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GROUP

RECEIVING ENVIRONMENT WATER BALANCE

KUDZ ZE KAYAH PROJECT

BMC-15-02-2352_027_Receving Environment Water Balance_Rev0_170113

January 13, 2017

Prepared for:

BMC
MINERALS

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EXECUTIVE SUMMARY

A physical measurement based, monthly time-step watershed model was developed to predict receiving environment flows for the Kudz Ze Kayah (KZK) Project in Yukon Territory for the purposes of assessing potential environmental impacts of the Project proposed by BMC Minerals (No. 1) Ltd. The Hydrometeorology Baseline Report (AEG, 2016a) describes the regional climate and hydrology, and summarizes baseline data that have been collected beginning April 2015 and continuing to present. These data, along with additional baseline data processed since that report have been used to inform the development of this model and water balance. The rigorous baseline data collection program combined with long term regional data has allowed the development of a strong baseline model for the evaluation of the Project effects.

The watershed model is based on physical processes and borrows methodology from the United States Geological Survey (USGS) Thornthwaite Monthly Water-Balance Model (McCabe and Markstrom, 2007). The model was calibrated using data observed on site from October 2015 through September 2016 and inputs were developed from both regional and site data. The model was used to predict monthly runoff for mean conditions, a 1/50 wet precipitation year and a 1/10 dry precipitation year based on inputs developed by comparing concurrent site observations to regional stations with long term records. Using the calibrated model, the water balance for the receiving environment for the Project was determined, which will be used to assess potential impacts on surface water runoff quantities or discharge during construction, operations and closure.

Surplus water volumes from the proposed Project site during operations were provided by Knight Piésold Ltd. (KP) in their water balance report (KP, 2016). Tetra Tech EBA Inc. (EBA) carried out hydrogeological assessment and modelling to estimate the impacts of the ABM open pit and subsequent pit lake (EBA, 2016). Information from both these reports are used in this report.

The model compared well with total annual runoff values predicted in the Hydrometeorology Baseline Report (AEG, 2016a). While some marked monthly differences were observed between the model and the predicted values from the Hydrometeorology Baseline Report, these were during season transition months were uncertainty is much greater. Baseline data collection continues at the site to further validate the model assumptions and improve calibration.

The construction phase of the Project will involve diversion of Fault Creek and catchment areas above the ABM open pit into South Creek. The impacts of these diversions on the downstream water volumes in Finlayson and Geona Creeks are expected to be minimal. The operations phase of the Project is expected to reduce discharge in Geona Creek the most at KZ-9, below the proposed Lower Water Management Pond, by a maximum of 61% under mean conditions with impacts decreasing downstream. In Finlayson Creek, under mean conditions, the reduction will be as high as 10% immediately below the confluence with Geona Creek and approximately 5% at the Robert Campbell Highway. Discharge in South Creek during operations will increase by approximately 24% annually with the diversion of Fault Creek to the South Creek watershed, but will decrease by approximately 8% in post closure. Mean annual runoff is expected to increase by 5% in Geona Creek at KZ-9 in post closure due to additional groundwater contributions from ABM Lake.

Further data collection for the Project will allow the model to be re-calibrated as the Project advances through the regulatory process. The model presented in this report provides a platform that can be easily adjusted and re-run as more data become available. The high quality baseline data collected at the Project site to date has allowed the development of a robust model which constitutes the best estimates of receiving environment runoff for baseline conditions and during the course the Project.

LIST OF ACRONYMS

AEG	Alexco Environmental Group Inc.
AET	Actual Evapotranspiration
EBA	Tetra Tech EBA Inc.
IEE	Initial Environmental Evaluation
km	Kilometre
km^2	Square kilometre
KP	Knight Piésold Ltd.
KZK	Kudz Ze Kayah
l/s	Litres per second
m	Metre
m^2	Square metre
m^3	Cubic metre
MAP	Mean Annual Precipitation
MAR	Mean Annual Runoff
masl	Meters Above Sea Level
mm	Millimetre
mm/yr	Millimetre per year
PET	Potential Evapotranspiration
PFS	Prefeasibility Study
USGS	United States Geological Survey
YESAA	*Yukon Environmental and Socio-economic Assessment Act*
YESAB	Yukon Environmental and Socio-economic Assessment Board

GLOSSARY

Antecedent: the state immediately preceding the period of discussion often used with particular reference to soil water. The pre-existing condition or volume of water in the soil.

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.

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

Groundwater: in this document, groundwater specifically refers to that component of subsurface water which leaves or flows through a specified catchment via the subsurface.

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

Initial Environmental Evaluation: document produced by Cominco in 1996 that summarises baseline studies at the Kudz Ze Kayah property, describes the Mine plan, waste material characterization, closure plan, environmental management, potential impacts and associated mitigation measures, and socio-economic impacts associated with the Project as it was defined in 1996.

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

Mean Annual Runoff: the average amount of discharge, expressed in millimeters, which will flow past a specified cross section in a single year.

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).

Thornthwaite: refers to Charles Warrant Thornthwaite, an American Geographer and climatologist, whose work contributed to the theory used in the USGS Thornthwaite Monthly Water-Balance Model.

Truncated Catchment: refers to catchments which contain the project footprint and are modelled as natural catchments less the Project foot print area. In closure it may also refer to catchments which are modelled as natural catchment but have the ABM open pit and associated catchment area removed.

Undercatch: the phenomenon commonly associated with precipitation gauges in which true precipitation totals are underrepresented due to turbulence created by the gauge itself, thereby not allowing the snow or rain to fall into the gauge.

Water management area: Project footprint where water is actively managed or diverted, stored, and discharged.

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*.

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1. INTRODUCTION

1.1 SCOPE OF REPORT

This report outlines the receiving environment water balance developed for the Yukon Environmental and Socio-Economic Assessment Board (YESAB) project proposal for the Kudz Ze Kayah (KZK) Project (the Project). Measured and estimated hydrometric parameters are used to predict the baseline surface water flow regime at KZK under different precipitation inputs and as a tool to assess the potential impact of the Project. The predicted flow volumes are also used for water quality modelling. The watershed model used to prepare the water balance is both a predictor of baseline conditions and a tool from which flows can be predicted in the receiving environment during construction and subsequent operations. This report outlines the modelling methodology, assumptions and input parameters used to develop the watershed model, as well as the resulting output of the model. Project operation inputs are provided by Knight Piésold Ltd. (KP) and covered in a separate report (KP, 2016). A hydrogeological model was developed by Tetra Tech EBA Inc. (EBA) to assess the impact of the project on groundwater (EBA, 2016). Results from the other two reports are used to predict flows during construction, operations, and closure based on simple additions or subtractions of estimated monthly totals.

1.2 MODELLING PHILOSOPHY

The watershed model was developed in spreadsheet format (Microsoft Excel) for various sub-catchments within the Finlayson Creek Watershed. The modelling goal was to predict surface water discharge for mean, 1/50 wet, and 1/10 dry precipitation years to assess the effects of the project on receiving environment water quantity and water quality (AEG, 2016b). Each sub-watershed is treated as a unique unit for which inputs and model parameters are calibrated. This recognizes that even within small geographic areas, watersheds will behave differently according to their individual characteristics including area, elevation, gradient, vegetation, soil, and geology. While inputs to the model vary based on their relationship to elevation, it is recognized that this may capture more than just the influence of elevation. Additionally, parameters such as evapotranspiration, groundwater, and storage terms are calibrated for each watershed.

The model is designed to be a simple tool for which inputs can be easily varied to model different hydrometeorological conditions. Storage and groundwater fluxes are simple linear reservoirs and functions based on an empirical approach as opposed to measured physical values.

Collection of on site data, and methods of estimating mean values, are described in more detail in the KZK Baseline Hydrometeorology Report (AEG, 2016a). However, the model was calibrated using concurrent precipitation, temperature, and discharge data collected on site from October 2015 to September 2016. These observations are used to adjust the parameters of the model which are held constant when other scenarios are applied. The baseline conditions are then modelled and compared to estimates based on the regional analysis (AEG, 2016a).

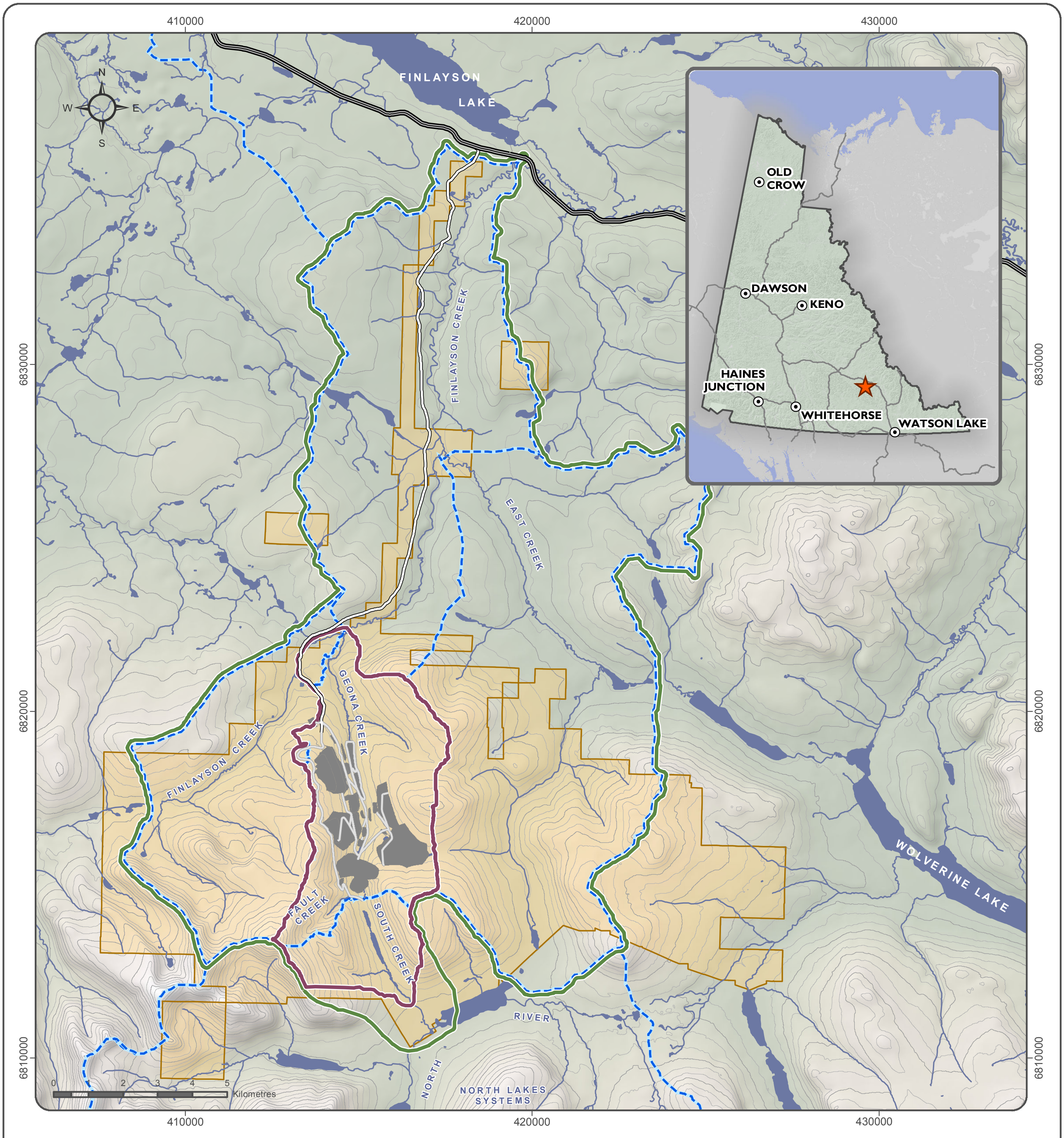
Modelling of dewatering, operations, and closure conditions simply truncates the watersheds by eliminating the area in which water management will occur and calculating new precipitation inputs based on the median elevation. Outputs from the water management area are taken from the KP's Mine Site Water Balance Report (KP, 2016), though discharges from the water management ponds have been determined by AEG to minimize potential effects on water quality concentrations in the receiving environment (AEG, 2016b). Dewatering rates and groundwater rate changes anticipated in closure are from EBA's Hydrogeology Model Report (EBA, 2016).

2. PROJECT DESCRIPITION

The Project is located approximately 260 km northwest of Watson Lake, 110 km southeast of Ross River and 250 km northeast of Whitehorse, Yukon, Canada. Access to the Project is via a 24 km long, all weather, single lane gravel tote road that connects the Project to the Robert Campbell Highway. The Project site is within the northern foothills of the Pelly Mountains of the Yukon Plateau and in the Finlayson Creek watershed. The Project location and study area are shown in Figure 2-1.

The Project is centred on the ABM Deposit, comprising the ABM Zone and the Krakatoa Zone. The ABM Deposit is a polymetallic volcanogenic massive sulphide deposit containing economic concentrations of copper, lead, zinc, gold, and silver. Mining is planned to be conducted via both open pit and underground mining methods, with ore processed into separate copper, lead, and zinc concentrates via sequential flotation through a processing plant at an approximate rate of 2.0 million tonnes (t) per annum. Tailings will be deposited in a dry stack tailings facility on the western slope of the Geona Creek valley, while waste rock will be stored separately according to acid generation and metal leaching potential. Strongly acid generating material will be co-disposed with the tailings or alternatively stored as paste backfill in the mined out underground workings; other waste rock material will be placed on the surface. The proposed mine site layout is shown in Figure 2-2 and the water management catchments are shown in Figure 2-3.

The mine is planned to operate for ten years, producing up to 180,000 t zinc, 35,000 t copper, and 25,000 t lead concentrates annually. Concentrate will be transported to the port of Stewart in British Columbia for sale to market.



★ Kudz Ze Kayah Project Location

▭ Local Study Area for Surface Water

▭ Regional Study Area for Surface Water

⬚ Regional Catchments

■ Location of Proposed Mine Infrastructure

■ BMC Minerals (No. 1) Ltd. Mineral Claim Areas

═ Robert Campbell Highway

═ Tote Road/Proposed Access Road

— Proposed Mine Road

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AEG

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KUDZ ZE KAYAH PROJECT

FIGURE 2-1

PROJECT OVERVIEW

JANUARY 2017

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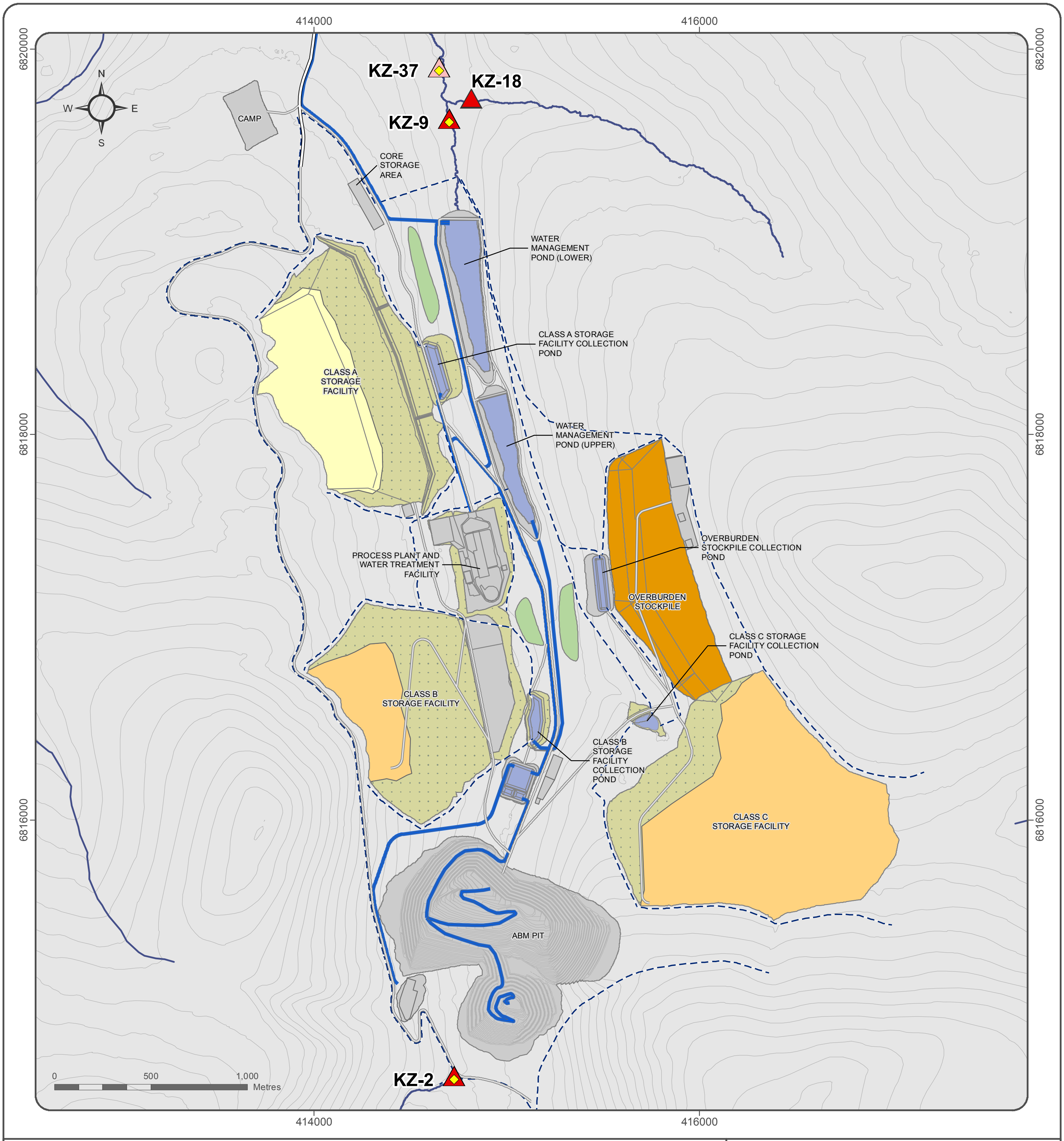

▲	Existing Water Quality and Hydrometric Station
▲	Existing Water Quality Sampling Location
△	Proposed Water Quality and Hydrometric Station
🟨	Class A Storage
🟧	Class B and C Storage Facility
🟧	Overburden Stockpile
🟩	Topsoil Stockpile
▨	Progressive Reclamation
🟦	Pond/Water
━	Pipeline
- - -	Diversion Ditch
═	Tote Road/Proposed Access Road
═	Proposed Mine Road

KUDZ ZE KAYAH PROJECT

FIGURE 2-2

PROJECT LAYOUT

JANUARY 2017

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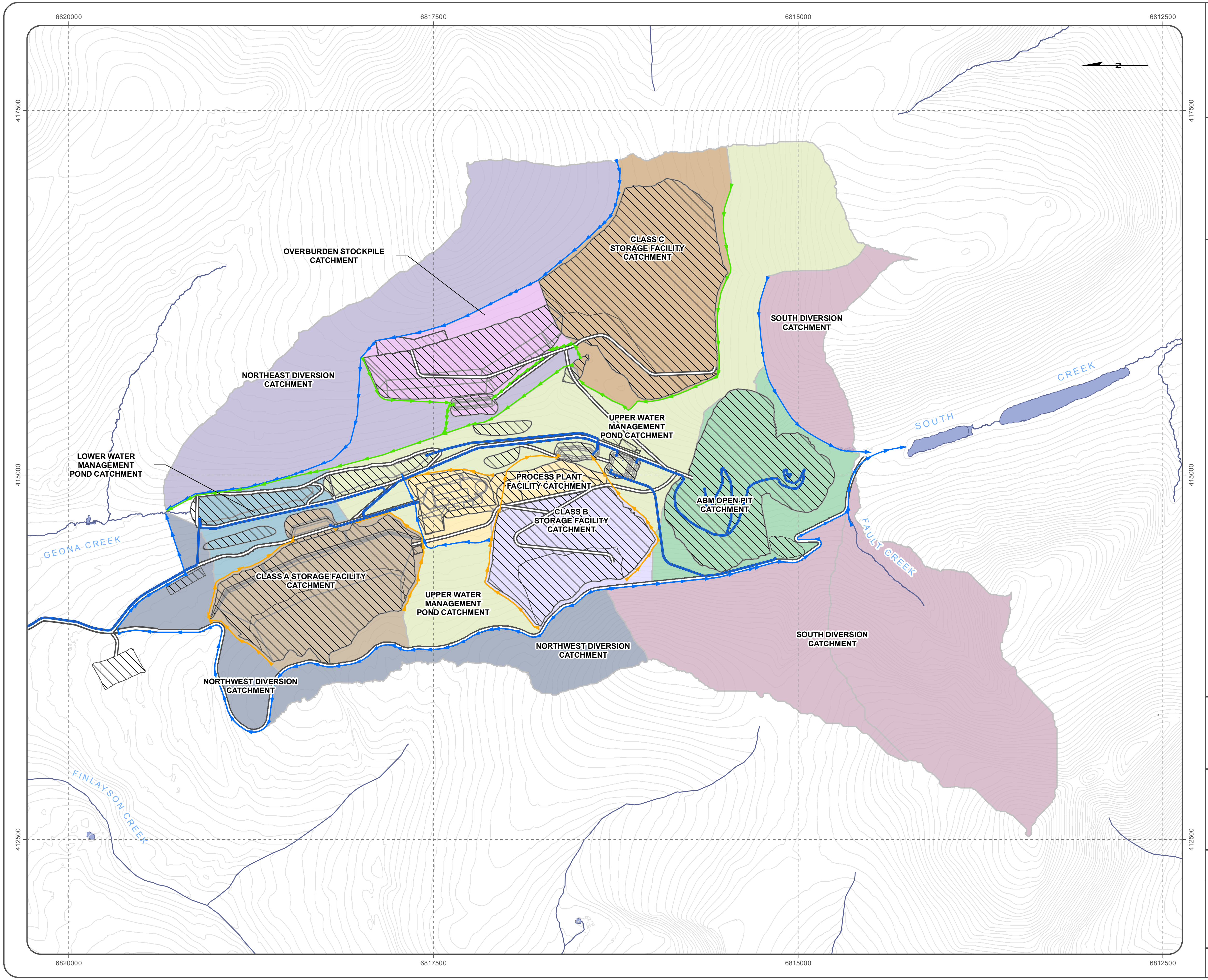

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KUDZ ZE KAYAH PROJECT

FIGURE 2 - 3

WATER MANAGEMENT CATCHMENTS

JANUARY 2017

Water Conveyance

- Pipeline
- Non Contact Diversion
- Contact Class A & B
- Contact Class C Diversion

Water Management Catchments

- Class A Storage
- Class B Storage Facility
- Class C Storage Facility
- ABM Open Pit
- Process Plant Facility
- Lower Water Management Pond
- Upper Water Management Pond
- South Diversion
- Overburden Stockpile
- Northwest Diversion
- Northeast Diversion

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Digital elevation model created by the Yukon Department of the Environment interpolated from the digital 1:50,000 Canadian National Topographic Database (NTDB Edition 2) contour and watercourse layers. Obtained from Geomatics Yukon.

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3. METHODS

The approach to determining the receiving environment discharge was to build a physically based watershed model calibrated with site data and utilizing various regional data to develop model inputs. The results of the watershed model coupled with the results of the KP water balance and EBA's Hydrogeology model, with adjustment by Alexco Environmental Group Inc. (AEG), allowed discharge to be predicted for various sub-catchments within the watershed. The following is a description of the watershed model, the assumptions and limitations of the model, how the model was calibrated, and how discharge predictions were calculated during different stages of the Project.

3.1 MODEL OVERVIEW

A watershed model is a tool for predicting runoff as part of the receiving environment water balance. The results are used in mass loading models and for planning purposes, including adaptive management and fish habitat compensation.

The watershed model is designed to be a changeable tool that can be updated and adjusted as estimates are refined and new data are gathered. It uses easy to understand data inputs of physical parameters, obtainable through either direct measurement or estimation. The model is partially informed by the United States Geological Survey (USGS) Thornthwaite Monthly Water Balance model, in particular how incoming precipitation is divided between rain and snow and how snowmelt is estimated (McCabe and Markstrom, 2007). This watershed model also uses a similar fixed parameter approach to the estimation of direct runoff and snowmelt. Some of the main differences in the model developed for the Project include; a fixed adjustment factor for calibrating actual evapotranspiration (AET) as it is not adequately represented in the USGS model, a fixed sublimation factor, a baseflow factor, and groundwater flows as a simple proportion of soil moisture.

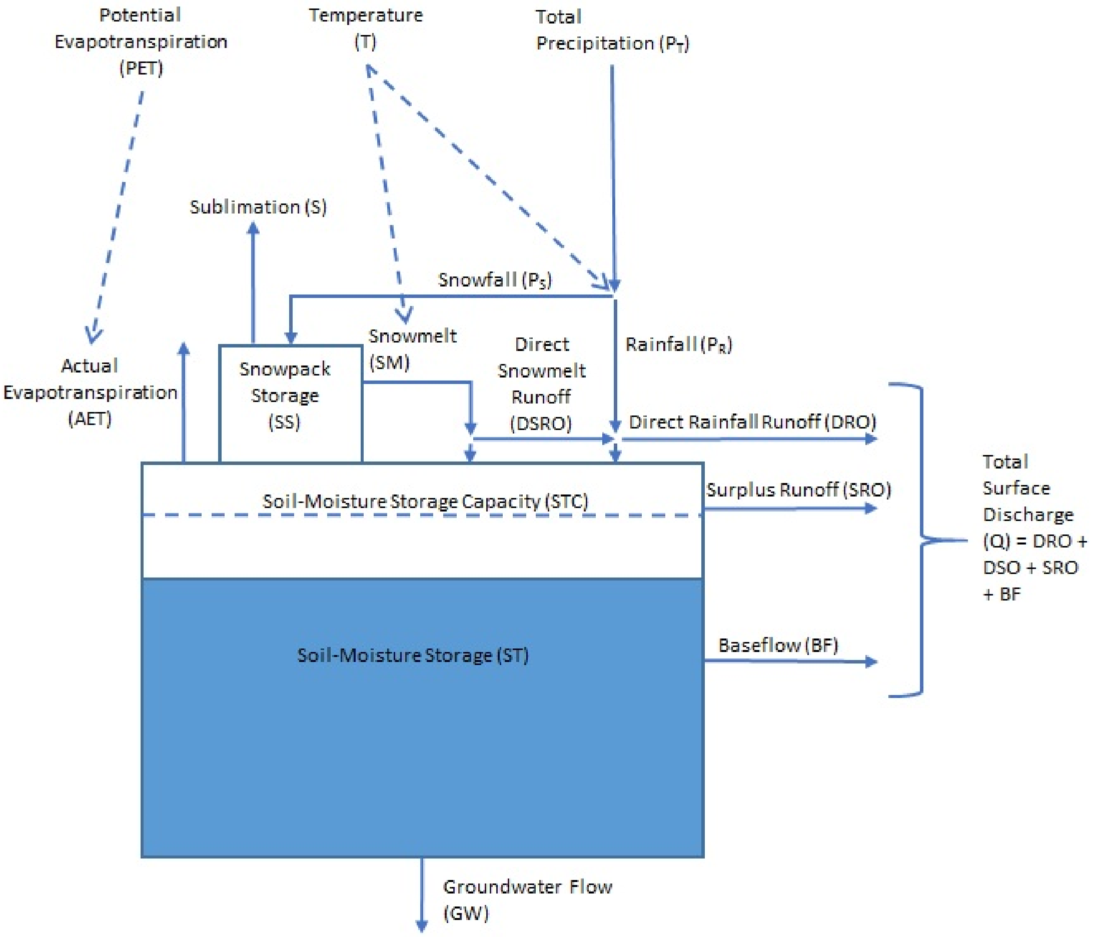
Surface water discharge is modelled on a monthly time-step. The model is run for a minimum two-year run-in period to ensure stability using mean values for all scenarios. Modelled wet and dry scenarios begin in October and are preceded by three years of mean conditions. The results presented for wet and dry scenarios are months eight (May) to nineteen (April). This ensures that the spring runoff is preceded by a wet or dry winter and that the baseflows presented are preceded by a wet or dry summer. Each sub-catchment, is modelled separately; and includes modelled flow for the following monitoring location points or nodes within the Finlayson Creek watershed:

- KZ-2 – Fault Creek;
- KZ-9 – Geona Creek immediately below the Project footprint;
- KZ-17 – Geona Creek near the mouth;
- KZ-18 – Tributary of Geona Creek below KZ-9;
- KZ-37 – Finlayson Creek below the confluence of KZ-9 and KZ-18;
- KZ-15 – Finlayson Creek below the confluence with Geona Creek;

- KZ-22 – Finlayson Creek below the confluence with East Creek;
- KZ-26 – Finlayson Creek at the Robert Campbell Highway; and
- KZ-13 – South Creek.

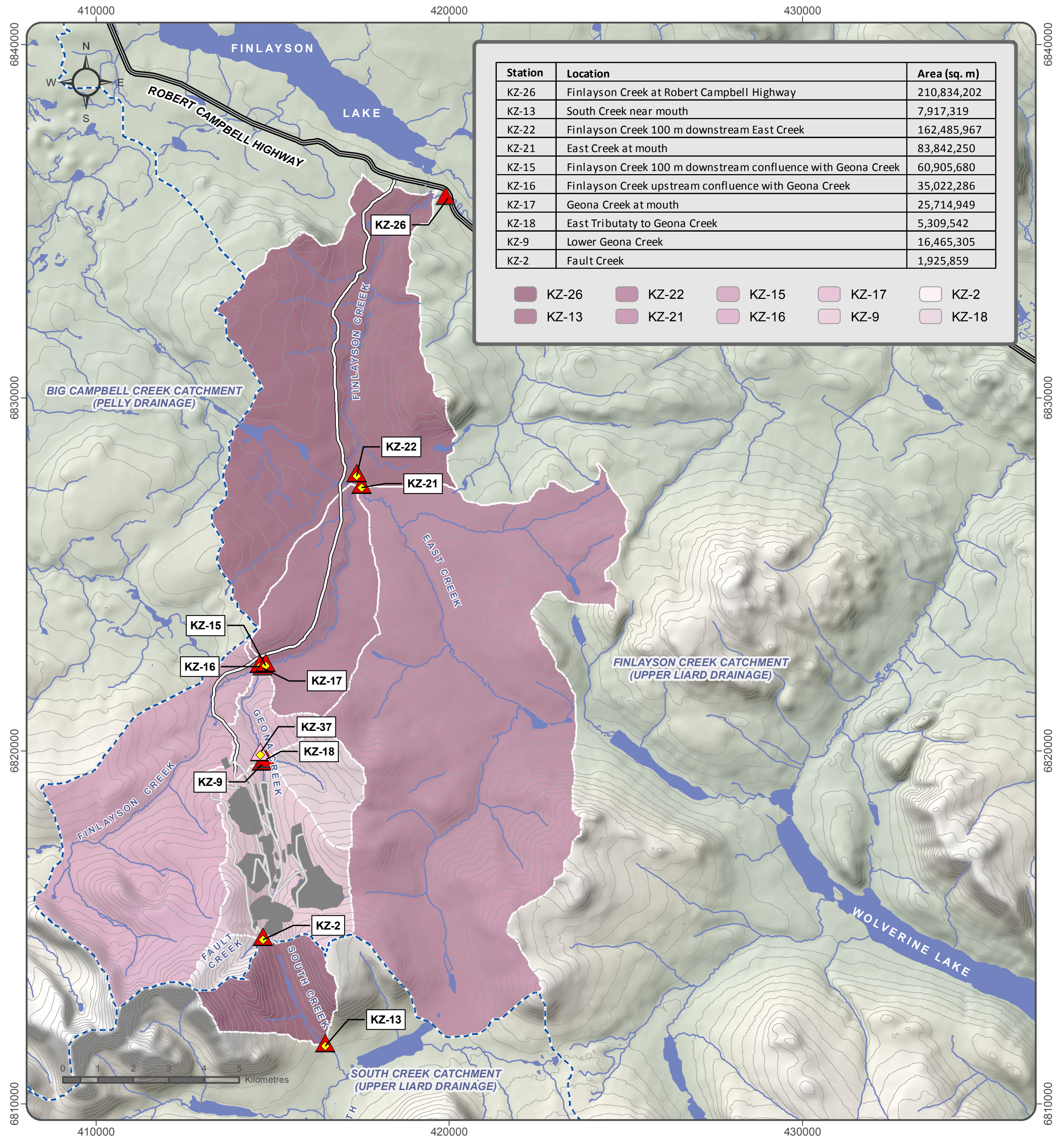
Figure 3-2 shows the delineation of each sub-catchment within the watershed. The model is calibrated using measured precipitation, temperature, and discharge from October 2015 through September 2016. The model estimates baseline conditions, pre-mining pit dewatering, full operational configuration, and closure. For each catchment, there are estimates for the mean annual precipitation (MAP), a 1/50 wet annual precipitation year, and a 1/10 dry annual precipitation year.

Figure 3-1 depicts the conceptual organization of the model in the form of a flow logic diagram. While groundwater and storage processes are likely more complex than suggested by the diagram, this simple approach is considered appropriate for the information available and is commonly used for watershed models of this kind.



** Adapted from USGS Thornthwaite Model (McCabe and Markstrom, 2007)*

Figure 3-1: Watershed Model Conceptual Diagram



Station	Location	Area (sq. m)
KZ-26	Finlayson Creek at Robert Campbell Highway	210,834,202
KZ-13	South Creek near mouth	7,917,319
KZ-22	Finlayson Creek 100 m downstream East Creek	162,485,967
KZ-21	East Creek at mouth	83,842,250
KZ-15	Finlayson Creek 100 m downstream confluence with Geona Creek	60,905,680
KZ-16	Finlayson Creek upstream confluence with Geona Creek	35,022,286
KZ-17	Geona Creek at mouth	25,714,949
KZ-18	East Tributaty to Geona Creek	5,309,542
KZ-9	Lower Geona Creek	16,465,305
KZ-2	Fault Creek	1,925,859

▨ KZ-26
▨ KZ-13
▨ KZ-22
▨ KZ-21
▨ KZ-15
▨ KZ-16
▨ KZ-17
▨ KZ-9
▨ KZ-2
▨ KZ-18

▲ Existing Water Quality and Hydrometric Station
▲ Existing Water Quality Sampling Location
△ Proposed Water Quality and Hydrometric Station
■ Location of Proposed Mine Infrastructure
═ Tote Road/Proposed Access Road
— Proposed Mine Road
═ Robert Campbell Highway
— Watercourse
■ Waterbody

KUDZ ZE KAYAH PROJECT

FIGURE 3-2

OVERVIEW OF CATCHMENTS

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3.2 MODEL INPUTS AND PARAMETERS

The monthly time-step, spreadsheet based, watershed model distributes incoming precipitation to various components of the hydrological cycle (snowpack, rain, evapotranspiration, surface runoff, soil moisture storage groundwater). Precipitation inputs and parameters are adjusted and calibrated for each sub-catchment while temperature is assumed to be constant for all sites. The treatment of each parameter is explained in its own sub-section below.

3.2.1 TEMPERATURE

Mean monthly temperature controls the proportion of rainfall to snowfall as well as snowmelt. The mean monthly temperature calibration was taken from recorded observations at the meteorological station, installed on site in August, 2015. Estimated mean monthly temperatures were calculated by comparing the concurrent September, 2015 through August, 2016 data from site to that of Environment Canada's Meteorological Stations at Watson Lake (Watson Lake A, 2101201) and Faro (Faro A, 2100519). The monthly mean temperatures were calculated for the two regional stations, and a factor relating those means to the September through August data were then calculated. These monthly factors were then applied to the field data from site to obtain estimated mean monthly temperatures at the Project for use in the model (Table 3-1).

Table 3-1: Mean Daily Temperature (°C) Used for Modelling

Temperature (°C)	Month											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Mean Daily	-1.2	-10.3	-12.3	-10.1	-11.4	-14.0	0.0	4.0	8.8	9.9	8.4	1.6

3.2.2 PRECIPITATION

Total precipitation used for model calibration is based upon measured on site precipitation from October 2015 through September 2016, while mean conditions are predicted by a factor generated through comparing concurrent regional data and site data (AEG, 2016a). A frequency analysis was undertaken on regional precipitation to obtain factors by which annual precipitation could be adjusted for various return periods (AEG, 2016a). An elevation factor of 9 mm per 100 m change in elevation is used to predict mean annual precipitation for individual catchments, based on the difference between Faro, Watson Lake and the Project station concurrent records (AEG, 2016a). The regionally derived precipitation distribution, presented in the Hydrometeorology Baseline Report (AEG, 2016a), versus the model distribution are shown in Table 3-2.

Table 3-2: Regionally Derived Precipitation Distribution versus the Model Distribution for KZ-9 catchment

		Month												
Parameter		**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Annual**
Total Precipitation (mm)		52	51.7	47.2	44.9	33.5	29.7	20.7	39.9	65.5	84	74.2	68.2	612
Regional	**Rain (mm)**	10.4	0	0	0	0	0	0	19.9	65.5	84	74.2	68.2	322
	Snow (mm)	41.6	51.7	47.2	44.9	33.5	29.7	20.7	19.9	0	0	0	0	289
	*** Snowmelt (%)**	-	-	-	-	-	-	10	50	40	-	-	-	-
Model	**Rain (mm)**	0	0	0	0	0	0	4.8	39.9	65.5	84.0	74.2	41.0	309

		Month												
Parameter		**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Annual**
	Snow (mm)	52.0	51.7	47.2	44.9	33.5	29.7	15.9	0	0	0	0	27.2	302
	Snowmelt Factor	-	-	-	-	-	-	0.12	0.50	1.00	-	-	-	-

* Percent of peak annual snowpack

Snowfall (P_T) is calculated based on the relevant formula used in the USGS Thornthwaite model (McCabe and Markstrom, 2007). Snow and rain temperature thresholds are adjustable parameters in the model, which set the limit below which all precipitation falls as snow (T_{snow}), and above which all precipitation falls as rain (T_{rain}). When the mean monthly temperature (T) is between those temperatures, the proportion to total monthly precipitation (P_T) falling as snow or rain changes linearly from 100 to 0 percent based on the following equation:

$$P_S = P_T \times \left[\frac{T_{rain} - T}{T_{rain} - T_{snow}}\right].$$

Thus, total rainfall (P_R) in any given month can be calculated as:

$$P_R = P_T - P_S.$$

Snow and rain temperature thresholds were varied to observe their effect on the model but ultimately, values of T_{rain} = 3.3°C and T_{snow} = -1°C were used as suggested in McCabe and Markstrom (2007). Snowfall then accumulates as the snowpack storage (SS) less the snowmelt (SM) and sublimation (S) such that the remaining snowpack at the end of each month is calculated as:

$$SS = SST_{i-1} + P_S - SM - S,$$

where SST_{i-1} is the snowpack storage at the end of the previous month, and sublimation is a fixed value in mm/day, set to 0.14 mm from October through April and based on field observations during the winter of 2015.

3.2.3 DIRECT RUNOFF AND SNOWMELT

Direct Runoff (DRO) is simply the incoming rainfall (P_R), which contributes directly to the total surface discharge (Q) based on a simple factor (F_{DRO}) and can be expressed as:

$$DRO = P_R \times F_{DRO}.$$

The rainfall that does not runoff directly becomes storage as described in subsequent sections.

The amount of snowmelt (SM) that occurs in a given month is calculated as a fraction (SMF) of the existing snowpack (SS) based on the mean monthly temperature, snow and rain temperature thresholds, and a maximum snowmelt rate ($meltmax$). This is calculated as follows:

$$SMF = \frac{T - T_{snow}}{T_{rain} - T_{snow}} \times meltmax.$$

If the calculated snowmelt fraction is greater than $meltmax$ and less than one, then SMF is set to $meltmax$. If the calculated snowmelt fraction is greater than one, then SMF is set to one. The use of one as a possible snowmelt fraction is a slight deviation from the USGS method, but otherwise the calculation is as taken from McCabe and Markstrom (2007). Allowing the snowmelt fraction to be set to one forces the remaining snowpack to melt in June, otherwise a minor fraction would remain throughout the year.

The snowmelt (SM) is then computed as:

$$SM = SMF \times (SST_{i-1} + P_S).$$

A portion of the snowmelt (SM) becomes direct runoff ($DSRO$) while the remainder goes into soil moisture storage (ST). The amount that runs off directly ($DSRO$) is calculated using the adjustable direct snowmelt runoff factor (F_{DSRO}) as follows:

$$DSRO = F_{DSRO} \times SM.$$

3.2.4 EVAPOTRANSPIRATION, SUBLIMATION AND SOIL-MOISTURE STORAGE

Evapotranspiration used in the model is taken from the potential evapotranspiration (PET) measured on site from May 2016 through September 2016 (AEG, 2016a). PET is modelled using a Penman-Monteith equation written directly into the meteorological station program code. The calculation is premised on a flat grassland site, and adjusted evaporation pan data from the Project agree with these values (AEG, 2016a). However, as this equation is based on vegetation specific parameters it may not be entirely appropriate for the northern location of the Project. Although the total value of PET may vary from year to year, it is reasonable to assume the monthly distribution is similar between years, and therefore actual evapotranspiration (AET) may be calculated from the measured PET. The AET and sublimation values used in the model for KZ-9 are shown in Table 3-3.

Table 3-3: Actual Evapotranspiration and Sublimation used in the Model

	Month											
Water losses	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Annual**
AET (mm)	0	0	0	0	0	0	0	37.2	46.7	33.7	26.2	14.8	159
Sublimation (mm)	4.3	4.2	4.3	4.3	3.9	4.3	4.2	0	0	0	0	0	30

The USGS Thornthwaite Monthly Water-Balance model approach to calculating AET was incorporated into the model, but the method overestimated . Therefore, PET was adjusted by a simple factor (F_E) in order to balance the model during calibration. The USGS method is described below.

AET is equal to the total soil water input (P_{total}) plus the amount of soil water that can be withdrawn from the water already stored in the soil. The soil storage withdrawal (STW) is dependent on the ratio of the volume in storage to the soil storage capacity (STC), computed as follows:

$$STW = ST_{i-1} - \left[abs(P_{total} - PET) \times \left(\frac{ST_{i-1}}{STC}\right)\right],$$

where ST_{i-1} is the soil-moisture storage from the previous month. When PET is less than STW, AET is equal to PET. PET is less than the soil storage withdrawal in all months such that PET is adjusted by a factor (F_E); otherwise AET is too high to allow the model to balance.

Sublimation was calculated as a simple mm per day factor (F_{SUB}). The factor was calibrated by altering it until the model produced a total snowpack volume at the end of March comparable to that observed in 2016.

Soil moisture storage (ST) is calculated as the sum of the total inputs from rainfall (P_{rain}) and snowmelt (SM), minus their direct runoff components, cumulatively P_{total}, added to the storage from the previous month (ST_{i-1}), minus the outputs of baseflow (BF), groundwater flow (GW), AET, and surplus discharges (SRO). This can be represented with the following equation:

$$ST = ST_{i-1} + P_{total} - AET - BF - GF - SRO,$$

where P_{total} is calculated as:

$$P_{total} = P_{rain} - DRO + SM - DSRO.$$

Soil moisture storage capacity (STC) is one of the adjustable parameters used to alter the distribution of runoff to fit the observed distribution and affects winter baseflow. The surplus runoff (SRO) simply takes the soil storage (ST_{i-1}) at the end of the previous month and assumes all water above the STC is discharged in the following month. Values for STC in the model range from 80 mm to 120 mm.

3.2.5 GROUNDWATER AND BASEFLOW

Groundwater and baseflow discharge from any given catchment is calibrated by an empirical factor (F_{GW} and F_{BS}, respectively) multiplied by the soil storage at the end of the previous month (ST_{i-1}). These factors are held constant for modelling other scenarios, but calibrated for each site. This simplistic approach is considered appropriate in the absence of measured data.

EBA has indicated that groundwater flow through the alluvium at the KZ-9 site on Geona Creek can be modelled at approximately 700 m^3/day, which works out to approximately 15 mm/year of subsurface groundwater flow past KZ-9 (Gutmann, pers. comm., 2016). This information was used to calibrate the model parameters at the KZ-9 site, and the assumption was then made that groundwater flows would be similar for other sites, but increasing with catchment size. The larger unit runoffs observed in higher elevation catchments cannot be explained entirely by increasing precipitation, which supports this assumption.

Baseflow also helps to retard the movement of water through the catchment by limiting a specific fraction of the stored water to runoff in any given month. This implies that the greater the soil moisture, the greater the baseflow. Groundwater flow is calculated in the same way by limiting groundwater flow to a specific fraction of available storage, but allowing for higher groundwater flow when there the storage volume is higher. This approach is based on the fact that as soil gets wetter, more area becomes saturated and more preferential pathways become active and subsurface flow increases. The baseflow and groundwater factor approach allows the model to predict discharge through the winter as soil moisture storage is slowly depleted.

3.2.6 RUNOFF

Runoff or Surface water discharge (Q) is the sum of the direct rainfall (DRO), snowmelt ($DSRO$), baseflow (BF), and the surplus from soil water storage (SRO) and can be expressed as follows:

$$Q = DRO + DSRO + BF + SRO.$$

This is a simplified version of the USGS Thornthwaite model equation as it does not use an *rfactor* to carry some of the surplus over to the next month. The *rfactor* is simply a multiplier between 0 and 1 that the month end surplus (or storage in this model) is multiplied by to determine the portion which becomes runoff versus the volume that goes back into storage. The *rfactor* is replaced by the baseflow and groundwater factors in the current model which perform a similar function.

3.3 ASSUMPTIONS AND LIMITATIONS

Modelling exercises are always a simplification of reality and, as such, must include some assumptions. The key assumptions made in the above described model are as follows:

- Each sub-watershed is unique and therefore requires its own inputs and calibration of components including precipitation (P_T), evapotranspiration factor (F_E), temperature thresholds (T_{rain} and T_{snow}), melt factor ($meltmax$), soil storage capacity (STC), baseflow factor ($F_{BS)}$, direct runoff factor (F_{DRO}), snowmelt runoff factor (F_{DSRO}), and groundwater runoff factor (F_{GW}) may vary for each catchment;
- Calibrated parameters remain constant across modelled scenarios (mean, 1/50 wet, and 1/10 dry precipitation years);
- Mean monthly temperature is similar for all catchments;
- Groundwater discharge is approximately 15 mm per year at KZ-9. Discharge will increase slightly but remain similar for downstream sites and decrease at smaller, higher elevation sites;
- Mean annual precipitation increases/decreases at a rate of 9 mm per 100 m;
- Sublimation is relatively similar from location to location and between modelled scenarios;
- Catchments truncated by the Project footprint in upper Geona Creek (above KZ-9) can be assumed to exhibit similar behaviour as their non-truncated baseline condition; and
- All water leaving the water management area of upper Geona Creek is conveyed as diversion flows or managed discharge from the water management ponds as provided by AEG (AEG, 2016b).

The model is dependent on the data available to calibrate and run it, and the following limitations should be taken into consideration when evaluating the model:

- Regional data are sparse so there is moderate confidence in the mean values derived from regional monitoring stations; the fact that estimates are developed from regional and site data in a hybrid approach reflects the need for continuing the data collection currently taking place on site;
- Model calibration is based on one year of site data and not multiple years approaching average conditions, and therefore the model should be updated as on site data collection continues;
- Many model parameters have a physical measurement basis, but are empirically derived through calibration as opposed to being measured. While the inputs and outputs controlling them were measured directly, empirically derived parameters lend greater uncertainty to the resulting model outputs; and
- Because there is only one year of data, the antecedent conditions are not known. The model calibration is run for three years using the same calibration data to give it some run in; however, a slightly different calibration may be achieved once multiple years of site data are collected.

3.4 MODEL CALIBRATION AND CALCULATIONS

For the majority of sites the watershed model is calibrated using the corrected monthly precipitation totals and derived runoff from continuous field monitoring stations (AEG, 2016a). KZ-17 was calibrated based on a synthetic time series of KZ-15 less KZ-16 and KZ-18 assumed the same calibration as KZ-9. KZ-37 is simply the addition of KZ-9 and KZ-18. Precipitation inputs for each catchment are adjusted for elevation by 9 mm per 100 m while temperature, as measured at the meteorological station, is assumed to be representative of the entire Project area. Discharge data from each location, as measured from October, 2015 through September, 2016, are used to calibrate the model with regard to total runoff for the twelve-month water year and the monthly distribution of those flows.

The first step in the calibration process was to set the parameters to average values as per McCabe and Markstrom (2007). Following that, the groundwater component was set to give an annual total of roughly 15 mm at KZ-9, and slightly higher or lower at other sites. The sublimation was set such that the modelled snowpack at the end of March was similar to that observed in 2016. In the next step the AET-PET factor (F_E) was adjusted until the total runoff of the last 12 months of the model run was +/- 2 mm of the measured total. The seven other parameters (STC, F_{BS}, F_{DRO}, F_{DRSO}, T_{rain}, T_{snow}, $meltmax$) were then adjusted until the modelled distribution achieved the closest fit to the measured distribution, followed by a return to the groundwater and evapotranspiration factors and adjusting them again as necessary to balance with observed runoff.

Once the best fit is achieved, the same configuration is applied to the estimated mean annual precipitation and the model is again run for three years. The 1/50 wet scenario and the 1/10 dry scenario are run with the preceding month as the last month (September) of the mean scenario. This effectively gives them a three year mean conditions run-in. The values reported from the wet and dry scenarios are from May to October. The reported values, then, are preceded by the wet or dry winter snowfall and are the results from the following May through

October such that the impact of high or snowfall are realized and the impact of a wet or dry summer are reflected in the winter baseflow.

To model the runoff in catchments truncated by the Project footprint a new area and median elevation were determined with the footprint removed. The truncated catchments use the same parameter calibration as the undisturbed catchments, but the precipitation is adjusted based on the new median catchment elevation.

Table 3-4 lists the sites which were modelled (Figure 3-2). Most of the sites are those which have hydrometric stations measuring stage at thirty minute intervals and therefore a continuous time series of derived discharge. KZ-17 is calculated as the difference between KZ-15 and KZ-16 (Finlayson Creek upstream of Geona Creek) due to the lack of a suitable site for a hydrometric station near the mouth of Geona Creek. KZ-18 is located near the mouth of the unnamed tributary immediately downstream of KZ-9 and is therefore assumed to be similar to KZ-9 for modelling purposes, using the same parameters but with precipitation input varied according to the catchment median elevation. KZ-37 is simply the addition of KZ-9 and KZ-18.

Table 3-4: Monitoring Stations Modelled Using the Watershed Model

Site	Description	Area (km^2)	Median Elev. (masl)
KZ-2	Fault Creek	1.9	1,708
KZ-9	Geona Creek below Project Footprint	16.5	1,497
KZ-18	Geona Creek Tributary adjacent to KZ-9	5.3	1,499
KZ-37	Geona Creek below confluence of KZ-9 and KZ-18	21.8	-
KZ-17	Geona Creek at the Mouth	25.7	1,479
KZ-15	Finlayson Creek below Geona Creek	60.9	1,495
KZ-22	Finlayson Creek below East Creek	162.5	1,359
KZ-26	Finlayson Creek at Robert Campbell Highway	210.8	1,291
KZ-13	South Creek	7.9	1,540

3.5 DEWATERING

The pre-mining construction phase will include dewatering of the area encompassing the proposed ABM open pit and the diversion of surface areas, including Fault Creek, which would drain into the ABM open pit into South Creek (Figure 2-3) (KP 2016). Dewatering pump rates were defined based on the Hydrogeology Report and in consultation with EBA (Table 3-5) (EBA, 2016). Dewatering is planned to occur over 18 months and initial rates will be at a high rate, decreasing to a steady rate which will be maintained for the following year while construction and the pre-stripping of overburden occurs. The estimated downstream discharges were modelled for the period of dewatering with an assumed starting month of July, for the mean, the 1/50 wet, and the 1/10 dry precipitation years. This period is modelled as a truncated catchment without the South Diversions and ABM open pit area but with additions from dewatering. Dewatering is defined as occurring over Year -2 and Year -1.

Table 3-5: Dewatering Rates (m^3/day) for ABM Open Pit Overburden During Construction

Month	Mean Rate (m^3/d)
1	17,700
2	8,500
3	7,367
4	5,525
5	4,142
6-18	3,600

3.6 OPERATIONS

Mine operations are defined as occurring in years 1 through 10. The magnitude of the impact of operations on the receiving environment will increase over that period until a peak in year 10. For simplicity, the operations water balance is modelled for full operations at year 10.

Mine operation discharges were determined by adjusting the mine footprint surplus volumes provided by KP, based on the proposed water management activities (AEG, 2016b). The details of the mine water balance for operations are included in KP's Mine Water Balance report where surplus water volumes during Year 10 operations were estimated for the mean, the 1/50 wet, and the 1/10 dry years (KP, 2016). Surplus water volumes are the monthly volumes which reach the lower water management pond on a monthly basis.

Fault Creek at site KZ-2 is unaffected by the Project at the measurement point; however, the catchment is proposed to be diverted into South Creek below KZ-2. The discharge at KZ-13 in South Creek is calculated as the discharge estimated for the baseline scenario plus the South Diversions, less the drawdown from the ABM open pit provided by KP (KP, 2016b) and EBA (EBA,2016), respectively.

Sites downstream of the Project are affected directly by the water management area. They will have additional inputs of the dewatering pumping rates, but flows will also be reduced by the amount diverted to South Creek. Runoff during operations was modelled at sites KZ-9, KZ-18, KZ-37, KZ-13, KZ-15, KZ-17, KZ-22, and KZ-16.

To model operations, monthly water volumes were provided by KP, which were redistributed over the calendar year by AEG (KP, 2016a and AEG, 2016b). Surplus water will be discharged in Geona Creek at KZ-9 and Finlayson Creek at KZ-15. Additionally, KP provided North and South Diversion discharge estimates (KP, 2016b). The North Diversions are those areas above the Project footprint which will be diverted with drainage ditches to minimize the volume of water entering the Project footprint with an assumed efficiency of 50% and the runoff from the Class C and overburden storage facilities (Figure 2-3) (KP, 2016b). The receiving environment water balance was modelled using the same parameters determined in calibration, but with precipitation input adjusted based on the median elevation of each catchment without the Project footprint. The flow volumes were then calculated using the new truncated catchment areas. The North Diversion volumes and the monthly surplus volumes were added to modelled runoff as determined in the water balance report (AEG, 2016b) to model flow during full operational conditions for the mean, the 1/50 wet, and the 1/10 dry scenarios.

3.7 CLOSURE

Closure is subdivided into the three main periods, Active Closure, Transition Closure and Post Closure.

Active Closure occurs in years 11 to 13 at which time operations have ceased, equipment and infrastructure are removed or decommissioned, and the South Diversions are removed allowing the ABM open pit to begin filling. Active Closure is modelled by again applying the came calibration parameters to truncated catchments. The catchments are modelled without the area of the ABM open pit and area draining into the pit (Fault Creek and the South Diversions). The North Diversions are still in place at the beginning and directing water below the Lower Water Management Pond, but removed prior to Post Closure.

Transition Closure occurs from years 14 to 26, during which time the ABM open pit continues filling and storage facility covers are in place. Although discharge will change over this period as storage facility covers become more mature and the ABM Lake nears static water surface level, one example year is modelled with the assumption of no contributions from the ABM Lake, Fault Creek and South Diversions. However, the ABM Lake will begin to contribute to downstream discharge via overburden drainage towards the end of the Transition Closure phase. The catchments continue to be modelled as truncated catchments without the ABM open pit and its drainage area. During this period the Geona Creek upper watershed is assumed to have returned to near baseline hydrological conditions but with the addition of two engineered wetlands, one in the location of the Lower Water Management Pond and a second at the outlet of ABM Lake (Figure 2-3).

The Post Closure period begins when the ABM Lake is full and begins to discharge to Geona Creek via the surface. At this time the catchments are assumed to return to baseline conditions, but with additional contributions from deep water via the ABM Lake of 1,225 (m^3/d). Additionally, the area of the ABM Lake is removed from the catchment total areas and modelled as a specific unit, given that precipitation will occur directly to the lake and evaporation values will be larger. The volumes added to or removed from the ABM Lake are then added to the modelled volumes at downstream locations. The model results are for year 30 onward when the system will be stabilized. The period between the modelled closure transition and post closure results will be a gradual transition, but the transition is not modelled as the uncertainty in the progression of timing is much higher than the final result.

4. RESULTS

4.1 CALIBRATION

Achieving model agreement with total measured flow volumes for the twelve-month calibration period was straight forward. AET and groundwater flow were adjusted until the runoff balanced with observed values from September 2015 through August 2016. Getting the modelled distribution to agree with the observed distribution involved changing the various model parameters to store and release water as appropriate. The snowfall to rainfall ratio could be altered slightly, but it was found that the same values could be used for all sites. Table 4-1 lists the parameters used for each site while Table 4-2 lists the calibrated model runoff and measured runoff for each site.

Table 4-1: Calibrated Parameters Used in the Watershed Model

Site ID	T_{rain}	T_{snow}	*meltmax*	*STC*	F_{BS}	F_{DRO}	F_{E}	F_{DRSO}	F_{GW}	F_{SUB}	F_{PW}
KZ-2	3.30	-1	0.6	100	0.3	0.18	0.32	0.7	0.01	0.14	3/1.5
KZ-9	3.30	-1	0.5	110	0.28	0.18	0.44	0.5	0.02	0.14	-
KZ-18	3.30	-1	0.5	110	0.28	0.18	0.44	0.5	0.02	0.14	-
KZ-17	3.30	-1	0.55	80	0.25	0.18	0.66	0.32	0.02	0.14	-
KZ-15	3.30	-1	0.6	95	0.25	0.16	0.61	0.4	0.05	0.14	-
KZ-22	3.30	-1	0.55	100	0.25	0.12	0.72	0.3	0.03	0.14	-
KZ-26	3.30	-1	0.5	90	0.25	0.12	0.79	0.3	0.03	0.14	-
KZ-13	3.30	-1	0.7	120	0.3	0.2	0.32	0.53	0.02	0.14	-

Table 4-2: Calibrated Model versus Measured Monthly Discharge (mm) for Kudz Ze Kayah Catchments, October 2015 through September 2016

Site		Month												Total
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	
KZ-2	**Observed**	40.3	17.5	9.7	8.3	5.2	4.2	4.0	126.6	84.8	50.1	107.1	91.5	549.3
	Modelled	21.8	15.1	10.4	7.2	4.9	3.4	27.5	115.7	92.4	46.1	107.0	96.9	548.3
	% difference	-45.9	-13.9	6.7	-14.1	-4.9	-18.2	581.0	-8.6	9.0	-8.0	-0.1	5.9	-0.2
KZ-9	**Observed**	27.0	13.7	10.9	7.6	5.8	4.7	6.0	26.7	30.2	27.5	41.6	74.8	276.5
	Modelled	22.8	16.0	11.2	7.8	5.5	3.8	7.0	27.4	26.3	26.9	47.0	73.7	275.4
	% difference	-15.5	16.6	2.5	2.3	-5.3	-18.8	17.3	2.6	-12.9	-2.2	12.9	-1.4	0.4
KZ-17	**Observed**	13.5	10.3	7.4	5.4	4.6	5.2	6.0	23.4	20.6	20.1	37.7	71.4	225.6
	Modelled	13.6	9.9	7.2	5.3	3.9	2.8	5.4	22.7	16.5	27.0	40.4	71.3	225.9
	% difference	0.2	-3.6	-2.2	-2.5	-15.8	-46.0	-11.3	-3.3	-19.8	34.4	7.0	0.0	0.1
KZ-15	**Observed**	19.5	11.9	7.5	4.6	3.8	3.8	5.0	25.2	20.3	22.1	39.7	63.9	227.2
	Modelled	16.4	11.5	8.1	5.6	3.9	2.8	6.0	25.1	17.7	24.2	39.5	66.2	227.1
	% difference	-15.7	-3.1	7.1	23.2	3.1	-27.8	20.9	-0.2	-12.4	9.4	-0.4	3.5	0.1
KZ-22	**Observed**	21.7	12.7	8.3	6.1	5.0	5.2	7.8	16.0	12.2	16.3	31.7	50.4	193.5
	Modelled	18.1	13.0	9.4	6.7	4.9	3.5	5.3	19.0	13.7	17.9	32.4	50.2	194.0
	% difference	-16.6	2.5	12.2	10.5	-3.5	-32.7	-32.7	19.0	12.1	9.5	2.1	-0.2	0.3
KZ-26	**Observed**	23.2	8.3	2.5	3.4	4.7	4.7	7.6	14.3	13.1	18.2	30.2	44.5	174.6
	Modelled	15.7	11.3	8.2	5.9	4.2	3.0	4.7	17.7	12.0	16.8	29.8	44.8	174.3
	% difference	-32.1	36.1	232.6	72.4	-9.7	-35.8	-37.8	24.0	-7.9	-7.4	-1.2	0.7	0.2
KZ-13	**Observed**	30.8	18.0	12.2	6.1	3.2	2.7	23.2	34.8	31.4	26.0	43.6	90.0	322.2
	Modelled	26.2	17.8	12.1	8.3	5.6	3.8	8.7	35.0	25.7	34.3	56.5	87.0	321.2
	% difference	-14.8	-0.9	-0.4	35.5	77.3	41.0	-62.4	0.5	-18.3	31.7	29.5	-3.4	0.3
Mean % Difference		-20.0	4.8	36.9	18.2	5.9	-19.8	67.9	4.9	-7.2	9.6	7.1	0.7	-

Figure 4-1 displays a bar graph of monthly discharge in millimeters at KZ-9 as an example. Most sites show reasonably similar agreement with the measured flows; however, some months did not compare quite as well: at sites KZ-2 and KZ-13 (Table 4-2).

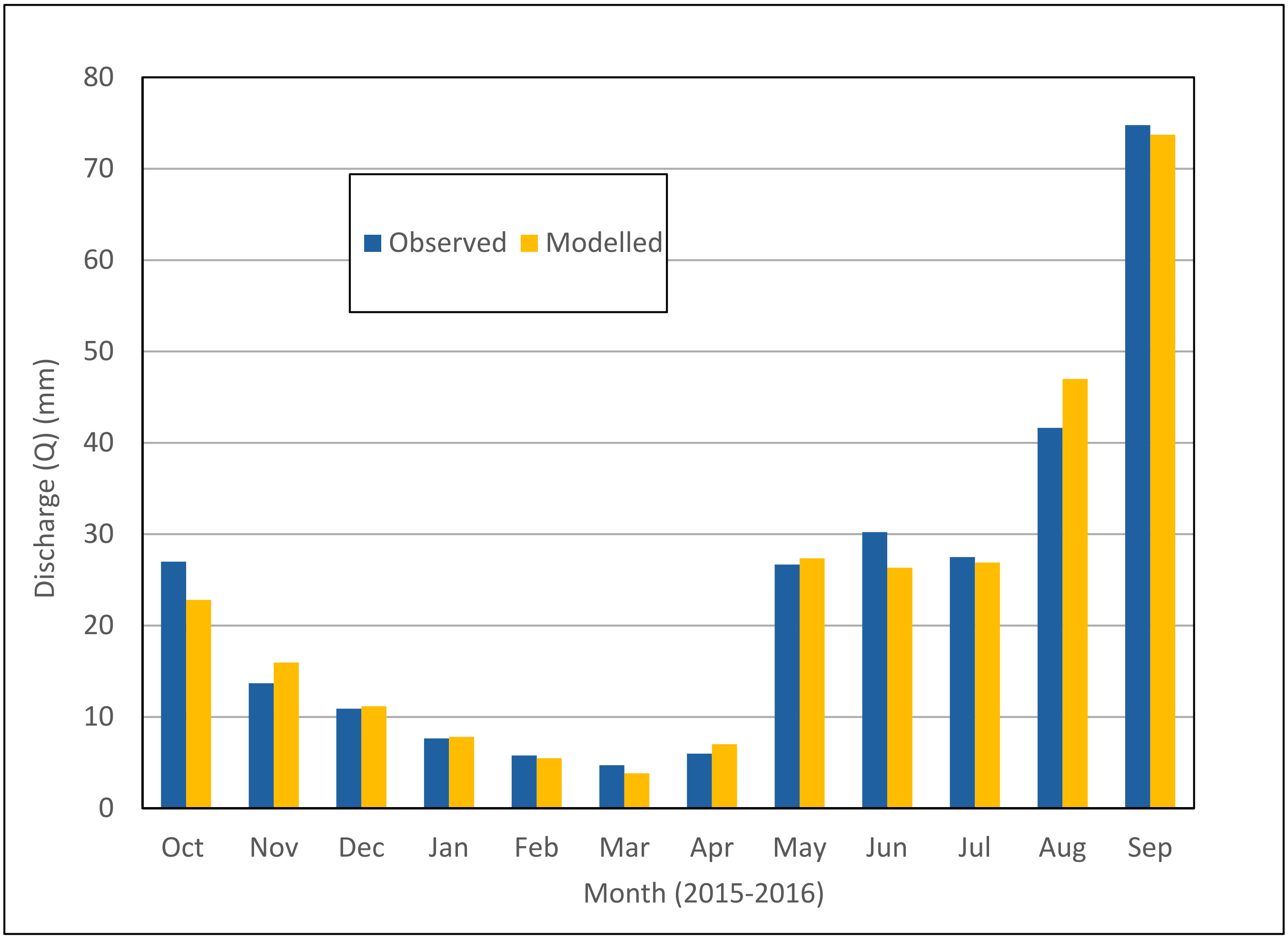

Figure 4-1: Modelled and Measured Monthly Discharge (mm) at KZ-9 October 2015 through September 2016

The average difference between modelled and observed monthly discharge was greatest in April. Although skewed by KZ-2, there are a number of factors (Table 4-2). First, the uncertainty in the observed flow is much higher in April, especially in 2016 when a warm spring caused early melt. April typically experiences increasing discharge prior to complete ice-out, so stage records are uncertain and often approximated based on visual inspection of the logger data and discrete measurements. A second factor is the impact of site aspect on snow melt which is not accounted for in the model. Snow distribution and melt are very difficult processes to model effectively and are therefore modelled by temperature which is assumed to be constant across all sites, ignoring the effects of site aspect. KZ-2 is at a higher elevation and its steep slopes likely shade the catchment from low angle sun. KZ-13 is a mostly southern aspect while the other sites are northern so increased solar insolation may drive earlier and more dramatic spring snowmelt. A third factor is uncertainty in snowfall data; precipitation gauges experience higher undercatch of snowfall in comparison to rainfall due to more the significant effects of wind disturbance. Underestimation of winter precipitation could lead to poorer model performance in the months following snowmelt, as soil moisture storage is under represented leading to higher direct runoff rates in the model than in reality to compensate for the lack of snowmelt inputs. Winter low flow periods can also be a challenge to model, but the model generally showed quite good agreement across sites with the exception of KZ-26. Winter discharge measurement is problematic at KZ-26, complicated by road culverts which freeze and cause a damming effect with significant ice buildup above the Robert Campbell Highway and low water levels on the downstream side. It is likely that the modelled flows are more representative of the baseline state in the winter months than the measured flows given the site conditions.

Fault Creek (KZ-2) is problematic in that much higher runoff than seems possible is observed at this site. However, observations by field personnel suggest that the steep gradients within the catchment and high wind velocities at the site may be responsible for significant lateral snow transport and surplus deposition into the catchment. As such, the winter precipitation (October through April) was adjusted by a factor (F_{PW}) of 3 in order to balance the model. However, the particularly dry winter of 2015/2016 may have caused an overestimation of the value of this factor. Therefore, the winter precipitation factor was reduced to 1.5 for the model runs to bring the precipitation and the discharge volumes to a more realistic value. The input uncertainties at KZ-2 make the site particularly difficult to model.

4.2 BASELINE SCENARIOS

Baseline scenarios include model runs for the mean predicted precipitation, the 1/50 wet year, and the 1/10 dry year. As described above, the median model results are preceded by two years of run-in while the wet and dry scenarios are preceded by three mean years of run-in to ensure model stability. Table 4-3, Table 4-4, and Table 4-5 present the results of the modelled monthly runoff at each site in millimetres (mm) for the predicted mean annual precipitation, 1/50 wet precipitation year, and 1/10 dry precipitation year, respectively. Monthly and annual volumes in cubic meters are included in Appendix A.

Site	Month												Total
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	
KZ-2	32.8	20.5	14.1	9.8	6.7	4.6	63.8	236.4	242.1	133.0	83.5	91.1	938.4
KZ-9	30.3	21.2	14.9	10.4	7.3	5.1	27.5	104.1	141.9	151.9	59.8	79.0	653.4
KZ-18	30.3	21.2	14.9	10.4	7.3	5.1	27.5	104.1	142.0	152.0	59.8	79.0	653.6
KZ-17	27.7	14.2	10.4	7.6	5.5	4.0	20.1	79.7	168.5	125.0	48.2	63.7	574.5
KZ-15	26.3	16.5	11.5	8.1	5.6	4.0	25.5	98.1	151.8	102.9	53.9	64.3	568.5
KZ-22	26.6	17.9	12.9	9.3	6.7	4.8	18.9	71.7	137.3	119.7	39.6	60.1	525.4
KZ-26	24.7	16.1	11.6	8.3	6.0	4.3	17.1	65.8	126.5	128.7	33.7	50.9	493.7
KZ-13	35.6	24.2	16.5	11.2	7.6	5.2	38.4	141.5	145.8	108.3	84.9	83.1	702.5

Table 4-3: Modelled Monthly Runoff (mm) at Monitoring Locations for the Predicted Mean Annual Precipitation

Site	Month												Total
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	
KZ-2	27.8	19.2	13.2	9.1	6.3	4.3	44.9	165.7	139.1	80.9	53.0	58.3	622.0
KZ-9	27.8	19.5	13.6	9.5	6.7	4.7	19.7	73.2	90.6	54.2	44.6	44.3	408.4
KZ-18	27.8	19.5	13.6	9.5	6.7	4.7	19.7	73.2	90.6	54.3	44.6	44.3	408.6
KZ-17	17.4	12.7	9.3	6.8	4.9	3.6	14.4	56.1	74.3	72.3	30.5	28.1	330.4
KZ-15	20.2	14.2	9.9	6.9	4.9	3.4	18.0	68.7	68.1	49.2	33.8	32.3	329.6

Site	Month												Total
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	
KZ-22	19.3	13.9	10.0	7.2	5.2	3.7	13.3	50.5	59.3	49.9	30.2	28.2	290.7
KZ-26	15.9	11.5	8.3	5.9	4.3	3.1	11.8	46.3	58.7	45.4	26.9	24.4	262.5
KZ-13	32.6	22.2	15.1	10.3	7.0	4.7	27.1	98.9	77.7	52.0	54.3	52.3	454.2

Table 4-4: Modelled Monthly Runoff (mm) at Monitoring Locations for the Predicted 1/50 Wet Annual Precipitation

Site	Month												Total
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	
KZ-2	32.8	20.5	14.1	9.8	6.7	4.6	63.8	236.4	242.1	133.0	83.5	91.1	938.4
KZ-9	30.3	21.2	14.9	10.4	7.3	5.1	27.5	104.1	141.9	151.9	59.8	79.0	653.4
KZ-18	30.3	21.2	14.9	10.4	7.3	5.1	27.5	104.1	142.0	152.0	59.8	79.0	653.6
KZ-17	27.7	14.2	10.4	7.6	5.5	4.0	20.1	79.7	168.5	125.0	48.2	63.7	574.5
KZ-15	26.3	16.5	11.5	8.1	5.6	4.0	25.5	98.1	151.8	102.9	53.9	64.3	568.5
KZ-22	26.6	17.9	12.9	9.3	6.7	4.8	18.9	71.7	137.3	119.7	39.6	60.1	525.4
KZ-26	24.7	16.1	11.6	8.3	6.0	4.3	17.1	65.8	126.5	128.7	33.7	50.9	493.7
KZ-13	35.6	24.2	16.5	11.2	7.6	5.2	38.4	141.5	145.8	108.3	84.9	83.1	702.5

Table 4-5: Modelled Monthly Runoff (mm) at Kudz Ze Kayah Monitoring Locations for the Predicted 1/10 Dry Annual Precipitation

Site	Month												Total
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	
KZ-2	25.9	17.9	12.3	8.5	5.9	4.0	35.9	132.1	109.2	39.9	39.6	40.8	471.9
KZ-9	19.2	13.4	9.4	6.6	4.6	3.2	15.1	58.5	70.0	34.1	32.1	30.5	296.8
KZ-18	19.2	13.5	9.4	6.6	4.6	3.2	15.1	58.5	70.1	34.1	32.1	30.5	296.9
KZ-17	11.6	8.5	6.2	4.5	3.3	2.4	10.9	44.9	50.3	29.9	24.8	20.8	218.1
KZ-15	11.9	8.3	5.8	4.1	2.9	2.0	13.6	54.7	51.5	26.5	23.0	21.2	225.6
KZ-22	10.2	7.3	5.3	3.8	2.7	2.0	9.7	40.4	44.1	24.2	19.4	17.0	186.1
KZ-26	6.7	4.8	3.5	2.5	1.8	1.3	8.4	37.0	43.3	21.2	15.8	13.0	159.4
KZ-13	23.8	16.2	11.0	7.5	5.1	3.5	21.0	78.6	60.2	38.3	37.7	37.6	340.4

The total annual modelled runoff is compared to those estimates produced through regional analysis in the Hydrometeorology Baseline Report, (AEG, 2016a), to assess the model performance. Table 4-6 compares the modelled total annual runoff for the mean, 1/50 wet, and 1/10 dry annual precipitation scenarios in comparison to the totals predicted through regional analysis. In general, the mean and 1/50 wet year modelled flows are greater than those predicted by regional analysis (Table 4-6). The exception is the mean for KZ-15 and KZ-17 which are approximately 15% and 12% lower, respectively. Low flows were lower than those predicted by regional analysis across at all sites except KZ-13. This is most likely due to the greater variation in the wet and dry precipitation return period than that of the regional hydrometric wet and dry year return periods (AEG, 2016a). The larger regional catchments may have a greater dampening capacity than the small catchments modelled here. The model is considered the best estimate in this case.

Table 4-6: Modelled Total Annual Runoff (mm) at Monitoring Locations for Various Precipitation Scenarios Compared to the Total Annual Runoff (mm) Predicted Through Regional Analysis

Site	Mean			1/50 Wet			1/10 Dry		
	Model	Regional	Difference (%)	Model	Regional	Difference (%)	Model	Regional	Difference (%)
KZ-2	622	610	1.9%	938	824	13.9%	472	482	-2.1%
KZ-9	408	388	5.3%	653	524	24.8%	297	306	-3.1%
KZ-18	409	390	4.9%	654	526	24.3%	297	308	-3.5%

Site	Mean			1/50 Wet			1/10 Dry		
	Model	Regional	Difference (%)	Model	Regional	Difference (%)	Model	Regional	Difference (%)
KZ-17	330	373	-11.5%	574	504	14.0%	218	295	-26.0%
KZ-15	330	386	-14.7%	568	521	9.0%	226	305	-26.1%
KZ-22	291	288	0.8%	525	389	35.0%	186	228	-18.3%
KZ-26	262	249	5.4%	494	336	46.8%	159	197	-19.0%
KZ-13	454	425	6.8%	702	574	22.3%	340	336	1.3%
Mean	-	-	-0.1%	-	-	23.8%	-	-	-12.1%

The modelled mean predictions agree well with the regional data at all sites except KZ-15, and KZ-17. Measured discharge at these sites also fell below the exponential trend used to predict the flows in the regional analysis so this is not an unexpected result (AEG, 2016a). The 1/50 wet year model results were higher at all sites, but particularly at KZ-22 and KZ-26. It may be that evapotranspiration and sublimation are higher in wet years and this is not adequately represented in the model. Additionally, the precipitation factor for the 1/50 wet year was much higher than the factor for the runoff data so the difference is not unexpected. Most sites were predicted to have lower runoff in a 1/10 dry year than predicted by the regional data. Again, this is mainly due to the difference in the factors applied to predicting the precipitation versus the runoff. However, the model does not increase or reduce AET and sublimation in wet and dry years which may also contribute to the under and over prediction of wet and dry as compared to regional analysis. Additionally, the snowfall measured in 2015 through 2016 was lower than modelled in a 1/10 dry year, which may be leading to estimates of sublimation that are lower than the actual values. Table 4-7 shows the modelled mean monthly runoff versus that predicted through regional analysis.

Table 4-7: Modelled Versus Regionally Derived Discharge Prediction (mm) for Kudz Ze Kayah Catchments

Site		Month												Total
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	
KZ-2	**Regional**	49	27	18	13	10	10	12	129	129	78	64	71	610
	Model	28	19	13	9	6	4	45	166	139	81	53	58	622
	% difference	-43	-28	-26	-30	-38	-58	275	29	7	3	-17	-18	2
KZ-9	**Regional**	31	17	11	8	6	7	8	82	82	50	41	45	388
	Model	28	19	14	10	7	5	20	73	91	54	45	44	408
	% difference	-11	16	21	16	3	-29	158	-11	10	9	9	-1	5
KZ-15	**Regional**	31	17	11	8	6	7	8	82	82	50	41	45	386
	Model	20	14	10	7	5	3	18	69	68	49	34	32	330
	% difference	-35	-16	-12	-16	-25	-49	137	-16	-17	-1	-17	-28	-15
KZ-17	**Regional**	30	16	11	8	6	6	7	79	79	48	39	43	373
	Model	17	13	9	7	5	4	14	56	74	72	30	28	330
	% difference	-42	-22	-15	-15	-21	-43	96	-29	-6	51	-22	-35	-11
KZ-22	**Regional**	23	13	8	6	5	5	6	61	61	37	30	33	288
	Model	19	14	10	7	5	4	13	50	59	50	30	28	291
	% difference	-17	11	19	17	7	-24	134	-17	-3	35	0	-15	1
KZ-26	**Regional**	31	17	11	8	6	7	8	81	81	49	40	44	383
	Model	16	11	8	6	4	3	12	46	59	45	27	24	262
	% difference	-48	-31	-26	-27	-33	-53	57	-43	-28	-8	-33	-45	-31
KZ-13	**Regional**	34	18	12	9	7	7	8	90	90	55	45	49	425
	Model	33	22	15	10	7	5	27	99	78	52	54	52	454
	% difference	-4	20	22	13	-2	-35	225	10	-14	-5	22	6	7
Mean % Difference		-29	-7	-2	-6	-16	-42	155	-11	-7	12	-8	-19	-6

While both the model and the regional analysis are informed by a combination of regional and site data, the model inputs are more directly based on the observed site data. The model benefits from concurrent site and regional meteorological data for the watershed model calibration, while concurrent site and hydrometric data were not available for regional analysis. The regional analysis did not have the benefit of concurrent hydrometric data. The monthly runoff distribution used in the hydrometeorology report was a hybrid based on the first year of hydrometric data and the regional data (AEG, 2016a). Though the differences between the modelled distribution and those estimated in the hydrometeorology report varied from site to site, there are some consistent differences.

April values at all sites differed the most between modelled and predicted. This is likely due to a combination of the difficulties associated with measuring stage accurately during ice cover, which mean derived discharge in April typically has higher uncertainty in all records, and the fact that April values can vary greatly from year to year depending on the timing and intensity of snowmelt. March displayed the next greatest variation due to the fact that runoff volumes are extremely low and these small volumetric differences translate into higher percentage differentials. October also proved somewhat problematic due to variation in the distribution between rain and snow and the degree of melt.

Figure 4-2 shows the modelled runoff compared to the predicted runoff using the site distribution applied in the hydrometeorology report and the regional distribution as an example (AEG, 2016a). Considering the limited data available for calibration, the monthly values agree quite well.

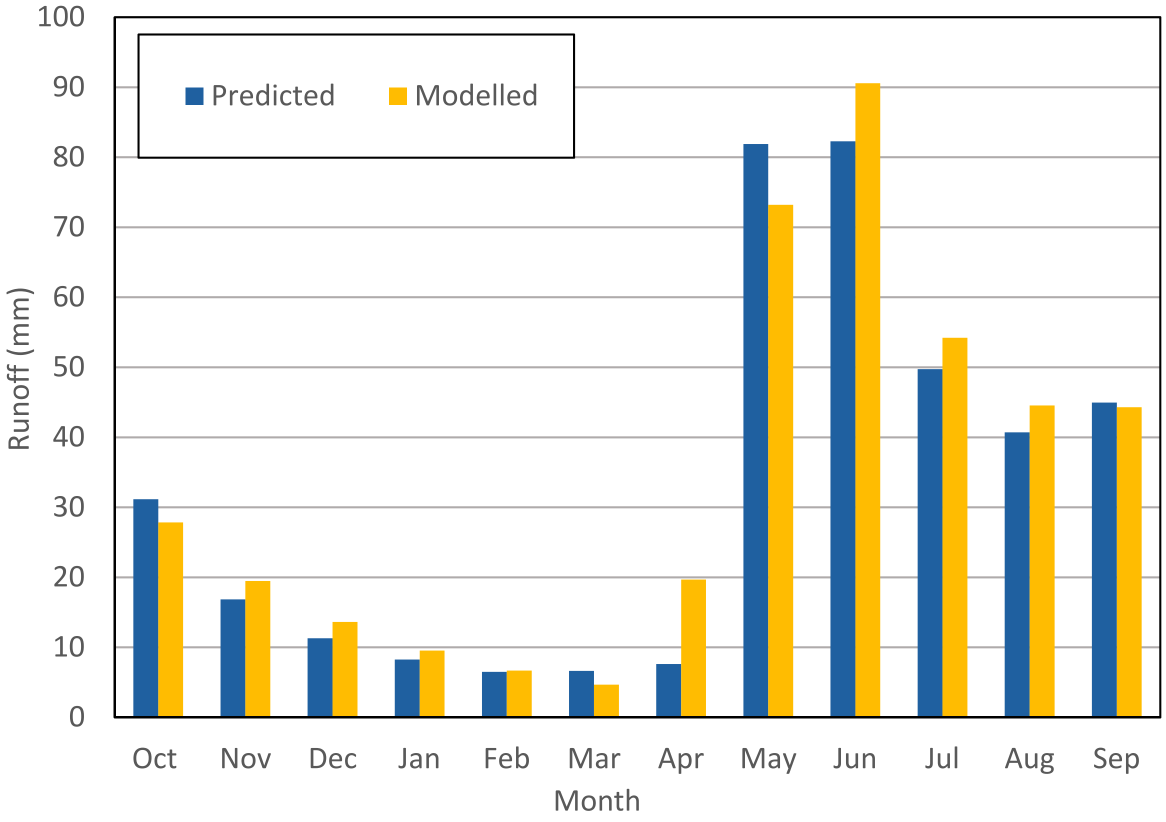

Figure 4-2: Modelled Mean Monthly Runoff at KZ-9 Compared to Predicted Using the Hybrid Distribution Selected for Predicting Mean Monthly Flows in the Hydrometeorology Baseline Report

4.3 DEWATERING

Baseline, dewatering (construction), operations and closure discharge estimates are presented in cubic meters in Appendix A owing to the volume of data. All values are in cubic meters to assist comparability across reports. EBA presented the dewatering estimates in the Hydrogeological Model Report (EBA, 2016), which were used to produce an 18-month dewatering rate as presented in Section 3 (Methods). Table A-6-4, Table A-6-5 and Table A-6-6 (Appendix A) present estimated runoff for the months in which dewatering occurs during Year -2 and Year -1, for the mean, 1/50 wet, and 1/10 dry years, respectively. The percentage difference in each month for the mean, the 1/50 wet and the 1/10 scenarios are presented in Table A-6-7, Table A-6-8, and Table A-6-9, respectively (Appendix A). At KZ-9 dewatering is predicted to result in a 25% increase in discharge over the 18-month period in the mean scenario, a 12% increase for the 1/50 wet scenario and a 64% increase in the dry scenario. The change decreases downstream as the relative volume of water flow in the channel increases, diluting the additional input. Dewatering is predicted to increase discharge at KZ-26 by 3% for the mean scenario. Dewatering rates were assumed to be the same in all scenarios, but the change is likely to be slightly more in the wet period and slightly less in the dry period as there will be more or less groundwater available according to differences in precipitation.

At KZ-13 (South Creek) discharge will also increase as a result of the construction of the South Diversions. Discharge is expected to be 33% higher for the 18-month period in the mean scenario, 35% in the wet scenario and 36% in the dry scenario. However, these modelled values are likely to be slightly exaggerated as drawdown from the small lakes at the top of South Creek (visible in Figure 2-3) will increase over the course of the dewatering and mining period. As such, this represents the maximum possible increase in runoff volumes above modelled baseline.

4.4 OPERATIONS

KP provided estimates of water volumes originating from the Project footprint during operations, including the North and South Diversions (KP, 2016). AEG determined monthly discharge volumes based on KPs results to meet water quality objectives (AEG, 2016b). These volumes are shown in tables Table 4-8, Table 4-9, and Table 4-10 for the mean, 1/50, and 1/10 years, respectively.

Table 4-8: Operations Discharges (m^3) during Mean Conditions

Month	South Diversions	North Diversions	Surplus Discharge to KZ-9	Surplus Discharge to KZ-15
Oct	94,000	89,000	78,000	310,000
Nov	51,000	44,000	49,000	205,000
Dec	34,000	30,000	34,000	145,000
Jan	25,000	23,000	24,500	100,000
Feb	20,000	17,000	17,250	70,000
Mar	20,000	17,000	13,750	52,000
Apr	23,000	38,000	47,000	255,000
May	247,000	321,000	235,000	999,500
Jun	248,000	334,000	270,000	949,000
Jul	150,000	186,000	158,000	730,000
Aug	123,000	156,000	130,000	515,000
Sep	135,000	164,000	133,000	500,000
Total	1,170,000	1,419,000	1,189,500	4,830,500

Table 4-9: Operations Discharges (m^3) during 1/50 Wet Year

Month	South Diversions	North Diversions	Surplus Discharge to KZ-9	Surplus Discharge to KZ-15
Oct	133,000	126,000	89,000	253,000
Nov	72,000	63,000	55,000	176,000
Dec	48,000	41,000	37,500	123,000
Jan	35,000	31,000	27,000	85,000
Feb	28,000	25,000	20,000	60,000
Mar	28,000	25,000	16,500	42,000
Apr	33,000	55,000	64,000	320,000
May	350,000	458,000	330,000	1,275,000
Jun	352,000	475,000	405,000	1,223,000
Jul	213,000	263,000	356,000	960,000
Aug	174,000	221,000	179,000	695,000
Sep	192,000	232,000	210,000	815,000
Total	1,658,000	2,015,000	1,789,000	6,027,000

Table 4-10: Operations Discharges (m^3) during 1/10 Dry Year

Month	South Diversions	North Diversions	Surplus Discharge to KZ-9	Surplus Discharge to KZ-15
Oct	75,000	71,000	72,000	330,000
Nov	41,000	36,000	46,000	226,000
Dec	27,000	24,000	32,000	160,000
Jan	20,000	18,000	22,750	112,000
Feb	16,000	14,000	16,000	80,000
Mar	16,000	14,000	12,750	58,000
Apr	18,000	31,000	39,000	235,000
May	197,000	257,000	189,000	920,000
Jun	198,000	266,000	212,500	880,000
Jul	120,000	148,000	108,000	450,000
Aug	98,000	123,000	97,000	405,000
Sep	108,000	130,000	93,000	370,000
Total	934,000	1,132,000	940,000	4,226,000

The modelled flow at KZ-9, KZ-37, KZ-13, KZ-15, KZ-17, KZ-22, and KZ-26 are shown in a series of tables (Appendix A). Table 4-11 lists the data tables available in Appendix A. Table 4-12 presents the percent difference between the modelled natural catchment runoff for the mean, the 1/50 wet, and the 1/10 dry annual precipitation scenarios and the modelled operations runoff for the same scenarios. Changes in total annual discharge decrease as catchment size increases due the proportionately smaller impact on larger catchments.

Table 4-11: List of Tables Detailing Estimated Catchment Runoff (m^3)

Table No.	Title
A-1	Modelled Natural Runoff (m^3) at Various Sites for Mean Precipitation Year
A-2	Modelled Natural Runoff (m^3) at Various Sites for 1/50 Wet Precipitation Year
A-3	Modelled Natural Runoff (m^3) at Various Sites for 1/10 Dry Precipitation Year
A-4	Modelled Runoff (m^3) During 18-Month Dewatering Period for Mean Scenario
A-5	Modelled Runoff (m^3) During 18-Month Dewatering (Construction) Period for 1/50 Wet Scenario
A-6	Modelled Runoff (m^3) During 18-Month Dewatering (Construction) Period for 1/10 Dry Scenario
A-7	Difference (%) Between Baseline and Dewatering (Construction) Monthly Runoff Volumes for Mean Scenario
A-8	Difference (%) Between Baseline and Dewatering (Construction) Monthly Runoff Volumes for 1/50 Wet Scenario
A-9	Difference (%) Between Baseline and Dewatering (Construction) Monthly Runoff Volumes for 1/10 Dry Scenario
A-10	Modelled Runoff (m^3) at Various Sites During Operations for Mean Precipitation Year
A-11	Modelled Runoff (m^3) at Various Sites During Operations for 1/50 Wet Precipitation Year
A-12	Modelled Runoff (m^3) at Various Sites During Operations for 1/10 Dry Precipitation Year
A-13	Modelled Runoff (m^3) at Various Sites During Active Closure for Mean Scenario
A-14	Modelled Runoff (m^3) at Various Sites During Active Closure for 1/50 Wet Scenario
A-15	Modelled Runoff (m^3) at Various Sites During Active Closure for 1/10 Dry Scenario
A-16	Modelled Runoff (m^3) at Various Sites During Transition Closure for Mean Scenario
A-17	Modelled Runoff (m^3) at Various Sites During Transition Closure for 1/50 Wet Scenario
A-18	Modelled Runoff (m^3) at Various Sites During Transition Closure for 1/10 Dry Scenario
A-19	Modelled Runoff (m^3) at Various Sites During Post Closure for Mean Scenario
A-20	Modelled Runoff (m^3) at Various Sites During Post Closure for 1/50 Wet Scenario
A-21	Modelled Runoff (m^3) at Various Sites During Post Closure for 1/10 Dry Scenario

Table 4-12: Difference (%) Between Modelled Baseline and Estimated Runoff During Operations (Year 10)

	Site						
Scenario	KZ-9	KZ-37	KZ-17	KZ-15	KZ-22	KZ-26	KZ-13
mean	-61.2	-46.3	-32.5	10.4	5.0	5.3	23.5
1/50 Wet	-64.6	-48.9	-37.4	1.8	0.9	1.4	23.9
1/10 Dry	-57.6	-43.6	-26.3	19.2	9.9	10.5	22.5

In the mean water year discharges at KZ-9 are expected to decrease by approximately 61% and by 46% immediately below the confluence with the KZ-18 tributary. At KZ-17, discharge is estimated to decrease by approximately 43%, though uncertainty is higher at this site due to the record being calculated and not measured directly. In Finlayson Creek immediately below Geona Creek (KZ-15), discharge is expected to decrease by 10% during mean conditions and further downstream at KZ-22 and KZ-26 the average decrease is 5%. In most cases changes are similar in the 1/50 west and 1/10 dry. Oddly, the impact appears greater at KZ-26 than KZ-22, this is due to a smaller decrease in total volume at KZ-26 when the catchments are truncated in the dry scenario, which results in a greater volumetric increase above baseline when the additions from operations are added.

4.5 CLOSURE

During active closure the impact transitions from increased receiving environment runoff volumes during operations to runoff volumes below baseline. At the onset of active closure, pumping from the ABM open pit ceases and it begins to fill with groundwater and the additional surface flow from the now removed South Diversions. Active closure will occur over three years (Years 11 through 13), during which time machinery will be removed and other infrastructure decommissioned as well as having a wetland constructed. The transitional closure period will last from the end of active closure until the ABM Lake is formed (years 14 through 26). Downstream runoff is expected to be below baseline during this period and was calculated with the same conditions as the active closure period therefore producing the same results. However, small variations are likely to occur as storage facility cover vegetation becomes more well established and flow paths change in response to the removal of the diversion ditches. While surface flows will begin to increase as the filling lake starts to discharge through the subsurface to Geona Creek, the impact is expected to be negligible and it is modelled as one average case. The post closure period begins in year 27 and is characterized by ABM Lake outflow contributing flow to Geona Creek. This will thereby reconnect Fault Creek and the other south diversion areas to Geona Creek. Furthermore, as a result of the additional deep groundwater influx, runoff is in perpetuity expected to be slightly higher than baseline in Geona Creek and downstream thereof. Runoff in South Creek at KZ-13 is expected to decrease as a result of the removal of the diversions plus the drawdown of water from the small lakes at the top of South Creek. This drawdown effect will remain once the ABM Lake outflow begins, but the impact will be lower in post closure than at the beginning of active closure.

Table 4-13 presents the percent change in total annual flow at the various sites in each closure phase for the mean, 1/50 wet and 1/10 dry scenario. Total monthly and annual modelled flow volumes for these sites are presented in Appendix A (Table A-6-13 through Table A-6-21).

Table 4-13: Difference (%) Between Modelled Baseline Runoff and Modelled Runoff for the Three Closure Phases

		Site						
Project Stage	**Scenario**	**KZ-9**	**KZ-37**	**KZ-17**	**KZ-15**	**KZ-22**	**KZ-26**	**KZ-13**
Active Closure	mean	-28.0	-21.2	-18.6	-7.7	-3.7	-2.7	-9.1
	1/50 Wet	-28.0	-21.1	-18.5	-7.6	-3.5	-2.6	-5.9
	1/10 Dry	-28.0	-21.2	-18.7	-7.7	-3.8	-2.8	-12.1
Transition	mean	-28.0	-21.2	-18.6	-7.7	-3.7	-2.7	-9.1
	1/50 Wet	-28.0	-21.1	-18.5	-7.6	-3.5	-2.6	-5.9
	1/10 Dry	-28.0	-21.2	-18.7	-7.7	-3.8	-2.8	-12.1
Post Closure	mean	5.1	3.9	4.5	1.9	0.9	0.8	-8.2
	1/50 Wet	3.2	2.5	2.6	1.1	0.5	0.4	-5.3
	1/10 Dry	7.0	5.3	6.8	2.7	1.3	1.2	-11.0

5. CONCLUSION

A physical measurement based, monthly time-step watershed model was developed to model environmental water runoff at the KZK property in Yukon with the aim of developing a receiving environment water balance for the Project. Monthly surplus volumes during operations for the Project were provided by KP, baseline hydrometeorology data was provided by AEG, and EBA conducted hydrogeological analysis and modelling (EBA, 2016). Additional baseline data was processed for development of the watershed model which allowed calibration of the model against observed site data. The rigorous baseline data collection program combined with long term regional data has allowed the development of a strong baseline model for the evaluation of the Project effects.

The model compares well with total annual runoff values predicted in the Hydrometeorology Baseline Report (AEG, 2016a) in most cases. While some marked monthly differences were observed between the model and the predicted values from the Hydrometeorology Baseline Report, they are interpreted to represent more appropriate estimates that those developed during the regional analysis. Some of these differences are supported directly by observations collected during the current baseline monitoring program. The greatest deviations occur under the modelled wet and dry scenarios where uncertainty in some parameters is high, and they are greatest at the furthest downstream stations where the impacts of the Project are minimal and therefore the modelled deviations in this context are considered to not be significant.

The pre-mining (construction) phase of the project will involve diversion of Fault Creek and catchment areas above the ABM open pit into South Creek and dewatering the pit area. The effect of this on the downstream water volumes in South Creek is an increase of approximately 33%, while Geona Creek at KZ-9 is expected to increase by 25% for the mean scenario. The operations phase of the project is expected to reduce the overall discharge in the receiving environment by as much as 65% in Geona Creek at KZ-9, but the percentage change in water volumes further downstream quickly diminishes. Discharge in South Creek will remain above baseline until closure. In active closure the impacts will diminish including a reversal to below baseline flows in South Creek. Post-closure, the hydrology of the area is expected to approach pre-Project behaviour, but discharge in Geona Creek and downstream will remain slightly elevated above baseline in perpetuity due to additional deep groundwater influx to the ABM Lake which will also result in slightly decreased runoff in South Creek.

The model provides a working template which will allow further refinement of estimates as more data become available and the Project moves forward. Uncertainty in the model is mostly a result of the uncertainty in the inputs and regional predictions; although, additional data will allow further testing of the model assumptions. The high quality baseline data collected at the Project site to date has allowed the development of a robust model which constitutes the best estimates of receiving environment runoff for baseline conditions and during the course the Project.

6. REFERENCES

Alexco Environmental Group Inc. (AEG). 2016a. *Baseline Hydrometeorology Report*, prepared for BMC Minerals (No.1) Ltd., Unpublished.

Alexco Environmental Group Inc. (AEG). 2016b. *Water Quality Model Report.* Prepared for BMC Minerals (No.1) Ltd., Unpublished.

Gutmann, Chris, P.G., pers. comm. 2016. Senior Hydrogeologist, Tetra Tech EBA Inc., Email 28th and 31st October, 2016 and phone conversations.

Knight Piésold Ltd. (KP). 2016a. Prefeasibility Design Report, prepared for BMC Minerals (No.1) Ltd., October 24, 2016.

Knight Piésold Ltd. (KP). 2016b. Mine Site Water Balance Report, prepared for BMC Minerals (No.1) Ltd., Unpublished.

McCabe, G.J., and Markstrom, S.L. 2007. *A monthly water-balance model driven by a graphical user interface.* U.S Geological Survey Open-File report 2—7-1088, 6p.

Tetra Tech EBA Inc. (EBA). 2016. *Hydrogeological Model Kudz Ze Kayah Project, Yukon.* Prepared for BMC Minerals (No.1) Ltd., December 14, 2016

APPENDIX A.

Estimated Phase Discharges

Table A-6-1: Modelled Natural Runoff (m^3) at Various Sites for Mean Precipitation Year

	Site							
Month	**KZ-2**	**KZ-9**	**KZ-37**	**KZ-17**	**KZ-15**	**KZ-22**	**KZ-26**	**KZ-13**
Oct	53,537	458,383	606,205	447,725	1,231,927	3,134,156	3,357,483	258,361
Nov	36,941	320,868	424,344	326,839	862,349	2,256,592	2,417,388	175,685
Dec	25,489	224,608	297,041	238,593	603,644	1,624,746	1,740,519	119,466
Jan	17,587	157,225	207,928	174,173	422,551	1,169,817	1,253,174	81,237
Feb	12,135	110,058	145,550	127,146	295,786	842,269	902,285	55,241
Mar	8,373	77,040	101,885	92,817	207,050	606,433	649,645	37,564
Apr	86,564	324,136	428,688	369,700	1,094,884	2,154,077	2,487,878	214,864
May	319,122	1,205,529	1,594,395	1,442,354	4,185,685	8,204,194	9,769,365	783,174
Jun	267,840	1,491,214	1,972,251	1,911,645	4,146,983	9,631,911	12,366,166	615,115
Jul	155,783	892,737	1,181,030	1,858,526	2,998,266	8,105,423	9,570,152	411,326
Aug	102,133	733,663	970,285	783,765	2,055,756	4,913,237	5,678,805	430,005
Sep	112,290	729,504	964,878	722,844	1,967,562	4,589,209	5,147,185	413,915
Total	1,197,796	6,724,963	8,894,480	8,496,127	20,072,441	47,232,064	55,340,045	3,595,954

Table A-6-2: Modelled Natural Runoff (m^3) at Various Sites for 1/50 Wet Precipitation Year

	Site							
Month	**KZ-2**	**KZ-9**	**KZ-37**	**KZ-17**	**KZ-15**	**KZ-22**	**KZ-26**	**KZ-13**
Oct	63,137	499,144	660,117	712,822	1,603,650	4,319,817	5,198,941	282,153
Nov	39,482	349,401	462,082	364,718	1,003,129	2,910,318	3,390,024	191,864
Dec	27,242	244,581	323,457	266,244	702,190	2,095,429	2,440,818	130,467
Jan	18,797	171,207	226,420	194,358	491,533	1,508,709	1,757,389	88,718
Feb	12,970	119,845	158,494	141,881	344,073	1,086,270	1,265,320	60,328
Mar	8,949	83,891	110,946	103,573	240,851	782,115	911,030	41,023
Apr	122,897	452,623	598,621	515,588	1,553,760	3,068,357	3,602,930	304,013
May	455,190	1,713,836	2,266,663	2,049,193	5,973,914	11,651,787	13,881,831	1,120,668
Jun	466,246	2,336,942	3,091,010	4,331,774	9,242,766	22,307,315	26,673,554	1,154,618
Jul	256,072	2,501,517	3,308,446	3,214,155	6,269,848	19,445,807	27,137,731	857,116
Aug	160,773	984,816	1,302,539	1,240,743	3,282,253	6,436,020	7,097,004	672,312
Sep	175,402	1,299,943	1,719,293	1,637,411	3,915,869	9,757,559	10,728,356	658,302
Total	1,807,157	10,757,746	14,228,088	14,772,462	34,623,834	85,369,503	104,084,928	5,561,583

Table A-6-3: Modelled Natural Runoff (m^3) at Various Sites for 1/10 Dry Precipitation Year

	Site							
Month	**KZ-2**	**KZ-9**	**KZ-37**	**KZ-17**	**KZ-15**	**KZ-22**	**KZ-26**	**KZ-13**
Oct	49,835	316,217	418,250	298,580	725,528	1,657,147	1,416,180	188,184
Nov	34,386	221,352	292,775	217,964	507,870	1,193,146	1,019,649	127,965
Dec	23,727	154,946	204,943	159,113	355,509	859,065	734,147	87,016

	Site							
Month	**KZ-2**	**KZ-9**	**KZ-37**	**KZ-17**	**KZ-15**	**KZ-22**	**KZ-26**	**KZ-13**
Jan	16,371	108,463	143,460	116,153	248,856	618,527	528,586	59,171
Feb	11,296	75,924	100,422	84,792	174,199	445,339	380,582	40,236
Mar	7,794	53,147	70,295	61,898	121,940	320,644	274,019	27,361
Apr	69,052	248,510	328,676	281,398	828,061	1,573,171	1,776,067	166,595
May	254,327	963,478	1,274,267	1,153,384	3,334,148	6,562,480	7,811,044	622,462
Jun	210,296	1,153,300	1,525,338	1,292,413	3,139,386	7,170,938	9,129,208	476,370
Jul	76,769	561,427	742,557	769,045	1,614,531	3,924,781	4,462,058	303,503
Aug	76,295	528,497	699,009	637,873	1,399,316	3,153,370	3,321,914	298,558
Sep	78,619	501,574	663,402	535,713	1,291,819	2,763,724	2,743,022	297,907
Total	908,768	4,886,834	6,463,394	5,608,324	13,741,163	30,242,331	33,596,477	2,695,328

Table A-6-4: Modelled Runoff (m^3) during 18-Month Dewatering (Construction) Period for Mean Scenario

	Site						
Month	**KZ-9**	**KZ-37**	**KZ-17**	**KZ-15**	**KZ-22**	**KZ-26**	**KZ-13**
Jul	1,291,437	1,579,730	2,257,226	3,396,966	8,504,123	9,968,852	561,326
Aug	874,163	1,110,785	924,265	2,196,256	5,053,737	5,819,305	553,005
Sep	815,526	1,050,900	808,867	2,053,585	4,675,232	5,233,208	548,915
Oct	535,668	683,490	525,010	1,309,212	3,211,441	3,434,768	352,361
Nov	394,126	497,602	400,097	935,607	2,329,851	2,490,646	226,685
Dec	302,208	374,641	316,193	681,244	1,702,346	1,818,119	153,466
Jan	243,825	294,528	260,773	509,151	1,256,417	1,339,774	106,237
Feb	191,758	227,250	208,846	377,486	923,969	983,985	75,241
Mar	168,640	193,485	184,417	298,650	698,033	741,245	57,564
Apr	409,136	513,688	454,700	1,179,884	2,239,077	2,572,878	237,864
May	1,070,129	1,458,995	1,306,954	4,050,285	8,068,794	9,633,965	1,030,174
Jun	1,351,214	1,832,251	1,771,645	4,006,983	9,491,911	12,226,166	863,115
Jul	854,337	1,142,630	1,820,126	2,959,866	8,067,023	9,531,752	561,326
Aug	722,263	958,885	772,365	2,044,356	4,901,837	5,667,405	553,005
Sep	702,504	937,878	695,844	1,940,562	4,562,209	5,120,185	548,915
Oct	475,983	623,805	465,325	1,249,527	3,151,756	3,375,083	352,361
Nov	377,868	481,344	383,839	919,349	2,313,592	2,474,388	226,685
Dec	302,208	374,641	316,193	681,244	1,702,346	1,818,119	153,466

Table A-6-5: Modelled Runoff (m^3) during 18-Month Dewatering (Construction) Period for 1/50 Wet Scenario

	Site						
Month	**KZ-9**	**KZ-37**	**KZ-17**	**KZ-15**	**KZ-22**	**KZ-26**	**KZ-13**
Jul	2,837,217	3,644,146	3,549,855	6,605,548	19,781,507	27,473,431	1,070,116
Aug	1,074,316	1,392,039	1,330,243	3,371,753	6,525,520	7,186,504	846,312
Sep	1,328,966	1,748,315	1,666,433	3,944,891	9,786,581	10,757,378	850,302
Oct	496,668	657,640	751,107	1,641,935	4,358,102	5,237,226	415,153

	Site						
Month	**KZ-9**	**KZ-37**	**KZ-17**	**KZ-15**	**KZ-22**	**KZ-26**	**KZ-13**
Nov	373,126	485,807	416,976	1,055,387	2,962,576	3,442,283	263,864
Dec	288,208	367,084	329,844	765,790	2,159,029	2,504,418	178,467
Jan	233,825	289,039	270,958	568,133	1,585,309	1,833,989	123,718
Feb	183,758	222,407	215,581	417,773	1,159,970	1,339,020	88,328
Mar	160,640	187,695	187,173	324,451	865,715	994,630	69,023
Apr	515,205	661,203	590,588	1,628,760	3,143,357	3,677,930	337,013
May	1,475,436	2,028,263	1,810,793	5,735,514	11,413,387	13,643,431	1,470,668
Jun	2,092,942	2,847,010	4,087,774	8,998,766	22,063,315	26,429,554	1,506,618
Jul	2,400,117	3,207,046	3,112,755	6,168,448	19,344,407	27,036,331	1,070,116
Aug	922,416	1,240,139	1,178,343	3,219,853	6,373,620	7,034,604	846,312
Sep	1,215,943	1,635,293	1,553,411	3,831,869	9,673,559	10,644,356	850,302
Oct	436,983	597,955	691,422	1,582,250	4,298,417	5,177,541	415,153
Nov	356,868	469,549	400,718	1,039,129	2,946,318	3,426,024	263,864
Dec	288,208	367,084	329,844	765,790	2,159,029	2,504,418	178,467

Table A-6-6: Modelled Runoff (m^3) during 18-Month Dewatering (Construction) Period for 1/10 Dry Scenario

	Site						
Month	**KZ-9**	**KZ-37**	**KZ-17**	**KZ-15**	**KZ-22**	**KZ-26**	**KZ-13**
Jul	990,127	1,171,257	1,197,745	2,043,231	4,353,481	4,890,758	423,503
Aug	693,997	864,509	803,373	1,564,816	3,318,870	3,487,414	396,558
Sep	614,597	776,424	648,736	1,404,842	2,876,746	2,856,044	405,907
Oct	554,668	656,701	394,865	821,814	1,753,432	1,512,465	263,184
Nov	404,126	475,549	301,222	591,128	1,276,404	1,102,908	168,965
Dec	309,208	359,204	243,713	440,109	943,665	818,747	114,016
Jan	248,825	283,823	207,753	340,456	710,127	620,186	79,171
Feb	195,758	220,256	170,492	259,899	531,039	466,282	56,236
Mar	172,640	189,789	157,498	217,540	416,244	369,619	43,361
Apr	358,865	439,031	371,398	918,061	1,663,171	1,866,067	184,595
May	878,078	1,188,867	1,067,984	3,248,748	6,477,080	7,725,644	819,462
Jun	1,063,300	1,435,338	1,202,413	3,049,386	7,080,938	9,039,208	674,370
Jul	553,027	734,157	760,645	1,606,131	3,916,381	4,453,658	423,503
Aug	542,097	712,609	651,473	1,412,916	3,166,970	3,335,514	396,558
Sep	501,574	663,402	535,713	1,291,819	2,763,724	2,743,022	405,907
Oct	494,983	597,016	335,180	762,128	1,693,747	1,452,780	263,184
Nov	387,868	459,291	284,964	574,870	1,260,146	1,086,649	168,965
Dec	309,208	359,204	243,713	440,109	943,665	818,747	114,016

Table A-6-7: Difference (%) Between Baseline and Dewatering (Construction) Monthly Runoff Volumes for Mean Scenario

	Site						
Month	**KZ-9**	**KZ-37**	**KZ-17**	**KZ-15**	**KZ-22**	**KZ-26**	**KZ-13**
Jul	44.7%	33.8%	21.5%	13.3%	4.9%	4.2%	36.5%
Aug	19.2%	14.5%	17.9%	6.8%	2.9%	2.5%	28.6%
Sep	11.8%	8.9%	11.9%	4.4%	1.9%	1.7%	32.6%
Oct	16.9%	12.7%	17.3%	6.3%	2.5%	2.3%	36.4%
Nov	22.8%	17.3%	22.4%	8.5%	3.2%	3.0%	29.0%
Dec	34.5%	26.1%	32.5%	12.9%	4.8%	4.5%	28.5%
Jan	55.1%	41.6%	49.7%	20.5%	7.4%	6.9%	30.8%
Feb	74.2%	56.1%	64.3%	27.6%	9.7%	9.1%	36.2%
Mar	118.9%	89.9%	98.7%	44.2%	15.1%	14.1%	53.2%
Apr	26.2%	19.8%	23.0%	7.8%	3.9%	3.4%	10.7%
May	-11.2%	-8.5%	-9.4%	-3.2%	-1.7%	-1.4%	31.5%
Jun	-9.4%	-7.1%	-7.3%	-3.4%	-1.5%	-1.1%	40.3%
Jul	-4.3%	-3.3%	-2.1%	-1.3%	-0.5%	-0.4%	36.5%
Aug	-1.6%	-1.2%	-1.5%	-0.6%	-0.2%	-0.2%	28.6%
Sep	-3.7%	-2.8%	-3.7%	-1.4%	-0.6%	-0.5%	32.6%
Oct	3.8%	2.9%	3.9%	1.4%	0.6%	0.5%	36.4%
Nov	17.8%	13.4%	17.4%	6.6%	2.5%	2.4%	29.0%
Dec	34.5%	26.1%	32.5%	12.9%	4.8%	4.5%	28.5%
Mean	25.0%	18.9%	21.6%	9.1%	3.3%	3.1%	32.6%

Table A-6-8: Difference (%) Between Baseline and Dewatering (Construction) Monthly Runoff Volumes for 1/50 Wet Scenario

	Site						
Month	**KZ-9**	**KZ-37**	**KZ-17**	**KZ-15**	**KZ-22**	**KZ-26**	**KZ-13**
Jul	13.4%	10.1%	10.4%	5.4%	1.7%	1.2%	24.9%
Aug	9.1%	6.9%	7.2%	2.7%	1.4%	1.3%	25.9%
Sep	2.2%	1.7%	1.8%	0.7%	0.3%	0.3%	29.2%
Oct	-0.5%	-0.4%	5.4%	2.4%	0.9%	0.7%	47.1%
Nov	6.8%	5.1%	14.3%	5.2%	1.8%	1.5%	37.5%
Dec	17.8%	13.5%	23.9%	9.1%	3.0%	2.6%	36.8%
Jan	36.6%	27.7%	39.4%	15.6%	5.1%	4.4%	39.5%
Feb	53.3%	40.3%	51.9%	21.4%	6.8%	5.8%	46.4%
Mar	91.5%	69.2%	80.7%	34.7%	10.7%	9.2%	68.3%
Apr	13.8%	10.5%	14.5%	4.8%	2.4%	2.1%	10.9%
May	-13.9%	-10.5%	-11.6%	-4.0%	-2.0%	-1.7%	31.2%
Jun	-10.4%	-7.9%	-5.6%	-2.6%	-1.1%	-0.9%	30.5%
Jul	-4.1%	-3.1%	-3.2%	-1.6%	-0.5%	-0.4%	24.9%
Aug	-6.3%	-4.8%	-5.0%	-1.9%	-1.0%	-0.9%	25.9%
Sep	-6.5%	-4.9%	-5.1%	-2.1%	-0.9%	-0.8%	29.2%
Oct	-12.5%	-9.4%	-3.0%	-1.3%	-0.5%	-0.4%	47.1%
Nov	2.1%	1.6%	9.9%	3.6%	1.2%	1.1%	37.5%
Dec	17.8%	13.5%	23.9%	9.1%	3.0%	2.6%	36.8%
Mean	11.7%	8.8%	13.9%	5.6%	1.8%	1.5%	35.0%

Table A-6-9: Difference (%) Between Baseline and Dewatering (Construction) Monthly Runoff Volumes for 1/10 Dry Scenario

	Site						
Month	**KZ-9**	**KZ-37**	**KZ-17**	**KZ-15**	**KZ-22**	**KZ-26**	**KZ-13**
Jul	76.4%	57.7%	55.7%	26.6%	10.9%	9.6%	39.5%
Aug	31.3%	23.7%	25.9%	11.8%	5.2%	5.0%	32.8%
Sep	22.5%	17.0%	21.1%	8.7%	4.1%	4.1%	36.3%
Oct	75.4%	57.0%	32.2%	13.3%	5.8%	6.8%	39.9%
Nov	82.6%	62.4%	38.2%	16.4%	7.0%	8.2%	32.0%
Dec	99.6%	75.3%	53.2%	23.8%	9.8%	11.5%	31.0%
Jan	129.4%	97.8%	78.9%	36.8%	14.8%	17.3%	33.8%
Feb	157.8%	119.3%	101.1%	49.2%	19.2%	22.5%	39.8%
Mar	224.8%	170.0%	154.4%	78.4%	29.8%	34.9%	58.5%
Apr	44.4%	33.6%	32.0%	10.9%	5.7%	5.1%	10.8%
May	-8.9%	-6.7%	-7.4%	-2.6%	-1.3%	-1.1%	31.6%
Jun	-7.8%	-5.9%	-7.0%	-2.9%	-1.3%	-1.0%	41.6%
Jul	-1.5%	-1.1%	-1.1%	-0.5%	-0.2%	-0.2%	39.5%
Aug	2.6%	1.9%	2.1%	1.0%	0.4%	0.4%	32.8%
Sep	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	36.3%

	Site						
Month	**KZ-9**	**KZ-37**	**KZ-17**	**KZ-15**	**KZ-22**	**KZ-26**	**KZ-13**
Oct	56.5%	42.7%	12.3%	5.0%	2.2%	2.6%	39.9%
Nov	75.2%	56.9%	30.7%	13.2%	5.6%	6.6%	32.0%
Dec	99.6%	75.3%	53.2%	23.8%	9.8%	11.5%	31.0%
Mean	64.4%	48.7%	37.5%	17.4%	7.1%	8.0%	35.5%

Table A-6-10: Modelled Runoff (m^3) at Various Sites during Operations for Mean Precipitation Year

	Site						
Month	**KZ-9**	**KZ-37**	**KZ-17**	**KZ-15**	**KZ-22**	**KZ-26**	**KZ-13**
Oct	167,000	314,823	331,992	1,381,257	3,284,772	3,566,823	324,668
Nov	93,000	196,476	213,444	930,980	2,319,596	2,522,673	199,886
Dec	64,000	136,433	151,924	652,086	1,664,549	1,810,764	125,773
Jan	47,500	98,203	111,685	457,660	1,195,495	1,300,770	78,544
Feb	34,250	69,742	81,105	321,362	858,807	934,605	50,005
Mar	30,750	55,595	64,954	234,728	626,031	680,605	29,871
Apr	85,000	189,552	221,470	1,143,655	2,270,171	2,630,759	211,065
May	556,000	944,866	1,088,575	4,627,807	8,906,937	10,551,544	1,002,481
Jun	604,000	1,085,037	1,302,825	4,596,561	10,173,483	12,932,204	836,316
Jul	344,000	632,293	1,028,267	3,268,668	8,163,481	9,759,511	533,633
Aug	286,000	522,622	575,801	2,310,557	5,219,140	6,040,009	525,313
Sep	297,000	532,374	563,803	2,241,423	4,913,903	5,538,533	522,116
Total	2,608,500	4,778,016	5,735,846	22,166,744	49,596,365	58,268,801	4,439,673

Table A-6-11: Modelled Runoff (m^3) at Various Sites during Operations for 1/50 Wet Precipitation Year

	Site						
Month	**KZ-9**	**KZ-37**	**KZ-17**	**KZ-15**	**KZ-22**	**KZ-26**	**KZ-13**
Oct	215,000	375,973	477,505	1,644,636	4,326,405	5,256,503	387,460
Nov	118,000	230,681	253,456	1,030,842	2,916,418	3,424,644	237,065
Dec	78,500	157,377	177,383	717,290	2,089,641	2,455,563	150,775
Jan	58,000	113,214	130,185	504,053	1,502,461	1,765,926	96,025
Feb	45,000	83,650	97,695	357,737	1,083,812	1,273,506	63,092
Mar	41,500	68,555	79,967	260,416	788,245	924,825	41,331
Apr	119,000	264,998	309,577	1,579,579	3,191,656	3,758,770	310,214
May	788,000	1,340,827	1,544,758	6,447,950	12,505,109	14,846,978	1,442,976
Jun	880,000	1,634,068	2,472,886	8,883,007	21,973,909	26,581,707	1,479,819
Jul	619,000	1,425,928	1,804,073	6,180,280	18,975,723	26,544,295	1,042,423
Aug	400,000	717,724	856,207	3,503,011	6,828,087	7,634,774	818,620
Sep	442,000	861,350	1,045,305	4,130,522	9,977,896	11,079,631	823,502
Total	3,804,000	7,274,342	9,248,997	35,239,323	86,159,362	105,547,122	6,893,301

Table A-6-12: Modelled Runoff (m^3) at Various Sites during Operations for 1/10 Dry Precipitation Year

	Site						
Month	**KZ-9**	**KZ-37**	**KZ-17**	**KZ-15**	**KZ-22**	**KZ-26**	**KZ-13**
Oct	143,000	245,033	251,925	1,004,869	1,936,658	1,760,211	235,491
Nov	82,000	153,423	161,515	680,308	1,361,834	1,234,792	142,166
Dec	56,000	105,996	114,046	476,616	974,760	883,290	86,324
Jan	40,750	75,747	83,124	335,181	699,058	633,199	51,478
Feb	30,000	54,498	60,933	237,702	503,341	455,923	31,000
Mar	26,750	43,899	49,331	174,141	367,956	333,815	15,668
Apr	70,000	150,166	173,703	912,716	1,711,616	1,938,100	157,795
May	446,000	756,789	871,822	3,813,239	7,245,686	8,558,263	791,770
Jun	478,500	850,538	955,032	3,662,439	7,772,790	9,756,188	647,570
Jul	256,000	437,130	538,713	1,890,394	4,202,090	4,798,436	395,811
Aug	220,000	390,512	454,088	1,651,337	3,426,858	3,665,131	368,866
Sep	223,000	384,828	419,346	1,540,442	3,045,607	3,099,947	379,108
Total	2,072,000	3,648,561	4,133,577	16,379,384	33,248,255	37,117,294	3,303,046

Table A-6-13: Modelled Runoff (m^3) at Various Sites during Active Closure for Mean Scenario

	Site							
Month	**LWMP**	**KZ-9**	**KZ-37**	**KZ-17**	**KZ-15**	**KZ-22**	**KZ-26**	**KZ-13**
Oct	221,136	331,725	479,548	364,953	1,138,043	3,029,713	3,273,398	230,668
Nov	173,095	232,207	335,683	266,416	796,630	2,181,394	2,356,847	148,886
Dec	121,967	162,545	234,978	194,484	557,641	1,570,603	1,696,930	91,773
Jan	83,377	113,782	164,485	141,973	390,349	1,130,834	1,221,789	53,544
Feb	57,464	79,647	115,139	103,640	273,244	814,201	879,688	30,005
Mar	35,125	55,753	80,598	75,657	191,271	586,225	633,376	9,871
Apr	196,734	251,455	356,007	301,866	1,011,432	2,082,742	2,426,860	188,065
May	546,965	930,023	1,318,889	1,178,031	3,866,623	7,932,534	9,530,525	755,481
Jun	612,204	1,014,121	1,495,158	1,545,767	3,830,445	9,301,893	12,055,275	588,316
Jul	372,645	603,663	891,957	1,513,566	2,762,079	7,649,872	9,201,542	383,633
Aug	348,647	540,188	776,810	641,025	1,899,839	4,767,373	5,550,274	402,313
Sep	326,709	526,712	762,086	590,156	1,817,864	4,442,325	5,023,241	387,116
Total	3,096,068	4,841,821	7,011,338	6,917,536	18,535,461	45,489,709	53,849,745	3,269,673

Table A-6-14: Modelled Runoff (m^3) at Various Sites during Active Closure for 1/50 Wet Scenario

	Site							
Month	**LWMP**	**KZ-9**	**KZ-37**	**KZ-17**	**KZ-15**	**KZ-22**	**KZ-26**	**KZ-13**
Oct	212,841	362,505	523,477	580,649	1,480,845	4,163,394	5,073,001	254,460
Nov	174,189	253,753	366,434	299,622	927,346	2,829,708	3,316,644	165,065
Dec	125,032	177,627	256,504	218,724	649,142	2,037,390	2,387,984	102,775
Jan	85,222	124,339	179,553	159,669	454,400	1,466,921	1,719,348	61,025
Feb	56,356	87,037	125,687	116,558	318,080	1,056,183	1,237,931	35,092
Mar	31,949	60,926	87,981	85,087	222,656	760,452	891,310	13,331
Apr	273,936	352,380	498,377	421,546	1,435,465	2,970,241	3,517,007	277,214
May	777,934	1,324,240	1,877,067	1,673,912	5,518,636	11,267,509	13,543,511	1,092,976
Jun	1,107,189	1,699,118	2,453,186	3,523,387	8,532,913	21,441,612	25,933,057	1,127,819
Jul	1,246,834	1,618,040	2,424,968	2,621,324	5,790,897	18,771,854	26,448,554	829,423
Aug	491,588	764,361	1,082,085	1,009,108	3,030,579	6,186,260	6,928,321	644,620
Sep	632,365	926,603	1,345,952	1,334,482	3,616,444	9,410,243	10,406,222	631,502
Total	5,215,435	7,750,929	11,221,271	12,044,069	31,977,401	82,361,765	101,402,890	5,235,301

Table A-6-15: Modelled Runoff (m^3) at Various Sites during Active Closure for 1/10 Dry Scenario

	Site							
Month	**LWMP**	**KZ-9**	**KZ-37**	**KZ-17**	**KZ-15**	**KZ-22**	**KZ-26**	**KZ-13**
Oct	139,858	226,423	328,456	240,937	669,379	1,579,354	1,363,688	160,491
Nov	111,600	158,496	229,919	175,884	468,565	1,137,135	981,855	101,166
Dec	79,320	110,947	160,943	128,396	327,996	818,737	706,936	59,324
Jan	54,324	77,663	112,660	93,729	229,597	589,491	508,994	31,478
Feb	36,627	54,364	78,862	68,422	160,718	424,433	366,475	15,000
Mar	21,439	38,055	55,204	49,948	112,502	305,592	263,862	-332
Apr	148,804	192,731	272,897	229,385	764,835	1,517,803	1,730,127	139,795
May	435,742	742,301	1,053,090	941,897	3,079,950	6,344,448	7,619,576	594,770
Jun	464,161	782,667	1,154,705	1,054,065	2,899,600	6,921,310	8,896,618	449,570
Jul	222,359	397,328	578,458	625,347	1,490,608	3,772,440	4,335,580	275,811
Aug	227,129	375,717	546,230	517,790	1,291,687	3,023,332	3,220,754	270,866
Sep	207,033	361,680	523,508	434,307	1,192,394	2,646,474	2,655,892	271,108
Total	2,148,396	3,518,371	5,094,932	4,560,108	12,687,830	29,080,547	32,650,357	2,369,046

Table A-6-16: Modelled Runoff (m^3) at Various Sites during Transition Closure for Mean Scenario

	Site							
Month	**LWMP**	**KZ-9**	**KZ-37**	**KZ-17**	**KZ-15**	**KZ-22**	**KZ-26**	**KZ-13**
Oct	310,136	331,725	479,548	364,953	1,138,043	3,029,713	3,273,398	230,668
Nov	217,095	232,207	335,683	266,416	796,630	2,181,394	2,356,847	148,886
Dec	151,967	162,545	234,978	194,484	557,641	1,570,603	1,696,930	91,773
Jan	106,377	113,782	164,485	141,973	390,349	1,130,834	1,221,789	53,544

	Site							
Month	**LWMP**	**KZ-9**	**KZ-37**	**KZ-17**	**KZ-15**	**KZ-22**	**KZ-26**	**KZ-13**
Feb	74,464	79,647	115,139	103,640	273,244	814,201	879,688	30,005
Mar	52,125	55,753	80,598	75,657	191,271	586,225	633,376	9,871
Apr	234,734	251,455	356,007	301,866	1,011,432	2,082,742	2,426,860	188,065
May	867,965	930,023	1,318,889	1,178,031	3,866,623	7,932,534	9,530,525	755,481
Jun	946,204	1,014,121	1,495,158	1,545,767	3,830,445	9,301,893	12,055,275	588,316
Jul	558,645	603,663	891,957	1,513,566	2,762,079	7,649,872	9,201,542	383,633
Aug	504,647	540,188	776,810	641,025	1,899,839	4,767,373	5,550,274	402,313
Sep	490,709	526,712	762,086	590,156	1,817,864	4,442,325	5,023,241	387,116
Total	4,515,068	4,841,821	7,011,338	6,917,536	18,535,461	45,489,709	53,849,745	3,269,673

Table A-6-17: Modelled Runoff (m^3) at Various Sites during Transition Closure for 1/50 Wet Scenario

	Site							
Month	**LWMP**	**KZ-9**	**KZ-37**	**KZ-17**	**KZ-15**	**KZ-22**	**KZ-26**	**KZ-13**
Oct	338,841	362,505	523,477	580,649	1,480,845	4,163,394	5,073,001	254,460
Nov	237,189	253,753	366,434	299,622	927,346	2,829,708	3,316,644	165,065
Dec	166,032	177,627	256,504	218,724	649,142	2,037,390	2,387,984	102,775
Jan	116,222	124,339	179,553	159,669	454,400	1,466,921	1,719,348	61,025
Feb	81,356	87,037	125,687	116,558	318,080	1,056,183	1,237,931	35,092
Mar	56,949	60,926	87,981	85,087	222,656	760,452	891,310	13,331
Apr	328,936	352,380	498,377	421,546	1,435,465	2,970,241	3,517,007	277,214
May	1,235,934	1,324,240	1,877,067	1,673,912	5,518,636	11,267,509	13,543,511	1,092,976
Jun	1,582,189	1,699,118	2,453,186	3,523,387	8,532,913	21,441,612	25,933,057	1,127,819
Jul	1,509,834	1,618,040	2,424,968	2,621,324	5,790,897	18,771,854	26,448,554	829,423
Aug	712,588	764,361	1,082,085	1,009,108	3,030,579	6,186,260	6,928,321	644,620
Sep	864,365	926,603	1,345,952	1,334,482	3,616,444	9,410,243	10,406,222	631,502
Total	7,230,435	7,750,929	11,221,271	12,044,069	31,977,401	82,361,765	101,402,890	5,235,301

Table A-6-18: Modelled Runoff (m^3) at Various Sites during Transition Closure for 1/10 Dry Scenario

	Site							
Month	**LWMP**	**KZ-9**	**KZ-37**	**KZ-17**	**KZ-15**	**KZ-22**	**KZ-26**	**KZ-13**
Oct	210,858	226,423	328,456	240,937	669,379	1,579,354	1,363,688	160,491
Nov	147,600	158,496	229,919	175,884	468,565	1,137,135	981,855	101,166
Dec	103,320	110,947	160,943	128,396	327,996	818,737	706,936	59,324
Jan	72,324	77,663	112,660	93,729	229,597	589,491	508,994	31,478
Feb	50,627	54,364	78,862	68,422	160,718	424,433	366,475	15,000
Mar	35,439	38,055	55,204	49,948	112,502	305,592	263,862	-332
Apr	179,804	192,731	272,897	229,385	764,835	1,517,803	1,730,127	139,795
May	692,742	742,301	1,053,090	941,897	3,079,950	6,344,448	7,619,576	594,770
Jun	730,161	782,667	1,154,705	1,054,065	2,899,600	6,921,310	8,896,618	449,570
Jul	370,359	397,328	578,458	625,347	1,490,608	3,772,440	4,335,580	275,811

	Site							
Month	**LWMP**	**KZ-9**	**KZ-37**	**KZ-17**	**KZ-15**	**KZ-22**	**KZ-26**	**KZ-13**
Aug	350,129	375,717	546,230	517,790	1,291,687	3,023,332	3,220,754	270,866
Sep	337,033	361,680	523,508	434,307	1,192,394	2,646,474	2,655,892	271,108
Total	3,280,396	3,518,371	5,094,932	4,560,108	12,687,830	29,080,547	32,650,357	2,369,046

Table A-6-19: Modelled Runoff (m^3) at Various Sites during Post Closure for Mean Scenario

	Site							
Month	**LWMP**	**KZ-9**	**KZ-37**	**KZ-17**	**KZ-15**	**KZ-22**	**KZ-26**	**KZ-13**
Oct	467,932	487,251	635,074	481,983	1,264,729	3,167,443	3,392,509	233,186
Nov	334,023	347,547	451,023	357,021	891,781	2,286,165	2,448,212	151,322
Dec	246,066	255,533	327,966	271,773	636,497	1,657,554	1,774,228	94,291
Jan	183,639	190,265	240,969	208,647	456,940	1,204,072	1,288,077	56,062
Feb	136,571	141,210	176,702	159,197	327,882	874,196	934,680	32,299
Mar	109,350	112,597	137,442	128,926	243,268	642,480	686,028	12,389
Apr	369,975	362,023	466,576	410,331	1,133,655	2,195,287	2,529,840	190,501
May	1,261,143	1,238,215	1,627,081	1,483,891	4,220,692	8,248,623	9,815,942	757,999
Jun	1,367,600	1,513,727	1,994,764	1,942,545	4,181,113	9,670,594	12,405,172	590,752
Jul	813,947	905,852	1,194,145	1,862,310	3,013,960	8,120,778	9,587,829	386,151
Aug	736,485	755,570	992,193	812,949	2,083,247	4,942,546	5,709,820	404,830
Sep	728,123	760,430	995,804	762,141	2,004,691	4,628,437	5,188,392	389,552
Total	6,754,854	7,070,221	9,239,737	8,881,713	20,458,456	47,638,174	55,760,730	3,299,334

Table A-6-20: Modelled Runoff (m^3) at Various Sites during Post Closure for 1/50 Wet Scenario

	Site							
Month	**LWMP**	**KZ-9**	**KZ-37**	**KZ-17**	**KZ-15**	**KZ-22**	**KZ-26**	**KZ-13**
Oct	509,554	528,952	689,924	743,971	1,635,517	4,351,552	5,231,672	256,978
Nov	361,606	375,184	487,865	394,138	1,031,367	2,937,811	3,418,465	167,501
Dec	265,374	274,879	353,756	298,868	734,207	2,126,739	2,472,810	105,292
Jan	197,154	203,808	259,021	228,427	525,337	1,541,885	1,791,056	63,543
Feb	146,032	150,689	189,339	173,636	375,760	1,117,422	1,296,825	37,386
Mar	115,973	119,233	146,288	139,467	276,782	817,602	946,772	15,848
Apr	504,484	491,782	637,780	558,592	1,593,942	3,111,963	3,647,464	279,650
May	1,801,370	1,766,117	2,318,944	2,114,083	6,029,297	11,720,801	13,953,877	1,095,493
Jun	2,283,625	2,371,999	3,126,067	4,353,125	9,272,746	22,344,772	26,716,579	1,130,255
Jul	2,130,488	2,482,069	3,288,997	3,208,627	6,275,714	19,443,025	27,130,277	831,941
Aug	1,039,311	1,014,678	1,332,402	1,276,581	3,315,175	6,476,323	7,140,381	647,137
Sep	1,254,615	1,327,517	1,746,866	1,672,878	3,951,016	9,794,899	10,770,433	633,939
Total	10,609,587	11,106,907	14,577,249	15,162,393	35,016,859	85,784,795	104,516,610	5,264,963

Table A-6-21: Modelled Runoff (m^3) at Various Sites during Post Closure for 1/10 Dry Scenario

	Site							
Month	**LWMP**	**KZ-9**	**KZ-37**	**KZ-17**	**KZ-15**	**KZ-22**	**KZ-26**	**KZ-13**
Oct	332,067	348,492	450,525	334,779	761,572	1,694,076	1,454,908	163,009
Nov	239,657	251,154	322,578	250,333	540,311	1,226,101	1,053,900	103,602
Dec	180,010	188,058	238,054	193,891	390,467	894,307	770,323	61,841
Jan	137,399	143,033	178,031	151,793	284,720	654,534	565,266	33,996
Feb	104,203	108,147	132,645	117,694	207,328	478,529	414,255	17,294
Mar	86,693	89,454	106,602	98,629	158,880	357,599	311,322	2,186
Apr	292,270	286,245	366,411	321,278	866,570	1,613,702	1,817,249	142,232
May	1,003,892	986,833	1,297,622	1,183,799	3,359,452	6,595,203	7,845,493	597,287
Jun	1,052,678	1,167,806	1,539,844	1,317,144	3,163,452	7,198,835	9,157,536	452,007
Jul	541,257	576,401	757,531	786,185	1,633,427	3,944,894	4,483,716	278,328
Aug	518,388	549,302	719,814	662,447	1,424,836	3,180,734	3,351,165	273,383
Sep	509,920	532,726	694,554	571,842	1,327,753	2,801,829	2,783,193	273,544
Total	4,998,434	5,227,650	6,804,211	5,989,813	14,118,767	30,640,344	34,008,326	2,398,708