, Pit Rim, and Process Plant Site Treatment Circuit – The rate of treatment of water from the combined facilities does not display much sensitivity to the assigned proportion of runoff. Runoff to the Class B and ROM/LGO facilities was increased (Table 6.2) and these facilities contribute up to 22% of this treatment circuit's inflows. The open pit groundwater and surface water dewatering flows comprise between 75 and 100% of the treatment circuit's inflows, and these values were unchanged as part of the sensitivity analysis.

Table 6.2 Runoff Percent in Sensitivity Scenarios

Facility	Mine Phase[1,2]	Decreased Runoff %	Base Case Runoff %	Increased Runoff %
Class A Storage Facility	Operations & Active Closure	10	20	30
	Transitional & Post Closure	40	50	60
Class B Storage Facility	Operations & Active Closure	10	20	30
	Transitional & Post Closure	40	50	60
Class C Storage Facility	Operations & Active Closure	5	10	20
	Transitional & Post Closure	10	20	30
Overburden Stockpile	Operations	10	20	30
ROM/LGO	Operations & Active Closure	5	10	20
	Transitional & Post Closure	40	50	60
Class A Buttress	Operations & Active Closure	5	10	20
	Transitional & Post Closure	10	20	30

NOTES:

1. FACILITIES IN OPERATIONS AND ACTIVE CLOSURE ARE REPRESENTED AS FULLY UNRECLAIMED IN THE MODEL ALTHOUGH PROGRESSIVE RECLAMATION IS PROPOSED FOR THE CLASS A AND B STORAGE FACILITIES DURING THIS PERIOD.
2. FACILITIES IN TRANSITIONAL CLOSURE AND POST-CLOSURE ARE REPRESENTED AS RECLAIMED IN THE MODEL.

Changing the proportion of runoff versus infiltration to a modelled facility does not change the total amount of water that flows through the facility on an annual basis, since any net precipitation that does not become runoff instead infiltrates into the facility and discharges from storage at a later time. The total water treated at the WTP ranges from 18 to 41 m^3/hr, consistent with base case model results. All WTP treatment rates in the runoff sensitivity analysis are below the maximum design treatment rates specified in Section 4.10 for each of the three treatment circuits.

The predicted range of water stored in the LWMP under increased and decreased runoff conditions is presented in Figure I.2 in Appendix I. The LWMP operational volume displays little sensitivity to the runoff proportion assigned on modelled facilities. Sufficient flows exist in the receiving environment to discharge all water that flows into the LWMP during the spring, summer, and fall months, even under the increased runoff scenario. Results of the runoff sensitivity scenarios indicate that a volume of water is predicted to be stored in the LWMP in winter months of Years 3 through 6, consistent with the base case results. The Open Pit and underground dewatering rates are the largest source of water to the LWMP during the winter months. There is little difference between the volume of water predicted to be held in the LWMP by the base case and runoff sensitivity scenario results since the open pit dewatering rates were not varied as part of the runoff sensitivity analysis.

7.0 VARIABLE CLIMATE MODEL

7.1 METHOD

A Variable Climate Case (VCC) Model was constructed to assess potential effects of climate variability on streamflow, groundwater flow, and mine water management during all Project phases. The long-term synthetic temperature and precipitation record from 1972 to 2017 (46 years) was iteratively cycled through the VCC Model to assess response of the system under a variable climate. Each climate iteration consisted of the following steps:

- The climate time-series input to the model was cycled forward by one year
- The model file was re-run with the updated climate input, and
- Simulated flows from the re-run were exported to a results file.

The above cycle was repeated until the entire historic climate record was cycled through every mine year in the LOM Water Balance Model. The resulting VCC Model consisted of 46 iterations that extended from Construction through Post-Closure, with each iteration producing time-series results of simulated streamflow at key model nodes and water storage volumes at major mine facilities. The simulated climate variability allows the mine water management plan to be assessed under wet and dry climate conditions. The range of values in the long-term synthetic temperature and precipitation record is provided in Table 7.1 and Table 7.2, respectively.

Table 7.1 Estimated Long-Term Air Temperature at KZK Climate Station

Value	Monthly Precipitation (mm)												Annual
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Max	-6.4	-8.3	-6.6	-0.2	6.4	12.1	11.4	12.2	5.3	-0.6	-4.7	-9.5	-1.0
Mean	**-10.8**	**-11.4**	**-11.2**	**-4.5**	**2.7**	**8.2**	**9.9**	**7.9**	**2.3**	**-2.7**	**-9.6**	**-12.9**	**-2.8**
Min	-17.4	-18.8	-15.8	-10.1	-0.3	5.5	7.5	5.3	-2.3	-5.4	-17.2	-19.6	-10.2

NOTES:

1. SOURCE: HYDROMETEOROLOGY ANALYSIS REPORT (KP, 2018A)

Table 7.2 Estimated Long-Term Precipitation at KZK Climate Station

Value	Monthly Precipitation (mm)												Annual
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Min	1	3	2	3	4	18	22	23	9	4	1	6	271
Mean	**28**	**20**	**22**	**13**	**37**	**66**	**91**	**82**	**59**	**40**	**28**	**29**	**516**
Max	121	45	74	48	125	141	198	190	172	90	71	71	722

7.2 RESULTS

7.2.1 OPERATIONAL WATER MANAGEMENT POND VOLUME

VCC Model results help assess potential variability in Project flows, which directly influences water management pond operational volume requirements (i.e., LWMP, Class A Collection Pond, Class B Collection Pond, and Pit Rim Pond) and WTP treatment rates. The results discussed below are percentiles based on the 46 values produced by each model iteration for a given facility. The iteration that generates the 90th percentile volume or rate for one facility does not necessarily match the iteration that generates the 90th percentile for another facility, as a unique distribution of values is generated for each facility.

The predicted range of water stored in the LWMP under variable climate conditions is presented in Figure 7.1. Similar to the base case model, results of the VCC model indicate that the LWMP has potential to store the most water during the winter months of Years 3, 4, and 5 when the Open Pit and underground dewatering rates are predicted to be highest and natural streamflows limit the volume of water than can be discharged to Geona and Finlayson creeks. The variability in predicted LWMP volume during winter months is controlled by the magnitude of streamflow in the downstream receiving environment and the resulting ability to discharge water from the pond at the specified discharge ratio. The modelled maximum pond volume that develops in the winter of Year 3 (Figure 7.1) develops during the year with the lowest freshet and summer streamflows of the 46-year record, which results in water storage in the LWMP starting during the fall and continuing through the winter. The 90th percentile pond volume is generated during a model year with winter streamflows at KZ-9 in Geona Creek that are 30 to 40% lower in Year 3 than the base case model flows. Inputs to the LWMP from the WTP and UWMP are less during the winter months when the LWMP volume grows, as would be expected when the streamflows in the receiving environment are lower. The maximum operational volume predicted for the LWMP is roughly 420,000 m^3, which is below the proposed pond size of 500,000 m^3 reported in the Project Proposal (BMC, 2017).

The dewatering rates from the Open Pit and underground are the largest source of water to the LWMP during the winter months. These relatively high dewatering flows cause the 10th percentile model results to include development of a pond in Years 3 through 5. A 10th percentile pond volume of 150,000 m^3 indicates that water may need to be held in the LWMP during winter months of Years 3 through 5, even during winters with relatively high baseflows.

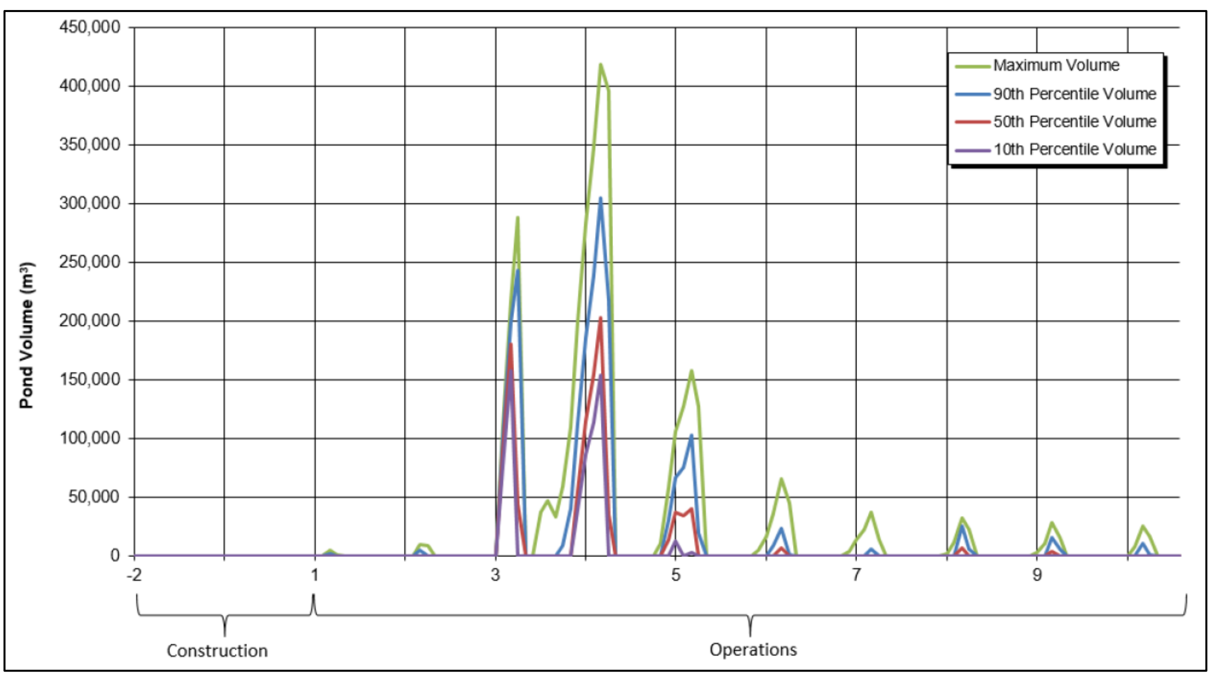

Figure 7.1 Lower Water Management Pond Operational Volume Range

VCC Model results indicate that the WTP has capacity during each month to treat all monthly inflows from the Class A Collection Pond, Class B Collection Pond, and Pit Rim Pond during all climate scenarios modelled. As a result, no water is stored in the Class A Collection Pond, Class B Collection Pond, or Pit Rim Pond in any of the VCC Model iterations. Additional discussion on the WTP rates in the VCC Model are discussed in Section 7.2.2.

7.2.2 WATER TREATMENT PLANT RATES

The WTP is designed to treat runoff in three circuits to a maximum treatment rate. As presented in Section 4.10, the maximum treatment rates for each circuit are (BQE Water, 2018):

- 287 m^3/hr - Class A Treatment Circuit
- 852 m^3/hr - Class B, ROM/LGO, Pit Rim and Process Plant Site Treatment Circuit, and
- 68 m^3/hr - Process Water Treatment Circuit.

Treatment rates from the VCC Model for the Class A Treatment Circuit are shown on Figure 7.2. The maximum treatment rate peaks near 180 m^3/hr at the end of Operations, when the Class A facility is at its maximum footprint. This maximum rate is about 60% of the maximum treatment capacity of Class A Treatment Circuit. This peak treatment rate is sustained during Active Closure while the cover is placed over the Class A Storage Facility and the facility reclaimed. The 90th percentile rates are approximately half of the maximum predicated rate and peak at 100 m^3/hr. The 50th percentile results match the rates predicted by the base case model shown in Figure 5.12 except the freshet peak is subdued. The mean results from the VCC Model (not shown) more closely match the predicted Class A treatment rate from the base case model.

Treatment rates for the Class B, ROM/LGO, Pit Rim and Process Plant Site Treatment Circuit are shown on Figure 7.3. The maximum treatment rate peaks near 700 m^3/hr in Year 3 when dewatering rates are at their peak and in Year 10 when the facilities have reached their maximum footprint. This maximum peak rate is roughly 85% of the maximum treatment capacity of this circuit. Maximum peak treatment rates vary between 650 m^3/hr and 700 m^3/hr for the remainder of Operations and peak rates drop significantly to roughly 200 m^3/hr during Active Closure when dewatering ceases. The 90th percentile results reach a maximum of 500 m^3/hr in Year 3. Dewatering flows from the Open Pit and underground comprise 75% or more of the water feeding this treatment circuit and comprise the majority of the water treated during the winter months. As a result, the minimum (winter) treatment rates display little predicted variability.

The influent rate of the Process Water Treatment Circuit is not influenced by a variable climate and the predicted treatment rate is unchanged through all of the climate iterations.

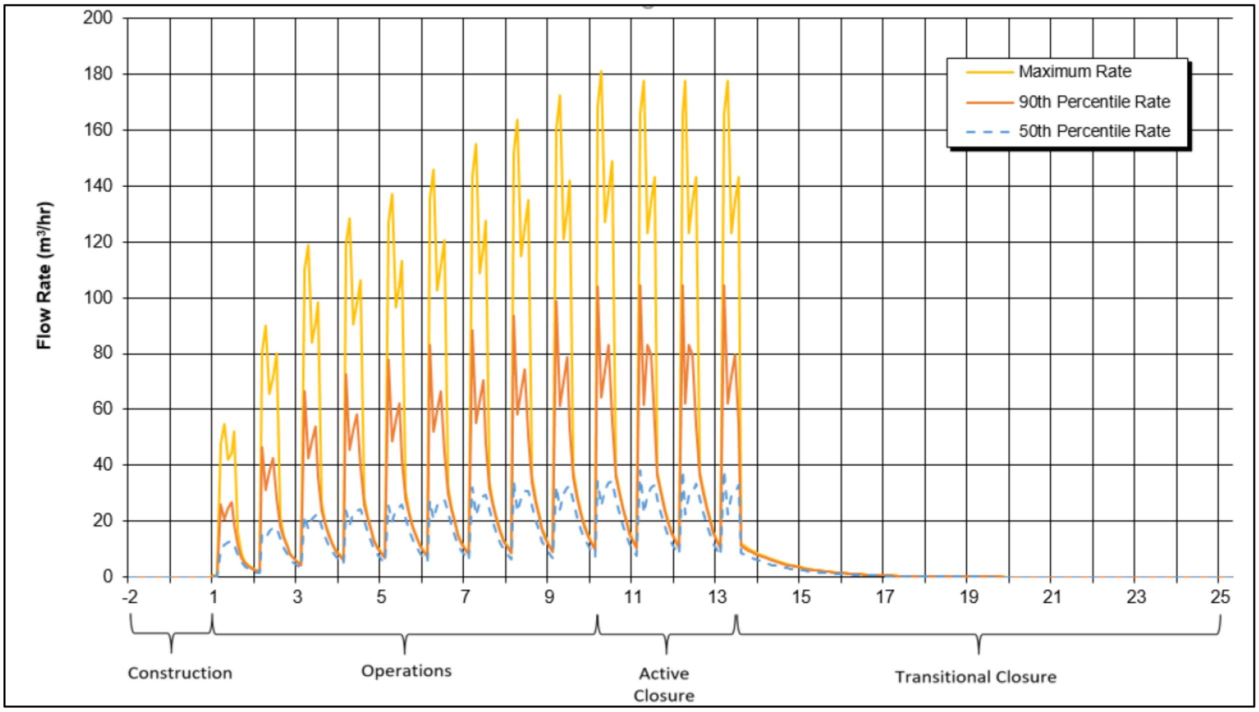

Figure 7.2 Class A Water Treatment Circuit

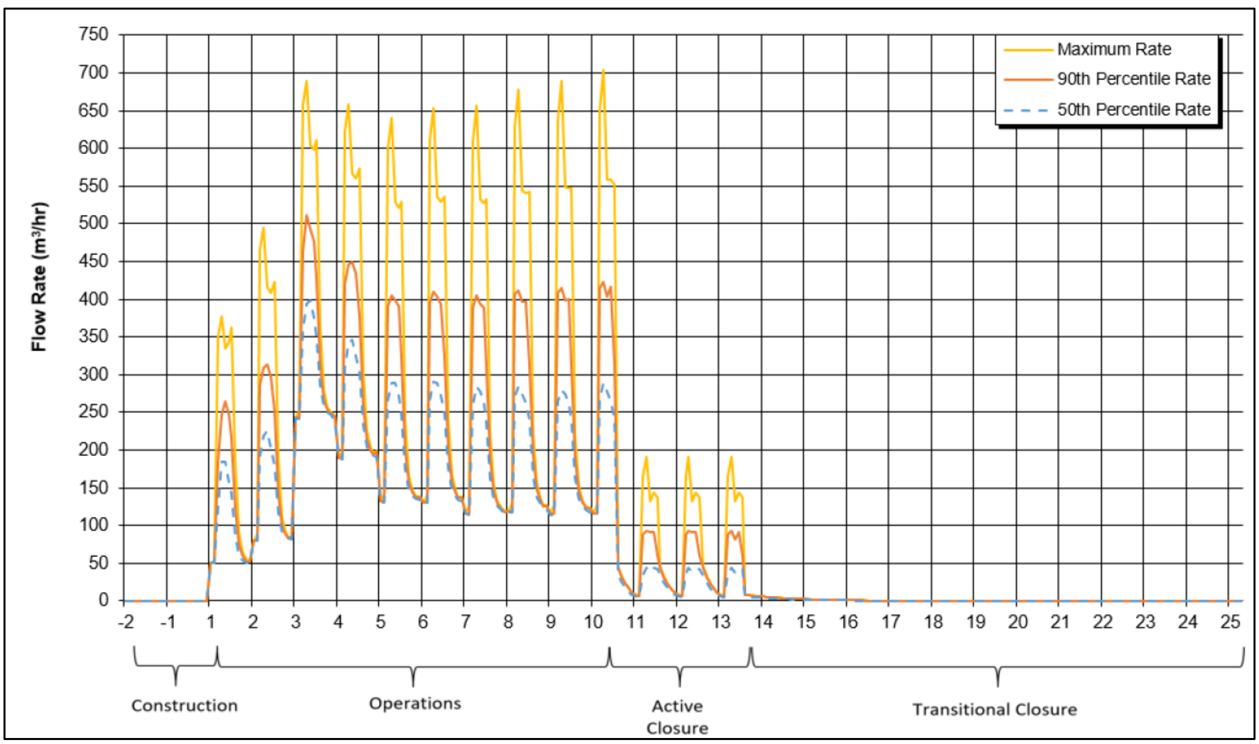

Figure 7.3 Class B, ROM/LGO, Pit Rim and Process Plant Site Water Treatment Circuit

8.0 SUMMARY AND DISCUSSION

8.1 SUMMARY

A Life-of-Mine (LOM) Water Balance Model was developed for the KZK Project to estimate surface water and groundwater flows through the life of the mine. The LOM Water Balance Model simulates water management flows, surface water, and groundwater flows using one continuous model that is built out through the entire life cycle of the mine. Climate inputs to the LOM Water Balance Model include mean monthly climate averaged over years 1972 to 2017.

Based on the results of the modelling, activities during the life cycle of the Project are expected to influence streamflows in Geona Creek, South Creek, and Finlayson Creek.

In Geona and Finlayson Creek:

- During Construction and Operations, streamflows are predicted to decrease primarily due to the Fault Creek Diversion and dewatering of the Open Pit. During Operations, the average annual decrease in streamflows is predicted to be the greatest immediately downstream of the Project at KZ-9, which is located immediately upstream of the point of discharge for mine site water from the LWMP. Discharge of mine site water immediately downstream of KZ-9 and at KZ-15 decrease the magnitude of flow reductions compared to KZ-9.
- During Active and Transitional Closure, streamflows at KZ-9 increase compared to Operations but flows remain lower than baseline flows due to pit filling by groundwater and surface water flows. Flows downstream of KZ-9 are lower in Active and Transitional Closure than during Operations attributed to the cessation of pit dewatering and these flows no longer being discharged to Geona Creek.
- During Post-Closure, average annual streamflows are approximately the same as baseline conditions, with a minor increase in flow (2 L/s) attributed to inter-basin groundwater flow from the South Creek catchment to the Geona Creek catchment. Flows during Post-Closure at all locations on Geona Creek and Finlayson Creek are predicted to be within 2% of baseline flows.

In South Creek:

- During Construction and Operations, predicted flows increase due to the Fault Creek Diversion and open pit diversions.
- During Active Closure through Post-Closure, flows are predicted to be less than baseline flows by 5 L/s due to the influence of the Open Pit on groundwater flows.

Sensitivity scenarios were developed using the water balance model to assess the sensitivity of water quality downstream of the Project under different climate inputs. A wet climate condition (1:50 year return period wet climate) and a dry climate condition (1:10 year return period dry climate) were placed into the climate string during each phase of mine development, resulting in twelve sensitivity scenarios. Streamflow results and supporting sensitivity case simulations were provided as inputs to the Water Quality Model (AEG, 2018b).

Runoff sensitivity scenarios were developed to address YESAB's Information Request IR3-1c (*The updated water balance model should include a sensitivity analysis for run-off coefficients).* Sensitivity scenarios were developed by increasing the proportion of runoff (versus infiltration) that is generated from a facility. Any water that does not runoff from a facility instead infiltrates the facility and is held in storage to be released at a later time. Results of the runoff sensitivity scenarios suggest that:

- The LWMP operational volume is insensitive to the runoff proportion assigned on modelled facilities. Sufficient flows exist in the receiving environment to discharge all water that flows into the LWMP during the spring, summer, and fall months, even under the increased runoff scenario. Water is predicted to be held in the LWMP during winter months of Years 3 through 6. The volume of water predicted to be held in the LWMP is generally consistent with the base case model results since surface water runoff is not generated during the winter months.
- A 10% increase in runoff causes the peak influent rate of water from the Class A Collection Pond to the WTP to increase by a similar amount. The peak treatment rate predicted with the increased runoff scenario is about 30% of the maximum treatment capacity of the Class A Treatment Circuit, which is an increase from 26% predicted using the base case model.

A Variable Climate Case (VCC) Model was constructed to assess potential effects of climate variability on streamflow, groundwater flow, and mine water management during the mine life. The 46-year long historic climate record was iteratively cycled through the VCC Model to assess response of the system under a variable climate. Results of the VCC Model indicate that water may need to be held in the LWMP during years with lower winter flows in the receiving environment. Years 3 through 6 are predicted to have higher dewatering flows from the Open Pit and underground and model results indicate water storage in the LWMP during these years is likely. All VCC Model iterations predicted that the maximum volume of water held in the LWMP would be less than the design pond volume.

8.2 DISCUSSION

Model results suggest sufficient flows exist in the receiving environment during the spring and summer months to discharge all mine site water routed to the LWMP using the current discharge ratios of mine site water to non-contact water. Model results suggest that it is likely that water will need to be held in the LWMP during the low flow winter period during mine years with higher open pit and underground dewatering requirements (i.e., Years 3 through 6). The dewatering rates from the Open Pit and underground are the largest source of water to the LWMP during the winter months. Results of the VCC model suggest that at the currently predicted dewatering rates, water storage in the LWMP may be required between Years 3 and 6 even in winters with baseflows (low flows) that are relatively high.

The monthly volume of water directed to the LWMP for discharge during the winter months of Years 3 through 6 is predicted to range from 75,000 to 130,000 m^3 using the base case model with mean monthly climate inputs. At these flow rates and a design volume of 500,000 m^3 (BMC, 2017), the LWMP has sufficient storage capacity to hold water for several consecutive winter months and release the stored volume of water during freshet when flows are higher.

Efforts to decrease the flows to the LWMP during the winter months may help to decrease the stored pond volume, if warranted. These efforts could include pre-emptive dewatering, by increasing the dewatering rate of the Open Pit and underground during the spring and summer months or initiating dewatering of the underground as early as feasibility possible. Dewatering rates in the LOM Water Balance Model are assigned as constant values during each mine year, where as variability would be expected as the Open Pit and underground works are advanced.

Influent rates to the water treatment plant are sensitive to climatic conditions due to the runoff generated from the facilities that is collected and sent for treatment. Treatment rates generated using the base case model with mean climate inputs and models that simulate increased runoff from facilities and a variable climate all predicted peak treatment rates that are below the design treatment rate for all treatment circuits of the WTP.

9.0 REFERENCES

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10.0 CERTIFICATION

This report was prepared and reviewed by the undersigned.

PROFESSIONAL YUKON [Signature Redacted] THIA STARZYK RITORY P.Eng ENGINEER OCT 10/18

Prepared:

Senior Engineer

Reviewed: [Signature Redacted]

Specialist Engineer | Associate

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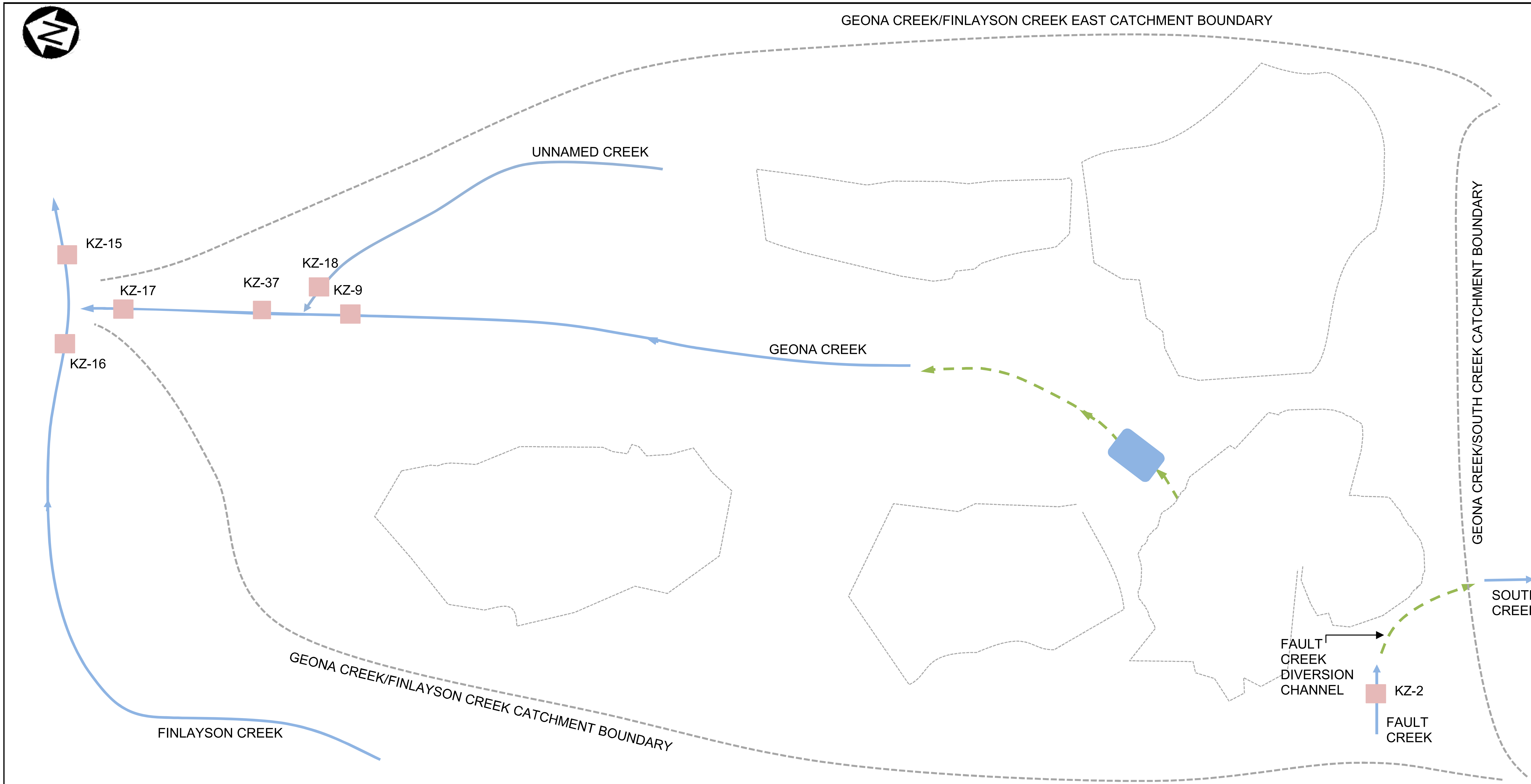
[Signature Redacted]

Approval that this document adheres to Knight Piésold Quality Systems:

APPENDIX A

Water Management Flow Diagrams

(Figures A.1 to A.7)



CONCEPTUAL DRAWING AND FOR ILLUSTRATION PURPOSES ONLY; FEATURES ARE NOT TO SCALE.

MODELLING LOCATIONS IN LOWER FINLAYSON CREEK, EAST CREEK AND SOUTH CREEK ARE NOT SHOWN.

LEGEND:

- WATER MANAGMENT/COLLECTION POND
- DIVERSION CHANNEL
- WATER QUALITY AND QUANTITY MODELLING LOCATION
- CATCHMENT DIVIDE
- WATER COURSE
- 10 YEAR FOOTPRINT

BMC MINERALS (NO. 1) LTD.

KUDZ ZE KAYAH PROJECT

WATER MANAGEMENT LAYOUT
CONSTRUCTION, YEAR -2

Knight Piésold CONSULTING

P/A NO. VA101-640/6

REF. NO. 3

FIGURE A.1

REV 0

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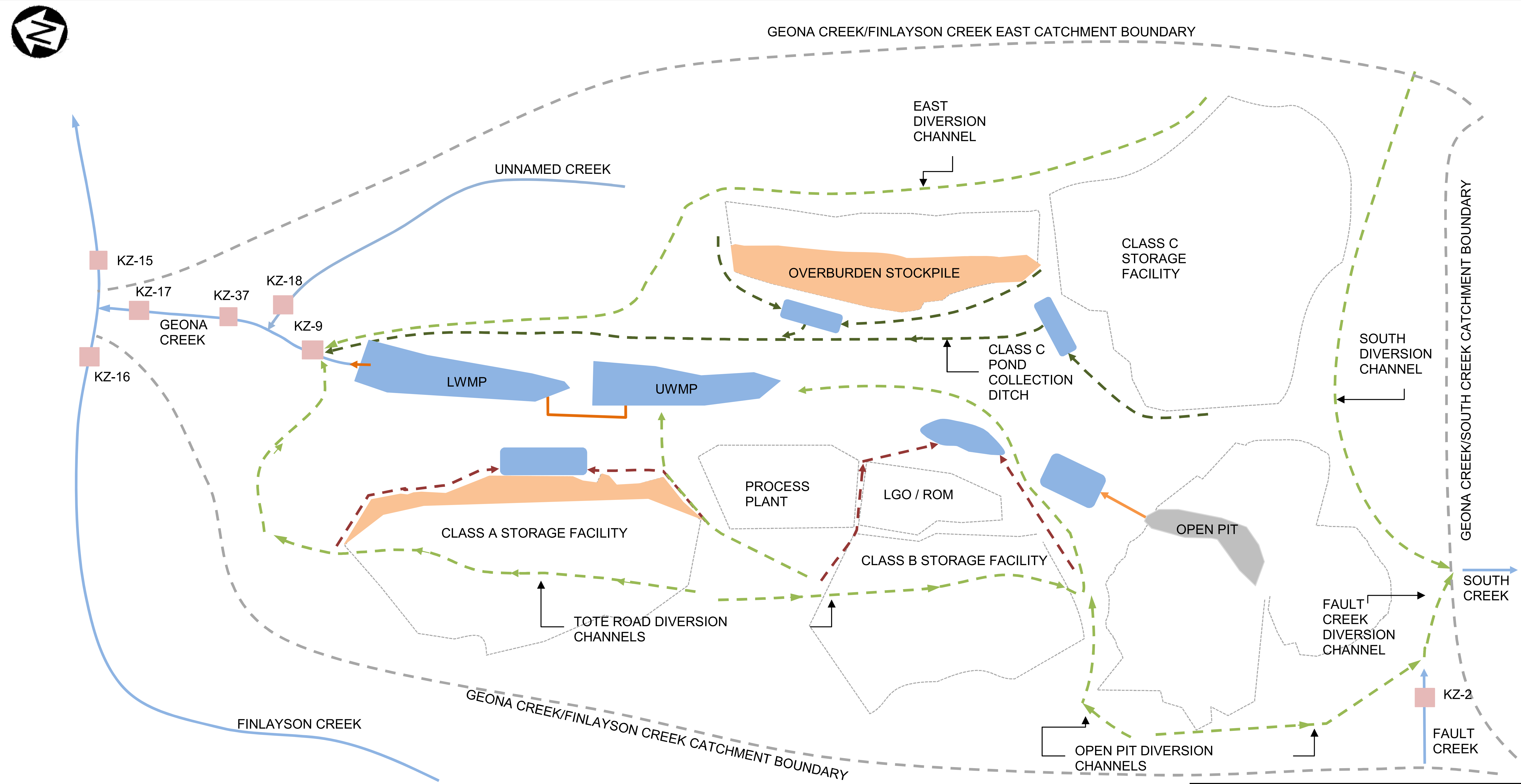


CONCEPTUAL DRAWING AND FOR ILLUSTRATION PURPOSES ONLY; FEATURES ARE NOT TO SCALE.

MODELLING LOCATIONS IN LOWER FINLAYSON CREEK, EAST CREEK AND SOUTH CREEK ARE NOT SHOWN.

LEGEND:

- WATER MANAGMENT/COLLECTION POND
- COLLECTION DITCH (CLASS A & B)
- COLLECTION DITCH (CLASS C)
- PIPELINE
- DIVERSION CHANNEL
- WATER QUALITY AND QUANTITY MODELLING LOCATION
- CATCHMENT DIVIDE
- WATER COURSE
- 10 YEAR FOOTPRINT

REV	DATE	DESCRIPTION	PREP'D	RVW'D
0	07SEP'18	ISSUED WITH REPORT	AA	MAP

BMC MINERALS (NO. 1) LTD.

KUDZ ZE KAYAH PROJECT

WATER MANAGEMENT LAYOUT
CONSTRUCTION, YEAR -1

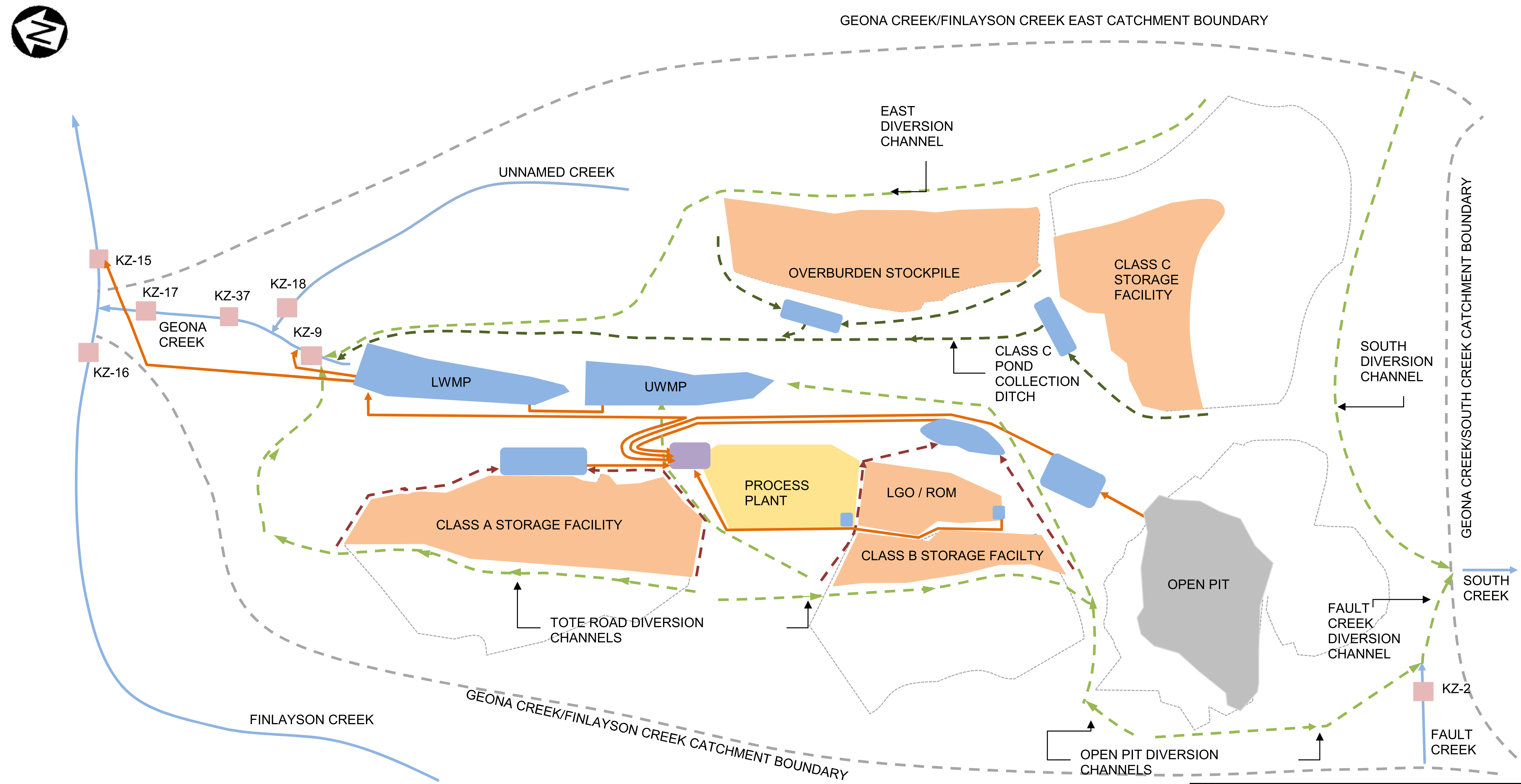
Knight Piésold CONSULTING

P/A NO. VA101-640/6

REF. NO. 3

FIGURE A.2

REV 0



CONCEPTUAL DRAWING AND FOR ILLUSTRATION PURPOSES ONLY; FEATURES ARE NOT TO SCALE.

MODELLING LOCATIONS IN LOWER FINLAYSON CREEK, EAST CREEK AND SOUTH CREEK ARE NOT SHOWN.

LEGEND:

- WATER MANAGMENT/COLLECTION POND
- WATER TREATMENT PLANT
- COLLECTION DITCH (CLASS A & B)
- COLLECTION DITCH (CLASS C)
- PIPELINE
- DIVERSION CHANNEL
- WATER QUALITY AND QUANTITY MODELLING LOCATION
- CATCHMENT DIVIDE
- WATER COURSE
- 10 YEAR FOOTPRINT

0	07SEP'18	ISSUED WITH REPORT	AA	MAP
REV	DATE	DESCRIPTION	PREP'D	RVW'D

BMC MINERALS (NO. 1) LTD.

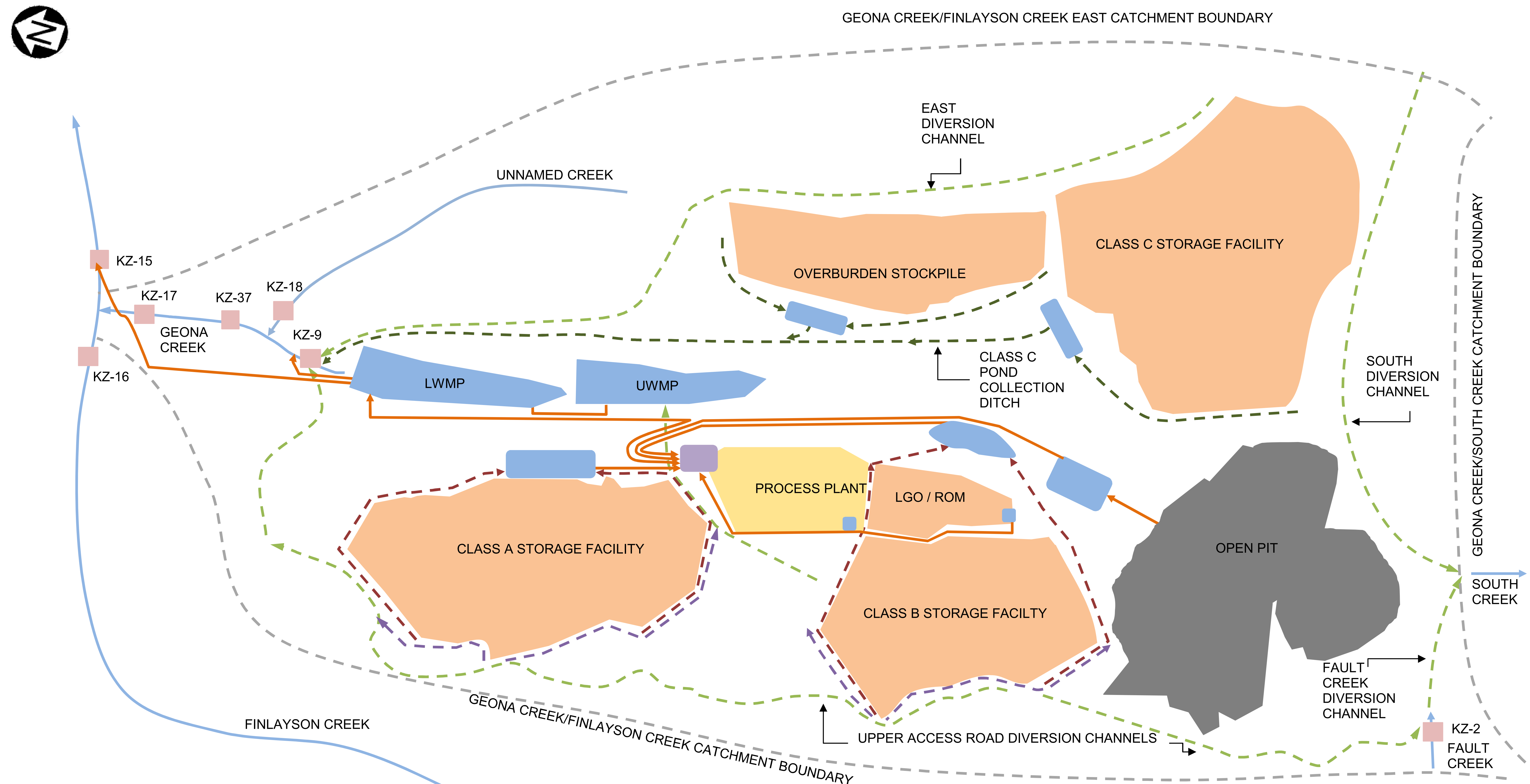
KUDZ ZE KAYAH PROJECT

WATER MANAGEMENT LAYOUT
YEAR 1 TO 2 LAYOUT

Knight Piésold CONSULTING

P/A NO. VA101-640/6 | REF. NO. 3

FIGURE A.3 | REV 0



CONCEPTUAL DRAWING AND FOR ILLUSTRATION PURPOSES ONLY; FEATURES ARE NOT TO SCALE.

MODELLING LOCATIONS IN LOWER FINLAYSON CREEK, EAST CREEK AND SOUTH CREEK ARE NOT SHOWN.

LEGEND:

- WATER MANAGMENT/COLLECTION POND
- WATER TREATMENT PLANT
- COLLECTION DITCH (CLASS A & B)
- COLLECTION DITCH (CLASS C)
- PIPELINE
- DIVERSION CHANNEL
- DIVERSION BERM
- WATER QUALITY AND QUANTITY MODELLING LOCATION
- CATCHMENT DIVIDE
- WATER COURSE

REV	DATE	DESCRIPTION	PREP'D	RVW'D
0	07SEP'18	ISSUED WITH REPORT	AA	MAP

BMC MINERALS (NO. 1) LTD.

KUDZ ZE KAYAH PROJECT

WATER MANAGEMENT LAYOUT
YEAR 3 TO 10 LAYOUT

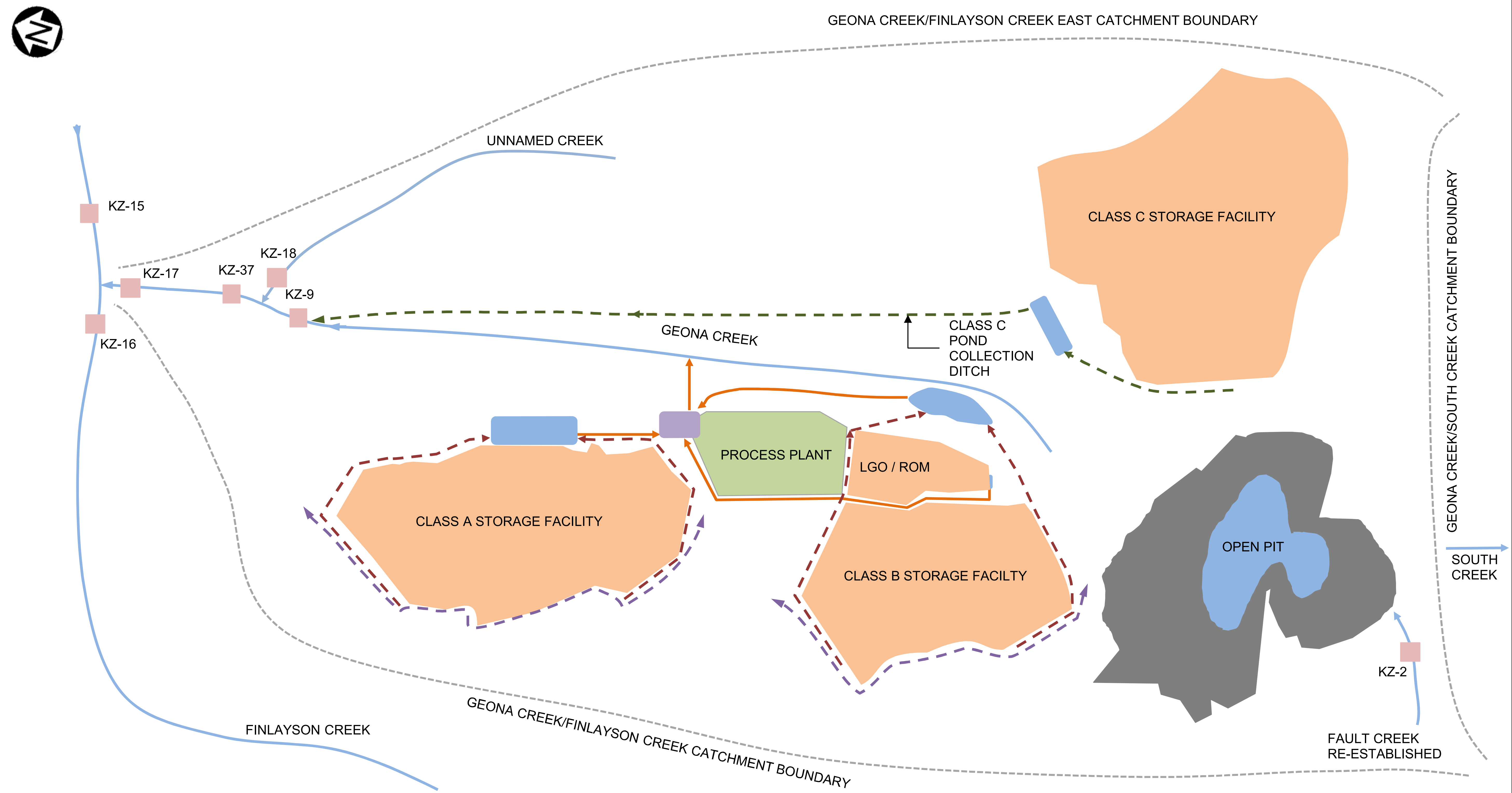
Knight Piésold CONSULTING

P/A NO. VA101-640/6

REF. NO. 3

FIGURE A.4

REV 0



CONCEPTUAL DRAWING AND FOR ILLUSTRATION PURPOSES ONLY; FEATURES ARE NOT TO SCALE.

MODELLING LOCATIONS IN LOWER FINLAYSON CREEK, EAST CREEK AND SOUTH CREEK ARE NOT SHOWN.

LEGEND:

- WATER MANAGMENT/COLLECTION POND
- WATER TREATMENT PLANT
- COLLECTION DITCH (CLASS A & B)
- COLLECTION DITCH (CLASS C)
- PIPELINE
- DIVERSION CHANNEL
- DIVERSION BERM
- WATER QUALITY AND QUANTITY MODELLING LOCATION
- CATCHMENT DIVIDE
- WATER COURSE

0	07SEP'18	ISSUED WITH REPORT	AA	MAP
REV	DATE	DESCRIPTION	PREP'D	RVW'D

BMC MINERALS (NO. 1) LTD.

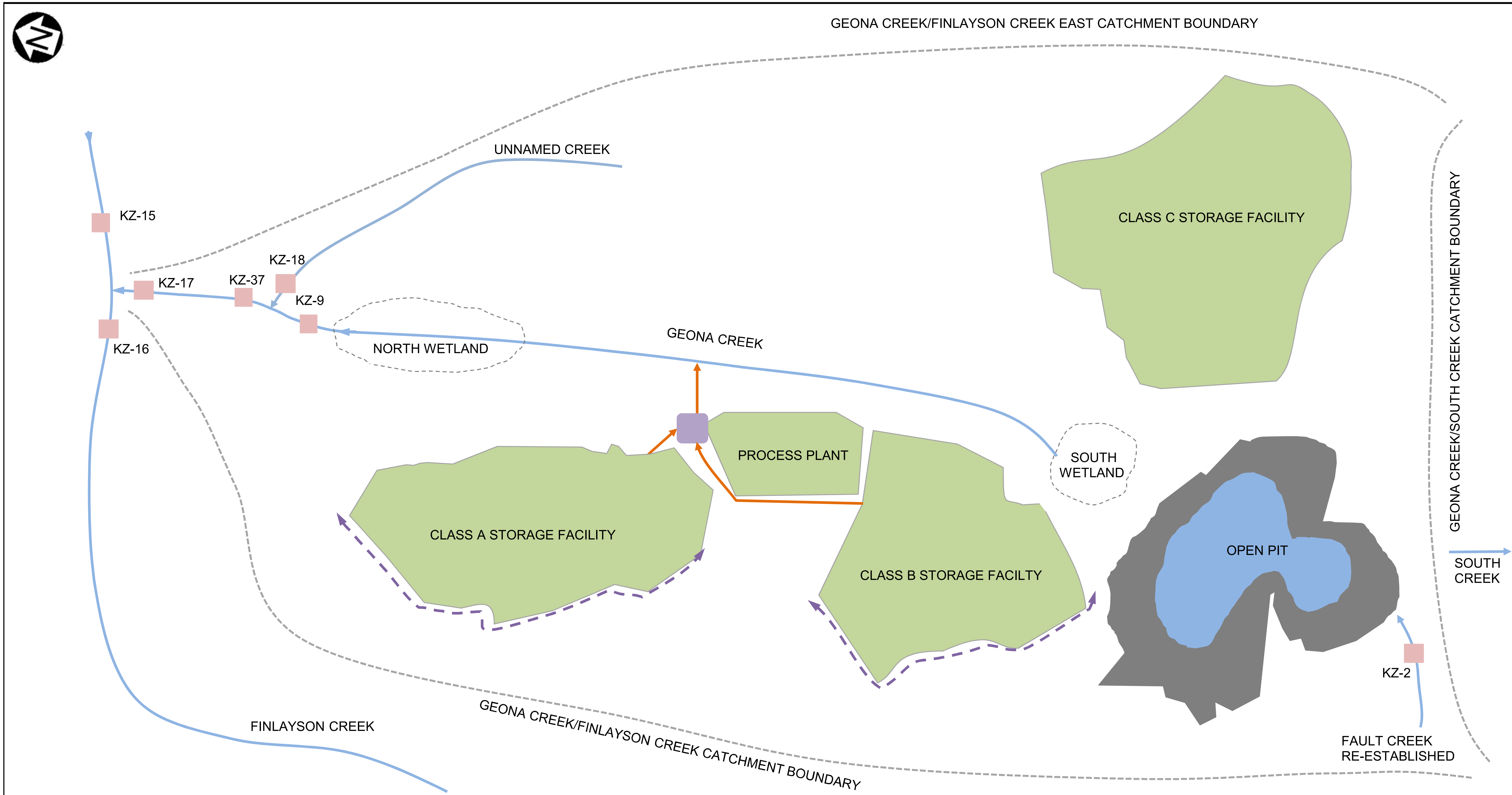
KUDZ ZE KAYAH PROJECT

WATER BALANCE LAYOUT
ACTIVE CLOSURE

Knight Piésold CONSULTING

P/A NO.	REF. NO.
VA101-640/6	3

FIGURE A.5 REV 0



CONCEPTUAL DRAWING AND FOR ILLUSTRATION PURPOSES ONLY; FEATURES ARE NOT TO SCALE.

MODELLING LOCATIONS IN LOWER FINLAYSON CREEK, EAST CREEK AND SOUTH CREEK ARE NOT SHOWN.

LEGEND:

- WATER TREATMENT PLANT
- PIPELINE
- DIVERSION BERM
- WATER QUALITY AND QUANTITY MODELLING LOCATION
- CATCHMENT DIVIDE
- WATER COURSE

REV	DATE	DESCRIPTION	PREP'D	RVW'D
0	07SEP'18	ISSUED WITH REPORT	AA	MAP

BMC MINERALS (NO. 1) LTD.

KUDZ ZE KAYAH PROJECT

WATER BALANCE LAYOUT
TRANSITIONAL CLOSURE

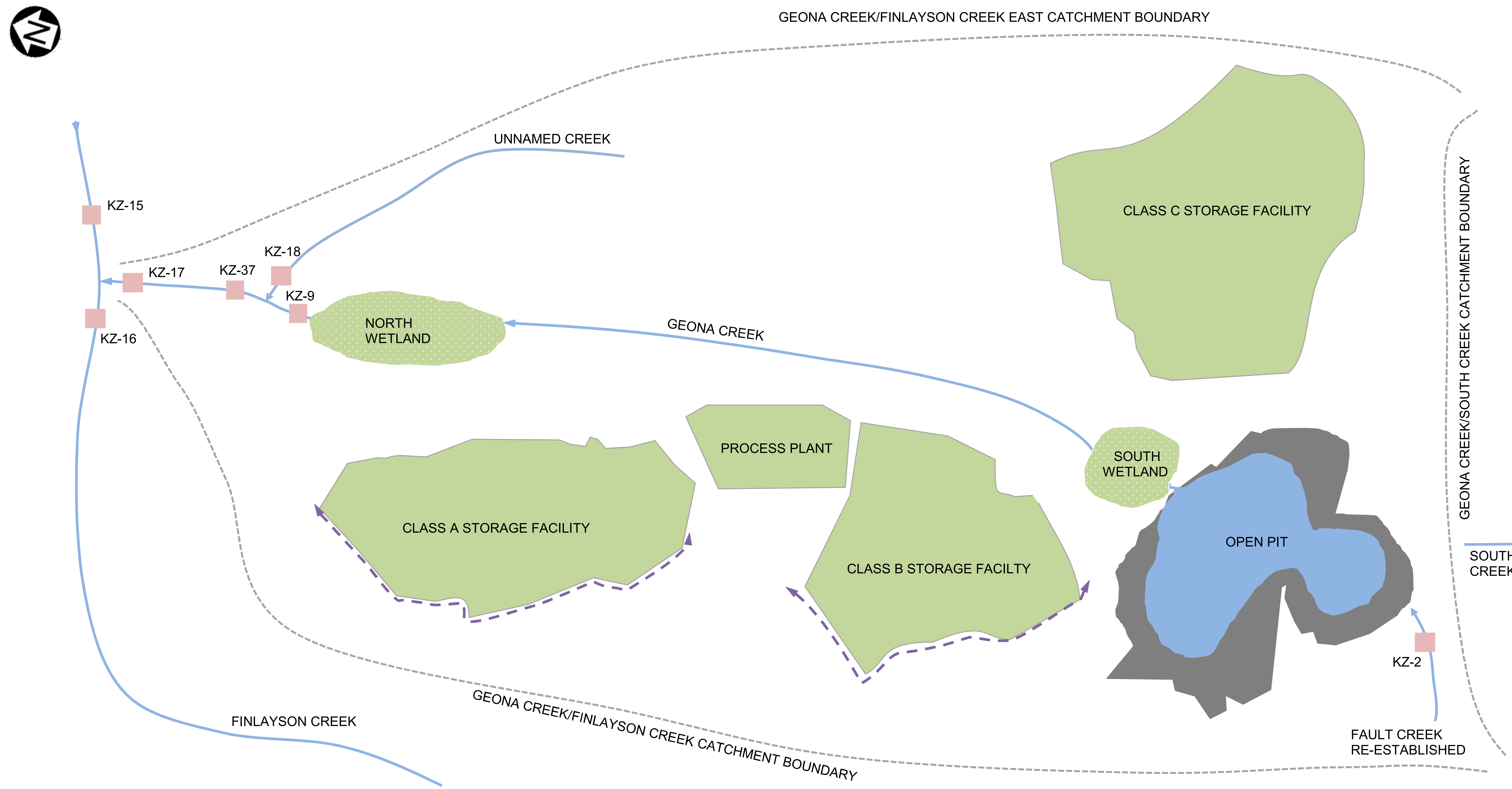
Knight Piésold CONSULTING

P/A NO. VA101-640/6

REF. NO. 3

FIGURE A.6

REV 0



CONCEPTUAL DRAWING AND FOR ILLUSTRATION PURPOSES ONLY; FEATURES ARE NOT TO SCALE.

MODELLING LOCATIONS IN LOWER FINLAYSON CREEK, EAST CREEK AND SOUTH CREEK ARE NOT SHOWN.

LEGEND:

- DIVERSION BERM
- WATER QUALITY AND QUANTITY MODELLING LOCATION
- CATCHMENT DIVIDE
- WATER COURSE

REV	DATE	DESCRIPTION	PREP'D	RVW'D
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BMC MINERALS (NO. 1) LTD.

KUDZ ZE KAYAH PROJECT

WATER BALANCE LAYOUT
POST CLOSURE

Knight Piésold CONSULTING

P/A NO. VA101-640/6

REF. NO. 3

FIGURE A.7

REV 0

APPENDIX B

Baseline Watershed Model Report

(Pages B-1 to B-31)

October 10, 2018

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Dear [Name R,

RE: Kudz Ze Kayah Baseline Watershed Model

1.0 INTRODUCTION

1.1 GENERAL

This letter presents the methods and results of baseline watershed modelling completed by Knight Piésold Ltd. (KP) to support the updated modelling for the Kudz Ze Kayah (KZK) Project (the Project). The KZK Project Proposal is currently undergoing a Screening Assessment by the Yukon Environmental and Socio-economic Assessment Board's (YESAB) Executive Committee, under the *Yukon Environmental and Socio-economic Assessment Act* (*YESAA*). As part of this Assessment, YESAB requested that BMC update the water balance and water quality models, prior to YESAB preparing the draft Screening Report (YESAB, 2018). This Baseline Watershed Model has been developed (in part) to support the YESAB request as well as additional site wide water balance modelling and water quality modelling.

A baseline watershed model was previously developed by Alexco Environmental Group (AEG) to support the Project Proposal (AEG, 2017 and was included as Appendix D-6 of the Project Proposal). The Baseline Watershed Model presented in this letter incorporates an additional year of climate and hydrology data measured at the Project and an updated understanding of Project climate and hydrologic flow conditions. The long-term synthetic temperature and precipitation data input to the model was also updated from the AEG model.

1.2 MODEL OVERVIEW

This Baseline Watershed Model was developed to estimate long-term surface water and groundwater flows in the Project area in order to better constrain estimates of hydrometeorological parameters and to assess groundwater/surface water interactions. Key characteristics of the KZK Baseline Watershed Model include:

- The model simulates monthly flows over a 46 year period extending from 1972 through 2017.
- Climate inputs to the model consist of long-term synthetic records of temperature and precipitation from 1972 to 2017. The climate data were developed by correlating available data from the Project climate station with data from regional climate stations.
- The study area is divided into 11 sub-catchments corresponding with several catchments of established stream gauging and water quality stations. One additional catchment corresponding to the area draining to the regional Water Survey of Canada (WSC) gauging station 09AH005 located on Drury Creek ("Drury Creek at km 469 Robert Campbell Highway") is also included in the model.

- The model was calibrated to measured streamflows at the regional WSC Drury Creek gauging station from 1995 to 2016 and to measured streamflows at seven Project gauging stations from 2015 to 2017.

2.0 MODELLING APPROACH

2.1 GENERAL

The model uses a month-to-month water balance modelling approach commonly used for hydrologic evaluations (see Alley, 1984; Steenhuis and Van der Molen, 1986) to evaluate surface water and groundwater flows in the Project area. The watershed model employs a spreadsheet format that allows input and output flexibility in process selection and representation of proposed mine facilities. The watershed model is a semi-distributed (or quasi-distributed) parameter model; the study area is divided into sub-catchments within which groundwater and surface water flows are modelled. Climate varies spatially within each sub-catchment according to differences in elevation. Adjacent sub-catchments are linked together to allow surface and groundwater flows to be routed to downstream sub-catchments. The watershed model uses a monthly time step.

The watershed model includes representation of the major aspects of the hydrologic cycle. The hydrologic processes considered in the model are presented in the schematic diagram shown on Figure 2.1, and include:

- Precipitation, which is distributed between rainfall and snowfall according to temperature.
- Snow accumulation and melt.
- Sublimation, which is modelled at a specified rate during snow accumulation.
- Rainfall and snowmelt, which are distributed amongst:
    - Surface runoff.
    - Recharge to groundwater.
    - Evapotranspiration, which is modelled after the Thornthwaite Method (1948).
- Groundwater recharge (a combination of meteoric recharge and stream leakage), which is accumulated in groundwater storage.
- Groundwater storage.
- Groundwater discharge, which is determined according to a linear relationship based on the amount of water in storage.
- Surface water detention in lakes, small ponds and wetlands, which is modelled using a linear reservoir assumption.
- Inflow from up-gradient sub-catchments, including surface runoff and groundwater flow.

Long-term monthly precipitation and temperature values for the Project area are estimated based on regional climate data. Precipitation and temperature values are adjusted for elevation (lapse rate and orographic) effects.

Model results are adjusted to provide a match to low flows, which represent the groundwater contribution to streamflows (baseflows), while still providing a good match to high flows, long-term streamflow mass balance, and the streamflow distribution.

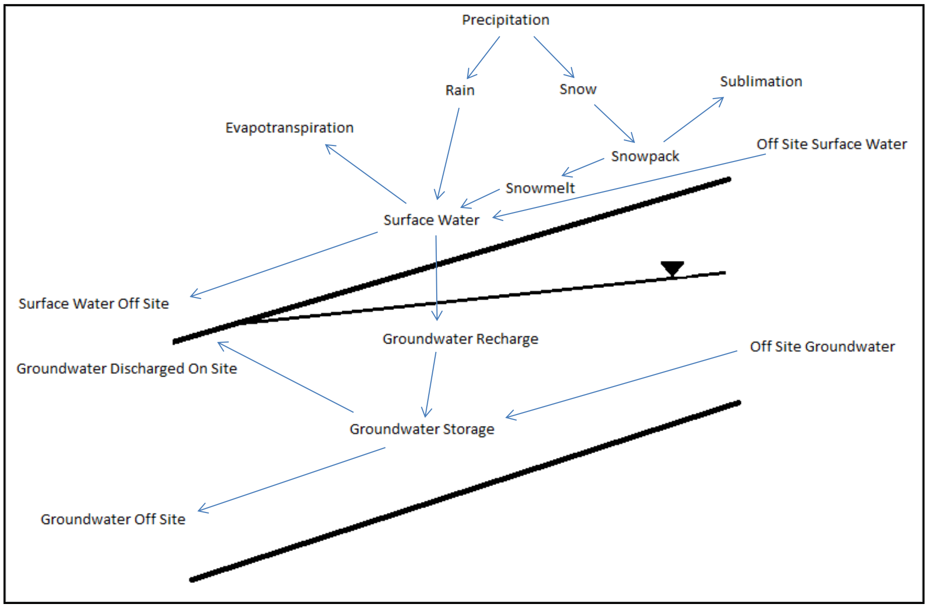


Figure 2.1 Water Balance Component Diagram

2.2 MODEL DISCRETIZATION

The Project study area includes the South Creek, East Creek, Geona Creek, and Finlayson Creek drainages (Figure 2.2). These drainages are divided into 11 sub-catchments, including one in South Creek, one in Fault Creek, four in Geona Creek, one in East Creek, and four in Finlayson Creek. Fault Creek flows into Geona Creek, which flows into the Finlayson Creek catchment along with East Creek. Sub-catchments are defined based on topographic controls on drainage and the locations of streamflow gauging stations. The watershed model also includes the drainage area for the regional WSC gauging station on Drury Creek (WSC 09AH005). The WSC gauging station on Drury Creek is located approximately 200 km northwest of the Project as shown on Figure 2.3.

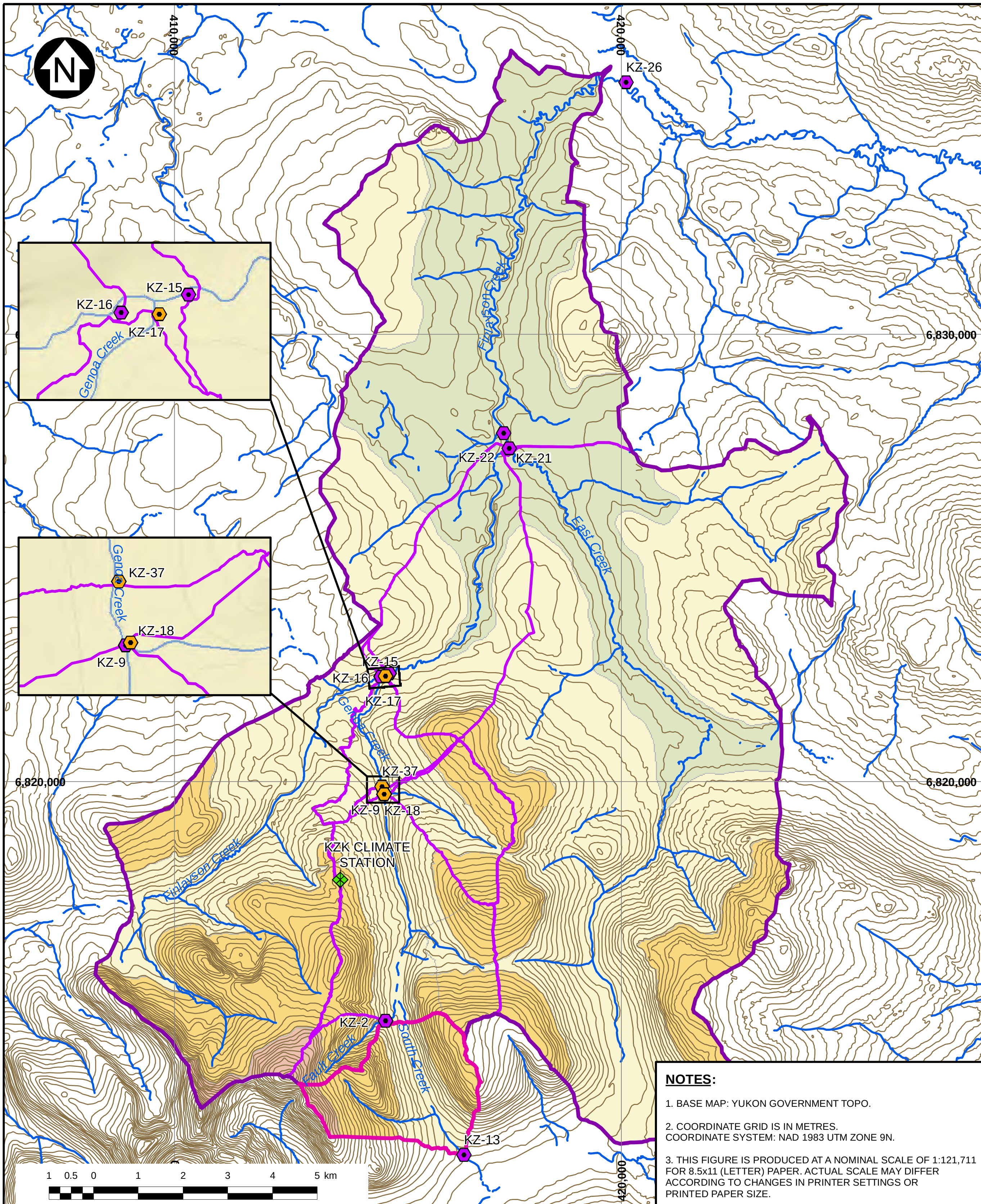
Each of the 12 modelled sub-catchments are further discretized by elevation using 300 m elevation bands, starting at 900 m above sea level (masl) and ending at 2,100 masl. The Drury Creek drainage area also includes a fifth elevation band for areas between 350 to 900 masl. Representative climate conditions (temperature and precipitation) are calculated based on the average elevation for each elevation band. Elevation band areas in each modelled sub-catchment are presented in Table 2.1.

2.3 CLIMATE INPUTS

Primary meteorological inputs to the model consist of long-term monthly temperature and precipitation data. Climate data are currently collected at one climate station on site, KZK Climate Station, and seven Project snow course survey stations. Temperature and precipitation data have been collected at the Project climate station since August 2015. The KZK Climate Station is located at an elevation of 1,542 masl.

A long-term climate dataset was generated by correlating available Project temperature and precipitation data with concurrent regional data at three regional stations located at Faro (Climate ID 2100516, 2100517 and 2100518). The Faro climate stations were considered the most suitable for estimating the long-term climate series for the Project due to Faro's location in a similar geoclimatic zone and based on a comparison of cumulative precipitation (KP, 2018). Faro is located approximately 170 km to the northwest of the Project at an elevation of 716 masl. Additional detail regarding the calculation of long-term temperature and precipitation values are provided in the project Hydrometeorology Analysis Report (KP, 2018).

A discussion of the long-term temperature and precipitation input to the model is provided below in Sections 2.3.1 and 2.3.2, respectively.



NOTES:

1. BASE MAP: YUKON GOVERNMENT TOPO.
2. COORDINATE GRID IS IN METRES.
COORDINATE SYSTEM: NAD 1983 UTM ZONE 9N.
3. THIS FIGURE IS PRODUCED AT A NOMINAL SCALE OF 1:121,711 FOR 8.5x11 (LETTER) PAPER. ACTUAL SCALE MAY DIFFER ACCORDING TO CHANGES IN PRINTER SETTINGS OR PRINTED PAPER SIZE.

LEGEND:

- ACTIVE CLIMATE STATION
- ACTIVE HYDROLOGY STATION & WATERSHED MODEL NODE
- WATERSHED MODEL NODE
- FINLAYSON CREEK SUB-CATCHMENTS
- FINLYASON CREEK CATCHMENT
- SOUTH CREEK CATCHMENT
- 10 M CONTOUR

ELEVATION BANDS (masl)

- 900 - 1,200
- 1,200 - 1,500
- 1,500 - 1,800
- 1,800 - 2,100

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KUDZ ZE KAYAH PROJECT

BASELINE WATERSHED MODEL DISCRETIZATION PROJECT STATIONS

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P/A NO.	REF NO.
VA101-640/06	VA18-00976

FIGURE 2.2 REV 0

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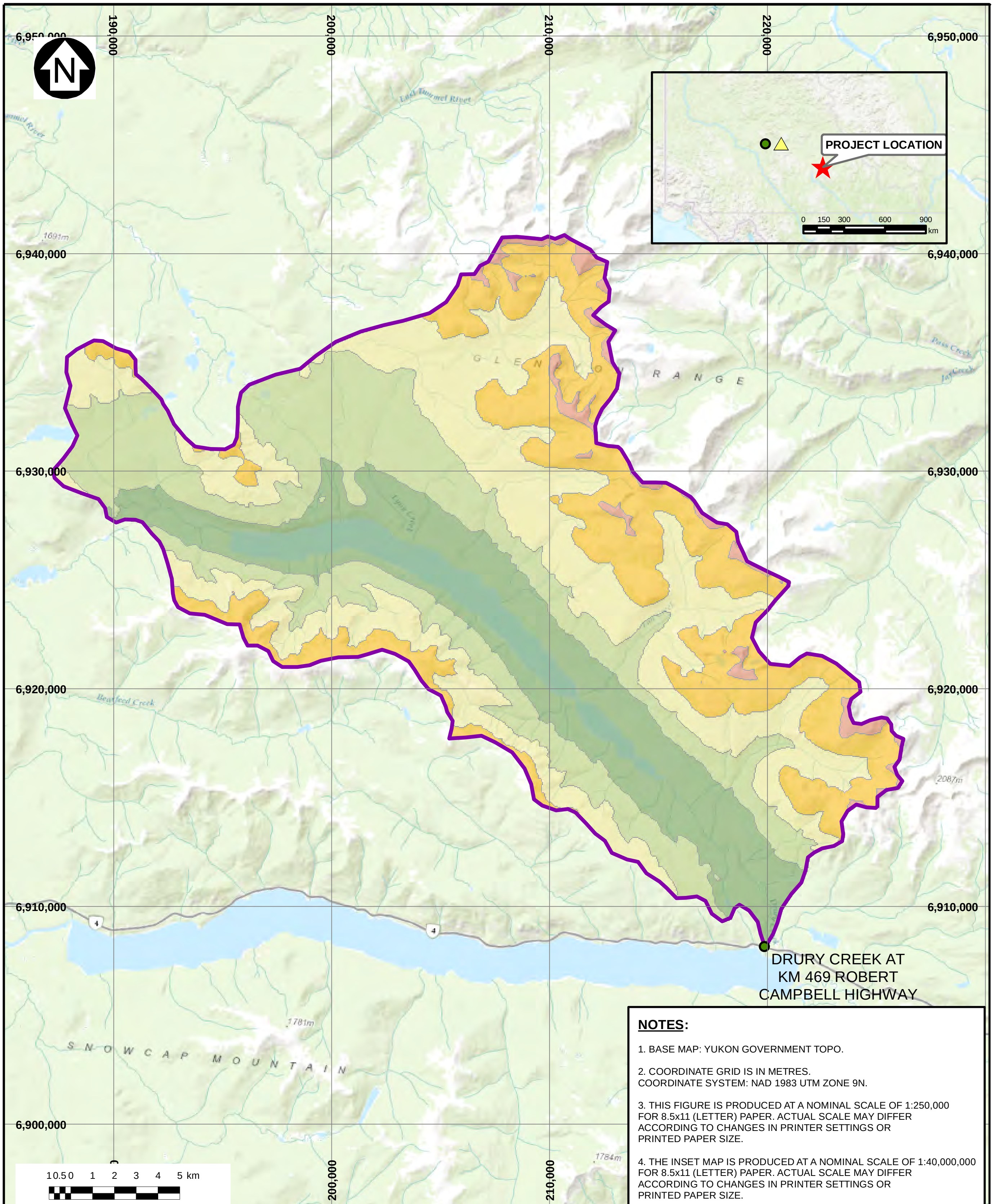

NOTES:

1. BASE MAP: YUKON GOVERNMENT TOPO.
2. COORDINATE GRID IS IN METRES. COORDINATE SYSTEM: NAD 1983 UTM ZONE 9N.
3. THIS FIGURE IS PRODUCED AT A NOMINAL SCALE OF 1:250,000 FOR 8.5x11 (LETTER) PAPER. ACTUAL SCALE MAY DIFFER ACCORDING TO CHANGES IN PRINTER SETTINGS OR PRINTED PAPER SIZE.
4. THE INSET MAP IS PRODUCED AT A NOMINAL SCALE OF 1:40,000,000 FOR 8.5x11 (LETTER) PAPER. ACTUAL SCALE MAY DIFFER ACCORDING TO CHANGES IN PRINTER SETTINGS OR PRINTED PAPER SIZE.

LEGEND:

- WSC GAUGE SITE
- CATCHMENT AREA
- PROJECT LOCATION
- FARO AIRPORT

ELEVATION BANDS

- 350 - 900
- 900 - 1,200
- 1,200 - 1,500
- 1,500 - 1,800
- 1,800 - 2200

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KUDZ ZE KAYAH PROJECT

BASELINE WATERSHED MODEL DISCRETIZATION DRURY CREEK (WSC 09AH005) CATCHMENT

Knight Piésold CONSULTING

P/A NO. VA101-640/06 | REF NO. VA18-00976

FIGURE 2.3 REV 0

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	REVIEWED
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TABLE 2.1

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BASELINE WATERSHED MODEL
WATERSHED MODEL SUB-CATCHMENT AREAS BY ELEVATION BAND

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Sub-Catchment	Catchment Area in Elevation Band (masl)					Total Sub-catchment Area (km^2)	Total Contributing Area (km^2)
	350 - 900 (masl)	900 - 1200 (masl)	1200 - 1500 (masl)	1500 - 1800 (masl)	1800 - 2100 (masl)		
Drury Ck (09AH005)	118.49	140.91	156.94	122.89	12.34	551.6	551.6
SOUTH CREEK							
KZ-13	0	0	3.42	4.08	0.43	7.9	7.9
GEONA CREEK							
KZ-2	0	0	0.10	1.36	0.46	1.9	1.9
KZ-9	0	0	8.21	6.31	0	14.5	16.4
KZ-18	0	0	2.49	2.82	0	5.3	5.3
KZ-37	0	0	0.22	0.00	0	0.2	22.0
KZ-17	0	0	3.33	0.39	0	3.7	25.7
EAST CREEK							
KZ-21	0	15.72	58.22	12.46	0	86.4	86.4
FINLAYSON CREEK							
KZ-16	0	0	16.71	16.65	1.63	35.0	35.0
KZ-15	0	0	0.17	0	0	0.2	60.8
KZ-22	0	4.65	9.78	0.68	0	15.1	162.4
KZ-26	0	33.25	15.08	0	0	48.3	210.7

M:\1\01\00640\06\A\Data\Task 700 - Watershed Model\1-BaselineModel\FinalModel_DruryCreek\[KZKBaselineWSM.xlsm]Table2-1_Areas

NOTES:

1. ALL AREAS ARE PRESENTED IN km^2.

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REV	DATE	DESCRIPTION	PREP'D	RVW'D

2.3.1 TEMPERATURE

The long-term synthetic temperature series input to the model consists of monthly mean temperatures from 1972 to 2017. The long-term temperature series was generated by correlating Project temperature from August 2015 to December 2017 with concurrent regional data. The long-term monthly mean temperature record is provided in Table A.1 in Appendix A.

During the modelling process, temperature assigned to each elevation band in the water balance is adjusted using a lapse rate. A lapse rate of -6°C/1,000 m of elevation is assigned to the model for the summer and shoulder months, consistent with the value presented in the Hydrometeorology Analysis Report (KP, 2018). A better fit between modelled and measured data is obtained by decreasing the lapse rate to -4°C/1,000 m during winter months (October through April).

2.3.2 PRECIPITATION

The long-term precipitation series input to the model consists of monthly mean precipitation values from 1972 to 2017. This long-term precipitation series was developed using only September 2015 to August 2016 data from the Project climate station due to concerns with accuracy of the precipitation gauge during some months of the available record. The long-term monthly mean precipitation record is provided in Table A.2 in Appendix A.

To account for orographic effects of precipitation in the Project area, a non-linear relationship between precipitation and elevation is adopted as follows.

$$P = P_s a^{(E-E_S)/100}$$

Where: P is the monthly precipitation at the selected elevation

P_s = the monthly precipitation at the project reference elevation

a = the orographic factor

E = elevation of middle of elevation band (m), and

E_s = reference elevation of the Project (1,470 masl)

The orographic factor was adjusted for best fit during the calibration process. An orographic factor of 5% is assigned to the model for summer months and 10% for winter months. The rationale for applying different summer and winter orographic factors is based on an understanding of the drivers of regional precipitation patterns, with convective storm systems dominant during the spring and summer and frontal storm systems that produce stronger orographic precipitation effects prevalent in winter.

2.4 CLIMATE WATER BALANCE

The following section describes the theory of the water balance components that determine how precipitation becomes water available for groundwater recharge and surface water runoff in the model. Values assigned to climate parameters in the calibrated Baseline Watershed Model are specified where applicable. Climate parameters are assigned the same value in each sub-catchment in the watershed model.

2.4.1 SNOW AND RAIN

The distribution of precipitation between snowfall and rainfall assumes that all precipitation falls as rain if the average monthly temperature is greater than 2°C and falls as snow if the average monthly temperature is below -2.5°C. The proportion of precipitation falling as rain or snow varies linearly for average monthly temperatures between -2.5°C and 2°C.

2.4.2 SUBLIMATION

Sublimation is typically estimated on the basis of values published in the technical literature, which are generally in the order of 20% to 30% of annual snowfall, depending on forest cover, solar radiation, temperature, wind speed and humidity. Increasing solar radiation, air temperature, and wind speed and decreasing atmospheric humidity all create an increase in sublimation. Sublimation is typically more significant in the north than in more temperate climates (Liston and Sturm, 2004). In this analysis, sublimation is modelled using an assumed constant rate of 0.25 mm/day. The snowpack is assumed to sublimate at the set rate until no snow remains on the ground.

2.4.3 SNOWPACK AND SNOWMELT

The meteorological parameters required to estimate snowmelt are not available on a long-term monthly basis for this site. Accordingly, a simple temperature index method was adopted for this model. The first-order estimate of the potential snowmelt is calculated using the equation:

$$\text{Monthly snowmelt (mm)} = 100(T-1)$$

Where: T is the monthly mean temperature in degrees Celsius.

The actual monthly snowmelt is calculated as the lesser of the potential snowmelt and the available snow after considering losses to sublimation.

Each month, the snowpack is calculated by adding the current month's snowfall to the previous month's snowpack and removing the estimate of sublimation and snowmelt. Sublimation and snowmelt are allowed to continue until no snowpack remains. The build up and melt of snowpack in the model was compared against snowpack records from the three Project snow course surveys in 2016 and 2017 (AEG, 2018).

2.4.4 EVAPOTRANSPIRATION

Potential evapotranspiration (PET) is calculated following the Thornthwaite (1948) method. First, the PET for each month is estimated based on the corresponding average monthly temperature. Next, the unadjusted rate is adjusted to account for the number of days in the month and the number of hours in a day between sunrise and sunset, which varies by latitude. Typically, PET represents the evapotranspiration for a full vegetation cover on relatively flat tilled ground with no shortage of water. The actual evapotranspiration (AET) is limited by the water available each month. If the sum of snowmelt and rainfall in a given month is less than the PET, then the AET is less than the PET. Evapotranspiration is also limited by the soil moisture condition. The PET is reduced linearly with soil moisture as follows:

$$\text{Adjusted evapotranspiration} = (S_2 + S_1)\ f\ (PET)/(2S_m)$$

Where: S_m is soil moisture capacity (assigned as 100 mm across the site)
S_1 is soil moisture at the beginning of the month
S_2 is soil moisture at the end of the month
PET is the calculated full PET, and
f is the PET reduction factor for non-ideal conditions for evapotranspiration (assigned as 0.4).

2.4.5 SOIL WATER

The monthly soil water balance is calculated assuming the soil profile could retain moisture from month to month. A maximum soil moisture retention of 100 mm is assumed to represent average site conditions. Consideration of sublimation, snowmelt, rainfall, and AET allows for an estimation of water available for infiltration and runoff. The soil moisture is calculated for the end of each month (S_2) based on the following formula:

$$S_2 = W + S_1 - (S_2 + S_1)\, f\,(PET)/(2S_m)$$

Where: W is sum of rainfall and snowmelt for the month
(other terms defined previously)

Solving for S_2

$$S_2 = (W + S_1(1 – f\,(PET)/(2S_m))/(1 + f\,(PET)/(2S_m))$$

Knowing the soil moisture at the beginning and the end of the month provides an estimate of the soil moisture change.

2.4.6 WATER AVAILABLE FOR RECHARGE AND RUNOFF

The water available for groundwater recharge and surface water runoff (V) is calculated by subtracting monthly evapotranspiration and soil moisture change from the sum of rainfall and snowmelt (W):

$$V = W – f(PET)(S_2 + S_1)/\,(2S_m) – (S_2 - S_1)$$

This unit value of available water is multiplied by the area for each elevation band in each sub-catchment to provide input to the water balance calculation.

2.5 SUB-CATCHMENT FLOW DISTRIBUTION

The following section describes the model theory for proportioning available water to the groundwater and surface water systems, and describes how water moves through each system.

2.5.1 GROUNDWATER RECHARGE

Groundwater recharge of the water available for runoff and recharge is estimated to account for the effects of variable surface conditions, soil permeability, and available storage capacity on recharge rates. Groundwater recharge is only allowed when evaporation and soil moisture requirements are met. Recharge therefore does not occur during the summer when the soil is not fully saturated or in the winter when the ground is covered by snow. The infiltration rate (I) within a sub-catchment is a specified parameter that varies during calibration and is set equal to the available water up to a volume equal to the product of an infiltration rate and the sub-catchment area (k_1A). For wetter months, a fraction (k_2) of the remaining available water also infiltrates ($k_2(V - k_1A)$). Therefore:

For precipitation less than or equal to k_1A

$$I\ (m^3/month) = V$$

For precipitation greater than k_1A

$$I\ (m^3/month) = k_1A + k_2(V - k_1A) = k_2V + k_1A(1 - k_2)$$

This procedure provides an estimate of groundwater recharge that is relevant at the time scale of the monthly water balance. Interflow and groundwater flow along very short paths are considered part of the surface water component with this monthly time increment. Available water that is not recharged remains as surface water.

2.5.2 GROUNDWATER STORAGE AND DISCHARGE

Groundwater storage and discharge within each sub-catchment are represented using a linear reservoir model. Water releases from groundwater storage at a rate determined by the product of the average volume of water in storage ($Z_1/2 + Z_2/2$) and a discharge factor (j). Monthly discharge (D) was set equal to:

$$D = j(Z_1/2 + Z_2/2).$$

Month-to-month storage is accounted within each sub-catchment and groundwater discharge increases with increasing storage. The volume of water in storage is the sum of the storage in the preceding month (Z_1) plus the volume of water entering the system (I) minus the quantity discharged:

$$\begin{aligned} Z_2 &= Z_1 + I - D \\ &= Z_1 + I - j(Z_1/2 + Z_2/2) \end{aligned}$$

Solving for Z_2:

$$Z_2 = (I + Z_1(1\text{-}jZ_1/2))/(1 + jZ_1/2)$$

The water entering the system includes groundwater recharge (meteoric recharge) and groundwater flow contributed from the upstream sub-catchment. Water released from groundwater storage within the sub-catchment is either routed to the next sub-catchment downstream as groundwater or discharged within the sub-catchment and routed downstream as surface water flow.

The maximum allowable groundwater flow leaving the sub-catchment as subsurface flow is estimated using Darcy's Law, which calculates groundwater flow as the product of transmissivity, width, and hydraulic gradient values estimated at a location beneath the hydrology station.

The volume of groundwater released from storage in excess of the groundwater flow offsite is added to the surface water leaving the catchment. Groundwater storage and flow rates are calibrated primarily using streamflows during the low flow season. For a given volume of recharge, a discharge factor lower in value results in larger accumulated storage and more uniform groundwater discharge rate.

2.5.3 SURFACE WATER DETENTION AND STORAGE

The volume of water reporting to the surface water component is estimated as the difference between water available for runoff and recharge and the volume of groundwater recharge. Some of the surface water component manifests as runoff during a month and the remainder is detained as surface storage in small-scale detention features, such as small ponds or as interflow. Within this watershed methodology, surface water detention features are managed using the same linear reservoir model as groundwater storage and discharge. However, the discharge factor for release from surface water storage is typically higher than for release from groundwater storage.

3.0 MODEL DEVELOPMENT AND CALIBRATION

3.1 MODEL DEVELOPMENT

Development of the watershed model was a multi-step process that proceeded as follows:

- Calibrate climate, groundwater and surface water parameters to measured streamflow at the WSC gauging station on Drury Creek for the period with coincident flow and climate data (1995 to 2009 and 2015 to 2016).
- Calibrate groundwater and surface water parameters in seven Project sub-catchments with records of monthly measured streamflow from 2015 to 2017 (KZ-2, KZ-9, KZ-13, KZ-15, KZ-16, KZ-22, and KZ-26).
- Assign parameter values to sub-catchments where records of monthly measured streamflow are unavailable (KZ-18, KZ-37, KZ-17, and KZ-21).

3.1.1 CALIBRATION TO MEASURED STREAMFLOW AT WSC REGIONAL STATION

The watershed model was initially calibrated to long-term measured streamflow at the WSC Drury Creek gauging station (WSC 09AH005). Measured flows at the WSC Drury Creek gauging site are available from January 1995 through December 2009 as well as August 2015 through December 2016. The watershed model is calibrated to the available Drury Creek flows from 1995 to 2016.

3.1.2 CALIBRATION TO STREAMFLOW AT PROJECT GAUGING STATIONS

The Baseline Watershed Model was calibrated to measured flows from 2015 to the end of 2017 at seven Project gauging stations. The calibration record starts in May 2015 for two Project gauging stations (KZ-15 and KZ-22) and in June 2015 for the remaining five Project gauging stations. Measured streamflows used in the calibration consist of monthly mean flows compiled from continuous flow measurement data and instantaneous flow measurements recorded during winter months. Winter flows are sustained by groundwater discharge and not expected to change rapidly.

The model was calibrated to streamflow at the following seven Project gauging stations:

- Gauge KZ-13 on South Creek
- Gauge KZ-2 on Fault Creek
- Gauge KZ-9 on Geona Creek, and
- Gauges KZ-15, KZ-16, KZ-22, and KZ-26 on Finlayson Creek.

3.1.3 ASSIGN PARAMETER VALUES TO REMAINING SUB-CATCHMENTS

Model parameters for sub-catchments without measured streamflow records were assigned suitable parameter values based on the results of the model calibration to stations with long-term streamflows, while considering sub-catchment specific characteristics. Model parameters were assigned as follows:

- The K1 and K2 groundwater factors were estimated based on the mapped proportion of sub-catchment area containing more permeable sand and gravel deposits at surface (as opposed to less permeable glacial till or bedrock outcrops). The K1 and K2 factors also considered the proportion of the catchment estimated to be permafrost. Estimated permafrost areas were delineated by Coregeo and Associates (2017). The value of the K2 factor is assigned as three times the value of the corresponding K1 factor, for both groundwater and surface water factors.
- The unit discharge values were assigned by considering the topography and extent of surficial sand and gravel within the sub-catchment. Higher unit discharge values were assigned to catchments with steeper slopes and incised drainages while lower unit discharge values were assigned to catchments with broad alluvial deposits underlying the drainage.

- Estimates of aquifer transmissivity, hydraulic gradient, and aquifer width were based on the mapped extent of surficial deposits at each sub-catchment node.

Surficial geology was determined from surficial geology maps by the Geologic Survey of Canada (Jackson, 1993a and 1993b; Ward and Jackson, 1993). Surficial geology across the Project site consists primarily of till and glaciofluvial deposits.

3.2 CALIBRATION TO STREAMFLOWS

3.2.1 CALIBRATION OBJECTIVE

The objective of the calibration was to develop a long-term climate and streamflow record that provides a representative distribution of high and low flows. The watershed model relies on climate input data representative of the Project site that was developed using correlation to long-term regional climate data. The imperfect correlation between this adopted synthetic climate record and the actual climate at the site limits the ability to accurately model flows on a month-to-month basis. The objective of the modelling is to therefore reproduce wet and dry trends within the region and a representative distribution of flows, so that wet and dry periods are correctly identified.

3.2.2 CALIBRATION CRITERIA

The fit between modelled and measured streamflows was optimized to provide a good match to the following criteria based on visual inspection:

- Cumulative mass balance: check that the measured and simulated total mass of water at a gauging site are similar and the total volume of water entering the modelled system is appropriate.
- Measured hydrograph: check that the measured time series of flows at Project gauging stations generally matches the simulated flows, including monthly mean flows and instantaneous winter flows.
- Flow distribution: check that the simulated flow record has a similar distribution of high and low flows as the measured record.

In addition to evaluating the goodness of fit between the measured and simulated streamflows using visual inspection, the fit to data was also assessed using the statistical Nash-Sutcliffe efficiency (1970) method (NSE). Visual inspection provides useful insight into the adequacy of the results; however, statistical measures provide a more objective approach that complements the visual inspection. The NSE is a commonly adopted statistical measure used in hydrology and is calculated by comparing monthly values of measured and modelled streamflows in each sub-catchment.

The performance rating for NSE values (Moriasi et al, 2006) is defined below:

- Very good: 0.75 < NSE < 1.00
- Good: 0.65 < NSE < 0.75
- Satisfactory: 0.50 < NSE < 0.65, and
- Unsatisfactory: NSE < 0.50.

3.2.3 CALIBRATION PROCESS

Climate, groundwater, and surface water parameters were adjusted during model calibration to obtain the best match between simulated and measured flows. The calibration process began by first assigning climate parameters to the model so that the measured and predicted cumulative volume of water passing the regional Drury Creek model node were similar and so that seasonal trends were well-matched. The comparison of cumulative modelled and measured streamflow helps assess whether the total volume of water entering the simulated system is appropriate. The groundwater and surface water parameters assigned to the Drury Creek catchment were then adjusted so that the distribution of measured and modelled high and low flows and the seasonal hydrograph are well matched. Next, the groundwater and surface water parameters were adjusted in the sub-catchments measured streamflow to refine the distribution of flows in these sub-catchments. Finally, groundwater and surface water parameters were assigned to remaining sub-catchments, based on the values assigned during calibration.

3.2.4 CALIBRATION RESULTS

Results of the model calibration to streamflows at the WSC station on Drury Creek and at the Project hydrology stations is discussed below. Figures showing the matches between modelled and measured streamflow are provided in Appendix B for the Drury Creek station and Appendix C for Project gauging stations. Calibrated groundwater and surface water parameters and estimated aquifer properties beneath gauging stations are listed in Table 3.1. The simulated amounts of groundwater recharge and surface water runoff in each sub-catchment are listed in Table 3.2.

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TABLE 3.1

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BASELINE WATERSHED MODEL
MODEL PARAMETERS

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Sub-Catchment	Groundwater Parameters						Surface Water Parameters			Precipitation Multiplier
	K1 Factor (m)	K2 Factor (%)	Unit Discharge	Aquifer Transmissivity (m^2/s)	Aquifer Width (m)	Hydraulic Gradient at Discharge Point (m/m)	K1 Factor (m)	K2 Factor (%)	Unit Discharge	
Drury Ck (09AH005)	0.024	0.072	0.14	1E-04	1500	0.02	0.2	0.6	1.9	1.18
SOUTH CREEK										
KZ-13	0.01	0.03	0.20	1E-04	430	0.05	0.1	0.3	1.2	1.00
GEONA CREEK										
KZ-2	0.02	0.06	0.20	2E-05	100	0.22	0.15	0.45	1.2	1.00
KZ-9	0.014	0.042	0.10	5E-05	100	0.03	0.1	0.3	1.2	1.00
KZ-18	0.01	0.03	0.10	5E-05	100	0.06	0.1	0.3	1.2	1.00
KZ-37	0.01	0.030	0.10	5E-05	100	0.03	0.1	0.3	1.2	1.00
KZ-17	0.01	0.03	0.10	1E-04	170	0.02	0.1	0.3	1.2	1.00
EAST CREEK										
KZ-21	0.01	0.03	0.10	1E-04	260	0.01	0.1	0.3	1.2	1.00
FINLAYSON CREEK										
KZ-16	0.014	0.042	0.15	1E-04	170	0.02	0.1	0.3	1.2	1.00
KZ-15	0.01	0.03	0.10	1E-04	170	0.02	0.1	0.3	1.2	1.00
KZ-22	0.01	0.03	0.10	1E-04	290	0.01	0.1	0.3	1.2	1.00
KZ-26	0.017	0.051	0.07	6E-03	500	0.01	0.1	0.3	1.2	0.90

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NOTES:

1. K1 FACTOR REPRESENTS THE FIRST QUANTITY OF AVAILABLE WATER TO RECHARGE GROUNDWATER / SURFACE WATER.
2. K2 FACTOR REPRESENTS THE PROPORTION OF REMAINING AVAILABLE WATER TO RECHARGE GROUNDWATER / SURFACE WATER.
3. AQUIFER TRANSMISSIVITY, WIDTH, AND HYDRAULIC GRADIENT ARE ESTIMATES OF THE AQUIFER PROPERTIES AT THE SURFACE WATER DISCHARGE LOCATION.

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TABLE 3.2

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BASELINE WATERSHED MODEL
SUMMARY OF MODEL RESULTS BY SUB-CATCHMENT

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Sub-Catchment	Total Contributing Area	Net Precipitation [1,2]	Mean Annual Recharge to Groundwater	Mean Annual Groundwater Discharge	Mean Annual Runoff	Modelled MAUD [3]
	km^2	mm/yr	mm/yr	mm/yr	mm/yr	$L/s/km^2$
Drury Ck (09AH005)	551.6	266	126	126	266	8.4
SOUTH CREEK						
KZ-13	7.9	285	59	69	302	9.3
GEONA CREEK						
KZ-2	1.9	615	130	125	609	19.3
KZ-9	16.4	265	78	68	302	9.4
KZ-18	5.3	275	58	56	279	8.6
KZ-37	22.0	222	56	102	296	9.2
KZ-17	25.7	233	57	55	288	8.9
EAST CREEK						
KZ-21	86.4	223	57	57	228	7.0
FINLAYSON CREEK						
KZ-16	35.0	280	79	79	285	8.8
KZ-15	60.8	222	56	132	286	8.9
KZ-22	162.4	204	56	57	248	7.7
KZ-26	210.7	135	79	60	219	6.7

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NOTES:

1. NET PRECIPITATION = RAINFALL + SNOWMELT - EVAPORATION - CHANGE IN SOIL MOISTURE
2. ADDITIONAL WINTER PRECIPITATION APPLIED TO SUB-CATCHMENT KZ-2 TO MATCH STREAMFLOW PATTERN.
3. MAUD = MEAN ANNUAL UNIT DISCHARGE.
4. VALUES ARE PRESENTED AS MEAN ANNUAL AND CALCULATED OVER THE PERIOD 1972 THROUGH 2017.
5. SUB-CATCHMENTS WITH VALUES OF GROUNDWATER DISCHARGE THAT EXCEED GROUNDWATER RECHARGE INDICATE THE CATCHMENT INCLUDES A LARGER PROPORTION OF GROUNDWATER FLOW FROM UPGRADIENT CATCHMENTS.

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3.2.4.1 DRURY CREEK SUB-CATCHMENT

The match between simulated and measured streamflow at the Drury Creek gauging station is shown on Figure B.1 (Appendix B). Modelled streamflows provide a good match to measured cumulative streamflows, mean monthly streamflows, and the flow distribution, as reflected in the plots. The good calibration to the regional data indicates that the water balance and the input parameters, such as precipitation and temperature, are well constrained in terms of flow volumes and distribution. A precipitation multiplier of 1.18 was required to match modelled and measured cumulative flows in the catchment (Table 3.1). This multiplier increases the precipitation applied to the catchment by a proportional amount above the record precipitation. The Drury Creek catchment is located close to the western edge of the Pelly Mountain range, west of Faro and appears to receive more precipitation than the Project. In comparison, all Project stations included in the model were assigned a precipitation multiplier value equal to 1, except for KZ-26 which was assigned a value of 0.9.

The NSE value calculated between monthly measured and modelled streamflows for the Drury Creek catchment is 0.59. This NSE performance rating is considered Satisfactory (defined in Section 3.2.2) for the model calibration to the Drury Creek measured hydrograph. The NSE value increases to 0.89 when just the low flow months of November through March (82 months total) are used in the NSE calculation.

3.2.4.2 PROJECT AREA SUB-CATCHMENTS CALIBRATION

Figures showing the matches between modelled and measured streamflow at the seven calibrated model nodes are provided in Appendix C. The cumulative streamflow at each model node are presented on Figure C.1 and show good agreement between the total modelled and measured flows leaving the sub-catchments. The time series of monthly mean streamflow at each model node over the calibration period are presented on Figure C.2 and streamflow frequency distributions are presented on Figure C.3. The mean monthly streamflow calculated at each model node over the full modelled period (1972 to 2017) are presented on Figure C.4.

The calibration focused on matching simulated and measured winter low flows, since the effects of Project development are expected to be greatest during low flow conditions. The timing of peak flows during the summer months display year-to-year variability in the measured records and the ability of the model to match measured flows varies during this period. The match between the simulated and measured flow duration curves in (Figure C.3) indicates that the occurrence of high and low flows in the simulated record are well represented overall by the modelled flows. Departures between modelled and measured monthly streamflow during the summer months may result from discrete precipitation and temperature events at the Project that do not correspond exactly to the climatic conditions experienced at the regional reference station.

Notable details about sub-catchment hydrology that influenced model calibration include:

- The results of numerical groundwater modelling suggest that groundwater flows from the Geona Creek KZ-9 sub-catchment to the South Creek KZ-13 sub-catchment at a rate of 400 m^3/day (Tetra Tech EBA, 2018). This groundwater transfer is incorporated into the model by transferring groundwater from the KZ-9 sub-catchment to groundwater storage in the KZ-13 sub-catchment.
- The mean annual unit discharge in the Fault Creek catchment (KZ-2) is the highest of all measured Project hydrology stations (Table 3.2). The aspect of the KZ-2 sub-catchment, along with visual observations of cornices, suggest that this sub-catchment receives and traps snow blown in from

adjacent sub-catchments (AEG, 2017). An increase in snow pack is represented in the model by increasing the winter precipitation by 20% and doubling the soil water equivalent of the modelled snow pack. As a result, sub-catchment KZ-2 also has a much higher net precipitation that the other catchments.

- Measured monthly mean and instantaneous fall and winter streamflow at gauging station KZ-26 were lower than corresponding streamflow measurements at the upstream KZ-22 hydrology station during several months of the measured record (September 2015 to December 2015; December 2016). This observation suggests that little to no groundwater discharges to the creek within this sub-catchment during months with little precipitation, and that some surface flows may infiltrate into and be transported within the subsurface alluvial aquifer. The KZ-26 hydrology station lies on a large alluvial deposit located at the edge of Finlayson Lake. The alluvial aquifer beneath the hydrology station at KZ-26 is assigned a higher transmissivity to represent the increased subsurface conveyance; the resulting groundwater flow rate beneath the gauge is modelled at 30 L/s. The KZ-26 sub-catchment has the lowest mean annual unit discharge of all the sub-catchments (Table 3.2). A lower mean annual unit discharge was achieved in the model by assigning a precipitation multiplier of 0.9 to the sub-catchment, this value provided a good match between cumulative and measured streamflows.

The statistical NSE values calculated between the measured and modelled streamflow for calibrated model nodes are provided in Table 3.3. Statistical NSE values were calculated using the full calibration record as well just the low flow winter months (November through March; 12 values total). The NSE values calculated for the low flow months are higher than the values calculated over the entire calibration record at all Project stations, reflecting the focus of the calibration on matching low flows and the low variability of the flows during this period.

Table 3.3 Logarithmic Nash Sutcliff Efficiency (NSE) Results for Project Gauging Stations

Project Station	KZ-13	KZ-2	KZ-9	KZ-16	KZ-15	KZ-22	KZ-26
NSE	0.72	0.65	0.71	0.58	0.41	0.35	0.43
NSE Rating	Good	Satisfactory	Good	Good	Unsatisfactory	Unsatisfactory	Unsatisfactory
Low Flow NSE	0.97	1.0	0.99	0.88	0.99	0.98	0.94
Low Flow NSE Rating	Very Good	Very Good	Very Good	Very Good	Very Good	Very Good	Very Good

4.0 RESULTS

The mean annual precipitation from 1972 through 2017 is estimated to be 520 mm at the Project elevation, with approximately 60% falling as rain and 40% falling as snow. The mean annual PET is approximately 400 mm calculated over the same period. This PET value was calculated using the Thornthwaite method (1948) adjusted for the number of daylight hours between sunrise and sunset. Upon review, this adjustment may not be applicable for such a northern climate. The mean annual lake evaporation estimated by Environment and Climate Change Canada for the region (Watson Lake A) is approximately 345 mm/year and is considered more representative. This lake evaporation is similar to the PET measured onsite in 2016 of 361 mm (KP, 2018). The use of a higher PET value in the watershed model does not affect the ability of the model to estimate streamflows since other parameter values were also adjusted during the calibration process to obtain the best match to streamflows. The estimated AET is approximately 160 mm, consistent with the range suggested by the Hydrometeorology Analysis Report (KP, 2018). The estimated sublimation is approximately 70 mm, which is equal to 35% of the annual snowfall.

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The average groundwater recharge within the calibrated Baseline Watershed Model is approximately 15% of the average annual precipitation at the project reference elevation.

5.0 SUMMARY

A Baseline Watershed Model was developed to assess pre-Project hydrologic conditions at the KZK Project. The model simulates monthly flows over a 46 year period from 1972 through 2017. The model was developed using climate inputs consisting of long-term temperature and precipitation data from 1972 to 2017. The Project area was divided into 11 sub-catchments based on locations of established stream gauging and water quality stations. The model was calibrated to flows measured at seven project hydrology stations in addition to one regional WSC station.

The 46 year record of variable climate input to the model results in a long-term series of simulated streamflows and groundwater flows that display seasonal variability. This simulated flow series includes a range of high and low flows along with regional wet and dry trends.

The Baseline Watershed Model will serve as the basis for developing a Life of Mine Water Balance Model to assess potential effects of mine development on hydrologic flows and water quality during permitting.

6.0 CLOSURE

We trust that this letter meets the current needs of the project team. Please contact the undersigned with any questions or comments.

Yours truly,
Knight Piésold Ltd.

PROFESSIONAL
YUKON
DR. CYNTHIA STARZYK
Oct 10/18

[Signature Redacted]

[Signature Redacted]

Prepared: ____________ Reviewed: ____________

Project Engineer Senior Engineer

[Signature Redacted]

Approval that this document adheres to Knight Piésold Quality Systems:

Attachments:

Appendix A Rev 0	Synthetic Climate and Measured Streamflow Data
Appendix B Rev 0	Drury Creek Reference Station (09AH005)
Appendix C Rev 0	Project Station Calibration Plots

References:

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APPENDIX A

Synthetic Climate and Measured Streamflow Data

(Tables A.1 to A.3)

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TABLE A.1

BMC MINERALS (NO. 1) LTD
KUDZ ZE KAYAH

KZK BASELINE WATERSHED MODEL
MONTHLY LONG-TERM SYNTHETIC TEMPERATURE SERIES (^{o}C)

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Month	Average	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
January	-11.1	-15.3	-13.5	-15.2	-12.2	-10.0	-11.1	-11.4	-13.3	-13.3	-6.4	-17.4	-11.7	-10.2	-6.5
February	-11.6	-15.7	-13.1	-12.3	-12.9	-13.2	-11.6	-10.5	-18.8	-9.1	-11.5	-14.2	-11.5	-8.4	-14.2
March	-11.3	-13.9	-9.6	-14.6	-11.6	-11.8	-11.3	-9.9	-8.2	-10.9	-7.3	-14.7	-12.0	-6.6	-10.9
April	-4.5	-9.3	-3.3	-4.7	-4.9	-3.2	-4.5	-4.6	-5.6	-2.4	-8.1	-6.8	-3.5	-2.5	-6.7
May	2.6	2.0	2.2	1.1	2.9	2.2	2.6	2.3	1.4	3.7	5.3	0.4	2.6	1.7	1.1
June	8.1	8.2	6.7	6.5	7.6	8.2	8.1	7.8	6.7	9.6	5.9	8.9	8.3	6.7	5.5
July	9.9	10.1	9.7	9.1	10.7	10.7	9.9	10.3	10.0	9.3	9.7	10.9	9.5	8.5	9.2
August	7.9	9.0	6.0	7.9	7.7	9.1	7.9	8.8	9.9	6.4	8.3	6.9	6.1	6.7	5.3
September	2.3	0.7	2.6	2.8	3.8	3.8	2.3	4.0	4.1	0.9	1.3	3.2	-0.2	1.6	1.6
October	-2.7	-3.8	-2.8	-1.8	-2.8	-2.1	-2.7	-1.1	-1.3	-0.6	-2.6	-4.0	-3.0	-3.9	-4.1
November	-9.6	-8.4	-15.6	-6.1	-9.6	-4.7	-9.6	-10.5	-6.1	-5.8	-6.4	-11.6	-9.9	-11.0	-15.5
December	-13.0	-14.4	-13.3	-10.9	-15.9	-12.0	-13.0	-13.2	-13.9	-19.6	-15.3	-12.8	-18.4	-15.0	-10.0
Annual	-2.8	-4.2	-3.7	-3.2	-3.1	-1.9	-2.8	-2.3	-2.9	-2.6	-2.3	-4.3	-3.6	-2.7	-3.7
Month	Average	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
January	-11.1	-7.7	-8.5	-11.3	-13.2	-11.0	-10.7	-8.1	-11.3	-12.2	-10.7	-16.3	-12.9	-12.8	-12.4
February	-11.6	-11.4	-9.3	-9.6	-13.2	-15.5	-9.2	-10.5	-11.4	-16.4	-11.0	-11.3	-9.0	-9.1	-12.5
March	-11.3	-10.6	-14.0	-7.6	-15.7	-8.9	-11.4	-8.6	-9.6	-7.7	-13.1	-13.3	-13.9	-10.6	-10.1
April	-4.5	-9.7	-4.4	-3.1	-3.4	-3.3	-3.2	-5.6	-2.1	-2.0	-1.5	-5.8	-3.7	-2.5	-4.1
May	2.6	0.5	2.1	3.4	4.0	3.9	3.5	-0.3	4.2	2.2	5.5	0.5	2.4	4.7	0.2
June	8.1	7.3	7.1	8.3	8.7	7.8	8.3	8.0	8.4	8.0	9.5	7.3	8.5	9.0	8.8
July	9.9	10.5	10.1	8.9	11.4	10.5	9.0	10.3	9.3	11.2	9.7	9.9	11.0	10.7	8.5
August	7.9	5.9	7.5	7.5	10.8	9.1	6.1	7.4	7.4	12.2	6.6	5.5	8.6	7.1	9.2
September	2.3	2.1	2.1	1.7	2.8	3.7	3.2	-2.3	2.5	1.4	5.3	1.5	3.7	2.1	2.5
October	-2.7	-1.6	-1.0	-2.9	-3.3	-3.6	-4.4	-4.2	-1.7	-1.9	-2.5	-5.4	-5.2	-2.8	-2.0
November	-9.6	-12.2	-6.2	-8.1	-10.0	-15.3	-9.0	-6.5	-8.1	-11.6	-11.4	-12.4	-7.5	-9.9	-9.0
December	-13.0	-10.2	-10.9	-11.5	-10.3	-14.6	-11.7	-14.7	-10.8	-13.3	-13.7	-15.1	-9.5	-14.0	-10.5
Annual	-2.8	-3.1	-2.1	-2.0	-2.6	-3.1	-2.5	-2.9	-1.9	-2.5	-2.3	-4.6	-2.3	-2.3	-2.6
Month	Average	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
January	-11.1	-11.8	-7.3	-9.9	-10.2	-13.6	-11.7	-10.8	-9.2	-12.3	-12.0	-9.8	-11.0	-11.4	-10.0
February	-11.6	-8.8	-11.8	-11.1	-10.4	-8.4	-11.2	-10.5	-14.6	-13.0	-13.8	-9.1	-12.5	-8.3	-8.6
March	-11.3	-8.1	-10.8	-15.4	-12.0	-11.5	-7.0	-13.6	-15.8	-10.2	-14.2	-8.7	-15.0	-11.7	-14.3
April	-4.5	-6.3	-4.3	-10.1	-4.5	-3.8	-3.1	-4.5	-4.6	-4.7	-5.3	-2.5	-4.6	-2.8	-9.7
May	2.6	0.6	0.2	0.9	0.9	3.1	5.6	1.6	2.7	3.2	2.8	3.4	4.1	1.7	2.3
June	8.1	8.7	8.4	7.6	7.1	12.1	8.3	8.8	9.2	6.9	9.0	7.7	8.3	8.4	9.8
July	9.9	9.2	9.4	9.7	11.4	10.7	8.6	10.2	10.8	7.5	10.7	10.0	9.3	8.8	10.3
August	7.9	5.7	9.5	6.3	7.6	9.3	8.4	7.2	9.0	6.6	8.2	9.4	6.4	7.9	10.3
September	2.3	0.8	2.9	2.3	1.1	0.2	2.9	3.0	1.7	1.8	3.0	2.0	2.3	3.0	3.9
October	-2.7	-2.8	-3.2	-1.4	-1.3	-3.2	-2.1	-2.6	-3.1	-3.0	-2.8	-2.2	-2.2	-5.0	-1.6
November	-9.6	-7.3	-9.6	-5.7	-11.4	-8.5	-6.8	-17.2	-8.0	-8.0	-8.9	-7.5	-12.0	-12.6	-11.0
December	-13.0	-12.9	-13.8	-11.0	-12.1	-12.0	-10.7	-10.4	-14.0	-16.0	-12.2	-14.9	-10.0	-16.3	-14.3
Annual	-2.8	-2.8	-2.5	-3.2	-2.8	-2.1	-1.6	-3.2	-3.0	-3.4	-3.0	-1.8	-3.1	-3.2	-2.7
Month	Average	2014	2015	2016	2017										
January	-11.1	-7.2	-9.7	-8.1	-9.4										
February	-11.6	-14.3	-11.8	-8.5	-11.2										
March	-11.3	-14.2	-9.4	-6.6	-15.0										
April	-4.5	-5.0	-3.4	-0.2	-3.3										
May	2.6	3.7	6.4	4.9	3.9										
June	8.1	6.8	8.3	9.6	8.4										
July	9.9	10.3	9.1	10.7	10.2										
August	7.9	8.2	7.0	9.5	9.8										
September	2.3	2.0	1.8	2.8	4.0										
October	-2.7	-2.1	-1.5	-4.6	-2.3										
November	-9.6	-9.4	-8.4	-7.5	-14.0										
December	-13.0	-11.2	-11.7	-13.6	-11.0										
Annual	-2.8	-2.8	-2.5	-3.2	-2.8										

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NOTES:

1. GREY HIGHLIGHTING INDICATES MONTHS MISSING DATA THAT ARE INFILLED WITH MEAN MONTHLY VALUES.

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TABLE A.2

BMC MINERALS (NO. 1) LTD
KUDZ ZE KAYAH

KZK BASELINE WATERSHED MODEL
MONTHLY LONG-TERM SYNTHETIC PRECIPITATION SERIES (mm)

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Month	Average	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
January	28	92	33	22	26	25	28	1	15	32	11	17	58	45	37
February	20	32	10	45	12	20	20	20	30	4	38	29	11	39	41
March	22	36	37	19	23	35	22	22	33	19	7	16	16	10	4
April	13	14	4	16	17	17	13	7	11	20	7	7	4	4	23
May	37	46	16	59	4	32	37	19	17	17	13	30	34	60	28
June	66	53	60	70	77	48	66	44	111	18	70	23	91	80	46
July	91	87	26	43	100	62	91	62	91	156	68	95	80	27	102
August	82	41	72	108	32	51	82	68	23	54	37	77	108	106	132
September	59	75	39	53	68	19	59	13	22	76	68	77	35	9	76
October	40	53	29	63	37	23	40	53	19	30	35	69	27	18	33
November	28	41	25	12	28	20	28	33	20	35	28	19	19	17	36
December	29	36	28	35	21	28	29	31	56	22	9	22	6	37	43
Annual	516	605	379	546	447	380	516	372	448	484	390	482	487	452	599
Month	Average	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
January	28	14	5	11	32	24	28	37	36	33	14	10	13	12	50
February	20	8	23	17	6	42	37	40	25	14	13	15	21	5	17
March	22	57	5	28	32	8	27	12	3	19	30	72	2	12	25
April	13	21	16	13	3	11	5	26	10	8	8	11	22	8	6
May	37	57	66	62	29	38	37	24	125	65	18	22	27	24	73
June	66	21	83	61	67	74	49	19	80	40	55	33	63	48	114
July	91	134	151	159	85	49	189	111	81	32	120	105	141	31	61
August	82	127	104	42	28	105	54	56	91	41	104	116	54	40	61
September	59	73	49	72	50	108	79	78	83	75	47	89	29	37	47
October	40	37	43	47	76	37	81	23	63	68	20	70	40	31	38
November	28	26	29	29	65	42	71	31	66	40	36	13	10	8	21
December	29	9	10	27	23	41	65	21	28	13	25	17	21	16	48
Annual	516	582	584	569	496	579	722	478	691	447	491	573	444	271	560
Month	Average	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
January	28	23	12	15	28	28	28	18	18	33	54	28	16	27	121
February	20	3	5	9	20	19	20	10	16	20	34	9	16	20	20
March	22	22	7	15	22	74	4	20	20	9	34	15	22	19	14
April	13	48	24	13	13	7	32	17	3	8	11	6	7	21	17
May	37	18	50	37	37	31	96	70	37	50	29	25	11	26	10
June	66	65	57	66	66	56	66	84	83	115	67	73	121	80	58
July	91	81	95	91	91	22	137	46	71	129	32	61	82	103	124
August	82	190	23	82	82	62	63	71	82	177	119	47	90	95	124
September	59	172	73	59	59	79	60	43	85	62	49	50	44	51	60
October	40	26	90	40	40	55	21	24	58	34	40	27	20	40	33
November	28	32	20	28	28	16	49	35	13	17	19	43	28	41	23
December	29	29	41	15	29	29	18	17	32	41	7	21	51	31	71
Annual	516	708	497	472	516	476	595	455	518	695	496	404	510	555	674
Month	Average	2014	2015	2016	2017										
January	28	35	28	28	2										
February	20	20	8	11	12										
March	22	13	29	9	19										
April	13	6	17	19	8										
May	37	45	8	34	7										
June	66	76	63	44	141										
July	91	94	104	81	198										
August	82	96	146	104	98										
September	59	66	48	31	36										
October	40	19	40	4	48										
November	28	1	28	8	28										
December	29	29	29	29	29										
Annual	516	498	550	403	625										

M:\1\01\00640\06\A\Data\Task 700 - Watershed Model\1-BaselineModel\FinalModel_DruryCreek\[ClimateInputs.xlsx]TableA2

NOTES:

1. GREY HIGHLIGHTING INDICATES MONTHS MISSING DATA THAT ARE INFILLED WITH MEAN MONTHLY VALUES.

0	09OCT'18	ISSUED WITH LETTER VA18-00976	MCW	CAS
REV	DATE	DESCRIPTION	PREP'D	RVW'D

Knight Piésold CONSULTING

TABLE A.3

BMC MINERALS (NO. 1) LTD
KUDZ ZE KAYAH

BASELINE WATERSHED MODEL
MEASURED MONTHLY STREAMFLOW

Print Oct/09/18 15:05:57

Month	SOUTH CREEK	GEONA CREEK		FINLAYSON CREEK			
	KZ-13	KZ-2	KZ-9	KZ-16	KZ-15	KZ-22	KZ-26
May 2015					1650	3646	
Jun 2015	163	80	309	546	927	1777	2364
Jul 2015	92	36	239	385	576	1396	1717
Aug 2015	110	41	237	461	663	1845	2313
Sep 2015	159	46	306	563	1087	2832	2663
Oct 2015	72	*28*		*309*	*698*	1781	*1545*
Nov 2015		*11*	*81*	*156*	*269*	*750*	*604*
Dec 2015	*48*	8	70	108	275	535	340
Jan 2016	*13*	6	50	57	127	*361*	372
Feb 2016	10	5	38	52	91	*772*	389
Mar 2016	*7*	4	30	76	87	*310*	354
Apr 2016		4	*44*	*85*	*104*	*541*	551
May 2016	105	53	145		632	997	1162
Jun 2016	101	65	156	241	499	796	960
Jul 2016	81	39	142	272	526	1041	1342
Aug 2016	132	56	241	525	945	1988	2329
Sep 2016	236	69	405	872	1626	3193	3488
Oct 2016	81	*37*		*486*	*781*	*2514*	*2532*
Nov 2016	*48*	*11*	*92*	*219*	*258*	*620*	*700*
Dec 2016	*25*	7	65	*127*	182	428	279
Jan 2017	23	4	51	*323*	153	323	474
Feb 2017	17	4	35	*77*	103	245	467
Mar 2017	19	4	29	96	85	215	542
Apr 2017	14	6	32	169	99	246	490
May 2017		25			1131	2737	
Jun 2017	246	130	413	784	1490	2989	
Jul 2017	384	125	595	1186	2103	5181	
Aug 2017	200	48	397	819	1294	2799	
Sep 2017	79	22	173	317	522	1099	
Oct 2017	*58*	*16*		*326*	*538*	*1295*	*1538*
Nov 2017	24	9	74	109	228	365	625
Dec 2017	*11*	5	43	*59*	*206*	*387*	*612*

M:\1\01\00640\06\A\Data\Task 700 - Watershed Model\1-BaselineModel\FinalModel_DruryCreek\[KZKBaselineWSM.xlsm]TABLE A3_Measured

NOTES:

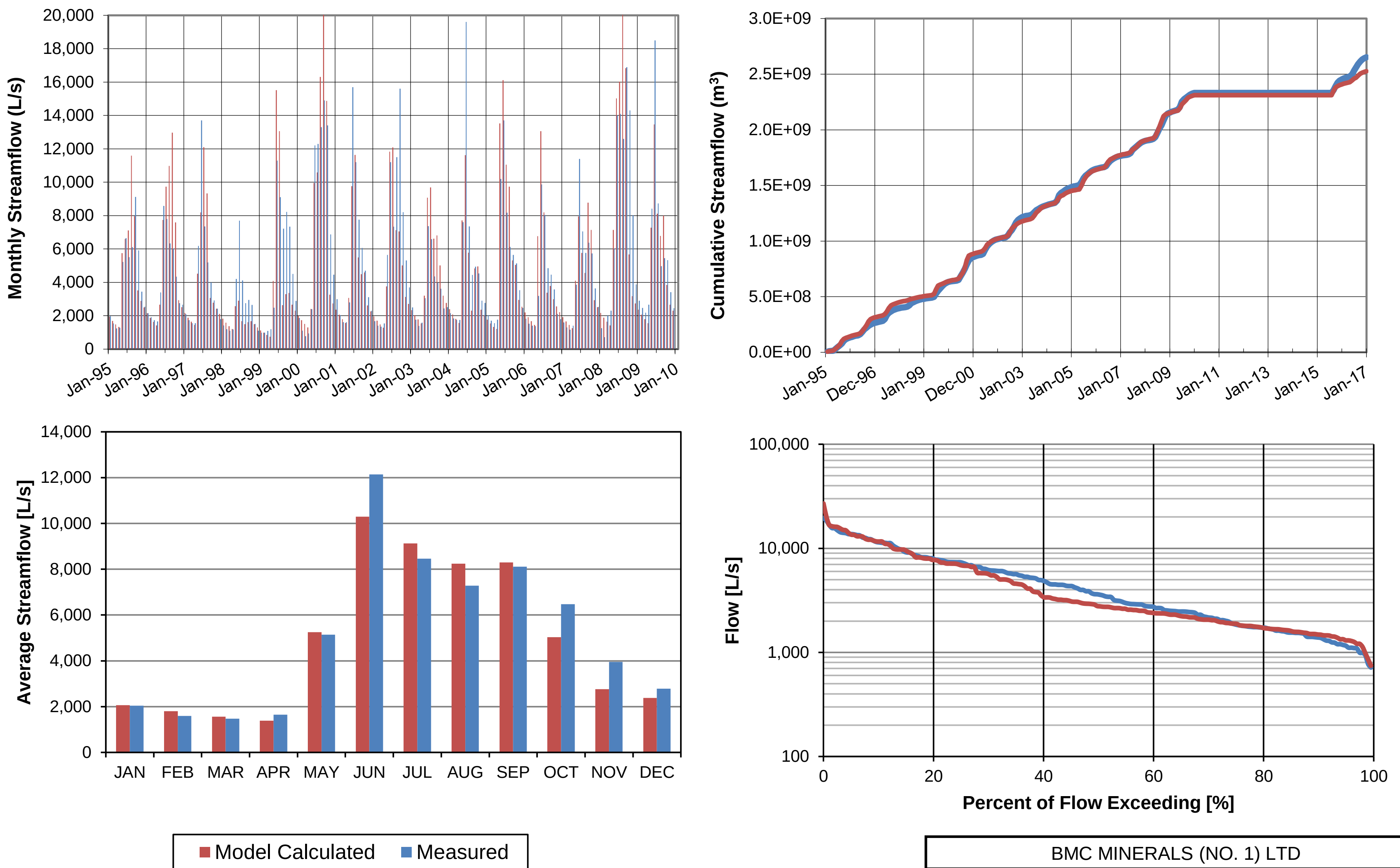
1. STREAMFLOWS ARE IN L/s.
2. MONTHLY MEAN MEASURED VALUES CALCULATED FROM DAILY AVERAGE MEASURED DISCHARGE DATA FOR MONTHS WITH AT LEAST 20 DAYS OF RECORD.
3. VALUES IN GREY ITALICS INDICATE INSTANTANEOUS STREAMFLOW MEASUREMENTS THAT ARE INTERPRETED TO BE REPRESENTATIVE OF MONTHLY MEAN STREAMFLOW CONDITIONS.

0	09OCT'18	ISSUED WITH LETTER VA18-00976	MCW	CAS
REV	DATE	DESCRIPTION	PREP'D	RVW'D

APPENDIX B

Drury Creek Reference Station (09ah005)

(Figure B.1)



NOTES:

1. MEAN MONTHLY STREAMFLOW AND FLOW DISTRIBUTION VALUES CALCULATED OVER THE PERIOD JANUARY 1995 TO DECEMBER 2016 WITH THE PERIOD JANUARY 2010 THROUGH JULY 2015 EXCLUDED. MEASURED DATA ARE UNAVAILABLE FOR THE PERIOD JANUARY 2010 THROUGH JULY 2015.

0	09OCT'18	ISSUED WITH LETTER	MCW	CAS
REV	DATE	DESCRIPTION	PREP'D	RVW'D

BMC MINERALS (NO. 1) LTD

KUDZ ZE KAYAH

BASELINE WATERSHED MODEL
DRURY CREEK REFERENCE STATION (09AH005)

Knight Piésold CONSULTING

P/A NO. VA101-640/06	REF. NO. VA18-00976	
FIGURE B.1		REV 0

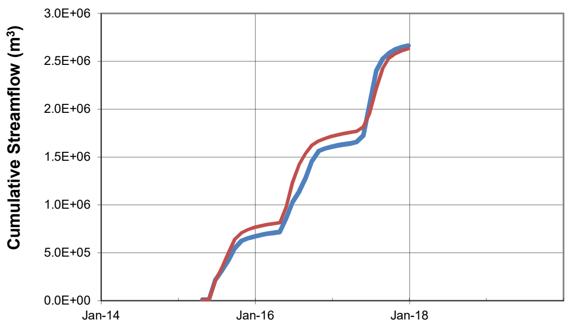
APPENDIX C

Project Station Calibration Plots

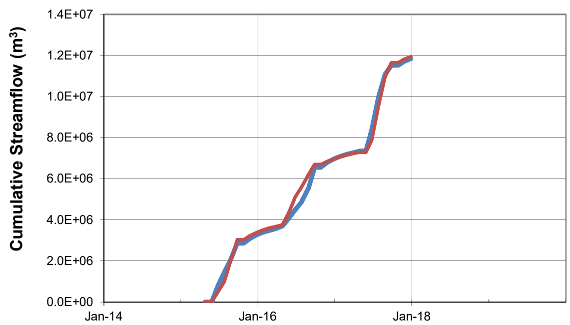
(Pages C-1 to C-4)

APPENDIX C.1 CUMULATIVE STREAMFLOWS

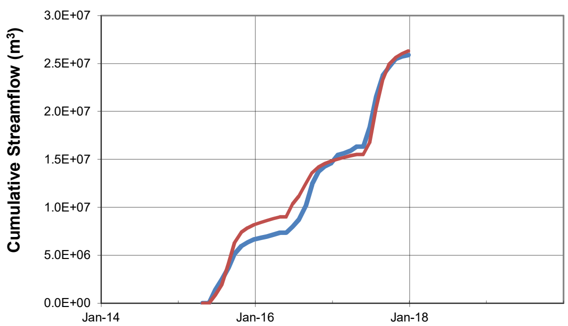
KZ-2



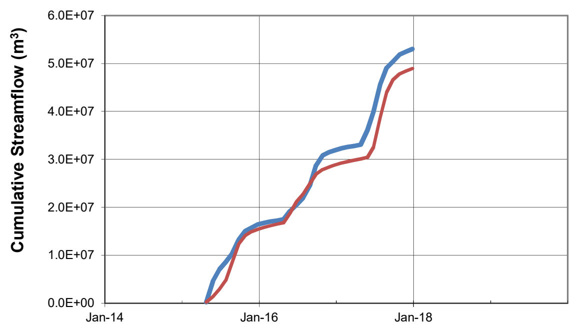
KZ-9



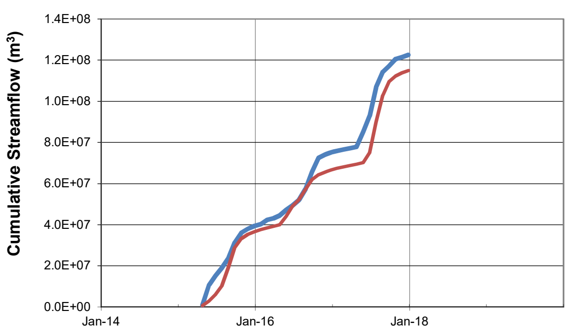
KZ-16



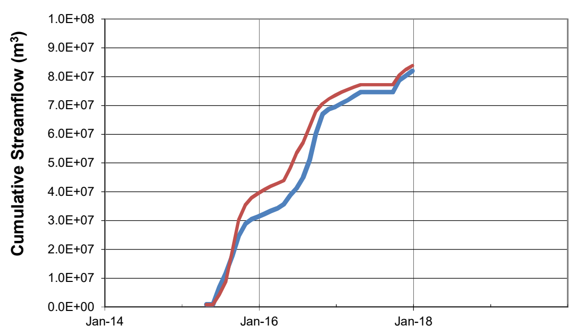
KZ-15



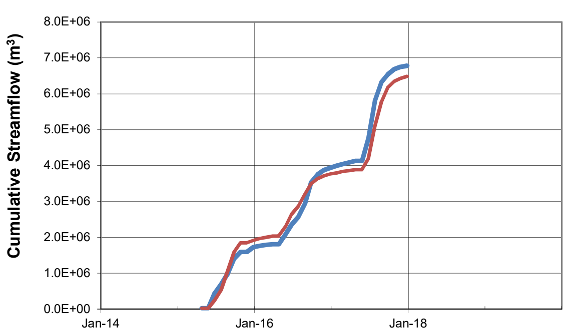
KZ-22



KZ-26



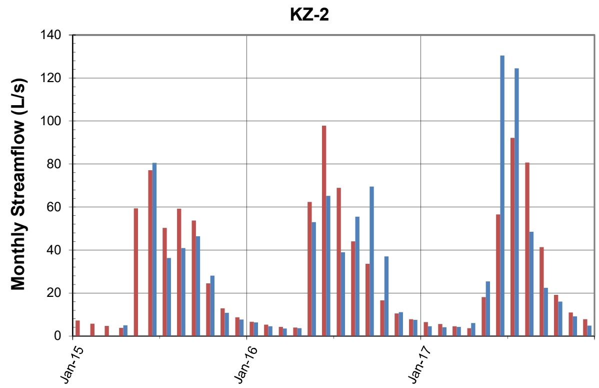
KZ-13

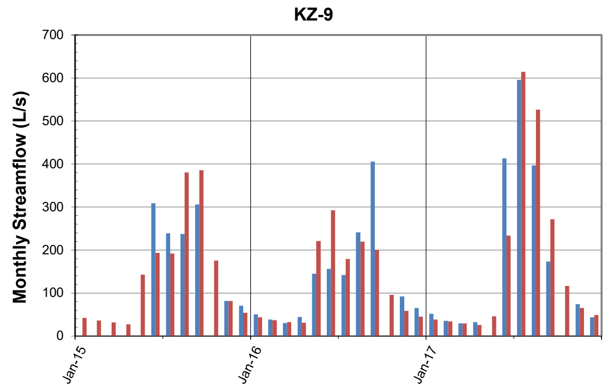


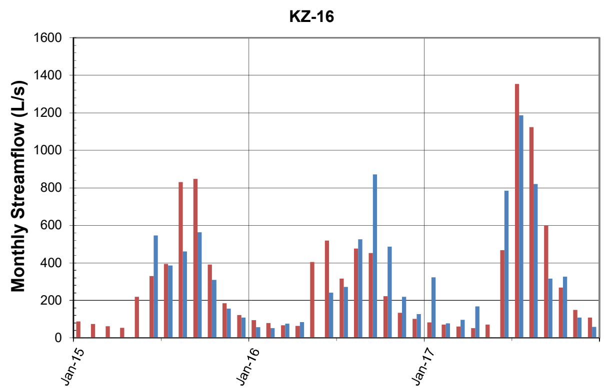
Model Calculated — Measured

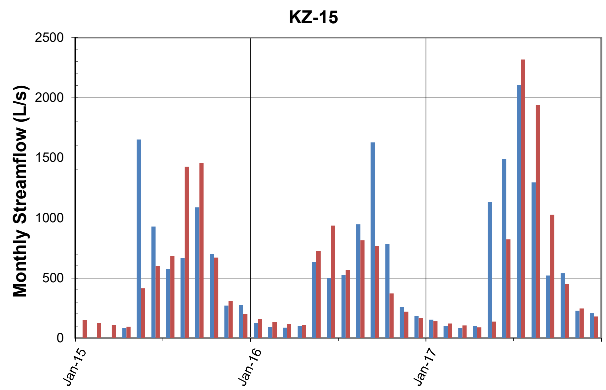
NOTES:
1. CUMULATIVE STREAMFLOWS CALCULATED FROM THE START OF THE MEASURED RECORD (APR. 2015) THROUGH DEC. 2017.
2. MONTHS MISSING MEASURED DATA ARE EXCLUDED FROM BOTH THE MODEL CALCULATED AND MEASURED CUMULATIVE CALCULATIONS.

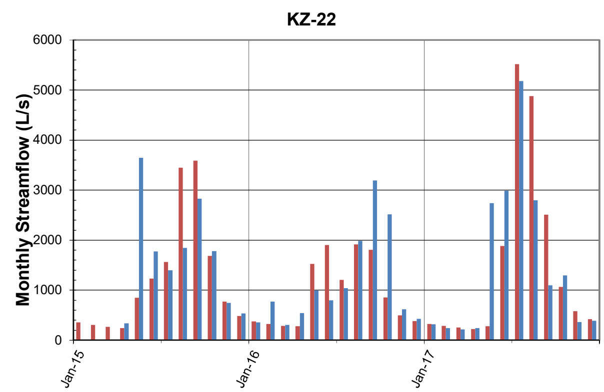
APPENDIX C.2 MONTHLY STREAMFLOW HYDROGRAPHS

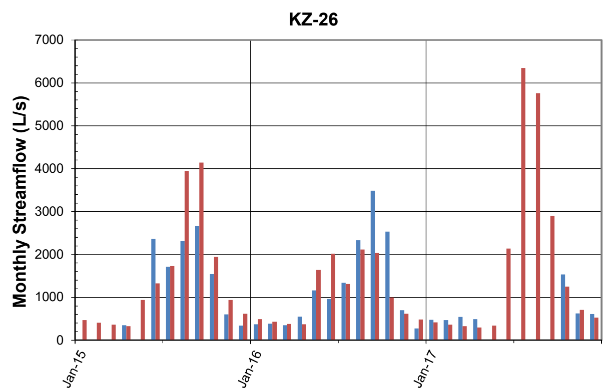


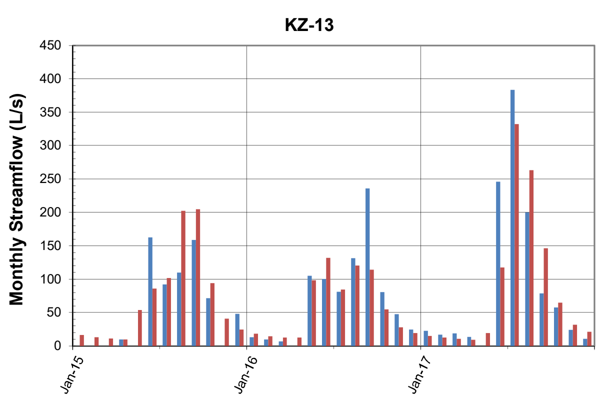










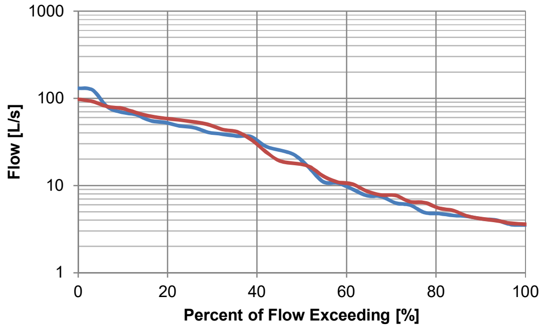


Model Calculated   Measured

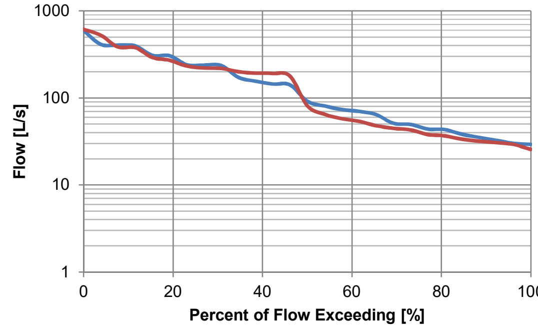
NOTES:
1. MEASURED FLOWS ARE NOT AVAILABLE FOR ALL MONTHS.

APPENDIX C.3 FLOW DISTRIBUTION CURVES

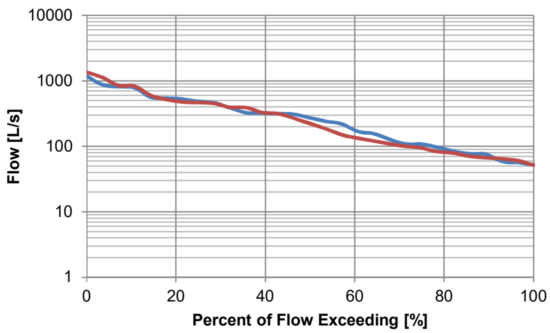
KZ-2



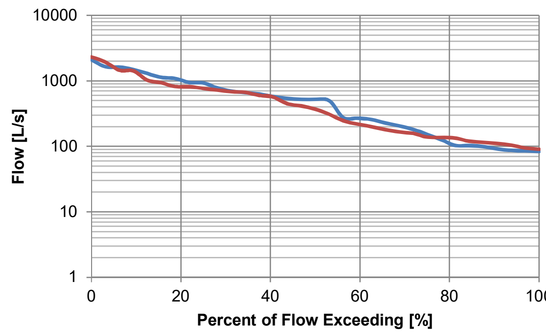
KZ-9



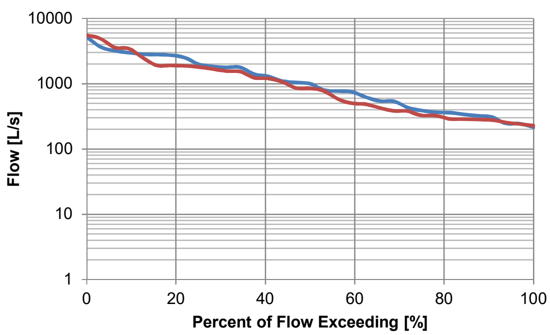
KZ-16



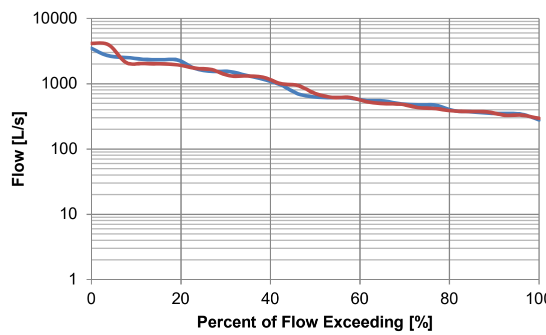
KZ-15



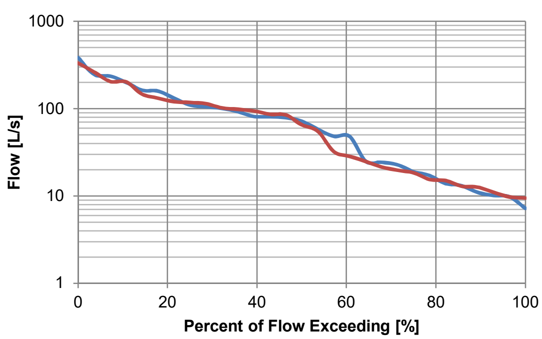
KZ-22



KZ-26



KZ-13



Measured   Model Calculated

NOTES:
1. FLOW DISTRIBUTIONS CALCULATED OVER THE PERIOD APR. 2015 THROUGH DEC. 2017.
2. MONTHS MISSING MEASURED DATA ARE EXCLUDED FROM BOTH THE MODEL CALCULATED AND MEASURED FLOW DISTRIBUTIONS.

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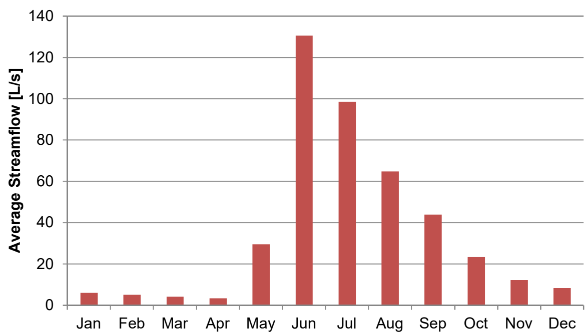
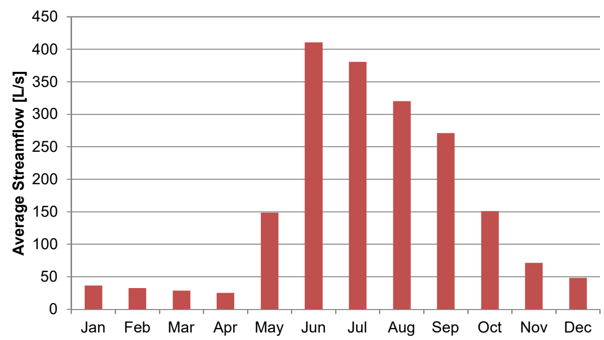
APPENDIX C.4 AVERAGE MONTHLY STREAMFLOWS

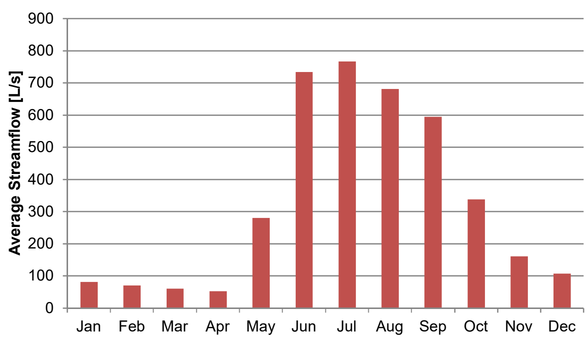
KZ-2



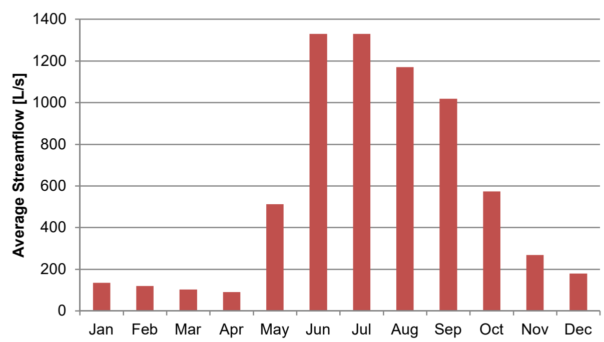
KZ-9



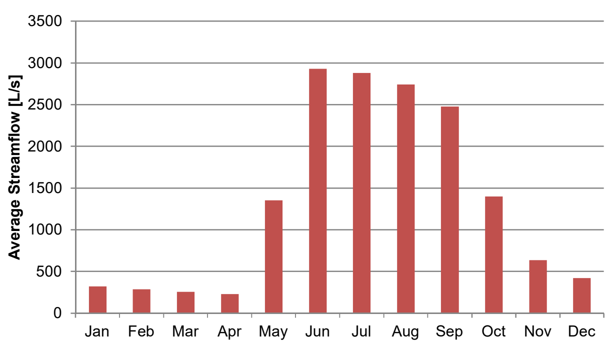
KZ-16



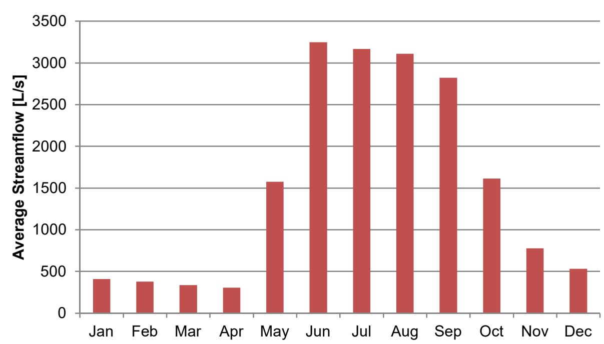
KZ-15



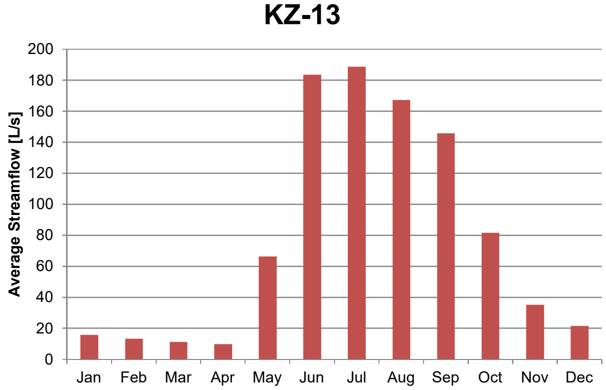
KZ-22



KZ-26



KZ-13



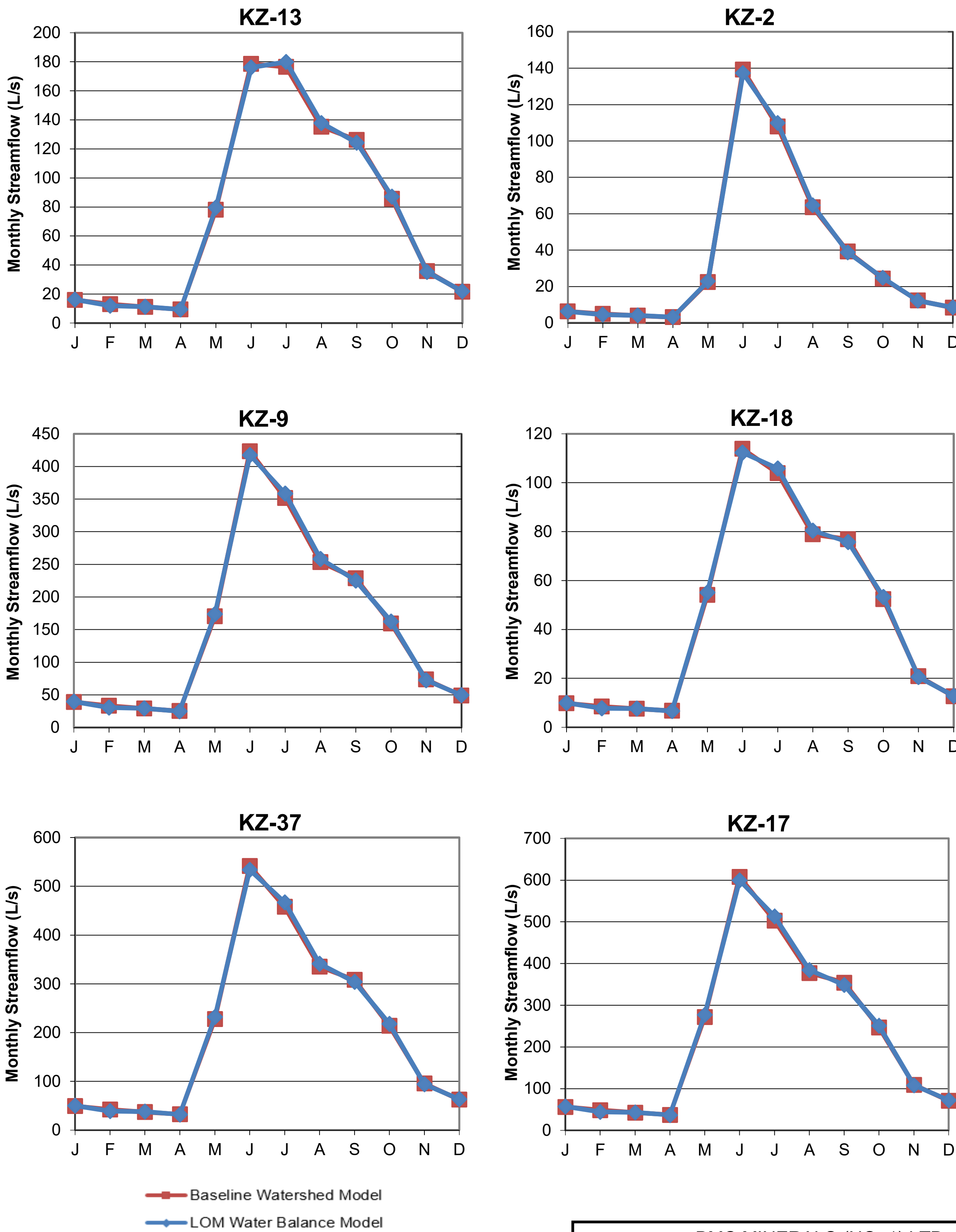
Model Calculated

NOTES:
1. MEAN MONTHLY VALUES CALCULATED OVER THE PERIOD JAN. 1972 THROUGH DEC. 2017.

APPENDIX C

Baseline Streamflow Comparison

(Figures C.1 to C.2)



NOTES:

1. LOM Water Balance Model data represents mean monthly flow results from the baseline period of the LOM Water Balance Model.

2. Baseline Watershed Model data represents mean monthly flow results from the Baseline Watershed Model (KP, 2018)

REV	DATE	DESCRIPTION	PREP'D	RVW'D
0	27JUL'18	ISSUED WITH REPORT	CDI	CAS

BMC MINERALS (NO. 1) LTD.

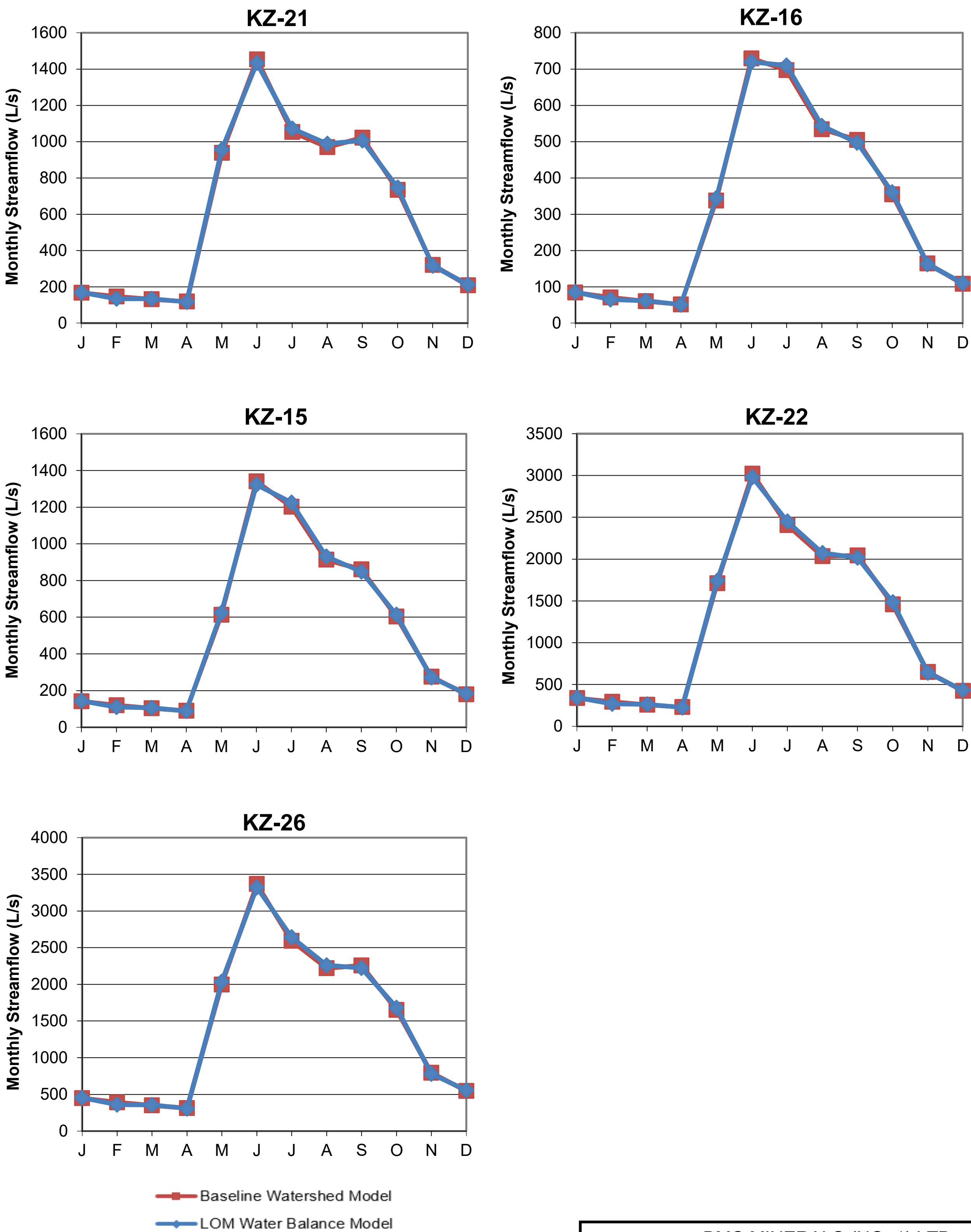
KUDZ ZE KAYAH PROJECT

BASELINE STREAMFLOW HYDROGRAPHS

Knight Piésold CONSULTING

P/A NO.	REF. NO.
VA101-00640/06	3

FIGURE C.1 REV 0



NOTES:

1. LOM Water Balance Model data represents mean monthly flow results from the baseline period of the LOM Water Balance Model.

2. Baseline Watershed Model data represents mean monthly flow results from the Baseline Watershed Model (KP, 2018)

0	27JUL'18	ISSUED WITH REPORT	CDI	CAS
REV	DATE	DESCRIPTION	PREP'D	RVW'D

BMC MINERALS (NO. 1) LTD.

KUDZ ZE KAYAH PROJECT

BASELINE STREAMFLOW HYDROGRAPHS

Knight Piésold CONSULTING

P/A NO. VA101-00640/06	REF. NO. 3	
FIGURE C.2		REV 0

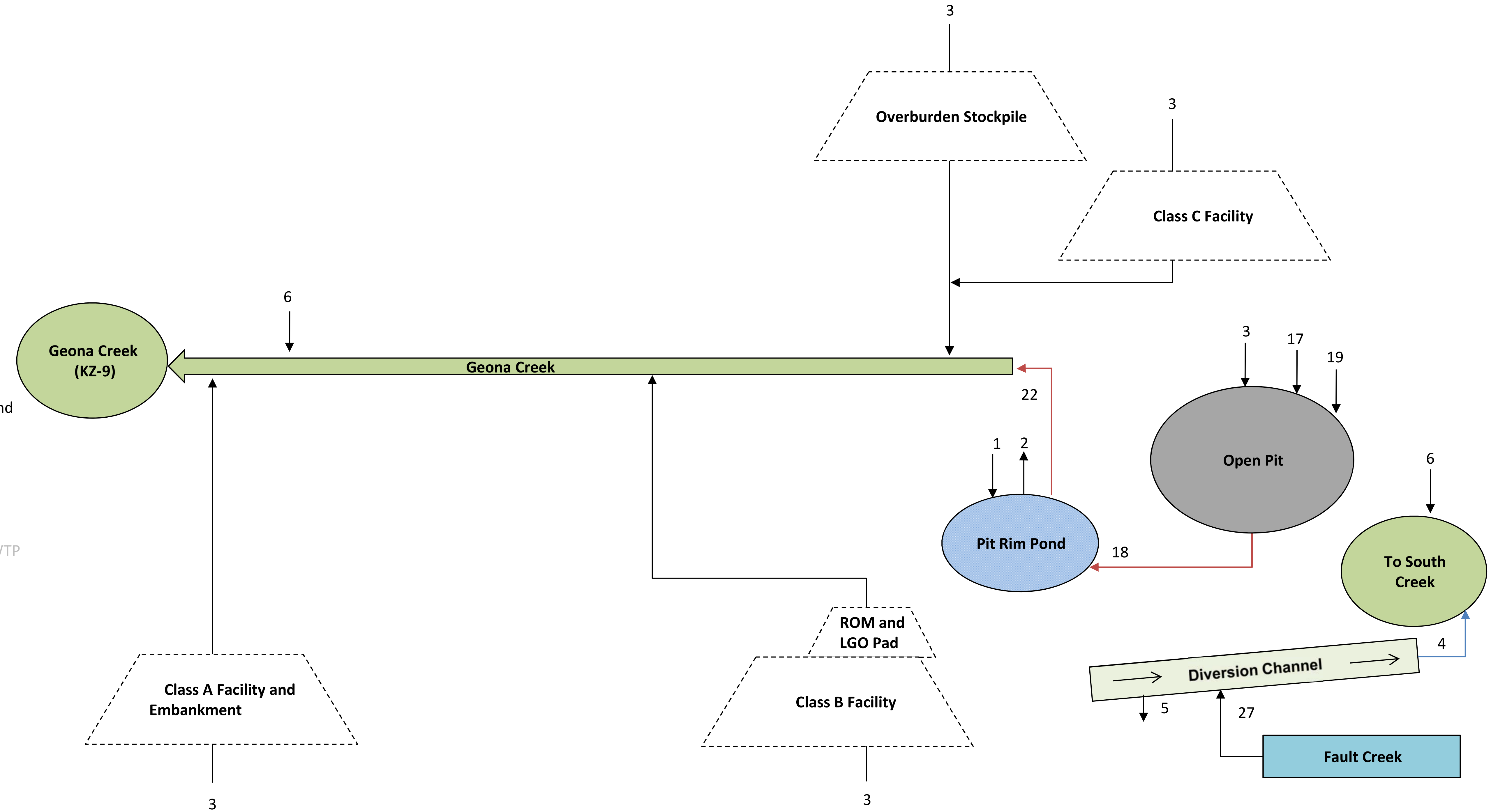
APPENDIX D

Water Balance Flow Schematics

(Figures D.1 to D.7)

FLOW PATHS

1 Net Precipitation
2 Evaporation
3 Runoff from Undiverted Area
4 Diverted Runoff
5 Seepage to Geona Creek (KZ-9) Groundwater System
6 Groundwater discharge from upstream catchment
7 Water in Tailings
8 Void Losses
9 Process Water from Mill to WTP
10 Makeup Water from LWMP
11 Mill Reclaim
12 Water in Ore
13 Water in Concentrate
14 Potable Water
15 Dust Suppression
16 Water to Paste Plant
17 Groundwater Inflow to Open Pit and Underground Workings
18 Open Pit Dewatering
19 Surface Runoff from Mine Facility
20 Toe Discharge
21 Seepage Collection System
22 Overflow from Sediment Pond
23 Surplus from Collection Pond to WTP
24 Treated Discharge from WTP
25 Surplus from UWMP or LWMP
26 Discharge from LWMP
27 Discharge from Fault Creek
28 Pit Lake Discharge
29 Discharge from Wetland
30 Diversion Channel Seepage to Groundwater System



NOTES:

1. ROM = RUN OF MINE, LGO = LOW GRADE ORE.
2. = DIVERSION OR COLLECTION DITCH, = PIPELINE, = OTHER FLOW PATHS.

0	11SEP'18	ISSUED WITH REPORT	AA	CAS
REV	DATE	DESCRIPTION	PREP'D	RVW'D

BMC MINERALS (NO.1) LTD.
KUDZ ZE KAYAH PROJECT

WATER BALANCE FLOW SCHEMATIC
CONSTRUCTION - YEAR -2

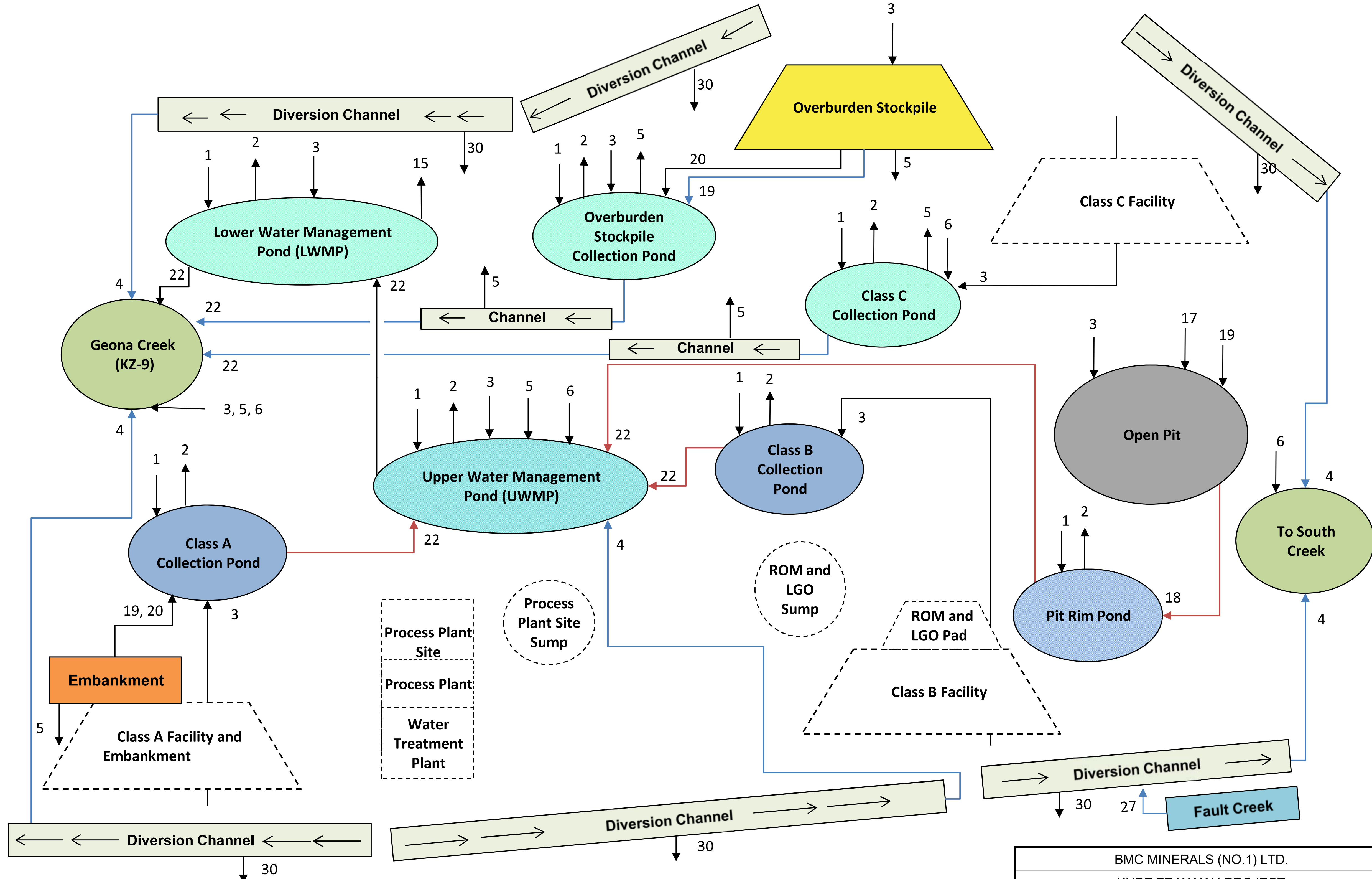
Knight Piésold CONSULTING

P/A NO. VA101-640/6 | REF. NO. 3

FIGURE D.1 | REV 0

FLOW PATHS

1 Net Precipitation
2 Evaporation
3 Runoff from Undiverted Area
4 Diverted Runoff
5 Seepage to Geona Creek (KZ-9) Groundwater System
6 Groundwater discharge from upstream catchment
7 Water in Tailings
8 Void Losses
9 Process Water from Mill to WTP
10 Makeup Water from LWMP
11 Mill Reclaim
12 Water in Ore
13 Water in Concentrate
14 Potable Water
15 Dust Suppression
16 Water to Paste Plant
17 Groundwater Inflow to Open Pit and Underground Workings
18 Open Pit Dewatering
19 Surface Runoff from Mine Facility
20 Toe Discharge
21 Seepage Collection System
22 Overflow from Sediment Pond
23 Surplus from Collection Pond to WTP
24 Treated Discharge from WTP
25 Surplus from UWMP or LWMP
26 Discharge from LWMP
27 Discharge from Fault Creek
28 Pit Lake Discharge
29 Discharge from Wetland
30 Diversion Channel Seepage to Groundwater System



NOTES:

1. ROM = RUN OF MINE, LGO = LOW GRADE ORE.
2. → = DIVERSION OR COLLECTION DITCH, → = PIPELINE, → = OTHER FLOW PATHS.

REV	DATE	DESCRIPTION	PREP'D	RVW'D
0	11SEP'18	ISSUED WITH REPORT	AA	CAS

BMC MINERALS (NO.1) LTD.

KUDZ ZE KAYAH PROJECT

WATER BALANCE FLOW SCHEMATIC
CONSTRUCTION - YEAR -1

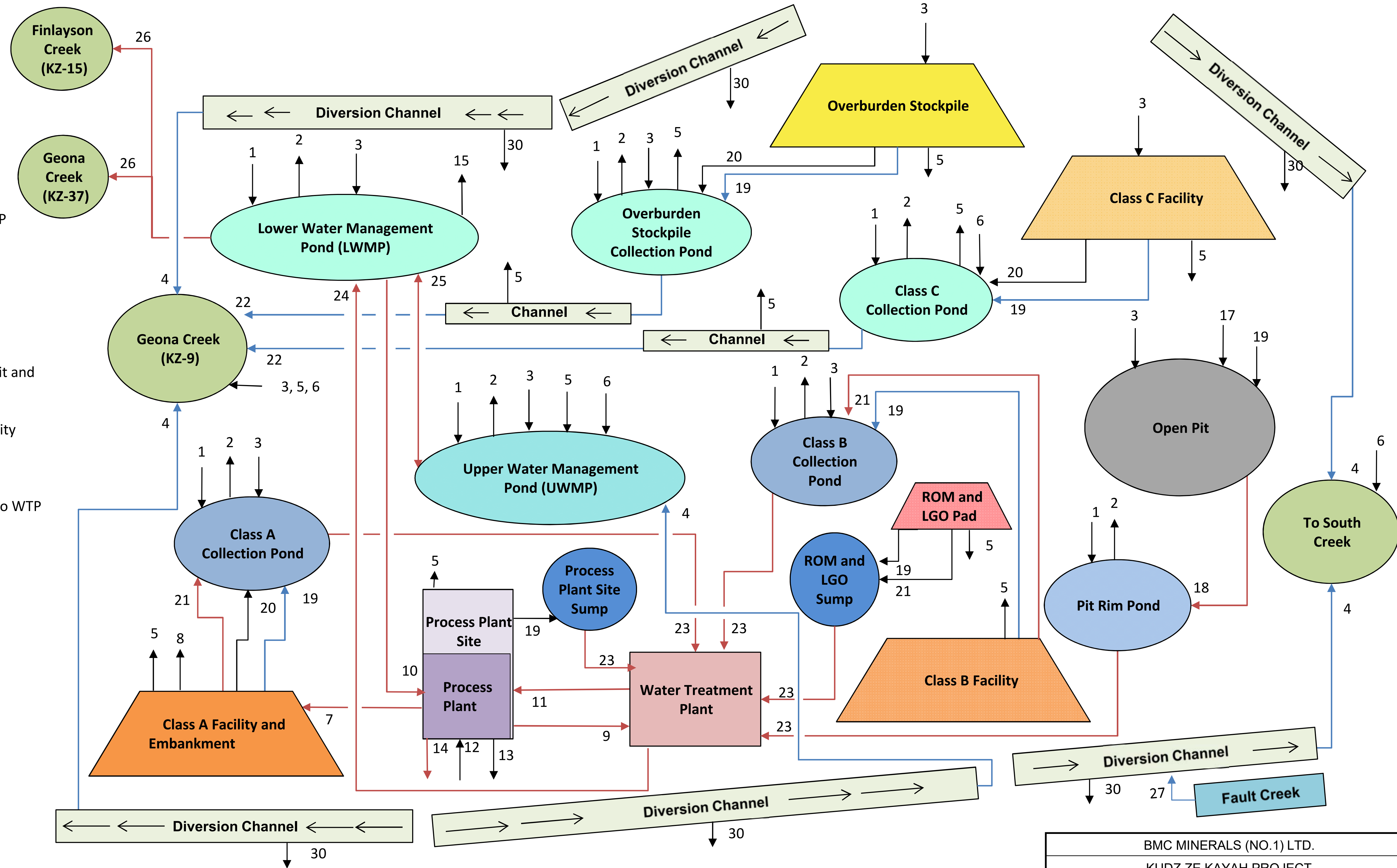
Knight Piésold CONSULTING

P/A NO. VA101-640/6 | REF. NO. 3

FIGURE D.2 | REV 0

FLOW PATHS

1 Net Precipitation
2 Evaporation
3 Runoff from Undiverted Area
4 Diverted Runoff
5 Seepage to Geona Creek (KZ-9) Groundwater System
6 Groundwater discharge from upstream catchment
7 Water in Tailings
8 Void Losses
9 Process Water from Mill to WTP
10 Makeup Water from LWMP
11 Mill Reclaim
12 Water in Ore
13 Water in Concentrate
14 Potable Water
15 Dust Suppression
16 Water to Paste Plant
17 Groundwater Inflow to Open Pit and Underground Workings
18 Open Pit Dewatering
19 Surface Runoff from Mine Facility
20 Toe Discharge
21 Seepage Collection System
22 Overflow from Sediment Pond
23 Surplus from Collection Pond to WTP
24 Treated Discharge from WTP
25 Surplus from UWMP or LWMP
26 Discharge from LWMP
27 Discharge from Fault Creek
28 Pit Lake Discharge
29 Discharge from Wetland
30 Diversion Channel Seepage to Groundwater System



NOTES:

1. ROM = RUN OF MINE, LGO = LOW GRADE ORE.
2. → = DIVERSION OR COLLECTION DITCH, → = PIPELINE, → = OTHER FLOW PATHS.

BMC MINERALS (NO.1) LTD.
KUDZ ZE KAYAH PROJECT

WATER BALANCE FLOW SCHEMATIC
OPERATIONS - YEAR 1 TO 2

Knight Piésold CONSULTING

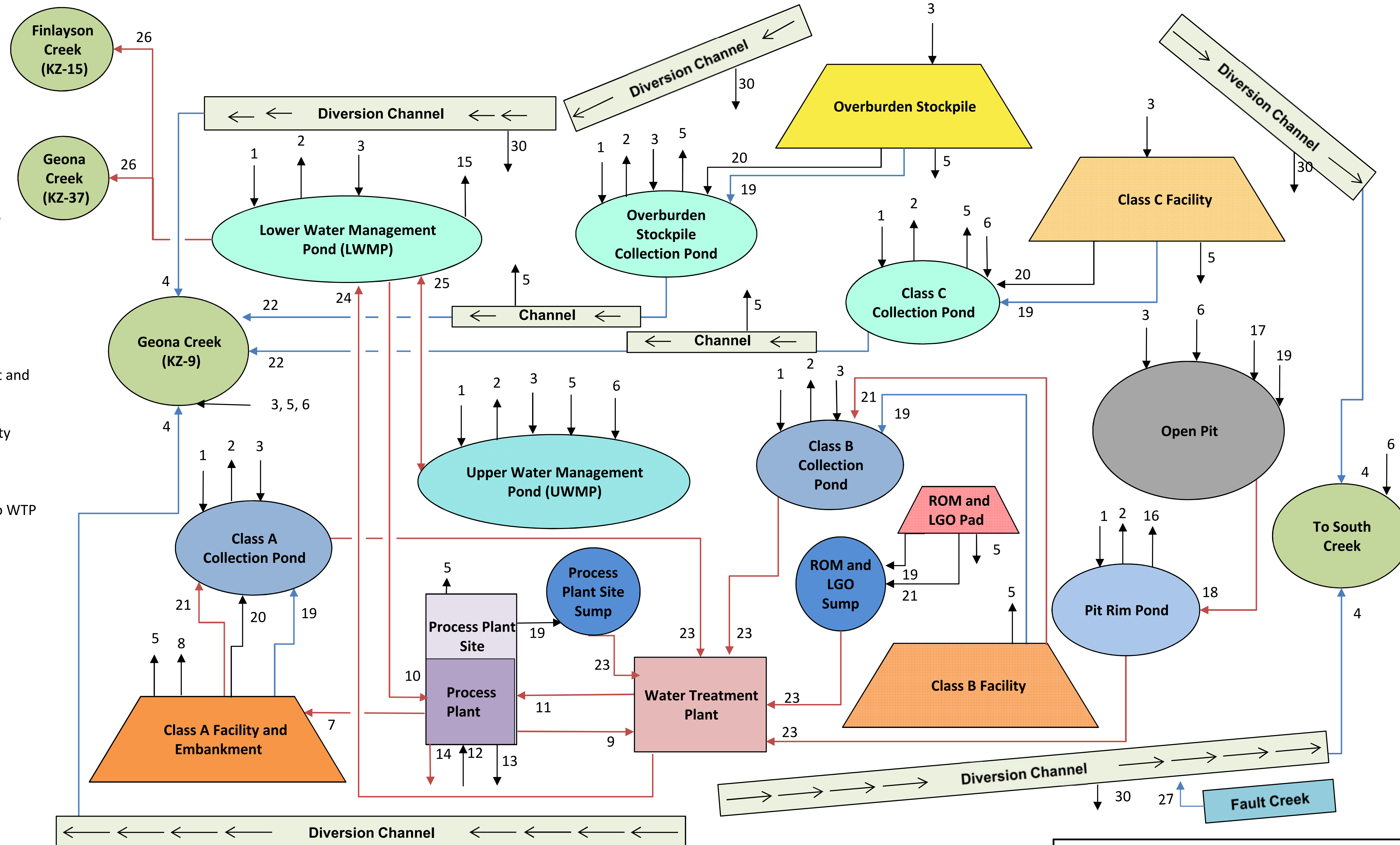
P/A NO. VA101-640/6 | REF. NO. 3

FIGURE D.3 REV 0

REV	DATE	DESCRIPTION	PREP'D	RVW'D
0	11SEP'18	ISSUED WITH REPORT	AA	CAS

FLOW PATHS

1 Net Precipitation
2 Evaporation
3 Runoff from Undiverted Area
4 Diverted Runoff
5 Seepage to Geona Creek (KZ-9) Groundwater System
6 Groundwater discharge from upstream catchment
7 Water in Tailings
8 Void Losses
9 Process Water from Mill to WTP
10 Makeup Water from LWMP
11 Mill Reclaim
12 Water in Ore
13 Water in Concentrate
14 Potable Water
15 Dust Suppression
16 Water to Paste Plant
17 Groundwater Inflow to Open Pit and Underground Workings
18 Open Pit Dewatering
19 Surface Runoff from Mine Facility
20 Toe Discharge
21 Seepage Collection System
22 Overflow from Sediment Pond
23 Surplus from Collection Pond to WTP
24 Treated Discharge from WTP
25 Surplus from UWMP or LWMP
26 Discharge from LWMP
27 Discharge from Fault Creek
28 Pit Lake Discharge
29 Discharge from Wetland
30 Diversion Channel Seepage to Groundwater System



NOTES:

1. ROM = RUN OF MINE, LGO = LOW GRADE ORE.
2. → = DIVERSION OR COLLECTION DITCH, → = PIPELINE, → = OTHER FLOW PATHS.

REV	DATE	DESCRIPTION	PREP'D	RVW'D
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KUDZ ZE KAYAH PROJECT

WATER BALANCE FLOW SCHEMATIC
OPERATIONS - YEAR 3 TO 10

Knight Piésold CONSULTING

P/A NO. VA101-640/6

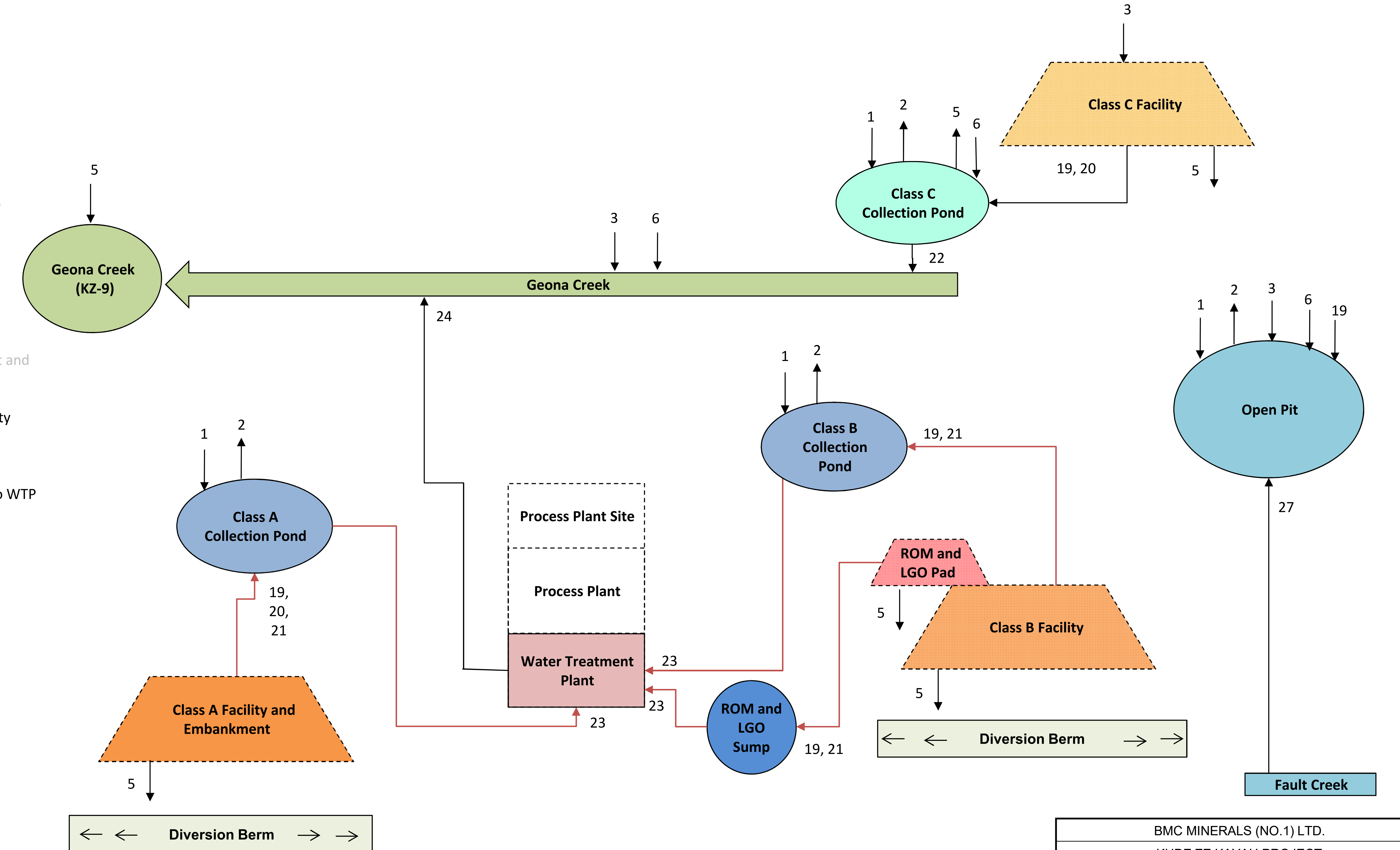
REF. NO. 3

FIGURE D.4

REV 0

FLOW PATHS

1 Net Precipitation
2 Evaporation
3 Runoff from Undiverted Area
4 Diverted Runoff
5 Seepage to Geona Creek (KZ-9) Groundwater System
6 Groundwater discharge from upstream catchment
7 Water in Tailings
8 Void Losses
9 Process Water from Mill to WTP
10 Makeup Water from LWMP
11 Mill Reclaim
12 Water in Ore
13 Water in Concentrate
14 Potable Water
15 Dust Suppression
16 Water to Paste Plant
17 Groundwater Inflow to Open Pit and Underground Workings
18 Open Pit Dewatering
19 Surface Runoff from Mine Facility
20 Toe Discharge
21 Seepage Collection System
22 Overflow from Sediment Pond
23 Surplus from Collection Pond to WTP
24 Treated Discharge from WTP
25 Surplus from UWMP or LWMP
26 Discharge from LWMP
27 Discharge from Fault Creek
28 Pit Lake Discharge
29 Discharge from Wetland
30 Diversion Channel Seepage to Groundwater System



NOTES:

1. ROM = RUN OF MINE, LGO = LOW GRADE ORE.
2. = DIVERSION OR COLLECTION DITCH, = PIPELINE, = OTHER FLOW PATHS.

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KUDZ ZE KAYAH PROJECT

WATER BALANCE FLOW SCHEMATIC
ACTIVE CLOSURE

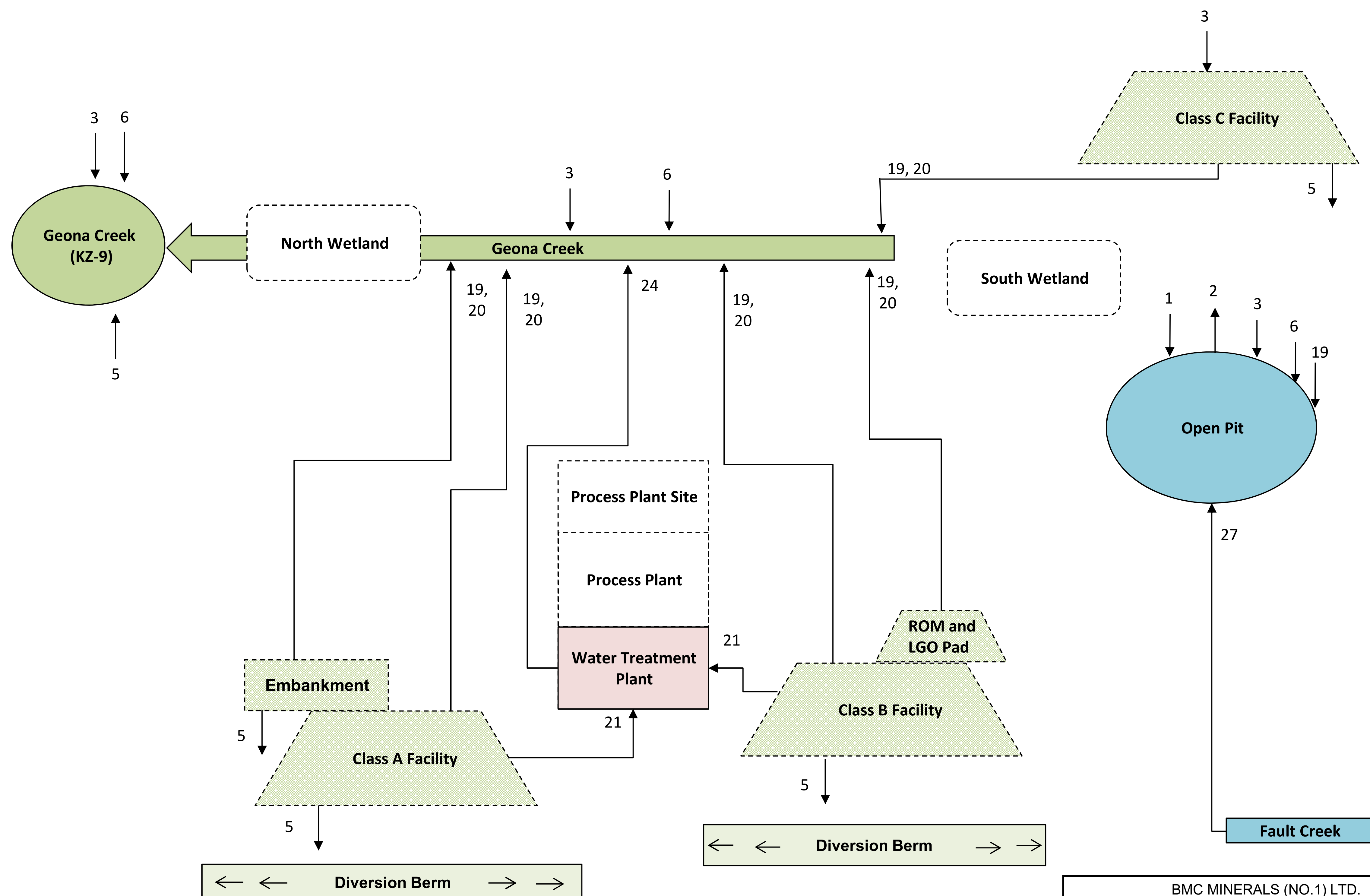
Knight Piésold CONSULTING

P/A NO. VA101-640/6 REF. NO. 3

FIGURE D.5 REV 0

FLOW PATHS

1 Net Precipitation
2 Evaporation
3 Runoff from Undiverted Area
4 Diverted Runoff
5 Seepage to Geona Creek (KZ-9) Groundwater System
6 Groundwater discharge from upstream catchment
7 Water in Tailings
8 Void Losses
9 Process Water from Mill to WTP
10 Makeup Water from LWMP
11 Mill Reclaim
12 Water in Ore
13 Water in Concentrate
14 Potable Water
15 Dust Suppression
16 Water to Paste Plant
17 Groundwater Inflow to Open Pit and Underground Workings
18 Open Pit Dewatering
19 Surface Runoff from Mine Facility
20 Toe Discharge
21 Seepage Collection System
22 Overflow from Sediment Pond
23 Surplus from Collection Pond to WTP
24 Treated Discharge from WTP
25 Surplus from UWMP or LWMP
26 Discharge from LWMP
27 Discharge from Fault Creek
28 Pit Lake Discharge
29 Discharge from Wetland
30 Diversion Channel Seepage to Groundwater System



NOTES:

1. ROM = RUN OF MINE, LGO = LOW GRADE ORE.
2. = DIVERSION OR COLLECTION DITCH, = PIPELINE, = OTHER FLOW PATHS.
3. WATER TREATMENT AS REQUIRED

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BMC MINERALS (NO.1) LTD.

KUDZ ZE KAYAH PROJECT

WATER BALANCE FLOW SCHEMATIC TRANSITIONAL CLOSURE

Knight Piésold CONSULTING

P/A NO. VA101-640/6

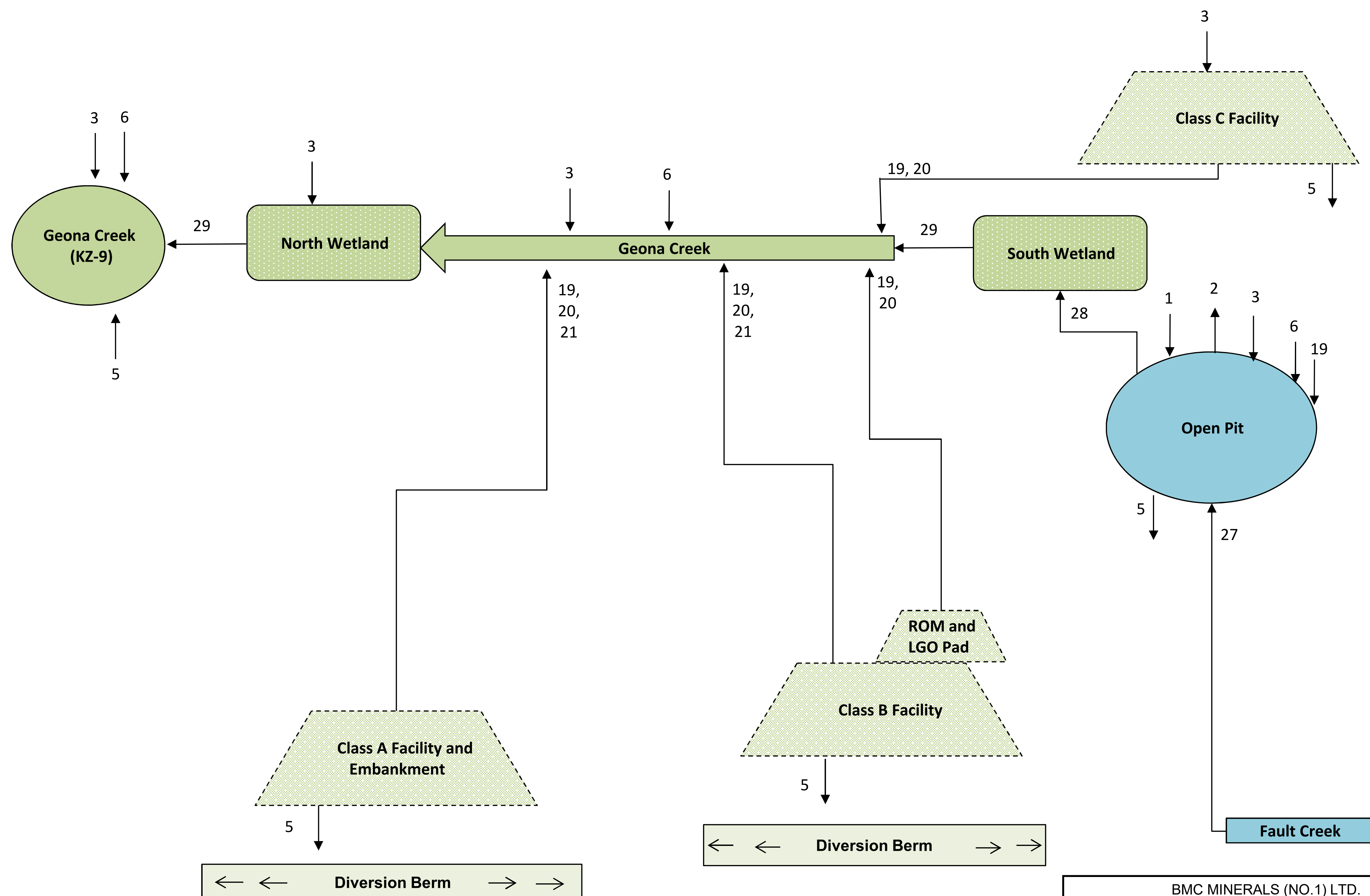
REF. NO. 3

FIGURE D.6

REV 0

FLOW PATHS

1 Net Precipitation
2 Evaporation
3 Runoff from Undiverted Area
4 Diverted Runoff
5 Seepage to Geona Creek (KZ-9) Groundwater System
6 Groundwater discharge from upstream catchment
7 Water in Tailings
8 Void Losses
9 Process Water from Mill to WTP
10 Makeup Water from LWMP
11 Mill Reclaim
12 Water in Ore
13 Water in Concentrate
14 Potable Water
15 Dust Suppression
16 Water to Paste Plant
17 Groundwater Inflow to Open Pit and Underground Workings
18 Open Pit Dewatering
19 Surface Runoff from Mine Facility
20 Toe Discharge
21 Seepage Collection System
22 Overflow from Sediment Pond
23 Surplus from Collection Pond to WTP
24 Treated Discharge from WTP
25 Surplus from UWMP or LWMP
26 Discharge from LWMP
27 Discharge from Fault Creek
28 Pit Lake Discharge
29 Discharge from Wetland
30 Diversion Channel Seepage to Groundwater System



NOTES:

1. ROM = RUN OF MINE, LGO = LOW GRADE ORE.
2. = DIVERSION OR COLLECTION DITCH, = PIPELINE, = OTHER FLOW PATHS.

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BMC MINERALS (NO.1) LTD.
KUDZ ZE KAYAH PROJECT

WATER BALANCE FLOW SCHEMATIC POST-CLOSURE

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P/A NO. VA101-640/6 | REF. NO. 3

FIGURE D.7 REV 0

APPENDIX E

Liner Leakage Estimate

(Pages E-1 to E-6)

October 9, 2018

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[Name Redacted]
Mining Engineer
BMC Minerals (No. 1) Ltd.
750 - 789 West Pender Street
Vancouver, British Columbia
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Dear [Name R,

RE: Estimate of Liner Leakage from the Class A and Class B Storage Facilities

1.0 INTRODUCTION

BMC Minerals (No.1) Ltd. (BMC) is currently proposing to develop the Kudz Ze Kayah Project (the Project), a proposed open pit and underground copper-zinc-lead-gold mine in Yukon Territory. Knight Piésold Ltd. (KP) is providing overall geotechnical support work for permitting and engineering design, including design of the tailings and waste rock storage facilities. This letter presents the results of a liner leakage assessment for the Class A and Class B Storage Facilities during Operations and Closure.

2.0 BACKGROUND

The Class A and Class B Storage Facilities will manage potentially acid generating (PAG) mine waste. The Class A Storage Facility will manage strongly potentially acid generating (PAG) filtered tailings and strongly PAG waste rock, and the Class B Storage Facility will manage weakly PAG waste rock.

Both facilities will have a basin liner and a closure cover that consists of a composite liner comprised of a geomembrane liner underlain by a low permeability soil. The basin liner and a closure cover will be comprised of the following materials, listed from bottom to top:

- Basin liner:
  - Compacted soil liner (glacial till) one metre thick overlying the foundation material (overburden or weathered bedrock)
  - High density polyethylene (HDPE) geomembrane, and
  - 0.5 m drainage material to provide a protective layer on top of the geomembrane.
- Closure Cover liner:
  - Compacted soil liner (glacial till) one metre thick overlying the Class A and B material
  - HDPE geomembrane
  - 0.5 m drainage material to provide a protective layer on top of the geomembrane, and
  - Minimum 3 m thickness of Class C rock cover for stability, erosion protection and frost protection.

The construction of the basin liner will be staged prior to placement of the mine tailings and waste rock. A foundation drainage system will be installed to convey groundwater downstream of the facility. The facility basin will be progressively covered with the soil liner (glacial till) prior to installation of the HDPE geomembrane. The placement of the drainage material on top of the liner will be completed when there are minimal wrinkles in the liner. Placement of the soil liner and geomembrane liner will following a Quality Assurance and Quality Control (QA/QC) program established prior to construction.

Site diversions and seepage collection systems will be operated so that tailings material placed into the Class A Storage Facility will be placed with an expected moisture content of approximately 12%.

The Class A Storage Facility will have a maximum footprint of approximately 728,000 m^2 (180 acres) at full build out and the Class B Storage Facility will have a maximum footprint of approximately 654,000 m^2 (162 acres).

3.0 METHOD

Two empirical methods were used to estimate leakage through a composite liner. Both methods assume a circular defect develops in the geomembrane liner. The methods assume different contact conditions between the geomembrane liner and the underlying low-permeability soil as follows:

1. Giroud and Bonaparte, 1989b – Leakage estimate through a defect assuming excellent contact between the geomembrane and low permeability soil.
2. Giroud, 1997 – Leakage estimate through a defect assuming good contact between the geomembrane and low permeability soil.

Method 1 (Giroud and Bonaparte, 1989b): Giroud and Bonaparte (1989b) present a set of industry-recognized equations for estimating leakage through a composite liner assuming excellent contact between a geomembrane liner and the underlying compacted low permeability soil. The solutions are based on leakage experiments that were performed for geomembranes in contact with conventional compacted soil at low confining stress and were established through curve fitting. The equations provide an approximate solution assuming the hydraulic gradient is near unity. Equations are provided for different contact conditions between the geomembrane liner and underlying low permeability soil. The equation describing excellent contact or "best" field conditions (Equation 51 in the paper), is adopted for this analysis. Giroud and Bonaparte (1989b) define best field conditions as "i) the soil is well compacted, flat and smooth, has not been deformed by rutting due to construction equipment, and has no clods nor cracks; ii) the geomembrane is flexible and has no wrinkles; and iii) the geomembrane and soil are in close contact".

The rate of leakage through a circular defect in a geomembrane liner assuming excellent contact (or "best" field conditions) is calculated using the following equation:

$$Q = 0.7a^{0.1}k_s^{0.88}h_w \quad [1]$$

Where:

- Q = leakage rate due to flow through a defect in the geomembrane liner
- a = area of hole in geomembrane (3.1 mm^2 for 2 mm diameter hole)
- h_w = liquid height on geomembrane (0.5 m), and
- k_s = hydraulic conductivity of the low permeability soil underlying the geomembrane (1x10^{-8} m/s)

This equation for best field conditions is suitable for a height of water on the geomembrane liner that is less than 3 m.

This analysis considered one defect (2 mm diameter) per acre (4,046 m^2) of geomembrane as suggested by Giroud and Bonaparte (1989a). The hydraulic conductivity of the low permeability soil liner is 1x10^{-8} m/s, consistent with the design specification for the engineered fill. The height of water on top of the liner is assumed to be 0.5 m for the calculation and is the same height as the drainage layer thickness overlying the geomembrane liner. A 0.5 m height of water is expected to be an upper bound of the hydraulic head that would develop on top of the geomembrane since the drainage layer will facilitate drainage and is not expected to be fully saturated, as the layer will be constructed at an approximately 4H:1V slope and will drain by gravity to the sump.

A defect hole size of 2 mm diameter (3.1 mm^2 defect area) is recommended by Giroud and Bonaparte (1989a) for calculations assessing the performance of the liner system such as serviceability and leakage. This size of defect is considered probable and Giroud and Bonaparte recommend its use for assessing conditions related to typical operating conditions. This hole size and frequency are selected based on the assumption that an intensive quality assurance monitoring program will be performed. A frequency of holes greater than one/acre is possible if quality assurance is limited.

Method 2 (Giroud, 1997): Giroud (1997) presents equations to determine the rate of leakage through defects in a composite liner assuming good contact conditions exist between the geomembrane and the low permeability soil. This approach is a refinement to the Giroud and Bonaparte (1989b) approach, which was based on curve reading to determine leakage rates for good contact conditions. Good contact is defined as conditions where the geomembrane has been installed with as few wrinkles as possible, on top of a low-permeability soil layer that has been adequately compacted and has a smooth surface (Giroud, 1997). Good contact conditions imply a slightly larger space exits between the geomembrane liner and the underlying low permeability soil than exists for excellent contact conditions. This space permits water to flow laterally between the geomembrane and soil once it flows through the defect.

Leakage through a circular defect in a geomembrane liner assuming good contact conditions is calculated using the following equation:

$$Q = C_{qo}[1 + 0.1\left(\frac{h_w}{t_s}\right)^{0.95}]a^{0.1}{h_w}^{0.9}k_s^{0.74} \quad [2]$$

Where:

C_{qo}= dimensionless coefficient describing the contact quality between the geomembrane liner and low permeability soil for a circular hole (assumes C_{qo} = 0.21 for good contact conditions and 1.15 for poor conditions), and

t_s = thickness of low permeability soil liner layer (1 m).

The other terms (a, hw, ks) and values assigned to them are as previously defined for Equation 1. The equation is suitable for a height of water on the geomembrane liner that is less than 3 m and a defect diameter between 0.5 mm and 25 mm.

Good contact conditions are considered appropriate for the leakage calculation since strict QA/QC requirements will be in place for construction and installation of the composite liner.

4.0 RESULTS AND DISCUSSION

The estimated rate of leakage through a composite liner in Operations is provided in Table 1. The leakage rate assumes the hydraulic head on the geomembrane liner is 0.5 m. Calculations for a defect in a geomembrane with excellent to good contact with the underlying low permeability soil liner estimate a unit leakage rate of up to 1×10^{-8} L/s/m^2. This corresponds to a leakage rate of 0.007 L/s from the Class A and Class B Storage Facilities (Method 2).

The leakage estimates in Table 1 assume the following conditions:

- The low permeability soil liner is 1 m thick and the hydraulic conductivity soil liner is $1x10^{-8}$ m/s, consistent with the design specification for the engineered fill.
- The height of water on top of the liner is 0.5 m, and is the same height as the thickness of the drainage layer over top of the geomembrane liner.
- The defect is circular with a diameter of 2 mm.
- One defect exists per acre of composite liner (2.5 defects per hectare).

The estimated leakage rate is considered applicable for both operations and closure conditions. This is a conservative assumption from the perspective of potential leakage to the downstream environment for closure, since the empirical leakage calculation was for only one composite liner. The facility at closure will be comprised of two composite liners; the cover liner will limit the water entering into the facility and is expected to limit the height of water available to pond on the basin liner to less than 0.5 m. These factors will limit the leakage leaving the bottom of the closed facility.

For comparative purposes, seepage from the Class A Storage Facility was also estimated assuming no geomembrane liners are installed, and the basin liner and cover each consist only of a compacted till layer. In this case, all of the recharge applied to the top of the facility could be assumed to infiltrate into the facility and flow out the bottom basin liner. The recharge to groundwater under existing conditions is estimated to be approximately 80 mm/year using the watershed model developed for the Project (KP, 2018b). The total seepage into and out of the facility estimated using the 80 mm recharge rate multiplied by the area of the facility is approximately 2 L/s. The seepage rate estimated using this approach is not considered a reasonable estimate of leakage for the composite liner system, but is provided for comparative purposes and indicates that the composite liner is expected to decrease leakage from the facility by a factor of 100 to 1,000 times.

Implementing a strict QA/QC program during liner installation is essential for establishing good contact conditions between the geomembrane and underlying low permeability soil and minimizing damage to the liner during installation, thereby minimizing the potential liner leakage. The QA/QC program will include requirements for placement of the compacted till layer and the condition of the till surface prior to placement of the geomembrane (e.g., smooth and free from clods) in order to attain good contact conditions between the geomembrane and soil. It is desirable to minimize wrinkles in the geomembrane liner to minimize the potential for leakage. Wrinkles may decrease the long-term performance of a geomembrane due to the potential for the development of stress cracking and increased leakage through the geomembrane at the location of the wrinkle (Rowe, 1998; 2012). Construction procedures will be adopted to limit the development of wrinkles at the time the geomembrane is covered. Care should be taken to cover the geomembrane liner early morning or late afternoon when conditions are less conducive to wrinkling.

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5.0 CLOSURE

We trust that the information contained within this letter meets your requirements at this time for the seepage analyses for the Class A and B Storage Facilities. Please do not hesitate to contact the undersigned if you have any queries or concerns relating to this letter.

Yours truly,
Knight Piésold Ltd.

PROFESSIONAL
YUKON
DR. CYNTHIA STARZYK
OCT 9/18

[Signature Redacted]

Prepared: Senior Engineer

[Signature Redacted]

Reviewed: for Senior Engineer

[Signature Redacted]

Approval that this document adheres to Knight Piésold Quality Systems:

Attachments:

Table 1 Rev 0 Estimate of Leakage Through Composite Liner

References:

Giroud, J.P. and Bonaparte, R., 1989a. Leakage through Liners Constructed with Geomembranes – Part I Geomembrane Liners. Geotextiles and Geomembranes, Vol. 8 pp. 27-67.

Giroud, J.P. and Bonaparte, R., 1989b. Leakage through Liners Constructed with Geomembranes – Part II Composite Liners. Geotextiles and Geomembranes, Vol. 8 pp. 71-111.

Giroud, J.P., 1997, "Equations for Calculating the Rate of Liquid Migration Through Composite Liners Due to Geomembrane Defects", Geosynthetics International. Vol. 4, Nos. 3-4, pp. 335-348.

Knight Piésold Ltd, 2018a. Hydrometeorology Report. KP Ref. No. 4 Rev C, dated May 16, 2018.

Knight Piésold Ltd, 2018b. Watershed Model Report. Letter report prepared for BMC Minerals. KP Ref. No. VA18-00976. In progress.

Rowe, R.K., 1998. Geosynthetics and minimization of contaminant migration through barrier systems beneath soild waste. In Proceedings of the 6th International Conference on Geosynthetics, Altlanta Ga., 25-29 March 1998. Edited by R.K. Rowe. Vol. 1 pp. 27-103.

Rowe, R.K., 2012. Short- and long-term leakage through composite liners. The 7th Arthur Casagrande lecture, Canadian Geotechnical Journal, Vol. 49 pp. 141-169.

/cas

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TABLE 1

BMC MINERALS (NO. 1) LTD
KUDZ ZE KAYAH PROJECT

CLASS A AND B STORAGE FACILITY SEEPAGE ANALYSIS
ESTIMATE OF LEAKAGE THROUGH COMPOSITE LINER

Print 09-Oct-18 11:56:43

Assumptions:

Hydraulic Conductivity of Subgrade:	1E-08	m/sec
Thickness of subgrade:	1.0	m
Height of water on liner:	0.5	m

Class A Storage Facility

Total Area of Class A Facility: 728,000 square metres (72.8 hectares)

Method		Defect in Composite Liner			Compacted Till Liner Only (No Geomembrane)
		Leakage Flow Per Defect	Leakage Flow Per Square Meter	Total Leakage through Liner	
		(m^3/s)	($L/s/m^2$)	(L/s)	(L/s)
1	Excellent Contact	9E-09	2E-09	0.002	-
2	Good Contact	4E-08	1E-08	0.007	-
3	Areal Recharge	-	-	-	2

Class B Storage Facility

Total Area of Class B Facility: 654,000 square metres (65.4 hectares)

Method		Defect in Composite Liner			Compacted Till Liner Only (No Geomembrane)
		Leakage Flow Per Defect	Leakage Flow Per Square Meter	Total Leakage through Liner	
		(m^3/s)	($L/s/m^2$)	(L/s)	(L/s)
1	Excellent Contact	9E-09	2E-09	0.001	-
2	Good Contact	4E-08	1E-08	0.007	-
3	Areal Recharge	-	-	-	2

M:\1\01\00640\06\A\Correspondence\VA18-00816 - Class A and Class B Facilities - Seepage Analysis\Attachments\[KZK Liner Leakage Estimate-Class A and B Facilities.xlsx]Table1_r0

NOTES:

1. SEEPAGE RATES REPRESENTATIVE OF OPERATIONS CONDITIONS.
2. METHODS 1 AND 2 ASSUME THE GEOMEMBRANE HAS ONE 2 mm DIAMETER DEFECT PER ACRE OF LINER (2.5 DEFECTS PER HECTARE).
3. METHOD 3 CONSIDERS THE CASE WHERE NO GEOMEMBRANE LINER IS PRESENT AND THE BASIN AND COVER LINERS ARE EACH COMPRISED OF A COMPACTED GLACIAL TILL LAYER ONLY. THIS VALUE IS PROVIDED FOR COMPARITIVE PURPOSES AND IS NOT CONSIDERED REPRESENTATIVE OF LEAKAGE THROUGH THECOMPOSITE LINER.

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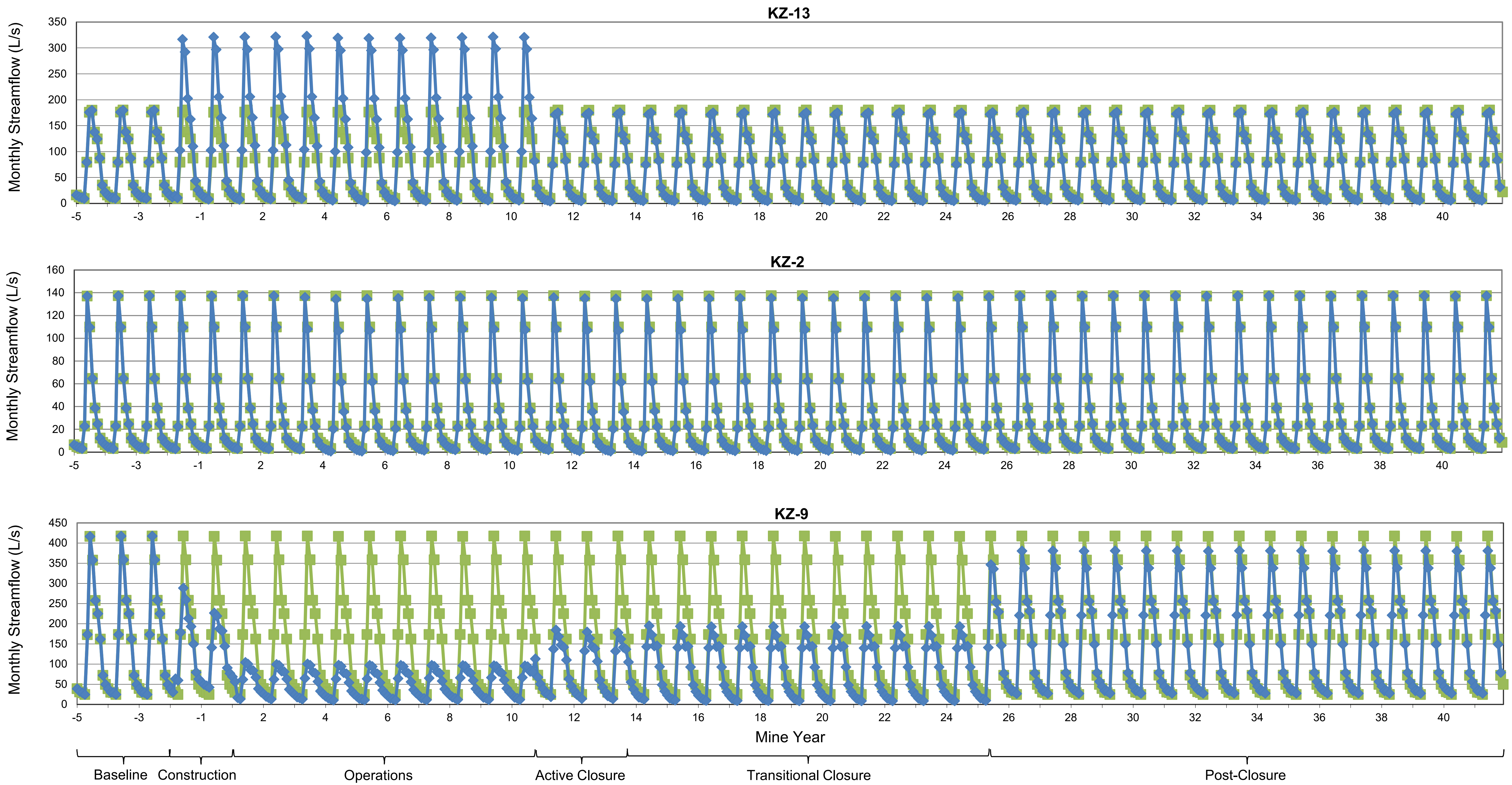
APPENDIX F

Life of Mine Streamflow Plots

(Figures F.1 to F.4)



NOTES: 1. Streamflows represent mean monthly flow results from the LOM Water Balance Model.

BMC MINERALS (NO. 1) LTD.

KUDZ ZE KAYAH PROJECT

LOM WATER BALANCE MODEL
MEAN MONTHLY STREAMFLOWS

Knight Piésold CONSULTING

P/A NO.	REF. NO.
VA101-00640/06	3

FIGURE F.1 REV 0

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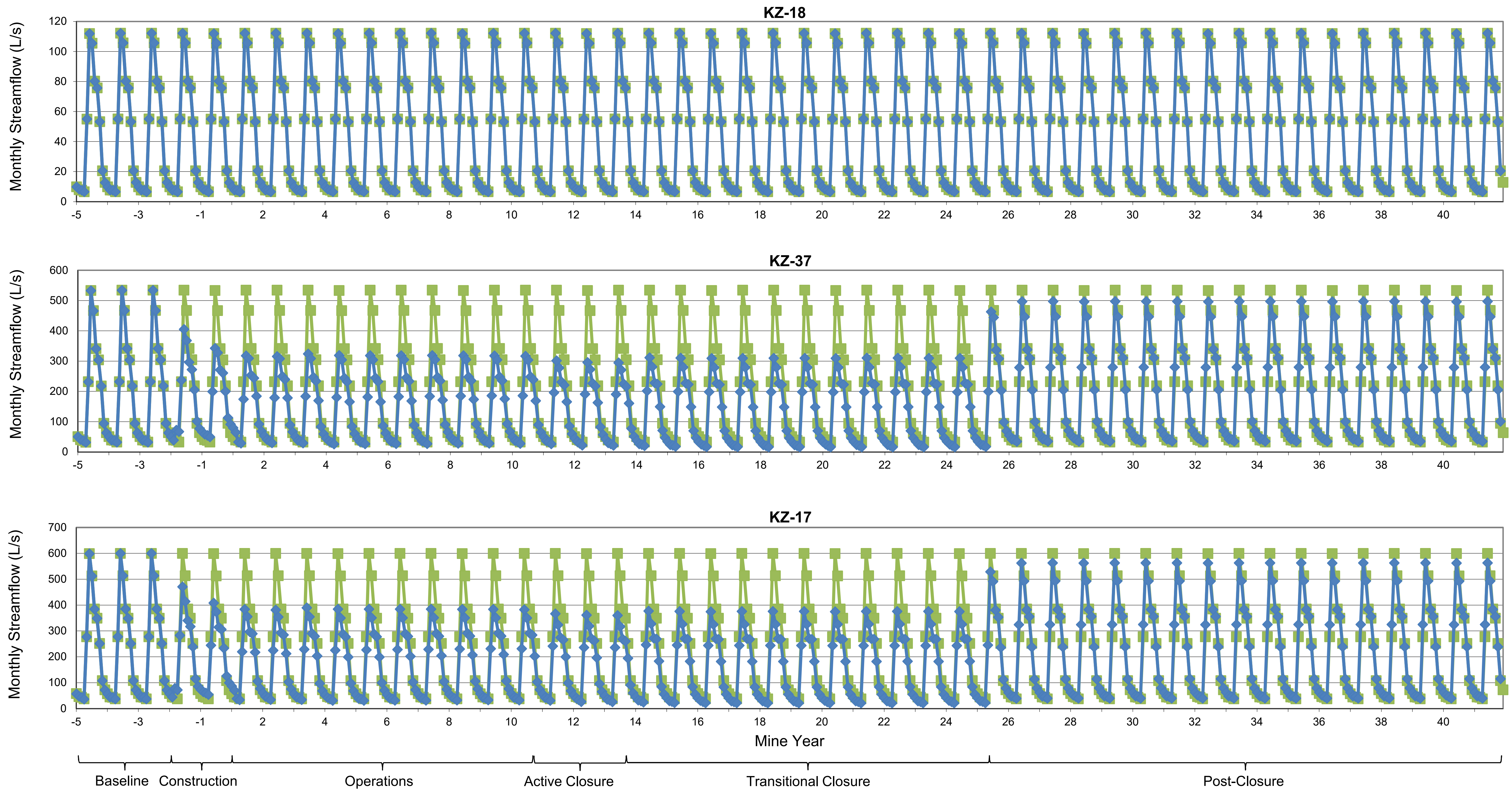


NOTES: 1. Streamflows represent mean monthly flow results from the LOM Water Balance Model.

REV	DATE	DESCRIPTION	PREP'D	RVW'D
0	20AUG'18	ISSUED WITH REPORT	CDI	CAS

BMC MINERALS (NO. 1) LTD.

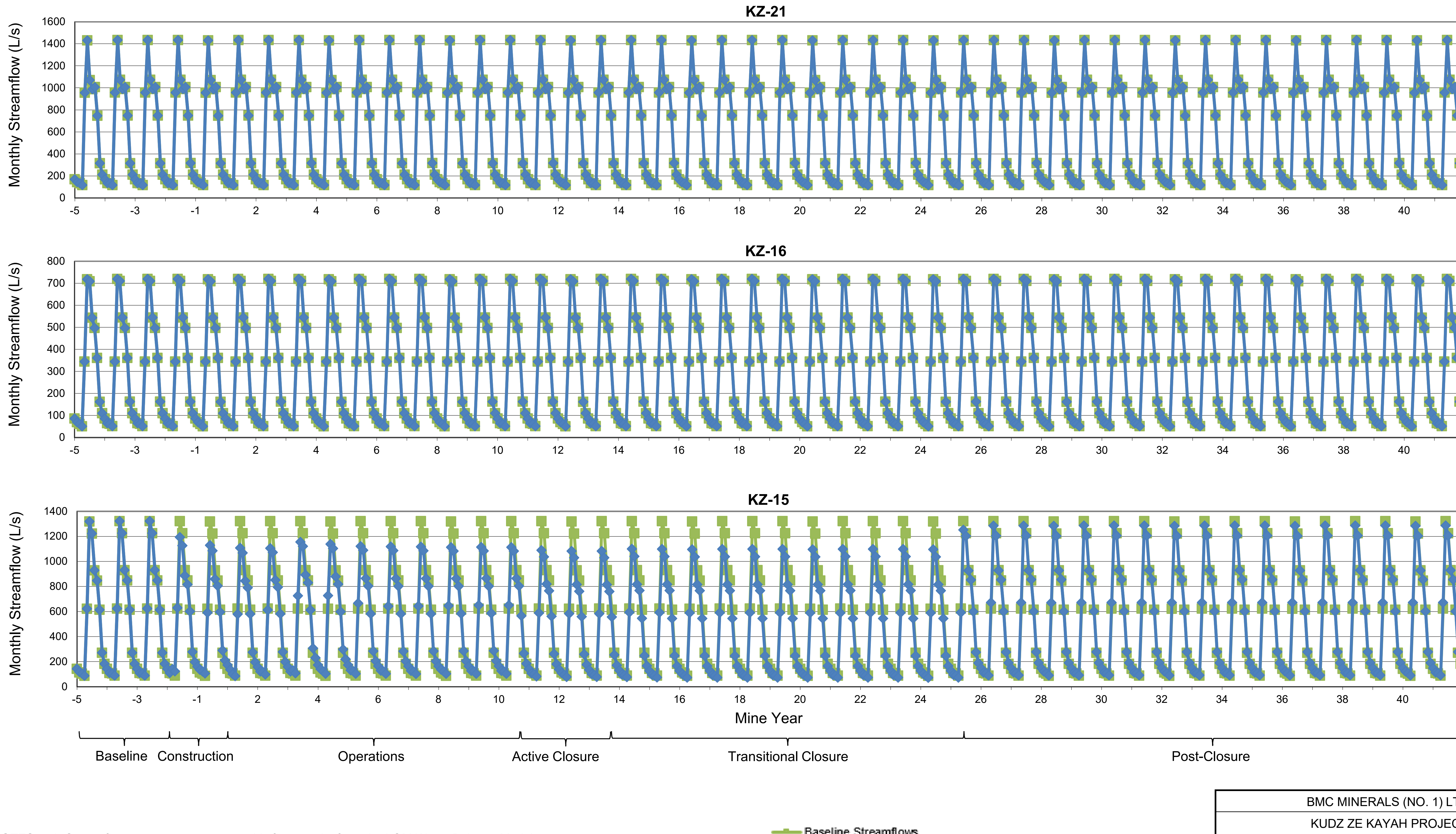
KUDZ ZE KAYAH PROJECT

LOM WATER BALANCE MODEL MEAN MONTHLY STREAMFLOWS

Knight Piésold CONSULTING

P/A NO. VA101-00640/06 | REF. NO. 3

FIGURE F.2 REV 0



NOTES: 1. Streamflows represent mean monthly flow results from the LOM Water Balance Model.

REV	DATE	DESCRIPTION	PREP'D	RVW'D
0	20AUG'18	ISSUED WITH REPORT	CDI	CAS

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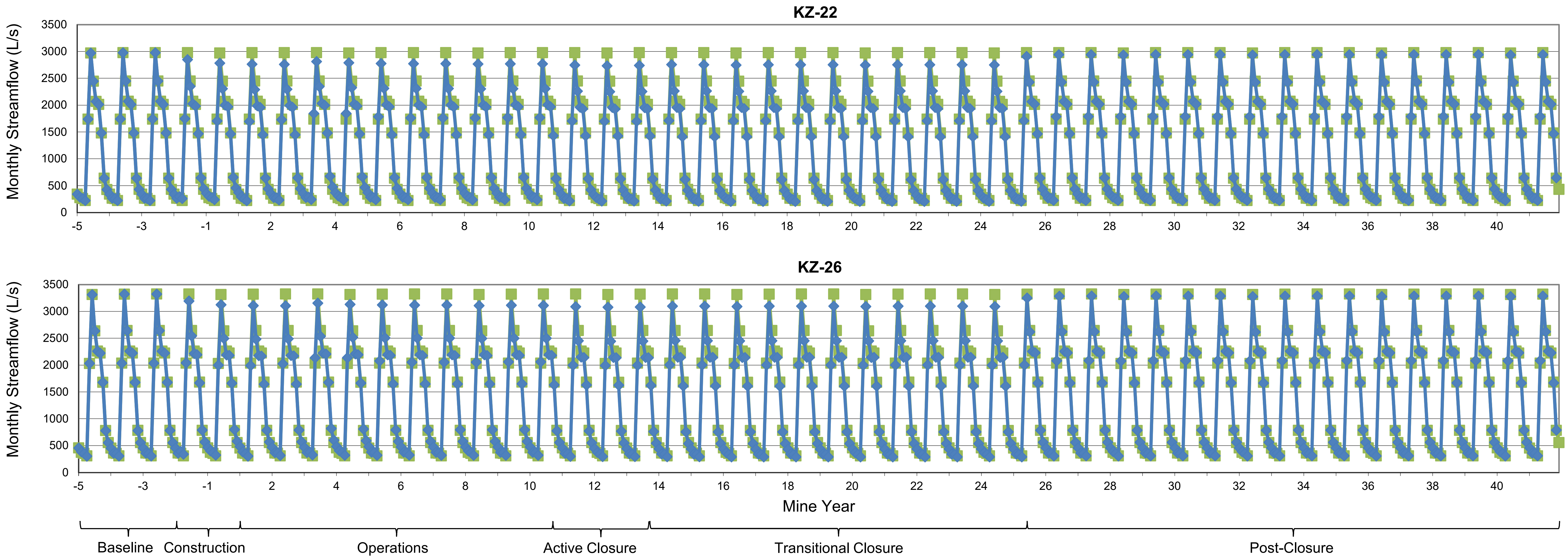
KUDZ ZE KAYAH PROJECT

LOM WATER BALANCE MODEL
MEAN MONTHLY STREAMFLOWS

Knight Piésold CONSULTING

P/A NO. VA101-00640/06 | REF. NO. 3

FIGURE F.3 REV 0



NOTES: 1. Streamflows represent mean monthly flow results from the LOM Water Balance Model.

Baseline Streamflows
Life of Mine Streamflows

REV	DATE	DESCRIPTION	PREP'D	RVW'D
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KUDZ ZE KAYAH PROJECT

LOM WATER BALANCE MODEL
MEAN MONTHLY STREAMFLOWS

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FIGURE F.4 REV 0

APPENDIX G

Mean Monthly Streamflows and Predicted Flow Changes

(Tables G.1 to G.3)

KNIGHT PIÉSOLD CONSULTING

TABLE G.1

BMC MINERALS (NO. 1) LTD
KUDZ ZE KAYAH

LIFE OF MINE WATER BALANCE MODEL
ESTIMATED AVERAGE MONTHLY STREAMFLOWS AND CHANGE IN FLOW DURING LIFE OF MINE

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South Creek – KZ-13

	Month	Baseline	Construction (Yr -1)	Early Operations (Yr 2)	Late Operations (Yr 9)	Active Closure (Yr 12)	Transitional Closure (Yr 23)	Post- Closure (Yr 38)
Streamflow (L/s)	January	16	17	20	16	11	11	11
	February	12	12	14	10	8	8	8
	March	11	11	11	9	6	7	7
	April	9	8	8	6	5	5	5
	May	80	103	103	100	75	75	75
	June	176	321	322	321	171	172	172
	July	180	297	298	298	175	175	175
	August	138	205	207	205	133	133	133
	September	124	165	167	164	120	120	120
	October	87	111	113	110	82	82	82
	November	35	43	45	42	31	31	31
	December	22	25	28	24	17	17	17
	Annual Average	74	110	111	109	70	70	70
Predicted Change in Streamflow from Baseline (L/s)	January	-	1	3	0	-5	-5	-5
	February	-	0	2	-2	-4	-4	-4
	March	-	0	0	-2	-5	-5	-5
	April	-	-1	-1	-3	-5	-5	-5
	May	-	23	23	21	-5	-5	-5
	June	-	145	146	145	-5	-5	-5
	July	-	117	118	118	-5	-5	-5
	August	-	68	69	67	-5	-5	-5
	September	-	41	42	40	-5	-5	-5
	October	-	24	26	23	-5	-5	-5
	November	-	8	10	7	-5	-5	-5
	December	-	3	6	2	-5	-5	-5
	Annual Average	-	36	37	35	-5	-5	-5
Predicted Change in Streamflow from Baseline (%)	January	-	7%	21%	-2%	-29%	-29%	-29%
	February	-	-2%	16%	-13%	-36%	-35%	-35%
	March	-	-2%	-4%	-22%	-42%	-42%	-42%
	April	-	-13%	-10%	-34%	-49%	-49%	-49%
	May	-	29%	29%	26%	-6%	-6%	-6%
	June	-	82%	83%	82%	-3%	-3%	-3%
	July	-	65%	66%	66%	-3%	-3%	-3%
	August	-	49%	50%	49%	-3%	-3%	-3%
	September	-	33%	34%	32%	-4%	-4%	-4%
	October	-	28%	30%	27%	-5%	-5%	-5%
	November	-	23%	29%	19%	-13%	-13%	-13%
	December	-	15%	26%	9%	-22%	-22%	-22%
	Annual Average	-	48%	50%	47%	-6%	-6%	-6%

Geona Creek – KZ-2

	Month	Baseline	Construction (Yr -1)	Early Operations (Yr 2)	Late Operations (Yr 9)	Active Closure (Yr 12)	Transitional Closure (Yr 23)	Post- Closure (Yr 38)
Streamflow (L/s)	January	6	6	6	5	4	6	6
	February	5	5	5	3	2	4	4
	March	4	4	4	3	2	3	3
	April	3	3	3	2	1	2	2
	May	23	23	23	21	21	22	22
	June	137	137	137	136	135	136	136
	July	110	110	110	108	107	109	109
	August	65	65	65	63	62	64	64
	September	39	39	39	37	36	38	38
	October	25	25	25	23	22	24	24
	November	12	12	12	11	9	12	12
	December	8	8	8	7	6	8	8
	Annual Average	36	36	36	35	34	36	36
Predicted Change in Streamflow from Baseline (L/s)	January	-	0	0	-1	-3	0	0
	February	-	0	0	-1	-2	0	0
	March	-	0	0	-1	-2	-1	-1
	April	-	0	0	-1	-2	-1	-1
	May	-	0	0	-1	-2	-1	-1
	June	-	0	0	-2	-2	-1	-1
	July	-	0	0	-2	-3	-1	-1
	August	-	0	0	-2	-3	-1	-1
	September	-	0	0	-2	-3	-1	-1
	October	-	0	0	-1	-3	0	0
	November	-	0	0	-1	-3	0	0
	December	-	0	0	-1	-3	0	0
	Annual Average	-	0	0	-1	-3	-1	-1
Predicted Change in Streamflow from Baseline (%)	January	-	0%	0%	-23%	-42%	-5%	-4%
	February	-	0%	0%	-28%	-49%	-9%	-7%
	March	-	-1%	0%	-29%	-57%	-17%	-15%
	April	-	-1%	0%	-38%	-67%	-26%	-24%
	May	-	0%	0%	-6%	-9%	-5%	-4%
	June	-	0%	0%	-1%	-2%	-1%	-1%
	July	-	0%	0%	-2%	-2%	-1%	-1%
	August	-	0%	0%	-3%	-5%	-1%	-1%
	September	-	0%	0%	-4%	-8%	-1%	-1%
	October	-	0%	0%	-6%	-11%	-2%	-2%
	November	-	0%	0%	-11%	-22%	-3%	-3%
	December	-	0%	0%	-17%	-33%	-4%	-4%
	Annual Average	-	0%	0%	-4%	-7%	-2%	-2%

Geona Creek – KZ-9

	Month	Baseline	Construction (Yr -1)	Early Operations (Yr 2)	Late Operations (Yr 9)	Active Closure (Yr 12)	Transitional Closure (Yr 23)	Post- Closure (Yr 38)
Streamflow (L/s)	January	39	55	24	24	33	22	46
	February	31	44	18	18	22	16	35
	March	29	53	17	16	19	14	34
	April	25	48	13	12	14	10	29
	May	174	153	62	67	133	148	229
	June	418	235	100	97	179	197	384
	July	359	228	97	94	164	177	343
	August	258	195	83	82	143	148	259
	September	225	168	81	79	138	147	234
	October	162	130	63	61	108	90	145
	November	72	77	37	40	61	46	77
	December	50	63	30	31	44	31	57
	Annual Average	154	121	52	52	88	87	156
Predicted Change in Streamflow from Baseline (L/s)	January	-	15	-15	-15	-7	-17	6
	February	-	13	-12	-13	-8	-15	5
	March	-	23	-13	-14	-11	-16	5
	April	-	24	-11	-12	-11	-15	4
	May	-	-21	-111	-107	-41	-26	55
	June	-	-183	-318	-321	-238	-220	-34
	July	-	-131	-262	-264	-195	-182	-15
	August	-	-63	-175	-176	-115	-110	1
	September	-	-57	-144	-147	-87	-78	8
	October	-	-32	-99	-101	-54	-72	-17
	November	-	4	-35	-32	-11	-27	5
	December	-	13	-19	-18	-5	-19	7
	Annual Average	-	-33	-101	-102	-65	-66	2
Predicted Change in Streamflow from Baseline (%)	January	-	39%	-38%	-38%	-17%	-43%	16%
	February	-	43%	-40%	-42%	-26%	-49%	16%
	March	-	79%	-44%	-46%	-36%	-54%	16%
	April	-	95%	-46%	-50%	-42%	-60%	16%
	May	-	-12%	-64%	-61%	-24%	-15%	32%
	June	-	-44%	-76%	-77%	-57%	-53%	-8%
	July	-	-36%	-73%	-74%	-54%	-51%	-4%
	August	-	-24%	-68%	-68%	-45%	-43%	0%
	September	-	-25%	-64%	-65%	-39%	-35%	4%
	October	-	-20%	-61%	-62%	-33%	-45%	-11%
	November	-	6%	-48%	-44%	-15%	-37%	6%
	December	-	27%	-39%	-37%	-11%	-38%	14%
	Annual Average	-	-21%	-66%	-66%	-42%	-43%	2%

Geona Creek – KZ-18

	Month	Baseline	Construction (Yr -1)	Early Operations (Yr 2)	Late Operations (Yr 9)	Active Closure (Yr 12)	Transitional Closure (Yr 23)	Post- Closure (Yr 38)
Streamflow (L/s)	January	10	10	10	10	10	10	10
	February	8	8	8	8	8	8	8
	March	8	8	8	8	8	8	8
	April	7	7	7	7	7	7	7
	May	55	55	55	55	55	55	55
	June	112	112	112	112	112	112	112
	July	106	106	106	106	106	106	106
	August	80	80	80	80	80	80	80
	September	76	76	76	76	76	76	76
	October	53	53	53	53	53	53	53
	November	21	21	21	21	21	21	21
	December	13	13	13	13	13	13	13
	Annual Average	46	46	46	46	46	46	46
Predicted Change in Streamflow from Baseline (L/s)	January	-	0	0	0	0	0	0
	February	-	0	0	0	0	0	0
	March	-	0	0	0	0	0	0
	April	-	0	0	0	0	0	0
	May	-	0	0	0	0	0	0
	June	-	0	0	0	0	0	0
	July	-	0	0	0	0	0	0
	August	-	0	0	0	0	0	0
	September	-	0	0	0	0	0	0
	October	-	0	0	0	0	0	0
	November	-	0	0	0	0	0	0
	December	-	0	0	0	0	0	0
	Annual Average	-	0	0	0	0	0	0
Predicted Change in Streamflow from Baseline (%)	January	-	0%	0%	0%	0%	0%	0%
	February	-	0%	0%	0%	0%	0%	0%
	March	-	0%	0%	0%	0%	0%	0%
	April	-	0%	0%	0%	0%	0%	0%
	May	-	0%	0%	0%	0%	0%	0%
	June	-	0%	0%	0%	0%	0%	0%
	July	-	0%	0%	0%	0%	0%	0%
	August	-	0%	0%	0%	0%	0%	0%
	September	-	0%	0%	0%	0%	0%	0%
	October	-	0%	0%	0%	0%	0%	0%
	November	-	0%	0%	0%	0%	0%	0%
	December	-	0%	0%	0%	0%	0%	0%
	Annual Average	-	0%	0%	0%	0%	0%	0%

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NOTES:

1. VALUES REPRESENT RESULTS OF THE LIFE OF MINE WATER BALANCE MODEL FOR EACH MINE PHASE.

0	25SEPT'18	ISSUED WITH REPORT VA101-640/06-3	AIF	CAS
REV	DATE	DESCRIPTION	PREP'D	RVW'D

Knight Piésold
CONSULTING

TABLE G.2

BMC MINERALS (NO. 1) LTD
KUDZ ZE KAYAH

LIFE OF MINE WATER BALANCE MODEL
ESTIMATED AVERAGE MONTHLY STREAMFLOWS AND CHANGE IN FLOW DURING LIFE OF MINE

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		Geona Creek														East Creek						
		KZ-37							KZ-17							KZ-21						
	Month	Baseline	Construction	Early Operations	Late Operations	Active Closure	Transitional Closure	Post- Closure	Baseline	Construction	Early Operations	Late Operations	Active Closure	Transitional Closure	Post- Closure	Baseline	Construction	Early Operations	Late Operations	Active Closure	Transitional Closure	Post- Closure
Streamflow (L/s)	January	50	65	51	51	43	33	56	57	72	58	58	50	40	63	170	170	170	170	170	170	170
	February	39	52	39	38	31	24	44	44	58	44	43	36	30	49	135	135	135	135	135	135	135
	March	38	61	36	35	27	22	42	43	66	41	40	33	27	48	134	134	134	134	134	134	134
	April	32	56	30	28	22	17	36	37	60	35	33	26	22	41	117	117	117	117	117	117	117
	May	232	211	179	186	191	206	287	277	257	225	231	236	251	333	957	957	957	957	957	957	957
	June	534	351	315	318	296	314	500	600	416	381	384	362	379	566	1434	1434	1434	1434	1434	1434	1434
	July	467	336	308	305	272	285	452	513	382	354	351	319	332	498	1073	1073	1073	1073	1073	1073	1073
	August	341	278	249	248	226	231	342	385	321	293	292	270	274	386	988	988	988	988	988	988	988
	September	304	247	240	236	217	226	312	349	292	285	281	262	271	357	1006	1006	1006	1006	1006	1006	1006
	October	218	186	179	176	164	145	201	251	219	212	209	197	179	234	747	747	747	747	747	747	747
	November	94	99	89	93	83	68	99	108	112	103	107	97	81	112	316	316	316	316	316	316	316
	December	63	77	66	68	58	45	70	72	86	75	77	67	54	79	212	212	212	212	211	212	212
	Annual Average	201	168	148	148	136	135	204	228	195	175	176	163	162	231	607	607	607	607	607	607	607
Predicted Change in Streamflow from Baseline (L/s)	January	-	15	1	1	-7	-17	6	-	15	1	1	-7	-17	6	-	0	0	0	0	0	0
	February	-	13	0	-1	-8	-15	5	-	13	0	-1	-8	-15	5	-	0	0	0	0	0	0
	March	-	23	-2	-3	-11	-16	5	-	23	-2	-3	-11	-16	5	-	0	0	0	0	0	0
	April	-	24	-2	-4	-11	-15	4	-	24	-2	-4	-11	-15	4	-	0	0	0	0	0	0
	May	-	-21	-53	-46	-41	-26	55	-	-21	-53	-46	-41	-26	55	-	0	0	0	0	0	0
	June	-	-183	-219	-216	-238	-220	-34	-	-183	-219	-216	-238	-220	-34	-	0	0	0	0	0	0
	July	-	-131	-159	-162	-195	-182	-15	-	-131	-159	-163	-195	-182	-15	-	0	0	0	0	0	0
	August	-	-63	-92	-93	-115	-110	1	-	-63	-92	-93	-115	-110	1	-	0	0	0	0	0	0
	September	-	-57	-64	-68	-87	-78	8	-	-57	-64	-68	-87	-78	8	-	0	0	0	0	0	0
	October	-	-32	-39	-42	-54	-72	-17	-	-32	-39	-42	-54	-72	-17	-	0	0	0	0	0	0
	November	-	4	-5	-1	-11	-26	5	-	4	-5	-1	-11	-26	5	-	0	0	0	0	0	0
	December	-	13	3	4	-5	-19	7	-	13	3	5	-5	-19	7	-	0	0	0	0	0	0
	Annual Average	-	-33	-53	-53	-65	-66	2	-	-33	-53	-53	-65	-66	2	-	0	0	0	0	0	0
Predicted Change in Streamflow from Baseline (%)	January	-	30%	1%	1%	-13%	-34%	12%	-	27%	1%	1%	-12%	-30%	11%	-	0%	0%	0%	0%	0%	0%
	February	-	34%	-1%	-3%	-21%	-38%	12%	-	30%	-1%	-3%	-18%	-34%	11%	-	0%	0%	0%	0%	0%	0%
	March	-	61%	-5%	-8%	-28%	-42%	12%	-	54%	-4%	-7%	-25%	-37%	11%	-	0%	0%	0%	0%	0%	0%
	April	-	73%	-7%	-12%	-33%	-46%	13%	-	64%	-6%	-10%	-29%	-40%	11%	-	0%	0%	0%	0%	0%	0%
	May	-	-9%	-23%	-20%	-18%	-11%	24%	-	-7%	-19%	-17%	-15%	-9%	20%	-	0%	0%	0%	0%	0%	0%
	June	-	-34%	-41%	-40%	-45%	-41%	-6%	-	-31%	-36%	-36%	-40%	-37%	-6%	-	0%	0%	0%	0%	0%	0%
	July	-	-28%	-34%	-35%	-42%	-39%	-3%	-	-26%	-31%	-32%	-38%	-35%	-3%	-	0%	0%	0%	0%	0%	0%
	August	-	-19%	-27%	-27%	-34%	-32%	0%	-	-16%	-24%	-24%	-30%	-29%	0%	-	0%	0%	0%	0%	0%	0%
	September	-	-19%	-21%	-22%	-29%	-26%	3%	-	-16%	-18%	-20%	-25%	-22%	2%	-	0%	0%	0%	0%	0%	0%
	October	-	-15%	-18%	-19%	-25%	-33%	-8%	-	-13%	-16%	-17%	-22%	-29%	-7%	-	0%	0%	0%	0%	0%	0%
	November	-	5%	-5%	-1%	-12%	-28%	5%	-	4%	-5%	-1%	-10%	-25%	4%	-	0%	0%	0%	0%	0%	0%
	December	-	21%	4%	7%	-9%	-30%	11%	-	18%	4%	6%	-8%	-26%	10%	-	0%	0%	0%	0%	0%	0%
	Annual Average	-	-16%	-26%	-26%	-32%	-33%	1%	-	-14%	-23%	-23%	-29%	-29%	1%	-	0%	0%	0%	0%	0%	0%

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NOTES:

1. VALUES REPRESENT RESULTS OF THE LIFE OF MINE WATER BALANCE MODEL FOR EACH MINE PHASE.

0	25SEPT'18	ISSUED WITH REPORT VA101-640/06-3	AIF	CAS
REV	DATE	DESCRIPTION	PREP'D	RVW'D

Knight Piésold CONSULTING

TABLE G.3

BMC MINERALS (NO. 1) LTD
KUDZ ZE KAYAH

LIFE OF MINE WATER BALANCE MODEL
ESTIMATED AVERAGE MONTHLY STREAMFLOWS AND CHANGE IN FLOW DURING LIFE OF MINE

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Streamflow (L/s)

	Finlayson Creek																											
	KZ-16							KZ-15							KZ-22							KZ-26						
Month	Baseline	Construction (Yr -1)	Early Operations (Yr 2)	Late Operations (Yr 9)	Active Closure (Yr 12)	Transitional Closure (Yr 23)	Post- Closure (Yr 38)	Baseline	Construction (Yr -1)	Early Operations (Yr 2)	Late Operations (Yr 9)	Active Closure (Yr 12)	Transitional Closure (Yr 23)	Post- Closure (Yr 38)	Baseline	Construction (Yr -1)	Early Operations (Yr 2)	Late Operations (Yr 9)	Active Closure (Yr 12)	Transitional Closure (Yr 23)	Post- Closure (Yr 38)	Baseline	Construction (Yr -1)	Early Operations (Yr 2)	Late Operations (Yr 9)	Active Closure (Yr 12)	Transitional Closure (Yr 23)	Post- Closure (Yr 38)
January	86	86	86	86	86	86	86	144	159	159	165	137	126	150	344	359	360	365	337	327	350	455	470	470	476	448	438	461
February	65	65	65	65	65	65	65	110	123	122	127	102	95	115	269	282	281	286	261	254	274	360	373	372	377	352	345	365
March	61	61	61	61	61	61	61	105	128	117	122	95	89	110	264	286	275	280	253	248	268	355	378	367	372	345	340	360
April	51	51	51	51	51	51	51	88	112	98	103	78	74	92	226	249	236	241	216	211	230	307	330	317	321	296	292	311
May	344	344	344	344	344	344	344	624	603	613	649	583	598	679	1744	1721	1732	1769	1703	1718	1799	2035	2011	2024	2060	1994	2009	2091
June	719	719	719	719	719	719	719	1322	1138	1105	1114	1084	1102	1289	2979	2791	2762	2771	2741	2759	2946	3322	3132	3104	3113	3083	3101	3288
July	710	710	710	710	710	710	710	1226	1093	1072	1083	1031	1044	1211	2452	2316	2298	2309	2257	2270	2437	2643	2507	2489	2500	2448	2461	2627
August	544	543	544	544	544	544	544	931	867	851	864	816	821	932	2074	2009	1994	2007	1958	1963	2075	2261	2196	2181	2194	2145	2150	2262
September	497	497	497	497	497	497	497	849	791	794	803	761	770	857	2016	1958	1962	1970	1929	1938	2024	2224	2166	2170	2178	2137	2146	2232
October	361	361	361	361	361	361	361	614	582	581	585	560	542	597	1484	1451	1450	1454	1429	1411	1466	1679	1647	1646	1650	1625	1607	1662
November	162	162	162	162	162	162	162	271	275	278	286	260	244	275	641	645	648	656	630	614	645	781	785	788	797	770	755	786
December	110	110	110	110	110	110	110	183	196	199	206	178	164	190	432	445	448	454	426	413	439	556	569	572	578	550	537	563
Annual Average	309	309	309	309	309	309	309	539	506	499	509	474	473	541	1244	1209	1204	1213	1178	1177	1246	1415	1380	1375	1385	1349	1348	1417

Predicted Change in Streamflow from Baseline (L/s)

Month	KZ-16 Baseline	Construction (Yr -1)	Early Operations (Yr 2)	Late Operations (Yr 9)	Active Closure (Yr 12)	Transitional Closure (Yr 23)	Post- Closure (Yr 38)	KZ-15 Baseline	Construction (Yr -1)	Early Operations (Yr 2)	Late Operations (Yr 9)	Active Closure (Yr 12)	Transitional Closure (Yr 23)	Post- Closure (Yr 38)	KZ-22 Baseline	Construction (Yr -1)	Early Operations (Yr 2)	Late Operations (Yr 9)	Active Closure (Yr 12)	Transitional Closure (Yr 23)	Post- Closure (Yr 38)	KZ-26 Baseline	Construction (Yr -1)	Early Operations (Yr 2)	Late Operations (Yr 9)	Active Closure (Yr 12)	Transitional Closure (Yr 23)	Post- Closure (Yr 38)
January	-	0	0	0	0	0	0	-	15	16	21	-7	-17	6	-	15	16	21	-7	-17	6	-	15	16	21	-7	-17	6
February	-	0	0	0	0	0	0	-	13	12	17	-8	-15	5	-	13	12	17	-8	-15	5	-	13	12	17	-8	-15	5
March	-	0	0	0	0	0	0	-	23	12	17	-11	-16	5	-	22	12	16	-11	-16	5	-	22	12	16	-11	-16	5
April	-	0	0	0	0	0	0	-	23	10	15	-11	-15	4	-	23	10	15	-11	-15	4	-	23	10	14	-11	-15	4
May	-	0	0	0	0	0	0	-	-21	-12	25	-41	-26	55	-	-23	-12	25	-41	-26	55	-	-24	-12	25	-41	-26	55
June	-	0	0	0	0	0	0	-	-185	-217	-209	-238	-220	-34	-	-189	-217	-209	-238	-220	-34	-	-190	-217	-209	-238	-220	-34
July	-	0	0	0	0	0	0	-	-133	-154	-143	-195	-182	-15	-	-135	-154	-143	-195	-182	-15	-	-136	-154	-143	-195	-182	-15
August	-	0	0	0	0	0	0	-	-64	-80	-67	-115	-110	1	-	-65	-80	-67	-115	-110	1	-	-65	-80	-67	-115	-110	1
September	-	0	0	0	0	0	0	-	-57	-54	-46	-87	-78	8	-	-58	-54	-46	-87	-78	8	-	-58	-54	-46	-87	-78	8
October	-	0	0	0	0	0	0	-	-32	-33	-29	-54	-72	-17	-	-33	-33	-29	-55	-72	-17	-	-33	-33	-29	-55	-72	-17
November	-	0	0	0	0	0	0	-	4	7	15	-11	-26	5	-	4	7	15	-11	-26	5	-	4	7	15	-12	-26	5
December	-	0	0	0	0	0	0	-	13	16	22	-6	-19	7	-	13	16	22	-6	-19	7	-	13	16	22	-6	-19	7
Annual Average	-	0	0	0	0	0	0	-	-33	-40	-30	-65	-66	2	-	-34	-40	-30	-65	-66	2	-	-35	-40	-30	-66	-66	2

Predicted Change in Streamflow from Baseline (%)

Month	KZ-16 Baseline	Construction (Yr -1)	Early Operations (Yr 2)	Late Operations (Yr 9)	Active Closure (Yr 12)	Transitional Closure (Yr 23)	Post- Closure (Yr 38)	KZ-15 Baseline	Construction (Yr -1)	Early Operations (Yr 2)	Late Operations (Yr 9)	Active Closure (Yr 12)	Transitional Closure (Yr 23)	Post- Closure (Yr 38)	KZ-22 Baseline	Construction (Yr -1)	Early Operations (Yr 2)	Late Operations (Yr 9)	Active Closure (Yr 12)	Transitional Closure (Yr 23)	Post- Closure (Yr 38)	KZ-26 Baseline	Construction (Yr -1)	Early Operations (Yr 2)	Late Operations (Yr 9)	Active Closure (Yr 12)	Transitional Closure (Yr 23)	Post- Closure (Yr 38)
January	-	0%	0%	0%	0%	0%	0%	-	11%	11%	15%	-5%	-12%	4%	-	4%	5%	6%	-2%	-5%	2%	-	3%	3%	5%	-2%	-4%	1%
February	-	0%	0%	0%	0%	0%	0%	-	12%	11%	15%	-7%	-14%	4%	-	5%	5%	6%	-3%	-6%	2%	-	4%	3%	5%	-2%	-4%	1%
March	-	0%	0%	0%	0%	0%	0%	-	22%	11%	16%	-10%	-15%	4%	-	8%	5%	6%	-4%	-6%	2%	-	6%	3%	5%	-3%	-4%	1%
April	-	0%	0%	0%	0%	0%	0%	-	26%	11%	17%	-12%	-17%	5%	-	10%	4%	6%	-5%	-7%	2%	-	7%	3%	5%	-4%	-5%	1%
May	-	0%	0%	0%	0%	0%	0%	-	-3%	-2%	4%	-7%	-4%	9%	-	-1%	-1%	1%	-2%	-1%	3%	-	-1%	-1%	1%	-2%	-1%	3%
June	-	0%	0%	0%	0%	0%	0%	-	-14%	-16%	-16%	-18%	-17%	-3%	-	-6%	-7%	-7%	-8%	-7%	-1%	-	-6%	-7%	-6%	-7%	-7%	-1%
July	-	0%	0%	0%	0%	0%	0%	-	-11%	-13%	-12%	-16%	-15%	-1%	-	-6%	-6%	-6%	-8%	-7%	-1%	-	-5%	-6%	-5%	-7%	-7%	-1%
August	-	0%	0%	0%	0%	0%	0%	-	-7%	-9%	-7%	-12%	-12%	0%	-	-3%	-4%	-3%	-6%	-5%	0%	-	-3%	-4%	-3%	-5%	-5%	0%
September	-	0%	0%	0%	0%	0%	0%	-	-7%	-6%	-5%	-10%	-9%	1%	-	-3%	-3%	-2%	-4%	-4%	0%	-	-3%	-2%	-2%	-4%	-4%	0%
October	-	0%	0%	0%	0%	0%	0%	-	-5%	-5%	-5%	-9%	-12%	-3%	-	-2%	-2%	-2%	-4%	-5%	-1%	-	-2%	-2%	-2%	-3%	-4%	-1%
November	-	0%	0%	0%	0%	0%	0%	-	2%	3%	6%	-4%	-10%	2%	-	1%	1%	2%	-2%	-4%	1%	-	0%	1%	2%	-1%	-3%	1%
December	-	0%	0%	0%	0%	0%	0%	-	7%	9%	12%	-3%	-10%	4%	-	3%	4%	5%	-1%	-4%	2%	-	2%	3%	4%	-1%	-3%	1%
Annual Average	-	0%	0%	0%	0%	0%	0%	-	-6%	-7%	-6%	-12%	-12%	0%	-	-3%	-3%	-2%	-5%	-5%	0%	-	-2%	-3%	-2%	-5%	-5%	0%

M:\1\01\00640\06\A\Report\3 - Life of Mine Water Balance Report\Rev 0\Appendices\App G - Mean Monthly Flow and Change Tables\[StreamflowSummaryTables_v9.xlsx]Finlayson Flows

NOTES:

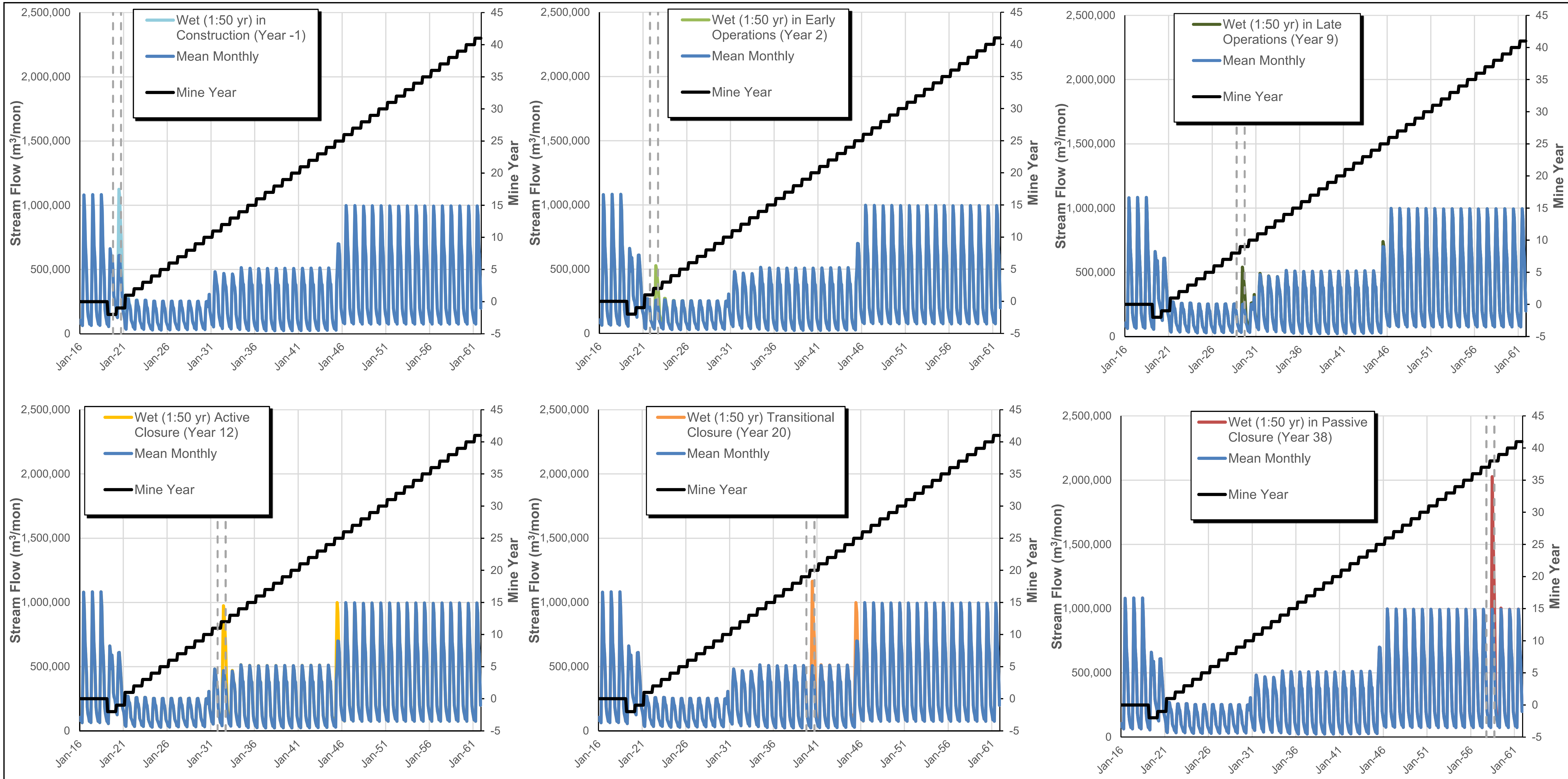
1. VALUES REPRESENT RESULTS OF THE LIFE OF MINE WATER BALANCE MODEL FOR EACH MINE PHASE.

0	25SEPT'18	ISSUED WITH REPORT VA101-640/06-3	AIF	CAS
REV	DATE	DESCRIPTION	PREP'D	RVW'D

APPENDIX H

Climate Sensitivity Scenario Streamflows

(Figures H1 to H2)



NOTES:

1. STREAMFLOW RESULTS FROM THE LIFE OF MINE WATER BALANCE MODEL WET CLIMATE SENSITIVITY SCENARIOS

0	24SEP'18	ISSUED WITH REPORT	CJ	CAS
REV	DATE	DESCRIPTION	PREP'D	RVW'D

BMC MINERALS (NO.1) LTD

KUDZ ZE KAYAH PROJECT

WET CLIMATE SENSITIVITY SCENARIOS
STREAMFLOW AT KZ-9

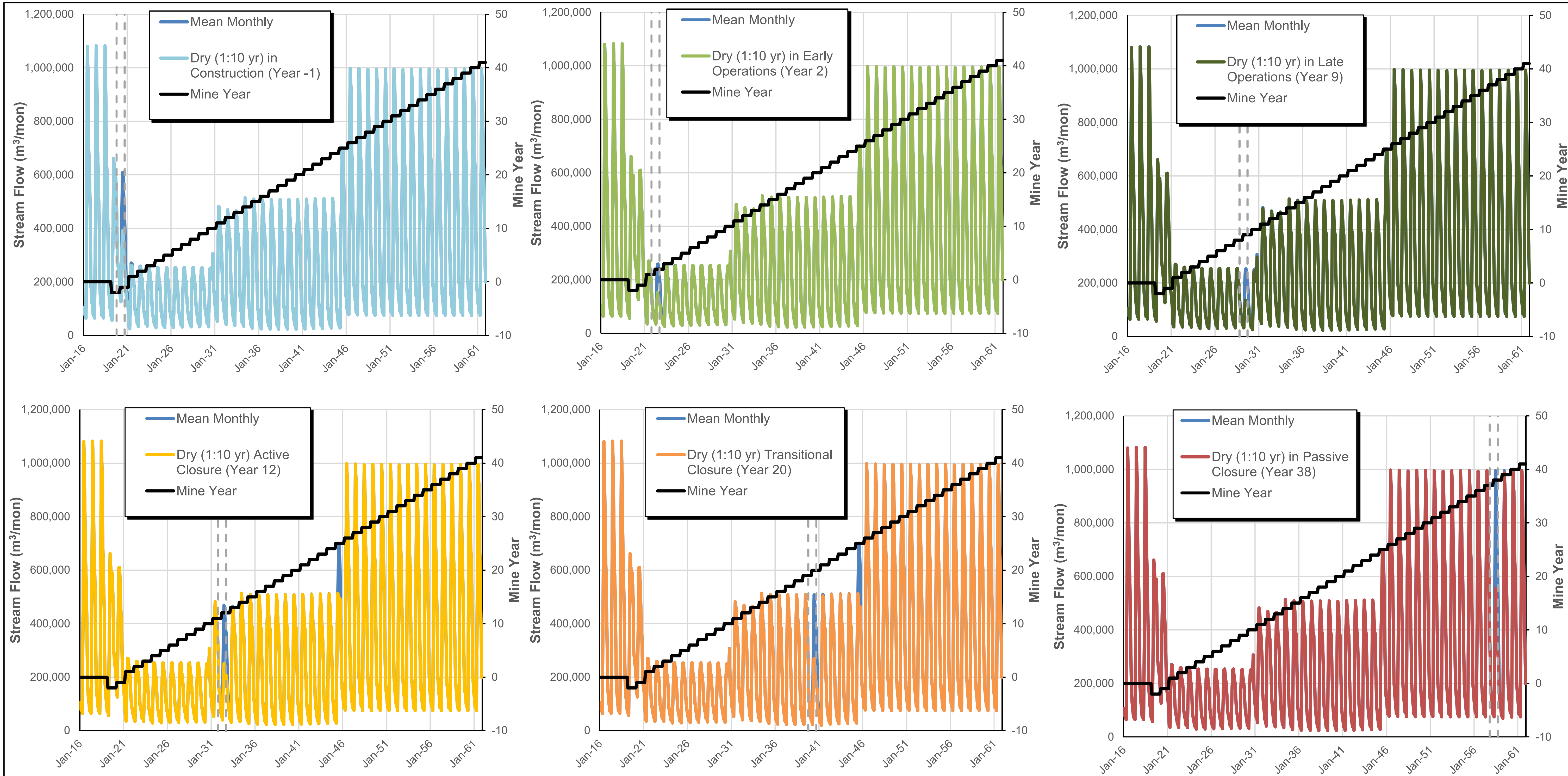
Knight Piésold CONSULTING

P/A NO. VA101-640/6

REF. NO. 3

FIGURE H1

REV 0



NOTES:

1. STREAMFLOW RESULTS FROM THE LIFE OF MINE WATER BALANCE MODEL DRY CLIMATE SENSITIVITY SCENARIOS.

0	24SEP'18	ISSUED WITH REPORT	CJ	CAS
REV	DATE	DESCRIPTION	PREP'D	RVW'D

BMC MINERALS (NO.1) LTD

KUDZ ZE KAYAH PROJECT

DRY CLIMATE SENSITIVITY SCENARIOS
STREAMFLOW AT KZ-9

Knight Piésold CONSULTING

P/A NO. VA101-640/6

REF. NO. 3

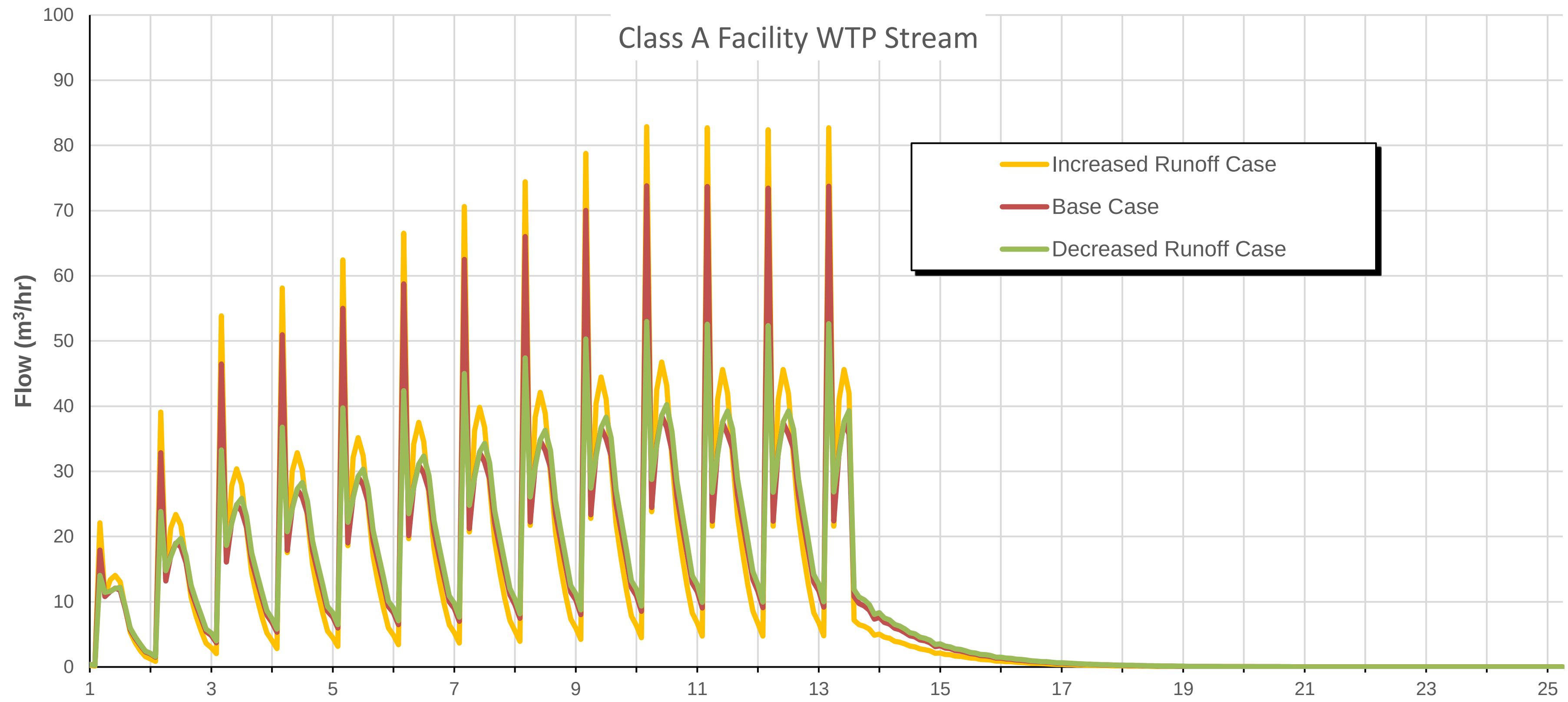
FIGURE H2

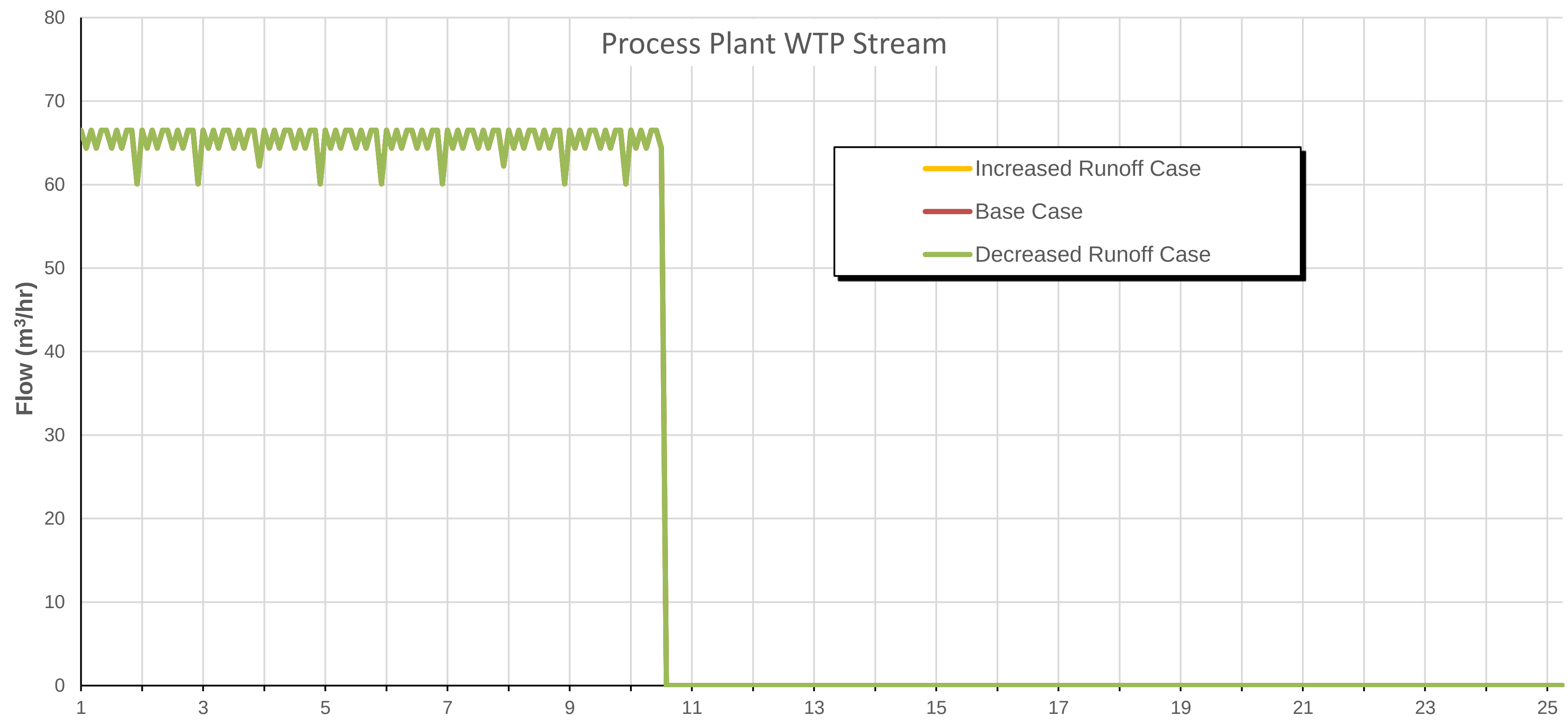
REV 0

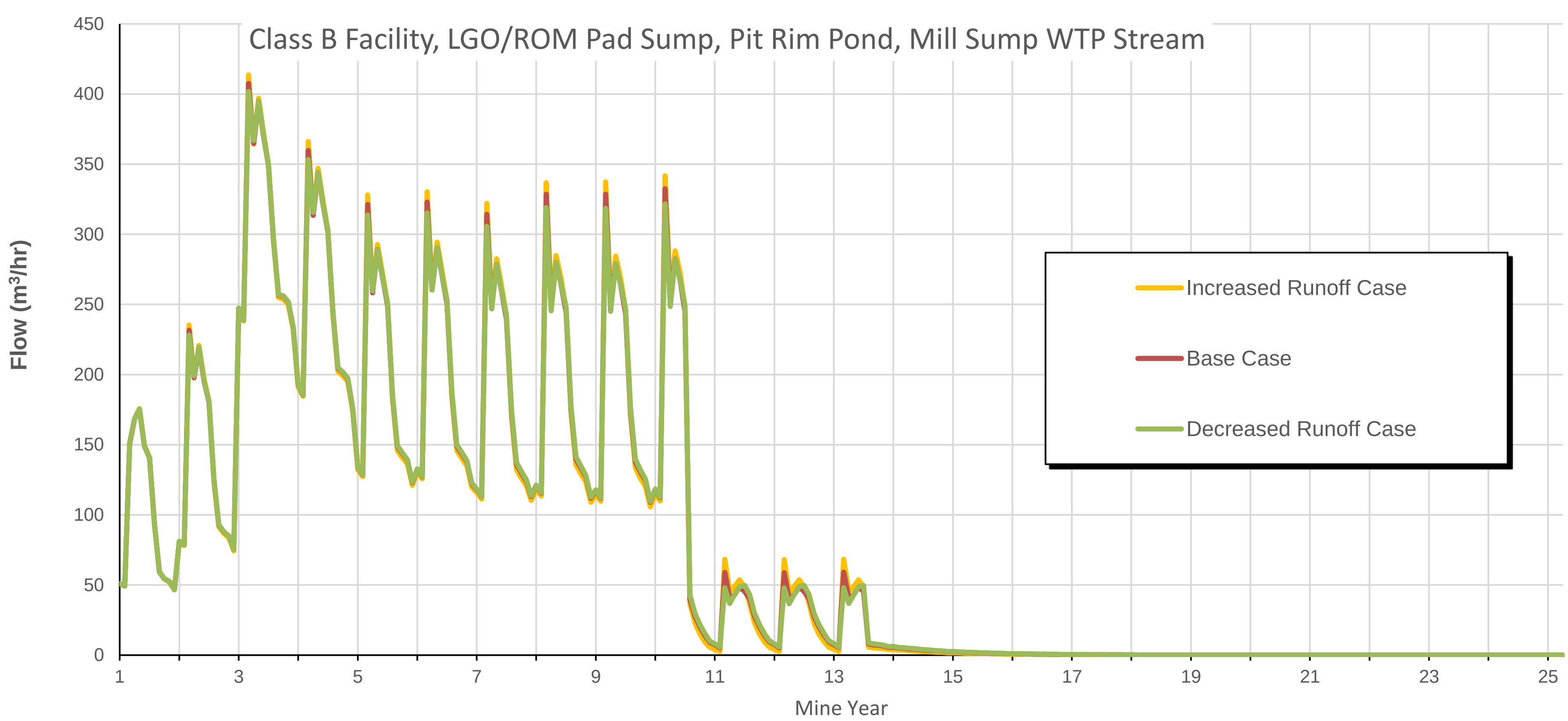
APPENDIX I

Runoff Sensitivity Scenario Streamflows

(Figures I.1 to I.2)







NOTES:

1. MAXIMUM TREATMENT RATE:
   CLASS A FACILITY STREAM = 287 m^3/hr
   PROCESS WATER STREAM = 68 m^3/hr
   CLASS B FACILITY et. al. STREAM = 852 m^3/hr

0	24SEP'18	ISSUED WITH REPORT	CJ	CAS
REV	DATE	DESCRIPTION	PREP'D	RVW'D

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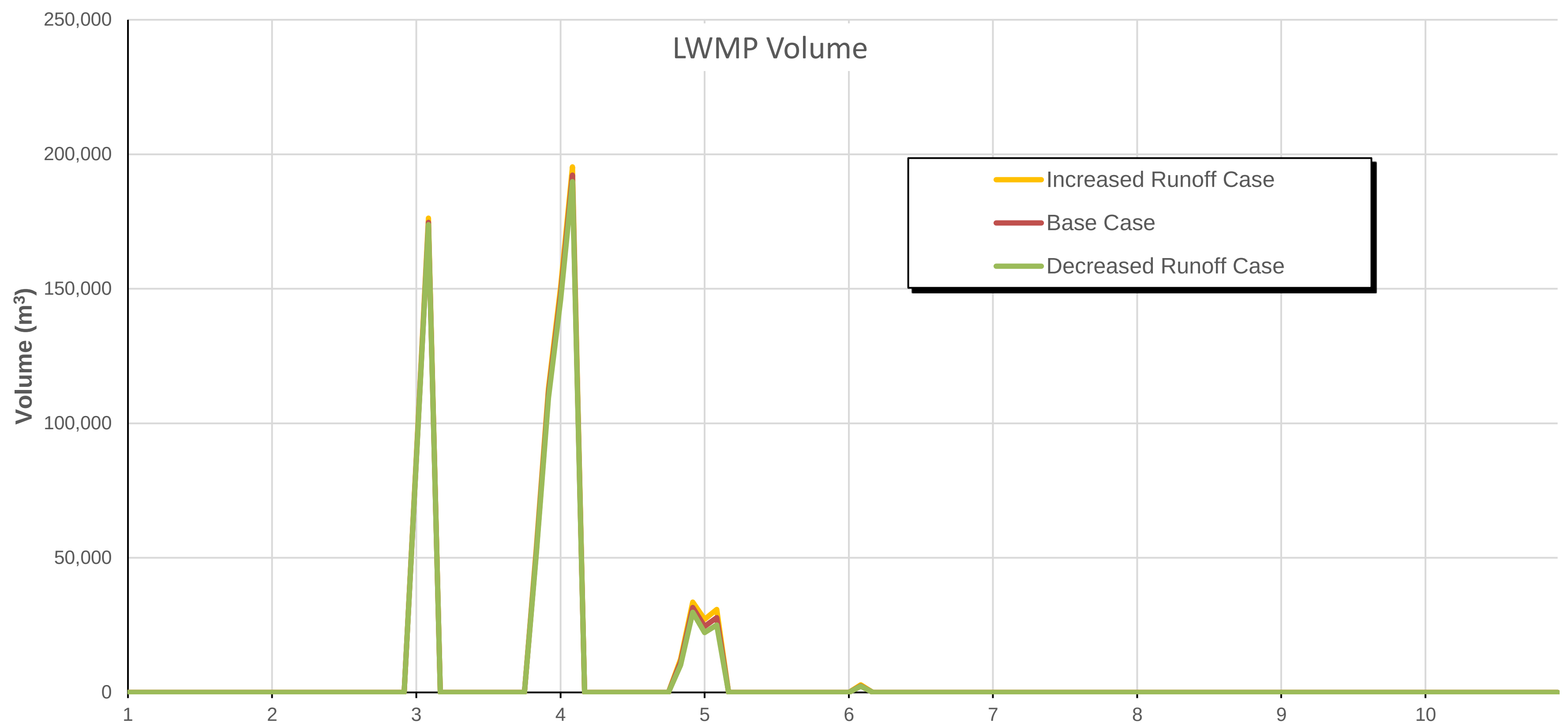
KUDZ ZE KAYAH PROJECT

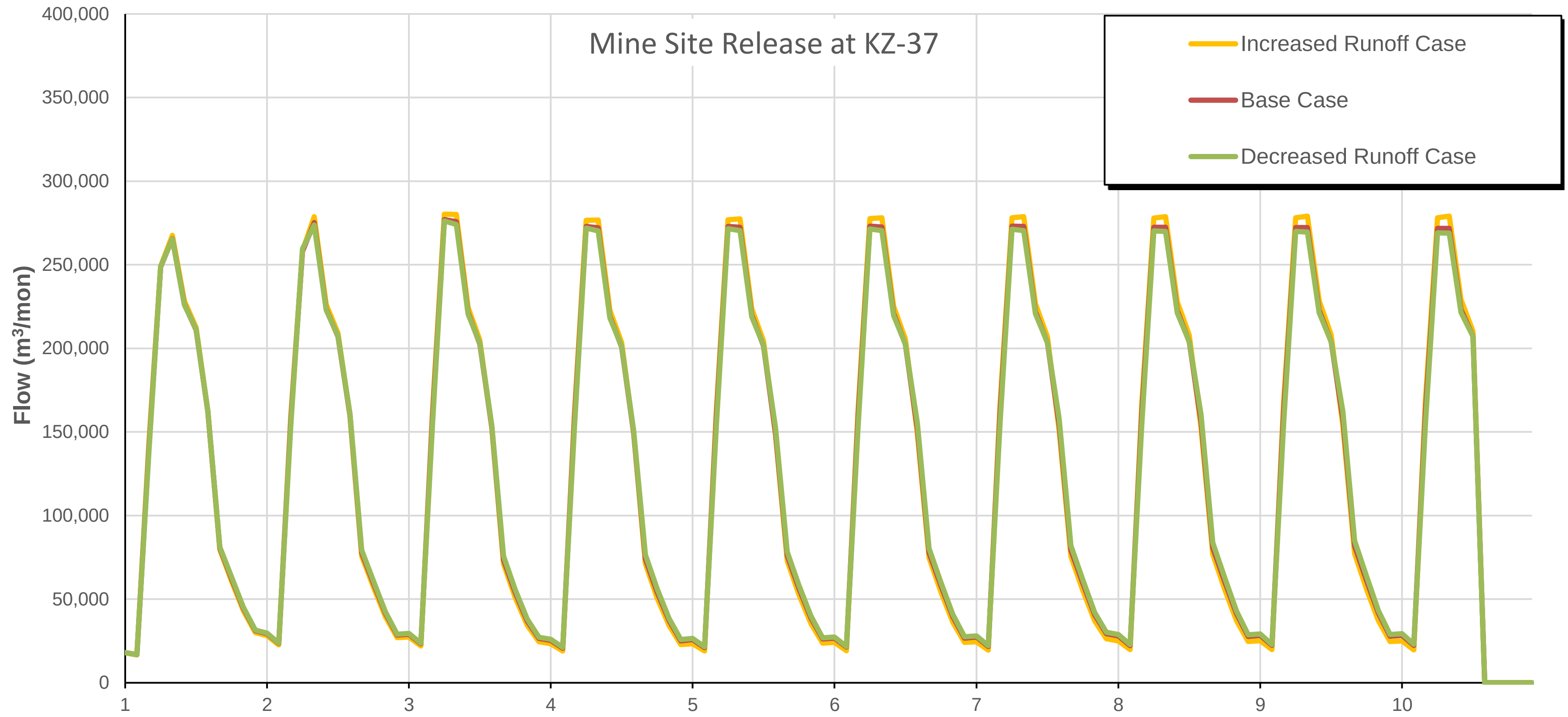
COMPARISON OF WATER TREATMENT PLANT STREAMS FOR DIFFERENT FACILITY RUNOFF CASES

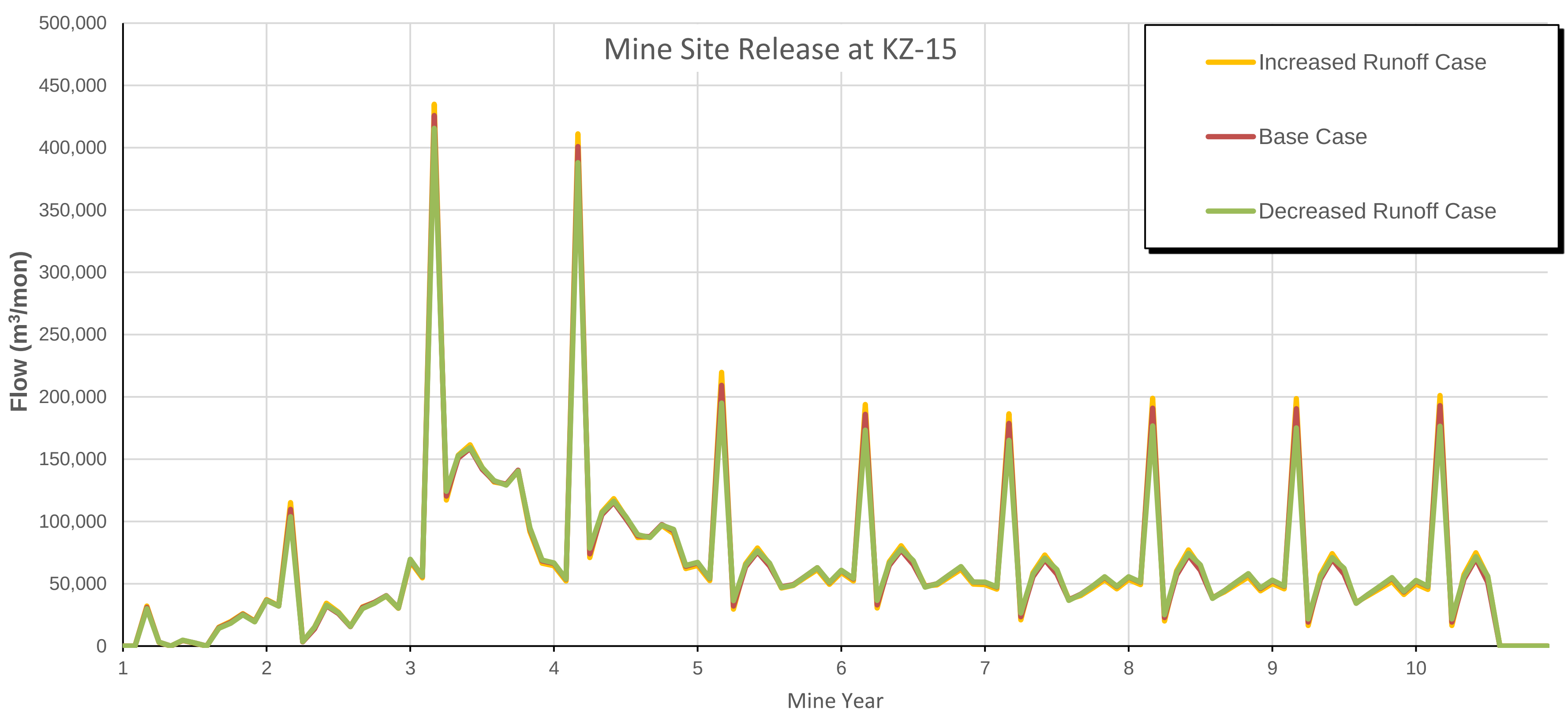
Knight Piésold CONSULTING

P/A NO.	REF. NO.
VA101-640/6	3

FIGURE I.1	REV 0







BMC MINERALS (NO.1) LTD

KUDZ ZE KAYAH PROJECT

COMPARISON OF LWMP VOLUME AND RELEASES FOR DIFFERENT FACILITY RUNOFF CASES

Knight Piésold CONSULTING

P/A NO. VA101-640/6

REF. NO. 3

FIGURE I.2

REV 0

REV	DATE	DESCRIPTION	PREP'D	RVW'D
0	24SEP'18	ISSUED WITH REPORT	CJ	CAS