BMC MINERALS (NO.1) LTD.

KUDZ ZE KAYAH PROJECT

RESPONSE #2 TO YESAB EXECUTIVE COMMITTEE ADEQUACY REVIEW OF KZK PROJECT PROPOSAL

November 2017

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Acronym	Definition
AEG	Alexco Environmental Group
AET	Actual Evapotranspiration
APEGBC	Association of Professional Engineers and Geoscientists of BC
AQ	Air Quality
ARD	Acid Rock Drainage
ARMP	Aquatic Resources Monitoring Plan
ARSD	Alberta Sustainable Resource Development
ASCE	American Society of Civil Engineers
BBS	Breeding Bird Survey
BCMOE	British Columbia Ministry of Environment
CAAQS	Canadian Ambient Air Quality Standards
CAC	Criteria Air Contaminants
CCME	Canadian Council of Ministers of the Environment
CNG	Compressed Natural Gas
COPC	Constituents of Potential Concern
COPI	Constituents of Potential Interest
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
CPUE	Catch per Unit Effort
CRCP	Conceptual Reclamation and Closure Plan
CTWS	Constructed Wetland Treatment Systems
DEM	Digital elevation model
DFO	Fisheries and Oceans Canada
DO	Dissolved Oxygen
EAP	Employee Assistance Program
ECCC	Environment and Climate Change Canada
EEM	Environmental Effects Monitoring
EMR	Energy Mines and Resources
EQS	Effluent Quality Standards
ERCB	Alberta Energy Resources Conservation Board
FAA	Fisheries Act Authorization
FCH	Finlayson Caribou Herd
FHCP	Fish Habitat Compensation Plan
FIFO	Fly-in, Fly-out
FMEA	Failure Modes Effects Analyses
FOP	Fisheries Offsetting Plan
GHG	Greenhouse Gas Emissions

Acronym	Definition
GIS	Geographical Information System
GPS	Global Positioning System
GSI	Geological Strength Index
HDPE	High Density Polyethylene
HPW	Government of the Yukon Highways and Public Works
HRIA	Heritage Resource Impact Assessment
HRMP	Heritage Resource Management Plan
HSERP	Health, Safety and Emergency Response Plan
HSI	Habitat Suitability Index
IMO	International Maritime Organization
INAC	Indigenous and Northern Affairs Canada
IUCN	International Union for Conservation of Nature
KZK	Kudz Ze Kayah
LFN	Liard First Nation
LMB	Land Management Branch.
LNG	Liquified Natural Gas
LSA	Local Study Area
LWMP	Lower Water Management Pond
MMER	Metal Mining Effluent Regulations
MOE	Ministry of Environment
MPERG	Mining and Petroleum Environmental Research Group
MPBX	Multipoint Borehole Extensometers
MRB	Mineral Resources Branch
NAG	Net Acid Generation
NIR	National Inventory Report
NP	Neutralization Potential
NRCS	Natural Resources Conservation Services
OEM	Original Equipment Manufacturer
ORP	Oxidation Reduction Potential
PAG	Potentially Acid Generating
PEM	Predictive Ecosystem Map
PET	Potential Evapotranspiration
PFS	Pre-feasibility Study
PQRA	Preliminary Quantitative Risk Assessment
PWQO	Preliminary Water Quality Objective
QML	Quartz Mining Licence
RCH	Robert Campbell Highway
RCP	Reclamation and Closure Plan

Acronym	Definition
RISC	Resources Inventory Standards Committee
RMR	Rock Mass Rating
RQD	Rock Quality Designation
RRDC	Ross River Dena Council
RSA	Regional Study Area
SARA	Species at Risk Act
SEPA	Socio-economic Participation Agreement
SSE	Senior Site Executive
SSWQO	Site-Specific Water Quality Objective
SWMP	Surface Water Management Plan
TEM	Terrestrial Ecosystem Map
TOC	Total Organic Carbon
TPM	Total Particulate Matter
TSP	Total Suspended Particles
TSS	Total Suspended Solids
USGS	United States Geological Survey
UTM	Universal Transverse Mercator
VEC	Valued Ecosystem Component
VOC	Volatile Organic Compounds
WKA	Wildlife Key Areas
WMP	Water Management Plan
WPP	Wildlife Protection Plan
WQO	Water Quality Objectives
WSC	Regional Water Survey of Canada
WSF	Waste Rock Storage Facility
WTP	Water Treatment Plant
WUL	Water Use Licence
YG	Yukon Government
YAAQS	Yukon Ambient Air Quality Standards
YBGO	Yukon Big Game Outfitters
YCDC	Yukon Conservation Data Centre
YESAA	Yukon Environmental and Socio-economic Assessment Act
YESAB	Yukon Environmental and Socio-economic Assessment Board
ZOI	Zone of Influence

1 INTRODUCTION

BMC Minerals (No.1) Ltd (BMC) has submitted the Kudz Ze Kayah Project Proposal to the Yukon Environmental and Socio-economic Assessment Board (YESAB) for adequacy review.

In order for YESAB to determine the adequacy of the Proposal, they have requested further information and clarification regarding certain aspects of the Proposal (YESAB, 2017a). Subsequently, BMC submitted the requested supplementary information (BMC, 2017) (referred herein as the Initial Response Report). YESAB reviewed the supplementary information proved by BMC in the Initial Response Report and determined that additional information is required for a number of the information requests (IRs) (YESAB, 2017b). This Response Report provides the additional information requested by YESAB.

For clarity and ease of understanding BMC have listed the initial IRs and corresponding responses from the Initial Response Report (in black text) followed by the corresponding IR number two and BMC's response (in blue text). The requests and responses follow the same numbering adopted by YESAB which follow the headings as the chapters in the Project Proposal.

The responses to IR number two are based on:

- YESAB (2017b);
- Technical meetings held between BMC and our consultants and YESAB and their consultants with a focus on the following subject matters: mine engineering, water management, wildlife and socio-economics; and
- Additional clarifications provided by YESAB (via email) as follow-up to the technical meetings for the following subject matters: permafrost mapping, water management and wildlife.

The YESAB Executive Committee has also identified information that does not require a response from BMC Minerals for the purposes of the adequacy review (YESAB, 2017a). BMC will endeavour to review this information during the Seeking Views and Information Stage.

2 FIRST NATIONS AND COMMUNITY CONSULTATION

No information required.

3 PROJECT LOCATION

No information required.

4 PROJECT DESCRIPTION

4.1 WASTE ROCK

YESAB ISSUE (WITH NO CORRESPONDING INITIAL REQUEST)

The tables provide a summary of sample numbers relative to geodomain, anticipated waste tonnage, and static test types / numbers. It is not clear that these tables incorporate KZK Formation (host to significant Volcanogenic Massive Sulphide (VMS) mineralization) geodomains since the rock codes vary from those presented on page 5 describing KZK geology and geodomains.

R2-1

Clarify if KZK Formation rocks are represented in Tables 4-1 and 4-2 and/or the apparent discrepancy in geodomain rock coding between these tables and the text description on page 5.

There is no discrepancy; this is simply a question of the level of detail used in the rock description. The text on page 5 describes the three main stratigraphic components and the major rock units within those packages. These are further subdivided into "geodomains", which are based on lithology and major mineral abundance, as described in Table 2-1 of Appendix D-5 (ARD/ML report) of the Project Proposal. This hierarchical classification is summarized in Table 4-1.

Tables 4-1 and 4-2 [of Appendix D-5 (ARD/ML report) of the Project Proposal] indicate the relative abundance of each geodomain within the ABM pit and the number of samples of each geodomain that were subjected to static testing.

Table 4-1: Main Stratigraphic Components, Lithologies, and Geodomains of Rock in the ABM Pit Area

Rock Classification Hierarchy	Description
Three main Stratigraphic Units on KZK Property	The KZK formation felsic volcanic package that hosts the significant VMS mineralization
	The overlying upper sedimentary and mafic volcanic sequence (or Wind Lake formation)
	The underlying lower sedimentary sequence.
Major Lithologies	**RHYv -** Felsic tuff
	RHYc - Coherent felsic flows/intrusives
	RHYi - Feldspar-quartz porphyry intrusive
	MDS - Mudstone
	MAFi - Undifferentiated mafic volcanic
Geodomains	**AK RHYc** – Moderate-strong ankeritic (AK) coherent (c) rhyolite (RHY)
	AK RHYv – Moderate-strong ankeritic (AK) volcaniclastic (v) rhyolite (RHY)
	CA CL MAF – Calcite (CA)-chlorite (CL) mafic (MAF) intrusive
	CARB MDS/RHY – Felsic volcanic rock (coherent and volcaniclastic) with carbonaceous (CARB) material and associated with thin mudstone (MDS) intervals. Generally, with disseminated pyrite and muscovite, locally minor ankerite.
	MDS – Upper, thick mudstone (MDS) package
	MU PY RHY – Moderate-strong muscovite (MU)-altered rhyolite (RHY) with disseminated pyrite (PY)
	PY AK RHYc – Moderate-strong ankeritic (AK) coherent (c) rhyolite with disseminated pyrite (PY)
	PY AK RHYv – Moderate-strong ankeritic (AK) volcaniclastic rhyolite (RHY) with disseminated pyrite (PY)
	PY CL RHY – Chloritic (CL) rhyolite coherent and volcaniclastic rhyolite (RHY) with disseminated pyrite (PY)
	RHYi – Hard, siliceous, fine-grained felsic intrusive (i) typically with 2-3% disseminated pyrite

YESAB ISSUE (WITH NO CORRESPONDING INITIAL REQUEST)

It is not clear whether samples listed for Krakatoa Zone in Tables 4-1 and 4-2 are exclusive to the Krakatoa open pit development or also include samples from underground development.

R2-2

Clarify the representation of Krakatoa underground samples by geodomain and expected waste tonnages.

The waste rock tonnage and associated geodomain composition for the Krakatoa underground development is shown below in Table 4-2. Approximately 373 kilotonnes (kt) of waste rock are anticipated to be produced from the Krakatoa underground operation, which is approximately 2% of the c. 17 million tonnes (Mt) of waste rock expected to be excavated from the Krakatoa Zone within the ABM open pit (Table 4-3). The underground and open pit components of the Krakatoa Zone share the same geology, therefore samples collected from the open pit area of the Krakatoa Zone (and indeed the ABM Zone) for geochemical testing adequately describes the acid rock drainage and metal leaching characteristics of waste rock extracted from the Krakatoa underground development.

Note that Tables 4-1 and 4-2 are reproduced from the KZK prefeasibility study and are consistent with what was presented in the Project Proposal, but have more detail than was initially presented in the Project Proposal.

Table 4-2: Geodomain Distribution and Tonnage for the Krakatoa Underground Development

Geodomain	Krakatoa Underground Waste Tonnage [a]	Krakatoa Underground Waste %
PY AK RHYv	302,913	81%
PY CL RHY	12,261	3%
MU PY RHY	3,196	1%
RHYi	6,965	2%
CA CL MAF	47,712	13%
Total	373,047	100%

[a] Based on prefeasibility study underground mine schedule

Table 4-3: Number of Rock Samples by Geodomain Relative to Sample Set, Zone and Anticipated Open Pit Waste Tonnage

Sample	Sample Set by Year			Sample Set by Zone				Anticipated Waste Tonnage [a]				
	1994 (Historic Cominco)	2015	Total	ABM Zone	% ABM Zone Samples	Krakatoa Zone	% Krakatoa Zone Samples	ABM Zone (t)	ABM (%)	Krakatoa Zone (t)	Krakatoa (%)	Total Waste Tonnage (t)
AK RHYc	0	6	6	6	1%	0	-	1,282,000	1%	-	0%	1,282,000
AK RHYv	52	42	94	88	17%	6	11%	29,800,000	28%	40,000	0%	29,841,000
PY AK RHYc	14	24	38	38	7%	0	-	9,562,000	9%	-	0%	9,562,000
PY AK RHYv	67	76	143	132	25%	11	20%	25,189,000	24%	8,538,000	50%	33,727,000
CARB MDS/RHY	46	40	86	83	16%	3	5%	9,877,000	10%	31,000	0.2%	9,908,000
MU PY RHY	20	36	56	47	9%	9	16%	9,964,000	9%	2,397,000	14%	12,361,000
PY CL RHY	26	15	41	41	8%	0	-	4,322,000	4%	-	0%	4,322,000
CA CL MAF	16	37	53	39	7%	14	25%	5,175,000	5%	3,347,000	21%	8,522,000
MDS	2	36	38	38	7%	0	-	11,551,000	11%	-	0%	11,551,000
RHYi	0	12	12	0	-	12	22%	-	0%	2,634,000	14%	2,634,000
Total	**243**	**324**	**567**	**512**	**100%**	**55**	**100%**	**106,722,000**	**100%**	**16,987,000**	**100%**	**123,709,000**

[a] Based on an estimate of waste rock tonnages produced from the ABM open pit. Tonnages are rounded to the nearest thousand tonnes. The relative abundance calculation excludes estimated tonnage of massive sulphide unit.

4.2 TAILINGS TECHNOLOGY

YESAB ISSUE

A thorough options assessment is a critical component of project planning and MRB (Mineral Resources Branch) would have expected the proponent to have conducted an assessment not only on the waste disposal locations but also on management methods and facility risks for all stages of the project. This options assessment needs to rigorously assess all feasible options and must describe the rationale for the selected option in a transparent manner.

In light of the long-term liability of the waste management facilities, particularly the Class A Facility, after closure to Yukon, it is imperative that all reasonable options for waste management are examined. These options need to be examined, not just in the light of the operational and near post closure period, but in the light of the benefits and costs over the long term. MRB strongly suggests that the proponent conduct a thorough options analysis coupled with a multiple accounts analysis, and a comprehensive risk assessment, which considers different mechanisms for disposal of mine waste.

R278

"Provide a risk assessment for mine waste management facilities including a failure modes effects analysis."

Failure Modes Effects Analyses (FMEA) are useful tools for evaluating a proposed system or structure, identifying possible failures in design, and ranking the hazards associated with those failures. The risk register can then be utilized to prioritize and guide risk mitigation measures, and to track the 'running risk' that the Project poses to a range of identified values.

Given the Project focus on designing for closure, the FMEA process has been identified in the Conceptual Closure and Reclamation Plan (Section 7.12.1, February 2017, Appendix H of the Project Proposal), and BMC is committed to utilizing this planning tool to advance the design and closure measure aspects of the waste management facilities. This will be undertaken to support the advancement and refinement of the facility design, and will be a component of the more detailed Reclamation and Closure Plan that will be developed in accordance with YG's 2013 Guidance Document: *Reclamation and Closure Planning for Quartz Mining Projects guide by Yukon Government and the Yukon Water Board.*

YESAB ISSUE WITH BMC'S RESPONSE TO R278

A project risk assessment with an FMEA will demonstrate that a systematic review of the mine development has considered potential hazards and assessed the risk to the development, health and safety and the environment. At this level of development, the assessment and FMEA will be high level but will examine the more significant risks with the most potential for harm. YESAB require evidence that the systematic review has occurred and that the primary hazards have been identified, classified and appropriate mitigations assigned.

R2-3

Insufficient Response: Provide a risk assessment for mine waste management facilities including a failure modes effects analysis.

A risk assessment is recommended at this stage of the project for mine waste management which can be further optimized and revised at the detailed design stage. The assessment can provide an understanding of the key risks in the current plan and how they can impact the success of the plan.

A Failure Modes Effects Assessment (FMEA) for the Class A Storage Facility has been conducted for the Project, and has been included as **Appendix R2-A** of this Response Report. Risks were identified, numbered and defined by attributes including phase of design, description, and consequence category. Each risk was given a likelihood and consequence ratings. The following components of the facility were assessed:

- The Class A Storage Facility (including cover, liner, constructability, etc.)
- Non-contact diversion ditch upslope of facility;
- Contact diversion ditches downslope of facility;
- Class A Storage Facility Collection Pond; and
- Buttress.

Each of the components was assessed for Construction, Operations and Closure phases. Multiple consequence types were also considered for each potential failure; for example; failure of a ditch may result in downstream *environmental impacts* as well as *consequence costs* for remediation, thus, both were evaluated.

Key defensive measures already considered in the proposed mine plan were identified where appropriate to provide context for the selected likelihood and consequence. Examples of key defensive measures include design criteria and management plans.

All assessed risks fell within the “Low” to “Very Low” categories (**Appendix R2-A**).

On September 14, 2017 BMC representatives met with YESAB representatives at the YESAB head office in Whitehorse and their consultant (SNC Lavalin) to clarify what additional Project components were required for the FMEA. The clarification provided indicated that the primary interest for the FMEA was not specific to waste management, rather the interest was regarding site wide risks from an operational and health and safety perspective, and that BMC had considered the mitigation measures or alternatives. Subsequent to this meeting BMC, has developed a Risk Register (**Appendix R2-B**). The risk register includes all aspects of the proposed operation, including open pit and underground mining, processing, tailings and waste, infrastructure and transportation. Similar to that of the FMEA for the Class A Storage Facility, key defensive measures that have been included in planning of the operation were identified to provide context for the selected likelihood and consequence. Risks were assessed to range between "Very Low" and "Medium", as detailed in **Appendix R2-B**.

It should be noted that the FMEA for the Class A Storage Facility and the Risk Register were prepared at the request of YESAB, and will be updated and refined during the detailed Project design/planning including during the development of the detailed reclamation and closure plan (as described in response to R278, above).

YESAB ISSUE

Chapter 4, Section 4.16.2 (page 4-148) states, "...as this has been successfully implemented at a number of mines already, BMC does not believe that the required operational practices will be unreasonable to implement and maintain". Filtration technology is widely used in arid environments, where water recycling is critical, and also for places with difficult foundation conditions for the tailings storage facility design. There are particular challenges to implement this technology in a northern climate; the Proponent referenced Greens Creek Mine in Alaska, often referred as a successful dry stacking facility in a northern climate; however, it took many years of operation and learning to develop feasible operational practices at Greens Creek Mine.

R21

"Describe if and how the tailings management plan has incorporated operational learnings and best practices from similar facilities and operations such as Greens Creek Mine, Alaska."

Dry stack tailings technology has evolved significantly around the world over the last 30 years and it is now used in locations that range from dry, hot arid climates to northern (and southern) cold climates. It is not reasonable to request, nor is it feasible to attempt to summarise the 30 years of advances in knowledge into a response document of this type. However, BMC recognises that it took Greens Creek Mine years of operation and learning to optimise the operational practices of the filtered tailings facility on Admiralty Island. There has been a similar learning curve at the Pogo Mine in Central Alaska. Despite the operational challenges at the commencement of the above two mines, the operational practices at the respective dry stack facilities were feasible. The fact that Greens Creek continues to be successfully operated within the Admiralty Island National Monument is a testament to the fact that a dry stack tailings facility in a cold climate is not only feasible but can be operated successfully in an environmentally sensitive area for decades.

There are lessons to be learned from both operations and these will be included in the Tailings Management Plan as it is further developed for the QML Application. There is likely to be a period of optimisation of operational practices at the Kudz Ze Kayah Project. The timeline for the optimisation will be dependent upon local climatic and operational conditions; however, it will be lessened due to operational lessons learnt from similar operations.

The Tailings Management Plan is conceptual at this stage; however, as the Project progresses, and more operational data becomes available it will be developed for inclusion in the Mill Development and Operations Plan required for approval of a Quartz Mining Licence by the Department of Energy, Mines and Resources.

Note that BMC has engaged Knight Piesold, an internationally recognised specialist is this field to advise us on the tailings management designs and operations. In providing their specialist advice, Knight Piesold has incorporated both their personal and published experiences from many mines including Greens Creek.

R22

"What mitigation strategies or alternatives have been considered in the event that the operation of the KZK mine cannot consistently meet design output?"

It is unclear what design outputs are being referenced. On the assumption, from context, that the reference is to the efficiency and effectiveness of the filtration technology, then all testing to date indicates that target outputs are achievable. In the event of the design outputs being consistently unmet then the Mill Development and Operations Plan will be adjusted accordingly and if necessary modifications made to the thickening and filtration circuits. This is normal practise in the commissioning process for new mines.

YESAB ISSUE WITH BMC'S RESPONSE TO R21 AND R22

Chapter 4, Section 4.16.2 (page 4-148) states, "...as this has been successfully implemented at a number of mines already, BMC does not believe that the required operational practices will be unreasonable to implement and maintain". Filtration technology is widely used in arid environments, where water recycling is critical, and also for places with difficult foundation conditions for the tailings storage facility design. There are particular challenges to implement this technology in a northern climate; the Proponent referenced Greens Creek Mine in Alaska, often referred as a successful dry stacking facility in a northern climate; however, it took many years of operation and learning to develop feasible operational practices at Greens Creek Mine.

Insufficient response: The Proponent provides a conceptual response on how there are lessons learned and knowledge gained from the Greens Creek and Pogo Mine operations; however, there is no detail on the elements of tailings management and environmental mitigation that will be incorporated as a part of this project and why these elements may have been chosen.

Insufficient response: The expectation of the proponent is not to "summarize 30 years of advances in knowledge" in the areas of filter tailings management. Rather it was to understand what realistic steps and approaches had been planned to incorporate some of the learning. This could include engaging internationally recognized experts on filter tailings management (this is already done by the proponent), set up a framework of communications with one or more successful mines (such as Greens Creek) to share knowledge and learning, carry out study/test plots to identify project specific operational challenges and develop mitigations options, etc.

The Proponent speaks to plans that are not filed as a part of the application, further underlining the need for EA reviewers to review said plans in order to satisfy the intent of the information request.

R2-4

Provide the conceptual tailings management plan and demonstrate how it has addressed issues that have arisen at other mine sites (e.g., Greens Greek and Pogo Mine.)

The management of the combined storage of filtered tailings and Class A waste rock in the Class A Storage Facility is an integral part of the Project and as such will be adapted through all steps of the design process and will continue to evolve during construction and operations as more practical and site-specific experience becomes available.

The Class A facility will store approximately 11.6 Mt of Class A waste rock and approximately 15.1 Mt of filtered tailings which gives an estimated volumetric tailings to waste ratio of 5:4 (using dry bulk densities of 2.1t/m^3 and 2.0 t/m^3 respectively) for the entire facility. Initial proctor testing of the tailings has provided an optimum water content of 14.9%.

Preliminary steps for the detailed design process has included;

- using consultants with specialised expertise in the area of filtered tailings storage design; and
- additional test work on samples of the tailings material and modelling of the Class A waste rock to obtain parameters for design.

BMC is committed to a program of ongoing communication and sharing of information with existing successful operations. This communication and sharing has already begun with operators of the Greens Creek mine in Alaska. BMC technical directors and senior management have visited Greens Creek mine and have met with its site management to learn more about the specific design and the operational aspects of both their processing plant (including the tailings thickeners and filters) and their dry stack facility and how they have adapted their initial plan(s) based on site experience. Such communication is expected to be ongoing through all construction and operational phases, and where applicable this knowledge has been incorporated into the BMC KZK Project Proposal.

BMC has, and will continue to incorporate the information gained from the ongoing technical exchanges into the design work to generate a feasible operating plan which can be subsequently optimized. The pre-operations tailings management plan, while important, will need to be reinforced, and perhaps adapted, by trials of the proposed methods of deposition of the waste that will occur during the commissioning phase of the process plant and storage facility. The trials will take place within the prosed storage facility in areas that will not alter the overall geotechnical or geochemical stability of the facility but will be designed to emulate real operating conditions. From these trials fine tuning of the required inputs of filtered tailings and Class A material will be developed as well as the required transport and handling of these materials. This plan will be used as operations are commenced, with continual monitoring and adapted as required, as operations continue.

Management Objectives

BMC will plan, design, construct, operate, monitor, and will eventually close the Class A Storage Facility with the intent of meeting the following management objectives:

- Safely receive approved waste material within the designed Class A Storage Facility capacity constraints during the operational period of the mine.
- Contain within the Class A Storage Facility all materials received so that there is no environmental impact from the operation of the Facility.
- Minimize water from entering the Class A Storage Facility from up gradient sources.
- Maintain water management system components as designed. Control surface water, ground water, and interior facility waters in order to prevent offsite water quality impacts.
- Minimize fugitive dust impacts from the Class A Storage Facility operations to surrounding land.
- Maintain Class A Facility geotechnical stability (short-term and long-term).
- Progressively reclaim the Class A Storage Facility so that early reclamation results are identifiable and measurable prior to cessation of production activity in order for final planning to be continuously optimized during the project life.
- Reduce impacts to the receiving environment and ultimately reclaim the facility in a manner that will support and protect long term designated uses.

Operational Criteria

At this preliminary stage several operating criteria have been identified. Once these criteria have been evaluated utilising further testwork and field operational learnings, standard operating procedures will be developed and further refined to ensure that the management objectives are achieved. The criteria include:

1. The Class A Storage Facility will be constructed as a number of main storage cells (approximately 10) which will be further divided on a volume basis into longitudinal strips oriented across the slope. Each cell will have two (2) sections; one in operational use and the other as a backup. The cells will be hydraulically isolated from the surrounding cells and will be capable of being sealed independently without impacting the overall operation of the Facility.
2. Tailings will be placed within these cells in defined work areas, and each work area will be filled, compacted and tested in lifts, before additional tailings are added.
3. The top surface of the cells shall be graded to control surface runoff, and compacted with a smooth drum roller to minimize infiltration from ruts or indentations.
4. If the tailings cannot be placed and compacted upon arrival at the tailings facility, they shall be stockpiled within the facility to minimize any additional moisture absorption during wet periods, or drying during warm periods. The tailings shall be handled such that specified placement bulk densities are achieved.
5. Ingress of water, from outside the facility, will be minimized and flow between cells will also be minimized or prevented.

6. Water on the current working areas will be channeled and removed to the greatest extent possible. This will include positive grades on all slopes with water directed to sumps for handling, and removing snow in winter.
7. Depending on trafficability of the compacted tailings, roadways within the Class A Storage Facility may be required in high traffic areas. These will consist of compacted Class A waste rock. The road material may be reclaimed, and used elsewhere in the facility, or become part of the facility.
8. Depending on the results of ongoing operational tests, there may be two or more combined forms of the deposition methodology. The proposed methods are:
    a. Class A waste and filtered tailings will be field dumped on the previous lift of compacted tailings and then spread, mixed and compacted using tracked dozers and rollers.
    b. Class A waste will be placed in cells and encapsulated by compacted filtered tailings.
    c. Class A waste will be placed in layers and encapsulated by compacted tailings.

    The final combination of methods used will depend on operational parameters, the result of ongoing field trials during the life of the project and may be driven by the following factors:

    - The maximum ratio of Class A waste to filtered tailings that can be efficiently compacted to achieve the required bulk density and permeability of the resultant product.
    - Relative amounts of Class A and filtered tailings available at any specific time.
    - The particle size distribution of the Class A waste rock. This could potentially be altered by screening and secondary breakage of some, or all, of the Class A waste to obtain material with a suitable size distribution for comingling and compaction.
9. There will be storage of tailings in a contained area at the filter building and Class A waste in the pit area so that scheduling and transport interruptions can be alleviated.
10. Areas that may be susceptible to desiccation of the tailings and dust migration will be covered with waste rock and the Class A Storage Facility will be an important focus of BMC's progressive reclamation program.
11. Monitoring of all facets of the operation will be ongoing and any observed deficiencies may result in changes to the operations plan and operating procedures.

Operations

The following description of day to day operations is preliminary at this stage and will need to be confirmed with field tests during commissioning and updated as operational experience is gained.

Filtered tailings will be loaded into 40 t trucks by front end loaders at the filtration building at the process plant. The trucks will transport the tailings via the haul road between the filter building and the current work areas on the Class A Storage Facility.

High traffic areas within the facility will have roads constructed of Class A waste to maintain trafficability on the compacted tailings. The roads will be constructed in any areas where rutting and disruption of the surface may potentially occur due to traffic. Trucks will end dump piles approximately 8m apart. The piles will be spread with a tracked dozer to an uncompacted height of approximately 0.3 m. The area will have an appropriate positive gradient to prevent ponding of water. Compaction will then proceed with the use of a roller with sufficient passes to bring the compaction up to the required proctor density (nominally a minimum of 90% of the Standard Proctor bulk density).

Operations in winter conditions will require additional work with snow and ice removed from the dumping area prior to use. Additionally, material will be spread and compacted within a nominal 3-day period, with the actual maximum period to be confirmed by field tests prior to finalizing the operational plan and is likely to be seasonally adjusted.

Notwithstanding that filtered tailings are somewhat hydrophobic, operations during precipitation events will have additional management requirements due to the potential for adverse effects with infiltrated water on compaction. The open or active tailings placement area will be kept as small as practical and if tailings cannot be compacted immediately they will not be spread and will instead be left in piles within the compound to limit water infiltration. Once tailings placement in the area is complete the tailings surface will be rolled smooth until free of potential ponding areas and then graded to allow water to run off the surface.

Class A waste rock will be transported from the open pit area using the standard haul trucks used in the pit. Class A waste will be encapsulated within compacted tailings. A minimum setback distance from the outer limits of the final facility profile will be incorporated into the deposition plan where Class A waste will not be placed. The dumping procedure will be dependent upon the deposition method used, however in all cases the piles will be end dumped a set distance apart in the current working area to achieve the required thickness when spread. The piles will be spread and compacted with a tracked dozer. If filtered tailings are to be comingled, then tailings will be dumped in the same work area at the required ratio and tracked dozers will be used to spread, mix, and compact with a smooth drummed roller used to achieve final compaction.

Moisture content, bulk densities after compaction, and records of deposition material amount and location will be recorded and reported as required. Visual observations and material sampling will be used to ensure that construction of the facility is according to preapproved construction plans. Inclinometer, piezometer and topographic survey data will be used in conjunction with engineering assessments to ensure the site is stable in the short and long term.

R2-5

What mitigation strategies or alternatives have been considered in the event that the operation of the KZK mine cannot consistently meet design output?

Potential risks have been identified and mitigation strategies implemented in the operation of the tailing facility and outlined in the operational plans. The identified mitigations have been used to define the operational criteria of the Class A Storage Facility and will be used to develop the management plan and standard operating procedures for the operation of the facility.

The key risks, separated into operational areas, are enumerated below along with potential mitigation processes.

Production of Class A Waste

1. Class A production exceeds the lowest ratio of filtered tailings/ Class A waste possible to achieve compaction
    - Appropriate scheduling of Class A waste production will be the main mitigation process aimed at maintaining an appropriate mixing ratio. It should be noted that prior to commencement of operations, BMC intends to carry out further investigations to determine the optimum ratio of tailings to rock and whether co-disposal or separate deposition of rock & tailings within the Class A Storage Facility is the best option for these materials. Depending on the results of this test work it may well be that the risk of a shortage of rock or tailings is immaterial.
    - A short-term stock pile for Class A waste within the pit will be established to alleviate scheduling fluctuations.
    - Disposal of separate Class A waste in cells within the facility may be required during periods of continuous high production if scheduling cannot address the situation. This will enable a higher disposal ratio of Class A waste to tailings and ensure that areas where comingling occurs have the optimum ratio. This will be facilitated by having several working areas available at all times.
2. Reduced or limited Class A production for an extended period.
    - Appropriate scheduling of Class A waste production will be the main mitigation process aimed at maintaining an appropriate mixing ratio.
    - Deposition and compaction of filtered tailings undertaken within the facility without Class A waste until Class A waste becomes available.

Production of Filtered Tailings

1. Filtered tailings production is consistently lower than planned due to low availability of tailings production equipment and/or design problems.
    - There will be thickener, pump & filter redundancy designed and installed (i.e. extra filter equipment) as a mitigation measure to ensure that the effects on production of maintenance and mechanical breakdown are negligible. In effect, the production system will be decoupled so that an unplanned breakdown of one part of the system will not have an immediate effect on the rest of the system. In addition, planned redundancy will ensure that where applicable, back-up units can be brought on line at short notice in the short term prior to long term maintenance solutions being implemented.
    - Long term solutions could involve simple mechanical repair/modification, variations in the number, or type of, filter plates utilised, reprogramming the cycle times and operating parameters of individual filter units and using different types of filter cloth to suit changing parameters.
2. Moisture content of filtered tailings is consistently higher than that required for adequate compaction and geotechnical stability.

- Modify the filtration system by lowering the production rate per unit (i.e. pressing time) and increasing the number of operating filtration units, or installing additional press plates in the case of a pressure plate unit.
- Changing the type of filter cloth used.
- Lower the moisture content of feed to the filter presses by modifying the upstream components' operating parameters to provide an optimised filter feed (in particular the feed density).

3. Short term variability of filtered tailings moisture content
   - Variability may be mitigated by blending with acceptable tailings or modifying the deposition and blending with Class A waste rock.
   - Continuous "real time" monitoring of the filter feed slurry to ensure that the bulk density of filter feed is maintained at optimum levels.
4. Filtration system must be shut down or shuts down in emergency and requires material to be removed from system
   - Filtration system design will incorporate sufficient storage redundancy to accommodate this.
5. Commissioning of filtration system may produce substandard product
   - There will be a short term storage area in the Class A Storage Facility set aside for substandard product. The area will be purpose designed, will be set back from the outer limits of the facility and will not affect the long or short term geotechnical or geochemical stability of the facility. This material will be blended with appropriate material as it becomes available and placed as part of normal operations.

Operations of the Tailings Storage Facility

- Precipitation may cause the moisture content of the filtered tailings to be higher than optimal and thus cause compaction issues.
  - Filtration moisture content "set point" targets will be designed lower than the Proctor optimum moisture content. An example of this is Greens Creek where the optimal Proctor moisture content is 15% and the filtration target is 12.5%. This may be a seasonal requirement and only applicable during the spring melt and higher rainfall months.
  - During periods of heavy rain tailings deposition may be curtailed or the tailings may be dumped but not spread. Operational experience at other sites including but not limited to Greens Creek has shown that filtered and pressed tailings are partially hydrophobic so that only the outer shell of dumped piles absorbs significant moisture and thus the overall increase in water content is minimal.
  - Spread tailings will be sloped to drain water and minimize pooling.
  - Tailings will be spread, compacted and rolled as soon as practicable thus sealing them from moisture absorption.
  - Depositional "live" areas will be small to enable prompt compaction and sealing.
- Winter temperatures and snowfall may affect compaction performance.
  - Snow will be removed from areas where deposition is taking place by pushing off and stockpiling.
  - Trials at other sites with similar winter temperatures indicate that tailings should be compacted within three days of dumping to prevent freezing of the tailings.

- Surface water flows into the facility from up slope.
  - Diversion ditches up slope from the facility will be enhanced to ensure maximum efficiency. This may include lining with HDPE, shotcrete or other methods that will minimize water ingress to the facility.
  - Secondary ditches and designed slopes will be constructed, if required, to divert water around the operational facility.
- Ground water flows into the facility.
  - Potential inflow areas will be identified during construction and the ground water will be drained away with French drains or similar.
  - Bentonite slurry walls may be keyed into the liner and used to deflect water from entering the facility if required. This style of wall has been used effectively at other facilities.
- Liner damaged or leaks are detected during operations.
  - The facility will be designed so that individual cells will be sealed and isolated from the rest of the facility. If a leak is detected in one cell then tailings and waste deposition will cease in that cell and the surface will be sealed. While the cell is being sealed deposition will be relocated to an alternative cell.
  - Additional bentonite slurry walls, or similar, may be used to ensure isolation from surrounding cells.
  - Once the damage or leak has been hydraulically isolated then the cell can be returned to operation.
- Equipment movement on the facility is hampered by climatic or road conditions.
  - Roads within the Class A Storage Facility will be built using compacted Class A waste rock to enable movement of traffic in all weather conditions.
  - If climatic conditions restrict or negate haulage then material will be stored at the relevant production facilities until conditions are suitable for haulage.
- Desiccation of the tailings causes dust migration
  - Live operational areas will be of limited extent and progressive reclamation will ensure that this remains the case over the life of mine.
  - Areas that are susceptible to desiccation will be covered in waste rock on an “as required” basis.
- Operational parameters at the facility are not achieved due to unforeseen flaws in operating procedures.
  - Conduct field trials of methods prior to use in a production scenario.
  - Monitor methods and results of compaction, and adjust methods if required.
  - Design sufficient redundancy into the system at every level so that the company has time available to rectify flaws as they are identified.

R2-6

Provide the Mill Development and Operations Plan.

The conceptual components of the Mill Development and Operations Plan as it relates to the management of tailings has been summarized above in response to R2-5 “Production of Filtered Tailings”.

R2-7

Does the proponent have any additional plan to incorporate operational learning other than what has been completed already (i.e. engaging external experts)?

As stated in the response to R2-4 there are a several avenues that will be used to develop the preliminary operational plans and standard operation procedures. Preliminary steps to assist during the design process will include using consultants with expertise in the area of filtered tailings storage design, additional test work on samples of tailings and modelling of the Class A waste rock to obtain parameters for design. Communication and sharing of information with existing successful operations has been initiated, and is expected to be ongoing through all operational phases.

The design work will generate a feasible operations plan though it may not be optimal. The pre-operations management plan, while important, will need to be reinforced, and perhaps adapted, by trials of the proposed methods of deposition of the waste that will occur during the commissioning of the process plant and storage facility. The trials will take place in the storage facility in areas that will not alter the overall geotechnical or geochemical stability of the facility but will be planned to emulate real operating conditions. From these trials the optimal inputs of filtered tailings and Class A rock will be developed as well as the required transport and handling of these materials. This plan will be used as operations are commenced but will continue to be monitored, and adapted if required, as operations continue.

YESAB ISSUE

A target of 15% moisture content for filter tailings appears reasonable and may have been set based on the success achieved at other metal mines.

R23

"Demonstrate why a target of 15% moisture content for filter tailings is realistic for this project and can be maintained."

The target of 15% moisture content for filtered tailings is realistic and has been demonstrated by the tailings filtration testwork completed to date, as described in R14 (BMC, 2017).

YESAB ISSUE WITH BMC'S RESPONSE TO R23

A target of 15% moisture content for filter tailings appears reasonable and may have been set based on the success achieved at other metal mines.

Insufficient response: It has not been demonstrated how the target of 15% moisture can be achieved or what measures will be used to ensure this target can be consistently reached.

R2-8

Demonstrate why a target of 15% moisture content for filter tailings is realistic for this project and can be maintained.

The target of 15% moisture content for filtered tailings is realistic and has been demonstrated by the tailings filtration testwork completed to date, as described in response to R14 (BMC, 2017). For clarity the information is provided again in the following paragraphs.

Dynamic thickening tests were completed for a range flux rates and flocculant doses, with results detailed in Table 4-4. The conclusion of the thickening testwork was that the tailings can be thickened by high rate thickening over a range of fluxes, with tailings densities of 73.8 to 75.7 % solids (w/w) achieved over flux rates of 0.50 to 1.50 t/(m^{2}h).

Table 4-4: Tailings Dynamic Thickening Testwork Results

	Feed		Flocculant		Underflow		Overflow
Run No.	Flux (t/(m^{2}h))	Liquor RR (m/h)	Type	Dose (g/t)	Meas. Solids (% (w/w))	Yield Stress (Pa)	Solids (mg/L)
1	0.50	2.97	Magnafloc 155	10	75.7	126	<100
2	1.50	8.90	Magnafloc 155	10	73.5	85	<100
3	1.50	8.90	Magnafloc 155	5	73.8	55	<100
4	1.50	8.90	Magnafloc 155	2.5	73.3	35	120
5	0.78	4.63	Magnafloc 155	5	75.5	96	<100
6	1.00	5.93	Magnafloc 155	5	75.1	80	<100

Vacuum filtration testing of tailings was completed for both horizontal vacuum belt and rotating vacuum disc technologies. Results from the horizontal vacuum belt filtration testwork, using the filter cloth S90 were:

- Test filtration rate 3,756 kgDS/m^{2}hr
- Cake moisture content 15.1 %wt
- Cake thickness 42 mm

Results from the rotating vacuum disc filtration testwork, using the filter cloth S2510 were:

- Test filtration rate 4,356 kgDS/m^{2}hr
- Cake moisture content 13.9 %wt
- Cake thickness 23 mm

The conclusion of the filtration testwork was that both horizontal vacuum belt and rotating vacuum disc technologies can dewater tailings to the PFS design moisture content of 15%.

Subsequently, the filtration test work on tailings completed for the prefeasibility study has demonstrated that a moisture content of 15% can be achieved for both horizontal vacuum belt and rotating vacuum disc technologies. To gain further confidence in the validity of the test results, an additional three filtration tests on representative tailings samples will be completed for the feasibility study for variability assessment. The variability tailings samples will represent three separate composites:

- a second sample of ABM Master Composite #1, to assess repeatability of the prefeasibility study test results;
- a composite representing material mined and processed in the first 18 months of Project life; and
- a composite representing the primary metallurgical domain (pyrite rich massive sulphide), which comprises approximately 70% of the ore planned to be processed.

In addition to the above it should be noted that the Company has allowed, within the plant design, for the tailings thickeners, pumps and filters to be oversized for the expected duty which will enable a high variability of waste feed to be catered for without compromising the expected outcomes (i.e. filter cake moisture content and throughput).

In the event that as a result of the subsequent confirmatory test work, the Company forms the view that achievement of a 15% moisture target with the current waste circuit might be problematic, the Company will be able to modify the waste treatment circuit to achieve the desired outcome. This may include modifying the type of filter but could also include other elements such as modifying thickeners, flocculant treatment, filter type and size, filter cycle times, filter cloth types, pump capacities etc. None of the above modifications will change the environmental footprint of the plant or the overall economics. Additional design of the filtration system will be undertaken as part of the Definitive Feasibility study and further detailed design will be undertaken at the detailed engineering phase prior to acquisition of components and construction commencement. Further information on potential mitigation measures in the event that 15% moisture is not achieved in practise have been presented in response to R2-4 and R2-5.

4.3 CONCEPTUAL CLOSURE AND RECLAMATION PLAN

4.3.1 Final Landform Design for Waste Storage Facilities

YESAB ISSUE

The submission proposes progressive construction of a closure cover system over each of the storage facility landforms as areas of the stockpiles reach their final design elevation. The cover system designs vary depending on the level of net percolation reduction required which is based on the results of downstream water quality modelling; however, each cover system design includes an upper 0.3 m thick growth media layer, comprising a mixture of local topsoil and glacial till materials, to support growth of a sustainable cover of native plant species. Until the vegetation covers mature, the growth media layer will be susceptible to erosion, particularly for longer and steeper slopes and on larger terrace footprints *(i.e., from slope catchments above the terrace during contributing to run-on from spring freshet and storm events).*

R25

"What is the risk and associated effects of the reclaimed slopes being susceptible to increased gully erosion as a result of runoff waters from upper terraces discharging over the crest?"

The risk of gully erosion on the reclaimed slopes of the storage facilities is that if not rectified the resultant erosion would expose the cover material and eventually the encapsulated material with the potential of ARD /ML in the case of the Class A and Class B Storage Facilities. Gully erosion would cause increased runoff velocity and thus increased sediment load on all the facilities.

Risks associated with increased gully erosion of the Class A, B and C Storage Facilities will be mitigated through the inclusion of benches to reduce the length of the overall slope. The benches will be sloped appropriately to minimise down slope flow, while the slopes will be contoured to minimise the potential for erosion. The upper terraces of the facilities will be graded to a slope of 2% to convey water at a reduced velocity and reduce ponding water. Concurrent reclamation and revegetation will minimise the areas susceptible to erosion during operations and the majority of the longer steeper slopes will be revegetated prior to the active closure phase. This design concept is commonly used for reducing the potential for gully erosion and has become accepted practise throughout the mining industry.

If gully erosion is observed in areas on the storage facilities it will be remedied by a combination of some or all of: armoring, backfilling, recontouring, and revegetation.

YESAB ISSUE WITH BMC'S RESPONSE TO R25

The submission proposes progressive construction of a closure cover system over each of the storage facility landforms as areas of the stockpiles reach their final design elevation. The cover system designs vary depending on the level of net percolation reduction required which is based on the results of downstream water quality modelling; however, each cover system design includes an upper 0.3 m thick growth media layer, comprising a mixture of local topsoil and glacial till materials, to support growth of a sustainable cover of native plant species. Until the vegetation covers mature, the growth media layer will be susceptible to erosion, particularly for longer and steeper slopes and on larger terrace footprints (i.e., from slope catchments above the terrace during contributing to run-on from spring freshet and storm events).

Insufficient Response: The Proponent notes that risks associated with increased gully erosion on the Class A, B and C Storage Facilities will be mitigated through the inclusion of benches to reduce the length of the overall slope. The Proponent further states that this design concept is commonly used for reducing the potential for gully erosion and has become accepted practise throughout the mining industry.
Benches with lateral drainage channels are prone to failure over the long term due to blockages from either sediments eroded from upslope areas (Hancock et al., 2003)1, overgrown vegetation or fallen trees, or glaciation (the accumulation of snow and ice) (MEND, 2012)2. Blockages within the bench drainage channels will lead to ponding and ultimately higher seepage through the spent heap leach material. Blockages within the bench drainage channels may also lead to overtopping and channelling

of water in concentrated flow paths onto lower slope areas, leading to severe gullying and damage to the closure cover systems (see Ayres et al., 2006 and, the Whistle Mine backfilled pit final landform design)3.

A benched final landform design for the Waste Storage Facilities represents a landform that is highly engineered and does not mimic natural slopes; natural slopes are characterized by a variety of shapes with drainage systems following natural drop lines and catchment sizes defined by undulating relief on the slope.

The Proponent also states that the upper terraces will be graded to a slope of 2% to convey water at a reduced velocity and reduce ponding water. The direction of the 2% slope on the upper terraces is unclear (i.e. whether it is forward or back sloped to the crest). The catchment sizes for the upper terraces are relatively large, ranging from 16 ha for the Class B Facility to 93 ha for the Class C Facility.

R2-9

Clarify the overall direction of the planned 2% slope on the upper terraces and, will incident precipitation waters be allowed to flow in an uncontrolled manner over the crest and onto the upper reaches of the reclaimed slopes?

The upper terrace of the Class A Storage Facility will be sloped at 2% towards the lower reclaimed slopes. The final surface with be shaped to direct runoff to multiple designed channels to safely convey surface runoff over the reclaimed facility and buttress. The surface runoff collection channels will be constructed during the mine life as the facility is progressively reclaimed.

R2-10

Provide further details on the planned final landform design for each of the Waste Storage Facilities and in particular, how a benched final slope profile will limit long-term liabilities in terms of maintenance requirements and sustainability of the low-infiltration cover systems.

The Class A Storage Facility will be constructed at an overall slope of 4H:1V, and will be progressively reclaimed with a low permeability cover, followed by approximately five meters of Class C waste rock material for frost protection and long-term stability. Topsoil and material from the overburden stockpile will be placed on the frost protection layer, and this will then be revegetated to mimic the current site conditions.

Gullies that may develop due to erosion will be limited to the depth of the topsoil layer and are unlikely to erode through the five-metre thick frost protection waste rock layer.

Benches will be added to the Class A and Class B facilities as an erosion mitigation measure. The benches will not include lateral drainage channels; rather the benches will be constructed to maintain a grade sloping towards the lower elevations and rely on gravity drainage, thereby eliminating the potential of ponding water on the benches.

The Class B Storage Facility will be constructed at an overall slope of 3H:1V for long-term physical stability and to allow for re-contouring if required for reclamation and closure. Note that the recontouring will include benches with berms/ditches to control runoff. The benches will be similar to the existing natural slope of the area. The Class B Storage Facility will be progressively covered and reclaimed. A layer of topsoil and overburden material will be placed above a layer of Class C waste rock (providing frost protection). These layers overlie a low permeability layer to minimize infiltration of precipitation into the Class B Storage Facility, and any gullies that may develop due to erosion will be limited to the depth of the topsoil layer. The frost protection layer constructed of Class C waste rock will also mitigate potential erosion.

The Class C Storage Facility is composed of potentially acid consuming waste rock and will have no infiltration restricting cover. The facility will have final overall face slopes of 3H: 1V while the top of the facility will have an overall flat gradient. The final facility bench crests will be rounded and the faces sloped to improve the long-term erosion stability of the facility. The recontouring will include benches with berms/ditches, constructed similar to the existing natural slope of the area, to control runoff. The placed waste rock will be compacted and a cap of growth medium will be placed on the facility and revegetation will take place up to a pre-determined elevation. The top of the facility will mimic a large flat valley and will be contoured to blend with the surrounding topography. Any gullies that may develop due to erosion will be limited to the depth of the topsoil layer, due to the Class C material below being resistant to erosion and this material will similarly allow precipitation to infiltrate and drain away rather than flow across the surface of the facility.

4.3.2 Cover System Design for Class A and B Waste Storage Facilities

YESAB ISSUE

The designer anticipates that a substantial portion of the estimated "runoff" for both cover systems will be diverted as interflow, not surface runoff. There is no indication of the estimated volume of interflow and, more importantly, how interflow waters will be managed to prevent excessive build-up of pore-water pressures (and potential softening or ponding) near the toe of the reclaimed facilities.

R31

"What is the differentiation between "surface runoff" and "interflow" volumes in the mean annual water balances completed for each waste storage facility cover system?"

The sum of these two flows make up the total run-off value. The surface run-off is the proportion of the precipitation that flows down the slope on the upper organic media layer. The interflow run-off is the proportion of the flow that is diverted by the underlying cover layers (e.g. very low permeability material layer in the Class A Storage Facility and the low permeability compacted till layer in the Class B Storage Facility), such that this diverted water runs through the overlying material.

A simplified water balance for each cover was provided in Conceptual Cover Design Report, provided as Appendix A to the Conceptual Reclamation and Closure Plan (Appendix H of the Project Proposal). These water balances describe the mean annual conditions. At this level of assessment, the water balance (ΔS) does not account for water storage within the cover system, as this is an optimization for a later stage once more site specific information has been obtained.

The Class A Storage Facility assumes a cover system water balance of no more than 2% of total annual precipitation will pass through the very low permeability layer. With approximately 30% evapotranspiration, 68% either flows along the upper organic growth layer as surface run-off or infiltrates into the upper frost protection layer until it reaches the very low permeability layer and flows along the surface of this layer until captured by the collection ponds.

The Class B Storage Facility assumes a cover system water balance of no more than 25% of total annual precipitation will pass through the low permeability layer. With approximately 30% evapotranspiration, 45% either flows along the upper organic growth layer as surface run-off or infiltrates into the upper frost protection layer until it reaches the very low permeability layer and flows along the surface of this layer until captured by the collection ponds.

YESAB ISSUE WITH BMC'S RESPONSE TO R31

The designer anticipates that a substantial portion of the estimated "runoff" for both cover systems will be diverted as interflow, not surface runoff. There is no indication of the estimated volume of interflow and, more importantly, how interflow waters will be managed to prevent excessive build-up of pore-water pressures (and potential softening or ponding) near the toe of the reclaimed facilities.

Insufficient response: Proponent has not provided the requested breakdown between "surface runoff" and "interflow" volumes.

R2-11

What is the differentiation between "surface runoff" and "interflow" volumes in the mean annual water balances completed for each waste storage facility cover system?

On October 17 2017, YESAB provided (via email) the following clarification regarding the information required in response to R2-11:

> *"After further consideration and discussion regarding R2-11, the Executive Committee does not require additional information with regards to the differentiation between "surface runoff" and "interflow" volumes in the mean annual water balances completed for each waste storage facility cover system at this time."*

YESAB ISSUE

Higher or lower evapotranspiration will affect the predicted net percolation rate, which ultimately affects seepage rates from base of the waste storage facilities.

R33

"How will higher or lower evapotranspiration rates from the 30 % estimate affect seepage rates from the base of the waste storage facilities and what are the implications to stability and water management?"

This is an important design consideration that is addressed through the landform design of the facility, and water management structures.

Less evapotranspiration would be associated with increased surface runoff, not necessarily increased seepage from the foundation of the facility. This will additionally be addressed though future detailed design studies and ongoing reclamation research during operations to determine the compaction and thickness of the lower permeability and frost protection layers, such that saturated flow conditions are not developed at the base of the Class B Storage Facility. Saturated conditions will not develop at the base of the Class A Storage Facility as the very low permeability layer will prevent sufficient seepage from creating these conditions.

YESAB ISSUE WITH BMC'S RESPONSE TO R33

Higher or lower evapotranspiration will affect the predicted net percolation rate, which ultimately affects seepage rates from base of the waste storage facilities.

Insufficient response: Given the uncertainty in estimation of PET and the assumption and use of a factor of 0.5 to convert PET to AET, the response to R33 should be in a more quantitative manner with a breakdown in water balance component volumes for various conditions (i.e., mean, dry wet). This will provide a better understanding of potential seepage rates from the base of the waste storage facilities. It is noted that landform and cover design will affect the factor assumed to convert PET to AET.

R2-12

How will higher or lower evapotranspiration rates from the 30 % estimate affect seepage rates from the base of the waste storage facilities and what are the implications to stability and water management?

During operations, seepage out of the base of the storage facilities is controlled by the till liner at the base of the Class A and B Storage Facilities. This liner directs water to the collection ponds prior to being conveyed into the site water management system. The liners of the Class A and B Storage Facilities have, as a design criteria, been assumed to prevent a minimum of 75% of mean annual precipitation from seeping through the bottom of each facility.

A conceptual water balance of the Class A Storage Facility for the till liner prior to placement of waste material, given these assumptions, indicates the following for a mean precipitation year:

- If evaporation was at a rate of 30% during a mean annual precipitation year, the seepage out of the bottom of the facility would be 17%.
- If evaporation was at a rate of 20% during a mean annual precipitation year, the seepage out of the bottom of the facility would be 20%.

By comparison; during a 1 in 50 wet precipitation year:

- If evaporation was at a rate of 30%, the seepage out of the bottom of the facility would be 20%.
- If evaporation was 20%, the seepage out of the bottom of the facility would be 21%.

As stated in the Project Optimizations and Updated Water Quality Performance Expectations for KZK Project (Appendix R2-C of this Response Report), the liner constructed under the Class A Storage Facility will be designed to prevent seepage from the facility to the groundwater system. It was assumed that the liner design will be of suitable material and will be carefully installed to ensure long-term performance, such that seepage from the base of the facility will be prevented during operations and at closure. The Class A Storage Facility liner design will be refined through the regulatory process. Therefore, variation in evapotranspiration will have a negligible effect on seepage from the Class A Storage Facility as it is assumed that the design criteria of the liner for the Class A Storage Facility will be met and seepage will be negligible.

Any seepage passing through the liner of the Class B Storage Facility has been modeled to enter the groundwater system and is reflected in the updated water quality model results (Appendix R2-C). Additional information on assumptions for waste covers and liners in the water quality predictions can also be found in Appendix R2-C.

R2-13

As per R30, provide documentation related to the statement that "a factor of 0.5 gives 180 mm per year which is within the reasonable range of estimates based on estimates for the region in the 200 mm range". In addition, it is noted that the factor of 0.5 was derived as part of the baseline hydrometeorology study. Justification is required for use of the factor of 0.5 for the cover system design.

The factor of 0.5 to convert PET to AET is an average for the site. The factors used for each sub-catchment were empirically derived and calibrated during water balance modelling and range from 0.32 to 0.79.

The 200 mm range estimate for the region is from the Hydrological Atlas of Canada (Government of Canada, 1978). Varying the factor used to convert PET to AET determines how much of the water is lost to evapotranspiration, which is reflected in the facility cover water balance. Given the cover systems on the Class A and B Storage facilities will have a combination of engineered and geosynthetic liners with a hydraulic conductivity of 0.05% to 1.5% (as outlined in Appendix R2-D of this Response Report), varying the percentage lost to evapotranspiration will only affect the volume of water lost as run-off. Seepage through the liner into the underlying waste will be minimal, given the very low hydraulic conductivity value of the liners.

4.3.3 Long-term Physical Integrity of Cover System Reduced Permeability Layers

YESAB ISSUE

The Class A and B facilities' cover system designs incorporate a reduced permeability layer. If the underlying foundation materials or stockpiled waste undergoes differential settlement, then the potential exists for cracks and other defects to develop in the reduced permeability layers. This may lead to substantial increases in net percolation rates into the waste. As well, geosynthetic products have a finite service life due to various factors that cause geosynthetic fibres to age or deteriorate over time.

The submission does not indicate the required longevity of the geosynthetic liner proposed for the Class A Storage Facility cover system.

R37

"Describe how the cover system will be monitored to ensure it continues to achieve design objectives. Describe mitigative measures or alternatives that may be implemented in the event that the cover system is not performing as expected."

It is agreed that the cover systems will need to be monitored to ensure performance criteria are being achieved. The details of the monitoring, mitigation measures, and alternatives will be advanced during the detailed design phase. Independent of the details of the cover design, the following points will apply to any of the cover system design or material selected.

A description of the monitoring and inspections for the Class A and B Storage Facilities, including the cover systems, are provided in Section 7.11.1 of the Conceptual Reclamation and Closure Plan, provided as Appendix H of the Project Proposal.

The collection ponds will be the first point to evaluate performance of the cover systems as the seepage from the Class A or Class B Storage Facilities is drained directly into these ponds. Additionally, throughout operation and into active closure there will be a groundwater and surface water monitoring program that will identify if seepage is being discharged from either of these facilities. The surface water monitoring network is provided in Chapter 8, Section 8.6, of the Project Proposal and is summarized in Table 8-49 of that section. The groundwater monitoring network of these facilities is provided in Chapter 9, Section 9.6 of the Project and summarized in Table 9-11.

In the case of the Class A Storage Facility there are currently three groundwater monitoring wells (MW15-09S, MW16-14D, and BH95G-15D) and three surface water monitoring sites (KZ-9, KZ-17 and KZ-37) located downgradient of the facility. For the Class B Storage Facility, there are currently three groundwater wells (BH95G-33D, MW16-7D, and MW16-07S) and two surface water sites (KZ-7 and KZ-9) located downgradient.

The Class A and B Storage Facilities will be progressively reclaimed throughout operations, and if issues are identified during facility construction it will be possible to adapt the closure design to remedy these issues. An Adaptive Management Plan will be advanced during the detailed design of these facilities and will include defined triggers to identify when actions such as a cover replacement or redesign must be undertaken. This plan may include extending the collection and treatment of the seepage beyond operations until an alternative measure is determined, implemented and shows evidence that the risk to the environment has been mitigated. The framework for the Adaptive Management Plan is provided in Section 7.12.2 of the Conceptual Reclamation and Closure Plan, provided as Appendix H of the Project Proposal.

YESAB ISSUE WITH BMC'S RESPONSE TO R37

The Class A and B facilities' cover system designs incorporate a reduced permeability layer. If the underlying foundation materials or stockpiled waste undergoes differential settlement, then the *potential exists for cracks and other defects to develop in the reduced permeability layers. This may lead to substantial increases in net percolation rates into the waste. As well, geosynthetic products have a finite service life due to various factors that cause geosynthetic fibres to age or deteriorate over time. The submission does not indicate the required longevity of the geosynthetic liner proposed for the Class A Storage Facility cover system.*

Insufficient response: The proponent did not address long-term performance of the class A and class B facilities' cover designs.

R2-14

Describe how the cover system will be monitored to ensure it continues to achieve design objectives. Describe mitigative measures or alternatives that may be implemented in the event that the cover system is not performing as expected.

It is agreed that the cover systems will need to be monitored to ensure they continue to achieve design objectives in the long term. The Project Closure Plan is conceptual at this stage and will be further developed and finalized during permitting in consultation with EMR, Yukon Water Board, and RRDC. Independent of the details of the cover design, the following 'tools" have been identified for long term monitoring of cover system performance:

- Lysimeters – to monitor seepage (if any) through the covers;
- Physical inspections (looking for unusual occurrences, such as settlement or sloughing, abnormal seepage from any area on the slopes, isolated pockets of vegetation stress, and physical damage); and
- Downgradient surface and groundwater quality stations. Water quality monitoring will occur downgradient of the facilities, which will be subject to a statistical review to monitor for any potential warning signs to determine if there is a problem with the cover.

Additionally, there will be an Adaptive Management Plan (AMP), which will identify specific thresholds from the monitoring and inspection program. These thresholds are staged as early warning indicators, to increase monitoring and implement mitigative actions ranging from statistical analysis of monitoring, installation of instrumentation, maintenance activities, to review of the design performance by the engineer.

The selection process and development of the AMP, detailed around the framework provided in Appendix H of the Project Proposal (Conceptual Reclamation and Research Plan, Section 7.12.2), will proceed when key elements of project design and their evaluation tools are advanced as the project moves through the planning continuum.

Inspections will be performed annually until the cover systems have been shown to have stabilized, which will be determined by the design engineers. Inspections will guide regular maintenance to ensure the cover systems are operating effectively. If it is indicated through inspections and monitoring that the cover is not meeting design objectives, alternatives will be assessed through the AMP. The Class A and B Facilities will have very low permeability liner cover systems, which will significantly reduce the seepage through each facility. However, one of the alternatives available, if the cover is not sufficiently reducing seepage as per the design basis, is to convert the collection ponds to bioreactors to treat the excess seepage. **Appendix R2-C** (Project Optimizations and Updated Water Quality Performance Expectations for Kudz Ze Kayah Project) includes an updated description of cover systems considered and more detail on Project optimizations and closure alternatives considered. Longevity of a geosynthetic liner for the Class A Storage Facility cover system is also addressed in **Appendix R2-C.**

R2-15

Describe the performance measures for the class A and class B facilities' covers that will be assessed during operations to ensure performance in the long term?

It is agreed that the cover systems will need performance measures for the Class A and B Facilities' covers during operations to ensure they continue to achieve design objectives in the long term. The Project Closure Plan outlined at this stage will be further developed and if required, optimised during the detailed engineering phase of the Project design and as part of final permitting in consultation with EMR, Yukon Water Board, and RRDC.

Some of the performance measures that may be selected are:

- Quality control measures during installation, such as inspecting seams after they have been welded, following specifications for drainage and bedding layers;
- Monitoring of seepage quality and quantity into the collection ponds, as the facility is progressively reclaimed;
- Field inspections looking for settling, sloughing, seeps, and erosion; and
- Instrumentation and lysimeters will be installed during progressive reclamation within and under the cover system to monitor moisture, frost depths, and pressure.

YESAB ISSUE

Section 9 of the CRCP includes a preliminary closure liability estimate, MRB would like to note that the estimate provided is not consistent with the 2013 guidance document prepared by Yukon government (YG) and the Yukon Water Board entitled "Reclamation and Closure Planning for Quartz Mining Projects." Specifically, the estimate does not provide for indirect costs such as reclamation research, engineering design, interim care and maintenance and other costs associated with the development of closure plans. Given the uncertainty surrounding the waste disposal methods and treatment of impacted water, it is important for the proponent to give full consideration to the costs associated closure plan development and implementation.

R279

"Provide an updated Conceptual Reclamation and Closure Plan demonstrating that the mine site will remain chemically and physically stable in the long-term using proven technologies demonstrated to work in northern climates."

BMC is committed to the selection of the most appropriate technologies for maintaining long-term stability of the Project site and for meeting all other closure goals and objectives. The CRCP provided as Appendix H to the Project Proposal proposes closure measures that are either routine, industry standard practices (e.g. runoff diversion, regrading, revegetation, low permeability mine waste covers) or Project-specific and developed by industry experts with substantial experience in the application of these technologies in comparable situations in the mining industry (e.g. *in situ* carbon-based water treatment, constructed wetland treatment systems [CTWS]).

Additional support for the application of some of these technologies at the Project is provided in responses to IR109 (CWTS), IR125 (*in situ* pit treatment, CWTS) and IR130 (waste cover systems). A detailed Reclamation and Closure Plan will be developed in accordance with YG's 2013 Guidance Document: *Reclamation and Closure Planning for Quartz Mining Projects guide by Yukon Government and the Yukon Water Board.* This plan will provide additional support for the application of site-specific closure measures.

YESAB ISSUE WITH BMC'S RESPONSE TO R279

Section 9 of the CRCP includes a preliminary closure liability estimate, MRB would like to note that the estimate provided is not consistent with the 2013 guidance document prepared by Yukon government (YG) and the Yukon Water Board entitled "Reclamation and Closure Planning for Quartz Mining Projects." Specifically, the estimate does not provide for indirect costs such as reclamation research, engineering design, interim care and maintenance and other costs associated with the development of closure plans. Given the uncertainty surrounding the waste disposal methods and treatment of impacted water, it is important for the proponent to give full consideration to the costs associated closure plan development and implementation.

Insufficient response: In response to R279, the proponent has not provided adequate information to demonstrate the long-term stability of the mine site. As with other mine sites in Yukon, a reclamation and research program will be required as a part of closure planning, this will include the need for demonstration scale testing to be conducted, and until the test plots demonstrate that the flow rates and contaminant loads can be adequately treated, alternative treatment technologies will be required. Without sufficient testing, it is not possible to determine whether or not this treatment technology will be sufficient for the site conditions and if another alternative is required. Until a pilot scale study supports the outcomes predicted, alternative treatments must also be considered in the assessment. The Yukon Mine Site Reclamation and Closure Policy does support the use of new technologies as long as they are supported by "feasibility assessments showing technical and economic viability in Yukon", as the water quality objectives of the site are not known, and the wetlands have not been tested in the field this condition has not been met.

The proponent has stated, "closure costs have little if any bearing on assessing effects of a project, beyond the insolvency on the part of a proponent." Given the long-term implications and the *uncertainties with waste management and water treatment, some estimation should be provided for the expected costs of temporary closure, permanent closure, and care and maintenance. This is important in the adequacy stage to be able to understand if financial security is a reasonable mitigative measure or whether it is so large as to be unreasonable. MRB understands the costs will not be exact, but are estimated based on the reclamation and closure methods being assessed, and should include costs for temporary closure, permanent closure, and post closure long term care and maintenance.*

R2-16

Provide an updated Conceptual Reclamation and Closure Plan demonstrating that the mine site will remain chemically and physically stable in the long-term using proven technologies demonstrated to work in northern climates.

Appendix R2-C (Project Optimizations and Updated Water Quality Performance Expectations for Kudz Ze Kayah Project) of this Response Report includes updates to the Conceptual Reclamation and Closure plan for the Project along with revised water quality predictions.

R2-17

Provide the following information in relation to the Conceptual Reclamation and Closure Plan:

a) A timeline for the implementation of the Constructed Wetland Treatment System (CWTS) using updated water quality objectives and predictions from the additional kinetic tests mentioned in R81 and R106;

On October 17 2017, YESAB provided (via email) the following clarification regarding the information required in response to R2-17a:

> *"Table 8-9: Closure Schedule and Execution Strategy provided in response to R107, provides a general timeline for all closure activities. Appendix H to the Proposal, Conceptual Closure and Reclamation Plan, identifies a phased approach to designing and implementing the Constructed Wetland Treatment System (CWTS). Phases 1 a and b are complete while Phases 2 through 5 will happen at some time during construction and operations. What is missing is the timeline for when these phases will be completed."*

A timeline for the implementation of the Constructed Wetland Treatment System (CWTS) was provided in response to R107 (BMC, 2017) and is reproduced below for clarity (Table 4-5). The final column in the table indicates "Earliest Period Applicable" for each of the phases. For phases 1b and 2, BMC indicated that these phases would be pre-operations, once water quality predictions are updated. For clarity phases 1b and 2 will be undertaken in 2018 using the updated model predictions that will be submitted during Water Licencing (i.e. pre-operational period). That being said, BMC has conducted an optimization assessment of the closure plan (including revised water quality modelling) to ensure receiving environment water quality meets the water quality objectives without the reliance on the proposed wetlands. This assessment confirms that the wetlands will function only to further improve water quality or "polishing" (**Appendix R2-C**) and is not needed nor is it intended to be the primary treatment mechanism.

Phase 3 will also be initiated in 2018 once Phase 2 is complete, and so the combined 24 months required for working completion will be completed in approximately mid-2020, although working results could be available for licensing support earlier, in 2019. The timing of the remaining phases should be clear from the Table 4-5 below, in the column "available time in operational/closure schedule". The Phase 4 demonstration scale installation will be constructed during the operational period and will be completed a number of years before initiation of Phase 5 (but could still be ongoing for refinement of results). Phase 5 will be initiated (construction) and completed (commissioned) as required to ensure maturity of the system when the pit begins spilling.

In addition, as per R2-33 and R2-52, BMC has committed to providing YESAB the requested updated baseline data and updated modelling, prior to the Executive Committee preparing the Screening Report.

Table 4-5: Conceptual Schedule of Completion of Phased Implementation of Constructed Wetland Treatment System

Phase		Time Required	Available Time in Operational/Closure Schedule	Earliest Period Applicable
Phase 1a	Information gathering and site assessment	3-6 months (completed)		Pre-operational
Phase 1b	Conceptual design and sizing			Pre-operational, once water quality predictions are available
Phase 2	Off-site bench-scale testing and optimization	3-6 months	2.5 years until start of *Mine Construction*, and another 1.5 years during *Mine Construction*	Pre-operational, once water quality predictions are updated and YESAB recommendations known
Phase 3	Off-site pilot-scale testing and optimization	8-16 months		After Phase 2 is complete
Phase 4	On-site confirmation-scale implementation and monitoring	2-5 years	10 years during *Mining Operations*	Operational period
Phase 5	Full-scale implementation – North CWTS	1 year for construction and 2 years for commissioning	2 years during *Transition Closure* as Pit is filling for construction 10 years during *Transition Closure* as Pit finishes filling for commissioning	After size refinement in Phase 4

b) Alternative closure approaches for the Kudz Ze Kayah site, demonstrating long-term chemical and physical stability, as an alternative to CWTS;

Appendix R2-C (Project Optimizations and Updated Water Quality Performance Expectations for Kudz Ze Kayah Project) provides details regarding bioreactors as an alternative closure approach to CWTS.

c) ***An updated closure liability estimate including costs for temporary closure, permanent closure, and care and maintenance costs in perpetuity. Costing should include periodic maintenance and repair costs as well as monitoring costs.***

On October 17, 2017, YESAB provided (via email) the following clarification regarding the information required in response to R2-17c:

> *"While closure estimates have been provided in conceptual closure and reclamation plan (CCRP) for final reclamation and closure liabilities, Government of Yukon has indicated that estimates should be provided for temporary closure and post closure long term care and maintenance. In addition, updated closure estimates must be directly related to the conceptual closure plan being presented. As such, closure estimates will likely need to be updated based on the response to R2-16 which has requested an updated CCRP."*

An updated closure liability estimate is provided below in This estimate should be considered preliminary, and will be further refined in accordance with the continual review and revision of the Plan required by the Quartz Mining Licence. These additions increase the closure liability estimate marginally, from CAD$ 90,500,000 to CAD$ 92,700,000. The closure liability estimate was further increased to $114,759,420 as a result of the change in cover design for the Class B Storage Facility from an enhanced store-and-release type cover to the same three-layer cover as that of the Class A Storage Facility.

Table 4-6 and is costed on the assumption that a third party would be implementing the closure measures (not BMC). It has included a two-year interim care and maintenance period and has utilized net present value calculations to estimate post-closure care and maintenance (PCMM) costs in perpetuity. It does not include temporary closure costs – by definition, these are costs incurred by the company (i.e. similar to operational costs) during a period under which the Project remains in control of the site. It is therefore not a component of site 'liability', and is likewise not a component of *Reclamation and Closure Planning for Quartz Mining Projects, Plan Requirements and Closure Costing Guidance* (Yukon Government, 2013). It should also be noted that liability estimation 'in perpetuity' is also not a typical component of security calculations for closure estimates. Although a predictable framework for site relinquishment is not established in Yukon, previous projects have assumed a reasonable post-closure period (10-25 years) for application of PCMM costing. The information included in the revised cost estimate below is strictly in response to this information request, and will not necessarily be provided this way for closure security calculations with Yukon Government in the future.

The full cost for the environmental site assessments, as well as the monitoring instrumentation equipment was included in the PCCMM cost, however all other values were discounted at a rate of 2.5% to Net Present Value (NPV). The PCCMM costs were calculated out to 500 years, at which point they had reduced to a NPV that was negligible.

The costs for a two-year interim care, maintenance, and monitoring period covers essential personnel, truck, equipment and fuel costs, transportation, and general site maintenance costs. Additionally, it includes active water treatment costs, monitoring, communication and reporting costs, as well as power, camp, and miscellaneous supply costs.

This estimate should be considered preliminary, and will be further refined in accordance with the continual review and revision of the Plan required by the Quartz Mining Licence. These additions increase the closure liability estimate marginally, from CAD$ 90,500,000 to CAD$ 92,700,000. The closure liability estimate was further increased to $114,759,420 as a result of the change in cover design for the Class B Storage Facility from an enhanced store-and-release type cover to the same three-layer cover as that of the Class A Storage Facility.

Table 4-6: Summary of Revised Estimated Reclamation and Closure Liability

Cost Area	Estimated Cost	Typical Description of Costs
Closure Implementation		
General & Administration	$3,500,000	Onsite management, camp costs, transport, mob/demob, health & safety
Closure Planning	$2,244,000	Reclamation research, adaptive management planning, materials testing
Open Pits	$1,500,000	Equipment removal, access control, wall and crest stabilization, lime amendment
Waste Rock and Tailings	$53,000,000	Re-grading, cover placement, revegetation
Surface Facilities	$1,500,000	Building and concrete demolition, debris removal, chemical removal, soil excavation
Water Storage Ponds	$750,000	Removal of embankments, pumping of water, placement of rip-rap and soils, slope stabilization
Infrastructure	$500,000	Disconnection of services, removal of equipment, site clean-up, hauling of scrap
Waste Disposal / Remediation	$100,000	Preparation of facility closure plan, recontouring, placement and compaction of cover
Roads and Trails	$250,000	Recontouring, scarification, erosion barriers
Water and Solutions Management	$11,650,000	Reclaim site diversions, active treatment costs, passive treatment costs
Quarries and Borrow Pits	$50,000	Access control, resloping, scarification
Sediment and Erosion Control	$100,000	Erosion barriers, silt fencing, sediment ponds

Cost Area	Estimated Cost	Typical Description of Costs
Interim Care, Maintenance, and Monitoring Costs	$2,815,000	Site personnel, monitoring, water treatment, site maintenance including equipment for 2 years
Post-Closure Care Maintenance, and Monitoring Costs	$5,200,000	Monitoring programs, instrumentation, environmental assessments, discounted for NPV
Sub-total	$83,159,000	
Indirect Costs (%)	15%	
Indirect Costs	$12,473,850	Insurance, taxes, administrative costs
Total Closure Implementation Costs	$95,632,850	
Contingency Allowance	20%	
Contingency Amount	$19,126,570	Contingency due to uncertainty of current level of design. This will reduce in line with the degree of future design.
Approximate Total Financial Security (including Contingency) for environmental assessment purposes	**$114,759,420**	

4.4 OPEN PIT AND UNDERGROUND MINING

4.4.1 Open Pit

YESAB ISSUE

In Section 4.6.2.1, a minimum 5 m wide bench at the pit crest is proposed to catch any material raveling down the pit wall slopes. The proposed bench width is very narrow. The rationale behind the selection of this bench width is not clear, and it is not clear that this will be sufficient to minimize the risk of rock fall to an adequate level.

R38

"Provide the rationale for selecting a 5 m wide bench and any relevant numerical analysis confirming the adequacy of the bench width."

As stated in Section 4.6.2.1 of the Project Proposal: "*A* **minimum** *5 m wide bench at the pit crest is required to catch any material ravelling down the slopes*." (Emphasis added.) The minimum crest bench width will be 5 m and the slopes of the overburden will have a maximum slope of 30°. Note that 5 m is a fairly standard minimum and is in accordance with custom & practise internationally in small circumferences and relatively shallow pits such and ABM and Krakatoa. The overburden thickness varies between 2 and 20 m and the designed width of the crest bench will be sufficient to catch all material that could potentially be dislodged from the slopes of the overburden. The bench width may be increased in areas due to a number of factors including; overburden thickness, material gradation, consolidation, and moisture content.

Numerical analysis has not been completed for the ABM Zone pit, given that the project has been completed to PFS level. This work will be completed as part of the Feasibility Study work programme that will be completed prior to applying for a Quartz Mining Licence from the Department of Energy, Mines and Resources. In the interim, BMC has used industry standard assessment of stability based upon its visual examination of relevant drill core by qualified geotechnical engineers and the historical reports from world renowned specialists Golder Associates (Jan 26, 1996).

YESAB ISSUE WITH BMC'S RESPONSE TO R38

In Section 4.6.2.1, a minimum 5 m wide bench at the pit crest is proposed to catch any material raveling down the pit wall slopes. The proposed bench width is very narrow. The rationale behind the selection of this bench width is not clear, and it is not clear that this will be sufficient to minimize the risk of rock fall to an adequate level.

Insufficient response: Proponent failed to provide any reference to justify this 'minimum' bench width. It was stated in their response that the minimum bench width is 'fairly standard minimum and is in accordance with custom & practise internationally in small circumferences and relatively shallow pits such as ABM and Krakatoa.
It is worth nothing that the minimum bench width is proposed to be 7 m in "Guidelines for Open Pit Slope Design (Read and Stacey, 2009). Moreover, and as another example, the minimum bench face is 8 m in British Columbia (Health, Safety and Reclamation Code for Mines in British Columbia, 2017).

R2-18

Provide the rationale for selecting a 5 m wide bench and any relevant numerical analysis confirming the adequacy of the bench width.

In reviewing the background text provided by the technical reviewer, and the example BC regulation referenced, it appears that there may have been a miscommunication as to what the 5 m wide bench refers to. Section 4.6.2.1 of the Project Proposal described the pit geometry and slope stability for the ABM Zone. The 5m bench described in this section relates to a single additional bench at the overburden – rock interface and is separate to the standard bench design in rock. Overburden above this bench is sloped at 25° to 30°, as recommended in the feasibility level geotechnical assessment completed by Golder Associates (Golder, 1996).

Once in rock, a different catch bench width has been used, again as recommended by Golder Associates. In reviewing the response to this question, it has become apparent that the slope configurations within the ABM Zone for rock were not identified in the Project Proposal (however they were provided for the Krakatoa Zone in Section 4.6.2.2), and BMC has interpreted this to be the potential source of miscommunication. The proposed slope configurations for the ABM Zone are provided below in Table 4-7.

Table 4-7: Proposed Slope Configurations for the ABM Zone

Range in Wall Sector Azimuth	Wall Designation	Bench Face Angle (degrees)	Catch Bench Width (m)	Vertical Bench Separation (m)	Interramp Angle (degrees)
210 – 340	West Endwall	70	8	20	52.5
340 – 020	North Highwall	65	8	20	49
020 – 070	East Cutwall	70	10	20	49
070 – 150	East Endwall	70	8	10	41
150 – 210	South Wall	Determined by deposit orientation; bench faces parallel to orebody footwall must not undercut the foliation and associated shears			

The minimum catch bench width within the pit is 8 m which meets the standards referenced by the technical reviewers.

With respect to the 5 m catch bench for the overburden interface, the Health, Safety and Reclamation Code for Mines in British Columbia (Ministry of Energy and Mines, British Columbia, 2017) referenced by the technical reviewer has a specific clause to unconsolidated material. Clause 6.23.1, Removal of Unconsolidated Material states:

> *"All trees and other vegetation, clay, earth, sand, gravel, loose rock, or other unconsolidated material lying within 2 m of the rim of a working face or wall in a surface mine shall be removed, and beyond this distance all unconsolidated material shall be sloped to an angle less than the natural angle of repose."*

The design criteria detailed earlier in this response (5 m wide bench and slope angles of 25° to 30°) meets this standard.

R2-19

The minimum bench width should be justified by widely accepted engineering references or numerical modelling. It is recommended to use the higher estimate in this level and then justify a narrower bench with more detailed method rather than the opposite.

Please see BMC's response to R2-18.

YESAB ISSUE

Golder Associates (January 26, 1996) stated in its Executive Summary that "groundwater levels are generally high and follow the topography, with some of the holes in the valley floor exhibiting artesian flow". In the Mine Dewatering section, the report stated that additional drain holes will also be required to investigate the potential for artesian pressure in the south wall.

R39

"Provide additional information related to rock characteristics and the potential for artesian conditions. Provide any additional detailed plans that are available and if they are not, describe the future investigations that will occur to check rock characteristics and artesian conditions."

The hydrogeological setting of the Project and dewatering strategy is presented in the December 14, 2016 Tetra Tech EBA Hydrogeological Model, Kudz Ze Kayah Project, Yukon report (Appendix D-4 of the Project Proposal). As part of the design work required for permitting, future site investigations will be undertaken to refine the hydrogeological model and rock characteristics.

YESAB ISSUE WITH BMC'S RESPONSE TO R39

Golder Associates (January 26, 1996) stated in its Executive Summary that "groundwater levels are generally high and follow the topography, with some of the holes in the valley floor exhibiting artesian flow". In the Mine Dewatering section, the report stated that additional drain holes will also be required to investigate the potential for artesian pressure in the south wall.

Insufficient response: Future investigations were not described.

R2-20

Provide additional information related to rock characteristics and the potential for artesian conditions. Provide any additional detailed plans that are available and if they are not, describe the future investigations that will occur to check rock characteristics and artesian conditions.

The potential for artesian conditions was addressed in hydrogeological investigation work completed by both BMC (Appendix D-4 of the Project Proposal) and Cominco (Golder, 1996). Section 2.3.1 of Appendix D-4 identifies that artesian conditions are present in the overburden layer and indicative of a confined aquifer. Artesian conditions were not identified within the bedrock rock mass:

> *"Groundwater in the basal sand and gravel unit is believed to be confined to semi-confined by the overlying compact to dense sand. At the completion of well installation in WW15-01, the water level rose approximately 6 m above the top of the sand and gravel and above the top of the inferred confining dense sand layer indicating a confining layer is present. The inference of a confining overburden unit is supported by the rapid response in the observation well during the pumping test at WW15-01, a reaction generally indicative of a confined aquifer".*

Similarly, Section 4.4.2 of the Golder report also identifies that artesian conditions are associated with the overburden layer:

> *"Groundwater flow is from the mountains to the valley bottoms. From there, the groundwater moves downgradient in the overburden material (north direction). Flowing wells and boreholes in the valley bottom are indicative of upward flowing groundwater. The flowing boreholes appear to result from high hydraulic heads and relatively high hydraulic conductivities in the overburden material only."*

Neither report concludes that artesian conditions will be present in bedrock. While it is currently expected that artesian conditions will not be present in bedrock, ongoing monitoring of bedrock water levels will continue through Project development and operations to assess and ensure the effectiveness of the ground water dewatering regime. As noted in Section 8.3.2 of the Golder report (and similarly confirmed in Section 4.2.2 of Appendix D-4):

> *"Based on available hydrogeological data, it is believed that the competent bedrock will drain naturally through the highwalls and endwalls. Existing piezometers will be used to monitor the draining of the rock and if required, horizontal drains will be installed in areas of high hydraulic heads."*
>
> *"Fault zones that do not intersect the pit may require depressurisation for slope stability purposes. These zones will be depressurised by horizontal drains drilled from the pitwall into the fault zone, or by vertical wells installed from the ground surface into the fault zone. To locate the fault zones, exploratory horizontal boreholes should be installed every 50 m along the benches at 30m intervals… Exploratory vertical drain holes will also be required to investigate the potential for artesian pressures in the south wall sequence. Any such pressures could be dissipated by vertical bleed holes."*

In summary;; artesian conditions are expected to be present within the overburden layer. Dewatering of the overburden and subsequent excavation of the open pit will effectively drain this material very early in the development of the open pit removing the risks of artesian conditions. Groundwater conditions in bedrock will continue to be monitored during operations, incorporating drain holes to address confined aquifers that are not successfully dewatered by the network of dewatering wells.

R2-21

Describe investigations that will provide information on rock characteristics and artesian conditions.

The response to this Request is discussed in the response to R2-20.

4.4.2 Underground Mining (In-Situ Stresses and Possible Failure Mechanism)

YESAB ISSUE

Section 3.4 states, "for the purpose of the underground mining at Krakatoa, the major and intermediate stresses are assumed to be 2.5 and 1.5 times the vertical stress respectively (Martin et.al. 2003)." It is correct that in Canada the horizontal stress is greater than vertical stress. However, it should be noted that Martin et al. is based on their investigation at the Underground Research Lab (URL) located in Manitoba.

Potential failure mechanisms such as structurally controlled failure (i.e., wedge failure) and stress-induced failure (i.e., spalling and slabbing) have not been discussed in the Rockland report.

The in-situ horizontal to vertical stress ratio will be the input for the underground mine design, support design, excavation geometry, potential failures (progressive or sudden) and other considerations. This information is normally obtainable by in-situ tests such dilatometer tests or plate load tests.

R49

"What are the expected potential failure mechanisms (both structural failure and stress-induced)?"

As stated in the Rockland report (**Appendix 2** of the Initial Response Report (BMC, 2017), Section 8 Recommendations), in the next stage of assessment, a dedicated geotechnical drilling program will be planned in order to obtain representative geotechnical information across the main lenses and where other important infrastructures such as the ramp will be located underground. The drilling will be oriented core drilling and therefore major joint sets will be defined. Further, as mentioned in Section 8, a laboratory program will be planned to establish required parameters such as Young's Modulus and Poisson's ratio for the main Krakatoa's rock types. This will subsequently be supported by geological and geotechnical mapping within the open pit. This information set will be used to define potential failure mechanisms and recommend ground support accordingly.

R50

"How have the outlined mitigation measures accounted for the potential scenario where assumptions made in the preliminary design are non-conservative?"

As stated in the Rockland report (**Appendix 2** of the Initial Response Report (BMC, 2017), Section 8 Recommendations) in the next stage of assessment, a dedicated geotechnical drilling program will be planned to obtain representative geotechnical information across the main lenses. Subsequently, geotechnical domains will be identified for Krakatoa and ground support will be recommended accordingly. Where locally, the recommended ground support is found to be insufficient, analytical /empirical/numerical methods will be used to assess stability and recommend ground support.

Should the assumptions made in the preliminary design be found to be non-conservative (as an example if it was determined that fibrecrete reinforcement of the main ramp was necessary), BMC will revise ground support designs to ensure that the integrity of the underground mine is maintained, and that safety of underground personnel is not compromised. BMC has allowed for sufficient financial and production contingencies within the planning of the mine to ensure that flexibility in ground support design can be maintained as and when required.

R51

"What are the gaps in information and what is the plan for addressing these gaps for the detailed design and operations?"

As noted in R48, the measurement of in-situ stresses has not been recommended by BMC's consultants to be completed at this time. Notwithstanding this, detailed design for the underground mine will be informed by additional data generated between completion of the PFS and commencement of underground mining, including additional geotechnical drilling, in pit mapping and experience gained with the rock mass during the first two years of open pit mining, prior to commencement of the underground mine.

Once the underground mine is in operation, data gathering and analysis will continue throughout the mine life to monitor the performance of ground support design, which will be updated where appropriate to reflect changes in understanding of the *in situ* rock mass and its response to mining activities.

YESAB ISSUE WITH BMC'S RESPONSE TO R49, 50 AND 51

Section 3.4 states, "for the purpose of the underground mining at Krakatoa, the major and intermediate stresses are assumed to be 2.5 and 1.5 times the vertical stress respectively (Martin et.al. 2003)." It is correct that in Canada the horizontal stress is greater than vertical stress. However, it should be noted that Martin et al. is based on their investigation at the Underground Research Lab (URL) located in Manitoba.

Potential failure mechanisms such as structurally controlled failure (i.e., wedge failure) and stress-induced failure (i.e., spalling and slabbing) have not been discussed in the Rockland report.
The in-situ horizontal to vertical stress ratio will be the input for the underground mine design, support design, excavation geometry, potential failures (progressive or sudden) and other considerations. This information is normally obtainable by in-situ tests such dilatometer tests or plate load tests.

Insufficient response: The proponent did not provide answers. Some of the gaps, as described in R51, are proposed to be deferred to a later stage.

The proponent referred to Rockland report Section 8 where it is stated that "in the next stage of assessment, a dedicated geotechnical drilling program will be planned in order to obtain representative geotechnical information across the main lenses and where other important infrastructure such as the ramp will be located underground". As per our initial reviews, there are no robust geotechnical findings provided in the Rockland report that explicitly address the anticipated challenges in open pit or underground design and operations. The Rockland report refers to future additional investigation, in line with the response provided by the proponent. However, the requested items are a crucial part of any investigation even at preliminary stage and SNC-Lavalin believes they should be addressed prior to permitting stages.

R2-22

What are the expected potential failure mechanisms (both structural failure and stress-induced)?

On September 14, 2017 BMC representatives met with YESAB representatives and their consultant SNC-Lavalin. During the meeting clarification was provided regarding the information required for response to R2-22. It was clarified that in the absence of Feasibility level underground geotechnical investigations, typical geotechnical failure mechanisms for open pit and underground operations be provided along with potential mitigation measures that BMC would use in the event that these mechanisms are encountered at KZK. This information will in turn provide YESAB with the confidence that BMC is committed to eliminating, minimizing or reducing risks in order to ensure that the Project doesn't encounter unforeseen health and safety issues and/or production delays.

The various possible failure mechanisms of underground excavations have been recognised and documented for centuries, with methods of detection and mitigation updated as technologies evolve. Failure mechanisms in underground mines are known to be governed by mining method, rock competency, structural controls, existing stress regimes, amount of water present, and other criteria. With this wealth of information and BMC's experience, all potential failure mechanisms that could be encountered at KZK have been experienced and overcome at numerous mines around the world by various strategies and there are not expected to be stability conditions that cannot be or are not routinely handled by current practices.

There are two major classes of failure mechanisms:

Structural Failures

The most prevalent potential failure mechanisms at KZK are expected to be wedge failures. In underground openings excavated at relatively shallow depths in jointed rock masses, the most common types of structural failure are those involving wedges falling from the back or sliding out of the walls of the openings. These wedges are formed by intersecting structural features, such as jointing and shears, which separate the rock mass into separate but interlocked units. When a free face is created by the excavation of an opening these units lose the effect of some of the locking mechanisms and may become physically unstable under the influence of gravity. The size of potential wedge failures is dependent on the geometry of the intersecting structures and the relative geometry of the underground excavation. Dependent on the number of structural controls present within the location of the excavation, one failure may lead to successive failures, as natural support is removed at each failure, until the excavation reaches a stable profile, both horizontally and vertically.

The key to mitigating for wedge failure is identification of the potential failure, and supporting it, prior to the excavation advancing to a point where failure becomes possible. Prior to commencing underground development, a preliminary Ground Control Plan will be developed utilizing all available geological information with regards to jointing and identified structural controls. Interpretation and assessment of this data will provide a minimum standard of ground support required for all excavation, in all identified rock quality domains, and will be appropriate for most joint configurations in all expected excavation profiles and spans. The initial data will be limited and the Ground Control Plan will be continuously updated by suitably qualified mine staff throughout the mine life and as excavations advance. A possible mitigation measure to limit exposure to the risk of wedge failures is to align excavations at an optimal angle to the jointing structure, however this is not always possible due to the operational necessity of achieving required elevation and position targets, and toto local variation in the orientation of the structural joint sets.

The Ground Control Plan will provide appropriate support for wedge failures that can be predicted with the existing data. These failures will be dependent on the joint spacing and geometry as well as the relative geometry between the joints and other structures. As mining progresses and more information is gained the Ground Control Plan will be modified by mine staff to more accurately reflect the observed ground conditions.

There will likely be structural controls, such as shears and local faults that have not been identified prior to mining due to their localized nature. These controls will be identified on a visual basis as mining advances, with each cut subject to face, rib and back mapping. The resultant data will be used to evaluate necessary ground support measures required, on a case by case and on a shift by shift basis. The minimum inputs required from underground mapping will be the extent, dip, and bearing of the structure, and this will aid in informing the strength of the required support and, importantly, the length of the support, to provide the minimum factor of safety required. Necessary support will be installed prior to any further advance of each heading and previously installed support will be evaluated for its effectiveness. Ground support available on site will include a suitable variation in support mechanisms with a variety of lengths to ensure that there is appropriate equipment to support the worst possible scenario.

Stress Related Failures

One of the issues encountered in mining and civil engineering in regard to tunnels is slabbing or spalling of material from the roof and walls. This can take the form of popping, in which dinner plate shaped slabs of rock can detach themselves from the walls with an audible sound, or gradual spalling where the rock slabs progressively fall away from the roof and floor. In all cases the rock surrounding the excavations is brittle and massive. In this context massive means that there are very few discontinuities such as joints or, alternatively, the spacing between the discontinuities is of the same order of magnitude as the dimensions of the opening. These types of potential failure are possible in the massive ore; however, due to the shallow nature of the ABM Deposit the more extreme forms of this failure mechanism (such as rockbursts) are not predicted.

As the underground mine excavation progresses the potential for stress related failures will become more prevalent. These failures are a direct result of an increasing amount of void space as mining production extracts ore and the resultant transfer of stresses. Despite backfilling of stoped areas there may be stress transferred to adjacent mining areas as stopes are depleted. This transfer of stress will, if mitigation measures are not implemented, potentially manifest itself in a number of ways ranging from localized spalling of walls and backs to potentially massive failures when combined with structural elements. The primary mitigation measure for stress related failures is the optimal scheduling and alignment of the excavations relative to each other and the structure of the surrounding rock. The optimal plan is generated by structural analysis and numerical modelling and this will also identify areas where (and sizes of) pillars that may be required, to limit the stress transferred. Development and stoping in the ore are the most susceptible to potential stress failures due to the massive nature of the ore (less jointing) and the relatively large volumes that will be removed.

A program of geotechnical monitoring will be implemented as part of the Ground Control Plan. This will include regular pull tests on support elements, visual inspection of installed ground support and ground conditions, and installation of geotechnical monitoring systems such as multipoint borehole extensometers (MPBX), and potentially micro-seismic monitoring systems, at critical locations. The monitoring systems will give advanced warning of symptoms of induced stress and structural failures.

Destressing of excavations due to the advance of headings will cause spalling on backs in headings, however the size of failures will be limited by the jointing and joint conditions and will be controlled by the meshing required in the Ground Control Plan. It may be necessary at times to rehabilitate the bolting due to a buildup of rock fragments behind the mesh however this is part of the routine maintenance regime required for ground support at most mines. Similarly, a buildup of rock fragments may occur, due to "air slack" which is caused by access of air to newly mined areas which may remove moisture from existing joints and the resultant loss of cohesive strength causes local instability.

Drilling and blasting designs will be monitored for their effectiveness in providing stable excavation profiles with limited blast-caused damage to the rock fabric. If necessary, the designs will be modified to reduce blast induced damage to the excavations. This will help minimize the amount of rehabilitation bolting required for existing excavations.

R2-23

How have the outlined mitigation measures accounted for the potential scenario where assumptions made in the preliminary design are non-conservative?

As updated design studies of the underground mine at Kudz Ze Kayah progress, data will be obtained from all available sources to determine if the assumptions made in the preliminary design are non-conservative. Data sources are enumerated in R2-24 and will include; additional core drilling of mine infrastructure, such as the decline, and geological mapping of the open pit. Information on jointing and structural features identified during this process will be used to update the preliminary Ground Control Plan prior to the commencement of underground excavations. As identified in the response to R2-22, should preliminary designs be found to be non-conservative, one mitigation measure that will be utilized is the review of ground support designs and installation of additional ground support to ensure that the integrity of the underground mine is maintained and that safety of underground personnel is not compromised.

It is expected that wedge type failures will be the prevalent failure mode that will require additional ground support above what is required by the Ground Control Plan. Because of the localized nature, the potential controls for this type of failure can often only be predicted during excavation. As stated in R2-22:

> *"These controls will be identified as mining advances, on a visual basis, with each cut subject to face, rib and back mapping with results of this used to evaluate necessary increased ground support required, on a case by case basis. The inputs required from the mapping will be the extent of the structure, dip, and bearing and this will inform the strength of the required support and, as important, the length of the support, to provide the minimum factor of safety required. The support will be installed prior to any further advance of the heading and previously installed support will be evaluated for its effectiveness. Ground support available on site will include a*

> *suitable variation of support mechanisms with a variety of lengths to ensure that there is appropriate equipment to support the worst possible scenario*."

The worst case of this type of failure is where one failure leads to multiple failures, due to the number of structural controls in an area. The failures continue until a stable profile is achieved. This normally occurs when there are number of weak joints combined with multiple local structural controls. If there are indications that this may occur then more intensive ground support regimes, such as fibrecrete or sets may be used to prevent the failure. This type of failure may occur where there had been no prior visible indications and generally occurs during the blasting of a heading. In this case there are several potential solutions including those described previously as well as the potential realignment of the heading.

Drilling and blasting designs will be monitored for their effectiveness in providing stable excavation profiles with limited blast-caused damage to the rock fabric. If necessary, the designs will be modified to reduce blast induced damage to the excavations. This is a standard operational expectation of any underground mine.

Stoping of the ore will utilize the cut and fill method as the primary mining method (92% of the ore from the underground mine is from development and cut and fill mining). Cut and fill mining allows a high degree of control with incremental advances and face exposure. This will ensure that opening of production areas is completed on a sequential and incremental basis, limiting the maximum open span and allowing for progressive observation of the rockmass as the production sequence is realized.

Stoping in the massive ore could potentially cause a massive structural failure in the hanging wall, particularly if the optimal production sequence is not followed. If the potential for this is identified prior to stoping operations commencing, ground support will be installed in the hangingwall to mitigate this issue. Potential support elements include cable bolts and these would be installed from the hanging wall drift on each level. Monitoring for movement of the hanging wall can be achieved with MPBX (multi-point bore hole extensometers) or potentially micro-seismic monitoring systems. These systems will give advance warning of movement and enable personnel and equipment to be removed from the relevant areas prior to any failure. Alternatives that could be required in the case of massive movement include leaving production levels as pillars or altering the extraction sequence. All of the above are common control mechanisms in underground mines.

The underground mine accesses approximately 20% of the total mineable resource, it encompasses the portion that is not amenable to open pit mining due to its depth and increased cost of extraction. As these resources are costlier to extract they have less margin for profit, and therefor have aa limited impact on the operations overall profitability. As such, part of this resource can be eschewed without a large effect on the overall economics of the Project. The inherent adaptability of underground mining to allow changes in short term designs and scheduling, provides the flexibility to ensure that any results of non-conservative assumptions will not have a major effect on the feasibility of the operation as a whole.

R2-24

What are the gaps in information and what is the plan for addressing these gaps for the detailed design and operations?

Gaps in information will be routinely addressed by the collection of the data below. This data shall be incorporated into the mine ground support planning on an ongoing basis. This planning includes excavation designs and ground support design and installation.

Information gaps;

- Additional rock data, to be sourced from additional diamond core drilling targeting both the mineralized production areas as well as underground mine infrastructure (for example the decline ramp).
- Additional rock and joint set data collected from the open pits above and around the underground excavation;
- Data obtained from logged core will typically include:
  - rock type;
  - geotechnical interval;
  - total length of recovered cores for the interval;
  - total length of cores larger than 10cm for the interval (RQD);
  - number of discontinuities;
  - type of discontinuities;
  - number of discontinuity sets;
  - roughness of discontinuities;
  - fill of discontinuities;
  - strength index of rock; and
  - discontinuity α and β measurements.
- Laboratory strength testing of drill core will typically include:
  - bulk density determination;
  - uniaxial compressive strength;
  - tensile strength;
  - elastic properties;
  - shear box testing for defect structures; and
  - stress measurements.
- In-situ stress field measurements will be completed;
- Geotechnical structural and mining rock mass models will be constructed; and
- Structural analysis and numerical modelling will be completed to assess the stability of planned excavations.

During operations data collected will be from direct observations and monitoring of installed monitoring systems. Data will include:

- Visual inspection of all workspaces every shift by qualified underground personnel;

- Face mapping of structures such as shears and faulting;
- Visual checking of support elements;
- Monitoring systems such as MPBX;
- Blast design evaluation and changes if required;
- Probe drilling for structural and groundwater information; and
- Re-evaluation and updating of the ground control management plan on a regular basis.

YESAB ISSUE

Transportation Engineering Branch also reviewed the information provided on the proposed upgrades to the airstrip and has identified that further, more detailed information on the proposed design, and how it relates to the surrounding terrain, is required. As indicated in the project proposal, HPW previously considered options for upgrading this airstrip. From this exercise HPW is aware that the surrounding terrain (e.g. close proximity to the lake), the location of the road, and the availability of materials for upgrading present challenges to the design, cost and feasibility of potential upgrades.

R287

"Provide more detailed design information and discussion in relation to the upgrades of the Finlayson Lake airstrip. Specifically:

a) consider how the proposed design will address/service multiple users, vehicle parking, plane parking and equipment and materials storage to support servicing of the airstrip;

b) given the surrounding terrain challenges, the detailed design information needs to demonstrate how the upgrades can be completed in the proposed location; and

c) identify any necessary mitigations or changes that may be required to the surrounding environment."

As stated in the Project Proposal (Section 4.12.2), BMC is only aware at a high level of Department of Highways and Public Works (HPW's) previous work on the Finlayson Lake airstrip, with regard to terrain challenges. Detailed designs have not been completed, however all designs will follow applicable Federal and Territorial regulations for airstrips.

The upgrading of the Finlayson Lake airstrip will involve lengthening, and widening as required, to a standard as specified in the Aerodrome Standards and Recommended Practices TP 312 (5th Edition). The upgrade is required to bring the airstrip up to a standard suitable for a nominally sized 18 passenger aircraft to land and takeoff. There is not expected to be any requirements for passengers, or aircraft to wait at the airstrip other than for passenger loading and unloading. Supplies for the aircraft, in the event that they are required, will be provided by transporting from the KZK Project site and maintenance of the airstrip will be on an "as required" basis, and will be fulfilled by equipment mobilised from the KZK Project site.

Current usage of the Finlayson Lake airstrip is minimal and even with the extension of the airstrip it is not expected to increase substantially. The airstrip is relatively isolated and the nearest area with land transport is Ross River thus incentive to land at Finlayson Lake, rather than at Ross River, is minimal. However, the Finlayson Lake airstrip could be used as an emergency alternative to Ross River airstrip if required due to bad weather, distance, or other factors.

Final designs have not been completed but initial construction designs will be discussed with the Transport Engineering Branch and the Aviation division prior to any design submissions and will require approval under relevant Federal and Territorial regulations before moving forward.

YESAB ISSUE WITH BMC'S RESPONSE TO R287

Transportation Engineering Branch also reviewed the information provided on the proposed upgrades to the airstrip and has identified that further, more detailed information on the proposed design, and how it relates to the surrounding terrain, is required. As indicated in the project proposal, HPW previously considered options for upgrading this airstrip. From this exercise HPW is aware that the surrounding terrain (e.g. close proximity to the lake), the location of the road, and the availability of materials for upgrading present challenges to the design, cost and feasibility of potential upgrades.

Insufficient response: In their response, the proponent has stated that because of the remoteness of the airstrip and because the current usage of the airstrip is "minimal," they do not believe any upgrade considerations will need to accommodate other aircraft or design components (e.g. apron) to allow for passengers, or the loading/unloading of aircraft. However, review of this response by the Aviation Branch has indicated that this information does need to be considered and incorporated into their design considerations for airstrip upgrades. The Aviation Branch has indicated that there is the need for this design consideration for the following reasons:

> *Breakdowns – Aircraft can break down or get grounded for other reasons, so there is a need for apron space to accommodate two 18-passenger aircraft. This includes space for the original aircraft that is grounded and additional space for another 18-passenger aircraft that needs to be flown in to pick up the stranded passengers.*
>
> *Cargo handling space – Aircraft need to be off the runway in order to have cargo loaded and unloaded, and there needs to be adequate space for delivery trucks to move safely around the aircraft.*
>
> *Multiple users of the site - More than one air carrier uses the Finlayson Airstrip, so if BMC's 18-passenger aircraft is parked on the apron, there needs to be adequate space for another carrier's plane to park on the apron.*
>
> *Furthermore, because this is an airstrip under the jurisdiction of the Yukon government, any upgrades being undertaken by the proponent will need to meet the specific design requirements (e.g. an apron as indicated above) as set out by the appropriate regulations and by Yukon government. The proponent does not have the authority to rationalize or make a determination as to which upgrades may or may not be required or undertaken. To date, the proponent has not had detailed discussions with either the Transportation Engineering Branch or the Aviation Branch about the details, requirements and considerations for upgrading the airstrip to the level of service that they are proposing.*

R2-25

Provide confirmation that the airstrip can be upgraded in accordance with specific design requirements as set out by the appropriate regulations and by Government of Yukon. Or provide an alternative for transportation to the mines site.

The lengthening of Finlayson Lake airstrip was originally selected as the preferred option after a comparison with other options, including building an airstrip on BMC mineral claims near the existing KZK Tote Road. The intent was that BMC would either carry out the work under the supervision/oversight of the Yukon Government or that BMC would fund the upgrade by the Yukon Government or a combination of both.

The reasoning behind this was two-fold:

1. There seemed little advantage in building a new private airstrip 12 km away from an existing airstrip; and
2. The opportunity to upgrade Yukon infrastructure at no cost to the Yukon, and no extra cost to BMC (above the other options), was seen as providing a long term and sustained economic benefit for all parties involved.

However, after further preliminary design work and discussions with the Highways and Public Works Department (HPW) of the Yukon Government, it is apparent that extending the airstrip to the extent proposed may not be a viable option for a number of reasons, including a lack of land tenure and the requirement of rerouting the Robert Campbell Highway.

Therefore, BMC is now proposing to use Finlayson Lake airstrip in its current configuration (with the exception of the addition of an apron) and charter suitable aircraft that are capable of landing and taking off on the current airstrip.

At present BMC uses Finlayson Lake airstrip to transport employees to and from Whitehorse for the current exploration programs. Aircraft used include Cessna Caravans and Grand Caravans.

Use of Finlayson Lake Airstrip in Current Configuration

The airstrip's current length has been evaluated and there are certain aircraft configurations that would be able to operate within the statutory regulations with passenger loads of 14. The optimum aircraft for the airstrip in its current configuration would be a Twin Otter which would be able to fly with a passenger load of 14. These aircraft are available through a licensed air charter operator who will be responsible for the safe and efficient transport of passengers and freight between Whitehorse, Watson Lake, Ross River, and Finlayson Lake airstrip.

There will be no substantial change in the airstrip conditions or amenities, except for the addition of an apron to safely facilitate traffic management. BMC expect that the reduced plane size will require just over 1 extra flight per week above the original Project Proposal.

HPW has indicated that maintenance or resurfacing of the airstrip may occur and if this does occur BMC will contribute finances to support such maintenance or resurfacing; however, the authority and responsibility relating to execution of the work will remain with HPW. HPW has also indicated that there is an apron area available for development near the airstrip and this area will be prepared for use as a loading/ unloading area for aircraft and support vehicle management.

When required, fuel for aircraft will be transported from the Project site to Finlayson Lake airstrip by a specialised fuel truck that will fulfill all statutory requirements for transportation of fuel In winter there will be adequate de-icing equipment available for the aircraft (which will also be transported from the Project site to the airstrip).

All scheduled aircraft will be met by vehicles from site for the transfer of passengers and occasional freight. All vehicles will have communication equipment available in case of breakdown, providing the ability to contact site and organize for help and backup should that be required.

Maintenance requirements for the airstrip will be discussed with the aviation branch of HPW and an agreement will be reached on responsibilities of all parties for required maintenance, including snow removal during winter, and how the costs will be apportioned. BMC expects to be responsible for all costs attributable to its activities.

Apron Management Safety Plan

An Apron Management Safety Plan specific to the air traffic chartered by BMC, will be required to ensure that airstrip operations are managed in a safe manner. The plan will be developed with input from all stakeholders and interested parties including all air charter companies using the airstrip, the aviation branch, HPW, BMC and other companies that may use the airstrip, any private pilots that may use the airstrip, and local land owners.

Prior to the increased airstrip use (expected during the construction and operations phase) all potential users of Finlayson Lake airstrip will be notified of the expected schedules of the charter flights and provided with contact details of the coordinator responsible.

The Apron Management Safety Plan will dictate how BMC and its chartered aircraft will use the airstrip and will include factors such as:

1. Where vehicles meeting the airplanes will wait;
2. Where the aircraft will unload and load;
3. Communication requirements between vehicles and airplanes;
4. Fueling procedures;
5. Required times between flights if multiple flights are anticipated;
6. Emergency procedures; and
7. Use of alternate airstrips.

It is recognised that there are various conditions that may lead to requirements where alternate airstrips would need to be used. Potential situations that may lead to the use of alternate airstrips include:

- Climatic situations that reduce visibility below the minimum required for landing, or takeoff;
- Aircraft, or other equipment, blocking the use of the airstrip; and

- Airstrip is unusable due to excess snowfall or precipitation.

The Ross River airstrip will be the primary alternate airstrip used in cases where the Finlayson Lake airstrip is not available. There are other airstrips available, for example at Faro, if Ross River is not a viable alternative. When the alternate airstrips are used, in and out going passengers will be transported to, and from, the relevant airstrip by bus. The details of the use of alternate airstrips will be part of the Plan.

5 EFFECTS ASSESSMENT METHODS

No information required.

6 AIR QUALITY

No information required.

7 NOISE LEVELS

No information required.

8 SURFACE WATER QUALITY AND QUANTITY

8.1 WASTE ROCK AND TAILINGS MANAGEMENT

YESAB ISSUE

The most critical deficiency in this assessment of water quality was the absence of acidic drainage estimates in the water quality modelling for post closure conditions. The use of the leach test results for neutral conditions represents a deficiency for water quality predictions over the long term. This also has implications for the proposed use of passive treatment with engineered wetlands after closure.

It was acknowledged in the geochemical assessment that the PAG waste rock and tailings, in the Class A stockpile, and the waste rock in the Class B stockpile will produce acid in the future. The depletion of the neutralization potential will result in times to onset of acid drainage that are expected to be after the proposed mine closure period. Nonetheless, the PAG materials will eventually produce acid drainage even though the drainage will be mitigated to some extent by lower infiltration covers. The significance of the acid drainage is that the low pH will be accompanied by increased loadings, and concentrations, of many metals and other constituents that can adversely affect water quality. Although mitigation of the stockpiles by limiting infiltration with covers is planned, the increased concentrations and loadings associated with acid conditions compared to those predicted for neutral pH in this assessment will result in increased loadings and concentrations in the residual drainage from the covered piles. This will increase the loadings and concentrations requiring mitigation post closure. The acidic drainage with higher concentrations that those in the neutral drainage may not be treatable in a passive engineered wetland system.

R82

"Using the above estimates, provide an assessment of the effects of the proposed mitigation of infiltration rates by engineered covers on the mine rock stockpiles and the residual loadings of constituents of potential concern (COPC) from the stockpiles and from the pit walls."

The unsubmerged portion of the pit wall above the final surface water elevation of ABM lake at closure will be primarily composed of geodomains that are largely Class C, non-acid generating rock (Table 8-1).

Overall, the pit wall rock above the final water level is predominantly not potentially acid generating. Nevertheless, any acidic load that does wash down into ABM lake will be neutralized by the circumneutral waters of ABM lake, with only minimal associated loading such that no significant effects to downstream water quality are anticipated.

Table 8-1: Approximate Proportions of Unsubmerged (Above 1,380 masl) Pit Wall Surface Area by Geodomain, the Proportion of Each Geodomain by Waste Classification and the Proportions of Total Unsubmerged Pit Wall by Waste Classification

Geodomain	Exposed Pit Wall Area	% Class A	% Class B	% Class C	Net Acid Generating Potential
AK RHYv	15%	0%	27%	73%	Predominantly acid consuming
CA CL MAF	5.0%	0%	100%	0%	All acid consuming but potential for metal leaching
CARB MDS/RHY	1.5%	23%	44%	33%	Predominantly potentially acid generating
MDS	25%	3%	8%	89%	Predominantly acid consuming
MU PY RHY	2.1%	25%	38%	38%	Predominantly potentially acid generating
PY AK RHYc	2.3%	8%	45%	47%	Equal parts potentially acid generating and acid consuming
PY AK RHYv	18%	5%	43%	52%	Equal parts potentially acid generating and acid consuming
PY CL RHY	1.1%	46%	24%	29%	Predominantly potentially acid generating
RHYi	1.2%	42%	42%	17%	Predominantly potentially acid generating
Massive Sulphide	0.1%	100%	0%	0%	Potentially acid generating
Overburden	28%	0%	0%	100%	Non potentially acid generating
Total	**100.0%**	**3.8%**	**22.1%**	**74.1%**	

The preliminary acidic release COPI loading rates presented in

Table 8-1 above were applied in the water quality model at Year 10 for Class A and Year 30 for Class B under both the mean and 1/10 dry year precipitation scenarios. The resulting estimates of COPI water quality for the near field site KZ-37 under the most conservative 1/10 dry year scenario (i.e. the scenario that results in the highest concentrations in the receiving environment) are reproduced below (Figure 8-1). The preliminary water quality objectives (pWQO) are presented for comparison for each COPI [note that some pWQO thresholds are dependent on hardness (cadmium, copper, lead, zinc) or sulphate (selenium) concentrations, giving rise to changing pWQO levels for these COPIs as the hardness and sulphate concentrations vary throughout the year and phase of the Project].

The updated model with preliminary acidic source terms estimates that in post-closure only concentrations of arsenic (May and June) and cadmium (May through August) exceed water quality objectives at KZ-37. The exceedances do not exceed 1.8 and 1.5 times the respective the water quality objectives for arsenic and cadmium, respectively. It is important to note that the model does not incorporate any natural attenuation that would occur along flow paths between the Class A and Class B Waste Storage Facilities, the wetlands and Geona Creek that may lower arsenic and cadmium concentrations. It is also important to note that arsenic and cadmium exceedances are not predicted at KZ-15 (Upper Finlayson Creek) downstream of KZ-37.

Acidic source terms will be refined upon the availability of NP-depleted kinetic testing data and the models and predictions will be updated accordingly. Appropriate refinements to the mitigation measures may be also be made at that time.

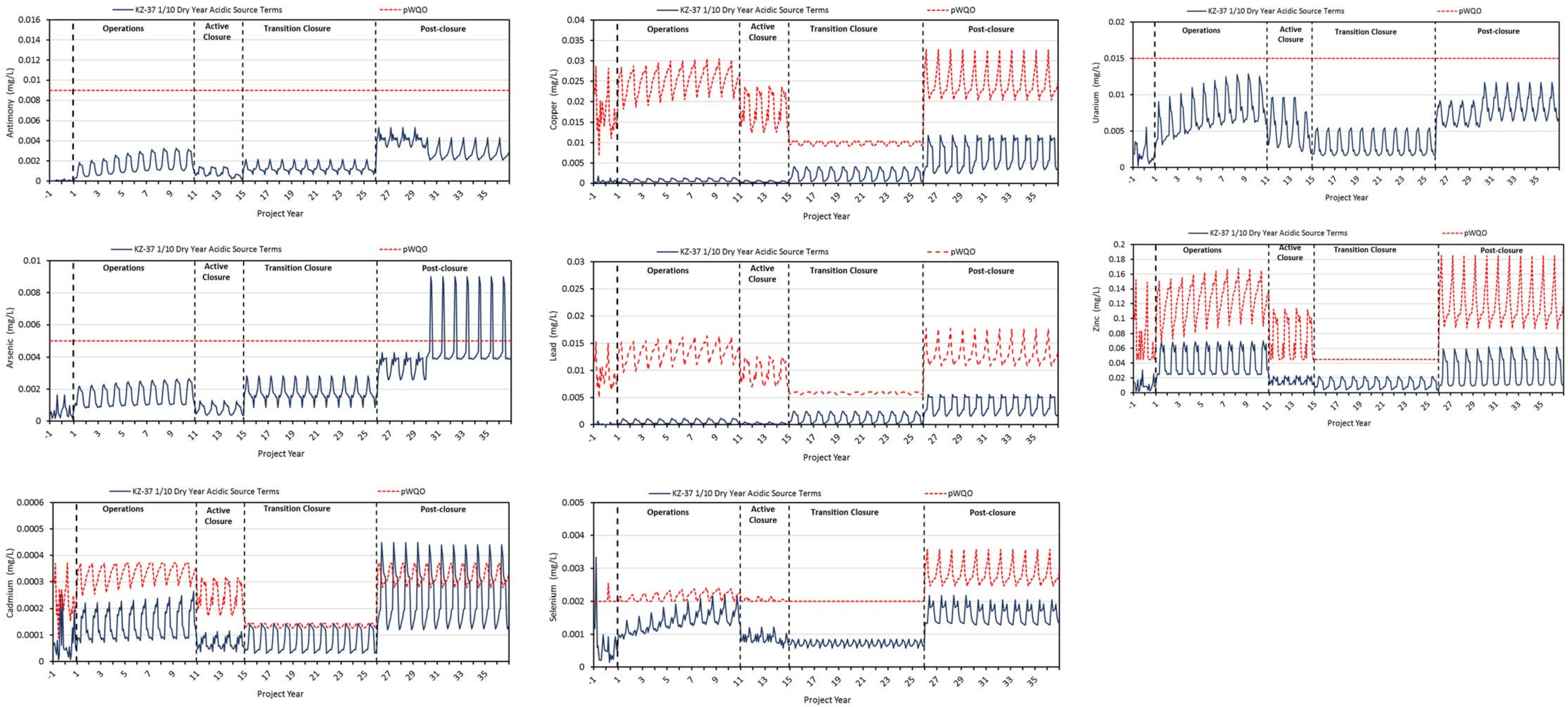


Figure 8-1: Updated Water Quality Predictions at KZ-37 in the 1/10 Dry Year Scenario Using Preliminary Acidic Drainage Loading Terms for Antimony, Arsenic, Cadmium, Copper, Lead, Selenium, Uranium, and Zinc

YESAB ISSUE WITH BMC'S RESPONSE TO R82

The most critical deficiency in this assessment of water quality was the absence of acidic drainage estimates in the water quality modelling for post closure conditions. The use of the leach test results for neutral conditions represents a deficiency for water quality predictions over the long term. This also has implications for the proposed use of passive treatment with engineered wetlands after closure.

It was acknowledged in the geochemical assessment that the PAG waste rock and tailings, in the Class A stockpile, and the waste rock in the Class B stockpile will produce acid in the future. The depletion of the neutralization potential will result in times to onset of acid drainage that are expected to be after the proposed mine closure period. Nonetheless, the PAG materials will eventually produce acid drainage even though the drainage will be mitigated to some extent by lower infiltration covers. The significance of the acid drainage is that the low pH will be accompanied by increased loadings, and concentrations, of many metals and other constituents that can adversely affect water quality. Although mitigation of the stockpiles by limiting infiltration with covers is planned, the increased concentrations and loadings associated with acid conditions compared to those predicted for neutral pH in this assessment will result in increased loadings and concentrations in the residual drainage from the covered piles. This will increase the loadings and concentrations requiring mitigation post closure. The acidic drainage with higher concentrations that those in the neutral drainage may not be treatable in a passive engineered wetland system.

Insufficient response: While the concentrations of many constituents of potential concern have been predicted for acidic conditions in the Class A and Class B stockpiles as well as the pit wall drainage, the pH of the site water has not been provided. In addition, iron that has a large loading rate as shown in table 8-1, was not shown or discussed in the predicted concentrations plots. The iron in the acidic drainage will be important because it represents a source of acidity and may affect the final pH of the receiving waters as the iron oxidizes and precipitates as ferric hydroxide.

R2-26

Present the results for predicted iron concentrations as well as the pH of the receiving waters in the post closure period.

The pH and iron concentrations in the receiving waters in the post closure period were predicted using the thermodynamic PHREEQC code and Minteq.v4 database. The following inputs to the receiving environment were considered:

- Acidic seepage from the Class A Storage Facility;
- Acidic seepage from the Class B Storage Facility;
- Runoff from the Class C Storage Facility;
- Flow from the ABM lake; and
- Background runoff.

The water quality and pH of each component are summarized in Table 8-2 and presented in Table 8-3 and Table 8-4. The relative volumetric proportions of each component per month are presented in Table 8-5, which are based on the Receiving Environment Water Balance (Appendix D-6 of the Project Proposal).

The following steps were followed in PHREEQC to estimate pH and iron concentrations in the receiving environment:

1. ABM lake water equilibrated with atmospheric CO_2 (i.e. P_{CO2} of $10^{-3.4}$) and ferrihydrite. Due to the gradual formation of the lake through the transition closure phase, the ABM lake water will have ample time to equilibrate with atmospheric CO_2. The equilibration with ferrihydrite - a hydrous ferric oxide – was performed as the ABM lake solution was oversaturated with respect to ferrihydrite due to the high concentrations of iron and the favourable conditions for precipitation of iron to form ferrihydrite (i.e., neutral pH conditions). The pE of the ABM lake solution was fixed at pE = +4 to maintain a reasonably oxidizing environment and avoid equilibration to an unrealistically low pE by PHREEQC.
2. The Class A solution was equilibrated with schwertmannite – an iron-oxyhydroxysulphate mineral – as the Class A solution was oversaturated with respect to schwertmannite due to the high concentrations of iron and the favourable conditions for precipitation of iron to form schwertmannite (i.e. low pH).
3. The solutions entered for the five components were mixed at the proportions outlined in Table 26-2 using the PHREEQC "MIX" function.
4. The solution resulting from the mix of the five components was again equilibrated with ferrihydrite due to the circumneutral pH estimated by PHREEQC and the expected well oxygenated environment.
5. These steps were repeated for each month to account for varying water quality and volumetric proportions.

At this time, an estimate of pH and iron concentration has only been made for the receiving environment at KZ-37. The PHREEQC simulations conducted for each month of the year in post-closure yielded pH ranging from pH 7.4 to 7.9 (Figure 8-2) and iron concentrations between 0.0003 to 0.008 mg/L. The PHREEQC simulation for May – during which the volumetric proportion of Class A drainage to the receiving environment is greatest – returned the lowest pH and highest iron concentrations. Since monitoring at KZ-37 commenced in February 2017, total iron concentrations at KZ-37 have ranged between 0.24 to 1.74 mg/L and dissolved iron concentrations have ranged between 0.072 to 0.24 mg/L. Thus, it is unlikely that drainage from the site would increase iron concentrations in the receiving environment.

Table 8-2: Summary of Water Quality and pH of Load Inputs to the Receiving Environment

Component	Water Quality	pH	pH Rationale/Conservatism
Class A	Acidic loading rates divided into monthly runoff volume from Class A Storage Facility	4.3	pH 2 for acidic drainage conservatively chosen to be less than final cycle of sequential NAG test of Class A tailings and waste rock column material (C-10; pH 2.05). The pH of the Class A run-off was derived by assuming a 200-fold dilution of the pH 2 acidic drainage into run-off water with no buffering capacity (since 99.5% infiltration reduction cover is estimated to result in 1,500 m3/yr seepage versus 314,000 m3/yr run-off under average precipitation conditions). The assumption of no buffering capacity of the surface runoff is considered to be conservative since such runoff is expected to have some alkalinity (i.e. in the pH range of 7.4 to 7.9).
Class B	Acidic loading rates divided into monthly runoff volume from Class B Storage Facility	5.2	pH 3.5 was selected for the Class B drainage, which is considered conservative given the drainage from kinetic testing of Class A waste rock material (trickle leach column C-7) is pH 3.77 (at week 77). The pH of the Class B run-off was derived by assuming a 50-fold dilution of the pH 3.5 acidic drainage into run-off water with no buffering capacity (since 98% infiltration reduction cover is estimated to result in 6,050 m3/yr seepage versus 302,600 m3/yr run-off under average precipitation conditions). The assumption of no buffering capacity of the surface runoff is considered to be conservative since such runoff is expected to have some alkalinity.
Class C	Post-closure loading rates divided into monthly runoff volume from Class C Storage Facility	7.5	Average pH of drainage from kinetic testing of Class C material that has broadly reached stability.
ABM Pit Lake	Pit water quality as predicted by Pit Water Quality Model upon formation of Pit lake at ~Year 26	7.3 - 7.9	Monthly median pH of Fault Creek (KZ-2).
Background	Monthly median baseline water quality of data collected from stations KZ-2, KZ-6, KZ-7 (in site area)	7.4 - 8	Monthly median pH of baseline data from KZ-2, KZ-6, KZ-7.

Table 8-3: Water Quality of Class A, Class B, Class C and ABM Lake Solutions

	Class A	Class B	Class C	Pit Lake
pH	4.3	5.2	7.5	7.7
	mg/L			
Iron	28	0.12	0.0032	29
Alkalinity	0.00006	0.09	88	130
Calcium	7	1.2	37.6	47.3
Magnesium	3	1.1	17.9	22.3

Table 8-4: Water Quality of Background Runoff Solution

	pH	Iron	Alkalinity	Calcium	Magnesium
		mg/L			
January	7.44	0.19	157	62	7.6
February	7.46	0.20	156	57	7.7
March	7.45	0.18	154	59	7.8
April	7.77	0.22	152	59	7.2
May	7.49	0.14	46	19	2.1
June	7.95	0.14	82	37	4.0
July	7.81	0.10	99	38	5.8
August	7.99	0.05	120	49	5.6
September	7.84	0.05	113	49	5.8
October	7.73	0.03	139	61	6.1
November	7.65	0.11	128	56	7.3
December	7.69	0.10	143	58	6.5

Table 8-5: Relative Volumetric Proportions of Class A, Class B, Class C, ABM Lake and Background to the Receiving Environment

	Class A	Class B	Class C	ABM lake	Background	Total
January	0.4%	2.9%	2.9%	32.1%	61.7%	100%
February	0.6%	3.4%	2.8%	35.1%	58.1%	100%
March	0.7%	4.4%	3.6%	41.6%	49.6%	100%
April	1.9%	5.1%	4.3%	29.0%	59.7%	100%
May	10.3%	10.1%	8.8%	24.2%	46.6%	100%
June	9.2%	8.8%	7.6%	21.1%	53.3%	100%
July	6.5%	7.2%	6.7%	21.4%	58.2%	100%
August	6.7%	7.4%	6.9%	23.4%	55.8%	100%
September	6.3%	7.3%	6.9%	23.8%	55.6%	100%
October	0.8%	5.0%	4.7%	24.8%	64.6%	100%
November	0.2%	3.1%	2.9%	25.9%	67.9%	100%
December	0.3%	2.7%	2.7%	28.7%	65.5%	100%
Average	3.7%	5.6%	5.1%	27.6%	58.0%	100%

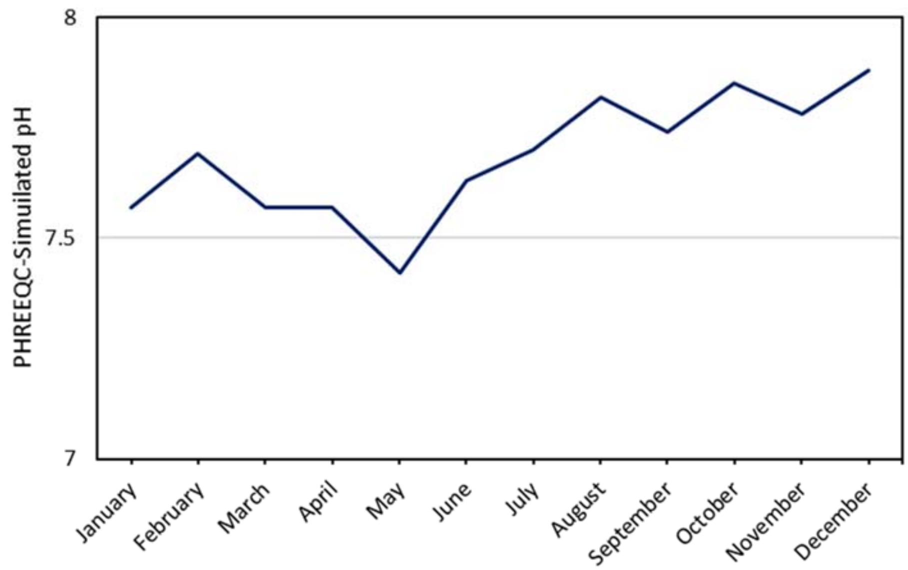


Figure 8-2: PHREEQC Simulated pH at KZ-37

R2-27

Clarify if the predicted concentrations at KZ-37 include any assumed mitigating effects from the proposed wetland treatment system and, if so, provide the untreated concentrations as well.

Appendix R2-C (Project Optimizations and Updated Water Quality Performance Expectations for Kudz Ze Kayah Project) includes the estimated concentrations for KZ-37 with and without the proposed constructed wetland treatment system.

YESAB ISSUE

The Class A facility is predicted to be net acid generating within the mine life, while the Class B facility is expected to be net acid generating during the closure period. As such, seepage collection from these facilities is required to ensure protection of both surface and ground water resources. It is unclear however how the proponent has tested the proposed liner system to ensure that all seepage from the facility will be collected.

R289

"Provide additional information to demonstrate that the proposed liner system will be sufficient to direct seepage from the Class A and Class B facilities to the seepage collection ponds for treatment. This should be demonstrated for both the operational and closure facilities."

The Class A and B Storage Facilities are designed for geochemical and geotechnical stability in perpetuity.

The Class A Storage Facility includes a progressively constructed low permeability cover system above the filtered tailings and waste rock to limit surface runoff and infiltration into the facility. A seepage collection system will be constructed above a low permeability foundation liner. Seepage that migrates through the material within the Class A Waste Storage Facility will be routed through the underdrain system to a sump and pumped to the Class A Collection Pond. The underdrain system of waste rock is a preferential pathway for seepage above the low permeability liner.

The Class B Storage Facility includes a progressively constructed low permeability cover system above the waste rock material, as well as a low permeability foundation liner. Infiltration of water within the Class B waste rock will be routed through the foundation of the facility to a sump and pumped to the Class B Collection Pond. Water will be routed preferentially through the free draining Class B waste rock material, above the low permeability foundation liner.

The foundation liner systems for the Class A and Class B Storage Facilities will be refined as part of the detailed design phase.

YESAB ISSUE WITH BMC'S RESPONSE TO R289

The Class A facility is predicted to be net acid generating within the mine life, while the Class B facility is expected to be net acid generating during the closure period. As such, seepage collection from these facilities is required to ensure protection of both surface and ground water resources. It is unclear however how the proponent has tested the proposed liner system to ensure that all seepage from the facility will be collected.

Insufficient response: In response to R289, the proponent did not provide adequate information to demonstrate the effectiveness of the liner systems beneath the Class A and Class B waste management facilities. BMC should provide additional information to demonstrate that the compacted till layer will be sufficient to act as a low permeability foundation layer, and that all seepage will be directed to the collection ponds. (See new information requests above)

The proponent has described the collection system and methods during operations when pumping from the sumps to the ponds will be active. There was no discussion of the post closure period after active pumping ceases. This is an important issue because the natural groundwater flow post closure (Figure 9-3 in response R138) clearly shows that all seepage from the Class A facility, without pumping, will bypass the lower water management pond that will be developed into the North Wetland Treatment system.

R2-28

Demonstrate that the proposed liner system will be sufficient to direct seepage from the Class A and Class B facilities to the seepage collection ponds for treatment. This should be demonstrated for both the operational and closure facilities.

Appendix R2-C (Project Optimizations and Updated Water Quality Performance Expectations for Kudz Ze Kayah Project) provides additional information regarding the performance of the liner system for the proposed Class A and B Storage Facilities and associated updated water quality concentrations for the Project.

R2-29

Clarify if the proponent intends to have active pumping in perpetuity after closure or if there will be other mitigation of the acidic seepage from the Class A facility.

There will be no active pumping in perpetuity after closure of the site per Yukon Government's Mine Closure Policy. All drainage and treatment will be passive or semi-passive.

YESAB ISSUE

The data suggest that the predicted selenium concentrations and/or loading rates associated to drainages from the stockpiles may be substantially underestimated.

Data provided in Appendix D-7 and Section 6.2.2.1 of the proposal show that the selenium leaching rates for waste rock are a function of the selenium content in the solids, a phenomenon that is observed at other mines, and indicates that a further assessment of selenium content in the mine rock is warranted.

Other results from the test program also suggest that selenium will be high in drainage from the tailings. The results of the field barrel tests as shown in Section 5.2.1.3 also indicate elevated concentrations of selenium in drainage.

Also, It was not clear whether the results from the tailings leach tests that included the humidity cell HC-3 and column test C-10 were used to estimate loading rates from the Class A storage facility that will contain the tailings along with the high sulphur waste rock.

R86

"Reconsider, and update if necessary, the predicted selenium concentrations in the context of water treatment technology that will be used and the effects on selenium removal during operations."

In consultation with our specialist consultants, BMC have reconsidered the matter of selenium concentrations in the context of water treatment technology and we confirm that as stated in responses to R84 and R85, the methods currently used to calculate selenium leaching rates are consistent with other parameters and reflect the selenium content in rock and tailings for the KZK Project. These leaching rates have been used to guide selenium removal requirements for water treatment during operations.

In order to assist assessment a water treatment memo has been included as **Appendix 4** of the initial Response Report (BMC, 2017).

YESAB ISSUE WITH BMC'S RESPONSE TO R86

The data suggest that the predicted selenium concentrations and/or loading rates associated to drainages from the stockpiles may be substantially underestimated.

Data provided in Appendix D-7 and Section 6.2.2.1 of the proposal show that the selenium leaching rates for waste rock are a function of the selenium content in the solids, a phenomenon that is observed at other mines, and indicates that a further assessment of selenium content in the mine rock is warranted. Other results from the test program also suggest that selenium will be high in drainage from the tailings. The results of the field barrel tests as shown in Section 5.2.1.3 also indicate elevated concentrations of selenium in drainage.

Also, It was not clear whether the results from the tailings leach tests that included the humidity cell HC-3 and column test C-10 were used to estimate loading rates from the Class A storage facility that will contain the tailings along with the high sulphur waste rock.

Insufficient response: While treatment options are discussed in greater detail (Appendix 4 in Response document) than in the Project Description, there was no resolution of the management of the ion exchange and RO waste streams that were identified as 5% and 21% of the original treated volumes, respectively. Although there was discussion of reducing volumes of residual in the RO system, it is clear that there will be a need for residual management. In Appendix 4, there is reference to KZK being able to "manage up to 7.5 m^3/hr (180 m^3/day) of reject". That is only 3% of the average annual treatment flow of about 6,000 m^3/day or less than 1 % of the maximum treatment flow of about 19,000 m^3/day in the month of June.

R2-30

Reconsider, and update if necessary, the predicted selenium concentrations in the context of water treatment technology that will be used and the effects on selenium removal during operations.

On October 17 2017, YESAB provided (via email) clarification regarding the information that is required to address R2-30. The clarification is as follows:

> *"Our main concern with the water treatment system is the management of residual waste streams from the ion exchange (IO) and reverse osmosis (RO) systems.*
>
> *While the proposed water treatment approach is appropriate technology to deal with selenium, there is the very practical issue of managing by-products. The proposal indicates that IO and RO waste streams were identified as 5% and 21% of the original treated volumes, respectively. These are significant volumes of waste, yet there is little discussion of how these wastes will be managed. In addition, given that brine waste from RO is not a solid, there are additional challenges with management that must be addressed."*

In order to address this concern, a revised version of the Integrated Sustainability Report "Water Treatment Summary" (included in the Initial Response Report as Appendix 4) (BMC, 2017) is included as **Appendix R2-D** of this document. The revisions made to the document were to further define the management of the waste stream of the Ion Exchange and the Reverse Osmosis (RO) components of the water treatment system. Subsequently, the process block diagram was updated as is illustrated in **Appendix R2-D** and reproduced below as Figure 8-3.

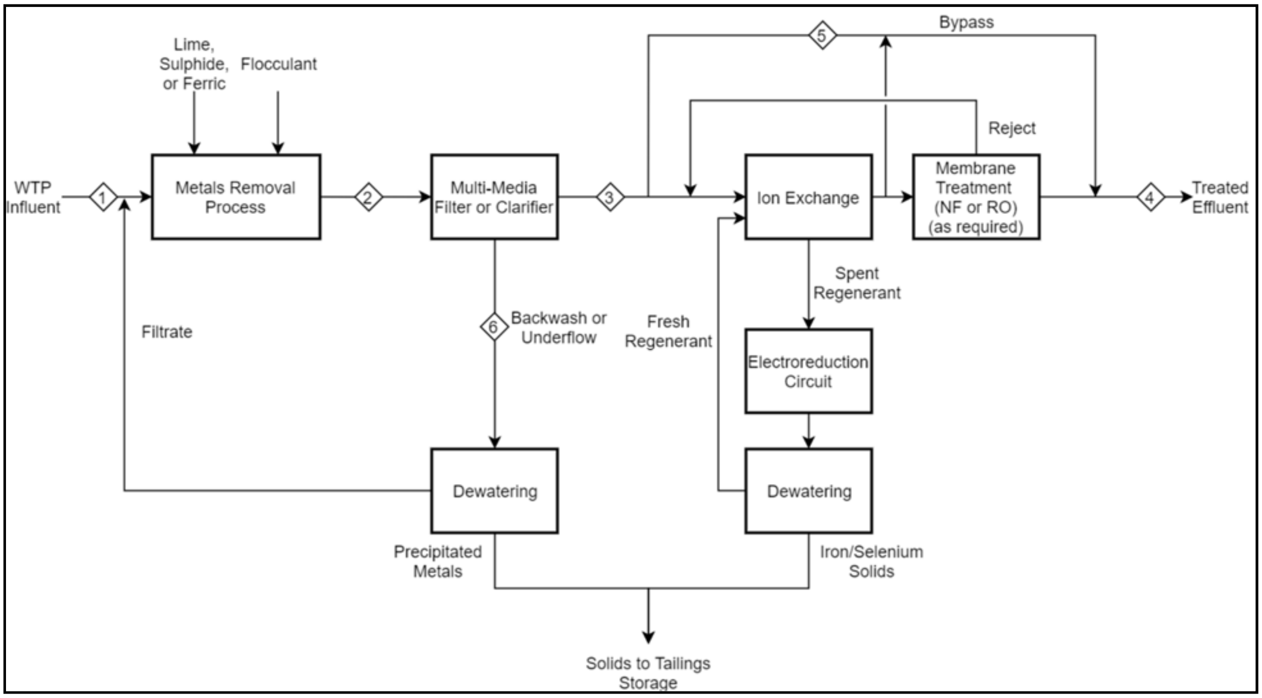


Figure 8-3: KZK Water Treatment Plant Block Diagram

The primary processes of the proposed water treatment system remain as were indicated in Appendix 4 of Initial Response Report (BMC, 2017) and are detailed as below:

1. Metals removal – addition of lime, sulphide and/or ferric to encourage precipitation of metals, and flocculation to improve separation of metals and metalloids.
2. Multi-media filtration – filtration to prevent carryover of precipitated metallic and non-metallic solids from metals removal system to the ion exchange and/or membrane systems. This improves the removal of precipitated species and protects the ion exchange system. A clarifier may also be utilized in lieu of a multi-media filter for sludge thickening, depending on precipitation chemistry.
3. Ion exchange (IX) – achieves removal of selenate via exchange within a fluidized resin bed.
4. Membrane filtration – ultrafiltration, nanofiltration or reverse osmosis may be included to achieve a high degree of removal of trace elements including fluoride and selenium in oxy-anionic forms.

Each of these primary processes have waste streams associated with them and these will be directed and handled as follows:

1. Metals Removal- The metals removal by precipitation process is a solids-separation technology that utilizes lime, sulphide and/or ferric addition to precipitate solids and produce a concentrated sludge that minimizes storage requirements and maximizes the sludge stability. This concentrated sludge will be dewatered together with the multi-media

filtration backwash with vacuum filtration or filter presses. The overflow from the metals removal system will be the input for the multi-media filtration.

2. Multi-media filtration-The processed water will be the feed for the Ion Exchange while the filter backwash from the multi-media filter will be passed through a dewatering process, with water returned to the front end of the process and a precipitated metals solid resulting. The dewatering process will consist of a technology such as vacuum filtration or filter press.
3. Ion Exchange (IX)- The spent regenerate is directed to the electro reduction circuit while processed water is the feed for the Reverse Osmosis system.
4. Reverse Osmosis- the RO unit is predicted to remove the remainder of dissolved solids to target effluent objectives at a 79% overall permeate recovery. The 21% reject stream is recirculated upstream of the ion exchange and will be recirculated through the Ion Exchange process.

The Electro Reduction Circuit is a technology developed by BQE Water and is designed to remove selenium from the spent IX regenerant as a solid. The selenium-rich spent regenerant is reduced and precipitated with iron from iron anodes in electrocells, forming a stable solid selenium-iron compound. The selenium-iron solids are separated and further dewatered, forming a stable selenium-iron solid that may be disposed of within the Class A Storage Facility or alternatively removed from site and disposed of through an appropriately licensed facility.

Using the above technologies, the water treatment system has two outputs; water treated to a standard suitable for discharge and filtered solids that may be disposed in the Class A Storage Facility. The integral part of the waste management is the electro reduction circuit developed by BQE Water. This system has also been proposed for Aurico's Kemess Underground Project in British Columbia which has successfully piloted the treatment process twice, advanced significantly through the BC permitting process and has regulatory buy-in to these treatment approaches.

Commercial sized testing of individual units of modules of the electro reduction circuit are planned for the 4th quarter of 2017 and pilot scale testing of the process using expected water inputs from the Kudz Ze Kayah Project will take place after the appropriate design work is completed.

Alternatives to the electro reduction circuit are a combination of the following:

- Additional stages of Reverse Osmosis to optimize lower reject volumes- this will decrease the volume of reject, however additional chemical dosage will be required to prevent scaling (for example, due to $CaSO_4$ saturation occurring at the RO membrane surface); and
- Additional treatment of the waste stream such as a thermal process (e.g. by evaporator/crystallizer or humidification/dehumidification process) may be considered to further reduce the volume of the waste stream. These processes are energy intensive and the cost of the energy required needs to be balanced against the cost of chemical dosage for additional RO stages to achieve the optimal result.

There are a number of mitigation measures available if the Water Treatment Plant does not perform as currently predicted or as indicated by future pilot plant testing. Failure, or malfunctions, of the Water Treatment Plant may be caused by various factors including:

- Water quality input variation from that modelled;

- Efficiencies and throughputs of the various components not performing as predicted;
- Mechanical breakdown of components;
- Insufficient plant capacity; and
- Power failure.

Possible mitigation measures include:

- Redundancy –the treatment plant components require regular maintenance including filter replacement, anode replacement, as well as scheduled preventative maintenance. To avoid limiting the throughput of the plant while these activities are taking place there will be extra components that can be bought on line when maintenance is required. These components could also be utilized in cases where there are mechanical breakdowns and may be used in cases where short term variations in flow rates occur;
- Oversizing of systems may be part of the design work. The system will have a nameplate capacity greater than the required throughputs and will have enough flexibility to manage all predicted water qualities;
- Storage of untreated water will be managed through the Class A and B collection ponds, and sumps at the Process Plant; and
- Power supply redundancy will be built into the Process Plant design to ensure that there is power available for essential services under all feasible circumstances. There will be available storage for untreated water, using gravity, in the case of a catastrophic failure of the power supply.

R2-31

Describe how the residual waste streams from ion exchange and RO treatment will be managed and update the water quality modelling if some of that residual is returned to the site/mine water system.

The management of the residual waste streams has been described in response to R2-30 above and in **Appendix R2-D** of this Response Report.

Up to three types of solids may occur from the precipitation process (metals removal), with expected totals of approximately 1 to 2 tonnes per day at average flow rate, depending on ultimate process selection (i.e. sulphide vs. lime precipitation, for example), and dewatering efficiency. The solids may include material derived from the removal of total suspended solids, precipitates from a lime or sulphide process, and/or ferric precipitation process. The quantity and characterization of expected solids will be further evaluated during geochemical and process modelling, and placement of solid waste will be determined to manage loading of metals and effects on water management and treatment infrastructure. Depending on solids quantity and characterization, one or more solids streams may be placed in a suitable location on site (i.e. within a lined dedicated cell within the Class A Storage Facility). Alternatively, solids may be transported to a suitable facility off-site. The relatively small amount and proposed disposal methods indicate that remodelling of the water quality model is not warranted.

The expected solid from the selenium removal process is a stable selenium-iron solid, approximately 2 tonnes per day at average flow rate compared to approximately 4,700 tonnes per day of tailings. This stable solid is expected to be suitable for onsite management, which may include co-mingling with the Class A Storage Facility or other methods. Because this process will result in a stable selenium-iron solid and its small volume compared to the volume of tailings, remodelling of the Class A Storage Facility water quality is not warranted.

8.2 WATER MANAGEMENT

YESAB ISSUE

The current baseline hydrometric program, as reported in Section 3.1.2.2 of the report, comprised a network of ten flow monitoring installations of which seven were continuous. The information provided in the report for the current baseline hydrometric program is from the end of April 2015 to late March 2016. Data for the continuous flow monitoring installations are available from the end of April 2015 to the Fall of 2015, are within the order of five spot measurements made from the Fall of 2015 through March of 2016, and are used to infer streamflow for that period.

Typically, the minimum period considered for collection of baseline hydrometric data to characterize streamflow response is three years. This is required to begin to understand the natural variability of hydrometric data. The hydrometric network coverage is considered good and data collected in the current hydrometric program considered reasonable, however, only eleven months of data are available. The 1995 hydrometric data are considered useful for general information purposes only, as these data are sparse, have gaps, and their quality cannot be confirmed.

The limited hydrometric information for the local study is considered an information gap. This information gap is important as results from the hydrometric monitoring program are used to calibrate and verify developed water balance models which are used to make projections related to receiving water quantity and quality. Additional hydrometric monitoring information would be useful to verify the work completed to-date and provide additional confidence in projections. Notwithstanding, it is anticipated this information could be collected through the next project phase and used to further verify developed water balance models and projections related to receiving water quantity and quality

R87

"Provide a detailed overview of the work planned to collect additional hydrometric monitoring information through the next project phase to further verify developed water balance models and projections related to receiving water quantity and quality."

Model validation and calibration will continually improve the precision and accuracy of the predictive tool. The Receiving Environment Water Balance (Appendix D-6, January 2017) of the Project Proposal used hydrometeorological data collected up to September 2016 for model calibration (outlined in Section 3.3) and collection of monthly surface water discharge (continuous and discrete measurements) and meteorological data collection continues.

Surface water quantity monitoring is continuing at a monthly sampling frequency at all baseline stations including site KZ-37, which was added to the monitoring program in February 2017. Further, monitoring has been outlined in Table 8-49 of the Project Proposal identifying monitoring during operations of the Project, which will be used during operations to further refine the model.

BMC will undertake revisions to modelling which will be based on this data, at future stages of Project permitting. However, we will undertake any revisions to the work plan for any potential re-modelling in consultation with the Yukon Water Board Secretariat (and their technical consultants). We recognize that it is important that our methodology for doing so is supported by the licensing agency.

R88

"Updated hydrometric baseline information, water quality objectives, and water models (e.g., water quality model, site and watershed balance models, surface water flows, etc.) for the site are required to be submitted prior to the Executive Committee drafting the screening report. To develop a reasonable understanding of short-term variability, sampling is required to be conducted and reported on at least two sampling events, including one during low-flow conditions and one during high-flow conditions, for each year in which 5 samples are collected in 30 days."

BMC appreciates that the review and eventual approval of Kudz Ze Kayah will undergo a number of stages, governed by separate legislation and specialized agencies. While we view the entire regime as a whole system, we recognize it is comprised of discrete segments. For example, groundwater modelling we submitted at the YESAB stage has been prepared and submitted to support YESAB's effects assessment at this stage. Because we continue to collect site water quality data as we progress, we will be in apposition to update modelling with additional data as required during the water licensing stage. At this stage in the Project it will be important to undertake our work with support of the specialist agency – the Yukon Water Board and their technical staff and consultants.

YESAB ISSUE WITH BMC'S RESPONSE TO R87 AND R88

The current baseline hydrometric program, as reported in Section 3.1.2.2 of the report, comprised a network of ten flow monitoring installations of which seven were continuous. The information provided in the report for the current baseline hydrometric program is from the end of April 2015 to late March 2016. Data for the continuous flow monitoring installations are available from the end of April 2015 to the Fall of 2015, are within the order of five spot measurements made from the Fall of 2015 through March of 2016, and are used to infer streamflow for that period.

Typically, the minimum period considered for collection of baseline hydrometric data to characterize streamflow response is three years. This is required to begin to understand the natural variability of hydrometric data. The hydrometric network coverage is considered good and data collected in the current hydrometric program considered reasonable, however, only eleven months of data are available. The 1995 hydrometric data are considered useful for general information purposes only, as these data are sparse, have gaps, and their quality cannot be confirmed.

The limited hydrometric information for the local study is considered an information gap. This information gap is important as results from the hydrometric monitoring program are used to calibrate and verify developed water balance models which are used to make projections related to receiving water quantity and quality. Additional hydrometric monitoring information would be useful to verify the work completed to-date and provide additional confidence in projections. Notwithstanding, it is anticipated this information could be collected through the next project phase and used to further verify developed water balance models and projections related to receiving water quantity and quality.

Insufficient response: Proponent has not provided a detailed overview of the work planned to collect additional hydrometric monitoring information.

Insufficient response: Proponent did not provide and did not commit to provide the Executive Committee with updated information prior to drafting the screening report. The Proponent has stated they will provide additional information to the Yukon Water Board to meet their obligation during licensing.
The Executive Committee requires updated hydrometric baseline information water quality objectives, and water models (e.g., water quality model, site and watershed water balance models, surface water flows, etc.) prior to drafting the screening report. This will ensure that our assessment is conducted on more accurate information for the site.

R2-32

Provide a detailed overview of the work planned to collect additional hydrometric monitoring information through the next project phase to further verify developed water balance models and projections related to receiving water quantity and quality.

On September 21, 2017 BMC representatives met with YESAB representatives and their consultant Ecometrix, to clarify, in part, what information regarding the ongoing hydrometric monitoring program was insufficient (based on BMC's initial response to R87 and R88). During the meeting, it was clarified that it was unclear in Table 8-49 whether KZ-13 was part of the monitoring program. BMC can confirm that KZ-13 is part of the ongoing monitoring program and it will continue to be monitored throughout the life of the Project (as listed in Table 8-49 and presented in Figure 8-50, of the Project Proposal).

R2-33

Updated hydrometric baseline information, water quality objectives, and water models (e.g., water quality model, site and watershed balance models, surface water flows, etc.) for the site are required to be submitted prior to the Executive Committee drafting the screening report. To develop a reasonable understanding of short-term variability, sampling is required to be conducted and reported on at least two sampling events, including one during low-flow conditions and one during high-flow conditions, for each year in which 5 samples are collected in 30 days.

BMC confirms that it will provide the requested information prior to the Executive Committee drafting the screening report.

YESAB ISSUE

A water balance modeling exercise was completed for average, wet, and dry climatic scenarios: average precipitation, 1 in 50 year precipitation, and 1 in 10 year dry precipitation. While it does not seem to be specified in the Water Balance Model Report, we understand that the water balance modeling exercise is for operations at year 10.

The water balance modelling exercise does not provide information for all phases of the mine life from construction through operations, and the active, transition, and post closure phases. This is not considered consistent with industry standards and is considered to be an information gap. Typically, through the different phases of mine life there are changes in the volumes of water generated from various sources, and how it is managed and discharged to the environment and these should be accounted for in the assessment.

Appendix D-6, s.1.2 Modelling Philosophy. The proponent refers to a Microsoft Excel spreadsheet format developed for the Finlayson Creek watershed model. The proponent should provide a functioning copy of the spreadsheet water balance.

The proponent states "The modelling goal was to estimate surface water discharge for mean, 50 year wet and 10 year dry precipitation years".

R90

"Update the detailed water balance model for the project site to include all phases of the mine life from construction through operations, and the active, transition, and post closure phases."

Water balances for the site for all phases of the mine life were provided in the original Proposal document supplied to YESAB. The site water balance for operations was provided in Appendix C-7, (Water Balance Model Report) of the Project Proposal. For construction and closure phases of the Project, the site water balance has been incorporated in the Receiving Environment Water Balance Report, Appendix D-6 of the Project Proposal.

R91

"Provide rationale for return periods used in modelling.

The dry and wet years were modelled to undertake sensitivity analysis using the maximum proposed discharge concentrations from the Lower Water Management Pond and resulting concentrations in Geona Creek and Finlayson Creek to determine potential effects on surface water using the preliminary water quality objectives. The 1 in 10 dry year was modelled as this is a typical scenario used in the Water Licencing proposed to establish effluent quality standards for compliance locations.

In addition, using the updated water balance model, evaluate the following scenarios:

a. impact of an event, such as the 24-hour design events used in sizing of water management facilities;
b. impact of an event such as extreme summer and winter low flows (7Q20 and 7Q10);
c. greater than normal snowfall accumulation; and
d. shorter and more critical snowmelt durations."

These scenarios, and other sensitivity analyses (which may include precipitation variability, pit groundwater inflow rates, potential implications related to climate change, etc.), will be modelled as part of the detailed design phase and on-going water balance model development.

R92

"Undertake a sensitivity analysis to assess variability of model predictions given variation in key model input parameters and assumptions."

No updates to the water balance were warranted or provided in response to question R90, and therefore the Surface Water Management Plan has not been updated. All management plans will be updated as Project planning progresses if preceding work is materially updated.

YESAB ISSUE WITH BMC'S RESPONSE TO R90, 91 AND 92

A water balance modeling exercise was completed for average, wet, and dry climatic scenarios: average precipitation, 1 in 50 year precipitation, and 1 in 10 year dry precipitation. While it does not seem to be specified in the Water Balance Model Report, we understand that the water balance modeling exercise is for operations at year 10.

The water balance modelling exercise does not provide information for all phases of the mine life from construction through operations, and the active, transition, and post closure phases. This is not considered consistent with industry standards and is considered to be an information gap. Typically, through the different phases of mine life there are changes in the volumes of water generated from various sources, and how it is managed and discharged to the environment and these should be accounted for in the assessment.

Appendix D-6, s.1.2 Modelling Philosophy. The proponent refers to a Microsoft Excel spreadsheet format developed for the Finlayson Creek watershed model. The proponent should provide a functioning copy of the spreadsheet water balance.

The proponent states "The modelling goal was to estimate surface water discharge for mean, 50 year wet and 10 year dry precipitation years".

Insufficient response: Proponent has not provided the requested information. The Proponent's response refers back to documentation, which was reviewed and provided the basis for the information request. The water balance for the operations phase is based on conditions in the final operational year (Year 10). In addition to Year 10, the water balance modelling exercise should include results separately for Year 1, Year 2, Year 3, Year 4, Year 5, Year 6, Year 7, Year 8, and Year 9 with the water balance set-up to reflect anticipated mine infrastructure for those respective years.

Insufficient response: Proponent has not provided the requested information pertaining to evaluation of the identified scenarios. It is important to evaluate additional potential scenarios and how they relate to the site water balance. This will allow a greater degree of confidence in the proposed water management works. As it stands, the water balance model and results are based on evaluation of only three specific scenarios (i.e., mean conditions, dry year, wet year) and associated assumptions.

Insufficient response: Proponent has not provided the requested sensitivity analysis. We note that it is stated in Section 4.1 of the Water Balance Report (Appendix C-7) "The water balance is sensitive to the input assumptions and the potential variability in the results should be considered when used for planning purposes. The input variables that have the greatest influence on the results are the water management assumptions, the diversion ditch efficiency, and the climatic values." In this regard, it is important to understand the effect that variation in assumptions related to water balance model parameters will have on water balance model results. This information can be provided by conducting a sensitivity analysis.

R2-34

Update the detailed water balance model for the project site to include all phases of the mine life from construction through operations, and the active, transition, and post closure phases.

The reviewer is correct. The Project Proposal presented model results for Year 10 of operations, for average, wet, and dry climatic scenarios: average precipitation, 1 in 50 year precipitation, and 1 in 10 year dry precipitation

Appendix R2-E (Operational Water Balance and Climate Variability and Sensitivity Analysis) of this response report summarizes the updated operational water balance for the KZK Project, which includes climate variability and sensitivity analysis. The same water balance model developed for the Project Proposal was used for this analysis, however, rather than evaluating three scenarios (mean annual precipitation, 50-year wet year and 10-year dry year), this model uses the long-term climate parameters to evaluate the water balance under a wide range of climate conditions. A sensitivity analysis was also completed on the key model input parameters and assumptions. These include the water management assumptions (which are addressed with the climate variability model), the climate values (which again are addressed with the climate variability model), and the diversion ditch efficiency. Appendix B (of the Operational Water Balance and Climate Variability and Sensitivity Analysis) includes results separately for Year 1, Year 2, Year 3, Year 4, Year 5, Year 6, Year 7, Year 8, and Year 9 (**Appendix R2-E)**.

The water balances for the site for all phases of the mine life were provided in the original Proposal document supplied to YESAB. The site water balance for operations was provided in Appendix C-7 of the Project Proposal (Water Balance Model Report). For construction and closure phases of the Project, the site water balance has been incorporated in the Receiving Environment Water Balance Report, Appendix D-6 of the Project Proposal. Additional information for the construction and closure water balances have been included in Tables A-6-4, A-6-5, A-6-6, A-6-13, A-6-14, A-6-15, A-6-16, A-6-17, A-6-18, A-6-19, A-6-20, and A-6-21 from Appendix D-6, and are presented in **Appendix R2-F** of this Response Report.

R2-35

Provide rationale for return periods used in modeling. In addition, using the updated water balance model, evaluate the following scenarios:

The rationale for the dry scenario (1 in 10 dry year) is based on the length of the operations phase of the Project. The scenario was used to develop appropriate mitigation measures (i.e. water treatment performance) during operations given the dry scenario is the most sensitive modelled for water quality to operations. The rationale for the wet scenario (1 in 50 wet year) was based on the full extent of the Project from construction through post closure to determine water management strategy for a potential wet year.

a. impact of an event, such as the 24-hour design events used in sizing of water management facilities;

The collection ponds for the Class A Storage Facility, Class B Storage Facility, Class C Storage Facility and Overburden Stockpile were assessed (in part) following receipt of R2-35. In order to avoid repetition, please refer to BMC's response to R2-39, which clarifies the design of ponds and the design basis criteria for 24-hour storm events. Note that the updated design will provide sufficient storage volumes necessary such that no impacts are predicted.

b. impact of an event such as extreme summer and winter low flows (7Q20 and 7Q10);

Appendix R2-E (Operational Water Balance and Climate Variability and Sensitivity Analysis) of this response report summarizes the updated operational water balance for the KZK Project, which includes climate variability and sensitivity analysis. The current water balance model uses a monthly time step, as a result, 7Q10 and 7Q20 are not applicable.

c. greater than normal snowfall accumulation; and

Appendix R2-E (Operational Water Balance and Climate Variability and Sensitivity Analysis) of this response report summarizes the updated operational water balance for the KZK Project, which includes climate variability and sensitivity analysis (including greater than normal snowfall accumulations).

d. shorter and more critical snowmelt durations.

Appendix R2-E (Operational Water Balance and Climate Variability and Sensitivity Analysis) of this response report summarizes the updated operational water balance for the KZK Project, which includes climate variability and sensitivity analysis (including shorter more critical snowmelt conditions).

R2-36

Undertake a sensitivity analysis to assess variability of model predictions given variation in key model input parameters and assumptions.

Appendix R2-E (Operational Water Balance and Climate Variability and Sensitivity Analysis) of this response report summarizes the updated operational water balance for the KZK Project, which includes climate variability and sensitivity analysis. The same water balance model developed for the Project Proposal was used for this analysis, however, rather than evaluating three scenarios (mean annual precipitation, 50-year wet year and 10-year dry year), this model uses the long-term climate parameters to evaluate the water balance under a wide range of climate conditions. A sensitivity analysis was also completed on the key model input parameters and assumptions. These include the water management assumptions (which are addressed with the climate variability model), the climate values (which again are addressed with the climate variability model), and the diversion ditch efficiency.

YESAB ISSUE

No information is provided on the detailed water balance computations illustrating the breakdown of typical water balance components (e.g., storm water, groundwater, seepage, evaporation/evapotranspiration, water management facility operations inclusive of projected pond water levels, and inter-basin water transfers). This information is important in understanding the Project Site water balance.

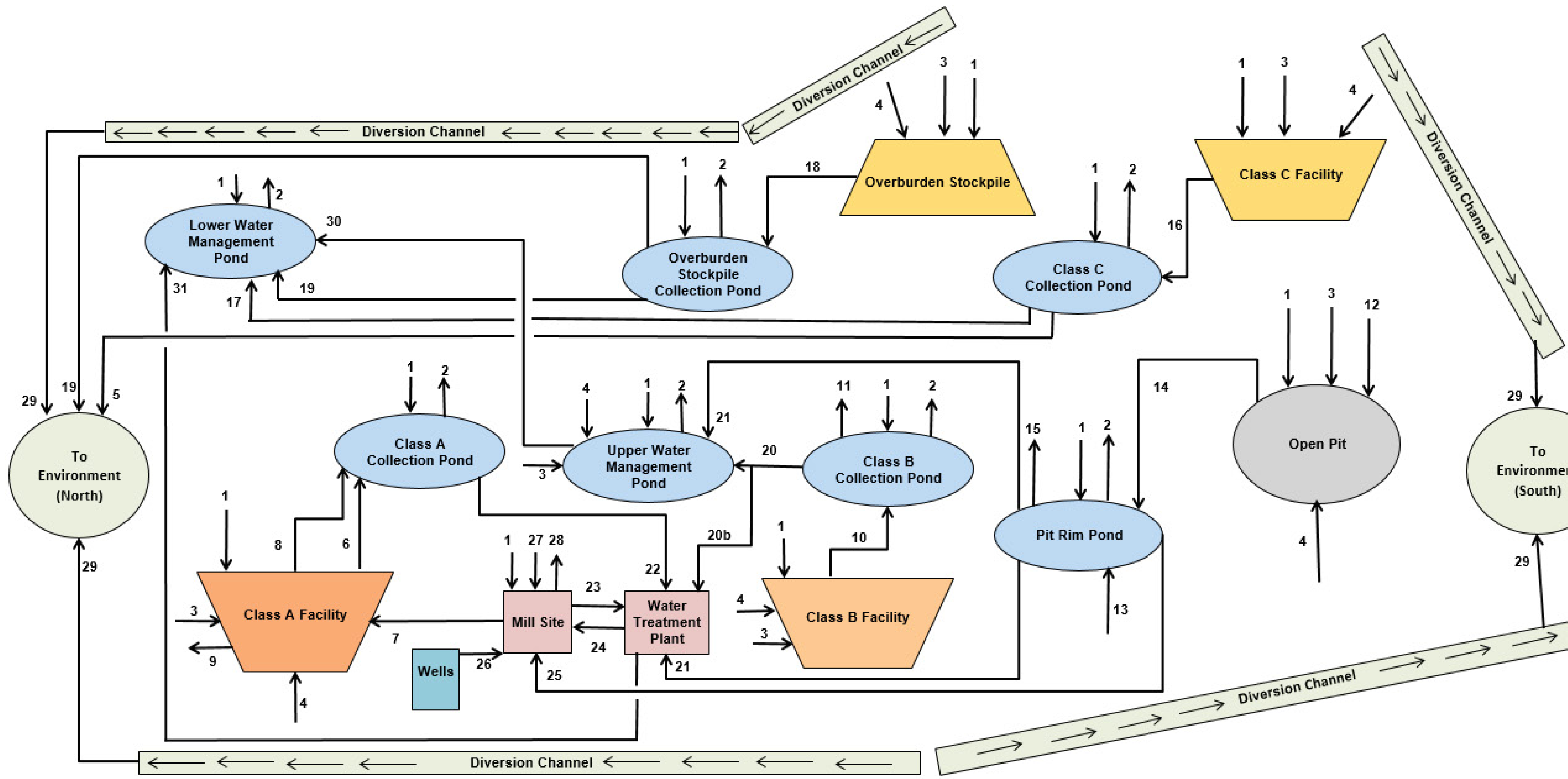
R93

"Include summary water balance model computations to the Water Balance Model Report, including the breakdown of typical water balance components, such as but not limited to: storm water; groundwater; seepage; evaporation/evapotranspiration, and; water management facility operations and inter-basin transfers."

Appendix C-7, Water Balance Model Report, of the Project Proposal describes the water balance components and Figure 3.1 Water Balance Flow Schematic illustrates the treatment of the components with regard to the water balance model. The schematic is reproduced below as Figure 8-4 to clarify the inputs that have all been included in the model.

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

Knight Piésold CONSULTING



FLOW PATHS	
1	Direct Precipitation
2	Evapotranspiration
3	Undiverted Runoff
4	Diversion Ditch Leakage
5	Collection Ditch Leakage
6	Seepage
7	Water in Tailings
8	Runoff from Class A Facility
9	Void Losses
10	Runoff from Class B Facility
11*	Dust suppression
12	Groundwater Inflow to Open Pit
13	Groundwater Inflow from Underground Workings
14	Open Pit Dewatering
15	Water to Paste Plant
16	Runoff from Class C Facility
17	Surplus from Class C Collection Pond
18	Runoff from Overburden Stockpile
19	Surplus from Overburden Stockpile Collection Pond
20	Surplus from Class B Collection Pond
20b	Suprlus from Class B Collection Pond to WTP
21	Surplus from Pit Rim Pond
22	Surplus from Class A Collection Pond
23	Mill Site Runoff
24	Mill Reclaim
25	Freshwater Source 1
26	Freshwater Source 2
27	Water in Ore
28	Water in Concentrate
29	Diversions to Environment
30	Surplus from Upper Water Management Pond
31	Treated Runoff from Water Treatment Plant

* Water for dust suppression can be supplied from various sources, depending on water quality, if required (i.e. Class B Collection Pond, Pit Rim Pond, Lower Water Management Pond, etc.).

Figure 8-4 Water Balance Flow Schematic

YESAB ISSUE WITH BMC'S RESPONSE TO R93

No information is provided on the detailed water balance computations illustrating the breakdown of typical water balance components (e.g., storm water, groundwater, seepage, evaporation/evapotranspiration, water management facility operations inclusive of projected pond water levels, and inter-basin water transfers). This information is important in understanding the Project Site water balance.

Insufficient response: Proponent provided a schematic illustrating water balance components but has not provided requested information pertaining to actual values (i.e., volumes) attributed to the various water balance components.

R2-37

Include summary water balance model computations to the Water Balance Model Report, including the breakdown of typical water balance components, such as but not limited to: storm water; groundwater; seepage; evaporation/evapotranspiration, and; water management facility operations and inter-basin transfers.

Appendix R2-E (Operational Water Balance and Climate Variability and Sensitivity Analysis) of this Response Report summarizes the updated operational water balance for the Project, which includes climate variability and sensitivity analysis. Appendix B of the Operational Water Balance and Climate Variability and Sensitivity Analysis provides a summary table of volumes associated with the flow schematic. A request was made to add the flows to the schematic; however, based on a review of the summary table of volumes it is not practicable to add these to the schematic given the amount of values that would need to be added.

YESAB ISSUE

The Surface Water Management Plan (SWMP) is based on a water balance modelling exercise that does not provide information for all phases of the mine life from construction through operations and closure. This is not considered consistent with industry standards and is considered to represent an information gap. Typically, through the different phases of mine life there are changes in the volumes of water generated from various sources, and how it is managed and discharged to the environment and the variation in volumes should be assessed.

R97

"Update the Surface Water Management Plan as appropriate based on the updated water balance model (requested in R90 of this Report)."

Water balances for the site for all phases of the mine life were provided in the original Proposal document supplied to YESAB. The site water balance for operations was provided in Appendix C-7, (Water Balance Model Report) of the Project Proposal. For construction and closure phases of the Project, the site water balance has been incorporated in the Receiving Environment Water Balance Report, Appendix D-6 of the Project Proposal.

No updates to the water balance were warranted or provided in response to question R90, and therefore the Surface Water Management Plan has not been updated. All management plans will be updated as Project planning and permitting progresses if preceding work is materially updated.

YESAB ISSUE WITH BMC'S RESPONSE TO R97

The Surface Water Management Plan (SWMP) is based on a water balance modelling exercise that does not provide information for all phases of the mine life from construction through operations and closure. This is not considered consistent with industry standards and is considered to represent an information gap. Typically, through the different phases of mine life there are changes in the volumes of water generated from various sources, and how it is managed and discharged to the environment and the variation in volumes should be assessed.

Insufficient response: Proponent has not provided the requested information. The Proponent's response refers back to documentation which was reviewed and provided the basis for the information request, and has not provided any water balance model updates.

Provided in the Water Balance Model Report (Appendix C-7) is a schematic with the various water balance components. For clarity, we require the annual values be included on the schematic for the various water balance components for the scenarios evaluated (i.e., mean conditions, dry year, and wet year).

R2-38

Update the Surface Water Management Plan as appropriate based on the updated water balance model (requested in R90 of this Report).

On September 21, 2017 BMC representatives met with YESAB and their consultant Ecometrix. Clarification was provided by YESAB at the meeting that indicated that updating the Surface Water Management Plan was only required based on a review of the annual model result for years 1 through 9. Given that the Surface Water Management Plan was based on the water balance at year 10 (which is the year when the most water would need to be managed on site, the model results for years 1 to 9 (in response to R2-34) do not result in any changes to the Surface Water Management Plan. This is why the model results for years 1 to 9 were not initially provided in the Project Proposal.

YESAB ISSUE

Water management structures include ponds and diversions. While design criteria are provided for the proposed ponds in Table 18-6, no design criteria are provided for the proposed diversions. However, it is noted in Section 4.10.1.1 (Water Diversions and Ditches) of the Proposal that all diversion ditches will be designed to manage a 1 in 200-year flood event. For both the ponds and diversions, no information is provided to assess if the provided volumes/designs are sized sufficiently to manage the stated design criteria or how the overall SWMP functions during the stated design conditions.

R99

"Provide computations demonstrating that proposed ponds as specified in the Proposal have sufficient storage volumes necessary to meet stated design criteria and safely convey the applicable Inflow Design Flood."

The design criteria for the Upper and Lower Water Management Ponds and the Class A and B Collection Ponds is the 1 in 200 year flood event.

The design criteria for the Class C and Overburden Collection Ponds is the 1 in 10 year flood event.

Details of the water management structure designs will be refined during the detailed design phase in preparation for licensing.

R100

"Provide water balance model computations demonstrating the Site Water Management Plan and proposed water management structures can function, on an overall basis, as intended under stated design conditions for all phases of the mine life."

Water balance model computations were completed as part of the water balance modelling (presented in Appendix C-7, Water Balance Model Report), which balanced the inflow and outflow rates to the water management ponds based on the predicted maximum total required capacity. The design basis for the ponds was to store the required inflow design flood events. Contact water is released as required so the ponds do not exceed their design volumes.

YESAB ISSUE WITH BMC'S RESPONSE TO R99 AND R100

Water management structures include ponds and diversions. While design criteria are provided for the proposed ponds in Table 18-6, no design criteria are provided for the proposed diversions. However, it is noted in Section 4.10.1.1 (Water Diversions and Ditches) of the Proposal that all diversion ditches will be designed to manage a 1 in 200-year flood event. For both the ponds and diversions, no information is provided to assess if the provided volumes/designs are sized sufficiently to manage the stated design criteria or how the overall SWMP functions during the stated design conditions.

Insufficient response: Proponent has not provided the requested information. Detailed information must be provided in order to determine whether the pond, diversion ditches, and spillways are sized sufficiently to manage the stated design criteria. As an example, there is no information related to spillway design (i.e., type and size) to give the Executive Committee confidence that they are appropriately sized to manage the design criteria.

Insufficient response: Proponent has not provided the requested information.

R2-39

Provide computations demonstrating that proposed ponds as specified in the Proposal have sufficient storage volumes necessary to meet stated design criteria and safely convey the applicable Inflow Design Flood.

The collection ponds for the Class A Storage Facility, Class B Storage Facility, Class C Storage Facility and Overburden Stockpile, and the water management ponds, were assessed following receipt of R2-39. Return period rainfall intensities have been updated by Knight Piésold Ltd. for the Project area based on 23 complete years of climate record from Faro Airport, Yukon using a conversion factor of approximately 2.0. The return period rainfall intensities for 24-hour design events are presented in Table 8-6, as well as inflated rainfall intensities to address climate variability. Additional details regarding the rainfall intensity modelling is provided in response to R2-122.

Pond volumes have been assessed with British Columbia Ministry of Environment (BC MOE) Technical Guidance #7 document (BC MOE, 2015) as minimum recommendations. Table 8-7 presents contributing areas and terrain characteristics used in determining inflow volumes. The Class A and Class B Collection Ponds were sized using the Runoff Method for inflow volumes, whereas Class C and Overburden Stockpile Ponds were modelled using HydroCAD (HydroCAD, 2015). Based on this more detailed design, the volumes of the water management facilities presented in Table 8-7 supersede those presented in the Project Proposal (specifically, Table 4-25 and Table 18-6).

Return periods for rainfall intensities used in sizing the collection ponds follow BC MOE guidelines, which recommend flow-through sediment ponds, be operationally sized for a 1 in 10 year event, and that ponds should safely pass a 1 in 200 year event with additional freeboard greater than 0.5 m. Collection pond design criteria are presented in Table 8-7.

This updated design provides sufficient storage volumes necessary to meet stated design criteria and safely convey the applicable Inflow Design Flood.

Table 8-6: Water Management Systems: Return Period Rainfall Intensities

Return Period (years)	Return Period Rainfall Intensity (mm/day)	Return Period Rainfall Intensity with Climate Change Adjustment, 15% (mm/day)
2	37	43
5	46	53
10	52	60
15	55	63
20	58	67
25	60	69

Return Period (years)	Return Period Rainfall Intensity (mm/day)	Return Period Rainfall Intensity with Climate Change Adjustment, 15% (mm/day)
50	65	75
100	71	82
200	77	89
500	84	97
1000	90	104
Probable Maximum Precipitation	220	253

Table 8-7: Water Management Systems: Design Basis

Design Criteria	Class A Storage	Class B Storage	Class C Storage	Overburden Stockpile
Operational Design Storm	1:200 Year, 24 h	1:200 Year, 24 h	1:10 Year 24 h	1:10 Year 24 h
Facility Design Storm			1:200 Year 24 h	1:200 Year 24 h
Operational Design Rainfall Intensity [mm/day]	89	89	52	52
Facility Design Rainfall Intensity [mm/day]			77	77
Additional Inflows / Storage [m^3]	8,000	9,500	-	-
Runoff Method (Q=CiA)				
Catchment Area (assuming diversion ditches operational) [m^2]	1,086,000	924,000	-	-
Runoff Coefficient [unitless]	1.0	1.0	-	-
Inflow Volume Estimate [m^3]	96,165	81,820	-	-
HydroCAD Model				
Storm Type	-	-	SCS Type I	
Catchment Area (assuming diversion ditches operational) [m^2]	-	-	2,470,000	678,040
Longest Flow Path [m]	-	-	1345	919
Slope [m/m]	-	-	0.08	0.11
Time of Concentration [hours]	-	-	18	11
Curve Number [unitless]	-	-	98	98
Inflow Volume Estimate [m^3]	-	-	103,924	31,298
Sediment Pond Design				
Bottom Dimensions (W x L) [m]	30 x 320	80 x 250	40 x 225	30 x 200
Bank Slopes H:V [m]	2:1	2:1	2:1	2:1
Embankment Height [m]	7.7	5.5	10.0	5.5
Maximum Water Depth [m]	6.7	4.5	8.8	4.5
Culverts	-		Sized to settle sediment from a 1:10 year event	
Spillway	To be sized to pass events greater than 1:200		Sized to pass a 1:200 year event	
Freeboard [m]	1	1	1	1
Retention Time [hours]	37 (2)	25 (2)	43	22
Design Volume [m^3]	**104,000**	**91,000**	**125,000**	**37,000**

R2-40

Provide water balance model computations demonstrating the Site Water Management Plan and proposed water management structures can function, on an overall basis, as intended under stated design conditions for all phases of the mine life.

Appendix R2-E (Operational Water Balance and Climate Variability and Sensitivity Analysis) of this Response Report summarizes the operational water balance for the Project, which includes climate variability and sensitivity analysis. This analysis demonstrates that the proposed water management structures can function as intended under stated design conditions throughout the life of mine under various climatic scenarios.

YESAB ISSUE (WITH NO CORRESPONDING INITIAL REQUEST)

ECCC notes that contact water from the ditches designed to divert flows around the proposed Overburden Stock pile and Class C Storage facilities is proposed to be discharged directly to Geona Creek at the same location as the non-contact water downstream from the lower water management pond (Figure 1.1 Appendix C-7 Water Balance Model Report). The Proponent states:

"The Class C Storage Facility is designed to contain Class C material. Class C material is potentially acid consuming and therefore specific ARD management strategies are not required. The Class C Storage Facility is located in a small hanging valley along the east side of the project area.

Overburden from the Open Pit excavation will be excavated and stockpiled. Glacial till material will be selectively sourced from the stockpile and used for the low permeability foundation and closure cover layers of the Class A and Class B Storage Facilities, and for construction of the Water Management and Collection Ponds. The stockpile will be located north of the Class C Storage Facility, along the western slope of the project area. The overburden material is not anticipated to be potentially acid generating and therefore specific ARD management strategies are not required."

The Proponent should note that the lack of acid conditions does not preclude metal leaching and as a result, contact water from project components should be properly monitored and managed prior to discharge into the environment.

R2-41

Provide rationale for not diverting contact mine water drained from the Overburden Stock pile and Class C Storage facilities into the water management or treatment facilities.

As part of the Water Quality Model (Appendix D-7 of the Project Proposal), runoff water from the Overburden Stockpile and Class C Storage facilities were modelled to flow into Geona Creek downstream of water management and treatment systems. Class C waste rock is not acid generating and has a low potential for metal leaching (Appendix D-5 of the Project Proposal). Acid base accounting and shake flask extraction (SFE) analysis of overburden samples also indicates that this material is not acid generating and has low levels of soluble metals.

The loading contribution from the Overburden Stockpile was developed from the median of shake SFE testing on overburden samples acquired from across the ABM open pit footprint (as shown in

Table 3-5 of the Water Quality Model Report (Appendix D-7 of the Project Proposal) and Table 8-8 below). Using SFE leachable concentrations as a surrogate for runoff water chemistry is considered conservative due to the agitation involved with SFE testing and associated more extensive flushing.

The loading from the Class C Storage facility was modelled using source terms developed from kinetic testing as discussed in the Water Quality Model Report (Appendix D-7 of the Project Proposal). Relative to loading from the Class A and Class B Storage facilities the Overburden Stockpile and Class C loading rates are minor and loading of constituents of potential interest (COPIs) to the receiving environment from the Class C and Overburden Stockpiles make up a small proportion of the total loading (as shown in Table 8-9 and Table 8-10). As the contribution of load from the Class C and Overburden Stockpile facilities will be relatively small, management and treatment of contact water from those facilities will have a minor impact on receiving water quality and is therefore not deemed necessary. However, it is noted that contact water from the Class C Storage Facility will be directed into the Class C Storage Facility collection pond. The chemistry of this pond will be monitored routinely until final closure. Should the water quality deteriorate such that degraded water quality in the receiving environment be expected, the water will be pumped to the water treatment plant for treatment prior to discharge.

Table 8-8: Median SFE Concentration from Project Site Overburden Samples

Parameter	Concentration (mg/L)	Parameter	Concentration (mg/L)
Hardness (from total)	6.5	Iron	0.11
Sulphate	0.55	Lead	0.00035
Phosphorus	0.0050	Manganese	0.0053
Fluoride	0.049	Nickel	0.00031
Aluminum	0.095	Silver	0.000040
Antimony	0.00012	Selenium	0.00010
Arsenic	0.00048	Uranium	0.000075
Cadmium	0.000065	Zinc	0.0030
Copper	0.0036		

Table 8-9: Proportion of modelled annual loading from KZK site components during Year 10 (operations phase)

	Fluoride	Antimony	Arsenic	Cadmium	Copper	Iron	Lead	Manganese	Nickel	Silver	Selenium	Uranium	Zinc
Water Management Pond	64%	95%	84%	98%	71%	85%	100%	97%	100%	100%	84%	84%	96%
Class C	25%	5%	11%	1%	5%	0%	0%	2%	0%	0%	9%	11%	1%
Overburden	0%	0%	0%	0%	5%	1%	0%	0%	0%	0%	0%	0%	0%
Background	11%	0%	4%	2%	19%	14%	0%	1%	0%	0%	7%	4%	3%
Total Load	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Table 8-10: Proportion of modelled annual loading from KZK site components during Year 35 (post-closure phase). Note: Overburden Stockpile would be decommissioned in post-closure

	Fluoride	Antimony	Arsenic	Cadmium	Copper	Iron	Lead	Manganese	Nickel	Silver	Selenium	Uranium	Zinc
Class A	3%	2%	26%	89%	94%	99%	94%	34%	59%	98%	60%	7%	93%
Class B	3%	0%	50%	1%	2%	1%	0%	4%	1%	0%	1%	23%	1%
Class C	25%	8%	2%	0%	0%	0%	0%	2%	2%	0%	7%	14%	0%
Pit Lake	54%	89%	22%	9%	4%	0%	5%	59%	32%	1%	27%	50%	5%
Background	15%	0%	1%	1%	0%	0%	0%	1%	7%	0%	5%	5%	1%
Total Load	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

R2-42

Clarify if/when there will be discharge to the environment from the Lower Water Management Pond and identify any losses to groundwater.

Discharge from the Lower Water Management Pond will occur year-round with quantities identified for the average, dry and wet climatic scenarios. This is presented in Chapter 4 of the Project Proposal (see Table 4-26, 4-27 and Table 4-28, respectively). The Lower Water Management Pond will be lined with HDPE (Section 4.10.1 of the Project Proposal), therefore no losses to groundwater were included in the Water Balance Model Report (Appendix C-7 of the Project Proposal).

YESAB ISSUE

It is uncertain if the proposed sediment collection pond volumes as specified in the Proposal have sufficient storage volumes to provide the hydraulic retention time necessary to achieve the design criterion identified.

Section 18.6.3.2 of the Proposal states that sediments ponds will be:

Designed to trap sediment particles of 10 microns in size or larger with flow volumes equivalent to a 1:200 year, 24-hour rainstorm for the Class A and Class B Storage Facilities Collection ponds and 1:10 year, 24-hour rainstorm for the Class C Storage Facilities Collection and Overburden Stockpile ponds.

R103

"Provide computations demonstrating that collection pond volumes as specified in the Proposal have sufficient storage volumes to provide the hydraulic retention time necessary to achieve the stated design criteria."

Detailed sediment pond designs will be included as part of the detailed design phase prior to application of the Water Licence.

YESAB ISSUE WITH BMC'S RESPONSE TO R103

It is uncertain if the proposed sediment collection pond volumes as specified in the Proposal have sufficient storage volumes to provide the hydraulic retention time necessary to achieve the design criterion identified.

Section 18.6.3.2 of the Proposal states that sediments ponds will be:
Designed to trap sediment particles of 10 microns in size or larger with flow volumes equivalent to a 1:200 year, 24-hour rainstorm for the Class A and Class B Storage Facilities Collection ponds and 1:10 year, 24-hour rainstorm for the Class C Storage Facilities Collection and Overburden Stockpile ponds.

Insufficient response: Proponent has not provided the requested information.

R2-43

Provide computations demonstrating that collection pond volumes as specified in the Proposal have sufficient storage volumes to provide the hydraulic retention time necessary to achieve the stated design criteria.

Retention times using Stoke's Equation as per BC MOE guidelines are presented in Table 8-7. The Class C and Overburden Stockpile Collection Ponds were modelled in HydroCAD to settle particles with diameter 10 microns and larger by restricting the flow-through velocity as per Method A in the BC MOE guidelines. Minimum retention times required to settle particles 10 microns and larger are included for the Class A and Class B Collection Ponds to reduce suspended sediment prior to water treatment.

YESAB ISSUE

Information provided in Table 16-9 of Section 16.6.1 provides a list of typical high and very high confidence findings related to climate change. However, no analyses related to the water balance analyses have been provided which consider changes in climatic input design assumptions or change in type of design events.

R104

"Undertake a sensitivity analysis, in support of the discussion of effects and mitigation measures associated with both extreme events and climate change, using the water balance models developed for the Project to obtain an understanding of potential effects on water management structures and discharges strategies with variation in both model input assumptions and type of events."

As stated in the Project Proposal Section 16.6.*3 "The likelihood of climate change occurring is overall likely; however, changes will occur over the long term and the magnitude of changes likely to occur over the Project's life is small."*

Extreme events have been allowed for in the design of the water containment structures which will be designed to operate with a 1 in 200year precipitation event. Mitigation measures have been included in Chapter 17 of the Project Proposal, Malfunctions and Accidents, in the unlikely event that the maximum precipitation event design parameters are exceeded. The mitigations are elaborated on in Section 17.2.5 of the Project Proposal.

The water balance model used in the Project Proposal is conservative and any fluctuations in model inputs, or types of event will be allowed for within this conservatism.

YESAB ISSUE WITH BMC'S RESPONSE TO R104

Information provided in Table 16-9 of Section 16.6.1 provides a list of typical high and very high confidence findings related to climate change. However, no analyses related to the water balance analyses have been provided which consider changes in climatic input design assumptions or change in type of design events.

Insufficient response: Proponent has not provided the requested information.

R2-44

Undertake a sensitivity analysis, in support of the discussion of effects and mitigation measures associated with both extreme events and climate change, using the water balance models developed for the Project to obtain an understanding of potential effects on water management structures and discharges strategies with variation in both model input assumptions and type of events.

Appendix R2-E (Operational Water Balance and Climate Variability and Sensitivity Analysis) of this Response Report summarizes the operational water balance for the Project, which includes climate variability and sensitivity analysis. This analysis demonstrates that the proposed water management structures can function as intended under stated design conditions throughout the life of mine under various climatic scenarios.

The results of the sensitivity analysis do not impact the discharge strategy, which is dependent on the volume of water in the receiving environment. If the climatic inputs increase or decrease water will proportionally increase, or decrease, for both the mine foot print (i.e. discharge volume) and flow in Geona and Finlayson Creeks. Similarly, if ditch efficiency is improved from 50% there would be more water in Geona Creek and Finlayson Creek for discharge capacity and less available to flow into and “flush” dumps. In the scenario where ditch efficiency is reduced to 25% this would account for an additional 350,000 m^3 of water per year in the mean scenario, which represents a minor increase of approximately 8% more water above the mean scenario.

YESAB ISSUE

The issue of downstream flow changes associated with the Project, specifically those related to alteration of natural hydrologic flow regime and associated impacts on downstream erosion, stream morphology and riparian vegetation may not have been assessed.

R105

“Provide an assessment of impacts associated with the Project on erosion, stream morphology and riparian vegetation of all affected drainages from projected downstream flow changes during all Project phases.”

During the construction phase, flows in Geona Creek are anticipated to initially increase above baseline due to dewatering (which offsets the loss of flow from Fault Creek) at least during the first 10 months, after which a decrease in flow will result during the open water season. During the winter, water pumped as a result of dewatering makes up a larger portion of the net flow and as such this translates into an overall increase in base flow from freeze-up until spring melt. This predicted flow pattern in Geona Creek translates into a similar pattern in Finlayson Creek but with a proportionally lower percent influence as discussed in Chapter 10 of the Project Proposal, Aquatic Ecosystem and Resources (Chapter 10). The effect is more pronounced at KZ-15 (immediately downstream of the

Geona Creek confluence) than at KZ-26 in lower Finlayson Creek during the open water months, where it is negligible. Overall the difference in flow from baseline during open water season is a maximum of 21.5% for the mean year scenario at KZ-15. The difference in winter flow rates is much more dramatic and again this is due to dewatering input which will remain at a high level throughout mine construction while winter baseline flows are substantially lower due to freezing.

The predicted change in flows in Geona Creek, South Creek and Finlayson Creek for each mine phase are illustrated in Figures 10-8, 10-9, and 10-10 respectively, of Chapter 10 of the Project Proposal Aquatic Ecosystem and Resources. Details concerning the effects mine development will have on groundwater are included in Chapter 9 of the Project Proposal (Groundwater Quality and Flow) and how that translates into effects on surface water quality and flow is detailed in Chapter 8 of the Project Proposal (Surface Water quality and Quantity). The aquatic effects discussed considers the influence the Project will have on water flows and how that influence translates into flows and water quality in the three waterways.

Due to minimal changes in water levels in Finlayson Creek during all stages of mine development and the stability of the bank and beds in the system, no changes to erosion potential, stream morphology or riparian vegetation are expected in Finlayson Creek. However, all physical attributes of the system will be monitored throughout the life of the Project and water discharge will be augmented if/when required.

As the South Creek channel will be constructed to handle high water events, originating in Fault Creek, no increases to erosion potential or changes in stream morphology are anticipated. Immediately downstream are two large lakes/ponds which will temper any downstream impacts.

In the near term, Geona Creek is an erosional system that will continue to evolve/change especially during high water events which would largely be responsible for the creeks overall width and morphology. Changes in flows originating from the Project are not anticipated to result in any changes in stream morphology as extreme events will be tempered as a result of the water management ponds and the ponds constructed as part of the Fisheries Offsetting Plan (FOP), and as a result channel-forming events should be less frequent and lower in magnitude than currently occurs.

YESAB ISSUE WITH BMC'S RESPONSE TO R105

The issue of downstream flow changes associated with the Project, specifically those related to alteration of natural hydrologic flow regime and associated impacts on downstream erosion, stream morphology and riparian vegetation may not have been assessed.

Insufficient response: Proponent has not provided the requested information. The response provided is qualitative. Statements have been made addressing the Information Request, however, no information has been provided substantiating the statements. The Proponent should provide an erosion assessment that considers key factors which affect erosion and sedimentation processes. For instance, average permissible velocities could be identified for reaches (sections) of affected watercourses, and an assessment made on whether average permissible velocities would be exceeded and if they are already being exceeded what would be the increase in duration of exceedance. Based on the results of the above, *an evaluation could be made on associated impacts on downstream erosion, stream morphology, and riparian vegetation.*

R2-45

***Provide an assessment of impacts associated with the Project on erosion, stream morphology and riparian vegetation of all affected drainages from projected downstream flow changes during all Project phases*.**

The following quantitative analysis, in addition to the information provided and referenced in the response to R105 above, provide confidence that the predicted alterations to the runoff regime in the Project receiving environment are not expected to cause significant impacts to stream morphology or riparian vegetation, or to cause problematic erosion.

The basis of this quantitative analysis was twofold:

1. The predicted range of discharges (and by extension, streamflow velocities – a key variable affecting erosion potential) in South Creek, Geona Creek and Finlayson Creek at key water monitoring stations was compared with the measured range of baseline observations to evaluate the variability expected in discharge and velocities vis-à-vis baseline variability; and

2. The expected monthly mean streamflow velocities were modelled using water balance modelling results and were compared to a determined threshold velocity for the erosion potential and channel stability.

When looking at variability, predicted changes in runoff volumes relative to baseline conditions during the various Project phases and under mean, wet and dry scenarios were presented in the Project Proposal (Figures 10-8 to 10-11) and are reproduced as Figure 8-5 to Figure 8-8 (below) for Geona Creek, Finlayson Creek and South Creek. Table 8-11 below summarizes the values used to generate the figures.

Table 8-11: Percent difference between estimated (no development) and modelled annual runoff volumes for key receiving stations by scenario and Project phase

Site	Scenario	Dewatering (Construction)	Operations (Yr 9)	Active Closure	Transition Closure	Post Closure
KZ-37	Mean	18.9%	-46.3%	-21.2%	-21.2%	3.9%
	1/50 Wet	8.8%	-48.9%	-21.1%	-21.1%	2.5%
	1/10 Dry	48.7%	-43.6%	-21.2%	-21.2%	5.3%
KZ-13	Mean	32.6%	23.5%	-9.1%	-9.1%	-8.2%
	1/50 Wet	35.0%	23.9%	-5.9%	-5.9%	-5.3%
	1/10 Dry	35.5%	22.5%	-12.1%	-12.1%	-11.0%
KZ-15	Mean	9.1%	10.4%	-7.7%	-7.7%	1.9%
	1/50 Wet	5.6%	1.8%	-7.6%	-7.6%	1.1%
	1/10 Dry	17.4%	19.2%	-7.7%	-7.7%	2.7%
KZ-26	Mean	3.1%	5.3%	-2.7%	-2.7%	0.8%

Site	Scenario	Dewatering (Construction)	Operations (Yr 9)	Active Closure	Transition Closure	Post Closure
	1/50 Wet	1.5%	1.4%	-2.6%	-2.6%	0.4%
	1/10 Dry	8.0%	10.5%	-2.8%	-2.8%	1.2%

Table 8-11 and the figures below shows that for the scenarios evaluated, the greatest predicted increase in runoff volumes is expected to occur during the dewatering (construction) phase, with the highest predicted increases expected at station KZ-13 (South Creek) for the mean and 1 in 50 wet year scenarios and at KZ-37 (Geona Creek) for the 1 in 10 dry year scenario.

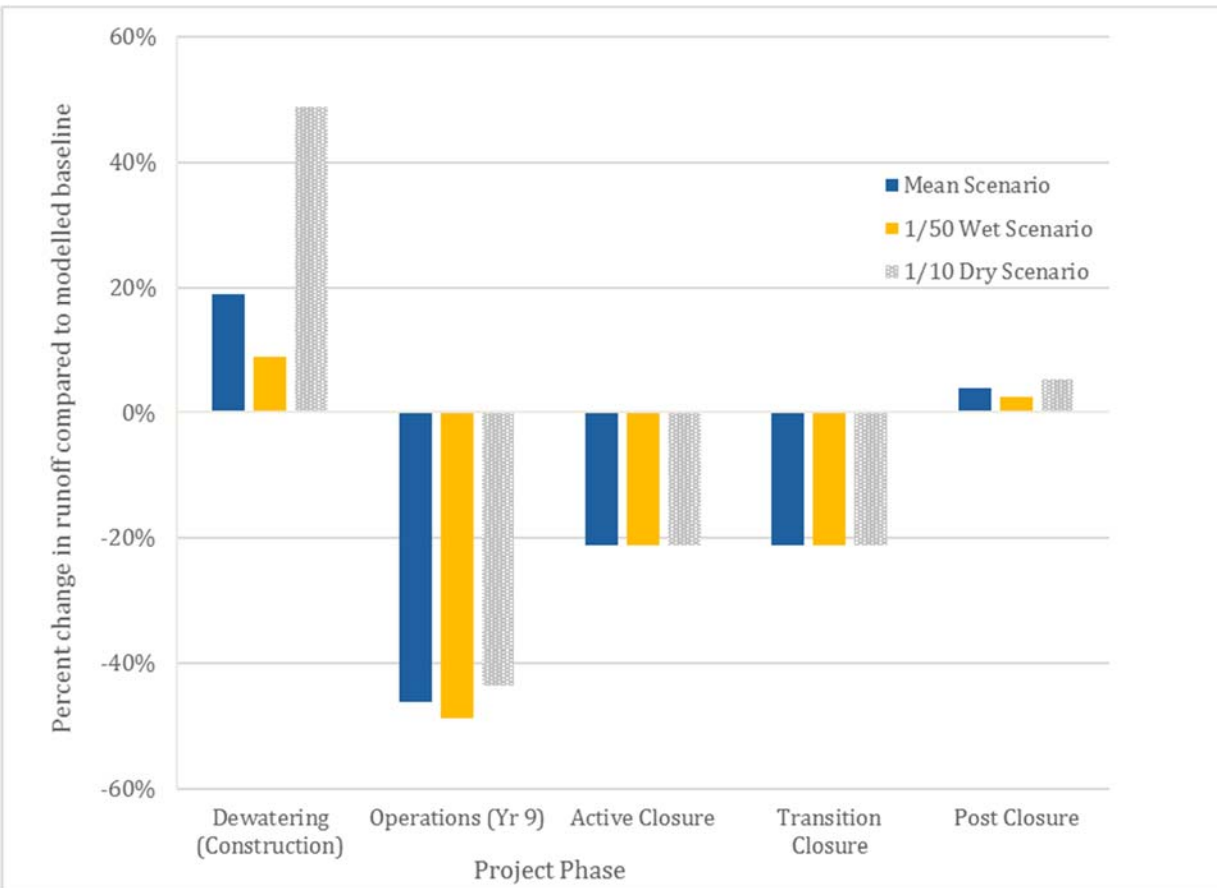


Figure 8-5: Predicted percent change in runoff relative to baseline in Geona Creek (KZ-37) throughout Project phases under three precipitation scenarios

Figure 8-6: Predicted percent change in runoff relative to baseline in South Creek (KZ-13) throughout Project phases under three precipitation scenarios

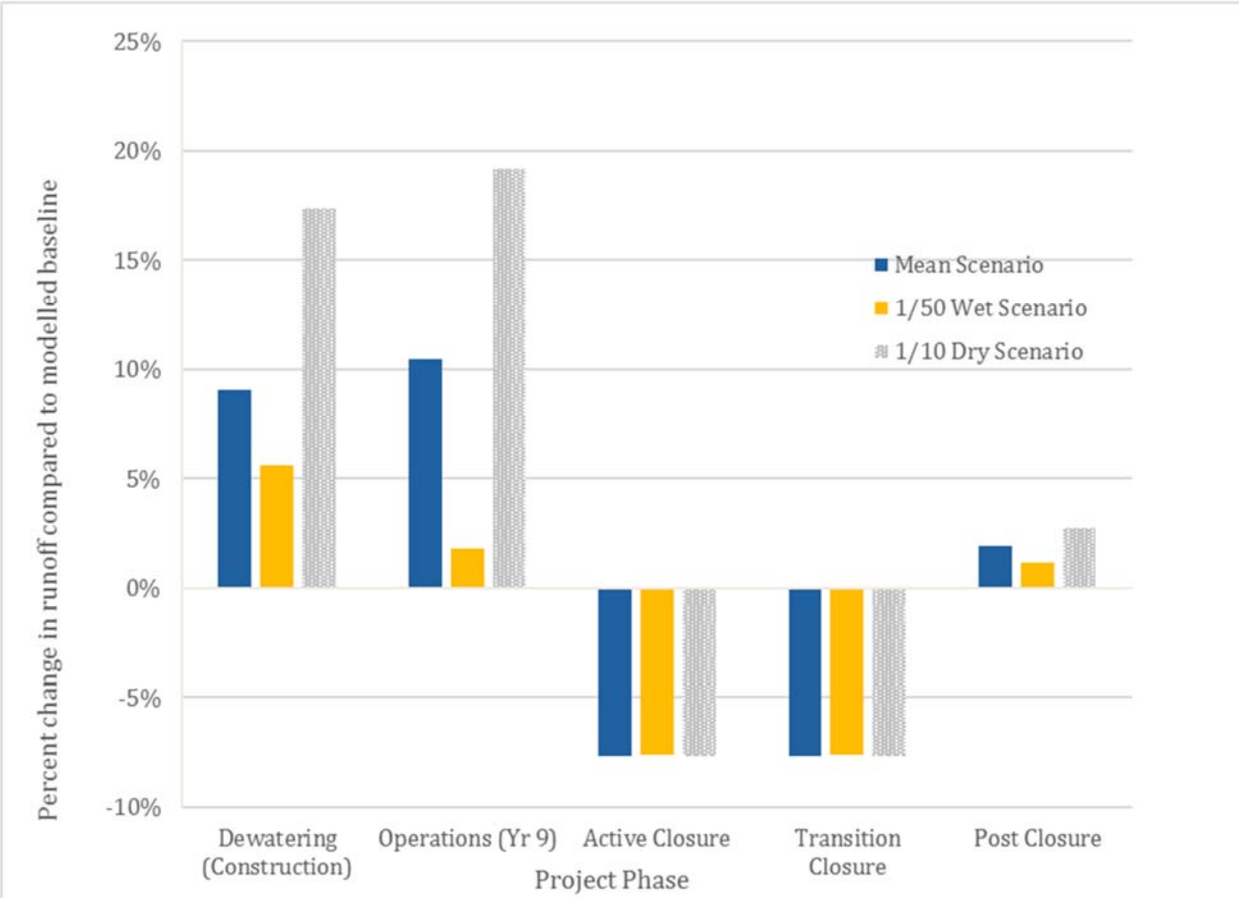


Figure 8-7: Predicted percent change in runoff relative to baseline in Finlayson Creek (KZ-15) throughout Project phases under three precipitation scenarios

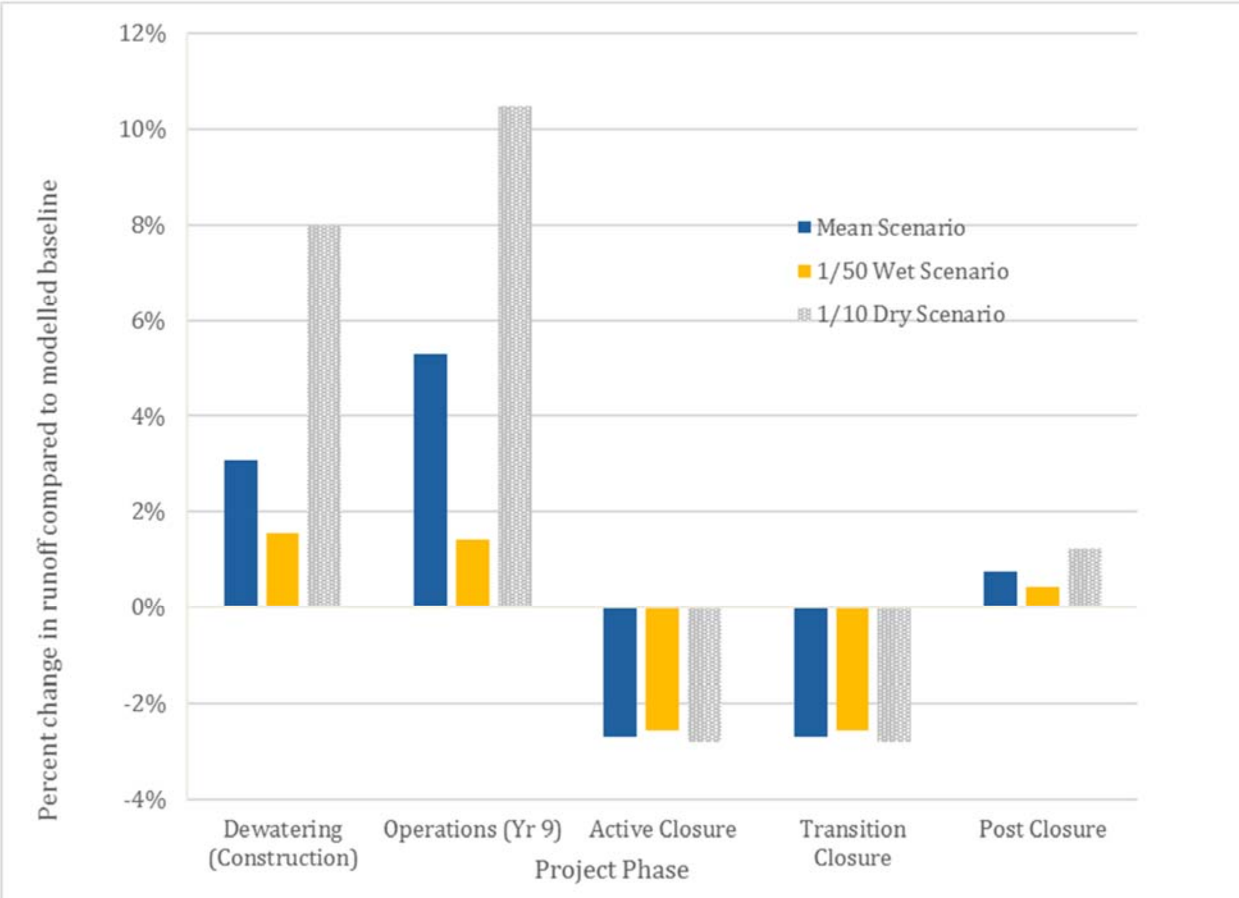


Figure 8-8: Predicted percent change in runoff relative to baseline in Finlayson Creek (KZ-26) throughout Project phases under three precipitation scenarios

Table 8-12 below (unpublished, from 2017 baseline surveys) presents a summary of baseline discrete discharge monitoring results at KZ-37 between April and October 2017 including maximum observed streamflow velocities. For this discrete velocity illustration, the method utilized for discharge measurements at this station was most often the velocity-area method with produced measured streamflow velocity readings (the salt dilution method was utilized at many other small order stations including KZ-13 and does not produce these readings.) The maximum observed velocities are typically mid-stream, mid-column readings and are typically much higher than the flows along the banks and substrate, and can therefore be used as a conservative comparison point for observed variability.

The table shows a difference of 147% between the maximum measured and calculated average flows during this short baseline monitoring period. KZ-37 was established as a monitoring station in April 2017, and therefore has a small dataset associated with it. It is therefore expected that natural variability in discharge at this location is much greater than the range reported in Table 8-12. Predicted changes in runoff during all Project stages are of lesser magnitude than this observed natural variability during one monitoring season.

The greatest reduction in flow is predicted to occur during the operational phase where a decrease of 48.9% relative to baseline (1 in 50 wet scenario) is expected at station KZ-37 (Table 8-11). During the April to October 2017 monitoring season, differences of 90% were observed between the minimum observed and average calculated discharge at KZ-37.

Table 8-12: Discrete Discharge Calculations and Water Velocities at KZ-37

Date	Calculated Discharge (m^3/s)	Maximum Observed Water Velocity (m/s) *
29/04/2017	0.041	n/a
17/05/2017	0.506	0.48
07/06/2017	0.302	0.34
19/07/2017	0.992	n/a
10/08/2017	0.596	0.56
14/09/2017	0.203	0.27
05/10/2017	0.169	0.28
Min	**0.041**	
Max	**0.992**	
Mean	**0.401**	
% difference between Max and Mean	**147%**	
% difference between Min and Mean	**-90%**	

** Only available for measurements conducted using the velocity-area method (salt dilution method was used in April and July 2017)*

Water velocity values do not vary as greatly as discharge values, since discharge is also dependent on channel wetted width and depth. At KZ-37 (where the greatest Project-related change in runoff is expected to occur), maximum water velocities observed during discrete velocity-area discharge measurements (May, June, August and September 2017) ranged from 0.27 m/s in September to 0.56 m/s in August (Table 8-12). This time period does not capture maximum (July) and minimum (April) flows, therefore the natural variability in water velocities are reasonably expected to span a larger range.

Predicted Project-related changes in runoff and water velocities are well within the range of natural variability observed at the Project site, even that observed in a very short monitoring period. It is therefore clear that the range of predicted flows (and associated expected water velocities) will not result in significant erosion, changes in stream morphology or impacts to riparian vegetation that would not occur in the system under natural runoff regimes.

The second part of the analysis involved calculating expected average velocities corresponding to the predicted discharge for the mean precipitation scenario presented in Appendix D-6 of the Project Proposal (Receiving Environment Water Balance Report). The average velocities were calculated for downstream stations KZ-37, KZ-15, and KZ-26 based on the predicted discharge values and the wetted cross-sectional areas in these stations. The wetted cross-sectional areas for each station were assumed to have the trapezoidal shape (except for KZ-13 which has a rectangular shape), and they were calculated based on the estimated depth from the predicted discharge using the calibrated depth-discharge rating curve, measured width, and a representative side slope.

Results, presented in Table 8-13 to Table 8-16, were compared to a threshold velocity for erosion and channel stability from the velocity-depth-grain size chart provided by the Natural Resources Conservation Service of United States Department of Agriculture (NRCS, 2007). For the Project area, an average grain size of 1 mm was used (see Project Proposal Appendix E-3 Aquatic Ecosystems and Resources Baseline Report), and the corresponding threshold velocity was 0.6 m/s.

Table 8-13: Modelled mean runoff, water depth[1], and average velocity[2] at KZ-37[3] at different stages of the Project

	Modelled Natural - Mean			Dewatering (Construction) – Mean			Operations - Mean			Active Closure - Mean			Transition Closure - Mean			Post Closure - Mean		
Month	Discharge (m^3/s)	Depth (m)	Velocity (m/s)	Discharge (m^3/s)	Depth (m)	Velocity (m/s)	Discharge (m^3/s)	Depth (m)	Velocity (m/s)	Discharge (m^3/s)	Depth (m)	Velocity (m/s)	Discharge (m^3/s)	Depth (m)	Velocity (m/s)	Discharge (m^3/s)	Depth (m)	Velocity (m/s)
Oct	0.226	0.394	0.169	0.255	0.416	0.180	0.118	0.310	0.113	0.179	0.357	0.148	0.179	0.357	0.148	0.237	0.402	0.174
Nov	0.164	0.346	0.140	0.192	0.367	0.154	0.076	0.278	0.082	0.130	0.319	0.121	0.130	0.319	0.121	0.174	0.353	0.146
Dec	0.111	0.305	0.108	0.140	0.327	0.127	0.051	0.259	0.059	0.088	0.287	0.091	0.088	0.287	0.091	0.122	0.314	0.116
Jan	0.078	0.280	0.083	0.110	0.304	0.108	0.037	0.248	0.044	0.061	0.267	0.069	0.061	0.267	0.069	0.090	0.289	0.093
Feb	0.060	0.266	0.068	0.094	0.292	0.096	0.029	0.242	0.036	0.048	0.257	0.056	0.048	0.257	0.056	0.073	0.276	0.079
Mar	0.038	0.249	0.046	0.072	0.276	0.079	0.021	0.236	0.026	0.030	0.243	0.037	0.030	0.243	0.037	0.051	0.260	0.059
Apr	0.165	0.347	0.141	0.198	0.372	0.157	0.073	0.276	0.079	0.137	0.325	0.126	0.137	0.325	0.126	0.180	0.358	0.149
May	0.595	0.676	0.249	0.545	0.637	0.243	0.353	0.490	0.209	0.492	0.597	0.236	0.492	0.597	0.236	0.607	0.685	0.250
Jun	0.761	0.803	0.263	0.707	0.761	0.259	0.419	0.541	0.223	0.577	0.662	0.247	0.577	0.662	0.247	0.770	0.809	0.264
Jul	0.441	0.558	0.227	0.427	0.547	0.225	0.236	0.401	0.173	0.333	0.475	0.204	0.333	0.475	0.204	0.446	0.561	0.228
Aug	0.362	0.498	0.211	0.358	0.494	0.210	0.195	0.370	0.156	0.290	0.442	0.192	0.290	0.442	0.192	0.370	0.504	0.213
Sep	0.372	0.505	0.213	0.362	0.497	0.211	0.205	0.377	0.161	0.294	0.445	0.193	0.294	0.445	0.193	0.384	0.514	0.216

[1] Depth was estimated from the discharge using calibrated depth-discharge rating curve.

[2] Velocity was estimated using estimated channel cross-sectional area for the respective depth assuming a trapezoidal cross-section.

[3] KZ-37 Bankfull Parameters: Discharge = 0.94 m^3/s, Width = 12.2 m, and Depth = 0.94 m.

Table 8-14: Modelled mean runoff, water depth[1], and average velocity[2] at KZ-13[3] at different stages of the Project

	Modelled Natural - Mean			Dewatering (Construction) - Mean			Operations - Mean			Active Closure - Mean			Transition Closure - Mean			Post Closure - Mean		
Month	Discharge (m^3/s)	Depth (m)	Velocity (m/s)	Discharge (m^3/s)	Depth (m)	Velocity (m/s)	Discharge (m^3/s)	Depth (m)	Velocity (m/s)	Discharge (m^3/s)	Depth (m)	Velocity (m/s)	Discharge (m^3/s)	Depth (m)	Velocity (m/s)	Discharge (m^3/s)	Depth (m)	Velocity (m/s)
Oct	0.096	0.232	0.277	0.132	0.314	0.279	0.121	0.290	0.279	0.086	0.208	0.276	0.086	0.208	0.276	0.087	0.210	0.276
Nov	0.068	0.165	0.274	0.087	0.211	0.276	0.077	0.187	0.275	0.057	0.141	0.272	0.057	0.141	0.272	0.058	0.143	0.272
Dec	0.045	0.111	0.268	0.057	0.141	0.272	0.047	0.117	0.269	0.034	0.087	0.263	0.034	0.087	0.263	0.035	0.089	0.263
Jan	0.030	0.078	0.260	0.040	0.099	0.266	0.029	0.075	0.259	0.020	0.054	0.249	0.020	0.054	0.249	0.021	0.056	0.250
Feb	0.023	0.060	0.253	0.031	0.080	0.261	0.021	0.055	0.250	0.012	0.036	0.230	0.012	0.036	0.230	0.013	0.038	0.233
Mar	0.014	0.040	0.235	0.021	0.057	0.251	0.011	0.033	0.225	0.004	0.016	0.158	0.004	0.016	0.158	0.005	0.018	0.173
Apr	0.083	0.200	0.276	0.092	0.221	0.277	0.081	0.197	0.276	0.073	0.176	0.275	0.073	0.176	0.275	0.073	0.178	0.275
May	0.292	0.689	0.283	0.385	0.904	0.284	0.374	0.880	0.284	0.282	0.665	0.283	0.282	0.665	0.283	0.283	0.667	0.283
Jun	0.237	0.560	0.282	0.333	0.784	0.283	0.323	0.759	0.283	0.227	0.536	0.282	0.227	0.536	0.282	0.228	0.539	0.282
Jul	0.154	0.365	0.280	0.210	0.496	0.282	0.199	0.472	0.282	0.143	0.341	0.280	0.143	0.341	0.280	0.144	0.343	0.280
Aug	0.161	0.381	0.281	0.206	0.488	0.282	0.196	0.464	0.282	0.150	0.357	0.280	0.150	0.357	0.280	0.151	0.359	0.280
Sep	0.160	0.379	0.281	0.212	0.501	0.282	0.201	0.477	0.282	0.149	0.355	0.280	0.149	0.355	0.280	0.150	0.357	0.280

[1] Depth was estimated from the discharge using calibrated depth-discharge rating curve.

[2] Velocity was estimated using estimated channel cross-sectional area for the respective depth assuming a rectangular cross-section.

[3] KZ-15 Bankfull Parameters: Discharge = 0.43 m3/s, Width = 1.5 m, and Depth = 1.0 m.

Table 8-15: Modelled mean runoff, water depth[1], and average velocity[2] at KZ-15[3] at different stages of the Project

	Modelled Natural - Mean			Dewatering (Construction) - Mean			Operations - Mean			Active Closure - Mean			Transition Closure - Mean			Post Closure - Mean		
Month	Discharge (m^3/s)	Depth (m)	Velocity (m/s)	Discharge (m^3/s)	Depth (m)	Velocity (m/s)	Discharge (m^3/s)	Depth (m)	Velocity (m/s)	Discharge (m^3/s)	Depth (m)	Velocity (m/s)	Discharge (m^3/s)	Depth (m)	Velocity (m/s)	Discharge (m^3/s)	Depth (m)	Velocity (m/s)
Oct	0.460	0.245	0.214	0.489	0.248	0.224	0.516	0.252	0.233	0.425	0.241	0.201	0.425	0.241	0.201	0.472	0.246	0.218
Nov	0.333	0.229	0.166	0.361	0.233	0.177	0.359	0.232	0.176	0.307	0.226	0.155	0.307	0.226	0.155	0.344	0.230	0.170
Dec	0.225	0.216	0.119	0.254	0.219	0.132	0.243	0.218	0.127	0.208	0.214	0.111	0.208	0.214	0.111	0.238	0.217	0.125
Jan	0.158	0.207	0.087	0.190	0.211	0.103	0.171	0.209	0.093	0.146	0.206	0.081	0.146	0.206	0.081	0.171	0.209	0.093
Feb	0.122	0.203	0.069	0.156	0.207	0.086	0.133	0.204	0.074	0.113	0.202	0.064	0.113	0.202	0.064	0.136	0.205	0.076
Mar	0.077	0.197	0.045	0.112	0.202	0.063	0.088	0.199	0.050	0.071	0.197	0.041	0.071	0.197	0.041	0.091	0.199	0.052
Apr	0.422	0.240	0.200	0.455	0.244	0.212	0.441	0.243	0.207	0.390	0.236	0.188	0.390	0.236	0.188	0.437	0.242	0.206
May	1.563	0.381	0.463	1.512	0.375	0.456	1.728	0.402	0.485	1.444	0.367	0.445	1.444	0.367	0.445	1.576	0.383	0.465
Jun	1.600	0.386	0.468	1.546	0.379	0.460	1.773	0.408	0.491	1.478	0.371	0.450	1.478	0.371	0.450	1.613	0.388	0.470
Jul	1.119	0.327	0.389	1.105	0.325	0.386	1.220	0.339	0.408	1.031	0.316	0.371	1.031	0.316	0.371	1.125	0.327	0.390
Aug	0.768	0.283	0.308	0.763	0.282	0.307	0.863	0.295	0.332	0.709	0.276	0.292	0.709	0.276	0.292	0.778	0.284	0.311
Sep	0.759	0.282	0.306	0.749	0.281	0.303	0.865	0.295	0.333	0.701	0.275	0.290	0.701	0.275	0.290	0.773	0.284	0.310

[1] Depth was estimated from the discharge using calibrated depth-discharge rating curve.

[2] Velocity was estimated using estimated channel cross-sectional area for the respective depth assuming a trapezoidal cross-section.

[3] KZ-15 Bankfull Parameters: Discharge = 7.12 m3/s, Width = 9.4 m, and Depth = 1.07 m.

Table 8-16: Modelled mean runoff, water depth[1], and average velocity[2] at KZ-26[3] at different stages of the Project

	Modelled Natural - Mean			Dewatering (Construction) - Mean			Operations - Mean			Active Closure - Mean			Transition Closure - Mean			Post Closure - Mean		
Month	Discharge (m^3/s)	Depth (m)	Velocity (m/s)	Discharge (m^3/s)	Depth (m)	Velocity (m/s)	Discharge (m^3/s)	Depth (m)	Velocity (m/s)	Discharge (m^3/s)	Depth (m)	Velocity (m/s)	Discharge (m^3/s)	Depth (m)	Velocity (m/s)	Discharge (m^3/s)	Depth (m)	Velocity (m/s)
Oct	1.254	0.502	0.144	1.282	0.505	0.146	1.332	0.510	0.150	1.222	0.499	0.141	1.222	0.499	0.141	1.267	0.503	0.145
Nov	0.933	0.470	0.114	0.961	0.473	0.117	0.973	0.474	0.118	0.909	0.468	0.112	0.909	0.468	0.112	0.945	0.471	0.116
Dec	0.650	0.442	0.085	0.679	0.444	0.088	0.676	0.444	0.088	0.634	0.440	0.083	0.634	0.440	0.083	0.662	0.443	0.086
Jan	0.468	0.423	0.064	0.500	0.427	0.068	0.486	0.425	0.066	0.456	0.422	0.062	0.456	0.422	0.062	0.481	0.425	0.065
Feb	0.373	0.414	0.052	0.407	0.417	0.056	0.386	0.415	0.054	0.364	0.413	0.051	0.364	0.413	0.051	0.386	0.415	0.054
Mar	0.243	0.401	0.035	0.277	0.404	0.040	0.254	0.402	0.037	0.236	0.400	0.034	0.236	0.400	0.034	0.256	0.402	0.037
Apr	0.960	0.473	0.117	0.993	0.476	0.120	1.015	0.478	0.122	0.936	0.470	0.115	0.936	0.470	0.115	0.976	0.474	0.119
May	3.647	0.742	0.281	3.597	0.737	0.279	3.939	0.772	0.292	3.558	0.733	0.278	3.558	0.733	0.278	3.665	0.744	0.282
Jun	4.771	0.855	0.318	4.717	0.850	0.317	4.989	0.877	0.324	4.651	0.843	0.315	4.651	0.843	0.315	4.786	0.856	0.319
Jul	3.573	0.735	0.278	3.559	0.733	0.278	3.644	0.742	0.281	3.435	0.721	0.273	3.435	0.721	0.273	3.580	0.735	0.279
Aug	2.120	0.589	0.207	2.116	0.589	0.207	2.255	0.603	0.215	2.072	0.584	0.204	2.072	0.584	0.204	2.132	0.590	0.208
Sep	1.986	0.576	0.198	1.975	0.575	0.198	2.137	0.591	0.208	1.938	0.571	0.195	1.938	0.571	0.195	2.002	0.577	0.199

[1] Depth was estimated from the discharge using calibrated depth-discharge rating curve.

[2] Velocity was estimated using estimated channel cross-sectional area for the respective depth assuming a trapezoidal cross-section.

[3] KZ-26 Bankfull Parameters: Discharge = 14.69 m^3/s, Width = 18.95 m, and Depth = 1.85 m

The values in these tables, and their comparison to the selected threshold velocity, show that expected average monthly velocities in Geona Creek and Finlayson Creek under the mean precipitation scenario are not expected to exceed the threshold velocity for erosion and channel stability. While there may be short term exceedances of this threshold, as expected and periodically observed in the natural condition, the evaluation of erosion potential is more appropriately considered on a longer-term basis as a representation of the potential effects of sustained flows above threshold values.

On this basis, and from the evaluation provided above, no significant impacts on the downstream environment are expected from the modeled runoff regime in terms of erosion, changes in stream morphology or impacts to riparian vegetation.

8.3 FUTURE ACIDIC CONDITIONS AT CLOSURE AND POST-CLOSURE

YESAB ISSUE

The mitigation measures proposed for the Class A, B and C stockpiles involve some types of engineered covers to be constructed at closure. It was assumed that the loadings from each stockpile will decrease by effectively limiting the infiltration into each facility.

The initial loadings prior to mitigation by the constructed covers were assumed to be the same as those predicted from the results of the neutral pH laboratory and field barrel tests. The use of these initial loadings is inconsistent with the understanding that the Class A rock and tailings, and Class B rock piles will eventually produce acidic drainage. Therefore, the predicted loadings after closure are biased low because they are based on the neutral pH leaching results. Once acidification occurs, the loading rates for many metals and other constituents would be expected to increase substantially above those that were estimated for neutral pH conditions. And, although the loadings from the stockpiles will be mitigated to some extent by reducing infiltration rates, the much greater intrinsic loading rates within the piles will affect the residual loadings of COPCs from each of the A and B stockpiles.

Ignoring the future acidic drainage conditions in the A and B stockpiles represents a critical deficiency in the water quality predictions and may represent a flaw in the assumption that passive treatment will be possible in an engineered wetland system after closure. Acidic drainage will be accompanied by substantial loading rates of many metals and other constituents and the final drainage from the facilities may not be treatable in a wetland system to the extent required to protect the receiving environment.

R106

"Provide an assessment of the long-term loadings and water quality associated with the acidic drainage that will eventually be produced in the A and B stockpiles as well as from the pit walls above the final water level."

The unsubmerged portion of the pit wall above the final surface water elevation of ABM lake at closure will be primarily composed of geodomains that are largely Class C, non-acid generating rock (Table 8-17 below). Overall, the pit wall rock above the final water level is predominantly not acid generating. Nevertheless, any acidic load that does wash down into ABM lake will be neutralized by the circumneutral waters of ABM lake, with only minimal associated loading such that no significant effects to downstream water quality are anticipated.

Table 8-17: Approximate Proportions of Unsubmerged (Above 1,380 masl) Pit Wall Surface Area by Geodomain, the Proportion of Each Geodomain by Waste Classification and the Proportions of Total Unsubmerged Pit Wall by Waste Classification

Geodomain	Exposed Pit Wall Area	% Class A	% Class B	% Class C	Net Acid Generating Potential
AK RHYv	15%	0%	27%	73%	Predominantly acid consuming
CA CL MAF	5.0%	0%	100%	0%	All acid consuming but potential for metal leaching
CARB MDS/RHY	1.5%	23%	44%	33%	Predominantly potentially acid generating
MDS	25%	3%	8%	89%	Predominantly acid consuming
MU PY RHY	2.1%	25%	38%	38%	Predominantly potentially acid generating
PY AK RHYc	2.3%	8%	45%	47%	Equal parts potentially acid generating and acid consuming
PY AK RHYv	18%	5%	43%	52%	Equal parts potentially acid generating and acid consuming
PY CL RHY	1.1%	46%	24%	29%	Predominantly potentially acid generating
RHYi	1.2%	42%	42%	17%	Predominantly potentially acid generating
Massive Sulphide	0.1%	100%	0%	0%	Potentially acid generating
Overburden	28%	0%	0%	100%	Non potentially acid generating
Total	**100.0%**	**3.8%**	**22.1%**	**74.1%**	

The importance of developing geochemical source terms to predict waste storage facility loading rates under acidic drainage conditions is recognized. Acidic conditions have only recently started to develop in one kinetic test column (C-7, which comprises Class A waste rock). As it may take many years of kinetic testing to deplete the neutralization potential (NP) of the material before leachate becomes acidic, two additional kinetic tests will be commissioned using Class A (comingled tailings and Class A waste rock) and Class B material that have been pre-treated to deplete NP before commencement of the test. In these kinetic tests the generation of acidic drainage will be accelerated and the leachate data can be used to predict acidic drainage loading rates. Once sufficient data are collected from the NP-depleted kinetic tests, the acidic loading rates will be refined and water quality models and predictions can be updated.

An assessment of metal loading under acidic conditions for the Class A and Class B Storage Facilities has been prepared using sequential net acid generation (NAG) testing of the material that is in the

Class A trickle leach column C-10 (tailings and Class A waste rock mixture) and the recent kinetic data from the Class A waste rock column C-7 which is now releasing acidic drainage.

The sequential NAG test on the tailings/Class A waste rock material in column C-10 was operated for three cycles. Filtered leachate from each cycle (pH 2.1 to 2.6) was combined and analyzed for sulphate and dissolved metals. For the Class A material, it was assumed that the sulphate loading rate under acidic conditions would be 10 times the sulphate loading rate observed at circumneutral pH based on a literature review of laboratory kinetic test data. The sulphate-to-COPI ratios in the sequential NAG test of the C-10 material were calculated assuming the COPIs are released due to the oxidation of sulphide material. Then, the “steady-state” (average of most recent two months) sulphate loading rate from column C-10 (i.e. circumneutral release rate) was multiplied by 10 and the COPI loading rates were calculated by multiplying this 10x sulphate loading rate by the sulphate-to-COPI ratios calculated from the NAG test. These preliminary COPI acidic loading rates for the Class A Storage Facility calculated using this method are provided in Table 8-18 below.

For the Class B material, the percentage change in the COPI loading rate for column C-7 moving from circumneutral conditions in the first two months of the test (average of cycles 2 to 10; pH 6.8 to 7.2) to that under the most recent acidic conditions (average of last four cycles 57 to 61; pH 4.1 to 4.4) was calculated. The percentage increase observed was applied to the “steady-state” (average of last two months of data) neutral COPI loading rates previously developed for the Class B Storage Facility (shown in Table 8-18). The loading rate for those COPIs that exhibited a decline in loading under acidic conditions for column C-7 (i.e., antimony, selenium) was not modified (i.e., the higher circumneutral COPI loading rate was retained). These preliminary acidic release COPI loading rates were applied in the water quality model at Year 10 for Class A material and Year 30 for Class B material under both the mean and 1/10 dry year precipitation scenarios. The resulting estimates of COPI water quality for the near field site KZ-37 are shown in Figure 8-9 below.

The updated model with preliminary acidic source terms, estimates that in post-closure only, concentrations of arsenic (May and June) and cadmium (May through August) exceed water quality objectives at KZ-37. The exceedances do not exceed 1.8 and 1.5 times the respective the water quality objectives for arsenic and cadmium, respectively. It is important to note that the model does not incorporate any natural attenuation that would occur along flow paths between the Class A and Class B Storage Facilities, the wetlands and Geona Creek that may lower arsenic and cadmium concentrations. It is also important to note that arsenic and cadmium exceedances are not predicted at KZ-15 (Upper Finlayson Creek) downstream of KZ-37.

Acidic source terms will be refined upon the availability of NP-depleted kinetic testing data and the models and predictions will be updated accordingly. Appropriate refinements to the mitigation measures may be also be made at that time.

Table 8-18: Preliminary Acidic Loading Rates for Class A and Class B Storage Facilities

	Class A		Class B	
	C-10 Neutral pH (average last 2 months kinetic data)	C-10 Acidic pH Calculated Loading Rates	Class B Neutral pH (average last 2 months kinetic data)	Class B Acidic pH Calculated Loading Rates
	mg/kg/wk			
Antimony	0.000017	0.000048	0.00021	0.00021
Arsenic	0.000012	0.0030	0.00026	0.0010
Cadmium	0.000019	0.0013	0.00000046	0.0000012
Copper	0.0000072	0.040	0.0000048	0.00027
Iron	0.000046	3.7	0.000012	0.0036
Lead	0.000010	0.025	0.00000077	0.000026
Manganese	0.006	0.058	0.00038	0.00080
Nickel	0.00031	0.0014	0.000013	0.000018
Silver	0.000000	0.00033	0.000000062	0.000000062
Selenium	0.0001	0.0019	0.000018	0.000018
Uranium	0.000014	0.000097	0.000084	0.00031
Zinc	0.0061	0.18	0.000031	0.00033

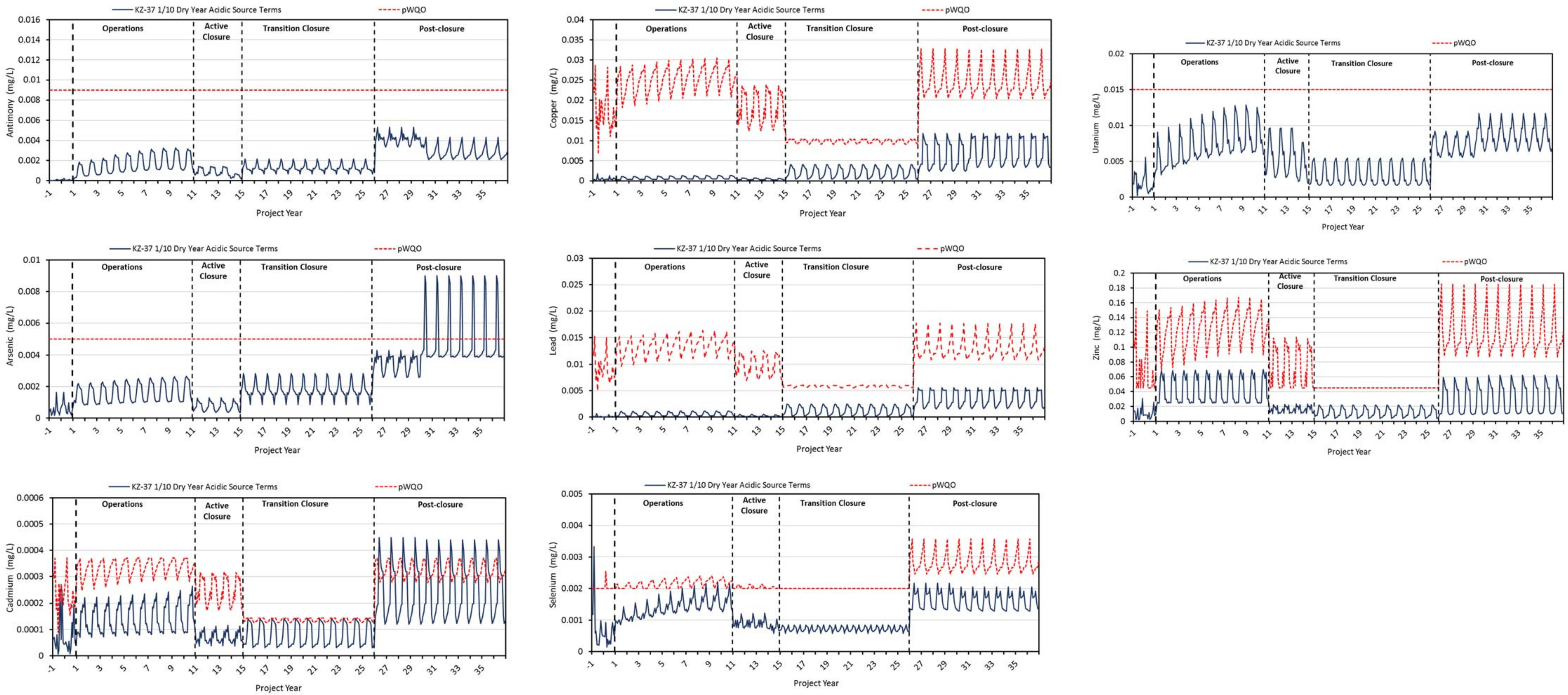


Figure 8-9: Updated Water Quality Predictions at KZ-37 in the 1/10 Dry Year Scenario Using Preliminary Acidic Drainage Loading Terms for Antimony, Arsenic, Cadmium, Copper, Lead, Selenium, Uranium, and Zinc

YESAB ISSUE WITH BMC'S RESPONSE TO R106

The mitigation measures proposed for the Class A, B and C stockpiles involve some types of engineered covers to be constructed at closure. It was assumed that the loadings from each stockpile will decrease by effectively limiting the infiltration into each facility.

The initial loadings prior to mitigation by the constructed covers were assumed to be the same as those predicted from the results of the neutral pH laboratory and field barrel tests. The use of these initial loadings is inconsistent with the understanding that the Class A rock and tailings, and Class B rock piles will eventually produce acidic drainage. Therefore, the predicted loadings after closure are biased low because they are based on the neutral pH leaching results. Once acidification occurs, the loading rates for many metals and other constituents would be expected to increase substantially above those that were estimated for neutral pH conditions. And, although the loadings from the stockpiles will be mitigated to some extent by reducing infiltration rates, the much greater intrinsic loading rates within the piles will affect the residual loadings of COPCs from each of the A and B stockpiles.

Ignoring the future acidic drainage conditions in the A and B stockpiles represents a critical deficiency in the water quality predictions and may represent a flaw in the assumption that passive treatment will be possible in an engineered wetland system after closure. Acidic drainage will be accompanied by substantial loading rates of many metals and other constituents and the final drainage from the facilities may not be treatable in a wetland system to the extent required to protect the receiving environment.

Insufficient response: In response to R81 and R106, the proponent has indicated that two additional kinetic tests will be commissioned using NP depleted Class A and Class B material; the results from these tests will be used to update the water quality models and water quality predictions. This information is critical to understand the potential environmental impacts of the project, determine closure objectives for the mine site, and in particular for this project is critical information to demonstrate the effectiveness of the constructed wetland treatment system.

R2-46

Provide an assessment of the long-term loadings and water quality associated with the acidic drainage that will eventually be produced in the A and B stockpiles as well as from the pit walls above the final water level.

Appendix R2-C (Project Optimizations and Updated Water Quality Performance Expectations for Kudz Ze Kayah Project) provides an updated assessment of long term loadings including acidic drainage from Class A and B materials.

8.4 CONSTRUCTED WETLAND TREATMENT SYSTEMS

YESAB ISSUE

The constructed wetland treatment system (CWTS) proposed for the Site has been developed to a conceptual level only at this time, reviewers require additional information to evaluate the long-term environmental effect of the site. We recognize that design and implementation of a wetland treatment *system will be site-specific and an iterative process. However, it is not clear to reviewers if the Proponent has a sufficiently developed plan to ensure that this can be achieved during the life of the Project.*

R108

"Provide details on the assumed water quality adjustment factor. Discuss these factors in the context of the predicted effluent concentrations for an engineered wetland in Tables 4 and 5 of the Contango report (Appendix B – Conceptual Wetland Design - of Appendix H-1 Conceptual Reclamation and Closure Plan)."

Treatment rate coefficients are developed for each constituent at each site, and are used as a tool to assist in the prediction of effluent concentrations, and/or to inform CWTS sizing requirements. They have been developed for and applied at numerous sites in North America (Huddleston and Rodgers, 2008; Murray-Gulde et al., 2008; Spacil et al., 2011; Schwindaman et al., 2014).

The information requested is provided in Section 7.2 of the memorandum *Conceptual Wetland Design based on Water Quality Objectives and Predicted Outflow Concentrations* (Contango Strategies Ltd., January 2017 - Appendix B of Appendix H of the Project Proposal). This section is reproduced below. The removal rate coefficients (Table 3, reproduced as Table 8-19) that were applied to determine the predicted effluent concentrations in Tables 4 and 5 are proxies that were developed for other projects with similar chemistry and conditions to the Project site, in advance of the development of removal rate coefficients specific to the Kudz Ze Kayah Project. The calculations provided in Equations 1-4 describe the formula for determining the removal rate coefficient for each COPC based on known influent and effluent concentrations, as well as a variation of the formula that applies to the coefficient to determine predicted effluent concentrations. As indicated below, Project specific treatment rate coefficients will be further refined during future pilot-scale and/or demonstration-scale testing. These elements of the reclamation research program are outlined in Section 2.5.3 of Appendix H.

7.2. Removal Rate Coefficients and Calculations

An important factor for wetland design is the rate of treatment, also known as the treatment rate coefficient (k). The treatment rate coefficient is based on the treatability of a specific constituent and the hydraulic retention time of the system, both of which are site-specific based on water chemistry, wetland designs, and characteristics of the system. Because site-specific treatment rate coefficients (k) have not yet been developed for the Project, proxies were applied from other projects with as similar of chemistry and conditions as possible in order to conceptually assess the CWTSs outflow concentrations given the pre-determined size of each wetland for the Project (Table 2).

The treatment rate coefficients applied here are intended to be a conservative estimate for theoretical outflow concentration purposes, and will need to be refined through pilot-scale (off site), and demonstration-scale (on site) testing, as removal rate coefficients are highly site-specific and must be developed in a site-specific manner, for each element of interest. While they may sometimes be applied in a conceptual manner to other situations/sites (as was done here), *caution should be taken in applying a removal rate coefficient developed for one design and water chemistry to a very different chemistry or design basis. It is also often the case that the treatment rate coefficient (k) must be calculated and applied for different ranges of certain constituents, which can be further refined with pilot-scale and demonstration-scale testing.*

Based on experience from treatment wetlands being used and developed in Yukon and Northwest Territories, the treatment rate coefficient (k) applied for As and Se follow a zero-order reaction kinetic, while the rate coefficients for Cd and U follow first-order kinetics. The treatment rate coefficients for As and U were derived from pilot-scale testing that has been conducted for a mine in the Northwest Territories, while the coefficients for Cd and Se were derived from demonstration-scale testing that is ongoing at a mine in Yukon (Contango, January 2017). There was no rate coefficient available specific to Sb, and so the rate coefficient from As was used as a proxy.

In Equation 1-4, Cf is final concentration, Ci is initial concentration, V is volume of water in the system, and Q is flow rate. Using the removal rate coefficients (k) in Table 3 and equations 1-4, parameters can be rearranged to solve for those of interest. The volume of water in each CWTS is calculated using the conceptual wetland size multiplied by the calculated water depth of the conceptual design. For this analysis, a conceptual water depth of 80 cm was used, which is calculated from the assumptions of a horizontal surface flow wetland with 30 cm of free water at the surface and 1.5 metres of substrate with an expected 33% pore space filled with the water. Using the conceptual volumes and predicted flow rates and initial concentrations, Equations 1 and 2 can be rearranged to calculate the theoretical outflow concentration (Cf) of each constituent for each CWTS. For conservativism, Cf values that are below the Geona Creek pWQO are set to equal that concentration.

Table 8-19: Elements considered in treatment wetland models, with respective treatment rate coefficient (k) values.

Element	*k*[1]
Zero order reaction kinetic	
As	0.01032
Se	0.000384
Sb	0.01032
First order reaction kinetic	
Cd	0.19272
U	0.192

$$k = \frac{-\ln\left(\frac{Cf}{Ci}\right)}{V} x\, Q \qquad k = \frac{-\ln\left(\frac{Cf}{Ci}\right)}{V} x\, Q$$

Equation 1 — Equation for calculation of first-order removal rate coefficient.

$$Cf = Ci \times e^{-k\, x \frac{V}{Q}}$$

Equation 2 — Equation for calculation of first-order removal rate coefficient, rearranged to solve for outflow concentration.

$$k = \frac{(Ci - Cf)}{V} x\, Q \qquad k = \frac{(Ci - Cf)}{V} x\, Q$$

Equation 3 — Equation for calculation of zero-order removal rate coefficient.

$$Cf = Ci - k\, x\, \frac{V}{Q}$$

Equation 4 — Equation for calculation of zero-order removal rate coefficient, rearranged to solve for outflow concentration.

YESAB ISSUE WITH BMC'S RESPONSE TO R108

The discussion of the transition and post closure periods for the mine as discussed in Section 7.2 of Appendix D-7 indicates that there are treatment factors for the wetlands that are proposed for passive treatment after closure. The treatment factors are constituent-specific and affected by hydraulic retention time of the system. Appendix B of Appendix H-1, states that "proxies were applied from other projects with as similar of chemistry and conditions as possible". However, there is no indication of what the treatment factor values are and how they affect the water quality leaving the wetlands. Clarification of the treatment factors is required.

Insufficient response: The proponent has not provided details on the treatment factors (Removal Rate Coefficients). The response only reiterates the original text of Section 2.5.3 of Appendix H in Appendix B. It is not sufficient to indicate that the values used "are proxies that were developed for other projects".

R2-47

Provide details on the assumed water quality adjustment factor. Discuss these factors in the context of the predicted effluent concentrations for an engineered wetland in Tables 4 and 5 of the Contango report (Appendix B – Conceptual Wetland Design - of Appendix H-1 Conceptual Reclamation and Closure Plan).

Appendix R2-C (Project Optimizations and Updated Water Quality Performance Expectations for Kudz Ze Kayah Project) provides updated assumptions and rationale for expected wetland treatment factors, and revised performance expectations for Project water quality at closure, both with and without the treatment influence of wetlands.

R2-48

Please provide details of the basis of the coefficients in order to understand whether these are supported by appropriate data that are relevant to the proposed wetland treatment.

Appendix R2-C (Project Optimizations and Updated Water Quality Performance Expectations for Kudz Ze Kayah Project) provides updated information on the treatment coefficients (k-rates) and the rationale behind their selection.

R2-49

Also, now that the post closure water quality has been updated to reflect acidic drainage (see R106 above), please provide an update on the expected treatment effects for the site water.

On October 17 2017, YESAB provided (via email) the following clarification regarding the information required in response to R2-49:

> *"In the technical meeting, we indicated that we have concerns that the environmental assessment presented by BMC is optimistic and that over the long-term drainage from the Class A and B storage areas will become acidic. This would have implications for the constructed wetland treatment system and its efficiency and managing drainage.*
>
> *BMC indicated that they have done further modeling, which will show that they don't anticipate having acidic drainage entering the wetlands or groundwater. There will be a revised set of predictions that encompass some project refinements (e.g., acidic source terms) and they will be accounted for and presented within the model. This will show that wetlands will not have acidic conditions and that they are not as influential or necessary as assumed.*
>
> *This approach may satisfy our requirements under R2-49. However, it will depend on how the revised water quality predictions and further modeling are presented. We still have the concern that in the long-term the site will produce acidic drainage."*

Appendix R2-C (Project Optimizations and Updated Water Quality Performance Expectations for Kudz Ze Kayah Project) provides revised performance expectations for Project water quality at closure, both with and without the treatment influence of wetlands. The revised model incorporates updates from the baseline water quality data set and source terms. This evaluation shows that although some acidic drainage may be expected to contribute to influent at the wetlands, overall, the combined influent to the wetlands from all sources is expected to be circumneutral in pH.

YESAB ISSUE

The Proposal recognized the potential for ARD to develop over time in the class A and B materials. There is a need to evaluate the potential effects of acidic drainage on wetland treatment performance. It is likely that the quality of inflow water to the wetland will change in the future as ARD develops in Class A rock and tailings, and the Class B rock. For example, as ARD develops, greater loading of metals such as aluminum, cadmium, copper, iron, manganese, nickel and zinc can be expected.

R109

"Provide cold weather case studies for passive wetland treatment systems designed for acidic conditions as well as case studies for passive wetland treatment systems that have successfully transitioned from treating neutral drainage to effectively treating acidic drainage with increased metal loadings."

Any acidic drainage from either the Class A or Class B Storage Facilities is expected to be volumetrically minor compared to the neutral to mildly alkaline outflow from the ABM lake at closure. Consideration of the monthly runoff volumes from the Class A and B Storage Facilities indicates that the Class A and Class B runoff would contribute approximately 0.3% and 3.3% of the flow to the constructed wetland, respectively. Given the year-round dilution from the ABM lake outflow, and the neutralizing capacity of the ABM lake discharge water, the constructed wetland treatment system is expected to only receive circumneutral influent.

As part of the site-specific CWTS design process, aspects that would facilitate continued treatment throughout cold-climate or freezing conditions are thoroughly assessed. Phase 3 of the CWTS design (off-site pilot-scale testing) incorporates freezing trials to inform on the effect that cold weather would have on treatment. While treatment wetlands are common place worldwide, including in cold-climates, there are several reported cases in peer-reviewed scientific literature of successful CWTS treatment in cold weather conditions, as provided in the as case studies in Table 8-20 below.

Predictions for wetland effluent concentrations for Kudz Ze Kayah were based on predicted influent water chemistry for the site, and developed though an iterative process that involved the integration of covers, diversion of water, and in pit treatment. Should the predictions for water influent chemistry change, the passive water treatment approach will be re-evaluated and designs will be adjusted accordingly. This is part of the process built into the phased approach to CWTS wetland design (R107 Response; Section 3 of Appendix B of Appendix H of the Project Proposal), allowing for assessment of designs, optimization, and adjustment as needed through the mine life, long prior to CWTS construction and commissioning timelines. Generally speaking, CWTS designed to treat constituents in neutral drainage and CWTS designed to treat acidic drainage conditions may have different designs, and are not expected to be readily transitioned from one to the other, nor should they be. Having said that, the CWTS implementation timeline outlined in the response to R107 includes contingencies in the form of additional time to reassess and reconfigure the CWTS design should any unanticipated water chemistry conditions arise.

Table 8-20: Summary of Selected Case Studies/References that have Treated Kudz Ze Kayah COPCs using Wetlands

Water Source	Location	Constituents (mg/L) [1]					Wetland Type	Freezes	Comments	Reference
		As	Cd	Se	Sb	U				
Smelter landfill	Trail, BC	150 to <0.5	4.7 to <0.02	n/a	n/a	n/a	On-site pilot scale	Yes	Year-round treatment, 15,000 L/d	Duncan (2010)
Gold-cobalt-bismuth-copper mine	Fortune Minerals Mine, NWT	0.48 to 0.11	n/a	n/a	n/a	n/a	Natural wetland	Yes	Information from natural wetland treatment utilized for pilot-scale design and testing	Contango (2014)
Silver-cooper-bismuth mine	Terra mine, NWT	0.05-0.08 to 0.005-0.07	n/a	n/a	n/a	n/a	Natural wetland	Yes	Natural wetland receiving mine tailing discharge	Sealey (2011)
Gold mine	Finland – Peatland 1	0.041 to 0.0082	n/a	n/a	0.16 to 0.12	n/a	Full scale	Yes	Natural peat wetlands receiving mine tailings discharge. Year round treatment with snow cover from November to May and mean annual temperatures between -3°C and 6°C.	Palmer et al. (2015)
	Finland – Peatland 4	0.14 to 0.014	n/a	n/a	0.036 to 0.0068	n/a				
Uranium mine	Curilo, Western Bulgaria	0.01-0.59 to <0.01-<0.1	0.01-0.12 to <0.01	n/a	n/a	0.28-4.82 to <0.10	Full-scale	Yes	Natural and CWTS receiving mine tailings discharge	Groudev et al. (2008)
Mine, milling, and smelting discharge	Butte Hill, Colorado	25.5 to 11.9 (CT)[2]	40.5 to 0.51; 39.6 to 1.2[2]	n/a	n/a	n/a	Demonstration-scale	Yes	Series of CWTS receiving mine, milling, and smelting discharge	Gammons et al. (2000)
Natural runoff and agricultural irrigation drainage	Great Falls, Montana	n/a	n/a	Se (0.026 to <0.001)	n/a	n/a	Full-scale	Yes	Engineered natural system separated into 6 ponds using dikes.	Zhang and Moore (1996)

[1] Maximum mean inflow concentration and corresponding outflow concentration.
[2] Concentrations measured in µg/kg

YESAB ISSUE WITH BMC'S RESPONSE TO R109

The Proposal recognized the potential for ARD to develop over time in the class A and B materials. There is a need to evaluate the potential effects of acidic drainage on wetland treatment performance. It is likely that the quality of inflow water to the wetland will change in the future as ARD develops in Class A rock and tailings, and the Class B rock. For example, as ARD develops, greater loading of metals such as aluminum, cadmium, copper, iron, manganese, nickel and zinc can be expected.

Insufficient response: While some case histories are presented for cold climate wetland type treatment systems, there is no indication of performance in the information provided. Therefore, although examples are given, there is no indication of the success of the wetland type treatment under the conditions described.

R2-50

Provide cold weather case studies for passive wetland treatment systems designed for acidic conditions as well as case studies for passive wetland treatment systems that have successfully transitioned from treating neutral drainage to effectively treating acidic drainage with increased metal loadings.

Appendix R2-C (Project Optimizations and Updated Water Quality Performance Expectations for Kudz Ze Kayah Project) provides additional rationale for why the information provided previously in response to R109 (including the examples cited in Table 8-20) is relevant, and also includes additional support for the example projects cited, information on the Minto Project as a further example, and updated KZK Project performance predictions for wetland treatment.

R2-51

Provide some indication of treatment performance for the case histories presented or for other relevant treatment systems.

Appendix R2-C (Project Optimizations and Updated Water Quality Performance Expectations for Kudz Ze Kayah Project) provides additional rationale for why the information provided previously in response to R109 (including the examples and their performance information cited in Table 8-20) are relevant, and also includes additional support for the example projects cited, information on the Minto Project as a further example, and updated KZK Project performance predictions for wetland treatment.

8.5 SURFACE WATER QUALITY AND QUANTITY

YESAB ISSUE

A statistician with a background in WQO derivation was recently contracted by Yukon government to prepare a statistical justification for baseline water quality data requirements for quartz mining projects.

The statistician was provided with available, relevant water quality data collected in Yukon, including data from the Wolverine mine, a mining project nearby and analogous to the proposed Kudz Ze Kayah project. The statistician concluded that three years of recent, continuous baseline water quality data is the minimum duration required to (a) generate a reasonable understanding of natural variability of water quality, and (b) detect systematic changes in water quality over time, if present.

R113

"Updated water quality baseline information, water quality objectives, and water models (e.g., water quality model, site and watershed balance models, surface water flows, etc.) for the site are required to be submitted prior to the Executive Committee drafting the screening report. To develop a reasonable understanding of short-term variability, sampling is required to be conducted and reported on at least two sampling events, including one during low-flow conditions and one during high-flow conditions, for each year in which 5 samples are collected in 30 days."

BMC appreciates that the review and eventual approval of the Project will undergo a number of stages, governed by separate legislation and specialized agencies. While we view the entire regime as a whole system, we recognize it is comprised of discrete segments. For example, data and modelling we submitted at the YESAB stage has been prepared and submitted to support YESAB's effects assessment at this stage. Because we continue to collect site water quality data as we progress, we will be in a position to update modelling with additional data as required during the water licensing stage. At this stage in the Project it will be important to undertake our work with support of the specialist agency, the Yukon Water Board and their technical staff and consultants.

YESAB ISSUE WITH BMC'S RESPONSE TO R113

A statistician with a background in WQO derivation was recently contracted by Yukon government to prepare a statistical justification for baseline water quality data requirements for quartz mining projects.

The statistician was provided with available, relevant water quality data collected in Yukon, including data from the Wolverine mine, a mining project nearby and analogous to the proposed Kudz Ze Kayah project. The statistician concluded that three years of recent, continuous baseline water quality data is the minimum duration required to (a) generate a reasonable understanding of natural variability of water quality, and (b) detect systematic changes in water quality over time, if present.

Insufficient response: Proponent did not provide and did not commit to provide the Executive Committee with updated information prior to drafting the screening report. The Proponent has stated they will provide additional information to the Yukon Water Board to meet their obligation during licensing.

The Executive Committee requires updated water quality baseline information, water quality objectives, and water models (e.g., water quality model, site and watershed water balance models, surface water flows, etc.) prior to drafting the screening report. This will ensure that our assessment is conducted on more accurate information for the site.

R2-52

Updated water quality baseline information, water quality objectives, and water models (e.g., water quality model, site and watershed balance models, surface water flows, etc.) for the site are required to be submitted prior to the Executive Committee drafting the screening report. To develop a reasonable understanding of short-term variability, sampling is required to be conducted and reported on at least two sampling events, including one during low-flow conditions and one during high-flow conditions, for each year in which 5 samples are collected in 30 days.

BMC confirms that it will provide the requested information prior to the Executive Committee drafting the screening report.

YESAB ISSUE

The water balance modeling exercise at the watershed scale was for operations at year 10 and several closure conditions. No information was provided in this report for the construction phase or any of the projected years of operation. This is not considered consistent with industry standards and considered an information gap.

The watershed water balance model was calibrated with data from the 2015/2016 hydrometric monitoring program. Additional hydrometric data would be useful to further calibrate the watershed water balance model, verify model development and *model parameter assumptions, verify work completed to-date, and provide additional confidence in projections.*

R114

"Update the watershed model to include all phases of the mine life from construction through operations, and the active, transition, and post closure phases."

Water balances for the site for all phases of the mine life were provided in the original Proposal document supplied to YESAB. The site water balance for operations was provided in Appendix C-7 of the Project Proposal (Water Balance Model Report). For construction and closure phases of the Project, the site water balance has been incorporated in the Receiving Environment Water Balance Report, Appendix D-6 of the Project Proposal.

R115

"Undertake a sensitivity analysis to assess variability of model predictions given variation in key model input parameters and assumptions."

No updates to the water balance were warranted or provided in response to question R90, and therefore the Surface Water Management Plan has not been updated. All management plans will be updated as Project planning progresses if preceding work is materially updated.

YESAB ISSUE WITH BMC'S RESPONSE TO R114 AND R115

The water balance modeling exercise at the watershed scale was for operations at year 10 and several closure conditions. No information was provided in this report for the construction phase or any of the projected years of operation. This is not considered consistent with industry standards and considered an information gap.

The watershed water balance model was calibrated with data from the 2015/2016 hydrometric monitoring program. Additional hydrometric data would be useful to further calibrate the watershed water balance model, verify model development and model parameter assumptions, verify work completed to-date, and provide additional confidence in projections.

Insufficient response: Updating the watershed model and undertaking a sensitivity analysis is the next step after updating the water balance model. Rationale for this requirement is essentially the same as the rationale identified under R2-34 (original R90 and R91) above.

R2-53

Update the watershed model to include all phases of the mine life from construction through operations, and the active, transition, and post closure phases.

The site water balance for operations was provided in Appendix C-7 of the Project Proposal (Water Balance Model Report). For construction and closure phases of the Project, the site water balance has been incorporated in the Receiving Environment Water Balance Report, Appendix D-6 of the Project Proposal. Additional information for the construction and closure water balances have been included in Tables A-6-4, A-6-5, A-6-6, A-6-13, A-6-14, A-6-15, A-6-16, A-6-17, A-6-18, A-6-19, A-6-20, and A-6-21 from Appendix D-6, and are presented in **Appendix R2-F** of this Response Report.

Appendix R2-E (Operational Water Balance and Climate Variability and Sensitivity Analysis) of this Response Report summarizes the operational water balance for the Project, which includes climate variability and sensitivity analysis. This analysis demonstrates that the proposed water management structures can function as intended under stated design conditions throughout the life of mine under various climatic scenarios.

The most sensitive parameters for the construction water balance are the groundwater dewatering rates, diversion ditch performance and climatic inputs, while the closure water balance is most sensitive to the climatic inputs. The sensitivity analysis for the groundwater dewatering rates of ABM pit has been prepared and is presented in **Appendix R2-G** and the sensitivity analysis for climatic inputs and ditch efficiencies was prepared and is presented in **Appendix R2-E**. The sensitivity analyses demonstrated that the Project has minor sensitivity to these parameters and confirms that the approach for the water balances for the construction and closure phases is conservative.

R2-54

Undertake a sensitivity analysis to assess variability of model predictions given variation in key model input parameters and assumptions.

Appendix R2-E (Operational Water Balance and Climate Variability and Sensitivity Analysis) of this Response Report summarizes the operational water balance for the Project, which includes climate variability and sensitivity analysis. This analysis demonstrates that the proposed water management structures can function as intended under stated design conditions throughout the life of mine under various climatic scenarios.

YESAB ISSUE

The proposed threshold criteria for surface water quantity and quality used to assess the magnitude of projected changes in the receiving environment seem arbitrary. For example, for water quality, exceedance of a pWQO is often considered to be a high effect, whereas the Proponent is proposing a threshold of 10 times the pWQO or greater to represent a high level effect.

R116

"Provide justification and rationale for the proposed threshold criteria for surface water quantity and quality used to assess the magnitude of projected changes in the receiving environment."

Water quality objectives have been established using a use-protection approach. The majority of the objectives have been established based on guidelines established by CCME or BCMoE for the protection of aquatic life. The CCME and BCMoE guidelines have been developed with safety factors relative to chronic toxicity literature values which are often 10-100 times greater than the guidelines. These chronic toxicity thresholds are taken from the most sensitive organism and life stages. Given a potential adverse effect to aquatic organisms would require long term exposure to chronic toxicity concentrations, the definition of high magnitude effect was established as 10 times the water quality objectives since concentrations at the generic guidelines would not have residual effects.

YESAB ISSUE WITH BMC'S RESPONSE TO R116

The proposed threshold criteria for surface water quantity and quality used to assess the magnitude of projected changes in the receiving environment seem arbitrary. For example, for water quality, exceedance of a pWQO is often considered to be a high effect, whereas the Proponent is proposing a threshold of 10 times the pWQO or greater to represent a high level effect.

Insufficient response: Proponent defends their definition of high magnitude effect as 10 times the water quality objective (WQO). Such an interpretation would establish a precedent. In our experience, other Yukon mining projects assessed by the EC have typically been evaluated based on a high magnitude effect threshold of 1 time the WQO. Without convincing rationale provided by the Proponent, we cannot recommend to the EC to deviate from the previously considered high magnitude effect threshold.

R2-55

Provide justification and rationale for the proposed threshold criteria for surface water quantity and quality used to assess the magnitude of projected changes in the receiving environment.

Appendix R2-C (Project Optimizations and Updated Water Quality Performance Expectations for Kudz Ze Kayah Project) provides a revised threshold of two times the pWQO for the evaluation of significance, with rationale for these revised surface water threshold criteria.

YESAB ISSUE

The Proponent proposes variable pWQOs for several water quality parameters, including sulphate, nitrite, selenium, cadmium and zinc. However, the Proposal does not clarify how such variability could be applied in a practical sense to control emissions during each phase of the Project (e.g. as part of licensing).

Variable WQOs may be justified from a toxicological perspective but can prove difficult to apply for regulatory purposes. It is common to reduce the complexity of variable objectives by applying a fixed WQO, a site specific WQO, or a seasonal WQO. In all cases, the most conservative WQO is generally applied.

R118

"Provide details on how variable Preliminary Water Quality Objectives (pWQOs) would be applied and enforced on an operational basis from a practical perspective."

Variable pWQOs (i.e. those that are hardness, sulphate, or chloride-dependent) will be calculated for each sample using actual dependency values and compared to the measured constituent concentration. Managers will have simple calculation tools developed to determine an immediate pWQO value upon receipt of analytical results.

As part of the operational Adaptive Management Plan both short term (i.e., for each sampling event) and long-term (i.e., annual or longer) water quality thresholds will be established which will outline specific responses should receiving water quality values trend towards the exceedance of the pWQOs in the receiving environment.

R119

"Provide evidence of other sites where this approach has been applied."

Variable water quality objectives and effluent quality standards have been incorporated into Water Licences by the Yukon Water Board on previous projects including the Minto Mine (QZ14-031), and Sa Dena Hes Mine (QZ16-051) and their respective Adaptive Management Plans.

YESAB ISSUE WITH BMC'S RESPONSE TO R118 AND 119

The Proponent proposes variable pWQOs for several water quality parameters, including sulphate, nitrite, selenium, cadmium and zinc. However, the Proposal does not clarify how such variability could be applied in a practical sense to control emissions during each phase of the Project (e.g. as part of licensing).

Variable WQOs may be justified from a toxicological perspective but can prove difficult to apply for regulatory purposes. It is common to reduce the complexity of variable objectives by applying a fixed WQO, a site specific WQO, or a seasonal WQO. In all cases, the most conservative WQO is generally applied.

Insufficient response: The proponent states they will establish water quality thresholds as part of the operational Adaptive Management Plan (AMP) that will be used to manage the discharge. But the proponent does not provide further information to assess the suitability of their proposed thresholds. Although the proponent points to the Adaptive Management Plans for Minto Mine (QZ14-031), and Sa Dena Hes Mine (QZ16-051) as examples of sites where this approach has been applied they do not detail aspects of these AMPs that could be pertinent for the KZK project. In our opinion, the responses to R118 and R119 do not provide the EC with sufficient information to evaluate the effectiveness of the proposed approach for managing the discharge to the environment for the KZK project.

R2-56

The proponent should provide additional information regarding the proposed water quality thresholds that could be proposed as part of an AMP for the KZK project so as to allow the Executive Committee to determine if they have confidence in the effectiveness of the proposed approach.

On September 21, 2017 BMC met with YESAB and their consultant EcoMetrix. During this meeting BMC suggested that further development of the specific thresholds for managing adaptive management of water quality performance cannot be undertaken until relevant aspects of the Project are further defined. BMC expects refinements to water quality predictions as more information becomes available and the level of design detail increases for the Project. In addition, BMC expects to incorporate YESAB's recommendations into the list of considerations for further threshold development. YESAB and EcoMetrix representatives understood this and it was agreed with all parties that identification of a range of options for defining thresholds (a 'toolbox' approach) would be determined to meet the intention of the line of questioning.

The Water Quality Objectives (WQOs) themselves will form the basis of the specific thresholds for the Water Quality AMP at receiving environment/effluent discharge stations. As outlined in Section 7.12.2.1 of Appendix H to the Project Proposal (Conceptual Reclamation and Closure Plan), specific thresholds "*are staged to accommodate levels of concern and diversity of actions. To the extent practicable, specific performance thresholds will include early warning thresholds.*" To this end, early warning thresholds could be based upon a percentage of a numerical WQO, or in the case where a WQO is based upon a summary statistic of the background dataset (e.g. 95th percentile for the Background Concentration Procedure) the earlier thresholds could be lower summary statistics for the same data set (e.g. 75th percentile of background). For variable, or calculated WQOs (i.e. hardness dependent), percentages of calculated WQOs can be utilized for early warning thresholds.

Further 'upstream' monitoring locations (e.g. water management ponds, ABM lake) may utilize different, more appropriate methods of developing specific thresholds. Trend analysis is also a tool that may be employed as a threshold, where water quality trends suggest a likelihood of contributing to the future exceedance of WQOs or effluent quality standards. Predicted concentrations from water quality modeling can also form the basis of specific threshold development; however, this approach can lead to administrative burden without affecting meaningful responses to protect downstream values. Percentages of calculated effluent quality standards can be used as thresholds for variable or calculated (i.e. hardness dependent) standards, if applicable.

Continued or consecutive exceedances of specific (lower or response trigger) thresholds can be the basis for higher level thresholds, where more substantial responses are triggered.

R2-57

The proponent should identify aspects of the Minto Mine and Sa Dena Hes Mine AMPs that could be pertinent for the KZK project.

The Minto Mine Operational AMP (Minto Explorations Ltd., 2017) utilizes many of the 'tools' identified above in determining specific thresholds for the specific indicator of water quality. These include:

- Water quality objectives, and percentages of those WQOs;
- Trend analysis (although this is more commonly utilized as an evaluation in response to exceedance of a specific threshold);
- Expected case and reasonable worst-case water quality estimates from modeling exercises; and
- Consecutive or continued threshold exceedance.

The Sa Dena Hes Mine Post-Reclamation AMP (Alexco Environmental Group, 2017) similarly uses tools identified in the response above to R2-56, including:

- Trend analysis, showing progressively increasing contaminant concentrations;
- Percentages of effluent quality standards; and
- Percentages of Water Quality Objectives.

As outlined in the response to R2-56, BMC will consider these approaches in selecting available tools from which to develop appropriate specific thresholds for water quality. The selection process and development of the AMP detail around the framework provided in Appendix H to the Project Proposal (Conceptual Reclamation and Research Plan, Section 7.12.2) will proceed when key elements of Project design and their evaluation tools are advanced as the Project moves through the planning continuum.

YESAB ISSUE

The Proponent's assessment of potential effects on the receiving environment assumes that a high degree of treatment efficiency will be achieved. The Proponent's conclusion of no significant adverse effects to surface water quality is substantially tied to the assumed treatment efficiencies. However, the Proposal does not provide sufficient information to defend the assumed efficiencies.

R121

"Provide justification for the assumed treatment efficiencies."

BMC have requested a supplementary report from specialists Integrated Sustainability (IS) on potential treatment methods to achieve the required discharge limits and treatment efficiencies. This report is included as **Appendix 4** of the initial Response Report (BMC, 2017).

The report summarizes the process selection criteria and modelling work that has been completed to advance the water treatment plant design.

Based on the site-specific requirements and recommended approach form IS, BMC proposes that a staged effluent treatment system be used that is designed to focus on bulk removal of dissolved and suspended species, as well as polishing to achieve the required discharge standards.

The proposed active water treatment systems include the unit processes oxidation, chemical addition, media and/or membrane filtration, and ion exchange to meet the discharge water quality requirements. Provisions have been made to develop a treatment approach that can be adapted as more data becomes available and engineering work progresses. This approach will have the added advantage of being capable of being flexible enough to adequately deal with any unexpected new data and as a result will deliver the required outcomes for the Project.

The staged treatment system proposed will include a combination of technologies including precipitation (via lime or sulphide addition), multimedia filtration, membrane filtration by nanofiltration or reverse osmosis, and ion exchange. A combination of these technologies was modelled and achieved the assumed treatment efficiencies.

Other candidate technologies capable of treating water to the requirements include:

- Advanced multi-stage ion exchange
    - Ion exchange is a common process and capable of removing various species of inorganic contaminants, heavy metals and selenium in different valence states. To account for variable selenium species, this process may include specialized, advanced reactive media.
- Thermal processes
    - Evaporation and/or crystallization for bulk removal of the key contaminants is expected to have extensive pre-treatment requirements
- Electrodeionization
    - Electrodeionization is used for very challenging wastewater and has precedent in ultra-pure water treatment applications
    - Suitable for low total dissolved solids (TDS) water (~150-200 ppm)
    - It is often used as an alternative to mixed bed deionization, since it does not require chemical addition for regeneration

R122

"Provide contingency options in the event that proposed water treatment options do not achieve their intended efficiencies."

As referenced in the response to R121, the proposed development methodology for the appropriate water treatment option will be flexible enough to enable BMC to deal with any contingency that may arise. The possibility that water treatment options do not achieve their intended efficiencies will be handled depending on which of the specific criteria is not being achieved. There are two main classes of criteria that potentially may not be achieved:

- Throughput too low- If the target throughputs are not met then additional modules will be put into service in parallel. The base design will include allowance for redundancy due to the high variability in throughput throughout the calendar year. Any indications that there may be problems achieving treatment of the required volumes will be apparent before the Water Treatment Plant is operating at design capacity and the plant can be easily expanded at that time.
- Water Treatment Plant Discharge targets not met-The solution to this will depend on which constituent is not being removed to the appropriate level. There are a number of methods to mitigate for this including adding additional treatment systems, both in parallel and as part of the polishing circuit, adjustment of dosing rates of chemicals, and adjustments of flow rates in parts of the circuit. Similar to 1), indications that the performance criteria are not being met will become apparent early in the operation of the treatment plant and will be mitigated prior to full operational status.

YESAB ISSUE WITH BMC'S RESPONSE TO R121 AND 122

The Proponent's assessment of potential effects on the receiving environment assumes that a high degree of treatment efficiency will be achieved. The Proponent's conclusion of no significant adverse effects to surface water quality is substantially tied to the assumed treatment efficiencies. However, the Proposal does not provide sufficient information to defend the assumed efficiencies.

Insufficient response: We acknowledge that in their responses to R121 and 122, the proponent has committed to identifying and resolving issues relating to variable throughputs before the WTP is operating at design capacity and to obtaining performance criteria prior to full operational status. Our concerns with the proposed water treatment options pertain to the lack of resolution of the management of the ion exchange and RO waste streams which was described for R86.

R2-58

Provide justification for the assumed treatment efficiencies.

On October 17 2017, YESAB provided (via email) clarification regarding the information that is required to address R2-58. The clarification is as follows:

'This question is related to R2-30 and the management of RO waste streams. In follow-up with our consultant, EcoMetrix, there is also a concern with the overall treatment efficiencies identified which require further clarification.

We required some additional details demonstrating that the assumed treatment efficiencies are directly related to the chosen water treatment system. In the technical meeting[1], BMC indicated that a new water treatment document is being prepared that will outline performance and efficiency of the system. A more detailed water treatment document, in combination with responses on waste stream management, will likely address R2-58. However, this will be dependent on the level of detail provided in response"

BMC's response to the management of RO waste steams is presented in response to R2-30 and **Appendix R2-D** of this Response Report. With respect to the expected removal performance, each system component is based on a combination of information sources. In order to derive predicted removal rates, a combination of modelling software and benchmark performance criteria were assessed, cross-referenced against bench, pilot or full-scale data and/or literature data, where possible. The basis is given below, by process.

Metals Removal

Modelling for metals removal performance using lime was undertaken using an electrolyte thermodynamic model to estimate removal rates from the influent, with the model focusing on metallic species. The modelling software used was *OLI Studio Stream Analyzer - Simulation Software for Electrolyte Chemistry & Aqueous Chemical Modelling Version 9.2*. The software uses the inlet water chemistry, physical parameters and the proposed chemical precipitation process to predict removal rates and the effluent chemistry.

Multimedia Filter

Multimedia filter performance was assessed using benchmark performance data from manufacturers. While the specific filter/clarifier has not yet been selected, multiple filter options and configurations exist that will be able to achieve the removal levels required for this application.

Ion Exchange

The performance of the specialized ion exchange system was modelled based on standard ion exchange breakthrough data in combination with bench and pilot scale testing with water similar to

[1] BMC met with YESAB and their consultant Ecometrix on September 21, 2017. The meeting was held at the YESAB head office in Whitehorse.

Kudz Ze Kayah, with selenium removal to 0.002 mg/L present as a key performance indicator. The major variant in testing and analysis results for selenate removal tends to be resin bed regeneration frequency and duration. During engineering, modelling will be undertaken to optimize ion exchange regeneration, configuration, and waste management. An upfront sacrificial column set may be required to prevent fluoride interference with selenium.

Membranes

Membrane removal performance was modelled using *Hydranautics – Integrated Membrane Solutions Design Software, 2017*, cross referenced against literature values, using as an example selenium removal with reverse osmosis membranes at Barrick Richmond Hill Gold Mine in California. During engineering, modelling will be undertaken to optimize membrane selection and configuration as required,

As stated in response to R2-30, as part of the detailed design phase of the Project BMC will initiate a pilot scale plant to test the efficiencies of the proposed design and has proposed mitigation measures in the event that the design does not meet the stated efficiencies (see response to R2-30).

R2-59

Provide contingency options in the event that proposed water treatment options do not achieve their intended efficiencies.

On October 17 2017, YESAB provided (via email) clarification regarding the information that is required to address R2-59. The clarification is as follows:

> *"As EcoMetrix indicated in the technical meeting1, in their experience RO systems require additional considerations because of the waste produced. It is not uncommon that these systems do not work properly due to the practicality of dealing with waste streams. R2-59 was requesting contingency options in the event that the water treatment systems do not achieve their goals.*
>
> *If BMC can demonstrate adequate management of waste streams and provide an updated water treatment document outlining performance and efficiencies, thereby increasing confidence in the proposed water treatment system, there may not be a need to provide additional contingency options"*

BMC's response to the management of RO waste streams and contingency/mitigation measures is presented in response to R2-30 and **Appendix R2-D** of this Response Report. Treatment efficiencies are also included in **Appendix R2-D** and been described in response to R2-58.

YESAB ISSUE

Comments provided by Mineral Resources Branch describe deficiencies related to waste management, *options assessment, and the conceptual reclamation and closure plan. Furthermore, limited details are provided concerning the proposed in situ treatment of the ABM lake or the conceptual constructed* *wetland treatment system. The removal rates and treatment factor used in the water quality model are not justified. It is not possible to assess potential significant, adverse effects to the downstream receiving environment without this information.*

R125

"Provide a report that details the proposed treatment methods, justifies site-specific treatment rate coefficients, and predicts the chemistry of the treated effluent. Based on the information in this report, provide an updated water quality model (i.e., with updated mine source loads) and, if necessary (e.g., if new contaminants of potential concern are identified), an updated water quality objectives report."

The *in situ* pit treatment and Constructed Wetland Treatment System (CWTS) conceptual designs and treatment details have been developed by acknowledged experts in passive and semi-passive mine water treatment. The proposed treatment methods have been effectively applied in a wide range of mining applications and conditions, and the treatment rate coefficients have been conservatively and appropriately selected based on the experts' substantial experience and professional judgement. The wetland assessment and conceptual design work, including identifying the treatment mechanisms and treatment rate coefficients, was conducted by Contango Strategies Ltd., industry leaders and experts in passive water treatment, constructed wetland treatment systems, and biogeochemical water treatment processes. Contango has led passive water treatment design efforts on numerous projects in Yukon, and on other cold-climate location projects, such as the Giant Mine in the NWT and Mount Polley in BC.

The information regarding the proposed methods is presented at the appropriate conceptual level, and reflects the current Project level of design. The design detail for the treatment installations and infrastructure will be appropriately advanced with further development of site facility designs and with the collection of additional water quality information. This will be provided in applications to support the regulatory permitting process.

As cited in the Project Proposal, Water Quality Model (Appendix D-7) and Conceptual Reclamation and Closure Plan (Appendix H), the *in situ* treatment method proposed for ABM lake has been successfully implemented at numerous pit lakes in the USA to treat the same COPCs [e.g., Sweetwater, WY (Harrington, 2002); Barite Hill, SC (Harrington et al., 2009); Anchor Hill, SD (Harrington et al., 2004)]. These studies, alongside related *in situ* treatment experience of flooded underground mine workings (e.g., Harrington et al., 2015), were the basis for the conservative COPC reduction percentages used in the water quality model for ABM lake (Table 6-16 of Appendix D-7).

Contango's technical memorandum titled Conceptual Wetland Design based on Water Quality objectives and Predicted Outflow Concentrations [January 2017, Appendix B of Appendix H of the Project Proposal (Conceptual Reclamation and Closure Plan, February 2017)] reports the treatment mechanisms (Page 7; Section 6), site-specific treatment rate coefficients (Page 11-13 and Table 3; Section 7.2), and equations (Page 12-13 and Equations 1-4; Section 7.2) used in predictions of water chemistry exiting the proposed North and South treatment wetlands. Predictions for the CWTSs were based on removal rates observed at other sites they have worked on in the north and cold climates and also in off-site pilot-scale studies. These include Capstone Mining Corp.'s Minto mine in the Yukon (Haakensen et al., 2015 and Appendix A2 of Capstone, 2017), Fortune Minerals' NICO project in the Northwest Territories (Contango, 2014), the Kumtor mine at high altitude (4,200 m) in Kyrgyzstan (Friesen et al., 2016), and numerous other sites in North America (Huddleston and Rodgers, 2008; Murray-Gulde et al., 2008; Spacil et al., 2011; Schwindaman et al., 2014).

The site-specific treatment information for the *in situ* pit and constructed wetland treatment systems as referenced above is appropriate, and is already incorporated into the Project Proposal (Appendix D-7, Water Quality Model, Kudz Ze Kayah Project). This report presents expected effluent concentrations for the site closure phases, and compares these concentrations with proposed water quality objectives for the Project. The reports referenced in the question above do not warrant any updates on the basis of the information provided or referenced in this response.

YESAB ISSUE WITH BMC'S RESPONSE TO R125

Comments provided by Mineral Resources Branch describe deficiencies related to waste management, options assessment, and the conceptual reclamation and closure plan. Furthermore, limited details are provided concerning the proposed in situ treatment of the ABM lake or the conceptual constructed wetland treatment system. The removal rates and treatment factor used in the water quality model are not justified. It is not possible to assess potential significant, adverse effects to the downstream receiving environment without this information.

Insufficient response: Similar to the Proponent's response to R108, the Proponent has not provided sufficient details to support the assumed treatment performance of the proposed water treatment systems.

R2-60

Provide a report that details the proposed treatment methods, justifies site-specific treatment rate coefficients, and predicts the chemistry of the treated effluent. Based on the information in this report, provide an updated water quality model (i.e., with updated mine source loads) and, if necessary (e.g., if new contaminants of potential concern are identified), an updated water quality objectives report.

On October 17 2017, YESAB provided (via email) the following clarification regarding the information required in response to R2-60:

> *"As discussed at the technical meeting, addressing the other questions and providing the information noted above should answer this request."*

Appendix R2-C (Project Optimizations and Updated Water Quality Performance Expectations for Kudz Ze Kayah Project) provides an updated water quality model which addresses R2-60 and the other related Requests.

YESAB ISSUE

A water treatment plant is proposed for the management of water quality during the operation. The necessity of a water treatment plant is based on the acknowledgement that the high sulphur PAG material will produce drainage during operations that requires management before release to the environment. The assumption of reverse osmosis technology for water treatment is reasonable. However, reverse osmosis is an expensive treatment option and the feasibility of treating large quantities of waste water should be proven.

In addition, the byproduct of reverse osmosis is a high concentration effluent that also requires management and this was not acknowledged or considered in water management or in the water quality model during the operation. The disposal of high contaminant concentration waste generated by the use of reverse osmosis can be problematic. The current assumptions for treated water quality are summarized in Table 5-15 and Appendix D-7. Treatment technologies other than reverse osmosis will lead to different concentrations than those shown in Table 5-15 for treated water and will alter the water quality predictions during operations.

R126

"Provide rationale and justification for the use of reverse osmosis as a feasible treatment option considering the large quantities of waste water needed to be treated."

BMC commissioned water treatment specialists Integrated Sustainability to prepare a report on potential treatment methods to achieve the required discharge limits and treatment efficiencies. This report is included as **Appendix 4** (Water Treatment Summary) of the Initial Response Report (BMC, 2017).

The processes selected for Kudz Ze Kayah consist of the following treatment processes:

- High density sludge – addition of lime, sulphide and/or ferric to encourage precipitation of metals, and flocculation to improve separation of metals and metalloids. Ballast may be included to increase the settling rate of the particles to reduce the footprint of the clarifier.
- Multi-media filtration – Filtration to prevent carryover of precipitated metallic and non-metallic solids from the HDS and flocculation clarification system to the ion exchange and/or membrane systems. This improves the removal of precipitated species and protects the ion exchange system.
- Ion exchange – Achieves removal of selenium and other trace metals via exchange of target species within a fluidized resin bed.
- Membrane filtration – ultrafiltration, nanofiltration or reverse osmosis may be included to achieve a high degree of removal of trace elements including fluoride and selenium in oxy-anionic forms. Filter backwash from the multi-media filter will be returned to the front-end of the process the volume of waste generated from this process.

These staged processes are modelled to achieve the discharge requirements at the predicted flow rates while minimising the by-product produced and are feasible using currently available proven technology.

The quantities treated, while large, are not without precedent. Capstone's Minto Mine treats larger quantities utilizing reverse osmosis as part of their water treatment process.

R127

"Provide details on how the by-product of a reverse osmosis water treatment plant will be addressed. This can be done by either including the by-product in the assessment or proposing an alternate treatment process. If an alternative to reverse osmosis is considered, update Section 5.2.1.7 of Appendix D-7 (Water Quality Report) of the proposal based on the revised assumptions for the quality of treated water."

Both Reverse Osmosis and Nanofiltration systems will ultimately generate a reject stream. Preliminary modeling estimates that up to 21% of the inlet flow will be retained as reject. Incorporating further RO passes will decrease the volume of reject, however additional chemical dosage will be required to prevent scaling (an example of which would be $CaSO_4$ saturation occurring at the RO membrane surface).

The management of this reject stream has been carefully considered in the planning work to date on WTP design and process selection.

The Kudz Ze Kayah Process Plant will be able to effectively manage up to 7.5 m3/hr (180 m3/d) of RO reject, whereas preliminary modelling indicates that the RO reject stream is likely to exceed this amount in a two-pass configuration. Additional treatment of the waste stream such as a thermal process (e.g. by evaporator/crystallizer or humidification/dehumidification process) will be considered and implemented if required to further reduce the volume of the waste stream.

To most economically manage the reject volume while achieving discharge objectives, consideration will be made for a chemical optimization program, in which the capital expenditures and operating expenses of increased RO passes and increased anti-scalant dosage would be compared against the costs of a thermal process.

YESAB ISSUE WITH BMC'S RESPONSE TO R126 AND R127

A water treatment plant is proposed for the management of water quality during the operation. The necessity of a water treatment plant is based on the acknowledgement that the high sulphur PAG material will produce drainage during operations that requires management before release to the environment. The assumption of reverse osmosis technology for water treatment is reasonable. However, reverse osmosis is an expensive treatment option and the feasibility of treating large quantities of waste water should be proven.

In addition, the byproduct of reverse osmosis is a high concentration effluent that also requires management and this was not acknowledged or considered in water management or in the water *quality model during the operation. The disposal of high contaminant concentration waste generated by the use of reverse osmosis can be problematic. The current assumptions for treated water quality are summarized in Table 5-15 and Appendix D-7. Treatment technologies other than reverse osmosis will lead to different concentrations than those shown in Table 5-15 for treated water and will alter the water quality predictions during operations.*

Insufficient response: Our concerns with the proposed water treatment options pertain to the lack of resolution of the management of the ion exchange and reverse osmosis waste streams.

While treatment options are discussed in greater detail (Appendix 4 in BMC Response to Executive Committee ARR) than in the Project Description, details were not provided on the management of the ion exchange and reverse osmosis waste streams. These waste streams have been identified as 5 percent and 21 percent of the original treated volumes, respectively. Although there was discussion of reducing volumes of residual in the reverse osmosis system, it is clear that there will be a need for residual management. In Appendix 4, there is reference to BMC being able to "manage up to 7.5 m^3/hr (180 m^3/day) of reject". That is only 3 percent of the average annual treatment flow of about 6,000 m^3/day or less than 1 percent of the maximum treatment flow of about 19,000 m^3/day in the month of June.

R2-61

Provide rationale and justification for the use of reverse osmosis as a feasible treatment option considering the large quantities of waste water needed to be treated.

The feasibility of the proposed treatment plant, management of the RO waste steams as well as contingency/mitigation measures is presented in response to R2-30, R2-31, and **Appendix R2-D** of this Response Report.

R2-62

Provide details on how the by-product of a reverse osmosis water treatment plant will be addressed. This can be done by either including the by-product in the assessment or proposing an alternate treatment process. If an alternative to reverse osmosis is considered, update Section 5.2.1.7 of Appendix D-7 (Water Quality Report) of the proposal based on the revised assumptions for the quality of treated water.

Management of the by-product of the proposed reverse osmosis water treatment plant is presented in response to R2-30 and **Appendix R2-D** of this Response Report. The rationale for not updating the water quality model based on the proposed management of the by-product is provided in response to R2-31.

YESAB ISSUE

It is not clear if the capacities of the water management ponds are sufficient to accommodate both demands, and if not, how this would affect water management, specifically release volume controls and discharge to Geona Creek and Finlayson Creek.

The operations water management strategy states that the discharge to Geona Creek and Finlayson Creek will be limited to discharge volume ratios no less than 3:1 at KZ-37 and 2:1 at KZ-15. The Proposal does not clarify how it intends to achieve this at all times.

R128

"Provide details and justification to support sufficient capacity in the water storage ponds to accommodate the design storm during a wet year, and how the water management ponds will be managed to achieve release volume controls at all times."

The capacity of the water management ponds is the total inflow design flood (the 1 in 200 year 24 hour event), plus the anticipated maximum operating water volume, plus freeboard. The design basis for the water management ponds is to store the required inflow design flood event. The pond design includes allowance for freeboard, as well as an emergency spillway to pass flows exceeding the inflow design flood event.

The water balance model was used to balance the inflow and outflow rates to the water management ponds based on the predicted maximum total required capacity, and the allowable surplus water discharge rate.

Discrete discharge at sites KZ-37 (Geona Creek) and KZ-15 (Finlayson Creek) will be measured weekly and recorded continuously by a datalogger in a stilling well. The maximum discharge rate for the Lower Water Management Pond (KZ-8) will be set at the beginning of each week based on the previous week's discharge measured in Geona Creek and Finlayson Creek. The Lower Water Management Pond discharge will be recorded daily and monitored continuously via a totalizer flow meter.

During freshet and significant rain events, discharge within the creeks will be monitored more frequently than weekly using the staff gauges and rating curves established for KZ-37 and KZ-15 to conduct daily spot checks to verify flow rates when week to week changes are suspected.

YESAB ISSUE WITH BMC'S RESPONSE TO R128

It is not clear if the capacities of the water management ponds are sufficient to accommodate both demands, and if not, how this would affect water management, specifically release volume controls and discharge to Geona Creek and Finlayson Creek.

The operations water management strategy states that the discharge to Geona Creek and Finlayson Creek will be limited to discharge volume ratios no less than 3:1 at KZ-37 and 2:1 at KZ-15. The Proposal does not clarify how it intends to achieve this at all times.

Insufficient response: Proponent has not provided the requested information.

R2-63

Provide details and justification to support sufficient capacity in the water storage ponds to accommodate the design storm during a wet year, and how the water management ponds will be managed to achieve release volume controls at all times.

The site water storage ponds have the capacity to store the Inflow Design Flood at all times, including during a wet year. Flows that exceed the pond storage capacity will be discharged through engineered spillways. The storage capacity and management of the ponds will ultimately incorporate the planned discharge strategy for different climatic conditions. Operational storage capacities for the Class A and Class B Collection Ponds, corresponding to a 1 in 50 year return period wet month, were incorporated from the water balance modelling results, as described in Appendix R2-E (Operational Water Balance and Climate Variability and Sensitivity Analysis). The Class A and Class B Collection Ponds contain storage capacities of 104,000m^3 and 91,000m$_3$, respectively to provide sufficient capacity for containment of both the Inflow Design Flood corresponding to the 1 in 200 year, 24 hr storm event, and the volume form the 1 in 50 year wet month, prior to water treatment for discharge. The operational storage capacities of the Upper and Lower Water Management Ponds will also include the discharge strategy of water to the receiving environment to ensure there is sufficient capacity to manage discharge flows that may be regulated by fluctuating downstream flows.

YESAB ISSUE

The equations used to predict surface water quality include an attenuation factor yet the Proposal does not specify the values used or their justification. The chemical loading discharged to the receiving environment may attenuate through various chemical, biochemical or physical process (other than dilution). The attenuation for nitrogen compounds may be high in headwater creeks, such as those which characterize the receiving environment. However, the attenuation for most metals may be low. It is common to conservatively assume no attenuation for those parameters having low potential for attenuation.

R131

"Provide the attenuation factors used in the model for each contaminant of potential concern (COPC) and provide justification for their use."

To clarify; the "attenuation factors" used in the model are better described as calibration factors rather than attenuation factors. The "attenuation factors" or calibration factors were applied to the model as part of calibrating the baseline scenario when comparing the predicted baseline concentrations to the actual baseline concentrations. For a few parameters in instances where there was not good agreement, the factors were calculated by comparing baseline monitoring data for each month to the predicted baseline concentration to more accurately represent the actual observed load along a flow path between the monitoring stations compared to the modelling points (KZ-37 to KZ-15 and KZ-15 to KZ-26). These calibration factors in some cases may reflect attenuation processes, however they more accurately address load that may enter above a modelling node from surface runoff or groundwater contribution. These factors only apply to the baseline load and not to the additional load during construction, operations and closure.

YESAB ISSUE WITH BMC'S RESPONSE TO R131

The equations used to predict surface water quality include an attenuation factor yet the Proposal does not specify the values used or their justification. The chemical loading discharged to the receiving environment may attenuate through various chemical, biochemical or physical process (other than dilution). The attenuation for nitrogen compounds may be high in headwater creeks, such as those which characterize the receiving environment. However, the attenuation for most metals may be low. It is common to conservatively assume no attenuation for those parameters having low potential for attenuation.

Insufficient response: The proponent states that the attenuation factor is being applied as a calibration factor for cases where the model was unable to accurately predict baseline concentrations. For transparency, the proponent should show which parameters they were unable to predict accurately and by how much.

R2-64

Provide the calibration factors used in the model for each contaminant of potential concern.

The calibration factors were calculated using baseline data collected at KZ-37, KZ-15 and KZ-26. The process is described in detail in the Water Quality Model Report (Appendix D-7 of the Project Proposal). The calibration factors for all COPIs at KZ-15 using KZ-37 data and at KZ-26 using KZ-15 data are presented in Table 8-21 and Table 8-22, respectively.

It is important to note that the calibration factors and added loads are only used for predictions of water quality at KZ-15 and KZ-26. It is also important to note that the reduction factor was used instead of subtracting a load to avoid calculating negative concentrations for certain parameters in certain months. In the model, an increase in load is achieved by adding a load as opposed to applying a factor, the added loads have been converted to factors for ease of presentation as loads are not intuitive.

In the case of some COPIs (cadmium, iron, selenium and zinc), calculated concentrations at KZ-15 and KZ-26 were in some instances lower than observed baseline concentrations. Thus, any calibration factors for these COPIs that were less than zero (indicating a decrease in load going downstream) were set to 1 (indicating no change in load).

Table 8-21: Calibration Factors for Estimating Loads at KZ-15 from KZ-37

	Hardness	Sulphate	Nitrate-N	Nitrite-N	Ammonia-N	Phosphorus	Fluoride	Chloride	Cyanide, Total	Cyanide, WAD	Aluminum	Antimony	Arsenic	Cadmium	Copper	Iron	Lead	Manganese	Nickel	Silver	Selenium	Uranium	Zinc	Dissolved Organic Carbon
	KZ-37 to KZ-15 (Median)																							
January	2.30	2.29	1.98	1.90	2.10	0.36	2.30	1.77	2.01	2.11	1.05	1.43	2.28	1.45	2.27	1.00	0.24	1.04	5.46	2.26	2.28	4.20	1.00	3.15
February	2.20	2.31	1.88	1.86	1.07	0.29	2.06	4.53	1.86	1.86	2.34	1.99	2.96	1.79	4.36	1.00	10.55	1.12	3.98	1.86	1.87	4.21	1.30	4.23
March	2.19	2.20	1.79	1.77	0.54	0.60	1.99	1.83	1.77	2.69	2.33	1.66	1.82	1.60	2.86	1.00	3.43	0.99	3.84	1.77	2.04	4.53	1.17	2.02
April	3.09	2.64	2.36	0.90	1.07	0.43	3.04	1.74	1.56	1.78	1.44	1.27	2.47	1.31	2.20	1.00	2.67	0.72	4.08	2.43	2.71	5.77	1.06	1.68
May	3.13	4.13	1.93	0.47	0.52	0.90	3.23	1.99	1.47	1.76	0.32	1.32	1.82	1.00	1.42	1.00	0.33	0.96	1.24	1.62	2.12	4.57	1.00	0.90
June	2.52	1.98	1.10	2.10	1.65	1.32	2.74	1.92	1.84	1.85	0.30	1.05	1.77	1.00	0.90	1.00	0.25	1.57	1.00	1.50	1.63	4.55	1.00	1.16
July	2.97	2.26	0.93	2.52	2.74	1.09	3.08	2.52	1.88	1.42	0.57	1.96	3.15	1.00	1.09	1.00	0.36	2.66	2.00	1.26	1.72	3.84	1.00	1.73
August	1.90	1.96	1.95	2.16	2.98	0.50	2.09	2.50	3.99	3.99	1.08	1.21	1.73	1.00	2.11	1.00	0.85	0.75	1.98	1.99	1.97	2.84	1.00	2.04
September	1.75	1.51	2.13	1.83	3.15	0.84	2.15	2.46	2.10	1.81	0.56	1.06	2.34	1.00	1.01	1.00	0.47	0.97	1.19	1.89	1.37	2.31	1.00	1.57
October	1.97	1.97	1.99	1.99	7.06	1.01	2.30	1.45	3.19	3.09	1.51	1.57	3.01	1.00	1.60	1.00	0.78	1.36	1.86	1.99	1.84	3.05	1.00	1.84
November	2.16	2.07	2.18	2.97	1.78	0.41	2.40	1.04	1.59	1.60	4.29	1.95	3.91	1.45	3.10	1.00	34.86	2.09	4.33	9.25	1.96	3.47	1.01	1.80
December	2.26	2.09	1.98	3.49	0.91	0.40	2.29	2.47	1.72	1.94	1.83	1.78	2.53	1.40	2.15	1.00	1.14	0.83	3.97	1.94	2.14	3.88	1.00	1.71
	KZ-37 to KZ-15 (1 in 10 Dry Year)																							
January	1.94	1.93	1.67	1.60	1.77	0.30	1.94	1.49	1.69	1.78	0.88	1.20	1.92	1.22	1.91	1.00	0.21	0.88	4.61	1.91	1.93	3.54	1.00	2.66
February	1.86	1.95	1.58	1.56	0.90	0.24	1.74	3.81	1.56	1.56	1.97	1.67	2.49	1.51	3.67	1.00	8.89	0.95	3.35	1.56	1.57	3.55	1.09	3.56
March	1.84	1.85	1.51	1.49	0.46	0.50	1.67	1.54	1.49	2.27	1.96	1.40	1.54	1.35	2.41	1.00	2.89	0.83	3.23	1.49	1.72	3.81	1.00	1.70
April	3.00	2.57	2.30	0.88	1.04	0.42	2.96	1.70	1.52	1.73	1.40	1.23	2.41	1.27	2.14	1.00	2.60	0.70	3.97	2.37	2.64	5.61	1.04	1.64
May	3.12	4.12	1.93	0.47	0.52	0.90	3.22	1.99	1.47	1.75	0.32	1.32	1.81	1.00	1.42	1.00	0.33	0.95	1.24	1.62	2.12	4.56	1.00	0.90
June	2.47	1.94	1.08	2.05	1.62	1.29	2.68	1.88	1.80	1.81	0.30	1.03	1.74	1.00	0.88	1.00	0.25	1.54	0.98	1.47	1.60	4.46	1.00	1.14
July	2.54	1.93	0.79	2.16	2.34	0.93	2.64	2.16	1.61	1.21	0.49	1.67	2.69	1.00	0.93	1.00	0.31	2.27	1.71	1.08	1.47	3.28	1.00	1.48
August	1.79	1.84	1.84	2.04	2.81	0.47	1.97	2.35	3.76	3.76	1.01	1.14	1.63	1.00	1.99	1.00	0.80	0.70	1.87	1.88	1.85	2.68	1.00	1.92
September	1.66	1.44	2.03	1.74	2.99	0.80	2.04	2.34	1.99	1.72	0.53	1.01	2.23	1.00	0.96	1.00	0.45	0.92	1.13	1.79	1.30	2.19	1.00	1.49
October	1.67	1.67	1.69	1.69	5.99	0.86	1.95	1.23	2.70	2.63	1.28	1.33	2.55	1.00	1.36	1.00	0.66	1.16	1.58	1.69	1.56	2.59	1.00	1.56
November	1.83	1.75	1.85	2.51	1.50	0.34	2.03	0.88	1.35	1.36	3.63	1.65	3.32	1.23	2.63	1.00	29.53	1.77	3.67	7.84	1.66	2.94	1.00	1.52
December	1.91	1.77	1.67	2.95	0.77	0.34	1.94	2.09	1.45	1.64	1.55	1.51	2.14	1.18	1.82	1.00	0.96	0.70	3.36	1.64	1.81	3.28	1.00	1.45
	KZ-37 to KZ-15 (1 in 50 Wet Year)																							
January	2.46	2.45	2.12	2.03	2.25	0.38	2.46	1.90	2.15	2.26	1.12	1.53	2.43	1.55	2.43	1.00	0.26	1.12	5.84	2.42	2.44	4.49	1.00	3.37
February	2.36	2.47	2.01	1.98	1.15	0.31	2.21	4.84	1.98	1.98	2.50	2.13	3.17	1.91	4.67	1.05	11.29	1.20	4.26	1.98	2.00	4.51	1.39	4.52
March	2.34	2.35	1.92	1.89	0.58	0.64	2.12	1.96	1.89	2.88	2.49	1.77	1.95	1.71	3.05	1.00	3.67	1.06	4.10	1.89	2.18	4.84	1.25	2.16
April	3.18	2.72	2.43	0.93	1.10	0.44	3.12	1.79	1.61	1.83	1.48	1.30	2.54	1.34	2.26	1.00	2.75	0.74	4.19	2.50	2.78	5.93	1.09	1.73
May	3.13	4.14	1.94	0.47	0.52	0.90	3.23	2.00	1.47	1.76	0.32	1.32	1.82	1.00	1.43	1.00	0.33	0.96	1.24	1.63	2.13	4.58	1.00	0.90
June	3.57	2.81	1.56	2.97	2.34	1.86	3.87	2.72	2.60	2.62	0.43	1.48	2.51	1.00	1.27	1.00	0.36	2.22	1.41	2.12	2.30	6.45	1.00	1.65
July	2.24	1.71	0.70	1.91	2.07	0.83	2.33	1.91	1.42	1.07	0.43	1.48	2.38	1.00	0.83	1.00	0.27	2.01	1.51	0.95	1.30	2.90	1.00	1.31
August	2.25	2.32	2.31	2.56	3.53	0.60	2.48	2.96	4.73	4.73	1.28	1.43	2.05	1.00	2.50	1.00	1.01	0.88	2.35	2.36	2.33	3.37	1.01	2.41
September	1.97	1.70	2.40	2.05	3.53	0.94	2.42	2.77	2.35	2.04	0.63	1.19	2.63	1.00	1.13	1.00	0.53	1.09	1.34	2.12	1.54	2.59	1.00	1.76
October	2.34	2.35	2.37	2.37	8.40	1.21	2.73	1.72	3.79	3.68	1.79	1.87	3.58	1.00	1.90	1.00	0.93	1.62	2.22	2.37	2.19	3.64	1.00	2.19
November	2.31	2.21	2.33	3.17	1.90	0.43	2.57	1.11	1.70	1.71	4.58	2.09	4.19	1.55	3.32	1.00	37.27	2.23	4.63	9.89	2.10	3.71	1.08	1.92
December	2.42	2.23	2.12	3.74	0.97	0.43	2.45	2.64	1.84	2.08	1.96	1.91	2.70	1.50	2.30	1.00	1.22	0.88	4.25	2.08	2.28	4.15	1.00	1.83

Table 8-22: Calibration Factors for Estimating Loads at KZ-26 from KZ-15

	Hardness	Sulphate	Nitrate-N	Nitrite-N	Ammonia-N	Phosphorus	Fluoride	Chloride	Cyanide, Total	Cyanide, WAD	Aluminum	Antimony	Arsenic	Cadmium	Copper	Iron	Lead	Manganese	Nickel	Silver	Selenium	Uranium	Zinc	Dissolved Organic Carbon
	KZ-15 to KZ-26 (Median)																							
January	3.21	3.25	2.98	2.82	3.68	9.16	3.38	3.52	1.85	1.60	3.08	9.46	2.85	1.77	7.15	1.98	114.32	0.61	1.83	4.45	1.97	2.18	2.14	2.56
February	3.26	3.67	3.53	2.85	2.11	3.33	3.42	2.96	1.88	1.62	13.65	6.80	10.42	2.59	8.79	16.02	35.08	5.87	3.24	1.88	1.67	2.20	1.49	4.35
March	3.90	3.69	3.68	2.82	3.57	2.66	3.38	2.43	1.86	3.85	2.64	5.46	2.66	1.00	2.76	1.93	1.65	0.40	1.43	1.86	2.52	2.31	1.00	3.58
April	2.49	2.76	2.32	2.23	0.49	3.29	2.90	1.59	3.00	2.54	1.98	4.68	2.76	1.00	2.02	2.07	1.55	0.22	1.33	1.47	1.30	1.66	1.00	7.61
May	1.11	1.30	0.31	2.33	0.71	12.08	1.98	3.05	3.67	2.96	16.41	5.85	7.42	1.00	8.24	14.50	2.45	2.54	3.10	2.33	1.00	1.24	1.00	11.05
June	1.76	1.91	0.17	2.97	1.71	8.24	2.91	3.15	3.90	3.37	34.17	9.86	4.50	1.70	13.85	8.49	18.21	0.88	3.93	10.38	1.00	1.27	1.00	12.23
July	2.55	2.78	0.19	5.73	1.26	17.41	3.50	2.19	4.19	3.98	4.68	13.14	6.39	1.00	6.19	4.20	13.52	0.66	3.37	4.19	1.03	1.48	1.00	17.74
August	2.22	2.25	0.12	6.85	0.33	6.85	2.63	2.06	3.61	3.11	9.49	17.95	2.65	1.00	5.53	4.49	15.23	0.45	4.95	3.61	1.00	1.24	1.00	20.03
September	1.94	2.20	0.23	4.66	1.06	3.52	2.48	3.20	4.29	3.94	10.18	8.52	3.68	1.00	7.79	4.34	9.27	0.86	3.23	2.59	1.00	1.09	1.00	14.84
October	2.14	2.70	0.83	2.68	7.39	3.35	2.95	2.21	1.76	1.52	3.27	6.58	4.73	1.00	4.56	2.70	1.86	0.41	1.83	1.76	1.24	1.56	1.00	11.39
November	2.62	3.09	1.61	2.75	1.18	1.22	3.29	1.37	1.81	1.56	1.68	5.93	2.65	1.00	3.88	1.15	0.99	0.26	1.48	1.81	1.68	1.72	1.00	6.51
December	3.02	3.30	2.40	5.02	3.66	11.46	3.07	2.23	3.74	1.58	0.25	5.75	2.95	1.00	2.74	1.00	0.19	0.04	1.36	1.83	2.17	1.97	1.00	4.71
	KZ-15 to KZ-26 (1 in 10 Dry Year)																							
January	2.26	2.29	2.10	1.99	2.59	6.45	2.38	2.48	1.31	1.13	2.17	6.66	2.01	1.25	5.03	1.39	80.52	0.43	1.29	3.13	1.39	1.53	1.51	1.80
February	2.29	2.57	2.48	2.00	1.48	2.33	2.40	2.07	1.31	1.14	9.57	4.77	7.30	1.81	6.16	11.23	24.59	4.11	2.27	1.31	1.17	1.54	1.04	3.05
March	2.71	2.57	2.56	1.96	2.48	1.85	2.35	1.69	1.29	2.67	1.83	3.79	1.85	0.40	1.91	1.34	1.14	0.28	0.99	1.29	1.75	1.60	1.00	2.48
April	2.34	2.59	2.18	2.10	0.46	3.09	2.73	1.49	2.81	2.38	1.87	4.40	2.60	0.47	1.90	1.94	1.46	0.21	1.25	1.38	1.22	1.56	1.00	7.16
May	1.11	1.31	0.32	2.34	0.71	12.13	1.99	3.07	3.69	2.97	16.48	5.88	7.45	0.69	8.28	14.56	2.47	2.55	3.11	2.34	0.58	1.24	1.00	11.10
June	1.72	1.86	0.17	2.89	1.67	8.04	2.84	3.08	3.81	3.29	33.34	9.62	4.39	1.66	13.51	8.28	17.77	0.86	3.84	10.13	0.83	1.24	1.00	11.94
July	2.20	2.40	0.16	4.94	1.08	15.02	3.02	1.89	3.61	3.43	4.04	11.33	5.51	0.76	5.34	3.63	11.67	0.57	2.90	3.61	0.89	1.28	1.00	15.31
August	1.91	1.93	0.11	5.88	0.29	5.88	2.26	1.76	3.09	2.67	8.14	15.40	2.27	0.44	4.74	3.85	13.07	0.39	4.24	3.09	0.73	1.06	1.00	17.19
September	1.57	1.78	0.19	3.77	0.86	2.85	2.01	2.59	3.48	3.19	8.25	6.90	2.98	0.58	6.31	3.51	7.51	0.69	2.61	2.10	0.50	0.88	1.00	12.02
October	1.53	1.92	0.59	1.91	5.27	2.39	2.10	1.58	1.26	1.09	2.33	4.68	3.37	0.39	3.25	1.92	1.33	0.29	1.30	1.26	0.88	1.11	1.00	8.11
November	1.86	2.20	1.14	1.95	0.84	0.87	2.34	0.98	1.28	1.11	1.19	4.22	1.88	0.36	2.75	0.82	0.70	0.19	1.05	1.28	1.19	1.23	1.00	4.63
December	2.14	2.33	1.70	3.55	2.59	8.11	2.17	1.58	2.65	1.12	0.18	4.07	2.09	0.18	1.94	0.32	0.14	0.03	0.96	1.30	1.54	1.39	1.00	3.34
	KZ-15 to KZ-26 (1 in 50 Wet Year)																							
January	3.89	3.93	3.61	3.41	4.46	11.08	4.09	4.26	2.24	1.94	3.72	11.44	3.45	2.15	8.65	2.39	138.27	0.74	2.22	5.38	2.38	2.63	2.59	3.09
February	3.95	4.44	4.28	3.45	2.56	4.03	4.14	3.58	2.27	1.96	16.53	8.24	12.62	3.13	10.64	19.40	42.47	7.11	3.93	2.27	2.02	2.66	1.80	5.27
March	4.73	4.48	4.47	3.42	4.34	3.23	4.10	2.95	2.25	4.66	3.20	6.62	3.23	0.70	3.34	2.34	2.00	0.48	1.73	2.25	3.05	2.80	1.00	4.34
April	2.55	2.83	2.38	2.29	0.50	3.37	2.97	1.63	3.07	2.60	2.04	4.80	2.83	0.52	2.07	2.12	1.59	0.23	1.36	1.51	1.33	1.71	1.00	7.81
May	1.10	1.29	0.31	2.31	0.70	12.02	1.97	3.04	3.65	2.95	16.34	5.82	7.39	0.69	8.20	14.42	2.44	2.52	3.09	2.31	0.58	1.23	1.00	11.00
June	1.71	1.86	0.16	2.88	1.66	8.00	2.82	3.06	3.79	3.27	33.18	9.57	4.37	1.65	13.45	8.24	17.69	0.86	3.82	10.08	0.82	1.23	1.00	11.88
July	3.47	3.78	0.25	7.78	1.71	23.66	4.76	2.97	5.69	5.40	6.36	17.85	8.68	1.19	8.41	5.71	18.37	0.89	4.57	5.69	1.40	2.01	1.00	24.11
August	1.75	1.76	0.10	5.38	0.26	5.38	2.07	1.62	2.83	2.45	7.45	14.10	2.08	0.40	4.34	3.53	11.97	0.36	3.89	2.83	0.67	0.97	1.00	15.74
September	2.04	2.32	0.25	4.91	1.12	3.71	2.62	3.37	4.52	4.15	10.72	8.97	3.87	0.76	8.21	4.57	9.77	0.90	3.40	2.73	0.65	1.14	1.00	15.63
October	2.56	3.22	0.99	3.20	8.82	4.00	3.52	2.64	2.10	1.82	3.90	7.84	5.65	0.65	5.44	3.22	2.22	0.48	2.18	2.10	1.48	1.86	1.00	13.59
November	3.16	3.73	1.94	3.31	1.43	1.47	3.98	1.66	2.18	1.88	2.03	7.16	3.20	0.61	4.68	1.39	1.20	0.32	1.79	2.18	2.03	2.08	1.00	7.86
December	3.65	3.99	2.90	6.06	4.42	13.85	3.70	2.69	4.52	1.91	0.31	6.95	3.57	0.31	3.31	0.55	0.23	0.04	1.64	2.22	2.62	2.38	1.00	5.69

YESAB ISSUE

The attenuation of nitrogen compounds (ammonia, nitrite, nitrate) is expected to be high for headwater creeks, such as those which characterize the receiving environment. However, the Proposal does not specify the values used or their justification.

In such creeks, ammonia generally nitrifies to nitrite followed by rapid oxidation of nitrite to nitrate. As such, the ammonia concentration is expected to attenuate during ice-free periods at a rate greater than dilution, and nitrate is expected to be elevated above the diluted concentration. Nitrite is expected to be negligible. The results presented differ from expectations.

R132

"Provide the attenuation factors used in the model for nitrogen compounds and provide justification for their use."

As mentioned in response R131, attenuation factors used in the model were only applied to baseline loads as a calibration factor and the nitrogen loads during construction, operations and closure were not attenuated within the receiving environment.

YESAB ISSUE WITH BMC'S RESPONSE TO R132

The attenuation of nitrogen compounds (ammonia, nitrite, nitrate) is expected to be high for headwater creeks, such as those which characterize the receiving environment. However, the Proposal does not specify the values used or their justification.

In such creeks, ammonia generally nitrifies to nitrite followed by rapid oxidation of nitrite to nitrate. As such, the ammonia concentration is expected to attenuate during ice-free periods at a rate greater than dilution, and nitrate is expected to be elevated above the diluted concentration. Nitrite is expected to be negligible. The results presented differ from expectations.

Insufficient response: The proponent states that the attenuation factor is being applied as a calibration factor for cases where the model was unable to accurately predict baseline concentrations. For transparency, the proponent should show the calibration factor used for each nitrogen compound. It is understood these apply to background loadings only and that no calibration factor was applied to loadings from the project.

R2-65

Provide the attenuation factors used in the model for nitrogen compounds and provide justification for their use.

No attenuation factors were used in the model aside from the calibration factors discussed and provided in the response for R2-64, based on observed baseline water quality data which demonstrate an increase in nitrogen species loads for most months going downstream from KZ-37 to KZ-15 and from KZ-15 to KZ-26. Attenuation, and specifically nitrification of ammonia to nitrite and rapid oxidation to nitrate, was not considered in the model. To address the effect of conversion of all nitrogen species to nitrate, the model was adjusted to assume that 100% of nitrogen from explosives modelled to leach from waste rock piles is in the nitrate form as opposed to the ratios presented in the model report (87% nitrate, 2% nitrite, 11% ammonia). The maximum predicted nitrate-N concentrations at the three modelled locations in the dry year (most conservative) scenario for the base case and where 100% of leached nitrogen from explosives is in the nitrate form are presented in Table 8-23. The calculated and predicted levels of nitrate-N did not exceed the pWQO (3 mg/L) at any station and the maximum predicted concentration (at KZ-37) was ~75% of the pWQO.

Table 8-23: Predicted Maximum Nitrate-N Concentrations in the Base Case (Proportions of Nitrogen Species from Explosives) and where 100% of Nitrogen from Explosives is Nitrate

	Nitrate-N pWQO (mg/L)	Maximum Predicted Nitrate-N - Base Case (mg/L)	Maximum Predicted Nitrate-N - 100% Nitrate from Explosives (mg/L)	Percent Change in Nitrate-N Concentration
KZ-37	3.00	1.96	2.23	14%
KZ-15		0.60	0.66	10%
KZ-26		0.31	0.33	6%

R2-66

The proponent should provide the calibration factor used for each nitrogen compound.

The calibration factors used for nitrogen compounds are provided in the response for R2-64. The derivation of these calibration factors and their application is also presented in R2-64.

9 GROUNDWATER QUALITY AND QUANTITY

YESAB ISSUE

Mine dewatering creates stress on groundwater flow regimes. Assessment of potential effects of mine dewatering on the quantity and quality of groundwater and related surface water are critical aspects of the EA. For ECCC to understand the effect of mine dewatering on quality and quantity of groundwater and surface water hydrology at Kudz Ze Kayah, a thorough understanding of groundwater inflow estimates with respect to the various mine phases is required.

The Proponent has indicated that overburden dewatering will initially be performed for a six-month period to permit access to the bedrock. Overburden dewatering will result in a reduction of the base flow to Geona Creek around the proposed open pit and immediately to the north. The Proponent has proposed flow augmentation in Geona Creek by discharging the ABM pit water into the creek, and is expecting that dewatering of the overburden will not to have any adverse effects on groundwater quality.

Groundwater quality in the overburden will likely differ from the water quality in Geona Creek. Further, mixing of groundwater in the pit from shallow overburden aquifer and bedrock aquifers will result in water quality different from Geona Creek. The overburden and bedrock dewatering will likely have adverse effects on water quality in the receiving environment. The Proponent's plan to discharge the ABM pit water to Geona Creek requires clarification. Further, the discharge water management plan (pp 9-20) has not clearly indicated the types of treatment that will be applied and the resulting water quality to be discharged into the receiving environment.

ECCC notes that the mineralized zone in the pit and underground workings could likely contribute contact groundwater with elevated concentrations of contaminants of concern. In addition, elevated concentrations of contaminants could mix with shallow groundwater via structures and impact water quality of shallow groundwater and receiving environment.

R136

"Provide an assessment of the potential impacts of mine dewatering on quantity and quality of the head waters of Finlayson Creek, unnamed creeks south and southwest of the ABM pit, and the North Lake Systems."

The information requested is an important part of the water quality and quantity assessment. It is provided in the Proposal document appendices, and is referenced and summarized here. The Receiving Environment Water Balance (Appendix D-6 of the Project Proposal) and Water Quality Model (Appendix D-7 of the Project Proposal) both consider the effects of dewatering on the water quality and quantity in Geona Creek, (at site KZ-37), Finlayson Creek (KZ-15 and KZ-26), and South Creek (KZ-13, upstream of the North Lakes).

Water balance modelling (Appendix D-7) included the effects of the Project construction phase (i.e., dewatering) on the receiving water quantity. During the construction phase of the Project, Fault Creek and the catchment areas upstream of the ABM open pit will be diverted into South Creek.

Modelling predicted minimal impact on water quantity in Finlayson and Geona Creeks as a result of these diversions. The predicted changes in discharge in South Creek (modelled at KZ-13, upstream of the North Lake systems) due to the proposed diversions are discussed in the Receiving Environment Water Balance Report (Appendix D-6) and are predicted to be 33 to 36%. However, these modelled values are likely exaggerated slightly due to the drawdown from the small ponds at the top of South Creek throughout the construction and operations phases.

The Water Quality Model (Appendix D-7) estimated constituents of potential interest (COPI) in the Geona Creek and Finlayson Creek receiving environment to be comparable to, or slightly lower than the baseline due to the diversion of Fault Creek and dilution from discharge of ABM open pit dewatering water. Only fluoride was predicted to very marginally exceed its preliminary water quality objective (pWQO) in Geona Creek (at KZ-37) and upper Finlayson Creek (at KZ-15) due to the contribution from pit dewatering. Changes in South Creek (at KZ-13) water quality were predicted for cadmium, selenium and zinc due to the elevated baseline concentrations of these elements in Fault Creek relative to South Creek; however, despite the higher COPI concentrations in the diverted Fault Creek, no constituents were estimated to exceed their respective water quality objectives. As such, the predicted water quality effects of the south diversion to South Creek are of low magnitude.

Although the North Lakes are not included in the current water quality sampling program (2015-present), the North Lakes water quality was examined in the Cominco baseline water quality characterization (Cominco, 1996). Cominco data collected between 1994 and 1995 indicated that metal concentrations in the North Lakes system, both upstream and downstream of the confluence with South Creek, were comparable to, or slightly lower than those observed in South Creek (Cominco, 1996). Low concentrations of metals/metalloids, including the COPIs, were reported such that water quality guidelines were not exceeded in the North Lakes system (Cominco 1996). Additional water quality data were collected between 2002 and 2016 in North Lakes Creek (site KZ-27) as part of the bi-annual aquatic monitoring program under Water Licence QZ97-026 (Laberge Environmental Services and Can-Nic-A-Nick Environmental, 2015, 2017). These studies also reported low metal concentrations that were below water quality guidelines and similar to, or lower than concentrations observed in South Creek. Given the comparable metal concentrations observed in the North Lakes system to that in South Creek, a similar low magnitude effect on water quality in the North Lakes is also anticipated.

YESAB ISSUE WITH BMC'S RESPONSE TO R136

Mine dewatering creates stress on groundwater flow regimes. Assessment of potential effects of mine dewatering on the quantity and quality of groundwater and related surface water are critical aspects of the EA. For ECCC to understand the effect of mine dewatering on quality and quantity of groundwater and surface water hydrology at Kudz Ze Kayah, a thorough understanding of groundwater inflow estimates with respect to the various mine phases is required.

The Proponent has indicated that overburden dewatering will initially be performed for a six-month period to permit access to the bedrock. Overburden dewatering will result in a reduction of the base flow to Geona Creek around the proposed open pit and immediately to the north. The Proponent has proposed flow augmentation in Geona Creek by discharging the ABM pit water into the creek, and is expecting that dewatering of the overburden will not to have any adverse effects on groundwater quality.

Groundwater quality in the overburden will likely differ from the water quality in Geona Creek. Further, mixing of groundwater in the pit from shallow overburden aquifer and bedrock aquifers will result in water quality different from Geona Creek. The overburden and bedrock dewatering will likely have adverse effects on water quality in the receiving environment. The Proponent's plan to discharge the ABM pit water to Geona Creek requires clarification. Further, the discharge water management plan (pp 9-20) has not clearly indicated the types of treatment that will be applied and the resulting water quality to be discharged into the receiving environment.

ECCC notes that the mineralized zone in the pit and underground workings could likely contribute contact groundwater with elevated concentrations of contaminants of concern. In addition, elevated concentrations of contaminants could mix with shallow groundwater via structures and impact water quality of shallow groundwater and receiving environment.

Insufficient response: The proponent has not provided the requested information. Refer also to R105 pertaining to water quantity impacts.

R2-67

Provide an assessment of the potential impacts of mine dewatering on quantity and quality of the head waters of Finlayson Creek, unnamed creeks south and southwest of the ABM pit, and the North Lake Systems.

The dewatering of the ABM pit during mine operation and the formation of ABM lake upon closure of the proposed mine will create a cone of depression of hydraulic heads. The maximum extent of the cone of depression during the final year of mining is presented in Figure 9-5 of the Project Proposal. The residual long-term drawdown of hydraulic heads following mine closure is shown in Figure 9-7 (30 years post mining) of the Project Proposal. Both figures show that the drawdown of hydraulic heads reaches into the Geona Creek, Finlayson Creek and South Creek/North Lakes watersheds. As stream baseflow (i.e., groundwater discharge) depends on the hydraulic head and gradient in the vicinity of the stream, a drawdown of hydraulic heads may result in a decrease in baseflow to the affected streams.

The assessment of potential changes to surface water quantity and quality related to mine dewatering is an important part of the environmental effects assessment and has been addressed in Section 9.4.1.3 of the Project Proposal.

As part of the effects assessment, changes to the flows of the affected streams caused by the diversion of Fault Creek, mine dewatering during operation, and ABM lake formation upon mine closure were assessed. The anticipated changes in stream flows are illustrated in Figure 9-9 of the Project Proposal and below as Figure 9-1.

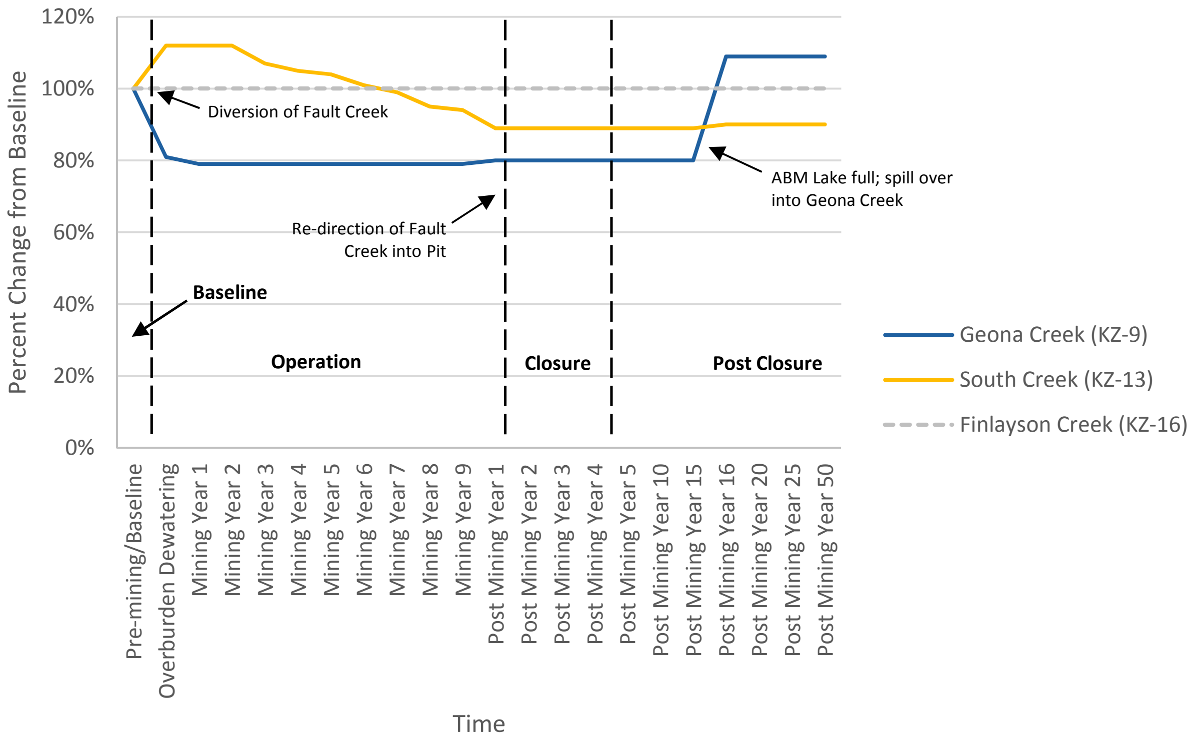


Figure 9-1: Predicted Flow in Geona Creek, South Creek, and Finlayson Creek during Operations, Closure, and Post Closure Relative to Baseline Conditions

Geona Creek

The flow in Geona Creek is anticipated to initially decrease due to the diversion of Fault Creek into the South Creek watershed. The flow will then remain relatively unchanged throughout mine operation, mine closure, and into the early post closure phase. Upon filling of ABM lake, which is estimated to require approximately 16 years following mine closure; water from ABM lake will spill over into Geona Creek, indicated in Figure 9-1 by a sharp increase in flow at KZ-9. The post closure flow in Geona Creek downstream of the mine site will reach a new steady-state equilibrium after approximately 20 years following closure with a flow of approximately 109% relative to baseline conditions. The increase in flow relative to baseline is due to the shift of the water divide between the Geona Creek and South Creek watersheds. This is a change of about 100 m to the south which is caused by the residual drawdown from mine dewatering and the formation of ABM lake. Note that the predicted flows in Figure 9-1 assume that all groundwater extracted for mine dewatering is returned to Geona Creek downstream of station KZ-9.

Finlayson Creek

The cone of depression caused by the mine dewatering and residual drawdown due to the formation of the ABM lake also reaches into the upper Finlayson Creek watershed. However, the predicted changes in piezometric elevations and associated effects on baseflow to Finlayson Creek are so small that no measurable changes in flow are anticipated at station KZ-16, which is located upstream of the confluence with Geona Creek (see Figure 9-1). Changes to the flow in upper Finlayson Creek (station KZ-16) were estimated using the numerical groundwater model to be less than 1% of the baseline conditions.

South Creek / North Lakes System

Figure 9-5 and 9-7 in Chapter 9 of the Project Proposal show that the cone of depression due to mine dewatering and residual drawdown of hydraulic heads due to the formation of the ABM lake will likely have effects on the South Creek and North Lakes watersheds. Due to the location of the South Creek watershed, which is part of the North Lakes System and located immediately to the south of the ABM deposit, it is expected that the most significant changes to water quantity within the South Creek and North Lakes watersheds will be to the flow in South Creek.

The flow in South Creek is expected to initially increase to approximately 112% of the average baseline flow upon the diversion of Fault Creek into South Creek. The flow then decreases gradually over the mine life to approximately 94% of the baseline conditions due to dewatering of the mine workings and the associated reduction in baseflow, and shift of the water divide between the Geona Creek and South Creek watersheds to the south. At closure, Fault Creek will be re-directed back to the north into the ABM open pit which will cause another reduction in South Creek flow by approximately 5% to 89% of the baseline conditions. With the partial recovery of the depressed hydraulic heads after cessation of the mine dewatering, the flow in South Creek will increase slightly again until a new steady-state equilibrium will be reached at approximately 90% of the average baseline flow at KZ-13 (Figure 9 9). The reduction in flow in South Creek will be permanent due to the formation of the ABM lake and the associated hydraulic changes in the area, i.e., shift of the water divide to the south and reduction in baseflow due to a decreased vertical hydraulic gradient.

As there is little spatial overlap between the predicted cone of depression of hydraulic heads and the remaining North Lakes watershed (except for the South Creek sub-watershed; see Figures 9-5 and 9-7 in Chapter 9 of the Project Proposal), no significant effects are expected to the North Lakes System.

Based on the relatively minor anticipated changes in stream flow of Geona Creek, Finlayson Creek, and South Creek, no considerable changes in surface water quality are expected as a result of mine dewatering. Any potentially measurable changes in water quality would be related to a slight reduction in baseflow and hence a smaller contribution of discharging groundwater to the overall stream flow and water quality. As groundwater is typically more mineralized than surface runoff, a smaller groundwater mixing component would be expected to result in a slightly less mineralized surface water quality.

Revised surface water quality predictions are presented and summarized in Appendix R2-C (Project Optimizations and Updated Water Quality Performance Expectations for Kudz Ze Kayah Project), which include the consideration of groundwater flow to surface water.

YESAB ISSUE

The Proponent has not conducted sensitivity analysis to capture those uncertainties associated with fault zone hydraulic properties. Faults may act as a barrier to groundwater flow, or as a conduit. Further analysis of the conductivity of the fault zones is required using the available site data.

R142

"Conduct a sensitivity analyses for the predictive hydrogeological model in order to assess potential impacts on quantity and quality of groundwater inflow to the pit and its impact on surface hydrology. The analysis should address uncertainties associated with fault zone hydraulic properties."

BMC's specialist consultants reviewed this request and in general support the concept of sensitivity analysis as a useful tool; however, upon review of the model it was determined that there is no apparent material benefit as the hydraulic characteristics of the fault zones are reasonably characterized through model calibration and there would be little benefit in performing a formal sensitivity analysis.

The numerical groundwater model includes an adequately detailed description of the preferential flow paths (potential conduits), as these were explicitly incorporated into the model. Discussions of these features are provided in the December 14, 2016 Tetra Tech EBA *Hydrogeological Model, Kudz Ze Kayah Project, Yukon*, (Appendix D-4 of the Project Proposal). The model included the NW-SW fault at the northern end of Geona Creek and three faults in the pit area. No initial assumptions were made regarding the significance of these features on groundwater flow. Through calibration, each of these features had the potential to become high permeability conduits. The final hydraulic conductivities assigned to the features were determined through model calibration, with informal sensitivity being performed during the calibration process. In the final calibrated model, these features did not greatly affect the groundwater flow system. However, this result was not due to pre-modeling assumptions, but rather to the process of model calibration. Assigning significantly higher hydraulic conductivities to these features (as evaluated through informal sensitivity), resulted in a less well calibrated numerical model.

Furthermore, the groundwater input to the ABM pit is included in the February 2017, Alexco Environmental Group report *Water Quality Model, Kudz Ze Kayah Project* (Appendix D-7 of the Project Proposal), which includes conservative assumptions regarding the groundwater chemistry (the 75th percentile of COPI concentrations in bedrock monitoring well samples from the ABM pit vicinity). Given this conservatism, sensitivity testing is not considered warranted.

YESAB ISSUE WITH BMC'S RESPONSE TO R142

The Proponent has not conducted sensitivity analysis to capture those uncertainties associated with fault zone hydraulic properties. Faults may act as a barrier to groundwater flow, or as a conduit. Further analysis of the conductivity of the fault zones is required using the available site data.

Insufficient response: The Proponent did not adequately address the uncertainties associated with the potential impacts of the major geological faults on groundwater-surface water interaction resulting from the project activities.

Conduct a formal sensitivity analysis to address the uncertainties resulting from the potential impacts of the major faults on the water quality and quantity in the project area.

R2-68

Conduct a sensitivity analyses for the predictive hydrogeological model in order to assess potential impacts on quantity and quality of groundwater inflow to the pit and its impact on surface hydrology. The analysis should address uncertainties associated with fault zone hydraulic properties.

As requested, a sensitivity analysis of the hydrogeological model has been undertaken, with a focus on the hydrogeological zones that represent the fault zones that intercept the proposed pit and surrounding bedrock. The sensitivity analysis is presented in **Appendix R2-G** of this Response Report.

The analysis concludes that the base case scenario (presented as Appendix D-4 of the Project Proposal) is a reasonable, yet conservative representation of the actual hydrogeological conditions at the KZK site and that the resulting inflow estimates and ABM lake water budget are sufficiently conservative for the purpose of the KZK Project Proposal and the current level of mine design.

10 AQUATIC ECOSYSTEM RESOURCES

YESAB ISSUE

The Proponent has proposed in their preliminary offsetting plan an option involving restoration of fish passage for the Robert Campbell Highway culvert crossing of Finlayson Creek.

The Proponent has identified that this culvert crossing structure is the responsibility (ownership) of the Yukon Government Highways and Public Works.

DFO's preference is for an open bottom structure (clear span or arch culvert) that mimics the natural stream channel to have confidence in the permanence of fish passage restoration.

Baseline information is available for Genoa Creek as well as for some locations in East Creek and in Finlayson Creek upstream of the Robert Campbell Highway; however, there is limited baseline information for areas in Finlayson Creek downstream of the Robert Campbell Highway and in the surrounding areas of the Finlayson River. The baseline data is required for both upper and lower reaches in sufficient quantity as to clearly demonstrate what the gaps in fisheries productivity are. The intent of offsetting measures is to result in increased fisheries productivity. The effectiveness monitoring plan and associated performance measures, in conjunction with the baseline data, should be robust enough to demonstrate that an overall increase in fisheries productivity has resulted and not simply a redistribution of fisheries productivity.

The Proponent cites two recent DFO guidance documents for the proposed Fish Offsetting plan in Appendix E-4:

- *Fisheries and Oceans Canada (DFO). 2013a. Implementing the New Fisheries Protection Provisions under the Fisheries Act. Discussion Paper. Fisheries and Oceans Canada, April 2013.*
- *Fisheries and Oceans Canada (DFO). 2013b. An Applicant's Guide to Submitting an Application for Authorization under Paragraph 35(2)(b) of the Fisheries Act, November 2013.*

However, the most recent Fisheries Productivity Investment Policy: A Proponent's Guide to Offsetting (DFO, 2013c) is not cited and it is not clear if this guidance was used. The proposed offsetting plan generally includes most of elements prescribed by DFO (2013c). However, some suggested components are not included in the plan. Losses and gains are not particularly well quantified and uncertainty is not accounted for.

R143

"Provide additional information in relation to the Fish Offsetting Plan as presented in Appendix 4. Details should include a discussion on:

a. the feasibility of including the culvert restoration as part of the plan given it is the jurisdiction of the Government of Yukon;

b. ***other potential offsetting measures that have been explored with reasons for discounting them;***
c. ***how the plan will take into account the most recent DFO policy, Fisheries Productivity Investment Policy: A Proponent's Guide to Offsetting (DFO, 2013c), including how the guidance will be incorporated into a revised offsetting plan (e.g., quantifying losses and gains, and accounting for uncertainties)."***

a. the feasibility of including the culvert restoration as part of the plan given it is the jurisdiction of the Government of Yukon

Discussions with several staff with the Government of the Yukon, Highways and Public Works (HPW), during the summer of 2016 indicated that they would be in favor of an endeavor to provide fish passage through the culvert to allow migratory species to access fish habitat upstream of the highway, as they are aware that the culverts are currently a barrier to fish passage (A. McCoy 2016. Manager Environmental Affairs HPW, pers. comm. 23 August). Approvals however, would be dependent on review from the Highway Engineering department, HPW. This has been identified as an opportunity to collaborate with BMC as there are no plans to replace the culverts for at least the next 10 years.

b. other potential offsetting measures that have been explored with reasons for discounting them

A list of potential fish habitat compensation options considered by BMC is provided below for evaluation. A preferred option(s) has been selected and a plan developed as discussed in detail in the following. The plan remains flexible in order to ensure it is adequate to provide sufficient fish habitat creation and improvement to offset losses. Any changes to the plan will be determined during the detailed design phase of the Fish Offsetting Plan (FOP), or if necessary, prior to that phase as a result of discussions with DFO and/or First Nations. Options considered are listed and discussed in detail below.

Each of these options was assessed based on the proximity of the Offsetting measures to the habitat that will be impacted, the similarity of the habitat to the impacts, if the area of compensation or the benefits gained are comparable, the environmental benefit, and the community/First Nations benefit (Table 10-1 and Table 10-2).

Table 10-1: Ratings Used to Compare Potential Fish Habitat Compensation Projects

Classification	Criteria/Rating	Value
Proximity to Impacted Habitat	Within LSA	1
	Within RSA	0
	Outside RSA	-1
Similarity to Impacted Habitat	Same	1
	Different	-1
Approximate Area of Compensation/Equivalence	Larger than Impacted Habitat	1
	Similar to Impacted Habitat	0
	Smaller than Impacted Habitat	-1

Classification	Criteria/Rating	Value
Environmental Benefit	High	1
	Moderate	0
	Low	-1
Community/Aboriginal Benefit	High	1
	Moderate	0
	Low	-1

Table 10-2: Comparison of Potential Fish Habitat Compensation Projects

Option	Proximity	Similarity/ Connectivity	Area Equivalence	Environmental Benefit	Community/ Aboriginal Benefit	Sum
Cominco FHCP	1	-1	0	0	-1	-1
East Creek Fish Passage	1	-1	-1	-1	-1	-3
South Lakes habitat enhancement	1	1	-1	-1	-1	-1
Finlayson Fish Passage	0	-1	1	1	1	2
Geona Creek habitat replacement	1	1	-1	0	-1	0

Cominco FHCP

The previous owners of the KZK property (i.e., Cominco Ltd) successfully obtained a *Fisheries Act* Authorization (FAA) in 1997 under previous requirements of the *Fisheries Act* (Authorization Yukon Area 1997-03), which allowed the company to undertake harmful alteration of fish habitat in the upper Geona Creek valley. The FAA largely relied on a Fish Habitat Compensation Plan (FHCP) to "ensure no net loss of fish production." The plan consisted of stocking two barren lakes in the local area primarily with Arctic grayling that were salvaged from upper Geona Creek and creation of new habitat, including an Arctic grayling spawning area in the upper South Creek drainage, resulting from a permanent diversion of Fault Creek from the Geona Creek watershed to the South Creek watershed.

Although previously approved by DFO in 1997 as an acceptable FHCP, the previous mine development proposal by another company had a larger footprint than the current design and intended to permanently divert Fault Creek into the South Lakes system (Section 1.3, Appendix E-4 of the Project Proposal). BMC has designed their Project footprint to have less impact on the Geona Creek watershed, and intends on restoring the site to as close to pre-existing conditions as practicable, which includes restoring Fault Creek back to the Geona Creek watershed during mine closure (Section 6).

For these reasons, the Cominco FHCP received the second lowest ranking. In addition, very few Arctic grayling actually inhabit Geona Creek. Therefore, the stocking program would have to access fish from outside the watershed to have any chance of success and would not provide any community benefit.

East Creek

The East Creek drainage appeared to be devoid of fish upstream of the beaver dams, based on extensive electrofishing in that area over the study period. Hubert et al. 1995 reported over 700 grayling moving upstream captured in a fish trap at the confluence with Geona Creek; however, current populations appear much lower (Section 4.2.1, Appendix E-4 of the Project Proposal). Numerous large beaver dams are now fish migration barriers, especially at low flows, reducing spawning availability and appear to have impacted the population. BMC considered opening up East Creek for passage as part of its FOP, but this plan received a low score based on the fact that is it a small creek, and although recruitment might increase marginally in Geona Creek as a result, it would provide low environmental benefit, and no community benefits. Additionally, keeping the creek free of beaver impoundments would be an ongoing issue.

South Lake Creek

The temporary diversion of Fault Creek into the upper reach of the South Creek/Lake system during operations will result in the creation of approximately 800 m^2 of fish habitat during the life of the mine. BMC considered the incorporation of fish habitat enhancement measures as part of the options assessment, as quality spawning habitat appears to be limiting to fish populations throughout the LSA. This plan received a low score given the fact that the diversion is temporary, and as a result would ultimately provide a low (short term) environmental benefit and no community benefit.

Finlayson Fisheries Passage

Concerns were noted by the Ross River Dena Council during public meetings, regarding the lack of fish passage through the twin culverts on Finlayson Creek at the Robert Campbell Highway (Table 2-3 in Chapter 2 of the Project Proposal). As a result, BMC investigated the crossing in the summer of 2016 as a potential FOP (Section 7.2 of Appendix E-4 of the Project Proposal). BMC fisheries biologists identified that the culverts appeared to be a complete barrier to fish passage under current conditions. As such, BMC included the possibility of providing fish passage by the way of a culvert backflood or bypass channel at the highway as part of the comparison of potential FOPs.

The Fish Passage plan for Finlayson Creek received the highest rating according to the comparison of potential FOPs based on the fact that it would provide a high Environmental Benefit by allowing migratory fish to once again access fish habitat in the Finlayson Creek watershed, including Geona Creek, and provide a community benefit with an increase in recruitment in the watershed by opening up 40 km of potential spawning habitat. This is discussed further in Section 7.2 of Appendix E-4, of the Project Proposal. The main shortcoming of this option is the distance from the Project site that the measure would occur; however, this is outweighed by the magnitude of the increase in potential spawning habitat which would extend to the Project site.

Geona Creek Habitat Enhancement

Current mine plans will result in a loss or isolation of approximately 5.4 ha of Geona Creek, therefore the first area that was considered for a potential FOP was in the immediate area downstream of the habitat loss. As described in the application, the watershed will be divided to accommodate construction of mine and waste storage facilities, and the conveyance of clean (non-contact) water downstream of mining operations. Potential fish habitat offsetting opportunities identified, included the development of pond habitat in lower Geona Creek to replace and offset loss of pond habitat in upper Geona Creek, and the development of Arctic grayling spawning habitat at the heads of the created ponds to replace and offset loss of grayling spawning habitat in upper Geona Creek.

Although the preferred option would be to complete the entire FOP in the Geona Creek watershed, limited opportunities were available. As a result of the incised nature of the valley, and short length of the stream (9.1 km), only an opportunity to compensate for the pond habitat was identified.

The pond replacement and spawning habitat creation FOP received the second highest rating during the comparison. Rating was lowered by the facts that habitat compensation only replaced pond habitat and there was no community benefit.

Summary

Even though the avoidance and mitigation measures are extensive, there will still be a residual impact to the fish and fish habitat of Geona Creek. There was limited opportunity to complete the required FOP in the Geona Creek watershed, as it was determined that only the pond habitat could be replaced. Therefore, BMC compared other opportunities within the RSA to compliment the creation of pond habitat in Geona Creek.

Four FOP opportunities were identified within the RSA and compared for their respective benefits; including benefits to the environment and community (presented in Table 10-2 above). A potential fish passage problem on the Robert Campbell Highway, as identified by the community, received the highest rating when compared to other potential projects and was further investigated by BMC (Table 10-2, above).

The comparison of potential FOP projects indicated that no project would fully replace the impacted habitat if conducted alone. However, the combination of Finlayson Creek Fish Passage and Geona Creek Pond/Spawning Habitat Replacement would result in a benefit/positive impact for each of the five rating categories used to compare the potential habitat improvement projects.

Therefore, three major offsetting measures are proposed in this plan to offset the impacts to fish habitat and to maintain or enhance the productive capacity of the system for Arctic grayling include:

- Development of pond habitat in lower Geona Creek to replace and offset loss of pond habitat in upper Geona Creek;
- Development of Arctic grayling spawning habitat at the heads of the created ponds to replace and offset loss of grayling spawning habitat in upper Geona Creek; and

- Reconnect fish habitat in Finlayson Creek by enhancing fish passage through the culverts at the Robert Campbell Highway that are currently acting as a barrier to fish passage in lower Finlayson Creek to replace the 5.4 km loss in Geona Creek with approximately 40 km of newly accessible fish habitat.

c. ***how the plan will take into account the most recent DFO policy, Fisheries Productivity Investment Policy: A Proponent's Guide to Offsetting (DFO, 2013c), including how the guidance will be incorporated into a revised offsetting plan (e.g., quantifying losses and gains, and accounting for uncertainties)."***

BMC has incorporated mitigation measures into the Project design to ensure there is not likely to be serious harm to fish as a result of the Project. However, the loss of fish habitat in upper Geona Creek is unavoidable. To compensate for the loss of fish habitat, in accordance with the *Fisheries Productivity Investment Policy: A Proponent's Guide to Offsetting (DFO, 2013c)* BMC has developed a plan to undertake offsetting measures to counterbalance the unavoidable residual loss of habitat. Offsetting measures, also known as offsets, are measures that are undertaken to counterbalance unavoidable harm to fish resulting from a Project, with the goal of maintaining or improving the productivity of the commercial, recreational or Aboriginal fishery.

The proposed Fisheries Offsetting plan developed by BMC, includes increasing the productive capacity for fish in Geona Creek and providing over a 10 fold increase in the amount of available habitat for migratory species in Finlayson Creek by allowing access for fish upstream of the Robert Campbell highway, which is currently impedes fish passage (Aquatic Ecosystem Baseline Report; Appendix E-3 of the Project Proposal).

YESAB ISSUE WITH BMC'S RESPONSE TO R143

The Proponent has proposed in their preliminary offsetting plan an option involving restoration of fish passage for the Robert Campbell Highway culvert crossing of Finlayson Creek.

The Proponent has identified that this culvert crossing structure is the responsibility (ownership) of the Yukon Government Highways and Public Works.

DFO's preference is for an open bottom structure (clear span or arch culvert) that mimics the natural stream channel to have confidence in the permanence of fish passage restoration.

Baseline information is available for Genoa Creek as well as for some locations in East Creek and in Finlayson Creek upstream of the Robert Campbell Highway; however, there is limited baseline information for areas in Finlayson Creek downstream of the Robert Campbell Highway and in the surrounding areas of the Finlayson River. The baseline data is required for both upper and lower reaches in sufficient quantity as to clearly demonstrate what the gaps in fisheries productivity are. The intent of offsetting measures is to result in increased fisheries productivity. The effectiveness monitoring plan and associated performance measures, in conjunction with the baseline data, should be robust enough to demonstrate that an overall increase in fisheries productivity has resulted and not simply a redistribution of fisheries productivity.

The Proponent cites two recent DFO guidance documents for the proposed Fish Offsetting plan in Appendix E-4:

• Fisheries and Oceans Canada (DFO). 2013a. Implementing the New Fisheries Protection Provisions under the Fisheries Act. Discussion Paper. Fisheries and Oceans Canada, April 2013.
• Fisheries and Oceans Canada (DFO). 2013b. An Applicant's Guide to Submitting an Application for Authorization under Paragraph 35(2)(b) of the Fisheries Act, November 2013.

However, the most recent Fisheries Productivity Investment Policy: A Proponent's Guide to Offsetting (DFO, 2013c) is not cited and it is not clear if this guidance was used. The proposed offsetting plan generally includes most of elements prescribed by DFO (2013c). However, some suggested components are not included in the plan. Losses and gains are not particularly well quantified and uncertainty is not accounted for.

Insufficient response: Although feasibility is addressed somewhat, the likelihood of culvert replacement occurring sooner than 10 years from now is not clear.

The rating system used to evaluate potential fish habitat compensation projects is reasonable. Ratings determined for most classifications are generally understood; however, the basis for determining the ratings for Environmental Benefit and Community/Aboriginal benefit is not clear.

R2-69

Provide additional information in relation to the Fish Offsetting Plan as presented in Appendix 4. Details should include a discussion on:

a. the feasibility of including the culvert restoration as part of the plan given it is the jurisdiction of the Government of Yukon;

On July 26, 2017 BMC representatives met with representatives from DFO, HPW and DAB. During the meeting BMC presented the FOP options that were provided in response to IR143a. There was consensus in the meeting that of the options proposed, removing the fish barrier at the culvert was the preferred option presented (in conjunction with the Geona Creek FOP option). The remainder of the meeting focussed on the options, timing and feasibility of removing the fish barrier.

Following the July 26th meeting, HPW met internally to discuss whether or not the department is amenable to the proposed Finlayson creek fish passage proposal, as well as whether or not the Department would consider the cost sharing for the installation of a structure that would in effect remove the fish barrier.

On October 12, 2017 BMC received notification from YG (via email from Monique Chatterton of Major Projects Yukon), that HPW's preference for addressing fish passage considerations at the Finlayson Creek crossing is in the form of a cost-sharing agreement between YG – HPW and BMC for the future replacement of the culvert. HPW would undertake the replacement of the culvert, with one that would then facilitate fish passage upstream of the road crossing. The culvert would become part of HPW infrastructure and would be maintained/repaired as part of their regular maintenance operations. HPW expects that the culvert replacement would likely be addressed within the next 3 to

10 years, but would also be dependent upon funding and work priorities. Subsequently, BMC will be having further discussions with HPW's directors and other managers regarding a cost sharing agreement and clarification regarding the timelines of when this component of the FOP could proceed (as the ideal timing would a shorter timeframe of the next 3 to 5 years).

b. other potential offsetting measures that have been explored with reasons for discounting them;

Other offsetting measures that have been explored with reasons for discounting them were presented in the Options assessment, which was a component of BMC's response to R143b (re-presented above).

c. how the plan will take into account the most recent DFO policy, Fisheries Productivity Investment Policy: A Proponent's Guide to Offsetting (DFO, 2013c), including how the guidance will be incorporated into a revised offsetting plan (e.g., quantifying losses and gains, and accounting for uncertainties).

BMC's plan to take into account the most recent DFO policy (2013c) was presented in BMC's response to R143c (re-presented above).

R2-70

Please provide some assurance that the proposed compensation can proceed within a shorter timeframe.

Please see response to R2-69a. The Geona Creek component of the FOP can start during the construction phase of the Project. Ideally the fish barrier can be removed at the culvert also during the construction period. Discussions with HPW are ongoing.

R2-71

How were High, Medium and Low values quantified?

The High, Medium, and Low values were simply a tool used to rank each of the FOP options/projects based on each classification. Values for each classification were not weighted based on importance (i.e. each classification used the same values for High, Medium and Low (i.e. 1, 0 or -1). Each value assigned to each classification was based on BMC's team of fish biologist's professional opinions. Note that on July 26 2017, BMC representatives met with representatives from DFO, HPW and DAB. During the meeting BMC presented the FOP options that were provided in response to IR143a. There was consensus in the meeting that, of the options proposed, removing the fish barrier at the culvert was the preferred option presented (in conjunction with the Geona Creek FOP option). Using a different ranking system would result in the same outcome, given the amount of fish habitat that would be opened up from the proposed fish barrier removal, compared to the other options assessed.

YESAB ISSUE

The proponent has chosen Arctic grayling for monitoring aquatic health among fish species. To identify potential effects, they state they will monitor for changes in fish distribution (presence/absence data), abundance estimates and fish condition factor. As it is currently written, the proponent has only used presence and absence electrofishing techniques to establish their baseline. They did not adequately sample for abundance, nor did we see estimates of condition factor.

The data above will aid in standardizing the sampling effort and therefore allow for repeatability when estimating abundance. To adequately address fish abundance the proponent should include the following:

- *To adequately sample for abundance the proponent must establish electrofishing stations of a defined length.*
- *UTMs should be reported at the top and bottom of each station (So that repeat trials can occur within each station, among years).*
- *Water conductivity and temperature, for each station, at the time of each sampling should be reported.*
- *Stream stage should be reported (How deep was the section (station) of stream, where and when it was sampled).*
- *Wetted width should also be reported within the section (station) area.*
- *Preferably, each station should be block netted and a removal method employed to allow for a reasonable assessment of abundance. Several sweeps (passes) should occur within each station*
- *Control stations should be established outside any potential impact area.*
- *Estimates or indices, of species abundance should be established for each station.*

R147

"Demonstrate how abundance estimates and fish condition factor have been considered in the sampling to date and proposed sampling moving forward."

During the 2015 and 2016 baseline monitoring programs, only one adult Grayling was captured during the sampling in Geona Creek and very low numbers of juveniles were encountered in each sampling event (i.e. < 10). As it is very difficult to calculate condition factor with any certainty for juvenile fish in such a rapid state of development, condition factor data were not presented.

R143 presented the monitoring plan moving forward. Spawning surveys will continue as indicated in R143.

The replacement of lost pond habitat as part of the FOP, will be constructed to provide higher quality habitat for both overwintering and spawning, which are considered limiting factors in Geona Creek.

With the implementation of the FOP, BMC expects fish recruitment to increase within Finlayson and Geona Creeks. With the corresponding increase in adult fish, population estimates and condition factors will be possible to calculate and included in annual reports.

YESAB ISSUE WITH BMC'S RESPONSE TO R143

The proponent has chosen Arctic grayling for monitoring aquatic health among fish species. To identify potential effects they state they will monitor for changes in fish distribution (presence/absence data), abundance estimates and fish condition factor. As it is currently written, the proponent has only used presence and absence electrofishing techniques to establish their baseline. They did not adequately sample for abundance, nor did we see estimates of condition factor.

The data above will aid in standardizing the sampling effort and therefore allow for repeatability when estimating abundance. To adequately address fish abundance the proponent should include the following:

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- *Water conductivity and temperature, for each station, at the time of each sampling should be reported.*
- *Stream stage should be reported (How deep was the section (station) of stream, where and when it was sampled).*
- *Wetted width should also be reported within the section (station) area.*
- *Preferably, each station should be block netted and a removal method employed to allow for a reasonable assessment of abundance. Several sweeps (passes) should occur within each station*
- *Control stations should be established outside any potential impact area.*
- *Estimates or indices, of species abundance should be established for each station.*

Insufficient response: Confirmation of proper reference is needed, therefore follow-up is suggested.

Insufficient response: The response identifies that fish tissue guidelines used will be CCME guidelines for protection of wildlife consumers, and CFIA guidelines for marketed fish. It also explains why testing on Arctic Grayling is not proposed (limited distribution and low population). Selenium is not included in the cited guidelines although BCMOE has guidelines for selenium in fish tissue based both fish health and human health considerations.

R2-72

Demonstrate how abundance estimates and fish condition factor have been considered in the sampling to date and proposed sampling moving forward.

During the 2015 and 2016 baseline monitoring programs, only one adult grayling was captured during the sampling in Geona Creek and very low numbers of juveniles were encountered in each sampling event (i.e. less than 10). It is very difficult to calculate condition factor with any significance for juvenile fish in such a rapid state of development. For instance, Arctic grayling juvenile growth rates are highly variable and dependent on food availability and water temperature. Deegan et al (1999) found that 60% of the variance in age-0 grayling weight at 40 days was associated with nutrient level, mean summer discharge and mean summer temperature. As a result of the highly variable flows and water temperatures experienced in Geona Creek during the assessment period, the comparison of a few juvenile individuals condition factors is not considered appropriate or useful for comparison to future monitoring programs (which will focus on assessment of condition factors of adults in the system, following the implementation of the FOP).

The following was presented as part of BMC's response to IR144 (BMC, 2017) as to how BMC will collect abundance estimates and condition factor information following the implementation of the FOP:

> *"A semi-quantitative fish sampling program will be conducted on an annual basis to monitor fish use in Geona, Finlayson, and South Creeks as has been completed in previous years (Appendix E-3 of the Project Proposal). Additional sampling will be conducted in the developed pond habitat in Geona Creek, once they are constructed. Sampling will be conducted in the spring, summer, fall and winter (overwintering determination). Fish sampling methods will include electrofishing, minnow trapping, beach seining, angling, and visual observations. Overwintering sampling may only include minnow trapping and visual observation which may be aided by the use of an underwater camera. All fish captured will be identified and enumerated, measured for fork length (mm) or total length, weighed, observed for abnormalities, and released at the location of capture. Results will be reported as Catch per Unit Effort (CPUE) to enable spatial and temporal comparisons as well as to provide a semi-quantitative assessment. Additional supporting information that will be collected includes: physical description and photo documentation of sampling locations, in situ water parameters (temperature, dissolved oxygen, conductivity) as well as weather conditions at time of sampling. A scientific collection licence that allows for fish sampling will be obtained from the DFO prior to sampling and a final report will be prepared and submitted to DFO at the termination of the assessment period as will be required as a condition of the permit."*

More specifically, condition factor will be measured as the ratio of body weight to body length and will be classified as follows in Table 10-3.

Table 10-3: Fish Health Condition Factor Values*

Condition Factor (K Value)	Fish Condition
1.60	Excellent condition
1.40	A good, well proportioned fish
1.20	A fair fish
1.00	A poor fish, long and thin
0.80	Extremely poor fish, big head and narrow, thin body

*Source = State of Victoria, Department of Primary industries Australia

R2-73

Please confirm that the references to R143 in the response should be to R144.

The reference to R143 in the initial response was indeed incorrect and should have referenced the response to R144.

YESAB ISSUE

Section 10.6.5 of the Proposal states that fish tissue monitoring for heavy metals and selenium will be conducted as per the existing water license, every two years, at Finlayson Creek stations, using slimy sculpins as the target species. There is no mention of how the fish tissue quality data will be interpreted, for example, by examination of trend, or by comparison to fish tissue guidelines. In the latter case, fish tissue guidelines, such as the BCMOE guidelines for selenium or others, have not been identified in the Proposal.

Metals Testing in fish was limited to Slimy Sculpin from the Geona Creek and Finlayson Creek systems. The South Creek, North Creek, and North Lakes systems have also been under represented for metals sampling. This sampling is of particular importance for the North Lake which is an important fisheries resource for First Nations in the area.

R148

"Identify the criteria to be used in the interpretation of fish tissue monitoring data over the course of the Project."

Fish tissue monitoring will continue as part of the Aquatic Effects Monitoring Program throughout the life of the Project. As discussed, very few fish are found in Finlayson Creek, but the three fish sampling sites are currently used as part of the water licence sampling program, and are known to have adequate populations of slimy sculpin to complete a tissue sampling program every two years throughout the life of the Project. These sites are located on Finlayson Creek (KZ15, KZ16, and KZ26) and are distributed throughout the upper reaches of the watershed. There are no sculpin in Geona Creek and very few Grayling, and therefore we are unable to include Geona Creek in the tissue sampling program.

The most upstream site in Finlayson Creek is at KZ16 (which is located along the Tote Road crossing of Finlayson Creek) approximately 10 km north of the BMC exploration camp and upstream of the confluence with Geona Creek. This site serves as a reference site. The site elevation is approximately 1,260 masl and is situated in a sub-alpine ecology consisting of expanses of dwarf birch and several species of riparian willow.

Site KZ15 on Finlayson Creek is just below the Geona Creek confluence, approximately four kilometres downstream of site KZ16. KZ15 represents a fish monitoring site for receiving waters originating from Geona Creek. The elevation of this site is 1,220 masl with riparian habitat consisting of large overhanging willows and patches of tall mature spruce trees forming a canopy with a moss covered forest floor.

Site KZ26 is at the location where the Robert Campbell Highway crosses Finlayson Creek. Two large multiplate culverts are installed at this location to convey flows of Finlayson Creek. Previous assessments have suggested that the crossing may act as a velocity barrier to upstream movement of fish during high flow periods. Quantitatively, site KZ26 represents the best aquatic habitat values compared to the other monitoring sites. The site also serves as a monitoring location that is well downstream and away from the exploration activities. The site is located just above the Finlayson River confluence at an elevation of approximately 964 masl and is characterized with dense stands of mature spruce and willow that dominate the riparian area.

Fish tissue sampling will be conducted in late summer. The presumption is that during the late summer fish distributions are at a maximum throughout the drainage. Late summer (July and August) also corresponds to a temporal period where streams reach their maximum temperatures and have their greatest densities of benthic organisms. The summer is the primary growth period for northern species of fish who forage on food items throughout the drainage, including reaches that are likely inaccessible during winter low flow periods.

Because of their importance in nutrient cycling and as a food source for fish, benthic invertebrates can provide a means of metals transfer to higher trophic levels. A major component of the diet of slimy sculpins is benthic invertebrates, particularly aquatic insect larvae. Sculpins from the three sites on Finlayson Creek will be sampled continually on an annual basis for metals throughout the life of the project.

Fish tissue samples will be compared to previous samples collected as part of the Water Licence and compared among sites. Sample results will additionally be compared to the current CCME (2004) guidelines for the protection of wildlife consumers of aquatic biota, that address those substances for which aquatic food sources are the main route of exposure. These guidelines apply to any aquatic species consumed by wildlife, including fish, shellfish, invertebrates, or aquatic plants. The tissue recommended guidelines (TRGs) represent the concentration of the specific contaminant in an aquatic organism that is not expected to result in adverse effects if consumed by other wildlife.

Conversely, the Canadian Food Inspection Agency (2009) has also developed TRGs for chemical contaminants and toxins in Canadian fish and fish products. These guidelines were prepared to promote product and processing standards that contribute to the achievement of acceptable quality and health safety of fish and seafood products in the consumer marketplace. For comparative purposes, the values for three of the elements (arsenic, lead and mercury) listed by the Canadian Food Inspection Agency will be compared to whole body slimy sculpins sampled from the three monitoring sites.

Note that, no impacts are predicted in North Lakes; therefore, it is not considered prudent to intrusively sample these lakes.

YESAB ISSUE WITH BMC'S RESPONSE TO R148

Section 10.6.5 of the Proposal states that fish tissue monitoring for heavy metals and selenium will be conducted as per the existing water license, every two years, at Finlayson Creek stations, using slimy sculpins as the target species. There is no mention of how the fish tissue quality data will be interpreted, for example, by examination of trend, or by comparison to fish tissue guidelines. In the latter case, fish tissue guidelines, such as the BCMOE guidelines for selenium or others, have not been identified in the Proposal.

Metals Testing in fish was limited to Slimy Sculpin from the Geona Creek and Finlayson Creek systems. The South Creek, North Creek, and North Lakes systems have also been under represented for metals sampling. This sampling is of particular importance for the North Lake which is an important fisheries resource for First Nations in the area.

Insufficient response: The response identifies that fish tissue guidelines used will be CCME guidelines for protection of wildlife consumers, and CFIA guidelines for marketed fish. It also explains why testing on Arctic Grayling is not proposed (limited distribution and low population). Selenium is not included in the cited guidelines although BCMOE has guidelines for selenium in fish tissue based both fish health and human health considerations.

R2-74

***Identify the criteria to be used in the interpretation of fish tissue monitoring data over the course of the Project**.*

BMC will compare selenium concentrations in fish tissue samples to the BCMOE guideline. Note that in the event that new guidelines are approved by BC or Health Canada prior to construction then the most applicable/most recent selenium guideline will be used.

R2-75

Given that selenium is not included in the cited guidelines, and that selenium uptake to fish is of concern, the Proponent should explain why selenium in fish tissue is not part of the proposed program or include selenium in fish tissue as part of the proposed program.

Selenium has been measured in the sculpin fish tissue monitoring program as part of the Project's Type A Water Licence monitoring requirements. Years of monitoring the concentrations of selenium are: 1995, 2002, 2004, 2006, 2008, 2010, 2012, 2014 and 2016. This data (up to and including 2014) is summarized in Figure 3-2 of the Fish and Aquatics Baseline Report (Appendix E-3 of the Project Proposal). Selenium will continue to be analysed in fish tissue as part of the proposed monitoring program. Selenium is a standard parameter that qualified laboratories analyse as part of their general "metals analysis package".

YESAB ISSUE

The proposed procedures for "careful control" of Project discharge water to meet WQOs in the receiving environment at all times are not clearly defined. The surface water management strategy described in Section 18.4.2 of the project proposal states that "Water will be discharged to both Geona Creek and Finlayson Creek at established water quality discharge standard concentrations and at discharge volume ratios no less than 3:1 (receiving water volume: effluent volume) for Geona Creek at KZ-37 and 2:1 for Finlayson Creek at KZ-15 to meet water quality objectives in the receiving environment". However, in Section 8.4.2 we do not see a description of how the effluent discharge will be controlled to ensure the WQOs are met. On one hand, the Proponent has suggested that the effluent meet MMER standards for release of deleterious substances. On the other hand, many of the proposed WQOs are variable, as discussed in section 6.3.3, and are adjusted based on water hardness or other parameters in the receiving environment.

It is important for reviewers to understand how the Proponent will manage effluent during releases to meet the WQOs. For example, is the Proponent suggesting that receiving environment conditions that affect the WQOs be considered prior to discharge to ensure no exceedance of WQOs upon discharge?

R154

"Provide details to demonstrate that there will be adequate storage capacity for effluent to allow holdback and controlled release of effluent."

The Upper and Lower Water Management Ponds have capacities of 250,000 m^3 and 500,000 m^3, respectively, and are both designed for 1:200 year 24-hour storm events, as stated in Section 18.4, Chapter 18 of the Project Proposal. The estimated water volumes present in the combined water management ponds on a monthly basis are shown in Table 10-4 (from Table 5-4, Appendix D-7 of the Project Proposal). Considering the highest estimated monthly volume (1/50 wet year, March), 54,000 m^3 of additional capacity would be available at minimum for effluent holdback and release.

Table 10-4: Estimated Water Volume Present in the water management ponds on a Monthly Basis (m^3) (Table 5-4, Appendix D-7)

	Mean	1/50 Wet Year	1/10 Dry Year
January	137,500	396,000	296,500
February	252,250	534,000	427,750
March	389,500	695,750	574,500
April	367,500	634,750	560,500
May	286,000	565,750	289,500
June	267,000	599,000	68,000
July	69,000	245,000	39,000
August	37,000	214,000	0[a]
September	27,000	0[a]	3,000
October	0[a]	114,000	46,000
November	3,000	181,000	97,500

	Mean	1/50 Wet Year	1/10 Dry Year
December	50,000	274,500	183,000

[a] In practice, the WMPs would not be pumped to a volume of zero.

For clarity, the Proponent is not suggesting that receiving environment conditions that affect the WQOs be considered prior to discharge to ensure no exceedance of WQOs upon discharge. It would not be feasible to measure COPI concentrations in the receiving environment and then adjust the concentrations in the discharge. Instead, the EQS could be set based on the dry year modelled scenario, at the lowest mixing ratio within Geona Creek and using the most sensitive month for each COPI. This should result in no (or very few) WQO exceedances. This approach is outlined in the response to R156.

YESAB ISSUE WITH BMC'S RESPONSE TO R154

The proposed procedures for "careful control" of Project discharge water to meet WQOs in the receiving environment at all times are not clearly defined. The surface water management strategy described in Section 18.4.2 of the project proposal states that "Water will be discharged to both Geona Creek and Finlayson Creek at established water quality discharge standard concentrations and at discharge volume ratios no less than 3:1 (receiving water volume: effluent volume) for Geona Creek at KZ-37 and 2:1 for Finlayson Creek at KZ-15 to meet water quality objectives in the receiving environment". However, in Section 8.4.2 we do not see a description of how the effluent discharge will be controlled to ensure the WQOs are met. On one hand, the Proponent has suggested that the effluent meet MMER standards for release of deleterious substances. On the other hand, many of the proposed WQOs are variable, as discussed in section 6.3.3, and are adjusted based on water hardness or other parameters in the receiving environment.

It is important for reviewers to understand how the Proponent will manage effluent during releases to meet the WQOs. For example, is the Proponent suggesting that receiving environment conditions that affect the WQOs be considered prior to discharge to ensure no exceedance of WQOs upon discharge?

Insufficient response: The proponent restated the information already presented in the project proposal. The intent of the question was for BMC to demonstrate that the 54,000 m^3 of additional storage was sufficient capacity to provide adequate storage of effluent to protect downstream water quality during periods of limited dilution (i.e., allow for holdback and controlled release of effluent).

R2-76

Provide details to demonstrate that there will be adequate storage capacity for effluent to allow holdback and controlled release of effluent.

On October 17 2017, YESAB provided (via email) the following clarification regarding the information required in response to R2-76:

> *"This question is related to pond sizing and capacity to retain water when needed. We require additional details demonstrating that there is sufficient storage to manage water during times*

> *when discharge will be limited. For example, is there sufficient storage capacity to deal with events when discharge is limited due to low-flow periods and a lack of dilution in the environment?"*

Appendix R2-E of this Response Report summarizes the details regarding pond sizing and capacity. This analysis demonstrates that the proposed water management ponds can function as intended under stated design conditions throughout the life of mine under various climatic scenarios. These site water ponds have been designed to collect the maximum amount of water in the wettest months providing additional capacity to the upper and lower water management ponds for storage, as required, during the lower flow months.

Further, the discharge scenarios modelled for the dry, mean and wet years incorporated the hold back and accumulation of water during the low flow period (October to March) due to the proposed mitigating mixing ratio of 3:1 in Geona Creek and 2:1 in Finlayson Creek.

11 TERRAIN AND SOILS

11.1 ACCESS ROAD AND MINE SITE TERRAIN ANALYSIS (TERRAIN STABILITY, GEOHAZARDS AND RISKS)

YESAB ISSUE

The study provided by the Proponent provides neither terrain stability mapping nor detailed definitions for the terrain stability classes presented. A preliminary hazard inventory (Terrain Analysis Map) is presented but it appears preliminary and coarse. Field assessment to confirm the extent and hazard processes has not been conducted. Appendix E-5 of the submission states that recent debris floods have impacted an active fan at Fault Creek in the proposed Open Pit footprint.

The proponent should produce a terrain map, terrain stability and hazard map for the mine footprint and access road (including associated methodology and analysis). The terrain stability and hazard maps should follow YESAB's geohazard guidelines for recommended scale, methodologies, and data collection. The guidelines can be found at:

http://www.yesab.ca/wp/wp-content/uploads/2015/11/Geohazards-Guide-Nov-1-2015-2.pdf

R162

"Provide a terrain map, terrain stability and hazard map for the mine footprint and access road (including associated methodology and analysis) that:

a. Identifies surficial geology and related geomorphologic processes;

b. Identifies the type, nature, relative frequency and magnitude of hazards (baseline map);

c. Evaluates how current hazard dynamic may be altered due to changes in climate;

d. Identifies specific risks to the proposed infrastructure; and,

e. Identifies specific risks to the environment from the proposed project (e.g.: changes to slope stability). The risk map should include consideration of climate change over the life of the Project."

Updated terrain hazard mapping and risk assessment will be completed as part of the detailed design phase. Work conducted to date is sufficient to support an effects assessment and the required data can be sourced in the Project Proposal. Details of a), and, b) are in the relevant sections of Appendix E-5 Kudz Ze Kayah Project - Findings of Terrain Analysis, and Section 11.3.6 of the Project Proposal. Details of specific risks to infrastructure (d) are included in Section 17.2 of the Project Proposal while the likely effects of climate change (c, and e) are outlined in Section 16.6 of the Project Proposal.

R163

"Describe how have permafrost degradation processes at the proposed Water Management Ponds footprint been addressed?"

Appendix E-5, Kudz Ze Kayah Project – Findings of Terrain Analysis, of the Project Proposal identified the possibility of permafrost degradation along the Geona Creek Valley floor being exacerbated by the development of the Water Management Ponds, and recommended that this was identified as a geotechnical consideration to be addressed in further studies.

Thermistor K15-336 installed in 2015 and proposed thermistor K17-C (to be installed in summer 2017) will continue to monitor ground temperatures in the area of the Upper and Lower Water Management Ponds. On-going monitoring and geotechnical site investigations will be included in updated site wide geotechnical, terrain hazard and permafrost characterization studies.

Geotechnical design considerations related to permafrost degradation in the area of the Water Management Ponds will be included in the detailed design study. Final design of these facilities will be completed prior to submission of permit applications to the regulatory authorities and will include mitigation for any identified hazards.

YESAB ISSUE WITH BMC'S RESPONSE TO R162 AND 163

The study provided by the Proponent provides neither terrain stability mapping nor detailed definitions for the terrain stability classes presented. A preliminary hazard inventory (Terrain Analysis Map) is presented but it appears preliminary and coarse. Field assessment to confirm the extent and hazard processes has not been conducted. Appendix E-5 of the submission states that recent debris floods have impacted an active fan at Fault Creek in the proposed Open Pit footprint.
The proponent should produce a terrain map, terrain stability and hazard map for the mine footprint and access road (including associated methodology and analysis). The terrain stability and hazard maps should follow YESAB's geohazard guidelines for recommended scale, methodologies, and data collection. The guidelines can be found at:

http://www.yesab.ca/wp/wp-content/uploads/2015/11/Geohazards-Guide-Nov-1-2015-2.pdf

Insufficient response: The proponent states that "updated terrain hazard mapping and risk assessment will be completed as part of the detailed design phase." Terrain and geohazards are baseline studies conducted to provide technical data to the environmental assessment and engineering. YESAB's Geohazards and Risk guidelines) establish that the geohazard and risk assessment should be designed to allow YESAB to adequately evaluate the effect of the proposed project environmental and socio-economic values required under YESAA (Guthrie and Cuervo 2015). Therefore the expectation is that terrain, and geohazard mapping should be provided at the proposal stage, not during the design phase. At the design phase, detailed geohazard studies are typically targeted to critical areas. Later, the proponent also states that "the work conducted to date is sufficient to support an effects assessment". Appendix E5 is a "preliminary overview of the geohazards at the site" (KP, 2016). The overview report is a desktop study, and no field validation was conducted. The spatial and temporal data utilized by the proponent is insufficient for the level of effort required to support a Project proposal. The same report recommends in its conclusion section that "reconnaissance terrain and terrain stability mapping of the project site be undertaken to provide baseline soils and terrain data to support on-going project development". Uncertainties remain concerning the extent and nature of deposits and permafrost conditions where proposed infrastructure, including the road alignment, will be located.

Risk assessment is specific to hazard types (e.g. debris flood, active layer detachment). The specific risks to infrastructure described in Section 17.2 of the Project Proposal refer mostly to the risk of failure of *the infrastructure rather than the risk from existing geohazards. Although this assessment is required to understand potential malfunctions and accidents, it is incomplete if potential terrain constraints and hazards have not been included in the analysis.*

Insufficient response: Failure to consider permafrost, in particular permafrost degradation could lead to loss of stability of the Water Management Ponds.

R2-77

Provide a terrain map, terrain stability and hazard map for the mine footprint and access road (including associated methodology and analysis) that:

a. Identifies surficial geology and related geomorphologic processes;

b. Identifies the type, nature, relative frequency and magnitude of hazards (baseline map);

c. Evaluates how current hazard dynamic may be altered due to changes in climate;

d. Identifies specific risks to the proposed infrastructure; and,

e. Identifies specific risks to the environment from the proposed project (e.g.: changes to slope stability). The risk map should include consideration of climate change over the life of the Project.

BMC has undertaken a Terrain Stability and Hazard Mapping study for the Project. This study is included as **Appendix R2-H** to this response report. A part of this study, a terrain map and two sets of terrain stability/hazard maps have been prepared within an area fully encompassing the proposed mine footprint and access road. **Appendix R2-H** details the methodology and analyses used in the preparation of the maps.

a. Identifies surficial geology and related geomorphologic processes;

Appendix R2-H presents the surficial geology and related geomorphologic processes are depicted on the terrain map and described, this includes use of representative field photos, in the report. More specifically please refer to the following sections of **Appendix R2-H**:

- Section 4.1 – Terrain unit descriptions, including representative field photos
- Section 4.2 – Active geomorphologic process descriptions, including representative field photos

b. Identifies the type, nature, relative frequency and magnitude of hazards (baseline map);

Baseline hazards (existing conditions) are represented by a combination of polygon, line and point features on an existing terrain stability map (**Appendix R2-H**). Characterizations of the general nature, relative frequency and magnitude of all the distinct types of hazards in the study area are provided in the report and summarized in tabular format. More specifically please refer to the following sections of **Appendix R2-H**:

- Section 4.2 – type and nature of hazards
- Section 5.2 – hazards overview; Table 5-1 provides likelihood (relative frequency) and magnitude for each of the main hazard types

c. Evaluates how current hazard dynamic may be altered due to changes in climate;

A 'disturbed' terrain stability map was prepared to represent areas of the landscape where the terrain stability class is anticipated to increase (stability decrease) relative to the existing terrain stability, in response to climate change and/or Project-related construction (**Appendix R2-H**). The 'applicable hazard category' classification for each polygon draws attention to areas where the terrain is most sensitive to climate change due to the inferred presence of ice-rich permafrost. More specifically please refer to the following sections of **Appendix R2-H**:

- Section 5 – Explanations and results pertinent to alterations in hazard dynamics

d. Identifies specific risks to the proposed infrastructure; and,

Site-specific, credible risks to proposed infrastructure were identified and evaluated as part of the Terrain Stability and Hazard Mapping study (**Appendix R2-H**). More specifically please refer to the following sections of **Appendix R2-H**:

- Section 6 – Risk evaluation and mitigation measures

e. Identifies specific risks to the environment from the proposed project (e.g.: changes to slope stability). The risk map should include consideration of climate change over the life of the Project.

The differences in hazards between the baseline (existing) and projected (disturbed) conditions establishes a basis for recognizing areas of the landscape most vulnerable to climate change over the life of the Project. Most of the site-specific risks identified and evaluated reflect changes in slope stability or thermokarst potential in response to unmitigated (conservative) Project-related construction. More specifically please refer to the following sections of **Appendix R2-H**:

- Section 5 – Explanations and results pertinent to alterations in hazard dynamics
- Section 6 – Risk evaluation and mitigation measures

R2-78

Describe how have permafrost degradation processes at the proposed Water Management Ponds footprint been addressed.

Potential mitigations due to permafrost and permafrost degradation in the vicinity of the proposed water management ponds are included in the Terrain Stability and Hazard Mapping study in Table 6-1 of **Appendix R2-H** and is repeated below in Table 11-1 (for clarity).

Table 11-1: Potential Risk and Mitigation Measures due to permafrost and Permafrost Degradation Related to the Upper and Lower Water Management Ponds

Facility	Hazard	Hazard Description	Likelihood (unmitigated)	Consequence (unmitigated)	Risk (unmitigated)	Mitigation Opportunities	Likelihood (mitigated)	Consequence (mitigated)	Residual Risk
Upper Water Management Pond The pond is situated on the valley bottom of upper Geona Creek. NOTE: The spur road paralleling the eastern shoreline of the pond traverses the same map units and thus is exposed to the same hazards.	Active-layer detachments & retrogressive thaw slumping (-Xf)	The proposed shoreline traverses the base of the eastern valley side, which is covered by a veneer of colluvium overlying moderately sloping till inferred to contain ice-moderate permafrost (Poly_IDs 304 and 309). Inundating the lower valley sides will saturate unfrozen surficial materials (e.g., active layer), and initiate or accelerate permafrost degradation, both of which promote mass movement. Several, small active-layer detachments have occurred near the base of the eastern valley side, within and immediately up-valley of the proposed dam footprint. Although all the active-layer detachments were short-travelled, having maximum runouts of <10 m, they were up to 40 m wide and have locally triggered degradation of ice-moderate permafrost. This degradation has resulted in thickening of the active layer and minor upslope retrogression of the headscarp through thaw slumping. This existing combination of active-layer detachments and retrogressive thaw slumping, which could be exacerbated following inundation, poses a risk to the stability of the dam through its effects on foundation materials and the possibility of overtopping by a displacement wave generated by a small mass movement (although any displacement waves from typical permafrost-related failures are likely to be small, rapidly attenuated and readily accommodated by the much larger pond). Excessive sedimentation could occur in the pond due to gradual thawing and erosion of shoreline materials, necessitating increased maintenance.	High	Moderate	High	Pre-strip all overburden with permafrost (to bedrock or competent, ice-free material) within the pond and dam footprints, and extend stripping long the pond perimeter/berm, including the immediate upslope area. Ensure the dam foundation is keyed into competent, ice-free material. Monitor and manage (as required) the stripped areas above the pond perimeter/berm for deposition of localized mass movements. Where required, implement spur road construction techniques specifically designed for ice-rich permafrost (as per OEL, 2016). All mitigations identified above are planned by BMC (pers. comm., 2017).	Negligible	Moderate	Negligible
Lower Water Management Pond The pond is situated on the valley bottom of upper Geona Creek. NOTE: The spur road paralleling the eastern shoreline of the pond traverses the same map units and thus is exposed to the same hazards.	Active-layer detachments & retrogressive thawslumping (-Xf)	The proposed shoreline traverses the base of the eastern valley side, which is covered by a veneer of colluvium overlying moderately sloping till inferred to contain ice-moderate permafrost (Poly_IDs 304 and 309), and the base of the western valley side, which is covered by a blanket of till also inferred to have moderate ice content (Poly_ID 290). Inundating the lower valley sides will saturate unfrozen surficial materials (e.g., active layer) and initiate or accelerate permafrost degradation, both of which promote mass movement. Several, small active-layer detachments have occurred along the base of both valley sides, below and along the proposed Shoreline. Although all the active-layer detachments were short- travelled, having maximum runouts of <20 m, they were up to 70 m wide and have locally triggered degradation of ice-moderate permafrost. This degradation has resulted in thickening of the active layer and minor upslope retrogression of the headscarp through thaw slumping. This existing potential for active-layer detachments and retrogressive thaw slumping, which could be exacerbated following inundation, poses a risk to the stability of the dam through its effects on foundation materials and the possibility of overtopping by a displacement wave generated by a small mass movement (although any displacement waves from typical permafrost-related failures are likely to be small, rapidly attenuated and readily accommodated by the much larger pond). Excessive sedimentation could occur in the pond due to gradual thawing and erosion of shoreline materials, necessitating increased maintenance.	High	Moderate	High	Pre-strip all overburden with permafrost (to bedrock or competent, ice-free material) within the pond and dam footprints, and extend stripping along pond perimeter/berm, including the immediate upslope area. Ensure the dam foundation is keyed into competent, ice-free material. Monitor and manage (as required) the stripped areas above the pond perimeter/berm for deposition of localized mass movements. Where required, implement spur road construction techniques specifically designed for ice-rich permafrost (as per OEL, 2016). All mitigations identified above are planned by BMC (pers. comm., 2017).	Negligible	Moderate	Negligible

11.2 ACCESS ROAD AND MINE SITE TERRAIN ANALYSIS (PERMAFROST AND RELATED HAZARDS)

YESAB ISSUE

Only a limited permafrost discussion has been provided in the submission. The proponent should produce a more comprehensive permafrost study, including mapping and related analysis indicating permafrost distribution within the mine footprint and access road area. The investigation should include an analysis of the permafrost degradation potential. The analysis should include a baseline scenario (current condition) and potential changes during the project operation (due to climate change and impact from proposed infrastructure). Sufficient detail should be provided in areas where surface water runoff is expected to be altered (e.g., water management ponds) and where existing geohazards may be exacerbated. The investigation should include a detailed permafrost hazard map (predictive) with an associated methodology and analysis identifying permafrost related hazards in the study area, including: type, nature and magnitude. The study should identify specific risks to the Project from the permafrost hazard map. The risk map should include consideration of climate change over the life of the Project. The study should also identify specific risks to the permafrost regime from the Project (e.g. potential permafrost degradation exacerbated by water management ponds, changes to slope stability due to the construction of road, stockpiles and storage facilities). The risk map should include consideration of climate change over the life of the Project.

R167

"Provide a comprehensive permafrost study, including mapping and related analysis indicating permafrost distribution within the mine footprint and access road area. Indicate the magnitude and extent of soil erosion potential within this area that is attributed to thermal erosion of permafrost."

A preliminary permafrost study has been completed with thermistors installed in the footprints of the major infrastructure components. Results of this investigation are included as **Appendix 1** of the initial Response Report (BMC, 2017). A preliminary terrain hazard analysis (Appendix E-5 of the Proposal) has indicated areas of soil erosion that could possibly be attributed to the presence of permafrost. A more comprehensive study will be completed as part of the on-going Project development and the detailed design phase.

YESAB ISSUE WITH BMC'S RESPONSE TO R167

Only a limited permafrost discussion has been provided in the submission. The proponent should produce a more comprehensive permafrost study, including mapping and related analysis indicating permafrost distribution within the mine footprint and access road area. The investigation should include an analysis of the permafrost degradation potential. The analysis should include a baseline scenario (current condition) and potential changes during the project operation (due to climate change and impact from proposed infrastructure). Sufficient detail should be provided in areas where surface water runoff is expected to be altered (e.g., water management ponds) and where existing geohazards may be exacerbated. The investigation should include a detailed permafrost hazard map (predictive) with an associated methodology and analysis identifying permafrost related hazards in the study area, including: type, nature and magnitude. The study should identify specific risks to the Project from the *permafrost hazard map. The risk map should include consideration of climate change over the life of the Project. The study should also identify specific risks to the permafrost regime from the Project (e.g. potential permafrost degradation exacerbated by water management ponds, changes to slope stability due to the construction of road, stockpiles and storage facilities). The risk map should include consideration of climate change over the life of the Project.*

Insufficient response: Proponent has not provided enough information. Permafrost distribution and degradation is paramount to understand potential constraints and limitations (with emphasis on geohazards) for Project development.

R2-79

Provide a comprehensive permafrost study, including mapping and related analysis indicating permafrost distribution within the mine footprint and access road area. Indicate the magnitude and extent of soil erosion potential within this area that is attributed to thermal erosion of permafrost.

BMC has completed a comprehensive permafrost study, including mapping and related analysis indicating permafrost distribution within the mine footprint and access road area (**Appendix R2-I**).

The magnitude and extent of soil erosion potential within the study area can be inferred based on the Terrain Stability and Hazard Mapping study (**Appendix R2-H**). This mapping package depicts evidence of existing thermal erosion (thermokarst gullies) and thermokarst subsidence (thaw ponds), using line or point symbols, and represents the polygon-scale magnitude and extent of thermal erosion potential through the interpretations of the relative ice content of permafrost within surficial material. Ice-rich permafrost is susceptible to the greatest magnitude of thermal erosion following disturbance (whether from anthropogenic activity or climate change). Ice-moderate permafrost is susceptible to a lower magnitude of thermal erosion, and ice-poor permafrost exhibits little to no susceptibility to thermal erosion, given its lack of excess ground ice.

Appendix A of the Permafrost Distribution Mapping study (**Appendix R2-I** of this Response Report) shows arrows that indicate discrete sites of thermal effect, however the attribution of each polygon as ice-rich, ice-moderate or no permafrost allows the reader to extract the “extent and magnitude” of thermal erosion potential that is being requested within the IR.

Extent of soil erosion potential from thermal erosion of permafrost: This can be summarized by observing the respective polygons and their associated certainty of containing permafrost. Polygons that were identified as ice-rich or ice-moderate are susceptible to increased “extent” of soil erosion potential when compared to polygons identified as being ice-poor or having no permafrost.

Magnitude of soil erosion potential from thermal erosion of permafrost: This can be summarized by observing the relative amount of permafrost ice within each polygon. Polygons that are ice-rich are prone to the greatest amount (depth) of thaw or subsidence. Ice-moderate polygons have slightly less potential magnitude, with ice-poor polygons and permafrost free polygons have little to no erosion potential attributed to the thermal erosion of permafrost.

Specific hazards due to thermal erosion are discussed within Section 6 of the Terrain Hazards mapping report (**Appendix R2-H**). Specific hazards within both the mine site and the Access Road corridor are identified in Table 6-1 (mine area) and Table 6-2 (Access Road). Thermal erosion hazards identified within these areas include active-layer detachments & retrogressive thaw slumping (-Xf), thermokarst subsidence (-Xt), and thermal erosion (-Xe). The risk assessment presented within Table 6-1 and Table 6-2 was conducted on these specific hazards based on the likelihood, consequences, mitigation opportunities, and residual risk. This more specifically addresses the potential magnitude of effect of specific thermal erosion hazards that have been identified at the site.

12 VEGETATION COVER AND COMPOSITION

No information required.

13 WILDLIFE AND WILDLIFE HABITAT

YESAB ISSUE

The selection of some subcomponents (notably cliff-nesting raptors and olive-sided flycatchers) and the use of these subcomponents to represent the habitat of other species could lead to an inaccurate assessment of potential project effects on other bird species, including species at risk, and consequently inadequate mitigation and monitoring measures for these species.

R170

"Comment on the risk of underestimating the potential effects of the Project on common nighthawk and short-eared owl by excluding the impacts of the Project on preferred habitats for these at-risk species."

BMC must comply with the *Migratory Birds Convention Act* and commits to this through addressing effects on individual species at risk in its Wildlife Protection Plan. Mitigation measures to prevent nest disturbance are presented in Section 18.7 of the Project Proposal.

The risk of underestimating the potential effects of the Project on common nighthawk and short-eared owl is low. The Project area does not contain any defined critical habitat for either species. Both species prefer open fields which is currently not extensive but is expected to increase which would result in an overall net gain during operations and potentially into post-closure. It should be noted that the Wildlife Protection Plan is a living document and will be updated through the adaptive management program if unexpected effects on birds or other wildlife are detected as discussed in Section 18 of the Project Proposal.

R171

"Comment on the risk of underestimating the potential effects of the Project on bank swallow, barn swallow, red-necked phalarope and rusty blackbird by using olive-sided flycatcher to represent habitat use by these at-risk species."

BMC must comply with the *Migratory Birds Convention Act* and commits to this through addressing effects on individual species at risk in its Wildlife Protection Plan as is currently undertaken through BMC's exploration Environmental Management Plan.

The effects assessment used olive-sided flycatcher (*Contopus cooperi*) to assess the magnitude of habitat loss. This is a conservative assessment since olive-sided flycatcher has specific habitat needs between riparian and treed habitat. This is more conservative than if a habitat generalist such as the dark-eyed junco (*Junco hyemalis*) was used which would result in the order of 10% habitat loss. The resulting estimated 20% loss of suitable habitat for olive-sided flycatcher was similar to the estimated 20% suitable habitat loss for waterfowl. Red-necked phalarope (*Phalaropus lobatus*) and rusty blackbird (*Euphagus carolinus*) also each occupy a habitat niche in riparian and wetland habitats and should be a similar magnitude of suitable habitat loss as the olive-sided flycatcher or waterfowl in general. As a result, there is little risk of underestimating habitat loss for red-necked phalarope or rusty blackbird.

Little habitat is currently available in the local study area (LSA) for bank swallow (*Riparia riparia*) which prefers sandy-silty banks for excavating nesting burrows. Similarly, barn swallow (*Hirundo rustica*) prefers caves and ledges on cliff faces and currently has little suitable habitat in the LSA. The risk of underestimating potential effects for either swallow species is considered very low.

YESAB ISSUE WITH BMC'S RESPONSE TO R170 AND 171

The selection of some subcomponents (notably cliff-nesting raptors and olive-sided flycatchers) and the use of these subcomponents to represent the habitat of other species could lead to an inaccurate assessment of potential project effects on other bird species, including species at risk, and consequently inadequate mitigation and monitoring measures for these species.

Insufficient Response: The project area is within the range of the Horned Grebe, Rusty Blackbird, and Short-eared Owl (all listed as Special Concern in Schedule 1 of SARA). The Short-eared Owl is being represented by raptors in the project proposal, but the owls are ground nesters and not appropriately represented by cliff nesting raptors. The Olive-sided Flycatcher and Rusty Blackbird have differences (e.g. elevation) that need to be considered.

R2-80

Describe the preferred habitats for the Horned Grebe, Rusty Blackbird, and Short-eared Owl and the effects of the project on these habitats.

Horned Grebe

The western population of Horned Grebe was listed in 2009 as a species of special concern by COSEWIC (COSEWIC, 2009). The Horned Grebe summer breeding range extends over much of the Yukon Territory including the Project area; however, Horned Grebe were not observed during baseline surveys, in the wildlife logs, or in the Finlayson Lake bird surveys. Nonetheless, there is some potential breeding habitat available on site. Horned Grebe are mainly aquatic and prefer to nest in emergent vegetation along the perimeter of small ponds from 0.1 hectares (ha) to 2 ha, but they are occasionally found on larger lakes (Fournier and Hines, 1999). Breeding habitat consists of pond margins preferably containing cattails and sedges with access to deeper areas for feeding on small fish and aquatic insects (Stedman, 2000; COSEWIC, 2009).

Habitat suitability mapping was completed to identify potential habitat in the LSA for the Kudz Ze Kayah Project. Habitat suitability was ranked in four levels according to the criteria presented in Table 13-1. The resulting distribution of potentially suitable habitat in the LSA is presented in Figure 13-1. The reliability of the model is low (i.e. no field verification, based on the definitions in the 1999 BC Resource Inventory Committee, Wildlife Habitat Rating Standards) since there were no field observations of any Horned Grebe to verify the ratings; although the lack of observations also suggests there is little suitable habitat in the LSA.

Table 13-1: Horned Grebe Habitat Suitability Criteria Summary

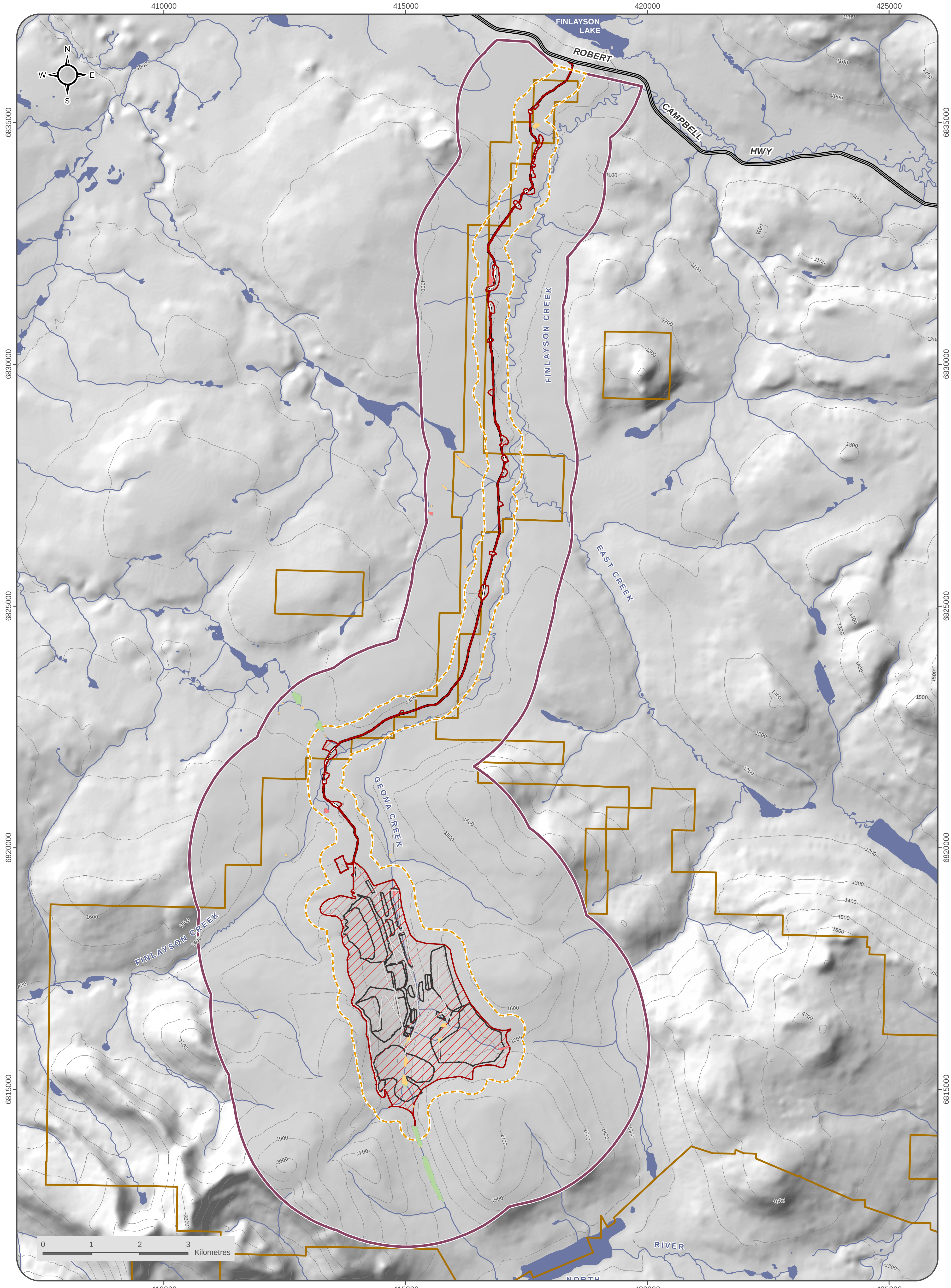
Suitability Rank	Structural Stage	Water Present	Pond Size
High	0, 1, 2	Yes	0.1 - 2 ha
Moderate	0, 1, 2	Yes	2-10 ha
Low	3-7	Yes	> 10 ha or < 0.1 ha
Vey Low / Nil	3-7	No	N/A

As summarized in Table 13-2, there is limited suitable habitat in the LSA and the proposed Project would result in a loss of potentially 0.44 km^2 of high and 0.71 km^2 of moderate suitability habitat for Horned Grebe. No further mitigation measures are proposed besides the fish offset ponds, reclaimed wetland and pond habitat post-closure, and the general wildlife protection measures as presented in Section 18.7 of the Project Proposal and **Appendix R2-J** of this Response Report (Draft Wildlife Protection Plan). The assessment of significance of effects is as described in Chapter 5 of the Project Proposal and the criteria for assessing magnitude are presented in Section 13.4.3 of the Project Proposal. The magnitude of effects is considered high (disturbance threshold >25%), local, continuous, and for the life of the Project. The effects are consequently rated as not significant for Horned Grebe.

Table 13-2: Change in Horned Grebe Nesting Habitat Quality Due to Project Effects in the LSA

Suitability Ranking	Baseline Conditions[1] (km^2)	Direct Habitat Loss[2] (km^2)	Indirect Habitat Loss[3] (km^2)	Total Habitat Loss[4] (%)
High	0.49	0.10	0.44	65.9%
Moderate	1.17	0.54	0.71	76.8%
Low	2.22	0.23	0.23	15.8%
Very Low / Nil	0.04	0.02	0.04	89.6%

[1] Amount of habitat prior to any construction
[2] Area of habitat lost to the Project Footprint, including Access Road
[3] Area of habitat lost located with a 300 m buffer around the Project Footprint and Access Road
[4] Percent change after direct and 50% of indirect habitat loss



Horned Grebe Suitability

- High
- Medium
- Low
- Very Low/Nill

- Tote Road/Proposed Access Road
- Proposed Mine Road
- Watercourse
- Waterbody

- Local Study Area
- Location of Proposed Infrastructure
- BMC Minerals (No.1) Ltd. Mineral Claim Areas
- Indirect Disturbance Area
- Direct Disturbance Area

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FIGURE 13-1
HORNED GREBE
HABITAT SUITABILITY

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Rusty Blackbird

Rusty Blackbird was listed as a species of special concern by COSEWIC in 2006. From the COSEWIC (2006) report, rusty blackbird prefer stands with trees and have higher nesting success where there is black spruce (Matsuoka, Shaw and Johnson 2010, Matsuoka et al., 2010). Rusty blackbird require water resulting in moderate and high suitability habitat within 75 m of water (Avery, 1995; Matsuoka et al., 2010, Powell et al., 2010).

Habitat suitability mapping was completed to identify potential habitat in the LSA for the Project. Habitat suitability was ranked in four levels from High to Very Low/Nil according to the criteria summarized in Table 13-3, based on the published habitat preferences described above. The resulting distribution of potentially suitable habitat in the LSA is presented in Figure 13-2. The model is limited by the resolution in the Terrestrial Ecosystem Mapping (TEM) resulting in the assumption that the characteristics for each polygon are evenly distributed which results in some error. The reliability of the model is low (i.e. no field verifications, based on the definitions in the BC Wildlife Habitat Rating Standards; RIC, 1999a) since there was only two occurrences of Rusty Blackbird in a reference site southeast of the LSA in 2015; however, the observations were in habitat mapped as moderately suitable. The lack of observations also suggests there is little use of suitable habitat in the LSA.

Table 13-3: Rusty Blackbird Habitat Suitability Criteria

Suitability Rank	Bioclimate Zone	Structural Stage and Dominant Tree	Water Access
High	Subalpine and boreal	2-7 with black spruce	< 75 m from water
Moderate	Subalpine and boreal	2-7 without black spruce	< 75 m from water
Low	Subalpine and boreal	2-7	> 75 m from water
Vey Low / Nil	Alpine and anything over 1450 m	0-1, non-vegetated	N/A

As summarized in Table 13-4, the Project would result in a loss of potentially 7.7% of high and 21.7% of moderately suitable habitat for Rusty Blackbird in the LSA. No further mitigation measures are proposed besides pre-clearing surveys during the bird breeding windows, and the general wildlife protection measures as presented in Section 18.7 of the Project Proposal and **Appendix R2-J** of this Response Report (Draft Wildlife Protection Plan). The assessment of significance of effects is as described in Section 5 of the Project Proposal and the criteria for assessing magnitude are presented in Section 13.4.3 of the Project Proposal. The magnitude of effects is considered moderate (disturbance threshold 10-25%), local, continuous, and for the life of the Project. The effects are consequently rated as not significant for Rusty Blackbird.

Table 13-4: Change in Rusty Blackbird Nesting Habitat Quality Due to Project Effects in the LSA

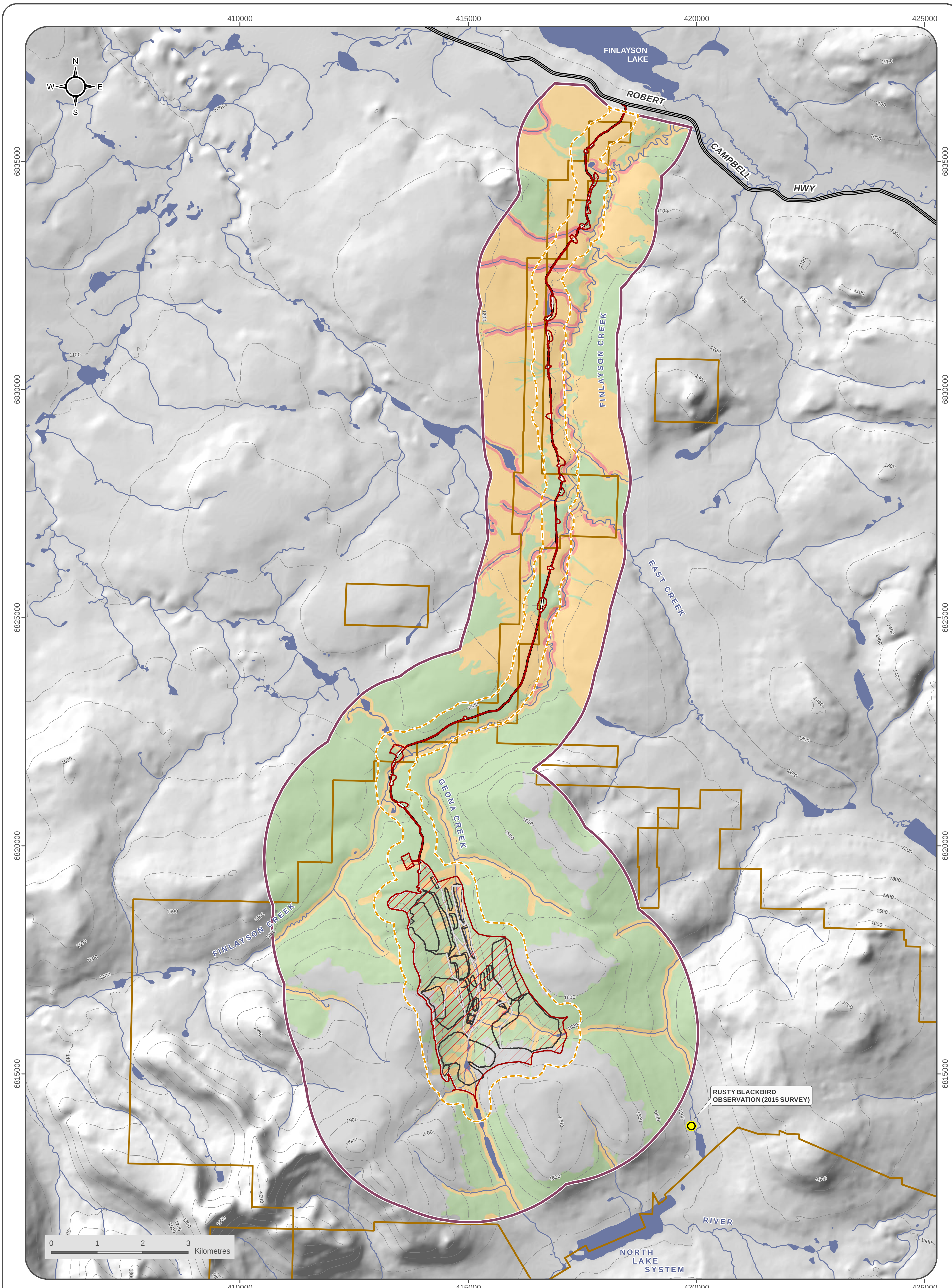
Suitability Ranking	Baseline Conditions[1] (km^2)	Direct Habitat Loss[2] (km^2)	Indirect Habitat Loss[3] (km^2)	Total Habitat Loss[4] (%)
High	251.9	7.5	23.7	7.7%
Moderate	590.7	60.2	135.9	21.7%
Low	368.9	29.2	102.0	21.8%
Very Low / Nil	31.6	1.1	10.9	20.7%

[1] Amount of habitat prior to any construction

[2] Area of habitat lost to the Project Footprint, including Access Road

[3] Area of habitat lost located with a 300 m buffer around the Project Footprint and Access Road

[4] Percent change after direct and 50% of indirect habitat loss



Rusty Blackbird Suitability

- High
- Moderate
- Low
- Very Low/Nil

- Tote Road/Proposed Access Road
- Proposed Mine Road
- Local Study Area
- Location of Proposed Infrastructure

- BMC Minerals (No.1) Ltd. Mineral Claim Areas
- Indirect Disturbance Area
- Direct Disturbance Area
- Waterbody
- Watercourse

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FIGURE 13-2
RUSTY BLACKBIRD HABITAT SUITABILITY

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Short-eared Owl

A Short-eared Owl survey was completed in July 2017. Survey methods and results are presented in **Appendix R2-K.**

Short-eared Owl is listed as a species of Special Concern by COSEWIC in 2012 (Environment Canada, 2016a). Preferred summer feeding and breeding habitat includes large expanses of land with low vegetation including grasslands and low shrublands with abundant prey and dry upland areas for nesting (Holt and Leasure, 1993 and Tate, 1992 in Environment Canada, 2016a). Voles are generally their primary prey (Dechant et al., 1999). In summer, expanses of more than 50 ha are preferred, but smaller patches as small as 20 ha are used in summer (Tate, 1992; Dechant et al, 2001; Clark 1975; Wiggins, 2004).

Habitat suitability mapping was completed to identify potential habitat in the LSA of the Project. Habitat suitability was ranked in four levels from High to Very Low/Nil according to the criteria summarized in Table 13-5 based on the published habitat preferences described above. The resulting distribution of potentially suitable habitat in the LSA is presented in Figure 13-3. Key potential suitable TEM ecosites were selected as 13, 21, 31, 33, and 35 since they contained grasses and low shrubs likely to support prey populations. The area of suitable habitat was determined based on the proportion of suitable ecosites in each polygon. The model is limited by the resolution in the Terrestrial Ecosystem Mapping and the interpretation of what ecosites within the LSA are considered preferred foraging and nesting habitat for the Short-eared Owl. It should also be noted that the habitat suitability mapping is not able to consider prey densities which are an important factor in owl distributions (Environment Canada, 2016a). The reliability of the model is low (i.e. no field verifications, based on the definitions in the BC Wildlife Habitat Rating Standards; RIC, 1999a) since there was only one occurrence of Short-eared Owl along the Tote Road in 2017 (**Appendix R2-K)**; however, its location was used to aid in interpreting preferred habitat in the LSA. The lack of observations also suggests there is little use of suitable habitat in the LSA.

Table 13-5: Short-eared Owl Habitat Suitability Criteria

Suitability Rank	Grassland Ecosites Area	Grassland Area
High	Area of polygon with ecosites 31,33,35,21, or 13	>50 ha
Moderate	Area of polygon with ecosites 31,33,35,21, or 13	20-50 ha
Low	Area of polygon with ecosites 31,33,35,21, or 13	<20 ha
Vey Low / Nil	All else	N/A

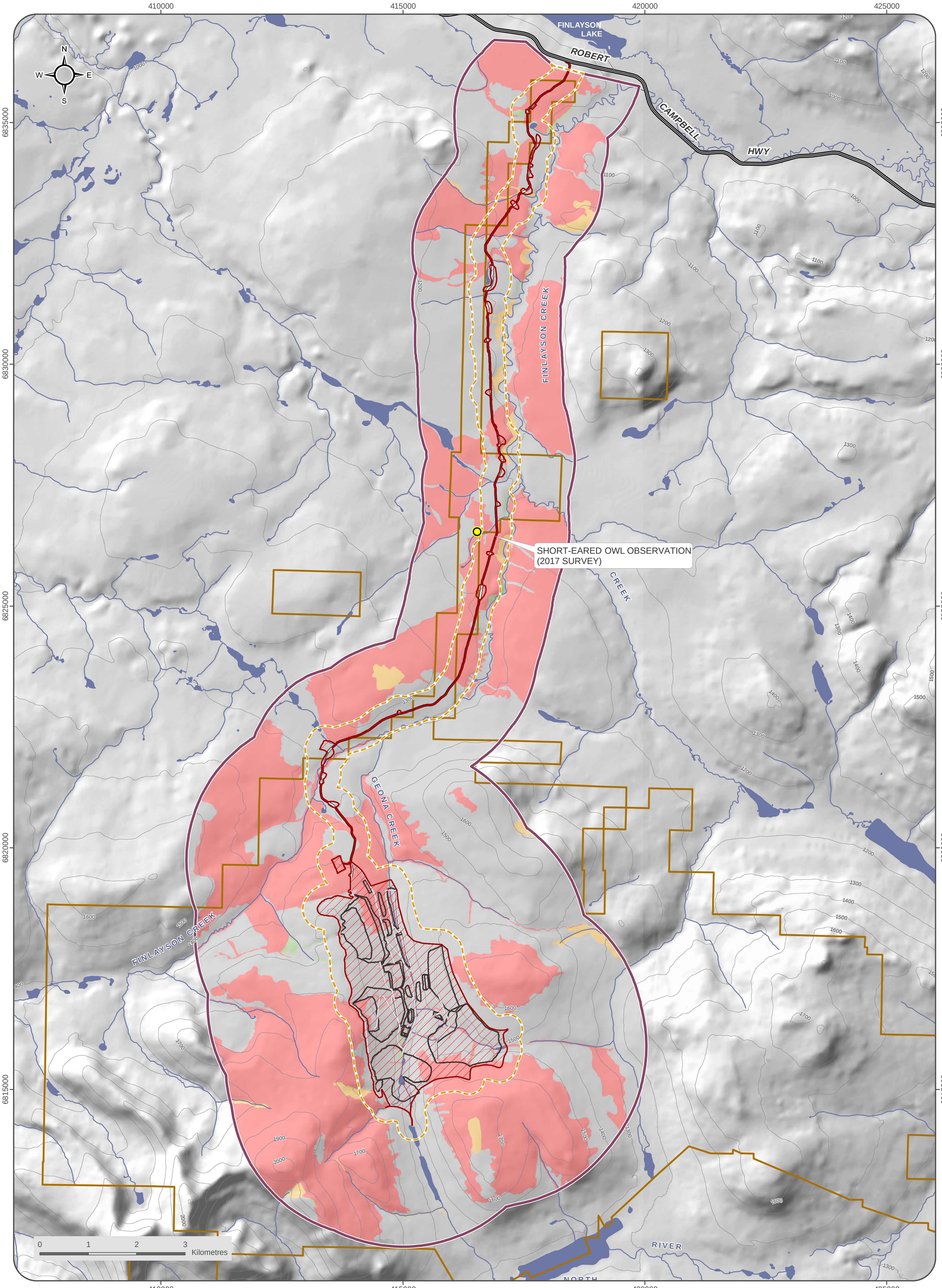
As summarized in Table 13-6, the Project would result in a loss of potentially 25.1% of high and 36.1% of moderately suitable habitat for Short-eared Owl in the LSA. No further mitigation measures are proposed besides pre-clearing surveys during the bird breeding windows and the general wildlife protection measures as presented in Section 18.7 of the Project Proposal and **Appendix R2-K** of this

Response Report (Draft Wildlife Protection Plan). The assessment of significance of effects is as described in Section 5 of the Project Proposal and the criteria for assessing magnitude are presented in Section 13.4.3 of the Project Proposal. The magnitude of effects is considered high (disturbance threshold >25%), local, continuous, and for the life of the Project. The effects are consequently rated as not significant for Short-eared Owl.

Table 13-6: Change in Short-eared Owl Nesting Habitat Quality Due to Project Effects in the LSA

Suitability Ranking	Baseline Conditions[1] (km^2)	Direct Habitat Loss[2] (km^2)	Indirect Habitat Loss[3] (km^2)	Total Habitat Loss[4] (%)
High	654.9	76.9	174.7	25.1%
Moderate	4.1	0.5	1.9	36.1%
Low	19.9	0.2	5.0	13.6%
Very Low / Nil	569.9	20.4	91.1	11.6%

[1] Amount of habitat prior to any construction
[2] Area of habitat lost to the Project Footprint, including Access Road
[3] Area of habitat lost located with a 300 m buffer around the Project Footprint and Access Road
[4] Percent change after direct and 50% of indirect habitat loss



Short-Eared Owl Suitability

- High
- Moderate
- Low
- Very Low/Nil

- Tote Road/Proposed Access Road
- Proposed Mine Road
- Watercourse
- Waterbody

- Local Study Area
- Location of Proposed Infrastructure
- BMC Minerals (No.1) Ltd. Mineral Claim Areas
- Indirect Disturbance Area
- Direct Disturbance Area

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FIGURE 13-3
SHORT-EARED OWL
HABITAT SUITABILITY

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Common Nighthawk

A nighthawk survey was completed in July 2017. Survey methods and results are presented in **Appendix R2-K.**

Common Nighthawk were listed as Threatened by COSEWIC in 2007 (Environment Canada, 2016b). Common Nighthawk nest on open ground or clearings in a variety of different habitats (Environment Canada, 2016b). Their foraging territories range from about 4 to 260 ha (average 86 ha) and they feed on insects during twilight (Ng, 2009; Environment Canada, 2016b). Terra (2014) habitat suitability modeling for the Trans Mountain Expansion Project was also referred to in determining suitability indices for the Project LSA. Alpine habitats and slopes over 100% are not used (Terra, 2014). Structural stages 1 and 2 with little vegetation, including grasslands, shrublands, clearings, pastures, and burns are preferred (Allen and Peters, 2012 and Lohnes, 2010 in Environment Canada, 2016b; COSEWIC 2007a; Terra, 2014). Although raised areas in some wetlands are sometimes used for nesting, very moist and wet sites were given lower ratings than drier sites (Terra, 2014).

Habitat suitability mapping was completed to identify potential habitat in the LSA for the Project. Habitat suitability was ranked in four levels from High to Very Low/Nil according to the criteria summarized in Table 13-7, based on the published habitat preferences described above. The resulting distribution of potentially suitable habitat in the LSA is presented in Figure 13-4. Key potential suitable stands were modified based on presence of specific TEM ecosites to identify the most suitable habitats. The model is limited by the resolution in the Terrestrial Ecosystem Mapping and the interpretation of ecosite distributions within each polygon. There are also limitations to the knowledge base of preferred habitat for Common Nighthawk both in the general literature and for the Kudz Ze Kayah Project area. The reliability of the model is low (i.e. no field verifications, based on the definitions in the BC Wildlife Habitat Rating Standards; RIC, 1999a) since there were no field observations of Common Nighthawk in the July 2017 survey (see **Appendix R2-K**) using any specific habitat types at the Project. The lack of observations also suggests there is little use of suitable habitat in the LSA.

Table 13-7: Common Nighthawk Habitat Suitability Criteria

Suitability Rank	Bioclimate Zone	Structural Stage (moisture ecosite restrictions)	Slope
High	Subalpine and boreal	0-2 (except 31,35,36,40,41,42,46,48)	< 100%
Moderate	Subalpine and boreal	0-2 (including 31,35,36,40,41,42,46,48) 3 (except 31,35,36,40,41,42,46,48,52,56)	< 100%
Low	Subalpine and boreal	0-2 (including 52,56) 3 (including 31,35,36,40,41,42,46,48) 4-7 (including 01,11,15,22,23,25,28)	<100%
Vey Low / Nil	Alpine, wetlands, ponds, creeks	All else	N/A

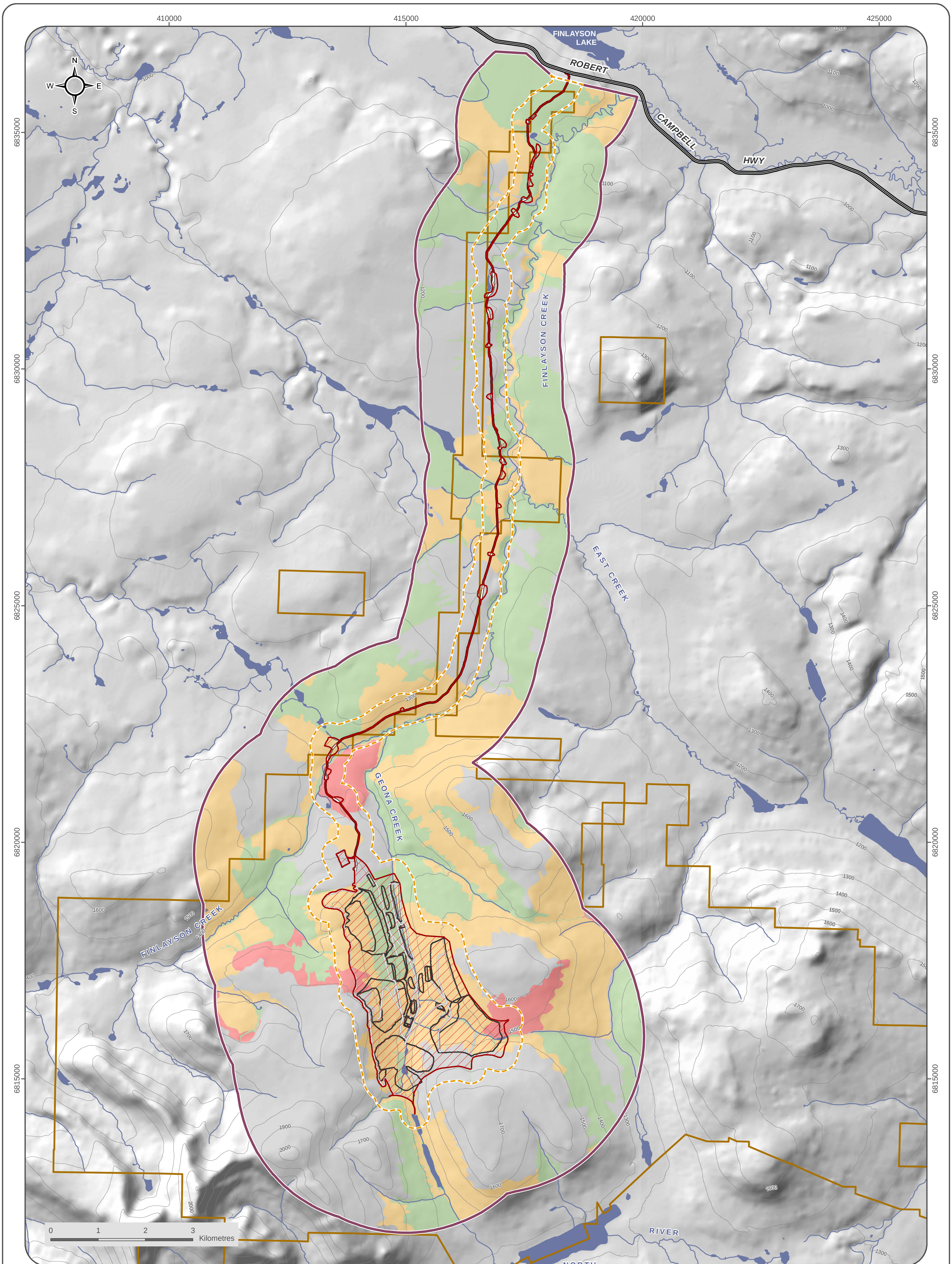
As summarized in Table 13-8, the Project would result in a loss of potentially 27% of high and 31% of moderately suitable habitat for Common Nighthawk in the LSA. It is likely that cleared and revegetating areas for Project development will result in some additional creation of suitable habitat, but the quantity at any one time is unknown at this stage of the Project (COSEWIC, 2007a). No further mitigation measures are proposed besides pre-clearing surveys during bird breeding windows and the general wildlife protection measures as presented in Section 18.7 of the Project Proposal and **Appendix R2-J** of this Response Report (Draft Wildlife Protection Plan). There is still little known about what is limiting the population of Common Nighthawk (Environment Canada, 2016b).

The magnitude of effects is considered high for limited available habitat (disturbance threshold >25%), local, continuous, and for the life of the Project. The effects are consequently rated as not significant for Common Nighthawk.

Table 13-8: Change in Common Nighthawk Nesting Habitat Quality Due to Project Effects in the LSA

Suitability Ranking	Baseline Conditions[1] (km^2)	Direct Habitat Loss[2] (km^2)	Indirect Habitat Loss[3] (km^2)	Total Habitat Loss[4] (%)
High	3.9	0.3	1.5	27%
Moderate	38.4	6.1	11.5	31%
Low	36.9	2.2	6.8	15%
Very Low / Nil	45.2	1.2	7.5	11%

[1] Amount of habitat prior to any construction
[2] Area of habitat lost to the Project Footprint, including Access Road
[3] Area of habitat lost located with a 300 m buffer around the Project Footprint and Access Road
[4] Percent change after direct and 50% of indirect habitat loss



Common Nighthawk Suitability

- High
- Moderate
- Low
- Very Low/Nil

- Tote Road/Proposed Access Road
- Proposed Mine Road
- Watercourse
- Waterbody

- Local Study Area
- Location of Proposed Infrastructure
- BMC Minerals (No.1) Ltd. Mineral Claim Areas
- Indirect Disturbance Area
- Direct Disturbance Area

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FIGURE 13-4
COMMON NIGHTHAWK HABITAT SUITABILITY

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YESAB ISSUE

An effects assessment for the Olive-sided Flycatcher is appropriate as per subsection 79(2) of SARA.

R175

"For the habitat suitability model provide justification for the rank classes, data limitations and any modifications or enhancements made and methods and results of any validation analyses conducted."

Justification for the habitat suitability model for olive-sided flycatcher is included in Section 13.5.1 of the Wildlife Baseline Report, Appendix E-8 of the Project Proposal. The terrestrial ecosystem map for the LSA was used in combination with a set of criteria that define the quality of habitat and predict areas that olive-sided flycatcher likely use. Table 13-9 (shown below) of Appendix E-8 summarizes the habitat suitability criteria chosen to rank habitat suitability based on structural stage, bioclimate subzone, and watercourses.

Table 13-9: Olive-sided Flycatcher Habitat Suitability Criteria

Suitability Rank	Structural Stage	Bioclimate Subzone	Watercourses
High	Leading ecosite >=50% structural stage 6 or 7	Boreal High-Boreal Subalpine	<500 m from waterbody
Medium	Leading ecosite >=50% structural stage 6 or 7	Boreal High- Boreal Subalpine	>500 m from waterbody
Low	Everything else	Boreal High- Boreal Subalpine	Everything else

Olive-sided flycatcher is a migratory bird that comes to the Yukon for nesting and feeding prior to migrating south for the winter. Olive-sided flycatcher nest at the edges of mature and old growth forests. Open areas may be forest clearings, forest edges located near natural openings, burned forest or openings within old-growth forest stands. Tall, live trees or snags for perching are associated with mature trees and large dead trees (i.e., structural stage 6, 7). Generally, forest habitat is either coniferous or mixed wood. In the boreal forest, suitable habitat is more likely to be in or near wetland areas (COSEWIC, 2007b). Suitable habitat for olive-sided flycatcher may occur in subalpine and boreal forest. Olive-sided flycatcher were heard or observed at locations in the LSA that aligned well with the predicted areas of suitable habitat.

As mentioned in Section 1.2 of Appendix E-8 of the Project Proposal, the olive-sided flycatcher habitat suitability mapping was completed to support the Project effects assessment. Observations are plotted on the habitat suitability map in Figure 13-2 as a simple validation. (This figure was presented in the Initial Response Report (BMC, 2017)). The model has a moderate reliability based on the definitions in the 1999 BC Wildlife Habitat Rating Standards, (i.e., Moderate Reliability. Available information is based mainly on studies, reports and expertise on the species-habitat relationships gained within British Columbia. Some information from ecosystems in the study area, but mostly extrapolated from similar ecosystems. No verification or limited verification has been done; RIC, 1999a).

YESAB ISSUE WITH BMC'S RESPONSE TO R175

An effects assessment for the Olive-sided Flycatcher is appropriate as per subsection 79(2) of SARA.

Insufficient Response: The methodology used for developing the olive-sided flycatcher model is not clearly defined and does not appear to follow standard modelling convention. Categories of high, medium and low habitat suitability are presented but no information is provided regards to the thresholds that are applied to define these categories. This is directly applicable to the effects assessment for this species as only high-suitability habitat is used to evaluate the potential impacts of the project on olive-sided flycatcher. This may underestimate the potential impacts to this species. Utilizing high suitability alone is not consistent with a conservative approach.

Figure 13-18 identifies habitat suitability for olive-sided flycatcher in addition to olive-sided flycatcher detections. We note that 7 out of 8 detections are within modelled low-value habitat - this does not represent a strong case for the model being able to predict suitable olive-sided flycatcher habitat. Only a single detection appears to occur within high-value habitat. As such, the model appears to do a poor job at quantifying potential olive-sided flycatcher habitat.

R2-81

For the habitat suitability model provide justification for the rank classes, data limitations and any modifications or enhancements made and methods and results of any validation analyses conducted.

The criteria or thresholds were defined in the Wildlife Baseline report in Appendix E-8 of the Project Proposal. Olive-sided flycatcher nest at the edges of mature and old growth forests. Open areas may be forest clearings, forest edges located near natural openings, burned forest or openings within old-growth forest stands. Tall, live trees or snags for perching are associated with mature trees and large dead trees (i.e., structural stage 6, 7). Generally, forest habitat is either coniferous or mixed wood. In the boreal forest, suitable habitat is more likely to be in or near wetland areas (COSEWIC, 2007b). Suitable habitat for olive-sided flycatcher may occur in subalpine and boreal forest. Olive-sided flycatcher were heard or observed at wetland locations at KZK sites with fewer trees than might be interpreted from the literature; therefore, the following table has been revised from the December 2016 Wildlife Baseline Report in order to capture all structural stages that have noted fir or spruce within 500 m of water in the moderate suitability category (see Table 13-10, below for the revised criteria search parameters for the GIS mapping). These criteria or thresholds can be described as follows:

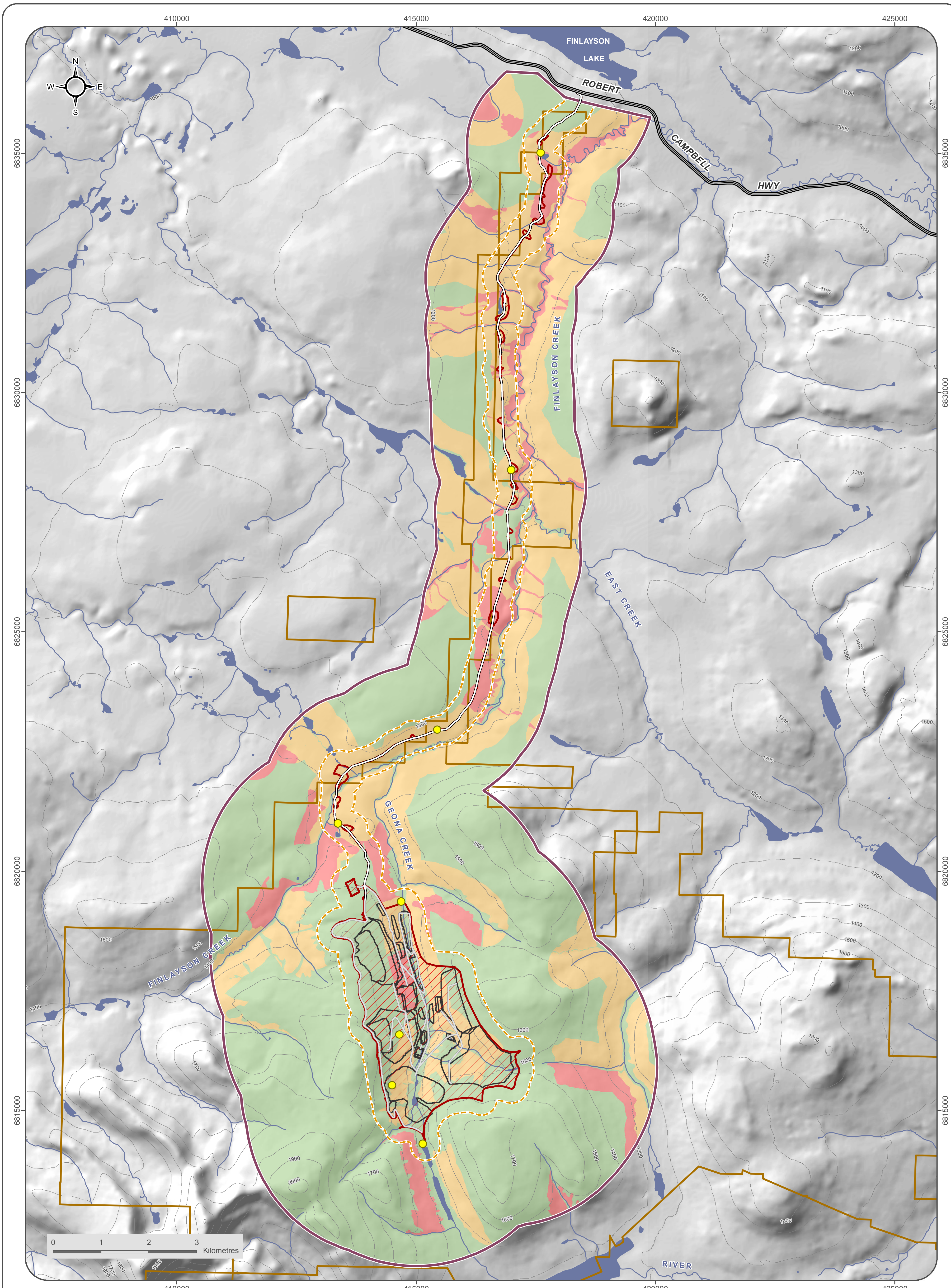
- Highly suitable habitat is located in boreal high or boreal subalpine, within 500 m of a waterbody, and in Terrestrial Ecosystem Map polygons where the leading ecosite is at least 50% of structural stage 6 or 7 (mature and old forests).
- Moderate habitat is located in boreal high or boreal subalpine, within 500 m of a waterbody, and in any Terrestrial Ecosystem Map polygon as long as it has fir or spruce trees.
- Low or nil habitat includes habitat in the alpine, farther than 500 m from a waterbody, and all other Terrestrial Ecosystem Map polygons.

Ranked habitat categories are based on ideal habitat for olive-sided flycatcher based on their distribution as described in the literature and then interpretation of where that ideal habitat would be in the LSA. The habitat rankings are relative to optimal habitat thresholds as defined in the COSEWIC (2007b) literature applied to habitat at the Project. Since little information is available specific to the Yukon, the ranks are not relative to the known highest suitability habitat in Yukon as might be done in British Columbia.

Table 13-10: Olive-sided Flycatcher Habitat Suitability Criteria - Revised

Suitability Rank	Structural Stage	Bioclimate Subzone	Watercourses
High	Leading ecosite >=50% structural stage 6 or 7	Boreal High-Boreal Subalpine	<500 m from waterbody
Moderate	Any structural stage containing fir or spruce	Boreal High- Boreal Subalpine	<500 m from waterbody
Low / Nil	Everything else	Boreal High- Boreal Subalpine	Everything else

For validation, it is agreed that the point locations for the field observations did not overlay well with the mapped suitability; however, the point locations were approximate since they were from point count surveys and it is uncertain as to how far away the birds were from the observer. This uncertainty should have been described or presented more clearly on Figure 13-2 of the Initial Response Report (BMC, 2017). There are limitations and uncertainty in interpretation of the terrestrial ecosystem mapping to suitable habitat. Structural stage was used; however, there can be sparse trees that are suitable for perching by olive-sided flycatcher in stands where there are some mature trees but the structural stage is not mature forest. These adjustments were made in the revised criteria shown in Table 13-10 and in the revised habitat suitability map in Figure 13-5 (below). Note that the observation points now fall within or very near to moderate and high suitability habitat. Statistical analysis was not completed to validate the model because there are too few observations to make it meaningful on a statistical basis.



Olive-Sided Flycatcher Suitable Nesting Habitat
- High
- Moderate
- Low/Nil

- Olive-Sided Flycatcher Observation
- Tote Road/Proposed Access Road
- Proposed Mine Road
- Watercourse
- Waterbody

- Local Study Area
- Location of Proposed Infrastructure
- BMC Minerals (No.1) Ltd. Mineral Claim Areas
- Indirect Disturbance Area
- Direct Disturbance Area

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FIGURE 13-5

OLIVE-SIDED FLYCATCHER HABITAT SUITABILITY - REVISED

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A three-class rating system was used since there was limited information to separately define a low and very low/nil category. A four-class rating system could have been used; however, the lower two classes would still have captured all the low rated habitat in the current model and are not used to calculate habitat lost. The updated model shown here has been revised to capture two categories of low and nil.

Habitat effects were recalculated for the revised habitat suitability mapping and are summarized in Table 13-11. When combined, there is a net -14% loss of moderate and highly suitable habitat (i.e., (0.7 km^2 direct loss + half of 3.6 km^2 indirect loss) / 17.6 km^2 baseline).

The magnitude of effects remains at moderate (10-25%) in the local area and the significance rating of the habitat effects presented in Table 13-12 below is the same as presented in Table 13-47 of the Project Proposal. The proposed mitigations do not change with the revised assessment and inclusion of both moderate and high suitability habitat.

Table 13-11: Olive-sided Flycatcher Habitat Change* - Revised

Suitability Ranking	Baseline Conditions (km^2)	Direct Habitat Loss (km^2)	Indirect Habitat Loss (km^2)	Total Habitat Loss in LSA (%)
High	10.9	0.6	3.1	- 20%
Moderate	6.7	0.1	0.5	- 6%
Low / Nil	106.7	9.1	13.8	- 15%

*Percent change after direct loss and 50% indirect loss of habitat in 300 m buffer

Table 13-12: Significance of Residual Effects – Passerines (Olive-sided Flycatcher)

Residual Effect	Direction	Magnitude	Geographic Extent	Duration	Frequency	Reversibility	Environmental and Socio-economic Context	Likelihood	Significance
Habitat Loss	Adverse	Moderate	Local	Long term	Continuous	Reversible long term	Neutral	Very likely Low uncertainty	Not significant
Direct mortality	Adverse	Low	Local	Long term	Sporadic	Irreversible	Neutral	Very likely Moderate uncertainty	Not significant

YESAB ISSUE

Information on methods is missing in the proposal. As noted in Chapter 5, Section 5.1 (effects assessment approach), the existing conditions should be described in enough detail to provide the benchmark against which the project effects will be evaluated. It is, therefore, important that an adequate baseline assessment is completed, including providing detailed description of methods and results.

R176

"Provide a complete description of the passerine survey methods, including information on number of times each station was visited, description of the point count methodology, and information on settling periods."

The Passerine survey methods are described in Section 13.3.1 of the Wildlife Baseline Report, Appendix E-8 of the Project Proposal. A point-count survey was conducted by a qualified biologist capable of identifying songbirds based on their visual appearance and mating songs. A point-count consisted of an observer remaining stationary and silent at the designated site for a 5-minute interval recording all birds detected by sight and sound. This is a modification of the North American Breeding Bird Survey (BBS) 3-minute methodology used by the Canadian Wildlife Service and United States Geological Survey (USGS, 2001; Environment and Climate Change Canada, 2016). When the surveyor arrived at a station, one minute of recovery time was taken to allow the birds to settle.

Most point-count sites were accessible by foot. Sites that were not accessible by foot were accessed with a Bell Jet Ranger Helicopter. The helicopter landed and powered down at a safe location near the point-count site. The observers walked to the point-count site and began the survey (including a one minute settling time). Results from the wetland and reference sites accessed by helicopter in 2015 and 2016 were not noticeably different in abundance or richness between road and helicopter accessed sites (see **Appendix 5** of the Initial Response Report, Figures A5-1 to A5-7 in response to R177) (BMC, 2017).

Alpine, subalpine, and boreal sites around the proposed Project footprint were generally visited once in each of 2015 and 2016. Seven additional road sites (RS_8 to RS_14), two alpine sites (BB_17 and BB_18), and three reference sites (REF_3 to REF_5) were added in 2016; four sites (BB_13 to BB_16) were not surveyed in 2016. Wetland sites were visited once in 2015 and 2016 except ABR-1 had two point counts and ABR-2 had three point counts in 2016. The main objective of the wetland surveys was to identify all species using the wetlands and point counts gave an indication of relative abundance.

The objective of the surveys was to identify and inventory bird species at the Project and obtain an unadjusted estimate of relative abundance. The BBS method was appropriate for identifying presence and was modified from 3-minute to 5-minute counts to increase the potential for detection.

As mentioned in Section 13.6.1 of the Project Proposal, the species of conservation concern observed in the Project site were consistent with the data and detection frequency for the area found in the

Finlayson Lake Breeding Bird Surveys from 1992 to 2014 (USGS, 2014). It is evident that most bird species have been detected for site based on the species accumulation graph in Figure 13-6 (below).

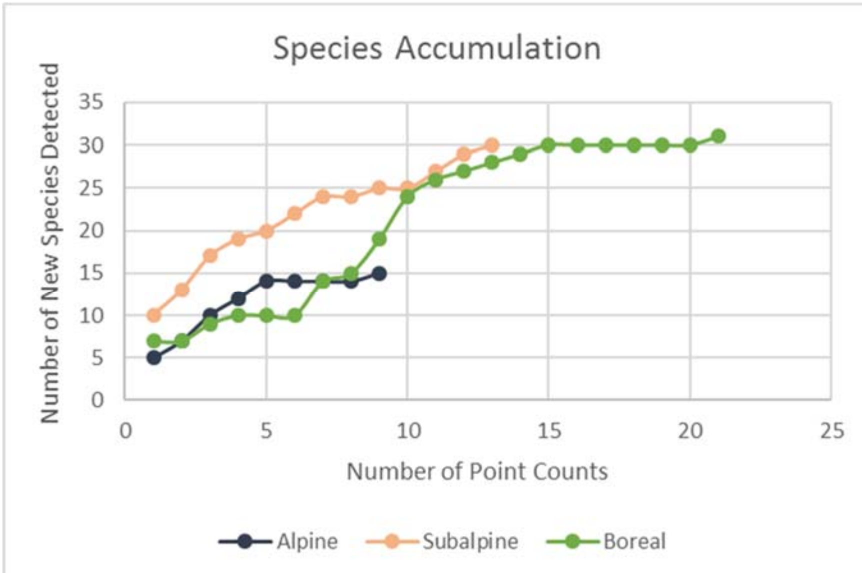


Figure 13-6: Species Accumulation from Surveys in the Project Area by Bioclimate Zone

R178

"Provide a summary of relative abundance of species by habitat type, based on the point count surveys. If there were habitat types that supported a higher proportion of detections, these habitat types could be identified as important for passerines and mitigations around protecting the habitat types could be developed."

Table 13-13 below summarizes species detected in 2015 and 2016 from most to least abundant (unadjusted). Table 13-14 then presents indices of species richness, evenness, and diversity calculated for each broad habitat type of alpine, subalpine, boreal, riparian, and wetland for 2015 and 2016. The least number of species were found in alpine habitats. Species were distributed evenly in each habitat with little dominance by any one species, with the exception of wetland habitats where aggregating waterfowl (in this case *Scaup sp.*) resulted in a lower evenness index. Diversity was relatively high in all habitats for the sample area. For background, the Shannon diversity index is logarithmic and will approach 7 when there are hundreds of species present; the Simpson diversity index ranges from 0 at infinite diversity to 1 with no diversity.

Table 13-13: Species Detected by Decreasing Abundance at Kudz Ze Kayah

Species	# Detected in 2015	# Detected in 2016	Total #		Species	# Detected in 2015	# Detected in 2016	Total #
Scaup species	50	60	110		Chipping Sparrow	2	2	4
White-crowned Sparrow	38	31	69		Common Loon	3	1	4

Species	# Detected in 2015	# Detected in 2016	Total #		Species	# Detected in 2015	# Detected in 2016	Total #
American Tree Sparrow	30	30	60		Violet-green Swallow	4	0	4
Wilson's Warbler	21	18	39		Orange-crowned Warbler	0	3	3
Dark-eyed Junco	8	20	28		Say's Phoebe	2	1	3
American Robin	8	19	27		Bank Swallow	0	2	2
Gray-cheeked Thrush	5	16	21		Barn Swallow	0	2	2
Yellow Warbler	17	1	18		Canada Goose	0	2	2
Blackpoll Warbler	6	11	17		Gold-crowned Sparrow	0	2	2
Savannah Sparrow	4	13	17		Golden Eagle	0	2	2
Ruby-crowned Kinglet	5	9	14		Northern Flicker	0	2	2
Common Redpoll	4	10	14		Pine Grosbeak	0	2	2
Lesser Yellowlegs	7	7	14		Swainson's Thrush	0	2	2
Red-necked Phalarope	4	10	14		Townsend's Solitaire	0	2	2
Gray Jay	2	11	13		Horned Lark	1	1	2
Spotted Sandpiper	4	9	13		Northern Harrier	1	1	2
Lincoln's Sparrow	8	4	12		Solitary Sandpiper	1	1	2
Olive-sided Flycatcher	4	8	12		Black-capped Chickadee	2	0	2
Common Yellowthroat	5	7	12		Northern Waterthrush	2	0	2
Alder Flycatcher	7	5	12		Rusty Blackbird	2	0	2
Green-winged Teal	0	11	11		Bonaparte's Gull	0	1	1
Common Goldeneye	0	10	10		Bufflehead	0	1	1
Willow Ptarmigan	3	7	10		Common Raven	0	1	1
Yellow-rumped Warbler	4	6	10		Hermit Thrush	0	1	1
Fox Sparrow	3	6	9		Northern Pintail	0	1	1
Mallard	0	9	9		Red-breasted Merganser	0	1	1
Tree Swallow	4	4	8		Yellow-bellied Flycatcher	0	1	1
Barrow's Goldeneye	3	4	7		Spruce Grouse	1	0	1

Species	# Detected in 2015	# Detected in 2016	Total #		Species	# Detected in 2015	# Detected in 2016	Total #
Semi-palmated Plover	1	6	7		Mew Gull	1	0	1
Northern Shrike	4	2	6		Tennessee Warbler	1	0	1
Boreal Chickadee	0	5	5		Red-winged Blackbird	1	0	1
Bohemian Waxwing	0	4	4					

Table 13-14: Bird Species Richness, Evenness, and Diversity by Habitat

	Alpine	Subalpine	Boreal	Subalpine Riparian	Wetlands
2015					
Species Richness	10	24	14	20	17
Evenness	0.95	0.91	0.95	0.87	0.75
Shannon Diversity (H)	2.18	2.88	2.50	2.61	2.14
Simpson Diversity (D)	0.13	0.07	0.09	0.11	0.21
2016					
Species Richness	13	15	26	17	24
Evenness	0.87	0.89	0.90	0.91	0.79
Shannon Diversity (H)	2.24	2.41	2.93	2.57	2.52
Simpson Diversity (D)	0.14	0.11	0.07	0.10	0.15

The similarity between habitat types was also assessed and summarized with the Bray-Curtis distance index which is the complement to percent similarity of two populations, and the Jaccard coefficient of similarity (Sj = number of common species/total number of species in both habitats). The indices of similarity are summarized in Table 13-15 below. The species composition shows low similarity between the alpine, subalpine, boreal, and wetland habitats. The results do not change the effects assessment or indicate a need for any changes in mitigation strategies. Results will be used to refine the ongoing monitoring program.

Table 13-15: Bird Species Similarity Between Habitats

	Habitat Comparison	Bray-Curtis Distance	Jaccard Coefficient
2015			
	Subalpine - Alpine	0.70	0.36
	Subalpine - Boreal	0.73	0.36
	Subalpine - Wetland	0.62	0.41
	Subalpine - Subalpine Riparian	0.38	0.41
	Riparian - Wetland	0.61	0.27

	Habitat Comparison	Bray-Curtis Distance	Jaccard Coefficient
	Alpine - Boreal	0.82	0.20
2016			
	Subalpine - Alpine	0.60	0.33
	Subalpine - Boreal	0.71	0.28
	Subalpine - Wetland	0.74	0.27
	Subalpine - Subalpine Riparian	0.41	0.52
	Riparian - Wetland	0.75	0.29
	Alpine - Boreal	0.67	0.18

YESAB Issue with BMC's Response to R176 and R178

Information on methods is missing in the proposal. As noted in Chapter 5, Section 5.1 (effects assessment approach), the existing conditions should be described in enough detail to provide the benchmark against which the project effects will be evaluated. It is, therefore, important that an adequate baseline assessment is completed, including providing detailed description of methods and results.

Insufficient response: Insufficient details are provided to replicate or validate the method. It is not clear whether temperature, weather, behaviour, vocalization type (song vs alarm) data was collected. Spacing of point counts in some cases is much closer than the BBS protocol. There is a risk of counting the same individuals twice.

R2-82

Provide a complete description of the passerine survey methods, including information on number of times each station was visited, description of the point count methodology, and information on settling periods.

On October 5 2017, YESAB provided (via email) the following further clarification regarding the information required in response to R2-82:

> *"Provide the protocols used to determine survey methodology and provide rationale for any changes to the protocol based on site conditions."*

The objective of the surveys was to identify and inventory bird species at the Project and obtain an unadjusted estimate of relative abundance. The Breeding Bird Survey (Environment and Climate Change Canada, 2016) method was appropriate for identifying presence and was modified from 3-minute to 5-minute counts to increase the potential for detection. The survey locations were modified from the BBS protocol which has sample sites located at 800 m intervals along the roads. Instead, the sample sites were distributed within the Project footprint and in surrounding reference sites that would not be disturbed by the Project.

YESAB ISSUE

As noted in Chapter 5, Section 5.1 (effects assessment approach), the existing conditions should be described in enough detail to provide the benchmark against which the project effects will be evaluated. Given this approach, it is important that an adequate baseline assessment is completed, including providing detailed description of methods and results. Consistency with methods and results is important to provide a reliable baseline review.

R178A

"Provide a complete description of survey methods, including survey effort; survey frequency; protocols used; and dates, duration and linear distance of waterfowl/shorebird surveys. What is the rationale for using 5-minute point count stations?"

The waterfowl survey methods are described in Section 13.3.2 of the Wildlife Baseline Report, Appendix E-8 of the Project Proposal. The objective of the waterfowl survey was to identify and create an inventory of bird species in the Project area. The methodology used to survey the wetlands consisted of either a walk around the wetland or a scan of the wetland surface area using binoculars and a spotting scope, as well as a 5-minute point-count at each wetland following the Breeding Bird Survey methodology used for passerines. This is a modification of the North American Breeding Bird Survey (BBS) 3-minute methodology used by the Canadian Wildlife Service and United States Geological Survey (USGS, 2001; Environment and Climate Change Canada, 2016).

R178B

"Provide a summary of species detected per wetland and year and ensure that Table 13-2 is complete? What are the results from the 2015 survey?"

The waterfowl species detected at the Project are presented in text in Section 13.4.2 of the Wildlife Baseline Report, Appendix E-8 of the Project Proposal. Species counts from the 2015 survey are included in Appendix F of the Wildlife Baseline Report. Species counts from the 2016 survey are included here in **Appendix 5** of the Initial Response Report (BMC, 2017). Table 13-2 in the Wildlife Baseline Report, Appendix E-8 includes the observed behaviour of aquatic bird species in 2016. Behavioural observations were not recorded in 2015 and therefore not presented. A summary description of species detected per wetland and year is presented below.

A total of 20 species of waterfowl and other aquatic birds were observed during the surveys conducted in 2015 and 2016. This included seven species of duck, seven shorebirds, three gull, one loon, one swan, and one goose species. Predominant waterfowl using the wetlands within the LSA and reference wetlands were scaup (*Aythya spp.*; at ABR_1, ABR_2, ABR_3) and goldeneye (*Bucephala spp.*; at ABR_1). Other waterfowl include green-winged teal (*Anas crecca*; at ABR_1, ABR_2), northern pintail (*Anas acuta*; ABR_1, ABR_3), mallard (at pond on Tote Road near the highway), bufflehead (*Bucephala albeola*; at a reference site), and red-breasted merganser (*Mergus serrator*; ABR_2). Waterfowl nesting on the wetlands within the LSA include mallard, green-winged teal, and northern pintail. Waterfowl nesting on the reference wetlands outside the LSA include goldeneye, scaup, and an unidentified dabbling duck. Trumpeter swans were observed in 2015 and 2016 on reference wetlands outside the LSA. It is assumed they are nesting on those wetlands given their defensive behaviour and the timing of observations. In addition, two juvenile trumpeter swans were observed with adults at the east end of North Lakes (not in the LSA) on July 10 and August 1, 2015.

Seven species of shorebird were observed within the LSA, including spotted sandpiper (*Actitis macularius*; at ABR_1, ABR_2, ABR_3), semipalmated plover (*Charadrius semipalmatus*; at ABR_1, ABR_2, ABR_3), lesser yellowlegs (*Tringa flavipes*; at ABR_1, ABR_2, ABR_3), solitary sandpiper (*Tringa solitaria*; at ABR_2), least sandpiper (*Calidris minutilla*), American golden-plover (*Pluvialis dominica*) and red-necked phalarope (*Phalaropus lobatus*).

YESAB ISSUE WITH BMC'S RESPONSE TO R178A AND R178B

As noted in Chapter 5, Section 5.1 (effects assessment approach), the existing conditions should be described in enough detail to provide the benchmark against which the project effects will be evaluated. Given this approach, it is important that an adequate baseline assessment is completed, including providing detailed description of methods and results. Consistency with methods and results is important to provide a reliable baseline review.

Insufficient response: The response does not include the following: no protocol for wetland survey given; no measure of survey effort (duration, linear distance, frequency); not clear on which dates different survey types were conducted.

R2-83

Provide a complete description of survey methods, including survey effort; survey frequency; protocols used; and dates, duration and linear distance of waterfowl/shorebird surveys. What is the rationale for using -minute point count stations?

On October 5 2017, YESAB provided (via email) the following clarification regarding the information required in response to R2-83:

> *"Clarify the intent of the survey. Provide the protocols used to determine survey methodology and provide rationale for any changes to the protocol based on site conditions."*

The intent of the waterfowl/shorebird surveys was to determine the species present in the Project area and obtain an indication of relative abundance.

The methodology used to survey the wetlands consisted of either a walk around the wetland or a scan of the wetland surface area using binoculars and a spotting scope, as well as a 5-minute point-count at each wetland following the Breeding Bird Survey methodology used for passerines. Five-minute point-count surveys were completed to be consistent with the other breeding bird surveys and allow for comparison of relative abundance (See above Response to R2-82).

YESAB ISSUE

Since habitat suitability mapping is utilized to define change in suitable habitat in the effects assessment, with the magnitude of the effect tied to this assessment, an accurate and validated habitat suitability model is an important component of the baseline assessment.

The habitat suitability modelling exercise should include a clear description of model assumptions, validation, reliability, and the incorporation of zones of influence, as appropriate. If the effects assessment, as is the case here, applies a fixed buffer to suitable habitat, in lieu of zones of influence for the modelling exercise, to account for indirect habitat loss, this should be noted in the baseline assessment.

R179

"Provide information on model assumptions, validation, reliability and zones of influence for the three habitat suitability maps for birds."

The descriptions of the habitat suitability models for olive-sided flycatcher, waterfowl, and cliff-nesting raptors are presented in Sections 13.5.1, 13.5.2, and 13.5.3 of the Wildlife Baseline Report (Appendix E-8 of the Project Proposal). The models used the Terrestrial Ecosystem Map (TEM) to determine where breeding habitat was located assuming preferred habitats for each species or group of species.

Model assumptions are captured in the criteria for each group as described and summarized in each table (repeated below). Olive-sided flycatcher is a migratory bird that comes to the Yukon for nesting and feeding prior to migrating south for the winter. Olive-sided flycatcher nest at the edges of mature and old growth forests. Open areas may be forest clearings, forest edges located near natural openings, burned forest or openings within old-growth forest stands. Tall, live trees or snags for perching are associated with mature trees and large dead trees (i.e., structural stage 6, 7). Generally, forest habitat is either coniferous or mixed wood. In the boreal forest, suitable habitat is more likely to be in or near wetland areas (COSEWIC, 2007b).

Table 13-16: Species Accumulation from Surveys in the Project Area by Bioclimate Zone

Suitability Rank	Structural Stage	Bioclimate Subzone	Watercourses
High	Leading ecosite >=50% structural stage 6 or 7	Boreal High-Boreal Subalpine	<500 m from waterbody
Medium	Leading ecosite >=50% structural stage 6 or 7	Boreal High- Boreal Subalpine	>500 m from waterbody
Low	Everything else	Boreal High- Boreal Subalpine	Everything else

Highly suitable waterfowl habitat was defined as any habitat type within 100 m of a water body (i.e., wetland and creek), including the water body itself. Moderately suitable waterfowl habitat was defined as any habitat type within 100 to 200 m from a waterbody. Low suitable waterfowl habitat was defined as all other habitat that does not meet the high or moderate ranking. These suitability rankings for preferred waterfowl habitat were based on data from Hickie (1985), which states that most nests in or near wetlands occur within 100 m of water.

Table 13-17: Waterfowl Habitat Suitability Criteria

Suitability Rank	Wetland Type	Nesting Area Around Wetland
High	Wetland / creeks	100 m
Medium	Wetland / creeks	100-200 m
Low	Everything else	All other

Highly suitable cliff-nesting raptor habitat was defined as any habitat that displayed a slope greater than 30^o and was at an elevation greater than 1,300 masl. Moderately suitable cliff-nesting raptor habitat was defined as any habitat that displayed a slope between 15^o and 30^o and was at an elevation greater than 1,300 masl. Low suitability cliff-nesting raptor habitat was defined as any habitat that displayed a slope between 0^o and 15^o and covered all ranges of elevation. The parameters for suitability rankings for preferred cliff-nesting raptor habitat were based on a known preference for cliff-nesting raptors to select nest sites on steep rock faces or rocky outcrops, as well as reviewing actual nest site locations around the Project site.

Table 13-18: Cliff-nesting Raptors Habitat Suitability Criteria (above 1,300 masl)

Suitability Rank	Slope (degrees)
High	>30
Medium	15-30
Low	<15

Each model used detections from the bird surveys as a simple validation of the predicted areas of suitable habitat. The objective of the modelling is to provide a visual representation of the distribution of predictive suitable habitat and quantitative assessment based on the known TEM for site and the literature. The model has a moderate reliability based on the definitions in the BC Wildlife Habitat Rating Standards (RIC, 1999a), (i.e., *Moderate Reliability. Available information is based mainly on studies, reports and expertise on the species-habitat relationships gained within British Columbia. Some information from ecosystems in the study area, but mostly extrapolated from similar ecosystems. No verification or limited verification has been done*).

For the zone of influence, the modelling was completed for baseline conditions with direct loss predictions quantified as the ultimate footprint of the Project and indirect loss based on a 50% reduction for the 300 m buffer around the Project footprint. This level of quantifying habitat loss from the Project was considered appropriate for the level of information and uncertainties. Additional modeling for different stages of the Project would unlikely change the magnitude of the effects assessment or the mitigation and management plans.

Note that three bird groupings were assessed to determine the general level of magnitude of effects on birds in general and determine overall mitigations. Species-specific details (highlighting species of conservation concern) will be included in the final Wildlife Protection Plan. Unforeseen effects detected by ongoing monitoring will be managed through application of the Adaptive Management Plan.

R180

"For the olive-side flycatcher map, is this for breeding habitat? Can you provide a more thorough literature review to support the assessment?"

The olive-sided flycatcher comes to Yukon for nesting and feeding prior to migrating south for the winter and the map is for all life requisites during this time (i.e. breeding). The COSEWIC 2007b reference used in Section 13.5.1 and Figure 13-2, Olive-sided Flycatcher Habitat Suitability Map, contained in the Wildlife Baseline Report, Appendix E-8 of the Project Proposal, is already based on an extensive literature search. Two further references were found that further supports the description and criteria chosen in Section 13.5.1. The preferred breeding habitat for olive-sided flycatchers are conifer or mixed-conifer forests with open canopies and at mid-high elevations (Shuford and Gardali, 2008). Olive-sided flycatchers prefer to use spruce and fir trees as nesting substrate, because their branching and leafing structure is suitable for the types of woven nests that they use (Robertson and Hutto, 2006). Therefore, Boreal High and/or Boreal Subalpine are the most suitable bioclimate subzone and mature and/or old forests are more suitable for the olive-sided flycatcher.

R181

"For the waterfowl map, what species (or groups of species) does the habitat suitability represent? Can you provide a more thorough literature review to support the assessment?"

The waterfowl map, Figure 13-3 Waterfowl Habitat Suitability (Appendix E-8 of the Project Proposal) represents the waterfowl species that occurred at and around the Project area in 2015 and 2016 including Barrow's goldeneye, bufflehead, common loon, green-winged teal, mallard, red-breasted merganser, greater and lesser scaup, and trumpeter swan.

The description and criteria chosen in Section 13.5.2 of the Wildlife Baseline Report, Appendix E-8 of the Project Proposal, defined wetlands within 100 m of a waterbody as highly suitable and wetlands between 100-200 m as moderately suitable for all waterfowl species identified. This is supported by additional literature. Waterfowl is a broad grouping and therefore waterfowl habitat suitability is also broad. The most important habitat requirement for waterfowl is access to shallow waters (Hickie, 1985). These waters produce high numbers of small aquatic invertebrates and form a high-quality diet for egg-laying females and actively growing young. Waterfowl may nest in water, on the edge of water, or near water (Hickie, 1985). Because of their affinity to water, waterfowl are unlikely to nest where there is no source of water nearby. Additional literature has found that the green-winged teal, mallard, greater, and lesser scaup all commonly use wetlands as their preferred habitat (Stralberg et. al, 2011). According to *The Birds of North America* (Rodewald (Ed.), 2017), all of the identified waterfowl will nest near water.

YESAB ISSUE WITH BMC'S RESPONSE TO R179, R180 AND R181

Since habitat suitability mapping is utilized to define change in suitable habitat in the effects assessment, with the magnitude of the effect tied to this assessment, an accurate and validated habitat suitability model is an important component of the baseline assessment.

The habitat suitability modelling exercise should include a clear description of model assumptions, validation, reliability, and the incorporation of zones of influence, as appropriate. If the effects assessment, as is the case here, applies a fixed buffer to suitable habitat, in lieu of zones of influence for the modelling exercise, to account for indirect habitat loss, this should be noted in the baseline assessment.

Insufficient Response: The methods used for developing models are not clearly defined and do not appear to follow standard modelling convention. Categories of high, medium and low are noted as being used but no information is provided with regards to the thresholds that are applied to define these categories.

Adequate model validation was not provided. It is noted by the proponent that detections were used as a simple validation of the predicted areas of suitable habitat. For olive-sided flycatcher there were 8 detections, one of which was within modelled high suitable habitat. For cliff-nesting raptors (Figure 13-7) there is one detection. For waterfowl (Figure 13-19) there are no detections noted. It is, therefore, unclear how the detections provide any level of validation.

R2-84

Provide information on model assumptions, validation, reliability and zones of influence for the three habitat suitability maps for birds.

On October 5 2017, YESAB provided (via email) the following clarification regarding the information required in response to R2-84:

> *"Clarify the thresholds used to identify "Low", "Moderate" and "High" and define each term. Describe the standards used to establish these thresholds."*

Revisions were made to the olive-sided flycatcher habitat suitability model and presented in the response to R2-81.

The descriptions and thresholds of the habitat suitability models for olive-sided flycatcher, waterfowl, and cliff-nesting raptors are presented in Sections 13.5.1, 13.5.2, and 13.5.3 of the Wildlife Baseline Report (Appendix E-8 of the Project Proposal). These were also re-presented in response to R179 (above). Ranked habitat categories (i.e. low, moderate, high) are based on ideal habitat for each species based on their distribution as described in the literature and then interpretation of that ideal habitat would be in the LSA.

The criteria or thresholds for cliff-nesting raptors were presented in Section 13.5.3 of the Wildlife Baseline Report and are described as follows:

- Highly suitable cliff-nesting raptor habitat was defined as any habitat that displayed a slope greater than 30o and was at an elevation greater than 1,300 masl.

- Moderately suitable cliff-nesting raptor habitat was defined as any habitat that displayed a slope between 15° and 30° and was at an elevation greater than 1,300 masl.

- Low suitability cliff-nesting raptor habitat was defined as any habitat that displayed a slope between 0° and 15° and covered all ranges of elevation.

The parameters for suitability rankings for preferred cliff-nesting raptor habitat were based on a known preference for cliff-nesting raptors to select nest sites on steep rock faces or rocky outcrops, as well as reviewing actual nest site locations around the Project site.

The criteria or thresholds for waterfowl were presented in Section 13.5.2 of the Wildlife Baseline Report and are described as follows:

- Highly suitable waterfowl habitat was defined as any habitat type within 100 m of a water body (i.e., wetland and creek), including the water body itself.

- Moderately suitable waterfowl habitat was defined as any habitat type within 100 to 200 m from a waterbody.

- Low suitable waterfowl habitat was defined as all other habitat that does not meet the high or moderate ranking.

These suitability rankings for preferred waterfowl habitat were based on data from Hickie (1985), which states that most nests in or near wetlands occur within 100 m of water. Waterfowl were observed using wetlands in the LSA which aligned with the predicted areas of suitable habitat.

Since little information is available specific to the Yukon, the ranks are not relative to the known highest suitability habitat in Yukon as might be done in British Columbia.

13.2 CARIBOU

YESAB ISSUE

The proposal does not adequately address all effects to caribou because key aspects of caribou ecology have not been discussed and included in the effects assessment and mitigation measures. Further discussion on each sub-point is available in the SLR technical memo.

R183

"Provide additional information on project interactions and effects with caribou in the context of each of the following parameters:

a. Migration

b. Predator/prey dynamics

c. Predator efficiency

d. Displacement

e. Calving habitat and neonatal calf mortality

f. Snow patches

g. Influence of fidelity to seasonally used areas

h. Population decline and caribou distribution

i. 'Range rotation' and increase in Finlayson Lake use during some seasons

For topics a) through d) listed above, consider also the indirect effects of the Project. For topics e) through i) listed above, provide information that will help determine how significant this geographic area is with respect to caribou population dynamics, rather than just to habitat suitability."

BMC appreciates the importance of the potential direct and indirect effects of the Project on the Finlayson Caribou Herd (FCH). BMC's baseline studies, habitat modelling, and effects assessment on FCH were led by [Name Redacted] who is a Yukon expert on the FCH. [Name Redacted] was Environment Yukon's caribou biologist from 1978 to 2006 and authored many publications on caribou including the 2009 publication, *Three Decades of Caribou Recovery Programs in Yukon: A Paradigm Shift in Wildlife Management*. [Name Redacted] continues to conduct surveys and consults on caribou in Yukon. The effects assessment focused on the key potential effects based on [Name Redacted] extensive experience on factors affecting the FCH.

a. Migration

Use of specific migration paths in the study area are not presented because they are unknown at this time. Providing observations at this level would require intense study (camera traps, high intensity aerial survey, frequent track counts, etc.) beyond the scope of environmental assessment studies and would be unprecedented. Much more specific migration path data in relation to the Project area will become available during the operational phase of the Project. Large scale migratory use of the area is clearly evident from range use maps that are provided in Chapter 3 of the Wildlife Baseline Report, Appendix E-8 of the Project Proposal. Detailed use by individuals and groups of caribou remains indefinable.

b. Predator/prey Dynamics

It is agreed that distribution and abundance of significant predators and prey and how this relates to caribou is a significant component of caribou population dynamics. It is also agreed that shifts in the predator/prey system can lead to caribou population declines. Any shifts in predator/prey relationships should be closely monitored by responsible wildlife agencies to determine not only proximate but also ultimate causes of population declines.

c. Predator Efficiency

It is fully acknowledged that linear features can result in increased predator efficiency (most notably, for wolves), which can lead to increased predation risk to caribou. Use of the road by wolves during winters is documented by aerial surveys. The road, which was built in the late 1990s would have resulted in easier access and hunting efficiency by wolves. The access road is the single linear movement corridor which will be used by the Project. During the operational phase, increased traffic intensity may deter wolves from using the road.

d. Displacement into Areas of Higher Mortality Risk

It is fully acknowledged and agreed that caribou behaviour (seasonal habitat use, range use) is largely influenced by predator avoidance. Therefore, displacing the caribou could result in increased mortality risk. For example, an impact of concern from oil and gas development on the caribou herds in northern Yukon and Alaska was increased mortality from shifting/displacing the herd from the coastal plain calving grounds to the foothills where there are more predators and less suitable forage (Griffith et al, 2002). It should be noted however that the FCH occurs at low density compared to previous numbers and has ample alternate range in which to disperse. Furthermore, the FCH does not have a key critical range outside of winter range such as the Porcupine caribou herds calving grounds in Alaska. The Project affects a small portion of the FCH winter range.

e. Calving Habitat and Neonatal Calf Mortality

It is acknowledged that neonatal calf mortality is one of the most significant components of caribou population dynamics. It is well known that woodland caribou are widely dispersed during calving as an anti-predation tactic and 50% mortality of calves by predation is normal during their first 10 days of life. The calving period for Yukon caribou extends from approximately May 6th to June 6th with a peak around May 16th. From [Name Redacted] considerable personal experience studying this possibility, it became evident that caribou are so efficient at calving dispersal that biologists presently do not have a way to evaluate neonatal calf mortality. Unfortunately, at present there is no way to answer this concern.

f. Snow Patches

It is acknowledged that snow patches were identified as important for avoiding insect harassment but there is no information about key snow patches in the study area or effects and measures to mitigate Project disturbance in these areas. Snow patches are an important habitat for caribou in summer. Climatic evidence has shown they are diminishing. A comparison can be made between the post-calving locations and locations of snow patches that can be seen on Google Earth and the post-calving locations are essentially equivalent to the locations of snow patches. In the LSA, snow patches are mainly on the ridges west of the proposed mine infrastructure and occasionally on the mountain to the east. Therefore, the degree that the Project interferes with snow patches would be equivalent to the habitat loss calculation for the post-calving assessment (i.e. 1.8% loss of highly suitable post calving habitat in the regional post calving study area).

The elevation of the snow patches may provide an indication of their longevity with climate change. The snow patches just west of the mine are around 1800 m elevation and located about 1.8 km from the centre of the mine infrastructure so there is a high likelihood that these patches will be abandoned during the construction and operations phases. Throughout the regional range, the snow patches appear to range from 1600 to 2150 m elevation. With climate change, the snow patches around the Project are unlikely to be the first to go, but unlikely to be the last either.

Mitigations to minimize caribou disturbance are already included in Section 18.7.3 of the Project Proposal for employees and equipment to remain within Project boundaries and in Section 18.10.3 for noise reduction measures. The post-calving monitoring program will be modified to take GPS locations and pictures of the boundaries of a number of reference snow patches to help track snow patch changes over time.

g. Influence of Fidelity to Seasonally Used Areas

It is acknowledged there is concern that caribou tend to show high fidelity to calving areas and to some rutting areas (meaning that they tend to return to the same areas year after year). This can mean that the potential loss of areas with consistent use and consistently higher calf survival may be of more significance than calculating a percentage loss of habitat would indicate. Fidelity to specific calving sites by cows has been documented in the FCH and elsewhere to a very low degree of prevalence. Fidelity to larger range use patterns such as rutting areas is far more prominent as reported. Clearly the FCH has traditional rutting areas during normal years – with some annual shifts in abundance. Disparity in calf survival between large, geographically separate rutting areas is well documented. Over the years higher calf survival by the rutting season has been documented for ranges north of the Robert Campbell Highway, while lower survival has been documented south of the highway and is supported by years of data. This is generally where two-thirds of the herd have traditionally ranged and the location of the Project area. The fidelity to rutting range may mean that caribou take longer than anticipated to return to local rutting habitat post-closure.

h. Influence of the Observed Finlayson Caribou Population Decline

It is acknowledged that when caribou populations decline, their distribution generally contracts and that may influence potential effects from the Project. Withdrawal of range use coincident with decline in population size has been well document for the more widespread arctic and interior Alaska caribou herds. However, this is so clear for woodland caribou, particularly in Yukon. Extirpation from an entire range of woodland caribou populations is well documented elsewhere, however experience shows that Yukon woodland caribou go through substantial population size shifts without losing or gaining home range. There are no anticipated changes in range use for the FCH as a result of density.

i. Influence of 'Range Rotation' During Winter

It is understood that there are concerns that the Finlayson Lake area may see more use from caribou than expected with climate change. Elements of the FCH made use of the Finlayson Lake area, often interacting with the lower access road, during the low snowfall years of both 2007 and 2016. Large numbers were also found here during the 2017 late winter ungulate survey. There is considerable uncertainty on what local changes on snowpack will take place with climate change and in what time frame. All winter range will be considered extremely important and management planning will include mitigation measures for wintering caribou in all years. The Robert Campbell Highway and Finlayson Lake airstrip are public lands. It is not clear how the proponent can influence their uses.

YESAB ISSUE WITH BMC'S RESPONSE TO R183

The proposal does not adequately address all effects to caribou because key aspects of caribou ecology have not been discussed and included in the effects assessment and mitigation measures. Further discussion on each sub-point is available in the SLR technical memo.

Insufficient Response: The response acknowledges the issues but does not provide the requested information on project interactions and effects with caribou in the context of each listed parameter. In general, statements are not backed up by references and some of the population dynamics topics are not fully addressed. For example, there is no information on snow patches or migration routes.

R2-85

Provide additional information on project interactions and effects with caribou in the context of each of the following parameters:
a. Migration
b. Predator/prey dynamics
c. Predator efficiency
d. Displacement
e. Calving habitat and neonatal calf mortality
f. Snow patches
g. Influence of fidelity to seasonally used areas
h. Population decline and caribou distribution
i. 'Range rotation' and increase in Finlayson Lake use during some seasons

For topics a) through d) listed above, consider also the indirect effects of the Project. For topics e) through i) listed above, provide information that will help determine how significant this geographic area is with respect to caribou population dynamics, rather than just to habitat suitability.

On October 5 2017, YESAB provided (via email) the following clarification regarding the information required in response to R2-85:

> *"Provide information that will give context to caribou use of the area and the relative importance of the mine site to caribou, particularly as it relates to migration between summer and winter areas and snow patches.*
>
> *Provide discussion on the FCH context, in particular the aspects of caribou ecology and their range that are specific to them (i.e. snow patches, movement between summer and winter ranges). Discuss how the project might impact these features."*

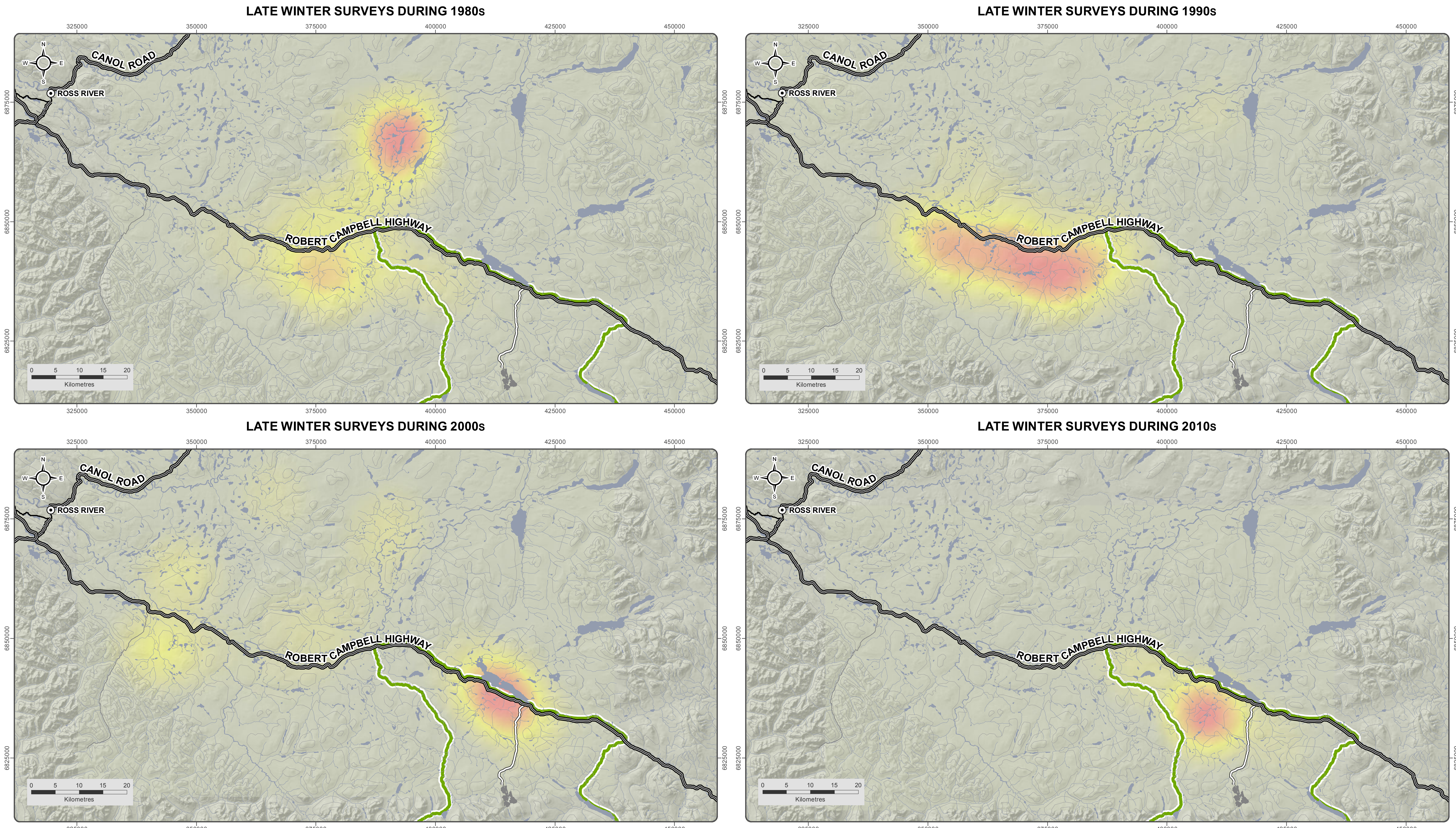
Appendix R2-L provides summary of the importance of the FCH use of the Project area and RSA, caribou ecology, and how the FCH may be affected by the Project. This information is supplemental to the Project Proposal where BMC recognised the importance (or significance) of the area for the FCH (Section 13.3.1, Caribou Existing Conditions, and in Section 13.4.1.1, Caribou Effects Assessment). In these sections of the Proposal it is made clear that the Project is located in part of the core habitat for part of the Finlayson Caribou Herd (FCH) and that the FCH is important to Kaska citizens. Approximately two thirds of the FCH utilize the Pelly Mountains south of the Robert Campbell Highway for calving, post-calving, and rutting life stages and then move to the Pelly River lowlands by late winter. FCH caribou move from the Pelly lowlands up into the mountain forests where they disperse for calving in June. The caribou then move to and congregate on alpine snow patches throughout the Pelly Mountains (the mountain range in which the Project is located) during the post-calving stage and summer to escape insects. In the fall, caribou move on to the alpine plateaus for the rut after which they move the Pelly lowlands where there is less snow and more food in winter. The FCH appears to move generally in a south-north direction between the mountains and the lowlands, but the movement patterns and any key corridors are not known.

Additional clarification regarding the variable seasonal distribution of caribou around the Project in late winter, post-calving, and rut is presented in Figure 13-7, Figure 13-8, and Figure 13-9, respectively. These figures are based on decades of study of the Finlayson caribou heard and reliably show the area of use and importance. However, specific migration paths in the study area are not presented because they are unknown at this time (Farnell, pers. comm., 2017). Providing observations at this level would require intense study (camera traps, high intensity aerial survey, frequent track counts, etc.) beyond the scope of environmental assessment studies and would be unprecedented. Nonetheless, it can be inferred that the caribou move across the landscape between the Pelly River and Finlayson lowlands wintering grounds and their montane calving and rutting grounds based on [Name Redacted] extensive knowledge and surveys of the herd (Farnell, pers. comm., 2017) ([Name Redacted] resume has been included in **Appendix R2-L** of this Response Report).

General wildlife road crossing areas have been identified in the Draft Wildlife Protection Plan (including mitigation measures) and additional precautions will be taken as more specific migration path data in relation to the Project area becomes available during the operational phase of the Project through the ongoing monitoring program and wildlife logs as presented in the Draft Wildlife Protection Plan in **Appendix R2-J**. Large scale migratory use of the area is clearly evident from range use maps that are provided in Chapter 3 of the Wildlife Baseline Report, Appendix E-8 of the Project Proposal. Detailed use by individuals and groups of caribou remains indefinable (Farnell, pers. comm., 2017) as well as Figure 13-7, Figure 13-8, and Figure 13-9 of this Response Report.

The Tote Road extends through the foothills and lowlands northeast of the Pelly Mountains and lies in a “rain shadow” that results in a drier environment and low snow depth in the winter. The shallow snow depths allow caribou (and moose) to move and find food more easily. The shallower snow depths are a factor in the distribution of wildlife in general in the area. The Geona Creek valley and the proposed mine site is similar in wildlife diversity, species, and habitats to the valleys and habitat found in surrounding valleys and throughout the Pelly Mountains.

The importance of snow patches was described above in response to R-183f and is further described in **Appendix R2-L** of this Response Report.



1980s, 1990s and 2000s results are based on Yukon Government data of the Finlayson Caribou Herd range.
2010s results are based on AEG survey that only covered GMS 10-07

Finlayson Caribou Herd Late Winter Regions map was produced based on YG Relocation Surveys, YG and AEG Aerial Surveys using Quantum GIS 1.8.0-Lisboa

Datum: NAD 83; Map Projection: UTM Zone 9N

AEG

CARIBOU PRESENCE IN LATE WINTER REGIONS

- High Presence
- Moderate Presence
- No Presence

OTHER MAP FEATURES

- Location of Proposed Infrastructure
- RSA (GMS 10-07)
- Waterbody
- Watercourse
- Tote Road/Proposed Access Road

BMC MINERALS

KUDZ ZE KAYAH PROJECT

FIGURE 13-7
FINLAYSON CARIBOU HERD LATE WINTER PRESENCE

OCTOBER 2017

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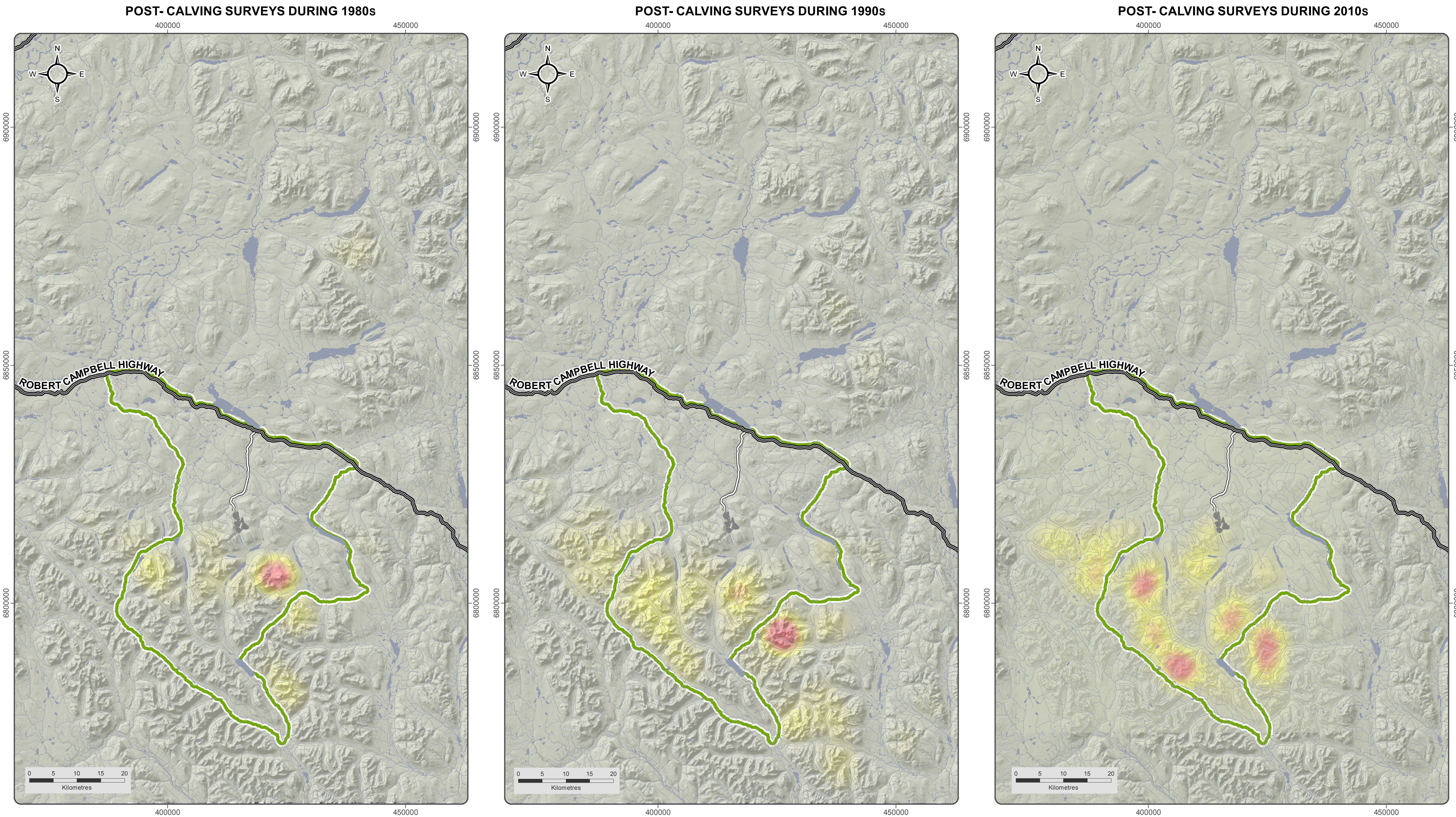
(*Last edited by: amatlashevska;20/10/2017/09:15 AM*)



1980s and 1990s results are based on Yukon Government data of the Finlayson Caribou Herd range. 2010s results are based on AEG survey that only covered GMS 10-07

Finlayson Caribou Herd Post-Calving Regions map was produced based on YG Relocation Surveys, YG and AEG Aerial Surveys using Quantum GIS 1.8.0-Lisboa

Datum: NAD 83; Map Projection: UTM Zone 9N

AEG

CARIBOU PRESENCE IN POST-CALVING REGIONS

- High Presence
- Moderate Presence
- No Presence

OTHER MAP FEATURES

- Location of Proposed Infrastructure
- RSA (GMS 10-07)
- Waterbody
- Watercourse
- Tote Road/Proposed Access Road

BMC MINERALS

KUDZ ZE KAYAH PROJECT

FIGURE 13-8

FINLAYSON CARIBOU HERD POST-CALVING PRESENCE

OCTOBER 2017

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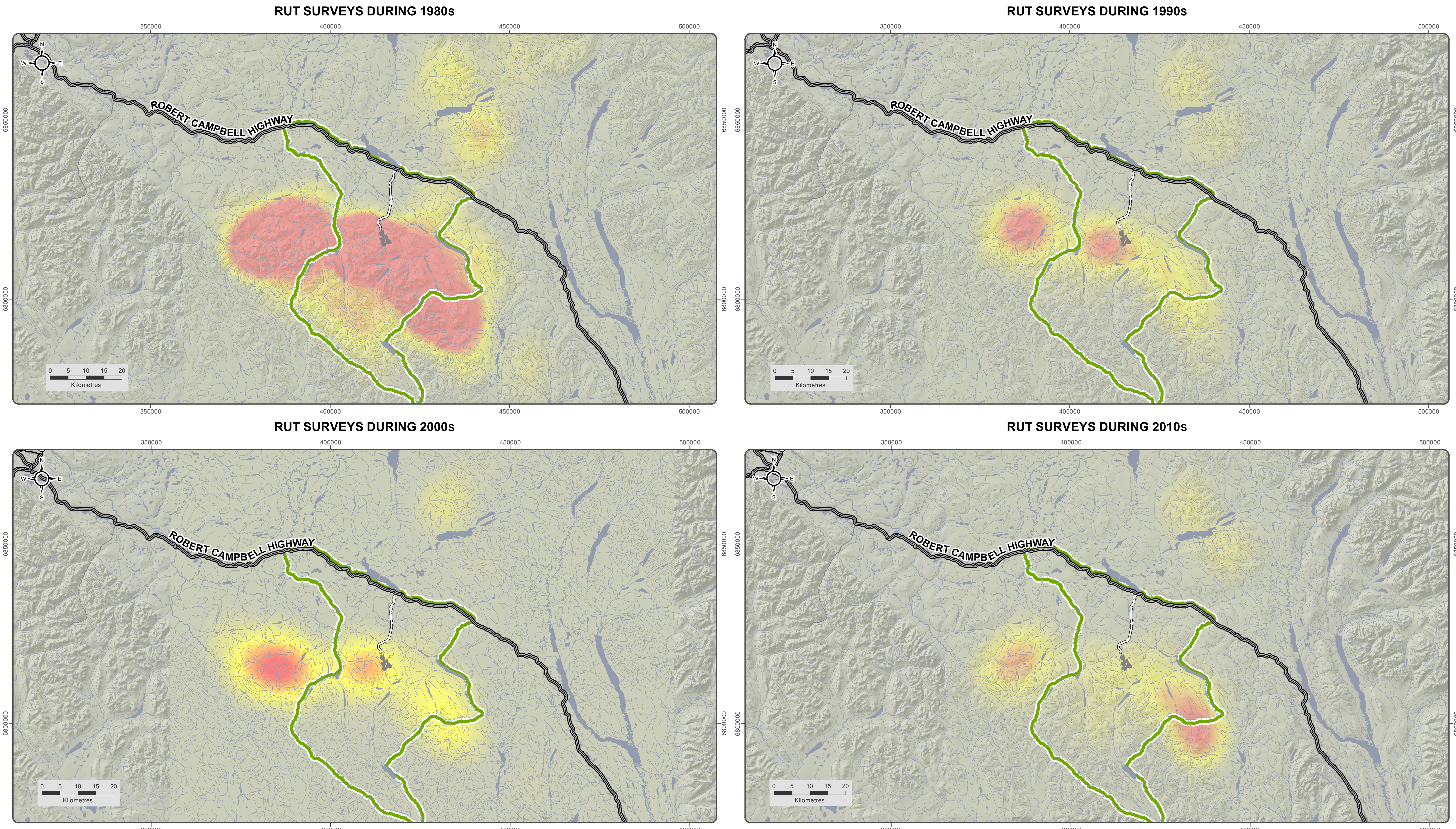
(*Last edited by: amatlashevska;20/10/2017/09:19 AM*)



1980s, 1990s and 2000s results are based on Yukon Government data of the Finlayson Caribou Herd range.
2010s results are based on Yukon Government data and AEG survey that only covered GMS 10-07

Finlayson Caribou Herd Rut Regions map was produced based on YG Relocation Surveys, YG and AEG Aerial Surveys using Quantum GIS 1.8.0-Lisboa

Datum: NAD 83; Map Projection: UTM Zone 9N

AEG

CARIBOU PRESENCE IN RUT REGIONS

- High Presence
- Moderate Presence
- No Presence

OTHER MAP FEATURES

- Location of Proposed Infrastructure
- RSA (GMS 10-07)
- Waterbody
- Watercourse
- Tote Road/Proposed Access Road

BMC MINERALS

KUDZ ZE KAYAH PROJECT

FIGURE 13-9
FINLAYSON CARIBOU HERD RUT PRESENCE

OCTOBER 2017

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(Last edited by: amatlashevska;20/10/2017/09:22 AM)

YESAB ISSUE

The caribou effects assessment seems to be based largely on percentage of habitat disturbed. This overlooks aspects of caribou ecology and potential stressors which could influence the outcome of the effects assessment for caribou.

R185

"Revise the caribou effects assessment, taking into consideration the significance of factors outlined below. Focus on caribou habitat and use related to proposed activities.

a. Rutting areas

b. Traditional use of post-calving areas

c. Snow patch use during post-calving

d. Calving success in the project area vs. the overall range

e. Stressors outside of post-calving season"

a. Rutting areas

FCH range-wide rutting areas are well documented from 30+ years of annual rut counts and during the 2015 and 2016 surveys. Traditional rutting areas are well documented and do occur within the study area and in close proximity to the Project site. This has been stated as such as presented in Section 13.4.1.1 of the Project Proposal and has been a major focus of BMC's wildlife studies and mitigation planning.

b. Traditional Use of Post-calving Areas

As presented in Chapter 3 of the Wildlife Baseline Report, Appendix E-8 of the Project Proposal, seven range-wide post-calving surveys were carried out by YG from 1982 to 1998. The number of caribou found in the FCH range was 270-2108 individuals. BMC carried out post-calving surveys within the Project study area in 2015 and 2016 and found 93 and 145 caribou, respectively. There was no indication that specific areas were traditionally used similar to those found during the rutting period.

c. Snow Patches Use During Post Calving

It is generally held that there are fewer persistent snow patches in the northern Pelly Mountains relative to most other Yukon mountain ranges, likely owing to lower mean elevations in the region. Snow patches are an important habitat for caribou in summer. A comparison can be made between the post-calving locations and locations of snow patches that can be seen on Google Earth. The post-calving locations are essentially equivalent to the locations of snow patches. In the LSA, snow patches are mainly on the ridges west of the proposed mine infrastructure and occasionally on the mountain to the east. Therefore, the degree that the Project interferes with snow patches will be equivalent to the habitat loss calculation for the post-calving assessment (i.e. 1.8% loss of highly suitable post calving habitat in the regional post calving study area).

The elevation of the snow patches may provide an indication of their longevity with climate change. The snow patches just west of the proposed mine infrastructure are around 1,800 m elevation and located about 1.8 km from the centre of the mine infrastructure so there is a high likelihood that these patches will be abandoned during the construction and operations phases. Throughout the regional range, the snow patches appear to range from 1,600 to 2,150 m elevation. With climate change, the snow patches around the Project are unlikely to be the first to go, but unlikely to be the last either.

Mitigations to minimize caribou disturbance are already included in Section 18.7.3 of the Project Proposal for employees and equipment to remain within Project boundaries and in Section 18.10.3 for noise reduction measures. The post-calving monitoring program will be modified to take GPS locations and pictures of the boundaries of a number of reference snow patches to help track snow patch changes over time.

d. Calving Success in the Project Area vs. the Overall Range

Rut count results consistently show a pattern of higher calf survival in ranges north of the Robert Campbell Highway as opposed to those south where generally two-thirds of the herd are found during counts. Disparity in calf survival across rutting areas has been observed for other Yukon woodland caribou herds and seems to be a trait with the FCH as well. Calving success in the Project area compared to the overall range does not affect the results of the effects assessment or the proposed mitigations.

e. Stressors Outside of Post-calving Season

Chapter 3 of the Wildlife Baseline Report, Appendix E-8 of the Project Proposal, and Section 13.4.1.1 Caribou Effects Characterization describe the key stressors and factors affecting the FCH in all seasons. Other stressors beyond those presented do not change the results of the effects assessment or the proposed mitigations.

R187

"Traffic effects on other caribou herds: What are the potential effects of increased hauling traffic on other Yukon caribou populations along the haul route between the mine and the boundary with B.C. (Little Rancheria and Horseranch herds)?"

Three alternative haul routes were reviewed during Project design, including a western route through Carmacks to Port of Skagway, and two eastern routes through Watson Lake and then to either Port of Skagway or Port of Stewart. Yukon Government indicated that the western route was not preferred due to the potential traffic impacts on FCH winter range. The eastern routes go along the edge of the Little Rancheria and Horseranch herd ranges and will result in an increase of approximately 26 trucks per day on the small portion of the Alaska Highway between Watson Lake and Upper Liard, and the northern part of Highway 37. The effects of increased traffic from hauling on the Alaska Highway and Highway 37 have not been assessed. There is a significant road collision problem with caribou on the Highways that are managed through signage and advisories (EDI, 2015). The highways are public facilities managed by the Department of Highways and Public Works with inputs from the Department of Environment concerning wildlife issues. BMC does not have the legal authority to manage highway traffic.

YESAB ISSUE WITH BMC'S RESPONSE TO R185 AND R187

The caribou effects assessment seems to be based largely on percentage of habitat disturbed. This overlooks aspects of caribou ecology which could influence the outcome of the effects assessment for caribou.

Insufficient Response: *The Information Request specifically asked for a revised effects assessment for caribou accounting for a variety of factors. This has not been provided. The response does not indicate any change to the effects assessment.*

Insufficient response*: The response only says how many trucks per day, but does not actually address the effects on the other caribou herds.*

R2-86

Revise the caribou effects assessment, taking into consideration the significance of factors outlined below. Focus on caribou habitat and use related to proposed activities.
a. Rutting areas
b. Traditional use of post-calving areas
c. Snow patch use during post-calving
d. Calving success in the project area vs. the overall range
e. Stressors outside of post-calving season

On October 5 2017, YESAB provided (via email) the following clarification regarding the information required in response to R2-86:

> *"In concert with the response provided to R 2-85, provide a description of the importance of the project area to caribou; i.e. how important is the project area for calving, post-calving, and rutting."*

Please refer to the caribou summary in **Appendix R2-L** for a description of the importance of the Project area to caribou.

The importance of the area was considered in the effects assessment and describing these factors do not change the mitigations and results of the effects assessment, thus the caribou effects assessment does not require revision. As presented in Section 13.4.3.1, significance of effects in the Project Proposal, there is an estimated 3.0% (7.8 km^2 direct and 47.7 km^2 indirect) loss of highly suitable rut habitat; 1.8% (1.2 km^2 direct and 27.8 km^2 indirect) loss of highly suitable post calving habitat in the regional ZOI. Even considering the factors presented above and discussed in the July 2017 adequacy response, the overall magnitude of the effects is not expected to increase above the 10% threshold; therefore, the effects remain low magnitude and local.

R2-87

Traffic effects on other caribou herds: What are the potential effects of increased hauling traffic on other Yukon caribou populations along the haul route between the mine and the boundary with B.C. (Little Rancheria and Horseranch herds)?

The transportation route goes through the range of the Little Rancheria and Horseranch caribou herds in southeast Yukon and northern BC near Watson Lake, Alaska Highway, and the north end of the Stewart-Cassiar Highway. The Little Rancheria Herd has a population of approximately 1,200 and the Horseranch Herd has a population of approximately 600 as of the last 1999 surveys (BC Ministry of Environmental Protection and Sustainability, 2017). There is some indication that they may be considered one herd and the status is that the herd is declining (Environment Yukon, 2016).

The highways pass through the core winter range of the Little Rancheria herd which has resulted in vehicle caused caribou mortalities mainly in the fall and winter (EDI, 2015; Florkiewicz et al., 2004). Vehicle traffic movement in the winter (December through March) around the Cassiar Junction averages around 250 vehicles/day (BC Ministry of Transportation and Infrastructure, 2014; Yukon Highways and Public Works, 2011). The risk of caribou mortalities will increase with the increased traffic (approximately 26 trucks per day or 10% increase in winter traffic) as a result of the proposed Project on sections of road along the transportation route west of Watson Lake and on the norther part of the Stewart-Cassiar Highway where Project trucks will be traveling. Mitigation measures are already in place in high collision areas and include cautionary signage at high incidence areas along the road that ask motorists to slow down and stay alert during key seasons of caribou use (EDI, 2015). Training of transport contractors by BMC will also include information and procedures to alert drivers to the higher potential for caribou and to maintain slower speeds in winter in these key areas. Driver training and information specific to the Little Rancheria and Horseranch Caribou Herds are included in the Draft Wildlife Protection Plan in **Appendix R2-J**.

The resulting incremental increase in adverse effects (in particular caribou mortality from collisions) on the Little Rancheria and Horseranch herds from the increased traffic after mitigations is expected to be of low magnitude (10% increase in traffic, but mitigated with awareness training for contractors), local, seasonal, long-term, and reversible (Table 13-19). The resulting effects are categorized as not significant. These caribou herds have a high social context, but given the magnitude of potential effects and that effects are very likely and have low uncertainty, the results are maintained as not significant.

Table 13-19: Significance of Residual Effects – Little Rancheria and Horseranch Caribou Herds

Residual Effect	Direction	Magnitude	Geographic Extent	Duration	Frequency	Reversibility	Environmental and Socio-economic Context	Likelihood	Significance
Disturbance and potential increased mortality in core winter range	Adverse	Low	Local	Long term	Seasonal	Reversible long term	High	Very likely; Low uncertainty	Not significant

Cumulative effects from existing traffic are already considered as part of the effects assessment above. There are no new proposed industrial projects that would overlap in time and space on the haul route through the ranges of the Little Rancheria and Horseranch herds, based on published information on surrounding projects as presented in the cumulative effects methodology in Section 5.7 and wildlife cumulative effects in Section 13.5 of the Project Proposal. There may be cumulative effects if the Wolverine Mine restarts. There would be an additional approximately 10 trucks per day (since Wolverine production was approximately 30% of Kudz Ze Kayah planned production) on the highways to Stewart which could increase winter traffic an additional 5% above current levels for a cumulative 15% increase in traffic.

It is assumed that Wolverine haul contractors will also be trained to adhere to speed limits and be made aware of the risks for winter caribou presence along the haul route. Yukon Government could implement further mitigation measures such as more signage and speed controls if warranted which would further reduce the risk of mortalities from collisions. It is uncertain as to if and/or when Wolverine mine will restart but both projects are linked to zinc prices. The significance of cumulative effects on the Little Rancheria and Horesranch caribou herds are low magnitude, local, seasonal, and moderate uncertainty, resulting in a rating of not significant (Table13-20).

Table 13-20: Cumulative Effects Significance Assessment for Little Rancheria and Horseranch Caribou Herds

Residual Cumulative Effect	Direction	Magnitude	Geographic Extent	Duration	Frequency	Reversibility	Environmental and Socio-economic Context	Likelihood	Cumulative Effect Significance
Increased sinter mortality in Little Rancheria and Horseranch caribou herds	Adverse	Low	Local in herd ranges	Long-term	Continuous	Reversible long term	High	Moderate uncertainty that timing of Wolverine and Kudz Ze Kayah projects timing will coincide	Not significant

Note: Criteria definitions are provided in Table 13-31 of the Project Proposal

YESAB ISSUE

Model methods have not been clearly disclosed. Information on the model methods will enable its adequacy to be evaluated and will assist in interpreting the model outputs.

R188

"Provide further detail on the parameters used in developing the model (elevation, vegetation cover, slope, and aspect.) In addition, provide the following information regarding the caribou habitat suitability model:

a. Sex/age classes: How many data points are in each age/sex class for each of the development and evaluation phases of the caribou HSI model?

b. Calving success and habitat alteration: Why has calving success not been used as part of the model for post-calving? Does the model take into account habitat alteration?

c. Expert opinion: Who provided expert opinion and for what aspects of the model?

d. Predictive Ecosystems Map: What is the accuracy of the PEM used?

e. Model equation: What model equation was used?"

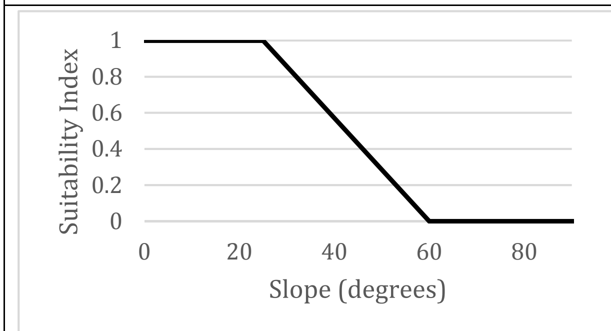
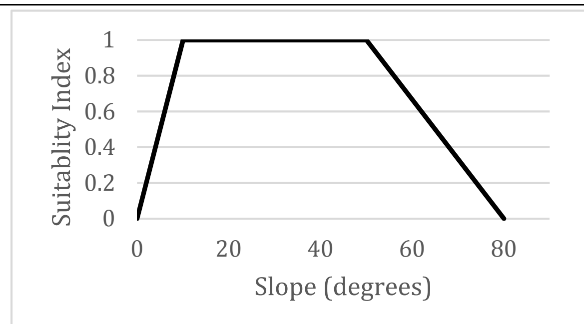
Parameters used to develop the Habitat Suitability model for the FCH are described in detail in Appendix B Caribou Habitat Suitability Report, of Appendix E-8 Wildlife Baseline Report, of the Project Proposal. The discussion on variables is reproduced below.

The four variables: elevation, slope, aspect, and vegetation cover were selected as model parameters to develop the caribou Habitat Suitability Index (HSI) for the rut and post calving seasons. These parameters describe the geographical context for habitat requirements and were the most readily available for assessing habitat suitability for the large range area being assessed. Other parameters such as minimum area, isolation, adjacency, and edge can also be used for suitability mapping (Clarke, 2012); however, the geographical context parameters captured key caribou habitat preferences described in the literature. The data used for model calibration and validation determined whether these four parameters provided an accurate model.

For each season, the respective variables were divided into classes ranging from 0 to 1, with 0 representing not suitable habitat (nil) and 1 representing highly suitable habitat (high). The classes within the variable were ranked based on their significance for caribou during the specific season. Significance of each class was determined using the distribution and frequency of observations from the calibration dataset.

Elevation data was interpreted from the 25 m digital elevation model (DEM) and was computed as a continuous variable for the purpose of the HSI. A linear fuzzy membership function was applied to determine the suitability ranking between suitable and not suitable habitat, based on elevation breaks derived from the frequency of occurrences of satellite and relocation data points at a given elevation. Suitable habitat for caribou during the post calving season is at a higher elevation than the rut season as caribou avoid predation, heat, and insects on high elevation ridges and plateaus (Ion and Kershaw, 1989). The equation and function used for post calving and rut seasons are shown in Table 13-21.

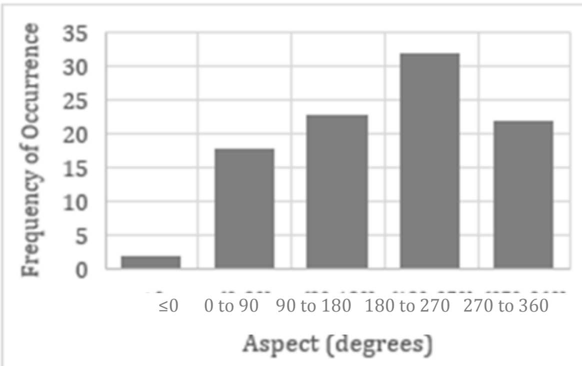
Table 13-21: Equation and Function Used for Post calving and Rut Seasons

Caribou Rut Season	Caribou Post Calving Season
Slope linear function $f(x) = \begin{cases} 0, & x \geq 60 \\ \left(\frac{x-25}{60-25}\right) & 25 < x < 60 \;\; x \in X \\ 1, & x \leq 25 \end{cases}$	Lower slope linear function $f(x) = \begin{cases} 0, & x \leq 0 \\ \left(\frac{x-0}{10-0}\right) & 0 < x < 10 \;\; x \in X \\ 1, & 10 \leq x \leq 50 \end{cases}$ Upper slope linear function $f(x) = \begin{cases} 0, & x \geq 80 \\ \left(\frac{x-50}{80-50}\right) & 50 < x < 80 \;\; x \in X \\ 1, & 10 \leq x \leq 50 \end{cases}$
	

Aspect was derived from the 25 m DEM using the aspect tool in ArcGIS. Aspect was classified into four quadrants of cardinal direction and treated as a discrete variable for the HIS. The satellite and relocation collar data was used to calibrate the aspect variable and provided the distribution shown in Table 13-22. Aspect did not show as strong of a variance between class values and as a result received a lower variable weighting in comparison to the other variables.

Table 13-22: Distribution and Class Ranking for Aspect Suitability

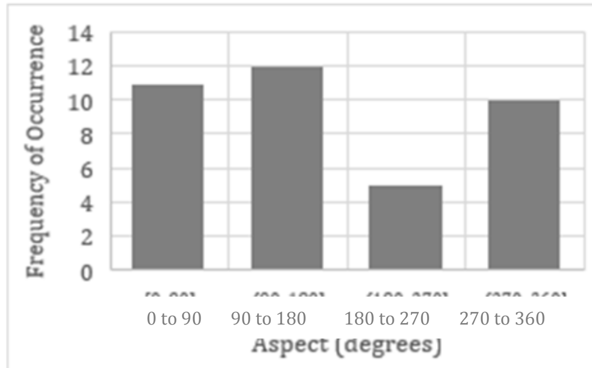
Caribou Rut Season



* x-axis represents range of values within a bin width of 90 degrees

Variable Class	Suitability Index Ranking
0-90	0.5
90-180	0.7
180-270	0.7
270-360	0.5
≤0	0.4

Caribou Post Calving Season



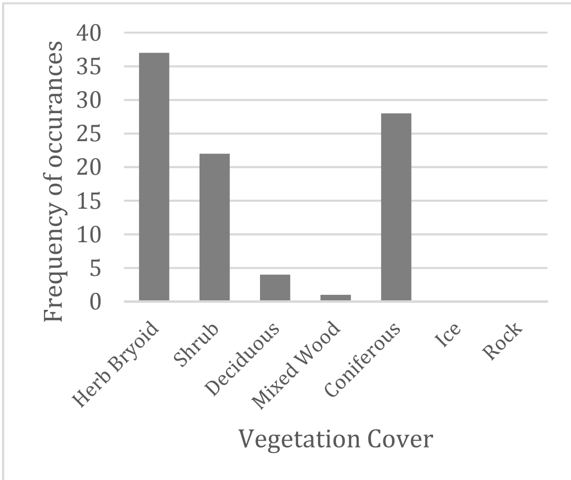
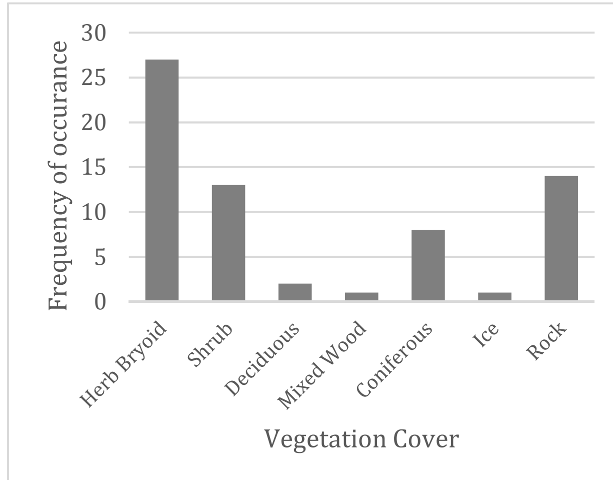
* x-axis represents range of values within a bin width of 90 degrees

Variable Class	Suitability Index Ranking
0-90	0.7
90-180	0.7
180-270	0.2
270-360	0.5
≤0	0.4

Note that <=0 aspect refers to flat ground that does not have an aspect.

Vegetation cover type was classified based on the Regional Ecosystems of *East-Central Yukon Predictive Ecosystem Map* (PEM) that was completed in 2013 by Makonis Consulting Ltd (Grods et al., 2013). The PEM spatial data and methodology was received from Environment Yukon. The PEM product was developed using land cover, surficial material, and base features (watercourses, waterbodies, and elevation) as a means to predict the broad ecosystem units in the defined study area. The final product was evaluated by ground-truthing, polygon interpretation through ecosystem plots measurements, and boundary traverses. The PEM is recommended to be used at a scale of 1:100,000 or smaller (Grods et al., 2013). For the purpose of the model, the PEM was classified into the dominant vegetation cover, not utilizing the landscape classification as these aspects were already addressed in the model. Satellite and relocation data were intersected with the PEM and the suitability index rating was developed based on the data distribution and expert knowledge as shown in Table 13-23.

Table 13-23: Distribution and Class Ranking for Vegetation Cover Suitability

Caribou Rut Season	Caribou Post Calving Season
	

Caribou Rut Season:

Variable Class	Suitability Index Ranking
Herb Bryoid	1.0
Shrub	0.8
Deciduous	0
Mixed Wood	0
Coniferous	0.5
Ice	0
Rock	0

Caribou Post Calving Season:

Variable Class	Suitability Index Ranking
Herb Bryoid	1.0
Shrub	0.5
Deciduous	0
Mixed Wood	0
Coniferous	0.1
Ice	0
Rock	0.3

a. Sex/age classes: How many data points are in each age/sex class for each of the development and evaluation phases of the caribou HSI model?

BMC does not have the data to provide this information. The age and the sex may be available from YG for the satellite collar location and relocation telemetry data. The breakdown of sex/age classes would not change the results of the effects assessment or the proposed mitigations.

b. Calving success and habitat alteration: Why has calving success not been used as part of the model for post-calving? Does the model take into account habitat alteration?

There is insufficient information about area-specific calving success surrounding the Project and the survey area to be included in the model. Long-term average calf:cow ratios for the FCH are similar to other Yukon caribou herds (Hegel, 2013). Habitat alteration was not considered in the model as the model only assessed baseline habitat suitability.

As presented in Appendix B, Caribou Habitat Suitability Report of Appendix E-8, Wildlife Baseline Report of the Project Proposal, the post-calving habitat model uses elevation, aspect, slope, and vegetation cover variables. The resulting model had a strong correlation (tau correlation coefficient = 1) with the 548 post-calving observations. Therefore, it was determined that no further variables were needed for the model to accurately define suitable post-calving habitat.

c. Expert opinion: Who provided expert opinion and for what aspects of the model?

BMC's baseline studies, habitat modelling, and effects assessment on FCH were led by [Name Redacted] who is a Yukon expert on the FCH. [Name Redacted] was Environment Yukon's caribou biologist from 1978 to 2006 and authored many publications on caribou including the 2009 publication, *Three Decades of Caribou Recovery Programs in Yukon: A Paradigm Shift in Wildlife Management*. [Name Redacted] continues to conduct surveys and consult on caribou in Yukon.

d. Predictive Ecosystems Map: What is the accuracy of the PEM used?

As presented in Section 4.6 of Appendix B, Caribou Habitat Suitability Report of the Wildlife Baseline Report, Appendix E-8 of the Project Proposal, the Regional Ecosystems of East-Central Yukon Predictive Ecosystem Map (PEM) was completed in 2013 by Makonis Consulting Ltd (Grods et al., 2013). The PEM spatial data and methodology was received from Environment Yukon. The final product was evaluated by ground-truthing, polygon interpretation through ecosystem plots measurements, and boundary traverses. The PEM is recommended to be used at a scale of 1:100,000 or smaller (Grods et al., 2013).

e. Model equation: What model equation was used?

The following are the equations used in the models:

Post calving Model: 0.5 * [Elevation] + 0.15 * [Slope] + 0.05 * [Aspect] + 0.3 * [vegetation]

Rut Model: 0.5 * [Elevation] + 0.15 * [Slope] + 0.05 * [Aspect] + 0.3 * [vegetation]

YESAB ISSUE WITH BMC'S RESPONSE TO R188

Model methods have not been clearly disclosed. Information on the model methods will enable its adequacy to be evaluated and will assist in interpreting the model outputs.

Insufficient response: Parameters have not been fully described and the responses to specific questions on the habitat suitability model have not been answered.

R2-88

Provide further detail on the parameters used in developing the model (elevation, vegetation cover, slope, and aspect.) In addition, provide the following information regarding the caribou habitat suitability model:
a. Sex/age classes: How many data points are in each age/sex class for each of the development and evaluation phases of the caribou HSI model?
b. Calving success and habitat alteration: Why has calving success not been used as part of the model for post-calving? Does the model take into account habitat alteration?
c. Expert opinion: Who provided expert opinion and for what aspects of the model?
d. Predictive Ecosystems Map: What is the accuracy of the PEM used?
e. Model equation: What model equation was used?

On October 5 2017, YESAB provided (via email) the following clarification regarding the information required in response to R2-88:

> *"Provide an updated model equation, in addition to an update on information and predictions that may be impacted by the use of a different equation."*

Aspect Index Model Revisions - It is acknowledged that the aspect index was in error for caribou as for moose as questioned in R2-100. Aspect was weighted at 5% in the model because the other components of the model (i.e., elevation, slope, and vegetation) appeared to capture the distribution accurately. Therefore, the equations remained as:

Post calving Model: 0.5 * [Elevation] + 0.15 * [Slope] + 0.05 * [Aspect] + 0.3 * [vegetation]

Rut Model: 0.5 * [Elevation] + 0.15 * [Slope] + 0.05 * [Aspect] + 0.3 * [vegetation]

The data collected for the frequency graphs for aspect were based on collared data from only a few individuals. The model was revised to set the maximum at 1.0. Table 13-24 shows the revised aspect index rankings for caribou rut and post-calving.

Table 13-24: Class Ranking for Aspect Suitability - Revised

Variable Class	Rut Aspect Index Ranking		Post-Calving Index Ranking	
	December 2016 Model	August 2017 Revised Model	December 2016 Model	August 2017 Revised Model
0-90	0.5	0.5	0.7	1
90-180	0.7	0.7	0.7	1
180-270	0.7	1	0.2	0.4
270-360	0.5	0.5	0.5	0.8

The revised model results are shown for rut and post-calving habitat (with the December 2016 model percentages shown for comparison) in Table 13-25, Table 13-26, Figure 13-10 and Figure 13-11. With these revisions, the model results in no change in direct and 2% increase in indirect loss of moderate to high suitability rut habitat in the Zone of Influence; and a 0.2% increase in direct and

2% increase in indirect loss of moderate to high suitability post-calving habitat in the Zone of Influence. These changes result in no change to the results of the effects assessment, nor the proposed mitigation measures.

Table 13-25: Summary of Finlayson Caribou Herd Rut Habitat Changes - August 2017 Revised

FCH Home Range Habitat Suitability Index Study Area				
Habitat Suitability Index*	Number of Cells**	Area (ha)	Percent of FCH home range (HSI) (December 2016 Model Percent for comparison)	
Nil	278,869	17,429	1% (0%)	
Very Low	9,113,890	569,618	28% (31%)	
Low	13,981,158	873,822	43% (41%)	
Moderate	3,439,383	214,961	11% (11%)	
Moderately High	3,052,825	190,802	9% (9%)	
High	2,729,029	170,564	8% (8%)	
Rut Habitat Suitability Index (Caribou Rut ZOI from AEG 2015-2016 survey)				
Habitat Suitability Index	Number of Cells	Area (ha)	Percent of FCH home range (HSI) (December 2016 Model Percent for comparison)	
Nil	20,682	1,293	7% (16%)	
Very Low	145,530	9,096	2% (2%)	
Low	758,851	47,428	5% (6%)	
Moderate	686,417	42,901	20% (20%)	
Moderately High	795,293	49,706	26% (26%)	
High	929,990	58,124	34% (34%)	
Indirectly Affected Habitat (based on LSA 3 km buffer around mine site and 1.5 km buffer around road)				
Habitat Suitability Index	Number of Cells	Area (ha)	Percent of FCH home range (HSI)	Percent of Rut ZOI (December 2016 Model Percent for comparison)
Nil	50	3	0.0%	0% (1%)
Very Low	17,071	1,067	0.2%	12% (11%)
Low	59,053	3,691	0.4%	8% (7%)
Moderate	34,424	2,152	1.0%	5% (4%)
Moderately High	39,322	2,458	1.3%	5% (4%)
High	49,744	3,109	1.8%	5% (5%)

Directly Affected Suitability Caribou Habitat from Project Feature Footprint				
Habitat Suitability Index	Number of Cells	Area (ha)	Percent of FCH home range (HSI)	Percent of Rut ZOI (December 2016 Model Percent for comparison)
Very Low	69	4	0.0%	0.0% (0.0%)
Low	1,037	65	0.0%	0.1% (0.1%)
Moderate	2,167	135	0.1%	0.3% (0.4%)
Moderately High	9,152	572	0.3%	1.2% (1.1%)
High	3,513	220	0.1%	0.4% (0.4%)

* Classifications of nil, very low and low are not located in the Project footprint

** Cell size 25 m x 25 m (625 m^2)

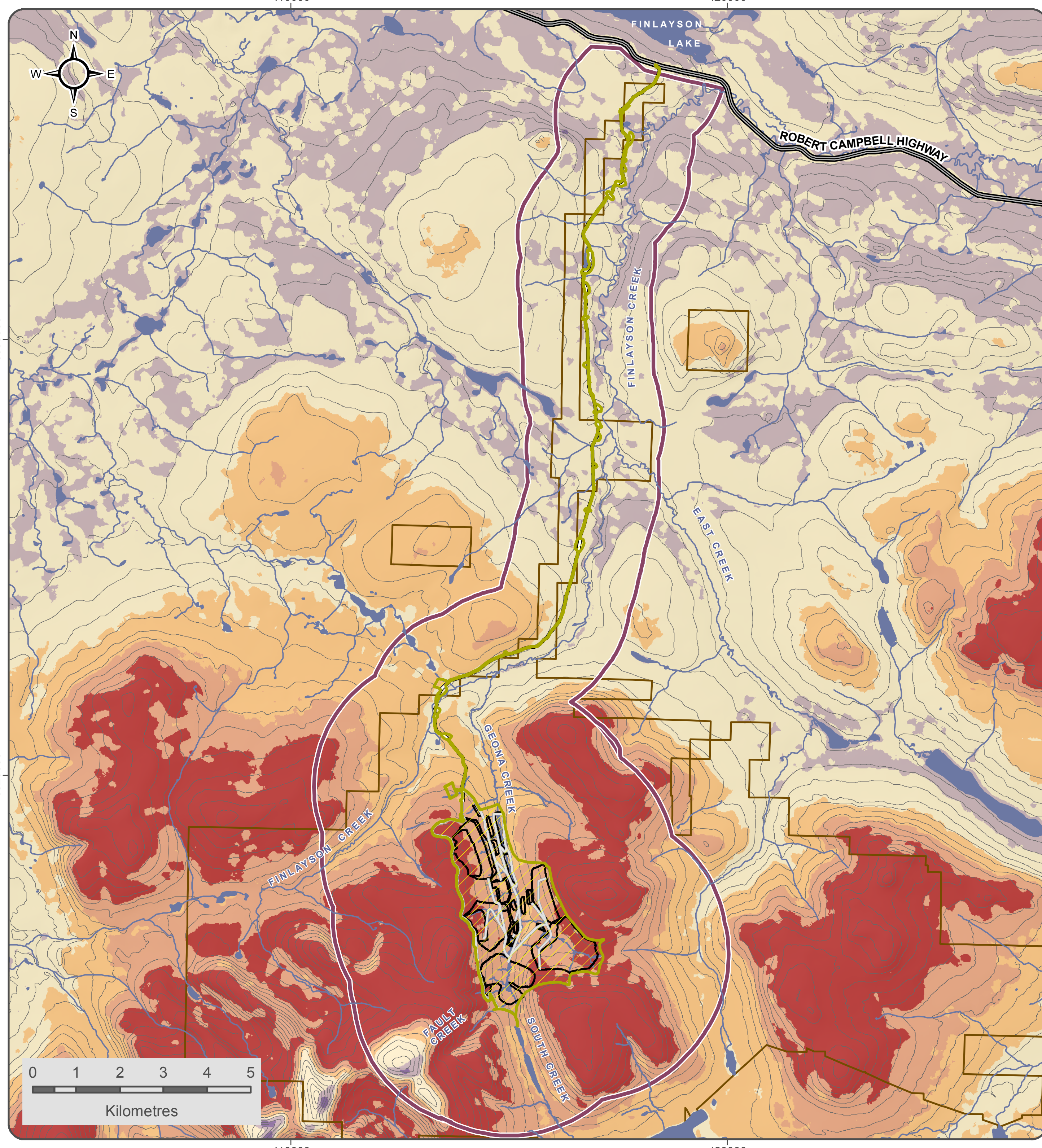
Table 13-26: Summary of Finlayson Caribou Herd Post-Calving Habitat Changes - August 2017 Revised

FCH Home Range Habitat Suitability Index Study Area			
Habitat Suitability Index*	Number of Cells**	Area (ha)	Percent of FCH home range (HSI) (December 2016 Model Percent for comparison)
Nil	6,196,925	387,308	19% (23%)
Very Low	17,269,323	1,079,333	53% (50%)
Low	3,645,616	227,851	11% (11%)
Moderate	1,661,751	103,859	5% (5%)
Moderately High	1,638,514	102,407	5% (5%)
High	2,179,413	136,213	7% (6%)
Post Calving Habitat Suitability Index (Caribou Post Calving ZOI from AEG 2015-2016 survey)			
Habitat Suitability Index	Number of Cells	Area (ha)	Percent of FCH home range (HSI) (December 2016 Model Percent for comparison)
Nil	142,516	8,907	2% (3%)
Very Low	1,283,398	80,212	7% (8%)
Low	609,244	38,078	17% (17%)
Moderate	480,307	30,019	29% (30%)
Moderately High	515,130	32,196	31% (32%)
High	882,087	55,130	40% (40%)

Indirectly Affected Habitat (based on LSA 3 km buffer around mine site and 1.5 km buffer around road)				
Habitat Suitability Index	Number of Cells	Area (ha)	Percent of FCH home range (HSI)	Percent of Post Calving ZOI (December 2016 Model Percent for comparison)
Nil	13,207	825	0.21	9.3% (9.7%)
Very Low	77,419	4,839	0.45	6.0% (5.4%)
Low	31,909	1,994	0.88	5.2% (4.6%)
Moderate	26,028	1,627	1.57	5.4% (4.1%)
Moderately High	18,926	1,183	1.16	3.7% (3.4%)
High	32,175	2,011	1.48	3.6% (3.2%)
Directly Affected Suitability Caribou Habitat from Project Feature Footprint				
Habitat Suitability Index	Number of Cells	Area (ha)	Percent of FCH home range (HSI)	Percent of Post Calving ZOI (December 2016 Model Percent for comparison)
Nil	38	2	0.0%	0.0% (0.0%)
Very Low	983	61	0.0%	0.1% (0.1%)
Low	6,464	404	0.2%	1.1% (1.1%)
Moderate	6,275	392	0.4%	1.3% (1.2%)
Moderately High	2,070	129	0.1%	0.4% (0.3%)
High	108	7	0.0%	0.0% (0.0%)

* Classifications of nil, very low and low are not located in the Project footprint

** Cell size 25 m x 25 m (625 m^2)



HABITAT SUITABILITY INDEX

- Nil
- Very Low
- Low
- Moderate
- Moderately High
- High

- Tote Road/Proposed Access Road
- Proposed Mine Road
- Direct Disturbance Area
- Local Study Area (Indirect Zone of Influence)
- Location of Proposed Infrastructure
- BMC Minerals (No.1) Ltd. Mineral Claim Areas

KUDZ ZE KAYAH PROJECT

FIGURE 13-10
FCH RUT HABITAT SUITABILITY - REVISED

OCTOBER 2017

National topographic Data Base (NTDB) compiled by Natural Resources Canada at a scale of 1:50,000. Reproduced under license from Her Majesty the Queen, as represented by the Minister of Natural Resources Canada. All rights reserved.
Datum: NAD 83; Projection: UTM Zone 9N

AEG

BMC MINERALS

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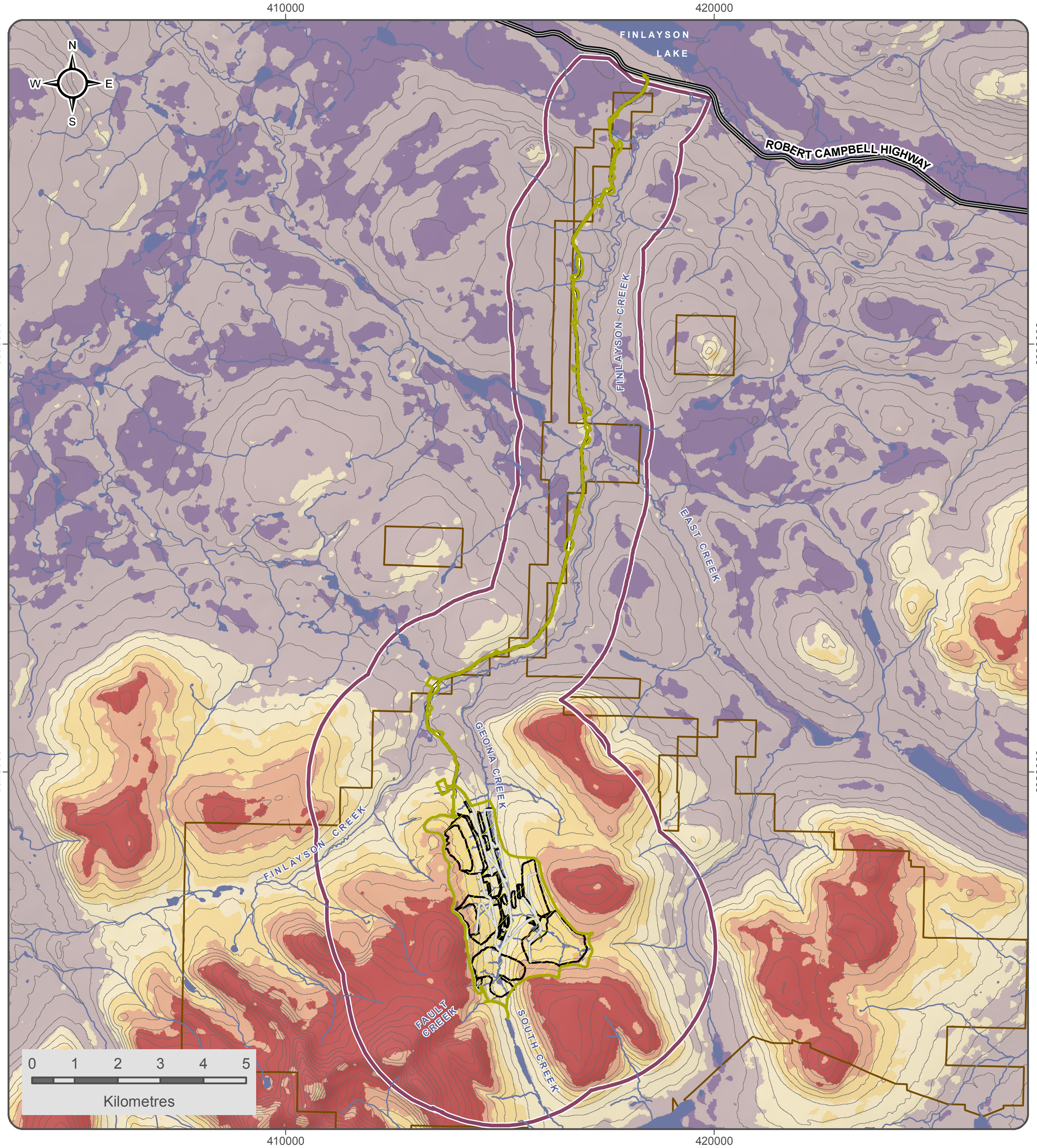

HABITAT SUITABILITY INDEX

- Nil
- Very Low
- Low
- Moderate
- Moderately High
- High

- Tote Road/Proposed Access Road
- Proposed Mine Road
- Direct Disturbance Area
- Local Study Area (Indirect Zone of Influence)
- Location of Proposed Infrastructure
- BMC Minerals (No.1) Ltd. Mineral Claim Areas

KUDZ ZE KAYAH PROJECT

FIGURE 13-11

FCH POST-CALVING HABITAT SUITABILITY - REVISED

OCTOBER 2017

Datum: NAD 83; Projection: UTM Zone 9N

AEG

BMC MINERALS

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(Last edited by: amatlashevska; 29/08/2017/14:57 PM)

a. Sex and Age Distribution - It is acknowledged that there may be differences in the accuracy model depending on the sex and age of the caribou. To test this theory for the FCH around the Project, the age and sex of caribou observed from all Yukon Government and BMC surveys (rut surveys annually since 1982 and post calving surveys from 1982 to 1985, 1995, 1996, 1998, 2015, and 2016) were separated out by habitat suitability area for rut and post-calving periods. Results are presented in Table 13-27 and Table 13-28 and the percentage distributions shown in Figure 13-12 and Figure 13-13 below. There is no significant difference between the observed distribution of cows and mature bulls in both rut and post-calving periods (Kolmogorov-Smirnov two sample, two-tailed test results for both rut and post-calving were D=0.33, p>0.05).

Table 13-27: Caribou Rut Sex and Age Distribution

Habitat Suitability Area	Cows	Mature Bulls	Immature Bulls	Calves	Yearlings	Unclassified
High	15,467	3,516	3,997	2,541	310	29
Moderately High	5,515	1,282	1,500	658	106	0
Moderate	1,044	261	322	182	33	0
Low	757	173	207	185	32	0
Very Low	124	31	28	37	15	0
Nil	8	6	0	2	1	0
Total	22,915	5,269	6,054	3,605	497	29

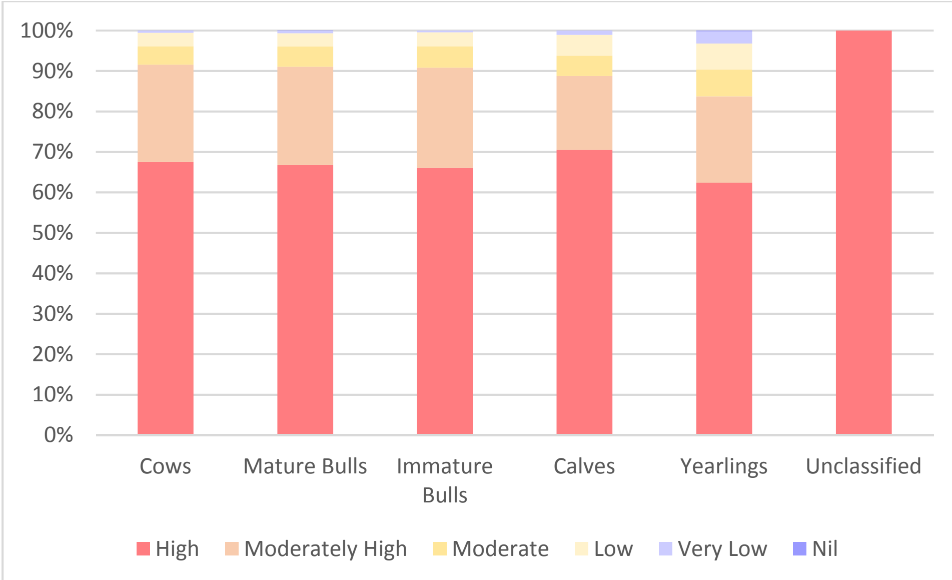


Figure 13-12: Caribou Rut Habitat Suitability Distribution by Sex and Age

Table 13-28: Caribou Post-Calving Sex and Age Distribution

Habitat Suitability Area	Cows	Bulls	Calves	Yearlings	Unclassified
High	1,392	284	508	55	18
Moderately High	416	121	127	16	4
Moderate	216	20	110	7	1
Low	17	15	3	0	0
Very Low	24	8	9	1	0
Nil	0	0	0	0	0
Total	2,248	454	835	113	23

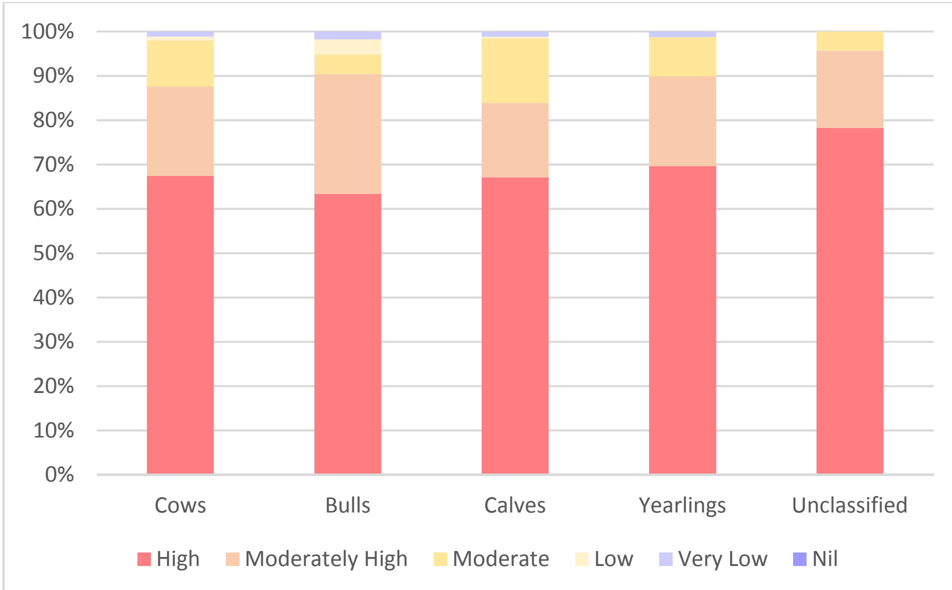


Figure 13-13: Caribou Post-Calving Habitat Suitability Distribution by Sex and Age

b. Calving Success and Habitat Alteration - Calving success was considered when developing the model; however, it was not included due to data limitations. Habitat alteration was considered when developing the model; however, the main habitat alteration affecting herd distribution is believed to be the Robert Campbell Highway. The Highway does not affect the distribution of suitable rut and post-calving habitat south of the Highway which is the focus of the assessment. Therefore, it was determined not to be material for the modeling.

c. Expert Opinion - [Name [Name Redacted] both in his role at Environment Yukon and later as a consultant, has studied, managed, and was part of the collaring program for the Finlayson Caribou Herd. [Name Redacted] was an integral part of developing all parts of the caribou and moose habitat suitability model indices and reviewed, edited, and signed the habitat suitability model reports. [Name Redacted] resume is included in **Appendix R2-M** of this Response Report. In addition, [Name Redacted] Ungulate Biologist of the Fish and Wildlife Branch of Environment Yukon, also an expert on the Finlayson Caribou Herd, was consulted during the development of the models to assess what could be modeled and what indices could be used given the available data sets.

d. PEM Accuracy - The final product was evaluated by air photos, ground-truthing, polygon interpretation through ecosystem plots measurements, and boundary traverses. The PEM is recommended to be used at a scale of 1:100,000 or smaller (Grods et al., 2013). There are no accuracy assessment standards in place yet for Yukon (Grods, pers comm.); however, there was an assessment of the mapping accuracy (Makonis, 2012). It was concluded that the PEM accuracy was 57% (36 of 63 plots were correct).

e. Model equation: What model equation was used?

The model equation remained the same as was provided above in response to R188e and has been reassessed with the revision in aspect ratings.

YESAB ISSUE

There are unclear points and inconsistencies in presentation of information which make it difficult to assess adequacy of the model.

R189

"Provide clarity on the inconsistencies detailed below.

a. Model methods and metrics inconsistency: The methods say that "observation density" was used to evaluate the model (p. 18) but the Results section (p.19) reports relationships between suitability classes and the number of occurrences (rather than the density). Clarify what metric was used to evaluate the model.

The stated number of occurrences in Appendix B, Caribou Habitat Suitability Report of the Wildlife Baseline Report, Appendix E-8 of the Project Proposal was incorrect. Observation density was used to evaluate the model rather than total number of observations as the latter is proportional to the surface area corresponding to each suitability class.

b. Aspect class clarification: Clarify what the aspect class ≤0 is. In what situation would an aspect be <0 degrees?

The dataset used in the model input for aspect is comprised of numbers from 0 to 359 to indicate aspects. The value of "0" is for North, 90 is East, 180 is South, etc. The value of -1 is used to indicate areas that are flat and hence have no aspect.

c. Measure of availability not included: It is useful to look at use, and use in relation to availability, when assessing value of a habitat category. What is the availability of each of the aspect and vegetation cover classes in relation to caribou use?"

Habitat availability was not considered in the model as the model only assessed baseline habitat suitability assuming no development/use. There were no limitations for access to habitats that affect availability in the area modelled for baseline conditions.

As presented in Appendix B, Caribou Habitat Suitability Report of Appendix E-8, Wildlife Baseline Report of the Project Proposal, the post-calving habitat model use elevation, aspect, slope, and vegetation cover variables. The resulting Habitat Suitability (HS) post-calving model had a strong correlation with actual densities (tau correlation coefficient = 1) based on 548 post-calving observations. The rut HS (p-value = 0.0278) suggests a significant correlation between related habitat suitability and actual densities within each class while the strength of the correlation is strong (tau correlation coefficient = 0.7333) based on 2124 rut observations. Therefore, it was determined that no further variables were needed for the model to understand the availability of suitable habitat for the purposes of the effects assessment and mitigation planning.

YESAB ISSUE WITH BMC'S RESPONSE TO R189

There are unclear points and inconsistencies in presentation of information which make it difficult to assess adequacy of the model.

Insufficient response: A simple measure of habitat availability is the area covered by each habitat category, which should be fairly simple to generate.

R2-89

Provide clarity on the inconsistency detailed below.
a. Measure of availability not included: It is useful to look at use, and use in relation to availability, when assessing value of a habitat category. What is the availability of each of the aspect and vegetation cover classes in relation to caribou use?

On October 5 2017, YESAB provided (via email) the following clarification regarding the information required in response to R2-89:

> *"BMC has asserted that there is sufficient suitable habitat and vegetation types for all seasons in relation to caribou ecology. The goal is to understand the impact of displacement in terms of forage availability.*
>
> *Provide rationale for the assertion that there is sufficient suitable habitat and vegetation availability throughout the FCH range."*

Available forage is not a limiting factor for the Finlayson Caribou Herd. This has best been demonstrated by the results from the wolf control program as discussed in Section 3.2.1 of the Wildlife Baseline Report, Appendix E-3 of the Project Proposal. The herd population went from approximately 2000 before the wolf control to approximately 6000 during the wolf control and then decreased to approximately 3000 following the wolf control as seen in the reproduction of Figure 3-2 from the Wildlife Baseline Report (below). This clearly shows that the habitat and available forage can support at least twice current population levels.

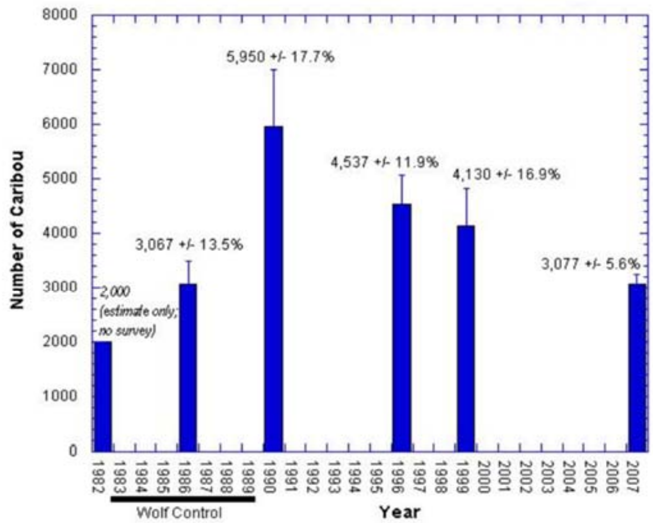


Figure 3-2: Estimated Population Size of Finlayson Caribou Herd from March Surveys, 1982 to 2007 (Farnell, 2009)

Habitat availability (directly related to availability of forage) for each habitat category was provided in the effects assessment in Tables 13-7 and 13-8 of the Project Proposal and in Appendix B, of the caribou habitat suitability of the Wildlife Baseline Report, Appendix E-8. Table 13-29 and

Table 13-30 summarize the available rut and post-calving habitat, respectively, in each habitat category for the FCH range, zone of influence, LSA, and Project Footprint. These tables and the findings of the wolf control programs are considered sufficient rationale that the habitat and vegetation types for all seasons is not a limiting factor for the Finlayson Caribou Herd.

Table 13-29: FCH Rut Available Habitat Summary by Area

Habitat Suitability	FCH Range (ha)	ZOI (ha)	LSA (ha)	Project Footprint (ha)
Nil	2,938	466	4	4
Very Low	631,895	10,423	1,151	63
Low	830,922	47,699	3,546	152
Moderate	213,789	42,803	1,849	569
Moderately High	192,737	50,403	1,991	208
High	164,978	56,754	2,780	4
Total	2,037,259	208,548	11,321	1,000

Table 13-30: FCH Post-Calving Available Habitat Summary by Area

Habitat Suitability	FCH Range (ha)	ZOI (ha)	LSA (ha)	Project Footprint (ha)
Nil	467,929	13,028	1,269	5
Very Low	1,012,818	79,009	4,268	70
Low	224,298	38,073	1,753	434
Moderate	102,307	30,313	1,254	369
Moderately High	101,316	32,595	1,109	112
High	128,251	51,526	1,669	6
Total	2,036,919	244,544	11,322	996

YESAB ISSUE

The Assessment Endpoint/Threshold Criterion for "Health condition" appears to be an error as it does not address health condition.

R190

What is the Assessment Endpoint/Threshold Criteria for Health condition for caribou?"

The health thresholds for subcomponents Finlayson Caribou Herd, moose, grizzly bear, grey wolf, wolverine, and collared pika should be corrected to qualitative, with no observable deterioration of physical condition. These thresholds were in error in Table 13-3 Wildlife Subcomponents, Measurable Parameters, Threshold Criteria, and Threshold Rationale of the Project Proposal, with table reproduced below with corrected thresholds as Table 13-31.

Table 13-31: Wildlife Subcomponents, Measurable Parameters, Threshold Criteria, and Threshold Rationale

Subcomponents	Measurable Parameters	Assessment Endpoint/Threshold Criteria	Threshold Rationale/Source
Finlayson Caribou Herd	Change in suitable habitat from baseline conditions (including both direct and indirect habitat loss)	Low: <10% change in RSA moderate-high to high suitability rut or post calving habitat Moderate: >10% but <15% change in RSA moderate-high to high suitability rut or post calving habitat High: >15% change in RSA moderate-high to high suitability rut or post calving habitat	Environment Canada (2011); Andrén (1994); Swift and Hannon (2010) Anderson et al (2002)

Subcomponents	Measurable Parameters	Assessment Endpoint/Threshold Criteria	Threshold Rationale/Source
	Change in wildlife movement Change in population distribution	Qualitative - no barriers to seasonal movement patterns	Professional opinion
	Change in wildlife mortality directly from Project activities (i.e., vehicle collisions and hunting)	No injuries or fatalities (unless required for human safety) directly attributed to the Project	Hegel (2013) BMC conservation philosophy[1]
	Health condition	Qualitative. No observable deterioration of physical condition.	BMC conservation philosophy[1]
Moose	Change in suitable habitat from baseline conditions (including both direct and indirect habitat loss)	Low: <10% change in RSA moderate-high to high suitability post rut or late winter habitat Moderate: >10% but <15% change in RSA moderate-high to high suitability post rut or late winter habitat High: >15% change in RSA moderate-high to high suitability post rut or late winter habitat	Environment Canada (2011); Andrén (1994); Swift and Hannon (2010)
	Change in wildlife movement Change in population distribution	Low: road density <0.2 km/km^2 Moderate: road density 0.2 to 0.4 km/km^2 High: road density >0.4 km/km^2	Beyer et al. (2013)
	Change in wildlife mortality directly from Project activities (i.e., vehicle collisions)	No injuries or fatalities (unless required for human safety) directly attributed to Project activity	BMC conservation philosophy[1]
	Health condition	Qualitative. No observable deterioration of physical condition.	BMC conservation philosophy[1]
Grizzly Bear	Change in suitable habitat from baseline conditions (including both direct and indirect habitat loss)	Low: <10% change in RSA moderate to high suitability denning habitat Moderate: >10% but <15% change in RSA moderate to high suitability denning habitat High: >15% change in RSA moderate to high suitability denning habitat	Environment Canada (2011); Andrén (1994); Swift and Hannon (2010) Dykstra (2004) and AXYS (2002)
	Change in wildlife movement and direct disturbance	High: road density >0.6 km/km^2	Beazley et al. (2004) Boulanger and Stenhouse (2014)

Subcomponents	Measurable Parameters	Assessment Endpoint/Threshold Criteria	Threshold Rationale/Source
	Change in wildlife mortality directly from Project activities (i.e., vehicle collisions, dispatched for human safety)	No injuries or fatalities (unless required for human safety) directly attributed to mine activity	BMC conservation philosophy[1]
	Health condition	Qualitative. No observable deterioration of physical condition.	BMC conservation philosophy[1]
Grey Wolf	Prey availability	Low: if moderate rating for loss of suitable habitat either caribou or moose and low for the other, or low for both Moderate: if high rating for loss of suitable habitat either caribou or moose and low for the other, or moderate for both High: if high rating for either loss of suitable habitat caribou and moose and moderate for the other, or high for both	Hayes and Harestad (2000); [Name Reda (2009)
	Mortality	No injuries or fatalities (unless required for human safety) directly attributed to mine activity	BMC conservation philosophy[1]
	Health condition	Qualitative. No observable deterioration of physical condition.	BMC conservation philosophy[1]
Wolverine	Habitat Avoidance	High: road density >0.6 km/km^2	Beazley et al. (2004)
	Mortality	No injuries or fatalities (unless required for human safety) directly attributed to mine activity	BMC conservation philosophy[1]
	Health condition	Qualitative. No observable deterioration of physical condition.	BMC conservation philosophy[1]
Collared Pika	Change in suitable habitat from baseline conditions (including both direct and indirect habitat loss)	Low: 0-10% in LSA high suitability habitat Moderate: 10-25% in LSA high suitability habitat High: >25% in LSA high suitability habitat	Habitat thresholds for birds and wildlife are determined from work by Swift and Hannon (2010); Andrén (1994); and others – see text below
	Health condition	Qualitative. No observable deterioration of physical condition.	BMC conservation philosophy[1]
Little Brown Bat	Change in suitable habitat from baseline conditions (including both direct and indirect habitat loss)	Low: 0-10% in LSA high suitability habitat Moderate: 10-25% in LSA high suitability habitat High: >25% in LSA high suitability habitat	Habitat thresholds for birds and wildlife are determined from work by Swift and Hannon (2010); Andrén (1994); and others – see text below
	Mortality	No injuries or fatalities (unless required for human safety) directly attributed to mine activity	BMC conservation philosophy[1]
	Health condition	Qualitative. No observable deterioration of physical condition.	BMC conservation philosophy[1]

Subcomponents	Measurable Parameters	Assessment Endpoint/Threshold Criteria	Threshold Rationale/Source
Cliff-Nesting Raptors	Change in suitable habitat from baseline conditions (including both direct and indirect habitat loss)	Low: 0-10% in LSA high suitability habitat Moderate: 10-25% in LSA high suitability habitat High: >25% in LSA high suitability habitat	Habitat thresholds for birds and wildlife are determined from work by Swift and Hannon (2010); Andrén (1994); and others – see text below
	Health condition	Qualitative. No observable deterioration of physical condition.	BMC conservation philosophy[1]
Passerine birds (represented by Olive-sided Flycatcher)	Change in suitable habitat from baseline conditions (including both direct and indirect habitat loss)	Low: 0-10% in LSA high suitability habitat Moderate: 10-25% in LSA high suitability habitat High: >25% in LSA high suitability habitat	Habitat thresholds for birds and wildlife are determined from work by Swift and Hannon (2010); Andrén (1994); and others – see text below
	Mortality	No injuries or fatalities (unless required for human safety) directly attributed to mine activity	BMC conservation philosophy[1]
	Health condition	Qualitative. No observable deterioration of physical condition.	BMC conservation philosophy[1]
Waterfowl	Change in suitable habitat from baseline conditions (including both direct and indirect habitat loss)	Low: 0-10% in LSA high suitability habitat Moderate: 10-25% in LSA high suitability habitat High: >25% in LSA high suitability habitat	Habitat thresholds for birds and wildlife are determined from work by Swift and Hannon (2010); Andrén (1994); and others – see text below
	Mortality	No injuries or fatalities (unless required for human safety) directly attributed to mine activity	BMC conservation philosophy[1]
	Health condition	Qualitative. No observable deterioration of physical condition.	BMC conservation philosophy[1]
Bumble bees	Change in available habitat	Low: 0-10% in LSA Moderate: 10-25% High: >25% in LSA	Habitat thresholds for birds and wildlife are determined from work by Swift and Hannon (2010); Andrén (1994); and others – see text below

[1] BMC has a conservation philosophy demonstrated through its environmental, no hunting/no fishing, no firearms, and no feeding of animals policies presented in Appendix A.

YESAB ISSUE WITH BMC'S RESPONSE TO R190

The Assessment Endpoint/Threshold Criterion for "Health condition" appears to be an error as it does not address health condition.

Insufficient Response: The health threshold for Finlayson caribou, moose, grizzly bear, grey wolf, wolverine and collared pika has been updated to a qualitative assessment of "no observable deterioration in physical condition". Assessing the health condition of any animal would require repeated observations of individuals.

R2-90

Provide details about the methodology for the proposed qualitative assessment of no observable deterioration in physical condition for caribou, moose, grizzly bear, grey wolf, wolverine, and collared pika.

Wildlife health effects are an important potential effect from mining activities. It is acknowledged that observing health conditions of individual animals is difficult and the threshold description should have been expanded to cross-reference the other indirect methods by which wildlife health will be protected and monitored. Indirect measures will include the air quality, soil quality and water quality monitoring programs that will be implemented to ensure air quality, soil quality and water quality protection measures are working effectively and contaminants are not entering the receiving environment in concentrations that would be a risk to wildlife health. In addition, the programs to monitor wildlife use of habitat around the Project will be used as indirect measures of the health of the wildlife populations that could result from displacement to less favourable habitat and/or changes in energy use by animals avoiding mine activities. This is further described in the Draft Wildlife Protection Plan (**Appendix R2-J** of this Response Report). It should be noted that the water quality modeling and management is presented in Section 8, soil monitoring is presented in Section 11, and the air quality modeling presented in Section 6 of the Project Proposal do not project any significant increases in contaminants in the surrounding environment.

Direct measures (i.e. capturing mammals and analysing their tissues) are not proposed to monitor wildlife health because, as the invasive measures necessary (i.e. mortality) to monitor health in one location over time are considered to be an unacceptable Project effect to wildlife and would not be supported by the Kaska First Nation. However, from experience on mine sites, personnel often see the same wildlife frequenting the Project area, and notes on animal health in the wildlife logs can be used to help identify changes to an animal's condition over time. The wildlife observation cards currently used in exploration and will continue to be used for the wildlife logs include a space to record the condition and behaviour of the animals (this is also included in the Draft Wildlife Protection Plan presented in **Appendix R2-J**). Yukon Government also monitors parasites and infection diseases of Yukon caribou herds (Hegel and Russell, 2013), which may be a source of reference during the implementation of the Wildlife Management Plan. Other sources that can be used to identify changes to wildlife condition can come from trappers, guide outfitters, and First Nations carrying out traditional activities around the Project.

YESAB ISSUE

Residual effects to caribou may not be considered fully. Although each individual effect may not be considered significant, the overall (additive) effect of all the effects combined is also important in assessing the impact to caribou.

R191

"Provide additional discussion on the additive effect of all residual effects of the project to caribou."

As presented in Section 13.4.3.1 Caribou, (Residual Effects, Consequence, and Significance Rating) and in Table 13-31 Significance of Residual Effects - Finlayson Caribou Herd in the Project Proposal, effects are low magnitude and local for loss of direct and indirect rut and post-calving habitat, disturbance of movement corridors between the Pelly River lowlands and the alpine areas around the Project, direct mortality from collisions with vehicles, and disturbance from flights using the Finlayson Lake airstrip. When these effects are taken together, caribou could be affected from Project disturbance in most seasons which could cumulatively affect the energetics of some individuals and result in lower birth rates and calf survival. Reduced energetics and displacement could also affect predation rates. However, the northern mountain ecotype has shown plasticity in seasonal habitat use and distributions (COSEWIC, 2014a) so the additive effects are uncertain. Overall, the combined effective habitat loss will still be low magnitude with respect to the herd range. The additional information does not change the proposed mitigations or the results of the assessment.

YESAB ISSUE WITH BMC'S RESPONSE TO R191

Residual effects to caribou may not be considered fully. Although each individual effect may not be considered significant, the overall (additive) effect of all the effects combined is also important in assessing the impact to caribou.

Insufficient Response: Additional discussion has been provided, but statements made have not been adequately supported or clarified with literature. Provide references for statements made.

R2-91

Provide additional discussion on the additive effect of all residual effects of the project to caribou.

The response above to R191 summarized the effects on the Finlayson Caribou Herd from the Project Proposal as low magnitude and local for loss of direct and indirect rut and post-calving habitat, disturbance of movement corridors between the Pelly River lowlands and the alpine areas around the Project, direct mortality from collisions with vehicles, and disturbance from flights using the Finlayson Lake airstrip. The response then indicated that when these effects are taken together (i.e. added), caribou could be affected from Project disturbance in most seasons which could cumulatively affect the energetics of some individuals and result in lower birth rates and calf survival. Reduced energetics and displacement could also affect predation rates. The reference to support this is the *Management Plan for Northern Mountain Population of Woodland Caribou* (*Rangifer tarandus caribou) in Canada* by Environment Canada (2012).

However, the northern mountain ecotype has shown plasticity in seasonal habitat use and distributions (COSEWIC, 2014a) and the Yukon caribou are predator-limited populations (Hayes et al, 2003) and climate change factors are also likely influencing the herds (Hegel et al, 2010), so the additive effects are uncertain. Modeling cumulative effects of caribou populations is known to have uncertainties in responses as was discussed in the cumulative effects assessment for caribou herds in the South Peace region of British Columbia (Johnson et al, 2015). Overall, the combined effective habitat loss will still be low magnitude with respect to the herd range (i.e., 124 km^2 potentially affected in the LSA which equates to approximately 0.5% of the FCH range; approximately 4 to 5% of moderate to high suitability post-calving and rut habitat potentially affected south of the Robert Campbell Highway; and, periodic disturbance of some winter range from scheduled landings at Finlayson Lake airstrip). The additional information on additive effects does not change the proposed mitigations or the results of the assessment.

YESAB ISSUE

Some of the surveys in 2015 and 2016 (and possibly in 1996) appear to have been conducted when exploration activities were occurring. Exploration activities could have affected distribution of caribou during those surveys. The authors do not address how the explorations activities may have affected survey results, which could affect some interpretations.

R193

"Clarify if exploration activities were occurring during surveys and, if so, detail the extent. Discuss how exploration activities may have influenced caribou distribution during these surveys and how this impacts interpretations of survey data."

Exploration activity at the Project area in 2015 included four drills operating from July to early December. In 2016, the camp opened on April 1st. The drilling program ramped up to four drills, one drill at a time from May to July and then scaled back to two drills from mid August to mid October. Drilling may have locally influenced caribou distribution results during the fall rut surveys in 2015 and 2016 and the early winter ungulate survey in 2015; however, there was no discernible change from historical distributions.

It should also be noted that a number of wildlife surveys were carried out when the camp was not operating. Of greater importance, it should also be noted that the outfitter was guiding caribou hunts before and during the 2015 and 2016 fall field season - an activity out of BMC's control. The outfitter has a permanent camp located 12.5 km to the west of the Project site. It is assumed that all large mammal survey areas were large enough to detect species that may have been displaced from human activity so the overall observation numbers and interpretations were not affected.

YESAB ISSUE WITH BMC'S RESPONSE TO R193

Some of the surveys in 2015 and 2016 (and possibly in 1996) appear to have been conducted when exploration activities were occurring. Exploration activities could have affected distribution of caribou during those surveys. The authors do not address how the explorations activities may have affected survey results, which could affect some interpretations.

Insufficient Response: Information on exploration activities was provided. However, it is difficult to verify the statement that "there was no discernible change from historical distributions." because historical distribution locations were not shown or perhaps not known.

R2-92

Provide information that has been used to come to the conclusion that "there was no discernible change from historical distributions.

The information for current distributions is based on observations by AEG as presented in the Wildlife Baseline Report, Appendix E-8 of the Project Proposal. Historical distributions are from Yukon Government published and unpublished data also as presented in the Wildlife Baseline Report. The distributions over the past few decades are further shown in the heat maps for winter, post-calving, and rut (Figure 13-7, Figure 13-8 and Figure 13-9).

YESAB ISSUE

If caribou are using the area near Finlayson Lake in deeper snow winters on the main winter range, then it suggests that the area around Finlayson Lake is important when winter conditions may be more limiting. If caribou are using the area during winters of low snow accumulation and lower snow levels are expected due to climate change, we should expect to see more use of the area.

R194

"Discuss the implications of the use of the area around Finlayson Lake during the late winter surveys of 2007 and 2016. Particular focus should be given to the displacement effects of increased traffic on the Robert Campbell Highway and the Finlayson air strip."

Please refer to response to R184. The detailed distribution of the FCH winter range was mapped from six winters of animal location data. Maps of this data are not presented here, at the request of YG. Some caribou may be displaced somewhat to areas further away from the lowlands near the roads and Finlayson Lake airstrip. The area of this key range affected by the Project will be treated as sensitive caribou habitat and management planning will provide the highest mitigation measures practicable.

The winter distribution is discussed in Section 13.3.1 of the Project Proposal and the reader was referred to Appendix E-8 of the Project Proposal for more detail. The focus of the FCH effects assessment in Section 13.4.1 of the Project Proposal was on the post-calving and rutting areas where the most interactions are expected with the Project. Nonetheless, the assessment in Section 13.4.1.1 addresses the winter period and states, "There is also expected to be interaction with caribou along the Access Road along Geona Creek during the post rut/early winter period as caribou move from adjacent alpine rutting grounds to their lowland winter range along the Pelly River. Interactions are also expected in the winter range of the Pelly River lowlands with scheduled flights and activity at the Finlayson Lake airstrip."

Further in Section 13.4.1.1, there is discussion of Project interactions and the impacts on movement patterns and mortality risk with the wintering range and caribou movement from the rutting grounds to late winter ranges. The mitigation and management plans include no hunting policy, traffic controls, access control, emergency egress, snow management, and minimizing barriers to minimize these effects on caribou movement to, movement from, and use in the late winter range.

YESAB ISSUE WITH BMC'S RESPONSE TO R194

If caribou are using the area near Finlayson Lake in deeper snow winters on the main winter range, then it suggests that the area around Finlayson Lake is important when winter conditions may be more *limiting. If caribou are using the area during winters of low snow accumulation and lower snow levels are expected due to climate change, we should expect to see more use of the area.*

Insufficient Response: It is not clear why maps of FCH winter locations from historical surveys could not be shown - they are presented in the 2007 winter survey report (Adamczewski et al. 2010). The response refers to the statement in Section 13.4.1.1, which states that there will be interactions, but the response does not address the implications of the interactions.

R2-93

Discuss the implications of the use of the area around Finlayson Lake during the late winter surveys of 2007 and 2016. Particular focus should be given to the displacement effects of increased traffic on the Robert Campbell Highway and the Finlayson air strip.

As mentioned in response to R202 (BMC, 2017), BMC is prohibited from showing individual data due to the data sharing agreement between BMC and YG. It is acknowledged that it is difficult to understand the information in the absence of maps. Figure 13-7 was prepared to indicate the range of caribou distribution in winter. Note that the distribution of caribou in the 2010s survey is skewed and over-represents caribou around Finlayson Lake because the survey was only for GMS 10-07 and did not show caribou throughout the full winter range. It should also be noted that the winter caribou distribution varies widely and the FCH is known to have weak fidelity to winter range and is likely dependent on local snow conditions that affect the ability of caribou to access food (Environment Yukon, 2016; Johnson et al, 2001).

The potential effects and implications from aircraft overflights at the Finlayson Lake airstrip are presented in Section 13.4.1.1 of the Project Proposal. Use of the Finlayson Lake airstrip has the potential to cause ongoing disturbance to caribou and will require choosing appropriate takeoff and landing flight paths to minimize disturbance. The number of flights planned per week and the length of disturbance time during takeoff/landing is not considered to be likely to cause significant disturbance.

YESAB ISSUE

Section 3.5.2 reports that fewer caribou were seen during post-calving surveys in 2015 and 2016 but does not consider how the population decline may have influenced the lower number of observations. As caribou populations decline, their ranges tend to contract, which could contribute to fewer caribou seen during surveys in 2015 and 2016.

R195

"What are the implications of the low calf:100 cow ratios during the post-calving surveys in 2015 and 2016? Provide a more thorough discussion about calf survival, including neonatal mortality, substantiated with references."

Caribou calves tallied during post-calving surveys were not considered recruits to the population as calf mortality rates are higher during this first summer. Significant research over the past 30 years indicates that five-month-olds tallied during rut counts do represent recruitment. Sample sizes from these post-calving counts have no power to make inferences of demographic trends. Therefore, they were not treated that way. The effect of the FCH decline on data results are repeatedly emphasized in the literature. Range use expansion and contraction relative to population recurrent fluctuation has been well documented for arctic and interior Alaska herds but puzzlingly not for Yukon woodland caribou herds in our limited time of reference. It is intuitive that caribou herds have a 'centre of habitation', the core range where all needs are met as proposed by Skoog (1968). All the evidence of range use studies for the FCH point to the notion that the Project area does fall within part of the perceived 'center of habitation' for the FCH. As presented in Sections 13.4.2.1 and 13.4.2.2 of the Project Proposal, mitigation and management plans will provide the highest mitigation measures practicable to minimize effects on the FCH.

R196

"Discuss the geographical importance of the project area to caribou considering their continued use of the area despite population decline."

As presented in Figure 3-1, Finlayson Caribou Herd Seasonal Distribution and Habitat Ranges, in the Wildlife Baseline Appendix E-8 of the Project Proposal, the Project is located in the southern portion of the Finlayson Caribou Herd range in part of the southern defined rutting area. The Project does not overlap the defined main post-calving or wintering areas. Figure 3-8 from the Wildlife Baseline Appendix E-8, confirms caribou are distributed mainly to the Project during post-calving. The FCH is migratory and moves to different habitats within their home range along seasonal routes to meet specific life cycle needs (Adamczewski et al., 2010). In the spring, two-thirds of the herd begin moving from their wintering grounds in the forested lowlands east of the Pelly River to the Pelly Mountains in the southeast. The remaining one-third of the herd travels to the mountains north of Finlayson Lake. As summer approaches, female caribou disperse in the mountains to calve on ridges and upper plateaus to avoid predators (Bergerud et al., 1984; Bergerud and Page, 1987; Bergerud, 1992). They remain dispersed in small bands in the uplands through summer, and seek out snow patches to escape insect harassment and warm temperatures (Morshel and Klein, 1997). The FCH's summer and fall ranges are primarily on alpine plateaus south of Finlayson Lake, which overlaps the Project area. A number of caribou utilize the areas adjacent to KZK for post calving and rutting, as identified by YG as Wildlife Key Areas (WKA) located south of the Project (Environment Yukon, 2013a).

The cause for the herd decline before 1982 was not established; however, the wolf control program proved that predation is a key limiting factor to the FCH population size (see Figure 3-2 of the Wildlife Baseline Appendix E-8 of the Project Proposal).

It is acknowledged that when caribou populations decline, their distribution generally contracts and that may influence potential effects from the Project. Withdrawal of range use coincident with decline in population size has been well documented for the more widespread arctic and interior Alaska caribou herds. Their ranges get smaller coincident with lower population size and vice versa. However, this is not so clear for woodland caribou, particularly in Yukon. Extirpation from an entire range of woodland caribou populations is well documented elsewhere, however experience shows that Yukon woodland caribou go through substantial population size shifts without losing or gaining home range. There are no anticipated changes in range use for the FCH as a result of density.

As presented in Sections 13.4.2.1 and 13.4.2.2 of the Project Proposal, mitigation and management plans will provide the highest mitigation measures possible to minimize effects on the FCH.

YESAB ISSUE WITH BMC'S RESPONSE TO R195 AND R196

Section 3.5.2 reports that fewer caribou were seen during post-calving surveys in 2015 and 2016 but does not consider how the population decline may have influenced the lower number of observations. As caribou populations decline, their ranges tend to contract, which could contribute to fewer caribou seen during surveys in 2015 and 2016.

Insufficient Response: The response states "Significant research over the past 30 years indicates that five-month-olds tallied during rut counts do represent recruitment." This statement needs to be supported with a reference and the response should specifically address how rut calf:cow ratios represent recruitment. There are still at least 6 or 7 months before calves are recruited into the 1-year old category, and mortality can occur during this time. Also, the response does not provide a more thorough discussion about calf survival, including neonatal mortality, substantiated with references, which was requested.

Insufficient Response: The response does not discuss the importance of the specific project area to caribou in the context of continued use despite the population decline. Also, in contrast to the statement referring to range contraction not being clear for woodland caribou, particularly in Yukon, there are examples of shrinking ranges in relation to declining populations for woodland caribou in BC and Alberta. Additionally, the statement "..however experience shows that Yukon woodland caribou go through substantial population shifts without losing or gaining home range." needs to be substantiated with data or with a reference.

R2-94

What are the implications of the low calf:100 cow ratios during the post-calving surveys in 2015 and 2016? Provide a more thorough discussion about calf survival, including neonatal mortality, substantiated with references.

It is agreed that the mortality of calves through the winter period still needs to be considered before recruited to the 1-year old category. The fall rut calf to cow ratio is typically measured in Yukon, and is a close indication of recruitment, and is used when late winter surveys are not available (Environment Yukon, 2016; Environment Canada, 2012). Fall counts and calf to cow ratios have been used to track recruitment and herd changes over 30 years in Yukon by the Yukon Government [Name F [Name Redacted] 2009; Environment Yukon 2016). Tracking trends over time in Yukon has shown that a fall recruitment rate of 20 to 25 calves per 100 cows is linked to a stable population (Environment Yukon, 2016).

As mentioned in the Wildlife Baseline, Appendix E-8 of the Project Proposal, the lower calf to cow ratios during the post-calving surveys in 2015 may have been a result of poor weather conditions during the survey. The 2016 post-calving calf to 100 cows ratio also likely undercounted calves since the 2016 rut survey resulted in 27 calves to 100 cows and should have been lower than the post-calving survey ratio. In conclusion, the low calf to cows ratio from the post-calving surveys in 2015 and 2016 are not indicative of any trend other than difficult survey conditions.

The number of calves born in 2015 and 2016 were likely higher given the 27 calves to 100 cows ratios observed in the fall rut of these two years. The 27 calves to 100 cows follows the similar ratio trend to that seen in the long-term surveys shown in Figure 3-4 of the Wildlife Baseline, Appendix E-8 of the Project Proposal, shown below in Figure 13-14.

As mentioned in response to R183 (BMC, 2017), it is acknowledged that neonatal calf mortality is one of the most significant components of caribou population dynamics. It is well known that woodland caribou are widely dispersed during calving as an anti-predation tactic and approximately 50% mortality of calves by predation is normal during their first 10 days of life (Adams et al, 1995). The wide dispersion during and immediately after calving makes surveying impractical during this period.

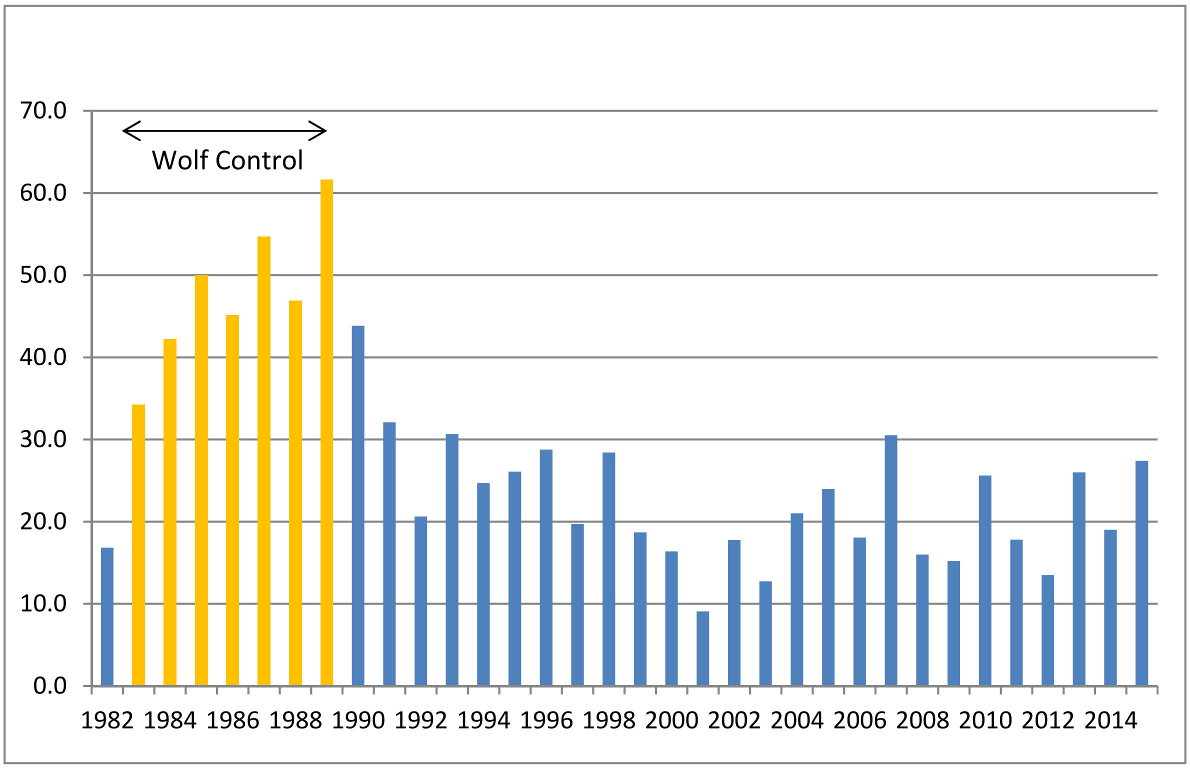


Figure 13-14: Ratio of calf per 100 cows in the FCH from 1982-2015

R2-95

Discuss the geographical importance of the project area to caribou considering their continued use of the area despite population decline.

Further to response R183(h) which stated, extirpation from an entire range of woodland caribou populations is well documented elsewhere; however, experience shows that Yukon woodland caribou go through substantial population size shifts without losing or gaining home range. There are no anticipated changes in range use for the FCH as a result of changes in caribou densities. This is seen by the post-calving and late winter distributions of caribou which was similar in extent over the past decades when the FCH expanded from approximately 2,000 to 6,000 and then contracted again to approximately 3000 (Figure 13-7. Figure 13-8, and Figure 13-9 of this Response Report). The Project location is shown in grey in these figures. The proposed open pit and mine infrastructure is located in core rutting area and is northeast of the core post-calving and southeast of the core winter ranges. The Finlayson Lake airstrip and Access Road traverse through the eastern end of the core winter ranges.

Mitigation measures are proposed to minimize effects from aircraft and traffic in these areas. The proposed mitigations for traffic and flight effects on late winter range are presented in Table 13-20 of the Project Proposal. Traffic management measures on the road include adherence to speed limits, radio controlled Access Road, and convoys of two or three vehicles to reduce sensory disturbance. To minimize effects at the Finlayson Lake airstrip, planes will follow designated flight and landing route for flights to Finlayson Lake airstrip during winter that stay 1.5 km away from animals and maximize height above ground as long as practicable at landing and takeoff (Dena Kayeh Institute, 2010) that minimizes herd disturbance. In addition, a more detailed Draft Wildlife Protection Plan is also included in **Appendix R2-J** of this Response Report.

YESAB ISSUE

Inconsistencies in interpretations of information or inappropriate conclusions drawn from data could lead to inaccuracies in assessing effects of the Project on caribou.

The potential questions for this set of issues all relate to resolving inconsistencies in interpretations of information or correcting inappropriate conclusions drawn from data. The points are very specific and detailed, but individually and collectively they could lead to inaccuracies in assessing effects of the Project on caribou.

R198

"Rut survey interpretation: What is the density of individuals (individuals/km^2), and density of groups (groups/km^2) for each 5-km concentric ring? Revise the discussion of use of the area surrounding the proposed Project by caribou as a function of distance category to reflect these densities."

It is acknowledged that caribou density can be a useful metric to describe caribou distribution. However, the radii to outer distance of concentric circles are not uniform and varied in topography; therefore, simple density would not accurately compare densities at distance from the Project. A visual estimation of observations, which cannot be published, at the request of YG, indicates that densities in their preferred habitats are very similar in each of the zones which would not be fully reflected by density metrics.

YESAB ISSUE WITH BMC'S RESPONSE TO R195 AND R196

Inconsistencies in interpretations of information or inappropriate conclusions drawn from data could lead to inaccuracies in assessing effects of the Project on caribou.

The potential questions for this set of issues all relate to resolving inconsistencies in interpretations of information or correcting inappropriate conclusions drawn from data. The points are very specific and detailed, but individually and collectively they could lead to inaccuracies in assessing effects of the Project on caribou.

Insufficient Response: It is not possible to assess the validity of the information outlined in the response without seeing some form of actual data.

R2-96

Rut survey interpretation: What is the density of individuals (individuals/km^2), and density of groups (groups/km^2) for each 5-km concentric ring? Revise the discussion of use of the area surrounding the proposed Project by caribou as a function of distance category to reflect these densities.

As presented in the Project Proposal and in response to R198, the rut survey information is not presented at the request of Yukon Government (under the data sharing agreement between BMC and YG) in order to protect the caribou during the hunting season. Heat maps are presented in Figure 13-9 (of this Response Report) to show the general distribution of caribou throughout their rutting range.

YESAB ISSUE

The baseline information needs to be adequate, and to be adequately described, to provide a solid basis upon which to build the effects assessment. Some of the points are related to lack of clarity or lack of information about methods and others are suggestions for additional information that will help in interpretation of the baseline data.

R202

"Provide additional information on baseline surveys and maps as detailed below.

a. Use of historical post-calving surveys: Are locations from historical post-calving surveys, available? If so, provide a map that displays these for the whole range of the herd.

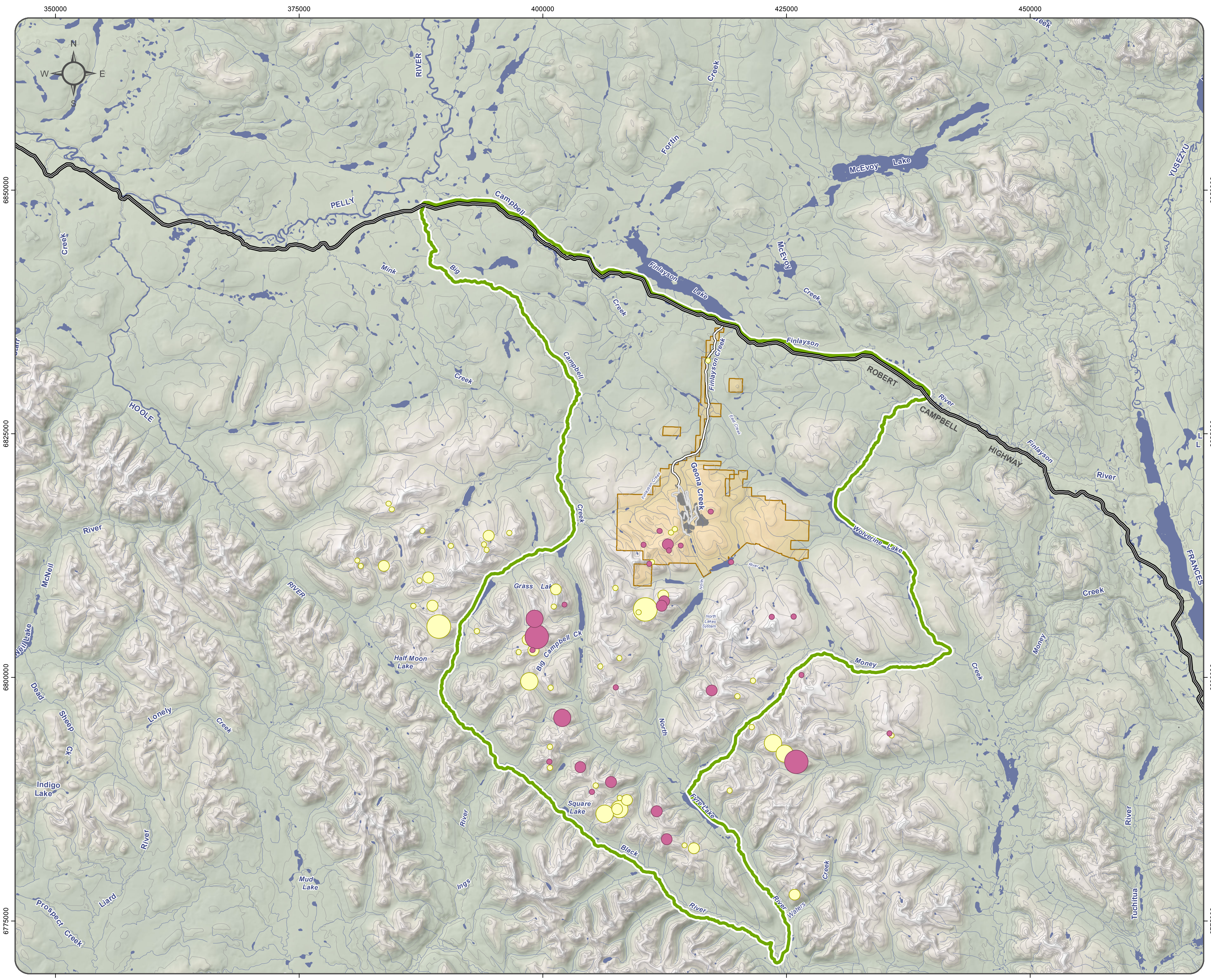
BMC has compared the historical and current post-calving survey observations. The locations confirm continued use and dispersion throughout the FCH southern post-calving range. The confidential map (containing the historical data) that was used for this comparison has not been included in this Response Report, in order to avoid potential conflict with the caribou data sharing agreement between YG and BMC.

b. Air survey methodology clarifications: How was the low number of caribou seen during the 2015 late winter survey influenced by the type of aircraft used (i.e. fixed-wing)? What type of aircraft was used for the early winter surveys described in section 3.3.1?

There is an inherent observability bias between the uses of fixed-wing aircraft and helicopters for early and late winter ungulate surveys. This likely accounted for the lower number of observations in the 2015 late-winter survey. The 2015 and 2016 early-winter surveys and the 2016 late-winter survey used a Bell Jet Ranger helicopter.

c. Improvement in post-calving information: Display locations for 2015 and 2016 in different colours on Figure 3-8 and comment on consistency in area use between the two years.

Figure 13-15 presents the corrected figure for Finlayson Caribou Herd, Post-calving Observations 2015-2016, from the Wildlife Baseline Report, Appendix E-8 of the Project Proposal and includes the 2016 observations in a different colour. Post-calving observations were distributed throughout the mountains south of the Project. There were more observations closer to the Project area in 2015 than in 2016 and the 2016 observations extended further to the west than in 2015.



MINERALS

KUDZ ZE KAYAH PROJECT

FIGURE 13-15
FINLAYSON CARIBOU HERD POST-CALVING OBSERVATIONS 2015-2016

OCTOBER 2017

NUMBER OF OBSERVATIONS

2015 Survey	2016 Survey
1 - 2	1 - 2
3 - 5	3 - 5
6 - 8	6 - 8
9 - 19	9 - 16

OTHER MAP FEATURES

- Tote Road/ Proposed Access Road
- Proposed Mine Road
- Watercourse
- Waterbody
- Game Management Sub Zone 10-07
- Location of Proposed Infrastructure
- BMC Minerals (No.1) Ltd. Mineral Claim Area

ALEXCO ENVIRONMENTAL GROUP

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.

Datum: NAD 83; Projection UTM Zone 9N

1:385,000 when printed on 11 x 17 inch paper

0 5 10 15 Kilometres

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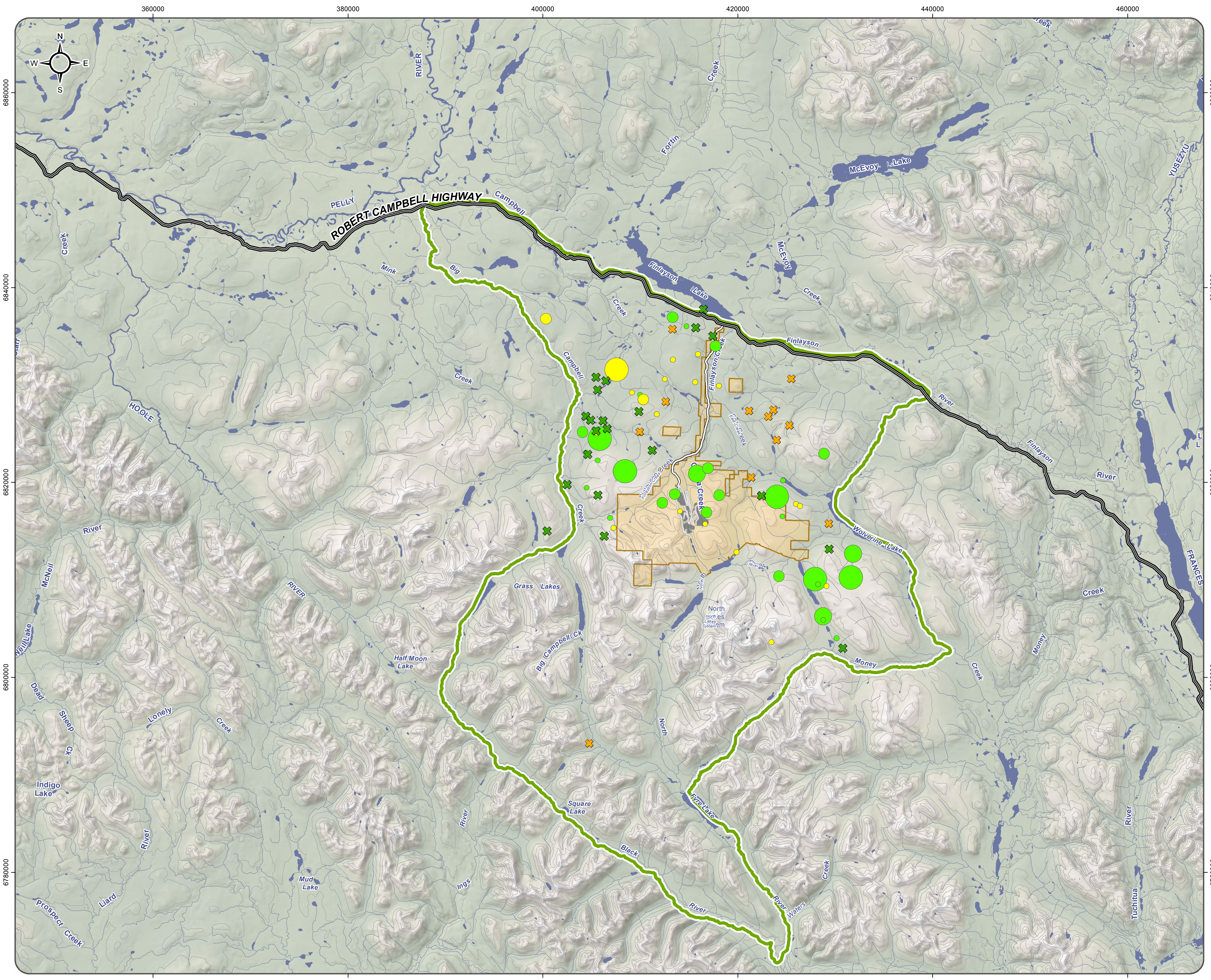
d. Methodology clarification for caribou distribution analysis: What do the categories in the "Radius from project" represent in Table 3-4? The actual radius, or radius categories? Revise interpretations if necessary.

The distance categories for Table 3-4 represent intervals of 0-5 km, 5-10 km, and 10-15 km even though they were expressed as <5 km, <10 km, and <15 km. Note that the radii are not uniform and are intended to provide information about the distribution while avoiding publishing exact locations during the hunting season.

e. Further information on early winter surveys: Provide a map showing caribou locations for 2015 and 2016 early winter surveys.

Caribou observations from the November 18-20, 2015 and December 5-6, 2016 ungulate surveys are presented in Figure 13-16. These observations were discussed in Section 3.5.4 of the Wildlife Baseline Report, Appendix E-8 of the Project Proposal. Surveys of caribou in early winter (a time when caribou are not normally scheduled for surveys) show that there is indeed annual variation in their post rut movements towards winter range. While November was assumed to be the fall migration period of the FCH to winter range, these surveys clearly show that these conditions can vary a great deal – possibly due to late fall weather conditions.



BMC MINERALS

KUDZ ZE KAYAH PROJECT

FIGURE 13-16
FINLAYSON CARIBOU HERD 2015-2016 EARLY WINTER OBSERVATIONS

OCTOBER 2017

NUMBER OF OBSERVATIONS

Incidental observations during moose survey

2015 SURVEY	2016 SURVEY
1 - 5	2 - 5
6 - 10	6 - 10
11 - 15	11 - 15
16 - 20	16 - 25

2015 Survey Caribou Tracks

2016 Survey Caribou Tracks

OTHER MAP FEATURES

- Tote Road/ Proposed Access Road
- Proposed Mine Road
- Watercourse
- Waterbody
- Game Management Sub Zone 10-07
- Location of Proposed Infrastructure
- BMC Minerals (No.1) Ltd. Mineral Claim Area

ALEXCO ENVIRONMENTAL GROUP

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.

Datum: NAD 83; Projection UTM Zone 9N

1:385,000 when printed on 11 x 17 inch paper

0 5 10 15 Kilometres

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(Last edited by: amatlashevska; 20/10/2017/10:09 AM)

f. Results of 2016 rut survey missing: Provide the results of the 2016 rut survey.

Results from the 2016 rut survey are included in Section 3.4.3 and Figure 3-11 of the Wildlife Baseline Report, Appendix E-8 of the Project Proposal. Due to the potential detriment to caribou by providing location data during hunting season, YG has requested that the caribou rut location information not be made public. Instead, the caribou distribution data is presented in terms of relative distance from the Project without providing direction. Location data was compiled for the period from 1982 through 2016 and is presented as a percentage of distribution within 0-5 km, 5-10 km, and 10-15 km from the Project footprint.

YESAB ISSUE WITH BMC'S RESPONSE TO R202

The baseline information needs to be adequate, and to be adequately described, to provide a solid basis upon which to build the effects assessment. Some of the points are related to lack of clarity or lack of information about methods and others are suggestions for additional information that will help in interpretation of the baseline data.

Insufficient Response:

a. The response states that the historical data are confidential due to the data sharing agreement between YG and BMC, but that the locations confirm continued use and dispersion throughout the FCH southern post-calving range. It is difficult to determine if this statement adequately reflects the data if the data are not provided.

b. The question has been partially answered. The only mention of the 2016 rut survey is in Table3-3. There is no further discussion of the 2016 rut survey in Appendix E-8. Figure 3-11 does not specify what period of time the numbers cover, but it does not appear specific to 2016.

R2-97

Provide additional information on baseline surveys and maps as detailed below.

a. Use of historical post-calving surveys: Are locations from historical post-calving surveys, available? If so, provide a map that displays these for the whole range of the herd.

b. Results of 2016 rut survey missing: Provide the results of the 2016 rut survey.

Historical and rut survey locational data are confidential as per the data sharing agreement between BMC and Environment Yukon. Therefore, the point data cannot be presented in map form; however, Figure 13-9 shows a general distribution over the decades. Historical post-calving data confirm that there is over three decades of use in the core post-calving area south of the Robert Campbell Highway as outlined in Figure 3-1 of the Wildlife Baseline, Appendix E-8 of the Project Proposal. Figure 13-8 was prepared to show reviewers the post-calving use of the region from surveys south of the Robert Campbell Highway over the last 30 years without showing locations of individual animals.

The 2016 rut survey results were included in Appendix E-8 of the Project Proposal, Figure 3-11. 2016 rut survey results were similar in numbers and distribution to the 2015 rut survey results. Both sets of data were used to validate the caribou rut habitat suitability model and map; therefore, the habitat suitability map can be used to assess the distribution of habitat and use around the Project site.

13.3 MOOSE

YESAB ISSUE

A post-rut moose survey was completed in 2016, but the results have not been included or incorporated into the discussion.

Information on ungulate survey methods is not sufficient to determine if methodology was sound.

The presentation and discussion of moose survey data is not clear enough for reviewers to understand movements of moose through the seasonal range.

R205

"Provide the results from the additional 2016 post-rut moose survey, and incorporate these results into the discussion and conclusion."

A total of 154 moose were observed including 31 bulls, 100 cows, and 23 calves in 49 groups (Table 13-32). These observations result in a recruitment rate of 23 calves per 100 cows, and a sex ratio of 31 bulls per 100 cows. These results should be used with caution, however, as many bulls had cast their antlers by early December and were recorded as cows. This skews the data for useful ratio assessment. All but two moose (1.3%) were found in upland shrub zone and treeline area in a similar distribution to 2015 (Figure 13-17). Forty-eight moose were found within the Project claim block area. Group sizes ranged from solitary to 12 individuals and averaged 3.1 moose. The 2016 survey was carried out over two days and did not cover all of GMS 10-07 therefore comparisons of density estimates were not carried out.

Table 13-32: 2016 Post-rut Moose Count

Observation #	Cows	Bulls	Calves	Group Size	Habitat/Behaviour
2	1		1	2	bedded down, open spruce hillside
34	7	3		12	large group located in alpine
35	1			1	Located in alpine
38	3			3	
39	3			4	
42	1			2	
43	3			3	
45	1			2	
48	4	1		7	Bedded down
49	4			6	Subalpine
51	1		1	2	Subalpine

Observation #	Cows	Bulls	Calves	Group Size	Habitat/Behaviour
54	2		2	2	Hillside; subalpine
55	1			1	Hillside; subalpine; running
56	1			1	Standing; subalpine
60	7	1	1	9	Subalpine
62	1		1	1	
65	1	3		4	Running; subalpine
66	2		1	2	Running; alpine
67	1	1	2	2	alpine
73	2		2	2	Standing near alpine
74	1		1	2	Standing, subalpine
77	3			3	Alpine - plateau
79	2			3	
82	4			5	Alpine - plateau
83	2		1	2	Alpine - plateau
84	1	1		3	Standing at treeline
85	1	1		2	Standing; riparian area at subalpine
91	2			2	near alpine
92	2	1		3	near alpine
93	2			2	near alpine
94	1		1	2	Subalpine fir valley
95	2	1		4	Bedded down at treeline
96	5	6	1	11	
97	7	2	1	10	Subalpine valley
98	1			1	Subalpine valley
99	1	1	1	2	Subalpine valley
100		2		2	Subalpine valley
101	1			1	Subalpine - hillside
103		2		2	Subalpine valley bottom
104	1			2	Subalpine valley bottom
106	5		1	5	alpine
107	1		1	1	Subalpine valley bottom
108	1			1	
109	1		1	1	Near treeline
110		3		3	riparian, valley bottom
111	1			1	Near treeline
114	2	1		4	Near treeline
116	1			2	Alpine valley
117	2	1		4	Valley bottom
Totals:	**100**	**31**	**23**	**154**	

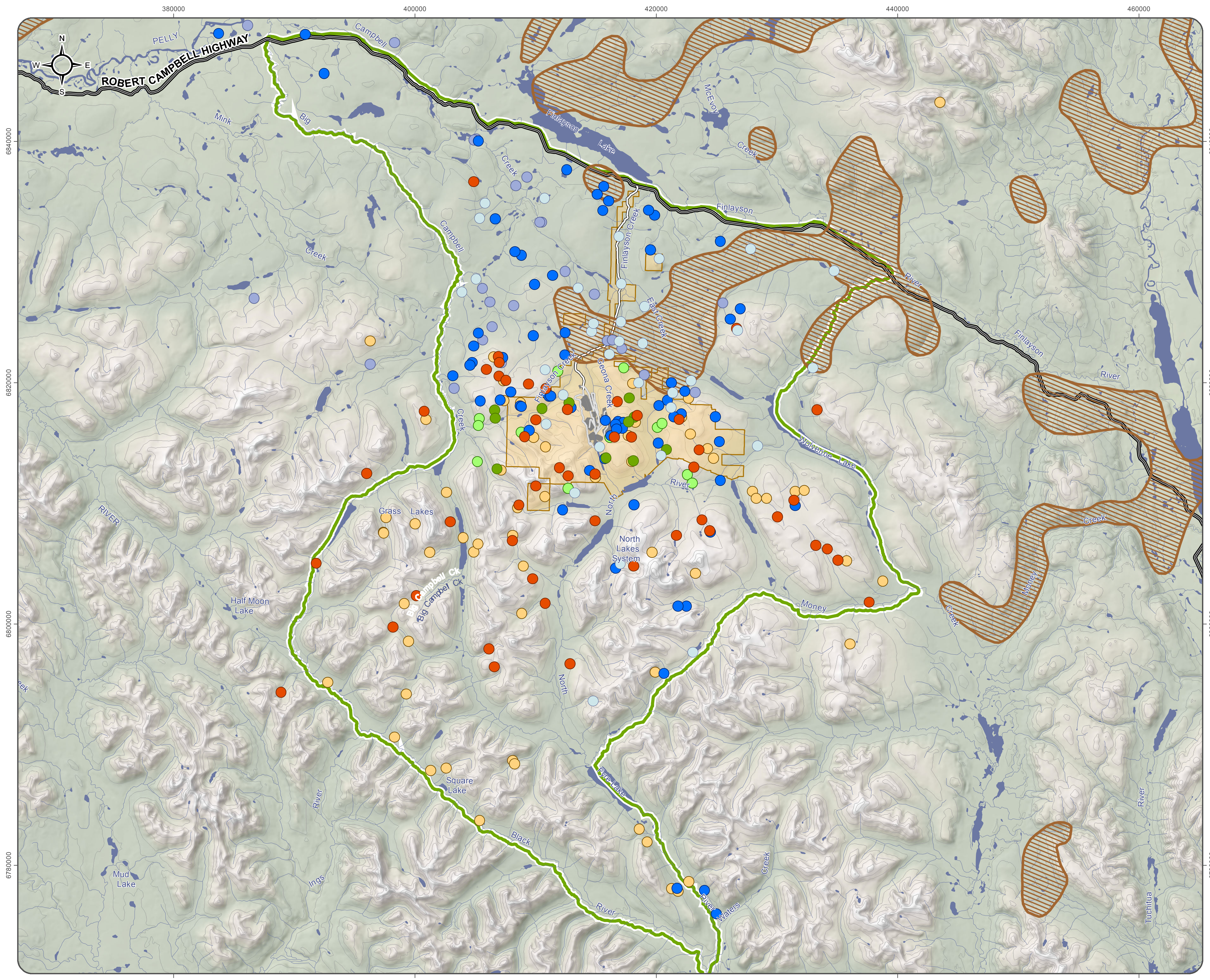
A late-winter ungulate survey was carried out March 23 and 24, 2017. A Jet Ranger helicopter was used for the late winter survey for a total survey time of 11.3 hours. A total of 57 moose were observed including 11 cows, 12 calves and the remaining 34 of unknown sex (Table 13-33). Approximately half of observations were solitary moose with the remaining in groups of two to four. Moose were scattered throughout much of the study area but were absent in the southern portion.

There was a significant difference between the 2015, 2016, and 2017 late winter surveys of the number of moose observed. Thirty-one were observed in 2015, 115 in 2016, and 57 in 2017. One explanation for the difference could be the fresh snowfall prior to the commencement of the 2016 survey that aided in the detection of moose.

Table 13-33: 2017 Late-winter Moose Observations

ID #	Bulls	Cows	Calves	Unknown	Group Size
16	1			1	2
17			1		1
18	1			1	2
19	1			1	2
36			3		3
38			1		1
39	1			1	2
40	1			1	2
41	1			2	3
42			1		1
43			2		2
44			1		1
45			1		1
46	1			1	2
47	1			1	2
48	1			1	2
49			1		1
50			1		1
51			1		1
52			1		1
53			1		1
54			1		1
55			3		3
56	1			1	2
57			1		1
58			2		2
62			1		1
68			1		1
70			1		1
72			2		2
75			1		1
77			2		2
82			4		4
83	1			1	2
Total	**11**	**0**	**34**	**12**	**57**

This additional information does not change the mitigation measures or results of the effects assessment.



BMC MINERALS

KUDZ ZE KAYAH PROJECT

FIGURE 13-17
2015, 2016 AND 2017 MOOSE SIGHTINGS

SEPTEMBER 2017

Moose Observations

- 2015 Late Winter Sightings (25)
- 2016 Late Winter Sightings (69)
- 2017 Late Winter Sightings (34)
- 2015 Early Winter Sightings (60)
- 2016 Early Winter Sightings (49)
- 2015 Summer Sightings (incidentals) (12)
- 2016 Summer Sightings (incidentals) (11)

Other Map Features

- Moose Key Area - Late Winter
- Regional Study Area (Game Management Subzone 10-07)
- Tote Road/ Proposed Access Road
- Proposed Mine Road
- Location of Proposed Infrastructure
- BMC Minerals (No.1) Ltd. Mineral Claim

ALEXCO ENVIRONMENTAL GROUP

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.

Datum: NAD 83; Projection UTM Zone 9N

1:310,000 when printed on 11 x 17 inch paper

0 3 6 9 12 15 Kilometres

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(*Last edited by: amatlashevska; 15/09/2017/11:23 AM*)

R206

"Provide details on survey methods and protocols used, including area covered or total length of survey paths."

Survey methods for the moose surveys are presented in Section 4.3 of the Wildlife Baseline Report, Appendix E-8 of the Project Proposal. The survey area covered the RSA which is defined as GMS 10-07 (as requested by YG).

The November 18-20, 2015 post rut survey was conducted using a Cessna 208 (Caravan) and an AS350-B2 A-star helicopter. The helicopter was necessary for part of the survey as wind conditions were too strong for a fixed wing plane to continue the survey. Surveys were flown at an average elevation of 200 m above ground; forested areas were flown at lower elevations compared to open spaces such as alpine habitats. The average speed during the survey was 105 km/h. The total time taken to accomplish the survey was 15 hours. From December 5-6, 2016, the post-rut survey was replicated using the same protocols for 16 hours of survey flight time.

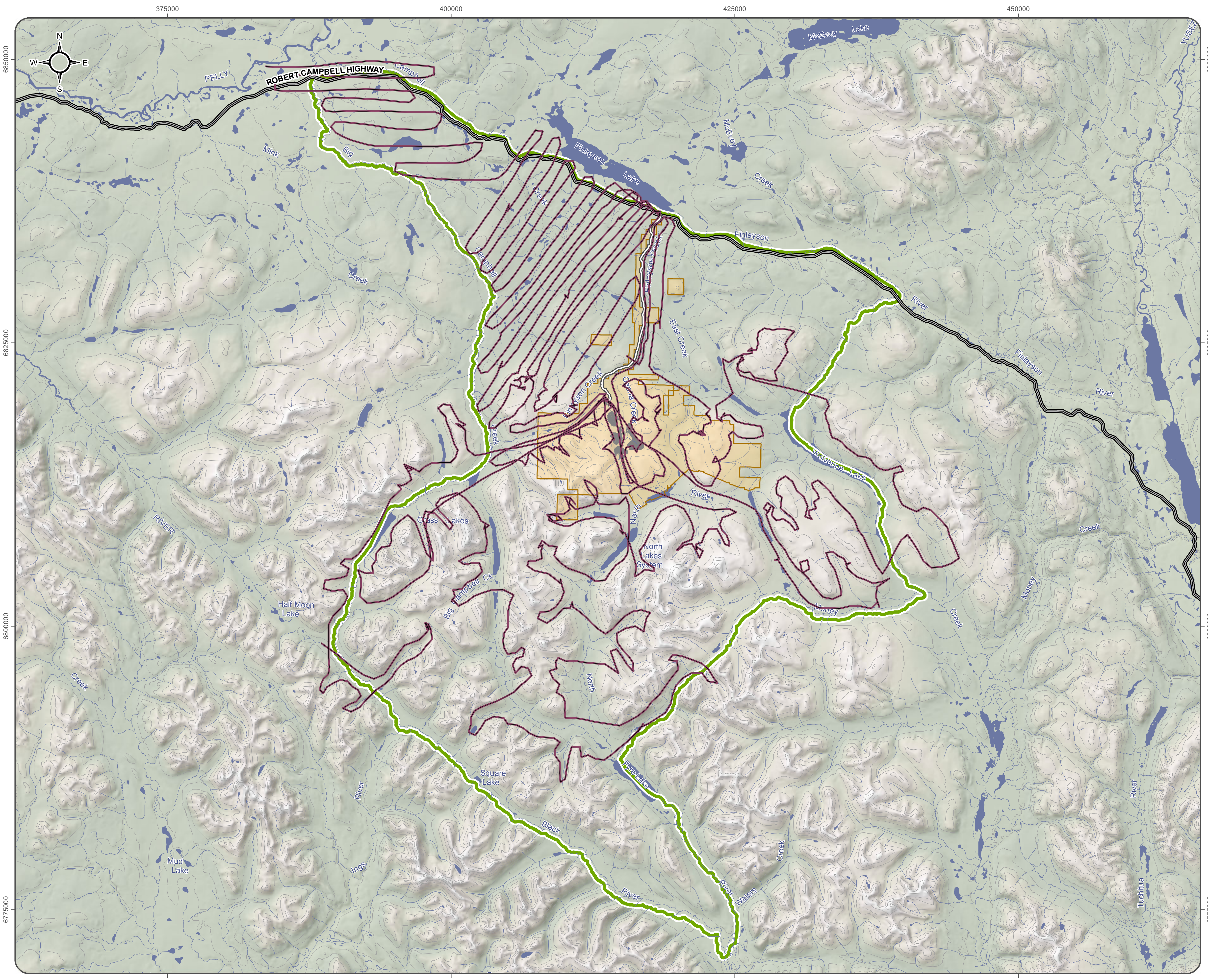
Figure 13-18 and Figure 13-19 show the flight paths for the 2015 and 2016 post-rut moose surveys, respectively.

BMC MINERALS

KUDZ ZE KAYAH PROJECT

FIGURE 13-19
2016 MOOSE POST RUT SURVEY FLIGHT PATHS

OCTOBER 2017



- Post Rut Moose Survey Flight Line
- RSA (GMS 10-07)
- Location of Proposed Infrastructure
- BMC Minerals (No.1) Ltd. Mineral Claim Areas
- Tote Road/Proposed Access Road
- Watercourse
- Waterbody

ALEXCO ENVIRONMENTAL GROUP

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.

Datum: NAD 83; Projection UTM Zone 9N

1:330,000 when printed on 11 x 17 inch paper

0 3 6 9 12 15

Kilometres

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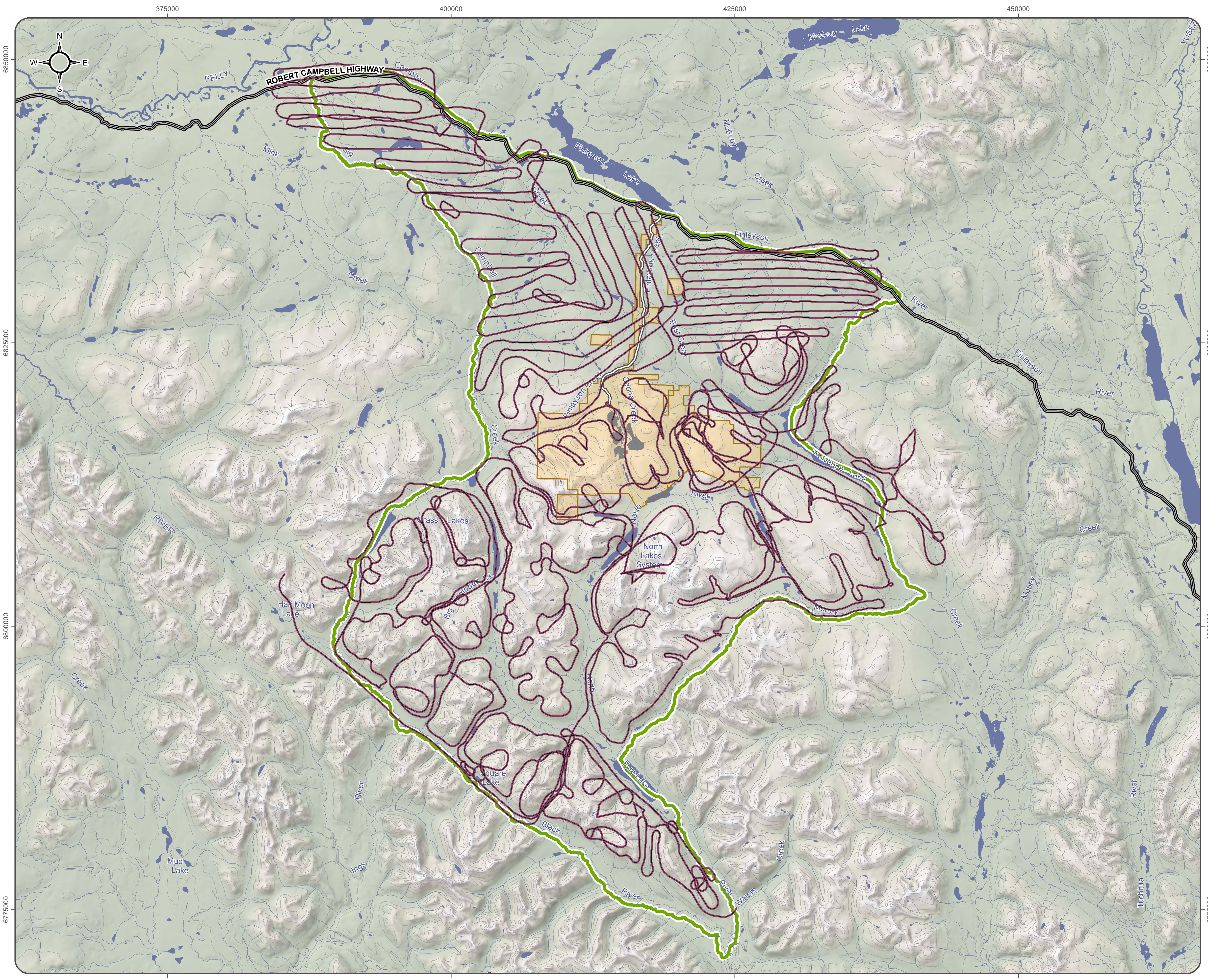

BMC MINERALS

KUDZ ZE KAYAH PROJECT

FIGURE 13-18
2015 MOOSE POST RUT SURVEY FLIGHT PATHS

OCTOBER 2017

- Post Rut Moose Survey Flight Line
- RSA (GMS 10-07)
- Location of Proposed Infrastructure
- BMC Minerals (No.1) Ltd. Mineral Claim Areas
- Tote Road/Proposed Access Road
- Watercourse
- Waterbody

ALEXCO ENVIRONMENTAL GROUP

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.

Datum: NAD 83; Projection UTM Zone 9N

1:330,000 when printed on 11 x 17 inch paper

0 3 6 9 12 15

Kilometres

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YESAB ISSUE WITH BMC'S RESPONSE TO R205 AND R206

A post-rut moose survey was completed in 2016, but the results have not been included or incorporated into the discussion.

Information on ungulate survey methods is not sufficient to determine if methodology was sound.

Insufficient Response: Late winter 2017 survey data and information has been provided but one section needs further review. Please check and revise Table 13-13, as the group sizes are different from the sum of the classified observations (i.e. cows + bulls + calves) in several cases.

Insufficient Response: Information on which survey standards/protocols were followed for the moose surveys has not been provided.

R2-98

Review the table provided (13-13) and revise so that group sizes and classified individual sightings align. Incorporate these results into the discussion and conclusion.

It is acknowledged that there was an error in the number in table presented in R205 (above). This table (now Table 13-34) was revised and is presented below and the groups sizes and classified individual sightings are now correct.

A discussion of the 2016 post-rut and 2017 late winter survey results was presented in response R205 which said a total of 154 moose were observed including 31 bulls, 100 cows, and 23 calves in 49 groups. These observations result in a recruitment rate of 23 calves per 100 cows, and a sex ratio of 31 bulls per 100 cows. These results should be used with caution, however, as many bulls had cast their antlers by early December and were recorded as cows. This skews the data for useful ratio assessment. All but two moose (1.3%) were found in upland shrub zone and treeline area in a similar distribution to 2015 (Figure 13-17). Forty-eight moose were found within the Project claim block area.

Group sizes ranged from solitary to 12 individuals and averaged 3.1 moose. The 2016 survey was carried out over two days and did not cover all of GMS 10-07 therefore comparisons of density estimates were not carried out.

A late-winter ungulate survey was carried out March 23 and 24, 2017. A Jet Ranger helicopter was used for the late winter survey for a total survey time of 11.3 hours. A total of 57 moose were observed including 11 cows, 12 calves and the remaining 34 of unknown sex (Table 13-33).

Approximately half of observations were solitary moose with the remaining in groups of two to four. Moose were scattered throughout much of the study area but were absent in the southern portion. There was a significant difference between the 2015, 2016, and 2017 late winter surveys of the number of moose observed. Thirty-one were observed in 2015, 115 in 2016, and 57 in 2017. One explanation for the difference could be the fresh snowfall prior to the commencement of the 2016 survey that aided in the detection of moose.

This additional information does not change the mitigation measures or results of the effects Assessment.

Table 13-34: 2016 Post-rut Moose Count - Revised

Observation #	Cows	Bulls	Calves	Group Size	Habitat/Behaviour
2	1		1	2	bedded down, open spruce hillside
34	7	3	2	12	large group located in alpine
35	1			1	Located in alpine
38	3			3	
39	3		1	4	
42	1		1	2	
43	3			3	
45	1		1	2	
48	4	1	2	7	Bedded down
49	4		2	6	Subalpine
51	1		1	2	Subalpine
54	2			2	Hillside; subalpine
55	1			1	Hillside; subalpine; running
56	1			1	Standing; subalpine
60	7	1	1	9	Subalpine
62	1			1	
65	1	3		4	Running; subalpine
66	2			2	Running; alpine
67	1	1		2	alpine
73	2			2	Standing near alpine
74	1		1	2	Standing, subalpine
77	3			3	Alpine - plateau
79	2		1	3	
82	4		1	5	Alpine - plateau
83	2			2	Alpine - plateau
84	1	1	1	3	Standing at treeline
85	1	1		2	Standing; riparian area at subalpine
91	2			2	near alpine
92	2	1		3	near alpine
93	2			2	near alpine
94	1		1	2	Subalpine fir valley
95	2	1	1	4	Bedded down at treeline
96	5	6		11	
97	7	2	1	10	Subalpine valley
98	1			1	Subalpine valley
99	1	1		2	Subalpine valley
100		2		2	Subalpine valley
101	1			1	Subalpine - hillside

Observation #	Cows	Bulls	Calves	Group Size	Habitat/Behaviour
103		2		2	Subalpine valley bottom
104	1		1	2	Subalpine valley bottom
106	5			5	alpine
107	1			1	Subalpine valley bottom
108	1			1	
109	1			1	Near treeline
110		3		3	riparian, valley bottom
111	1			1	Near treeline
114	2	1	1	4	Near treeline
116	1		1	2	Alpine valley
117	2	1	1	4	Valley bottom
Totals:	**100**	**31**	**23**	**154**	

R2-99

Provide details on survey methods and protocols used, including area covered or total length of survey paths.

The requested information was presented in the response to R206 (BMC, 2017). Survey methods for the moose surveys are presented in Section 4.3 of the Wildlife Baseline Report, Appendix E-8 of the Project Proposal and Section 2.1 of the EDI Late Winter Ungulate report (Appendix D of Appendix E-8, Wildlife Baseline Report). The information is repeated below, with additional details added for clarity.

Survey path lengths for the moose surveys and all other aerial surveys from 2015 to 2017 are summarized inTable 13-35. Note that the aerial surveys were focused on tracking distribution and relative abundance.

Table 13-35: Survey Path Length Summary

Survey	Survey Path Length (km)	Survey Area Notes
2015 Bear Den Survey #1	743	10 km radius along contours
2015 Bear Den Survey #2	727	10 km radius along contours
2015 Bear Den Survey #3	752	10 km radius along contours
2015 Caribou Post Calving Survey	1025	FCH post-calving range blocks
2015 Caribou Rut Survey	1540	FCH Rut Range
2015 Late Winter Ungulate Survey	2319	GMS 10--07 in high probability areas

Survey	Survey Path Length (km)	Survey Area Notes
2015 Post Rut Moose Survey	2701	GMS 10--07 in high probability areas
2016 Bear Den Survey #1	355	10 km radius along contours
2016 Bear Den Survey #2	242	10 km radius along contours
2016 Caribou Post Calving Survey	932	FCH post-calving range blocks
2016 Caribou Rut Survey	1211	FCH Rut Range
2016 Late Winter Ungulate Survey	2626	GMS 10--07 in high probability areas
2016 Post Rut Moose Survey	1189	GMS 10--07 in high probability areas
2017 Caribou Post Calving Survey	1368	FCH post-calving range blocks
2017 Late Winter Ungulate Survey	1570	GMS 10--07 in high probability areas

The November 18-20, 2015 post rut survey was conducted using a Cessna 208 (Caravan) and an AS350-B2 A-star helicopter. The helicopter was necessary for part of the survey as wind conditions were too strong for a fixed wing plane to continue the survey. Surveys were flown at an average elevation of 200 m above ground; forested areas were flown at lower elevations compared to open spaces such as alpine habitats. The average speed during the survey was 105 km/h. The total time taken to accomplish the survey was 15 hours. From December 5-6, 2016, the post-rut survey was replicated using the same protocols for 16 hours of survey flight time. Figure 13-18 and Figure 13-19 were prepared in response to R206 and show the 2015 and 2016 post-rut moose surveys, respectively. Post rut survey intensity was 0.4 minutes/km^2 in 2015 and 1 minute/km^2 in 2016.

The surveys followed the Yukon Government aerial ungulate survey methods. In late winter 2015, the ungulate surveys were stratified random blocks for the RSA. The survey area was gridded into survey blocks with a dimension of 5 minutes longitude by 2 minutes latitude (approximately 4×4 km at the survey latitude) for consistency with Yukon Government late winter survey methods. The survey blocks do not match the GMA boundaries and therefore blocks were included in the survey area if the majority of a block was within the GMA. An additional three blocks were included to reduce the edge effects of the survey area.

Late winter 2016 and 2017 surveys followed similar flight paths to 2015. The survey patterns were stratified to cover likely habitat specific for the season being surveyed, following contours in the mountains and parallel flight lines across flatter areas. The survey area covered the RSA which is defined as GMS 10-07 (as requested by YG).

Late winter ungulate survey flight times, totaled 14.2 hours in March 2015, 25.5 hrs in March 2016, and 11.3 hours in March 2017. As presented in Appendix D of the Wildlife Baseline Report, Appendix E-8 of the Project Proposal, survey intensity was calculated at 0.41 minutes/km^2 in 2015; however, survey intensity was higher since alpine habitats in the southern portion of the study area were not surveyed. Survey intensity in 2016 was 0.7 minutes/km^2 when flight speeds were 80 to 90 km/hr; and survey intensity in 2017 was approximately 0.5 minutes/km^2.

YESAB ISSUE

Clear articulation of methods and assumptions is required to properly assess the suitability of the HSI model.

Interspersion of habitat: It is unclear why the habitat suitability index (HSI) model does not account for the interspersion of available habitat (available forage with security and thermal cover). Moose are known to be rely on access to forage that is closely associated with security and thermal cover.

Interspersion of habitat: It is unclear why the habitat suitability index (HSI) model does not account for the interspersion of available habitat (available forage with security and thermal cover). Moose are known to rely on access to forage that is closely associated with security and thermal cover.

Elevation range used in model. It is unclear why Table 4-2 shows relationships with suitability and elevation for a range of 800 to 1800 masl when as per page 3 the elevation range of the entire Project area is 1300 to 1900 masl.

R208

"Articulate methods and assumptions used in the moose habitat suitability index model as indicated below.

a. Interspersion of habitat: Consider adapting the HSI model to account for the interspersion of available habitat.

As presented in Appendix C, Moose Habitat Suitability Report of Appendix E-8, Wildlife Baseline Report of the Project Proposal, the post-rut and late winter habitat models use elevation, aspect, slope, and vegetation cover variables. The post rut HSI (p-value = 0.0083) suggests a significant ($p<0.05$) correlation between the model and actual densities while the strength of the correlation is strong (tau correlation coefficient = 0.87) based on 47 observations. The late winter HSI (p-value = 0.028) suggests a significant correlation while the strength of the correlation is strong (tau correlation coefficient = 0.73) based on 86 observations. The tau correlation coefficients increased to 0.94 for both post-rut and late winter models, respectively, with the addition of the 2016 post-rut and 2017 late winter survey data for a total of 91 post-rut and 119 late winter observations. Therefore, it was determined that no further variables were needed for the model to understand the availability of suitable habitat for the purposes of the effects assessment and mitigation planning.

b. Interspersion of habitat: Specify why the habitat suitability index (HSI) model does not account for the interspersion of available habitat (available forage with security and thermal cover) as this will directly impact model outputs.

As presented in Appendix C, Moose Habitat Suitability Report of Appendix E-8, Wildlife Baseline Report of the Project Proposal, the objective of the habitat suitability modelling for moose was to understand the availability of suitable habitat to grow, reproduce, and survive (RIC, 1999a). The moose populations are not under pressure in the Project area and available mapping for the RSA is bound by the available Predictive Ecosystem Mapping level of detail. The model was then built on observations and the expert opinion of moose distributions by [Name Redacted] who has considerable experience conducting ungulate surveys in Yukon.

Elevation, aspect, slope and vegetation cover variables were determined to be the best available variables to define the observed moose distribution. The evaluation of the model showed a significantly high level of accuracy with observed distributions (tau correlation coefficient of 0.94 as discussed above). Interspersion can assist with refining habitat suitability; however, it is not always needed. Food suitability index was determined to be less accurate than an edge index (interspersion of food and cover) at identifying preferred habitat at finer scales (Dussault et al, 2006). Therefore, it was determined that no further variables were needed for the model to understand the availability of suitable habitat for the purposes of the effects assessment and mitigation planning.

c. ***Elevation range used in model: Clarify if adjusting the suitability and elevation range to correspond with the area modelled change the outputs.***

As presented in the Terrestrial Ecosystem Map and Report in the Vegetation Baseline Report, Appendix E-6 of the Project Proposal, treeline elevation is somewhat variable ranging from ~1,490 masl on northern aspect and 1,550 masl on southern aspect slopes. This accounts for the discrepancy between the caribou and moose habitat suitability reports. The variable treeline was accounted for in the model. The minimum elevation range used in the modelling corresponded to the area modelled for the RSA which has a lowest elevation of 800 masl. Indeed, all elevations in and around the Project area were used in the developing the HSI. The elevation suitability ranking, developed using fuzzy membership functions and expert opinion, returned a suitability of zero for elevation above 1,700 masl for post rut and 1,600 masl for late winter. The dataset used to test the model (Moose Aerial Survey Points 2015-2016) acquired by AEG did not include any moose sightings above 1,750 masl during post rut and above 1,650 masl during late winter. No change is needed in the models.

d. ***Segregation of habitat use: Clarify how suitable habitat for moose during the late season was segregated and provide the corresponding model outputs.***

As presented in Appendix C, Moose Habitat Suitability Report of the Wildlife Baseline Report, Appendix E-8 of the Project Proposal, segregation by sex (male/female) was not explicitly defined in the modelling for moose habitat suitability; however, the vegetation suitability index was corrected to account for some bull moose segregation into somewhat higher elevation shrub habitat than the lower conifer forest preferred for cows in winter. Model changes would not change the results of the effects assessment and mitigation planning.

e. ***Model equation: Clarify how models were developed for each season and provide the equation used.***

The models were developed based on expert knowledge and observations of the distribution of local moose populations from the post-rut and late winter surveys. These are often more accurate models for the population of interest than models based on distribution patterns found in other geographical areas. The survey data verified the models' accuracies.

The following are the equations used in the models:

Post Rut Model: (0.5 * [Elevation]) + (0.15 * [Slope]) + (0.05 * [Aspect]) + (0.3 * [Vegetation])

Late Winter Model: (0.4 * [Elevation]) + (0.25*[Slope]) + (0.05*[Aspect]) + (0.3 * [Vegetation])

f. Model assumptions: Provide the model assumptions.

The assumptions for the models are presented in Section 4 of Appendix C, Moose Habitat Suitability Report of the Wildlife Baseline Report, Appendix E-8 of the Project Proposal.

Post-rut Assumptions: moose prefer elevations between 1,300 and 1,600 masl, and are unlikely to be found at elevations below 1,300 or above 1,600 masl. Moose will select areas where the slope is slight, up to 20 degrees, and suitability will decrease as slope increases beyond 20 degrees. Moose prefer northeast and southeast facing aspects during the post-rut season. Moose were found most often in shrub habitat (suitability 1.0) in post-rut period followed by a preference for coniferous forest (suitability 0.6).

Late Winter Assumptions: Moose use all elevation equally and prefer elevation just at or below the treeline (1,450 m), as there is less snow and more vegetation, although some larger males will reside in upper elevation mountain draws. Moose will select areas where the slope is slight, up to 20 degrees, and suitability will decrease as slope increases beyond 20 degrees. Moose prefer northeast and northwest aspect during the late winter. Moose distribution showed higher frequency occurrence in coniferous forest, but the band distribution was fairly even between shrubs and conifer habitat. To further accommodate the segregation of bulls to shrub habitat in late winter, shrub habitat was rated as 1.0 and coniferous forest was rated as 0.6.

g. Zones of influence: Are zones of influence incorporated into the model, accounting for functional habitat use? If not, please provide the rationale for this and discuss how this may affect the outcome of the effects assessment for moose habitat.

For the zone of influence, the modelling was completed for baseline conditions with direct loss predictions quantified as the ultimate footprint of the Project and indirect loss based on a 50% reduction for the LSA around the Project footprint. This level of quantifying habitat loss from the Project was considered appropriate for the level of information and uncertainties. Additional modeling for different stages of the Project would unlikely change the magnitude of the effects assessment or the mitigation and management plans. Unforeseen effects detected by ongoing monitoring will be managed through the Adaptive Management Plan.

YESAB ISSUE WITH BMC'S RESPONSE TO R208

Clear articulation of methods and assumptions is required to properly assess the suitability of the HSI model.

Interspersion of habitat: It is unclear why the habitat suitability index (HSI) model does not account for the interspersion of available habitat (available forage with security and thermal cover). Moose are known to be rely on access to forage that is closely associated with security and thermal cover.

Insufficient Response: (a): The equations as depicted for both post rut and late winter moose habitat use do not allow for an output of 1.0 owing to a maximum rating of 0.8 for aspect classes. The equation also assumes that aspect is nearly inconsequential for moose habitat use (maximum contribution of 0.04). The contribution of aspect to moose habitat selection may be underrepresented by the current models.

R2-100

Articulate methods and assumptions used in the moose habitat suitability index model as indicated below.

a. Model equation: Clarify how models were developed for each season and provide the equation used.

It is acknowledged that the maximum aspect index should have been 1.0 rather than 0.8 in Table 4-4 of the Moose Habitat Suitability Report. The post rut and late winter habitat suitability indices for aspect are presented in Table 13-36 and the model updates are presented in Table 13-37 and Table 13-38, and Figure 13-20 and Figure 13-21, respectively. It should be noted that aspect was included to refine suitability similar to other moose habitat suitability models; however, aspect was given a 5% weighting in the suitability model since it was observed not to be a large factor in moose habitat selection in the Project area. Aspect has been determined to have less influence on late winter moose habitat in studies in the East Kootenay (Poole and Stuart-Smithe 2004), but more influence in Wyoming when there is more snow (Baigas et al., 2010). Shallower snow depths are therefore likely the reason why aspect appears to have less affect on habitat selection in the Project area.

There is little change in resulting suitable habitat between the December 2016 and August 2017 models (Table 13-37 and Table 13-38). The change in aspect suitability ranks did not change the validation of the model and there is still a high correlation between the model and field observations.

Table 13-36: Moose Distribution and Class Ranking for Aspect Suitability - Revised

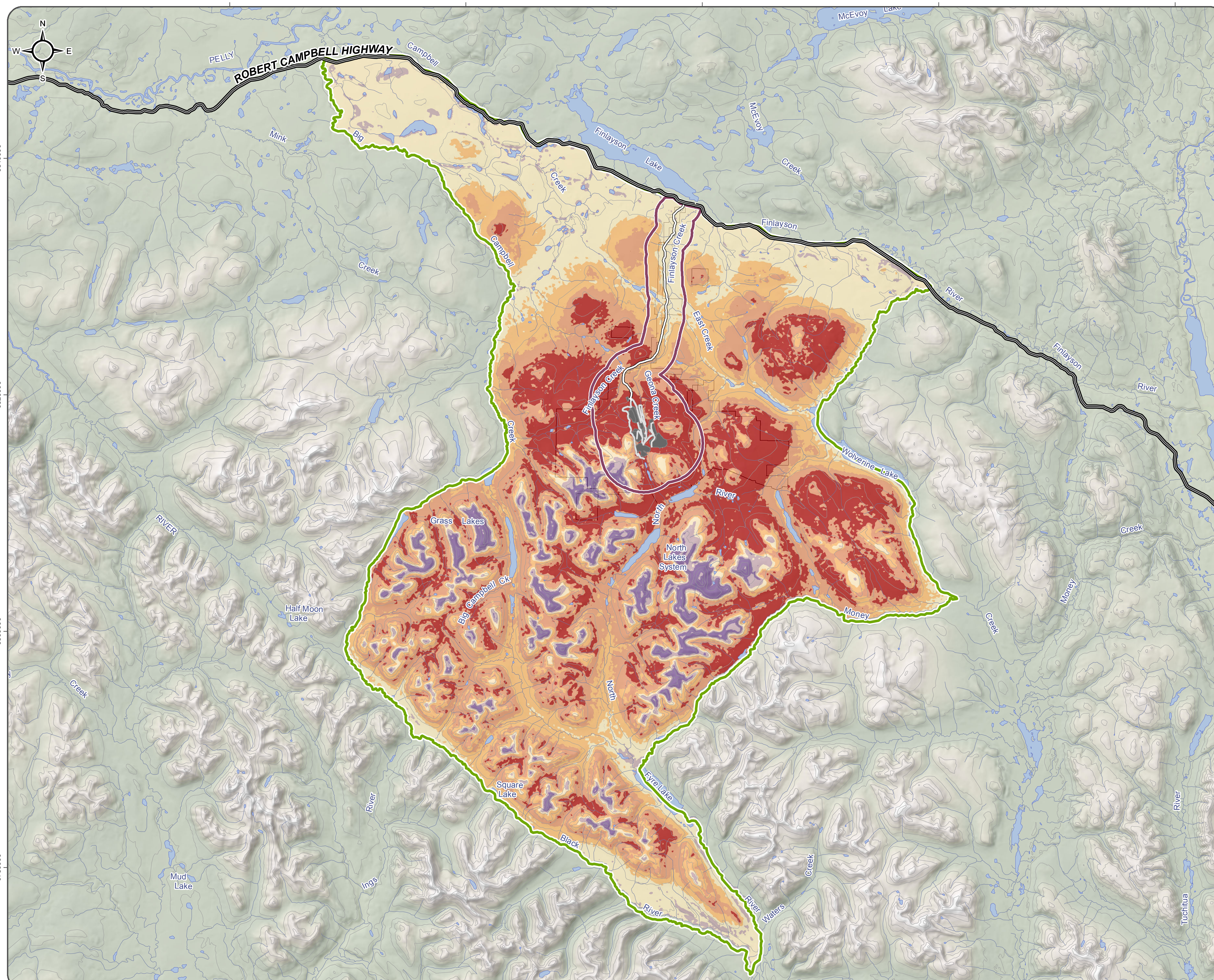
Variable Class	Post Rut Aspect Index Ranking		Late Winter Index Ranking	
	December 2016 Model	August 2017 Revised Model	December 2016 Model	August 2017 Revised Model
0-90	0.8	1.0	0.8	1.0
90-180	0.8	0.8	0.2	0.6
180-270	0.4	0.6	0.3	0.6
270-360	0.4	0.4	0.8	1.0

Table 13-37: Moose Post Rut Habitat Suitability Effects - Revised

Moose Habitat Suitability Index Regional Study Area (GMS 10-07)				
Habitat Suitability Index	December 2016 Model Area (ha)	August 2017 Model Area (ha)	December 2016 Model Percent of RSA (%)	August 2017 Model Percent of RSA (%)
Nil	5,975	5,762	3%	3%
Very Low	9,833	9,564	5%	5%
Low	43,498	43,184	23%	23%
Moderate	41,025	40,525	22%	22%
Moderately High	51,925	51,807	28%	28%
High	35,648	37,061	19%	20%
Indirectly Affected Suitable Moose Habitat in LSA				
Habitat Suitability Index	December 2016 Model Area (ha)	August 2017 Model Area (ha)	December 2016 Model Percent of RSA (%)	August 2017 Model Percent of RSA (%)
Nil	105	157	2%	3%
Very Low	239	254	2%	3%
Low	2,715	2,700	6%	6%
Moderate	1,935	1,992	5%	5%
Moderately High	2,462	2,658	5%	5%
High	3,865	4,729	11%	13%
Directly Affected Suitable Moose Habitat from Project Feature Footprint				
Habitat Suitability Index	December 2016 Model Area (ha)	August 2017 Model Area (ha)	December 2016 Model Percent of RSA (%)	August 2017 Model Percent of RSA (%)
Very Low	11	10	0%	0%
Low	37	38	0%	0%
Moderate	13	13	0%	0%
Moderately High	136	113	0%	0%
High	800	823	2%	2%

Table 13-38: Moose Late Winter Habitat Suitability Effects - Revised

Moose Habitat Suitability Index Regional Study Area (GMS 10-07)				
Habitat Suitability Index	December 2016 Model Area (ha)	August 2017 Model Area (ha)	December 2016 Model Percent of RSA (%)	August 2017 Model Percent of RSA (%)
Nil	12,865	11,613	7%	6%
Very Low	18,156	18,425	10%	10%
Low	12,630	12,551	7%	7%
Moderate	14,705	14,291	8%	8%
Moderately High	37,045	33,288	20%	18%
High	92,504	97,736	49%	52%
Indirectly Affected Suitable Moose Habitat in LSA				
Habitat Suitability Index	December 2016 Model Area (ha)	August 2017 Model Area (ha)	December 2016 Model Percent of RSA (%)	August 2017 Model Percent of RSA (%)
Nil	74	123	1%	1%
Very Low	945	972	5%	5%
Low	935	993	7%	8%
Moderate	1,065	1,164	7%	8%
Moderately High	1,721	1,925	5%	6%
High	6,580	7,313	7%	7%
Directly Affected Suitable Moose Habitat from Project Feature Footprint				
Habitat Suitability Index	December 2016 Model Area (ha)	August 2017 Model Area (ha)	December 2016 Model Percent of RSA (%)	August 2017 Model Percent of RSA (%)
Nil	0.25	0	0%	0%
Very Low	5	4	0%	0%
Low	21	20	0%	0%
Moderate	133	117	1%	1%
Moderately High	428	415	1%	1%
High	409	441	0%	0%



KUDZ ZE KAYAH PROJECT

FIGURE 13-20

MOOSE POST RUT HABITAT SUITABILITY - REVISED

OCTOBER 2017

HABITAT SUITABILITY INDEX

- Nil
- Very Low
- Low
- Moderate
- Moderately High
- High

OTHER MAP FEATURES

- Local Study Area
- Regional Study Area (Game Management Subzone 10-07)
- Location of Proposed Infrastructure
- BMC Minerals (No.1) Ltd. Mineral Claim Areas
- Tote Road/Proposed Access Road
- Proposed Mine Road
- Watercourse
- Waterbody

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.

Datum: NAD 83; Projection UTM Zone 9N

1:325,000 when printed on 11 x 17 inch paper

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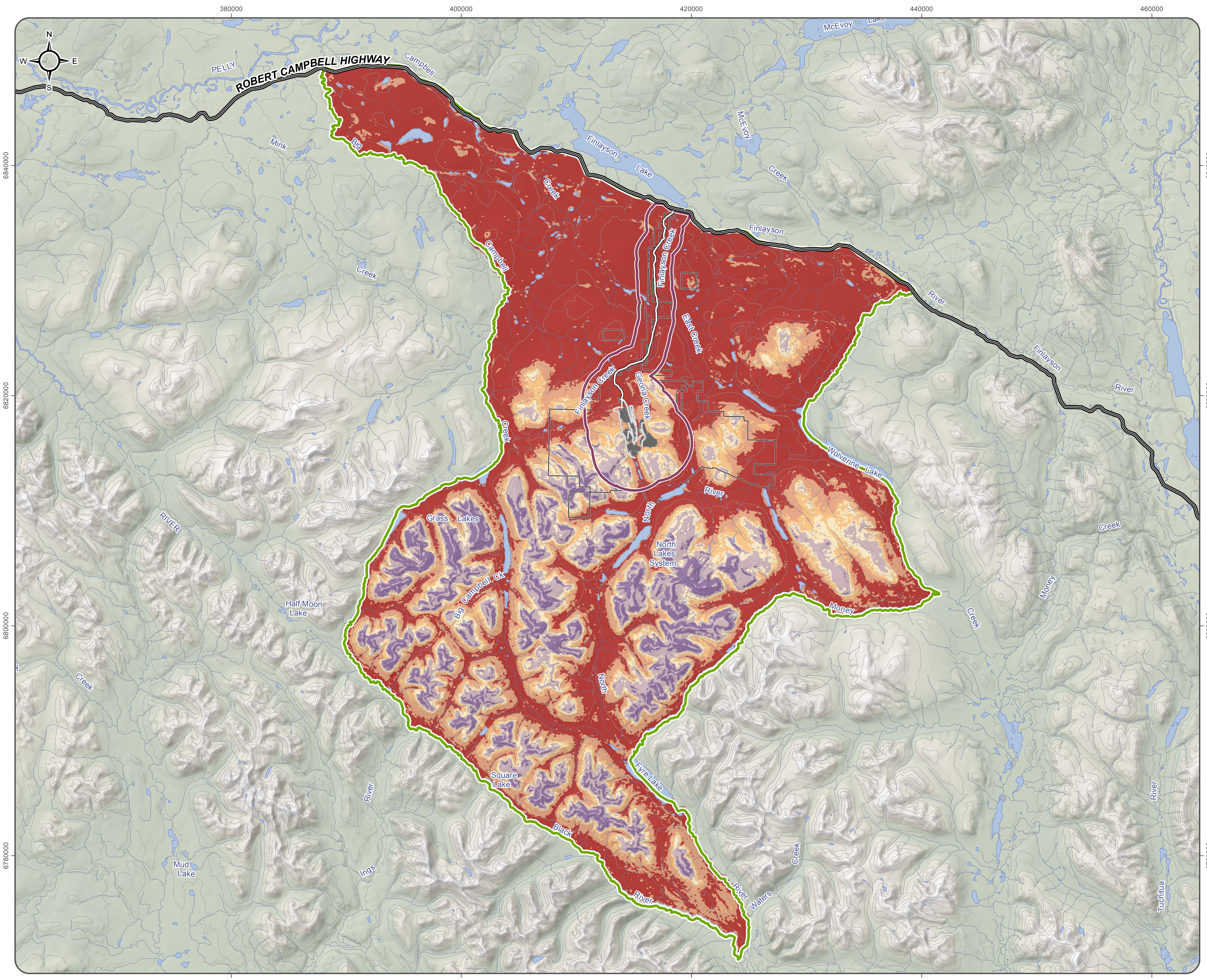

KUDZ ZE KAYAH PROJECT

FIGURE 13-21
MOOSE LATE WINTER HABITAT SUITABILITY - REVISED

OCTOBER 2017

HABITAT SUITABILITY INDEX

- Nil
- Very Low
- Low
- Moderate
- Moderately High
- High

OTHER MAP FEATURES

- Local Study Area
- Regional Study Area (Game Management Subzone 10-07)
- Location of Proposed Infrastructure
- BMC Minerals (No.1) Ltd. Mineral Claim Areas
- Tote Road/Proposed Access Road
- Proposed Mine Road
- Watercourse
- Waterbody

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.

Datum: NAD 83; Projection UTM Zone 9N

1:325,000 when printed on 11 x 17 inch paper

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YESAB ISSUE

Failure to include moderate suitability habitat in the project area during the effects assessment could lead to underestimating impacts to moose.

R209

"Include moderate suitability habitat for moose in the assessment."

Moderately high to high suitability habitat were included to determine habitat loss in the effects assessment. Inclusion of moderate habitat in the calculations would result in a slight increase in percent habitat loss for late winter and a decrease in percent habitat loss for post rut. The results have been reproduced in Table 13-39 below. Therefore, inclusion of moderate habitat does not change the effects assessment or mitigation planning.

Table 13-39: Moose Habitat Loss Differences with Range of Habitat Suitability Categories

	Post Rut			Late Winter		
Habitat Suitability Categories	**Directly Affected (Project footprint)**	**Indirectly Affected (LSA)**	**% Loss of RSA***	**Directly Affected (Project footprint)**	**Indirectly Affected (LSA)**	**% Loss of RSA***
Moderately High to High	9.4 km^2	63.3 km^2	-4.7%	8.4 km^2	83.0 km^2	-3.9%
Moderate to High	9.5 km^2	82.6 km^2	-4.0%	9.7 km^2	93.7 km^2	-3.9%

*Percent change after direct loss and 50% indirect loss of habitat in LSA.

YESAB ISSUE WITH BMC'S RESPONSE TO R209

Failure to include moderate suitability habitat in the project area during the effects assessment could lead to underestimating impacts to moose.

Insufficient Response: *It remains unclear what the effect of not including moderate habitat in the assessment is, and the methods for modeling moose habitat are unclear.*

R2-101

Confirm that the methods utilized for modeling moose habitat followed standards as depicted in RISC (1999) and provide the thresholds that were used to identify habitat into the three classes (high, moderate and low). Note that RISC (1999) does not utilize 3 class models.

As presented in Section 4 of the Moose Habitat Suitability Report, Appendix C of the Wildlife Baseline Report, Appendix E-8 of the Project Proposal, the moose habitat suitability modeling general methodology is consistent with Environment Yukon's *Knowledge-Based Habitat Suitability Modelling Guidelines* (Clarke, 2012). The moose habitat suitability modeling used six classes, the same as for the caribou habitat suitability modeling.

The six classes were divided equally from 0 to 1 based on results from the model equation as follows:

- High = 1.00 - 0.84
- Moderately High = 0.83 - 0.68
- Moderate = 0.67 - 0.51
- Moderately Low = 0.50 - 0.34
- Low = 0.33 - 0.18
- Very Low = 0 - 0.17

Ranked habitat categories are based on ideal habitat for moose based on their distribution as described in the literature and based on their actual distribution in the 2015 and 2016 surveys in the RSA. The habitat rankings are relative to optimal habitat in the RSA. Since little information is available specific to the Yukon, the ranks are not relative to the known highest suitability habitat in Yukon as might be done in British Columbia.

This question also requests clarification for the rationale of why moderate habitat suitability was not included in the Project Proposal effects assessment. Since most moose were found in the moderately high and high suitability habitat and this habitat may be more limiting, these two categories were thought to be more appropriate to measure the magnitude of change in habitat suitability. However, it is agreed that moderate habitat should also be considered and one might or might not be more conservative than the other. As presented in the response and Table 13-25 to R254, moose post rut habitat loss is estimated at 4.7% if moderately high and high habitat classes are included, and 4% if moderate habitat is included. In late winter, the percentage lost for moderate high to high is 3.9% and remains at 3.9% when moderate habitat is included.

The other habitat suitability models were broken into three classes. A three-class rating system was used since there was limited information to separately define a low and very low/nil category and the purpose of the modeling for these species was to show the distribution of more suitable habitat and to give a coarse estimation of magnitude of effects. The class thresholds were based on ideal habitat in the literature interpreted for equivalent habitat found in the LSA. These thresholds were defined by the criteria used for the GIS mapping for each species. A four-class rating system probably could have been used; however, the lower two classes would still have captured all the low rated habitat in the current model and are not used to calculate habitat lost. The new models (for horned grebe, rusty blackbird, short-eared owl, and common nighthawk) presented in response to R2-80 have been broken into four classes.

13.4 GRIZZLY AND BLACK BEARS

YESAB ISSUE

The proponent uses thresholds about acceptable amounts of habitat loss and disturbance for grizzly bears. It is unclear how thresholds were established. The primary reference provided for Grizzly Bear thresholds in Table 13-3 is for woodland caribou (Environment Canada. 2011. Scientific assessment to inform the identification of critical habitat for woodland caribou (Rangifer tarandus caribou), boreal population, in Canada. Ottawa, ON, pp. 102.)

R210

"Provide a reference for the thresholds used regarding acceptable amounts of habitat loss and disturbance for grizzly bears."

Regarding thresholds, the reference for the grizzly bear threshold in Table 13-3 of the Project Proposal was incomplete. The correct reference list should have included Dykstra (2004) and AXYS (2002). Threshold habitat areas required to sustain grizzly bear populations were determined to be 700 to 10,000 km^2 to sustain a population of 35 to 70 grizzly bear in Yellowstone and from 8,556 to 17,843 km^2 to sustain a population of 200 to 250 grizzly bear in British Columbia (Dykstra, 2004). Since overall habitat areas are not known to be limiting in Yukon and there is limited information on grizzly bear and their habitat use in this area of Yukon, a more conservative and general threshold of habitat change was chosen in line with other wildlife habitat thresholds (i.e. 0-10% low, 10-15% moderate, and >15% high) for assessing effects. This provides an industrial target and social acceptance threshold for the effects assessment that is measurable, practical, and reasonable (AXYS, 2002).

YESAB ISSUE WITH BMC'S RESPONSE TO R210

The proponent uses thresholds about acceptable amounts of habitat loss and disturbance for grizzly bears. It is unclear how thresholds were established. The primary reference provided for Grizzly Bear thresholds in Table 13-3 is for woodland caribou (Environment Canada. 2011. Scientific assessment to inform the identification of critical habitat for woodland caribou (Rangifer tarandus caribou), boreal population, in Canada. Ottawa, ON, pp. 102.)

Insufficient Response: *The response is incomplete. Literature to support selected thresholds for disturbance to grizzly bears is not provided.*

R2-102

Provide a reference for the thresholds used regarding acceptable amounts of habitat loss and disturbance for grizzly bears.

References for the thresholds for habitat loss were Dykstra (2004) and AXYS (2002), as provided in response to R210. Since there is little development pressure on grizzly bear habitat in Yukon, management thresholds used are considered appropriate. In addition, in Yukon annual harvest and non-hunted mortalities are below the 2-3% cap to maintain stable grizzly bear populations [Name Senior Conservation Officer, pers. comm. 2017).

YESAB ISSUE

The proposal contains insufficient analysis of mortality rates. In the baseline report, the proponent only describes harvest history in GMA 10-07 and not surrounding GMAs or bear management unit.

R213

"Discuss the population of grizzly bears and mortality rates in the area. This should include a discussion of mortality of female bears."

BMC recognizes the importance of safe practices when working in bear country and adopting proper waste management so as not to attract bears. There have been no adverse grizzly bear interactions during BMC's exploration work on the KZK Project. Grizzly bear mortality rates are dependent on risk factors which are changing as companies and contractors implement better practices. The discussion in the Project Proposal was short but not for a lack of importance. More discussion could have been included on mortality rates and the importance of female bears, however the focus was on minimizing risk. The importance and sensitivities of grizzly bears is presented more fully in Section 6 of the Wildlife Baseline Report, Appendix E-8 of the Project Proposal. As indicated in Table 13-3 of the Project Proposal, the threshold or target for the Project is preventing grizzly bear mortalities (i.e., no injuries or fatalities (unless required for human safety) directly attributed to mine activity). This is the primary focus of the mitigation and management measures in place for exploration and proposed Project development. As further indication of importance, the reason for not including specific locations of dens on the maps was to protect female bears.

The regional study area was GMS 10-07 since KZK Project residual effects are not expected outside of this area. The focus of study on GMS 10-07 was presented and commented on by Environment Yukon for baseline studies and no request was made to expand this area for grizzly bear. Nonetheless, additional harvest data was received but not reported. Table 13-40 (below) presents harvest data for GMSs 10-06, 10-07, 10-08, and 10-09 (Environment Yukon, unpublished data). From these data, grizzly bear mortality from reported hunting in these surrounding management zones is low. Further, in the 2015-2016 season six grizzly bear were harvested in Zone 10 and ten grizzly bear were harvested in Zone 11 (Environment Yukon, Yukon Hunting Regulation Summary, 2016-2017). These data do not change the results of the effects assessment or the mitigation plans.

Table 13-40: Yukon Government Grizzly Bear Harvest for Regional Game Management Areas

Year	Game Management Area			
	10-06	10-07	10-08	10-09
1995		5		
1998				2
1999		1		

Year	Game Management Area			
	10-06	10-07	10-08	10-09
2006		1		
2007	1	2		
2008	1	1		
2009		1		
2010		2		
2011		1		
2012		1	1	
2013	1			
2014	1			
Grand Total	**4**	**15**	**1**	**2**

YESAB ISSUE WITH BMC'S RESPONSE TO R213

The proposal contains insufficient analysis of mortality rates. In the baseline report, the proponent only describes harvest history in GMA 10-07 and not surrounding GMAs or bear management unit.

Insufficient Response: *The question remains unanswered as little information is provided on populations and mortality rates of grizzly bears beyond harvest rates.*

R2-103

Discuss the population of grizzly bears and mortality rates in the area. This should include a discussion of mortality of female bears.

Grizzly bear mortality in Yukon from human-bear conflict ranges from 10 to 15 bears annually (Environment Yukon, 2008).

Over 36 years from 1980 to 2016, there have been 29 recorded non-hunted mortalities in Game Management Zone 10 and only two from Game Management Area 10-07 (2,063 km^2) where the Project is located (Environment Yukon, [Name Redacted] Wildlife Harvest Specialist, unpublished data). Non-hunted mortality in the surrounding Game Management Areas are similar to GMA 10-07 (Environment Yukon, unpublished data). Non-hunted data includes mortality from vehicle collisions and destruction of bears for defense of life or property. Yukon wildlife managers include non-hunted data with harvest data when setting harvest quotas ([Name Redacted], Senior Conservation Officer, pers. comm. 2017). Annual harvest and non-hunted mortalities are kept below the 2-3% cap to maintain stable grizzly bear populations [Name Redacted] Senior Conservation Officer, pers. comm. 2017).

Grizzly bear densities and harvest data were presented in Section 6.1 and 6.4 of the Wildlife Baseline, Appendix E-8 of the Project Proposal. Accurate densities for the Project area are unknown; however, Larsen et al. (1989) estimated densities between 10 to 16 bears per 1,000 km^2, based on studies completed in the Southern Lakes region of Yukon. It is anticipated that the density of grizzly bears is higher in east-central Yukon, compared to the Southern Lake region, as there is less human effect on wilderness, fewer roads, and lower hunting pressure compared with the Southern Lakes region (Desrochers et al., 2002; Environment Yukon, 2005). Hunter harvest has averaged less than one grizzly bear annually in GMS 10-07 over 22 years from 1995 through 2016. Combined hunted and non-hunted mortality is less than one grizzly bear annually from an area (GMS 10-07) that is estimated to support at least 20 to 30 grizzly bears. This equates to less than 0.5% mortality per year which is well below the sustainability cap of 2-3%. Fully mitigated activity and transportation associated with development and operation of the mine is not expected to affect the current mortality rates or sustainability of the population.

It is acknowledged that female bear mortality rates need to be kept low to sustain the population due to their low fecundity. However, it is not expected that effects from the Project will preferentially affect either sex of grizzly bear.

YESAB ISSUE

Aerial den surveys focused on modelled high and moderate suitable grizzly bear den habitat. If the surveys were completed based on a model that may need to be refined then the spatial focus of these surveys may have been incorrect.

Lack of use of Yukon information. Please make use of geographically/ecologically appropriate literature as background to the habitat suitability model.

Slope thresholds and den site selection. A focus on geographically and biologically appropriate information may influence model inputs and outputs. This may influence the delineation of grizzly bear denning habitat.

The lack of information on model assumptions, model reliability and model validation make it not possible to fully assess the adequacy of the model.

R215

"Which model was used to provide focus for the den surveys?"

As presented in Section 6.3 of the Wildlife Baseline Report, Appendix E-8 of the Project Proposal, prior to fieldwork, a model displaying high to moderately suitable grizzly denning habitat in the study area was completed. The model was created using a geographical information system (GIS), a digital elevation model (DEM), and aerial photogrammetry. The parameters to model and map grizzly bear den habitat suitability were assessed based on the following criteria:

- 20 to 40° slopes;
- 600 to 1,500 masl elevation; and
- Exclusion of wet habitat types.

R218

"Provide further consideration of slope thresholds making use of readily available and geographically appropriate literature to support model development for slope thresholds, i.e., Reynolds et al. (1974), Harding (1976), McLoughlin et al. (2002), Schwartz et al. (2003) and Libal et al. (2012)."

It is acknowledged that additional literature can be reviewed to further define slope thresholds. The Predictive Ecosystem Mapping in the RSA is limited to map microscale site selections as presented in Libal et al (2012). It should also be noted that there are considerable differences in preferred denning habitat between geographic areas as presented by Reynolds et al. (1976). Site-specific use of the Project area is limited. Therefore, the grizzly bear denning habitat suitability model can continue to be refined as more site-specific grizzly bear use observations are obtained. However, the current model provides an appropriate level of accuracy for the effects assessment and mitigation planning for the Project.

YESAB ISSUE WITH BMC'S RESPONSE TO R215 AND R218

Aerial den surveys focused on modelled high and moderate suitable grizzly bear den habitat. If the surveys were completed based on a model that may need to be refined then the spatial focus of these surveys may have been incorrect.

Lack of use of Yukon information. Please make use of geographically/ecologically appropriate literature as background to the habitat suitability model.

Slope thresholds and den site selection. A focus on geographically and biologically appropriate information may influence model inputs and outputs. This may influence the delineation of grizzly bear denning habitat.

The lack of information on model assumptions, model reliability and model validation make it not possible to fully assess the adequacy of the model.

Insufficient Response: *Two different models are provided in the Project Proposal. It is unclear why different models were used and whether this would have impacted the ability to detect grizzly bear dens. It is unclear how potentially differing results were rationalized.*

Insufficient Response: *Flight lines are not provided.*

Insufficient Response: *The methods used for developing models are not clearly defined and do not appear to follow standard modelling convention. Categories of high, medium and low are noted as being used but no information is provided with regards to the thresholds that are applied to define these categories. The use of a three-class system does not follow standard convention. No model validation was completed, so it is difficult to agree with the assertion of moderate reliability. In addition, it is impossible to validate the model equation without having a comprehensive presentation of model inputs, including a description of how slope, elevation, aspect and vegetation communities were ranked.*

R2-104

Which model was used to provide focus for the den surveys?

As presented in R217 and as presented in Section 6.3 of the Wildlife Baseline Report, Appendix E-8 of the Project Proposal, the model parameters for preparation for the field den surveys were broad categories (20-40° slopes, 600-1,500 masl elevation, and exclusion of wet habitat types) to identify a wide range of potential denning habitat. The categories were further refined for the habitat suitability (HS) mapping presented in Section 6.5 of the Wildlife Baseline Report, Appendix E-8 of the Project Proposal. The final HS map criteria separated out high, medium, and low suitability to take into account results from the denning surveys and further refinement from the literature. Aspect and a narrower categorization of slope were added to the criteria for the final mapping.

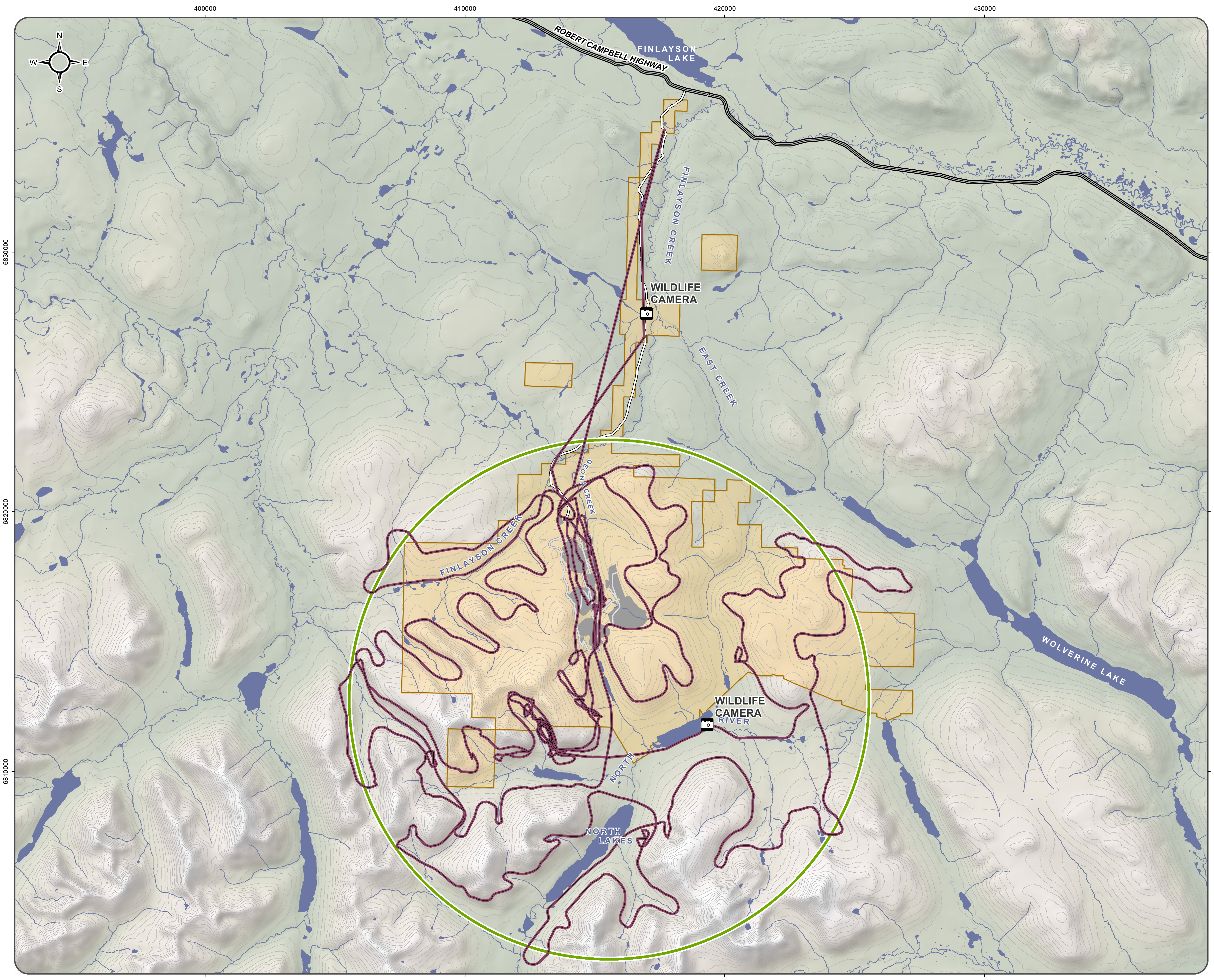
R2-105

What survey methods standards were used for den surveys? What was the survey effort by date? Provide information on the daily flight lines. How was the Project area stratified? How many observers were there and what were their qualifications?

On October 5 2017, YESAB provided (via email) the following clarification regarding the information required in response to R2-105:

> *"Provide the flight lines, the rest of the question has been answered sufficiently in the previous response."*

The 2015 survey flight paths were similar to the 2016 survey flight paths shown in Figure 13-22 and Figure 13-23. The 2015 survey flight paths are shown in Figure 13-24, Figure 13-25, and Figure 13-26.



BMC MINERALS

KUDZ ZE KAYAH PROJECT

FIGURE 13-22

SPRING BEAR SURVEY 1 -
(APRIL 19TH 2016)

OCTOBER 2017

- Wildlife Camera Location
- Bear Survey Flight Path
- Tote Road/Proposed Access
- Proposed Mine Road
- Bear Den Study
- Location of Proposed Infrastructure
- BMC Minerals (No.1) Ltd. Mineral Claim Areas

ALEXCO ENVIRONMENTAL GROUP

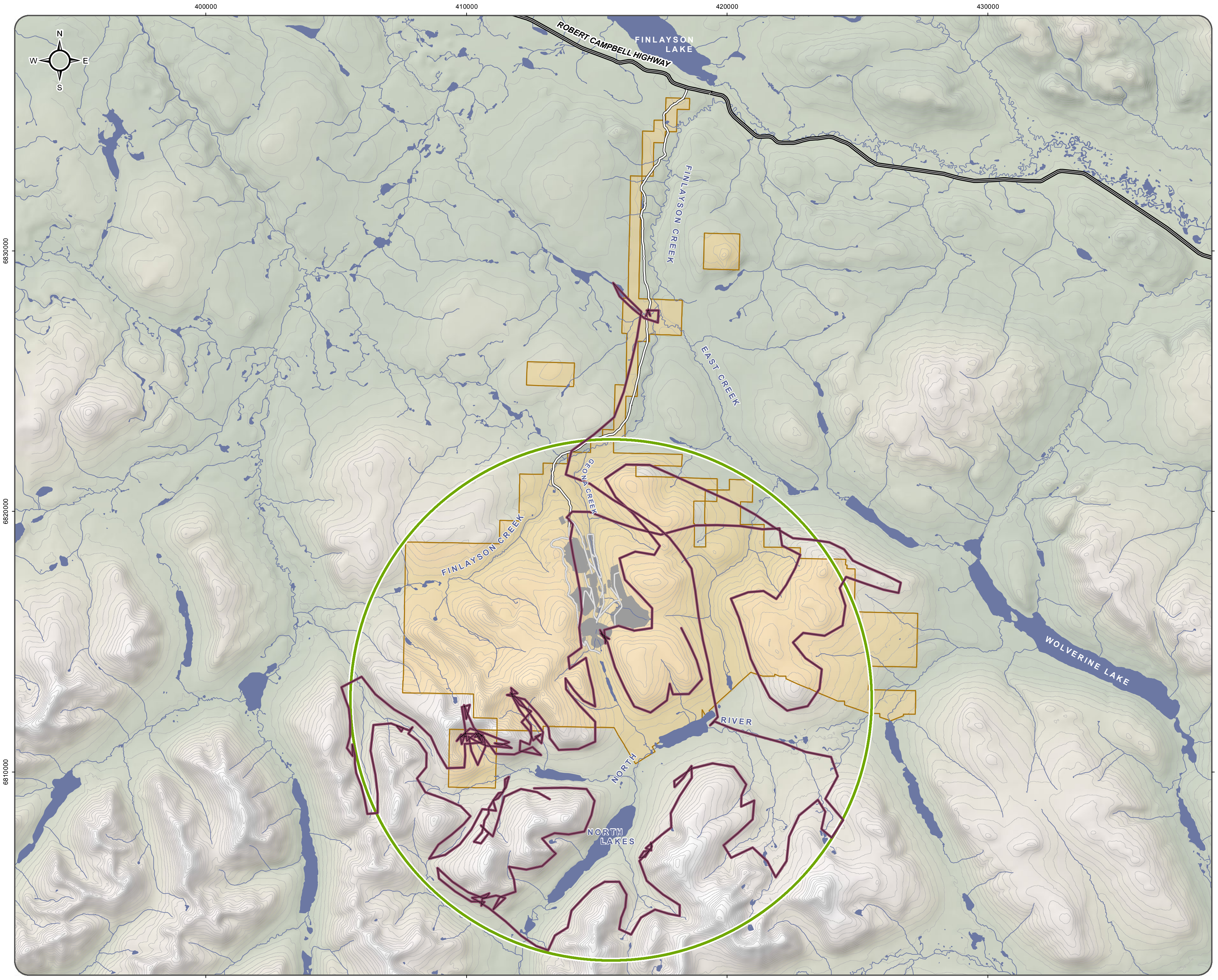
Digital elevation model created by the Yukon Department of the Environment interpolated from the digital 1:50,000 Canadian National Topographic Database (NTDB Edition 2) contour and watercourse layers. Obtained from Geomatics Yukon.

Datum: NAD 83; Projection UTM Zone 9N

when printed on 11 x 17 inch paper

0 2 4 6 8
Kilometers

D:\Project\AllProjects\Kudz_Ze_Kayah\Maps\03_Study\Wildlife\BearDen\06-Bear_Observations\Tracks\GB_Tracks_Survey1_2016_20170824.mxd
(Last edited by: amatlashevska; 19/10/2017/15:26 PM)



BMC MINERALS

KUDZ ZE KAYAH PROJECT

FIGURE 13-23

SPRING BEAR SURVEY 2 -
(APRIL 27TH 2016)

OCTOBER 2017

Bear Survey Flight Path
Tote Road/Proposed Access Road
Proposed Mine Road
Bear Den Study Area
Location of Proposed Infrastructure
BMC Minerals (No.1) Ltd. Mineral Claim Areas

ALEXCO ENVIRONMENTAL GROUP

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.

Datum: NAD 83; Projection UTM Zone 9N

when printed on 11 x 17 inch paper

0 2 4 6 8
Kilometers

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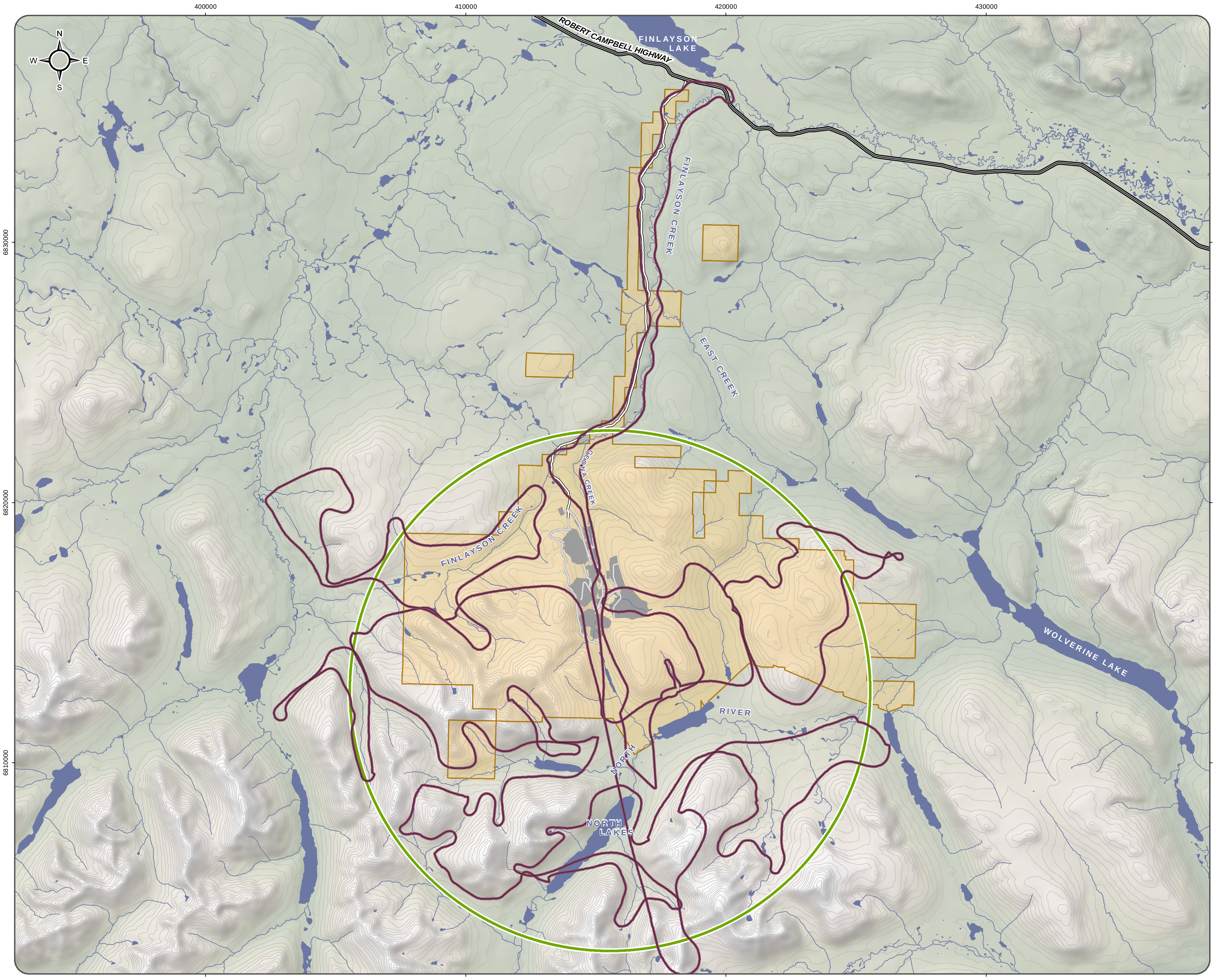
(*Last edited by: amatlashevska; 19/10/2017/15:37 PM*)

BMC MINERALS

KUDZ ZE KAYAH PROJECT

FIGURE 13-24
SPRING BEAR SURVEY 1 -
(APRIL 24TH 2015)

OCTOBER 2017



- Bear Survey Flight Path
- Tote Road/Proposed Access Road
- Proposed Mine Road
- Bear Den Study Area
- Location of Proposed Infrastructure
- BMC Minerals (No.1) Ltd. Mineral Claim Areas

ALEXCO ENVIRONMENTAL GROUP

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.

Datum: NAD 83; Projection UTM Zone 9N

when printed on 11 x 17 inch paper

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Kilometers

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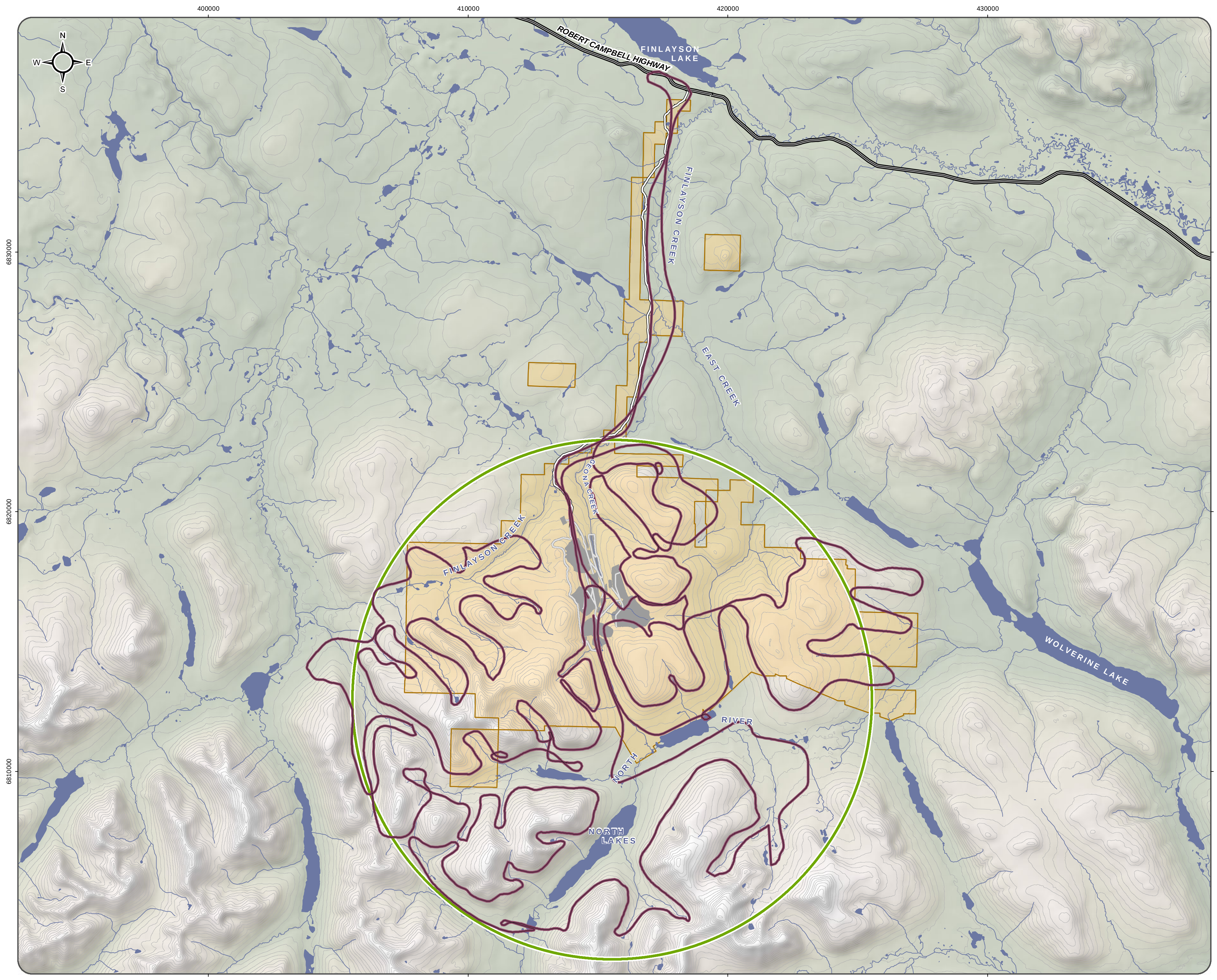
(Last edited by: amatlashevska; 19/10/2017/15:10 PM)



BMC MINERALS

KUDZ ZE KAYAH PROJECT

FIGURE 13-25

SPRING BEAR SURVEY 2 -
(MAY 5TH 2015)

OCTOBER 2017

- Bear Survey Flight Path
- Tote Road/Proposed Access Road
- Proposed Mine Road
- Bear Den Study Area
- Location of Proposed Infrastructure
- BMC Minerals (No.1) Ltd. Mineral Claim Areas

ALEXCO ENVIRONMENTAL GROUP

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.

Datum: NAD 83; Projection UTM Zone 9N

when printed on 11 x 17 inch paper

0 2 4 6 8
Kilometers

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(Last edited by: amatlashevska; 19/10/2017/15:13 PM)

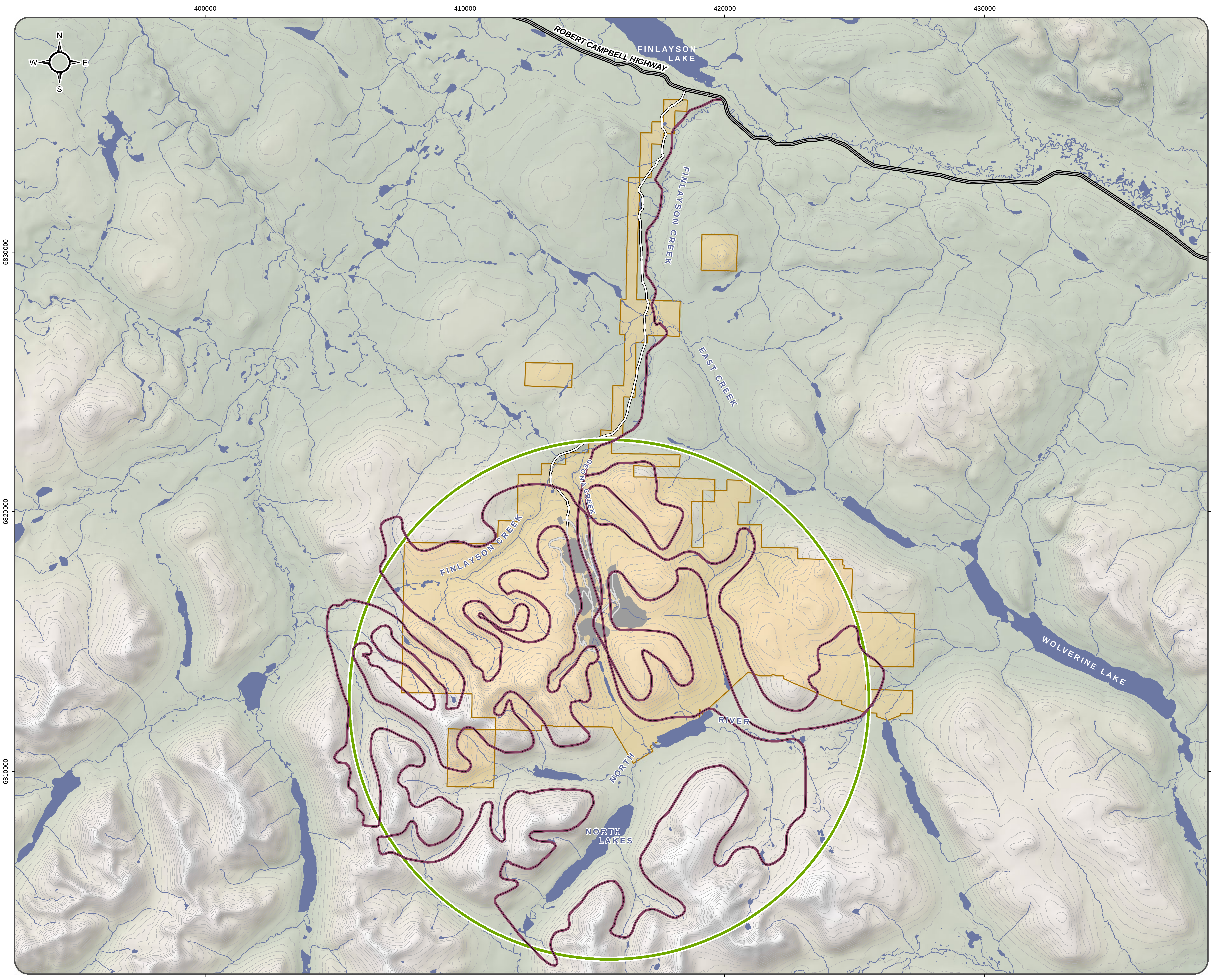
BMC MINERALS

KUDZ ZE KAYAH PROJECT

FIGURE 13-26

SPRING BEAR SURVEY 3 - (MAY 15TH 2015)

OCTOBER 2017



- Bear Survey Flight Path
- Tote Road/Proposed Access Road
- Proposed Mine Road
- Bear Den Study Area
- Location of Proposed Infrastructure
- BMC Minerals (No.1) Ltd. Mineral Claim Areas

ALEXCO ENVIRONMENTAL GROUP

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.

Datum: NAD 83; Projection UTM Zone 9N

when printed on 11 x 17 inch paper

0 2 4 6 8
Kilometers

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(Last edited by: amatlashevska; 19/10/2017/15:23 PM)

R2-106

What were the model assumptions that were used to build the model? Was model reliability determined? Was the model statistically validated?

On October 5 2017, YESAB provided (via email) clarification regarding the information required for R2-106. The clarification is as follows:

> *"Clarify the thresholds used to identify "Low", "Moderate" and "High" suitability habitat and define each term. Describe the standards used to establish these thresholds.*
>
> *The model has been described as moderately reliable, but we cannot see evidence of how that determination was made. Please provide the rationale for this determination."*

Ranked habitat categories are based on ideal habitat for grizzly bear denning, based on their distribution as described in the literature and then interpretation of that ideal habitat that would be in the RSA. The habitat rankings are relative to optimal habitat thresholds as defined in Hamilton (1989), Riddell (2005), and RISC (1998b) and applied to habitat in the RSA.

- High suitability habitat is in the alpine at a slope of 30-38º, south and southeast aspects with colluvium or moraine surficial materials.
- Moderate suitability habitat is in the alpine or subalpine on 22 to 29º or 29-40º slopes, south and southeast aspects with colluvium or moraine surficial materials.
- Low (and nil) suitability habitat is everything else.

The rankings are not relative to the known highest suitability habitat in Yukon as might be done in British Columbia.

The model has a moderate reliability based on the definitions in the BC Wildlife Habitat Rating Standards, (i.e., Moderate Reliability means available information is based mainly on studies, reports and expertise on the species-habitat relationships gained within British Columbia; RIC, 1999a). No verification or limited verification has been undertaken. Two years of grizzly bear den surveys in the RSA observed bears denning in areas that are modeled as high suitability habitat. This means that the habitat preferences from literature have proven to be appropriate and applicable based on the observations at the RSA.

YESAB ISSUE

Although RISC (2001) standards were identified as being used, the methods described vary in some important aspects from these standards.

Completing a total of fourteen 75-m transects (1,050 m total length) within an LSA that is 11,321 hectares may be inadequate to reflect actual baseline conditions.

To determine the baseline conditions for a project it is important that:

a. Appropriate survey standards are utilized, so that results are comparable and reliable; and

b. An appropriate level of effort is completed for an adequate assessment of baseline conditions. Completing a total of fourteen 75-m transects (1,050 m total length) within an LSA that is 11,321 hectares may be inadequate to reflect actual baseline conditions.

R228

"Provide rationale for the methods used, including how sample sites and transect lengths were selected."

As presented in Section 8.1 of the Wildlife Baseline Report, Appendix E-8 of the Project Proposal, the protocol used for the snow track survey was based on the British Columbia RISC Committee Ground Based Inventory Methods for Ungulate Snow-track Survey (RISC, 2006). The snow track survey is intended to be a presence/non-detection level study to discern the variety of wildlife utilizing the Project footprint and Tote Road, as well as, to locate main sites of wildlife interaction with the proposed mine infrastructure.

Best sites for snow tracking are along riparian corridors and along mountain passes where wildlife can travel between adjacent valleys. Also, at pinch points, where movement is constrained as a result of natural barriers such as steep cliff faces and rivers. These areas were identified through desktop analysis and confirmed as active wildlife sites in the field in an effort to maximize track detection. Nine of the transects were located around the proposed Project footprint in the upper Geona Creek valley and five transects were located along the Tote Road. The rationale for selection of the sample sites is that the transects were established in habitat types that commonly occur within the LSA to assess habitat use in the area directly affected by the Project. In total, the survey consisted of establishing fourteen 75 m transects, and then identifying and recording the number of tracks per mammal species that intersected within 2 m either side along the length of the transect.

The length of each transect was determined based on terrain and the number, variety of species tracks encountered, and accessibility. There is a high level of confidence that the 2016 and 2017 snow track surveys, 2015 and 2016 wildlife logs, and the various other aerial and terrestrial baseline studies on the property have identified most species that use the LSA and RSA.

R230

"Are transect lengths sufficient to provide reliable baseline information on habitat use in the area affected by the Project?"

The snow track survey is intended to be a presence/non-detection level study to discern the variety of wildlife utilizing the Project footprint and Tote Road, as well as, to locate main sites of wildlife interaction with proposed mine infrastructure and vicinity. The winter track survey transects were established in habitat types that commonly occur within the LSA to assess habitat use in the area directly affected by the proposed Project. For this purpose, the transect lengths are considered sufficient to provide reliable baseline information at the key areas within the Project footprint and Tote Road.

YESAB ISSUE WITH BMC'S RESPONSE TO R228 AND R230

Although RISC (2001) standards were identified as being used, the methods described vary in some important aspects from these standards.

Completing a total of fourteen 75-m transects (1,050 m total length) within an LSA that is 11,321 hectares may be inadequate to reflect actual baseline conditions.

To determine the baseline conditions for a project it is important that:

a. *Appropriate survey standards are utilized, so that results are comparable and reliable; and*
b. *An appropriate level of effort is completed for an adequate assessment of baseline conditions. Completing a total of fourteen 75-m transects (1,050 m total length) within an LSA that is 11,321 hectares may be inadequate to reflect actual baseline conditions.*

Insufficient Response: *The rationale provided for survey transect length is insufficient. Rationale and literature are needed to support the assertion that 75-m transects are adequate, with consideration that RISC standards identify 1,000 m transect length.*

Insufficient Response: *The proponent has not adequately supported, through reference to relevant literature, the assertion that 75-m transects are sufficient to document the variety of wildlife utilizing the Project footprint and to locate main sites of wildlife use with consideration of RISC standards. The response should include reference to appropriate literature to support the assertion that 75-m transects would be sufficient to document the occurrence of rare or elusive species.*

R2-107

Provide rationale for the methods used, including how sample sites and transect lengths were selected.

The RISC (2006) protocols on snow tracking transects vary depending on the species and their home range sizes. The main objective of the winter snow tracking was to determine presence of small or medium mammals not recorded during aerial or ground surveys rather than ungulates. The RISC Ground-based Inventory Methods for Ungulate Snow-track Surveys is cited as the methodology most closely followed; however, the Government of Saskatchewan (2014) Species Detection Survey Protocol, Snow Track Surveys was also used to help guide the survey design. As mentioned in the Sampling Design section of the RISC protocol #33a "*The number and location of transects will depend on objectives, existing budgets, the size of the project area, and ecological variability*."

The home ranges of the animals we were anticipating to encounter were small (e.g., pine marten ranges are 1.5 to 2.2 km^2). Ungulates have much larger ranges; therefore, the transect length for these larger and widely dispersed animals would have been longer, in the order of 1000 m for mountainous terrain (RISC, 2006). The small mammal surveys as prescribed by RISC #31 Inventory Methods for Small Mammals: Shrews, Voles, Mice & Rats (RISC, 1998a) are very involved and are meant to determine relative or absolute population estimates using live trapping and mark-recapture methods which is not typically required for YESAB project proposals and was not the objective of the Kudz Ze Kayah baseline program. The objective for the baseline was to determine presence and a preliminary indication of relative abundance in the Project footprint; therefore, the shorter transect snow track survey was used.

R2-108

Are transect lengths sufficient to provide reliable baseline information on habitat use in the area affected by the Project?

The snow track survey transects are sufficient when combined with historical studies, the two years of baseline wildlife logs, eight aerial surveys, and the incidental observations recorded during the other environmental field programs.

The RISC (2006) protocols on snow tracking transects vary depending on the species and their home range sizes. The main objective of the winter snow tracking was to determine presence of small or medium mammals not recorded during aerial or ground surveys rather than ungulates. The RISC Ground-based Inventory Methods for Ungulate Snow-track Surveys is cited as the methodology most closely followed; however, the Government of Saskatchewan (2014) Species Detection Survey Protocol, Snow Track Surveys was also used to help guide the survey design. As mentioned in the Sampling Design section of the RISC protocol #33a *"The number and location of transects will depend on objectives, existing budgets, the size of the project area, and ecological variability."*

The home ranges of the animals we were anticipating to encounter were small (e.g., pine marten ranges are 1.5 to 2.2 km^2). Ungulates have much larger ranges; therefore, the transect length for these larger and widely dispersed animals would have been longer, in the order of 1000 m for mountainous terrain (RISC, 2006). The small mammal surveys as prescribed by RISC #31 Inventory Methods for Small Mammals: Shrews, Voles, Mice & Rats (RISC, 1998a) are very involved are meant to determine relative or absolute population estimates using live trapping and mark-recapture methods which is not typically required for YESAB project proposals and was not the objective of the Kudz Ze Kayah baseline program. The objective for the baseline was to determine presence and a preliminary indication of relative abundance in the Project footprint; therefore, the shorter transect snow track survey was used.

R235

"What does "several incidences" of Myotis spp. Mean? The results for the bat detection surveys note that "The detector established at the wetland at km 5 along the Tote Road had "several incidences" of Myotis spp." and is further stated that it "It is unknown how many bats "several incidences" equates to."

As presented in the Project Proposal in Appendix E-8 (Wildlife Baseline Report, Section 12.4) there were several instances of bats at the 5 km station on three days in 2016. Unfortunately, the number could not be discerned due to significant ambient noise, but it was more than one.

As presented in Section 13.4.1.7, Table 13-15 and Figure 13-16 of the Project Proposal, effects on bats are within the boreal forest zone along the road corridor and not at the mine site. An estimated 1.5% of high quality roosting habitat would be directly lost and a 14.3% of moderate roosting habitat indirectly affected. No barrier effects or mortalities from collisions are expected. The overall effects are rated as not significant (Section 13.4.3.7) and likely not measurable; therefore, a bat monitoring program has not been proposed.

R237

"Provide a description of model assumptions, validation, reliability and zones of influence."

The description of the habitat suitability model for little brown bat is presented in Section 12.5 of the Wildlife Baseline Report, Appendix E-8 of the Project Proposal. The model used the Terrestrial Ecosystem Map (TEM) to determine where roosting habitat was located assuming little brown bat prefers to roost and forage in mature/old growth boreal forest adjacent to wetlands (Randall et al, 2014; Slough and Jung, 2008; COSEWIC, 2013; Environment Canada, 2015). This habitat equates to structural stage 6 and 7 in the TEM as is re-presented in the criteria table below (Table 13-41).

Little brown bats were detected at the northern two survey locations and not at the southern detectors, which aligned with the predicted areas of suitable habitat. The objective of the modelling is to provide a visual representation of the distribution of predictive suitable habitat and quantitative assessment based on the known TEM for site and the literature. The model has a moderate reliability based on the definitions in the 1999 BC Wildlife Habitat Rating Standards (i.e., "*Moderate Reliability. Available information is based mainly on studies, reports and expertise on the species-habitat relationships gained within British Columbia. Some information from ecosystems in the study area, but mostly extrapolated from similar ecosystems. No verification or limited verification has been done*").

For the zone of influence, the modelling was completed for baseline conditions with direct loss predictions quantified as the ultimate footprint of the Project and indirect loss based on a 50% reduction for the 300-m buffer around the Project footprint. This level of quantifying habitat loss from the Project was considered appropriate for the level of information and uncertainties. Additional modeling for different stages of the Project would unlikely change the magnitude of the effects assessment or the mitigation and management plans. Unforeseen effects detected by ongoing monitoring will be managed through the Adaptive Management Plan.

Table 13-41: Little Brown Bat Habitat Suitability Criteria

Suitability Rank	Structural Stage	Bioclimate Subzone
High	Leading ecosite >=70% structural stage 6 or 7	Boreal High
Medium	Leading ecosite <70% structural stage 6 or 7	Boreal High
Low	Everything else	Boreal High, Boreal Subalpine, Alpine

YESAB ISSUE WITH BMC'S RESPONSE TO R235 AND R237

The little brown myotis is listed as endangered under the Species at Risk Act (SARA) and by the Committee on the Status of Wildlife in Canada (COSEWIC), as is the northern myotis. Under Section 37 of SARA a recovery strategy (proposed) has been developed for these two species (Environment Canada 2015). This recovery strategy details the threats and issues associated with these bats and the justification for required protections. This includes habitat loss and degradation as well as heavy mortality that have occurred in eastern Canada as a result of white nose syndrome.

Bat capture program. It is recognized that the calls of some bat species, in particular some Myotis species, can be difficult to distinguish through echolocation analysis alone. As such, it is typical that a bat capture program, under approved permit where required, co-occurs with echolocation surveys to aid in species detection confirmation.

Survey period length. Surveys completed in 2015 and 2016 were limited to 7 days and 18 days, respectively. Given the seasonality of habitat use, including migration, this is a very short survey period which will not fully account for the potential occurrence of bats within the Project area during their active seasons.

Analysis of recordings. Information on the methods used for the analysis of recordings is missing.

The assertion that non-detection results for subalpine habitats equate to non-occurrence is not supported. Considering the limited deployment of detectors, the potential seasonal occurrence of use of subalpine habitats by bats is potentially missed.

According to Government of Yukon comments, "Baseline monitoring conducted in 2016 had "several instances" of bat detections."

***Insufficient Response:** The analysis of bat detector data typically includes the sorting of noise files from bat echolocation calls (with noise files requiring manual review for the presence of bat echolocation detections). As such, the files that were simply noise would have been filtered out and the bat echolocation calls available for analysis to species and for notation on relative abundance, including the number of calls per day, etc.*

***Insufficient Response:** No model validation is provided. The response should include further information as to how model reliability was defined as moderate. The response should also include references to appropriate literature to support the >=70% threshold for structural stage.*

R2-109

What does "several incidences" of Myotis spp. Mean? The results for the bat detection surveys note that "The detector established at the wetland at km 5 along the Tote Road had "several incidences" of Myotis spp." and is further stated that it "It is unknown how many bats "several incidences" equates to."

On October 5 2017, YESAB provided (via email) clarification regarding the information required for R2-109. The clarification is as follows:

> *"Clarify the intent of the survey (i.e. presence/absence vs. abundance)."*

BMC confirms that the goal of the study was to determine presence/absence vs abundance.

Bat calls were identified on four days during the survey period (July 20, 23, 24 and 27) from the two detectors. From the detector at Kilometre 5 on the Tote Road there were two passes on July 20 and one each on July 23 and 27. The detector located at Kilometre 1 on the Tote Road captured a single pass on July 24.

The recordings are no longer available to be able to analyze specific bat species further; therefore, only the genus Myotis is confirmed and has the potential to be Little Brown Myotis (*Myotis lucifugus*) or the Northern Myotis (*Myotis septentrionalis*). Based on discussions with [Name Redacted] wildlife biologist at Yukon Government, Little Brown Myotis is the only species of bat found in the Ross River area [Name Redacted], pers. comm., 2016). Northern Myotis has been found in Watson Lake and is thought to occur in the Liard River watershed south of the KZK Project (Yukon Government, 2016). Note that the habitat requirements and mitigations in the Project area are essentially the same.

R2-110

Please provide information on the analytical methods that were used for the bat detection data including, at a minimum, information on software used and reference libraries utilized.

On October 5 2017, YESAB provided (via email) clarification regarding the information required for R2-111. The YESAB clarification is as follows:

> *"Based on the clarification of survey intention that will be provided in response to R 2-109, this information is not needed."*

Please refer to BMC's response to R2-109.

R2-111

Provide a description of model assumptions, validation, reliability and zones of influence.

On October 5 2017, YESAB provided (via email) clarification regarding the information required for R2-111. The YESAB clarification is as follows:

> *"Based on the clarification of survey intention that will be provided in response to R 2-109, this information is not needed."*

Please refer to BMC's response to R2-109.

YESAB ISSUE

No methodology is described for monitoring waterfowl use at water management facilities, water treatment ponds, and ponds built for fish habitat compensation.

R238

"Provide methodology to monitor ponds for waterfowl use."

Waterfowl use at water management facilities will vary by facility and purpose, and details will be finalized in the Wildlife Protection Plan (as part of licencing). In general, the BC Resource Inventory Committee, Standards for Components of British Columbia's Biodiversity No. 18, Inventory Methods for Waterfowl and Allied Species (1999b) or similar updated protocol will be followed. For water management facilities that are part of the mine site infrastructure (other than those where waterfowl access is controlled), waterfowl will be monitored with a total count from an observation station to determine presence/absence.

For monitoring the fish habitat ponds, more than one observation station will be set up and a total count survey will be completed. This will preferably occur in the spring nesting period and will be integrated into the program described in the FOP. Determining presence is the main objective of this program.

YESAB ISSUE WITH BMC'S RESPONSE TO R238

No methodology is described for monitoring waterfowl use at water management facilities, water treatment ponds, and ponds built for fish habitat compensation.

Insufficient Response: *Insufficient detail has been provided to understand what is planned.*

R2-112

Provide methodology to monitor ponds for waterfowl use.

On October 5 2017, YESAB provided (vis email) clarification regarding the information required for R2-112. The clarification is as follows:

> *"As stated in the email sent August 31, 2017, the Executive Committee cannot have confidence that the wildlife mitigation and monitoring plans will be effective without further detail.*
>
> *The absence of details on how monitoring will take place may lead to additional conditions during the assessment process".*

Additional monitoring details were presented in to R238 (above). However, in response to YESAB's email dated August 31, 2017, BMC has prepared a more detailed draft Wildlife Protection Plan for the Project. This draft Plan is included in **Appendix R2-J** of this Response Report, in order to provide further information on the monitoring plans and how they will be implemented (including waterfowl use monitoring at water treatment ponds, and ponds built for fish habitat compensation).

YESAB ISSUE

Insufficient detail regarding future monitoring plans throughout the life of the project.

The proponent states that the monitoring program will occur every three years (or more frequently if adaptive management plan deems required), and will follow baseline study protocols with focus on key species and seasons.

R241

"For the construction, operations, decommissioning and post-closure phases of the project, provide details on the monitoring plans including:

a. methods

b. timing

c. duration

d. frequency

e. location

f. personnel conducting surveys, etc."

The information regarding the monitoring plan for wildlife is provided in Section 13.6 of the Project Proposal and is summarized in Table 13-42 (below). Note that the table has been updated from the table that was presented in the Project Proposal. The proposed monitoring for the caribou rut is annual while the late winter ungulate surveys are every three years. Species-specific details will be further defined in the final Wildlife Protection Plan as the Project progresses into detailed design and also refined through the Adaptive Management Plan.

Table 13-42: Wildlife Monitoring Program Summary

Monitoring Program Component	Project Phase	Methods	Timing	Duration	Frequency	Location	Personnel Conducting Surveys
Wildlife Records Program	Construction, operations, decommissioning and post-closure	Observations and locations reported by employees and contractors on site and along access road recorded in onsite log.	Ongoing, reported annually.	Ongoing	Ongoing	Project site and access road	All employees and contractors for the project. Assistance with species recognition will be provided by onsite environmental staff.
Winter Wildlife Monitoring	Construction, operations, decommissioning	Surveys will include snow track surveys to be completed at least every month shortly after fresh snow fall. This will provide information on presence and use of Project areas by small and medium furbearers as well as larger mammals.	Each month where there is snow cover. Survey to be conducted approximately between October to April each year that the survey is scheduled (dependent on weather and snow conditions).	2 days, once per month (~Oct-Apr)	Surveys will be carried out every three years depending on the results following the adaptive management plan.	Project site and access road at baseline transect sites	Onsite environmental staff, First Nation members, and/or external experts.
Finlayson Caribou Herd Fall Composition Counts	Construction, operations, decommissioning	Aerial surveys to be carried out by helicopter during the fall rut period. Survey will be consistent with the methods and area surveyed in 2015 and 2016. Late winter ungulate surveys consistent with baseline surveys.	During the fall rut period (from late- September to early October) and late winter (March - April)	2 days	Annual for rut. Every three years for late winter.	Survey areas as per baseline surveys. Late winter habitat in GMS 10-07.	Onsite environmental staff, YG, First Nation members, and/or external experts.
Moose Late Winter Survey	Construction, operations, decommissioning	Aerial surveys of ungulates in late winter in the study area to locate critical late winter habitat. Survey will be consistent with the methods and area surveyed in 2015 and 2016.	Survey to be conducted in late winter (March - April).	2 days	Surveys will be carried out every three years depending on the results following the adaptive management plan.	Late winter habitat in GMS 10-07 around site, in particular east and west of the Access Road	Onsite environmental staff, First Nation members, and/or external experts.

Monitoring Program Component	Project Phase	Methods	Timing	Duration	Frequency	Location	Personnel Conducting Surveys
Grizzly bear	Construction, operations	The main purpose of the grizzly bear monitoring program is to prevent the disturbance of mining on hibernating bears. The area surrounding the open pit will be monitored during the pre-denning period to determine if there are any bears that show indications of preparing to den near the open pit.	Conducted in conjunction with the caribou fall rut survey (from late September to early October)	Weekly during pre-denning period	Annual	Area around open pit	Onsite environmental staff.
Breeding Bird Counts	Construction, operations, decommissioning	Point count surveys to determine trends in nesting bird species and relative abundance in local study areas. Control sites established outside of Zone of Influence.	Survey to be conducted from Spring May – June.	2 days	Surveys will be carried out every three years depending on the results following the adaptive management plan.	At baseline survey sites at the Project site and along the Access Road	Onsite environmental staff, First Nation members, and/or external experts.
Facility Monitoring	Construction, operations, decommissioning	Routine checking for wildlife issues on the site. Include checks to remove/prevent potential nesting locations during the pre-nesting period. Regular checks of wildlife species use of water management ponds. Regular inspections of beaver dams to ensure culverts and creeks are flowing and not inhibiting correct operation of water management facilities.	Emphasis on bird migration periods spring (~April - June). Checks will be carried out regularly during the spring, summer and fall.	Ongoing	Ongoing	Project infrastructure	Onsite environmental staff

YESAB Issue with BMC's Response to R241

Insufficient detail regarding future monitoring plans throughout the life of the project.

The proponent states that the monitoring program will occur every three years (or more frequently if adaptive management plan deems required), and will follow baseline study protocols with focus on key species and seasons.

Insufficient Response: *Overall, Table 13-20 requires updates to reflect a clear description of methods to be utilized.*

R2-113

For the construction, operations, decommissioning and post-closure phases of the project, provide details on the monitoring plans including:

a. methods

b. timing

c. duration

d. frequency

e. location

On October 5 2017, YESAB provided BMC (via email) additional clarification regarding the information required for R2-113. The clarification is as follows:

> *"As stated in the email sent August 31, 2017, the Executive Committee cannot have confidence that the wildlife mitigation and monitoring plans will be effective without further detail.*
>
> *The absence of details on how monitoring will take place may lead to additional conditions during the assessment process."*

Additional monitoring details were presented in response to R241 (above). However, in response to YESAB's email dated August 31 2017 and October 5 2017, BMC has prepared a more detailed draft Wildlife Protection Plan for the Project. This draft Plan is included in **Appendix R2-J** of this Response Report, in order to provide further information on the monitoring plans and how they will be implemented.

YESAB ISSUE

The assessment is limited to defining habitat suitability within Geona Creek. The baseline assessment assumes that no other areas within the LSA will support beaver. Given that there are several other streams and small waterbodies within the LSA, this assumption is not supported.

There are inconsistencies in the report regarding the suitability of habitat for beaver in this upper reach of Geona Creek.

The information on modelling methods, model assumptions, reliability and validation is needed to assess the reliability of the model outputs, which form part of the effects assessment.

R252

"What is the rationale for only including Geona Creek in the assessment?

As presented in Section 9 of the Wildlife Baseline Report, Appendix E-8 of the Project Proposal, regional beaver presence and activity was reviewed. The review of historical information for the site noted that beavers have been observed in Finlayson, Geona, and North Lake drainages (Norecol, Dames and Moore, 1996). The field study focused on Geona Creek as it is the main creek that will be affected by the Project.

a. How was the Allen (1982) model adapted and applied to the LSA?

As described in Section 9.3 of the Wildlife Baseline Report, Appendix E-8 of the Project Proposal, a Habitat Suitability Index (HSI) was used for Geona Creek to determine the suitability of the creek for beaver occupancy. The criteria used to determine the HSI was based on the 1982 habitat assessment model developed by [Name Redacted] from the U.S. Department of Fish and Wildlife (Allen, 1982). To assess the quality of beaver habitat, a desktop and field examination of the Geona riparian corridor system was undertaken and interpreted based on four criteria:

- Stable hydrological system providing adequate water (number of deep pools);
- Channel gradient of less than 15%;
- Quality food species present in sufficient quantity; and
- Signs of beaver occupancy.

The above criteria definitions are based on those defined in Allan (1982). Stable hydrological system means there is a regular and constant flow of water throughout the year, and there are pools deep enough so beavers can swim to access food and cover during winter. A channel gradient of less than 15% is required, a preferable gradient is usually less than 6%. Quality food species in order of preference are aspen (*Populus tremuloides*), willow (*Salix* spp.), cottonwood (*Populus balsamifera*), and alder (*Alnus* spp.). Beavers switch to herbaceous vegetation during the summer, but are reliant on caches of woody vegetation to feed them during the winter. Lastly, evidence that beaver are actually living and breeding in the area is a strong indicator that the habitat is of sufficient quality to support a colony. The model was adapted for the LSA by identifying local vegetation species that have been used for food and building materials by beavers in the local area.

b. Provide information on model assumptions, an assessment of model reliability and model validation.

Other than the preliminary habitat suitability model to guide the field study (as presented in Section 9.3 of the Wildlife Baseline Report, Appendix E-8 of the Project Proposal) a beaver habitat assessment model was not developed specifically for the effects assessment.

c. Provide information on whether the model delineates habitat suitability within the LSA.

The methods and results of the baseline beaver survey are presented in Sections 9.3 and 9.4 of the Wildlife Baseline Report, Appendix E-8 of the Project Proposal. Maps, aerial photography and aerial survey were used to delineate beaver habitat in Geona Creek as per the criteria used for the preliminary habitat suitability model. As noted above, a model was not used for the effects assessment.

The best beaver habitat observed during this survey was in the lower 1.2 km of Geona Creek (upstream of the confluence with Finlayson Creek). This area had forest within 10 m of the water channel, abundant willow, and deep pools (average 0.8 m deep) created by resident beavers. There were also signs of current beaver use in this area, and it was classified as moderate grade habitat.

Beaver habitat from 1.2 km to 6 km upstream was poor quality. Although there were pools, they were shallow with minimal vegetation complexity. The upper 2.7 km of Geona Creek was rated poor to moderate quality habitat because of the high number of wetlands in the area, which provided cover and ample food for beavers; however, pond depth was shallow, averaging 0.3 m deep.

d. Provide a clearer justification for the assumption that the upper 2.7 km of Geona Creek is poor beaver habitat.

As presented in Section 9.4 of the Wildlife Baseline Report, Appendix E-8 of the Project Proposal, the upper 2.7 km of Geona Creek was rated poor to moderate quality habitat because of the high number of wetlands in the area, which provided cover and ample food for beavers; however, pond depth was shallow, averaging 0.3 m deep.

There is evidence that Geona Creek has been historically occupied by beavers; however, in most cases the dams have been breached and the lodges are in a state of disrepair. No signs of freshly harvested shrub or tree boles or limbs were observed during the survey, as well as no scat or signs of actively used trails were present. The lack of poplar stands in this area probably prevent the habitat from being highly suitable for beaver usage; beaver are limited to using large willow for building dams or lodges and for winter diet.

Although the habitat meets the criteria for channel gradient, the habitat is lacking in suitable pool depth, lack of poplar stands, and lack of recent evidence of use.

YESAB ISSUE WITH BMC'S RESPONSE TO R252

The assessment is limited to defining habitat suitability within Geona Creek. The baseline assessment assumes that no other areas within the LSA will support beaver. Given that there are several other streams and small waterbodies within the LSA, this assumption is not supported.

There are inconsistencies in the report regarding the suitability of habitat for beaver in this upper reach of Geona Creek.

The information on modelling methods, model assumptions, reliability and validation is needed to assess the reliability of the model outputs, which form part of the effects assessment.

Insufficient Response: *Baseline surveys are intended to document the occurrence of species within the entire study area (often the LSA and/or the RSA). As noted, several other areas were documented as supporting beaver It is not clear why an HSI model was produced to determine the suitability of Geona Creek for beaver occupancy.*

R2-114

What is the rationale for only including Geona Creek in the assessment?

a. How was the Allen (1982) model adapted and applied to the LSA?

b. Provide information on model assumptions, an assessment of model reliability and model validation.

c. Provide information on whether the model delineates habitat suitability within the LSA.

d. Provide a clearer justification for the assumption that the upper 2.7 km of Geona Creek is poor beaver habitat.

On October 5 2017, YESAB provided BMC (vis email) additional clarification regarding the information required for R2-113. The clarification is as follows:

> *"Parts a-c of the question were considered sufficient. Respond to part d."*

As presented in Section 9.3 of the Wildlife Baseline Report, ideal beaver habitat needs a stable hydrological system means there is a regular and constant flow of water throughout the year, and there are pools deep enough so beavers can swim to access food and cover during winter. A channel gradient of less than 15% is required, a preferable gradient is usually less than 6% (Allen, 1982). Quality food species in order of preference are aspen (*Populus tremuloides*), willow (*Salix spp*.), cottonwood (*Populus balsamifera*), and alder (*Alnus spp*.) (Allen, 1982).

The habitat in upper Geona Creek did not include deep enough ponds and the food sources and complexity were limited. No evidence of recent beaver activity also indicated that the habitat was poor quality given beavers are found in surrounding valleys.

YESAB ISSUE

The assessment may underestimate the potential effects of the Project on caribou, moose, grizzly bear, waterfowl, collared pika, cliff-nesting raptors and passerine birds related to habitat loss through the exclusion of moderate suitability habitat.

Threshold criteria for grizzly bear for change in wildlife movement and direct disturbance is based on a reference that does not support the threshold selected and there is an error in the reference provided for the threshold criteria for moose (it is a caribou reference).

The absence of a detailed assessment of the Project's effects on wolverine and wolf at the RSA scale may lead to inadequate mitigation measures and monitoring.

R253

"Provide discussion and rationale regarding the inclusion or exclusion of specific habitat suitability ratings. Include assessment of the risk of underestimating the potential effects of the Project on wildlife by excluding moderate suitability habitat."

Area and percent losses for all suitability classes are presented in Tables 13-7 and 13-8, Tables 13-10 and 13-11, and Table 13-13 of the Project Proposal for caribou, moose, and grizzly bear, respectively. Area and percent losses of high, moderate, and low suitability habitat are presented in Tables 13-18, 13-14, 13-16, and 13-17 of the Project Proposal for waterfowl, collared pika, cliff-nesting raptors, and olive-sided flycatcher, respectively. The chosen suitability classes were presented because they are the most conservative estimates of percent loss in most cases; however, full information is presented in the tables of the Project Proposal for transparency and so the reader can make their own assessment.

The exclusion of moderate and low suitability habitat for the assessment of magnitude carries very little risk for underestimating potential effects. For caribou, the loss in rut habitat reduces from 3.0% to 2.8% and the loss in post-calving habitat increases from 1.8% to 2.2% in the zone of influence (regional study area for caribou) with the inclusion of moderate suitability habitat. For moose, post rut loss decreases from 4.7% to 4.0% and late winter habitat remains at 3.9%. Grizzly bear denning habitat loss increases from 1% to 3%. The change remains approximately the same for waterfowl and collared pika when moderate suitability habitat is included. Habitat loss increases for cliff-nesting raptors from 7% to 15% and decreases for olive-sided flycatcher from 20% to 14%. Tables showing the changes are included in the response to R254 and R255.

This does not change the overall effects assessment or mitigation planning.

R255

"Why is only high-suitability habitat included for waterfowl, collared pika, cliff-nesting raptors and passerine birds?"

Area and percent losses of high, moderate, and low suitability habitat are presented in Tables 13-18, 13-14, 13-16, and 13-17 of the Project Proposal for waterfowl, collared pika, cliff-nesting raptors, and olive-sided flycatcher, respectively. High suitability changes were presented because they are the most conservative estimates of percent loss in most cases. It should be noted that the habitat suitability models have a moderate reliability, literature focuses on what is the most suitable habitat, and local variability will be influenced by site-specific variables and interspecies interactions that aren't included in the models. Therefore, it must be kept in mind that the objectives of the habitat suitability models are to provide an estimate of magnitude of effects and assist with understanding the spatial distribution of effects for mitigation planning.

Table 13-43 to Table 13-46, below, present the habitat change for only high suitability habitat and for both moderate and high suitability habitat. There is no significant change for waterfowl and collared pika. Habitat loss increases for cliff-nesting raptors from 7% to 15% and decreases for olive-sided flycatcher from 20% to 14%. The effects assessment for cliff-nesting raptors would change from a low to a moderate magnitude effect; however, the proposed mitigations do not change. The percent loss is approximately the same for waterfowl and collared pika when moderate suitability changes are added, and the proposed mitigations remain the same

Table 13-43: Waterfowl Habitat Change with Range of Habitat Suitability Categories

Habitat Suitability Categories	Habitat in LSA	Directly Affected (Project footprint)	Indirectly Affected (300 m buffer)	% Change in LSA*
High	18.2 km^2	1.9 km^2	3.4 km^2	-20%
Moderate and High	34.4 km^2	3.4 km^2	6.4 km^2	-19%

*Percent change after direct loss and 50% indirect loss of habitat in 300 m buffer

Table 13-44: Collared Pika Habitat Change with Range of Habitat Suitability Categories

Habitat Suitability Categories	Habitat in LSA	Directly Affected (Project footprint)	Indirectly Affected (300 m buffer)	% Change in LSA*
High	8.7 km^2	0.0 km^2	0.1 km^2	-0.6%
Moderate and High	9.7 km^2	0.0 km^2	0.1 km^2	-0.6%

*Percent change after direct loss and 50% indirect loss of habitat in 300 m buffer

Table 13-45: Cliff-nesting Raptors Habitat Change with Range of Habitat Suitability Categories

Habitat Suitability Categories	Habitat in LSA	Directly Affected (Project footprint)	Indirectly Affected (300 m buffer)	% Change in LSA*
High	1.7 km^2	0.1 km^2	0.1 km^2	-7%
Moderate and High	20.3 km^2	2.1 km^2	1.7 km^2	-15%

*Percent change after direct loss and 50% indirect loss of habitat in 300 m buffer

Table 13-46: Olive-sided Flycatcher Habitat Change with Range of Habitat Suitability Categories

Habitat Suitability Categories	Habitat in LSA	Directly Affected (Project footprint)	Indirectly Affected (300 m buffer)	% Change in LSA*
High	10.9 km^2	0.6 km^2	3.1 km^2	-20%
Moderate and High	17.7 km^2	0.7 km^2	3.6 km^2	-14%

*Percent change after direct loss and 50% indirect loss of habitat in 300 m buffer

YESAB ISSUE WITH BMC'S RESPONSE TO R253 AND R255

The assessment may underestimate the potential effects of the Project on waterfowl, collared pika, cliff-nesting raptors and passerine birds related to habitat loss through the exclusion of moderate suitability habitat.

Insufficient Response: *Utilizing high suitability alone is not a conservative approach. The relevance of the approach cannot be adequately assessed without a full understanding of how the categories of high, moderate and low were assigned.*

R2-115

Provide details on how the categories of high, moderate, and low habitat were assigned for waterfowl, collared pika, cliff-nesting raptors, and passerine birds.

High suitability habitat is defined as habitat that includes all the characteristics that the species requires for the life requisites modelled (e.g. nesting habitat include the correct trees or shrubs that the species likes to build a nest in and has a nearby food supply). Moderate suitability habitat is defined as habitat that includes most of the required features for the life stage and the species is known to occur in this type of habitat, but the conditions are not ideal and the densities are usually lower. Low (and nil) suitability habitat is defined as the habitat that does not include sufficient features needed for the life stage, but the species may still occasionally occur. The ranking of habitat types is based on habitat available in the Project area in relation to what are defined habitat preferences in published studies.

14 HERITAGE RESOURCES

No information required.

15 SOCIO-ECONOMIC EFFECTS ASSESSMENT

YESAB ISSUE

The Socio-economic Baseline Report does not provide any analysis about economic stability within the communities of the study area. Information provided in Tables 3 and 4 of the Socio-economic Baseline Report is not further analyzed. An understanding of financial resiliency at the community level is needed to assess the effects of the boom and bust cycle.

Further, the proposal does not provide details about the 'conservative assumptions' made in the prefeasibility study as they relate to operation of the mine and temporary or unplanned closures.

R262

"Identify situations or scenarios where the project might operate on a reduced scale (including temporary or unplanned closure). This should include detail about assumptions made in the financial assessment of the prefeasibility study (referred to in Section 17.4 of the proposal). Characterize the potential effects of these scenario's and proposed mitigation."

As the Kudz Ze Kayah Project is a private sector economic venture based on revenues exceeding expenses, an unforeseen significant decrease in revenues or increase in expenses could temporarily upset the economic balance of the Project. In the worst case scenario, production could potentially be temporarily halted to allow commodity prices to increase, and/or to retool any aspects of production costs that would result in a resumption of production.

The financial analysis of the Kudz Ze Kayah Project, which includes third party review of the Prefeasibility Study by internationally recognized accounting firm Ernst & Young, sets out the case for a robust economic performance of the Project which can withstand minor to moderate upsets in either revenue or expense forecasts. Economic modelling for the Project has a high degree of confidence.

A catastrophic weather, seismic or other event either naturally occurring or caused by human error could potentially result in a temporary cessation of operations until the situation was rectified. The Kudz Ze Kayah Project will be staffed by experienced mining tradespeople and professionals, who are experienced in rapid response to exigencies and will be well prepared to deal with any emergency situation promptly and adroitly. The protection of human health and safety is of paramount concern for BMC, and as such the inculcation of a 'worksite safe' culture, supplemented by continual safety training will be hallmark of the Project.

YESAB ISSUE WITH BMC'S RESPONSE TO R262

Further, the proposal does not provide details about the 'conservative assumptions' made in the prefeasibility study as they relate to operation of the mine and temporary or unplanned closures.

Insufficient Response: *The proponent has not provided detail about assumptions made in the financial analysis of mitigation measures for temporary or unplanned closure.*

R2-116

Identify situations or scenarios where the project might operate on a reduced scale (including temporary or unplanned closure). This should include detail about assumptions made in the financial assessment of the prefeasibility study (referred to in Section 17.4 of the proposal). Characterize the potential effects of these scenario's and proposed mitigation.

In certain circumstances it may be necessary to operate the mine on a reduced scale from that considered in the Project Proposal. As noted in BMC's response to R262, this could include a catastrophic weather, seismic or other event either naturally occurring or caused by human error, or alternatively a sustained period of reduced metal prices that threatened the ongoing economic viability of the Project.

With regard to the first mentioned natural or human error induced conditions, BMC anticipates that such events would be short lived and dealt with by experienced mining personnel trained and experienced in rapid response to any emergency situation in a prompt and efficient manner. The protection of human health and safety is of paramount concern for BMC, and as such the inculcation of a 'worksite safe' culture, supplemented by continual safety training will be a hallmark of the Project.

With regard to the second item of a sustained period of reduced metal prices; in preparing the prefeasibility economic assessment of the Project, BMC utilized financial analyst consensus long term metal prices of US$1.07/lb zinc, US$0.94/lb lead, US$2.95/lb copper, US$1,292/oz gold and US$19.31/oz silver. As of the date of preparing this response (November 13, 2017) current metal prices are in general notably higher than that used in the prefeasibility study; namely US$1.49/lb zinc, US$1.15/lb lead, US$3.08/lb copper, US$1,278/oz gold and US$16.92/oz silver, indicating a degree of flexibility from that used for the economic assessment (prices were obtained from the following source: http://www.indexmundi.com/commodities/).

In the event that metal prices fell below that adopted for prefeasibility study economic analysis, a considerable margin exists before the operating viability of the Project would be called into question. Annual operating costs are projected to be in the order of US$120 million per year. Metal prices would need to fall by an average of 50% from that considered in the prefeasibility study before the average annual operating costs would no longer be covered by revenue generated from concentrate sales. This equates to metal prices of US$0.54/lb zinc, US$0.47/lb lead, US$1.48/lb copper, US$646/oz gold and US$9.65/oz silver. A comparison to historical metal prices over the last ten years as shown in Figure 15-1 to Figure 15-5, demonstrates that metal prices would need to fall significantly below their long term averages before the average annual operating costs could no longer be covered by regular operations and hence the long term economic viability of the Project could possibly be placed in doubt.

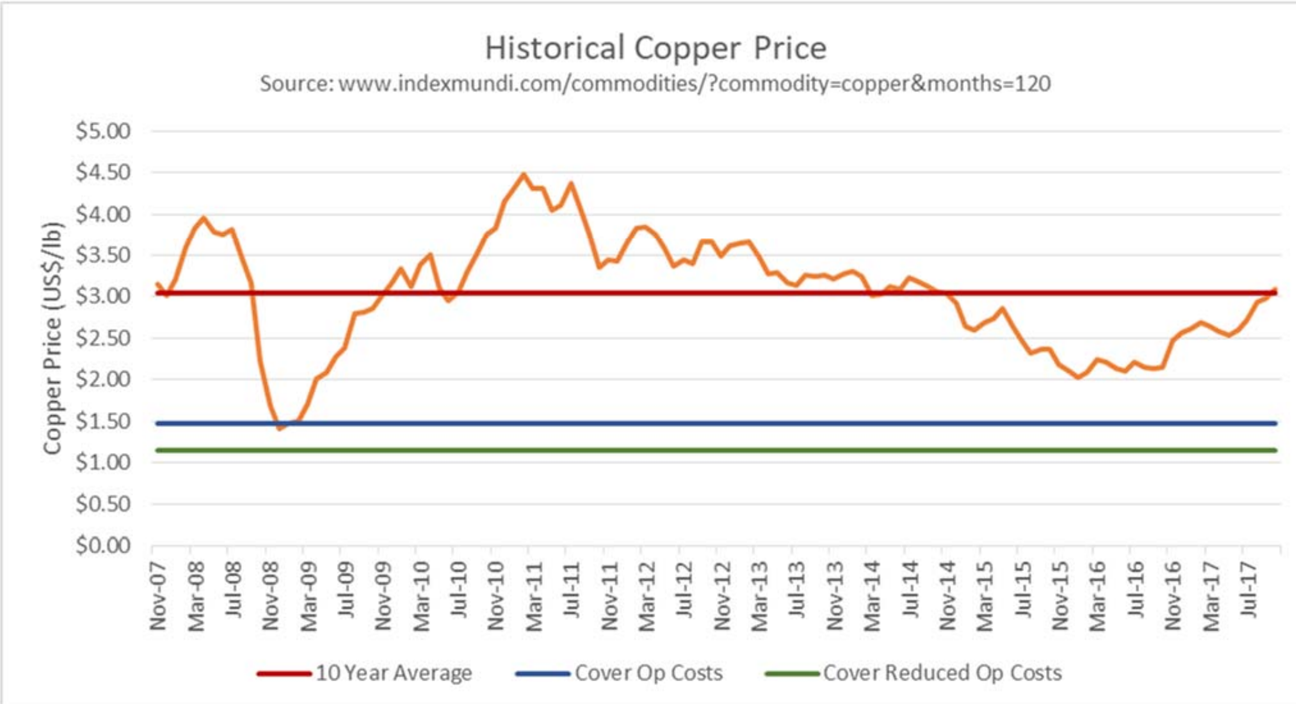

Figure 15-1: Historical Copper Price Compared to Operating Costs and Reduced Operating Costs

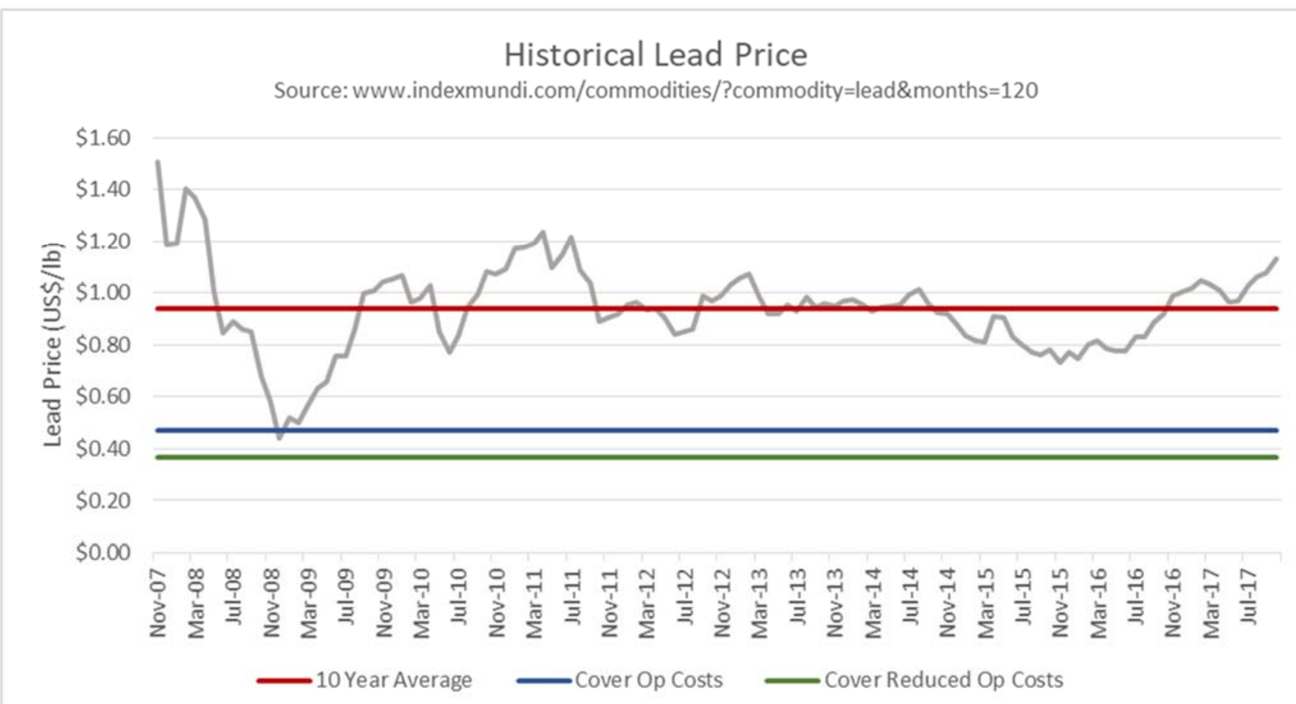

Figure 15-2: Historical Lead Price Compared to Operating Costs and Reduced Operating Costs

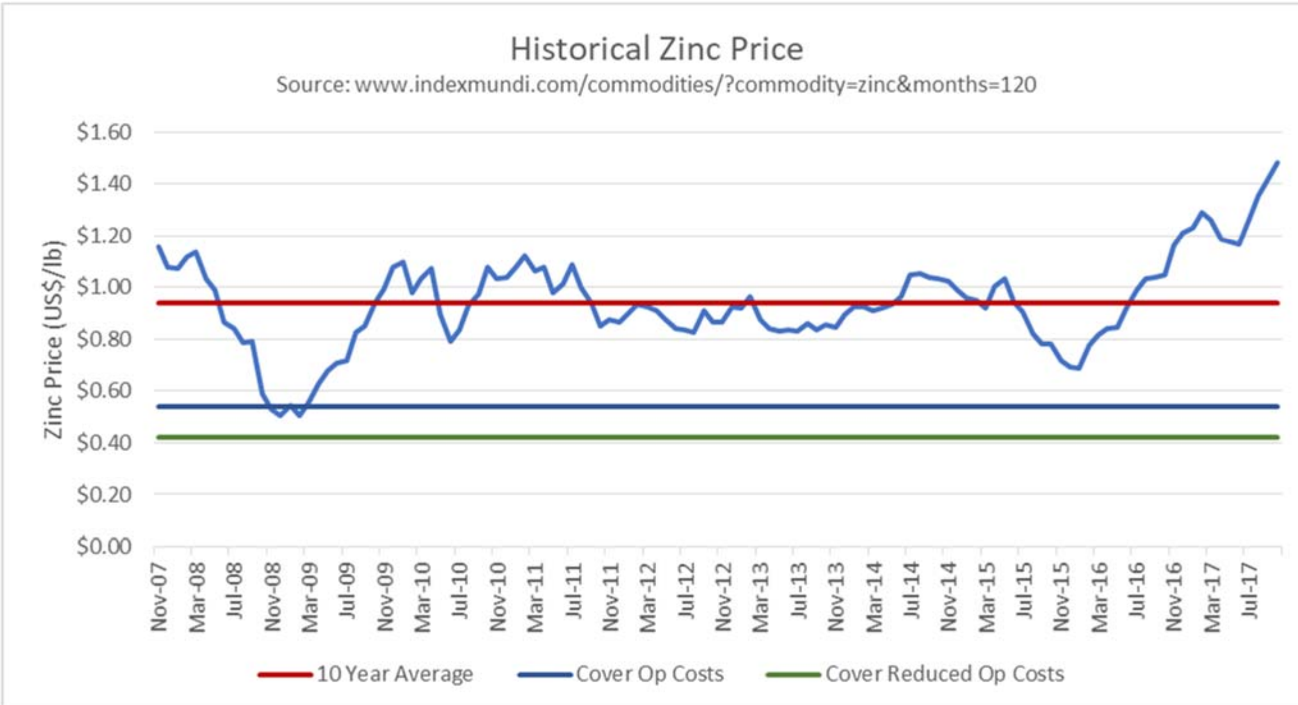

Figure 15-3: Historical Zinc Price Compared to Operating Costs and Reduced Operating Costs

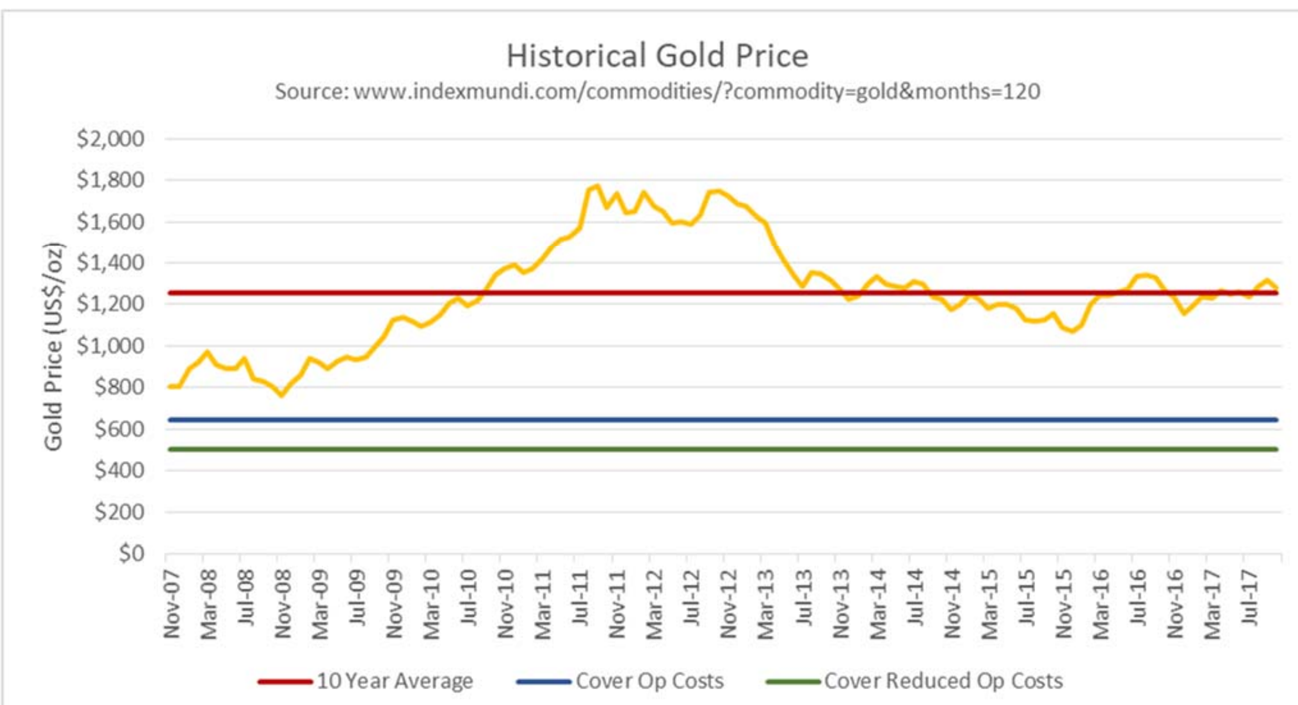

Figure 15-4: Historical Gold Price Compared to Operating Costs and Reduced Operating Costs

Figure 15-5: Historical Silver Price Compared to Operating Costs and Reduced Operating Costs

In addition to the financial strength of the Project noted above, should a sustained period of low metal prices be experienced, BMC would review its operating expenditures and make appropriate short term reductions to defer the need to place the operation in a temporary closure phase. This could include cessation or reduction of open pit waste stripping to focus on mining of previously exposed ore and ore that has a lower waste to ore stripping ratio. Typically, the open pit mine would have between one and six months supply of ore exposed within the open pit available for blasting and haulage to the processing plant. This ensures that a reliable supply of ore can be maintained to the processing plant and that blending and scheduling requirements can be adequately managed. However, should it be necessary to temporarily cease mining of open pit waste, operating costs would be reduced by approximately 45% of that of regular operations, allowing metal prices to reduce to US$0.42/lb zinc, US$0.37/lb lead, US$1.15/lb copper, US$505/oz gold and US$7.50/oz silver before operating costs could no longer be covered by day to day operations. These metal prices are also detailed in Figure 15-1 to Figure 15-5. Clearly, as a polymetallic mining project the mix of metals, by their very nature, provide a natural hedging effect. It would be unlikely that all metals would be reduced or at a cyclical low at the same time and so while the above metal prices are theoretically possible at the same time there is no sensible scenario that makes them likely.

Should low metal prices persist, the company will also have stockpiled ore on the ROM Pad to draw from to continue to feed the processing plant, without the need of incurring additional mining costs. Stockpile levels vary by month according to the mine plan, but are typically in the order of three to four months of processing plant requirements.

In summary, the Kudz Ze Kayah Project has been demonstrated to be a robust economic Project, able to withstand a significant reduction (50%) in metal prices before operating costs would no longer be covered and the ongoing viability of the operation could be called into question. In the unlikely event that this were to occur, the company has additional operating strategies to reduce ongoing operating costs to ensure that the operation can continue as a going concern until metal prices recover to long term historical fundamentals. This is common practice in the international mining industry.

YESAB ISSUE

The proponent has identified a desire to source goods and services locally. Additional information about the timing of the need for these goods and services will allow the local community to anticipate these needs and be more likely to fill them.

R263

"In order to assess how the proponent has considered competing demands for goods and services within communities, provide tables with anticipated procurement needs by project phase."

BMC is committed to ongoing consultation with the goods and services providers in the local communities, RRDC and LFN's development corporations, and mayor and councils of the local communities with respect to the goods and services that are available or could be available during each of the Project phases. Competing demands will largely be based on the timing of Project construction and overlap with other projects. Due to the uncertainty of both these factors, the development of detailed lists of procurement needs by Project phase is not considered warranted at this stage. However, BMC will continue to consult with the parties listed above to ensure that there is capacity to provide the goods and services in advance of when they are needed.

Note that preliminary confidential lists have been provided to RRDC and their development corporation, as part of BMC's ongoing commitment to working with RRDC to ensure that they have capacity to work with BMC during all Project phases so as to maximise where practicable local input metrics.

YESAB ISSUE WITH BMC'S RESPONSE TO R263

The proponent has identified a desire to source goods and services locally. Additional information about the timing of the need for these goods and services will allow the local community to anticipate these needs and be more likely to fill them.

Insufficient Response: *In order to understand the potential economic impact of this project on local communities, a general list of procurement needs by project phase is warranted.*

R2-117

In order to assess how the proponent has considered competing demands for goods and services within communities, provide tables with anticipated procurement needs by project phase.

BMC has prepared a provisional table of general procurement needs by Project phase as requested (Table 15-1). This data excludes the purchase of specialist construction items and includes local procurement only. This data represents BMC's best understanding of local procurement needs at the current time, however this will be subject to revision as more detailed planning for Project development progresses over the coming years. This table is intended for YESAB's assessment purposes only and does not supersede the confidential procurement information/opportunities that have been presented to RRDC.

Table 15-1: Provisional General Procurement Needs by Project Phase (CAD$ per total phase, unless otherwise noted)

Procurement Need	Construction	Operations	Closure
Access Road construction and maintenance	$5.0M	$0.3M annually	$0.1M annually
Access Road gatehouse security services	$0.3 M	$0.2M annually	$0.2M annually
Miscellaneous "civil" work	$3.0M	$0.5M	-
Camp catering, cleaning, laundry	$7.2M	$4.4M annually	$1.1M annually
General Equipment Rental	$1.0M	$0.5M annually	$0.2M annually
Expediting / logistics / freight	$1.5M	$1.0M annually	-
ROM Crusher Services	-	$2.0 M annually	-
Light vehicle maintenance	-	$0.5M annually	-
Local Bus Services	$1.0M	$0.25 M annually	-
Mine site fuel supply (diesel, gasoline, propane, LNG)	$2.0M	$23.5M annually	$0.7M annually
Concentrate haulage	-	$51.8M annually	-
Reclamation work such as reseeding	-	$0.3M annually	$0.5M for three years
Reclamation civil works		$3.0M annually	$30 M
Other Miscellaneous contracts and supply	$0.5M	$0.3M annually	$0,1 M annually

YESAB ISSUE

Aside from statistical data about divorces and separations, the Socio-economic Baseline Report does not contain any information or analysis relating to family structure in the project communities. Families in small communities with little-no access to childcare may experience additional stress based on the fly-in, fly-out shift structure.

R265

"Provide additional statistical data about family structure in the project communities, with a particular focus on single parent households and couples with children."

BMC understands that the information requested does not exist for the communities or is not publicly available.

However, the evolution of workforce housing from the past practice of mines establishing mining towns was the subject of a national discussion in Canada in the mid to late 1980s. The negative situation of abandoned mining towns after mines were depleted was the subject of concern from government and industry. The discussion on the subject including government and industry representatives resulted in the adoption of the fly-in, fly-out model (given the acronym "FIFO"), with temporary worker camps located at new remote mining sites. The decision to adopt the policy of FIFO was based in environmental and socioeconomic considerations. There have been criticisms of the model mostly by mining companies themselves, nevertheless government policy is to serve any and all new mines from existing centres, with temporary camps located at mining sites.

It is noted that that staff are likely to be between 1.5 to 6 hours drive from family and less than 1 hr flight in any family crisis.

YESAB ISSUE WITH BMC'S RESPONSE TO R265

Aside from statistical data about divorces and separations, the Socio-economic Baseline Report does not contain any information or analysis relating to family structure in the project communities. Families in small communities with little-no access to childcare may experience additional stress based on the fly-in, fly-out shift structure.

Insufficient Response: *The proponent states that this information is not publicly available. It can be found on the Government of Yukon Socio-Economic Web Portal.*

R2-118

Provide additional statistical data about family structure in the project communities, with a particular focus on single parent households and couples with children.

Family Stress was assessed a sub-component of the valued component Human and Health and Well Being (Section 16.6.2.2 of the Project Proposal). Although potential effects to families with various structures were not assessed separately, the mitigation measures to minimize the effects remain the same as proposed in Section 16.6.2. BMC intends to mitigate possible family stress of its employees through:

- Extensive screening of employees before hire to gauge their suitability for shift work and to help educate them on its potential effects;

- Point of hire being in the Yukon reduces travel time of employees to get back to their families both as part of the regular work cycle and in the case of family emergency;
- Provide assistance and education through its Employee Assistance Program (EAP) to all employees and their families as required including:
    - Stress management/coping techniques;
    - Financial management training;
    - Drug and alcohol counselling (including time off for employees who need treatment);
    - Relationship and family counselling; and
    - Healthy living education (i.e., benefits of diet and exercise);
- BMC currently hosts annual family days at the mine site to show spouses and children of employees the site and associated facilities (BMC's experience is that families are more comfortable with their spouses being away if they have seen the site and facilities first hand allowing some context for the absence of a family member "at the mine");
- Communications at the site will be via microwave (to maximize bandwidth) and individual connections in each room to ensure that employees can easily communicate via Skype/Facetime etc. with their spouses and children in the privacy of their room rather than in a communal area. BMC's experience is that regular communication from the absent family member is a substantial mitigation towards family stress through absence and "face-time" is the best communication;
- BMC will provide recreational facilities at the site and all meal times will have healthy food options, to promote health and well-being of employees while on-shift (with the intent that this would also extend to off-shift healthy living);
- Training of employees (e.g., trades, apprenticeships, management) to promote progression in their careers (which may enhance job satisfaction for the employee as well as benefit the company);
- Bereavement and Special leave will be available to all employees; and
- The two week-in and one week-out shift rotations, when combined with the four weeks of annual vacation available after the first year of employment, will allow employees to take one month off twice per year.

Table 15-2 through Table 15-4 present the demographic data for Watson Lake, Whitehorse and Faro from the Government of Yukon Socioeconomic web portal. Data for Ross River is unavailable. However, based on the available information, there is a wide variety of types of families within 3 of the 4 potentially affected communities.

The mitigation measures presented in the Project Proposal and summarized above demonstrates that BMC is committed to maximizing employee quality of life in areas for which it has direct control or influence, and appreciates that minimizing family stress is critical to this commitment. BMC's experience is that implementing the above will provide significant positive family support.

Table 15-2: Watson Lake Population & Community Make-up – Marital Status and Census Family Structure

Topic	Value
Total population 15 years and over by marital status	870
Married or living with a common-law partner	490
Married (and not separated)	305
Living common-law	185
Not married and not living with a common-law partner	380
Single (never legally married)	265
Separated	20
Divorced	55
Widowed	35
Total number of census families in private households	305
Size of census family: 2 persons	175
Size of census family: 3 persons	55
Size of census family: 4 persons	50
Size of census family: 5 or more persons	25
Total number of census families in private households	305
Total couple families by family structure and number of children	235
Married couples	145
Without children at home	80
With children at home	65
1	25
2	25
3	10
Common-law couples	95
Without children at home	55
With children at home	40
1	15
2	20
3	10
Total lone-parent families by sex of parent and number of children	65
Female parent	50
1	30
2	10
3	5
Male parent	20
1	10
2	5
3	0
Total children in census families in private households	300
Under six years of age	80
6	95
15	45
18	50
25	30

Topic	Value
Average number of children at home per census family	1
Total number of persons in private households	1050
Number of persons not in census families	200
Living with relatives	35
Living with non-relatives only	30
Living alone	140
Number of census family persons	845
Average number of persons per census family	2.8
Total number of persons aged 65 years and over in private households	120
Number of persons not in census families aged 65 years and over	40
Living with relatives	0
Living with non-relatives only	0
Living alone	30
Number of census family persons aged 65 years and over	85
Last Updated: 2013-12-07	

Table 15-3: Whitehorse Population & Community Make-up – Marital Status and Census Family Structure

Topic	Value
Total population 15 years and over by marital status	19070
Married or living with a common-law partner	10215
Married (and not separated)	7335
Living common-law	2880
Not married and not living with a common-law partner	8855
Single (never legally married)	6175
Separated	560
Divorced	1460
Widowed	660
Total number of census families in private households	6300
Size of census family: 2 persons	3095
Size of census family: 3 persons	1465
Size of census family: 4 persons	1265
Size of census family: 5 or more persons	475
Total number of census families in private households	6300
Total couple families by family structure and number of children	4965
Married couples	3540
Without children at home	1485
With children at home	2050
1	770
2	930
3	355
Common-law couples	1430
Without children at home	820
With children at home	605

Topic	Value
1	300
2	225
3	85
Total lone-parent families by sex of parent and number of children	1340
Female parent	1005
1	580
2	305
3	125
Male parent	330
1	215
2	90
3	30
Total children in census families in private households	6875
Under six years of age	1630
6	2480
15	845
18	1410
25	515
Average number of children at home per census family	1.1
Total number of persons in private households	22810
Number of persons not in census families	4670
Living with relatives	610
Living with non-relatives only	1405
Living alone	2655
Number of census family persons	18145
Average number of persons per census family	2.9
Total number of persons aged 65 years and over in private households	1770
Number of persons not in census families aged 65 years and over	775
Living with relatives	90
Living with non-relatives only	40
Living alone	640
Number of census family persons aged 65 years and over	990
Last Updated: 2013-12-07	

Table 15-4: Faro Population & Community Make-up - Marital Status and Census Family Structure

Topic	Value
Total population 15 years and over by marital status	295
Married or living with a common-law partner	175
Married (and not separated)	135
Living common-law	40
Not married and not living with a common-law partner	115
Single (never legally married)	70

Topic	Value
Separated	15
Divorced	20
Widowed	10
Total number of census families in private households	100
Size of census family: 2 persons	65
Size of census family: 3 persons	15
Size of census family: 4 persons	10
Size of census family: 5 or more persons	10
Total number of census families in private households	100
Total couple families by family structure and number of children	90
Married couples	65
Without children at home	45
With children at home	25
1	10
2	5
3	5
Common-law couples	25
Without children at home	15
With children at home	10
1	5
2	5
3	5
Total lone-parent families by sex of parent and number of children	10
Female parent	5
1	5
2	0
3	0
Male parent	5
1	5
2	0
3	0
Total children in census families in private households	80
Under six years of age	25
6	20
15	10
18	10
25	10
Average number of children at home per census family	0.8
Total number of persons in private households	345
Number of persons not in census families	80
Living with relatives	5
Living with non-relatives only	5
Living alone	65
Number of census family persons	260
Average number of persons per census family	2.6

Topic	Value
Total number of persons aged 65 years and over in private households	55
Number of persons not in census families aged 65 years and over	15
Living with relatives	0
Living with non-relatives only	0
Living alone	15
Number of census family persons aged 65 years and over	35
Last Updated: 2013-12-07	

BMC can provide some context to the characterization of the availability of daycare in Yukon's small communities. BMC is aware of Yukon's unique socioeconomic circumstances, where the City of Whitehorse hosts a fully capable daycare capacity at levels found in larger, southern city centres, and in the smaller communities of Ross River and Watson Lake, family-related daycare is more prevalent. Certainly, in Yukon First Nation culture a significant percentage of the population of the communities rely on family members; therefore family-related daycare is more readily available than might be thought based solely on population. Independently operated daycare is expected to be currently limited in the communities; however, as in any other community experiencing economic growth, additional daycare capacity, if required, will emerge in response to market demand. If BMC becomes aware that lack of available daycare becomes a disincentive to employment at Kudz Ze Kayah, it will engage with community and First Nation input to develop appropriate solutions. However, it should not be assumed that single parent families without strong family support will see the proposed mine as an employer of choice. BMC expects that many parents in such circumstances may not wish to work away from their family at all.

YESAB ISSUE

The proposed Project is located in close proximity to areas where traditional activities are taking place (e.g. hunting, trapping, fishing, gathering plants, etc.). There are also registered traplines and First Nations' cabins in the areas of North Lakes, Wolverine Lakes, Money Peak, all of which are adjacent to the local study area.

This project proposal did not include an assessment of human health, with the justification that there are no permanent or semi-permanent residents nearby.

However, people using the cabins at the project boundary were not considered in the assessment.

There was no assessment of the Project's effects on country foods and the potential for human health impacts.

However, the project proposal notes that culturally significant species are hunted (caribou, moose, sheep) and fished (grayling, trout, jackfish, whitefish, sucker fish) in the Ross River Dena Council and Liard First Nation traditional territory which overlaps with the Project footprint.

R267

"Provide a preliminary quantitative Human Health Risk Assessment for each stage of the project. This assessment should be informed by Heath Canada's Part I: Guidance on Human Health Preliminary Quantitative Risk Assessment (PQRA) Version 2.0 (2012). At minimum, this assessment will address the following:

a. risks associated with human use of the area (e.g. the cabins at the project boundary or for traditional activities such as hunting, trapping, harvesting) potentially impacted by the project;

b. risks associated with consumption of country foods (e.g., fish, caribou, migratory birds, and other animals exposed to environmental contaminants from the project in the air, water, or soil) harvested through traditional hunting, fishing, and gathering activities; and

c. risks associated with consumption of surface and ground well water used for drinking potentially impacted by the project."

The requested Assessment is included as **Appendix 3** of the initial Response Report (BMC, 2017).

YESAB ISSUE WITH BMC'S RESPONSE TO R267

The proposed Project is located in close proximity to areas where traditional activities are taking place (e.g. hunting, trapping, fishing, gathering plants, etc.). There are also registered traplines and First Nations' cabins in the areas of North Lakes, Wolverine Lakes, Money Peak, all of which are adjacent to the local study area.

This project proposal did not include an assessment of human health, with the justification that there are no permanent or semi-permanent residents nearby.

However, people using the cabins at the project boundary were not considered in the assessment.

There was no assessment of the Project's effects on country foods and the potential for human health impacts.

However, the project proposal notes that culturally significant species are hunted (caribou, moose, sheep) and fished (grayling, trout, jackfish, whitefish, sucker fish) in the Ross River Dena Council and Liard First Nation traditional territory which overlaps with the Project footprint.

Insufficient Response: *The preliminary quantitative risk assessment presented in response to R267 does not contain a quantitative assessment of human health. The assessment should include quantitative analysis on human health from the following: project related air quality effects, drinking water assessment including potential effects from atmospheric deposition, consumption of country foods (including waterfowl), and soil ingestion and inhalation. The proponent notes that soil (and by proxy vegetation) are two environmental media through which people and animals can be exposed to contaminants. However the frequency of proposed soil monitoring for control and exposure sites during the operations phase does not seem sufficient to properly monitor adverse effects.*

R2-119

Provide a preliminary quantitative Human Health Risk Assessment for each stage of the project. This assessment should be informed by Heath Canada's Part I: Guidance on Human Health Preliminary Quantitative Risk Assessment (PQRA) Version 2.0 (2012). At minimum this assessment will address the following:

a. risks associated with human use of the area (e.g. the cabins at the project boundary or for traditional activities such as hunting, trapping, harvesting) potentially impacted by the project;

b. risks associated with consumption of country foods (e.g., fish, caribou, migratory birds, and other animals exposed to environmental contaminants from the project in the air, water, or soil) harvested through traditional hunting, fishing, and gathering activities; and

c. risks associated with consumption of surface and ground well water used for drinking potentially impacted by the project.

On October 5 2017, BMC met with YESAB (via conference call and in person at the YESAB office) to clarify (in part) what was missing from the PQRA that was submitted as Appendix 3, to the Initial Response Report (BMC, 2017). During the meeting it was indicated that although risks from single exposure pathways are not predicted to have unacceptable risks (based on the initial PQRA), the assessment should consider multi-media risks and present how the combined risks are predicted to change from baseline due to Project development. Based on this clarification, an amended PQRA is included as **Appendix R2-N** to this Response Report (which includes the requested information).

YESAB ISSUE

A shortage of rental housing capacity in Whitehorse was brought up at one of the meetings in the consultation record. However, the proponent states in its proposal that Whitehorse is understood to have the capacity to absorb an in-migration of workers, which is likely to happen during the construction phase of the project.

R269

"Provide additional information to support the assumption that there is sufficient rental housing capacity in Whitehorse. Provide an understanding of the current rental housing capacity in Whitehorse and projections that consider likely demands and in particular demand from other proposed mining developments such as the Coffee Gold mine (Goldcorp Inc.) and the Casino mine (CMC Inc.)."

A brief survey of available houses for sale showed 101 advertisements for residential property within 10 km of Whitehorse.

It should also be noted that the proponent is assuming that a significant proportion of the employees will be sourced locally from either unemployed, or personnel that are currently part time or are seeking full time employment. In the Yukon Employment Annual Review (2016) published by the

Yukon Bureau of Statistics, Yukon's unemployment rate of 5.6% was the lowest in Canada. However, it also showed that in 2016, of the 6,900 persons who were not in the labour force, 500 did want to work. It is a reasonable hypothesis that these 500 are currently resident in the Yukon and have housing. As such, employment of a small portion of these people at the Project will not put stress on the existing housing market.

To the best of the proponent's knowledge, neither the Casino nor the Coffee mine is permitted and the proponent does not consider it to be reasonable to be expected to make definitive "what if" analyses and statements about projects where the proponents have made no decision to commence construction. To answer this question requires a degree of knowledge about the timing of the other projects that BMC is not aware of.

Note that during the public consultation period prior to submission of the Kudz Ze Kayah Project Proposal to YESAB, BMC representatives met with municipal government representatives in Faro, Watson Lake and Whitehorse to discuss the Project in general and housing in particular. These discussions yielded useful information and served to alert municipal planners that an intensification of housing requirements was likely to accompany the coming resurgence of mining activity throughout the Yukon. From these discussions, BMC understands that perhaps the most pressing housing needs occurred in Whitehorse.

YESAB ISSUE WITH BMC'S RESPONSE TO R269

A shortage of rental housing capacity in Whitehorse was brought up at one of the meetings in the consultation record. However, the proponent states in its proposal that Whitehorse is understood to have the capacity to absorb an in-migration of workers, which is likely to happen during the construction phase of the project.

Insufficient Response: *The proponent does not adequately address worker influx in its response. Worker influx is driven by project demand for employees with specialized skill sets who do not exist in the local labour market. Unless the proponent has a viable plan to meet project requirements for specialized labour by providing specialized training to local employees (at a scale not currently described in the proposal), there will be an influx of skilled workers in Whitehorse during the construction phase. In its response the proponent does not address the demand side of the housing/rental equation and does not provide any additional information to support the assumption that there is sufficient rental housing capacity in Whitehorse. The proponent has provided a cumulative effects assessment that is not in accordance with Section 42 (1) (d) of YESAA which requires consideration of projects for which proposals have been submitted and/or activities that are likely to be carried out.*

R2-120

Provide additional information to support the assumption that there is sufficient rental housing capacity in Whitehorse. Provide an understanding of the current rental housing capacity in Whitehorse and projections that consider likely demands and in particular demand from other

proposed mining developments such as the Coffee Gold mine (Goldcorp Inc.) and the Casino mine (CMC Inc.).

BMC notes that the YESAB issue seems to be predicated on the truth/accuracy of the following YESAB statement: "Worker influx is driven by Project demand for employees with specialized skill sets who do not exist in the local labour market." BMC doesn't dispute this but questions the true definition of "specialized" skills and how it is being used by YESAB in the context of Project construction and housing. In BMC's experience the trades and skills of most of the personnel required to construct a mine are transferrable with little difficulty from other industries to mining construction. For example, most mine construction employees will fit into one of the following categories of work:

- Earthworks (equipment operators and miners);
- Civil works (concreters, steel fixers, formwork carpenters etc.)
- Mechanical (welders, mechanics etc.)
- Electrical, Communications, Data (electricians, instrument technicians, telecommunications installers etc.)
- Specialist Lifting (Riggers, Crane operators etc.)
- Metallurgical & Process (including laboratory equipment & process control installation crews);
- Specialist equipment installers (unique to each processing module installed);
- Other miscellaneous (general labourers etc.)

BMC notes that in our experience perhaps 10-15% of the trades required in mine construction are truly "specialist" in nature and the rest are simply tradesmen and women with skills that are readily transferrable between industries with a small to moderate amount of "on the job" training. It would be expected that the majority (but by no means all) of these "specialist" bodies would be provided by their construction firms from outside the Yukon and due to the relatively short nature of their individual work programs (often only on site for 1 to 6 weeks in total over the nearly two-year build period) would be unlikely to take up residence in Whitehorse. Instead these "specialists" would be non-Yukon FIFO. The majority of the remainder and long-term construction workers are expected to be residential within the Yukon and that is discussed below.

Part 1.

BMC notes the statement from YESAB regarding specialized training to local employees and accepts that it has not provided detail on this very relevant matter. We offer the following additional information regarding training and capacity building that is relevant to future housing needs.

In 2015, BMC held discussions with the Ross River Dena Council, Yukon College, various Yukon Government officials and other interested parties about the presence or absence of a skilled mining and construction workforce in the Yukon and specifically within the "Finlayson district" towns of Ross River, Watson Lake and Faro.

BMC's view was and still is that its preference is to employ locally rather than to rely on a fly-in fly-out (FIFO) workforce sourced outside the Yukon. That is not to say that there would be no FIFO employees at all, rather that the best outcomes for the company, the mine and the local community would occur if BMC preferentially employed locally. This is a philosophy that BMC has adopted for exploration activities at the project since 2015. By extension, the same comparison can be made between employees sourced from local towns versus from Whitehorse. In those discussions, there were two constantly recurring themes. One was the capacity of the local communities to provide experienced and skilled support services and the other was the lack of technical and trade skills. BMC has, since 2015, looked to address both these issues so as to be ready for mine construction and operation.

BMC has since 2015 adopted a policy of building capacity in the local communities by preferentially awarding contracts for services to local businesses. In 2015, BMC awarded 30% of the Kudz Ze Kayah major contracts to local Yukon businesses. In 2016, 70% of BMC's major contracts at the Project were awarded to Yukon businesses. 100% of these contracts are with companies that have a significant ownership by Kaska or other Yukon First Nations. This commitment to building the capacity of local businesses has continued into 2017 at the same level as 2016 and will continue through into 2018, 2019 and beyond the development of the mine. This philosophy is aimed at building capacity in areas of specialized services such as drilling, mechanical, electrical, carpentry, welding, plumbing etc.

In conjunction with the above BMC and Ross River Dena Council have successfully implemented two other programs for individuals. These are the Mentor program and the Kaska-BMC Scholarship program and are in addition to on the job and other training offered by the company.

The Employee Mentoring Program was initiated through discussions between BMC and Ross River Dena Council in 2015. It commenced formally in 2016 and has continued into 2017. In this program, BMC has employed a Ross River Elder who is tasked with mentoring local Kaska and other First Nations employees. The mentors' role is to assist locals in preparing for employment at Kudz Ze Kayah, provide advice and assistance during the job application process and then to continue to provide ongoing support to the successful candidate during their employment. This support is offered both on site and in the community and is sometimes extended to immediate family members. This program was first trialled in 2016 and has been so successful that BMC have agreed to make this an ongoing program. BMC has also held initial discussions with the Liard First Nation Chief and Council and is considering the extension/expansion of this program.

The Kaska-BMC Scholarship program was conceived by BMC and Ross River Dena Council members in 2015 and was formally initiated in 2016. The program is administered by Ross River Dena Council, BMC and Yukon College representatives. The concept is relatively simple: the lead in to mining and mine construction at KZK will take several years. In consultation with Kaska, BMC has decided to use this time to provide the opportunity for members of the local communities to learn the trade, technical and business skills to be considered as future mining tradespeople, professionals and/or managers at the Project. The program:

- Supports and encourages Kaska secondary students to complete their final year of school;
- Encourages and supports completion of trade certificates and apprenticeships through Yukon College;
- Encourages and supports completion of certain technical studies that will result in achievement of diplomas, certificates and other recognizable qualifications through Yukon College; and

- Supports degree level technical studies in both mining related and other fields of study through any recognized university in Canada. Scholarship holders for mining related degrees studies are further supported by a guarantee of paid vacation employment to gain work experience.

In 2016, the program supported approximately 25 (27 initial recipients, 2 did not complete) Kaska students from the final year of school (18 students at Ross River and Watson Lake schools) to attending Yukon College trade, diploma and certificate courses (5 students), one non-mining degree and two mining related degrees. In June 2017, BMC received approximately 30 applications for this program and has awarded some 26 scholarships and bursaries for the 2017/18 school year. BMC anticipates that by the time the Project enters construction it would have supported approximately 100 local Kaska into specialist trades, diplomas, certificates and degrees. By the time the project enters production, this number will be above 130. Most of these people will be available for employment at the Project or will be able to provide locally based Project support services. This commitment will continue throughout the life of the Project.

It is important to note within the context of the question being raised around housing by YESAB, that almost all of the above +100 people that have or will receive training, currently already reside in the Yukon with the majority residing in Ross River, Watson Lake, Faro and Lower Post (BC). However, BMC has taken a very conservative view of the potential employment numbers sourced from within these communities and this conservative view has been used in the numbers assumed in our models within the Proposal document. People employed from these communities will not place any stress on Whitehorse or other regional community housing.

BMC also maintains representation on the Governing Council of the *Centre for Northern Innovation in Mining* (CNIM), which is Yukon College's mining-focused trades training facility located in Whitehorse, Yukon. Governed by industry leaders in close cooperation with Yukon College and Government of Yukon, CNIM has developed innovative and flexible employment and career training to best suit Yukon labour needs. The training offered by CNIM provides Yukon residents, and those wanting to live and work in Yukon, access to a variety of learning opportunities that are nationally recognized and uniquely customized for the North. An additional outcome of membership on CNIM's Governing Council is the direct regular communication with other companies currently advancing projects (membership currently includes senior representatives of Alexco, Western Copper, GoldCorp, BMC, Golden Predator, Victoria Gold, Selwyn Chihong and others). This allows BMC to stay current with respect to timing and nature of requirements for a trained workforce for the upcoming significant mining projects in Yukon.

Part 2.

In relation to mine construction, BMC is not aware of any other company proposing to build a mine at the same time as BMC. The Casino mine is not expected to go into construction until some years after Kudz Ze Kayah and even though it has not yet been approved, public statements from Goldcorp indicate that they expect to have completed construction of the Coffee project prior to BMC commencing construction of Kudz Ze Kayah. Similarly, Victoria Gold will complete construction of the Eagle mine prior to BMC's construction commencing. There is therefore no reason to expect undue competition for specialist skills within the Yukon during the construction of the Kudz Ze Kayah Project. Indeed, it does appear as if the "planets will align" since the completion of construction of each mine may well dovetail conveniently with the commencement of construction of the next ensuring continuity of skills and employment within the Yukon for an extended period.

Part 3.

YESAB has questioned the capacity of Whitehorse City to cater for an influx of specialized personnel related to the construction and operation of the mine.

BMC draws attention to public statements by the Faro Town Council ("Faro") as reported in the media over the last 6 months. BMC notes that Faro is in the process of selling off several dozen residential properties that currently exist in the town. This process will likely take some time but will expand the available capacity, population and available workforce of the town considerably. This is expected to be completed prior to BMC commencing construction activities at Kudz Ze Kayah and will substantially increase the available pool of labour for the Project outside of Whitehorse.

In Watson Lake, BMC notes that two operating mines which each drew employees heavily from the town have closed since 2015 (Wolverine Mine and Cantung Mine). In March 2015, CBC reported the following statements by Watson Lake Mayor:

> '[Name Redacted] *says 30 to 50 people in the area were employed directly or indirectly by the mine, which shut down in January. Wolverine, owned by Yukon Zinc, is located approximately halfway between Watson Lake and Ross River."*

In July 2015 in papers submitted to the courts, Cantung confirmed its closure and the loss of jobs for 50 people. It is clear, therefore that significant "mining experienced" residential labour, is available in the region around Watson Lake. A very small portion of that labour is currently employed at the Silvertip Mine in BC, which is only operated seasonally. Given that Wolverine and Cantung mines operated concurrently it is clear that significant accommodation capacity exists in Watson Lake and surrounds to support the proposed development of Kudz Ze Kayah and this will further reduce any perceived load on Whitehorse accommodation if required.

BMC also draws attention to the fact that the City of Whitehorse has approved the development of the Whistle Bend subdivision and has planned for 3,500 new lots to be developed and sold at Whistle Bend over the next 3-4 years. We note that City of Whitehorse Council was briefed in October 2017 by city planners and it was reported by media outlets that the new Whistle Bend subdivision was *"...expected to bring hundreds more lots and housing units – from condos and townhouses to single family homes – onto the market in the next few years. Phase three of the development is already underway, with lots expected to be for sale by next spring."* BMC notes that CBC also reports that*:" phase three of the development is already underway and phase four lots could be ready by this fall."* [CBC, Sept 19, 2017].

BMC also notes publicly reported statements from the acting manager of planning and sustainability for the City of Whitehorse that a further 13 locations have been identified as potential sites for new lots to come into the market place.

Further, BMC notes other public statements from the City of Whitehorse in relation to development of an internal target for City of Whitehorse in order to ensure that there is always a two-year supply of residential lots on the market at any given time. [CBC, May 16, 2017].

BMC acknowledges that current housing availability in Whitehorse is an important issue. However, from these media reports and from direct discussions with elected officials and planning/management staff on Whitehorse City council BMC believes that the City is working through its plan and as the Project progresses through assessment and licensing and advances into construction, municipal and territorial and possibly First Nation governments will respond with planning and construction of new housing subdivisions in and around Whitehorse, and market forces will respond with new construction of rental housing.

BMC is aware that the housing construction industry in Whitehorse is maintained at a relatively healthy capacity through targeted Yukon Government spending on infrastructure projects during mining industry downturns. BMC is aware that historically, various Governments of Yukon regardless of political party have adopted this policy and practice. This has the desired effect of softening the downturn impacts on the housing construction industry, which enables them to rebound quickly when market demand returns.

Also, typically, workers involved in Project construction will work in/out shiftwork cycles from their existing homes, and will seek local residency once the mine commences operations and full-time employment can be found. This will provide another two years for the abovementioned government action and construction response to meet the demand.

While BMC's plans are not solely reliant upon the above statements from the City of Whitehorse officials, it does note that such statements do provide a degree of certainty that the supply of rental and other accommodation in Whitehorse is being considered by the City and is likely to increase over the period prior to BMC commencing construction at the Project. BMC will continue to regularly engage with municipal, Territorial and First Nation governments as the Project progresses to ensure accurate timing forecasts and appropriate housing-related responses can be made by decision makers.

YESAB ISSUE

In order to assess effects from project waste, YESAB requires further information on where the following types of waste will be disposed of: beverage containers and other recyclables, steel/copper/rubber, tires, batteries, antifreeze (and used containers), solvents (and used containers), and all other forms of hazardous waste.

R72

"Provide plans for waste management given that open burning of plastics will not be permitted."

Plastics will be collected separately, compressed and packaged for shipment to a designated waste management facility, preferably Whitehorse Waste Management Facility, as part of backhaul of material shipped to site. BMC understands that this component of waste management for the Kudz Ze Kayah mine, along with all specific details, schedules, signage, policies and procedures of the waste management program will be developed during the permitting stage, once the YESAB environmental and socioeconomic assessment has concluded.

R271

"Identify the final destination for each type of waste that will be disposed of off-site, including licensed recycling or disposal facilities."

BMC will develop a fully equipped and properly designed Solid Waste Management Facility on site, in accordance with appropriate regulations under the *Environment Act*. In addition, KZK will have a hydrocarbon-contaminated soil remediation facility on site; this facility will also be designed, built and operated in accordance with *Environment Act* regulatory requirements.

Any special waste as defined by the *Environment Act Regulations* would be transported off site and out of the Yukon to authorized sites in Southern Canada. Collection and transportation of wastes will be handled by authorized contractors, with the responsibility for sourcing these outside facilities.

YESAB ISSUE WITH BMC'S RESPONSE TO R72 AND R271

In order to assess effects from project waste, YESAB requires further information on where the following types of waste will be disposed of: beverage containers and other recyclables, steel/copper/rubber, tires, batteries, antifreeze (and used containers), solvents (and used containers), and all other forms of hazardous waste.

Insufficient Response: *The proponent has identified specific waste streams that will not be disposed of on-site but has not provided any details about where the final disposal facilities will be located.*

R2-121

Provide a waste management plan that identifies predicted waste streams (e.g. (rubber, special waste, and solid wastes) and includes details on anticipated volumes and disposal methods. Where the disposal plan is to utilize facilities in Yukon, demonstrate that there is capacity for the additional waste.

In support of the Kudz Ze Kayah Project Proposal, BMC submitted a Conceptual Waste Management Plan (Section 18.2 of the Project Proposal) which is based on details as set out in the Project Description for the Kudz Ze Kayah Mine and informed by BMC management's experience operating mines in Yukon and other jurisdictions. This conceptual plan will be completed as a detailed final management plan during subsequent licensing stages.

However, BMC acknowledges the request for additional information during the environmental assessment stage, specifically volume estimates for the various types of waste that will be transported off site. BMC has had discussions with local waste management contractors and representatives of local mines to determine capacity for receiving waste that will be shipped off site for final disposal or recycling.

For Type B waste materials – those that will be shipped off site - the Kudz Ze Kayah Mine is expected to generate a total of approximately 500 tonnes of this type of waste materials per year. Local contractors have the option of shipping waste materials to either local Yukon facilities or to outside facilities, based on capacity at the time, and cost effectiveness.

BMC wishes to note that it understands the capacity restrictions associated with small community landfills. BMC will not overwhelm local landfills (such as the Ross River Solid Waste Management Facility) which have been designed to accommodate the requirements of the local population and expected growth in the number of residents, and in local light industry and/or commercial waste.

Table 15-5 provides management protocols for the major waste categories, together with expected volumes of waste materials that will be shipped offsite.

Table 15-5: Management Protocols According to Waste Types

Type A Onsite Management	Site Location
Kitchen waste, camp and office garbage	Incinerator at Waste Management Facility
Cardboard	Incinerator at Waste Management Facility
Sewage and grey water	Sewage treatment facility near camp
Waste oil	Waste oil burner located near shop
Hydrocarbon contaminated soils and snow	Site Land Treatment Facility
Treated wood	Incinerator at Waste Management Facility
Untreated wood	Waste Management Facility
Ash from incinerator	Waste Management Facility
Type B Transported Offsite[1]	**Estimated volume per year**
Recyclable material (glass, beverage containers, steel rubber, plastics etc.)	3 to 4 tonnes per year to Yukon facility
Tires	25 tonnes per year to an outside facility for recycling
Special Wastes[2] (e.g. batteries, antifreeze, solvents, chemicals etc.)	13 to 16 loads (28 tonnes per load) per year to outside facility

Notes:

[1] Transported by specialised third party contractor to licensed special waste disposal facilities in either Yukon or BC/Alberta. There are privately operated waste service companies located in Whitehorse that act as transfer locations for all types of waste, including transshipments en route to outside facilities. All special waste transported off site subject to special documentation procedures for load manifest tracking as per *Transportation of Dangerous Goods Act*.

[2] Special Waste are all those as defined in the *Yukon Environment Act* & the regulations.

16 EFFECTS OF THE ENVIRONMENT ON THE PROJECT

YESAB ISSUE

Most, if not all of the extreme weather event discussion involves impacts to operations of the Project (e.g., reduction of activities, minimize traffic, damage to infrastructure). There is no information with respect to potential impacts on the environment (e.g., to water quality in nearby streams).

Return periods associated with design 24-hour precipitation events (Table 16-5) and likelihood of flooding from infrastructure (Table 16-6) appear to be calculated with respect to historical and not projected future climate.

Although some general information on climate change is provided (including associated temperature and precipitation maps over the region associated with various emission scenarios and future time periods), there is no information or analyses regarding how these projections will be reflected in changes to extreme 24-hour precipitation and associated flooding events. It is therefore difficult to discern if there will be significant future changes to hydrological flow regimes in watercourses around the Project area affecting water conveyance and storage systems or surrounding infrastructure.

R272

"Incorporate climate change information to re-assess the return periods associated with design 24-hour precipitation events and likelihood of flooding from infrastructure."

As stated in the Project Proposal Section 16.6.*3 "The likelihood of climate change occurring is overall likely; however, changes will occur over the long term and the magnitude of changes likely to occur over the Project's life is small."*

Extreme events have been allowed for in the design of the water containment structures which will be designed to operate with a 1 in 200 year flood event. Mitigation measures have been included in Chapter 17 Malfunctions and Accidents of the Project Proposal, in the unlikely event that the maximum precipitation event designs are based on is exceeded. The mitigation measures are outlined in Section 17.2.5 of the Project Proposal.

The water balance model used in the Project Proposal is conservative and any fluctuations in model inputs, or types of event will be allowed for within this conservatism.

R273

"Given this information, re-assess whether there will be significant future changes to hydrological flow regimes in watercourses around the Project area affecting water conveyance and storage systems or surrounding infrastructure."

Given that the magnitude of effects of climate change over the Project's life are small, (Section 16.6.3 of the Project Proposal), there is little likelihood of future changes of hydrological flow regimes in watercourses around the Project area and thus no significant effects on water conveyance and storage systems.

YESAB ISSUE WITH BMC'S RESPONSE TO R272 AND R273

Most, if not all of the extreme weather event discussion involves impacts to operations of the Project (e.g., reduction of activities, minimize traffic, damage to infrastructure). There is no information with respect to potential impacts on the environment (e.g., to water quality in nearby streams).

Return periods associated with design 24-hour precipitation events (Table 16-5) and likelihood of flooding from infrastructure (Table 16-6) appear to be calculated with respect to historical and not projected future climate.

Although some general information on climate change is provided (including associated temperature and precipitation maps over the region associated with various emission scenarios and future time periods), there is no information or analyses regarding how these projections will be reflected in changes to extreme 24-hour precipitation and associated flooding events. It is therefore difficult to discern if there will be significant future changes to hydrological flow regimes in watercourses around the Project area affecting water conveyance and storage systems or surrounding infrastructure.

Insufficient response*: Proponent has not provided the requested information. Climate change information should be addressed as part of the sensitivity analysis conducted for the updated water balance model.*

Insufficient response: *Proponent has not provided the requested information.*

R2-122

Incorporate climate change information to re-assess the return periods associated with design 24-hour precipitation events and likelihood of flooding from infrastructure.

A global climate model effects tool *IDF CC*, developed at Western University (Western U., 2017), was used to gauge forecasted climate variability, however, the model forecast is presented at a minimum of 50 years. *IDF CC*'s most aggressive global climate model results set, *RCP 8.5*, predicts that by 2070, precipitation may increase by between 10% and 20% at nearby Watson Lake Airport, Yukon. The Project's proposed period of operations is 10 years, therefore there is no strong evidence to suggest that regional climate change is trending in a manner that will materially affect peak flow estimates within that time frame, however, a 15% climate change factor has evolved in engineering practice as a "de facto" standard to address this concern (APEGBC, 2012). A 15% increase to the return period rainfall intensities has been incorporated into the currently designed Class A and Class B Collection Pond storage capacities as these facilities will exist during the active closure phase until water quality objectives are met, at which point they are expected to be removed (

Table 8-6 and

Table 8-7). The Class C and Overburden Stockpile Collection Ponds are sized without the 15% increase to rainfall intensities, as these facilities are expected to exist only during the relatively short Operations phase.

R2-123

Given this information, re-assess whether there will be significant future changes to hydrological flow regimes in watercourses around the Project area affecting water conveyance and storage systems or surrounding infrastructure.

Appendix R2-E (Operational Water Balance and Climate Variability and Sensitivity Analysis) and the response to IR2-39 (regarding Water Management Ponds) of this Response Report summarize the updated operational water balance and sizing of water management ponds for the KZK Project, which has been updated for climate change factors and climate input sensitivity analysis for the Project.

17 MALFUNCTIONS, ACCIDENTS AND UNPLANNED CLOSURE

YESAB ISSUE

In Accidents and Malfunctions a discussion of the impacts on fish and fish habitat and the associated affects to Commercial, Recreational or Aboriginal (CRA) Fisheries that would result from a catastrophic failure of the water management ponds on Genoa Creek should be provided. The expectations for this analysis would be a robust assessment of potential impacts and risks to CRA Fisheries that would include modelling of wave inundation and erosional forces associated with an event that occurred during a dry or wet year in combination with a dry (piping) or wet (precipitation) event. This assessment would include discussion of how far the inundation wave would travel, how far erosional forces would extend, the range of potential effects.

R274

"Provide a discussion of the impacts on fish and fish habitat and the associated affects to Commercial, Recreational or Aboriginal (CRA) Fisheries that would result from a catastrophic failure of the water management ponds on Genoa Creek"

The potential impacts of a failure of the proposed WMPs to CRA fisheries resources under current conditions would be considered negligible. As discussed in the Aquatic Ecosystem Baseline Report (Appendix E-3 of the Project Proposal), fisheries resources through the length of Geona Creek are considered minimal as only a very few resident grayling inhabit the system and do not contribute to CRA Fisheries. Similarly, fisheries resources in Finlayson Creek downstream of the confluence with Geona are also considered limited with only slimy sculpin captured during two years of baseline data collection upstream of the Robert Campbell Highway.

From a sedimentation perspective, the combination of a large beaver impoundment immediately downstream of the WMP location and the ponds to be constructed as part of the Fisheries Offsetting Plan (FOP), should act as a sink for a large majority of any potential catastrophic release of particulates from a WMP failure, which would additionally ease any clean-up that may be required.

Potential impacts to water quality would also be considered minimal if the lower water management pond (LWMP) failed, as the water held in the LWMP will contain water that is within three times the long term/chronic water quality guidelines and would not exceed the short term/acute guidelines. It will also not contain significant sediments.

Preliminary examination of the hydrological impacts following a WMP failure anticipates a large influence in the Geona Creek watershed but smaller in Finlayson Creek decreasing to undetectable by the Finlayson River confluence. This will be modelled when final WMP designs are completed, to quantify potential impacts.

Under current conditions, the preliminary assessment of a potential failure of the WMPs indicated that impacts to Geona Creek CRA fisheries would be limited to areas downstream of the Robert Campbell Highway to the confluence with Finlayson River. As these potential impacts appear minimal, BMC will incorporate mitigative measures into the final WMP detailed design to restrict potential impacts to areas upstream of the RCH.

YESAB ISSUE WITH BMC'S RESPONSE TO R274

In Accidents and Malfunctions a discussion of the impacts on fish and fish habitat and the associated affects to Commercial, Recreational or Aboriginal (CRA) Fisheries that would result from a catastrophic failure of the water management ponds on Genoa Creek should be provided. The expectations for this analysis would be a robust assessment of potential impacts and risks to CRA Fisheries that would include modelling of wave inundation and erosional forces associated with an event that occurred during a dry or wet year in combination with a dry (piping) or wet (precipitation) event. This assessment would include discussion of how far the inundation wave would travel, how far erosional forces would extend, the range of potential effects.

Insufficient response: *Proponent has provided a qualitative response focused on commercial, recreational, or aboriginal (CRA) fisheries. In addition to CRA fisheries, the questions asked for information on impacts on fish and fish habitat.*

With respect to potential hydrologic/hydraulic impacts, there is potential, at least in Geona Creek, to result in an impact to stream morphology which could have a subsequent impact on fish and fish habitat. For instance, failure of the WMPs could result in (i) release of sediment downstream, (ii) erosion of sections of Geona Creek, (iii) sediment deposition in sections of Geona Creek, and (iv) change in stream morphology as a result of the erosion/sedimentation and alteration of natural erosion/sedimentation processes.

In addition to the above, the stated reliance on a beaver pond to offset potential impacts is questionable.

R2-124

Provide an assessment of catastrophic failure of the water management ponds on Genoa Creek. This may be included in the response to R2-45 which requests an assessment of impacts associated with the Project on erosion, stream morphology and riparian vegetation of all affected drainages from projected downstream flow changes during all Project phases.

This assessment has been undertaken, and is provided in **Appendix R2-O** of this Response Report. It presents an evaluation of potential impacts to the downstream aquatic and riparian receiving environment from a 'worst-case' scenario of both (full) water management ponds breaching during a high runoff natural event when the downstream waters are already flowing at bankfull depths. Section 2.1 of the assessment discusses how the likelihood of all of these events co-occurring at the same time to produce the worst-case scenario evaluated in *extremely low*. In a classic risk assessment context, this extremely low likelihood does not produce a recommendation for substantial changes to planned management to reduce overall risk, regardless of the consequence identified.

R2-125

The statement in the last paragraph that reads "impacts to Geona Creek CRA fisheries would be limited to areas downstream of the Robert Campbell Highway to the confluence with Finlayson River" is confusing. Geona Creek is not traversed by RCH. Please clarify.

The statement from the previous response should have read *"impacts to **Finlayson Creek** CRA fisheries would be limited to areas……"* This response, however, has been superseded by the assessment undertaken in response to R2-124 above.

YESAB ISSUE

Section 17.4 references the additional cycle of boom and bust that would occur in the event of unplanned closure and recognizes the negative effect this may have on employees. Several mitigation measures have been provided for this effect. However, the proposal does not mention the risk of this event to local contractors and businesses. There is also no detail on how BMC will ensure that the mitigation measures proposed for employees will be carried out.

R275

"Provide additional information on the risks of temporary or permanent unscheduled closure of the Project focusing on socio-economic effects to employees, contractors, and businesses, and others who have been impacted economically. Include details and description on how adverse socio-economic effects will be mitigated and financed, particularly if an unscheduled closure occurs (i.e., how will BMC be able to finance the costs associated with mitigation measures)."

1. Risk of Closure:

Any unplanned or temporary closure of the Project is most likely to occur through some unanticipated technical or financial occurrence that renders the mine either uneconomic or otherwise unfeasible to operate.

Prior to submitting and in preparation of the Project Proposal to YESAB, BMC has carried out feasibility studies that include likely technical and economic Project elements. These studies have been carried out by experienced industry professionals both in house and through world renowned specialist mining consultancies that have a demonstrated track record of developing mining projects worldwide. At all stages of the investigations to date, BMC has been conscious of the technical and economic risks that can beset a mining project and has ensured that there is an appropriate level of conservatism in the assumptions and the technical and economic assessments. For example, BMC does not use short term metal price and exchange rate data in our Project assessments but rather uses long term consensus forecasts provided by industry specialists in such diverse fields as commercial and merchant banking, metals and commodity traders, government economic groups, central banks, and mining industry bodies. In addition to adopting a longer term view, BMC has carried out its own internal stress testing of Project economics under a range of scenarios including unplanned unfavourable short and long term movements in metals prices and exchange rates outside expected norms. The work completed to date has helped us to form our view regarding the financial metrics for the Project. Final financing decisions with respect to Project development will incorporate provision of various scenarios in relation to product pricing and technical risk to ensure that BMC is able to finance costs related to any temporary closure.

2. Mitigation of outcomes from an unplanned closure:

a) The effects on employees of an unplanned or temporary closure;

As outlined in the Socio-Economic report, the local region around the Project and the Yukon generally has a relatively low level of mining employment and an overall high rate of youth and other unemployment. There are also a high number of working age people who have never had the opportunity to hold a full time or steady job due to the lack of availability of an opportunity. The proposed Project offers local community members the possibility to gain employment and improves their potential for future employment should this employment end after a period of time. Once workers have a demonstrated record of employment and transferable work skills, future employment is more likely.

Furthermore, BMC has certain programs already in place that promote education and on the job training. The most public of these is the current three year BMC-Kaska Scholarship program. This program is designed to run until June 2019 at which time it is expected that it will be superseded by the final mining related program. The current program:

- Supports and encourages Kaska secondary students to complete their final year of school;
- Encourages and supports completion of trade certificates and apprenticeships through Yukon College;
- Encourages and supports completion of certain technical studies that will result in achievement of diplomas, certificates and other recognisable qualifications through Yukon College; and
- Supports degree level technical studies in both mining related and other fields of study through any recognised university in Canada. Scholarship holders for mining related degrees studies are further supported by a guarantee of vocational employment to gain work experience.

In 2016, the above program provided direct support to 27 Kaska members and it is expected that the 2017 and 2018 programs will provide benefits to similar or greater numbers. By the time the proposed mine is in operation, it is likely that over 100 local Kaska members will have enhanced their education due to the BMC-Kaska Scholarship program.

During the operation of the proposed mine, the company intends to continue a similar program to the above but will supplement this program by:

- Various on the job training programs; and
- Employment of apprentices and trainees.

The above programs will result in an overall upskilling of the workforce over the life of the Project which is independent of the time that the Project is open. Unplanned closure or interruption of operations either for a short period or longer period will not detract from this outcome. It should also be noted that the skills and experience gained through the Projects life will be transferrable across different mine sites and across different industries. This upskilling will result in Project employees being seen as valuable additions to any workforce in the Yukon or Canadian as well as the international mining industry or in any non-mining employment scenario that they choose to go into. As a result of the increased experience, the upskilling of the workforce and the mobility of that experience and skills gained, it is expected that any temporary closure of the Project should not result in undue financial hardship for employees unless they choose to not take up work with other employers.

b) The effects on local contractors of an unplanned or temporary closure

The above explanation a) is no different for local contractors who will all gain through experience, contracting history and upskilling of their workforce. This will lead to an increase in their ability and capacity to compete for contracting opportunities both within the Yukon mining industry and in outside industries.

BMC has a policy of supporting local businesses with an established track record. In 2016, the BMC awarded over 70% of its major contracts at the Kudz Ze Kayah Project to local First Nation and other Yukon companies. In the event of a planned or unplanned temporary closure of the Project the company anticipates maintaining support for local businesses through BMC policy and practise.

c) Funding mitigation measures around an unplanned or temporary closure event

The Company is an international mining company with significant funds and funding commitments established. In order to develop the Project, the company will generate additional funding through a combination of equity and debt. This funding level will be calculated to take into consideration working capital requirements and the risk of temporary cessation of revenue from Project activities. Where there exists a risk from metal price and foreign exchange the company may put in place certain hedging arrangements or other financial measures should the Directors in consultation with the Company's bankers and other advisors deem that it is prudent to do so.

In addition to this, the extensive studies that have been carried out on behalf of the company to date have demonstrated that the Project is economically viable under a broad range of economic and technical conditions. The company expects to make a profit from the Project and intends to adopt prudent and well tested cash management policies in order to ensure that it retains sufficient cash reserves on hand to adequately deal with any unforeseen revenue interruption over the Project life.

Finally, it is normal practise for regulators to impose environmental bonding obligations on mine developers prior to issuing licences and permits to construct and operate. These bond requirements are normally calculated by the regulator to ensure that sufficient funds are available for an orderly closure of the mining Project at any stage of its life. The company expects that this Project will be no different in that regard and has included allowances within its financial models for this to occur.

YESAB ISSUE WITH BMC'S RESPONSE TO R275

Section 17.4 references the additional cycle of boom and bust that would occur in the event of unplanned closure and recognizes the negative effect this may have on employees. Several mitigation measures have been provided for this effect. However, the proposal does not mention the risk of this event to local contractors and businesses. There is also no detail on how BMC will ensure that the mitigation measures proposed for employees will be carried out.

While it describes benefits/enhancement measures associated with upskilling of the workforce, the proponent has not provided any specific mitigation measures that would be implemented in the event that a temporary or unplanned closure takes place.

Insufficient Response: *The response fails to identify effects and mitigations to employees and contractors if there is unscheduled closure.*

R2-126

Provide additional information on the risks of temporary or permanent unscheduled closure of the Project focusing on socio-economic effects to employees, contractors, and businesses, and others who have been impacted economically. Include details and description of adverse effects; on how these effects will be mitigated and how they will be financed.

BMC believes that the likelihood or risk of temporary or permanent unscheduled closure occurring has been well described in its previous response to R275. With regards to the matter of effects of temporary or unscheduled closure the Company offers the following additional comments:

In the case of a temporary closure or reduction in activity, the activity on site does not diminish immediately. A relevant local example of this can be seen at Capstones' Minto Mine in north-east Yukon. Due to a sustained reduction in copper prices the company announced that it was considering its options in relation to operations at the mine (2014). In 2015, it announced that it was putting in place certain cost reduction measures including the treatment of existing low-grade stockpiles, reduction in waste stripping and deferral of certain other capital expenditures. It was several months after the initial statements before there were any significant reductions in site personnel numbers and during this period ore that had already been stripped of waste continued to be mined. As part of its plan it maintained an orderly reduction in activities for all of its contractors and ensured that the contractors were able to manage the reduction in revenues from the Project. In 2017, Capstone announced resumption of normal site activities and those same contractors (and the company) were well placed to ramp up site operations. The Minto mine example is reasonably typical of a well managed temporary closure or reduction of activity on a mining project.

In the case of Kudz Ze Kayah, BMC notes that the Project intends to operate with ore stockpiles equivalent to 1 to 4 months of processing plant feed (between 150,000t and 600,000t). The intrinsic value of those stockpiles will vary with grade however as the Project is predominantly open pit with low operating costs and robust operating margins and the cost of treating stockpiles is approximately half the costs if mining is required, these stockpiles will generate substantial revenues should there be a temporary cessation or reduction of mining activity. In addition to those stockpiles, at any discrete point in time there will be certain ore in the pit (or underground) where capital waste movement has been completed and that ore can be mined at low incremental cost. The combination of available exposed ore and existing ore stockpiles means that in any unexpected closure, the Company will have multiple options available to it and will be able to reduce site mining and processing activity over a controlled and extended period whilst maintaining strong cashflows to protect creditors and employee entitlements. During this period, employees and contractors will be able to similarly make decisions and put in place mitigation measures of their own in a controlled manner over a reasonable timeframe.

In the case of an unexpected total closure of the mine it should be noted that closure of a mine does not correlate to cessation of all activity. In the case of Kudz Ze Kayah, a full closure would still require treatment of all ore stockpiles (taking 2 to 4 months) and then subsequent treatment of any accumulated low- grade stockpiles (the level of which will vary throughout the Project life). Treatment of these stockpiles would generate substantial cashflow which would provide funding for an orderly closure of the processing plant associated infrastructure. The period of time from a decision to close to cessation of activity to only Care & Maintenance would be no less than six (6) months and could be as high as 18 months under some circumstances. Given that activity during this period would be fully funded by the extraction of value from the stockpiles this is considered adequate mitigation.

In addition to the above, it is expected that as a condition of permitting the Project, the regulator will require the lodgement of an appropriate level of environmental bonds (either cash, bank guarantees or some other form of funding acceptable to the Yukon Government). It is normal practise for the bond amount lodged to be regularly reviewed and adjusted to ensure that it is appropriate to cover the full remediation of the Project. In the absolute worst-case scenario, these funds would therefore be available to the government to fund remediation activity independent of the financial health of the company. In the case of an unexpected and sudden full closure of the Project then the focus of the mining fleet and personnel and significant numbers of other staff would change from mining to reclamation. The period of active reclamation is expected to take at least 3 years. This period is more than enough to allow mining, maintenance and related employees and contractors an orderly departure from the site.

The above deals primarily with the financial implications of unexpected temporary or permanent closure. It should be noted that the company accepts that there is a clear link between financial stress and emotional well-being and personal health. Provision of a controlled closure will provide some protection for employee on this front but it cannot be the only tool. BMC reiterates its comments made in response to question R275 regarding the provision of an Employee Assistance Program (EAP). These programs are very flexible and will be made available to employees and contractors working on site and their immediate families. In the case of a temporary or unplanned closure, the EAP will still be in place and will be funded by the company (and in certain circumstances by the company's insurer). This program will provide additional emotional and mental health support for those that are in need of it. This program will be supplemented by the provision of externally managed outplacement services for all personnel employed by the company at the Project. Typically, these programs run from between 1 month to 1 year from the cessation of employment (but can run longer if required) and are designed to help employees to either obtain other employment in the same field or to prepare for and subsequently obtain employment if a different field if that is their wish. The employment upskilling identified in R275 will combine with the above to provide significant mitigation in the event of full unplanned closure.

18 CONCEPTUAL MANAGEMENT PLANS

No information required.

19 SUMMARY AND CONCLUSIONS

No Information required.

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Appendix R2-A

KZK Project – Class A Storage Facility – Failure Modes Effects Assessment

September 29, 2017

File No.:VA101-00640/05-A.01
Cont. No.:VA17-01558

[Name Redacted]
Mining Engineer
BMC Minerals (No. 1) Ltd.
530 - 1130 West Pender Street
Vancouver, British Columbia
Canada, V6E 4A4

Dear [Name R,

Re: KZK Project – Class A Storage Facility – Failure Modes Effects Assessment

1 – INTRODUCTION

This letter report presents a response to the Yukon Environmental and Socio-economic Assessment Board (YESAB) information request R2-3, for the YESAB Adequacy Review of the Kudz Ze Kayah Project. YESAB's Request R2-3 is as follows:

- Provide a risk assessment for mine waste management facilities including a failure modes effects analysis (FMEA).

A qualitative Multiple Accounts Analysis (MAA) was conducted to select the location and method of tailings management, and is summarized in the 2016 KP Report VA101-640/2-2 *Tailings Management Alternatives Assessment*. The MAA indicated the preferred tailings management strategy was filtered tailings stored in a facility located on the western hillside of Geona Creek, referred to as the Class A Storage Facility. The design of the Class A Storage Facility is described in KP Report VA101-640/2-3 *Prefeasibility Design Report*.

This memorandum presents the FMEA for the Class A Storage Facility. The FMEA involves identification and characterization of risks specific to the Class A Storage Facility.

1.1 CLASS A FACILITY DETAILS

The following components of the Class A Storage Facility mitigate risk by design, and therefore require consideration in the risk identification process:

- **Basin preparation and grading:** The foundation of the facility will be excavated until suitable overburden or bedrock is encountered, and the basin will be graded so that flow is directed to downstream collection points and cannot pond within the facility.
- **Liner system:** A low permeability liner comprised of natural glacial till material will be constructed above the foundation material.
- **Seepage collection system:** Seepage within the facility will be conveyed in a series of internal drains, constructed above the low permeability foundation liner, and collected in a sump at the lowest elevation area of the facility and pumped to the Class A Facility Seepage Collection Pond.
- **Class A Seepage Collection Pond:** The Seepage Collection Pond will manage seepage and runoff water during the life of mine and active closure.
- **Co-mingling of tailings and waste rock**: Co-mingling with rock will provide additional strength to the tailings material.
- **Diversion ditches**: Diversion ditches and berms constructed around the facility collect and convey contact water away from the facility. The ditches are designed to manage the 1 in 200 year 24-hour rainfall event.
- **Cover system**: A progressive cover system will encapsulate the Class A material. The cover system consists of a layer a low permeability material covered with 5 m of non-reactive rockfill, to provide a frost barrier and erosion protection. A growth media layer to promote re-vegetation will be placed above the rockfill. The facility

will be constructed in lifts and the cover will be advanced up the working surface, forming a 4H:1V overall final slope, which will convey surface runoff water to the Class A Seepage Collection Pond. Erosion of the growth media layer will be reduced through sediment and erosion control best management practices.

- **Buttress**: A buttress of non-reactive waste rock material will be constructed at the downstream toe of the Class A Facility to increase the factor of safety and allow the facility to be constructed a lower overall slope (closer to natural ground slopes pre-mining).

2 – FMEA WORKSHOP

2.1 PARTICIPANTS

The FMEA workshop was held on August 30, 2017. The objective of the workshop was for the various parties of the design team to identify, discuss and quantify risks to the Class A Storage Facility. The workshop involved participants from BMC Minerals (No. 1) Ltd., Knight Piésold Ltd., and Alexco Environmental Group. Participants and organizations are outlined in Table 1.

Table 1 FMEA Workshop Participants

Company	Participant
BMC Minerals (No. 1) Ltd.	[Name Redacted]
	[Name Redacted]
Alexco Environmental Group	[Name Redacted]
	[Name Redacted]
Knight Piésold Ltd.	[Name Redacted]
	[Name Redacted]
	[Name Redacted]

2.2 WORKSHOP METHODOLOGY

Risk is defined as likelihood multiplied by consequence:

Risk = Likelihood x Consequence

Likelihood and consequence ratings were defined at the beginning of the FMEA workshop and were agreed upon by all participants. Ratings for likelihood and consequence range from 1 to 5. Tables 2 summarizes the likelihood ratings.

Table 2 Likelihood Descriptions

Likelihood					
Rating	**Rare**	**Unlikely**	**Possible**	**Likely**	**Highly likely**
	1	**2**	**3**	**4**	**5**
Description	1 in 1,000 year event	1 in 200 year event	1 in 10 year event	Less than one event per year	More than one event per year

Consequence ratings were developed for a range of project impacts: environmental impact, special considerations, legal obligations, consequence costs, community and media reputation, human health and safety. Table 3 summarizes the consequence ratings.

Table 3 Consequence Descriptions

Categories	Low	Minor	Moderate	Major	Critical
	1	2	3	4	5
Environmental Impact (EI)	No impact	Minor localized or short-term impacts	Significant impact on valued ecosystem component	Significant impact on valued ecosystem component and medium-term impairment of ecosystem function	Serious long-term impairment of ecosystem function
Special Considerations (SC)	Some disturbance but no impact to traditional land use	Minor or perceived impact to traditional land use	Some mitigable impact to traditional land use	Significant temporary impact of traditional land use	Significant permanent impact on traditional land use
Legal Obligations (LO)	Informal advice from a regulatory agency	Technical / Administrative non-compliance with permit, approval or regulatory requirement Warning letter issued	Breach of regulations, permits or approvals (e.g. 1 day violation of discharge limits) Order or direction issued	Substantive breach of regulations, permits or approvals (e.g. multi-day violation of discharge limits) Prosecution	Major breach of regulation - willful violation Court order issued
Consequence Costs (CC)	< $100,000	$100,000 - $500,000	$500,000 - $2.5 Million	$2.5 - $10 Million	> $10 Million
Community / Media Reputation (C/MR)	Local concerns, but no local complaints or adverse press coverage	Public concern restricted to local complaints or local adverse press coverage	Heightened concern by local community, criticism by NGOs or adverse local/regional media attention	Significant adverse national public, NGO or media attention	Serious public outcry / demonstrations and adverse international NGO attention or media coverage
Human Health & Safety (HHS)	Low-level short-term subjective symptoms. No measurable physical effect. No medical treatment	Objective but reversible disability, impairment and/or medical treatment injuries requiring hospitalization	Moderate irreversible disability or impairment to one or more people	Single fatality and/or serve irreversible disability or impairment to one or more people	Multiple fatalities

Multiplying the likelihood and consequence scores will provide the risk rating from 1 to 25, as shown in Table 4.

Table 4 Risk Rating

Risk		
Very Low	0 to 3	Very Low
Low	4 to 6	Low
Medium	7 to 12	Medium
High	13 to 20	High
Very High	21 to 25	Very High

2.3 KEY CONSIDERATIONS AND ASSUMPTIONS

The following items were discussed at the beginning of the workshop and established as core assumptions or considerations to the assessment:

- The phases of the project were defined as:
  - **Construction:** Years -2 and -1. Runoff through the area of the Class A Facility footprint during construction is considered "non-contact" as no Class A material is placed during this time.
  - **Operations:** Years 1 through 9.
  - **Closure:** Includes active and final closure. The Class A Facility cover is in place and Geona Creek is re-established. Collection ponds and diversion ditches are removed. Issues that are identified during construction and operations will be mitigated/repaired and were not assumed to carry through to closure, as the site would not meet closure objectives if things such as water quality objectives cannot be achieved.
- Only conceivable failure modes were identified and discussed.
- A detailed site wide terrain hazards assessment is on-going at the time of this assessment and will include assessment of permafrost, seismicity, landslide and avalanche risks therefore risks related to these areas have not been included in this assessment at this time.
- Class A Storage Facility design details are sourced from Knight Piésold Report *Pre-Feasibility Design Report for Waste and Water Management Facilities*, October, 2016.

3 – METHODOLOGY AND RESULTS

Risks were identified and numbered starting at 1, and defined by attributes including phase of design, description, and consequence category. One by one, risks were given likelihood and consequence ratings, through group discussion. The following components of the facility were assessed:

- The Class A Storage Facility (including cover, liner, constructability, etc.)
- Non-contact diversion ditch upslope of facility
- Contact diversion ditches downslope facility
- Class A Storage Facility Collection Pond, and
- Buttress.

Each of the components was assessed for Construction, Operations and Closure phases. Multiple consequences were also considered for each failure, for example failure of a ditch may result in downstream environmental impacts as well as consequence costs, so both were evaluated.

Key defensive measures already considered in the proposed mine plan were identified where appropriate to provide context for the selected likelihood and consequence. Examples of key defensive measures include design criteria and management plans.

Appendix A includes a detailed summary of the results of the risk assessment and Table 5 presents the results in a risk matrix chart.

Table 5 Risk Ratings – Results of FMEA

Likelihood		Consequence 1	Consequence 2	Consequence 3	Consequence 4	Consequence 5
	5	1, 37				
	4	2, 39				
	3	40				
	2	41	45	43, 44		
	1	4, 11, 12, 13, 28, 42	3, 6, 7, 8, 14, 15, 16, 19, 22, 27, 29, 33, 35	10, 18, 20, 23, 24, 25, 32, 36, 38	34	5, 9, 17, 21, 26

All assessed risks fell within the "Low" to "Very Low" categories. The most significant risks identified at this phase of project development (with a risk rating of 6) are 43 and 44. These risks are further summarized below:

Risk #43:

There is a failure to follow the Operations, Maintenance and Surveillance procedures for temporary closure of the Class A Storage Facility leading to an improper cover and an environmental consequence.

Key defensive measures in place include:

- Parties involved reduce likelihood (construction supervision and Quality Assurance / Quality Control (QA/QC), Engineer of Record, operators, supervisors, regulators), and
- Modern and routinely updated construction QA/QC practices reduce likelihood.

The following ratings were determined:

- Likelihood: 2 (unlikely, 1 in 200 year event), and
- Consequence: 3 (moderate, significant impact on valued ecosystem component).

Risk #44:

Poor trafficability of Class A material during operations (due to moisture content, precipitation, temperature, etc.) leads to short term delay of material placement, causing delays and consequence costs.

Key defensive measures in place include:

- Adaptive management plan will include strategies such as snow removal, strategic material placement, or temporary covers.

The following ratings were determined:

- Likelihood: 2 (unlikely, 1 in 200 year event)
- Consequence: 3 (moderate, significant impact on valued ecosystem component)

Future iterations of project development and design may include mitigation measures to further reduce the risks identified in Table 5.

Yours truly,
Knight Piésold Ltd.

Prepared: [Name Redacted] ______ Reviewed: [Name Redacted] ________

[Name Redacted]
Approval that this document adheres to Knight Piésold Quality Systems:

Attachments:
Table A1 Rev A Class A Storage Facility Failure Modes and Effects Assessment

TABLE A1

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

CLASS A STORAGE FACILITY
FAILURES MODES AND EFFECTS ASSESSMENT

RISK NO.	CATERGORY	PHASE	RISK DESCRIPTION	CONSEQUENCE	TYPE	KEY DEFENSIVE MEASURES IN PLACE	RISK RATING L	RISK RATING C	RISK RATING SCORE	CLASSIFICATION
1	Non Contact Diversion Ditches	Construction	Overtopping or seepage in discrete areas due to construction or ground conditions	Run off through construction of Class A Facility, high suspended solids and sediment loading, erosion of liner	CC	● Quality Assurance and Quality Control (QA/QC) during construction will identify and address construction issues. ● Management Plans will include emergency preparedness and response for unforeseen construction issues.	5	1	5	Low
2	Non Contact Diversion Ditches	Operations	Overtopping or seepage in discrete areas due to construction or ground conditions	Larger surplus of contact water requiring management (pumping and treatment)	CC	● Water Management Plan anticipates collection and treatment of surplus contact water.	4	1	4	Low
3	Non Contact Diversion Ditches	Construction	Precipitation or runoff event exceeding design of the diversion ditches (1 in 200 year 24-hr event)	Ditches overflowing over total length, beyond water management capability, incremental sediment load to downstream catchment	E	● Emergency Management Plan will require timely repairs.	1	2	2	Very Low
4	Non Contact Diversion Ditches	Construction	Precipitation or runoff event exceeding design of the diversion ditches (1 in 200 year 24-hr event)	Ditches overflowing over total length, beyond water management capability, incremental sediment load to downstream catchment	CC		1	1	1	Very Low
5	Non Contact Diversion Ditches	Construction	Precipitation or runoff event exceeding design of the diversion ditches (1 in 200 year 24-hr event)	Flooding and/or sloughing leads to worker fatality	HHS	● Occupational Health and Safety (OHS) plan will include emergency preparedness.	1	5	5	Low
6	Non Contact Diversion Ditches	Operations	Precipitation or runoff event exceeding design of the diversion ditches (1 in 200 year 24-hr event)	Ditches overflowing over total length, beyond water management capability, leading to incremental mobilization of tailings and waste rock contact water through site water management facilities and to downstream environment	E	● Emergency Management Plan will require timely repairs.	1	2	2	Very Low
7	Non Contact Diversion Ditches	Operations	Precipitation or runoff event exceeding design of the diversion ditches (1 in 200 year 24-hr event)	Multi-day violation of discharge limits	R/L		1	2	2	Very Low
8	Non Contact Diversion Ditches	Operations	Precipitation or runoff event exceeding design of the diversion ditches (1 in 200 year 24-hr event)	Repairs to diversion structures and other facilities	CC		1	2	2	Very Low
9	Non Contact Diversion Ditches	Operations	Precipitation or runoff event exceeding design of the diversion ditches (1 in 200 year 24-hr event)	Flooding and/or sloughing leads to worker fatality	HHS	● Occupational Health and Safety (OHS) plan will include emergency preparedness.	1	5	5	Low
10	Contact Diversion Ditches	Operations	Overtopping or seepage in discrete areas	Contact water by-passes water collection systems, reporting to receiving environment and resulting in unacceptable downstream water quality (exceeding water quality objective)	E	● Progressively reclaimed surface limits exposed Class A material. ● Design of facilities and site topography conveys runoff to Lower WMP.	1	3	3	Very Low
11	Contact Diversion Ditches	Operations	Overtopping or seepage in discrete areas	Contact water by-passes water collection systems, reporting to receiving environment and resulting in unacceptable downstream water quality (exceeding water quality objective)	R/L	● Adaptive management plan will include response and mitigative actions.	1	1	1	Very Low
12	Contact Diversion Ditches	Operations	Overtopping or seepage in discrete areas	Contact water by-passes water collection systems, reporting to receiving environment and resulting in unacceptable downstream water quality (exceeding water quality objective)	CC	● Adaptive management plan will include response and mitigative actions.	1	1	1	Very Low
13	Contact Diversion Ditches	Operations	Overtopping or seepage in discrete areas	Contact water by-passes water collection systems, reporting to receiving environment and resulting in unacceptable downstream water quality (exceeding water quality objective)	C/MR	● Adaptive management plan will include response and mitigative actions.	1	1	1	Very Low
14	Contact Diversion Ditches	Operations	Precipitation or runoff event exceeding design event of the diversion ditches (1 in 200 year 24-hr event)	Ditches overflowing over total length, beyond water management capability, leading to incremental mobilization of tailings and waste rock contact water through site water management facilities and to downstream environment	E	● Emergency Management Plan will require timely repairs.	1	2	2	Very Low
15	Contact Diversion Ditches	Operations	Precipitation or runoff event exceeding design event of the diversion ditches (1 in 200 year 24-hr event)	Multi-day violation of discharge limits	R/L	● Emergency Management Plan will require timely repairs.	1	2	2	Very Low
16	Contact Diversion Ditches	Operations	Precipitation or runoff event exceeding design event of the diversion ditches (1 in 200 year 24-hr event)	Repairs to diversion structures and other facilities	CC		1	2	2	Very Low
17	Contact Diversion Ditches	Operations	Precipitation or runoff event exceeding design event of the diversion ditches (1 in 200 year 24-hr event)	Flooding and/or sloughing leads to worker fatality	HHS	● OHS plan will include emergency preparedness.	1	5	5	Low
18	Collection Pond	Operations	Collection Pond embankment failure (resulting from deformation due to foundation failure, seismic event, piping, human error etc.)	Embankment damage, water released to Lower WMP	CC	● Lower WMP is located immediately down-gradient of the collection pond. ● Operationally, the Class A Collection pond will be maintained at a minimum volume (pumped out entirely for water treatment). ● The rock embankment will be constructed on a bedrock foundation to mitigate deformation and liquefaction. ● The embankment design considers seismic design criteria. ● Annual dam inspections and reporting will be completed as per CDA guidelines. ● Regular OMS during operations will include daily inspections and monitoring. ● Instrumentation installed in the embankment will provide on-going monitoring and warnings.	1	3	3	Very Low
19	Collection Pond	Operations	Collection Pond embankment failure (resulting from deformation due to foundation failure, seismic event, piping, human error etc.)	Embankment damage, water released to Lower WMP	R/L	● Lower WMP is located immediately down-gradient of the collection pond. ● Operationally, the Class A Collection pond will be maintained at a minimum volume (pumped out entirely for water treatment). ● The rock embankment will be constructed on a bedrock foundation to mitigate deformation and liquefaction. ● The embankment design considers seismic design criteria. ● Annual dam inspections and reporting will be completed as per CDA guidelines. ● Regular OMS during operations will include daily inspections and monitoring. ● Instrumentation installed in the embankment will provide on-going monitoring and warnings.	1	2	2	Very Low
20	Collection Pond	Operations	Collection Pond embankment failure (resulting from deformation due to foundation failure, seismic event, piping, human error etc.)	Embankment damage, water released to Lower WMP	C/MR	● Lower WMP immediately down-gradient, ● Capacity to contain Class A Collection pond, ● Rock embankment built on rock foundation will mitigate deformation / no liquefaction potential, ● Embankment design considers seismic design criteria, ● CDA annual dam inspections, ● Regular OMS will include daily inspections and monitoring, ● Instrumentation warnings	1	3	3	Very Low

TABLE A1

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

CLASS A STORAGE FACILITY
FAILURES MODES AND EFFECTS ASSESSMENT

RISK NO.	CATERGORY	PHASE	RISK DESCRIPTION	CONSEQUENCE	TYPE	KEY DEFENSIVE MEASURES IN PLACE	RISK RATING L	RISK RATING C	RISK RATING SCORE	CLASSIFICATION
21	Collection Pond	Operations	Collection Pond embankment failure (resulting from deformation due to foundation failure, seismic event, piping, human error etc.)	Flooding and/or sloughing leads to worker fatality	HHS	• Lower WMP is located immediately down-gradient of the collection pond. • Operationally, the Class A Collection pond will be maintained at a minimum volume (pumped out entirely for water treatment). • The rock embankment will be constructed on a bedrock foundation to mitigate deformation and liquefaction. • The embankment design considers seismic design criteria. • Annual dam inspections and reporting will be completed as per CDA guidelines. • Regular OMS during operations will include daily inspections and monitoring. • Instrumentation installed in the embankment will provide on-going monitoring and warnings.	1	5	5	Low
22	Collection Pond	Operations	Precipitation or runoff event exceeding design event of the Collection Pond (1 in 200 year 24-hr event)	Water released from pond beyond water management capability, leading to incremental release of Class A contact water through site water management facilities and to downstream environment	E	• Design includes spillway to pass design storm events exceeding the Collection Pond capacity.	1	2	2	Very Low
23	Collection Pond	Operations	Precipitation or runoff event exceeding design event of the Collection Pond (1 in 200 year 24-hr event)	Embankment failure and release of Class A contact water to Lower WMP, water is managed by Lower WMP	E	• Emergency Management Plan will require timely repairs.	1	3	3	Very Low
24	Collection Pond	Operations	Precipitation or runoff event exceeding design event of the Collection Pond (1 in 200 year 24-hr event)	Multi-day violation of discharge limits	R/L	• Emergency Management Plan will require timely repairs.	1	3	3	Very Low
25	Collection Pond	Operations	Precipitation or runoff event exceeding design event of the Collection Pond (1 in 200 year 24-hr event)	Embankment repair / construction required	CC		1	3	3	Very Low
26	Collection Pond	Operations	Precipitation or runoff event exceeding design event of the Collection Pond (1 in 200 year 24-hr event)	Flooding and/or sloughing leads to worker fatality	HHS	• OHS plan will include emergency preparedness.	1	5	5	Low
27	Collection Pond	Operations	Liner system not installed correctly, damaged	Class A Contact Water seepage from pond directly to the receiving environment creating unacceptable water quality	E	• QA/QC during construction will identify and address construction issues. • Liner replaced as required. • Hydrostatic testing during construction to identify possible leaks. • Monitoring systems downstream in combination with adaptive management plan would identify a response to unacceptable seepage.	1	2	2	Very Low
28	Collection Pond	Operations	Liner system not installed correctly, damaged	Class A Contact Water seepage from pond directly to the receiving environment creating unacceptable water quality	R/L	• Monitoring systems downstream. • Adaptive management plan.	1	1	1	Very Low
29	Collection Pond	Operations	Liner system not installed correctly, damaged	Repair or replace liner, install wells and pump back system	CC	• QA/QC and construction supervision will reduce likelihood of damage.	1	2	2	Very Low
30	Buttress	Operations	Class A Storage Facility buttress slumping, deformation	Slow movement of buttress requiring repairs, re-assessment of design	CC	• Buttress constructed on bedrock foundation. • Constructed from non-reactive waste rock at a slope of 3H:1V. • The embankment design considers seismic design criteria. • Regular OMS during operations will include daily inspections and monitoring. • Instrumentation installed in the embankment will provide on-going monitoring and warnings.			0	Very Low
31	Buttress	Closure	Class A Storage Facility buttress slumping, deformation	Slow movement of buttress leading to cracks in cover and increased runoff contact with Class A Material and increased seepage	E	• Emergency Management Plan will require timely repairs.			0	Very Low
32	Buttress	Operations	Class A Storage Facility buttress sudden failure	Movement of facility compromises contact diversion ditches, interruption to operations to make repairs	CC	• Buttress constructed on bedrock foundation. • Constructed from non-reactive waste rock at a slope of 3H:1V. • The embankment design considers seismic design criteria. • Operations, Maintenance and Surveillance (OMS) during operations will include daily inspections and monitoring. • Instrumentation installed in the embankment will provide on-going monitoring and warnings.	1	3	3	Very Low
33	Buttress	Operations	Class A Storage Facility buttress sudden failure	Movement of facility compromises contact diversion ditches, contact water routed to Lower WMP and managed accordingly (no release to environment)	E	• Lower WMP located immediately down gradient, to collect and manage contact water. • Buttress constructed on bedrock foundation. • Constructed from non-reactive waste rock at a slope of 3H:1V.	1	2	2	Very Low
34	Buttress	Operations	Class A Storage Facility buttress sudden failure	Movement of facility compromises contact diversion ditches, contact water routed to Lower WMP and managed accordingly (no release to environment)	R/L	• Emergency Management Plan will require timely repairs.	1	4	4	Low
35	Buttress	Closure	Class A Storage Facility buttress sudden failure	Movement of facility causes damage to cover system and increases infiltration resulting in poor quality water released to downstream environment	E	• Emergency Management Plan will require timely repairs.	1	2	2	Very Low
36	Class A Storage Facility	Operations	Erosion of Class A Facility cover slope	Localized scour / damage to cover	CC	• Emergency Management Plan will require timely repairs. • Regular OMS during operations will include daily inspections and monitoring. • Layer of frost protection (non-reactive waste rock) will protect low permeability liner from scour.	1	3	3	Very Low
37	Class A Storage Facility	Closure	Erosion of Class A Facility cover slope	Localized scour / damage to cover	CC	• Vegetation growth with time. • Progressive cover will limit exposed areas. • Cover materials are self-armored.	5	1	5	Low
38	Class A Storage Facility	Operations	Inclusion of ice or snow in tailings and waste rock	Settlement of material (deformation) leads to damage of cover and increased seepage to downstream environment	E	• Snow management included in tailings management plan. • Lift thickness and compaction requirements for placement as part of QA/QC.	1	3	3	Very Low
39	Class A Storage Facility	Closure	Inclusion of ice or snow in tailings and waste rock	Settlement of material (deformation) leads to damage of cover and increased seepage to downstream environment	E	• Winter placement of tailings and waste rock material will require procedures for snow and ice removal.	4	1	4	Low
40	Class A Storage Facility	Construction	Failure to follow OMS	Facility not performing to design leads to environmental impact	E	• Parties involved reduce likelihood (QA/QC, Engineer of Record, operators, supervisors, regulators). • Modern and routinely updated construction QA/QC practices reduce likelihood.	3	1	3	Very Low
41	Class A Storage Facility	Operations	Failure to follow OMS	Facility not performing to design leads to environmental impact	E	• Parties involved reduce likelihood (QA/QC, Engineer of Record, operators, supervisors, regulators). • Modern and routinely updated construction QA/QC practices reduce likelihood.	2	1	2	Very Low
42	Class A Storage Facility	Operations	Failure to follow OMS	Facility not performing to design leads to environmental impact	C/MR	• Parties involved reduce likelihood (QA/QC, Engineer of Record, operators, supervisors, regulators). • Modern and routinely updated construction QA/QC practices reduce likelihood.	1	1	1	Very Low
43	Class A Storage Facility	Closure	Failure to follow OMS	Temporary closure plan not followed leading to improper cover	E	• Parties involved reduce likelihood (QA/QC, Engineer of Record, operators, supervisors, regulators). • Modern and routinely updated construction QA/QC practices reduce likelihood.	2	3	6	Low

TABLE A1

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KUDZ ZE KAYAH PROJECT

CLASS A STORAGE FACILITY
FAILURES MODES AND EFFECTS ASSESSMENT

RISK NO.	CATERGORY	PHASE	RISK DESCRIPTION	CONSEQUENCE	TYPE	KEY DEFENSIVE MEASURES IN PLACE	RISK RATING			CLASSIFICATION
							L	C	SCORE	
44	Class A Storage Facility	Operations	Poor trafficability of Class A Material (due to moisture content, precipitation, temperature, etc.)	Short term delay of material placement	CC	● Adaptive management plan will include response and mitigative actions.	2	3	6	Low
45	Class A Storage Facility	Operations	Liner construction	Liner system does not function as intended resulting in incremental seepage to downstream environment	E	● QA/QC during construction will identify and address construction issues. ● Regular OMS during operations will include daily inspections and monitoring. ● Adaptive management plan will include response and mitigative actions. ● Monitoring systems downstream.	2	2	4	Low

NOTES:

1. LIKELIHOOD, CONSEQUENCE AND RISK RATINGS BASED ON TABLES SUMMARIZED IN "RISK MATRIX' TAB.
2. C - CONSTRUCTION; O - OPERATIONS; CL - CLOSURE.

A	29SEP'17	ISSUED WITH LETTER VA17-01558	MAP	LJG
REV	DATE	DESCRIPTION	PREP'D	RVW'D

Appendix R2-B

KZK Project – Risk Register

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

RISK REGISTER

RISK NO.	CATERGORY	PHASE	RISK DESCRIPTION	CONSEQUENCE	TYPE	KEY DEFENSIVE MEASURES IN PLACE	RISK RATING L	RISK RATING C	RISK RATING SCORE	CLASSIFICATION	COMMENTS
1	Open Pit Mining	Operations	Pit wall slope failure or instability	Loss or delay in accessing ore reserves, safety risk to personnel and equipment	CC	• Site specific geotechnical and hydrogeological data used to develop slope design criteria, that has gone through a rigorous review to assess potential of failure mechanisms and Factor of Safety. • Regular geotechnical mapping of open pit benches during operations to update and refine geotechnical models, supported by pit slope monitoring program.	3	4	12	Medium	Consequence score on cost criteria of $2.5-$10M due to potential lost production.
2	Open Pit Mining	Operations	Pit wall slope failure or instability	Loss or delay in accessing ore reserves, safety risk to personnel and equipment	HHS	• Site specific geotechnical and hydrogeological data used to develop slope design criteria, that has gone through a rigorous review to assess potential of failure mechanisms and Factor of Safety. • Regular geotechnical mapping of open pit benches during operations to update and refine geotechnical models, supported by pit slope monitoring program.	3	1	3	Very Low	Mitigations in place would give adequate time for advance warning and withdrawal of all personnel in affected area.
3	Open Pit Mining	Operations	Uncontrolled rockfall on south wall due to geotechnical slope design not including catch benches in this sector	Equipment or personnel on ramp or on pit floor struck by falling rocks	CC / HHS	• Design slope of this sector is relatively flat, following foliation and therefore limiting the potential for loose rock to fall in an uncontrolled manner for a great distance. • A catch fence will be constructed to intercept loose rock upslope of the haul road to protect vehicles travelling within the pit. A second catch fence may be constructed deeper in the pit if considered necessary based on observed ground conditions, although foliation dip reduces to approximately 15° at depth and hence risk of loose rocks falling is greatly reduced. • Controlled blasting to minimise damage to final pit wall and follow foliation correctly.	3	2	6	Low	
4	Open Pit Mining	Operations	Uncontrolled flyrock from blasting	Injury or damage to personnel, wildlife or infrastructure	EI / CC / HHS	• Appropriate drill and blast designs, including appropriate hole diameters, lengths and adequate use of stemming to confine explosive energy within the blast hole. • Blasting operations carried out by a licenced explosives contractor. • Recording of drill and blast performance to refine design parameters based on operating experience. • Blast designs to utilise where practicable "single shot" firing and low gas explosive mixes and types • Blasting operations to possibly utilise electronic detonators if appropriate.	3	2	6	Low	
5	Open Pit Mining	Operations	Spill of fuel from mobile equipment during operation or refuelling, or release of hydraulic oil due to equipment (hose) failure	Release of hydrocarbons into the environment	EI	• Refuelling of equipment within the open pit to be completed using purpose designed refuelling / maintenance trucks. • Refuelling of equipment at fuel storage facility will be conducted over a concrete apron with any spills drained to a sump for collection and subsequent treatment. • Mobile equipment will have spill kits on board to contain and clean up local spills if they occur. • Spill Management Plan.	5	2	10	Medium	Rated as 5 for hydraulic oil spills. Spill of fuel would be lower.
6	Open Pit Mining	Operations	Vehicle catches fire	Loss of equipment and impact on production	CC	• Mobile equipment will be equipped with AFFF suppression systems as well as hand held extinguishers for treatment of small fires. • Mine rescue team, trained in fire fighting techniques, will be maintained on site with appropriate fire fighting equipment. • Training for all operators in "what to do if.." to be provided. • Emergency Response Plan.	4	2	8	Medium	
7	Open Pit Mining	Operations	Vehicle- vehicle collision	Loss of equipment and impact on production	CC	• Procedures to ensure vehicles maintain safe distance, communications and do not park in high hazard areas. • Warning flags and high visibility apparatus on all vehicles. • Proximity detectors on equipment.	3	3	9	Medium	
8	Open Pit Mining	Operations	Vehicle- vehicle collision	Injury to personnel	HHS	• Procedures to ensure vehicles maintain safe distance, communications and do not park in high hazard areas. • Warning flags and high visibility apparatus on all vehicles. • Proximity detectors on equipment.	3	4	12	Medium	
9	Open Pit Mining	Operations	Equipment or personnel falling into pit from pit crest or from pit ramp	Equipment damage or injury to personnel	CC / HHS	• Safety bunding around the perimeter of the pit to prevent equipment access. • Safety bunding on pit ramp will be no less than three quarters the height of the largest vehicle tyre to prevent vehicle access off ramp. • Safety bunds will be of sufficient size to prevent access and will be properly maintained. • Safety requirements for personnel working near pit edge or ramp will include the use of fall restraint equipment.	2	4	8	Medium	
10	Open Pit Mining	Operations	Equipment or personnel backing over edge when dumping into waste management facilities - or facility edge failing while tipping	Equipment damage or injury to personnel		• Safety bunding along the length of the dumping area. • Complete over edge dumping will not be permitted. • Dumping areas will be kept clean and well lit. • Material dumped will be pushed over edge by suitable equipment. • Dump edges and surrounding area will be inspected on a regular basis by qualified personnel.	3	4	12	Medium	
11	Open Pit Mining	Operations	Slippery pit ramp conditions due to rain, snow or ice	Uncontrolled vehicle movement resulting in equipment damage	CC	• Regular road maintenance, clearing snow from roadway as required and keeping ramp drainage clear of debris. • Placement of roadbase to ensure a running surface with good traction is maintained.	4	1	4	Low	

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RISK REGISTER

RISK NO.	CATERGORY	PHASE	RISK DESCRIPTION	CONSEQUENCE	TYPE	KEY DEFENSIVE MEASURES IN PLACE	RISK RATING L	RISK RATING C	RISK RATING SCORE	CLASSIFICATION	COMMENTS
12	Underground Mining	Operations	Wall or back rock instability	Rock fall leading to injury to personnel, equipment damage and / or loss or delay in accessing reserves	CC	• Site specific geotechnical and hydrogeological data will be used to develop development and stope design criteria. • Installation of recommended ground support regime to safely support designed excavations. • Regular geotechnical mapping of underground excavations during operations to update and refine geotechnical models. • SOP for vehicle operations.	5	2	10	Medium	
13	Underground Mining	Operations	Wall or back rock instability	Rock fall leading to injury to personnel, equipment damage and / or loss or delay in accessing reserves	HHS	• Site specific geotechnical and hydrogeological data will be used to develop development and stope design criteria. • Procedures that limit entry of personel into unsupported areas, including the use of remote mucking. • Installation of recommended ground support regime to safely support designed excavations. • Regular geotechnical mapping of underground excavations during operations to update and refine geotechnical models.	5	2	10	Medium	
14	Underground Mining	Operations	Massive failure of hanging wall in stope	Massive collapse leading to permanent inability to access reserves.	CC	• Site specific geotechnical and hydrogeological data will be used to develop development and stope design criteria. • Installation of recommended ground support regime to safely support designed excavations. • Geotechnical monitoring of stopes and pillars. • Quality control on backfilling process.	3	4	12	Medium	
15	Underground Mining	Operations	Massive failure of hanging wall in stope	Massive collapse leading to injury to personnel, equipment damage and / or loss or delay in accessing reserves	HHS	• Geotechnical monitoring of stopes and pillars will give warning prior to failure. • Remote controlled mucking will be used. • Quality control on backfilling process.	3	2	6	Low	
16	Underground Mining	Operations	Underground blasting	Damage to equipment	CC	• Evacuation of personnel from underground prior to blasting. • Removal of equipment for areas where blasting will take place. • Inspection of blasted and surrounding areas on reentry to the underground mine.	3	3	9	Medium	
17	Underground Mining	Operations	Underground blasting	Injury to personnel	HHS	• Evacuation of personnel from underground prior to blasting. •Ventilation gas monitoring. • Adequate ventilation to clear blasting fumes from underground mine • Inspection of blasted and surrounding areas on reentry to the underground mine.	3	2	6	Low	
17	Underground Mining	Operations	Spill of fuel from mobile equipment during operation or refuelling, or release of hydraulic oil due to equipment (hose) failure	Release of hydrocarbons into the environment	EI	• Refuelling of equipment within the underground mine to be completed using purpose designed refuelling / maintenance trucks. • Refuelling of equipment at fuel storage facility will be conducted over a concrete apron with any spills drained to a sump for collection and subsequent treatment. • Mobile equipment will have spill kits on board to contain and clean up local spills if they occur. • Spill Management Plan.	5	1	5	Low	Rated as 5 for hydraulic oil spills. Spill of fuel would be lower. Any release would be contained within the underground environment and would not reach the surface.
18	Underground Mining	Operations	Excessive dust generated by mining operations	Permitted air quality standards exceeded	LO	• Water applied to broken rock stocks after blasting and in mine as required. • Regular air quality monitoring.	3	1		Very Low	
19	Underground Mining	Operations	Equipment fire	Damage to equipment and loss of production	CC	• All equipment appropriately maintained to manufacturers specifications. • Where approriate, all relevant equipment (turbos, etc) to have AFFF systems. • All mobile fleet to have prestart walk around checks for oily rages, leaks etc prior to operation. • All site personnel to receive basic fire fighting and first aid training. • All underground personnel to wear oxygen rebreathing equipment on their person in case of fire underground and underground refuge chambers to be established.	3	3	9	Medium	Cost will be equipment plus lost production for time of incident and investigation.
20	Underground Mining	Operations	Equipment fire	Injury to personnel, damage to equipment	HHS	• All equipment appropriately maintained to manufacturers specifications. • Where approriate, all relevant equipment (turbos, etc) to have AFFF systems. • All mobile fleet to have prestart walk around checks for oily rages, leaks etc prior to operation. • All site personnel to receive basic fire fighting and first aid training. • All underground personnel to wear oxygen rebreathing equipment on their person in case of fire underground and underground refuge chambers to be established. • Secondary escapeway will be available during all phases of mine operations.	3	2	6	Low	Consequence is low because of mitigations of refuge chambers, second escapeway, training, and availability of self-rescuers.
20	Processing	Operations	Spill of fuel from mobile equipment during operation or refuelling, or release of hydraulic oil due to equipment (hose) failure	Release of hydrocarbons into the environment	EI	• Refuelling of equipment at fuel storage facility will be conducted over a concrete apron with any spills drained to a sump for collection and subsequent treatment. • Mobile equipment will have spill kits on board to contain and clean up local spills if they occur. • Spill Management Plan	4	2	8	Medium	

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RISK REGISTER

RISK NO.	CATERGORY	PHASE	RISK DESCRIPTION	CONSEQUENCE	TYPE	KEY DEFENSIVE MEASURES IN PLACE	RISK RATING L	C	SCORE	CLASSIFICATION	COMMENTS
21	Processing	Operations	Spill of reagents	Release of chemicals into the environment	EI / HHS	• Reagent handling and mixing completed within a purpose designed facility, divided into dry and wet sections; the dry area serves as a bulk store for the reagents as delivered and the wet area is where reagents are mixed prior to distribution within the processing plant. The wet area has been designed as a concrete floor with reinforced concrete containment bunds for each reagent, sloped so it drains to sumps to contain and clean up spills. • Reagent use within the processing facility will be via dedicated distribution lines, and use of reagents will only be within areas nominated as wet areas, designed with concretes floor with reinforced concrete containment bunds, sloped to drain to a sump to contain and clean up spills. • Emergency response personnel will be trained in appropriate measures to manage the cleanup of hazardous reagents.	4	2	8	Medium	
22	Processing	Operations	Spill of ore slurry	Release of ore slurry into the environment	EI	• All parts of the processing plant that require slurry for operation have been designated as wet areas for process plant design, designed with concrete floors with reinforced concrete containment bunds sloped to drain to sumps to contain and clean up spills. • Containment bunds will be sized to accommodate process spillage from overflow events or drainage of piping and vessels if required for maintenance.	4	1	4	Low	
23	Processing	Operations	Spill of concentrate	Release of metal concentrates into the environment	EI	• Concentrate will be produced within an enclosed building, limiting spill potential of concentrates. • The concentrate storage and loading facility will be equipped with roller doors to allow vehicle movements, but will be closed when loading of concentrates is in progress. • Prior to departing the concentrate loading facility, all vehicles will pass through a wheel wash facility to remove any fugitive concentrate dust. • Exhaust fans in concentrate building will have dust collection systems to remove entrained dust from air.	4	1	4	Low	
24	Processing	Operations	Excessive dust on ROM Pad	Permitted air quality standards exceeded	LO	• ROM pad sprinkler system will be constructed to allow wetting of ROM ore if dust is present. • Regular air quality monitoring.	4	2	8	Medium	
25	Processing	Operations	Personnel exposed to lead contamination through dust or concentrate exposure	Absorbed lead impacting human health	HHR	• Sitewide training on the hazards associated with lead. • Control of dust by water where appropriate. • Chute design and dust collection systems to filter out fugitive dust. • Promote proper hygiene practices (eg washing hands prior to eating). • Dirty coveralls to be changed and remain in mine dry prior to entering office area or camp facility. • Dirty coveralls to be washed on site, not returned to camp to be washed. • Regular monitoring of lead levels in blood for employees. • Employees given work in alternate areas if lead levels reach prescribed levels. • No smoking in designated areas (i.e. process plant and concentrate storage areas). • Mandatory wearing of dust masks in designated high risk areas.	3	2	6	Low	
26	Processing	Operations	Equipment (stationary or mobile) catches fire	Loss of equipment and impact on production	CC	• Fixed fire fighting facilities via hydrants installed around the processing plant facility. Fire water supply has been design to provide 400m3/hr for a two hour period. Water supply can be supplemented by open pit water trucks where access is available. • Appropriate maintenance processes and systems on site. All equipment maintained in accordance with law and manufacturers specifications. • Mobile equipment will be equipped with AFFF suppression systems as well as hand held extinguishers for treatment of small fires. • Mine rescue team, trained in fire fighting techniques, will be maintained on site with appropriate fire fighting equipment. • All site personnel to recieve basic fire fighting and first aid training.	3	2	6	Low	
27	Processing	Operations	Uncontrolled release of contaminated water from processing facility	Release of water to the environment that does not meet water quality objectives	EI	• Process plant site grading designed to slope to catchment sumps for containment and management of precipitation falling within the processing plant footprint. • Captured water will be transferred to the water treatment plant for treatment to meet site water quality objectives. • Project design ensures that no spillage can enter the natural environment before being processed and treated irrespective of where spillage occurs.	3	1	3	Very Low	

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

RISK REGISTER

RISK NO.	CATERGORY	PHASE	RISK DESCRIPTION	CONSEQUENCE	TYPE	KEY DEFENSIVE MEASURES IN PLACE	RISK RATING L	C	SCORE	CLASSIFICATION	COMMENTS
28	Processing	Operations	Inadequate tailings filtration capacity or performance	Tailings are not dewatered sufficiently for subsequent disposal in Class A storage facility	LO	• Final Filtration Filter equipment currently selected for the production of tailings has a spare capacity of 24%, after consideration of equipment availability and based on tailings filtration testwork completed to date. • Tailings dewatering depends to some extent on the density of the feed slurry. Process plant design includes significant redundancy to ensure that slurry feed to filters is optimised in both density and supply quantity. • Feed work to increase data on filtration performance, and filtration design may be updated depending on test results. • Additional tailings filtration tests will be completed in feasibility work to increase data on filtration performance, and filtration design may be updated depending on test results. • Revisions to design could include increasing filter sizes to increase spare capacity, allowing space in the plant footprint for the installation of additional filtration capacity if required in the future and reviewing filtration technology utilised. • Process plant throughput can be reduced to match tailings filtration capacity if this is determined to be a limiting factor.	3	2	6	Low	
29	Infrastructure	Operations	Spill of fuel from power generation fuel storage facilities (LNG or diesel)	Release of hydrocarbons into the environment	EI	• Fuel storage tanks are located within lined containment bunds with capacity of 110% of the stored fuel volume. • Transfer of fuel will take place on a concrete apron to contain spills and collect into a sump for subsequent management. • Spill kits will be available at fuel storage facilities for spill management. • If spilled, LNG fuel will evaporate as it absorbs heat from the environment.	3	2	6	Low	
30	Infrastructure	Operations	Failure of waste rock or tailings storage facility	Sloughing of waste or tailings into valley and Geona Creek	EI	• Excavation and removal of permafrost from facility footprint prior to construction. • Engineered design to meet a minimum Factor of Safety under static conditions of 1.5. • Water management integrated into facility design. • Compaction of tailings will be designed to achieve +90% of the optimum compaction limit. • Regular inspection and maintenance of waste storage facilities. • Design of overall site layout means that any failures of any type will result in the sloughing or waste or tailings being captured prior to uncontrolled release.	2	3	6	Low	
31	Infrastructure	Operations	Failure of waste rock or tailings storage facility	Sloughing of waste or tailings into valley and Geona Creek	EI	• Excavation and removal of permafrost from facility footprint prior to construction. • Engineered design to meet a minimum Factor of Safety under static conditions of 1.5. • Water management integrated into facility design. • Compaction of tailings will be designed to achieve +90% of the optimum compaction limit. • Regular inspection and maintenance of waste storage facilities. • Design of overall site layout means that any failures of any type will result in the sloughing or waste or tailings being captured prior to uncontrolled release.	2	3	6	Low	
32	Infrastructure	Operations	Loss of power generation for extended period of time	Loss of production and damage to Process Plant facilities due to material clogging plant equipment, flooding due to pumping facilities not functioning	CC	• Regular maintenance of generating equipment. • Redundancy in generating plant. • Backup generators for vital infrastructure. • Gravity bypasses (or spillways) for water storage equipment. • Backup furnaces for heating of vital areas.	3	2	6	Low	
33	Tranportation	Operations	Metal concentrates or mine consumables spilled onto land or water during transportation to / from site	Release of contaminants into the environment	EI	• Transportation to be conducted by appropriately trained contractors. • Spill kits to be carried on vehicles for goods carried. • Speed limits for site based travel, with Territorial / Provincial speed limits applying offsite. • Radio communication between vehicles on site access road. • Lead concentrates to be transported in sealed containers.	3	2	6	Low	
34	Tranportation	Operations	Vehicle collides with wildlife or another vehicle	Injury to personnel or wildlife, damage to equipment	EI / CC / HHS	• Transportation to be conducted by appropriately trained contractors. • Speed limits for site based travel, with Territorial / Provincial speed limits applying offsite. • Radio communication between vehicles on site access road. • Road access for majority of traffic is to be via the southern route to Watson Lake.	4	2	8	Medium	
35	Tranportation	Operations	Aircraft / helicopter accident	Injury to personnel	HHS	• Transportation to be conducted by appropriately trained providers. • Runway / helipad designed in accordance with relevant Canadian standards.	3	2	6	Low	

NOTES:
1. LIKELIHOOD, CONSEQUENCE AND RISK RATINGS BASED ON TABLES SUMMARIZED IN "RISK MATRIX' TAB.
2. C - CONSTRUCTION; O - OPERATIONS; CL - CLOSURE.

Appendix R2-C

KZK Project – Project Optimizations and Updated Water Quality Performance Expectations

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Memorandum

To: [Name Redacted]

From: [Name Redacted]

Date: November 15, 2017

Re: **Project Optimizations and Updated Water Quality Performance Expectations for Kudz Ze Kayah Project**

1. Introduction

This memorandum has been prepared in response to Adequacy Stage information requests (IRs) from the Yukon Environmental and Socio-economic Assessment Board (YESAB) Executive Committee regarding the Kudz Ze Kayah (KZK) Project Proposal (BMC, 2017 and YESAB, 2017). It specifically addresses the following information requests from YESAB's Adequacy Review Report – Information Request #2 (August 4, 2017):

- R2-16: Provide an updated Conceptual Reclamation and Closure Plan demonstrating that the mine site will remain chemically and physically stable in the long-term using proven technologies demonstrated to work in northern climates.
- R2-17b: Alternative closure approaches for the Kudz Ze Kayah site, demonstrating long-term chemical and physical stability, as an alternative to CWTS.
- R2-27: Clarify if the predicted concentrations at KZ-37 include any assumed mitigating effects from the proposed wetland treatment system and, if so, provide the untreated concentrations as well.
- R2-28: Demonstrate that the proposed liner system will be sufficient to direct seepage from the Class A and Class B facilities to the seepage collection ponds for treatment. This should be demonstrated for both the operational and closure facilities.
- R2-46: Provide an assessment of the long-term loadings and water quality associated with the acidic drainage that will eventually be produced in the A and B stockpiles as well as from the pit walls above the final water level.
- R2-47: Provide details on the assumed water quality adjustment factor. Discuss these factors in the context of the predicted effluent concentrations for an engineered wetland in Tables 4 and 5 of the Contango report (Appendix B – Conceptual Wetland Design - of Appendix H-1 Conceptual Reclamation and Closure Plan of the Project Proposal).
- R2-48: Please provide details of the basis of the coefficients in order to understand whether these are supported by appropriate data that are relevant to the proposed wetland treatment.

- R2-49: Also, now that the post closure water quality has been updated to reflect acidic drainage (see R106 above), please provide an update on the expected treatment effects for the site water.
- R2-50: Provide cold weather case studies for passive wetland treatment systems designed for acidic conditions as well as case studies for passive wetland treatment systems that have successfully transitioned from treating neutral drainage to effectively treating acidic drainage with increased metal loadings.
- R2-51: Provide some indication of treatment performance for the case histories presented or for other relevant treatment systems.
- R2-55: Provide justification and rationale for the proposed threshold criteria for surface water quantity and quality used to assess the magnitude of projected changes in the receiving environment.
- R2:60: Provide a report that details the proposed treatment methods, justifies site-specific treatment rate coefficients, and predicts the chemistry of the treated effluent. Based on the information in this report, provide an updated water quality model (i.e., with updated mine source loads) and, if necessary (e.g., if new contaminants of potential concern are identified), an updated water quality objectives report.

To address the information requests, the Project planning team evaluated several options aimed at improving the water quality performance from the Project, particularly in the closure phase. This included optimizations to the mine plan and to the Conceptual Reclamation and Closure Plan (RCP). Optimizations included both re-evaluation of proposed closure measures and the evaluation of new closure measures and alternatives to those initially proposed in the Project Proposal.

The water quality model utilized to evaluate the performance of these measures in terms of expected site drainage chemistry has been updated based on further Project planning and additional information collected from ongoing surveys and testwork. Section 2 of this memorandum outlines the components updated for the water quality model framework.

Section 3 of this memorandum outlines Project mine plan and closure plan optimizations evaluated to reduce constituent of potential interest (COPI) loading to the receiving environment. Section 4 presents the associated performance expectations for predicted drainage chemistry utilizing the updated water quality model for the optimized plan.

The optimized plan includes:

- Revised *in situ* ABM Pit treatment and constructed wetland treatment system efficiencies;
- Shotcreting of the ABM Pit wall;
- Revised performance of the liner at the base of the Class A and B Storage Facility;
- Revised performance of the Class A and Class B Storage Facility covers; and
- Constructed Wetland Treatment Systems.

2. WATER QUALITY MODEL UPDATES

The report entitled Water Quality Model - Kudz Ze Kayah Project (AEG, 2017) was submitted as Appendix D-7 of the Project Proposal. The following sections describe updates to the Project Water Quality Model since the submission of the Project Proposal and associated modelling repost. This includes updates to:

- Model source terms;
- Baseline water quality;
- Active water treatment performance; and
- Preliminary Water Quality Objectives.

Each of these model component updates are outlined in the sections following.

2.1 MODEL SOURCE TERMS

The COPI source terms were updated based on laboratory-based kinetic tests reported to August 10, 2017 (Table 2-1). These updates resulted in changes to COPI loading rates for the Class A, B and C Storage Facilities and the ABM Pit walls, which resulted in an updated set of COPIs. The acidic conditions COPI loading terms employed for the Class A and Class B Storage Facilities are based on sequential net acid generation data for Class A material and scalars provided from comparison of COPI release rates from kinetic trickle leach column C-7 under initial neutral and recent acidic conditions for Class B material as described in the response to YESAB IR106 and provided below a Table 2-2. Although kinetic tests have been commissioned that are designed to produce accelerated acidic conditions, insufficient data are available to provide robust acidic COPI source terms at this time; however, they will be incorporated into the revised water quality modelling once these tests stabilize. Acidic conditions were assumed to start in Year 15 for the Class A Storage Facility and Year 30 for the Class B Storage Facility.

Table 2-1: Summary of Kinetic Testing Program

	Sample ID	Geodomain [a]	Test Duration (in weeks)
Humidity Cell	HC-1	PY AK RHYv	60
	HC-2	CARB MDS/RHY	60
	HC-3	Tailings	54
Trickle Leach Column	C-1	Mainly AK RHYv	60
	C-2	Mainly PY AK RHYv + PY AK RHYc	60
	C-3	MU PY RHY only	64
	C-4	CARB MDS/RHY only	74
	C-5	Mainly PY AK RHYv	60
	C-6	Mix of geodomains	60
	C-7	Mainly CARB MDS/RHY + PY CL RHY	74
	C-8	RHYi only	68
	C-9	MDS only	51
	C-10	Tailings + class A waste rock	43
	C-11	CA CL MAF	34

[a] Description of geodomain rock characteristics can be found in Appendix D-5 of the Project Proposal (BMC, 2017)

Table 2-2: Acidic Loading Rates for Class A and Class B Storage Facilities

Loading Rate	Arsenic	Cadmium	Copper	Iron	Fluoride	Lead	Selenium	Zinc
	mg/kg/month							
Class A Neutral Drainage	0.00011	0.00021	0.00028	0.0032	0.0030	0.00062	0.0056	0.011
Class A Acidic Drainage	0.0098	0.0039	0.14	14	0.0057	0.10	0.0055	0.64
Class B Neutral Drainage	0.00010	0.00000026	0.0000014	0.0000074	0.00039	0.00000039	0.000011	0.000020
Class B Acidic Drainage	0.00086	0.0000011	0.00011	0.0060	0.00033	0.000020	0.0000052	0.00033

2.2 BASELINE WATER QUALITY

Baseline water quality used in the water quality model comprised historic data collected by Cominco in 1994-95 and more recent data collection by Alexco Environmental Group Inc. (AEG) starting in April 2015 has been updated to include monitoring data up to October 2017. The baseline water quality data set includes 12 samples for KZ-37, 49 samples for KZ-9, 53 samples for KZ-15 and 51 samples for KZ-26. The monthly median water quality data used in the water quality model is provided in Appendix A1.

2.3 ACTIVE WATER TREATMENT PLANT

The performance of the active water treatment plant has been updated based on the updated Water Treatment Summary Outline prepared by Integrated Sustainability Consultants Ltd. (Integrated Sustainability, 2017). This updated summary is provided as Appendix R2-D in BMC's second Response Report (BMC, 2017b). The water treatment plant COPI removal efficiencies are presented in Table 2-3. Arsenic was not included in the Water Treatment Summary Outline as arsenic treatment during operations is not required to meet pWQOs. The water treatment plant effluent for arsenic used in the model is included below in Table 2-3, which was originally outlined in *Water Quality Model, Kudz Ze Kayah Project* (AEG, 2017).

Table 2-3 KZK Water Treatment Plant Effluent Quality for COPIs

Parameter	Water Treatment Plant Effluent (mg/L)
Arsenic, total	0.0020
Cadmium, total	0.00045
Copper, total	0.002
Fluoride	0..015
Iron, total	0.01
Lead, total	0.001
Selenium, total	0.001
Zinc, total	0.14

2.4 WATER QUALITY OBJECTIVES

A preliminary water quality objective (pWQO) for iron was developed in response to the YESAB information requests (R2-26). As part of this process, the pWQOs for all parameters were updated with surface water quality baseline data collected up to October 2017, which comprises historic data collected by Cominco in 1994-95 and more recent data collection by AEG starting in April 2015.

When the preliminary water quality objectives (pWQO) were initially developed, insufficient baseline data had been collected at KZ-37 to formulate pWQOs for this site. Since then, 12 water quality samples have been collected (February to October 2017; Appendix A2) and the pWQOs were re-evaluated (Table 2-4). Baseline total iron concentrations at KZ-37 regularly exceed the Canadian Council of Ministers of the Environment (CCME) guideline for total iron (0.3 mg/L). Where baseline concentrations of a constituent routinely exceeded Canadian water quality guidelines, the background concentration procedure (BCP) was used to develop a site-specific water quality objective (SSWQO; AEG, 2016). Consistent with the CCME (2003) guidelines in developing SSWQO using the BCP, the 95th percentile of the baseline constituent concentration dataset was used as the statistical basis for the pWQO for parameters whose concentrations routinely exceed Canadian water quality guidelines (AEG, 2016). As such, the 95th percentile (1.27 mg/L) was selected as the pWQO for total iron at KZ-37.

The derivation of the pWQO for cadmium has also been updated since the initial water quality model to reflect the most recent research. A hardness-dependent guideline developed by BC Ministry of Environment (BCMOE, 2015) has been used for comparison with calculated cadmium concentrations. An updated preliminary water quality objectives report will be submitted to the YESAB Executive Committee prior to them issuing the draft screening report as part of BMC's response to YESAB IR R2-52.

Table 2-4: Preliminary Water Quality Objectives for COPIs at Site KZ-37

Parameter		KZ-37 (mg/L)	Source	KZ-37 pWQO Rationale
Arsenic, total	mg/L	0.005	CCME	CCME is most recent guideline
Cadmium, total	mg/L	Hardness dependent: (e[0.736 × ln(hardness*) – 4.943])/1000 for hardness between 3.4 and 285 mg/L	BCMOE	BCMOE is most recent guideline; BCMOE guideline developed for dissolved cadmium, so conservative when applied to total cadmium
Copper, total	mg/L	Hardness dependent: 0.002 mg/L at hardness <50 mg/L (0.04 * hardness)/1000 for hardness between 50 mg/L and 250 mg/L	BCMOE	BCMOE is most recent guideline
Iron, total	mg/L	1.27	95th percentile of water quality data collected to date	95th percentile is greater than generic guidelines
Fluoride	mg/L	0.12	CCME	CCME is the most recent guideline
Lead, total	mg/L	Hardness dependent; (3.31 + e[1.273 ln (hardness*) - 4.704])/1000 for hardness between 8 and 360 mg/L	BCMOE	BCMOE is most recent guideline
Selenium, total	mg/L	0.002 mg/L at sulphate ≤60 mg/L; (0.1736*[sulphate]0.597)/1000 at sulphate >60 mg/L	BCMOE and site specific water quality objective reported in AEG (2016)	BCMOE is most recent guideline and forms the lower threshold for sulphate <60 mg/L. At sulphate >60 mg/L, sulphate ameliorates selenium uptake
Zinc, total	mg/L	Hardness dependent; (7.5 + 0.75 (hardness* - 90))/1000 for hardness between 90 and 330 mg/L	BCMOE	BCMOE is most recent guideline

3. PROJECT OPTIMIZATIONS

The Project planning team evaluated a number of options aimed at improving the water quality performance of the Project, particularly in the closure phase. This included both newly considered measures (e.g. shotcreting pit walls) and optimizations for performance of measures already proposed in the Project Proposal, such as waste facility covers and liners. Details regarding how these Project optimizations were incorporated into the water quality modeling work and associated water quality calculations are presented in Section 4.

The following Project optimizations were re-evaluated and are now all proposed for Project closure:

- *In situ* treatment of ABM Lake;
- Applying shotcrete to ABM Pit Walls;
- Covers for Class A and B Storage Facilities;
- Liners for Class A and B Storage Facilities; and
- Constructed Wetland Treatment Systems.

Regarding optimized liners and covers, to date there has been no engineered design, modelling or testing of a specific cover for the facilities, nor of the saturated/unsaturated flow through the Class A or Class Waste Storage Facilities. The estimated or predicted reductions in infiltration and resultant water chemistry are based on industry experience and theoretical understanding of the controls. At this stage of the design, and without the engineering design and modelling, the approach to environmental predictions must be to define a reduction in loading, and then determine the reduction in flux that the constructed cover/liner system must achieve. At this point it is not possible to determine what a specified reduction in flux would equate to a reduction in loading.

There is experience to demonstrate that a very low permeability cover and a very low permeability liner can be designed and constructed e.g. landfills, uranium tailings facilities. The initial performance of the cover and liner depends on the “foundation” preparation (particularly for the underlying waste rock for a cover), the materials used for construction, and the construction quality controls. The longer-term performance depends on the maintenance of those covers and the facilities.

3.1 IN SITU TREATMENT OF ABM LAKE

In situ treatment is proposed to treat elevated COPI concentrations that are anticipated in ABM Lake at closure. As part of a wider YESAB adequacy IRs (R1-124, R2-60) regarding additional details to support the water treatment technologies proposed for the Project, examples of pit lake *in situ* treatment are summarized here to support the assumptions used in the water quality modelling. These also provide field scale evidence over the long term that *in situ* treatment is capable of treating the COPIs in the ABM Lake.

As part of the *in situ* treatment process, soluble organic carbon, such as alcohol and/or molasses, will be distributed throughout the ABM Lake, either via direct addition to the discharging Fault Creek water or via piping or water cannons, to stimulate native microorganisms to form reducing conditions in the water column. Enough organic carbon will be added to consume dissolved oxygen, nitrate and nitrite, and cause the partial conversion of some dissolved sulphate to sulphide. Under such reducing conditions, elements such as selenium and uranium are largely transformed to less soluble forms (e.g., elemental selenium and uraninite phases). Chalcophile elements such as cadmium, zinc, copper, antimony, and lead will precipitate as poorly soluble sulphide minerals. The insoluble phases formed will agglomerate and eventually settle to the lake bottom for long term storage. Over time, the initially amorphous metal sulphides will transition to more crystalline mineral assemblages that are less susceptible to remobilization. Settlement of organic matter from photosynthesizing algae in the surface photic layer of the lake will help bury the precipitated metal sulphides in the sediment column while also supplying labile organic matter to maintain reducing conditions in the sediment column under which the metal sulphides are stable. Reactive iron sulphide minerals will also form during treatment, which will help scavenge some COPIs via co-precipitation and also act as a sacrificial anode to maintain the reduced COPIs in their stable precipitated forms in the lake sediment.

The use of *in situ* treatment to significantly lower contaminant concentrations in pit lakes, underground mine workings, and shallow groundwater has been described in detail in numerous reports (Harrington et al, 2015; Lindsay, 2009; Murphy et al, 2008; Houston et al, 2005; Addison et al, 2005; Harrington et al, 2004; Saunders et al, 2004; Morie et al, 2004; Harrington, 2002; Harrington et al, 1999). In particular, *in situ* treatment has been successfully implemented at numerous pit lakes in the USA to treat the COPIs that are expected in ABM Lake (Harrington, 2002; Harrington et al., 2004, 2009). The pit lake at the Barite Hill gold mine (SC, USA) was subjected to *in situ* treatment. Prior to treatment, this pit lake was acidic (pH 1.5 to 2) and had high trace element concentrations (Table 3-1). Carbide lime was used to raise the pit lake pH closer to circumneutral conditions while injection of soluble organic carbon created sulphate-reducing conditions that sequestered the metals as metal sulphides and/or less soluble reduced phases. Comparison of constituent concentrations before and after *in situ* treatment indicated >70% removal of antimony from the pit lake water column and >90% removal was achieved for other metal(loid)s of concern (Table 3-1; Harrington et al., 2009).

Table 3-1: Barite Hill Pit Lake Constituent Concentrations Before and After *In Situ* Treatment (Harrington et al., 2009)

Parameter	Untreated	*In situ* treated	% reduction
	mg/L	mg/L	
Antimony	0.02	<0.006	>70%
Arsenic	0.968	<0.01	>99%
Cadmium	1.57	<0.005	>99%
Chromium	0.141	<0.01	>92%
Copper	287	<0.01	>99%
Lead	0.161	<0.01	>93%
Nickel	0.404	<0.02	>95%
Selenium	0.23	0.01	96%
Zinc	40.2	<0.02	>99%

The Anchor Hill pit lake at the Gilt Edge Mine Superfund site (SD, USA) was also subjected to *in situ* treatment to significantly lower elevated metal and nitrate concentrations. The acidic pit (pH 3) was treated with lime initially to raise the pH before methanol and molasses were added to stimulate the development of sulphate-reducing conditions and associated metals removal. This resulted in near complete nitrate removal (from 55 mg/L to 0.01 mg/L) and reductions in pit lake trace element concentrations of between 86% and >99% (Table 3-2; Harrington et al., 2009).

Table 3-2: Anchor Hill Pit Lake Constituent Concentrations Before and After *In Situ* Treatment (Harrington et al., 2004)

Parameter	Untreated maximum concentration	*In situ* treated maximum concentration	% reduction
	mg/L	mg/L	
Nitrate-N	55	0.013	>99%
Arsenic	0.017	Below detection [a]	-
Cadmium	0.284	0.007	98%
Copper	13.6	0.028	>99%
Lead	0.0281	Below detection [a]	-
Nickel	0.348	0.048	86%
Selenium	0.0222	<0.0009	>96%
Zinc	6.66	0.15	98%

[a] detection limit not reported

In situ treatment was also employed for the circumneutral pH pit lake at the Sweetwater uranium mine (WY, USA) to address elevated uranium and selenium concentrations. Addition of soluble organic carbon resulted in the decrease of nitrate-N concentrations from 1.1 mg/L to below detection within the first two weeks of treatment (Harrington, 2002). Within four months, uranium and selenium concentrations decreased from 8.4 mg/L to ~4.5 mg/L and 0.45 mg/L to ~0.005 mg/L, respectively, and have remained at those levels two years following *in situ* treatment (Harrington, 2002), with follow up sampling indicating that such levels have been maintained over a ten-year monitoring period.

It is important to note that both the Anchor Hill and Sweetwater pit lake locations experience cold winters similar to those of Kudz Ze Kayah. The pit lakes both freeze over during winter, but this has not impeded the COPI removal obtained by *in situ* treatment. Indeed, the ice cover may be viewed as beneficial in that it acts as a barrier to the mixing and diffusion of oxygen from the atmosphere into the lake. As such, carbon additions at both Anchor Hill and Sweetwater pit lakes were typically performed in the late summer or fall to prolong the period that the lake would remain reducing and therefore maximize COPI removal.

Although acidic conditions are not expected to develop in ABM Lake, in cases where the pit lake is strongly acidic (i.e. pH <4), alkali amendment has been used, sometimes with simultaneous organic carbon addition, to raise the pH to produce a more favourable environment for sulphate-reducing microorganisms. Such pre-treatment has been performed with a variety of alkali sources, including water treatment sludge residues, which may be a cost-effective solution and allow for conversion of voluminous lime-based treatment sludges into denser and more compact metal sulphide phases (e.g., Harrington et al., 2015). Although initial alkali pre-treatment of acidic pit lakes will result in a reduction in the concentration of many metals of concern, it is unlikely to significantly lower the concentrations of nitrate, selenium, and uranium, while elevated concentrations of some elements such as cadmium and zinc may persist at circumneutral pH; *in situ* treatment has been shown to effectively treat these constituents.

The percent removal anticipated for each parameter in ABM Lake that is used in the water quality modelling is presented in Table 3-3. These removal percentages are based on the presented field case studies, alongside experience of *in situ* treatment in other mine settings, and are considered conservative. It also should be noted that while continued low concentrations have been achieved elsewhere, on-going long-term monitoring and management of ABM Lake will be required to both ensure that treated parameter concentrations are sustained and inform any additional reagent injections to maintain the desired level of removal.

Table 3-3: Percent Reduction of Parameters Used in Water Quality Modelling of *In Situ* Treatment of ABM Lake

Parameter	In Situ Treatment Reduction (% Removal)
Nitrate-N	90%
Nitrite-N	90%
Ammonia-N	50%
Phosphorus	25%
Antimony	50%
Cadmium	90%
Copper	90%
Lead	90%
Nickel	50%
Selenium	90%
Uranium	50%
Zinc	90%

3.2 SHOTCRETE ABM PIT WALL

The ABM Lake contributes a sizeable proportion of the arsenic load experienced in the receiving environment and so the primary source of arsenic within the pit were examined. The calcite(CA)-chlorite(CL) mafic geodomain (CA CL MAF, Table 3-4 was found to contribute a significant fraction of the arsenic load. Therefore, it was assumed that shotcreting would be performed on CA CL MAF surfaces. It was assumed that shotcreting coverage was such that 90% of the load accumulated on the pit wall and floor surfaces was isolated, thereby conferring a 90% reduction in the COPI load that was dissolved into ABM Lake upon flooding of the ABM Pit and that runoff loading from shotcreted pit wall surfaces was also reduced by 90%.

Since the toxicity of many COPIs decreases with increasing water hardness (e.g., cadmium, copper, lead, zinc), an ancillary benefit of shotcreting would likely include an increase in hardness levels in ABM Lake due to calcium dissolution from the shotcrete. Equilibration of the shotcrete with ABM Lake waters would also provide alkalinity to ABM Lake, therefore offsetting any localized acid rock drainage from exposed ore, stockwork, or other acid generating rock. Although both these measures would provide additional water quality benefit to ABM Lake (and the downstream receiving environment), they have not been included in the modelling at present.

Table 3-4: Loading Rates used for ABM Pit Wall Runoff and Submerged Load Calculations based on Kinetic Testing

Geodomain	Arsenic	Cadmium	Copper	Fluoride	Iron	Lead	Selenium	Zinc
	mg/kg/wk							
AK RHYv/ AK RHYc	0.0000042	0.00000053	0.0000074	0.0014	0.000071	0.0000018	0.000041	0.000074
MU PY RHY	0.00059	0.00033	0.0015	0.0019	0.018	0.0034	0.00026	0.037
CARB MDS/RHY	0.00059	0.00033	0.0015	0.0017	0.018	0.0034	0.00049	0.037
PY AK RHYv/ PY AK RHYc	0.00024	0.00013	0.00062	0.0013	0.0072	0.0014	0.00015	0.015
PY CL RHY	0.0024	0.0013	0.0060	0.0037	0.072	0.014	0.00054	0.15
RHYi	0.0050	0.0000073	0.000016	0.0011	0.000071	0.000015	0.000032	0.00047
CA CL MAF	0.0048	0.00000032	0.000024	0.0012	0.00010	0.0000018	0.000025	0.000057
MDS	0.000062	0.00000060	0.000018	0.0026	0.000068	0.0000017	0.000063	0.000047

3.3 PERFORMANCE OF LINER BENEATH CLASS A AND B STORAGE FACILITIES

The Project Proposal described the liner underneath the Class A and B Storage Facilities to be constructed by removing the overburden to bedrock and a 1 m layer of low permeability glacial till placed and compacted in thin lifts, to provide a low permeability seepage barrier beneath the facility.

The model has been updated to include seepage from the liner at the base of the Class B Storage Facility for a design criteria of 75% reduction of mean annual precipitation with the seepage entering the groundwater system during operations, and emerging prior to KZ-37. The water quality model has continued to assume the Class A Storage Facility liner will prevent seepage from the facility to the groundwater system. The liner design will be constructed of suitable material, and carefully installed to ensure long term performance, such that it will prevent seepage from the base of the facility in operations and closure. The Class A liner design will be refined though the regulatory process to meet these demands.

3.4 IMPROVED CLOSURE COVER ON CLASS B STORAGE FACILITY

An improvement in WQ estimates from the Class B Waste Storage Facility was evaluated in the optimization, as requested by BMC. Originally, the load reduction from the Class B Facility was 75%; however, with an improved cover system, this was increased to a 98% load reduction. This change in load reduction from the Class B Storage Facility was modelled by adjusting the calculated COPI loads so that they are multiplied by 0.02 instead of 0.25 before they are added to the receiving environment.

The Class B Storage Facility has the potential to contribute a significant arsenic load to the receiving environment if unmitigated, particularly under acidic conditions, due to the propensity of the stored mafic volcanics (i.e., Calcite (CA)-Chlorite (CL) Mafic (MAF) geodomain) to leach arsenic. To achieve the original load reduction design requirement of 75% the original cover design proposed for the Class B Storage Facility was an “enhanced store-and-release” type cover system; this included an underlying 1.0 m layer of compacted till to minimize net percolation beneath a minimum of 3.0 m of Class C waste rock to act as a frost protection layer, with a surface layer of 0.3 m growth medium (Section 4.13.2.3 of Project Proposal; BMC, 2017). The performance of this cover was expected to provide at least a 75% reduction in net percolation (Section 7.4.3 of Appendix H to Project Proposal; BMC, 2017).

In order to improve this facility’s performance, reduce arsenic loading, and achieve the design requirement of 98% load reduction, a new cover system is proposed that must achieve a 98% reduction in net percolation. It is proposed that the Class B Storage Facility utilize the cover system that was originally proposed for the Class A Storage Facility. This multi-layer cover system includes a very low permeability layer, such as either a geosynthetic liner material (e.g., HDPE), a geosynthetic clay liner (GCL), or a highly modified soil layer that achieve the same reduction in net percolation as the geosynthetics. The stored material is then covered with a frost protection layer (≥3 m) and overlain by 0.3 m growth medium

3.5 REDUCED LOAD FROM CLASS A STORAGE FACILITY COVER WITH REVISED BASE LINER

An improvement in WQ estimates from the Class A Waste Storage Facility was evaluated in the optimization, as requested by BMC. Originally, the load reduction from the Class A Facility was 98%; however, with an improved cover system, this was increased to be a 99.5% load reduction. This change in load reduction from the Class A Storage Facility was modelled by adjusting the calculated COPI loads so that they are multiplied by 0.005 instead of 0.02 before they are added to the receiving environment.

To achieve this load reduction design requirement the Class A Storage Facility requires a multi-layer cover system with a very low permeability layer, such as either a geosynthetic liner material (e.g., HDPE), a geosynthetic clay liner (GCL), or a composite cover that would reduce the net percolation by a minimum of 98% (Section 7.4.2 of Appendix H to Project Proposal; BMC, 2017). This may be achieved through selection of geosynthetics with very low hydraulic conductivities, typically geomembranes can achieve hydraulic conductivities in the order of 10^{-13} to 10^{-15} m/s (Haug and Pauls, 2002). Seepage through geomembranes is primarily due to defects which may have resulted from tears, punctures or improper welding of seams. Proper maintenance and monitoring are required to achieve this performance in the long term, however some estimates of the half-life of an HDPE geomembrane, for example, are 450 years in a landfill application (Koerner, R.M. et al., 2016).

Geosynthetic clay layers (GCL) have been observed to achieve hydraulic conductivities in the order of 10^{-10} to 10^{-11} m/s (Benson et al., 2011). However, maintaining these hydraulic conductivities over time is heavily dependent on proper installation, and the ability to maintain hydration of the GCL, which can increase hydraulic conductivities by as much as 5 orders of magnitude (10^{-13} m/s) (Rowe, 2014). In situations where it is critical that very low net percolation be achieved and maintained, GCLs are best used as a composite liner, where they are overlain by a geomembrane, such as PVC, LLDPE, or HDPE (Rowe, 2014). The United States Environmental Protection Agency (USEPA) conducted an Alternative Cover Assessment Program (ACAP) at 12 field sites nationwide. Two of these sites were geomembrane and GCL composite covers which were run for more than 3 years. During that period there was no percolation through either of the composite cover systems was measured (Albright, W.H. et al., 2010).

The Grum Sulphide cell at the Faro mine was covered with a 60 mil HDPE geosynthetic liner in 2010 and results indicate the cover achieved a reduction of surface water infiltration to less than 0.5% of mean annual precipitation. 60 mil HDPE liners have also successfully reduced net percolation to less than 0.1% of precipitation at the Franklin and Victoria Junction mines in Nova Scotia (Meiers et al., 2016).

Installation instruction and quality control checks during installation will be outlined during detailed design and will be part of the construction drawings, to ensure that the cover system achieves the design criteria. BMC will undertake engineering studies to refine the design to confirm the performance of the proposed cover, which will determine final cover design. Section 2.5.1 of Appendix H to Project Proposal; (BMC, 2017) presents the details regarding the approach for the reclamation research plan for waste cover systems.

As outlined in section 3.3 the performance of the liner at the base of the facility has been revised to prevent seepage from leaving the facility and entering the groundwater system. Therefore, the liner will provide additional control, on top of the seepage control the cover provides.

3.6 CONSTRUCTED WETLAND TREATMENT SYSTEMS

YESAB have requested additional information regarding the assumed treatment factors of the proposed constructed wetland treatment systems (CWTS). Information requests R2-47 through R2-51 inclusive are related to assumed and modelled treatment performance for the CWTSs. These requests are identified in Section 1 of this report.

Wetland treatment assumptions were one of the topics discussed on September 21st, 2017 in an in-person meeting at the YESAB head office between BMC representatives and YESAB and their technical reviewers for water-related IRs. On October 171717, 2017, YESAB provided (via email) the following clarification regarding the information required in response to R2-49:

> *"In the technical meeting, we indicated that we have concerns that the environmental assessment presented by BMC is optimistic and that over the long-term drainage from the Class A and B storage areas will become acidic. This would have implications for the constructed wetland treatment system and its efficiency and managing drainage.*
>
> *BMC indicated that they have done further modeling, which will show that they don't anticipate having acidic drainage entering the wetlands or groundwater. There will be a revised set of predictions that encompass some project refinements (e.g., acidic source terms) and they will be accounted for and presented within the model. This will show that wetlands will not have acidic conditions and that they are not as influential or necessary as assumed.*
>
> *This approach may satisfy our requirements under R2-49. However, it will depend on how the revised water quality predictions and further modeling are presented. We still have the concern that in the long-term the site will produce acidic drainage."*

This Section will address the information requests related to treatment factors and substantiation for the values utilized.

Section 4 presents the updated water quality performance expectations with updates for water quality predictions that incorporate CWTS treatment (using the updated information in this Section), and a set of water quality predictions without CWTS treatment.

3.6.1 Treatment Factors

Passive treatment of water leaving the Project site was modelled to occur in two CWTSs. The "South Wetland" located north and downstream of the ABM Lake was modelled to treat outflow from ABM Lake during post-closure. The "North Wetland" to be constructed in the footprint of the Lower Water Management Pond was modelled to treat the combined flow from the Class A, and Class B Storage Facilities and the flow from the South Wetland. The drainage from the Class C Storage Facility was modelled to bypass the North Wetland.

Outflow concentrations from the CWTSs were determined with treatment rate coefficients (k) that are based on site-specific factors and projects with similar chemistry and conditions, as originally described in the Conceptual Wetland Design Report (Contango Strategies Ltd., Appendix B of Appendix H-1 of the RCP of the Project Proposal). For conceptual design, proxies were applied from projects with similar chemistry and conditions. Table 3-5 below has been updated from Appendix B of Appendix H-1 of the RCP to reflect updates to the k-rates utilized in the initial water quality modeling. Treatment rate coefficients have been updated owing to the availability of additional information from peer-reviewed publications, and from further progress in ongoing pilot- and demonstration-scale (on-site and off-site) testing at various mines across Canada. Two k-values from literature are now applied (arsenic and lead), while cadmium, copper, selenium, and zinc have been updated based on additional pilot and demonstration scale testing performed by Contango Strategies Ltd. (Contango) in 2015-2017 for other relevant sites.

Table 3-5: Elements considered in treatment wetland modeling, with respective first-order treatment rate coefficient (*k*) values and reference information

Element	*k* (days^{-1})	Average C_i (mg/L)	Average C_f (mg/L)	HRT (days)	Source
As	0.077	0.145	0.128	4.0	Schwindaman et al.[1]
Cd	0.480	0.00284	0.000113	8.1	Other pilot and demonstration testing[2]
Cu	0.480	2.00	0.0487	8.5	Other pilot and demonstration testing[2]
Pb	0.723	0.744	<0.006	N/A	Rodgers and Castle[3]
Se	0.456	0.00662	0.000873	8.1	Other pilot and demonstration testing[3]
Zn	0.480	0.002	0.00008	7.4	Other pilot and demonstration testing[3]

k – treatment rate coefficient (these are rounded for use as proxies and include factors additional to the C_i, C_f, and HRT provided); Ci – inflow concentration (average); Cf – outflow concentration (average); HRT – hydraulic retention time.
[1] Schwindaman et al, 2014.
[2] Derived from pilot- and demonstration-scale testing done by Contango for other projects in Northern Canada.
[3] Rodgers and Castle, 2008. Warm climate biological treatment in CWTS, with 25% inefficiency factor applied for conservatism.

It should also be noted that arsenic, and selenium have been changed from zero-order to first-order to reflect a recent peer-reviewed publication (Schwindaman et al, 2014) and that the k-rate previously provided for arsenic (0.01023) was erroneous, and should have been 0.1023. Selenium has been updated to a first-order reaction kinetic based on advances in pilot- and demonstration-scale testing performed at Contango in 2015 – 2017. Iron is currently not modelled to be treated as it passes through the CWTS, which is viewed as conservative since iron precipitation and particulate settling would likely occur at circumneutral pH during its passage through the CWTS.

The water quality model assumes that the CWTS does not produce concentrations lower than a constituent's pWQO. That is to say if a COPI CWTS treatment factor is calculated to lower the COPI concentration below its pWQO, the model instead fixes the CWTS outflow concentration at the pWQO concentration; similarly, if the influent COPI concentration is at or below its pWQO, the COPI concentration is modelled to pass unchanged through the CWTS). This lends some further conservatism to the CWTS treated concentrations.

3.6.2 Seasonal Treatment Considerations

BMC's initial response to IR109 regarding cold climate performance of treatment wetlands included the following summary table and is reproduced here as Table 3-6, with additional supporting information included and provided in the sections following.

Table 3-6: Summary of Selected Wetland Case Studies/References.

Water Source	Location	Constituents (mg/L) [1]						Wetland Type	Comments	Reference
		As	Cd	Se	Pb	Zn	Cu			
Copper Mine	Minto Mine, YT	n/a	0.000336 to 0.000027	0.01 to 0.006	0.00059 to 0.00020	0.04 to 0.0032	0.15 to 0.013	Pilot Scale	Designed to mimic worst-case post-closure water quality	Haakensen et.al., 2015
		n/a	0.000022 to 0.000008	0.0052 to 0.0033	0.00005 to 0.00003	0.03762 to 0.01224	0.0461 to 0.0288 (D-Cu)	Demonstration scale	Spring/Summer/Fall trial using combined waste rock and dry tailings seepage water	Haakensen et.al., 2015
Smelter landfill	Trail, BC	150 to <0.5	4.7 to <0.02	n/a	n/a	n/a	n/a	On-site pilot scale	Year-round treatment, 15,000 L/d	Duncan (2010)
Gold-cobalt-bismuth-copper mine	Fortune Minerals Mine, NWT	0.48 to 0.11	n/a	n/a	n/a	n/a	n/a	Natural wetland	Information from natural wetland treatment utilized for pilot-scale design and testing	Contango (2014)
Silver-copper-bismuth mine	Terra mine, NWT	0.05-0.08 to 0.005-0.07	n/a	n/a	n/a	n/a	n/a	Natural wetland	Natural wetland receiving mine tailing discharge	Sealey (2011)
Gold mine	Finland – Peatland 1	0.041 to 0.0082	n/a	n/a	n/a	n/a	n/a	Full scale	Natural peat wetlands receiving mine tailings discharge. Year round treatment with snow cover from November to May and mean annual temperatures between -3°C and 6°C.	Palmer et al. (2015)
	Finland – Peatland 4	0.14 to 0.014	n/a	n/a	n/a	n/a	n/a			
Uranium mine	Curilo, Western Bulgaria	0.01-0.59 to <0.01-<0.1	0.01-0.12 to <0.01	n/a	n/a	n/a	n/a	Full-scale	Natural and CWTS receiving mine tailings discharge	Groudev et al. (2008)
Mine, milling, and smelting discharge	Butte Hill, Colorado	25.5 to 11.9 (CT)[2]	40.5 to 0.51; 39.6 to 1.2[2]	n/a	n/a	n/a	n/a	Demonstration-scale	Series of CWTS receiving mine, milling, and smelting discharge	Gammons et al. (2000)
Natural runoff and agricultural irrigation drainage	Great Falls, Montana	n/a	n/a	0.026 to <0.001	n/a	n/a	n/a	Full-scale	Engineered natural system separated into 6 ponds using dikes.	Zhang and Moore (1996)

Based on YESAB's review of BMC's response IR109, YESAB requested additional information (R2-50 and R2-51). Rationale for requesting further supporting information on the examples presented above suggested that no indication of treatment performance was provided for these examples:

> *"While some case histories are presented for cold climate wetland type treatment systems, there is no indication of performance in the information provided. Therefore, although examples are given, there is no indication of the success of the wetland type treatment under the conditions described".*

Table 3-6 did identify this information (in the columns under Constituents), but the following additional information is provided for each of these examples below, referring to particular aspects of the treatment example that is relevant to the proposed system and conditions at Kudz Ze Kayah. The results over multiple seasonal conditions support the effectiveness of treatment of COPIs in cold climates.

Despite these examples, a conservative approach to CWTS treatment was adopted and we no longer assume the CWTS to be active during winter months (November through April) due to the potential for ice build-up and overflow of the CWTS. While treatment of seepage through the CWTS would still likely occur under an ice cover, no treatment was assumed as a conservative measure to account for the possibility of CWTS overflow. In the modelling of the receiving environment water quality (Section 4), the expected COPI concentrations at KZ-37 are presented with and without the benefit of the CWTS.

Copper Mine, Minto Mine, Yukon Territory

The Minto Mine is an open pit and subsurface copper mine that has several constituents in water for which treatment is desired, including Cd, Se, NO_3, and Zn. Upon closure, it is planned that some of the mine contact water will be treated by CWTS. Following a site visit in which vegetation and natural treatment processes were identified, pilot-scale testing was undertaken. Pilot-scale testing determined that plants, including *Carex aquatilis* and aquatic bryophytes (moss), and beneficial microbes found at the Minto site could be used to ameliorate the quality of mine drainage in a CWTS (Contango, 2014b). During off-site (controlled climate) pilot-scale testing, the selected CWTS design achieved on average 92% removal of cadmium, 41% removal of selenium, and 92% removal of zinc, using synthetic influent designed to mimic the worst-case water chemistry of a long-term closure scenario (Haakensen et.al., 2015)

A demonstration-scale CWTS was constructed on site at the Minto Mine in fall 2014 (Contango, 2015), and has operated since (now winter 2017). Due to elevated concentrations of copper in the substrates used for construction, an extended commissioning period was undertaken from Sept 2014-2016 to allow establishment of plants and microbes as well as maturation of the CWTS (aging of copper into stable sulphide mineral forms). The results of the on-site demonstration-scale CWTS performance indicated that the CWTS has matured as expected, and is beginning to treat constituents). Although still being in a commissioning phase, by the end of 2016, treatment of constituents was continuously improving, with on average 64% removal of cadmium, 41% removal of selenium, and 69% removal of zinc achieved (Contango, 2017b). As the commissioning period is still in effect, the removal of constituents is expected to continue to improve through operations.

Smelter Landfill, Trail BC

A large on-site demonstration-scale wetland system was built at the Trail Smelter in British Columbia to collect and divert contaminated seepage water for treatment of high concentrations of zinc, arsenic, and cadmium (Duncan, 2010). The final system configuration consisted of two vertical upflow anaerobic (compost) biochemical reactors (BCR) followed by three horizontal subsurface flow vegetated wetland cells, a slow sand filter, and a final holding cell. The system received seepage with up to 3,800 mg/L (average 260 mg/L) of zinc, and up to 3,600 mg/L (average 150 mg/L) of arsenic, and reduced both constituents to <0.5 mg/L. The system also received cadmium concentrations up to 83 mg/L (average 4.7 mg/L) and decreased concentrations to <0.02 mg/L.

The treatment train design at the smelter landfill was successful with a series of treatment cells built, and each cell addressing specific contaminants. In order for these types of treatment trains to be successful, the placement of the treatment cells in the series was a fundamental design consideration. An additional consideration for the design of the wetland system included frost penetration into the wetland sediment, which could restrict efficiency of the CWTS. It was recommended to bury BCR or install permeable reactive barriers close to the seep to prevent freezing and contain any heat in the seepage or groundwater source.

Based on the information gathered through the implementation of the on-site pilot-scale passive treatment system, it was determined that anaerobic bioreactors are finite, but can be designed to last over 20 years, while vegetated wetlands should be able to last 100's of years.

The conceptual CWTS design proposed for KZK includes the use of a treatment train, with treatment primarily occurring in-pit and the CWTSs used as secondary treatment and/or polishing. Use of a treatment train is supported by the work done at the Trail Smelter.

Gold-Cobalt-Bismuth-Copper Mine, Fortune Minerals, NT

CWTS were identified as a potential closure water treatment strategy for the Fortune Minerals NICO gold-cobalt-bismuth-copper project (NICO Project) northwest of Yellowknife. Water entering a wetland system at the NICO site contained naturally elevated concentrations of arsenic (>480 µg/L), and as the water passed through the natural wetlands, this concentration decreased; however, it was not known whether certain regions or features of the natural wetland system were responsible for treatment. A site visit was conducted to identify natural water treatment processes that were occurring at the NICO site within the wetland system, and determine how these could be optimized in the design of a CWTS for passive water treatment (Contango, 2014).

Arsenic was found to be naturally removed from the water through the wetlands, decreasing to 110 µg/L with oxidizing conditions, presumably by binding to iron-oxides. The natural wetlands were also found to be removing other constituents through precipitation as sulphides. These findings informed pilot-scale testing of CWTS designs that incorporated oxidizing cells followed by reducing cells for removal of other constituents of concern in closure.

The success of the NICO site with removal of arsenic in a wetland system supports the use of CWTS in the similar cold, northern climate found at KZK.

Silver-Copper-Bismuth Mine, Terra Mine, NWT

A natural wetland 390 km northwest of Yellowknife was receiving water from a lake previously used as a tailings storage pond (Sealey, 2011). This natural wetland was studied and many insights were gained into the conditions under which arsenic can be treated. A concentration of 50-80 µg/L of arsenic in the surface water entering the natural wetland was decreased to 5-75 µg/L when the surface water discharged from the wetland (Sealey, 2011). The variability of arsenic concentrations in surface water were found to be influenced by seasonal variations, and physicochemical properties associated with periods with and without treatment were identified. These insights can be applied to a CWTS designed to target arsenic removal so that mobilization of arsenic is minimized and sequestration is maximized.

Gold Mine, Finland

Natural peatlands located near a gold mine operating in Finnish Lappland at latitude of 68° north have been used for water treatment since 2008 (Palmer et al., 2015). The mine drainage is being treated by two peatlands (peatland 1 and peatland 4) prior to discharge into a nearby river. Peatland 1, initiated for treatment purposes in 2008, is 17 ha in area and receives 6,500 m^3/d of drainage water from open pits and underground mining. Peatland 4, initiated for treatment purposes in 2010, is 44 ha in area and receives 2700 m^3/d of mine-process water that has been pre-treated in a tailings pond. On average, 82% of incoming arsenic, 28% of incoming antimony, and 76% of incoming nickel was retained in peatland 1. On average, 90% of incoming arsenic, 81% of incoming antimony, and 90% of incoming nickel was retained in peatland 4. These constituents were bound to the surface layer of the peat soil. The majority of the contaminants were retained near the inflow area and decreased in concentration with increasing distance (from inflow).

The peatlands operated until 2013 and effectively retained contaminants (arsenic, antimony, and nickel) from mine waters for 4 to 6 years, however, the retention efficiencies for different contaminants were temporally variable between the two peatlands. The peatlands' ability to remove high concentrations of these constituents was theorized to be due to the high adsorptive capacity of the porous peat soils. However, constituents such as iron and sulphur were retained less effectively by the peatlands. Further studies into the removal efficiencies, capacities, and leaching risks were identified as key future activities to be undertaken.

Uranium Mine, Curilo, Western Bulgaria

Acid mine drainage originating from long term intensive uranium mining activities in Curilo, Bulgaria, was high in heavy metals including cadmium, copper, cobalt, iron, manganese, nickel, lead and zinc as well as arsenic and sulphate. A portion of the mining effluent was treated by natural and constructed wetlands. Data were collected from within the wetlands over a period of 10 years, covering all seasonal temperature fluctuations. Several natural wetlands (with surface areas from less than 100 m^2 to approximately 600 m^2) and four constructed wetlands (the largest of which is 25 m long and 4 to 6 m wide), predominantly vegetated with *Phragmites australis*, *Typha latifolia*, and *Typha angustifolia*, were utilized in treating mine effluent. The flow rate in the constructed wetland during the study period ranged from 0.2 to 1.0 L/s. Water quality parameters, including pH, Eh, dissolved oxygen, temperature, and total dissolved solids, were monitored at various points at the inlet and outlet of the systems, as well as at various depths within the systems, and a sequential extraction procedure was performed on the solids to determine the mobility of the contaminants within the soil column.

The contaminants were efficiently removed within the wetland, as the concentrations for most constituents within the wetland effluent were decreased to below the permissible level. The constituent removal efficiency was dependent on temperature, although, effective removal was also seen in cold winter months (with ambient temperatures close to 0^{o}C). Constituent removal in the wetland was predominantly attributed to microbial dissimilatory sulphate reduction (heavy metals precipitation as insoluble sulphide minerals) and sorption. The content of sulphate reducing bacteria increased throughout the flow of the wetland.

3.6.3 Summary

Even with the revisions to the water quality modeling identified in Section 2 and their results presented in Section 4, the COPI list and concentrations expected in terms of influent to the CWTSs have not changed substantially enough to change the relevance and appropriateness of the examples cited in the previous table. The load reduction targets modeled for the wetlands proposed for the Project are modest in comparison to actual examples, and but are proposed to work in conjunction with the other key closure water quality mitigation measures (i.e. facility design, source control and *in situ* treatment). The CWTSs themselves are not critical on their own to overall site water quality performance in the closure condition, and as such the examples cited and their performance referenced are appropriate analogs for predicting performance of these installations at Kudz Ze Kayah. BMC is currently planning for the initiation of the next phase of CWTS research for the Project (pilot scale testing), which will further refine the site-specific performance expectations, as outlined in the RCP, Section 2.5 of Appendix H to the Project Proposal (Conceptual Reclamation and Closure Plan). The next phase will be initiated in 2018.

4. OPTIMIZED PLAN EXPECTED WATER QUALITY PERFORMANCE

The optimizations identified in Section 3 are combined here with associated estimates of water quality performance for a range of parameters. These water quality predictions were generated using the updated water quality model. Concentrations for arsenic, cadmium, copper, fluoride, lead, selenium, and zinc are presented in this Section, as these are the parameters estimated to exceed their respective pWQO in the receiving environment (as calculated at one of the following stations: KZ-37, KZ-15 and KZ-26) without the modelled load reduction expected from the CWTSs. Additionally, iron is presented as part of the response to R2-26.

4.1 OPTIMIZED PLAN – SHOTCRETE HIGH ARSENIC LEACHING SURFACES OF ABM PIT, AND REDUCED INFILTRATION RATE FOR CLASS A AND B FACILITY COVERS

This Section presents the COPI concentrations modelled for the optimized plan that consists of applying shotcrete to potentially high arsenic leaching surfaces of the ABM Pit (Section 3.2), reduced loading rates through the Class A and Class B Storage Facility through improved cover and liner (Sections 3.4 and 3.5) and the revised CWTS treatment factors (Section 3.6). The optimized plan also includes seepage rate from the Class B Storage Facility liner (Section 3.3) and revised water treatment plant performance (Section 2.3). The results have been compared to the revised preliminary water quality objectives outlined in Section 2.4.

4.1.1 Results

The modelled concentrations in the receiving environment at KZ-37 for each COPI with and without CWTS treatment are shown in As such, CWTS treatment minimized arsenic, cadmium, and zinc exceedances.

Without CWTS treatment, iron was calculated to be below its pWQO year-round (Figure 4-2). Fluoride was calculated to be below its pWQO for nine months of the year and marginally exceed the pWQO by 3 to 23% from January to March (Figure 4-3).

Table 4-1 and discussed in Sections 4.1.1.1 and 4.1.1.2 for the 1 in 10 dry year (as it is the most sensitive scenario modelled) for the Project.

With CWTS Treatment for 1 in 10 year dry scenario

With this optimised plan, post-closure copper, iron, lead and selenium were calculated to not exceed their respective pWQOs at KZ-37 (Figure 4-1 and Figure 4-2). Calculated cadmium concentrations were below the cadmium pWQO for nine months of the year (Figure 4-1). The calculated cadmium concentration was 1.1 to 1.5 times the cadmium pWQO during May through July. Zinc was below its pWQO in all but one month (12% over the pWQO in June) (Figure 4-3). Arsenic was calculated to be below its pWQO for six months of the year but slightly exceed (6 to 34% greater than pWQO) in February and May through September (Figure 4-1).

Without CWTS Treatment for 1 in 10 year dry scenario

In the absence of CWTS treatment, selenium concentrations were still calculated to be below the selenium pWQO year-round during post-closure for this optimized plan (Figure 4-2). Copper and lead which were not calculated to exceed their respective pWQOs with CWTS treatment were calculated to exceed the pWQO for copper by 2 to 7% in May and June and the pWQO for lead by 12% to 48% in May through July (Figure 4-1 and Figure 4-2). Zinc was calculated to be below its pWQO for nine months of the year with CWTS treatment and exceed its pWQO by 1 to 51% in May through July (Figure 4-3). Cadmium was calculated to exceed its pWQO for five months of the year (May to September) by 1.4 to 2.1 times the pWQO (Figure 4-1). Without CWTS treatment, post-closure arsenic concentrations (0.0065 to 0.011mg/L) exceeded the pWQO (0.005 mg/L) year-round by a maximum of 2.2 times the pWQO (Figure 4-1). As such, CWTS treatment minimized arsenic, cadmium, and zinc exceedances.

Without CWTS treatment, iron was calculated to be below its pWQO year-round (Figure 4-2). Fluoride was calculated to be below its pWQO for nine months of the year and marginally exceed the pWQO by 3 to 23% from January to March (Figure 4-3).

Table 4-1: Model Calculated Post-Closure Annual Maximum and Median COPI Concentrations at KZ-37 with and without CWTS Treatment for 1 in 10 Dry Year

COPI	Without CWTS (mg/L)		With CWTS (mg/L)		Average CWTS % Reduction
	Max	Median	Max	Median	
Arsenic	0.011	0.0073	0.0067	0.0050	32%
Cadmium	0.00072	0.00027	0.00047	0.00027	16%
Copper	0.021	0.0035	0.014	0.0030	19%
Fluoride	0.15	0.11	0.15	0.11	0%
Iron	0.43	0.022	0.43	0.22	0%
Lead	0.015	0.0028	0.009	0.0023	25%
Selenium	0.0016	0.0013	0.0016	0.0013	0%
Zinc	0.10	0.024	0.074	0.035	29%

4.1.2 Summary

Reviewing the water quality changes in the receiving environment under this optimized plan, the following observations can be made at KZ-37 for the 1/10 dry year model:

- Arsenic concentrations were calculated to be below its pWQO for six months of the year (6 to 34% over pWQO); however, CWTS treatment was required to meet the arsenic pWQO in the other six months of the year;
- Cadmium concentrations were calculated to be below its pWQO for nine months of the year with CWTS treatment exceeding the pWQO May to July (1.1 to 1.5 times the pWQO). Without CWTS

treatment, cadmium concentrations were calculated to be below its pWQO for seven months of the year and exceed May through September (1.4 to 2.1 times the pWQO);

- Copper concentrations were calculated to be below the pWQO year-round with CWTS treatment and, without CWTS treatment, only fractionally exceed the pWQO in May and June by 2 to 7% over pWQO;
- Iron concentrations were calculated to be below the pWQO year-round with this optimization plan;
- Lead concentrations were calculated to be below the pWQO year-round with CWTS treatment and for three months of the year without CWTS treatment (exceeding the pWQO in May through July by a maximum 1.5 times);
- Selenium concentrations were calculated to be below the pWQO year-round with this optimized plan both with and without CWTS treatment;
- Zinc concentrations were calculated to exceed the pWQO by 1.1-fold May with CWTS treatment and by a maximum of 1.5 times the pWQO for three months of the year without CWTS treatment; and
- Fluoride concentrations were calculated to be below the pWQO (0.12 mg/L) for nine months of the year and marginally exceed the pWQO from January to March by 3 to 23%.

The following observations can be made at KZ-37 for the mean precipitation year model:

- Arsenic concentrations were calculated to be below the pWQO (0.005 mg/L) for five months with CWTS treatment with exceedances March through September (<1 to 32% over pWQO) and were calculated to exceed the pWQO year-round without CWTS treatment by a maximum of 1.9-fold;
- Cadmium concentrations were calculated to be below the pWQO for 10 months of the year with CWTS treatment (exceeding the pWQO in May and June by 1.3 times) and were calculated to be below the pWQO for seven months of the year without CWTS treatment (exceeding the pWQO in May through September by a maximum of 1.7 times);
- Copper was calculated to be below the pWQO year-round with and without CWTS treatment;
- Iron concentrations were calculated to be below the pWQO year-round;
- Lead was calculated to be below the pWQO for year-round with CWTS treatment and was calculated to be below the pWQO for 10 months of the year without CWTS treatment (13 to 17% over pWQO in June and July);
- Selenium was calculated to be below the pWQO year-round with and without CWTS treatment;
- Zinc was calculated to be below the pWQO for 11 months of the year with CWTS treatment (11% over the pWQO in June) and was calculated to be below the pWQO for ten months of the year without CWTS treatment (4 to 24% over the pWQO in May and June); and
- Fluoride was calculated to be below the pWQO (0.12 mg/L) for ten months of the year with marginal exceedances of the pWQO by 1 to 16% in February and March.

The following observations can be made at KZ-37 for the 1/50 wet year precipitation model:

- Arsenic concentrations were calculated to be below the pWQO (0.005 mg/L) for nine months of the year with CWTS treatment and above the pWQO for 11 months of the year by a maximum of 1.9 times the pWQO without CWTS treatment;
- Cadmium concentrations were calculated to be below the pWQO year-round with CWTS treatment and below the pWQO for ten months of the year without CWTS (20 to 35% over the pWQO in May and June);
- Copper concentrations were calculated to be below the pWQO year-round with and without CWTS treatment;
- Iron concentrations were calculated to be below the pWQO year-round;
- Lead concentrations were calculated to be below the pWQO year-round with and without CWTS treatment;
- Selenium concentrations were calculated to be below the pWQO year-round with and without CWTS treatment;
- Zinc concentrations were calculated to be below the pWQO year-round with and without CWTS treatment; and
- Fluoride concentrations were calculated to be below the pWQO (0.12 mg/L) for ten months of the year with marginal exceedances of the pWQO by 3 to 19% in February and March.

All COPIs were calculated to be below pWQOs in Finlayson Creek at KZ-15 and KZ-26 for the mean, 1/10 dry year and 1/50 wet year precipitation models with the exception of fluoride. Fluoride was calculated to marginally exceed the pWQO (0.12 mg/L) in the 1/10 dry scenario at KZ-15 for four months (January to April; 0.125 to 0.143 mg/L calculated), in the mean precipitation scenario for three months (February to April; 0.121 to 0.134 mg/L) and in the 1/50 wet precipitation scenario three months (February to April; 0.121 to 0.134 mg/L). Fluoride was also calculated to exceed the pWQO at KZ-26 (0.133 mg/L) for three months in the dry precipitation model (February to April; 0.135 to 0.142 mg/L calculated) and for one month in the mean and 1/50 wet precipitation models (April; 0.134 and 0.141 mg/L). These exceedances of fluoride pWQOs at KZ-15 and KZ-26 are primarily due to the naturally high baseline fluoride concentration observed in Finlayson Creek in the winter months. Model calculated fluoride concentrations are only marginally higher than baseline fluoride concentrations for those months.

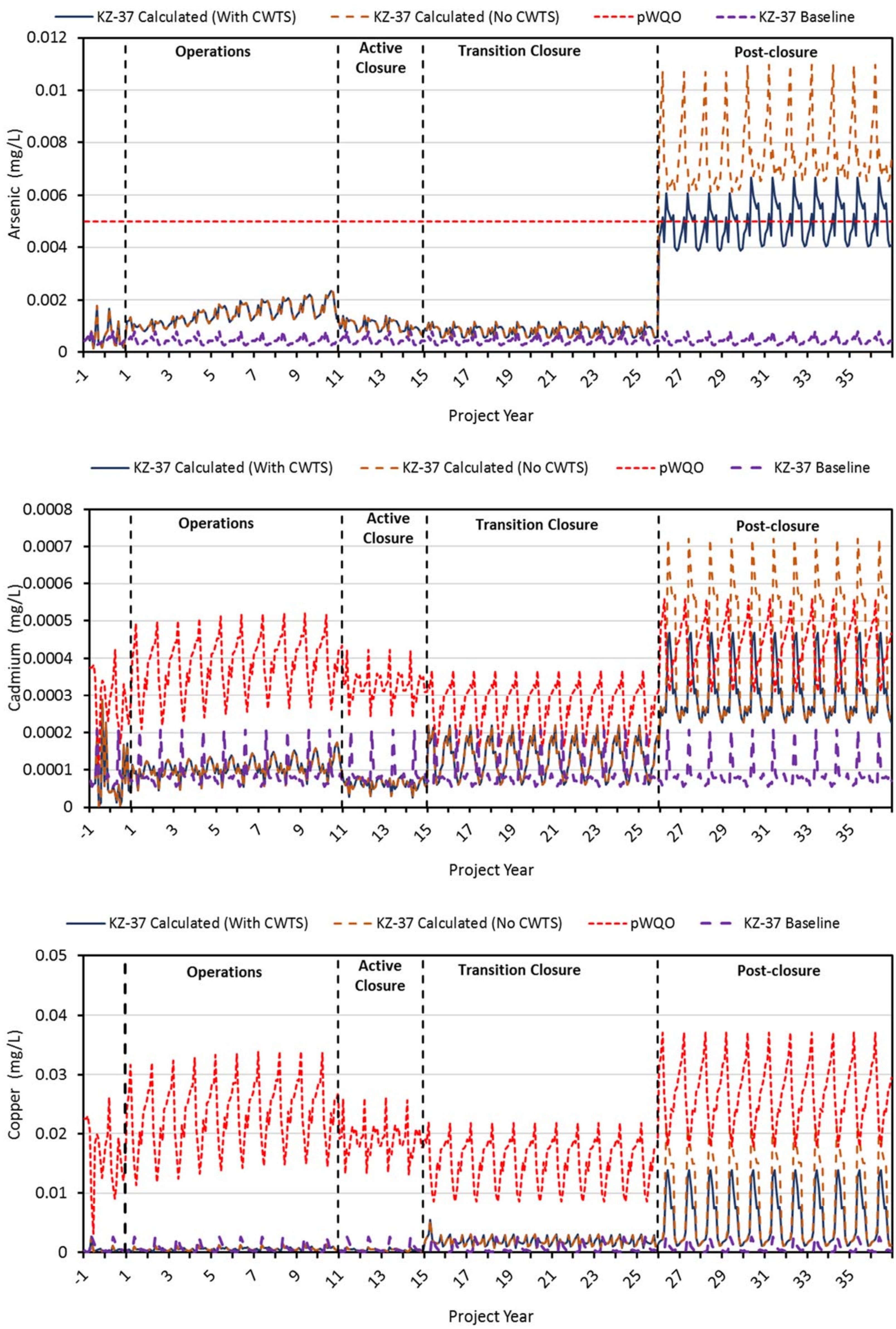

Figure 4-1: Model Calculated Arsenic, Cadmium and Copper Concentrations at site KZ-37 in Geona Creek in the 1/10 Dry Year Precipitation Model with and without CWTS Treatment

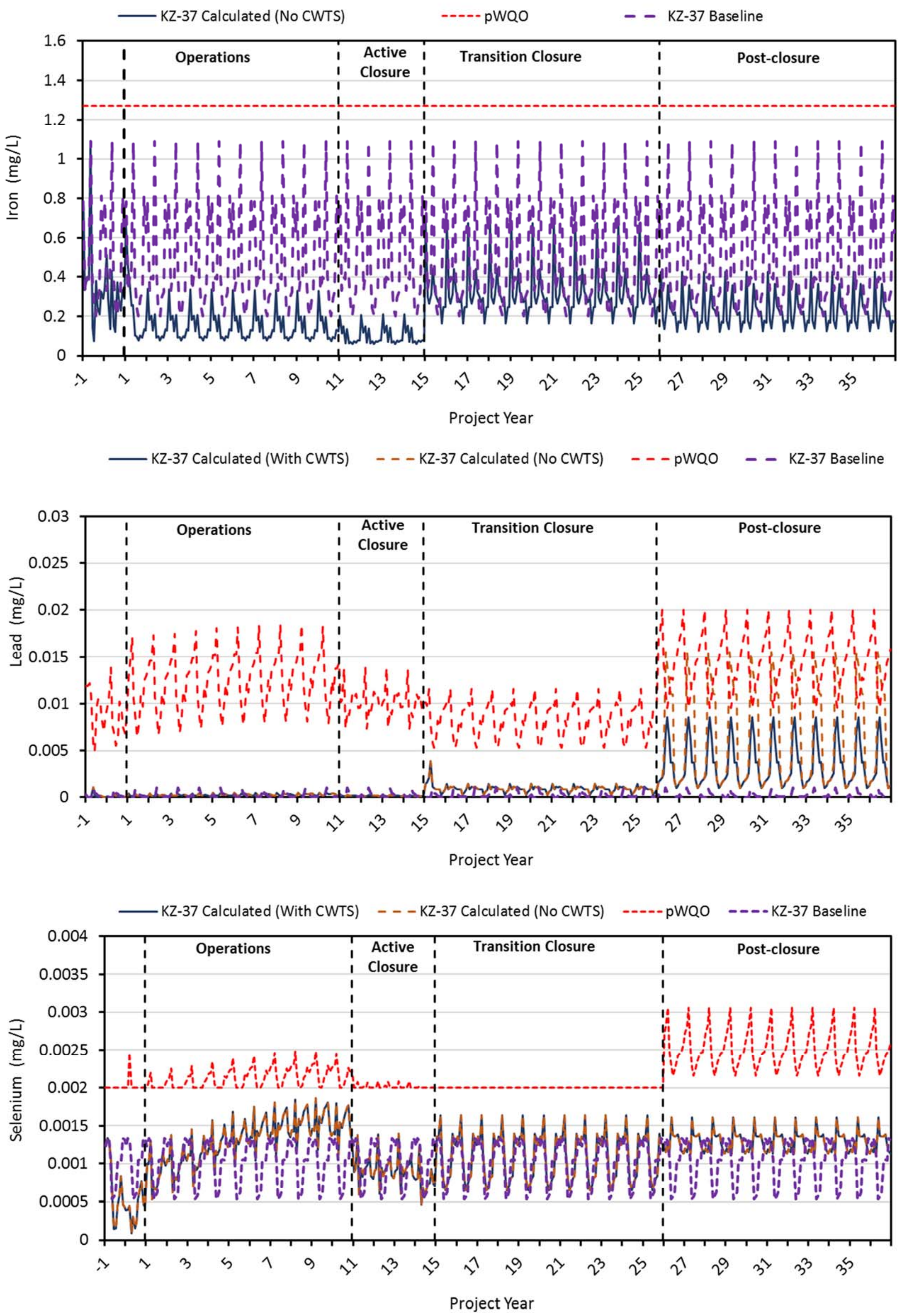

Figure 4-2: Model Calculated Iron, Lead and Selenium Concentrations at site KZ-37 in Geona Creek in the 1/10 Dry Year Precipitation Model with and without CWTS Treatment

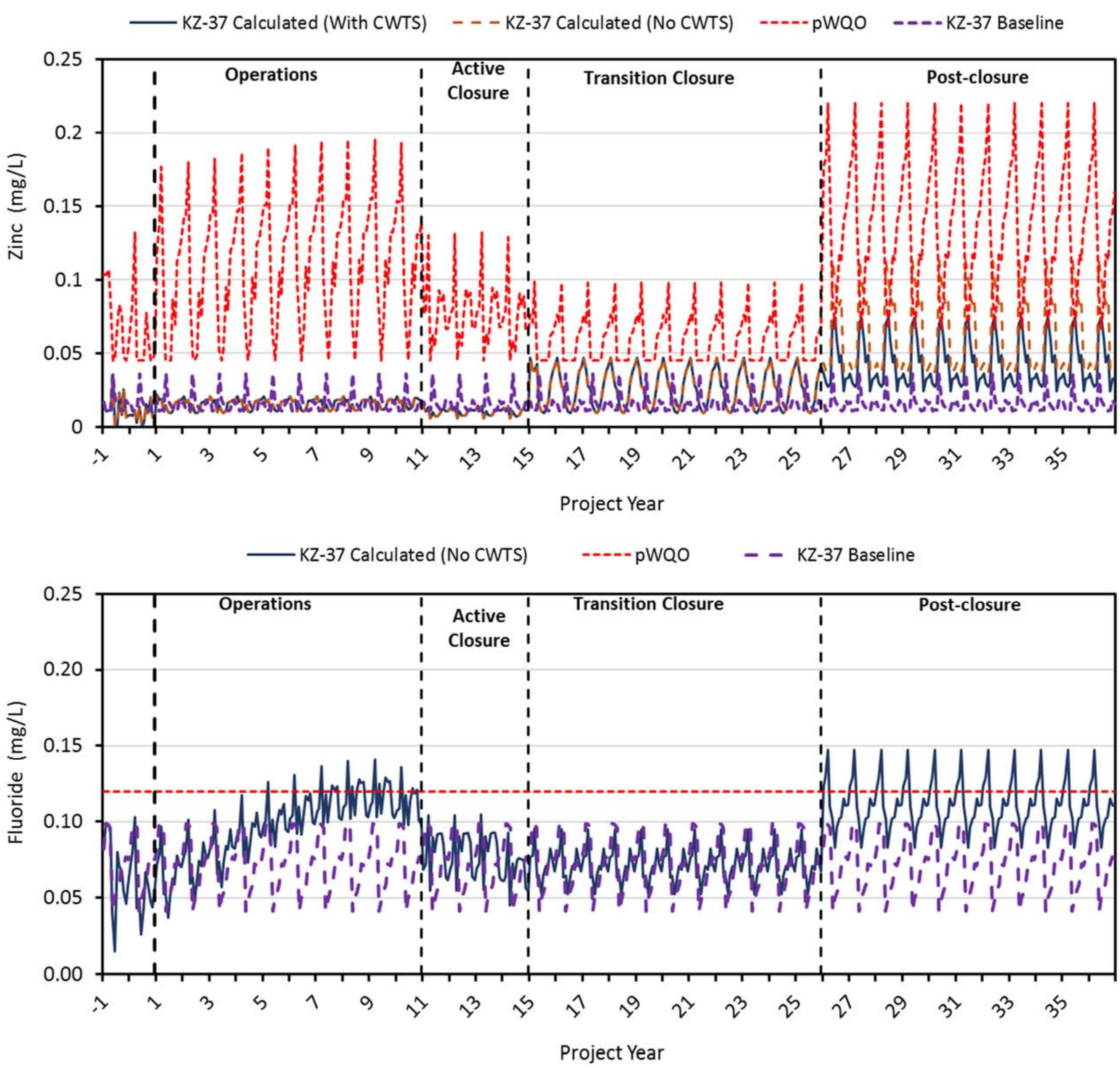

Figure 4-3: Model Calculated Lead, Selenium and Zinc Concentrations at site KZ-37 in Geona Creek in the 1/10 Dry Year Precipitation Model with and without CWTS Treatment

5. DISCUSSION

This section summarises the responses to the information requests identified in Section 1.

5.1 R2-16

- R2-16: Provide an updated Conceptual Reclamation and Closure Plan demonstrating that the mine site will remain chemically and physically stable in the long-term using proven technologies demonstrated to work in northern climates.

Updates to the Conceptual Reclamation and Closure Plan (CCRP) have been provided in Section 3 of this report and the calculated concentrations for the COPIs presented in Section 4 shows the performance (discharge water quality) expected under the optimized plan. The conceptual information provided as updates to the CCRP in these Sections suggests that the Project can indeed be reclaimed in the long term to a chemically stable condition that will not result in significant adverse effects to the receiving environment.

5.2 R2-17B

- R2-17b: Alternative closure approaches for the Kudz Ze Kayah site, demonstrating long-term chemical and physical stability, as an alternative to CWTS.

The updated closure approach presented in Section 3, when modeled, produces improved water quality expectations in the receiving environment (Section 0), including the predictions in the absence of CWTSs. It is important to reiterate that the CWTS is now modelled to provide full COPI treatment only during the ice-free months, and provides “polishing” of COPI concentrations with average reductions of 16% to 32% for arsenic, cadmium, copper, lead, and zinc levels under the optimized plan. No CWTS treatment is modelled for fluoride and iron whereas no reduction in selenium concentrations was modelled for the CWTS since the influent selenium concentration was calculated to be lower than its pWQO. Without the benefit of the CWTS, water quality modelling of the optimized plan still suggests that no significant water quality effects are predicted in the receiving environment. As such, the successful closure of the Project does not rely on the CWTS, but rather uses the CWTS as additional treatment redundancy to ensure receiving environment water quality remains in good condition.

However, if the closure measures do not produce the reductions in COPI loading required, the construction of passive treatment system(s) such as bioreactor(s) as an additional mitigation measure is contemplated to ensure there are no significant water quality effects in the receiving environment. AEG has experience in the design, construction, and operation of bioreactors for the treatment of mine drainage such as at the Galkeno 900 adit at Keno Hill, Yukon (Harrington et al., 2015). Based on this experience, the model calculated Class A and Class B drainage chemistry, and precipitation of COPIs within the bioreactor as metal sulphides or reduced phases (e.g., elemental selenium), it is anticipated that COPI removal may be on the order of 89% to 99% for Class A drainage and 23% to 99% for Class B drainage (Table 5-1), depending on the parameter.

Table 5-1: Scoping COPI Bioreactor Removal Rates from Class A and Class B Storage Facility Drainage

Parameter	COPI Removal Percentage	
	Class A Storage Facility	Class B Storage Facility
Arsenic	98%	99%
Cadmium	98%	63%
Copper	99%	64%
Iron	99%	93%
Lead	99%	79%
Selenium	89%	23%
Zinc	99%	85%

Preliminary bioreactor designs may include a seepage collection pond at the base of the storage facility to allow for:

- Comingling with and partial neutralization of drainage by circumneutral run-off waters, resulting in lower COPI concentrations and a moderate increase in pH in the influent to the bioreactor(s);
- Precipitation of iron and aluminum (oxyhydr) oxides, resulting in lower dissolved iron and aluminum concentrations in the bioreactor(s) influent, and potentially lower COPI concentrations due to incorporation and/or sorption on the precipitated iron and aluminum phases; and
- Regulation of flow to the bioreactor(s).

The bioreactor would be designed such that the hydraulic residence time would be sufficient to allow for reaction of COPI with dissolved sulphide produced within the bioreactor and subsequent precipitation and settling of metal sulphides and reduced COPIs.

At present, the installation of any bioreactor technology at the Class A and/or Class B Storage Facility would be an adaptive management response in post-closure to provide a long-term solution to unexpectedly high COPI loads from either facility. However, the design of any such bioreactor as an alternative mitigation measure would be initiated in support of the water licencing process, and include laboratory and fieldscale testing informed by drainage data collected during the operations period of the Project.

5.3 R2-27

- R2-27: Clarify if the predicted concentrations at KZ-37 include any assumed mitigating effects from the proposed wetland treatment system and, if so, provide the untreated concentrations as well.

The results presented in section 4 include concentrations at KZ-37 with and without CWTS for the optimized plan.

5.4 R2-28

- R2-28: Demonstrate that the proposed liner system will be sufficient to direct seepage from the Class A and Class B facilities to the seepage collection ponds for treatment. This should be demonstrated for both the operational and closure facilities.

Seepage through the liner of the base of the Class A and B Storage Facilities was not incorporated into the original water quality predictions. The revised model incorporated seepage from the Class B Storage Facility based on a reduction of 75% of mean annual precipitation during operations through the compacted till liner, whereas the Class A Storage Facility does not incorporate seepage into the model as the final design will be optimised to ensure negligible seepage and may include a geosynthetic liner. The updated water quality model calculations demonstrate that if seepage from the Class B Storage Facility did bypass the CWTS the COPI concentrations at KZ-37 would less than twice their respective pWQOs; however, numerical modelling indicates that groundwater flow from the Class B Storage Facility would be captured by the North CWTS (Section 9.4.1.5 of Project Proposal; BMC, 2017).

5.5 R2-46

- R2-46: Provide an assessment of the long-term loadings and water quality associated with the acidic drainage that will eventually be produced in the A and B stockpiles as well as from the pit walls above the final water level.

The results presented within this report have incorporated acidic drainage loading rates along with the optimised closure measures. Acidic drainage loading rates for the Class A and Class B Storage Facilities are provided in Section 2.1. The unsubmerged portion of the pit wall above the final surface water elevation of ABM Lake at closure will be primarily composed of geodomains that are largely Class C, non-acid generating rock. Overall, the pit wall rock above the final water level is predominantly not acid generating and thus no acidic source terms were developed for the unsubmerged portion of the pit wall. COPI concentrations at post-closure assuming the onset of acidic drainage from Class A and Class B Storage Facilities are provided in Sections 4.1 and **Error! Reference source not found.**. Dilution and buffering of acidic drainage from the Class A and B Storage Facilities by local run-off and outflow from ABM Lake in closure is expected to result in circumneutral pH conditions in the CWTS. The acidic source terms will be updated using the ongoing kinetic results and incorporated in the revised Water Quality Model report, which will be submitted prior to YESAB preparing the draft screening report.

5.6 R2-47

- Provide details on the assumed water quality adjustment factor. Discuss these factors in the context of the predicted effluent concentrations for an engineered wetland in Tables 4 and 5 of the Contango report (Appendix B – Conceptual Wetland Design - of Appendix H-1 Conceptual Reclamation and Closure Plan).

Section 3.5 of this report provides the information requested regarding water quality adjustments for expected wetland treatment, and updated water quality predictions (with and without wetland performance) are included in Section 4.

5.7 R2-48

- Please provide details of the basis of the coefficients in order to understand whether these are supported by appropriate data that are relevant to the proposed wetland treatment.

This information is provided in Section 3.5.1.

5.8 R2-49

- Also, now that the post closure water quality has been updated to reflect acidic drainage (see R106 above), please provide an update on the expected treatment effects for the site water.

This information is provided in Section 4.

5.9 R2-50

- Provide cold weather case studies for passive wetland treatment systems designed for acidic conditions as well as case studies for passive wetland treatment systems that have successfully transitioned from treating neutral drainage to effectively treating acidic drainage with increased metal loadings.

The information provided in Section 3.5.2 supports the examples cited earlier in the Adequacy Review process. Additionally, the updated terms in Section 2 with the revised water quality expectations in Section 4 illustrate how despite expectations of acidic seepage from site storage facilities, the overall site drainage at closure (including expected CWTS influent) is reasonably expected to remain circumneutral in pH, further supporting the treatment factors and examples utilized in modeling closure water quality at the Project.

5.10 R2-51

- Provide some indication of treatment performance for the case histories presented or for other relevant treatment systems.

The information provided in Section 3.5.2 supports the examples cited earlier in the Adequacy Review process and includes supporting information for the pilot and demonstration scale wetland trials at Yukon's Minto Mine project. This Section also provides additional supporting rationale for each example and its relevance to planning and performance modeling for the Project.

5.11 R2-55

- R2-55: Provide justification and rationale for the proposed threshold criteria for surface water quantity and quality used to assess the magnitude of projected changes in the receiving environment.

As mentioned in the Project Proposal Section 8.1 (BMC, 2017), generic water quality guidelines are developed based on the most sensitive species and life stages, typically using a long-term lowest observed effect concentration, before applying a tenfold (or more) factor of safety. Such guidelines therefore define concentrations at which no adverse effects are expected for aquatic life; however, they do not indicate levels at which adverse effects may be expected. Rather, the generic water quality guidelines can be viewed as very conservative in nature such that their exceedance does not necessarily result in an adverse effect to aquatic life. Furthermore, generic water quality guidelines do not account for site specific conditions and speciation of metals which may lower the relative ecotoxicity of some parameters (e.g., the ameliorative effect of dissolved organic carbon and copper). In addition, the Project model predictions are developed based on total constituent concentrations, which have much lower bioavailability of particulate-bound metals compared to dissolved forms (Prothro, 1993).

Despite the conservatism associated with these generic guidelines, the environmental effects assessment significance threshold has been revised to being two times the pWQO from the ten times pWQO outlined in the original Project Proposal. A significance threshold of two times the pWQO is conservative and results less than two times the pWQO have a minimal risk to cause significant adverse effects to surface water quality and aquatic biota. The water quality objectives for the Project at this stage are preliminary and will continue to be updated through the regulatory process including further investigation into developing additional site specific water quality objectives. Therefore, a significance of two times the pWQO is warranted given the factors of safety applied to the generic water quality guidelines and modelling approach.

BMC has proposed a comprehensive Aquatic Environment Effects Monitoring Program (Section 10.6 in the Project Proposal). It includes:

- Water quality monitoring (included in Section 8 of the Project Proposal, but a key part of interpretation of the other monitoring program components below);
- Benthic invertebrate monitoring;
- Sediment monitoring;
- Fisheries monitoring;
- Fish tissue sampling; and
- toxicity testing using Project effluent and receiving environment water.

The Project will be subject to formal Environmental Effects Monitoring under the Metal Mining Effluent Regulations (Section 10.6.6 of the Project Proposal). Combined, the results of these monitoring programs will assist managers in determining the effects (if any) of the post-closure modelled water quality on aquatic biota. The Adaptive Management Framework presented in the CCRP (Section 7.12.2 of Appendix H to the Project Proposal) presents how the monitoring data (among other monitoring program results) will be compared against established threshold values to ensure that responsive mitigative measures are implemented in advance of effects to the receiving environment from water discharged from Project. An example of an more aggressive response to triggered adaptive management thresholds could be the installation of bioreactors to treat seepage from waste facilities that is not meeting performance expectations in post-closure.

5.12 R2-60

- R2-60: Provide a report that details the proposed treatment methods, justifies site-specific treatment rate coefficients, and predicts the chemistry of the treated effluent. Based on the information in this report, provide an updated water quality model (i.e., with updated mine source loads) and, if necessary (e.g., if new contaminants of potential concern are identified), an updated water quality objectives report.

On October 17 2017, YESAB provided (via email) the following clarification regarding the information required in response to R2-60:

> *"As discussed at the technical meeting, addressing the other questions and providing the information noted above should answer this request."*

COPI removal percentages for *in situ* treatment of ABM Lake are provided in Section 3.1, while treatment rates for the constructed wetland system are presented in Section 3.6. The active water treatment plant effluent chemistry was revised based on the updated water treatment plant design provided by Integrated Sustainability Consultants Ltd (Integrated Sustainability, 2017) and the COPI treatment efficiencies are presented in Table 2-3. These updated water treatment efficiencies along with the other model updates including use of acid source terms have been presented in Section 4. The pWQOs for the Project were also updated with data collected up to October 2017 and the pWQOs for KZ-37 are presented in Table 2-4.

The results of the water quality modelling for the optimized closure plan indicate that no significant exceedances of pWQOs (i.e., greater than twice the pWQO) are anticipated for the COPIs in the near field receiving environment (i.e., site KZ-37) for all the precipitation settings modelled. The pWQO exceedances modelled under the conservative 1/10 dry year setting are typically restricted to a few months per year in post-closure at KZ-37 for the optimized plan (between zero and six months of the post-closure year with the CWTS). For the higher flow mean precipitation and 1/50 wet year settings, the modelled COPI concentrations in post-closure at KZ-37 were lower and generally had fewer model calculated monthly pWQO exceedances.

Under the higher flow mean precipitation conditions, copper and lead were calculated to remain below its pWQO year-round at KZ-37 in post-closure with CWTS, while cadmium (two months), zinc (one month) and fluoride (two months) displayed fewer pWQO exceedances in the post-closure year. Arsenic was calculated to be marginally higher in the higher flow mean precipitation condition due to a higher contribution of load from the ABM Pit Lake.

For the highest flow 1/50 wet year setting, model calculated cadmium, copper, lead, and zinc concentrations with CWTS were below their respective pWQOs year-round at KZ-37; only fluoride (two months) and arsenic (three months) were calculated to be fractionally higher than their pWQO in the post-closure year.

At sites located within the regional study area (i.e., KZ-15 and KZ-26 in Finlayson Creek), the modelling indicated that no pWQOs were exceeded in post-closure for the COPIs considered here under any precipitation setting. Only fluoride marginally exceeded its pWQO at KZ-15 (0.12 mg/L) for four months per year (January through March; 0.125 to 0.143 mg/L) under the conservative 1/10 dry year scenario and three months per year under the mean and 1/50 wet year scenarios (0.121 to 0.134 mg/L). Similarly, fluoride was the only constituent that was modelled to exceed its pWQO (0.133 mg/L) at site KZ-26, where exceedances were confined to February through April (0.135 to 0.142 mg/L) under the dry scenario and April (0.134 to 141 mg/L) in the mean and wet year scenarios. Fluoride is naturally elevated in the KZK receiving environment, particularly in the lower reach of Finlayson Creek due to inputs from East Creek. The BCMOE short term fluoride guideline for Finlayson Creek ranges between 1.2 mg/L and 1.9 mg/L depending on the water hardness, which is approximately one order of magnitude higher than the slight pWQO fluoride exceedances estimated by the water quality model in Finlayson Creek.

Overall, no significant adverse effects to aquatic life are envisaged for the optimized closure plan modelled here.

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Appendix A1

Monthly Median of Baseline Water Quality Data to October 2017

	Hardness (from total)	Sulphate, dissolved	Nitrate (N)	Nitrite (N)	Ammonia (N)	Phosphorus,total-colourimetric	Phosphorus (P), total	Fluoride	Chloride	Cyanide, total	Cyanide, Weak Acid Dissociable	Aluminum (Al), total	Antimony (Sb), total	Arsenic (As), total	Cadmium (Cd), total
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
KZ-2															
January	134	58.7	0.164	0.001	0.0224	0.001	0.003	0.051	0.41	0.00039	0.00044	0.00453	0.000029	0.000073	0.000237
February	134	56.6	0.172	0.001	0.0217	0.0015	0.0042	0.044	0.25	0.00025	0.00025	0.0115	0.000027	0.00009	0.00024
March	141	57.5	0.171	0.001	0.0155	0.002	0.0022	0.045	0.47	0.00025	0.00025	0.00255	0.000031	0.000083	0.000245
April	130	48.2	0.124	0.0018	0.0165	0.0013	0.0034	0.05	0.61	0.00025	0.00025	0.0202	0.000033	0.000093	0.000223
May	68.5	24.6	0.0536	0.001	0.0164	0.0063	0.0089	0.043	0.66	0.00065	0.00025	0.0475	0.000031	0.000127	0.000194
June	60	27.2	0.0788	0.001	0.011	0.0022	0.0036	0.033	0.55	0.00056	0.00038	0.02615	0.000028	0.000099	0.000225
July	78.7	35.9	0.0668	0.001	0.016	0.0023	0.0029	0.035	0.25	0.00025	0.00064	0.02295	0.000026	0.000094	0.00028
August	90.7	42.2	0.105	0.001	0.0047	0.0028	0.0054	0.035	0.25	0.00038	0.00038	0.02	0.000038	0.000162	0.000313
September	104	51.5	0.1165	0.001	0.0038	0.001	0.001	0.043	0.25	0.00058	0.00055	0.01034	0.000023	0.000077	0.000273
October	112	53.7	0.125	0.001	0.0054	0.0022	0.003	0.039	0.25	0.00025	0.00025	0.00637	0.000022	0.000067	0.000217
November	118	52.3	0.147	0.0015	0.0051	0.001	0.002	0.053	2.83	0.00038	0.00042	0.007	0.000024	0.000073	0.000243
December	124	48.4	0.165	0.001	0.005	0.001	0.0018	0.042	0.25	0.00025	0.00025	0.00361	0.000032	0.000079	0.000237
KZ-13															
January	96.9	15.4	0.132	0.001	0.026	0.003	0.0027	0.048	0.72	0.00044	0.00049	0.01224	0.000022	0.000215	0.000045
February	97.5	15.7	0.151	0.0016	0.0303	0.0034	0.006	0.052	0.4	0.00025	0.00045	0.022	0.00002	0.000295	0.000043
March	109.4	17.2	0.15	0.001	0.059	0.0074	0.0209	0.052	0.56	0.00025	0.0004	0.0169	0.000108	0.000255	0.000044
April	105.5	14.1	0.1177	0.001	0.0099	0.0042	0.007	0.061	0.59	0.0005	0.00038	0.01446	0.000025	0.000182	0.0000235
May	45.5	2.62	0.0322	0.0021	0.0072	0.0217	0.0398	0.036	0.59	0.00079	0.00075	0.291	0.000025	0.00037	0.0000542
June	57.2	9.3	0.0335	0.001	0.0078	0.0062	0.009	0.042	0.57	0.00067	0.00038	0.0698	0.000031	0.000242	0.000023
July	66	10.95	0.0193	0.001	0.0141	0.0044	0.0066	0.043	0.25	0.00055	0.00063	0.0352	0.000028	0.000235	0.0000265
August	64.1	9.08	0.0339	0.0018	0.0025	0.0045	0.0055	0.042	0.25	0.0005	0.0005	0.028	0.000025	0.000227	0.0000305
September	66.3	12.3	0.0492	0.001	0.007	0.005	0.0038	0.046	0.25	0.0005	0.0005	0.0262	0.000026	0.000199	0.000028
October	70.9	13.6	0.0618	0.001	0.012	0.0029	0.0049	0.044	0.57	0.00025	0.00025	0.0273	0.00003	0.000207	0.000026
November	81.8	16	0.0881	0.001	0.0127	0.0019	0.0075	0.047	0.25	0.00061	0.00048	0.0249	0.000034	0.000201	0.000036
December	89.8	15.4	0.11	0.001	0.011	0.004	0.0038	0.044	0.41	0.00051	0.00025	0.0234	0.000034	0.000222	0.000038

	Copper (Cu), total	Iron (Fe), total	Lead (Pb), total	Manganese (Mn), total	Nickel (Ni), total	Silver (Ag), total	Selenium (Se), total	Uranium (U), total	Zinc (Zn), total	Dissolved Organic Carbon	pH (field)	pH (lab)	Discharge (Flow)	Temperature (field)	Aluminum (Al), dissolved
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	pH units	pH units	L/s	C	mg/L
KZ-2															
January	0.000519	0.0074	0.000102	0.000228	0.000307	0.0000025	0.00226	0.0046	0.0309	0.53	7.74	7.86	5.3	-0.1	0.00167
February	0.000652	0.0279	0.000293	0.001122	0.000317	0.0000025	0.00228	0.00461	0.0317	0.25	7.79	7.96	4.4	-0.1	0.00181
March	0.000458	0.0017	0.000044	0.000077	0.000291	0.0000025	0.00249	0.00526	0.0306	0.62	7.8	7.89	3.5	0.2	0.00376
April	0.001132	0.0422	0.000338	0.000919	0.00049	0.0000025	0.00275	0.00506	0.0275	1.37	7.62	8.08	4.9	0	0.00376
May	0.00434	0.0711	0.000371	0.0021	0.00074	0.000005	0.00125	0.00175	0.0239	4.47	7.82	7.82	12.9	1.6	0.023
June	0.001595	0.0259	0.000135	0.001017	0.000525	0.0000038	0.000438	0.00106	0.0397	1.72	7.79	7.77	76.7	5.2	0.0133
July	0.000906	0.0198	0.000115	0.00096	0.000398	0.0000025	0.000558	0.00133	0.0411	1.4	7.7	7.79	35	6.2	0.00429
August	0.001	0.019	0.0001222	0.0006	0.000481	0.0000025	0.0005	0.00165	0.0326	0.95	7.72	7.77	67.1	6	0.01
September	0.000725	0.0128	0.000057	0.000501	0.000464	0.0000025	0.000731	0.00202	0.0361	0.77	7.8	7.89	69.1	4.7	0.0048
October	0.000609	0.007	0.000065	0.000312	0.000327	0.0000025	0.00116	0.00261	0.0265	1.13	7.6	7.87	27.8	0.4	0.00281
November	0.00102	0.0099	0.000029	0.000209	0.001043	0.0000025	0.00167	0.00317	0.0324	0.8	7.8	7.82	11	0.2	0.00417
December	0.000541	0.0043	0.000261	0.00038	0.00035	0.0000025	0.00178	0.00379	0.0361	1.01	7.64	7.83	7.6	0.2	0.00152
KZ-13															
January	0.000356	0.161	0.000035	0.0957	0.000367	0.0000025	0.000294	0.001125	0.00419	1.88	7.5	8.05	18.1	-0.1	0.00378
February	0.003316	0.277	0.000074	0.119	0.000401	0.0000025	0.000335	0.001182	0.0046	1.36	7.5	8.01	12.9	-0.1	0.00304
March	0.000514	0.231	0.000249	0.1148	0.000438	0.0000025	0.000369	0.001262	0.00892	2.33	7.29	7.89	14.2	0.3	0.00415
April	0.00048	0.141	0.000111	0.0599	0.000451	0.0000038	0.000244	0.00191	0.00317	3.39	7.56	8.13	9.6	0	0.00592
May	0.00165	0.2215	0.000109	0.086	0.00149	0.000005	0.000146	0.000402	0.0077	9.68	7.63	7.64	244.9	1.7	0.0348
June	0.00084	0.1755	0.000139	0.0187	0.000571	0.0000055	0.00014	0.000433	0.00432	3.77	7.84	7.88	142	9	0.01313
July	0.000712	0.105	0.0000674	0.0291	0.000527	0.0000038	0.000162	0.000568	0.00366	3.9	7.74	7.86	107.9	9.7	0.00827
August	0.0008	0.0877	0.000078	0.021	0.0005	0.0000038	0.000123	0.000456	0.0045	4.63	7.69	7.83	235.7	6.8	0.009
September	0.000583	0.0884	0.000045	0.019	0.000472	0.0000025	0.000135	0.00054	0.004	3.97	7.75	7.95	195.9	5.3	0.00915
October	0.000501	0.0779	0.000058	0.0233	0.000484	0.0000025	0.000165	0.000676	0.00316	3.47	7.75	7.89	94.8	1.5	0.00667
November	0.000498	0.105	0.000081	0.0393	0.000411	0.0000025	0.000246	0.000855	0.00385	3.1	7.46	8.02	40.9	-1.1	0.01323
December	0.000492	0.138	0.000051	0.049	0.000426	0.0000025	0.000311	0.00111	0.00388	3.21	7.49	7.98	36.6	0.2	0.00455

	Antimony (Sb), dissolved	Arsenic (As), dissolved	Cadmium (Cd), dissolved	Copper (Cu), dissolved	Iron (Fe), dissolved	Lead (Pb), dissolved	Manganese (Mn), dissolved	Nickel (Ni), dissolved	Silver (Ag), dissolved	Selenium (Se), dissolved	Uranium (U), dissolved	Zinc (Zn), dissolved
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
KZ-2												
January	0.000023	0.00007	0.000237	0.000441	0.0011	0.000029	0.000159	0.000317	0.0000025	0.00208	0.00447	0.0294
February	0.000028	0.00007	0.000247	0.000688	0.0005	0.000039	0.000078	0.000299	0.0000025	0.00229	0.0046	0.0301
March	0.000036	0.000063	0.000237	0.000438	0.0005	0.000018	0.000038	0.000279	0.0000025	0.0024	0.00507	0.0295
April	0.000032	0.000087	0.000215	0.000767	0.0046	0.000036	0.000374	0.00028	0.0000025	0.00279	0.00498	0.0252
May	0.000036	0.000103	0.000182	0.00437	0.0212	0.000114	0.00079	0.000751	0.0000075	0.00112	0.00189	0.0235
June	0.000023	0.000093	0.000218	0.00155	0.0082	0.0000595	0.000503	0.000527	0.0000025	0.000464	0.000997	0.0372
July	0.000028	0.000091	0.000274	0.000748	0.0019	0.0000929	0.000133	0.000363	0.0000025	0.0006	0.0013	0.0385
August	0.000032	0.000102	0.000287	0.000818	0.0015	0.0000361	0.0004	0.000475	0.0000025	0.000427	0.00157	0.0317
September	0.000022	0.000076	0.000256	0.00065	0.0011	0.000015	0.000145	0.000453	0.0000025	0.000736	0.00182	0.0328
October	0.000021	0.000076	0.000211	0.000501	0.0005	0.000018	0.000052	0.000302	0.0000025	0.0011	0.00251	0.0236
November	0.000022	0.000068	0.000228	0.000533	0.0008	0.000018	0.000025	0.000348	0.0000025	0.00159	0.00309	0.0321
December	0.000023	0.000048	0.000171	0.00043	0.0005	0.00001	0.000025	0.000323	0.0000025	0.0018	0.00357	0.0333
KZ-13												
January	0.000022	0.000155	0.000034	0.000304	0.045	0.000007	0.0828	0.000366	0.0000025	0.000295	0.001124	0.00311
February	0.000018	0.000177	0.000027	0.000272	0.0451	0.0000073	0.0878	0.000331	0.0000025	0.000337	0.001147	0.00281
March	0.000056	0.000152	0.00003	0.000373	0.0444	0.000032	0.099	0.000369	0.0000025	0.000326	0.001332	0.00694
April	0.000032	0.000188	0.00002	0.000363	0.066	0.0000056	0.0339	0.000441	0.0000025	0.000255	0.002	0.00183
May	0.00001	0.000205	0.000016	0.00085	0.0995	0.000016	0.025795	0.00074	0.0000038	0.000115	0.00033	0.00165
June	0.000027	0.000177	0.0000126	0.000697	0.0358	0.000014	0.00635	0.000483	0.0000038	0.00012	0.000401	0.00182
July	0.000032	0.000217	0.0000127	0.000536	0.0326	0.0000078	0.011	0.000496	0.0000025	0.000144	0.000565	0.00227
August	0.000028	0.000193	0.000012	0.0005	0.03	0.0000345	0.013	0.0005	0.0000038	0.000128	0.000403	0.003
September	0.000027	0.00016	0.00002	0.0005	0.035	0.000014	0.012	0.000438	0.0000025	0.00015	0.000521	0.00285
October	0.000027	0.000188	0.000019	0.000437	0.0195	0.000005	0.00972	0.00039	0.0000025	0.000174	0.000649	0.00213
November	0.00003	0.000146	0.000021	0.000496	0.0301	0.000031	0.0236	0.000358	0.0000025	0.000247	0.000804	0.00249
December	0.000029	0.000168	0.000024	0.000393	0.0535	0.0000133	0.0226	0.000375	0.0000025	0.000318	0.00103	0.00257

	Hardness (from total)	Sulphate, dissolved	Nitrate (N)	Nitrite (N)	Ammonia (N)	Phosphorus,total-colourimetric	Phosphorus (P), total	Fluoride	Chloride	Cyanide, total	Cyanide, Weak Acid Dissociable	Aluminum (Al), total	Antimony (Sb), total	Arsenic (As), total	Cadmium (Cd), total
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
KZ-7															
January	186	38	0.129	0.001	0.0364	0.0025	0.0132	0.07	0.59	0.00042	0.00046	0.0716	0.000045	0.000802	0.000292
February	179	35.5	0.143	0.001	0.028	0.0031	0.008	0.073	0.44	0.00025	0.00025	0.01211	0.00003	0.000405	0.000158
March	186	34.4	0.145	0.001	0.0226	0.0026	0.0111	0.071	0.25	0.00025	0.00025	0.01286	0.000036	0.000289	0.000131
April	178	29.6	0.0973	0.0025	0.0116	0.0021	0.0065	0.068	0.45	0.0005	0.00025	0.018	0.000043	0.0003	0.0000859
May	114	18.7	0.0524	0.0015	0.0064	0.008	0.005	0.055	1.1	0.00062	0.00057	0.0587	0.000066	0.000622	0.00017
June	111	27	0.01	0.001	0.0025	0.0015	0.0069	0.048	0.48	0.00068	0.0006	0.0206	0.000068	0.0003	0.000071
July	127	31.6	0.0109	0.001	0.0121	0.0043	0.0065	0.052	0.39	0.00038	0.00045	0.0227	0.000092	0.000398	0.000185
August	136	28.7	0.0103	0.0025	0.0059	0.007	0.008	0.052	0.57	0.0005	0.0005	0.0174	0.00008	0.000298	0.00012
September	146	33.3	0.0441	0.0018	0.0067	0.0034	0.0063	0.054	0.78	0.00061	0.00061	0.0314	0.000087	0.000236	0.000203
October	163	35.6	0.0954	0.001	0.0091	0.0052	0.0038	0.079	0.4	0.0004	0.00042	0.0222	0.000049	0.000357	0.000352
November	172	38.3	0.1086	0.0021	0.0215	0.002	0.0049	0.07	0.25	0.00041	0.00045	0.0135	0.000052	0.000352	0.00031
December	182	38.5	0.134	0.001	0.0229	0.002	0.004	0.06	0.5	0.00025	0.00025	0.0199	0.000053	0.000334	0.000223
KZ-9															
January	220	33.4	0.205	0.001	0.0345	0.0036	0.0058	0.087	0.9	0.0004	0.00045	0.01062	0.000036	0.000329	0.000074
February	220	34.2	0.209	0.001	0.0281	0.0032	0.0138	0.093	0.81	0.00025	0.00025	0.0173	0.00003	0.000499	0.000129
March	232	37.4	0.364	0.001	0.0248	0.0024	0.0168	0.081	1.02	0.00025	0.00025	0.01521	0.00003	0.000264	0.000065
April	190	27.9	0.145	0.0016	0.0215	0.0043	0.005	0.097	0.75	0.00051	0.00038	0.0118	0.00003	0.000296	0.0000684
May	95.6	16.6	0.0355	0.001	0.0171	0.0168	0.0229	0.05	1	0.00072	0.0006	0.175	0.000056	0.000522	0.000105
June	116	23.7	0.0263	0.001	0.017	0.01	0.0132	0.048	0.53	0.00072	0.00068	0.0784	0.000063	0.00046	0.000072
July	132	27.5	0.034	0.001	0.019	0.004	0.0053	0.056	0.25	0.00025	0.00068	0.028	0.000063	0.000296	0.0000703
August	162	25.2	0.028	0.0025	0.0051	0.0065	0.0164	0.063	0.25	0.00038	0.00038	0.0209	0.000063	0.00045	0.000058
September	169	33.6	0.0678	0.001	0.0057	0.0042	0.0077	0.062	0.58	0.00057	0.0006	0.0346	0.000051	0.000268	0.000105
October	172	33.3	0.139	0.001	0.017	0.0038	0.0052	0.067	0.66	0.00025	0.00025	0.0227	0.000044	0.000357	0.000096
November	192	34.2	0.19	0.001	0.0197	0.0026	0.0063	0.081	0.57	0.00041	0.00043	0.017	0.000043	0.000379	0.000113
December	199	31.5	0.18	0.001	0.025	0.0023	0.0053	0.077	0.5	0.0004	0.00025	0.01545	0.000038	0.000302	0.000078

	Copper (Cu), total	Iron (Fe), total	Lead (Pb), total	Manganese (Mn), total	Nickel (Ni), total	Silver (Ag), total	Selenium (Se), total	Uranium (U), total	Zinc (Zn), total	Dissolved Organic Carbon	pH (field)	pH (lab)	Discharge (Flow)	Temperature (field)	Aluminum (Al), dissolved
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	pH units	pH units	L/s	C	mg/L
KZ-7															
January	0.000815	1.328	0.000557	0.167	0.000762	0.0000038	0.00103	0.00156	0.0785	0.93	7.34	8.12	34	0	0.00179
February	0.000336	0.523	0.00018	0.1017	0.000479	0.0000025	0.000941	0.00148	0.0546	0.42	7.38	8.14	25.9	-0.1	0.00264
March	0.00026	0.414	0.0001	0.0834	0.000479	0.0000025	0.000934	0.00155	0.0483	0.25	7.38	8.05	19	0.2	0.00318
April	0.0003	0.525	0.000119	0.081	0.000498	0.0000025	0.000777	0.00138	0.034	2.37	7.75	8.22	26.1	0.6	0.00655
May	0.00134	0.506	0.000631	0.0418	0.00067	0.0000025	0.000643	0.000796	0.035	4.85	7.32	7.98	173.9	0.4	0.00764
June	0.00077	0.3	0.000196	0.032	0.000472	0.0000025	0.0006	0.000732	0.018	1.9	7.96	7.83	180.8	9.1	0.00301
July	0.001	0.311	0.000157	0.0374	0.000434	0.0000038	0.0007	0.000803	0.0298	2.19	7.74	8.01	124.4	8.2	0.00225
August	0.0008	0.226	0.0002	0.03	0.0005	0.000005	0.000481	0.000784	0.02	2.36	8.02	8.1	290.1	8.3	0.003
September	0.00174	0.31	0.00034	0.042	0.000595	0.0000038	0.00048	0.001037	0.0361	2.15	7.78	8.03	239.9	4.9	0.00437
October	0.000967	0.347	0.000307	0.0447	0.0005	0.0000025	0.00133	0.0014	0.0613	2.32	7.73	8.05	107.4	0.6	0.00311
November	0.000485	0.513	0.000144	0.13	0.00054	0.0000025	0.00115	0.00135	0.0701	1.23	7.58	8.11	63.2	0.1	0.00416
December	0.000374	0.479	0.000125	0.119	0.000561	0.0000025	0.001044	0.00142	0.0703	1.67	7.61	8.07	44	0.2	0.00117
KZ-9															
January	0.000275	1.039	0.000201	0.119	0.000509	0.0000025	0.00121	0.00175	0.0219	0.54	7.19	7.96	49	-0.1	0.00213
February	0.000354	1.774	0.000135	0.134	0.000543	0.0000025	0.00121	0.00177	0.0192	0.65	6.88	7.8	35.2	-0.2	0.0014
March	0.000191	0.4634	0.000084	0.08649	0.000338	0.0000025	0.00217	0.0024	0.01056	0.68	6.92	7.73	27.8	0.3	0.00255
April	0.000415	0.49	0.000106	0.1285	0.000584	0.0000038	0.000935	0.00156	0.01155	2.16	7.31	7.88	39	0	0.0033
May	0.00192	0.671	0.000623	0.0573	0.00099	0.000005	0.000529	0.000635	0.0231	5.49	7.48	7.87	466.1	2.6	0.0157
June	0.001135	0.463	0.000491	0.0308	0.000591	0.0000085	0.000583	0.000624	0.0141	2.63	7.49	8.07	275.3	6.3	0.00764
July	0.00089	0.278	0.0000966	0.0337	0.000475	0.000005	0.000628	0.000778	0.0102	2.62	7.52	8.06	192.8	8.4	0.00169
August	0.000605	0.309	0.0002	0.056	0.0005	0.0000025	0.0006	0.00112	0.00835	2.3	7.64	8.02	435.1	6.9	0.0047
September	0.000879	0.377	0.000227	0.0431	0.000489	0.0000025	0.00104	0.00123	0.0202	1.6	7.6	8.05	313.4	5.7	0.00386
October	0.000514	0.548	0.000165	0.0609	0.000504	0.0000025	0.00138	0.00134	0.0186	1.59	7.5	8.05	165.5	0	0.00227
November	0.00037	1.14	0.000097	0.0869	0.00044	0.0000025	0.00134	0.00161	0.0248	1.5	7.88	8.02	83.2	-0.1	0.00188
December	0.000311	0.814	0.000063	0.096	0.000424	0.0000025	0.00131	0.00167	0.02	1.8	7.09	7.75	69.8	-0.1	0.00135

	Antimony (Sb), dissolved	Arsenic (As), dissolved	Cadmium (Cd), dissolved	Copper (Cu), dissolved	Iron (Fe), dissolved	Lead (Pb), dissolved	Manganese (Mn), dissolved	Nickel (Ni), dissolved	Silver (Ag), dissolved	Selenium (Se), dissolved	Uranium (U), dissolved	Zinc (Zn), dissolved
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
KZ-7												
January	0.000036	0.000132	0.00006	0.000153	0.022	0.0000157	0.0925	0.000431	0.0000025	0.000988	0.00147	0.0453
February	0.000027	0.000106	0.000048	0.000142	0.0125	0.0000025	0.0745	0.000407	0.0000025	0.000909	0.0015	0.0402
March	0.000033	0.000112	0.000054	0.000151	0.0141	0.0000042	0.0663	0.000403	0.0000025	0.000926	0.00147	0.0389
April	0.000068	0.000164	0.00008	0.0004	0.073	0.000012	0.0592	0.000419	0.0000025	0.000811	0.00139	0.029
May	0.00006	0.000327	0.000107	0.000853	0.246	0.0000658	0.0348	0.00048	0.0000025	0.000562	0.000764	0.0248
June	0.000066	0.0002	0.000069	0.000602	0.0553	0.0000232	0.00829	0.00046	0.000005	0.000529	0.000725	0.015
July	0.00009	0.00025	0.0001099	0.000628	0.0587	0.0000189	0.00728	0.000401	0.0000025	0.000702	0.000791	0.0219
August	0.000078	0.000233	0.000064	0.00055	0.05	0.00005	0.0128	0.0005	0.000005	0.0005	0.000734	0.0111
September	0.000082	0.000179	0.0001	0.000808	0.0892	0.000082	0.0278	0.0005	0.0000038	0.00043	0.001014	0.0267
October	0.000048	0.000161	0.000226	0.000539	0.048	0.000027	0.0175	0.000372	0.0000025	0.00123	0.00139	0.0432
November	0.000049	0.000153	0.000104	0.000267	0.0373	0.000007	0.1111	0.000491	0.0000025	0.00111	0.00133	0.0558
December	0.000045	0.000147	0.000101	0.000196	0.0728	0.0000025	0.11	0.000489	0.0000025	0.001083	0.00138	0.0522
KZ-9												
January	0.000033	0.000175	0.000063	0.000222	0.1494	0.0000993	0.111	0.000476	0.0000025	0.00121	0.00171	0.016
February	0.000029	0.000179	0.000055	0.000166	0.1087	0.0000025	0.119	0.000454	0.0000025	0.00117	0.00168	0.0133
March	0.000033	0.000165	0.000046	0.00015	0.1288	0.000009	0.06823	0.000276	0.0000025	0.00222	0.0024	0.00858
April	0.000056	0.000264	0.0000663	0.000399	0.158	0.0000193	0.125	0.000607	0.0000025	0.000972	0.00159	0.01065
May	0.000046	0.000309	0.000068	0.00147	0.238	0.000085	0.0436	0.00071	0.0000025	0.000626	0.000637	0.0134
June	0.000063	0.000231	0.0000385	0.000903	0.09	0.0000395	0.0167	0.00046	0.0000025	0.000571	0.000707	0.0108
July	0.000066	0.000212	0.000046	0.000499	0.0749	0.000006	0.0266	0.000332	0.0000025	0.000625	0.000772	0.00646
August	0.000059	0.0003	0.000037	0.0005	0.0931	0.0001	0.0481	0.000468	0.0000025	0.0005	0.0011	0.005
September	0.000054	0.00022	0.000077	0.000657	0.174	0.00003	0.043	0.000377	0.0000025	0.000923	0.00118	0.0137
October	0.00005	0.000185	0.000075	0.000339	0.0735	0.000006	0.0471	0.000323	0.0000025	0.00126	0.00138	0.0139
November	0.000039	0.000156	0.00007	0.000232	0.0456	0.0000038	0.08	0.000387	0.0000025	0.00126	0.00147	0.0207
December	0.000034	0.000198	0.000063	0.000227	0.19	0.0000083	0.098	0.000418	0.0000025	0.00131	0.00163	0.0166

	Hardness (from total)	Sulphate, dissolved	Nitrate (N)	Nitrite (N)	Ammonia (N)	Phosphorus,total-colourimetric	Phosphorus (P), total	Fluoride	Chloride	Cyanide, total	Cyanide, Weak Acid Dissociable	Aluminum (Al), total	Antimony (Sb), total	Arsenic (As), total	Cadmium (Cd), total
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
KZ-17															
January	270	35.8	0.239	0.001	0.0119	0.0022	0.0055	0.089	1.11	0.00043	0.00049	0.00377	0.000029	0.000486	0.000044
February	276	40.3	0.271	0.001	0.0192	0.0033	0.0074	0.082	0.55	0.00025	0.00025	0.0075	0.00003	0.000561	0.000053
March	278	38.4	0.274	0.001	0.021	0.003	0.0054	0.081	0.71	0.00025	0.00039	0.00472	0.00003	0.000424	0.000037
April	258	32.7	0.169	0.0016	0.0202	0.0028	0.0066	0.12	0.55	0.00038	0.00038	0.00517	0.00003	0.000596	0.0000392
May	122.5	16.2	0.061	0.001	0.0107	0.0065	0.0085	0.084	0.85	0.0006	0.00071	0.0128	0.000029	0.000636	0.0000415
June	144	22.1	0.0149	0.001	0.0115	0.0037	0.0054	0.084	0.25	0.00064	0.00053	0.0073	0.000044	0.0005	0.000023
July	174	26.7	0.0269	0.001	0.0084	0.003	0.0037	0.098	0.25	0.00025	0.00065	0.0077	0.000052	0.00054	0.0000341
August	170	25.4	0.0145	0.0025	0.0025	0.0067	0.0059	0.082	0.25	0.00038	0.00025	0.0075	0.000061	0.00054	0.000037
September	174	27.2	0.0553	0.001	0.0059	0.0027	0.0036	0.094	0.61	0.00059	0.00059	0.00707	0.000043	0.000299	0.000019
October	165	29.4	0.158	0.001	0.021	0.0047	0.0066	0.089	0.58	0.00025	0.00025	0.00137	0.000033	0.000241	0.00002
November	204	33.4	0.208	0.001	0.0132	0.002	0.0067	0.099	0.62	0.00047	0.00046	0.01081	0.000034	0.000495	0.000039
December	221	31.6	0.17	0.001	0.012	0.0033	0.0046	0.083	0.62	0.00042	0.00025	0.00789	0.000038	0.00049	0.000036
KZ-15															
January	264	36.5	0.222	0.001	0.0329	0.0036	0.0074	0.1	0.8	0.00038	0.00044	0.00877	0.000031	0.000528	0.000054
February	259	38.5	0.235	0.001	0.0214	0.0028	0.0087	0.11	0.61	0.00025	0.00025	0.00964	0.00003	0.000793	0.000054
March	276	37.6	0.232	0.001	0.0184	0.0053	0.0062	0.11	0.62	0.00025	0.00038	0.00795	0.00003	0.0006	0.000057
April	249	34.5	0.182	0.001	0.0132	0.0033	0.007	0.12	0.61	0.00038	0.00038	0.006	0.000025	0.000463	0.0000344
May	93.2	12.6	0.03	0.001	0.006	0.0106	0.0214	0.051	0.76	0.00073	0.00084	0.0366	0.000029	0.000554	0.00004
June	108	19.5	0.0237	0.001	0.015	0.0054	0.007	0.064	0.55	0.00064	0.00053	0.0165	0.000034	0.000408	0.000027
July	147	23.1	0.0136	0.001	0.0163	0.0029	0.0056	0.066	0.25	0.0005	0.00069	0.0128	0.000031	0.000364	0.0000214
August	148	22.7	0.0229	0.0025	0.006	0.0033	0.005	0.065	0.25	0.0005	0.0005	0.01	0.000038	0.000438	0.000024
September	146	24.6	0.05	0.001	0.0037	0.003	0.0022	0.066	0.6	0.00061	0.00056	0.00682	0.00003	0.000403	0.000034
October	178	30.7	0.135	0.001	0.0101	0.0036	0.0078	0.078	0.59	0.00025	0.00025	0.0118	0.000031	0.000561	0.000038
November	213	32.5	0.208	0.0015	0.0154	0.0023	0.0169	0.093	0.25	0.0004	0.00042	0.0324	0.000039	0.000838	0.000066
December	236	31.9	0.194	0.0018	0.011	0.0028	0.0051	0.089	0.67	0.00043	0.00025	0.0149	0.000034	0.00055	0.000051

	Copper (Cu), total	Iron (Fe), total	Lead (Pb), total	Manganese (Mn), total	Nickel (Ni), total	Silver (Ag), total	Selenium (Se), total	Uranium (U), total	Zinc (Zn), total	Dissolved Organic Carbon	pH (field)	pH (lab)	Discharge (Flow)	Temperature (field)	Aluminum (Al), dissolved
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	pH units	pH units	L/s	C	mg/L
KZ-17															
January	0.000332	0.0769	0.000073	0.03552	0.000748	0.0000025	0.00152	0.00421	0.0053	0.89	7.1	8.16	47.9	-0.1	0.00155
February	0.000307	0.101	0.00004	0.03026	0.000762	0.0000025	0.00153	0.00422	0.00445	0.58	7.07	8.09	24.6	0	0.00095
March	0.000255	0.0646	0.0000218	0.02447	0.000769	0.0000025	0.0015	0.00434	0.0038	1.1	7.12	7.85	9.5	0.3	0.00284
April	0.000286	0.0748	0.000025	0.0442	0.00104	0.0000038	0.00126	0.00557	0.00528	1.59	7.64	8.2	32.9	0.2	0.00106
May	0.00151	0.1575	0.000079	0.02855	0.000895	0.0000038	0.000612	0.000979	0.00435	3.62	7.62	7.95	710.8	0.9	0.00434
June	0.00068	0.11	0.000025	0.015	0.000534	0.0000025	0.00058	0.001835	0.004	2.19	7.46	8.12	415.8	5.45	0.00234
July	0.000671	0.0941	0.0000315	0.0254	0.00059	0.0000025	0.000541	0.00226	0.00345	1.82	7.63	8.25	319.6	8.5	0.00156
August	0.0006	0.1145	0.0001	0.03605	0.000644	0.0000038	0.000544	0.00233	0.0033	1.7	8.03	8.14	754.2	5.8	0.00188
September	0.000635	0.0926	0.0000325	0.0128	0.000463	0.0000025	0.000725	0.00189	0.00325	1.58	7.8	8.12	490.9	5.7	0.00224
October	0.000384	0.0037	0.000035	0.000682	0.000369	0.0000025	0.000968	0.00199	0.00103	1.19	7.69	8.23	295.1	4.2	0.00092
November	0.000383	0.089	0.000064	0.03574	0.00058	0.0000025	0.00134	0.00329	0.00468	1.54	7.62	8.14	77.8	0.8	0.00126
December	0.000284	0.0738	0.000021	0.031	0.000655	0.0000025	0.00148	0.00398	0.00428	2.08	7.26	8	125.1	0.4	0.00067
KZ-15															
January	0.000347	0.1014	0.000036	0.0505	0.00138	0.0000038	0.00149	0.0046	0.00806	0.97	7.21	8.18	126.8	0.1	0.00156
February	0.000355	0.175	0.000091	0.0559	0.001	0.0000025	0.00135	0.00495	0.00755	0.57	7.37	8.14	86.1	-0.1	0.00087
March	0.000234	0.106	0.000031	0.0633	0.001086	0.0000025	0.0015	0.00537	0.00747	0.73	7.27	7.92	85.2	0.4	0.00167
April	0.000278	0.0533	0.0000275	0.0284	0.000903	0.0000025	0.00117	0.00477	0.00495	1.3	7.63	8.29	103.5	0.4	0.00105
May	0.00146	0.174	0.000133	0.026	0.0009	0.000005	0.000434	0.000927	0.0057	3.92	7.78	7.98	1803.6	1.5	0.0157
June	0.000876	0.0949	0.0000561	0.0176	0.0005	0.000005	0.000441	0.00113	0.00364	2.02	7.81	8.14	789.5	7.3	0.00661
July	0.000463	0.058	0.0000538	0.0155	0.000491	0.0000025	0.000429	0.00121	0.00304	2.54	7.9	8.14	804.3	8.5	0.00386
August	0.000588	0.066	0.00008	0.019	0.000501	0.0000025	0.0005	0.0017	0.00341	2.02	8	8.14	1636.5	7.8	0.003
September	0.00043	0.0607	0.000036	0.0173	0.0005	0.0000025	0.00065	0.00146	0.00313	1.75	8	8.1	1085.3	5.8	0.00327
October	0.000417	0.0934	0.000049	0.0335	0.000485	0.0000025	0.00117	0.00234	0.00417	1.17	7.86	8.25	700.2	0.8	0.00156
November	0.000481	0.234	0.001271	0.0668	0.00092	0.0000117	0.00133	0.0033	0.00913	1.17	7.73	8.29	263.5	0.1	0.0025
December	0.000307	0.0972	0.000036	0.032	0.00083	0.0000025	0.00145	0.00386	0.00645	1.56	7.21	8.01	254	0	0.0007

	Antimony (Sb), dissolved	Arsenic (As), dissolved	Cadmium (Cd), dissolved	Copper (Cu), dissolved	Iron (Fe), dissolved	Lead (Pb), dissolved	Manganese (Mn), dissolved	Nickel (Ni), dissolved	Silver (Ag), dissolved	Selenium (Se), dissolved	Uranium (U), dissolved	Zinc (Zn), dissolved
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
KZ-17												
January	0.00003	0.00031	0.000032	0.000293	0.002	0.000005	0.015234	0.000661	0.0000025	0.00148	0.00438	0.00387
February	0.000025	0.000262	0.00003	0.000233	0.0015	0.0000025	0.01009	0.000648	0.0000025	0.00154	0.00419	0.00336
March	0.000033	0.000258	0.000035	0.000239	0.0019	0.000005	0.012539	0.000715	0.0000025	0.00138	0.00426	0.00316
April	0.000038	0.00042	0.0000335	0.000234	0.0074	0.0000038	0.0252	0.000829	0.0000025	0.00123	0.00567	0.00448
May	0.000032	0.000421	0.0000265	0.00142	0.0379	0.0000113	0.01105	0.000747	0.0000025	0.00053	0.000958	0.00217
June	0.000044	0.000455	0.0000213	0.000584	0.0306	0.000008	0.0051	0.000524	0.0000025	0.000705	0.001775	0.00239
July	0.000054	0.000411	0.000018	0.000459	0.0116	0.0000025	0.0054	0.000484	0.0000025	0.000503	0.00225	0.00106
August	0.000056	0.000485	0.000025	0.000574	0.0304	0.000072	0.0235	0.0005	0.0000025	0.000533	0.00196	0.0025
September	0.000045	0.000276	0.000019	0.000516	0.0245	0.0000058	0.00921	0.000443	0.0000025	0.000659	0.00196	0.0026
October	0.000036	0.000271	0.000019	0.000324	0.0005	0.0000025	0.000807	0.000371	0.0000025	0.00103	0.00203	0.00091
November	0.000033	0.000333	0.000025	0.000262	0.005	0.0000025	0.0159	0.000514	0.0000025	0.00125	0.00326	0.00347
December	0.000032	0.000385	0.000027	0.000257	0.0094	0.0000025	0.015	0.000582	0.0000025	0.00152	0.00367	0.00248
KZ-15												
January	0.000029	0.000359	0.000043	0.000242	0.0069	0.0000178	0.0365	0.000852	0.0000025	0.0015	0.00474	0.00648
February	0.000028	0.000358	0.000044	0.000195	0.0053	0.0000025	0.0396	0.000954	0.0000025	0.00158	0.00517	0.00659
March	0.000038	0.00035	0.000049	0.000216	0.0049	0.0000042	0.0452	0.000972	0.0000025	0.00145	0.00532	0.00638
April	0.000033	0.000366	0.0000308	0.000261	0.0166	0.0000025	0.0161	0.000972	0.0000025	0.00123	0.00472	0.00458
May	0.00003	0.00041	0.000023	0.00129	0.0607	0.000036	0.00842	0.000695	0.0000025	0.000442	0.000879	0.00273
June	0.000037	0.000347	0.000017	0.000773	0.026	0.000014	0.00731	0.0005	0.0000025	0.000465	0.00111	0.00273
July	0.000033	0.000319	0.0000175	0.000462	0.0183	0.0000097	0.0072	0.00045	0.0000025	0.00042	0.00114	0.00209
August	0.000031	0.0004	0.0000205	0.000485	0.0174	0.00005	0.0117	0.0005	0.0000025	0.000504	0.00164	0.0025
September	0.00003	0.000344	0.000022	0.000518	0.019	0.000007	0.01015	0.000456	0.0000025	0.000597	0.00143	0.00225
October	0.00003	0.000458	0.000022	0.000298	0.0127	0.0000025	0.016	0.000409	0.0000025	0.00108	0.00229	0.00213
November	0.000031	0.000334	0.000033	0.000231	0.006	0.0000025	0.0249	0.000586	0.0000025	0.00129	0.00319	0.00446
December	0.000029	0.000383	0.000035	0.000206	0.0104	0.0000025	0.0191	0.000695	0.0000025	0.00156	0.00387	0.00496

	Hardness (from total)	Sulphate, dissolved	Nitrate (N)	Nitrite (N)	Ammonia (N)	Phosphorus,total-colourimetric	Phosphorus (P), total	Fluoride	Chloride	Cyanide, total	Cyanide, Weak Acid Dissociable	Aluminum (Al), total	Antimony (Sb), total	Arsenic (As), total	Cadmium (Cd), total
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
KZ-16															
January	288	41.1	0.268	0.001	0.0152	0.0024	0.0036	0.08	0.76	0.00038	0.00049	0.00526	0.000058	0.000209	0.000043
February	290	43.5	0.279	0.001	0.0222	0.001	0.0036	0.081	0.75	0.00025	0.00025	0.00304	0.000017	0.000188	0.000038
March	286	39.6	0.286	0.001	0.0265	0.0018	0.0022	0.083	0.73	0.00025	0.00046	0.00177	0.000016	0.000167	0.000034
April	254	36.8	0.207	0.0018	0.0126	0.0025	0.0034	0.087	0.51	0.00038	0.00038	0.00166	0.00001	0.000254	0.000026
May	85.2	11.6	0.04	0.001	0.016	0.0055	0.0102	0.044	0.67	0.00068	0.00072	0.015	0.000017	0.000292	0.000019
June	90.4	14.4	0.0252	0.001	0.0063	0.0036	0.0021	0.053	0.61	0.00063	0.00063	0.01	0.000022	0.000234	0.0000131
July	128	19.8	0.0139	0.001	0.0117	0.0013	0.0024	0.053	0.25	0.00038	0.00075	0.00494	0.00001	0.000246	0.0000146
August	132	21	0.0248	0.0025	0.008	0.0032	0.0029	0.052	0.25	0.0005	0.0005	0.007	0.000022	0.000322	0.0000218
September	135	21.7	0.06	0.001	0.006	0.0015	0.001	0.054	0.25	0.00058	0.0005	0.00362	0.00001	0.000212	0.000015
October	164	27.7	0.172	0.001	0.0111	0.0024	0.001	0.057	0.41	0.00054	0.00044	0.00311	0.00001	0.000304	0.000017
November	242	32.9	0.247	0.001	0.0107	0.001	0.0026	0.071	0.83	0.00042	0.00041	0.00286	0.000035	0.000202	0.000035
December	258	37.7	0.267	0.0016	0.0208	0.001	0.0022	0.067	0.4	0.00025	0.00025	0.006	0.00001	0.000212	0.000023
KZ-21															
January	348	39.2	0.191	0.001	0.1227	0.0193	0.0287	0.2	1.2	0.00045	0.00043	0.0165	0.00014	0.00315	0.000103
February	341	41.7	0.196	0.001	0.1056	0.0159	0.0398	0.22	1.1	0.00025	0.00025	0.00992	0.000035	0.00511	0.000024
March	358	44.3	0.224	0.0016	0.0996	0.0143	0.0256	0.22	6.88	0.00042	0.00053	0.0069	0.000036	0.00347	0.000017
April	306	42.6	0.0993	0.0027	0.0586	0.0249	0.0305	0.2	1.1	0.00063	0.00053	0.0093	0.000071	0.00322	0.0000173
May	132	21.4	0.01	0.0022	0.0147	0.0267	0.0287	0.115	0.94	0.0008	0.00083	0.0328	0.000102	0.00373	0.000019
June	174	26.3	0.0039	0.001	0.011	0.017	0.025	0.15	0.69	0.00069	0.00063	0.0264	0.000133	0.00224	0.000013
July	228	39	0.0033	0.0018	0.0152	0.0202	0.0342	0.16	0.76	0.00075	0.00076	0.0401	0.000205	0.00284	0.0000224
August	240	35.7	0.01	0.0025	0.006	0.0129	0.0165	0.13	0.56	0.0005	0.0005	0.012	0.00014	0.00264	0.0000128
September	229	38.5	0.01	0.001	0.005	0.009	0.011	0.15	0.8	0.00056	0.0005	0.014	0.000143	0.00219	0.000011
October	240	42	0.0122	0.001	0.022	0.0144	0.018	0.15	0.7	0.00057	0.00025	0.0128	0.00009	0.0028	0.000013
November	282	41.8	0.0963	0.0028	0.0722	0.0098	0.0128	0.18	0.74	0.00048	0.00046	0.00439	0.000051	0.00152	0.000015
December	320	44.6	0.127	0.0023	0.0977	0.0142	0.0109	0.17	1.21	0.00054	0.00025	0.00409	0.000039	0.00164	0.000013

	Copper (Cu), total	Iron (Fe), total	Lead (Pb), total	Manganese (Mn), total	Nickel (Ni), total	Silver (Ag), total	Selenium (Se), total	Uranium (U), total	Zinc (Zn), total	Dissolved Organic Carbon	pH (field)	pH (lab)	Discharge (Flow)	Temperature (field)	Aluminum (Al), dissolved
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	pH units	pH units	L/s	C	mg/L
KZ-16															
January	0.000559	0.025	0.0009562	0.0167	0.000914	0.0000063	0.00166	0.00313	0.00335	0.91	7.17	7.96	125.2	-0.1	0.00155
February	0.000251	0.0252	0.0000232	0.0223	0.00083	0.0000025	0.00163	0.00305	0.0016	0.58	7.26	7.91	61.5	-0.2	0.00145
March	0.000166	0.0219	0.0000048	0.0294	0.000989	0.0000025	0.00162	0.00295	0.00106	0.92	7	7.66	95.1	0.2	0.00172
April	0.000244	0.0324	0.0000072	0.0224	0.001	0.0000025	0.00128	0.00268	0.00103	1.46	7.5	8.11	82.4	-0.1	0.00102
May	0.00138	0.0677	0.000025	0.0094	0.000621	0.000005	0.000359	0.000577	0.00109	4.28	7.67	7.95	947.1	1.55	0.0138
June	0.0008	0.019	0.000011	0.0029	0.000497	0.0000025	0.000327	0.000614	0.0006	1.64	7.73	8.03	396.9	9.3	0.00538
July	0.00048	0.0161	0.0000125	0.00349	0.000339	0.0000025	0.000409	0.000704	0.0008	2.2	7.89	8.11	484.7	9	0.00343
August	0.0005	0.011	0.000075	0.0027	0.000426	0.0000025	0.000529	0.00122	0.002	2.33	7.85	8.1	882.3	9.2	0.003
September	0.000416	0.013	0.000007	0.0032	0.000408	0.0000025	0.000454	0.001	0.0007	1.5	7.87	8.07	594.4	6.6	0.00546
October	0.000298	0.0197	0.0000083	0.00685	0.000322	0.0000025	0.000972	0.00171	0.00062	1.3	7.83	8.17	326.1	0.5	0.0012
November	0.000373	0.0199	0.000159	0.01008	0.000474	0.0000025	0.00148	0.0026	0.00146	0.62	7.51	8.09	185.6	-0.1	0.00126
December	0.000236	0.0182	0.000008	0.01237	0.000602	0.0000025	0.0015	0.00276	0.0009	1.44	7.13	7.91	128.9	-0.1	0.00069
KZ-21															
January	0.001811	1.062	0.002459	0.235	0.00266	0.0000138	0.000615	0.00317	0.00877	2.08	6.97	7.97	191.2	-0.1	0.00129
February	0.000266	1.406	0.000077	0.264	0.0026	0.0000025	0.000555	0.00303	0.00245	1.56	6.98	7.95	142.8	-0.1	0.0008
March	0.000218	1.18	0.000149	0.254	0.00264	0.0000025	0.000516	0.00311	0.00235	2.44	7.17	7.79	116	0.2	0.00168
April	0.00046	1.04	0.000036	0.175	0.00234	0.000005	0.000275	0.00296	0.0024	6.21	7.39	8.24	156.3	-0.1	0.00183
May	0.001	0.811	0.00005	0.11	0.00313	0.000005	0.000344	0.00147	0.002	7.45	7.81	8.04	1615.5	3.9	0.00619
June	0.00108	0.42	0.00003	0.036	0.003	0.000005	0.00041	0.00213	0.0021	6.79	7.83	8.25	867.9	9.1	0.00599
July	0.000964	0.722	0.0000755	0.0673	0.00406	0.000005	0.000538	0.00224	0.00331	10.3	7.72	8.2	925	9.8	0.00625
August	0.0006	0.484	0.0000527	0.0553	0.00287	0.0000038	0.000433	0.0024	0.0025	10	7.81	8.14	1618.2	9.8	0.005
September	0.000688	0.43	0.000041	0.0572	0.0028	0.0000025	0.00065	0.00262	0.0028	6.9	7.9	8.25	1149.6	5	0.0105
October	0.0006	0.581	0.000023	0.0906	0.00208	0.0000025	0.000683	0.00323	0.0019	4.74	7.74	8.29	855.8	1.1	0.00179
November	0.000269	0.349	0.000011	0.1134	0.0019	0.0000025	0.000739	0.00311	0.00133	3.08	7.88	8.27	388.4	-0.2	0.00133
December	0.000211	0.3432	0.0000228	0.1592	0.00208	0.0000025	0.000749	0.00315	0.00093	3.21	7.36	7.85	223.6	0	0.00093

	Antimony (Sb), dissolved	Arsenic (As), dissolved	Cadmium (Cd), dissolved	Copper (Cu), dissolved	Iron (Fe), dissolved	Lead (Pb), dissolved	Manganese (Mn), dissolved	Nickel (Ni), dissolved	Silver (Ag), dissolved	Selenium (Se), dissolved	Uranium (U), dissolved	Zinc (Zn), dissolved
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
KZ-16												
January	0.000016	0.00017	0.000027	0.000219	0.0054	0.0000178	0.0143	0.000731	0.0000025	0.00166	0.00311	0.00136
February	0.000024	0.000141	0.000034	0.000235	0.0047	0.0000042	0.0181	0.000823	0.0000025	0.00157	0.00298	0.00159
March	0.000022	0.000159	0.000039	0.000189	0.0065	0.000008	0.0282	0.001081	0.0000025	0.0017	0.00275	0.00115
April	0.000027	0.00019	0.000026	0.000245	0.0114	0.0000025	0.0198	0.00101	0.0000025	0.00135	0.00291	0.0011
May	0.00001	0.000238	0.000016	0.00128	0.0223	0.000009	0.00312	0.000637	0.0000025	0.000365	0.000545	0.00066
June	0.00001	0.000233	0.000013	0.000776	0.009	0.0000025	0.00185	0.000441	0.0000025	0.00034	0.000576	0.00062
July	0.000021	0.000221	0.000012	0.000383	0.0052	0.0000025	0.0017	0.000344	0.0000025	0.000389	0.000666	0.00048
August	0.00002	0.00032	0.0000198	0.000442	0.007	0.000075	0.002	0.000477	0.0000025	0.000498	0.000905	0.002
September	0.00001	0.000202	0.000014	0.000427	0.005	0.0000025	0.0028	0.000344	0.0000025	0.000401	0.000974	0.00081
October	0.00001	0.000313	0.000014	0.000282	0.0049	0.0000025	0.00477	0.000272	0.0000025	0.001044	0.00171	0.00032
November	0.00001	0.000213	0.000022	0.000235	0.0044	0.000015	0.00824	0.000461	0.0000025	0.00134	0.0022	0.0008
December	0.000015	0.000186	0.00002	0.000208	0.0072	0.0000097	0.01082	0.000563	0.0000025	0.00148	0.00268	0.00068
KZ-21												
January	0.000036	0.000628	0.000015	0.000305	0.0438	0.000024	0.194	0.00228	0.0000025	0.00057	0.00325	0.00183
February	0.000029	0.000654	0.000011	0.000171	0.0698	0.0000025	0.202	0.00226	0.0000025	0.000572	0.00311	0.00132
March	0.000034	0.000454	0.000013	0.000193	0.035	0.0000092	0.223	0.00249	0.0000025	0.000487	0.00307	0.00234
April	0.000069	0.00139	0.000012	0.000342	0.1986	0.0000048	0.15	0.00281	0.0000025	0.000336	0.00314	0.00134
May	0.000093	0.00168	0.00001	0.0007	0.273	0.00001	0.0303	0.0025	0.0000025	0.000322	0.00142	0.00073
June	0.00012	0.00151	0.000006	0.000627	0.19	0.000009	0.0177	0.00267	0.0000025	0.000414	0.00217	0.0009
July	0.000169	0.00163	0.0000087	0.000749	0.161	0.0000122	0.0207	0.00289	0.0000025	0.000545	0.00221	0.00206
August	0.000129	0.00171	0.000006	0.00049	0.1	0.00005	0.032	0.002	0.0000025	0.000457	0.00237	0.00195
September	0.000132	0.00153	0.000005	0.0006	0.115	0.0000025	0.035	0.0025	0.0000025	0.000624	0.00272	0.00161
October	0.000087	0.00141	0.000007	0.000287	0.0784	0.0000025	0.0658	0.00193	0.0000025	0.000716	0.0033	0.0005
November	0.000051	0.000651	0.000011	0.000362	0.0256	0.000012	0.0988	0.00196	0.0000025	0.0007	0.00308	0.00136
December	0.000039	0.000863	0.000014	0.000243	0.0781	0.0000168	0.153	0.00199	0.0000025	0.000718	0.00312	0.00122

	Hardness (from total)	Sulphate, dissolved	Nitrate (N)	Nitrite (N)	Ammonia (N)	Phosphorus,total-colourimetric	Phosphorus (P), total	Fluoride	Chloride	Cyanide, total	Cyanide, Weak Acid Dissociable	Aluminum (Al), total	Antimony (Sb), total	Arsenic (As), total	Cadmium (Cd), total
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
KZ-22															
January	336	42.5	0.219	0.001	0.0561	0.0072	0.0124	0.15	0.89	0.00042	0.00051	0.00709	0.00003	0.00196	0.000023
February	340	44.3	0.229	0.0015	0.0754	0.0075	0.0244	0.17	1.02	0.00025	0.0004	0.00936	0.000031	0.00305	0.000022
March	330	47.8	0.257	0.001	0.065	0.006	0.0168	0.16	0.76	0.00041	0.00047	0.00575	0.000033	0.00251	0.000021
April	278	42.9	0.1056	0.0018	0.0452	0.0152	0.0154	0.16	0.75	0.00053	0.00052	0.00566	0.000055	0.00218	0.0000205
May	117	18	0.016	0.001	0.0129	0.0151	0.0171	0.084	0.84	0.00078	0.00075	0.0271	0.000069	0.00197	0.000026
June	141	23.2	0.0112	0.001	0.018	0.0097	0.011	0.099	0.7	0.00066	0.00063	0.0123	0.000082	0.00117	0.000015
July	188	32.7	0.0074	0.001	0.023	0.0185	0.0222	0.12	0.5	0.00078	0.00091	0.0195	0.000119	0.00175	0.0000268
August	179.5	31	0.0148	0.001	0.0136	0.0087	0.0108	0.096	0.25	0.00038	0.00038	0.0198	0.000097	0.00136	0.0000685
September	185	33	0.0254	0.001	0.0037	0.006	0.0052	0.11	0.74	0.00067	0.00071	0.0109	0.00007	0.00126	0.000021
October	220	35.6	0.0772	0.001	0.054	0.0063	0.0094	0.11	0.67	0.0005	0.00025	0.0102	0.000052	0.00143	0.000019
November	254	40.5	0.138	0.001	0.0404	0.0037	0.0075	0.14	0.44	0.00053	0.00045	0.00617	0.000043	0.00127	0.000019
December	290	44	0.18	0.001	0.0599	0.0073	0.0068	0.13	0.57	0.00059	0.00025	0.00453	0.000038	0.001117	0.000017
KZ-26															
January	301	42.1	0.235	0.001	0.043	0.0117	0.0103	0.12	1	0.00025	0.00025	0.00958	0.000104	0.000534	0.000034
February	302	47	0.275	0.001	0.0244	0.0042	0.0174	0.12	0.83	0.00025	0.00025	0.0297	0.000073	0.001234	0.000035
March	365	47.8	0.29	0.001	0.0417	0.0034	0.0038	0.12	0.69	0.00025	0.00042	0.0049	0.000059	0.000463	0.000013
April	294	45.1	0.231	0.001	0.0072	0.0053	0.0072	0.13	0.57	0.00055	0.00038	0.0093	0.000067	0.000674	0.0000136
May	126	20.4	0.03	0.001	0.01	0.0187	0.0241	0.085	1.05	0.0007	0.00062	0.0414	0.000074	0.00131	0.000021
June	157	23.5	0.0127	0.001	0.019	0.01	0.0227	0.098	0.85	0.00067	0.0005	0.11	0.000123	0.00119	0.00004
July	212	31.9	0.013	0.0018	0.013	0.0197	0.0119	0.11	0.55	0.00055	0.00061	0.0461	0.000159	0.00122	0.00002
August	210	29.9	0.01	0.0025	0.0054	0.0128	0.0235	0.092	0.25	0.0005	0.0005	0.0307	0.000125	0.000584	0.000014
September	200	31.1	0.03	0.001	0.009	0.006	0.009	0.1	0.88	0.00051	0.00053	0.0283	0.000102	0.00114	0.0000187
October	223	36.9	0.0752	0.001	0.0114	0.0049	0.0103	0.11	0.73	0.00025	0.00025	0.0325	0.000076	0.00107	0.000022
November	252	41.1	0.13	0.001	0.0142	0.0016	0.0046	0.12	0.4	0.00049	0.00053	0.00432	0.000068	0.000508	0.000012
December	286	43.2	0.191	0.0018	0.0432	0.0148	0.0358	0.11	0.64	0.0006	0.00025	0.1469	0.000108	0.001414	0.000079

	Copper (Cu), total	Iron (Fe), total	Lead (Pb), total	Manganese (Mn), total	Nickel (Ni), total	Silver (Ag), total	Selenium (Se), total	Uranium (U), total	Zinc (Zn), total	Dissolved Organic Carbon	pH (field)	pH (lab)	Discharge (Flow)	Temperature (field)	Aluminum (Al), dissolved
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	pH units	pH units	L/s	C	mg/L
KZ-22															
January	0.000262	0.503	0.00003	0.107	0.0015	0.0000025	0.00118	0.004	0.00226	1.64	7.55	8.17	336	-0.1	0.0014
February	0.000235	0.852	0.000041	0.147	0.00176	0.0000025	0.00096	0.00359	0.0019	1.07	7.5	8.04	497.2	-0.1	0.00126
March	0.000227	0.721	0.000053	0.129	0.00157	0.0000025	0.00113	0.00427	0.00192	1.33	7.37	7.92	253.8	0.3	0.00132
April	0.000287	0.659	0.00002	0.1215	0.00173	0.0000025	0.000736	0.00392	0.00156	3.36	7.53	8.23	337.4	0	0.00135
May	0.00119	0.398	0.000066	0.0473	0.00182	0.000005	0.000437	0.001195	0.0027	5.23	7.88	8.05	2697.3	2.9	0.01147
June	0.00086	0.196	0.000037	0.0202	0.00159	0.000005	0.000462	0.0017	0.0018	4.75	8.01	8.22	1768	7.6	0.0049
July	0.00096	0.472	0.0000279	0.0514	0.00205	0.000005	0.000503	0.00181	0.00629	6.29	7.84	8.25	1766.8	10.4	0.00456
August	0.00102	0.211	0.000137	0.0309	0.002	0.0000038	0.000498	0.00194	0.00266	5.14	7.95	8.27	4177	8.4	0.00475
September	0.000504	0.207	0.000038	0.0382	0.00146	0.0000025	0.000652	0.00209	0.00184	4.5	7.86	8.21	2504.8	3.8	0.00348
October	0.000422	0.243	0.000017	0.0504	0.00125	0.0000025	0.001	0.00294	0.00164	2.88	7.87	8.32	1402	1.5	0.00134
November	0.00032	0.272	0.000067	0.0607	0.00114	0.0000025	0.001054	0.00336	0.002	2.06	7.78	8.3	675.4	-0.1	0.00225
December	0.00025	0.1503	0.0000133	0.0681	0.00125	0.0000025	0.00113	0.00356	0.00125	2.11	7.54	7.94	497.8	-0.1	0.0007
KZ-26															
January	0.00088	0.0712	0.00146	0.011	0.000898	0.000006	0.00104	0.00355	0.00612	0.88	7.44	8.31	564.4	-0.5	0.00144
February	0.0008	0.362	0.000325	0.0576	0.001233	0.0000025	0.000947	0.00355	0.00346	1.55	7.69	8.33	435	-0.2	0.00272
March	0.000315	0.0549	0.0000117	0.00711	0.000761	0.0000025	0.00121	0.00362	0.00063	1.3	7.84	8.26	459.4	-0.2	0.00162
April	0.000335	0.122	0.000022	0.00874	0.00085	0.0000025	0.000857	0.00363	0.0005	1.84	8.16	8.38	376.5	0.1	0.00125
May	0.00133	0.311	0.000092	0.021	0.00187	0.000005	0.000401	0.001305	0.0023	5.49	8.12	8.14	5208.2	2.9	0.00908
June	0.00162	0.309	0.000278	0.0174	0.002	0.0000133	0.000427	0.00167	0.0036	4.42	8.07	8.22	2299	6.5	0.00664
July	0.001043	0.222	0.0001765	0.0161	0.00178	0.000005	0.000486	0.0019	0.00128	6.5	8.21	8.25	2930.8	8.5	0.00588
August	0.0009	0.174	0.00022	0.009	0.00169	0.000005	0.000483	0.00195	0.0025	5.08	8.27	8.29	3823.6	9.1	0.004
September	0.001	0.18	0.000058	0.0245	0.00165	0.000005	0.000569	0.00204	0.002	5.53	7.89	8.25	3412.8	4	0.00583
October	0.000608	0.229	0.000069	0.0255	0.00121	0.0000025	0.000846	0.00267	0.00154	3.99	8.06	8.36	1544.8	0.7	0.00168
November	0.00048	0.038	0.000027	0.00451	0.000789	0.0000025	0.000937	0.003	0.00073	2.38	7.97	8.34	700	-0.1	0.00465
December	0.001646	0.6683	0.0009462	0.058825	0.001871	0.0000142	0.00112	0.00328	0.02249	2.35	7.67	8.17	226.4	0	0.00082

	Antimony (Sb), dissolved	Arsenic (As), dissolved	Cadmium (Cd), dissolved	Copper (Cu), dissolved	Iron (Fe), dissolved	Lead (Pb), dissolved	Manganese (Mn), dissolved	Nickel (Ni), dissolved	Silver (Ag), dissolved	Selenium (Se), dissolved	Uranium (U), dissolved	Zinc (Zn), dissolved
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
KZ-22												
January	0.000036	0.000684	0.000015	0.000276	0.0207	0.000007	0.0842	0.00139	0.0000025	0.00108	0.00404	0.00169
February	0.000027	0.0006	0.000016	0.00022	0.0515	0.0000042	0.113	0.00165	0.0000025	0.000941	0.00376	0.00126
March	0.000035	0.000491	0.000017	0.000204	0.0192	0.0000058	0.1001	0.00146	0.0000025	0.00104	0.0041	0.00152
April	0.000038	0.001071	0.0000119	0.000254	0.1031	0.0000025	0.1102	0.00166	0.0000025	0.000809	0.00399	0.00129
May	0.000058	0.00105	0.000016	0.000955	0.164	0.0000144	0.0218	0.00166	0.0000025	0.000394	0.00118	0.00146
June	0.000081	0.000997	0.0000098	0.000666	0.113	0.00001	0.00822	0.00148	0.0000025	0.000472	0.00168	0.00151
July	0.000108	0.00114	0.0000114	0.000687	0.0897	0.0000025	0.0151	0.00171	0.0000025	0.000524	0.00183	0.00111
August	0.000082	0.00106	0.0000136	0.000623	0.0697	0.0000067	0.0078	0.00159	0.0000025	0.000467	0.00198	0.00132
September	0.000071	0.000929	0.000014	0.000517	0.0643	0.0000038	0.01344	0.00136	0.0000025	0.000617	0.00211	0.00111
October	0.000056	0.000989	0.000011	0.000334	0.0532	0.0000025	0.027	0.000985	0.0000025	0.000936	0.00286	0.00076
November	0.000045	0.000571	0.000013	0.000353	0.0203	0.000016	0.0427	0.0018	0.0000025	0.001053	0.00326	0.00155
December	0.000038	0.000785	0.000014	0.000231	0.0544	0.0000048	0.0658	0.00119	0.0000025	0.00113	0.00355	0.00114
KZ-26												
January	0.000063	0.000323	0.000013	0.000401	0.0085	0.000101	0.0058	0.000699	0.0000025	0.00105	0.00347	0.00126
February	0.000063	0.000414	0.000013	0.000433	0.0046	0.0000257	0.00424	0.00075	0.0000025	0.000996	0.00362	0.00176
March	0.000064	0.000376	0.00001	0.000315	0.0042	0.0000038	0.00281	0.000674	0.0000025	0.000973	0.00388	0.00051
April	0.000055	0.000476	0.0000129	0.000367	0.0135	0.0000025	0.00436	0.000816	0.0000025	0.000861	0.00365	0.00061
May	0.000066	0.000775	0.000011	0.000995	0.101	0.000015	0.00401	0.00126	0.0000025	0.000396	0.00131	0.00101
June	0.000094	0.000749	0.000011	0.00086	0.05	0.000023	0.0024	0.00123	0.0000025	0.000403	0.00167	0.00064
July	0.000119	0.000883	0.0000093	0.000712	0.0433	0.000024	0.00573	0.00136	0.0000025	0.000476	0.00182	0.00052
August	0.000097	0.000607	0.000009	0.000631	0.0335	0.00005	0.0037	0.000856	0.0000025	0.000454	0.00191	0.002
September	0.000092	0.000789	0.000011	0.000771	0.036	0.000009	0.0046	0.00111	0.0000025	0.000543	0.00202	0.00081
October	0.000071	0.000875	0.000011	0.000438	0.0363	0.000005	0.0119	0.000974	0.0000025	0.000835	0.00267	0.00058
November	0.000072	0.000402	0.000009	0.000427	0.006	0.00001	0.00194	0.000791	0.0000025	0.000965	0.00302	0.00059
December	0.000062	0.000435	0.000012	0.000384	0.0099	0.0000278	0.002439	0.000702	0.0000025	0.00104	0.00315	0.0018

	Hardness (from total)	Sulphate, dissolved	Nitrate (N)	Nitrite (N)	Ammonia (N)	Phosphorus,total-colourimetric	Phosphorus (P), total	Fluoride	Chloride	Cyanide, total	Cyanide, Weak Acid Dissociable	Aluminum (Al), total	Antimony (Sb), total	Arsenic (As), total	Cadmium (Cd), total
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
KZ-6															
January	182	23.9	0.175	0.001	0.0188	0.0036	0.0065	0.066	0.25	0.00025	0.00025	0.00813	0.000028	0.000082	0.000038
February	177	25.1	0.211	0.001	0.032	0.0029	0.0066	0.074	0.61	0.00025	0.00025	0.00351	0.00001	0.00007	0.000023
March	181	24.8	0.214	0.001	0.026	0.0026	0.0038	0.074	0.5	0.00025	0.00025	0.00267	0.00001	0.000083	0.000028
April	167	20.6	0.2	0.001	0.0069	0.0025	0.006	0.069	0.99	0.0005	0.00025	0.00809	0.000032	0.000114	0.00003
May	59.4	11.5	0.0209	0.001	0.0025	0.0212	0.0219	0.043	0.84	0.00064	0.00052	0.0525	0.000018	0.000109	0.000023
June	96.7	14.7	0.0107	0.001	0.01	0.0052	0.0077	0.045	0.58	0.00073	0.00059	0.0271	0.00001	0.000105	0.000029
July	132	18.9	0.0094	0.001	0.018	0.0032	0.0086	0.056	0.38	0.00025	0.00049	0.0159	0.00003	0.000068	0.0000225
August	148	16.8	0.01	0.001	0.01	0.0028	0.005	0.055	0.61	0.00057	0.0005	0.0117	0.000019	0.000101	0.0000174
September	150	21.3	0.04	0.001	0.005	0.0015	0.002	0.064	0.64	0.0005	0.0005	0.0051	0.00001	0.000067	0.000018
October	150	22.4	0.0762	0.001	0.0067	0.0033	0.0022	0.061	0.81	0.00025	0.00025	0.004	0.00001	0.000075	0.000015
November	179	25.1	0.161	0.001	0.025	0.001	0.001	0.07	0.57	0.00051	0.00062	0.00129	0.00001	0.000062	0.000009
December	170	23.6	0.15	0.001	0.0116	0.0022	0.0035	0.061	0.25	0.00025	0.00025	0.00314	0.00001	0.000073	0.000015
KZ-18															
January	212	22	0.232	0.001	0.017	0.0597	0.062	0.07	0.74	0.00025	0.00025	0.0297	0.000055	0.000732	0.000062
February	225	21.4	0.246	0.001	0.027	0.0587	0.0692	0.078	0.52	0.00025	0.00025	0.0183	0.000041	0.000993	0.000066
March	225	22.1	0.251	0.001	0.019	0.063	0.0731	0.084	0.56	0.00025	0.00025	0.0141	0.000038	0.00115	0.000059
April	210	19.4	0.227	0.0018	0.024	0.0387	0.0779	0.089	0.74	0.00038	0.00038	0.0134	0.000076	0.00112	0.000042
May	64.7	1.8	0.0296	0.0055	0.0277	0.0341	0.0395	0.035	1.2	0.0013	0.00114	0.1828	0.000018	0.000337	0.0000467
June	162	14.6	0.0936	0.001	0.021	0.0357	0.0376	0.055	0.62	0.00078	0.00064	0.0324	0.000038	0.000548	0.000033
July	147	22.2	0.0168	0.001	0.015	0.0088	0.0119	0.051	0.25	0.00062	0.0015	0.0217	0.00001	0.000244	0.0000229
August	187	17.9	0.0395	0.001	0.014	0.0206	0.0243	0.056	0.48	0.0005	0.00025	0.0124	0.000029	0.000468	0.000072
September	192	22.1	0.0601	0.001	0.0025	0.0223	0.0191	0.062	0.8	0.0005	0.00052	0.0108	0.000024	0.00034	0.000024
October	184	25.5	0.139	0.001	0.0097	0.0289	0.0185	0.063	0.85	0.00025	0.00025	0.0091	0.000022	0.000411	0.000022
November	202	23.5	0.186	0.001	0.011	0.032	0.0342	0.066	0.25	0.00071	0.00073	0.01	0.000031	0.00053	0.000034
December	214	23.9	0.221	0.001	0.019	0.0484	0.043	0.07	0.61	0.00075	0.00025	0.0169	0.000034	0.000792	0.000048

	Copper (Cu), total	Iron (Fe), total	Lead (Pb), total	Manganese (Mn), total	Nickel (Ni), total	Silver (Ag), total	Selenium (Se), total	Uranium (U), total	Zinc (Zn), total	Dissolved Organic Carbon	pH (field)	pH (lab)	Discharge (Flow)	Temperature (field)	Aluminum (Al), dissolved
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	pH units	pH units	L/s	C	mg/L
KZ-6															
January	0.000267	0.0771	0.000363	0.01201	0.000188	0.0000025	0.00122	0.00133	0.0021	1.05	7.77	8.18	5.4	0	0.00272
February	0.000114	0.0213	0.00001	0.00285	0.000146	0.0000025	0.0013	0.00127	0.00084	0.25	7.7	8.19	3.3	-0.2	0.00185
March	0.000112	0.0159	0.000158	0.0025	0.000126	0.0000025	0.00138	0.00125	0.00113	0.73	7.8	8.02		-0.1	0.00152
April	0.0005	0.0339	0.000045	0.0059	0.000339	0.000005	0.00122	0.00132	0.00101	2.19	8.1	8.3	2.6	0.1	0.00702
May	0.00089	0.11	0.000038	0.0118	0.00063	0.000005	0.000446	0.000445	0.0012	6.69	8.06	7.78	52.9	1.5	0.021
June	0.000533	0.0613	0.000128	0.00531	0.0005	0.0000025	0.00034	0.000369	0.0014	3.07	8.06	8.14	47.4	5.2	0.011
July	0.00062	0.06	0.0000373	0.00476	0.000263	0.0000138	0.000412	0.000611	0.0025	2.7	8.22	8.21	18.3	8.7	0.01019
August	0.000346	0.0692	0.000016	0.00579	0.000315	0.0000025	0.000291	0.000543	0.00094	2.94	7.99	8.18	67.7	8.1	0.00751
September	0.000214	0.0293	0.000008	0.00174	0.000195	0.0000025	0.000619	0.000792	0.00058	1.95	7.98	8.26	41.6	4.5	0.00347
October	0.000159	0.0413	0.0000067	0.00628	0.000171	0.0000025	0.000704	0.000849	0.00056	1.48	7.98	8.12	33.6	1.3	0.00216
November	0.00011	0.0125	0.0000025	0.000372	0.000122	0.0000025	0.0011	0.00116	0.00017	1.04	7.84	8.26	14.9	-0.1	0.00177
December	0.000105	0.0315	0.0000083	0.003	0.000139	0.0000025	0.00108	0.00113	0.00041	1.22	7.91	8.12	8.8	0.1	0.00124
KZ-18															
January	0.00033	0.114	0.000488	0.0197	0.0004	0.000005	0.00131	0.00294	0.0029	0.7	6.94	8.12	18.6	-0.1	0.00371
February	0.00101	0.111	0.000147	0.0198	0.00056	0.000005	0.00141	0.00316	0.0023	0.25	6.87	7.98	13.1	-0.3	0.0252
March	0.000108	0.136	0.000031	0.0254	0.000463	0.0000025	0.00143	0.00322	0.00229	0.25	6.97	7.8	13.3	-0.1	0.00188
April	0.00015	0.081	0.000262	0.0142	0.00051	0.000005	0.00112	0.00326	0.005	1.1	7.24	8.13	10.6	0.5	0.00945
May	0.00123	0.089	0.000029	0.00561	0.00202	0.000005	0.000348	0.000558	0.0031	16.39	7.44	7.67	139.4	1.5	0.1587
June	0.00051	0.0386	0.000022	0.00626	0.00071	0.0000038	0.000706	0.00183	0.00169	2.99	7.26	8.02	20.7	2.6	0.0173
July	0.000345	0.0136	0.0000071	0.00154	0.000636	0.0000025	0.00055	0.00108	0.00093	3.7	7.6	8.3		4.7	0.0176
August	0.000325	0.015	0.000132	0.00165	0.000584	0.0000025	0.000729	0.00148	0.00376	2.66	7.54	8.04	93	4.5	0.012
September	0.000182	0.009	0.000006	0.00342	0.000373	0.0000025	0.000996	0.00199	0.00133	1.81	7.38	8.1	55.3	2.8	0.00694
October	0.00017	0.0115	0.0000058	0.00443	0.000357	0.0000025	0.00113	0.00198	0.00097	1.59	7.46	8.18	59.6	0.8	0.00563
November	0.000154	0.0225	0.000012	0.00629	0.000371	0.0000025	0.00134	0.00254	0.00115	0.77	7.29	8.1	34.5	0.2	0.00344
December	0.000172	0.0436	0.000056	0.0109	0.000349	0.0000025	0.00134	0.00274	0.0016	1.67	7.14	7.96	22.7	-0.1	0.00269

	Antimony (Sb), dissolved	Arsenic (As), dissolved	Cadmium (Cd), dissolved	Copper (Cu), dissolved	Iron (Fe), dissolved	Lead (Pb), dissolved	Manganese (Mn), dissolved	Nickel (Ni), dissolved	Silver (Ag), dissolved	Selenium (Se), dissolved	Uranium (U), dissolved	Zinc (Zn), dissolved
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
KZ-6												
January	0.000022	0.000095	0.000019	0.00018	0.0062	0.000223	0.000607	0.00016	0.0000025	0.00118	0.00128	0.00161
February	0.00001	0.000073	0.000016	0.000104	0.002	0.0000025	0.000266	0.000126	0.0000025	0.00137	0.00132	0.00117
March	0.000047	0.000067	0.000021	0.000128	0.0025	0.000005	0.000465	0.00013	0.0000025	0.00136	0.00128	0.00074
April	0.00001	0.000049	0.000013	0.0005	0.0089	0.0000025	0.0006	0.000298	0.0000025	0.00121	0.00133	0.00061
May	0.00001	0.0001	0.000017	0.000856	0.0234	0.000011	0.00284	0.0005	0.000005	0.000403	0.00042	0.00091
June	0.00001	0.000086	0.000011	0.0005	0.0258	0.000009	0.000949	0.000412	0.0000025	0.000395	0.000345	0.00046
July	0.000051	0.000077	0.000011	0.000249	0.0129	0.0000038	0.000683	0.000224	0.0000025	0.000461	0.000599	0.00035
August	0.000023	0.00008	0.0000118	0.000373	0.0181	0.0000025	0.00147	0.00027	0.0000025	0.000276	0.000527	0.00069
September	0.00001	0.000074	0.000016	0.000199	0.015	0.0000025	0.0011	0.000189	0.0000025	0.000551	0.000784	0.00041
October	0.00001	0.000068	0.000011	0.000134	0.0101	0.0000025	0.000606	0.000144	0.0000025	0.000626	0.000871	0.0003
November	0.00001	0.000074	0.000014	0.000146	0.0084	0.000013	0.000436	0.000159	0.0000025	0.000934	0.00103	0.00082
December	0.00001	0.000063	0.000013	0.000102	0.0077	0.0000025	0.000411	0.00013	0.0000025	0.0011	0.00117	0.00032
KZ-18												
January	0.000045	0.000796	0.000043	0.000164	0.0256	0.000378	0.0116	0.000355	0.0000025	0.00137	0.00294	0.00207
February	0.000031	0.00101	0.000051	0.000058	0.0441	0.0000025	0.0167	0.000326	0.0000025	0.00142	0.00303	0.00271
March	0.000058	0.00103	0.000058	0.000087	0.0668	0.000005	0.0226	0.000364	0.0000025	0.0015	0.00312	0.00196
April	0.000031	0.00075	0.000043	0.000126	0.045	0.0002013	0.0136	0.000498	0.0000038	0.0008	0.00316	0.00404
May	0.00002	0.000311	0.000037	0.00112	0.0622	0.0000096	0.00399	0.00183	0.000006	0.000358	0.000523	0.00255
June	0.000037	0.000525	0.000033	0.000393	0.0226	0.0000042	0.00575	0.000741	0.0000025	0.000704	0.00187	0.00148
July	0.000025	0.000262	0.00002	0.000348	0.0067	0.0000025	0.00133	0.000612	0.0000025	0.000593	0.00107	0.0011
August	0.000031	0.000493	0.000023	0.000306	0.0089	0.000041	0.00154	0.000568	0.0000025	0.000712	0.00147	0.00095
September	0.000025	0.000352	0.000021	0.000178	0.0047	0.0000025	0.00284	0.000349	0.0000025	0.000962	0.00198	0.00092
October	0.000019	0.000392	0.000022	0.000111	0.0047	0.0000025	0.00325	0.000322	0.0000025	0.0011	0.00198	0.00076
November	0.000031	0.000562	0.00003	0.000137	0.0082	0.0000025	0.00483	0.000298	0.0000025	0.00132	0.00238	0.00092
December	0.000029	0.000698	0.000037	0.000101	0.0213	0.0000025	0.00898	0.000318	0.0000025	0.00129	0.00275	0.00117

	Hardness (from total)	Sulphate, dissolved	Nitrate (N)	Nitrite (N)	Ammonia (N)	Phosphorus,total-colourimetric	Phosphorus (P), total	Fluoride	Chloride	Cyanide, total	Cyanide, Weak Acid Dissociable	Aluminum (Al), total	Antimony (Sb), total	Arsenic (As), total	Cadmium (Cd), total
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
KZ-37															
January															
February	218	30.9	0.232	0.001	0.037	0.018	0.0255	0.099	0.25	0.00025	0.00025	0.00764	0.000028	0.000497	0.000056
March	223	30.3	0.229	0.001	0.06	0.0157	0.0287	0.098	0.6	0.00025	0.00025	0.00605	0.000032	0.000582	0.000063
April	196	31.7	0.187	0.0027	0.03	0.0188	0.0209	0.096	0.85	0.00059	0.00052	0.0101	0.000048	0.000455	0.000064
May	77.3	7.92	0.0403	0.0055	0.03	0.0306	0.049	0.041	0.99	0.00129	0.00124	0.2972	0.000057	0.000791	0.000207
June	89.7	20.6	0.0452	0.001	0.019	0.0086	0.0191	0.049	0.6	0.00073	0.0006	0.114	0.000068	0.000482	0.00009
July	125	25.8	0.037	0.001	0.015	0.0067	0.037	0.054	0.25	0.00067	0.00123	0.0568	0.00004	0.000292	0.0000795
August	156	30.8	0.0776	0.001	0.011	0.0058	0.0139	0.059	0.25	0.00068	0.00025	0.0308	0.000062	0.00027	0.000078
September	174	32.9	0.111	0.001	0.0025	0.0066	0.0066	0.072	0.68	0.00025	0.00025	0.0146	0.000043	0.000325	0.000083
October	182	31.2	0.119	0.001	0.028	0.0053	0.008	0.071	1.1	0.00025	0.00025	0.00847	0.000039	0.000317	0.000077
November															
December															

	Copper (Cu), total	Iron (Fe), total	Lead (Pb), total	Manganese (Mn), total	Nickel (Ni), total	Silver (Ag), total	Selenium (Se), total	Uranium (U), total	Zinc (Zn), total	Dissolved Organic Carbon	pH (field)	pH (lab)	Discharge (Flow)	Temperature (field)	Aluminum (Al), dissolved
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	pH units	pH units	L/s	C	mg/L
KZ-37															
January															
February	0.000151	0.331	0.000016	0.0923	0.000466	0.0000025	0.00134	0.00218	0.0108	0.25	7.31	7.9	42.7	-0.1	0.0016
March	0.000145	0.398	0.000016	0.113	0.000501	0.0000025	0.0013	0.0021	0.0113	0.64	6.96	7.44	43.4	0	0.00177
April	0.000307	0.388	0.000025	0.0957	0.000538	0.0000025	0.00105	0.00201	0.0113	1.88	8.16	8.27	40.7	0.1	0.00273
May	0.00266	1.09	0.001048	0.0706	0.00188	0.000008	0.000531	0.000526	0.0358	11.3	8.06	7.86	506.4	2.1	0.0874
June	0.00205	0.407	0.000464	0.0235	0.00105	0.000007	0.000568	0.00052	0.0187	3.64	7.43	8.08	301.8	4.6	0.0104
July	0.00107	0.241	0.000374	0.0147	0.00062	0.000005	0.00063	0.000796	0.0153	3.7	7.65	8.24		7	0.00979
August	0.000608	0.2	0.000116	0.0252	0.000402	0.0000025	0.00105	0.00114	0.0129	2.4	7.92	8.31	595.5	7.3	0.00663
September	0.000395	0.294	0.000051	0.0497	0.000417	0.0000025	0.00106	0.00154	0.0112	1.58	7.55	8.33	203.1	2.2	0.00329
October	0.000406	0.322	0.000033	0.061	0.000457	0.0000025	0.00105	0.00143	0.0118	1.31	7.89	8.23	168.5	1.4	0.00259
November															
December															

	Antimony (Sb), dissolved	Arsenic (As), dissolved	Cadmium (Cd), dissolved	Copper (Cu), dissolved	Iron (Fe), dissolved	Lead (Pb), dissolved	Manganese (Mn), dissolved	Nickel (Ni), dissolved	Silver (Ag), dissolved	Selenium (Se), dissolved	Uranium (U), dissolved	Zinc (Zn), dissolved
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
KZ-37												
January												
February	0.000024	0.000384	0.000041	0.000109	0.133	0.0000025	0.0897	0.000445	0.0000025	0.00125	0.00215	0.0106
March	0.000034	0.000382	0.000057	0.000156	0.189	0.000006	0.0992	0.000479	0.0000025	0.0012	0.00218	0.00988
April	0.000026	0.000395	0.000063	0.000257	0.225	0.0000025	0.0994	0.000545	0.0000025	0.00112	0.002	0.0121
May	0.000043	0.000315	0.000082	0.00163	0.217	0.0000984	0.0295	0.00117	0.0000052	0.000474	0.000474	0.0178
June	0.000067	0.00026	0.000042	0.00133	0.127	0.000042	0.0164	0.000581	0.0000025	0.000583	0.000502	0.0108
July	0.000048	0.000223	0.00006	0.000791	0.0719	0.000074	0.0102	0.000456	0.0000025	0.000813	0.000845	0.0111
August	0.000063	0.000211	0.0000617	0.00045	0.103	0.0000111	0.0223	0.000384	0.0000025	0.00104	0.00116	0.0112
September	0.00004	0.000262	0.00007	0.000328	0.17	0.000006	0.0487	0.000376	0.0000025	0.00105	0.00157	0.0102
October	0.000038	0.00025	0.000069	0.000284	0.196	0.000006	0.0556	0.000384	0.0000025	0.00105	0.00151	0.0107
November												
December												

Appendix A2

Baseline Water Quality Data Collected at Site KZ-37 to October 2017

Station Name	Sample Date	Hardness (from total)	Sulphate, dissolved	Nitrate (N)	Nitrite (N)	Ammonia (N)	Phosphorus,total-colourimetric	Fluoride	Chloride	Cyanide, total	Cyanide, Weak Acid Dissociable	Aluminum (Al), total	Antimony (Sb), total	Arsenic (As), total	Cadmium (Cd), total
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
KZ-37	23/02/2017	218	30.9	0.232	<0.0020	0.037	0.018	0.099	<0.50	<0.00050	<0.00050	0.00764	0.000028	0.000497	0.000056
KZ-37	21/03/2017	223	30.3	0.229	<0.0020	0.06	0.0157	0.098	0.6	<0.00050	<0.00050	0.00605	0.000032	0.000582	0.000063
KZ-37	29/04/2017	196	31.7	0.187	0.0027	0.03	0.0188	0.096	0.85	0.00059	0.00052	0.0101	0.000048	0.000455	0.000064
KZ-37	17/05/2017	59	<0.50	<0.020	<0.020	0.049	0.0452	0.034	1.4	0.00182	0.00163	0.503	0.00005	0.00105	0.000323
KZ-37	27/05/2017	95.6	15.6	0.0706	<0.0020	0.012	0.016	0.047	0.59	0.00075	0.00085	0.0914	0.000063	0.000533	0.00009
KZ-37	01/06/2017	85.9	17.4	0.0452	<0.0020	0.019	0.0241	0.044	0.52	0.0007	<0.00050	0.234	0.000068	0.000719	0.000131
KZ-37	07/06/2017	118	25.1	0.0737	<0.0020	0.018	0.0069	0.049	0.6	0.00083	0.0006	0.0712	0.000072	0.000358	0.000062
KZ-37	13/06/2017	89.7	20.6	0.0252	0.0025	0.097	0.0086	0.053	0.73	0.00073	0.00089	0.114	0.00006	0.000482	0.00009
KZ-37	19/07/2017	125	25.8	0.037	<0.0020	0.015	0.0067	0.054	<0.50	0.00067	0.00123	0.0568	0.00004	0.000292	0.0000795
KZ-37	10/08/2017	156	30.8	0.0776	<0.0020	0.011	0.0058	0.059	<0.50	0.00068	<0.00050	0.0308	0.000062	0.00027	0.000078
KZ-37	14/09/2017	174	32.9	0.111	<0.0020	<0.0050	0.0066	0.072	0.68	<0.00050	<0.00050	0.0146	0.000043	0.000325	0.000083
KZ-37	05/10/2017	182	31.2	0.119	<0.0020	0.028	0.0053	0.071	1.1	<0.00050	<0.00050	0.00847	0.000039	0.000317	0.000077

Station Name	Sample Date	Copper (Cu), total	Iron (Fe), total	Lead (Pb), total	Manganese (Mn), total	Nickel (Ni), total	Silver (Ag), total	Selenium (Se), total	Uranium (U), total	Zinc (Zn), total	Dissolved Organic Carbon	pH (field)	Discharge (Flow)	Temperature (field)
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	pH units	L/s	C
KZ-37	23/02/2017	0.000151	0.331	0.000016	0.0923	0.000466	<0.0000050	0.00134	0.0022	0.0108	<0.50	7.31	42.70	-0.10000
KZ-37	21/03/2017	0.000145	0.398	0.000016	0.113	0.000501	<0.0000050	0.0013	0.0021	0.0113	0.64	6.96	43.4	0.00000
KZ-37	29/04/2017	0.000307	0.388	0.000025	0.0957	0.000538	<0.0000050	0.00105	0.00201	0.0113	1.88	8.16	40.7	0.1
KZ-37	17/05/2017	0.00346	1.74	0.00161	0.108	0.00272	0.00	0.000	0.000	0.0525	18.5	8.71	506.4	0.5
KZ-37	27/05/2017	0.00185	0.45	0.000486	0.0331	0.00103	<0.000010	0.000666	0.0007	0.0192	4.11	7.41		3.8
KZ-37	01/06/2017	0.00253	0.88	0.0011	0.0375	0.00131	0.000011	0.000568	0.0005	0.0268	3.64	7.4		4.3
KZ-37	07/06/2017	0.00114	0.316	0.000271	0.0235	0.000672	<0.0000050	0.000761	0.0009	0.014	2.62	7.87	301.8	4.6
KZ-37	13/06/2017	0.00205	0.407	0.000464	0.0217	0.00105	0.000007	0.000558	0.000447	0.0187	5.99	7.43		6.2
KZ-37	19/07/2017	0.00107	0.241	0.000374	0.0147	0.00062	<0.000010	0.00063	0.0008	0.0153	3.7	7.65		7
KZ-37	10/08/2017	0.000608	0.2	0.000116	0.0252	0.000402	<0.0000050	0.00105	0.0011	0.0129	2.4	7.92	595.50	7.3
KZ-37	14/09/2017	0.000395	0.294	0.000051	0.0497	0.000417	<0.0000050	0.00106	0.0015	0.0112	1.58	7.55	203.1	2.20000
KZ-37	05/10/2017	0.000406	0.322	0.000033	0.061	0.000457	<0.0000050	0.00105	0.0014	0.0118	1.31	7.89	168.5	1.40000

Appendix R2-D

KZK Project – Water Treatment Summary

INTEGRATED SUSTAINABILITY

Memo

To:	[Name Redacted]
Cc:	[Name Redacted]
From:	[Name Redacted]
Date:	September 13, 2017
Project #:	VP17-BMC-01-00
Priority:	Normal
Subject:	Water Treatment Summary Outline - Draft

1 INTRODUCTION

BMC Minerals (BMC) has retained Integrated Sustainability Consultants Ltd. (Integrated Sustainability) to develop a technical outline for water treatment at the Kudz Ze Kayah mine project east of Whitehorse, Yukon.

In support of the Kudz Ze Kayah water treatment work, this memorandum is intended to summarize the process selection and modelling work that has been completed to advance water treatment plant (WTP) design and inform key stakeholders.

1.1 Water Treatment Basis

The water treatment plant will be designed to treat:

- All class A and class B contact water from the class A and B storage facility collection ponds
- Runoff from the process plant facility site collected in the perimeter sumps, including low grade ore (LGO) and run of mine (ROM) contact water

The intent is to treat all class A and B water classes of contact water in the WTP prior to discharge to the environment. The species requiring treatment/removal are expected to be fluoride, cadmium, selenium, and zinc.

Treatment of the class A and B contact water is expected to meet discharge objectives when blended with untreated pit rim pond water.

2 BACKGROUND

The following reports have been commissioned by BMC Minerals, and provide the basis for site water management:

- BMC-15-02-2351_019_Preliminary Water Quality Objectives_Rev3_161212
- BMC-15-02-2352_027_Receiving Environment Water Balance_Rev0_170113
- BMC-15-02-2353_038_KZK WQ Model_Rev0_170226

Further to the above reports, Integrated Sustainability have reviewed associated field and lab work provided.

2.1 Water Treatment for Project Water Management Phases

The candidate technologies consider the following project phases of the Kudz Ze Kayah project:

- Operations Phase
- Active Closure Water Management Phase
- Transition Closure Phase
- Post-Closure Phase

3 PREDICTED WATER QUANTITY AND QUALITY

The volume of water expected to be delivered to the treatment system is summarized in Table A.

Table A. Predicted Water Quantity

Parameter	Units	Flow
January	m^3/d	387
February	m^3/d	318
March	m^3/d	290
April	m^3/d	2,134
May	m^3/d	17,290
June	m^3/d	19,233
July	m^3/d	8,774
August	m^3/d	7,485
September	m^3/d	7,534
October	m^3/d	2,000
November	m^3/d	734
December	m^3/d	451
Total	m^3/yr	2,034,941
Daily Average	m^3/d	5,553

The flow rates in Table A correspond to treating all of the class A and B contact water and runoff water. These flow estimates are preliminary, and may change as WTP influent flow and chemistry estimates are refined in subsequent phases of the project.

The opportunity for flow equalization is somewhat limited by the available space for water containment. Opportunities for flow equalization will be considered during engineering in order to reduce the size, capital cost and required turn-down of the WTP infrastructure.

3.1 Water Quality

Predicted WTP inflow data compiled from flow and concentration information is summarized in Table B.

Table B. Predicted Water Quality

Parameter	Units	Predicted WTP Influent	WTP Effluent Objectives
Hardness	mg/L	2338	N/A
Sulphate, dissolved	mg/L	2057	N/A
Nitrate (N)	mg/L	4.92	N/A
Nitrite (N)	mg/L	0.11	N/A
Ammonia (N)	mg/L	0.62	N/A
Phosphorus (P)	mg/L	0.037	N/A
Fluoride (F)	mg/L	0.72	0.058
Chloride	mg/L	64	N/A

Aluminum (Al), total	mg/L	0.053	N/A
Antimony (Sb), total	mg/L	0.035	N/A
Arsenic (As), total	mg/L	0.033	N/A
Cadmium (Cd), total	mg/L	0.048	0.00042
Copper (Cu), total	mg/L	0.0073	N/A
Iron (Fe), total	mg/L	0.0076	N/A
Lead (Pb), total	mg/L	0.024	N/A
Manganese (Mn), total	mg/L	4.80	N/A
Nickel (Ni), total	mg/L	0.089	N/A
Silver (Ag), total	mg/L	0.000076	N/A
Selenium (Se), total	mg/L	0.65	0.0022
Uranium (U), total	mg/L	0.014	N/A
Zinc (Zn), total	mg/L	2.81	0.09

The concentrations in Table B correspond to the 1/10 dry season concentrations of class A and B contact water.

Key water quality considerations include:

- High concentration of sulphate, which may inhibit the removal of selenium
- Total dissolved solids (TDS) concentration is not included in the analysis. Elevated concentration of TDS (including salinity) may reduce the effectiveness of specific ion removal, depending on membrane selection.
- The pH is not indicated, but impacts the oxidation state of the selenium and thus the mechanisms for removal (treatment processes). The mine water is assumed to have a circumneutral pH, given the natural buffering capacity of the local geology.

4 PROPOSED TREATMENT METHODS

Based on the site-specific requirements, we recommend a staged effluent treatment system that is designed to focus on bulk removal of dissolved and suspended species, as well as provisional unit processes that can provide polishing to achieve the required discharge standards.

The proposed active water treatment systems include the unit processes precipitation, chemical addition, media and/or membrane filtration, and ion exchange to meet the discharge water quality requirements. Provisions have been made to develop a treatment approach that can be adapted as more data becomes available and engineering work progresses.

4.1 Proposed Treatment

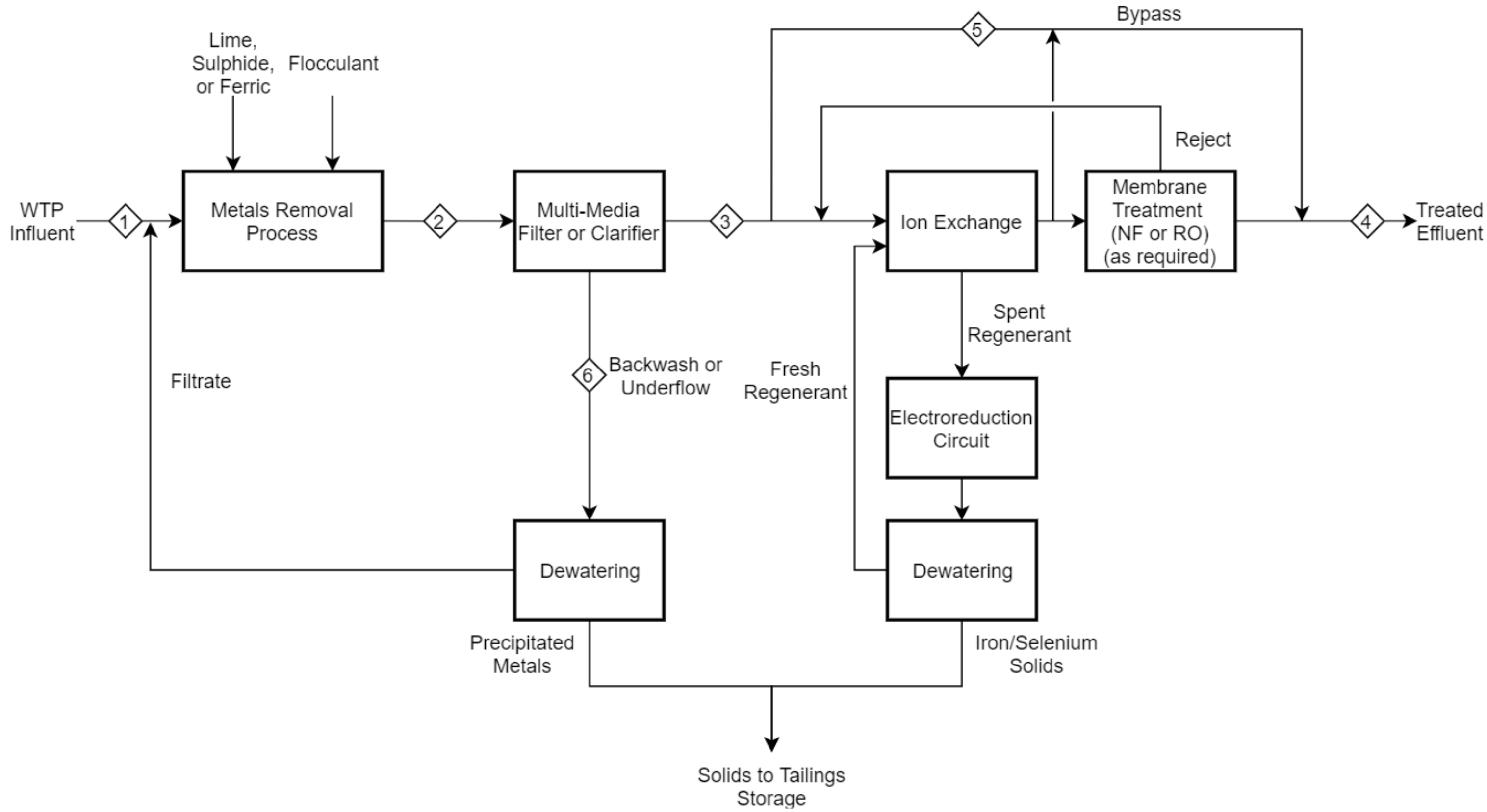
Preliminary candidate technologies include a metals removal by precipitation process (via lime, sulphide or ferric addition), multimedia filtration, membrane filtration by nanofiltration (NF) or reverse osmosis (RO), and ion exchange (IX).

This approach assumes that the speciation of selenium may include elemental selenium and other oxidation states that produce oxygenated anions, e.g. selenite (HSeO4-;

oxidation state +IV) and selenate (SeO42-; oxidation state +VI). Permutations of the proposed processes could be configured to accommodate the requirement for targeting a variety of oxidation states of selenium with downstream polishing (e.g. an advanced reactive media ion exchange and/or reverse osmosis). The requirements for selenium removal will be confirmed pending a speciation of selenium, however preliminary thermodynamic modelling has been conducted to predict selenium speciation at the expected pH and reduction-oxidation potential ranges.

The metals removal process is suitable option for removal of selenium in the elemental or selenite form, heavy metals and metalloids as well as other organic and inorganic parameters. Selenate will be targeted with specialized ion exchange resins, or polishing with membrane filtration.

The treatment process is detailed in Figure A with a preliminary stream balance. Stream flows are for a single-pass system only and do not reflect recycle stream volumes. Flow rates will be confirmed during development of a detailed mass balance in the engineering phase of the project.



Stream	Average Estimated Flow (m^3/d)
1	5,553
2	5,386
3	4,848
4	4,848
5	3,232
6	539

Figure A. Block Flow Diagram of Treatment

Treatment consists of the following treatment processes:

- Metals removal – addition of lime, sulphide and/or ferric to encourage precipitation of metals, and flocculation to improve separation of metals and metalloids. Ballast may be included to increase the settling rate of the particles to reduce the footprint of the clarifier. Sulphidation is expected to generate less waste than a lime system.
- Multi-media filtration – filtration to prevent carryover of precipitated metallic and non-metallic solids from metals removal system to the ion exchange and/or membrane systems. This improves the removal of precipitated species and protects the ion exchange system. A clarifier may also be utilized in lieu of a multi-media filter for sludge thickening, depending on precipitation chemistry.
- Ion exchange – achieves removal of selenate via exchange within a fluidized resin bed.
- Membrane filtration – ultrafiltration, nanofiltration or reverse osmosis may be included to achieve a high degree of removal of trace elements including fluoride and selenium in oxy-anionic forms.
- Electroreduction – selenium from the ion exchange process is removed as an iron-selenium solid.
- Dewatering – dewatering of MMF backwash and electroreduction effluent to minimize liquid waste streams from the process. May be achieved through vacuum filtration, a filter press, or another suitable technology. Solids from dewatering may be co-mingled with tailings and directed to tailings storage.

Filter backwash from the multi-media filter will be passed through a dewatering process, with water returned to the front end of the process.

Further evaluation will be conducted to determine the efficacy of different precipitation processes and any additional pre-treatment for ion exchange, as well as requirements for downstream membrane treatment.

The treatment process will generate a precipitated metals and a selenium-iron solid waste. Disposal of the solids may be achieved through conveyance to an acceptable storage location (e.g. co-mingled with tailings).

4.1.1 Metals Removal by Precipitation Process

The metals removal by precipitation process is a solids-separation technology that utilizes lime, sulphide and/or ferric addition to precipitate solids and produce a concentrated sludge that minimizes storage requirements and maximizes the sludge stability. Lime addition is the more conventional process, although metal sulphides have lower solubility than hydroxide species, so there can be significant advantages in effluent quality and sludge generation where the water chemistry supports sulphide precipitation. Ferric co-precipitation is also effective at removing elemental selenium and other heavy metals and may be employed to optimize the downstream process. Another benefit of ferric precipitation is that it may also be effective at removing uranium, which has been identified in water balance and geochemistry work. It is not expected to exceed the receiving water proposed limit but may become a treatment objective if elevated levels are developed in subsequent modelling or sampling.

A metals removal by precipitation process consists of the following components:

- Clarifier/thickener
- Lime, sulphide and/or ferric dosing
- Reactor tank (including aeration and agitation)
- Flocculant dosing
- Flocculant tank

Performance

Modelling for metals removal performance using lime was undertaken using an electrolyte thermodynamic model to estimate removal rates from the influent, with the model focusing on metallic species. Results are summarized in Table C, and provided in detail in the Appendix. In order to support preliminary process selection with respect to polishing with advanced reactive ion exchange resin and/or reverse osmosis, selenium speciation was estimated by considering the generation of selenate from selenite as alkalinity increased while considering the effects of sulphate in maintaining a portion as selenite.

Modelling for sulphide and/or ferric addition will be completed during preliminary engineering process selection to optimize the metals removal process. The predicted effluent water quality in Table C is based on a thermodynamic model. If lime addition is implemented, effluent water quality shall be confirmed with lab testing, as model results may not reflect accurate treatment performance for all metallic species.

The following assumptions were incorporated into the model:

- WTP influent is slightly acidic (pH 6.5 used to assume oxidation states of elements for chemical modelling)
- Selenium speciation is 60% selenate, 40% selenite
- Metals removal process will be run at pH of 10
- Assumes equilibrium is reached

Table C. Metals Removal System (Lime) – Influent and Effluent Water Qualities

Parameter (units)	Units	Influent Water Quality	Predicted Effluent Water Quality
Cadmium (Cd), total	mg/L	0.048	Feed
Copper (Cu), total	mg/L	0.0073	0.00040
Iron (Fe), total	mg/L	0.0076	0.00070

Parameter (units)	Units	Influent Water Quality	Predicted Effluent Water Quality
Lead (Pb), total	mg/L	0.0237	Feed
Manganese (Mn), total	mg/L	4.8	Feed
Nickel (Ni), total	mg/L	0.089	0.019
Silver (Ag), total	mg/L	0.000076	Feed
Selenium (Se), total	mg/L	0.65	Feed
Uranium (U), total	mg/L	0.01351	0.0021
Zinc (Zn), total	mg/L	2.81	Feed[1]

[1]Zinc is expected to transition from Zn^{2+} to $Zn(OH)_2$ at a pH of 10, however, model results suggest zinc hydroxide will remain soluble. Additional optimization and sensitivity testing if the model is planned to further examine zinc removal in the metals removal system

For comparison, preliminary estimated removal rates for a sulphidation process have been included below, and will be further refined during preliminary engineering.

Table D. Metals Removal System (Sulphide) – Influent and Effluent Water Qualities

Parameter (units)	Units	Influent Water Quality	Predicted Effluent Water Quality
Cadmium (Cd), total	mg/L	0.048	<0.0001
Copper (Cu), total	mg/L	0.0073	<0.002
Iron (Fe), total	mg/L	0.0076	<0.1
Lead (Pb), total	mg/L	0.0237	<0.001
Manganese (Mn), total	mg/L	4.8	Feed
Nickel (Ni), total	mg/L	0.089	<0.2
Silver (Ag), total	mg/L	0.000076	<0.0005
Selenium (Se), total	mg/L	0.65	Feed
Uranium (U), total	mg/L	0.01351	Feed
Zinc (Zn), total	mg/L	2.81	<0.04

4.1.2 Multi-media Filtration

Overflow from the metals removal system will be filtered through a multimedia filter, which will remove suspended solids as well as dissolved metals that can be precipitated by oxidation (e.g. iron, manganese). The feed water from the metals removal will be dosed with flocculant to aid in the agglomeration and retention of suspended solids. Filtered water will then flow to a dedicated filtered water tank.

The filter will periodically perform an automated backwash based on pressure differential or total filter throughput. During filter backwash, water from the Filtered Water Tank is pumped up through the filter. After backwash, the filter is rinsed to return the filtrate to acceptable quality. The backwash stream is sent to a dewatering process for solids removal and water recovery.

The multimedia filter consists of an specialized coarse and fine media that provides effective pre-treatment for the downstream processes which may include ion exchange and/or membrane filtration processes. Effective pre-treatment will protect the ion exchange resin beds and/or membranes from fouling and will increase the operational run-time and life span of the systems, thus reducing operating costs.

Performance

The multimedia filter performance was assessed using benchmark performance data from manufacturers. The filter is anticipated to remove total suspended solids from the metals removal effluent down to a concentration of 4 mg/L, with manganese and un-oxidized iron being oxidized and removed in the filtration process simultaneously.

4.1.3 Dewatering System

A dewatering system such as vacuum filtration, filter press, or other suitable technology will be implemented to dewater the metals removal system sludge and multimedia filter backwash. The filter backwash will contain suspended solids and other contaminants. The dewatering system will dewater the suspended solids within the filter backwash.

The water recovered will be returned to the influent line upstream of the metals removal system.

4.1.4 Ion Exchange

A specialized ion exchange system[1] is included to target selenate from the influent. During operation, the resin will become saturated with the target parameters and is periodically regenerated using a brine solution that reverses the ion exchange process. The process is designed to further concentrate and precipitate the dissolved components of the waste regenerant to produce a solid waste product, which can be dewatered and stockpiled or trucked away.

During engineering, modelling will be undertaken to optimize ion exchange configuration and waste management. An upfront sacrificial column set may be required to prevent fluoride interference with selenium.

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[1] Selen-IX™: Selenium Removal from Mining Affected Runoff Using Ion Exchange Based Technology, BQE Water 2014

Table E. Ion Exchange System – Estimated Influent and Effluent Water Qualities

Parameter (units)	Units	Influent Water Quality	Predicted Effluent Water Quality
Selenate	mg/L	0.39	<0.0011
Selenite	mg/L	<0.0011	<0.0011
Selenium (Se), total	mg/L	0.39	<0.0022

The influent selenite in Table E assumes that selenite has been removed in an upstream ferric co-precipitation process. The ion exchange process is expected to remove selenate, lowering the total selenium to effluent targets. Additional work in engineering will confirm removal rates based on a detailed process model.

4.1.5 Electroreduction Circuit

The electroreduction circuit is used to remove selenium from the spent IX regenerant as a solid. The selenium-rich spent regenerant is reduced and precipitated with iron from iron anodes in electrocells, forming a solid selenium-iron solid. The selenium-iron solids are separated and further dewatered, forming a selenium-iron solid that can be co-mingled with tailing on site[2].

4.1.6 Membrane Treatment

Membrane filtration is a pressure-membrane technology that can filter out suspended particles, and other dissolved and non-soluble contaminants, such as oil, bacteria, metals, suspended and dissolved solids. A succession of membranes of increasingly discriminating pore sizes may be used at successively higher feed pressures. For example, ultrafiltration (UF), when used as a pre-treatment system for an RO, helps reduce fouling of the RO membranes.

Membrane treatment may include UF pretreatment, nanofiltration (likely without UF pre-treatment), or reverse osmosis (with UF pretreatment).

4.1.7 Ultrafiltration

The UF unit operation includes multiple treatment trains in parallel to accommodate variable flow requirements. UF permeate is expected to consistently produce a permeate with turbidity less than 0.2 NTU, regardless of feed water quality. The high quality permeate will be free of suspended solids, and will provide pre-treatment that will improve efficiency of the RO membranes.

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[2] Technical Report for the Kemess Underground Project and Kemess East Resource Estimate, British Columbia, Canada, SRK Consulting 2016

The UF concentrate waste stream that will flow to the sludge thickener for dewatering, or to the metals removal system for an additional pass through the metals removal circuit. The UF concentrate waste stream will consist mostly of suspended solids that are too large to pass through the membrane pores. The permeate water quality will be characterized by dissolved parameters such as calcium ions, and chloride, which will be removed in the RO process, respectively.

Advantages and Disadvantages of Ultrafiltration Systems

- Small footprint
- Longer operational service life than RO membranes
- High tolerance to feed water quality upsets
- Does not require pre-treatment chemicals
- When operated as a pre-treatment, UF improves the performance and reduces maintenance costs of the RO system
- Cannot separate low molecular weight or dissolved contaminants

Table F. Ultrafiltration – Influent and Effluent Water Qualities

Parameter (units)	Units	Influent Water Quality	Predicted Effluent Water Quality
Turbidity	NTU	2	<0.2
Total Suspended Solids (TSS)	mg/L	4	<0.5
Silt Density Index (SDI)[1]	N/A	N/A	3

[1]The silt density index is used to indicate the quantity of particulate matter in water and is applicable to relatively low (<1.0 NTU) turbidity waters such as well water, filtered water, or clarified effluent samples (ASTM D4189-07, 2014).

Performance

The UF unit is projected to recover 96% of the influent as a permeate, with the remaining 4% as a reject stream. This was determined via industry UF modelling software, assuming four racks of HYDRAcap MAX 80 modules, with 105 m^2 of membrane area per module. UF model results have been included in Appendix 1.

4.1.8 Nanofiltration and Reverse Osmosis

Nanofiltration and reverse osmosis are used to remove microorganisms and multivalent ions from influent water. Nanofiltration has a larger pore size and better tolerance to suspended solids, but is only marginally effective at removing small multivalent ions and monovalent ions. Because of the sensitivity of RO to suspended solids, UF is often used upstream. In this application, some modelling has been done to evaluate a UF/RO system, although further evaluation will be conducted to determine the optimal membrane system which may contain UF/RO or NF.

The RO system is configured to allow for a full or partial bypass of the RO after the ion exchange system, as ion exchange is expected to reach <0.0022 mg/L of selenium[3]. A two-stage fully automatic RO system was modelled for purposes of removing the dissolved fraction of target parameters and remaining heavy metals as required by the environmental discharge requirements. The proposed RO system is expected to provide 79 % recovery. Subsequent process modelling may include additional stages of RO to optimize higher recovery rate (and, consequently, lower reject volumes) vs capital and operating cost (including power and chemical consumption). The RO system will produce high-purity water that is suitable for discharge to the environment.

The model for RO conservatively assumed little to no reduction of selenium in the metals removal process. Software sensitivity limited evaluation of selenium removal over less than 0.005 mg/L, but is supported by full scale applications in which selenium was reduced to 0.002 mg/L at the Barrick Richmond Hill Mine, and to less than 0.005 mg/L at a former gold mine in California[4]. Additional modelling to improve sensitivity to low effluent concentration and incorporate upstream ion exchange will be conducted to establish consistent removal to below 0.002 mg/L.

The 2nd stage RO system may be included to increase the throughput by treating the concentrate waste stream from the first stage. Concentrate from the first-stage membrane module will be sent to the second stage RO membrane module for treatment, and the concentrate from the second RO stage will be sent to the inlet of the ion exchange process.

The RO equipment will be furnished with a fully automatic Clean in Place (CIP) and permeate flush system.

Further evaluation of whether the ammonia entering the WTP is ionized or un-ionized is required, as pH adjustment may be required prior to the RO. Additional RO stages may decrease the volume of brine generated, however, increased anti-scalant usage may be required to prevent fouling in successive stages. Any reject from the RO will be returned upstream of the ion exchange.

Advantages and Disadvantages of Reverse Osmosis Systems

- Risk of fouling and scaling membranes
- Membranes are sensitive to process upset (e.g. chemical or suspended solids breakthrough)
- Modularized system

[3] Technical Report for the Kemess Underground Project and Kemess East Resource Estimate, British Columbia, Canada, SRK Consulting 2016

[4] U.S. Environmental Protection Agency. (2014). Reference Guide to Treatment Technologies for Mining-Influenced Waters. US EPA.

- Demonstrated at full scale to remove selenium (selenite or selenate) to less than 5 µg/L
- Reject stream must be properly managed

Table G. Reverse Osmosis – Influent and Effluent Water Qualities

Parameter (units)	Units	Influent Water Quality	Predicted Effluent Water Quality
Hardness	mg/L	2110	6.39
Sulphate, dissolved	mg/L	2057	5.52
Cadmium (Cd), total	mg/L	0.048	0.00042
Nitrate (N)	mg/L	4.92	0.27
Ammonia (N)	mg/L	0.62	0.011
Fluoride (F)	mg/L	0.72	0.015
Chloride	mg/L	64	0.69
Lead (Pb), total	mg/L	0.0237	0.0012
Manganese (Mn), total	mg/L	0.05	<0.001
Selenium (Se), total	mg/L	0.65	<0.005
Silver (Ag), total	mg/L	0.000076	<0.00001
Zinc (Zn), total	mg/L	2.81	0.009

Performance

The RO unit is predicted to remove the remainder of dissolved solids to target effluent objectives at a 79% overall permeate recovery (i.e. 21% reject stream recirculated upstream of ion exchange). The effluent quality was determined with industry RO modelling software, assuming four trains using CPA5-LD RO membrane elements. RO model results have been included in Appendix 1.

5 PROCESS SELECTION – RATIONALE

Based on the treatment requirements identified, it is expected that the treatment requirements can be achieved using the treatment approach shown in Figure A.

Membrane filtration is included as provisional process steps, but may be excluded if the base case ion exchange effluent meets the target criteria for discharge.

Reverse osmosis was selected as the preferred provisional polishing unit process as it was deemed the most reliable to achieve the effluent objectives required. While the process steps upstream of the RO system will reduce the concentration of a large number of these species, the RO (if required) will provide a polishing step to reach target concentrations and provide treatment for any species not removed in earlier steps, such as ammonia.

Ion exchange is a common process and capable of removing various species of inorganic contaminants, heavy metals and selenium in different valence states. To account for variable selenium species, this process may include specialized, advanced reactive media. Multi-stage ion exchange would require skilled operators and may require targeted lab testing due to the sensitivity to site specific water quality.

Other candidate technologies capable of treating water to the requirements include:

- Thermal processes
  - Evaporation and/or crystallization for bulk removal of the key contaminants is expected to have extensive pre-treatment requirements
  - The capital and operating costs associated with this treatment method may be significantly higher than the membrane treatment (i.e. the ultrafiltration and RO system proposed)
  - Thermal process may be useful to treat membrane reject as a waste-reduction process
- Electrodeionization
  - Electrodeionization is used for very challenging wastewater and has precedent in ultra-pure water treatment applications
  - Suitable for low TDS water (~150-200 ppm)
  - It is often used as an alternative to mixed bed deionization, since it does not require chemical addition for regeneration
  - Often used as a replacement for Reverse Osmosis, if the chemistry of the water suits the technology (most are affected by the presence of dissolved gasses)
  - The capital and operating costs associated with this treatment method may be significantly higher than membrane treatment (i.e. the ultrafiltration, nanofiltration and RO systems)
- Biological treatment
  - Various biological methods exist for treatment of selenium, which reduce the oxyanion species to elemental selenium, including:
    - Fixed film bacterial attenuation
    - Algal volatilization
    - Constructed wetlands
    - Phytoremediation
  - For the removal of selenium during the operations phase, piloting would likely be required, and long-term operational information on the performance and optimization of biological systems for removing selenium (particularly in cold-weather) is limited
  - Biological treatment may be suitable the treatment of mining-impacted water during closure

5.1 Similar Applications

The process selection employed to date has referenced various other mining applications in which similar influent flow and chemistry has been targeted to meet similar effluent objectives. Examples of operating projects, successful pilots or projects in advanced engineering include:

- JDS Silver Silvertip mine – To target Cd, Zn, Cu the SilverTip mine uses sulphide precipitation followed by media filtration. Ferric addition for co-precipitation is included to target selenium, but is not used full-time.
- AuRico Gold Kemess Underground Mine – Current plans for the Kemess underground mine include ferric co-precipitation, sulphide precipitation followed by ion exchange to remove total selenium to 0.002 mg/L.[5] The treatment plant is currently in the detailed engineering and permitting phase, and successful piloting of the treatment process took place in 2015 and 2017.
- IDM Mining Red Mountain – Current plans for the Red Mountain mine include lime and ferric co-precipitation for metals removal. The mine is currently in feasibility-level engineering
- Wolverine mine - Two treatment methods for removal of selenium and dissolved metals from tailings storage facility water at the Wolverine mine were evaluated at a scoping level:
  - In-situ biological reduction combined with ferric/lime treatment, and
  - Zero-valent iron treatment combined with ferric/lime treatment. [6]

The JDS Silver Silvertip mine is currently in operation, and the AuRico Gold Kemess Underground Mine has advanced significantly through the process of regulatory approval, leading to a level of regulatory buy-in to these water treatment approaches, and allowing Kudz Ze Kayah to be a second or third mover in the permitting process.

5.2 Residuals Management

The multi-media filter backwash, ion exchange system, and membrane filtration systems (if required) will ultimately generate waste streams.

We understand that the Kudz Ze Kayah mill will be able to effectively manage up to 7.5 m^3/hr (180 m^3/d) of flow from the WTP. Preliminary estimates are that the daily MMF backwash flow would amount to approximately 10% of the flow rate to the WTP, which exceeds the mill's capacity from April through October. To decrease liquid volumes to the mill from the metals removal waste stream, further thickening/dewatering is required. This can be achieved using vacuum filtration, a filter press, clarifier, or other suitable technology.

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[5] Feasibility Study Update Kemess Underground Project British Columbia, Canada, SRK Consulting

[6] Wolverine Mine Reclamation and Closure Plan Version 2016-07, Yukon Zinc Corporation

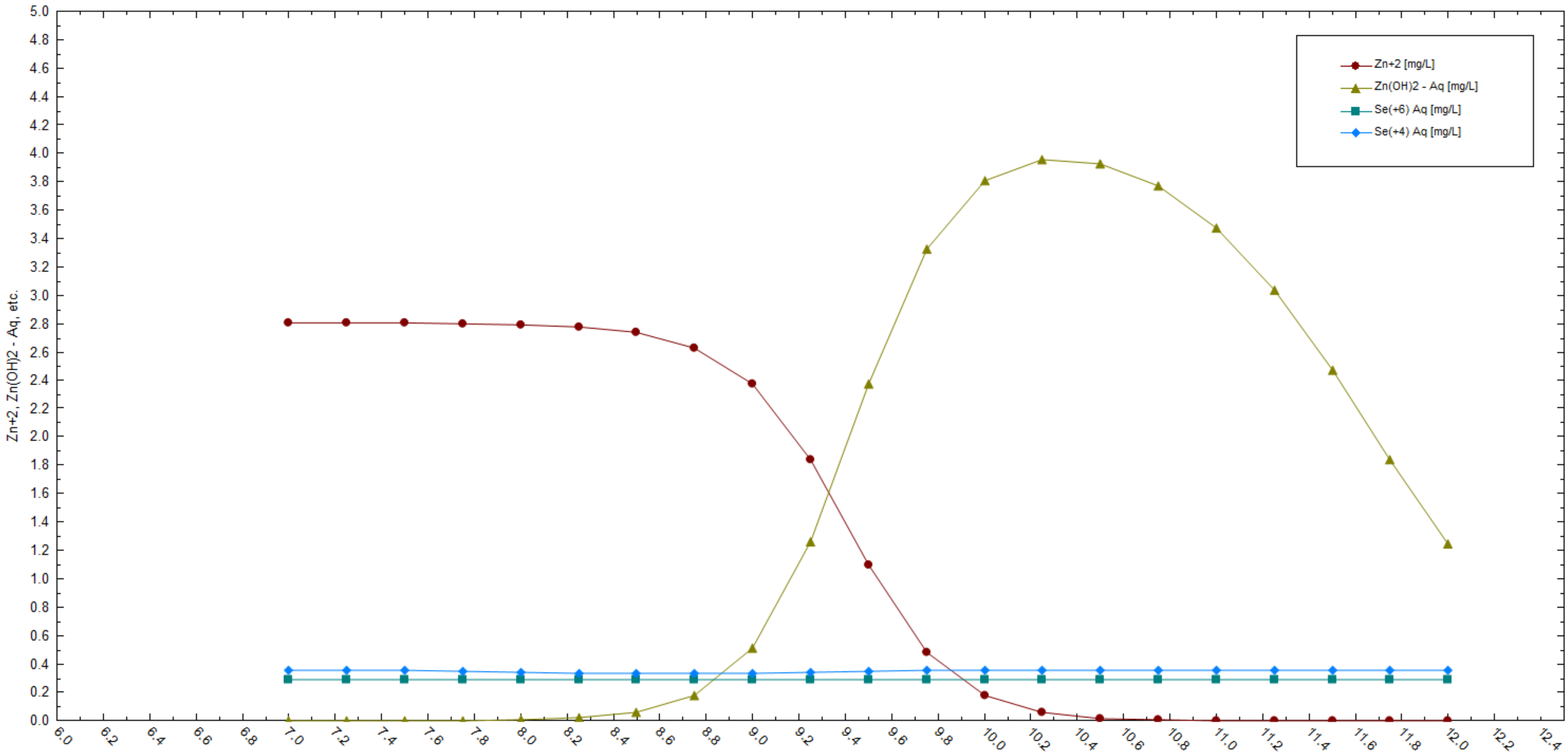
The ion exchange process is expected to only generate a solid selenium-iron waste stream, with lean "shoulder" regenerant recovered and recycled. The selenium-iron solids can then be co-mingled with tailings on-site and directed to tailings storage.

For the RO system, preliminary modeling estimates that up to 21% of the expected average flow will be retained as reject and recycled to the front of the ion exchange process. The RO will be bypassed to the greatest extent possible while meeting effluent requirements.

Incorporating further RO passes will decrease the volume of reject, however additional chemical dosage will be required to prevent scaling (for example, due to $CaSO_4$ saturation occurring at the RO membrane surface).

Appendix 1 – Technical Documentation

HDS Modelling Results – Selenium and Zinc Species vs pH



HDS Modelling Results – Select Species in Aqueous Phase vs pH

	Target pH	Zn+2	Zn(OH)2 - Aq	U(+6) Aq	Se(+6) Aq	Se(+4) Aq	Pb(+2) Aq	Ni(+2) Aq	Mn(+2) Aq	Fe(+3) Aq	Cu(+2) Aq	Cd(+2) Aq	Ag(+1) Aq
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
1	7.00000	2.80684	6.06521e-5	0.0135077	0.291152	0.358749	0.0236960	0.0889850	4.79919	5.38768e-4	7.29877e-3	0.0479919	7.59872e-5
2	7.25000	2.80586	1.91730e-4	0.0135077	0.291152	0.358750	0.0236960	0.0889850	4.79919	5.31694e-4	7.29877e-3	0.0479919	7.59872e-5
3	7.50000	2.80401	6.05902e-4	0.0135077	0.291151	0.355955	0.0236960	0.0869088	4.79919	5.28147e-4	7.29876e-3	0.0479919	7.59872e-5
4	7.75000	2.80035	1.91353e-3	0.0135077	0.291151	0.345513	0.0236960	0.0791498	4.79919	5.26510e-4	7.29876e-3	0.0479919	7.59872e-5
5	8.00000	2.79267	6.03452e-3	0.0135077	0.291151	0.339580	0.0236960	0.0747411	4.79919	5.26115e-4	7.29875e-3	0.0479919	7.59872e-5
6	8.25000	2.77544	0.0189651	0.0105358	0.291151	0.336454	0.0236960	0.0724183	4.79919	5.26797e-4	7.29874e-3	0.0479919	7.59872e-5
7	8.50000	2.73393	0.0590769	6.75583e-3	0.291151	0.335180	0.0236960	0.0714716	4.79919	5.28781e-4	5.28027e-3	0.0479919	7.59872e-5
8	8.75000	2.62950	0.179688	4.63836e-3	0.291151	0.335354	0.0236960	0.0716011	4.79919	5.32739e-4	2.35916e-3	0.0479919	7.59872e-5
9	9.00000	2.37340	0.512918	3.45019e-3	0.291151	0.337027	0.0236960	0.0728442	4.79919	5.40021e-4	1.15100e-3	0.0479919	7.59872e-5
10	9.25000	1.84307	1.25975	2.78285e-3	0.291152	0.340714	0.0236960	0.0755837	4.79919	5.53106e-4	6.23407e-4	0.0479919	7.59873e-5
11	9.50000	1.09678	2.37114	2.40785e-3	0.291152	0.347518	0.0236960	0.0806393	4.79920	5.76448e-4	3.99782e-4	0.0479920	7.59873e-5
12	9.75000	0.485611	3.32063	2.19706e-3	0.291152	0.358750	0.0236960	0.0491059	4.79920	6.17995e-4	3.40455e-4	0.0479920	7.59873e-5
13	10.0000	0.176008	3.80652	2.07856e-3	0.291152	0.358750	0.0236961	0.0190909	4.79920	6.91898e-4	4.02948e-4	0.0479920	7.59873e-5
14	10.2500	0.0578401	3.95619	2.01193e-3	0.291152	0.358751	0.0236961	8.03476e-3	4.79920	8.23329e-4	5.98426e-4	0.0479920	7.59874e-5
15	10.5000	0.0169277	3.92744	1.97676e-3	0.291178	0.358783	0.0236982	3.50319e-3	4.63563	1.04841e-3	9.70277e-4	0.0479964	7.59942e-5
16	10.7500	4.95110e-3	3.76580	1.95724e-3	0.291191	0.358798	0.0236992	1.70195e-3	1.52140	1.44853e-3	1.65294e-3	0.0479984	7.59975e-5
17	11.0000	1.42866e-3	3.47277	1.94603e-3	0.291199	0.358799	0.0236995	8.91428e-4	0.542836	2.16361e-3	2.88215e-3	0.0479991	6.42392e-5
18	11.2500	3.93991e-4	3.03633	1.93959e-3	0.291211	0.358791	0.0236997	4.97814e-4	0.210337	3.43766e-3	5.07736e-3	0.0417026	3.62555e-5
19	11.5000	1.01443e-4	2.47094	1.93583e-3	0.291219	0.358787	0.0236998	3.07857e-4	0.0897529	5.70614e-3	7.29995e-3	0.0311700	2.04832e-5
20	11.7500	2.39752e-5	1.84205	1.93352e-3	0.291224	0.358787	0.0237000	2.33457e-4	0.0427411	7.60001e-3	7.30001e-3	0.0271946	1.16101e-5
21	12.0000	5.16322e-6	1.24813	1.93186e-3	0.291230	0.358790	0.0237004	2.42401e-4	0.0229475	7.60012e-3	7.30011e-3	0.0258239	6.63141e-6

Basic Design

Project name	H2OI Mining WTP RO			Page : 1/4
Calculated by	UDY		Permeate flow/train	1800.0 m3/d
HP Pump flow		94.93 m3/h	Total product flow	7200.00 m3/d
Feed pressure		14.3 bar	Number of trains	4
Feed temperature		4.0 °C(39.2°F)	Raw water flow/train	2278.5 m3/d
Feed water pH		7.50	Permeate recovery	79.00 %
Chem dose, mg/l, -		H2SO4	Element age	0.0 years
Specific energy		0.66 kwh/m3	Flux decline %, first year	12.0
Pass NDP		11.9 bar	Fouling factor	1.00
Average flux rate		16.8 lmh	SP increase, per year	10.0 %
			Inter-stage pipe loss	0.2 bar
			Feed type	Waste MF/UF

Pass - Stage	Perm. Flow m3/h	Flow / Vessel Feed m3/h	Flow / Vessel Conc m3/h	Flux lmh	DP bar	Flux Max lmh	Beta	Stagewise Pressure Perm. bar	Stagewise Pressure Boost bar	Stagewise Pressure Conc bar	Perm. TDS mg/l	Element Type	Element Quantity	PV# x Elem #
1-1	52.5	7.3	3.3	18.2	0.4	19	1.17	0	0	13.9	9.2	CPA5-LD	78	13 x 6M
1-2	22.5	6.1	2.8	14.4	0.3	16.1	1.15	0	0	13.3	28.6	CPA5-LD	42	7 x 6M

Ion (mg/l)	Raw Water	Feed Water	Permeate Water	Concentrate 1	Concentrate 2
Hardness, as CaCO3	2110.62	2110.62	6.388	4719.9	10060.1
Ca	559.00	559.00	1.692	1250.1	2664.4
Mg	174.00	174.00	0.527	389.1	829.4
Na	117.38	117.38	1.696	261.5	554.4
K	16.05	16.05	0.289	35.7	75.6
NH4	0.62	0.62	0.011	1.4	2.9
Ba	0.000	0.000	0.000	0.0	0.0
Sr	0.000	0.000	0.000	0.0	0.0
Mn	0.050	0.050	0.000	0.1	0.2
Pb	0.020	0.020	0.000	0.0	0.1
Zn	2.810	2.810	0.009	6.3	13.4
H	0.00	0.00	0.001	0.0	0.0
CO3	0.41	0.41	0.000	2.5	13.6
HCO3	186.66	186.66	4.289	410.0	854.7
SO4	2057.00	2057.00	5.522	4600.5	9807.2
Cl	64.00	64.00	0.685	142.7	303.2
F	0.72	0.72	0.015	1.6	3.4
NO3	4.92	4.92	0.268	10.8	22.5
PO4	0.00	0.00	0.000	0.0	0.0
OH	0.00	0.00	0.000	0.0	0.0
SiO2	2.73	2.73	0.028	6.1	12.9
B	0.00	0.00	0.000	0.0	0.0
CO2	11.30	11.30	11.30	11.30	11.30
TDS	**3186.37**	**3186.37**	**15.03**	**7118.41**	**15158.02**
pH	**7.50**	**7.50**	**5.96**	**7.81**	**8.10**

Saturations	**Raw Water**	**Feed Water**	**Concentrate**	**Limits**
CaSO4 / ksp * 100, %	133	133	936	400
SrSO4 / ksp * 100, %	0	0	0	1200
BaSO4 / ksp * 100, %	0	0	0	10000
SiO2 saturation, %	3	3	13	140
CaF2 / ksp * 100, %	20	20	1266	50000
Ca3(PO4)2 saturation index	0.0	0.0	0.0	2.4
CCPP, mg/l	51.87	51.87	564.01	
Langelier saturation index	0.46	0.46	2.33	2.5
Ionic strength	0.09	0.09	0.43	
Osmotic pressure, bar	1.0	1.0	4.7	

Basic Design

Project name	H2OI Mining WTP RO		Page : 2/4
Calculated by	UDY	Permeate flow/train	1800.0 m3/d
HP Pump flow	94.93 m3/h	Total product flow	7200.00 m3/d
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Feed temperature	4.0 °C(39.2°F)	Raw water flow/train	2278.5 m3/d
Feed water pH	7.50	Permeate recovery	79.00 %
Chem dose, mg/l, -	H2SO4	Element age	0.0 years
Specific energy	0.66 kwh/m3	Flux decline %, first year	12.0
Pass NDP	11.9 bar	Fouling factor	1.00
Average flux rate	16.8 lmh	SP increase, per year	10.0 %
		Inter-stage pipe loss	0.2 bar
		Feed type	Waste MF/UF

Pass - Stage	Perm. Flow m3/h	Flow / Vessel Feed m3/h	Flow / Vessel Conc m3/h	Flux lmh	DP bar	Flux Max lmh	Beta	Stagewise Pressure Perm. bar	Stagewise Pressure Boost bar	Stagewise Pressure Conc bar	Perm. TDS mg/l	Element Type	Element Quantity	PV# x Elem #
1-1	52.5	7.3	3.3	18.2	0.4	19	1.17	0	0	13.9	9.2	CPA5-LD	78	13 x 6M
1-2	22.5	6.1	2.8	14.4	0.3	16.1	1.15	0	0	13.3	28.6	CPA5-LD	42	7 x 6M

Pass - Stage	Element no.	Feed Pressure bar	Pressure Drop bar	Conc Osmo. bar	NDP bar	Permeate Water Flow m3/h	Permeate Water Flux lmh	Beta	Permeate (Passwise cumulative) TDS	Ca	Mg	Na	Cl
1-1	1	14.3	0.1	1.1	13.2	0.7	19	1.1	5.1	0.573	0.178	0.577	0.232
1-1	2	14.2	0.09	1.2	13	0.7	18.7	1.11	5.6	0.63	0.196	0.634	0.256
1-1	3	14.1	0.07	1.4	12.7	0.7	18.3	1.12	6.2	0.7	0.218	0.705	0.284
1-1	4	14	0.06	1.6	12.5	0.7	18	1.13	7	0.789	0.245	0.794	0.32
1-1	5	14	0.05	1.9	12.2	0.7	17.5	1.15	8	0.903	0.281	0.908	0.366
1-1	6	13.9	0.04	2.2	11.8	0.6	17	1.17	9.2	1.031	0.321	1.037	0.418
1-2	1	13.7	0.08	2.5	11.3	0.6	16.1	1.1	9.9	1.11	0.346	1.116	0.45
1-2	2	13.6	0.07	2.8	10.9	0.6	15.6	1.11	10.7	1.198	0.373	1.203	0.485
1-2	3	13.5	0.06	3.1	10.6	0.6	14.9	1.11	11.5	1.295	0.403	1.301	0.525
1-2	4	13.5	0.05	3.5	10.1	0.5	14.3	1.12	12.5	1.407	0.438	1.412	0.57
1-2	5	13.4	0.04	4.1	9.6	0.5	13.4	1.13	13.7	1.537	0.478	1.542	0.622
1-2	6	13.4	0.03	4.7	9	0.5	12.4	1.15	15	1.69	0.526	1.695	0.684

Basic Design

Project name	H2OI Mining WTP RO			Page : 3/4
Calculated by	UDY		Permeate flow/train	1800.0 m3/d
HP Pump flow	94.93	m3/h	Total product flow	7200.00 m3/d
Feed pressure	14.3	bar	Number of trains	4
Feed temperature	4.0	°C(39.2°F)	Raw water flow/train	2278.5 m3/d
Feed water pH	7.50		Permeate recovery	79.00 %
Chem dose, mg/l, -	H2SO4		Element age	0.0 years
Specific energy	0.66	kwh/m3	Flux decline %, first year	12.0
Pass NDP	11.9	bar	Fouling factor	1.00
Average flux rate	16.8	lmh	SP increase, per year	10.0 %
			Inter-stage pipe loss	0.2 bar
			Feed type	Waste MF/UF

THE FOLLOWING PARAMETERS EXCEED RECOMMENDED DESIGN LIMITS

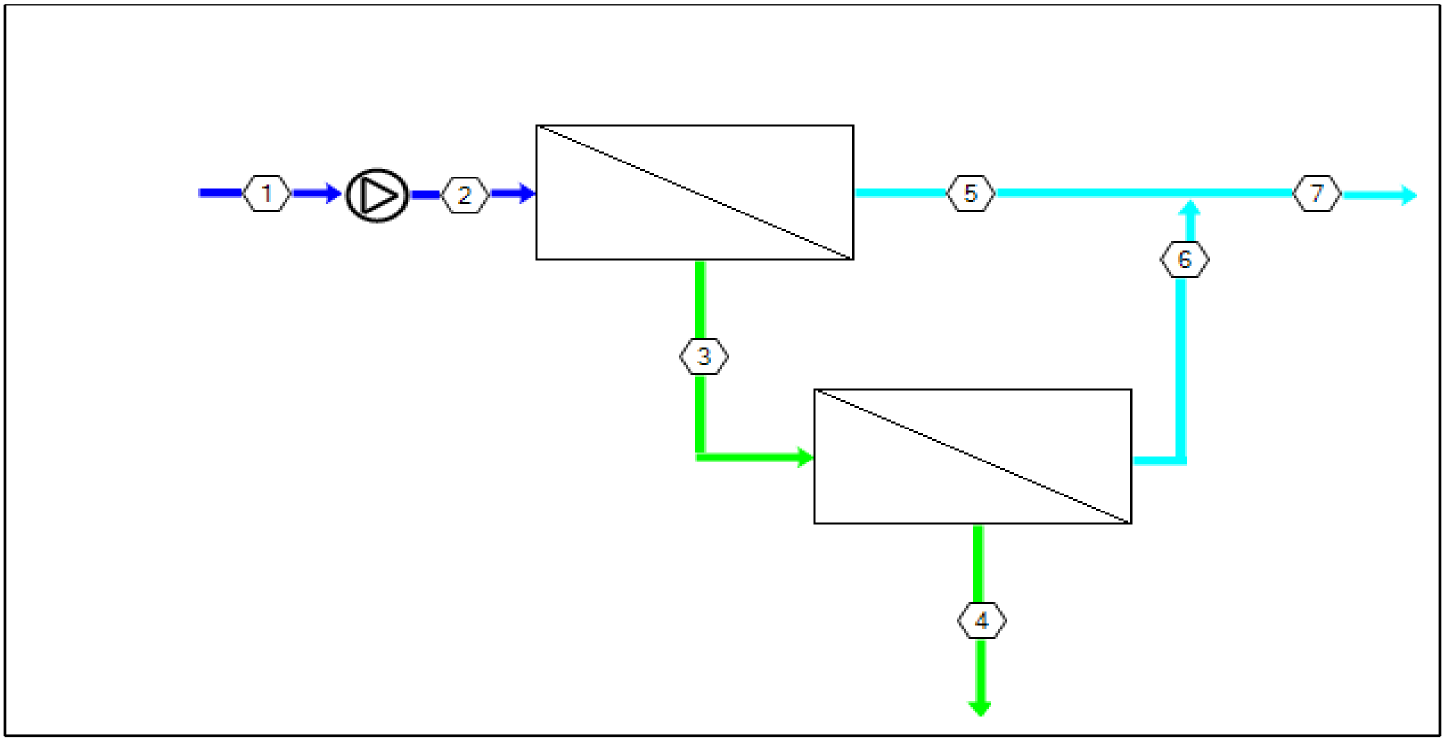
Concentrate saturation of $CaSO_4$ (936.49 %) is higher than limit 400 %.

The above saturations limits only apply when using effective scale inhibitor or dispersant. Without scale inhibitor or dispersant, the saturation and precipitation limit of the contaminant should not exceed its solubility in solution.

Basic Design

Project name H2OI Mining WTP RO

Temperature : 4.0 °C Element age, P1 : 0.0 years



Stream No.	Flow (m3/h)	Pressure (bar)	TDS (mg/l)	pH	Econd (µs/cm)
1	94.9	0	3186	7.50	5438
2	94.9	14.3	3186	7.50	5438
3	42.4	13.9	7118	7.81	11351
4	19.9	13.3	15158	8.10	22896
5	52.5	0	9.18	5.75	16.4
6	22.5	0	28.6	6.23	49.3
7	75.0	0	15.0	5.96	26.2

Calculation Summary				
Post-HDS Stream				
Stream Inflows				
Row Filter Applied: Only Non Zero Values				
Species	mg/L			
H2O	1.00E+06			
CaO	958.291			
NaCl	0.118085			
NH3	0.59304			
As	0.0246054			
N2O5	4.08572			
SO3	1187.76			
CdSe	0.0779119			
PbSe	0.0312077			
ZnSe	1.0505			
MnCl2	8.23371			
P2O5	6.25E-06			
HCl	657.486			
Al2O3	0.0271351			
Al(NO2)3	0.128801			
FeO	9.32E-03			
MgO	275.106			
NiO	0.0163138			
ZnCl2.5ZnO	3.05073			
O2	0.0562737			
Na2O	7.59E-06			
Ag2Se	9.90E-05			
As2O3	8.89E-03			
Cu2Se	0.0112843			
H2	1.99E-04			
UO2	0.0146126			
CaSO4.2H2O	960.855			
Sb2O3	0.0387651			
Al(OH)3	0.0442306			
Ca5(PO4)3F	0.193017			
MnF2	1.66124			
Ni(OH)2	0.113803			
As2O5	4.82E-05			

FeAsO4	2.71E-07			
Sb	7.94E-04			
Stream Parameters				
Row Filter Applied: Only Non Zero Values				
column Filter Applied: Only Non Zero Values				
Mixture Properties				
Stream Amount	1048.83	L		
Temperature	10	ÁC		
Pressure	1	atm		
Aqueous Properties				
pH	9.9276			
Ionic Strength (x-based)	1.46E-03	mol/mol		
Ionic Strength (m-based)	0.0809153	mol/kg		
ORP	0.600745	V (SHE)		
Osmotic Pressure	1.19754	atm		
Specific Electrical Conductivity	2580.34	µmho/cm		
Electrical Conductivity, molar	4.12E-03	m2/ohm-mol		
Viscosity, absolute	1.32234	cP		
Viscosity, relative	1.01279			
Standard Liquid Volume	1052.51	L		
Volume, Std. Conditions	1051.98	L		
Solid Properties				
Standard Liquid Volume	0.489904	L		
Thermodynamic Properties				
	Unit	Total	Aqueous	Solid
Density	g/ml	1.0036	1.00301	2.59098
Enthalpy	cal	-4.00E+09	-4.00E+09	-2.84E+06
Species Output (True Species)				
Row Filter Applied: Only Non Zero Values				
column Filter Applied: Only Non Zero Values				
	Total	Aqueous	Solid	
	mg/L	mg/L	mg/L	
H2O	1.00E+06	1.00E+06	0	

SO4-2	1282.96	1283.43	0	
CaSO4.2H2O (Gypsum)	960.849	0	961.206	
Cl-1	644.364	644.604	0	
Ca+2	643.975	644.214	0	
Mg+2	154.849	154.907	0	
CaSO4 (Anhydrite)	138.418	138.47	0	
MgSO4	53.3157	53.3355	0	
NO3-1	4.61663	4.61834	0	
Mn+2	3.17932	3.1805	0	
Zn(OH)2	2.99435	2.99546	0	
MnSO4	2.90638	2.90746	0	
ZnSe (Stilleite)	1.0505	0	1.05089	
F-1	0.679083	0.679335	0	
OH-1	0.554745	0.554951	0	
MgOH+1	0.482501	0.48268	0	
NH3	0.320713	0.320832	0	
NH4+1	0.272352	0.272453	0	
Mn(OH)+1	0.259849	0.259945	0	
Ca5(PO4)3F (Fluorapatite)	0.193017	0	0.193089	
CaOH+1	0.15977	0.159829	0	
MnCl+1	0.138027	0.138079	0	
Ca(NO3)+1	0.12169	0.121736	0	
Al(OH)4-1	0.117	0.117044	0	
Ni(OH)2 (Theophrastite)	0.111716	1.00E-10	0.111758	
Zn(OH)3-1	0.110172	0.110213	0	
NO2-1	0.107739	0.107779	0	
Zn+2	0.102637	0.102675	0	
NH4SO4-1	0.100604	0.100642	0	
ZnOH+1	0.0857961	0.0858279	0	
CdSe (Cadmoselite)	0.0779119	0	0.0779408	
MnO4-1	0.069933	0.069959	0	
HAsO4-2	0.0585841	0.0586059	0	
MnO4-2	0.0528695	0.0528892	0	
Al(OH)3 (Bayerite)	0.0505837	5.49E-05	0.0505477	
Sb(OH)3	0.0468295	0.0468469	0	
Na+1	0.0444627	0.0444792	0	
PbSe (Clausthalite)	0.0312077	0	0.0312193	
UO2(OH)2	0.0163133	3.47E-03	0.0128501	
Fe(OH)3 (Bernalite)	0.0131645	1.30E-03	0.01187	
Cu2Se (Bellidoite)	0.011283	0	0.0112872	
NaSO4-1	0.0103242	0.010328	0	
NiOH+1	8.12E-03	8.12E-03	0	

Ni+2	6.14E-03	6.14E-03	0	
NiSO4	4.27E-03	4.27E-03	0	
Mn(OH)2 (Pyrochroite)	9.28E-04	9.29E-04	0	
Fe(OH)4-1	8.13E-04	8.14E-04	0	
ZnCl+1	7.34E-04	7.35E-04	0	
ZnNH3+2	5.00E-04	5.01E-04	0	
MnNO3+1	3.67E-04	3.67E-04	0	
CaF+1	3.34E-04	3.34E-04	0	
O2	3.18E-04	3.18E-04	0	
Sb(OH)4-1	2.74E-04	2.74E-04	0	
NH4NO3 (Gwihabaite)	2.34E-04	2.34E-04	0	
Zn(OH)4-2	1.23E-04	1.23E-04	0	
(UO2)3(OH)5+1	1.04E-04	1.04E-04	0	
NiNH3+2	1.04E-04	1.04E-04	0	
Ag2Se (Naumannite)	9.90E-05	0	9.90E-05	
CaCl+1	5.93E-05	5.94E-05	0	
UO2OH+1	3.17E-05	3.17E-05	0	
MgF+1	2.99E-05	2.99E-05	0	
ZnNO3+1	2.02E-05	2.02E-05	0	
ZnCl2	1.64E-05	1.64E-05	0	
CaPO4-1	7.39E-06	7.39E-06	0	
NiCl+1	5.90E-06	5.90E-06	0	
ZnF+1	5.72E-06	5.72E-06	0	
Ni(OH)3-1	5.14E-06	5.14E-06	0	
HSO4-1	4.36E-06	4.36E-06	0	
MgPO4-1	3.32E-06	3.32E-06	0	
Zn(NH3)2+2	2.88E-06	2.88E-06	0	
NaF (Villiaumite)	1.48E-06	1.48E-06	0	
NiNO3+1	1.30E-06	1.30E-06	0	
Mn(OH)3-1	1.28E-06	1.28E-06	0	
Cu(OH)3-1	1.09E-06	1.09E-06	0	
AsO4-3	6.22E-07	6.22E-07	0	
NaNO3 (Nitratine)	5.76E-07	5.76E-07	0	
Ni(NH3)2+2	4.95E-07	4.96E-07	0	
CaHPO4 (Monetite)	2.74E-07	2.75E-07	0	
HPO4-2	2.54E-07	2.54E-07	0	
NiF+1	2.25E-07	2.25E-07	0	
Cu(OH)2 (Spertiniite)	2.12E-07	2.12E-07	0	
ZnCl3-1	1.65E-07	1.65E-07	0	
H+1	1.52E-07	1.53E-07	0	
MgHPO4	1.40E-07	1.40E-07	0	
HF	1.01E-07	1.01E-07	0	

Mn(NO3)2	8.13E-08	8.13E-08	0	
CuNH3+2	7.82E-08	7.82E-08	0	
Fe(OH)2+1	3.41E-08	3.41E-08	0	
HNO2	2.33E-08	2.33E-08	0	
Zn(NH3)3+2	1.98E-08	1.98E-08	0	
CuOH+1	1.23E-08	1.23E-08	0	
Cu(NH3)2+2	7.45E-09	7.45E-09	0	
UO2SO4	5.74E-09	5.74E-09	0	
UO2F+1	4.73E-09	4.73E-09	0	
Cu+2	4.27E-09	4.27E-09	0	
Al(OH)2+1	3.49E-09	3.49E-09	0	
UO2+2	3.15E-09	3.15E-09	0	
PO4-3	2.61E-09	2.61E-09	0	
(UO2)2(OH)2+2	1.88E-09	1.89E-09	0	
Ni(NH3)3+2	6.90E-10	6.90E-10	0	
UO2(SO4)2-2	5.83E-10	5.84E-10	0	
Ni2OH+3	4.47E-10	4.47E-10	0	
Mn(OH)4-2	4.23E-10	4.23E-10	0	
Zn(NO3)2	3.36E-10	3.36E-10	0	
UO2F2	3.35E-10	3.35E-10	0	
H2AsO4-1	2.93E-10	2.93E-10	0	
Ni(OH)4-2	2.60E-10	2.60E-10	0	
H2PO4-1	2.59E-10	2.59E-10	0	
HSe-1	2.27E-10	2.27E-10	0	
CuCl+1	2.18E-10	2.18E-10	0	
Cu(NH3)3+2	1.68E-10	1.68E-10	0	
Sb(OH)2+1	1.62E-10	1.62E-10	0	
ZnHPO4	1.49E-10	1.49E-10	0	
Cu(OH)4-2	1.49E-10	1.49E-10	0	
Zn(NH3)4+2	6.77E-11	6.77E-11	0	
UO2Cl+1	3.01E-11	3.01E-11	0	
Ni(NH3)4+2	2.69E-11	2.69E-11	0	
CaH2PO4+1	1.79E-11	1.80E-11	0	
Ni(OH)3(H2PO4)-2	4.35E-12	4.35E-12	0	
UO2F3-1	2.24E-12	2.24E-12	0	
CuCl2 (Tolbachite)	1.95E-12	1.95E-12	0	
HF2-1	1.72E-12	1.72E-12	0	
CuNO3+1	1.03E-12	1.03E-12	0	
CuNO2+1	9.14E-13	9.14E-13	0	
FeOH+2	8.60E-13	8.60E-13	0	
Cu(NH3)4+2	6.20E-13	6.20E-13	0	
Ni4(OH)4+4	6.03E-13	6.04E-13	0	

AlOH+2	3.88E-13	3.88E-13	0	
MgH2PO4+1	5.59E-14	5.59E-14	0	
Na2F+1	3.93E-14	3.93E-14	0	
AlF2+1	2.61E-14	2.61E-14	0	
AlOHCl+1	1.77E-14	1.77E-14	0	
UO2Cl2	1.58E-14	1.58E-14	0	
HCl	1.38E-14	1.38E-14	0	
ZnH2PO4+1	1.25E-14	1.25E-14	0	
AlF3	7.02E-15	7.03E-15	0	
AlF+2	3.77E-15	3.77E-15	0	
Se-2	1.57E-15	1.57E-15	0	
HNO3	1.53E-15	1.53E-15	0	
UO2F4-2	8.59E-16	8.60E-16	0	
H3AsO4	2.58E-16	2.58E-16	0	
H2Se	1.30E-16	1.30E-16	0	
CuCl3-1	1.13E-16	1.13E-16	0	
AlF4-1	8.03E-17	8.04E-17	0	
AlSO4+1	7.91E-17	7.91E-17	0	
Al(SO4)2-1	5.27E-17	5.27E-17	0	
Al+3	2.80E-17	2.80E-17	0	
Cu(NO2)2	2.40E-17	2.40E-17	0	
Cu+1	1.29E-17	1.29E-17	0	
CuCl	1.15E-17	1.15E-17	0	
Cu(NO3)2	1.02E-17	1.02E-17	0	
Fe+2	9.82E-18	9.83E-18	0	
Ni(OH)2(HPO4)-2	9.31E-18	9.31E-18	0	
FeOH+1	8.42E-18	8.42E-18	0	
PbOH+1	6.93E-18	6.93E-18	0	
Cu(NH3)5+2	5.40E-18	5.41E-18	0	
AgCl2-1	3.30E-18	3.30E-18	0	
H3PO4	3.11E-18	3.11E-18	0	
CuCl2-1	2.51E-18	2.51E-18	0	
MgP2O7-2	1.86E-18	1.86E-18	0	
Ni(NH3)5+2	8.04E-19	8.05E-19	0	
UO2+1	6.82E-19	6.82E-19	0	
AgCl	6.71E-19	6.71E-19	0	
CdSO4	3.72E-19	3.72E-19	0	
Cd+2	3.42E-19	3.42E-19	0	
CdCl+1	2.76E-19	2.76E-19	0	
AlF5-2	1.19E-19	1.19E-19	0	
FeO	1.14E-19	1.14E-19	0	
Fe+3	1.03E-19	1.03E-19	0	

CdCl2	8.77E-20	8.78E-20	0	
CdOH+1	3.57E-20	3.57E-20	0	
PbO (Massicot)	3.52E-20	3.52E-20	0	
Ag+1	1.73E-20	1.73E-20	0	
FeSO4+1	8.72E-21	8.72E-21	0	
HPbO2-1	7.64E-21	7.64E-21	0	
Cd(OH)2	7.45E-21	7.45E-21	0	
Fe(NH3)+2	4.81E-21	4.82E-21	0	
PbSO4 (Anglesite)	3.80E-21	3.81E-21	0	
AgSO4-1	3.76E-21	3.76E-21	0	
CdNH3+2	3.59E-21	3.60E-21	0	
Pb+2	3.47E-21	3.47E-21	0	
FeF+2	1.20E-21	1.20E-21	0	
HFeO2-1	1.05E-21	1.05E-21	0	
CdNO2+1	9.21E-22	9.21E-22	0	
PbCl+1	7.59E-22	7.59E-22	0	
P2O7-4	7.56E-22	7.56E-22	0	
CaCl2 (Hydrophilite)	4.84E-22	4.84E-22	0	
Ag(NH3)2+1	4.43E-22	4.43E-22	0	
FeF2+1	1.26E-22	1.27E-22	0	
CdCl3-1	8.35E-23	8.35E-23	0	
FeCl+1	7.34E-23	7.34E-23	0	
FeCl+2	5.77E-23	5.77E-23	0	
AlF6-3	4.46E-23	4.46E-23	0	
CdNO3+1	4.30E-23	4.31E-23	0	
AgOH	4.12E-23	4.12E-23	0	
HP2O7-3	3.66E-23	3.66E-23	0	
PbNO2+1	3.42E-23	3.42E-23	0	
PbCl2 (Cotunnite)	3.40E-23	3.41E-23	0	
FeHPO4+1	2.93E-23	2.93E-23	0	
Ni(NH3)6+2	2.14E-23	2.14E-23	0	
(HF)2	1.63E-23	1.63E-23	0	
CdF+1	1.38E-23	1.39E-23	0	
Cd(NH3)2+2	1.05E-23	1.05E-23	0	
AgNO2	9.87E-24	9.88E-24	0	
Fe(NH3)2+2	9.51E-24	9.51E-24	0	
CdCl4-2	7.09E-24	7.09E-24	0	
FeCl2+1	6.01E-24	6.01E-24	0	
Cd(OH)3-1	4.82E-24	4.82E-24	0	
PbNO3+1	2.25E-24	2.26E-24	0	
AgCl3-2	1.43E-24	1.43E-24	0	
FeF3	1.31E-24	1.31E-24	0	

AgNO3	9.88E-25	9.89E-25	0	
AgF	9.35E-25	9.35E-25	0	
PbF+1	7.29E-25	7.29E-25	0	
FeNO3+2	6.41E-25	6.41E-25	0	
PbCl3-1	3.61E-25	3.62E-25	0	
Cd(NO2)2	2.09E-25	2.09E-25	0	
Fe(HAsO4)+1	1.94E-25	1.94E-25	0	
Ag(OH)2-1	1.80E-25	1.81E-25	0	
U(OH)4	2.25E-26	2.25E-26	0	
H2SO4	1.83E-26	1.83E-26	0	
Al(OH)2Cl	1.53E-26	1.53E-26	0	
PbCl4-2	1.16E-26	1.16E-26	0	
FeCl3 (Molysite)	8.01E-27	8.02E-27	0	
Cd(NH3)3+2	6.46E-27	6.47E-27	0	
H2P2O7-2	5.23E-27	5.23E-27	0	
Fe(NH3)3+2	4.11E-27	4.11E-27	0	
FeCl2 (Lawrencite)	3.98E-27	3.98E-27	0	
U(OH)5-1	3.66E-27	3.66E-27	0	
Ag(NO2)2-1	2.82E-27	2.82E-27	0	
Pb(NO2)2	2.69E-27	2.69E-27	0	
FeHPO4	1.75E-28	1.75E-28	0	
PbF2	1.60E-28	1.60E-28	0	
CdF2	1.24E-28	1.24E-28	0	
Pb(NO3)2	9.58E-29	9.59E-29	0	
Cd(OH)4-2	9.07E-29	9.07E-29	0	
Cd(NO2)3-1	1.16E-29	1.16E-29	0	
FeCl4-1	3.76E-30	3.76E-30	0	
PbHPO4	2.39E-30	2.39E-30	0	
FeAsO4	1.78E-30	1.78E-30	0	
SO3	1.67E-30	1.67E-30	0	
Cd(NH3)4+2	1.04E-30	1.04E-30	0	
FeH2PO4+2	5.41E-31	5.41E-31	0	
Fe2(OH)2+4	3.57E-31	3.57E-31	0	
Pb(NO2)3-1	1.44E-31	1.44E-31	0	
FeH2PO4+1	9.81E-32	9.82E-32	0	
PbF3-1	9.31E-32	9.31E-32	0	
Pb(NO3)3-1	2.66E-33	2.66E-33	0	
Fe(NH3)4+2	1.37E-33	1.37E-33	0	
PbH2PO4+1	2.08E-34	2.08E-34	0	
H3P2O7-1	6.27E-35	6.27E-35	0	
U(OH)3+1	4.06E-35	4.06E-35	0	
Cd(NH3)5+2	1.22E-35	1.22E-35	0	

PbF4-2	2.67E-36	2.67E-36	0	
AsO2-1	1.78E-37	1.78E-37	0	
HAsO2	5.00E-38	5.00E-38	0	
Fe(NH3)5+2	4.46E-40	4.46E-40	0	
HAsO3-2	7.93E-42	7.93E-42	0	
Cd(NH3)6+2	5.47E-42	5.47E-42	0	
H2	4.39E-42	4.39E-42	0	
H4P2O7	1.79E-43	1.79E-43	0	
U(OH)2+2	1.22E-43	1.22E-43	0	
AsO3-3	6.37E-46	6.37E-46	0	
Fe(NH3)6+2	1.43E-46	1.44E-46	0	
AsO+1	9.18E-48	9.19E-48	0	
UOH+3	9.73E-51	9.73E-51	0	
UF3+1	5.09E-53	5.10E-53	0	
UF2+2	3.06E-53	3.06E-53	0	
UF4	2.58E-53	2.58E-53	0	
UF+3	3.62E-55	3.62E-55	0	
U(SO4)2	3.08E-55	3.08E-55	0	
USO4+2	3.08E-56	3.08E-56	0	
As(OH)2Cl3	1.53E-58	1.53E-58	0	
U+4	3.34E-59	3.34E-59	0	
UCl+3	9.58E-60	9.58E-60	0	
U+3	2.57E-80	2.57E-80	0	
Total (by phase)	1.00E+06	1.00E+06	962.758	
Element Balance				
Row Filter Applied: Only Non Zero Values				
column Filter Applied: Only Non Zero Values				
	Total	Aqueous	Solid	
	mg/L	mg/L	mg/L	
H(+1)	1.12E+05	1.12E+05	22.5141	
Na(+1)	0.0464573	0.0464745	0	
N(-3)	0.487741	0.487923	0	
Ca(+2)	908.625	685.138	223.825	
Zn(+2)	2.67917	2.20411	0.47605	
Cu(+2)	8.25E-07	8.26E-07	0	
Fe(+2)	1.64E-17	1.64E-17	0	
Mg(+2)	165.899	165.96	0	
Pb(+2)	0.0225965	6.45E-18	0.0226049	
Al(+3)	0.050723	0.0332574	0.0174845	

Mn(+2)	4.51979	4.52147	0	
Fe(+3)	7.25E-03	1.05E-03	6.20E-03	
Ni(+2)	0.0848562	0.0141443	0.0707435	
F(-1)	0.686477	0.679458	7.27E-03	
O(-2)	8.89E+05	8.89E+05	536.081	
Cl(-1)	644.419	644.658	0	
P(+5)	0.0355676	2.74E-06	0.035578	
S(+6)	654.658	475.882	179.019	
N(+3)	0.0328019	0.0328141	0	
N(+5)	1.05967	1.06006	0	
H	4.39E-42	4.39E-42	0	
O(0)	3.18E-04	3.18E-04	0	
As(+5)	0.0313682	0.0313799	0	
As(+3)	1.60E-37	1.60E-37	0	
Se(-2)	0.619736	2.24E-10	0.619967	
Cu(+1)	6.96E-03	2.14E-17	6.96E-03	
Mn(+7)	0.032303	0.032315	0	
Mn(+6)	0.0244212	0.0244302	0	
Cd(+2)	0.0457651	8.47E-19	0.0457822	
Ag(+1)	7.25E-05	2.51E-18	7.25E-05	
U(+4)	2.02E-26	2.02E-26	0	
U(+6)	0.012881	2.83E-03	0.0100601	
Sb(+3)	0.033176	0.0331883	0	
U(+3)	2.57E-80	2.57E-80	0	
U(+5)	6.01E-19	6.01E-19	0	
Element Distribution				
	Total	Total	Aqueous	Solid
	mol	mole %	% of Total	% of Total
H(+1)	1.16E+05	66.6065	99.9799	0.020114
Na(+1)	2.12E-03	1.21E-06	100	0
N(-3)	0.0365225	2.09E-05	100	0
Ca(+2)	23.7785	0.0136034	75.3758	24.6242
Zn(+2)	0.0429729	2.46E-05	82.238	17.762
Cu(+2)	1.36E-08	7.79E-12	100	0
Fe(+2)	3.07E-19	1.76E-22	100	0
Mg(+2)	7.15902	4.10E-03	100	0
Pb(+2)	1.14E-04	6.54E-08	2.85E-14	100
Al(+3)	1.97E-03	1.13E-06	65.5423	34.4577
Mn(+2)	0.0862883	4.94E-05	100	0

Fe(+3)	1.36E-04	7.79E-08	14.4285	85.5715
Ni(+2)	1.52E-03	8.68E-07	16.6623	83.3377
F(-1)	0.0378979	2.17E-05	98.9408	1.05924
O(-2)	58299.3	33.3524	99.9397	0.0602572
Cl(-1)	19.0643	0.0109065	100	0
P(+5)	1.20E-03	6.89E-07	7.70E-03	99.9923
S(+6)	21.4129	0.0122501	72.6648	27.3352
N(+3)	2.46E-03	1.41E-06	100	0
N(+5)	0.0793486	4.54E-05	100	0
H	4.57E-42	2.61E-45	100	0
O(0)	2.09E-05	1.19E-08	100	0
As(+5)	4.39E-04	2.51E-07	100	0
As(+3)	2.24E-39	1.28E-42	100	0
Se(-2)	8.23E-03	4.71E-06	3.62E-08	100
Cu(+1)	1.15E-04	6.57E-08	3.08E-13	100
Mn(+7)	6.17E-04	3.53E-07	100	0
Mn(+6)	4.66E-04	2.67E-07	100	0
Cd(+2)	4.27E-04	2.44E-07	1.85E-15	100
Ag(+1)	7.05E-07	4.03E-10	3.47E-12	100
U(+4)	8.90E-29	5.09E-32	100	0
U(+6)	5.68E-05	3.25E-08	21.9286	78.0714
Sb(+3)	2.86E-04	1.64E-07	100	0
U(+3)	1.13E-82	6.49E-86	100	0
U(+5)	2.65E-21	1.51E-24	100	0

Appendix R2-E

Operational Water Balance and Climate Variability Sensitivity Analysis

November 2, 2017

File No.:VA101-00640/05-A.01
Cont. No.:VA17-01585

[Name Redacted]

BMC Minerals (No. 1) Ltd.
530 - 1130 West Pender Street
Vancouver, British Columbia
Canada, V6E 4A4

Dear [Name Reda

Re: Response to IR R2-35 – Operational Water Balance and Climate Variability and Sensitivity Analysis

1 – INTRODUCTION

BMC Minerals (No. 1) Ltd. submitted the Project Proposal for the Kudz Ze Kayah (KZK) Project to the Yukon Environmental and Socio-Economic Assessment Board (YESAB) in March 2017. The Proposal was based, in part, on a pre-feasibility waste and water management design, completed by Knight Piésold Ltd. (KP) in December 2016.

YESAB is currently completing the Adequacy Review of the Project Proposal. The following Information Requests (IRs), which pertain to the site water balance, were received as part of the Adequacy Review:

- ***R2-35:*** *Provide rationale for return periods used in modeling. In addition, using the updated water balance model, evaluate the following scenarios:*
    - *c. greater than normal snowfall accumulation; and*
    - *d. shorter and more critical snowmelt durations.*
- ***R2-36:*** *Undertake a sensitivity analysis to assess variability of model predictions given variation in key model input parameters and assumptions.*
- ***R2-38:*** *We require the annual values be included on the schematic for the various water balance components for the scenarios evaluated (i.e., mean conditions, dry year, and wet year).*
- ***R2-44:*** *Undertake a sensitivity analysis, in support of the discussion of effects and mitigation measures associated with both extreme events and climate change, using the water balance models developed for the Project to obtain an understanding of potential effects on water management structures and discharges strategies with variation in both model input assumptions and type of events.*
- ***R2-122***: *Climate change information should be addressed as part of the sensitivity analysis conducted for the updated water balance model.*

This letter summarizes the updated operational water balance for the KZK project, which includes climate variability and sensitivity analysis. The same water balance model developed for the YESAB Proposal was used for this analysis, however, rather than evaluating three scenarios (mean annual precipitation, 50-year wet year and 10-year dry year), this model uses the long-term climate parameters to evaluate the water balance under a wide range of climate conditions. A sensitivity analysis was also completed on the key model input parameters and assumptions. These include the water management assumptions (which are addressed with the climate variability model), the climate values (which again are addressed with the climate variability model), and the diversion ditch efficiency.

The long-term precipitation and temperature records developed for the KZK project were used as direct inputs to the water balance model. The time series data were used to estimate the amount of runoff available from rainfall and snowmelt events. The long-term data sets were stepped through incrementally by year for the entire record, thereby preserving the inherent cyclical natural of the climate record, to produce a range of climate inputs, and therefore a range of predicted results for the operational water balance.

This model uses the actual precipitation and air temperature records to estimate the amount of rainfall versus snowfall, which varies by year, and the timing and magnitude of the snowmelt, which varies by year. Incorporating climate variability into the water balance accounts for such situations as wet and dry months, greater than normal snowfall accumulation and shorter more critical snowmelt durations.

2 – INPUTS AND ASSUMPTIONS

2.1 STOCHASTIC MODELLING APPROACH

The water balance model used to produce the results presented in this letter involved a stochastic approach for modelling precipitation. The previous water balance used a simple deterministic approach for modelling precipitation, where the precipitation values were fixed for each month of the year, and the annual distribution of monthly precipitation values was repeated for every year of the model. The stochastic approach involved varying the precipitation inputs for each month of each year of the model, and then varying the time series a number of times (in this particular instance, 38 times) according to historical precipitation patterns for the project area. In this way, the model considers a full range of precipitation conditions, from extremely wet to extremely dry, for every month of every year of the model. The approach produces 38 different output values for each parameter of interest, such as a pond size in Year 5 of operations or a make-up water requirement in Year 7 of operations. The values reported here are percentiles based on the 38 values produced for each parameter. The 90th percentile of one parameter does not necessarily match the 90th percentile of another parameter, as each parameter has its own distribution. This is evident in the result tables in Section 3, and is particularly apparent in the 98th percentile results.

2.2 WATER BALANCE ASSUMPTIONS

The same inputs and assumptions were used for the climate variability water balance model as were used for the previous water balance model, however, this model uses long-term climate inputs rather than mean annual, 50-year wet, or 10-year dry precipitation. The Knight Piésold operational water balance model report is included in Appendix A.

The water management strategy used for the climate variability model is included in Appendix B.

The overall objective of the water management strategy is to divert non-contact water away from the site using diversion channels. Contact water on the site will either be conveyed to the Water Management Ponds if it is of acceptable quality for discharge, or else it will be treated at the Water Treatment Plant prior to being released.

The tailings will be filtered and stored in the Class A Facility. This facility will be surrounded by ditches and berms to reduce the volume of water contacting the Class A material. Limiting upstream runoff reduces the volume of contact water, and improves trafficability and tailings placement. Non-contact runoff from upstream of the Class A Facility will be diverted using berms and ditches constructed progressively as the facility expands. The diversions surrounding the Class A Facility are assumed to be 100% efficient. Runoff from the tailings beach will be conveyed into the Class A Collection Pond, where it will be pumped to the Water Treatment Plant. Treated water is then conveyed to the Upper Water Management Pond.

Weakly potentially acid generating waste rock will be stored in the Class B Facility. Runoff from the Class B Facility will be conveyed to the Class B Collection Pond, where it will be pumped to the Water Treatment Plant. The Class A and Class B ponds will be maintained at low volumes during operations, to provide storage for storm events. In the event that the volume of water in the Class B Collection Pond exceeds the maximum operating pond volume of 10,000 m^3, and there is not sufficient capacity in the Water Treatment Plant to treat it, the excess volume will be pumped to the open pit where it will be temporarily stored until it can be treated.

The assumed Water Treatment Plant capacity is presented in Table 1 below. The priority for the Water Treatment Plant is the Class A Collection Pond, followed by the Class B Collection Pond. Remaining capacity in the Water Treatment Plant will be used to treat excess contact water generated at the mill site.

Table 1 Water Treatment Plant Capacity

Month	Capacity (m³/day)
January	387
February	318
March	290
April	17,290
May	17,290
June	19,233
July	8,774
August	7,485
September	7,534
October	2,000
November	734
December	451

3 – RESULTS OF CLIMATE VARIABILITY MODELLING

A stochastic model was used to calculate the 10th percentile (which corresponds to a 1 in 10 dry year,) the 90th percentile (which corresponds to a 1 in 10 wet year,) and the 98th percentile (which corresponds to a 1 in 50 wet year) volume for each of the major facilities.

These results quantify the potential impacts of climate change, as the 98th percentile results represent much wetter conditions than are likely to be experienced in an average year. The potential variability in precipitation and snowpack depth under a climate change scenario will be much less than the variability between median, and 1 in 50 wet year.

3.1 FLOWS BETWEEN MAJOR FACILITIES

The results for the Class A Facility, Class A Collection Pond, Class B Collection Pond, Class C Collection Pond, Upper and Lower Water Management Ponds, and the Water Treatment Plant are presented in Appendix B for the Median, 10th percentile, 90th percentile, and 98th percentile. This is in response to R2-38. Values are presented in tabular form, accompanied by a general flow schematic demonstrating the water management strategy.

The values on the tables are rounded to the nearest 1,000 m³, with a positive value indicating an inflow and a negative value indicating an outflow. The tables indicate that the maximum volume released to the environment from the Lower Water Management Pond occurs in Years 8 and 9 of the project. This volume varies from approximately 4.2 million m³ in a 10th percentile year, to approximately 5.9 million m³ in a 98th percentile year.

Most facilities in the water balance model are treated as flow-through systems, with the exception of the Class A and Class B Collection Ponds. Detailed results for the volumes of these two ponds are presented below.

3.2 CLASS A COLLECTION POND

The modelling results for the Class A Collection Pond are presented on Figure 1 below.

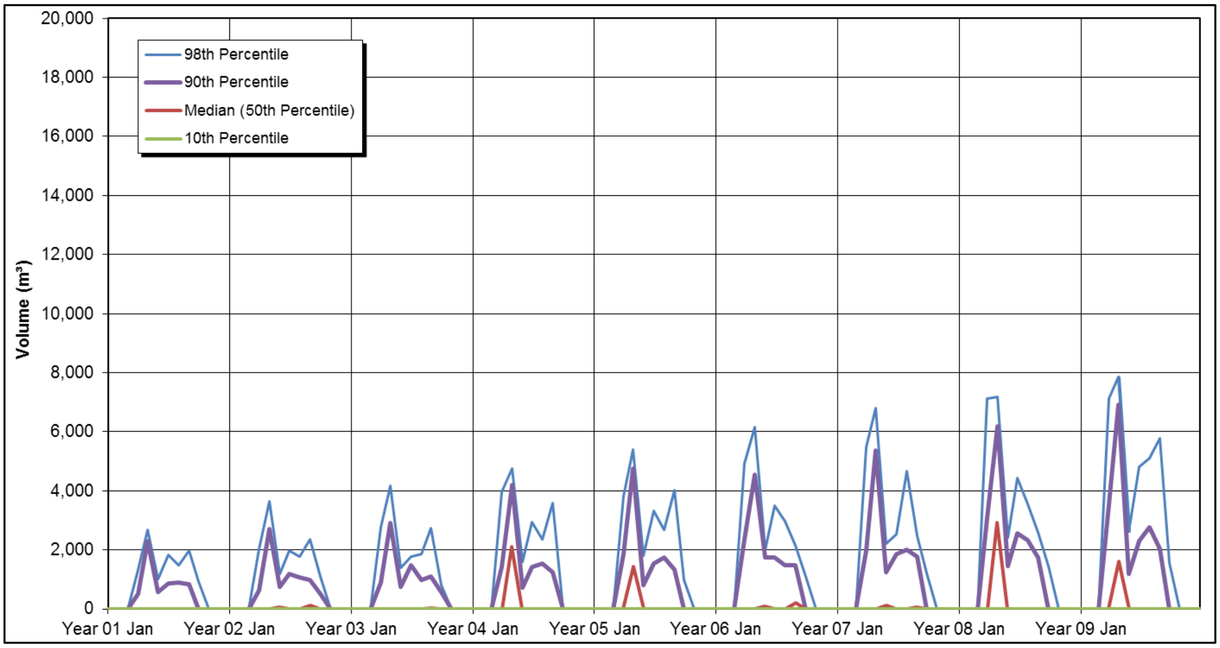


Figure 1 Class A Collection Pond Volumes

The modelling results indicate the maximum volume in a 1 in 50 wet year would be approximately 8,000 m³, in the event that Year 9 of operations is a 1 in 50 wet year.

3.3 CLASS B COLLECTION POND

The modelling results for the Class B collection pond are presented on Figure 2 below.

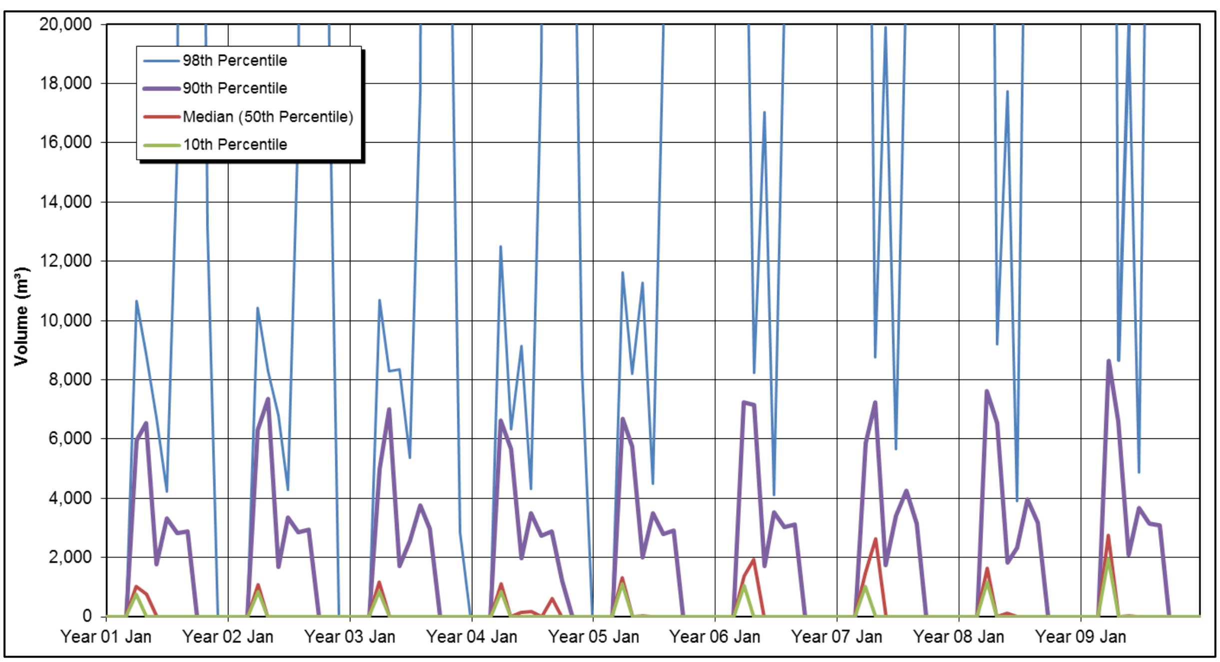


Figure 2 Class B Collection Pond Volumes

The Class B pond is operationally managed at a maximum volume of 10,000 m³, which maintains storm storage requirements and freeboard in the pond. This operational maximum will be exceeded in the 98th percentile case. The excess volume will be pumped to the open pit, where it will be temporarily held until there is capacity in the treatment plant. There is no transfer of volume in the median case.

4 – RESULTS OF SENSITIVITY ANALYSIS

The most significant variables affecting the water balance results are the diversion ditch efficiency and the climatic inputs. The climate variability modelling addresses the climatic inputs. A sensitivity analysis was carried out on the diversion ditch efficiency, which was assumed to be 50% in the base case. The model was run with diversion ditch efficiency ranging from 25% to 75%. The result that will be most impacted by this change is the annual volume released to the environment from the Lower Water Management Pond, as the diversion ditches primarily convey non-contact water away from the project site, bypassing the Lower Water Management Pond.

The results of the sensitivity analysis are presented in Table 2.

Table 2 Sensitivity Analysis Results

Diversion Ditch Efficiency (%)	Year 9 Volume Release from LWMP (m³)
25	4,546,000
50 (Base case)	4,196,000
75	3,845,000

NOTES:
1. The results in this table are for the median case.

These results indicate the impact of diversion ditch efficiency in modelling is significantly less than the impact of climatic variability, as varying the efficiency from 25% to 75% only changes the maximum annual volume by approximately 700,000 m³.

5 – DISCUSSION

Water balance modelling does not consider short duration storm events (24 hour precipitation) as water balance modelling is used to determine normal operating conditions. The storm events will be considered in a separate document, using the results of this letter as a base case.

The results of the climate variability modelling indicate the water management strategy assumed for this model is sufficient to manage the accumulation of water on site in conditions ranging from 10th percentile (1 in 10 year dry) to 98th percentile (1 in 50 year wet). In the 98th percentile case, the water management plan includes pumping water from the Class B Collection Pond to the pit, where it temporarily held. This volume could be reduced by enlarging the Class B Collection Pond, or by expanding the capacity of the Water Treatment Plant.

If you have any questions, please contact the undersigned.

Yours truly,
Knight Piésold Ltd.

[Name Redacted]

[Name Redacted]

Prepared: Reviewed:

Reviewed: [Name Redacted]

[Name Redacted]

Approval that this document adheres to Knight Piésold Quality Systems

Attachments:
Appendix A KP Report VA101-640/2-5 Rev 0
Appendix B Flow Schematic and Result Tables

/scr

APPENDIX A

KP REPORT VA101-640/2-5 REV 0 – WATER BALANCE MODEL REPORT

(Pages A-1 to A-22)

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



WATER BALANCE MODEL REPORT

PREPARED FOR:

BMC Minerals (No. 1) Ltd.
530 – 1130 West Pender Street
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PREPARED BY:

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VA101-640/2-5
Rev 0
December 16, 2016

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ISO 9001
ISO 14001
OHSAS 18001

FS 64925
EMS 550121
OHS 550122

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

WATER BALANCE MODEL REPORT
VA101-640/2-5

Rev	Description	Date
0	Issued in Final	December 16, 2016

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Knight Piésold
CONSULTING

EXECUTIVE SUMMARY

The Kudz Ze Kayah Project (the Project) is a proposed copper-zinc-lead-gold mine located approximately 250 km northeast of Whitehorse, Yukon Territory, Canada. The development of the project will be by open pit and underground mining methods, at a mill throughput rate of 5,500 tonnes per day over a mine life of approximately 9.5 years.

A prefeasibility design has been completed by Knight Piésold Ltd., which included a water balance modeling exercise. The water balance model was executed with average, wet, and dry climatic conditions. The main objectives of the water balance are as follows:

1. Estimate the volume of non-contact water diverted north to the outlet structure in Geona Creek
2. Estimate the volume of non-contact water diverted to the south of the Project
3. Estimate the annual surplus of Project-wide contact water

The main findings of the water balance model under average climatic conditions are as follows:

1. The volume of non-contact water diverted north of the project is estimated to be 1.42 Mm^3
2. The volume of non-contact water diverted south of the project is estimated to be 1.17 Mm^3
3. The annual surplus of Project-wide contact water is estimated to be 5.93 Mm^3

The main findings of the water balance model under 1 in 50 year wet climatic conditions are as follows:

1. The volume of non-contact water diverted north of the project is estimated to be 2.02 Mm^3
2. The volume of non-contact water diverted south of the project is estimated to be 1.66 Mm^3
3. The annual surplus of Project-wide contact water is estimated to be 7.7 Mm^3

The main findings of the water balance model under 1 in 10 year dry climatic conditions are as follows:

1. The volume of non-contact water diverted north of the project is estimated to be 1.13 Mm^3
2. The volume of non-contact water diverted south of the project is estimated to be 0.93 Mm^3
3. The annual surplus of Project-wide contact water is estimated to be 5.14 Mm^3

TABLE OF CONTENTS

TABLES

FIGURES

Knight Piésold CONSULTING

ABBREVIATIONS

Kudz Ze Kayah Project .... the project
BMC Minerals (No.1) Ltd. .... BMC
Kudz Ze Kayah .... KZK
Potentially Acid Consuming .... PAC
pre-feasibility study .... PFS
Strongly Potentially Acid Generating .... SPAG
Weakly Potentially Acid Generating .... WPAG

1 – INTRODUCTION

1.1 PROJECT DESCRIPTION

BMC Minerals (No.1) Ltd. (BMC) is currently developing the Kudz Ze Kayah Project (the Project), a proposed copper-zinc-lead-gold mine located approximately 250 km northeast of Whitehorse, Yukon Territory, Canada.

The development of the project will be by open pit and underground mining methods, at a mill throughput rate of 5,500 tonnes per day (tpd) over a mine life of approximately 9.5 years. The project has two open pits, referred to as the ABM Open Pit and the Krakatoa Phase. Underground portals are located in the ABM Open Pit.

The development of the deposit will produce the following materials:

- Class A material – Filtered tailings and Strongly Potentially Acid Generating (SPAG) waste rock
- Class B material – Weakly Potentially Acid Generating (WPAG) waste rock
- Class C material – Potentially Acid Consuming (PAC) waste rock, and
- Overburden and Topsoil material – Surficial material removed from the Open Pit area.

A prefeasibility study (PFS) design of the tailings, waste rock and water management facilities was completed by Knight Piésold Ltd. (KP), and is described in further detail below (KP, 2016).

The Class A Storage Facility is designed to contain filtered tailings and Class A waste rock material. Class A material is described as strongly potentially acid generating and therefore requires encapsulation to prevent contact with oxygen and water. The facility is located on the western hillside of Geona Creek, north of the Mill Site location. The Class B Storage Facility is designed to contain Class B material, which is described as weakly potentially acid generating. Class B material requires encapsulation to limit contact with oxygen and water. The facility is located north of the Open Pit, along the western slope of Geona Creek. The Run of Mine (ROM) Pad and Low Grade Ore (LGO) Stockpile are incorporated into the design of the Class B Storage Facility.

The Class C Storage Facility is designed to contain Class C material. Class C material is potentially acid consuming and therefore specific ARD management strategies are not required. The Class C Storage Facility is located in a small hanging valley along the east side of the project area.

Overburden from the Open Pit excavation will be excavated and stockpiled. Glacial till material will be selectively sourced from the stockpile and used for the low permeability foundation and closure cover layers of the Class A and Class B Storage Facilities, and for construction of the Water Management and Collection Ponds. The stockpile will be located north of the Class C Storage Facility, along the western slope of the project area. The overburden material is not anticipated to be potentially acid generating and therefore specific ARD management strategies are not required.

The site incorporates diversion ditches, collection ditches, collection ponds, and sediment control ponds to manage surface runoff. Diversion ditching will be used to convey non-contact runoff to the north and south of the project area. Collection ditching will be used within the project footprint to collect and convey contact runoff to the various water management ponds, where the water will be used in the mill process or treated and released to the environment.

Fault Creek will be intercepted and diverted south away from the Open Pit areas and towards the North Lakes during operations.

Overburden dewatering in the Open Pit area will occur during the pre-production period to facilitate mining activity in the pit. The Pit Rim Pond will temporarily store water that is pumped from Open Pit Dewatering activies. Water from the Pit Rim Pond will either be used in the paste plant, pumped to the Water Treatment Plant, or routed to the Upper Water Management Pond, as required.

All water in contact with the mine facilities, including the Class A, Class B, Class C and Overburden Storage Facilities, the Open Pit, and the Mill Site and other infrastructure, will be collected and conveyed to the Upper and Lower Water Management Ponds and ultimately released to Finlayson Creek and Geona Creek.

1.2 SCOPE OF REPORT

This report provides a summary of the water balance scenarios modelled and the results obtained. This document is intended to provide an overview of the water management plan for the mine, to assist in planning the process operations, and to provide an assessment of the potential for surface water surplus or deficit conditions to occur during the mine operation.

The main objectives of the water balance exercise are as follows:

1. Estimate the volume of non-contact water diverted north to the outlet structure in Geona Creek
2. Estimate the volume of non-contact water diverted to the south of the Project, and
3. Estimate the annual surplus of Project-wide contact water.

1.3 MODELLED SCENARIOS

Three climatic scenarios were modelled as part of the PFS water balance exercise: average precipitation, 1 in 50 year wet precipitation, and 1 in 10 year dry precipitation, as requested by Alexco Environmental Group (Alexco) for use in the water quality model. The average annual precipitation was used for the average scenario, while the corresponding return period wet and dry annual precipitation values were used for the other two scenarios. The average monthly precipitation distribution (as a percentage of annual) was used for all three scenarios.

The catchment areas, applicable to all three scenarios, are shown on Figure 1.1.

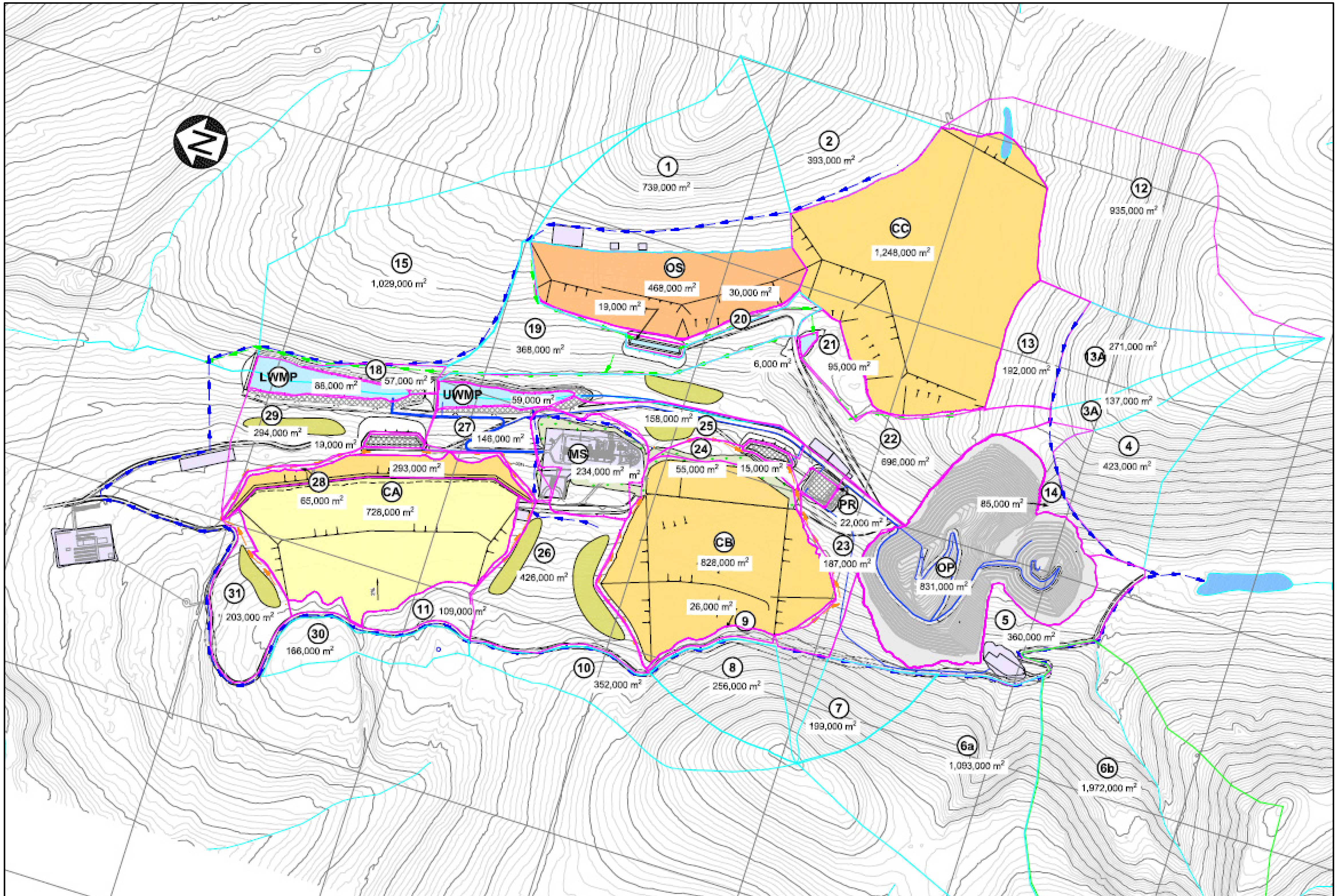


Figure 1.1 Catchment Area Map

2 – PARAMETERS AND ASSUMPTIONS

2.1 GENERAL

The modelling parameters for all scenarios are presented in Table 2.1 and are described in the following sections. The catchment areas were determined from the project topographic information as provided by BMC, and are summarized on Figure 1.1 and under Item 2.0 of Table 2.1.

Table 2.1 Water Balance Parameters

Parameter	Units	Value	Source
1.0 Hydrometeorology			
Mean Annual Precipitation	mm	612	Alexco
1 in 50 Year Wet Precipitation	mm	868	Alexco
1 in 10 Year Dry Precipitation	mm	489	Alexco
Mean Annual Pond Evaporation	mm	304	Alexco
Runoff Coefficient (Undisturbed Ground)	%	63	Mean annual runoff / Mean annual precipitation
Runoff Coefficient (Pond Surface)	%	100	KP Assumption
Runoff Coefficient (Overburden Stockpile)	%	70	KP Assumption
Runoff Coefficient (Waste Rock Stockpile)	%	80	KP Assumption
Runoff Coefficient (Open Pit Walls)	%	90	KP Assumption
Runoff Coefficient (Mill Site Area)	%	90	KP Assumption
Diversion Ditch Efficiency	%	50	KP Assumption
2.0 Catchment Areas (Final Year, full footprint)			
Class A Facility	km^2	0.73	Site topography
Area Reporting to Class A Facility	km^2	0.31	Site topography
Area Directly Reporting to Class A Facility Collection Pond	km^2	0.38	Site topography
Class B Facility	km^2	0.83	Site topography
Area Reporting to Class B Facility	km^2	0.03	Site topography
Area Directly Reporting to Class B Facility Collection Pond	km^2	0.07	Site topography
Class C Facility	km^2	1.25	Site topography
Area Reporting to Class C Facility	km^2	1.13	Site topography
Area Directly Reporting to Class C Facility Collection Pond	km^2	0.10	Site topography
Overburden Stockpile	km^2	0.47	Site topography
Area Directly Reporting to Overburden Stockpile Collection Pond	km^2	0.05	Site topography
Open Pit	km^2	0.83	Site topography

Area Reporting to Open Pit	km^2	0.45	Site topography
Area Directly Reporting Pit Rim Pond	km^2	0.02	Site topography
Area Directly Reporting to Upper Water Management Pond	km^2	1.06	Site topography
Area Directly Reporting to Lower Water Management Pond	km^2	0.44	Site topography
Area Diverted to the South of the Project	km^2	2.12	Site topography
Area Diverted to the North of the Project	km^2	3.30	Site topography
3.0 Process Plant			
Dry Ore Production	tpd	5,500	BMC
Tailings Solids Content	%	87	BMC
Tailings Specific Gravity	-	4.10	BMC
Tailings Dry Density	t/m^3	1.90	BMC
Water in Ore	m^3/hr	12.9	BMC
Minimum Fresh Water Required	m^3/hr	24.9	BMC

Estimates of the KZK groundwater inflows are provided in the Tetra Tech EBA (TTE) *Hydrogeological Model Report* (TTE, 2016), and are summarized in Table 2.2. Groundwater flux rates are provided from pre-mining through year 9 for the open pit and underground workings.

Table 2.2 Groundwater Inflow Rates

Year	Groundwater Inflow (US gpm)	
	Open Pit	Underground Workings
Pre-Mining	1,401	0
Year 1	664	0
Year 2	643	0
Year 3	384	459
Year 4	382	436
Year 5	337	489
Year 6	297	701
Year 7	322	665
Year 8	281	862
Year 9	263	847

2.2 HYDROMETEROLOGY

The climate in the Project area can be classified as a typical northern interior climate (Alexco, 2016), with cool short summers, and long cold winters. Annual mean temperatures range from approximately 0°C in warm years to -5°C in cold years.

The rainfall and evapotranspiration distributions used for the water balance are based on long-term records from regional stations as well as short-term data site specific data collected in 1995 and from a new station commissioned in August 2015. The mean annual precipitation and evaporation values used in the models are 612 mm and 304 mm, respectively. The mean monthly precipitation and evaporation are shown in Table 2.3. The wettest month is typically July, with an average precipitation of 84 mm, all of which falls as rain. The driest month is typically April, with an average precipitation of 21 mm. The highest evapotranspiration occurs in June and July, with 80 mm estimated to occur in each month.

Table 2.3 Monthly Hydrometeorological Parameters

Month	Total Precipitation (mm)	Rainfall (mm)	Snow Water Equivalent (mm)	Evapotranspiration (mm)
January	44.9	0	44.9	0.0
February	33.5	0	33.5	0.0
March	29.7	0	29.7	4.0
April	20.7	0	20.7	16.0
May	39.9	19.9	19.9	36.0
June	65.5	65.5	0	80.0
July	84.0	84.0	0	80.0
August	74.2	74.2	0	44.0
September	68.2	68.2	0	24.0
October	52.0	10.4	41.6	16.0
November	51.7	0	51.7	4.0
December	47.2	0	47.2	0.0
Annual	**612**	**322**	**289**	**304**

2.3 SEEPAGE CONSIDERATIONS

Seepage considerations are based on the assumed permeability of the foundation material, and were only accounted for in the Class A Facility at this time. The water balance model assumes that all the facilities have seepage collection systems. It was assumed that 5,000 m^3 of seepage is captured in the Class A Water Management Pond annually.

2.4 PROCESS PLANT

The tailings properties used in the water balance are listed in Table 2.1, Item 3.0.

The Open Pit will produce approximately 2.0 Mtonnes per year. The tailings slurry has a specific gravity of 4.10, and contains 87% solids. As such there is 302,000 m^3 of water in the slurry reporting to the Class A Facility each year. The assumed process water requirement was 276,000 m^3, sourced from the Open Pit, freshwater wells, and treated Class A runoff.

3 – WATER MANAGEMENT ASSUMPTIONS

3.1 GENERAL OPERATIONS

The PFS design for the tailings, waste rock, and water management systems includes the following facilities:

Class A Storage Facility and Collection Pond

- The Class A Storage Facility will be used to manage filtered tailings and Class A material. The waste rock will be co-disposed with the filtered tailings solids. The Class A Facility is located north of the Mill Site on the western hillside of Geona Creek.
- All surface runoff will be routed to the Class A Facility Collection Pond via appropriate grading of the Class A Storage Facility and collection ditches.
- Seepage from the facility will be collected in sumps and pumped to the Class A Collection Pond.
- All collected runoff and seepage will be stored in the Class A Collection Pond prior to being pumped to the Water Treatment Plant or used in the Mill as make-up water.

Class B Storage Facility and Collection Pond

- The Class B Storage Facility will be used to manage Class B material. The Class B Storage Facility is located on the western hillside of Geona Creek adjacent to the Open Pit.
- All surface runoff will be routed to the Class B Facility Collection Pond via appropriate grading of the Class B Storage Facility and collection ditches.
- Seepage from the facility will be collected in sumps and pumped to the Class B Collection Pond.
- The water required for dust suppression will be sourced from the Class B Collection Pond during the summer season from May through September, annually, assuming that the Class B runoff does not require treatment. Dust suppression may also be sourced from other collection ponds such as the Pit Rim Pond and the Lower Water Management Pond, if required.
- All collected runoff and seepage will be stored in the Class B Collection Pond prior to being routed to the Upper Water Management Pond.

Class C Storage Facility and Collection Pond

- The Class C Storage Facility will be used to manage Class C material. The Class C Storage Facility is located on the east side of Geona Creek in the East Creek drainage.
- All surface runoff from the facility will be routed to the Class C Storage Facility Collection Pond via appropriate grading of the Class C Storage Facility and collection ditches.
- Retention time in the pond will allow sediment to settle to an appropriate level before routing the water to Geona Creek.

Overburden Stockpile and Collection Pond

- The overburden stockpile will be used to manage the overburden material removed from the Open Pit area. The stockpile is located on the east side of Geona Creek to the north of the Class C Storage Facility. Runoff will be collected in the Overburden Collection Pond for sediment control prior to discharge to Geona Creek.
- All surface runoff from the facility will be routed to the Overburden Collection Pond via appropriate grading of the Overburden Stockpile and collection ditches.
- Retention time in the pond will allow sediment to settle to an appropriate level before routing the water to Geona Creek.

Mill Site

- The Mill Site is located on the western hillside of Geona Creek between the Class A and Class B Storage Facilities. The Run of Mine (ROM) pad and Low Grade Ore (LGO) stockpile are located at the base of the Class B Storage Facility, adjacent to the Mill. Runoff from the Mill Site area will be collected at the Mill Site and treated before discharge.
- All surface runoff from the ROM Pad and LGO Stockpile will be routed to the Mill Site via appropriate grading and collection ditches.

Upper and Lower Water Management Ponds

- Two Water Management Ponds are located in Geona Creek downstream of the Mill Site to manage contact runoff water and seepage. Site contact water will be routed to the Upper Water Management pond for settling of sediments, and then decanted to the Lower Pond for additonal storage prior to discharge. Water will be discharged seasonally to Finalyson Creek, and year round to Geona Creek.

Fault Creek Diversion

- Fault Creek will be diverted during operations to restrict flow into the project area and will be re-established at closure.

Pit Rim Pond

- The Pit Rim Pond will temporarily store water that is pumped from Open Pit Dewatering activies. Water from the Pit Rim Pond will be used in the paste plant, pumped to the Water Treatment Plant, or routed to the Upper Water Management Pond, as required.

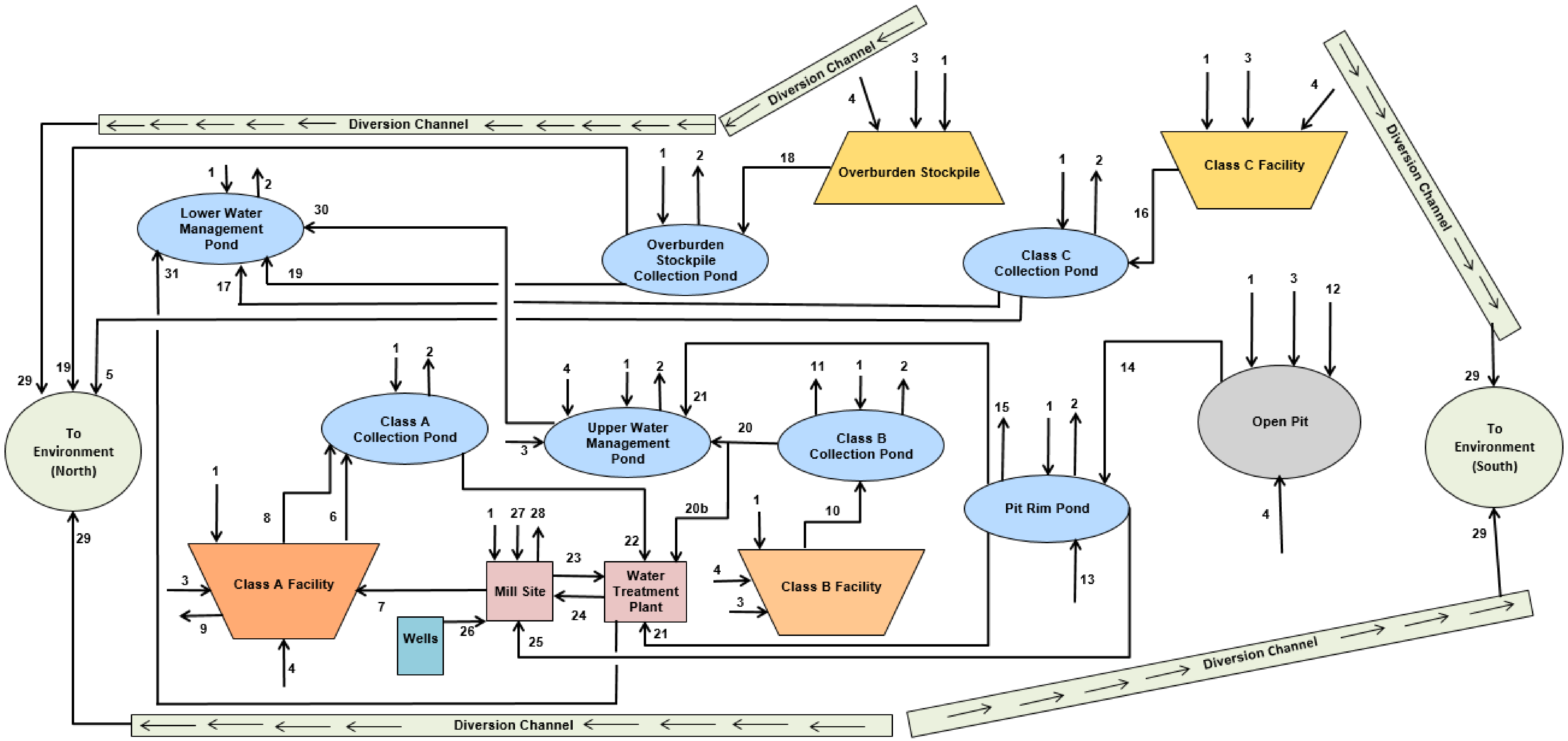
Open Pit

- Open Pit dewatering will continue throughout the mine life with dewatering flows being directed to the Pit Rim Pond and then to the Mill Site for use, treatment, and/or discharge to the environment.
- Underground dewatering will be completed by others; however, the underground dewatering flows have been included in the design of the Pit Rim Pond.

Water Treatment Plant

- It was assumed that the water treatment plant (WTP) will operate at a maximum treatment rate of 41,500 m^3/month during the low flow months of November through April.
- It was assumed that the WTP will operate at a maximum treatment rate of 161,000 m^3/month during the high flow months of May through October.
- The WTP will preferentially treat runoff from the following facilities, up to the maximum treatment rate:
    - Class A Facility Collection Pond
    - Mill Site Runoff
    - Open Pit
    - Class B Facility Collection Pond (if required)
- The WTP will discharge treated flows to the Lower Water Management Pond.

The water management plan is shown schematically on Figure 3.1.



FLOW PATHS

1	Direct Precipitation
2	Evapotranspiration
3	Undiverted Runoff
4	Diversion Ditch Leakage
5	Collection Ditch Leakage
6	Seepage
7	Water in Tailings
8	Runoff from Class A Facility
9	Void Losses
10	Runoff from Class B Facility
11*	Dust suppression
12	Groundwater Inflow to Open Pit
13	Groundwater Inflow from Underground Workings
14	Open Pit Dewatering
15	Water to Paste Plant
16	Runoff from Class C Facility
17	Surplus from Class C Collection Pond
18	Runoff from Overburden Stockpile
19	Surplus from Overburden Stockpile Collection Pond
20	Surplus from Class B Collection Pond
20b	Surplus from Class B Collection Pond to WTP
21	Surplus from Pit Rim Pond
22	Surplus from Class A Collection Pond
23	Mill Site Runoff
24	Mill Reclaim
25	Freshwater Source 1
26	Freshwater Source 2
27	Water in Ore
28	Water in Concentrate
29	Diversions to Environment
30	Surplus from Upper Water Management Pond
31	Treated Runoff from Water Treatment Plant

* Water for dust suppression can be supplied from various sources, depending on water quality, if required (i.e. Class B Collection Pond, Pit Rim Pond, Lower Water Management Pond, etc.).

Figure 3.1 Water Balance Flow Schematic

4 – RESULTS

4.1 GENERAL

The preliminary water balance results, for all three climatic conditions considered, suggest that the site is in an annual water surplus. The water balance is sensitive to the input assumptions and the potential variability in the results should be considered when used for planning purposes. The input variables that have the greatest influence on the results are the water management assumptions, the diversion ditch efficiency, and the climatic values.

The water management plan could be optimized by staging the development of the mine site to potentially reduce contact water volume requiring treatment in the initial years of project development, and by additional progressive reclamation.

4.2 AVERAGE CLIMATIC CONDITIONS

The total annual surplus, under average climatic conditions, is 5.93 Mm^3, as summarized in Table 4.1. This surplus includes treated and untreated runoff. The treated portion of this total is 1.16 Mm^3, while the untreated portion is the remaining 4.77 Mm^3. The total volume of runoff diverted around the project site is 2.59 Mm^3, with 1.17 Mm^3 reporting south of the project site and 1.42 Mm^3 reporting north of the site.

Table 4.1 Results from Average Climatic Conditions (Mm^3/month)

Month	Diverted Runoff		Collection Pond Surplus							Post Water Treatment Plant	Total Site Surplus
	North	South	Pit Rim	Class A	Class B	Class C	Overburden Stockpile	Upper WMP	Lower WMP		
Jan	0.023	0.025	0.140	0.000	0.007	0.014	0.003	0.011	0.016	0.037	0.211
Feb	0.017	0.020	0.137	0.000	0.006	0.011	0.003	0.009	0.012	0.037	0.201
Mar	0.017	0.020	0.137	0.000	0.006	0.011	0.003	0.009	0.012	0.037	0.201
Apr	0.038	0.023	0.172	0.000	0.024	0.039	0.013	0.011	0.034	0.037	0.278
May	0.321	0.247	0.399	0.007	0.165	0.287	0.089	0.119	0.270	0.156	1.116
Jun	0.334	0.248	0.412	0.022	0.175	0.303	0.094	0.118	0.278	0.156	1.161
Jul	0.186	0.150	0.233	0.000	0.086	0.159	0.047	0.068	0.146	0.156	0.689
Aug	0.156	0.123	0.199	0.000	0.073	0.136	0.041	0.057	0.126	0.156	0.611
Sep	0.164	0.135	0.196	0.000	0.073	0.137	0.041	0.064	0.132	0.156	0.621
Oct	0.089	0.094	0.065	0.000	0.032	0.059	0.016	0.042	0.064	0.156	0.359
Nov	0.044	0.051	0.152	0.000	0.014	0.026	0.007	0.023	0.031	0.037	0.257
Dec	0.030	0.034	0.143	0.000	0.009	0.018	0.004	0.015	0.021	0.037	0.225
Annual (m^3/yr)	**1.42**	**1.17**	**2.39**	**0.03**	**0.67**	**1.20**	**0.36**	**0.55**	**1.14**	**1.16**	**5.93**

NOTES:

1. THE UPPER WATER MANAGEMENT POND VOLUME DOES NOT INCLUDE SURPLUS RUNOFF FROM THE PIT RIM POND OR CLASS B COLLECTION POND. IT ONLY REPRESENTS DIRECT RUNOFF FROM ITS REPORTING CATCHMENT AREAS.
2. THE LOWER WATER MANAGEMENT POND VOLUME DOES NOT INCLUDE SURPLUS RUNOFF FROM THE CLASS C COLLECTION POND, OVERBURDEN STOCKPILE POND, UPPER WATER MANAGEMENT POND OR WATER TREAMENT PLANT. IT ONLY REPRESENTS DIRECT RUNOFF FROM ITS REPORTING CATCHMENT AREAS..

4.3 1 IN 50 YEAR WET CLIMATIC CONDITIONS

The total annual surplus, under wet climatic conditions, is 7.70 Mm^3, as summarized in Table 4.2. This surplus includes treated and untreated runoff. The treated portion of this total is 1.16 Mm^3, while the untreated portion is the remaining 6.54 Mm^3. The total volume of runoff diverted around the project site is 3.67 Mm^3, with 1.66 Mm^3 reporting south of the project site and 2.02 Mm^3 reporting north of the site.

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Table 4.2 Results from 1 in 50 Year Wet Climatic Conditions (Mm^3/month)

Month	Diverted Runoff		Collection Pond Surplus							Post Water Treatment Plant	Total Site Surplus
	North	South	Pit Rim	Class A	Class B	Class C	Overburden Stockpile	Upper WMP	Lower WMP		
Jan	0.031	0.035	0.145	0.000	0.011	0.020	0.005	0.016	0.022	0.037	0.231
Feb	0.025	0.028	0.141	0.000	0.008	0.015	0.004	0.013	0.017	0.037	0.216
Mar	0.025	0.028	0.141	0.000	0.008	0.016	0.004	0.013	0.017	0.037	0.216
Apr	0.055	0.033	0.199	0.000	0.035	0.056	0.018	0.016	0.048	0.037	0.335
May	0.458	0.350	0.496	0.088	0.238	0.407	0.126	0.170	0.384	0.156	1.532
Jun	0.475	0.352	0.514	0.109	0.253	0.431	0.134	0.170	0.399	0.156	1.601
Jul	0.263	0.213	0.338	0.000	0.126	0.227	0.068	0.098	0.211	0.156	0.929
Aug	0.221	0.174	0.289	0.000	0.107	0.193	0.059	0.082	0.181	0.156	0.815
Sep	0.232	0.192	0.285	0.000	0.107	0.195	0.058	0.091	0.188	0.156	0.827
Oct	0.126	0.133	0.095	0.000	0.046	0.084	0.022	0.060	0.091	0.156	0.448
Nov	0.063	0.072	0.162	0.000	0.020	0.037	0.009	0.032	0.044	0.037	0.295
Dec	0.041	0.048	0.150	0.000	0.013	0.025	0.006	0.022	0.029	0.037	0.251
Annual (m^3/yr)	**2.02**	**1.66**	**2.96**	**0.20**	**0.97**	**1.71**	**0.51**	**0.78**	**1.63**	**1.16**	**7.70**

NOTES:

1. THE UPPER WATER MANAGEMENT POND VOLUME DOES NOT INCLUDE SURPLUS RUNOFF FROM THE PIT RIM POND OR CLASS B COLLECTION POND. IT ONLY REPRESENTS DIRECT RUNOFF FROM ITS REPORTING CATCHMENT AREAS.
2. THE LOWER WATER MANAGEMENT POND VOLUME DOES NOT INCLUDE SURPLUS RUNOFF FROM THE CLASS C COLLECTION POND, OVERBURDEN STOCKPILE POND, UPPER WATER MANAGEMENT POND OR WATER TREAMENT PLANT. IT ONLY REPRESENTS DIRECT RUNOFF FROM ITS REPORTING CATCHMENT AREAS.

4.4 1 IN 10 YEAR DRY CLIMATIC CONDITIONS

The total annual surplus, under dry climatic conditions, is 5.14 Mm^3, as summarized in Table 4.3. This surplus includes treated and untreated runoff. The treated portion of this total is 1.16 Mm^3, while the untreated portion is the remaining 3.98 Mm^3. The total volume of runoff diverted around the project site is 2.07 Mm^3, with 0.93 Mm^3 reporting south of the project site and 1.13 Mm^3 reporting north of the site.

Table 4.3 Results from 1 in 10 Year Dry Climatic Conditions (Mm^3/month)

Month	Diverted Runoff		Collection Pond Surplus							Post Water Treatment Plant	Total Site Surplus
	North	South	Pit Rim	Class A	Class B	Class C	Overburden Stockpile	Upper WMP	Lower WMP		
Jan	0.018	0.020	0.137	0.000	0.006	0.011	0.003	0.009	0.013	0.037	0.202
Feb	0.014	0.016	0.135	0.000	0.005	0.009	0.002	0.007	0.010	0.037	0.194
Mar	0.014	0.016	0.135	0.000	0.005	0.009	0.002	0.007	0.010	0.037	0.194
Apr	0.031	0.018	0.163	0.000	0.019	0.031	0.010	0.009	0.027	0.037	0.255
May	0.257	0.197	0.350	0.000	0.130	0.229	0.071	0.095	0.215	0.156	0.946
Jun	0.266	0.198	0.363	0.000	0.138	0.243	0.075	0.093	0.221	0.156	0.971
Jul	0.148	0.120	0.183	0.000	0.067	0.127	0.038	0.053	0.116	0.156	0.575
Aug	0.123	0.098	0.156	0.000	0.056	0.109	0.033	0.045	0.100	0.156	0.513
Sep	0.130	0.108	0.154	0.000	0.056	0.110	0.033	0.051	0.105	0.156	0.522
Oct	0.071	0.075	0.054	0.000	0.026	0.047	0.012	0.033	0.051	0.156	0.320
Nov	0.036	0.041	0.147	0.000	0.011	0.021	0.005	0.018	0.024	0.037	0.237
Dec	0.024	0.027	0.140	0.000	0.007	0.014	0.004	0.012	0.017	0.037	0.213
Annual (m^3/yr)	**1.13**	**0.93**	**2.12**	**0.00**	**0.53**	**0.96**	**0.29**	**0.43**	**0.91**	**1.16**	**5.14**

NOTES:

1. THE UPPER WATER MANAGEMENT POND VOLUME DOES NOT INCLUDE SURPLUS RUNOFF FROM THE PIT RIM POND OR CLASS B COLLECTION POND. IT ONLY REPRESENTS DIRECT RUNOFF FROM ITS REPORTING CATCHMENT AREAS.
2. THE LOWER WATER MANAGEMENT POND VOLUME DOES NOT INCLUDE SURPLUS RUNOFF FROM THE CLASS C COLLECTION POND, OVERBURDEN STOCKPILE POND, UPPER WATER MANAGEMENT POND OR WATER TREAMENT PLANT. IT ONLY REPRESENTS DIRECT RUNOFF FROM ITS REPORTING CATCHMENT AREAS.

5 – REFERENCES

Alexco Environmental Group (Alexco). 2016. Hydrometeorology Baseline Report – Kudz Ze Kayah Project. Prepared for BMC Minerals (No.1) Ltd. Ref. No.: BMC-16-01-530_001_Hydrometeorology Baseline Report_RevA_160923. Revision A.

Knight Piésold, 2016. Prefeasibility Design Report. Ref. No.: VA101-640/2-3 Rev 0. October 24, 2016.

Tetra Tech EBA (TTE). 2016. Hydrogeological Model Report. Prepared for BMC Minerals (No.1) Ltd. Ref. No.: WTR.GWTR0321-01. November 18, 2016.

6 – CERTIFICATION

This report was prepared and reviewed by the undersigned.

[Name Redacted]

Prepared: ______________________

[Name Redacted]

Reviewed: ______________________

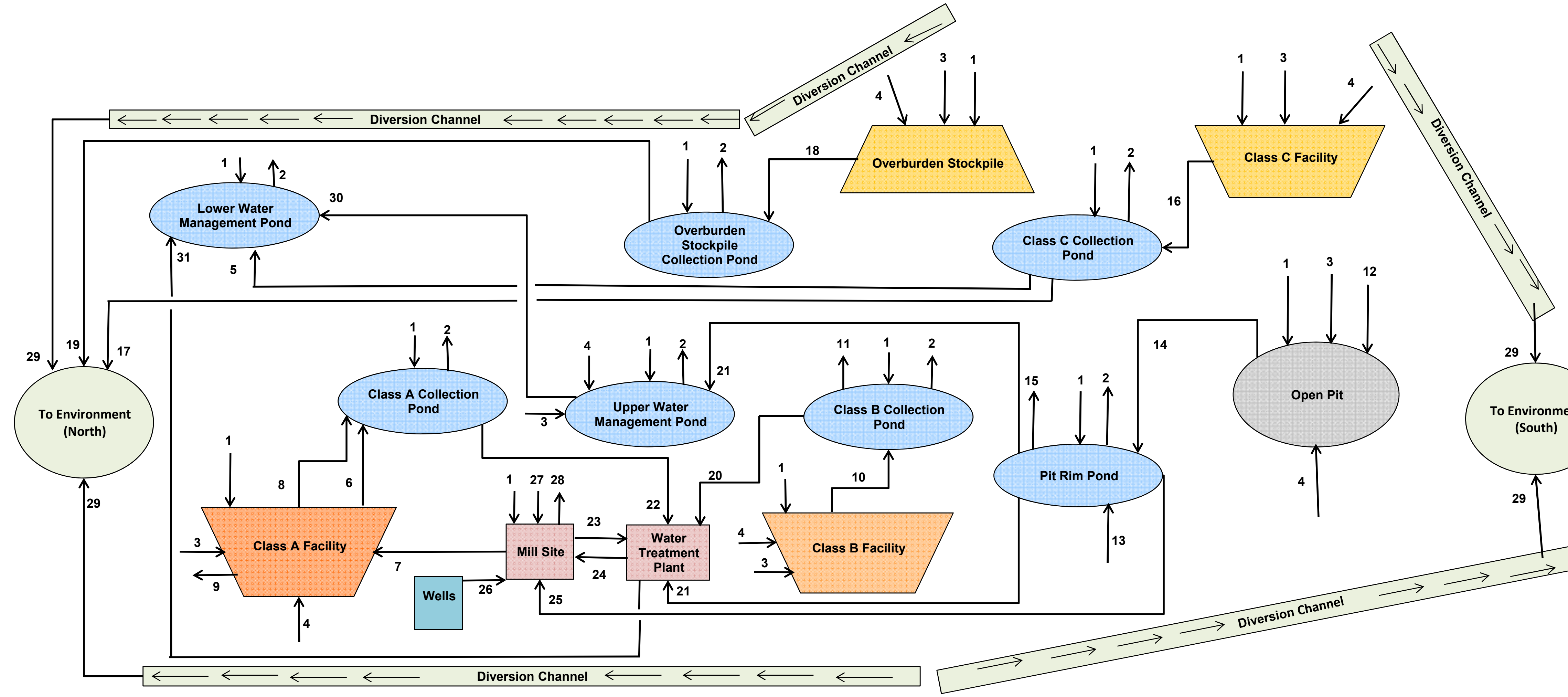
[Name Redacted]

Approval that this document adheres to Knight Piésold Quality Systems:

APPENDIX B

FLOW SCHEMATIC AND RESULT TABLES

(Pages B-1 to B-5)



FLOW PATHS

1	Direct Precipitation
2	Evapotranspiration
3	Undiverted Runoff
4	Diversion Ditch Leakage
5	Collection Ditch Leakage
6	Seepage
7	Water in Tailings
8	Runoff from Class A Facility
9	Void Losses
10	Runoff from Class B Facility
11*	Dust suppression
12	Groundwater Inflow to Open Pit
13	Groundwater Inflow from Underground Workings
14	Open Pit Dewatering
15	Water to Paste Plant
16	Runoff from Class C Facility
17	Surplus from Class C Collection Pond
18	Runoff from Overburden Stockpile
19	Surplus from Overburden Stockpile Collection Pond
20	Surplus from Class B Collection Pond
21	Surplus from Pit Rim Pond
22	Surplus from Class A Collection Pond
23	Mill Site Runoff
24	Mill Reclaim
25	Freshwater Source 1
26	Freshwater Source 2
27	Water in Ore
28	Water in Concentrate
29	Diversions to Environment
30	Surplus
31	Treated Runoff from Water Treatment Plant

* Water for dust suppression can be supplied from various sources, depending on water quality, if required (i.e. Class B Collection Pond, Pit Rim Pond, Lower Water Management Pond, etc.).

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Figure B.1 - Water Balance Flow Schematic

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TABLE B.1

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

WATER BALANCE FLOW RESULTS - MEDIAN CASE

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Facility	Flow Path	Yearly Flow (m³)								
		Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9
Class A Pond	Direct Precipitation	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000
	Runoff	98,000	98,000	95,000	98,000	95,000	95,000	95,000	95,000	98,000
	Runoff from Class A Facility	10,000	34,000	55,000	81,000	100,000	123,000	146,000	169,000	198,000
	Evaporation	-3,000	-3,000	-3,000	-3,000	-3,000	-3,000	-3,000	-3,000	-3,000
	Volume to Water Treatment	-116,000	-139,000	-157,000	-186,000	-203,000	-226,000	-249,000	-271,000	-304,000
Class B Pond	Direct Precipitation	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000
	Runoff	273,000	278,000	275,000	288,000	284,000	289,000	294,000	299,000	313,000
	Ditch Leakage	62,000	62,000	60,000	62,000	60,000	60,000	60,000	60,000	62,000
	Evaporation	-2,000	-2,000	-2,000	-2,000	-2,000	-2,000	-2,000	-2,000	-2,000
	Volume to Water Treatment	-341,000	-346,000	-340,000	-356,000	-350,000	-357,000	-368,000	-376,000	-388,000
Class C Pond	Direct Precipitation	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000
	Runoff	505,000	512,000	504,000	528,000	519,000	526,000	534,000	541,000	565,000
	Ditch Leakage	67,000	67,000	65,000	67,000	65,000	65,000	65,000	65,000	67,000
	Evaporation	-2,000	-2,000	-2,000	-2,000	-2,000	-2,000	-2,000	-2,000	-2,000
	Volume Released to Environment	-287,000	-291,000	-286,000	-298,000	-293,000	-297,000	-300,000	-304,000	-317,000
	Volume Conveyed to LWMP	-287,000	-291,000	-286,000	-298,000	-293,000	-297,000	-300,000	-304,000	-317,000
Overburden Stockpile Pond	Direct Precipitation	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000
	Runoff	112,000	112,000	108,000	112,000	108,000	108,000	108,000	108,000	112,000
	Ditch Leakage	75,000	75,000	73,000	75,000	73,000	73,000	73,000	73,000	75,000
	Evaporation	-6,000	-6,000	-6,000	-6,000	-6,000	-6,000	-6,000	-6,000	-6,000
	Volume Released to Environment	-96,000	-96,000	-93,000	-96,000	-93,000	-93,000	-93,000	-93,000	-96,000
	Volume Conveyed to LWMP	-96,000	-96,000	-93,000	-96,000	-93,000	-93,000	-93,000	-93,000	-96,000
Water Treatment Plant	Volume from Class A Pond	116,000	139,000	157,000	186,000	203,000	226,000	249,000	271,000	304,000
	Volume from Class B Pond	341,000	346,000	340,000	356,000	350,000	357,000	368,000	376,000	388,000
	Runoff from Mill Surfaces	68,000	68,000	67,000	68,000	66,000	64,000	57,000	57,000	61,000
	Treated Water to LWMP	-467,000	-495,000	-506,000	-552,000	-561,000	-589,000	-616,000	-646,000	-695,000
	Treated Water to Mill	-58,000	-58,000	-58,000	-58,000	-58,000	-58,000	-58,000	-58,000	-58,000
Upper Water Management Pond	Direct Precipitation	33,000	33,000	32,000	33,000	32,000	32,000	32,000	32,000	33,000
	Runoff	445,000	429,000	400,000	396,000	368,000	353,000	337,000	321,000	314,000
	Ditch Leakage	54,000	54,000	53,000	54,000	53,000	53,000	53,000	53,000	54,000
	Water from Open Pit	1,582,000	1,549,000	1,941,000	1,917,000	1,922,000	2,272,000	2,258,000	2,582,000	2,528,000
	Evaporation	-18,000	-18,000	-18,000	-18,000	-18,000	-18,000	-18,000	-18,000	-18,000
	Surplus Volume to LWMP	2,096,000	2,046,000	2,408,000	2,382,000	2,357,000	2,692,000	2,661,000	2,970,000	2,911,000
Lower Water Management Pond	Direct Precipitation	48,000	48,000	48,000	48,000	48,000	48,000	48,000	48,000	48,000
	Runoff	176,000	176,000	170,000	176,000	170,000	170,000	170,000	171,000	176,000
	Ditch Leakage	383,000	386,000	379,000	394,000	386,000	390,000	393,000	397,000	413,000
	Volume from Water Treatment Plant	467,000	495,000	506,000	552,000	561,000	589,000	616,000	646,000	695,000
	Volume from UWMP	2,096,000	2,046,000	2,408,000	2,382,000	2,357,000	2,692,000	2,661,000	2,970,000	2,911,000
	Evaporation	-27,000	-27,000	-27,000	-27,000	-27,000	-27,000	-27,000	-27,000	-27,000
	Dust Suppression	-46,000	-46,000	-46,000	-46,000	-46,000	-46,000	-46,000	-46,000	-46,000
	Volume Released to Environment	3,097,000	3,078,000	3,438,000	3,479,000	3,449,000	3,816,000	3,815,000	4,159,000	4,170,000

\\KPL\VA-Prj$\1\01\00640\05\A\Data\Updated Water Balance to Answer IR Round 2\WaterBalanceUpdate\GoldSim\Results\[KZK Results - Rev 4.xlsx]Median Results

NOTES:

1. VALUES ARE ROUNDED TO THE NEAREST 1000 m³.
2. POSITIVE NUMBERS REPRESENT INFLOW, NEGATIVE NUMBERS REPRESENT OUTFLOW.

0	02NOV'17	ISSUED WITH LETTER VA17-01585	SCR	LG
REV	DATE	DESCRIPTION	PREP'D	RVW'D

Knight Piésold
CONSULTING

TABLE B.2

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

WATER BALANCE FLOW RESULTS - 10th PERCENTILE

Print: 11/2/2017 10:39

Facility	Flow Path	Yearly Flow (m³)								
		Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9
Class A Pond	Direct Precipitation	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000
	Runoff	31,000	33,000	33,000	33,000	33,000	33,000	33,000	33,000	33,000
	Runoff from Class A Facility	3,000	11,000	19,000	26,000	34,000	42,000	50,000	58,000	65,000
	Evaporation	-3,000	-3,000	-3,000	-3,000	-3,000	-3,000	-3,000	-3,000	-3,000
	Volume to Water Treatment	-37,000	-48,000	-56,000	-64,000	-71,000	-79,000	-87,000	-95,000	-102,000
Class B Pond	Direct Precipitation	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000
	Runoff	87,000	92,000	94,000	96,000	97,000	99,000	101,000	103,000	104,000
	Ditch Leakage	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000
	Evaporation	-2,000	-2,000	-2,000	-2,000	-2,000	-2,000	-2,000	-2,000	-2,000
	Volume to Water Treatment	-109,000	-116,000	-117,000	-119,000	-121,000	-122,000	-124,000	-126,000	-127,000
Class C Pond	Direct Precipitation	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000
	Runoff	161,000	170,000	173,000	175,000	178,000	180,000	183,000	185,000	188,000
	Ditch Leakage	21,000	22,000	22,000	22,000	22,000	22,000	22,000	22,000	22,000
	Evaporation	-2,000	-2,000	-2,000	-2,000	-2,000	-2,000	-2,000	-2,000	-2,000
	Volume Released to Environment	-91,000	-96,000	-98,000	-99,000	-100,000	-101,000	-103,000	-104,000	-105,000
	Volume Conveyed to LWMP	-91,000	-96,000	-98,000	-99,000	-100,000	-101,000	-103,000	-104,000	-105,000
Overburden Stockpile Pond	Direct Precipitation	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000
	Runoff	36,000	37,000	37,000	37,000	37,000	37,000	37,000	37,000	37,000
	Ditch Leakage	24,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000
	Evaporation	-6,000	-6,000	-6,000	-6,000	-6,000	-6,000	-6,000	-6,000	-6,000
	Volume Released to Environment	-31,000	-31,000	-31,000	-32,000	-31,000	-31,000	-31,000	-32,000	-31,000
	Volume Conveyed to LWMP	-31,000	-31,000	-31,000	-32,000	-31,000	-31,000	-31,000	-32,000	-31,000
Water Treatment Plant	Volume from Class A Pond	37,000	48,000	56,000	64,000	71,000	79,000	87,000	95,000	102,000
	Volume from Class B Pond	109,000	116,000	117,000	119,000	121,000	122,000	124,000	126,000	127,000
	Runoff from Mill Surfaces	22,000	22,000	23,000	22,000	22,000	23,000	22,000	22,000	23,000
	Treated Water to LWMP	-110,000	-128,000	-138,000	-147,000	-156,000	-166,000	-175,000	-185,000	-194,000
	Treated Water to Mill	-58,000	-58,000	-58,000	-58,000	-58,000	-58,000	-58,000	-58,000	-58,000
Upper Water Management Pond	Direct Precipitation	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000
	Runoff	142,000	142,000	136,000	131,000	125,000	120,000	115,000	109,000	104,000
	Ditch Leakage	17,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000
	Water from Open Pit	1,275,000	1,242,000	1,643,000	1,600,000	1,614,000	1,959,000	1,940,000	2,259,000	2,185,000
	Evaporation	-18,000	-18,000	-18,000	-18,000	-18,000	-18,000	-18,000	-18,000	-18,000
	Surplus Volume to LWMP	1,435,000	1,404,000	1,799,000	1,751,000	1,760,000	2,099,000	2,075,000	2,388,000	2,308,000
Lower Water Management Pond	Direct Precipitation	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000
	Runoff	56,000	58,000	58,000	58,000	58,000	58,000	58,000	58,000	58,000
	Ditch Leakage	122,000	128,000	129,000	131,000	132,000	133,000	134,000	136,000	137,000
	Volume from Water Treatment Plant	110,000	128,000	138,000	147,000	156,000	166,000	175,000	185,000	194,000
	Volume from UWMP	1,435,000	1,404,000	1,799,000	1,751,000	1,760,000	2,099,000	2,075,000	2,388,000	2,308,000
	Evaporation	-27,000	-27,000	-27,000	-27,000	-27,000	-27,000	-27,000	-27,000	-27,000
	Dust Suppression	-46,000	-46,000	-46,000	-46,000	-46,000	-46,000	-46,000	-46,000	-46,000
	Volume Released to Environment	1,680,000	1,675,000	2,081,000	2,044,000	2,063,000	2,413,000	2,399,000	2,724,000	2,654,000

\\KPL\VA-Prj$\1\01\00640\05\A\Data\Updated Water Balance to Answer IR Round 2\WaterBalanceUpdate\GoldSim\Results\[KZK Results - Rev 4.xlsx]10th Percentile Results

NOTES:

1. VALUES ARE ROUNDED TO THE NEAREST 1000 m³.
2. POSITIVE NUMBERS REPRESENT INFLOW, NEGATIVE NUMBERS REPRESENT OUTFLOW.

0	02NOV'17	ISSUED WITH LETTER VA17-01585	SCR	LG
REV	DATE	DESCRIPTION	PREP'D	RVW'D

TABLE B.3

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

WATER BALANCE FLOW RESULTS - 90th PERCENTILE

Print: 11/2/2017 10:39

Facility	Flow Path	Yearly Flow (m³)								
		Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9
Class A Pond	Direct Precipitation	14,000	14,000	14,000	14,000	14,000	13,000	14,000	14,000	14,000
	Runoff	150,000	150,000	150,000	151,000	150,000	145,000	150,000	151,000	150,000
	Runoff from Class A Facility	17,000	52,000	88,000	124,000	160,000	189,000	232,000	268,000	304,000
	Evaporation	-3,000	-3,000	-3,000	-3,000	-3,000	-3,000	-3,000	-3,000	-3,000
	Volume to Water Treatment	-177,000	-213,000	-249,000	-285,000	-321,000	-344,000	-393,000	-429,000	-465,000
Class B Pond	Direct Precipitation	11,000	11,000	11,000	11,000	11,000	10,000	11,000	11,000	11,000
	Runoff	419,000	426,000	434,000	442,000	450,000	442,000	465,000	473,000	481,000
	Ditch Leakage	95,000	95,000	95,000	95,000	95,000	91,000	95,000	95,000	95,000
	Evaporation	-2,000	-2,000	-2,000	-3,000	-3,000	-3,000	-3,000	-3,000	-3,000
	Volume to Water Treatment	-521,000	-529,000	-537,000	-545,000	-552,000	-541,000	-568,000	-576,000	-565,000
Class C Pond	Direct Precipitation	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000
	Runoff	774,000	785,000	797,000	809,000	820,000	803,000	844,000	856,000	867,000
	Ditch Leakage	103,000	103,000	103,000	103,000	103,000	100,000	103,000	103,000	103,000
	Evaporation	-2,000	-2,000	-2,000	-2,000	-2,000	-2,000	-2,000	-2,000	-2,000
	Volume Released to Environment	-440,000	-446,000	-451,000	-457,000	-463,000	-453,000	-475,000	-481,000	-486,000
	Volume Conveyed to LWMP	-440,000	-446,000	-451,000	-457,000	-463,000	-453,000	-475,000	-481,000	-486,000
Overburden Stockpile Pond	Direct Precipitation	14,000	14,000	14,000	14,000	14,000	13,000	14,000	14,000	14,000
	Runoff	171,000	171,000	171,000	171,000	171,000	165,000	171,000	171,000	171,000
	Ditch Leakage	115,000	115,000	115,000	115,000	115,000	111,000	115,000	115,000	115,000
	Evaporation	-6,000	-6,000	-6,000	-6,000	-6,000	-6,000	-6,000	-6,000	-6,000
	Volume Released to Environment	-147,000	-147,000	-147,000	-147,000	-147,000	-142,000	-147,000	-147,000	-147,000
	Volume Conveyed to LWMP	-147,000	-147,000	-147,000	-147,000	-147,000	-142,000	-147,000	-147,000	-147,000
Water Treatment Plant	Volume from Class A Pond	177,000	213,000	249,000	285,000	321,000	344,000	393,000	429,000	465,000
	Volume from Class B Pond	521,000	529,000	537,000	545,000	552,000	541,000	568,000	576,000	565,000
	Runoff from Mill Surfaces	104,000	104,000	104,000	104,000	104,000	101,000	104,000	104,000	122,000
	Treated Water to LWMP	-744,000	-788,000	-832,000	-876,000	-919,000	-928,000	-1,007,000	-1,051,000	-1,094,000
	Treated Water to Mill	-58,000	-58,000	-58,000	-58,000	-58,000	-58,000	-58,000	-58,000	-58,000
Upper Water Management Pond	Direct Precipitation	42,000	42,000	42,000	42,000	42,000	41,000	42,000	42,000	42,000
	Runoff	806,000	776,000	746,000	717,000	686,000	657,000	627,000	597,000	567,000
	Ditch Leakage	83,000	83,000	83,000	83,000	83,000	80,000	83,000	83,000	83,000
	Water from Open Pit	1,822,000	1,793,000	2,203,000	2,170,000	2,194,000	2,523,000	2,539,000	2,868,000	2,803,000
	Evaporation	-18,000	-18,000	-18,000	-18,000	-18,000	-18,000	-18,000	-18,000	-18,000
	Surplus Volume to LWMP	2,611,000	2,556,000	2,942,000	2,884,000	2,882,000	3,163,000	3,177,000	3,481,000	3,390,000
Lower Water Management Pond	Direct Precipitation	63,000	63,000	63,000	63,000	63,000	61,000	63,000	63,000	63,000
	Runoff	269,000	269,000	269,000	269,000	269,000	260,000	269,000	269,000	269,000
	Ditch Leakage	587,000	593,000	599,000	605,000	610,000	595,000	622,000	628,000	633,000
	Volume from Water Treatment Plant	744,000	788,000	832,000	876,000	919,000	928,000	1,007,000	1,051,000	1,094,000
	Volume from UWMP	2,611,000	2,556,000	2,942,000	2,884,000	2,882,000	3,163,000	3,177,000	3,481,000	3,390,000
	Evaporation	-27,000	-27,000	-27,000	-27,000	-27,000	-27,000	-27,000	-27,000	-27,000
	Dust Suppression	-46,000	-46,000	-46,000	-46,000	-46,000	-46,000	-46,000	-46,000	-46,000
	Volume Released to Environment	4,201,000	4,196,000	4,632,000	4,624,000	4,670,000	4,934,000	5,065,000	5,419,000	5,376,000

\\KPL\VA-Prj$\1\01\00640\05\A\Data\Updated Water Balance to Answer IR Round 2\WaterBalanceUpdate\GoldSim\Results\[KZK Results - Rev 4.xlsx]90th Percentile Results

NOTES:

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0	02NOV'17	ISSUED WITH LETTER VA17-01585	SCR	LG
REV	DATE	DESCRIPTION	PREP'D	RVW'D

Knight Piésold CONSULTING

TABLE B.4

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

WATER BALANCE FLOW RESULTS - 98th PERCENTILE

Print: 11/2/2017 10:39

Facility	Flow Path	Yearly Flow (m³)								
		Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9
Class A Pond	Direct Precipitation	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000
	Runoff	178,000	178,000	178,000	178,000	178,000	178,000	178,000	178,000	178,000
	Runoff from Class A Facility	22,000	65,000	107,000	150,000	192,000	234,000	277,000	320,000	363,000
	Evaporation	-3,000	-3,000	-3,000	-3,000	-3,000	-3,000	-3,000	-3,000	-3,000
	Volume to Water Treatment	-212,000	-255,000	-297,000	-340,000	-382,000	-425,000	-468,000	-510,000	-553,000
Class B Pond	Direct Precipitation	12,000	12,000	12,000	12,000	12,000	12,000	12,000	12,000	12,000
	Runoff	497,000	506,000	515,000	524,000	533,000	542,000	552,000	561,000	570,000
	Ditch Leakage	112,000	112,000	112,000	112,000	112,000	112,000	112,000	112,000	112,000
	Evaporation	-3,000	-3,000	-3,000	-3,000	-3,000	-3,000	-3,000	-3,000	-3,000
	Volume to Water Treatment	-618,000	-627,000	-636,000	-645,000	-616,000	-615,000	-617,000	-626,000	-634,000
Class C Pond	Direct Precipitation	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000
	Runoff	917,000	931,000	945,000	959,000	972,000	986,000	1,000,000	1,014,000	1,028,000
	Ditch Leakage	122,000	122,000	122,000	122,000	122,000	122,000	122,000	122,000	122,000
	Evaporation	-2,000	-2,000	-2,000	-2,000	-2,000	-2,000	-2,000	-2,000	-2,000
	Volume Released to Environment	-521,000	-528,000	-535,000	-542,000	-549,000	-556,000	-563,000	-570,000	-577,000
	Volume Conveyed to LWMP	-521,000	-528,000	-535,000	-542,000	-549,000	-556,000	-563,000	-570,000	-577,000
Overburden Stockpile Pond	Direct Precipitation	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000
	Runoff	203,000	203,000	203,000	203,000	203,000	203,000	203,000	203,000	203,000
	Ditch Leakage	136,000	136,000	136,000	136,000	136,000	136,000	136,000	136,000	136,000
	Evaporation	-6,000	-6,000	-6,000	-6,000	-6,000	-6,000	-6,000	-6,000	-6,000
	Volume Released to Environment	-174,000	-174,000	-174,000	-174,000	-174,000	-174,000	-174,000	-174,000	-174,000
	Volume Conveyed to LWMP	-174,000	-174,000	-174,000	-174,000	-174,000	-174,000	-174,000	-174,000	-174,000
Water Treatment Plant	Volume from Class A Pond	212,000	255,000	297,000	340,000	382,000	425,000	468,000	510,000	553,000
	Volume from Class B Pond	618,000	627,000	636,000	645,000	616,000	615,000	617,000	626,000	634,000
	Runoff from Mill Surfaces	123,000	123,000	123,000	117,000	123,000	123,000	107,000	86,000	65,000
	Treated Water to LWMP	-895,000	-947,000	-998,000	-1,044,000	-1,063,000	-1,105,000	-1,134,000	-1,164,000	-1,194,000
	Treated Water to Mill	-58,000	-58,000	-58,000	-58,000	-58,000	-58,000	-58,000	-58,000	-58,000
Upper Water Management Pond	Direct Precipitation	47,000	47,000	47,000	47,000	47,000	47,000	47,000	47,000	47,000
	Runoff	806,000	776,000	746,000	717,000	686,000	657,000	627,000	597,000	567,000
	Ditch Leakage	98,000	98,000	98,000	98,000	98,000	98,000	98,000	98,000	98,000
	Water from Open Pit	1,951,000	1,924,000	2,336,000	2,306,000	2,332,000	2,688,000	2,681,000	3,012,000	2,950,000
	Evaporation	-18,000	-18,000	-18,000	-18,000	-18,000	-18,000	-18,000	-18,000	-18,000
	Surplus Volume to LWMP	2,884,000	2,827,000	3,210,000	3,149,000	3,145,000	3,472,000	3,435,000	3,737,000	3,644,000
Lower Water Management Pond	Direct Precipitation	70,000	70,000	70,000	70,000	70,000	70,000	70,000	70,000	70,000
	Runoff	319,000	319,000	319,000	319,000	319,000	319,000	319,000	319,000	319,000
	Ditch Leakage	696,000	702,000	709,000	717,000	723,000	730,000	737,000	744,000	751,000
	Volume from Water Treatment Plant	895,000	947,000	998,000	1,044,000	1,063,000	1,105,000	1,134,000	1,164,000	1,194,000
	Volume from UWMP	2,884,000	2,827,000	3,210,000	3,149,000	3,145,000	3,472,000	3,435,000	3,737,000	3,644,000
	Evaporation	-27,000	-27,000	-27,000	-27,000	-27,000	-27,000	-27,000	-27,000	-27,000
	Dust Suppression	-46,000	-46,000	-46,000	-46,000	-46,000	-46,000	-46,000	-46,000	-46,000
	Volume Released to Environment	4,791,000	4,792,000	5,233,000	5,226,000	5,247,000	5,623,000	5,622,000	5,961,000	5,905,000

\\KPL\VA-Prj$\1\01\00640\05\A\Data\Updated Water Balance to Answer IR Round 2\WaterBalanceUpdate\GoldSim\Results\[KZK Results - Rev 4.xlsx]98th Percentile Results

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0	02NOV'17	ISSUED WITH LETTER VA17-01585	SCR	LG
REV	DATE	DESCRIPTION	PREP'D	RVW'D

Appendix R2-F

Modelled Runoff for Construction, Active Closure and Closure

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

Month	ABM Pit Dewatering Pumping Rate (L/s)	ABM Pit Dewatering Rate Pumping Volume (m^3)	South Diversions (m^3)	KZ-9 Baseline (m^3)	KZ-9 Discharge (m^3)	KZ-37 Discharge (m^3)	KZ-15 Discharge (m^3)	KZ-17 Discharge (m^3)	KZ-22 Discharge (m^3)	KZ-26 Discharge (m^3)	KZ-13 Discharge (m^3)
Column =>	A	B	C	D	E	F	G	H	I	J	K
Jul	17700	548700	150000	892737	1291437	1579730	3396966	2257226	8504123	9968852	561326
Aug	8500	263500	123000	733663	874163	1110785	2196256	924265	5053737	5819305	553005
Sep	7367	221022	135000	729504	815526	1050900	2053585	808867	4675232	5233208	548915
Oct	5525	171285	94000	458383	535668	683490	1309212	525010	3211441	3434768	352361
Nov	4142	124258	51000	320868	394126	497602	935607	400097	2329851	2490646	226685
Dec	3600	111600	34000	224608	302208	374641	681244	316193	1702346	1818119	153466
Jan	3600	111600	25000	157225	243825	294528	509151	260773	1256417	1339774	106237
Feb	3600	101700	20000	110058	191758	227250	377486	208846	923969	983985	75241
Mar	3600	111600	20000	77040	168640	193485	298650	184417	698033	741245	57564
Apr	3600	108000	23000	324136	409136	513688	1179884	454700	2239077	2572878	237864
May	3600	111600	247000	1205529	1070129	1458995	4050285	1306954	8068794	9633965	1030174
Jun	3600	108000	248000	1491214	1351214	1832251	4006983	1771645	9491911	12226166	863115
Jul	3600	111600	150000	892737	854337	1142630	2959866	1820126	8067023	9531752	561326
Aug	3600	111600	123000	733663	722263	958885	2044356	772365	4901837	5667405	553005
Sep	3600	108000	135000	729504	702504	937878	1940562	695844	4562209	5120185	548915
Oct	3600	111600	94000	458383	475983	623805	1249527	465325	3151756	3375083	352361
Nov	3600	108000	51000	320868	377868	481344	919349	383839	2313592	2474388	226685
Dec	3600	111600	34000	224608	302208	374641	681244	316193	1702346	1818119	153466

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

Month	ABM Pit Dewatering Pumping Rate (L/s)	ABM Pit Dewatering Rate Pumping Volume (m^3)	South Diversions (m^3)	KZ-9 Baseline (m^3)	KZ-9 Discharge (m^3)	KZ-37 Discharge (m^3)	KZ-15 Discharge (m^3)	KZ-17 Discharge (m^3)	KZ-22 Discharge (m^3)	KZ-26 Discharge (m^3)	KZ-13 Discharge (m^3)
Column =>	A	B	C	D	E	F	G	H	I	J	K
Jul	17700	548700	213000	2501517	2837217	3644146	6605548	3549855	19781507	27473431	1070116
Aug	8500	263500	174000	984816	1074316	1392039	3371753	1330243	6525520	7186504	846312
Sep	7367	221022	192000	1299943	1328966	1748315	3944891	1666433	9786581	10757378	850302
Oct	5525	171285	133000	458383	496668	657640	1641935	751107	4358102	5237226	415153
Nov	4142	124258	72000	320868	373126	485807	1055387	416976	2962576	3442283	263864
Dec	3600	111600	48000	224608	288208	367084	765790	329844	2159029	2504418	178467
Jan	3600	111600	35000	157225	233825	289039	568133	270958	1585309	1833989	123718
Feb	3600	101700	28000	110058	183758	222407	417773	215581	1159970	1339020	88328
Mar	3600	111600	28000	77040	160640	187695	324451	187173	865715	994630	69023
Apr	3600	108000	33000	440205	515205	661203	1628760	590588	3143357	3677930	337013
May	3600	111600	350000	1713836	1475436	2028263	5735514	1810793	11413387	13643431	1470668
Jun	3600	108000	352000	2336942	2092942	2847010	8998766	4087774	22063315	26429554	1506618
Jul	3600	111600	213000	2501517	2400117	3207046	6168448	3112755	19344407	27036331	1070116
Aug	3600	111600	174000	984816	922416	1240139	3219853	1178343	6373620	7034604	846312
Sep	3600	108000	192000	1299943	1215943	1635293	3831869	1553411	9673559	10644356	850302
Oct	3600	111600	133000	458383	436983	597955	1582250	691422	4298417	5177541	415153
Nov	3600	108000	72000	320868	356868	469549	1039129	400718	2946318	3426024	263864
Dec	3600	111600	48000	224608	288208	367084	765790	329844	2159029	2504418	178467

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

Month	ABM Pit Dewatering Pumping Rate (L/s)	ABM Pit Dewatering Rate Pumping Volume (m^3)	South Diversions (m^3)	KZ-9 Baseline (m^3)	KZ-9 Discharge (m^3)	KZ-37 Discharge (m^3)	KZ-15 Discharge (m^3)	KZ-17 Discharge (m^3)	KZ-22 Discharge (m^3)	KZ-26 Discharge (m^3)	KZ-13 Discharge (m^3)
Column =>	A	B	C	D	E	F	G	H	I	J	K
Jul	17700	548700	120000	561427	990127	1171257	2043231	1197745	4353481	4890758	423503
Aug	8500	263500	98000	528497	693997	864509	1564816	803373	3318870	3487414	396558
Sep	7367	221022	108000	501574	614597	776424	1404842	648736	2876746	2856044	405907
Oct	5525	171285	75000	458383	554668	656701	821814	394865	1753432	1512465	263184
Nov	4142	124258	41000	320868	404126	475549	591128	301222	1276404	1102908	168965
Dec	3600	111600	27000	224608	309208	359204	440109	243713	943665	818747	114016
Jan	3600	111600	20000	157225	248825	283823	340456	207753	710127	620186	79171
Feb	3600	101700	16000	110058	195758	220256	259899	170492	531039	466282	56236
Mar	3600	111600	16000	77040	172640	189789	217540	157498	416244	369619	43361
Apr	3600	108000	18000	268865	358865	439031	918061	371398	1663171	1866067	184595
May	3600	111600	197000	963478	878078	1188867	3248748	1067984	6477080	7725644	819462
Jun	3600	108000	198000	1153300	1063300	1435338	3049386	1202413	7080938	9039208	674370
Jul	3600	111600	120000	561427	553027	734157	1606131	760645	3916381	4453658	423503
Aug	3600	111600	98000	528497	542097	712609	1412916	651473	3166970	3335514	396558
Sep	3600	108000	108000	501574	501574	663402	1291819	535713	2763724	2743022	405907
Oct	3600	111600	75000	458383	494983	597016	762128	335180	1693747	1452780	263184
Nov	3600	108000	41000	320868	387868	459291	574870	284964	1260146	1086649	168965
Dec	3600	111600	27000	224608	309208	359204	440109	243713	943665	818747	114016

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

Month	North Diversions Div. (m^3)	Abm Lake Drawdown from South Creek (m^3)	Lower Water Management Pond (m^3)	KZ-9 Discharge (m^3)	KZ-37 Discharge (m^3)	KZ-17 Discharge (m^3)	KZ-15 Discharge (m^3)	KZ-22 Discharge (m^3)	KZ-26 Discharge (m^3)	KZ-13 Discharge (m^3)
Column =>	A	B	C	D	E	F	G	H	I	J
	Input	Input	Output	Output	Output	Output	Output	Output	Output	Output
Oct	89000	-27693	221,136	331,725	479,548	364,953	1,138,043	3,029,713	3,273,398	230,668
Nov	44000	-26799	173,095	232,207	335,683	266,416	796,630	2,181,394	2,356,847	148,886
Dec	30000	-27693	121,967	162,545	234,978	194,484	557,641	1,570,603	1,696,930	91,773
Jan	23000	-27693	83,377	113,782	164,485	141,973	390,349	1,130,834	1,221,789	53,544
Feb	17000	-25236	57,464	79,647	115,139	103,640	273,244	814,201	879,688	30,005
Mar	17000	-27693	35,125	55,753	80,598	75,657	191,271	586,225	633,376	9,871
Apr	38000	-26799	196,734	251,455	356,007	301,866	1,011,432	2,082,742	2,426,860	188,065
May	321000	-27693	546,965	930,023	1,318,889	1,178,031	3,866,623	7,932,534	9,530,525	755,481
Jun	334000	-26799	612,204	1,014,121	1,495,158	1,545,767	3,830,445	9,301,893	12,055,275	588,316
Jul	186000	-27693	372,645	603,663	891,957	1,513,566	2,762,079	7,649,872	9,201,542	383,633
Aug	156000	-27693	348,647	540,188	776,810	641,025	1,899,839	4,767,373	5,550,274	402,313
Sep	164000	-26799	326,709	526,712	762,086	590,156	1,817,864	4,442,325	5,023,241	387,116
Total	1419000	-326281	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

Month	North Diversions Div. (m^3)	Abm Lake Drawdown from South Creek (m^3)	Lower Water Management Pond (m^3)	KZ-9 Discharge (m^3)	KZ-37 Discharge (m^3)	KZ-17 Discharge (m^3)	KZ-15 Discharge (m^3)	KZ-22 Discharge (m^3)	KZ-26 Discharge (m^3)	KZ-13 Discharge (m^3)
Column =>	A	B	C	D	E	F	G	H	I	J
	Input	Input	Output	Output	Output	Output	Output	Output	Output	Output
Oct	126000	-27693	212,841	362,505	523,477	580,649	1,480,845	4,163,394	5,073,001	254,460
Nov	63000	-26799	174,189	253,753	366,434	299,622	927,346	2,829,708	3,316,644	165,065
Dec	41000	-27693	125,032	177,627	256,504	218,724	649,142	2,037,390	2,387,984	102,775
Jan	31000	-27693	85,222	124,339	179,553	159,669	454,400	1,466,921	1,719,348	61,025
Feb	25000	-25236	56,356	87,037	125,687	116,558	318,080	1,056,183	1,237,931	35,092
Mar	25000	-27693	31,949	60,926	87,981	85,087	222,656	760,452	891,310	13,331
Apr	55000	-26799	273,936	352,380	498,377	421,546	1,435,465	2,970,241	3,517,007	277,214
May	458000	-27693	777,934	1,324,240	1,877,067	1,673,912	5,518,636	11,267,509	13,543,511	1,092,976
Jun	475000	-26799	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	263000	-27693	1,246,834	1,618,040	2,424,968	2,621,324	5,790,897	18,771,854	26,448,554	829,423
Aug	221000	-27693	491,588	764,361	1,082,085	1,009,108	3,030,579	6,186,260	6,928,321	644,620
Sep	232000	-26799	632,365	926,603	1,345,952	1,334,482	3,616,444	9,410,243	10,406,222	631,502
Total	2015000		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

Month	North Diversions Div. (m^3)	Abm Lake Drawdown from South Creek (m^3)	Lower Water Management Pond (m^3)	KZ-9 Discharge (m^3)	KZ-37 Discharge (m^3)	KZ-17 Discharge (m^3)	KZ-15 Discharge (m^3)	KZ-22 Discharge (m^3)	KZ-26 Discharge (m^3)	KZ-13 Discharge (m^3)
Column =>	A	B	C	D	E	F	G	H	I	J
	Input	Input	Output	Output	Output	Output	Output	Output	Output	Output
Oct	71000	-27693	139,858	226,423	328,456	240,937	669,379	1,579,354	1,363,688	160,491
Nov	36000	-26799	111,600	158,496	229,919	175,884	468,565	1,137,135	981,855	101,166
Dec	24000	-27693	79,320	110,947	160,943	128,396	327,996	818,737	706,936	59,324
Jan	18000	-27693	54,324	77,663	112,660	93,729	229,597	589,491	508,994	31,478
Feb	14000	-25236	36,627	54,364	78,862	68,422	160,718	424,433	366,475	15,000
Mar	14000	-27693	21,439	38,055	55,204	49,948	112,502	305,592	263,862	-332
Apr	31000	-26799	148,804	192,731	272,897	229,385	764,835	1,517,803	1,730,127	139,795
May	257000	-27693	435,742	742,301	1,053,090	941,897	3,079,950	6,344,448	7,619,576	594,770
Jun	266000	-26799	464,161	782,667	1,154,705	1,054,065	2,899,600	6,921,310	8,896,618	449,570
Jul	148000	-27693	222,359	397,328	578,458	625,347	1,490,608	3,772,440	4,335,580	275,811
Aug	123000	-27693	227,129	375,717	546,230	517,790	1,291,687	3,023,332	3,220,754	270,866
Sep	130000	-26799	207,033	361,680	523,508	434,307	1,192,394	2,646,474	2,655,892	271,108
Total	1132000.00		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

Month	Abm Lake Drawdown from South Creek (m^3)	Lower Water Management Pond (m^3)	KZ-9 Discharge (m^3)	KZ-37 Discharge (m^3)	KZ-17 Discharge (m^3)	KZ-15 Discharge (m^3)	KZ-22 Discharge (m^3)	KZ-26 Discharge (m^3)	KZ-13 Discharge (m^3)
Column =>	A	B	C	D	E	F	G	H	I
	Input	Output	Output	Output	Output	Output	Output	Output	Output
Oct	-27693	310,136	331,725	479,548	364,953	1,138,043	3,029,713	3,273,398	230,668
Nov	-26799	217,095	232,207	335,683	266,416	796,630	2,181,394	2,356,847	148,886
Dec	-27693	151,967	162,545	234,978	194,484	557,641	1,570,603	1,696,930	91,773
Jan	-27693	106,377	113,782	164,485	141,973	390,349	1,130,834	1,221,789	53,544
Feb	-25236	74,464	79,647	115,139	103,640	273,244	814,201	879,688	30,005
Mar	-27693	52,125	55,753	80,598	75,657	191,271	586,225	633,376	9,871
Apr	-26799	234,734	251,455	356,007	301,866	1,011,432	2,082,742	2,426,860	188,065
May	-27693	867,965	930,023	1,318,889	1,178,031	3,866,623	7,932,534	9,530,525	755,481
Jun	-26799	946,204	1,014,121	1,495,158	1,545,767	3,830,445	9,301,893	12,055,275	588,316
Jul	-27693	558,645	603,663	891,957	1,513,566	2,762,079	7,649,872	9,201,542	383,633
Aug	-27693	504,647	540,188	776,810	641,025	1,899,839	4,767,373	5,550,274	402,313
Sep	-26799	490,709	526,712	762,086	590,156	1,817,864	4,442,325	5,023,241	387,116
Total	-326281	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

Month	Abm Lake Drawdown from South Creek (m^3)	Lower Water Management Pond (m^3)	KZ-9 Discharge (m^3)	KZ-37 Discharge (m^3)	KZ-17 Discharge (m^3)	KZ-15 Discharge (m^3)	KZ-22 Discharge (m^3)	KZ-26 Discharge (m^3)	KZ-13 Discharge (m^3)
Column =>	A	B	C	D	E	F	G	H	I
	Input	Output	Output	Output	Output	Output	Output	Output	Output
Oct	-27693	338,841	362,505	523,477	580,649	1,480,845	4,163,394	5,073,001	254,460
Nov	-26799	237,189	253,753	366,434	299,622	927,346	2,829,708	3,316,644	165,065
Dec	-27693	166,032	177,627	256,504	218,724	649,142	2,037,390	2,387,984	102,775
Jan	-27693	116,222	124,339	179,553	159,669	454,400	1,466,921	1,719,348	61,025
Feb	-25236	81,356	87,037	125,687	116,558	318,080	1,056,183	1,237,931	35,092
Mar	-27693	56,949	60,926	87,981	85,087	222,656	760,452	891,310	13,331
Apr	-26799	328,936	352,380	498,377	421,546	1,435,465	2,970,241	3,517,007	277,214
May	-27693	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	-26799	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	-27693	1,509,834	1,618,040	2,424,968	2,621,324	5,790,897	18,771,854	26,448,554	829,423
Aug	-27693	712,588	764,361	1,082,085	1,009,108	3,030,579	6,186,260	6,928,321	644,620
Sep	-26799	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

Month	Abm Lake Drawdown from South Creek (m^3)	Lower Water Management Pond (m^3)	KZ-9 Discharge (m^3)	KZ-37 Discharge (m^3)	KZ-17 Discharge (m^3)	KZ-15 Discharge (m^3)	KZ-22 Discharge (m^3)	KZ-26 Discharge (m^3)	KZ-13 Discharge (m^3)
Column =>	A	B	C	D	E	F	G	H	I
	Input	Output	Output	Output	Output	Output	Output	Output	Output
Oct	-27693	210,858	226,423	328,456	240,937	669,379	1,579,354	1,363,688	160,491
Nov	-26799	147,600	158,496	229,919	175,884	468,565	1,137,135	981,855	101,166
Dec	-27693	103,320	110,947	160,943	128,396	327,996	818,737	706,936	59,324
Jan	-27693	72,324	77,663	112,660	93,729	229,597	589,491	508,994	31,478
Feb	-25236	50,627	54,364	78,862	68,422	160,718	424,433	366,475	15,000
Mar	-27693	35,439	38,055	55,204	49,948	112,502	305,592	263,862	-332
Apr	-26799	179,804	192,731	272,897	229,385	764,835	1,517,803	1,730,127	139,795
May	-27693	692,742	742,301	1,053,090	941,897	3,079,950	6,344,448	7,619,576	594,770
Jun	-26799	730,161	782,667	1,154,705	1,054,065	2,899,600	6,921,310	8,896,618	449,570
Jul	-27693	370,359	397,328	578,458	625,347	1,490,608	3,772,440	4,335,580	275,811
Aug	-27693	350,129	375,717	546,230	517,790	1,291,687	3,023,332	3,220,754	270,866
Sep	-26799	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

Month	Abm Lake Drawdown from South Creek (m^3)	ABM Lake Discharge (m^3)	ABM Lake Groundwater to Geona Creek (m^3)	Lower Water Management Pond (m^3)	KZ-9 Discharge (m^3)	KZ-37 Discharge (m^3)	KZ-17 Discharge (m^3)	KZ-15 Discharge (m^3)	KZ-22 Discharge (m^3)	KZ-26 Discharge (m^3)	KZ-13 Discharge (m^3)
Column =>	A	B	C	D	E	F	G	H	I	J	K
Oct	-25,175	5,281	37,975	467,932	487,251	635,074	481,983	1,264,729	3,167,443	3,392,509	233,186
Nov	-24,363	0	36,750	334,023	347,547	451,023	357,021	891,781	2,286,165	2,448,212	151,322
Dec	-25,175	0	37,975	246,066	255,533	327,966	271,773	636,497	1,657,554	1,774,228	94,291
Jan	-25,175	0	37,975	183,639	190,265	240,969	208,647	456,940	1,204,072	1,288,077	56,062
Feb	-22,942	0	34,606	136,571	141,210	176,702	159,197	327,882	874,196	934,680	32,299
Mar	-25,175	0	37,975	109,350	112,597	137,442	128,926	243,268	642,480	686,028	12,389
Apr	-24,363	11,311	36,750	369,975	362,023	466,576	410,331	1,133,655	2,195,287	2,529,840	190,501
May	-25,175	32,549	37,975	1,261,143	1,238,215	1,627,081	1,483,891	4,220,692	8,248,623	9,815,942	757,999
Jun	-24,363	32,569	36,750	1,367,600	1,513,727	1,994,764	1,942,545	4,181,113	9,670,594	12,405,172	590,752
Jul	-25,175	3,160	37,975	813,947	905,852	1,194,145	1,862,310	3,013,960	8,120,778	9,587,829	386,151
Aug	-25,175	6,960	37,975	736,485	755,570	992,193	812,949	2,083,247	4,942,546	5,709,820	404,830
Sep	-24,363	17,074	36,750	728,123	760,430	995,804	762,141	2,004,691	4,628,437	5,188,392	389,552
Total	-296,620	108,904	447,431	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

Month	Abm Lake Drawdown from South Creek (m^3)	ABM Lake Discharge (m^3)	ABM Lake Groundwater to Geona Creek (m^3)	Lower Water Management Pond (m^3)	KZ-9 Discharge (m^3)	KZ-37 Discharge (m^3)	KZ-17 Discharge (m^3)	KZ-15 Discharge (m^3)	KZ-22 Discharge (m^3)	KZ-26 Discharge (m^3)	KZ-13 Discharge (m^3)
Column =>	A	B	C	D	E	F	G	H	I	J	K
Oct	-25,175	7,499	37,975	509,554	528,952	689,924	743,971	1,635,517	4,351,552	5,231,672	256,978
Nov	-24,363	0	36,750	361,606	375,184	487,865	394,138	1,031,367	2,937,811	3,418,465	167,501
Dec	-25,175	0	37,975	265,374	274,879	353,756	298,868	734,207	2,126,739	2,472,810	105,292
Jan	-25,175	0	37,975	197,154	203,808	259,021	228,427	525,337	1,541,885	1,791,056	63,543
Feb	-22,942	0	34,606	146,032	150,689	189,339	173,636	375,760	1,117,422	1,296,825	37,386
Mar	-25,175	0	37,975	115,973	119,233	146,288	139,467	276,782	817,602	946,772	15,848
Apr	-24,363	16,616	36,750	504,484	491,782	637,780	558,592	1,593,942	3,111,963	3,647,464	279,650
May	-25,175	68,098	37,975	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	-24,363	71,657	36,750	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	-25,175	21,092	37,975	2,130,488	2,482,069	3,288,997	3,208,627	6,275,714	19,443,025	27,130,277	831,941
Aug	-25,175	22,798	37,975	1,039,311	1,014,678	1,332,402	1,276,581	3,315,175	6,476,323	7,140,381	647,137
Sep	-24,363	31,625	36,750	1,254,615	1,327,517	1,746,866	1,672,878	3,951,016	9,794,899	10,770,433	633,939
Total	-296,620	239,385	447,431	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

Month	Abm Lake Drawdown from South Creek (m^3)	ABM Lake Discharge (m^3)	ABM Lake Groundwater to Geona Creek (m^3)	Lower Water Management Pond (m^3)	KZ-9 Discharge (m^3)	KZ-37 Discharge (m^3)	KZ-17 Discharge (m^3)	KZ-15 Discharge (m^3)	KZ-22 Discharge (m^3)	KZ-26 Discharge (m^3)	KZ-13 Discharge (m^3)
Column =>	A	B	C	D	E	F	G	H	I	J	K
	Input	Output	Output	Output	Output	Output	Output	Output	Output	Output	Output
Oct	-25,175	4,225	37,975	332,067	348,492	450,525	334,779	761,572	1,694,076	1,454,908	163,009
Nov	-24,363	0	36,750	239,657	251,154	322,578	250,333	540,311	1,226,101	1,053,900	103,602
Dec	-25,175	0	37,975	180,010	188,058	238,054	193,891	390,467	894,307	770,323	61,841
Jan	-25,175	0	37,975	137,399	143,033	178,031	151,793	284,720	654,534	565,266	33,996
Feb	-22,942	0	34,606	104,203	108,147	132,645	117,694	207,328	478,529	414,255	17,294
Mar	-25,175	0	37,975	86,693	89,454	106,602	98,629	158,880	357,599	311,322	2,186
Apr	-24,363	8,785	36,750	292,270	286,245	366,411	321,278	866,570	1,613,702	1,817,249	142,232
May	-25,175	15,621	37,975	1,003,892	986,833	1,297,622	1,183,799	3,359,452	6,595,203	7,845,493	597,287
Jun	-24,363	13,955	36,750	1,052,678	1,167,806	1,539,844	1,317,144	3,163,452	7,198,835	9,157,536	452,007
Jul	-25,175	-5,379	37,975	541,257	576,401	757,531	786,185	1,633,427	3,944,894	4,483,716	278,328
Aug	-25,175	-582	37,975	518,388	549,302	719,814	662,447	1,424,836	3,180,734	3,351,165	273,383
Sep	-24,363	10,145	36,750	509,920	532,726	694,554	571,842	1,327,753	2,801,829	2,783,193	273,544
Total	-296,620	46,770	447,431	4,998,434	5,227,650	6,804,211	5,989,813	14,118,767	30,640,344	34,008,326	2,398,708

Appendix R2-G

Evaluation of Groundwater Model Sensitivity to Bedrock Hydraulic Conductivity

October 27, 2017

ISSUED FOR USE
FILE: ENW.WENW03070-01
Via Email: [Name Redacted]

BMC Minerals (No. 1) Ltd
530-1130 West Pender Street
Vancouver, BC Canada
V6E 4A4

Attention: [Name Redacted]

Subject: Evaluation of Groundwater Model Sensitivity to Bedrock Hydraulic Conductivity, Kudz Ze Kayah Project, Yukon

This 'Issued for Review' document is provided solely for the purpose of client review and presents our interim findings and recommendations to date. Our usable findings and recommendations are provided only through an 'Issued for Use' document, which will be issued subsequent to this review. Final design should not be undertaken based on the interim recommendations made herein. Once our report is issued for use, the 'Issued for Review' document should be either returned to Tetra Tech Canada Inc. (Tetra Tech) or destroyed.

1.0 INTRODUCTION

Following review of the Project proposal for the Kudz Ze Kayah (KZK) Project submitted by BMC Minerals (No.1) Ltd. (BMC), the Yukon Environmental and Socio-economic Assessment Board (YESAB) provided comments regarding groundwater conditions, identifying that the information provided was insufficient.

In response to BMC's comments on R142, YESAB provided response IR2-68:

YESAB ISSUE

The Proponent has not conducted sensitivity analysis to capture those uncertainties associated with fault zone hydraulic properties. Faults may act as a barrier to groundwater flow, or as a conduit. Further analysis of the conductivity of the fault zones is required using the available site data."

"***Insufficient response:*** *The Proponent did not adequately address the uncertainties associated with the potential impacts of the major geological faults on groundwater-surface water interaction resulting from the project activities.*

Conduct a formal sensitivity analysis to address the uncertainties resulting from the potential impacts of the major faults on the water quality and quantity in the project area.

Conduct a sensitivity analyses for the predictive hydrogeological model in order to assess potential impacts on quantity and quality of groundwater inflow to the pit and its impact on surface hydrology. The analysis should address uncertainties associated with fault zone hydraulic properties."

To satisfy the comments from YESAB, Tetra Tech has performed a formal sensitivity analysis using the previously developed groundwater flow model with focus on a set of hydrogeologic zones that represent the fault zones that intercept the pit and the surrounding bedrock.

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Tel 867.668.3068 Fax 867.668.4349

2.0 METHODOLOGY AND SIMULATION RESULTS

The groundwater model developed in 2016 for the KZK Property and surrounding area was used to evaluate the sensitivity of pit dewatering inflows, post-mining pit-lake formation and long-term streamflow from ABM Lake (*Hydrogeological Model, Kudz Ze Kayah Project, Yukon*, Tetra Tech, 2016) to variation of hydraulic conductivity. Generally, this model consists of seven numerical layers whose thicknesses increase progressively with depth. In the vicinity of the proposed open pit, model layers 1 and 2 are used to represent the overburden sediments, layers 3 and 4 represent the upper 20-40 meters of fractured or weathered shallow bedrock and model layers 5 through 7 represent the deeper, unweathered and competent bedrock. Numeric zones were assigned to these layers on the basis of geology for the purposes of subsequent evaluation of flux distribution within a model layer. Three linear fault features were also implemented into the numerical model structure, corresponding to the East Fault, the Northwest Fault, and the lineation of Fault Creek.

During performance of the sensitivity analysis documented in this report, it was discovered that the parameterization listed in Tetra Tech (2016) was erroneous. We have therefore used the corrected input parameters as the base case for the sensitivity analysis. It is important to note that the model output, i.e., the inferred inflow rates to the open pit and underground workings, presented in Tetra Tech (2016) were correct and will not change.

2.1 Implementation of Sensitivity Analysis

Tetra Tech performed a sensitivity analysis focusing on a set of hydrogeologic zones that represent the fault zones that intercept the pit and the surrounding bedrock. As the sensitivity analysis is the result of a direct request from YESAB to evaluate the bedrock fault properties and the associated uncertainty, the hydraulic-conductivity parameters for the overburden material were not included as part of this effort.

These model zones included:

Horizontal hydraulic conductivity

- the combined zone representing the faults intercepting the pit (Model zones 8, 11 and 12)
- the weathered pit bedrock zone (zone 13)
- the unweathered pit bedrock zone (zone 7)

Vertical hydraulic conductivity

- the combined zone representing the faults intercepting the pit (Model zones 8, 11 and 12)
- the weathered pit bedrock zone (zone 13)
- the unweathered pit bedrock zone (zone 7)

Sensitivity analysis was performed by varying each of these parameters based on conventional sensitivity analysis methods in which a model value is varied by a consistent factor higher and lower than the base case scenario and the resulting changes to simulation results evaluated. For the purposes of this analysis, the weathered and unweathered bedrock parameters were believed to be reasonably well constrained based on the number of aquifer test results and the model calibration process. These parameters were therefore doubled and halved and the resulting changes recorded. In each case, variation of a parameter was performed in an isolated sense, rather than in combination with the variation of other parameters.

In the case of the fault zones, sensitivity analysis was performed by varying each of the hydraulic-conductivity parameters (Kx and Kz) to values judged to be representative of the upper and lower bounds. The upper-bound hydraulic conductivity was based on the high value from the range of data observed in the packer testing results (7.50E-06 m/s, measured in borehole K16-371). This upper bound, which is 3.75 or 32.4 times higher than the base case horizontal and vertical hydraulic conductivities, respectively, is judged to be conservative because the implementation of each of the faults in the model involves 2 to 3 cells to retain diagonal hydraulic connection, with each cell 50 meters wide. Since the fault zones have been judged to be 1-5 meters wide in the field, the implementation of the faults in the model is artificially wider than in reality. The lower bound was assigned based on the lowest observed measurement of hydraulic conductivity observed during packer testing of faulted or unfaulted bedrock (results (3.50E-09 m/s, measured in ABM6), thus evaluating the possibility that the faults behave as gouge-filled hydraulic barriers to flow. This lower bound is more than 570 or 66 times lower than the base case horizontal and vertical hydraulic conductivities, respectively. Insufficient data are available to justify separating the zones for each of the faults to evaluate separately. Table 1 shows the base case parameterization as well as the variation in the parameters implemented in the sensitivity analysis.

Table 1. Parameterization for Sensitivity Analysis

Simulation	Parameter	Base Case K (m/s)	Kx (m/s)	Kz (m/s)
Run 1	Zone 7. Unweathered Pit Bedrock (Kx High)	2.40E-08	4.80E-08	-
Run 2	Zone 7. Unweathered Pit Bedrock (Kx Low)	2.40E-08	1.20E-08	-
Run 3	Zone 7. Unweathered Pit Bedrock (Kz High)	4.81E-08	-	9.63E-08
Run 4	Zone 7. Unweathered Pit Bedrock (Kz Low)	4.81E-08	-	2.41E-08
Run 5	Zones 8, 11, 12. Fault Zones (Kx High)	2.00E-06	7.50E-06	-
Run 6	Zones 8, 11, 12. Fault Zones (Kx Low)	2.00E-06	3.50E-09	-
Run 7	Zones 8, 11, 12. Fault Zones (Kz High)	2.31E-07	-	7.50E-06
Run 8	Zones 8, 11, 12. Fault Zones (Kz Low)	2.31E-07	-	3.50E-09
Run 9	Zone 13. Weathered Pit Bedrock (Kx High)	3.63E-07	7.25E-07	-
Run 10	Zone 13. Weathered Pit Bedrock (Kx Low)	3.63E-07	1.81E-07	-
Run 11	Zone 13. Weathered Pit Bedrock (Kz High)	1.51E-07	-	3.01E-07
Run 12	Zone 13. Weathered Pit Bedrock (Kz Low)	1.51E-07	-	7.54E-08

Results

Evaluation of the impact of each of the individual parameterization changes was performed by reporting the dewatering flux rates for each of the mining years, the rate of inflow associated with ABM Lake formation and the ABM Lake overflow contributions to the Geona Creek watershed, as well as the timing for the lake stage change.

Base Case Simulation

The base case conditions for the model are provided for comparison to the subsequent sensitivity runs. These results represent the model-predicted output for dewatering and post-mining filling of ABM Lake. The base case dewatering conditions are identical to the model results presented in the project proposal (*Kudz Ze Kayah Project. Project Proposal for YESAB Executive Committee Screening.* BMC, 2017). Table 2a shows the dewatering flux rates associated with the calibrated model (base case conditions). Table 2b presents the annual dewatering flux rates by hydrogeologic model zone. Table 2c contains the simulated base case details for the formation of ABM Lake including the groundwater and surface water fluxes into the lake, and eventual lake overflow into Geona Creek which occurs after 14.5 years.

Table 2a. Base Case Dewatering Flux Rates (m^3/d) [USgpm]

	Annual Mean	Week 2	Final Month
Pre-Mining	7,642 [1,402] (6-month mean)	13,955 [2,560]	4,161 [763]
Year 1	3,617 [664]	4,116 [755]	3,320 [609]
Year 2	3,504 [643]	3,794 [696]	3,386 [621]
Year 3	4,596 [843]	5,890 [1,081]	4,198 [770]
Year 4	4,458 [818]	4,740 [869]	4,315 [792]
Year 5	4,503 [826]	4,659 [855]	4,429 [812]
Year 6	5,445 [999]	6,308 [1,157]	5,190 [952]
Year 7	5,381 [987]	5,652 [1,037]	5,281 [969]
Year 8	6,230 [1,143]	7,012 [1,286]	5,998 [1,100]
Year 9	6,047 [1,109]	6,205 [1,138]	5,982 [1,097]

Table 2b. Annual Dewatering Rates by Zone (m^3/d) [USgpm]

	Storage	Overburden	Pit Fault Zone	Pit Bedrock	Workings Fault Zone	Workings Bedrock
Pre-mining	78.2%	7078 [1298]	0 [0]	564 [103]	0 [0]	0 [0]
Year 1	18.1%	3013 [553]	0 [0]	604 [111]	0 [0]	0 [0]
Year 2	7.6%	2487 [456]	200 [37]	817 [150]	0 [0]	0 [0]
Year 3	16.4%	839 [154]	436 [80]	818 [150]	0 [0]	2503 [459]
Year 4	4.8%	543 [100]	744 [136]	794 [146]	0 [0]	2376 [436]
Year 5	2.7%	562 [103]	516 [95]	757 [139]	0 [0]	2663 [489]
Year 6	5.8%	464 [85]	474 [87]	683 [125]	1424 [261]	2399 [440]
Year 7	2.1%	414 [76]	635 [116]	707 [130]	1203 [221]	2422 [444]
Year 8	3.5%	325 [60]	541 [99]	664 [122]	2599 [477]	2100 [385]
Year 9	0.8%	293 [54]	510 [94]	627 [115]	2809 [515]	1808 [332]

Table 2c: ABM Lake Formation and Water Budget (m^3/d)

Years after Mine Closure	Precipitation (m3/d)	Evaporation (m3/d)	Streams		Groundwater		ABM Lake	ABM Lake	Pit
			Inflow (m3/d)	Outflow (m3/d)	Inflow (m3/d)	Outflow (m3/d)	Stage (m)	Volume (m3)	Lake Area (m2)
0	1,122	2	3,073	0	16,204	0	1,224	5,203	1,727
1	1,122	106	3,073	0	3,803	0	1,272	2,493,730	116,860
2	1,122	157	3,074	0	3,813	0	1,290	4,958,104	173,170
3	1,122	192	3,074	0	3,809	0	1,303	7,406,174	212,510
4	1,122	225	3,075	0	3,786	0	1,314	9,833,970	249,320
5	1,122	255	3,077	0	3,762	0	1,323	12,244,410	282,520
6	1,122	284	3,080	0	3,734	0	1,331	14,638,060	314,630
7	1,122	310	3,082	0	3,714	0	1,338	17,011,710	343,110
8	1,122	336	3,085	0	3,687	0	1,345	19,368,090	371,380
9	1,122	359	3,089	0	3,656	0	1,352	21,705,390	397,580
10	1,122	379	3,093	0	3,635	0	1,357	24,028,260	419,750
15	1,122	467	3,646	6,973	1,799	45	1,380	34,351,620	516,760
16	1,122	467	3,646	6,139	1,793	41	1,380	34,362,850	516,870
17	1,122	467	3,646	6,061	1,792	41	1,380	34,363,900	516,880
20	1,122	467	3,646	6,058	1,796	41	1,380	34,364,090	516,880
25	1,122	467	3,646	6,061	1,800	40	1,380	34,364,140	516,880
30	1,122	467	3,646	6,062	1,801	40	1,380	34,364,160	516,880
40	1,122	467	3,646	6,063	1,802	40	1,380	34,364,180	516,880
50	1,122	467	3,646	6,063	1,802	40	1,380	34,364,180	516,880

The results for each of the sensitivity runs are presented in tabular format below.

Sensitivity Run #1

In this simulation, the horizontal hydraulic conductivity for the unfractured, unweathered bedrock in the area of the ABM deposit is doubled. Table 3a shows the dewatering flux, Table 3b presents the annual dewatering flux rates by hydrogeologic model zone, and Table 3c contains the simulated details for the formation of ABM Lake including the groundwater and surface water fluxes into the lake, and eventual lake overflow into Geona Creek. As expected, dewatering flux rates increase, ABM Lake fills more quickly, reaching overflow after 14.2 years and eventually discharges at a slightly higher rate (2%) than under base case conditions.

Table 3a. Run 1 Dewatering Flux Rates (m^3/d) [USgpm]

	Annual Mean	Week 2	Final Month
Pre-Mining	7782 [1428]	14103 [2587]	4291 [787]
Year 1	3751 [688]	4271 [784]	3449 [633]
Year 2	3666 [672]	3990 [732]	3541 [650]
Year 3	4866 [893]	6254 [1147]	4449 [816]
Year 4	4717 [865]	5009 [919]	4571 [839]
Year 5	4766 [874]	4943 [907]	4683 [859]
Year 6	5943 [1090]	6967 [1278]	5651 [1037]
Year 7	5905 [1083]	6248 [1146]	5787 [1062]
Year 8	6653 [1220]	7417 [1361]	6425 [1179]
Year 9	6486 [1190]	6662 [1222]	6416 [1177]

Table 3b. Run 1 Annual Dewatering Rates by Zone (m^3/d) [USgpm]

	Storage	Overburden	Pit Fault Zone	Pit Bedrock	Workings Fault Zone	Workings Bedrock
Pre-mining	77.1%	7205 [1322]	0 [0]	577 [106]	0 [0]	0 [0]
Year 1	17.9%	3092 [567]	0 [0]	659 [121]	0 [0]	0 [0]
Year 2	7.8%	2517 [462]	194 [36]	955 [175]	0 [0]	0 [0]
Year 3	16.1%	818 [150]	424 [78]	915 [168]	0 [0]	2710 [497]
Year 4	4.6%	521 [96]	742 [136]	918 [168]	0 [0]	2536 [465]
Year 5	2.6%	534 [98]	518 [95]	879 [161]	0 [0]	2836 [520]
Year 6	5.9%	426 [78]	435 [80]	721 [132]	1526 [280]	2835 [520]
Year 7	2.3%	363 [67]	604 [111]	763 [140]	1235 [227]	2939 [539]
Year 8	3.1%	284 [52]	503 [92]	685 [126]	2614 [479]	2567 [471]
Year 9	0.8%	253 [46]	465 [85]	635 [117]	2811 [516]	2322 [426]

Table 3c: Run 1 ABM Lake Formation and Water Budget (m^3/d)

Years after Mine Closure	Precipitation (m^3/d)	Evaporation (m^3/d)	Streams		Groundwater		ABM Lake	ABM Lake	Pit
			Inflow (m^3/d)	Outflow (m^3/d)	Inflow (m^3/d)	Outflow (m^3/d)	Stage (m)	Volume (m^3)	Lake Area (m^2)
0	1,122	2	3,073	0	17,378	0	1,224	6,075	1,778
1	1,122	107	3,073	0	3,974	0	1,273	2,553,829	118,240
2	1,122	158	3,073	0	3,980	0	1,291	5,078,555	175,110
3	1,122	195	3,074	0	3,976	0	1,303	7,587,278	215,420
4	1,122	228	3,074	0	3,953	0	1,315	10,074,530	252,630
5	1,122	259	3,076	0	3,926	0	1,324	12,543,660	286,650
6	1,122	288	3,078	0	3,896	0	1,332	14,994,720	318,910
7	1,122	315	3,081	0	3,870	0	1,340	17,424,310	348,060
8	1,122	341	3,085	0	3,837	0	1,347	19,834,040	376,970
9	1,122	364	3,088	0	3,806	0	1,353	22,223,520	402,530
10	1,122	384	3,092	0	3,779	0	1,359	24,597,360	425,190
15	1,122	467	3,647	6,662	1,943	43	1,380	34,360,280	516,840
16	1,122	467	3,646	6,235	1,929	41	1,380	34,365,680	516,900
17	1,122	467	3,646	6,192	1,926	41	1,380	34,366,200	516,900
20	1,122	467	3,646	6,191	1,929	41	1,380	34,366,310	516,900
25	1,122	467	3,646	6,194	1,932	41	1,380	34,366,360	516,900
30	1,122	467	3,646	6,195	1,933	41	1,380	34,366,380	516,900
40	1,122	467	3,646	6,196	1,934	41	1,380	34,366,400	516,900
50	1,122	467	3,646	6,196	1,934	41	1,380	34,366,400	516,900

Sensitivity Run #2

In this simulation, the horizontal hydraulic conductivity for the unfractured, unweathered bedrock in the area of the ABM deposit is reduced by half. Table 4a shows the dewatering flux, Table 4b presents the annual dewatering flux rates by hydrogeologic model zone, and Table 4c contains the simulated details for the formation of ABM Lake including the groundwater and surface water fluxes into the lake, and eventual lake overflow into Geona Creek. Relative to base case conditions, dewatering flux rates decrease and ABM Lake fills more slowly, overflowing at a 2% reduced rate relative to baseline conditions approximately 1 month before the beginning of year 15.

Table 4a. Run 2 Dewatering Flux Rates (m^3/d) [USgpm]

	Annual Mean	Week 2	Final Month
Pre-Mining	7511 [1378]	13811 [2534]	4044 [742]
Year 1	3500 [642]	3984 [731]	3210 [589]
Year 2	3374 [619]	3646 [669]	3260 [598]
Year 3	4392 [806]	5619 [1031]	4011 [736]
Year 4	4261 [782]	4533 [832]	4119 [756]
Year 5	4304 [790]	4439 [814]	4224 [775]
Year 6	5071 [930]	5823 [1068]	4841 [888]
Year 7	4973 [912]	5187 [952]	4885 [896]
Year 8	5916 [1085]	6742 [1237]	5678 [1042]
Year 9	5719 [1049]	5865 [1076]	5656 [1038]

Table 4b. Run 2 Annual Dewatering Rates by Zone (m^3/d) [USgpm]

	Storage	Overburden	Pit Fault Zone	Pit Bedrock	Workings Fault Zone	Workings Bedrock
Pre-mining	79.0%	6960 [1277]	0 [0]	551 [101]	0 [0]	0 [0]
Year 1	18.3%	2941 [539]	0 [0]	559 [103]	0 [0]	0 [0]
Year 2	7.5%	2448 [449]	198 [36]	728 [134]	0 [0]	0 [0]
Year 3	16.4%	853 [156]	434 [80]	750 [137]	0 [0]	2356 [432]
Year 4	4.8%	561 [103]	731 [134]	712 [131]	0 [0]	2258 [414]
Year 5	2.8%	585 [107]	508 [93]	678 [124]	0 [0]	2533 [465]
Year 6	5.5%	494 [91]	488 [89]	663 [122]	1322 [242]	2104 [386]
Year 7	1.9%	455 [84]	637 [117]	676 [124]	1147 [210]	2058 [378]
Year 8	3.8%	361 [66]	548 [101]	656 [120]	2580 [473]	1771 [325]
Year 9	0.8%	327 [60]	516 [95]	627 [115]	2798 [513]	1451 [266]

Table 4c: Run 2 ABM Lake Formation and Water Budget (m^3/d)

Years after Mine Closure	Precipitation (m^3/d)	Evaporation (m^3/d)	Streams		Groundwater		ABM Lake	ABM Lake	Pit
			Inflow (m^3/d)	Outflow (m^3/d)	Inflow (m^3/d)	Outflow (m^3/d)	Stage (m)	Volume (m^3)	Lake Area (m^2)
0	1,122	2	3,073	0	15,540	0	1,224	4,421	1,680
1	1,122	104	3,073	0	3,644	0	1,272	2,438,210	115,590
2	1,122	154	3,074	0	3,658	0	1,289	4,846,268	170,860
3	1,122	190	3,074	0	3,656	0	1,302	7,238,346	209,810
4	1,122	223	3,076	0	3,634	0	1,313	9,611,888	246,260
5	1,122	252	3,078	0	3,615	0	1,322	11,969,310	278,740
6	1,122	281	3,080	0	3,592	0	1,330	14,311,840	310,710
7	1,122	306	3,083	0	3,575	0	1,337	16,635,400	338,590
8	1,122	331	3,085	0	3,551	0	1,344	18,943,530	366,290
9	1,122	355	3,089	0	3,524	0	1,351	21,234,200	393,080
10	1,122	375	3,093	0	3,507	0	1,356	23,510,960	414,820
15	1,122	467	3,646	4,103	1,672	41	1,380	34,384,150	517,070
16	1,122	467	3,646	5,798	1,670	40	1,380	34,363,780	516,880
17	1,122	467	3,646	5,920	1,672	41	1,380	34,362,180	516,860
20	1,122	467	3,646	5,939	1,678	40	1,380	34,362,100	516,860
25	1,122	467	3,646	5,943	1,682	40	1,380	34,362,160	516,860
30	1,122	467	3,646	5,944	1,683	40	1,380	34,362,190	516,860
40	1,122	467	3,646	5,945	1,684	40	1,380	34,362,200	516,860
50	1,122	467	3,646	5,945	1,684	40	1,380	34,362,200	516,860

Sensitivity Run #3

In this simulation, the vertical hydraulic conductivity for the unfractured, unweathered bedrock in the area of the ABM deposit is doubled. Table 5a shows the dewatering flux, Table 5b presents the annual dewatering flux rates by hydrogeologic model zone, and Table 5c contains the simulated details for the formation of ABM Lake including the groundwater and surface water fluxes into the lake, and eventual lake overflow into Geona Creek. Relative to base case conditions, dewatering flux rates and ABM-Lake filling rates are almost unchanged (<2% lower).

Table 5a. Run 3 Dewatering Flux Rates (m^3/d) [USgpm]

	Annual Mean	Week 2	Final Month
Pre-Mining	7772 [1426]	14116 [2590]	4268 [783]
Year 1	3703 [679]	4239 [778]	3403 [624]
Year 2	3587 [658]	3901 [716]	3464 [636]
Year 3	4679 [858]	6082 [1116]	4259 [781]
Year 4	4533 [832]	4829 [886]	4384 [804]
Year 5	4578 [840]	4742 [870]	4498 [825]
Year 6	5462 [1002]	6342 [1163]	5209 [956]
Year 7	5408 [992]	5684 [1043]	5312 [974]
Year 8	6283 [1153]	7131 [1308]	6042 [1108]
Year 9	6099 [1119]	6254 [1147]	6038 [1108]

Table 5b. Run 3 Annual Dewatering Rates by Zone (m^3/d) [USgpm]

	Storage	Overburden	Pit Fault Zone	Pit Bedrock	Workings Fault Zone	Workings Bedrock
Pre-mining	77.2%	7198 [1320]	0 [0]	574 [105]	0 [0]	0 [0]
Year 1	17.9%	3073 [564]	0 [0]	630 [116]	0 [0]	0 [0]
Year 2	7.4%	2535 [465]	182 [33]	871 [160]	0 [0]	0 [0]
Year 3	16.1%	819 [150]	412 [76]	874 [160]	0 [0]	2575 [472]
Year 4	4.7%	525 [96]	715 [131]	853 [157]	0 [0]	2439 [447]
Year 5	2.6%	537 [99]	483 [89]	824 [151]	0 [0]	2734 [502]
Year 6	5.6%	437 [80]	449 [82]	720 [132]	1422 [261]	2434 [446]
Year 7	2.1%	382 [70]	608 [112]	741 [136]	1211 [222]	2466 [452]
Year 8	3.6%	262 [48]	520 [95]	688 [126]	2644 [485]	2169 [398]
Year 9	0.8%	221 [40]	492 [90]	650 [119]	2867 [526]	1869 [343]

Table 5c: Run 3 ABM Lake Formation and Water Budget (m^3/d)

Years after Mine Closure	Precipitation (m^3/d)	Evaporation (m^3/d)	Streams		Groundwater		ABM Lake	ABM Lake	Pit
			Inflow (m^3/d)	Outflow (m^3/d)	Inflow (m^3/d)	Outflow (m^3/d)	Stage (m)	Volume (m^3)	Lake Area (m^2)
0	1,122	2	3,073	0	15,801	0	1,224	6,442	1,800
1	1,122	106	3,073	0	3,860	0	1,272	2,522,503	117,520
2	1,122	157	3,073	0	3,856	0	1,290	5,003,916	173,910
3	1,122	193	3,074	0	3,849	0	1,303	7,466,824	213,480
4	1,122	226	3,074	0	3,822	0	1,314	9,907,258	250,330
5	1,122	256	3,075	0	3,795	0	1,323	12,329,340	283,690
6	1,122	285	3,078	0	3,763	0	1,332	14,733,350	315,770
7	1,122	311	3,081	0	3,741	0	1,339	17,116,370	344,360
8	1,122	337	3,084	0	3,713	0	1,346	19,481,210	372,740
9	1,122	360	3,087	0	3,682	0	1,352	21,826,800	398,740
10	1,122	381	3,090	0	3,661	0	1,358	24,157,740	420,990
15	1,122	467	3,646	5,588	1,832	40	1,380	34,371,540	516,950
16	1,122	467	3,646	6,028	1,817	41	1,380	34,365,090	516,890
17	1,122	467	3,646	6,072	1,815	41	1,380	34,364,470	516,880
20	1,122	467	3,646	6,080	1,819	41	1,380	34,364,470	516,880
25	1,122	467	3,646	6,083	1,822	41	1,380	34,364,520	516,880
30	1,122	467	3,646	6,085	1,823	40	1,380	34,364,540	516,880
40	1,122	467	3,646	6,085	1,824	40	1,380	34,364,550	516,880
50	1,122	467	3,646	6,085	1,824	40	1,380	34,364,550	516,880

Sensitivity Run #4

In this simulation, the vertical hydraulic conductivity for the unfractured, unweathered bedrock in the area of the ABM deposit is reduced by half. Table 6a shows the dewatering flux, Table 6b presents the annual dewatering flux rates by hydrogeologic model zone, and Table 6c contains the simulated details for the formation of ABM Lake including the groundwater and surface water fluxes into the lake, and eventual lake overflow into Geona Creek. Relative to base case conditions, dewatering flux rates decrease slightly (<1% lower) and ABM Lake filling rates are almost unchanged (<1% lower), overflowing one month later than under base case conditions.

Table 6a. Run 4 Dewatering Flux Rates (m^3/d) [USgpm]

	Annual Mean	Week 2	Final Month
Pre-Mining	7540 [1383]	13828 [2537]	4075 [747]
Year 1	3542 [650]	4016 [737]	3251 [596]
Year 2	3434 [630]	3713 [681]	3321 [609]
Year 3	4519 [829]	5752 [1055]	4140 [760]
Year 4	4397 [807]	4674 [857]	4255 [781]
Year 5	4436 [814]	4597 [843]	4354 [799]
Year 6	5419 [994]	6294 [1155]	5169 [948]
Year 7	5355 [982]	5629 [1033]	5254 [964]
Year 8	6173 [1132]	6924 [1270]	5953 [1092]
Year 9	5996 [1100]	6155 [1129]	5929 [1088]

Table 6b. Run 4 Annual Dewatering Rates by Zone (m^3/d) [USgpm]

	Storage	Overburden	Pit Fault Zone	Pit Bedrock	Workings Fault Zone	Workings Bedrock
Pre-mining	78.9%	6986 [1282]	0 [0]	554 [102]	0 [0]	0 [0]
Year 1	18.3%	2969 [545]	0 [0]	573 [105]	0 [0]	0 [0]
Year 2	7.8%	2452 [450]	214 [39]	767 [141]	0 [0]	0 [0]
Year 3	16.3%	859 [158]	453 [83]	767 [141]	0 [0]	2440 [448]
Year 4	5.0%	564 [103]	761 [140]	756 [139]	0 [0]	2316 [425]
Year 5	2.9%	588 [108]	538 [99]	715 [131]	0 [0]	2595 [476]
Year 6	6.0%	493 [90]	483 [89]	673 [123]	1418 [260]	2352 [431]
Year 7	2.2%	445 [82]	641 [118]	703 [129]	1192 [219]	2374 [436]
Year 8	3.4%	377 [69]	548 [101]	670 [123]	2555 [469]	2023 [371]
Year 9	0.8%	350 [64]	515 [94]	637 [117]	2758 [506]	1737 [319]

Table 6c: Run 4 ABM Lake Formation and Water Budget (m^3/d)

Years after Mine Closure	Precipitation (m^3/d)	Evaporation (m^3/d)	Streams		Groundwater		ABM Lake	ABM Lake	Pit
			Inflow (m^3/d)	Outflow (m^3/d)	Inflow (m^3/d)	Outflow (m^3/d)	Stage (m)	Volume (m^3)	Lake Area (m^2)
0	1,122	2	3,073	0	16,639	0	1,224	4,238	1,670
1	1,122	105	3,073	0	3,755	0	1,272	2,474,338	116,420
2	1,122	156	3,074	0	3,772	0	1,290	4,923,253	172,610
3	1,122	191	3,074	0	3,773	0	1,302	7,357,660	211,730
4	1,122	225	3,076	0	3,751	0	1,313	9,773,400	248,480
5	1,122	255	3,079	0	3,730	0	1,323	12,172,490	281,530
6	1,122	284	3,081	0	3,705	0	1,331	14,555,630	313,640
7	1,122	309	3,084	0	3,687	0	1,338	16,919,680	342,000
8	1,122	335	3,087	0	3,660	0	1,345	19,266,880	370,170
9	1,122	358	3,092	0	3,628	0	1,352	21,595,680	396,530
10	1,122	378	3,096	0	3,609	0	1,357	23,910,150	418,630
15	1,122	467	3,646	7,548	1,770	50	1,380	34,342,040	516,670
16	1,122	467	3,646	6,115	1,768	41	1,380	34,362,430	516,870
17	1,122	467	3,646	6,020	1,769	41	1,380	34,363,760	516,880
20	1,122	467	3,646	6,035	1,774	41	1,380	34,363,710	516,880
25	1,122	467	3,646	6,039	1,778	40	1,380	34,363,780	516,880
30	1,122	467	3,646	6,041	1,780	40	1,380	34,363,810	516,880
40	1,122	467	3,646	6,042	1,780	40	1,380	34,363,820	516,880
50	1,122	467	3,646	6,042	1,781	40	1,380	34,363,820	516,880

Sensitivity Run #5

In this simulation, the horizontal hydraulic conductivity for the fault zones intersecting the proposed ABM pit are increased to the highest measured hydraulic conductivity value observed during packer testing. Table 7a shows the dewatering flux, Table 7b presents the annual dewatering flux rates by hydrogeologic model zone, and Table 7c contains the simulated details for the formation of ABM Lake including the groundwater and surface water fluxes into the lake, and eventual lake overflow into Geona Creek. The increase in fault conductivity results in mean annual dewatering-rate increases of between 11% and 42% relative to base case conditions. ABM Lake reaches full capacity in 14 years.

Table 7a. Run 5 Dewatering Flux Rates (m^3/d) [USgpm]

	Annual Mean	Week 2	Final Month
Pre-Mining	8511 [1561]	14964 [2745]	4926 [904]
Year 1	4373 [802]	4844 [889]	4101 [752]
Year 2	4319 [792]	4659 [855]	4192 [769]
Year 3	6487 [1190]	8516 [1562]	5931 [1088]
Year 4	6055 [1111]	6306 [1157]	5898 [1082]
Year 5	6272 [1151]	6500 [1192]	6153 [1129]
Year 6	7531 [1381]	8697 [1596]	7149 [1311]
Year 7	7418 [1361]	7839 [1438]	7205 [1322]
Year 8	8717 [1599]	10286 [1887]	8109 [1488]
Year 9	8089 [1484]	8466 [1553]	7867 [1443]

Table 7b. Run 5 Annual Dewatering Rates by Zone (m^3/d) [USgpm]

	Storage	Overburden	Pit Fault Zone	Pit Bedrock	Workings Fault Zone	Workings Bedrock
Pre-mining	70.5%	7901 [1450]	0 [0]	610 [112]	0 [0]	0 [0]
Year 1	14.5%	3756 [689]	0 [0]	617 [113]	0 [0]	0 [0]
Year 2	6.7%	3166 [581]	298 [55]	854 [157]	0 [0]	0 [0]
Year 3	14.2%	878 [161]	611 [112]	791 [145]	0 [0]	4207 [772]
Year 4	3.3%	481 [88]	1293 [237]	770 [141]	0 [0]	3510 [644]
Year 5	2.3%	527 [97]	808 [148]	828 [152]	0 [0]	4109 [754]
Year 6	4.2%	404 [74]	730 [134]	727 [133]	1982 [364]	3688 [677]
Year 7	2.0%	355 [65]	952 [175]	729 [134]	1766 [324]	3617 [664]
Year 8	2.9%	230 [42]	667 [122]	736 [135]	4057 [744]	3027 [555]
Year 9	0.8%	179 [33]	585 [107]	666 [122]	4346 [797]	2314 [424]

Table 7c: Run 5 ABM Lake Formation and Water Budget (m^3/d)

Years after Mine Closure	Precipitation (m^3/d)	Evaporation (m^3/d)	Streams		Groundwater		ABM Lake	ABM Lake	Pit
			Inflow (m^3/d)	Outflow (m^3/d)	Inflow (m^3/d)	Outflow (m^3/d)	Stage (m)	Volume (m^3)	Lake Area (m^2)
0	1,122	2	3,073	0	23,041	0	1,224	6,109	1,780
1	1,122	106	3,073	0	3,854	0	1,272	2,499,849	117,000
2	1,122	157	3,073	0	3,915	0	1,290	4,992,504	173,720
3	1,122	193	3,073	0	3,958	0	1,303	7,486,095	213,790
4	1,122	227	3,073	0	3,973	0	1,314	9,973,319	251,240
5	1,122	258	3,073	0	3,979	0	1,324	12,455,360	285,430
6	1,122	288	3,072	0	3,978	0	1,332	14,931,830	318,150
7	1,122	314	3,072	0	3,981	0	1,340	17,395,640	347,710
8	1,122	341	3,072	0	3,975	0	1,347	19,848,340	377,140
9	1,122	364	3,072	0	3,968	0	1,353	22,288,030	403,140
10	1,122	385	3,073	0	3,965	0	1,359	24,719,690	426,350
15	1,122	467	3,645	6,841	2,133	44	1,380	34,363,540	516,880
16	1,122	467	3,645	6,450	2,147	42	1,380	34,369,320	516,930
17	1,122	467	3,645	6,421	2,157	42	1,380	34,370,040	516,940
20	1,122	467	3,645	6,435	2,176	42	1,380	34,370,400	516,940
25	1,122	467	3,645	6,447	2,188	42	1,380	34,370,600	516,940
30	1,122	467	3,645	6,452	2,192	42	1,380	34,370,680	516,940
40	1,122	467	3,645	6,454	2,195	42	1,380	34,370,720	516,940
50	1,122	467	3,645	6,455	2,195	42	1,380	34,370,730	516,940

Sensitivity Run #6

In this simulation, the horizontal hydraulic conductivity values for the fault zones intersecting the proposed ABM pit are reduced to the value of the lowest hydraulic conductivity measured during packer testing to simulate the case where they do not represent conduits for additional horizontal flow to the pit, but possibly even gouge-filled barriers to pit-inflow. Table 8a shows the dewatering flux, Table 8b presents the annual dewatering flux rates by hydrogeologic model zone, and Table 8c contains the simulated details for the formation of ABM Lake including the groundwater and surface water fluxes into the lake, and eventual lake overflow into Geona Creek. As expected, dewatering flux rates significantly decrease. ABM Lake fills about 40% more slowly, overflowing in year 17, and eventually discharges at a 16% lower rate than under base case conditions.

Table 8a. Run 6 Dewatering Flux Rates (m^3/d) [USgpm]

	Annual Mean	Week 2	Final Month
Pre-Mining	6187 [1135]	12191 [2237]	2991 [549]
Year 1	2566 [471]	3078 [565]	2161 [397]
Year 2	2318 [425]	2522 [463]	2177 [399]
Year 3	2424 [445]	2881 [528]	2226 [408]
Year 4	2444 [448]	2678 [491]	2281 [418]
Year 5	2347 [431]	2409 [442]	2284 [419]
Year 6	2478 [455]	2806 [515]	2362 [433]
Year 7	2539 [466]	2518 [462]	2359 [433]
Year 8	2630 [483]	3126 [573]	2512 [461]
Year 9	2518 [462]	2594 [476]	2494 [457]

Table 8b. Run 6 Annual Dewatering Rates by Zone (m^3/d) [USgpm]

	Storage	Overburden	Pit Fault Zone	Pit Bedrock	Workings Fault Zone	Workings Bedrock
Pre-mining	86.4%	5711 [1048]	0 [0]	476 [87]	0 [0]	0 [0]
Year 1	27.3%	1998 [366]	19 [4]	549 [101]	0 [0]	0 [0]
Year 2	10.7%	1474 [270]	56 [10]	788 [145]	0 [0]	0 [0]
Year 3	13.3%	964 [177]	96 [18]	839 [154]	0 [0]	525 [96]
Year 4	7.8%	875 [160]	228 [42]	871 [160]	0 [0]	471 [86]
Year 5	3.2%	789 [145]	152 [28]	898 [165]	0 [0]	509 [93]
Year 6	6.6%	685 [126]	185 [34]	900 [165]	118 [22]	590 [108]
Year 7	3.1%	781 [143]	190 [35]	908 [167]	90 [17]	570 [105]
Year 8	7.0%	607 [111]	127 [23]	823 [151]	229 [42]	844 [155]
Year 9	1.7%	588 [108]	107 [20]	790 [145]	229 [42]	804 [147]

Table 8c: Run 6 ABM Lake Formation and Water Budget (m^3/d)

Years after Mine Closure	Precipitation (m^3/d)	Evaporation (m^3/d)	Streams		Groundwater		ABM Lake	ABM Lake	Pit
			Inflow (m^3/d)	Outflow (m^3/d)	Inflow (m^3/d)	Outflow (m^3/d)	Stage (m)	Volume (m^3)	Lake Area (m^2)
0	1,122	1	3,555	0	5,298	0	1,224	3,560	1,630
1	1,122	98	3,577	0	2,286	0	1,269	2,151,780	108,290
2	1,122	142	3,577	0	2,271	0	1,285	4,243,336	157,020
3	1,122	176	3,577	0	2,264	0	1,297	6,315,772	194,990
4	1,122	206	3,577	0	2,255	0	1,307	8,374,966	228,070
5	1,122	233	3,578	0	2,252	0	1,316	10,421,570	257,410
6	1,122	258	3,578	0	2,246	0	1,324	12,458,430	285,470
7	1,122	283	3,578	0	2,237	0	1,331	14,482,390	312,760
8	1,122	305	3,579	0	2,237	0	1,337	16,497,160	336,930
9	1,122	326	3,580	0	2,233	0	1,343	18,503,120	361,000
10	1,122	348	3,580	0	2,228	0	1,349	20,499,690	384,960
15	1,122	434	3,855	0	821	0	1,372	30,324,310	479,590
16	1,122	450	3,860	0	763	0	1,376	32,242,220	497,390
17	1,122	465	3,869	6,575	568	64	1,380	34,325,900	516,520
20	1,122	467	3,870	5,088	602	40	1,380	34,347,170	516,720
25	1,122	467	3,871	5,092	606	40	1,380	34,347,240	516,720
30	1,122	467	3,871	5,093	606	40	1,380	34,347,260	516,720
40	1,122	467	3,871	5,094	607	40	1,380	34,347,270	516,720
50	1,122	467	3,871	5,094	607	40	1,380	34,347,270	516,720

Sensitivity Run #7

In this simulation, the vertical hydraulic conductivity for the fault zones intersecting the proposed ABM pit are increased to the highest measured hydraulic conductivity value observed during packer testing. Table 9a shows the dewatering flux, Table 9b presents the annual dewatering flux rates by hydrogeologic model zone, and Table 9c contains the simulated details for the formation of ABM Lake including the groundwater and surface water fluxes into the lake, and eventual lake overflow into Geona Creek. Relative to base case conditions, dewatering flux rates increase significantly (21-43% higher), and ABM-Lake filling rates increase, overflowing 7% faster approximately 3 months into year 14.

Table 9a. Run 7 Dewatering Flux Rates (m^3/d) [USgpm]

	Annual Mean	Week 2	Final Month
Pre-Mining	9644 [1769]	16837 [3089]	5771 [1059]
Year 1	5091 [934]	5598 [1027]	4836 [887]
Year 2	4993 [916]	5348 [981]	4868 [893]
Year 3	6139 [1126]	7741 [1420]	5699 [1045]
Year 4	6080 [1115]	6496 [1192]	5913 [1085]
Year 5	6433 [1180]	6942 [1274]	6254 [1147]
Year 6	6890 [1264]	7929 [1455]	6625 [1215]
Year 7	6786 [1245]	7123 [1307]	6673 [1224]
Year 8	7544 [1384]	8859 [1625]	7239 [1328]
Year 9	7336 [1346]	7651 [1404]	7243 [1329]

Table 9b. Run 7 Annual Dewatering Rates by Zone (m^3/d) [USgpm]

	Storage	Overburden	Pit Fault Zone	Pit Bedrock	Workings Fault Zone	Workings Bedrock
Pre-mining	63.6%	8925 [1637]	0 [0]	719 [132]	0 [0]	0 [0]
Year 1	11.5%	4562 [837]	0 [0]	529 [97]	0 [0]	0 [0]
Year 2	5.1%	4041 [741]	284 [52]	668 [123]	0 [0]	0 [0]
Year 3	12.4%	460 [84]	801 [147]	611 [112]	0 [0]	4267 [783]
Year 4	3.5%	336 [62]	1524 [280]	601 [110]	0 [0]	3618 [664]
Year 5	2.8%	336 [62]	901 [165]	555 [102]	0 [0]	4640 [851]
Year 6	3.6%	245 [45]	858 [157]	526 [97]	1526 [280]	3734 [685]
Year 7	1.4%	223 [41]	1055 [193]	568 [104]	1359 [249]	3581 [657]
Year 8	2.3%	173 [32]	887 [163]	482 [88]	3508 [644]	2494 [458]
Year 9	0.6%	155 [28]	817 [150]	442 [81]	3954 [725]	1968 [361]

Table 9c: Run 7 ABM Lake Formation and Water Budget (m^3/d)

Years after Mine Closure	Precipitation (m^3/d)	Evaporation (m^3/d)	Streams		Groundwater		ABM Lake	ABM Lake	Pit
			Inflow (m^3/d)	Outflow (m^3/d)	Inflow (m^3/d)	Outflow (m^3/d)	Stage (m)	Volume (m^3)	Lake Area (m^2)
0	1,122	2	3,073	0	21,309	0	1,224	5,414	1,739
1	1,122	113	3,073	0	4,407	0	1,275	2,842,881	124,880
2	1,122	164	3,073	0	4,215	0	1,293	5,470,474	181,400
3	1,122	201	3,073	0	4,128	0	1,306	8,042,173	222,730
4	1,122	235	3,073	0	4,098	0	1,316	10,577,550	259,560
5	1,122	266	3,073	0	4,057	0	1,326	13,091,220	294,190
6	1,122	295	3,072	0	4,043	0	1,334	15,590,250	326,050
7	1,122	322	3,072	0	4,019	0	1,342	18,068,520	355,790
8	1,122	348	3,072	0	3,992	0	1,349	20,526,990	385,280
9	1,122	370	3,072	0	3,984	0	1,355	22,970,450	409,660
10	1,122	391	3,072	0	3,971	0	1,361	25,403,380	432,880
15	1,122	467	3,645	6,685	2,207	46	1,380	34,367,820	516,920
16	1,122	467	3,645	6,488	2,209	45	1,380	34,370,600	516,940
17	1,122	467	3,645	6,472	2,214	45	1,380	34,370,950	516,940
20	1,122	467	3,645	6,481	2,225	45	1,380	34,371,170	516,950
25	1,122	467	3,645	6,490	2,234	45	1,380	34,371,320	516,950
30	1,122	467	3,645	6,494	2,237	45	1,380	34,371,380	516,950
40	1,122	467	3,645	6,496	2,240	44	1,380	34,371,420	516,950
50	1,122	467	3,645	6,497	2,241	44	1,380	34,371,440	516,950

Sensitivity Run #8

In this simulation, the vertical hydraulic fault zones intersecting the proposed ABM pit are reduced to the value of the lowest hydraulic conductivity measured during packer testing to simulate the case where they do not represent conduits for additional flow to the pit, but possibly even gouge-filled barriers to pit-inflow. Table 10a shows the dewatering flux, Table 10b presents the annual dewatering flux rates by hydrogeologic model zone, and Table 10c contains the simulated details for the formation of ABM Lake including the groundwater and surface water fluxes into the lake, and eventual lake overflow into Geona Creek. Under this scenario, dewatering flux rates decrease by 12-20% and ABM Lake fills at a lower rate than under base case conditions, overflowing at a 5% lower rate than baseline conditions approximately 3 months into year 15.

Table 10a. Run 8 Dewatering Flux Rates (m^3/d) [USgpm]

	Annual Mean	Week 2	Final Month
Pre-Mining	7000 [1284]	13253 [2431]	3609 [662]
Year 1	3190 [585]	3644 [668]	2830 [519]
Year 2	3008 [552]	3307 [607]	2885 [529]
Year 3	3851 [706]	4900 [899]	3489 [640]
Year 4	3716 [682]	4102 [752]	3542 [650]
Year 5	3860 [708]	4020 [738]	3545 [650]
Year 6	4630 [849]	5573 [1022]	4332 [795]
Year 7	4467 [820]	4763 [874]	4355 [799]
Year 8	4900 [899]	5508 [1010]	4704 [863]
Year 9	4977 [913]	4813 [883]	4639 [851]

Table 10b. Run 8 Annual Dewatering Rates by Zone (m^3/d) [USgpm]

	Storage	Overburden	Pit Fault Zone	Pit Bedrock	Workings Fault Zone	Workings Bedrock
Pre-mining	83.1%	6517 [1196]	0 [0]	483 [89]	0 [0]	0 [0]
Year 1	21.5%	2545 [467]	8 [2]	637 [117]	0 [0]	0 [0]
Year 2	9.6%	1983 [364]	131 [24]	893 [164]	0 [0]	0 [0]
Year 3	16.6%	1055 [194]	212 [39]	934 [171]	0 [0]	1650 [303]
Year 4	6.6%	892 [164]	378 [69]	917 [168]	0 [0]	1529 [281]
Year 5	3.0%	810 [149]	361 [66]	1133 [208]	0 [0]	1557 [286]
Year 6	7.9%	721 [132]	353 [65]	783 [144]	1169 [214]	1604 [294]
Year 7	3.0%	676 [124]	506 [93]	770 [141]	925 [170]	1591 [292]
Year 8	3.7%	616 [113]	442 [81]	747 [137]	1767 [324]	1327 [243]
Year 9	0.9%	754 [138]	416 [76]	827 [152]	1844 [338]	1135 [208]

Table 10c: Run 8 ABM Lake Formation and Water Budget (m^3/d)

Years after Mine Closure	Precipitation (m^3/d)	Evaporation (m^3/d)	Streams		Groundwater		ABM Lake	ABM Lake	Pit
			Inflow (m^3/d)	Outflow (m^3/d)	Inflow (m^3/d)	Outflow (m^3/d)	Stage (m)	Volume (m^3)	Lake Area (m^2)
0	1,122	2	3,243	0	19,121	0	1,224	5,811	1,763
1	1,122	102	3,269	0	3,138	0	1,271	2,299,411	112,400
2	1,122	150	3,278	0	3,205	0	1,288	4,609,078	165,420
3	1,122	185	3,284	0	3,223	0	1,300	6,917,664	204,660
4	1,122	218	3,289	0	3,219	0	1,311	9,217,743	240,830
5	1,122	246	3,294	0	3,216	0	1,320	11,508,020	272,380
6	1,122	275	3,298	0	3,208	0	1,329	13,788,730	303,800
7	1,122	300	3,301	0	3,199	0	1,336	16,055,550	331,640
8	1,122	324	3,305	0	3,188	0	1,342	18,311,630	358,700
9	1,122	349	3,308	0	3,174	0	1,349	20,555,280	385,620
10	1,122	369	3,312	0	3,163	0	1,354	22,787,270	407,910
15	1,122	462	3,650	0	1,518	2	1,379	33,737,280	511,260
16	1,122	467	3,650	5,396	1,463	37	1,380	34,363,100	516,870
17	1,122	467	3,649	5,707	1,472	37	1,380	34,359,200	516,830
20	1,122	467	3,649	5,754	1,486	37	1,380	34,359,000	516,830
25	1,122	467	3,649	5,763	1,495	37	1,380	34,359,160	516,830
30	1,122	467	3,649	5,767	1,498	37	1,380	34,359,220	516,840
40	1,122	467	3,650	5,769	1,501	37	1,380	34,359,260	516,840
50	1,122	467	3,650	5,770	1,501	37	1,380	34,359,270	516,840

Sensitivity Run #9

In this simulation, the horizontal hydraulic conductivity for the weathered bedrock in the area of the ABM deposit is doubled. Table 11a shows the dewatering flux, Table 11b presents the annual dewatering flux rates by hydrogeologic model zone, and Table 11c contains the simulated details for the formation of ABM Lake including the groundwater and surface water fluxes into the lake, and eventual lake overflow into Geona Creek in Year 14. The increased hydraulic conductivity for the weathered bedrock results in slightly increased dewatering rates, however the rate of ABM lake filling and discharge to Geona Creek remains essentially unchanged (<2%difference).

Table 11a. Run 9 Dewatering Flux Rates (m^3/d) [USgpm]

	Annual Mean	Week 2	Final Month
Pre-Mining	7731 [1418]	14118 [2590]	4226 [775]
Year 1	3659 [671]	4173 [766]	3400 [624]
Year 2	3582 [657]	3891 [714]	3464 [635]
Year 3	4657 [854]	5961 [1094]	4265 [782]
Year 4	4520 [829]	4794 [880]	4378 [803]
Year 5	4561 [837]	4724 [867]	4481 [822]
Year 6	5505 [1010]	6364 [1168]	5251 [963]
Year 7	5442 [998]	5714 [1048]	5343 [980]
Year 8	6289 [1154]	7074 [1298]	6056 [1111]
Year 9	6104 [1120]	6263 [1149]	6039 [1108]

Table 11b. Run 9 Annual Dewatering Rates by Zone (m^3/d) [USgpm]

	Storage	Overburden	Pit Fault Zone	Pit Bedrock	Workings Fault Zone	Workings Bedrock
Pre-mining	77.2%	7149 [1312]	0 [0]	582 [107]	0 [0]	0 [0]
Year 1	16.7%	3048 [559]	0 [0]	611 [112]	0 [0]	0 [0]
Year 2	7.4%	2545 [467]	200 [37]	837 [154]	0 [0]	0 [0]
Year 3	15.8%	885 [162]	440 [81]	828 [152]	0 [0]	2504 [459]
Year 4	4.7%	567 [104]	772 [142]	800 [147]	0 [0]	2381 [437]
Year 5	2.7%	580 [106]	544 [100]	763 [140]	0 [0]	2674 [491]
Year 6	5.7%	472 [87]	498 [91]	700 [128]	1426 [262]	2408 [442]
Year 7	2.1%	422 [77]	658 [121]	724 [133]	1205 [221]	2433 [446]
Year 8	3.5%	332 [61]	556 [102]	681 [125]	2603 [478]	2117 [388]
Year 9	0.8%	297 [55]	525 [96]	643 [118]	2814 [516]	1825 [335]

Table 11c: Run 9 ABM Lake Formation and Water Budget (m^3/d)

Years after Mine Closure	Precipitation (m^3/d)	Evaporation (m^3/d)	Streams		Groundwater		ABM Lake	ABM Lake	Pit
			Inflow (m^3/d)	Outflow (m^3/d)	Inflow (m^3/d)	Outflow (m^3/d)	Stage (m)	Volume (m^3)	Lake Area (m^2)
0	1,122	2	3,073	0	16,539	0	1,224	5,235	1,729
1	1,122	106	3,073	0	3,820	0	1,272	2,500,563	117,020
2	1,122	157	3,073	0	3,831	0	1,290	4,971,152	173,380
3	1,122	192	3,074	0	3,829	0	1,303	7,426,404	212,830
4	1,122	226	3,074	0	3,804	0	1,314	9,860,844	249,690
5	1,122	256	3,076	0	3,780	0	1,323	12,277,430	282,980
6	1,122	285	3,078	0	3,753	0	1,332	14,677,230	315,100
7	1,122	311	3,081	0	3,732	0	1,339	17,056,990	343,650
8	1,122	336	3,084	0	3,704	0	1,345	19,418,700	371,990
9	1,122	360	3,087	0	3,674	0	1,352	21,761,680	398,120
10	1,122	380	3,092	0	3,652	0	1,357	24,090,030	420,340
15	1,122	467	3,646	6,777	1,805	44	1,380	34,354,490	516,790
16	1,122	467	3,646	6,128	1,797	41	1,380	34,363,140	516,870
17	1,122	467	3,646	6,064	1,796	41	1,380	34,363,980	516,880
20	1,122	467	3,646	6,061	1,800	41	1,380	34,364,150	516,880
25	1,122	467	3,646	6,065	1,804	40	1,380	34,364,210	516,880
30	1,122	467	3,646	6,066	1,805	40	1,380	34,364,230	516,880
40	1,122	467	3,646	6,067	1,805	40	1,380	34,364,240	516,880
50	1,122	467	3,646	6,067	1,806	40	1,380	34,364,240	516,880

Sensitivity Run #10

In this simulation, the horizontal hydraulic conductivity for the weathered bedrock in the area of the ABM deposit is reduced by half. Table 12a shows the dewatering flux, Table 12b presents the annual dewatering flux rates by hydrogeologic model zone, and Table 12c contains the simulated details for the formation of ABM Lake including the groundwater and surface water fluxes into the lake, and eventual lake overflow into Geona Creek. The reduction in weathered bedrock conductivity results in slightly higher initial dewatering rates for the overburden but lower pit bedrock rates. The rate of lake filling and discharge to Geona Creek remains essentially unchanged (<1% different).

Table 12a. Run 10 Dewatering Flux Rates (m^3/d) [USgpm]

	Annual Mean	Week 2	Final Month
Pre-Mining	7796 [1430]	13924 [2554]	4402 [807]
Year 1	3881 [712]	4374 [802]	3502 [642]
Year 2	3608 [662]	3962 [727]	3436 [630]
Year 3	4625 [849]	5941 [1090]	4204 [771]
Year 4	4451 [817]	4750 [871]	4296 [788]
Year 5	4481 [822]	4640 [851]	4396 [806]
Year 6	5415 [993]	6279 [1152]	5158 [946]
Year 7	5348 [981]	5620 [1031]	5247 [962]
Year 8	6196 [1137]	6977 [1280]	5963 [1094]
Year 9	6011 [1103]	6170 [1132]	5946 [1091]

Table 12b. Run 10 Annual Dewatering Rates by Zone (m^3/d) [USgpm]

	Storage	Overburden	Pit Fault Zone	Pit Bedrock	Workings Fault Zone	Workings Bedrock
Pre-mining	76.2%	7241 [1328]	0 [0]	555 [102]	0 [0]	0 [0]
Year 1	18.0%	3279 [602]	0 [0]	601 [110]	0 [0]	0 [0]
Year 2	7.7%	2595 [476]	202 [37]	812 [149]	0 [0]	0 [0]
Year 3	16.6%	864 [158]	441 [81]	818 [150]	0 [0]	2504 [459]
Year 4	4.8%	544 [100]	733 [134]	801 [147]	0 [0]	2374 [436]
Year 5	3.0%	564 [103]	503 [92]	757 [139]	0 [0]	2657 [487]
Year 6	5.9%	467 [86]	461 [84]	674 [124]	1423 [261]	2390 [439]
Year 7	2.2%	414 [76]	623 [114]	698 [128]	1201 [220]	2411 [442]
Year 8	3.5%	325 [60]	532 [98]	655 [120]	2597 [476]	2087 [383]
Year 9	0.8%	292 [54]	501 [92]	618 [113]	2807 [515]	1794 [329]

Table 12c: Run 10 ABM Lake Formation and Water Budget (m^3/d)

Years after Mine Closure	Precipitation (m^3/d)	Evaporation (m^3/d)	Streams		Groundwater		ABM Lake	ABM Lake	Pit
			Inflow (m^3/d)	Outflow (m^3/d)	Inflow (m^3/d)	Outflow (m^3/d)	Stage (m)	Volume (m^3)	Lake Area (m^2)
0	1,122	2	3,073	0	15,993	0	1,224	5,183	1,725
1	1,122	106	3,073	0	3,788	0	1,272	2,488,346	116,740
2	1,122	156	3,074	0	3,797	0	1,290	4,947,153	173,000
3	1,122	192	3,074	0	3,795	0	1,302	7,389,674	212,240
4	1,122	225	3,076	0	3,771	0	1,314	9,812,483	249,020
5	1,122	255	3,078	0	3,746	0	1,323	12,217,660	282,160
6	1,122	284	3,080	0	3,718	0	1,331	14,605,980	314,240
7	1,122	310	3,083	0	3,700	0	1,338	16,975,050	342,670
8	1,122	335	3,086	0	3,672	0	1,345	19,326,500	370,880
9	1,122	359	3,090	0	3,641	0	1,352	21,658,940	397,140
10	1,122	379	3,094	0	3,621	0	1,357	23,977,000	419,260
15	1,122	467	3,646	5,920	1,796	42	1,380	34,365,910	516,900
16	1,122	467	3,646	6,035	1,787	41	1,380	34,364,100	516,880
17	1,122	467	3,646	6,046	1,786	41	1,380	34,363,930	516,880
20	1,122	467	3,646	6,052	1,791	41	1,380	34,363,990	516,880
25	1,122	467	3,646	6,055	1,794	41	1,380	34,364,050	516,880
30	1,122	467	3,646	6,057	1,795	40	1,380	34,364,070	516,880
40	1,122	467	3,646	6,058	1,796	40	1,380	34,364,090	516,880
50	1,122	467	3,646	6,058	1,796	40	1,380	34,364,090	516,880

Sensitivity Run #11

In this simulation, the vertical hydraulic conductivity for the weathered bedrock in the area of the ABM deposit is doubled. Table 13a shows the dewatering flux, Table 13b presents the annual dewatering flux rates by hydrogeologic model zone, and Table 13c contains the simulated details for the formation of ABM Lake including the groundwater and surface water fluxes into the lake, and eventual lake overflow into Geona Creek approximately 3 months earlier than under base case conditions. Relative to base case conditions, dewatering flux rates were essentially unchanged (<1% difference) and lake discharge increased by approximately 2%.

Table 13a. Run 11 Dewatering Flux Rates (m^3/d) [USgpm]

	Annual Mean	Week 2	Final Month
Pre-Mining	7664 [1406]	13976 [2564]	4170 [765]
Year 1	3616 [663]	4097 [752]	3329 [611]
Year 2	3515 [645]	3826 [702]	3395 [623]
Year 3	4600 [844]	5940 [1090]	4204 [771]
Year 4	4466 [819]	4744 [870]	4323 [793]
Year 5	4511 [827]	4667 [856]	4438 [814]
Year 6	5454 [1001]	6318 [1159]	5199 [954]
Year 7	5390 [989]	5662 [1039]	5291 [971]
Year 8	6240 [1145]	7021 [1288]	6008 [1102]
Year 9	6057 [1111]	6215 [1140]	5992 [1099]

Table 13b. Run 11 Annual Dewatering Rates by Zone (m^3/d) [USgpm]

	Storage	Overburden	Pit Fault Zone	Pit Bedrock	Workings Fault Zone	Workings Bedrock
Pre-mining	78.2%	6960 [1277]	0 [0]	704 [129]	0 [0]	0 [0]
Year 1	17.5%	3001 [551]	0 [0]	615 [113]	0 [0]	0 [0]
Year 2	7.7%	2467 [453]	200 [37]	848 [156]	0 [0]	0 [0]
Year 3	16.3%	837 [154]	437 [80]	823 [151]	0 [0]	2503 [459]
Year 4	4.8%	541 [99]	752 [138]	795 [146]	0 [0]	2378 [436]
Year 5	2.7%	545 [100]	525 [96]	771 [141]	0 [0]	2670 [490]
Year 6	5.8%	410 [75]	476 [87]	747 [137]	1424 [261]	2397 [440]
Year 7	2.1%	359 [66]	639 [117]	770 [141]	1203 [221]	2420 [444]
Year 8	3.5%	282 [52]	545 [100]	712 [131]	2600 [477]	2102 [386]
Year 9	0.8%	257 [47]	513 [94]	665 [122]	2810 [516]	1812 [332]

Table 13c: Run 11 ABM Lake Formation and Water Budget (m^3/d)

Years after Mine Closure	Precipitation (m^3/d)	Evaporation (m^3/d)	Streams		Groundwater		ABM Lake	ABM Lake	Pit
			Inflow (m^3/d)	Outflow (m^3/d)	Inflow (m^3/d)	Outflow (m^3/d)	Stage (m)	Volume (m^3)	Lake Area (m^2)
0	1,122	2	3,073	0	17,378	0	1,224	6,075	1,778
1	1,122	107	3,073	0	3,974	0	1,273	2,553,829	118,240
2	1,122	158	3,073	0	3,980	0	1,291	5,078,555	175,110
3	1,122	195	3,074	0	3,976	0	1,303	7,587,278	215,420
4	1,122	228	3,074	0	3,953	0	1,315	10,074,530	252,630
5	1,122	259	3,076	0	3,926	0	1,324	12,543,660	286,650
6	1,122	288	3,078	0	3,896	0	1,332	14,994,720	318,910
7	1,122	315	3,081	0	3,870	0	1,340	17,424,310	348,060
8	1,122	341	3,085	0	3,837	0	1,347	19,834,040	376,970
9	1,122	364	3,088	0	3,806	0	1,353	22,223,520	402,530
10	1,122	384	3,092	0	3,779	0	1,359	24,597,360	425,190
15	1,122	467	3,647	6,662	1,943	43	1,380	34,360,280	516,840
16	1,122	467	3,646	6,235	1,929	41	1,380	34,365,680	516,900
17	1,122	467	3,646	6,192	1,926	41	1,380	34,366,200	516,900
20	1,122	467	3,646	6,191	1,929	41	1,380	34,366,310	516,900
25	1,122	467	3,646	6,194	1,932	41	1,380	34,366,360	516,900
30	1,122	467	3,646	6,195	1,933	41	1,380	34,366,380	516,900
40	1,122	467	3,646	6,196	1,934	41	1,380	34,366,400	516,900
50	1,122	467	3,646	6,196	1,934	41	1,380	34,366,400	516,900

Sensitivity Run #12

In this simulation, the vertical hydraulic conductivity for the weathered bedrock in the area of the ABM deposit is reduced by half. Table 14a shows the dewatering flux, Table 14b presents the annual dewatering flux rates by hydrogeologic model zone, and Table 14c contains the simulated details for the formation of ABM Lake including the groundwater and surface water fluxes into the lake, and eventual lake overflow into Geona Creek. Relative to base case conditions, dewatering flux rates and ABM-Lake filling rates are essentially unchanged (<1% difference).

Table 14a. Run 12 Dewatering Flux Rates (m^3/d) [USgpm]

	Annual Mean	Week 2	Final Month
Pre-Mining	7621 [1398]	13925 [2555]	4135 [759]
Year 1	3614 [663]	4109 [754]	3308 [607]
Year 2	3491 [640]	3761 [690]	3373 [619]
Year 3	4589 [842]	5874 [1078]	4189 [768]
Year 4	4448 [816]	4735 [869]	4304 [790]
Year 5	4492 [824]	4648 [853]	4410 [809]
Year 6	5432 [997]	6292 [1154]	5178 [950]
Year 7	5368 [985]	5639 [1035]	5268 [966]
Year 8	6215 [1140]	6997 [1284]	5983 [1098]
Year 9	6031 [1106]	6189 [1135]	5966 [1095]

Table 14b. Run 12 Annual Dewatering Rates by Zone (m^3/d) [USgpm]

	Storage	Overburden	Pit Fault Zone	Pit Bedrock	Workings Fault Zone	Workings Bedrock
Pre-mining	78.2%	7226 [1326]	0 [0]	396 [73]	0 [0]	0 [0]
Year 1	18.6%	3022 [554]	0 [0]	593 [109]	0 [0]	0 [0]
Year 2	7.6%	2496 [458]	201 [37]	793 [146]	0 [0]	0 [0]
Year 3	16.4%	843 [155]	435 [80]	810 [149]	0 [0]	2501 [459]
Year 4	4.7%	547 [100]	734 [135]	793 [146]	0 [0]	2374 [435]
Year 5	2.9%	575 [105]	505 [93]	756 [139]	0 [0]	2656 [487]
Year 6	5.8%	503 [92]	466 [86]	645 [118]	1424 [261]	2394 [439]
Year 7	2.1%	452 [83]	628 [115]	669 [123]	1202 [221]	2416 [443]
Year 8	3.5%	362 [66]	535 [98]	628 [115]	2598 [477]	2092 [384]
Year 9	0.8%	328 [60]	504 [92]	591 [108]	2808 [515]	1800 [330]

Table 14c: Run 12 ABM Lake Formation and Water Budget (m^3/d)

Years after Mine Closure	Precipitation (m^3/d)	Evaporation (m^3/d)	Streams		Groundwater		ABM Lake	ABM Lake	Pit
			Inflow (m^3/d)	Outflow (m^3/d)	Inflow (m^3/d)	Outflow (m^3/d)	Stage (m)	Volume (m^3)	Lake Area (m^2)
0	1,122	2	3,073	0	16,207	0	1,224	5,206	1,727
1	1,122	106	3,073	0	3,801	0	1,272	2,493,122	116,850
2	1,122	157	3,074	0	3,810	0	1,290	4,956,602	173,150
3	1,122	192	3,074	0	3,809	0	1,303	7,404,183	212,480
4	1,122	225	3,077	0	3,784	0	1,314	9,831,792	249,290
5	1,122	255	3,078	0	3,759	0	1,323	12,241,710	282,490
6	1,122	284	3,081	0	3,732	0	1,331	14,634,790	314,590
7	1,122	310	3,084	0	3,713	0	1,338	17,008,580	343,070
8	1,122	336	3,086	0	3,685	0	1,345	19,364,700	371,340
9	1,122	359	3,090	0	3,655	0	1,352	21,701,820	397,550
10	1,122	379	3,094	0	3,634	0	1,357	24,024,540	419,720
15	1,122	467	3,646	6,945	1,800	45	1,380	34,352,040	516,770
16	1,122	467	3,646	6,138	1,794	41	1,380	34,362,900	516,870
17	1,122	467	3,646	6,062	1,793	41	1,380	34,363,920	516,880
20	1,122	467	3,646	6,059	1,797	41	1,380	34,364,100	516,880
25	1,122	467	3,646	6,062	1,801	41	1,380	34,364,160	516,880
30	1,122	467	3,646	6,063	1,802	41	1,380	34,364,180	516,880
40	1,122	467	3,646	6,064	1,803	40	1,380	34,364,200	516,880
50	1,122	467	3,646	6,064	1,803	40	1,380	34,364,200	516,880

3.0 CONCLUSIONS

Using the inflow of groundwater into the pit during mining year 9 and the discharge from ABM Lake during post-closure year 20 as reference, the relative change in flux due to each of the sensitivity scenarios is presented in Table 15.

Table 15: Sensitivity Analysis Summary

Model Scenario	Description	Groundwater Inflow Mining Year 9 (m^3/d)	Groundwater Inflow Relative to Base Case (Percent Change)	ABM Lake Discharge Closure Year 20 (m^3/d)	Surface Discharge Relative to Base Case (Percent Change)
Base Case	-	6,047	0.0%	6,058	0.0%
1	Increased Bedrock Kh	6,486	7.3%	6,191	2.2%
2	Decreased Bedrock Kh	5,719	-5.4%	5,939	-2.0%
3	Increased Bedrock Kz	6,099	0.9%	6,080	0.4%
4	Decreased Bedrock Kz	5,996	-0.8%	6,035	-0.4%
5	Increased Fault Zone Kh	8,089	33.8%	6,435	6.2%
6	Decreased Fault Zone Kh	2,518	-58.4%	5,088	-16.0%
7	Increased Fault Zone Kz	7,336	21.3%	6,481	7.0%
8	Decreased Fault Zone Kz	4,977	-17.7%	5,754	-5.0%
9	Increased Weathered Bedrock Kh	6,104	1.0%	6,061	0.1%
10	Decreased Weathered Bedrock Kh	6,011	-0.6%	6,052	-0.1%
11	Increased Weathered Bedrock Kz	6,057	0.2%	6,191	2.2%
12	Decreased Weathered Bedrock Kz	6,031	-0.3%	6,059	0.0%

With the exception of the model scenarios where the hydraulic conductivity of the pit-intersecting fault zones is modified (Runs 5 through 8), the relative change to groundwater inflow to the mine workings is generally within 8% of the base case scenario, and, the relative change of ABM Lake discharge to Geona Creek is within 3% of the base case scenario.

Variation over the extreme bounds of fault zone hydraulic conductivities inferred from packer testing resulted in changes ranging from a 58% decrease in dewatering rates due to reduction of fault zone hydraulic conductivity to a 33.8% increase when the horizontal hydraulic conductivity of the fault zones was set to the upper bound. The relative change of ABM Lake discharge due to the same variation in fault zone parameters ranged from a 16% decrease in surface flow due to decreased horizontal hydraulic conductivity, to a 7% increase in surface flow due to the increase in vertical hydraulic conductivity.

The only model scenarios that resulted in a significantly higher groundwater inflow to the mine workings were Scenario Runs 5 and 7 where the fault zone hydraulic conductivities were increased to the highest values inferred from packer test data. These scenarios are believed to be overly conservative because (i) the highest hydraulic conductivity inferred from all packer tests was used for all three faults and all associated model cells and (ii) the faults are represented in the model by 50 m wide cells and two to three adjacent cells to ensure spatial continuity. However, in reality the fault zones are likely much smaller on the order of several metres wide (not several 10s of metres or more as in the model representation). Therefore, Scenarios 5 and 7 are likely to significantly overestimate the inflow to the mine workings due to an overrepresentation of the fault zones.

It should be noted that even the base case is very conservative with respect to the fault zone representation. The fault zone hydraulic conductivities of the base case scenario are close to the upper bound of values inferred from packer testing and the fault zones are represented by model cells with a larger width than the actual fault thickness. Tetra Tech, therefore, concludes that the base case scenario is a reasonable, yet conservative representation of the actual hydrogeological conditions at the KZK site and that the resulting inflow estimates and ABM Lake water budget are sufficiently conservative for the purpose of the KZK project proposal and the current level of mine design.

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5.0 CLOSURE

We trust this document meets your present requirements. If you have any questions or comments, please contact the undersigned.

Respectfully submitted,
Tetra Tech Canada Inc.

[Name Redacted]

[Name Redacted]

[Name Redacted]

Attachments:

- Tetra Tech's Limitations on use of this Document

LIMITATIONS ON USE OF THIS DOCUMENT

GEOENVIRONMENTAL

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Appendix R2-H, Part 1

Terrain Stability and Hazard Mapping for the KZK Project

Coregeo and Associates

Terrain Stability and Hazard Mapping for the Kudz Ze Kayah Project, Yukon

Project #s
BMC-17-01/170341

Prepared For
BMC Minerals (No. 1) LTD

October 30, 2017

C o r e g e o   a n d   A s s o c i a t e s

11 Dolly Varden Drive, Whitehorse, YT Y1A 6A1 t: 867-336-2673

October 30, 2017

Kelli Bergh, B.Sc., MET, R.P.Bio.
Environmental Manager
BMC Minerals (No. 1) LTD
530-1130 West Pender Street
Vancouver, BC V6E 4A4

Dear Ms. Bergh:

Re: Terrain Stability and Hazard Mapping for the Kudz Ze Kayah Project, Yukon
Project #s: BMC-17-01/170341

Coregeo and Associates is pleased to provide BMC Minerals (No. 1) LTD with the results of the terrain stability and hazard mapping and related risk assessment for the Kudz Ze Kayah (KZK) Project, in southeastern Yukon.

This report, in combination with the appended terrain map (Map 1) and terrain stability, hazards and risks maps (Maps 2 and 3), provides the information necessary to support a response to an information request (R162) made by the Yukon Environmental and Socio-economic Assessment Board (YESAB) in its adequacy review of the Project Proposal. The report and accompanying maps characterize the types and distribution of terrain hazards within the proposed mine site area and along the access road corridor, many of which are influenced by permafrost or periglacial processes. A distinction is made between existing terrain stability and projected terrain stability in response to potential disturbance from project-related construction and/or climate change. Opportunities for mitigating site-specific risks to the project are identified to demonstrate the feasibility of reducing risk to negligible levels.

Should you, YESAB or YESAB's technical reviewers have any questions or require additional information related to this study, please feel free to contact me, Eri Boye, at 867-336-2673 or via email at eri@coregeo.ca.

We appreciate the opportunity to support the advancement of the KZK Project.

Yours truly,
Coregeo and Associates

Signature Redacted

Eri Boye, M.Sc., P.Geo.

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List of Abbreviations

ABM	Name of mineral deposit
AEG	Alexco Environmental Group
BMC	BMC Minerals (No. 1) LTD
Coregeo	Core Geoscience Services Inc.
DEM	Digital elevation model
Golder	Golder Associates Ltd.
IPCC	Intergovernmental Panel on Climate Change
IR	Information request
km	Kilometres
KM	Kilometre marker (along proposed access road, including existing sections)
KP	Knight Piésold
KZK	Kudz Ze Kayah
LiDAR	Light Detection and Ranging
m	Metres
m.a.s.l	Metres above sea level
OEL	Onsite Engineering Ltd.
PECG	Palmer Environmental Consulting Group Inc.
RCP	Representative Concentration Pathway
SNAP	Scenarios Network for Alaska + Arctic Planning
VMS	Volcanogenic massive sulphide
YESAB	Yukon Environmental and Socio-economic Assessment Board
YGS	Yukon Geological Survey

1. Introduction

Coregeo and Associates, a collaboration of Core Geoscience Services Inc. (Coregeo) and Palmer Environmental Consulting Group Inc. (PECG) with Dr. Derek Turner in the role of a technical advisor, is pleased to provide BMC Minerals (No. 1) LTD (BMC) with the results of our team's terrain stability and hazard mapping for the Kudz Ze Kayah (KZK) Project (the Project), in southeastern Yukon. The mapping and assessment work was completed in accordance with the hazard assessment guidelines of Yukon Environmental and Socio-economic Assessment Board (YESAB) (Guthrie and Cuervo, 2015; hereinafter referred to as YESAB's Geohazards Guide), in order to address the information request (IR) R162 made by YESAB in association with its review of the adequacy of the Project Proposal and subsequent responses from BMC. Terrain, terrain stability and hazards were mapped within the proposed mine area and along its access corridor. Projected terrain stability and hazards were distinguished from existing conditions in order to document where and how climate change and/or mine development could increase instabilities in the absence of appropriate mitigation. A risk assessment was completed for each hazard that poses a credible risk to project infrastructure.

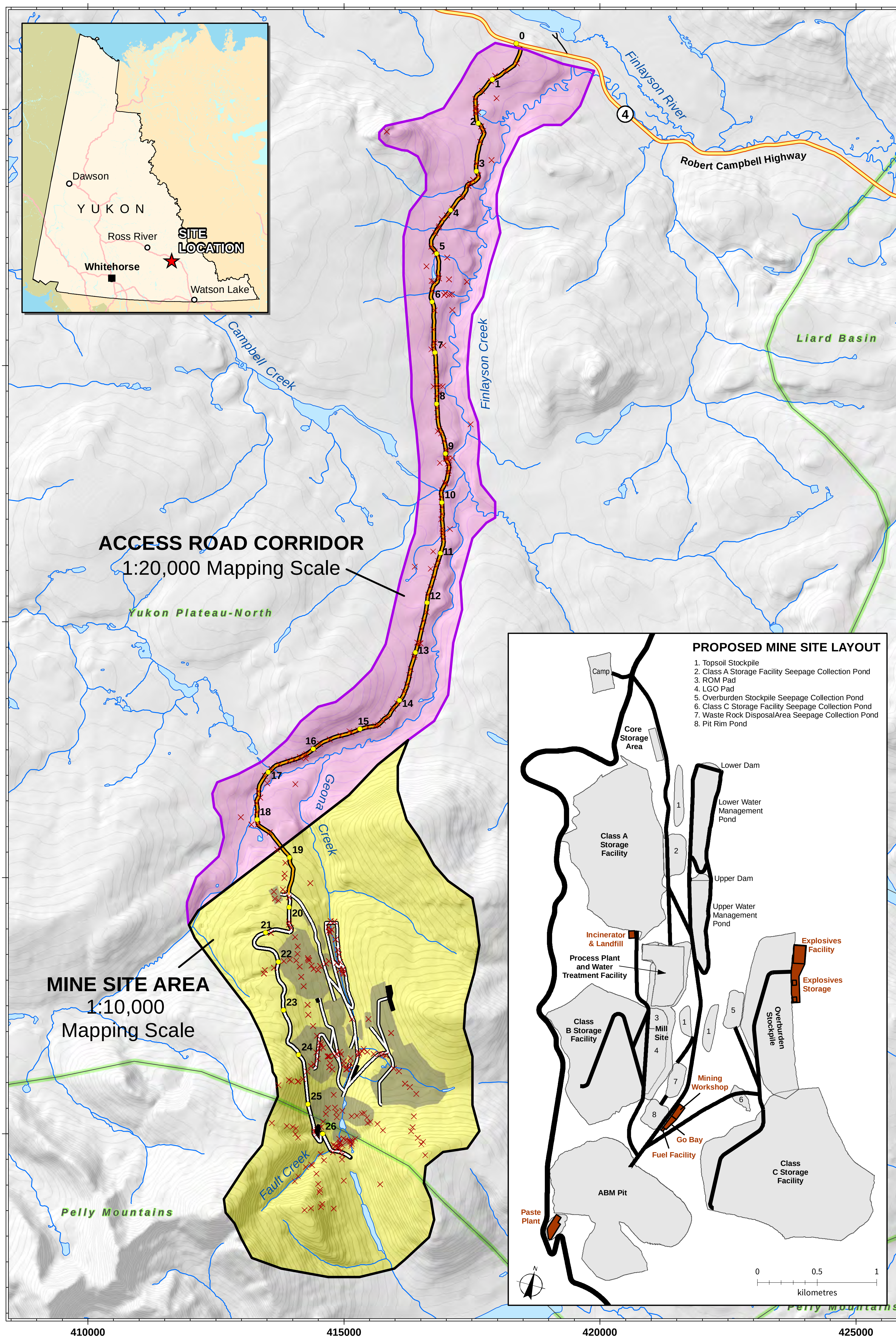
Pertinent background information to this study is provided in Section 1, followed by a description of the region's physical setting in Section 2. The methods used for field work, mapping, hazard identification and risk evaluation are detailed in Section 3. Dominant terrain units and geomorphological processes encountered within the study area are characterized in Section 4. Section 5 presents the results of the terrain stability and hazard mapping, and summarizes the general distribution, characteristics and implications of hazards. Site-specific risks to project infrastructure, whether natural or driven by effects of the project on terrain stability, are identified and evaluated in Section 6 along with consideration of opportunities for mitigation. Key conclusions are highlighted in Section 7, followed by acknowledgment of study limitations in Section 8.

Mapping of terrain (Map 1), existing (baseline conditions) terrain stability and hazards (Map 2), and disturbed (projected conditions) terrain stability, hazards and unmitigated risks (Map 3) are provided in **Appendices A**, **B** and **C**, respectively.

1.1 Background

BMC is proposing to develop the KZK Project, a volcanogenic massive sulphide (VMS) deposit containing economic concentrations of copper, lead, zinc, gold and silver (Alexco Environmental Group (AEG), 2017). The proposed mine area is situated in the headwaters of Geona Creek, a tributary of Finlayson Creek, approximately 115 km southeast of Ross River, Yukon (**Figure 1-1**)[1]. Mining is proposed using both open pit and underground methods. Ore will be processed into separate copper, lead and zinc concentrates via sequential flotation at ~2 million tonnes per year, over an approximate ten-year mine life. Dry stack tailings are proposed to be deposited in the Class A Storage Facility on the western slope of the valley. Waste rock will be stored according to acid generation and metal leaching potential; strongly acid-generating material will be disposed within tailings or alternatively stored in mined-out areas of the open pit and underground workings, while other waste rock material will be placed on the surface in managed facilities.

[1] *All proposed infrastructure/building footprints and related terminologies used in this report and the accompanying mapping are based on the ArcGIS shapefiles provided by BMC on September 5, 2017.*



Client: BMC Minerals
Project: Kudz Ze Kayah Project

PREPARED BY:

PALMER ENVIRONMENTAL CONSULTING GROUP INC.

BMC MINERALS

CORE GEOSCIENCE SERVICES

PROJECT: 170341
DATE: Oct 2, 2017
DRAWN: Name Redacted
CHECKED: Name Redac

LEGEND

- Mine Site Area (1:10,000 Mapping)
- Access Road Corridor (1:20,000 Mapping)
- Proposed Mine Footprint
- Proposed Mine Building
- Ecoregion boundary
- Existing Section of Access Road
- Proposed Section of Access Road
- Kilometre Marker
- Field Observation Site

Note: contour interval is 20 metres.

N

0 1 2 3
kilometres

COORDINATE SYSTEM:
NAD 1983 UTM ZONE 9N
SCALE: 1:70,000

Study Area

FIGURE 1-1

Document Path: C:\Egnyte\Shared\Projects\Active\17034 - Core Geoscience Services Inc\170341 KZK Terrain Hazard\Mapping\mxd\170341_KZK_Figure1-1_StudyArea.mxd

DATA SOURCES: Base data from CanVec, CDEM. Contains information licensed under the Open Government Licence - Canada.

An existing 25 km-long road used to access the proposed mine area from the Robert Campbell Highway will be upgraded to accommodate increased traffic and heavy equipment. Concentrate will be trucked 911 km to the port of Stewart, British Columbia, for sale to market.

In March 2017, BMC submitted its Project Proposal to YESAB for developing the KZK Project. Following a preliminary review of the Project Proposal, YESAB identified areas that required additional information, and provided a number of IRs for BMC to address in order for YESAB to deem the submission adequate for formal review. This study was completed in response to YESAB's identification of the omission of terrain stability mapping, the "preliminary and coarse" nature of the terrain analysis and hazard inventory (Knight Píesold Ltd. (KP), 2016a), and a lack of field assessment to confirm the extent of hazard processes within the Project area. Specifically, YESAB's IR R162 requested the following:

> *"Provide a terrain map, terrain stability and hazard map for the mine footprint and access road (including associated methodology and analysis) that:*
>
> *a. Identifies surficial geology and related geomorphologic processes;*
> *b. Identifies the type, nature, relative frequency and magnitude of hazards (baseline map);*
> *c. Evaluates how current hazard dynamic may be altered due to changes in climate;*
> *d. Identifies specific risks to the proposed infrastructure; and,*
> *e. Identifies specific risks to the environment from the proposed project (e.g.: changes to slope stability). The risk map should include consideration of climate change over the life of the Project."*

Deferring completion of such mapping to subsequent detailed design of the Project has been deemed unacceptable by YESAB. As such, BMC approached Coregeo to help complete the necessary mapping to help satisfy YESAB's IRs and to support general engineering planning. Coregeo then solicited the support of Dr. Derek Turner and PECG, recognized experts in slope- and permafrost-related terrain stability mapping in Yukon, to co-lead the technical aspects of the hazard mapping and risk assessment work.

1.2 Study Area

The Project is located in the eastern foothills of the Pelly Mountains, approximately 115 km southeast of Ross River and 250 km northeast of Whitehorse, Yukon (**Figure 1-1**). Detailed terrain stability and hazard mapping were completed to fully encompass all proposed mine site facilities and the existing access road from the Robert Campbell Highway. The buffer around the overall Project footprint was delineated such that any upslope or downslope instabilities or hazards could be identified, and minor adjustments in site or route selection could be accommodated. The 64 km^2 study area consists of two main sections:

1. **Access Road Corridor** – The proposed access to the proposed mine site generally follows an existing, two-lane gravel access road that extends from the Robert Campbell Highway southwestward for a distance of approximately 25 km to the mine site area. The proposed access road diverges from the existing alignment near KM 20.5[2], apart from a minor realignment between

[2] *Kilometre marker (KM) references made throughout the report are based on GIS-based generation of points at consistent distance intervals along the proposed (including existing) road shapefile (Figure 1-1); they may differ slightly from references by others.*

KMs 19 and 20, and terminates beside the proposed open pit at KM 26.75. Mapping was completed within a 27 km^2 corridor that has a minimum width of 1 km roughly centred along the existing road alignment, to inform plans for road upgrades, widenings and local realignments. The corridor was locally widened up to a width of 2.5 km to encompass heights of land where natural processes upslope could potentially affect infrastructure, and lower slopes potentially susceptible to retrogressive mass movements (**Figure 1-1**). From north to south, the road leaves the Robert Campbell Highway near KM 232 and follows gentle terrain west of the Finlayson Creek valley for approximately 17.5 km. The road crosses Finlayson Creek just upstream of its confluence with Geona Creek, and steadily climbs the western valley side of Geona Creek to the proposed mine site area just north of Fault Creek.

2. **Mine Site Area** – The proposed mine site is situated in the headwaters of Geona Creek, just north of Fault Creek. The 37 km^2 mine site study area encompasses the footprints of all proposed mine infrastructure, with a surrounding buffer that includes relevant heights of land. Key infrastructure within the overall mine footprint includes an open pit, waste rock and tailings storage facilities, an overburden stockpile, water management ponds and a mill site (**Figure 1-1**).

1.3 Objective

Coregeo and Associates completed project-specific terrain stability and hazard mapping to inform the siting and design of mine site facilities and the access road, and to comply with YESAB's hazard mapping expectations for Project Proposal submission (Guthrie and Cuervo, 2015). Three main tasks facilitated the successful completion of this project:

1. Delineation and characterization of distinct terrain units and geomorphological processes within the study area;
2. Identification of potential hazards posed by the environment on the Project, and by the Project on the environment (terrain stability effects); and
3. Evaluation of risks to project infrastructure, giving consideration to the implications of climate change.

2. Physical Setting

2.1 Physiography

The KZK Project straddles the Yukon Plateau-North and Pelly Mountain ecoregions as defined by Yukon Ecoregions Working Group (2004) (**Figure 1-1**). The northern part of the project area is located in the southeastern part of the Yukon Plateau-North ecoregion region, also known as the Ross Lowland physiographic region (Mathews, 1986). This area is characterized by rolling, east-west trending highlands and broadly incised river valleys, with elevations between 900 and 1,500 metres above sea level (m.a.s.l.) (Yukon Ecoregions Working Group, 2004). The southern portion of the project, encompassing the proposed mine area, is located within the Pelly Mountain ecoregion, characterized as a rolling plateau with numerous mountain peaks that are dissected by small rivers. Elevation in this region is generally above

1,500 m.a.s.l. (Yukon Ecoregions Working Group, 2004). The relief in the study area between valley bottoms and adjacent ridges ranges from about 300 to 900 m.

The proposed access road parallels and then crosses the Finlayson Creek valley, before ascending the western side of the tributary Geona Creek valley to the proposed mine site area near Fault Creek. Finlayson Creek, which flows into Finlayson River just downstream of the Robert Campbell Highway, has incised up to about 60 m through glacial drift into bedrock, which is locally exposed at the base of high cut-banks. Geona Creek exhibits little evidence of down-cutting, so its lower valley walls are generally gentle and lack prominent cut-banks.

2.2 Climate

2.2.1 Current

The climate of the Yukon Plateau-North ecoregion has a strong seasonal variability that is largely controlled by elevation changes throughout the region. Mean annual air temperature is near -5 ºC. In lower valleys, the mean January temperatures are generally below -30 ºC. At higher elevations, the mean January temperatures are above -20 ºC (Yukon Ecoregions Working Group, 2004). Extreme temperature inversions commonly develop during winter once strong high pressure ridges develop. The gradient is reversed by July when mean temperatures are around 15 ºC in the lower valley floors, and near 8 ºC in higher terrain (Yukon Ecoregions Working Group, 2004). Between 1950 and 1998, the Canadian western Arctic experienced warming of 1.5 to 2 ºC (Zhang et al., 2000). Observed mean annual air temperatures from 2000 to 2009 are in the -4 to -3 ºC range (Scenarios Network for Alaska + Arctic Planning (SNAP), 2016).

Mean annual precipitation ranges from 300 to 600 mm across the region. The wettest period occurs during July and August, with convective rain showers and thunderstorms producing 40 mm to 80 mm of rain per month (Yukon Ecoregions Working Group, 2004). Observed annual precipitation conditions from 2000 to 2009 are in the 600 to 700 mm range (SNAP, 2016).

Lightning strikes are a common trigger for wildfires in the region. Yoshikawa et al. (2003) estimate natural wildfire recurrence of 50 to 300 years in the similar boreal forest of interior Alaska. Field observations from the study area corroborate the absence of recent wildfires in Yukon Government's fire history mapping database. The lack of recent wildfires is noteworthy, because fire has important implications for ground stability in areas of permafrost. Conditions may now be primed for an intense burn, and ongoing climate change has already increased lightning strikes elsewhere in south-central Yukon (Yukon Ecoregions Working Group, 2004).

2.2.2 Projected

Changing climate conditions for mean annual air temperature and precipitation have been modelled using different Representative Concentration Pathway (RCP) scenarios (Intergovernmental Panel on Climate Change (IPCC), 2013), and then downscaled for the region (SNAP, 2016), as reported by AEG (2017). The scenarios describe different climate futures dependant on how much greenhouse gas is emitted into the atmosphere. RCPs represent a range in radiative forcing values, measured in Watts per square metre (W/m^2), in the year 2100 compared to pre-industrial conditions. The specific climate change projection for the study area focuses on RCP values of +4.5 W/m^2 (RCP4.5) and +8.5 W/m^2 (RCP8.5), which correspond to low and high radiative forcing scenarios, respectively. Some modelling results are different for the access road corridor and the mine site area due to physiographic differences (**Table 2-1**). In general, continued warming is projected over the mine life, with greater temperature increases forecasted along the access road corridor. Precipitation is only modelled to increase in the mine site area above 2,030 m.a.s.l. at the highest radiative forcing scenario. Because the modelled precipitation increase in the study area is within the spatial error of the modelling, some local increases may be expected.

Table 2-1. Summary of projected changes in mean annual temperature and precipitation in the region

	Observed 2000-2009		Projected 2020-2029		Projected 2030-2039	
RCP (W/m^2)	Temp. (^{o}C)	Precip. (mm)	Temp. (^{o}C)	Precip. (mm)	Temp. (^{o}C)	Precip. (mm)
Access Road Corridor						
4.5	-4 to -3	500 to 600	-3 to -2	500 to 600	-3 to -2	500 to 600
8.5	-4 to -3	600 to 700	-3 to -2	500 to 600	-2 to -1	500 to 600
Mine Site Area						
4.5	-4 to -3	600 to 700	-4 to -3	600 to 700	-3 to -2	600 to 700
8.5	-4 to -3	600 to 700	-3 to -2	600 to 700	-3 to -2	700 to 800

Note: All data from SNAP (2016).

Climate variations have a significant impact on permafrost stability, with the potential to impact ground stability and infrastructure integrity (Benkert et al., 2015). The effects of climate change, specifically temperature increase, are already being observed on terrain stability within the study area. Active thermokarst subsidence and gullying have been observed throughout the study area, especially along the access road corridor, and the frequency of active-layer detachments may be increasing based on the lack of evidence of previous events in the same areas.

2.3 Bedrock Geology

2.3.1 Regional-scale

The following summary of regional bedrock geology has been adapted from Equity Exploration Consultants Ltd. (2016), AEG (2016) and Murphy et al. (2001). The KZK Project is located within the Finlayson Lake District, a crescent-shaped area located between Ross River in the north and Watson Lake in the south. The Finlayson Lake District is composed of Devonian to Mississippian volcanic, intrusive and sedimentary rocks. It is underlain by polydeformed, metamorphosed sedimentary, volcanic and plutonic rocks of the Yukon–Tanana terrane, which extends from central British Columbia to eastern Alaska.

In the vicinity of the Finlayson Lake District, the Yukon–Tanana terrane comprises foliated and lineated greenschist to lower amphibolite-grade metasedimentary, metavolcanic and metaplutonic rocks. The Yukon–Tanana terrane was imbricated by Permian thrust faulting into the Cleaver Lake, Money and Big Campbell thrust sheets. The KZK Project is located within the Big Campbell thrust sheet, which is the structurally deepest of the Yukon–Tanana terrane. The Grass Lake and Wolverine middle Palaeozoic unconformity-bound groups are exposed in the Big Campbell thrust.

The VMS deposit (including the ABM Deposit and its deep Krakatoa zone) occurs within the KZK formation, which is primarily hosted within felsic metavolcanic and metaplutonic rocks of the upper Grass Lakes sequence. The KZK formation in the vicinity of the ABM deposit comprises a thick sequence of felsic volcanic schist interbedded with variably carbonaceous metasedimentary and calcareous mafic schist units.

2.3.2 Site-scale

Surface bedrock in the mine site area is expressed as highly fractured, strongly foliated, polydeformed, metavolcanic and metasedimentary schist with frequent mafic intrusions. Foliation dips gently to the north. The northern portion of the mine and mill infrastructure area consists of the upper KZK formation and the Wind Lake formation, which are primarily carbonaceous metasedimentary schist. Outcrops with significant relief are infrequent in the study area. The best bedrock exposures are a result of faulting, meltwater incision or post-glacial erosion along creeks. Significant phylosillicate content results in fissile bedrock that is commonly highly weathered within its upper few metres. Occasional, more resistant, metre-scale layers form blocky outcrops and float. The weathering of micaceous bedrock has resulted in the formation of micaceous B and C soil horizons. Competent, stream-cut bluffs of limestone occur along lower Finlayson Creek and punctuate a prominent hill southwest of the access road's divergence from the Robert Campbell Highway.

2.3.3 Seismicity

According to Cominco (1997), Hyndman et al. (2005) and KP (2016b), the project is in an area of low seismic activity. Despite being only about 30 km away, the Tintina Fault is not considered to be active by the Geological Survey of Canada (Cominco, 1997). No earthquakes with magnitudes >6.0 have occurred in the vicinity of the project since 1600, and only a few with magnitudes >3.5 have occurred between 1973 and 2012 (KP, 2016b). As such, triggers other than earthquakes are likely responsible for most mass movements within the study area.

2.4 Surficial Geology and Quaternary History

The study area has been glaciated repeatedly throughout the Pleistocene. Most of the remnant glacial features seen in the current landscape were formed during the most recent, McConnell glaciation that occurred roughly 25-10 ka (Bostock, 1966; Bond and Plouffe, 2002). Glacial advance in the region is characterized by localized valley glaciers that coalesced into several distinct ice lobes, forming an ice sheet, with an ice divide thought to be just east of the project area, in the Wolverine Lake region (Bond and Plouffe, 2002). At glacial maximum, the Cordilleran Ice Sheet reached elevations between 1,550 and 1,900 m.a.s.l. near Faro and Ross River (Jackson, 1994), and ice flowed north-northwest from the Pelly Mountains across the study area.

Deglaciation in the study area was complicated. Initial active frontal retreat of the ice sheet, with minor re-advances, progressed until the equilibrium line rose above the ice elevation, leading to final stagnation and downwasting of the ice sheet (Jackson, 1994; Benkert et al., 2015). Deglaciation first occurred in alpine regions where ice was thinner and may have stagnated for much longer in valley bottoms (Bond and Plouffe, 2002), leading to deposition of thick and highly disturbed supraglacial sediments in valley bottoms and progressively lower lake elevations blocked by melting ice in the valley floor (Benkert et al., 2015).

Much of the region is underlain by till of variable thickness, locally overlain by glaciolacustrine sand, silt and clay, and glaciofluvial sand and gravel (outwash) (Turner, 2014). Till is also the dominant surficial material within the study area; however, thick deposits are confined to the Finlayson Creek valley bottom, while thinner veneers and blankets up to 10 m in thickness occur on valley sides and at higher elevations. Large glaciofluvial complexes overlie the till near the Robert Campbell Highway, at the confluence of Geona and Finlayson Creeks, and in localized areas within the mine site area. Colluvial aprons are localized at the base of steeper slopes, and colluvial veneers to blankets predominate in steep, mountainous terrain. Bedrock exposure is restricted to mountain ridges and spurs, and stream-cut bluffs.

A conspicuous layer of White River Ash is commonly visible at or near surface in road cuts and soil pits, providing a convenient stratigraphic marker and evidence of localized ground stability for the past 1,147 years (Clague et al., 1995).

2.5 Permafrost

2.5.1 Distribution

Permafrost is ground that remains below 0ºC for more than one year. The study area is within the zone of extensive discontinuous permafrost, in which 50 to 90% of the ground is underlain by permafrost (Heginbottom et al., 1995). Recent permafrost modelling completed by Bonnaventure et al. (2012) for southern Yukon indicates that there is a 60 to 90% probability of encountering permafrost within most of the study area, with the highest probabilities at higher elevations. Locally, permafrost distribution is related to slope aspect, angle and shape, soil texture and moisture, and the thickness and type of organic cover (Williams, 1995; Williams and Burn, 1996). Permafrost is most common on high-elevation, north-facing slopes and in thick deposits of fine-grained material, particularly where insulated by a thick organic cover. Steep, well drained, south-facing slopes are permafrost-free.

A variety of landforms indicates the presence of permafrost within the study area, including thermokarst ponds and gullies, active-layer detachments, solifluction[3] lobes and terraces, and slopewash runnels. Vegetation distribution and growth habitat can be reasonable predictors of permafrost presence or absence within surficial material, although local disequilibrium of permafrost and present climate can mislead these inferences. In general, deciduous trees root more deeply than coniferous trees, and are unable to grow in thin active layers where soils are permanently wet or saturated. Stands of trembling aspen are invariably restricted to permafrost-free ground (Zoltai and Pettapiece, 1973; Williams, 1995). Conversely, black spruce is tolerant of cool, saturated soils and commonly grows in areas underlain by permafrost. A sparse, stunted canopy of black spruce with thick moss cover is a reliable indicator of shallow permafrost. Permafrost is commonly absent from riparian zones along active channels due to sufficiently deep flows that remain unfrozen at depth during winter (i.e., talik), and a high groundwater table with efficient down-valley flow through permeable sand and gravel.

[3] Solifluction is most commonly associated with gradual downslope movement of saturated material over the permafrost table ("gelifluction"), but its occurrence over other impermeable surfaces such as bedrock preclude it from being a definitive indication of permafrost.

Maximum thicknesses of permafrost within the study area and broader Yukon Plateau-North and Pelly Mountain ecoregions are variable. In the southern part of the Yukon Plateau-North ecoregion, permafrost thicknesses of up to 24 m are reported, but are more commonly 15 to 18 m (Yukon Ecoregions Working Group, 2004). A thickness of 40 m has been measured in the Pelly Mountains southwest of the project area (Heginbottom et al., 1995).

2.5.2 Active Layer

The active layer is the upper layer of ground that freezes and thaws seasonally above the permafrost table. It may be restricted to soils and unconsolidated surficial materials, or it may extend into underlying, weathered or intact bedrock. At a local scale, its thickness primarily depends on elevation, aspect, soil texture, drainage, snow pack, vegetation cover and wildfire history (Williams and Burn, 1996; McKillop et al., 2013). The active layer is generally 1 to 2 m thick within the region encompassing the study area (Yukon Ecoregions Working Group, 2004; this study). Well drained, coarse-grained soils tend to have thicker active layers than poorly drained and fine-grained areas. In areas of thick, mossy organic cover, permafrost may be encountered at depths as shallow as just a few tens of centimetres. Areas with thick organic cover and variable moisture contents exhibit the greatest spatial variability in active layer thickness (Smith et al., 2009).

Active layer thickness varies seasonally and in response to natural and anthropogenic disturbances. Each year, active layer thickness increases following spring snowmelt and typically peaks in late summer (September), before refreezing in the autumn. Active layers thicken by up to several times their original thickness following wildfire, which burns most or all of the insulating surface organic mat, reduces interception of snow by trees (where present), lowers the surface albedo, increases exposure to solar radiation, and decreases evapotranspiration (Burn, 1998; Smith et al., 2015).

2.5.3 Ground Ice

Permafrost may or may not contain ice. The ice content of permafrost is highly variable at both the regional and local scale. Areas of intact or weathered bedrock and well drained, coarse-grained colluvial mantles with permafrost generally contain little to no visible ice. Such ice-poor permafrost is common in upland settings, on summits and along ridges and spurs, and on moderate to moderately steep valley sides with convex slopes. Permafrost more commonly contains excess ice[4] in the form of thin seams and lenses in thick, silt-rich lower-slope and till deposits, and in organic terrain. Ice-rich permafrost with extensive, segregated ice is most commonly encountered in thick deposits of silty till that underlie northern portions of the access road in valley bottom settings. A freshly exposed, vertical sidescarp along the wall of a deep thermokarst gully near KM 7.5 of the access road revealed more than 1 m of permafrost visually estimated to have volumetric ice content in excess of 50% (**Photo 2-1**). Enlarging thermokarst (thaw) lakes in valley bottoms and along adjacent, flat-topped benches provide evidence of locally high ice contents. Golder Associates Ltd. (Golder) (1996) reports encountering permafrost with discontinuous ice lenses and volumetric ice contents of 5 to 30% in geotechnical boreholes within the footprints of several of the proposed mine facilities.

[4] The term excess ice is used throughout the report to represent the condition in which the volume of ice in the ground exceeds the total pore volume the ground would have under natural, unfrozen conditions.

Photo 2-1. Ice-rich permafrost within till exposed in sidescarp of thermokarst gully near KM 7.5 of the existing access road to the KZK Project

Ground ice is sensitive to melting in response to permafrost degradation (thaw). Permafrost degradation occurs naturally over different time scales in response to localized surface disturbances such as wildfire or windthrow, which alter the ground thermal regime by removing the insulating surface organics. Similarly, climate change can result in permafrost degradation. Warmer air temperatures, especially in winter, can inhibit complete freezing of the active layer and, in turn, promote its thickening. Anomalously intense or prolonged late-summer rainfalls or anomalously deep winter snowpacks can further accelerate thaw and the melting of ground ice.

Anthropogenic disturbances also alter the ground thermal regime and are a common trigger for permafrost degradation. The most common triggers are (1) stripping or compaction of surface organic layer, which insulates the ground in summer; (2) unnatural concentration of surface and near-surface runoff through culverts and along ditches, increasing the potential for thermal (ponding) or fluvio-thermal (flowing) erosion; (3) repeated ploughing of snow into the same locations, commonly along roadside ditches, such that it accumulates and inhibits cold penetration that normally freezes the active layer during winter. Permafrost degradation has little to no effect on ground surface topography or stability in areas of ice-poor permafrost or where the permafrost table is below surficial material within weathered or intact bedrock. Areas of ice-rich permafrost within fine-grained materials, even if mantled by coarser-grained material, may be susceptible to thermokarst subsidence in response to permafrost degradation.

3. Methods

Coregeo and Associates employed a systematic approach for completing terrain stability and hazard mapping for the Project, leveraging extensive experience mapping permafrost-related mass movement hazards throughout Yukon. Each main phase of work is described below.

3.1 Background Review and Consultation

Coregeo and Associates strengthened our pre-existing understanding of terrain characteristics and related hazards within the study area by reviewing the following data sources:

- Terrain analysis report and accompanying maps for the KZK Project (KP, 2016a);
- Terrain and soils chapter of the Project Proposal submission to YESAB (AEG, 2017);
- Geotechnical and hydrogeological site investigation for the KZK Project (Golder, 1996);
- Geotechnical site investigation data reports for the KZK Project (KP, 2016c,d, 2017);
- Prefeasibility design report for the KZK Project (KP, 2016b);
- Access road upgrade construction management plan for the KZK Project (Onsite Engineering Ltd. (OEL), 2017);
- High-resolution (30 cm) aerial photography (orthorectified, 2016; stereo-models, 2017) (2017) encompassing the study area;
- Historical aerial photography (georeferenced, 1992 and 1995) encompassing the mine area, with select coverage of older imagery to encompass particular hazard sites;
- High-resolution (50 cm) LiDAR-derived digital elevation model (DEM) from 2016, with derived bare earth hillshade and slope classification models;
- Regional-scale (1:100,000) surficial geology encompassing the study area (Jackson, 1993a,b);
- Regional-scale bedrock geological mapping (Gordey and Makepeace, 2003);
- Quaternary geology characterization of the region encompassing Finlayson Lake (Bond and Plouffe, 2002);
- 30 m-resolution permafrost probability model for southern Yukon (Bonnaventure et al., 2012);
- Shapefile of territory-wide wildfire history (from GeoYukon) fire history;
- Territory-wide glacial limits mapping (Duk-Rodkin, 1999); and
- Earthquakes and seismic hazard mapping encompassing Yukon (Hyndman et al., 2005; KP, 2016b).

Coregeo and Associates also took advantage of our existing collaborative working relationships with senior staff at Yukon Geological Survey (YGS) to acquire local knowledge from their field experience in the study area. Name Redacted , Surficial Geology, YGS) was consulted about his knowledge of the surficial geology and terrain hazards within the study area. Name Redacted alerted us to the potential for outburst floods from sudden breaches of beaver dams, based on his awareness of such an event not far from the project area.

3.2 Field Investigations

Field work was completed prior to completion of the terrain stability mapping to ensure on-the-ground observations were made in the absence of snow and ice cover, and to allow time for the processing of newly acquired 2017 aerial photography on which subsequent mapping was based. A thorough review of available data sources identified above in Section 3.1 in advance of field work ensured field investigations provided satisfactory representation of the diversity of terrain and hazards within the study area. Areas with the greatest potential for instability were prioritized for field investigation.

Field investigations were conducted throughout the study area by a two-person crew comprising PECG's Senior Geomorphologist, Name Redacted, M.Sc., P.Geo. and Coregeo's Senior Environmental Geoscientist, Name Redacted, M.Sc. from September 8 to 11, 2017. Conditions were favourable for field work: the ground was free of frost and snow, active layer thicknesses were near their annual maxima, and weather conditions were typically a mix of sun and cloud without any significant showers. A helicopter was used strategically to conduct an overview reconnaissance flight of the mine site and access corridor at the start of the program, to facilitate access for foot traverses through proposed infrastructure footprints, and to optimize photographic perspectives of observed hazard sites. A 4WD pick-up truck was used to access sites along maintained sections of the existing access road.

Observations from more than 300 sites were recorded based on visual reconnaissance during short stops along foot traverses, vehicle-supported access or helicopter fly-overs (**Figure 1-1**). Most observations related to surficial material thickness, vegetation associations, drainage, and evidence of instability or permafrost characteristics. Accompanying photographic documentation was collected at the majority of observation sites. During foot traverses, existing natural (e.g., landslide headscarp, stream cut-bank) and anthropogenic (e.g., road cut, borrow pit) exposures of surficial materials were targeted for examination. Hand-dug soil pits were excavated and studied in areas without good exposures. A 1.2 m-long steel frost probe was used to investigate variability in active layer thickness across the study area and for detecting shallow bedrock. An increment (tree) borer was used to extract a thin (~5 mm) core from trees or shrubs growing on or against slope hazard deposits, where basic dendrochronology could help provide insight into the timing and frequency of events.

3.3 Terrain and Terrain Stability Mapping

PECG completed terrain and terrain stability mapping within the 64 km^2 study area in accordance with YESAB's Geohazards Guide (Guthrie and Cuervo, 2015). Terrain mapping is the process of dividing the landscape according to surficial materials, textures, surface expressions and geomorphological processes. Terrain stability mapping involves further consideration of drainage, slope and, in this case, permafrost characteristics, resulting in a terrain stability classification for each polygon. Classes I, II and III are considered stable, Class VI is considered potentially unstable, and Class V is considered unstable.

3.3.1 Mapping Protocols and Attributes

PECG completed all mapping based on field-calibrated interpretations of high-resolution digital aerial photography and LiDAR-derived elevation data, using softcopy photo-interpretation workstations with either

DAT/EM Summit Lite or PurVIEW software packages. Polygon delineation was completed at a scale of 1:10,000 within the 37 km^2 area encompassing the proposed mine site and at a scale of 1:20,000 within the 27 km^2 access corridor, which aligns with YESAB's expectations for "large scale" geohazards assessment associated with the environmental assessment process (Guthrie and Cuervo, 2015). The previous terrain analysis map prepared for the mine area of the KZK Project by KP (2016a) was reviewed, and relevant data were incorporated and refined as necessary for terrain stability mapping purposes.

Terrain stability polygons were delineated primarily based on the YGS' adaptation of the Terrain Classification System for British Columbia (Howes and Kenk, 1997) and the Mapping and Assessing Terrain Stability Guidebook (BC Ministry of Forests, 1999). A User's Guide to Terrain Stability Mapping in British Columbia (J.M. Ryder and Associates, Terrain Analysis Inc., 2002) and A Guide for Management of Landslide-Prone Terrain in the Pacific Northwest (BC Ministry of Forests, 1994) were also consulted. Certain refinements were made based on unique conditions encountered in the study area and to better meet project-specific objectives (e.g., the geomorphological process of 'debris flood' was attributed as '-Rt'). Explicit consideration was also given to the distribution and the relative depth and ice contents of permafrost, given its pronounced influence on ground stability.

Terrain stability polygons were delineated with consideration for seven main attributes, each of which is defined below, in addition to the terrain stability classes described in Section 3.3.2. Complete explanations and descriptions of attribute values are available on the terrain map and its cover page of code definitions (Map 1, **Appendix A**).

- **Surficial Material** – e.g., morainal (till) deposits (M), colluvial deposits (C), fluvial deposits (F)

  This attribute defines the surficial material present and its depositional (genetic) origin. The surficial material represents the core element of a particular terrain unit and label.

- **Surface Expression** – e.g., veneer (v), blanket (b), terrace (t)

  This attribute refers to the form, or pattern of forms, expressed by the surficial material. Up to three surface expressions describe a particular surficial material, in order of decreasing relevance.

- **Texture** – e.g., silt (z), sand (s), mixed angular fragments (x), gravel (g)

  This attribute refers to the size, sorting and shape of the particles comprising the surficial material. Standardized textures were assigned to all polygons, including those not investigated in the field, based on typical conditions observed at field sites and documented in previous investigations in the region (e.g., Bond and Plouffe, 2002). Such an approach is consistent with textural characterization in YGS' surficial geology mapping (Lipovsky and Bond (compilers), 2014) and aids standardization of terrain units. Up to three textures describe a particular surficial material, in order of increasing proportion[5].

[5] *This convention is used in place of YGS' opposite convention – in order of decreasing proportion – due to its consistency with verbal description (e.g., sgF is a sandy gravel fluvial deposit dominated by gravel).*

- **Geomorphological Process** – e.g., gully erosion (-V), thaw flow slide (-Xf)

  This attribute refers to geomorphological processes that are either occurring, or have occurred, within a polygon. Up to three geomorphological processes and respective subclasses can be identified, in order of decreasing relevance to the polygon.

- **Drainage Class** – e.g., well drained (w), imperfectly drained (i), poorly drained (p)

  This attribute refers to the speed and extent to which water is removed from the soil in relation to additions. It considers both the rate at which water is able to be removed from an area as a result of landscape characteristics (e.g., slope), and the permeability of the surficial materials themselves. In this study area, drainage class is strongly influenced by the depth to permafrost, where present. Drainage class is represented by a single value, or a range between two values with the dominant class listed first.

- **Relative Ice Content of Permafrost in Surficial Material** – e.g., ice-rich (r), ice-moderate (m), ice-poor (p), no permafrost (n)

  This attribute refers to the relative volumetric ice content of permafrost, interpreted based on field observations of ground ice in different hydrogeomorphic settings, and on applicable results from test pitting, geotechnical drilling and thermistor installations (Golder, 1996; KP, 2016a,c,d, 2017). Implicit is an initial interpretation of whether permafrost is present within surficial material, only present at depth (i.e., below at least a few metres) within overburden or underlying bedrock and relatively insensitive to road/facility construction or climate change over the mine life (*no permafrost*), or altogether absent (*no permafrost*). Permafrost classifications were defined conservatively at the polygon scale, based on site-specific indicators, but do not necessarily indicative the presence of continuous permafrost within the polygon. In polygons that exhibit stratigraphic relationships, the classification considered the relative ice content of permafrost within the underlying material if within a few metres of ground surface and potentially sensitive to project-related or climatic disturbance. This attribute is not based on precise thresholds of ice content, but instead distinguishes areas relatively and according to forms of ground ice. *Ice-poor* permafrost is inferred to contain little to no visible (pore) ice; *ice-moderate* permafrost is inferred to contain thin seams and/or small, isolated lenses of segregated ice; and *ice-rich* permafrost is inferred to contain large accumulations of segregated ice in the form of interconnected seams, lenses and/or massive bodies. The terms ice-poor, ice-moderate and ice-rich are used throughout the report and on Map 1 (**Appendix A**).

- **Slope Class** – e.g., 2 (gentle, 6-26%), 4 (moderately steep, 50-70%)

  This attribute refers to the dominant range in slope steepness based on the slope-defined surface expressions in Howes and Kenk (1997). Slope class was visually assigned based on a five-level raster model of slope class generated from the LiDAR-derived elevation data that were smoothed using a roaming box-average of 5 m.

Additional point and linear features too small to be mapped as polygons were identified using on-site symbols. Examples include thermokarst ponds (point) and slope failures (line). Whether or not processes represented by on-site symbols were also included in the polygon's terrain label depended on the proportional area of the polygon that is affected by the process. For example, a single gully did not necessarily require inclusion of the gullying process in the polygon label.

3.3.2 Terrain Stability Classification

Terrain stability mapping in British Columbia typically involves the assignment of a single terrain stability class to each polygon, in order to provide a relative ranking of the likelihood of a landslide occurring after timber harvesting or road construction (BC Ministry of Forests, 1999). This protocol yields a map depicting terrain stability classes after a disturbance – for example, following road construction – but does not readily distinguish the stability of polygons in the absence of disturbance. The hazards posed by a slope above (or below) a facility/road and unaffected by facility/road construction (i.e., potential effects of the environment on the Project), for example, could be inaccurately represented on this type of conventional terrain stability map. It is particularly important to differentiate terrain stability classes for both the existing baseline and disturbed conditions in this landscape of discontinuous permafrost, some of which is ice-rich and prone to thermokarst activity. As such, both *existing* and *disturbed* terrain stability classes were assigned to each polygon to enable accurate evaluation of risks posed locally and by hazards upslope or downslope of the proposed infrastructure.

In addition to considering the potential influence of project-related construction on terrain stability, Coregeo and Associates also considered the potential effects of climate change on stability conditions, recognizing that a variable landscape response is expected. Climate change is already driving observed degradation of permafrost throughout Yukon, and it is expected to continue. Benkert et al. (2015) demonstrate that even a modest 1-2 ºC increase in mean annual air temperature in Ross River is likely to thicken the active layer to a point where the probability of encountering permafrost in a given area is reduced by 20%. Localized and widespread degradation of permafrost is expected primarily as a result of climatic warming, but also through changes in precipitation patterns and the frequency of lightning strikes, which can initiate wildfires that alter ground thermal regimes. Although the proposed mine has an expected operational life of approximately ten years (plus construction and closure phases), Coregeo and Associates has conservatively assumed that some of the projected implications of climate change will advance sufficiently to influence terrain stability and hazards. The persistence of certain infrastructure components of the project into perpetuity, such as reclaimed waste rock piles, also necessitates a longer-term perspective on the implications of climate change. While the influence of climate change on permafrost terrain is the most obvious linkage, consideration was also given to the more conventional influence of increased precipitation on slope stability in permafrost-free areas when classifying disturbed stability conditions.

The *'existing terrain stability'* class represents current conditions (summer 2017), in the absence of any major project-related activity or projected climate change effects. The *'disturbed terrain stability'* class represents conditions following disturbance to ground conditions from road/facility construction without mitigation and/or in response to projected climate change effects (**Table 3-1**). The context for the polygon-specific disturbed stability class is specified as project-related construction, climate change or both. Whether or not an increase in the stability class is warranted between the existing and disturbed scenarios depends on the interpreted magnitude of the potential effect of the disturbance. Conservatively, the disturbed stability class assumes typical cut-and-fill road construction without any measures to mitigate potential instability on steep slopes or from disturbance to permafrost with excess ice. Stripping or compaction of organics, and only regular surface water management, would be typical disturbances. Full details for both the existing and disturbed terrain stability classes are provided on the mapping of terrain stability and hazards and the cover page of code definitions (Map 2 (**Appendix B**) and Map 3 (**Appendix C**)). Acknowledgment of the ways in which BMC plans to address hazards typical of disturbed terrain stability classes of III and IV is provided in Section 6. This section also specifies the measures planned to mitigate risks identified for specific mine infrastructure footprints and sections of the existing/proposed access road.

Further modifications to the conventional terrain stability classes used in British Columbia were necessary to accommodate the potential for instability related to thermokarst processes. If overlooked in the siting and design of project infrastructure, thermokarst could significantly increase infrastructure maintenance costs and potentially affect worker safety through its influence on ground stability (McGregor et al., 2010; Guthrie and Cuervo, 2015). Therefore, the assignment of terrain stability classes additionally considers the inferred presence or absence of ice-moderate or ice-rich permafrost (as shown on the cover page of the mapping of terrain stability and hazards (Map 2 (**Appendix B**) and Map 3 (**Appendix C**)). Each disturbed terrain stability class is qualified according to its main category of hazard process consideration: slope, thermokarst or both.

The disturbed terrain stability class was also qualified according to the influential type of disturbance: project-related construction, climate change, or both. This distinction enables users to determine where the Project has the potential to affect terrain stability, which in turn could affect the nearby environment.

Table 3-1. Terrain stability classification system developed for the KZK Project

Symbol	Class	Condition	Interpretation: Existing (current conditions)	Interpretation: Disturbed (following disturbance to ground conditions from climate change and/or road/facility construction without mitigation)	Common terrain characteristics*: Existing (current conditions)	Common terrain characteristics*: Disturbed (following disturbance to ground conditions from climate change and/or road/facility construction without mitigation)
I	stable	permafrost	No significant stability problems.		Planar to gently sloping till veneer with ice-poor permafrost.	Planar to gently sloping till veneer with ice-poor permafrost.
		no permafrost			Planar to gently sloping bedrock, till and active fluvial units; glaciofluvial terraces.	
II	generally stable	permafrost	Very low likelihood of slope instability.	Very low likelihood of slope instability; no thermokarst subsidence or thermal erosion expected.	Gently sloping till and fluvial units; moderately steep bedrock; glaciofluvial mantles over ice-rich till.	Gently sloping till or colluvium with ice-poor permafrost.
		no permafrost	Very low likelihood of slope instability.		Gently to moderately sloping till, colluvial, fluvial and glaciofluvial units; moderately steep bedrock.	
III	generally stable with minor potential for instability	permafrost	Low to moderate likelihood of slope instability.	Low to moderate likelihood of slope instability and/or minor thermokarst subsidence or thermal erosion possible.	Moderately to moderately steep sloping till and colluvial blankets; gently sloping till and colluvial units exhibiting significant solifluction.	Gentle to moderately sloping till and colluvial units with ice-moderate permafrost; ice-rich till units overlain by glaciofluvial material.
		no permafrost	Low to moderate likelihood of slope instability.		Moderate to moderately steep till, colluvial and glaciofluvial units.	
IV	potentially unstable	permafrost	Expected to contain areas with a high likelihood of slope instability.	Expected to contain areas with a high likelihood of slope instability and/or moderate thermokarst subsidence or thermal erosion.	Moderately steep till and colluvial units with ice-rich permafrost.	Gentle to moderately sloping till and colluvial units with ice-rich permafrost; moderately steep to steeply sloping till and colluvial units.
		no permafrost	Expected to contain areas with a high likelihood of slope instability.		Till and colluvial units on moderately steep to steep slopes.	
V	unstable	permafrost	Expected to contain areas with a very high likelihood of slope instability and/or thermokarst activity; may or may not exhibit evidence of previous slope failure and/or thermokarst activity.	Expected to contain areas with a very high likelihood of slope instability and/or major thermokarst subsidence or thermal erosion; typically exhibits evidence of previous slope failure and/or thermokarst activity.	Any unit with evidence of slope failure and/or thermokarst subsidence or thermal erosion.	Any unit with evidence of slope failure; moderately steep and steep till scarps with ice-rich permafrost.
		no permafrost	Expected to contain areas with a very high likelihood of slope instability; typically exhibits evidence of previous slope failure.		Any unit with evidence of slope failure; typically occur on moderately steep to steep slopes.	

** Common characteristics are broad generalizations and may differ from individual polygons where site-specific attributes were considered.*

3.4 Hazard Identification

The type and distribution of mass movement (slope failure) and thermokarst hazards within the study area were identified using geomorphological process codes (polygon label), on-site symbols (point or linear features) and terrain characteristics (Map 2 (**Appendix B**) and Map 3 (**Appendix C**); see Section 4.2 for hazard process descriptions). Mass movements involve the downslope transport of material, such as soil and/or rock, under the influence of gravity. Mass movements may or may not be associated with water, snow or ice[6]. Landslide terminology used in this report follows the standards defined by Hungr et al. (2014), a recent update to the classic classifications established by Varnes (1978) and Cruden and Varnes (1996), which describe the process as well as the type of material involved in the mass movement. Where two modes of failure contribute to movement, terminology was assigned based on the apparent dominant mode.

Where more accurate representation of the role of permafrost was required, refinements to standardized landslide terminology were made based on the multi-language glossary of permafrost and related ground-ice terms (van Everdingen, 2005), which is consistent with the approach applied in the regional characterization of landslides along Yukon's Alaska Highway corridor (Huscroft et al., 2004). For example, permafrost environments also uniquely include active-layer detachments, thermokarst subsidence, thermokarst gullying/erosion and solifluction, each of which is described below (Section 4.2). Slopewash (sheetwash) is also described, as it is widespread in permafrost terrain along the access road corridor, although it does not in itself constitute a hazard.

Each polygon was broadly categorized according to its dominant hazard potential in order to clearly depict the nature of the hazard governing the terrain stability class of each polygon. One of three hazard categories was used: 1) slope failure potential is dominant; 2) thermokarst potential is dominant; and 3) slope failure and thermokarst potential are co-dominant. A hatch pattern was overlaid to indicate the 'applicable hazard category' in mapping of terrain stability and hazards (Map 2 (**Appendix B**) and Map 3 (**Appendix C**)). This designation does not indicate whether or not the polygon exhibits any evidence of such hazards; the geomorphological process codes or on-site symbols serve that purpose. The 'slope failure potential is dominant' category is the default, thus all units that do not pose a thermokarst hazard (e.g., gentle, ice-poor colluvium and even flat, permafrost-free fluvial plains) are represented by this category. A terrain unit generally must exhibit ice-rich permafrost to be considered for the 'thermokarst potential is dominant' category. Polygons with ice-rich permafrost and slope classes of 3 or higher are candidates for the 'slope failure and thermokarst potential are co-dominant' category. Thermokarst potential was generally considered within the upper surficial material; in map units exhibiting stratigraphy, however, subsurface materials were also considered where the overlying material was interpreted as sufficiently thin that project-related construction and/or climate change could affect underlying permafrost (e.g., glaciofluvial veneer overlying ice-rich till).

A generalized characterization was made of the nature of the hazard posed by different geomorphological processes – in terms of likelihood, magnitude and project considerations – based on review of historical aerial photography in conjunction with field observations and professional experience in the region.

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[6] *Snow avalanches were not included in this description of mass movement processes because there is no mappable evidence (e.g., vegetation patterns) of their occurrence within the study area; small loose snow or slab avalanches may occur on moderate to steep slopes in wind-loaded alpine areas.*

3.5 Risk Evaluation

All mapped, credible hazards to the Project, whether related to slope, thermokarst processes, or both, were identified for subsequent risk evaluation. The results provide a basis for site-to-site comparisons, with respect to potential implications, and for considering and prioritizing mitigation requirements. The proposed footprints of each main component of mine infrastructure were overlaid on the terrain stability and hazard maps (Map 2 (**Appendix B**) and Map 3 (**Appendix C**)), such that processes capable of impacting the infrastructure and mine facilities could be identified and evaluated. Segments of the existing/proposed access road at risk from one or more geomorphological processes were identified and evaluated. Equal consideration was given to mapped hazards defined by polygons, lines and points. In order to appropriately focus attention and potential follow-up efforts, only those polygons with disturbed terrain stability classifications of IV or V were considered to pose credible risks worthy of site-specific evaluation.

Coregeo and Associates developed a qualitative 'risk matrix' that facilitates combined evaluation of the likelihood and potential consequence of occurrence (**Figure 3-1**). The relative thresholds of 'likelihood' and 'consequence' have been established with practical implications in mind, enabling BMC to more effectively prioritize sites for follow-up investigation and mitigation. The likelihood classes consider expected, approximate timeframes within which a particular mass movement may occur (or recur), with respect to the expected lifespan of the mine. The consequence classes consider general maintenance and reconstruction implications for proposed mine infrastructure and the access road. The risk evaluation completed for each site incorporated insight from both the desktop interpretations and the field reconnaissance investigations. A "negligible" likelihood or consequence was assumed to yield a "negligible" risk in all cases.

The full results of the risk evaluations were tabulated (Section 6), with separate evaluations for each distinct type of geomorphological process that may pose a risk to the Project. Spatial or locational information was communicated, where needed, by referencing unique polygon identification numbers (e.g., Poly_ID 123). The outline of the facility footprint or the pertinent segment of the access road was colour-symbolized according to the unmitigated risk, or the highest (most conservative) of multiple unmitigated risks. A determination was made of the residual risk to the Project that can be achieved for each mapped, credible hazard through the assumed implementation of appropriate mitigation measures, which would reduce the likelihood and/or consequence of the hazard.

Table 3.2. Risk evaluation matrix for credible slope and/or thermokarst hazards

RISK EVALUATION MATRIX			**CONSEQUENCE**			
			Negligible	Low	Moderate	High
				Minor road or facility ditch/edge maintenance, necessitating <1 day closure	Road or facility maintenance due to coverage/settlement, necessitating ≥1 day closure	Road or facility damage/collapse, necessitating local reconstruction
LIKELIHOOD	High	Occurrence in <2 years (construction phase)	Negligible	Moderate	High	Very High
	Moderate	Occurrence in 2-15 years (operations & closure)	Negligible	Low	Moderate	High
	Low	Occurrence in >15 years (post-closure)	Negligible	Very Low	Low	Moderate
	Negligible		Negligible	Negligible	Negligible	Negligible

*Note: Risks to proposed mine infrastructure and the access road are symbolized using a purple colour spectrum on Map 3 (**Appendix C**) in order to visibly contrast with the underlying green-to-red terrain stability classifications.*

4. Terrain Description

The main terrain units within the study area are described in the following sections, with text overviews accompanied by a table that summarizes key characteristics and presents typical aerial and ground perspectives (Section 4.1). The areal proportion of the study area occupied by each of the dominant surficial materials is presented in **Figure 4-1**. Active geomorphological processes within the study area that represent potential hazards are described in Section 4.2.

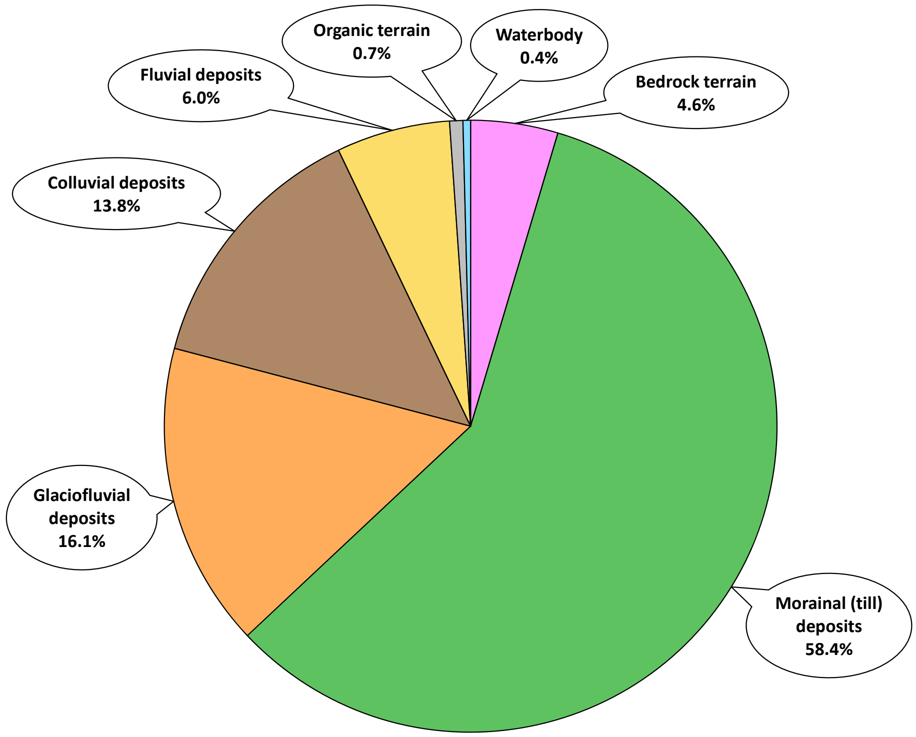


Figure 4-1. Areal proportion (%) of dominant surficial materials within the study area

4.1 Terrain Units

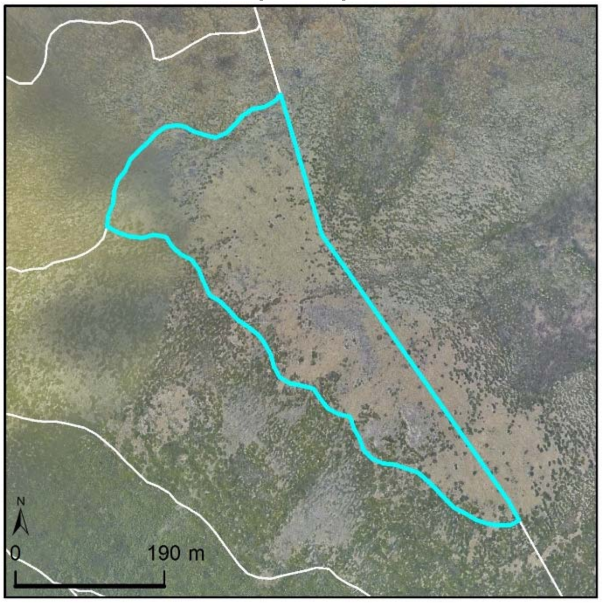
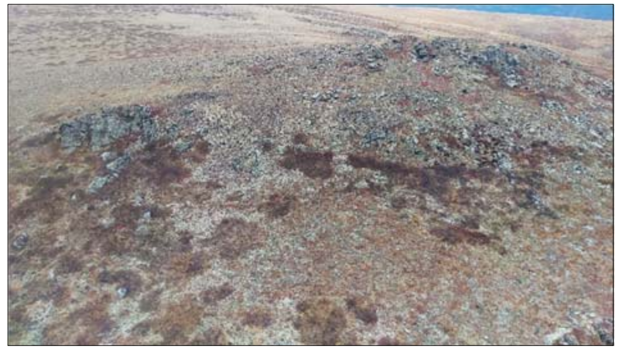
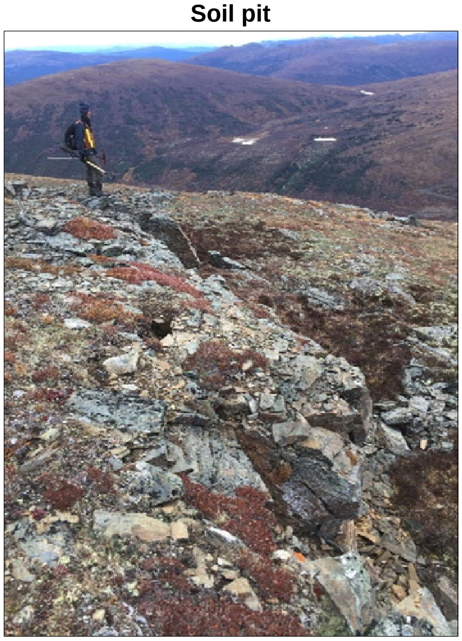
4.1.1 Bedrock Terrain

Bedrock (R) exposure within the study area is limited to isolated outcrops (Rh) along ridges and spurs, mid-slope bluffs (Rs) and stream-cut banks (Rs), overall representing only about 5% of the study area (**Figure 4-1, Table 4-1**). Relatively weak schists that underlie most of the mine area and the southern portion of the access corridor are contrasted by competent limestone that forms prominent outcrops and bluffs along the northern portion of the corridor. The schists, in particular, are weathered in their upper few metres, such that backhoes can generally excavate road cuts by ripping. Bedrock outcrops are commonly ringed by angular fragments that have become detached through frost-shattering and thermal cracking.

Bedrock terrain units may or may not contain permafrost. Where present, it is at depth within weathered or competent bedrock and likely has little potential to contain volumes of ground ice of significance to proposed surface or near-surface development activities[7]. Geomorphological processes within bedrock terrain units are mainly limited to isolated rockfall and nivation.

[7] *Follow-up investigations may be required to assess permafrost conditions within bedrock that will ultimately form the walls of the open pit, in case there is ground ice with potential implications for stability.*

Table 4-1. Typical characteristics of bedrock in the study area[8]

<table>
<tr><th>Map example</th><th colspan="2">Oblique aerial view</th></tr>
<tr><td>
</td><td colspan="2"></td></tr>
<tr><td rowspan="8">Soil pit
</td><td>General distribution</td><td>Summits; ridges and spurs; stream-cut banks</td></tr>
<tr><td>Common terrain units</td><td>Ru/zsdMv, Rs/zsxCv</td></tr>
<tr><td>Dominant processes</td><td>In-situ weathering; rockfall; nivation</td></tr>
<tr><td>Drainage range</td><td>Well to rapid</td></tr>
<tr><td>Dominant slope range</td><td>Gentle to steep</td></tr>
<tr><td>Permafrost</td><td>Absent or at depth within bedrock; ice-poor</td></tr>
<tr><td>Other characteristics</td><td>Weathered schists are easily rippable with an excavator</td></tr>
<tr><td>Hazard considerations</td><td>Localized rockfall; effects of weathering on stability</td></tr>
</table>

[8] Terrain labels and slope classes used in this and all other summary tables in Section 4.1 defined in Howes and Kenk (1997); drainage classes defined in BC Ministry of Forests and Range and BC Ministry of Environment (2010).

4.1.2 Morainal (Till) Deposits

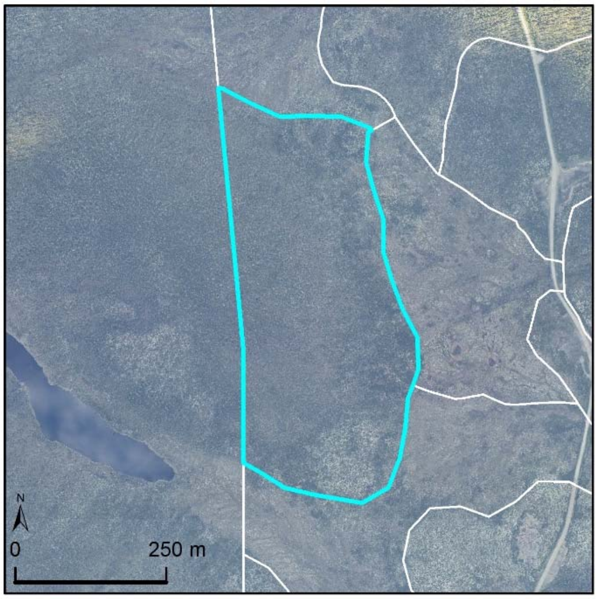
Morainal deposits (M) are accumulations of till, a diamicton deposited directly from glacial ice. Approximately 58% of the study area exhibits till as the dominant surficial material, although this proportion under-represents its actual extent due to the commonness of its burial beneath a mantle of glaciofluvial or colluvial material (**Figure 4-1, Table 4-2**). Most of the till within the study area appears to have been deposited beneath the ice sheet (i.e., subglacial till), although ablation till was likely also deposited in areas of stagnant and down-wasting ice, commonly in association with areas of ice-contact glaciofluvial deposits. Till thicknesses varies greatly. Till veneers (<1 m, Mv) are common around the proposed mine area, especially on rounded ridges and gentle upper slopes. Till thickness generally increases northward, such that blankets (>1 m, Mb) are more common along the road corridor. Most blankets are probably in the order of a few metres thick, based on road cuts, but areas of blankets in excess of 10 m are indicated by exposures in stream-cut banks along the northern portion of the access corridor.

The till within the study area generally has a silty fine sand to fine sandy silt matrix and a low (10-15%) clast content. In some areas, the till has sufficient clay content to be manually rolled to 3 mm without cracking (~plastic limit). Clasts range from granule to boulder in size, and are generally subangular to subrounded. Field observations suggest that the thinner tills around the proposed mine area may be slightly sandier than the thicker tills along the access road corridor.

Permafrost appears ubiquitous in thick (>3 m) till blankets, based on observation of widespread slopewash runnels along portions of the road corridor. Ground ice is inferred to be common and significant in thick tills, based on the extent of thermokarst gullying and first-hand observation of localized seams to interconnected lenses of segregated ice. Permafrost is not typically encountered in comparatively thin till veneers, which are commonly sandier and better drained. Geomorphological processes common to till deposits include slopewash, solifluction, gullying (regular and thermokarst) and active-layer detachments.

Table 4-2. Typical characteristics of morainal (till) deposits in the study area

Map example



Oblique aerial view

Soil pit

General distribution	Broad valleys, rounded summits
Common terrain units	zsdMv, zsdMb-S, zsdMb-Xs
Dominant processes	Slopewash, solifluction, gullying (regular and thermokarst), retrogressive thaw slumps
Drainage range	Poorly to moderately well
Dominant slope range	Gentle to moderate
Permafrost	Extensive and locally ice-rich, especially in thicker blankets
Other characteristics	Commonly veneered or blanketed by glaciofluvial or colluvial deposits
Hazard considerations	At-depth thawing of ice-rich permafrost affects surface

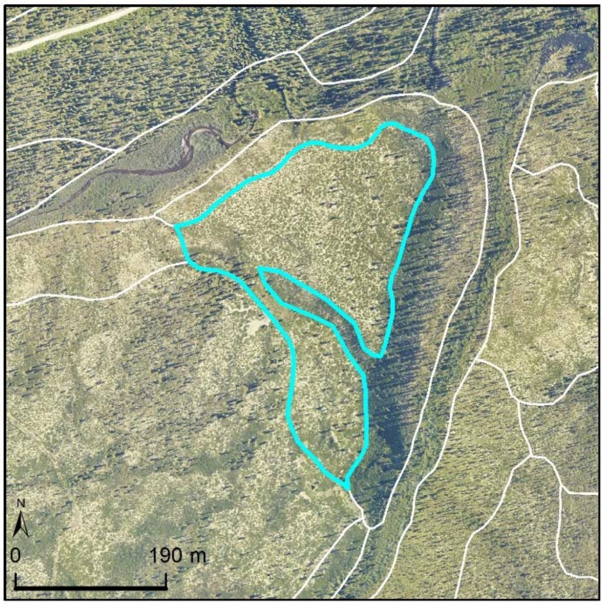
4.1.3 Glaciofluvial Deposits

Glaciofluvial deposits (FG) are the result of sedimentation in flowing glacial meltwater. Glaciofluvial deposits occupy approximately 16% of the study area and are concentrated in a number of locations, locally representing the dominant surficial material (**Figure 4-1, Table 4-3**). Glaciofluvial landforms originate in two distinct settings: ice-contact and proglacial. Both occur within the study area. Large complexes of ice-contact glaciofluvial deposits, forming kame-and-kettle topography, occupy lowland settings at several locations within the study area. Relief of these ice-contact deposits is typically less than a few tens of metres. Eskers (FGr) and hummocky kames (FGh) likely formed in relatively high-energy environments, given their sandy gravel composition. Deposits are clast-supported and dominated by rounded stones. Many of the kames, especially smaller and lower-relief ones, are best described as 'dirty' sand and gravel; they are more poorly sorted, commonly contain a notable silt fraction, and exhibit more subrounded clasts. Outwash deposits (FGt) were deposited in comparatively low-energy environments, based on their better-sorted, gravelly sand composition. Along the northern portion of the access corridor, a veneer to blanket of outwash sediments commonly covers underlying till. Isolated glaciofluvial deposits occur throughout the study area, including within the proposed mine area.

Permafrost is uncommon in glaciofluvial landforms, due to their well-drained, granular composition. Important exceptions occur where glaciofluvial deposits occupy depressions or are relatively thin (e.g., veneer) and overlie a lower-permeability material such as a thick blanket of till. Identification of thermokarst subsidence in areas of glaciofluvial material necessitate consideration be given to underlying materials in cases of only thin surficial coverage. Ice contents are expected to be low in well-drained glaciofluvial deposits. Active, mappable geomorphological processes are uncommon in glaciofluvial landforms, but localized gullying or ravelling may be present.

Table 4-3. Typical characteristics of glaciofluvial deposits in the study area

Map example



Oblique aerial view

Soil pit

General distribution	Valley bottoms, benches
Common terrain units	sgFGr, gsFGt, gsFGv
Dominant processes	Localized gullying
Drainage range	Well to rapid
Dominant slope range	Level to moderately steep
Permafrost	Uncommon and ice-poor, where present
Other characteristics	Well-drained scarps prone to ravelling if undercut by creek erosion or exposed in steep road cuts
Hazard considerations	Instabilities in underlying material may affect surface

4.1.4 Colluvial Deposits

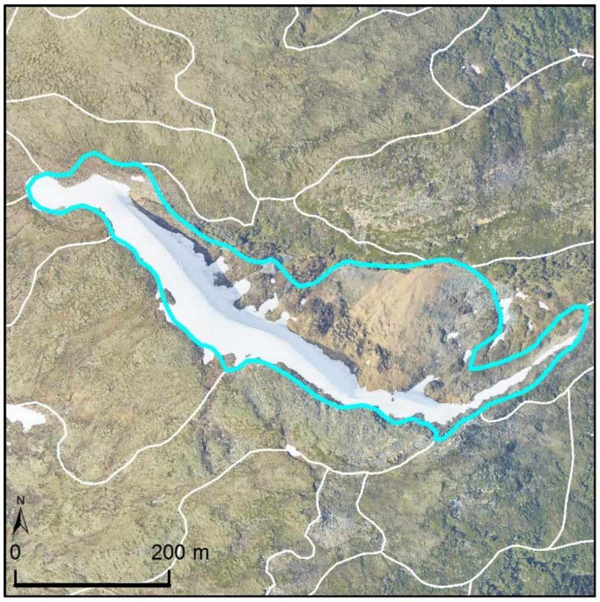
Colluvium (C) is material that has been transported and subsequently deposited by gravity. Minor colluviation (e.g., soil creep) is widespread throughout the study area on gentle to moderate slopes. Colluvial materials are most pronounced and mappable within approximately 14% of the study area (**Figure 4-1, Table 4-4**). Colluvial veneers (<1 m, Cv) are widespread on moderately steep to steep slopes, exhibiting evidence of downslope movement of materials. In some areas, veneers of colluvium overlie another material such as till instead of bedrock. In these cases, a stratigraphic relation is expressed in the terrain unit label (e.g. Cv\Mb). Colluvial veneers are mainly encountered on mountainsides within the proposed mine area. Colluvial blankets (>1 m, Cb) and aprons (Ca) are more common on lower slopes and at prominent concave slope-breaks, respectively. Thicker colluvial deposits generally contain more silt and are less well drained. The eastern valley side near the proposed open pit exhibits a conspicuous colluvial apron at its base.

Colluvial materials derive their properties largely from the materials from which they originate. Therefore, colluvium derived primarily from weathered bedrock in the study area tends to be angular, clast-supported granules to large blocks, with a matrix of silty sand. Bedrock-derived colluvium is generally well-drained and permafrost-free. Colluvium derived primarily from the downslope movement of till tends to exhibit subrounded to angular clasts supported within a silty sand matrix, much like its parent material but with a looser, less compact structure. Where sufficiently thick and silty, colluvial deposits contain permafrost. Colluvium commonly exhibits crude stratification parallel to the slope, including buried organic horizons, indicating the incremental movement and layering of materials downslope.

Colluviation occurs through a variety of processes within the study area, including both slow and rapid mass movements. Areas of soil creep (ubiquitous and unmapped), rockfall, and debris slides and flows (including active-layer detachments and retrogressive thaw slumps) have been observed. Solifluction is also a conspicuous form of downslope movement of material on mountainsides, although terrain units exhibiting mappable solifluction generally retain their original material classification (e.g., till) unless lobes are pronounced and thick or particularly elongated downslope (in which case they are generally mapped as colluvial materials). Periglacial processes influence and accelerate colluviation through mechanisms such as nivation and slopewash.

Table 4-4. Typical characteristics of colluvium in the study area

Map example



Oblique aerial view

Soil pit

General distribution	Mountainsides, stream-cut scarps
Common terrain units	zsxCv, zsdCb, zsdCv\zsdMb-S
Dominant processes	Soil creep (unmapped), debris slides, debris flows, rockfall
Drainage range	Imperfect to well
Dominant slope range	Moderate to steep
Permafrost	Uncommon and ice-poor, where present
Other characteristics	May be crudely stratified, influenced by periglacial processes
Hazard considerations	Recurrence potential, runout limits

4.1.5 Fluvial Deposits

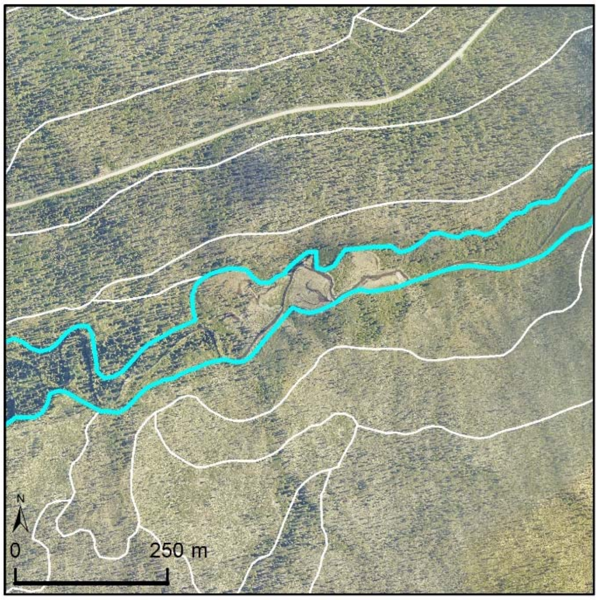
Fluvial deposits (F) have been transported and subsequently deposited by modern (post-glacial) streams. Fluvial deposits invariably occur along modern creeks and localized widenings along their tributary drainages, representing <1% of the study area (**Figure 4-1, Table 4-5**). Most of the Geona and Finlayson Creek valley bottoms are mapped as active fluvial plains (FAp), which exhibit sinuous to irregularly meandering channels within a level floodplain and localized organic cover. Remnants of former channel deposits, now perched above the floodplain, are mapped as terraces (Ft). Several active fluvial fans (FAf) from tributaries project into the floodplains, indicating that material deposition from the tributaries is outpacing the erosional capacity of the main creeks. Some of the tributary drainages and even the slopewash runnels descending the gentle valley sides exhibit evidence of fluvial transport and deposition; as such, they have been mapped as having fluvial veneers (FAv).

The grain size distribution of fluvial deposits is a function of the source material and the channel morphology, namely energy gradient (slope). Most fluvial deposits within the study area are a mixture of subrounded to rounded, pebble- to cobble-sized clasts along the active channel and interbedded silt, sand and organics in adjacent floodplain areas. Fluvial fan deposits tend to be coarser gravels and have a lower silt fraction, mainly due to the comparatively steeper gradient than on plains. Evidence of beaver activity is widespread along the bottoms of both main creeks; many of the small on-line or riparian ponds may actually relate to former beaver activity. Open meadows have established in areas once impounded by beaver dams, and clusters of dead or dying trees are commonly a sign of drowning behind existing or former beaver dams.

Permafrost is generally inferred to be absent within fluvial deposits within the study area based on previous geotechnical investigations (e.g., KP, 2016c,d), a consistently high groundwater table along the valley bottoms (indicated by vegetation communities and slope-toe springs), and an absence of evidence of thermokarst activity. There is sufficient flow within the active channels and through-flow of water within permeable fluvial sands and gravels, even during winter, to inhibit freezing and at least maintain a talik. Exceptions occur in some inactive floodplains and terraces covered with organic material. Geomorphological processes are mainly meander migration, irregularly sinuous channelling and localized (beaver dams) and seasonal (freshet) inundation of floodplain areas.

Table 4-5. Typical characteristics of fluvial deposits in the study area

Map example



Oblique aerial view

Soil pit

General distribution	Valley bottoms, tributary drainages
Common terrain units	zsgFAp-M, zsgFt, zsgFAf
Dominant processes	Meander migration, irregularly sinuous channel, inundation
Drainage range	Imperfect to well
Dominant slope range	Level to gentle
Permafrost	Generally absent or at depth below
Other characteristics	Irregular channel and floodplain morphology may reflect former beaver activity
Hazard considerations	Bank erosion, bed down-cutting, avulsion potential, beaver dam outbursts

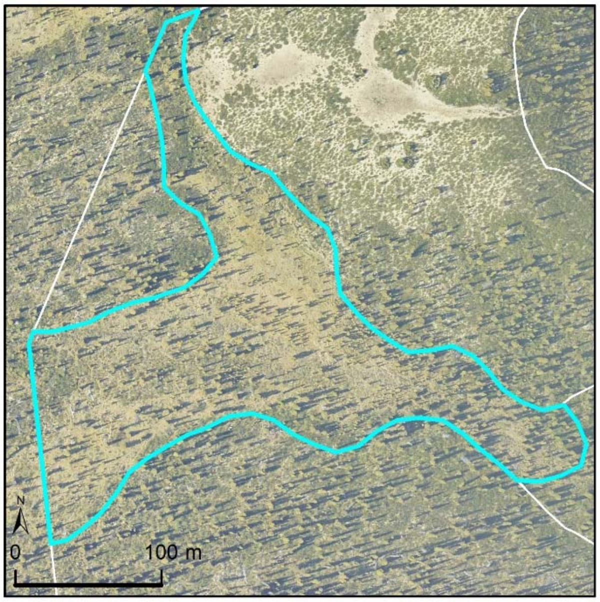
4.1.6 Organic Terrain

Organic terrain (O), composed of peat and muck, occurs wherever organic material has accumulated with thicknesses of at least half a metre. Organic material accumulates in poorly drained areas where water slows the decomposition of plant matter, generally in closed depressions, in riparian zones or on gentle ground with a thin active layer (shallow permafrost). Mappable organic terrain represents <1% of the study area (**Figure 4-1, Table 4-6**). The thickness of organic material is variable, and generally expected to be less than a metre or two. KP (2016a), however, notes one of the test pits near the proposed Lower Water Management Pond penetrating more than 5 m of organics. Organic terrain is mapped as veneers (<1 m, Ov), blankets (>1 m, Ob) or plains (Op), depending on the inferred thickness and relation of the organic surface to underlying topography.

Organic material can be described according to its general degree of decomposition: fibric (poorly decomposed), mesic (moderately decomposed) or humic (well decomposed). All three degrees of decomposition occur within the study area, although fibric to mesic decomposition predominates. Organic soils (>40 cm) were encountered in many areas where there was no seepage or particular wetness at the bottom of hand-dug soil pits, possibly reflecting thickening of the active layer or end-of-summer conditions when the groundwater table is relatively low.

Organic terrain is commonly associated with permafrost, especially in areas rich in peat. Peat has highly insulative properties, and inhibits penetration of warm summer temperatures. Organic terrain may be ice-rich, especially where it overlies thick deposits of till. Few mappable geomorphological processes occur in organic terrain, except thermokarst in some areas.

Table 4-6. Typical characteristics of organic terrain in the study area

<table>
<tr><th>Map example</th><th colspan="2">Oblique aerial view</th></tr>
<tr><td>
</td><td colspan="2"></td></tr>
<tr><td rowspan="8">Soil pit
</td><td>General distribution</td><td>Closed depressions, riparian zones, lower slopes with shallow permafrost</td></tr>
<tr><td>Common terrain units</td><td>euOv, euOb, euOp</td></tr>
<tr><td>Dominant processes</td><td>Seasonal inundation, thermokarst</td></tr>
<tr><td>Drainage range</td><td>Very poor to poor</td></tr>
<tr><td>Dominant slope range</td><td>Level to gentle</td></tr>
<tr><td>Permafrost</td><td>Common, shallow and locally ice-rich</td></tr>
<tr><td>Other characteristics</td><td>Lack of wetness in organic soils may indicate thickening of active layer</td></tr>
<tr><td>Hazard considerations</td><td>Compressible soils, episodic and seasonal inundation, thermokarst potential</td></tr>
</table>

4.2 Active Geomorphological Processes

A variety of geomorphological processes were mapped within the study area, including erosional, fluvial, mass movement, periglacial, deglacial and hydrologic processes (Howes and Kenk, 1997). Subclasses of these primary processes were distinguished where necessary to more accurately represent different potential hazard characteristics and implications. Only active processes that may represent hazards are detailed below. Complete descriptions for these and other mapped, non-hazard processes (e.g., cryoturbation, nivation) are available in Howes and Kenk (1997).

4.2.1 Rockfall (-Rb)

Rockfall is the rapid detachment, fall, rolling and bouncing of rock fragments (Hungr et al., 2014). Rockfall occurrences within the study area are restricted to isolated bedrock bluffs and steep colluvial slopes with bedrock outcrops (**Photo 4-1**). Active rockfall zones are recognized by the presence of an unweathered patch of bedrock bluff upslope and/or a pile of lichen-free rubbly debris at the base of the bluff. Rockfall is typically recurrent and most likely to occur during periods of freeze-thaw (frost shatter) or rapid and prolonged warming (thermal cracking).

Photo 4-1. Recent rockfall (-Rb) from bluff near upslope limit of proposed Class B Storage Facility

4.2.2 Debris Slides (-Rs)

A debris slide is the slow to rapid sliding of a mass of surficial material on a shallow, planar surface parallel with the ground (Hungr et al., 2014). Debris slides are distinguished from the more specific process of active-layer detachment, which occurs only on slopes underlain by permafrost. Debris slides within the study area most commonly occur on the steep walls of gullies and tributary drainages (e.g., Fault Creek) (**Photo 4-2**) and along steep, south-facing scarps alongside Finlayson Creek.

Photo 4-2. Gullied (-V) scarp prone to debris slides (-Rs) scarp along the north (left) side of Fault Creek

4.2.3 Debris Flows (-Rd)

A debris flow is a very rapid to extremely rapid surging flow of saturated debris in a steep channel (Hungr et al., 2014). Evidence of the occurrence of debris flows within the study area is provided by conspicuous levees that form along the edges of the deposits within the runout zones (**Photo 4-3**). Most are small, short-travelled (<100 m runout) and initiate on steep slopes at high elevations within remnant till deposits or highly weathered bedrock. Although not explicitly mappable, evidence of debris flows was also noted in deep thermokarst gullies incised into moderately steep valley walls.

Photo 4-3. Recent debris flow (-Rd) deposit with levees on alpine slopes west of the mine site area

4.2.4 Debris Floods (-Rt)

A debris flood is a very rapid flow of water, heavily charged with debris, in a steep channel (Hungr et al., 2014). Peak discharges are comparable to those of water floods. Sediment transport rates during debris floods far exceed normal bed material movement through rolling and saltation, but still rely on the tractive forces of water. Debris floods can transport large quantities of sediment onto their fans, such has been documented historically on the Fault Creek fan (KP, 2016a and this study) (**Photo 4-4**). Debris floods likely initiate along the narrowly confined lower reaches of Fault Creek, following saturation and mobilization of material that accumulates behind temporary dams on the creek bed caused by debris slides from the gullied sidewalls. Debris floods cause sudden aggradation on fan surfaces, which commonly infills channels and triggers an avulsion with a different distributary trajectory. Unlike a debris flow, a debris flood usually does not develop high impact forces (Hungr et al., 2014).

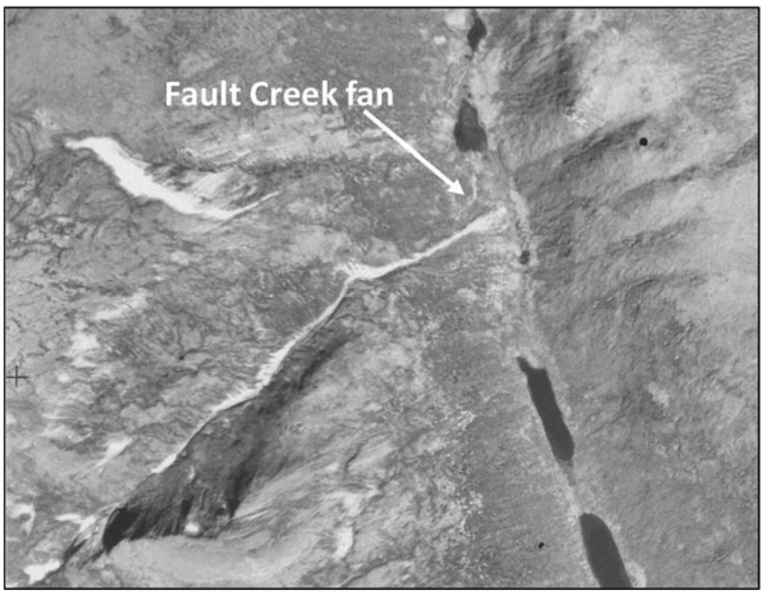


Photo 4-4. Fresh debris flood (-Rt) deposit on Fault Creek fan in 1949 aerial photography

4.2.5 Rock Creep (-Fg)

Rock creep is the slow movement of angular debris under periglacial conditions (Howes and Kenk, 1997). Within the study area, rock creep occurs in subalpine to alpine areas with exposed or thinly covered weathered bedrock, especially on northerly aspects. It is recognized by flow-like patterns on lower talus slopes or by a conspicuously irregular, undulating slope typified by patches of fresh talus amongst intact and weathered bedrock (**Photo 4-5**). Slopes prone to rock creep are likely only slightly sensitive to surface disturbance, due to their skeletal and typically ice-poor composition.

Photo 4-5. Flow-like pattern on lower talus slope indicative of rock creep (-Fg)

4.2.6 Gullying (-V)

Gullying is the modification of unconsolidated (surficial material) and consolidated (bedrock) surfaces by various processes such as surface runoff, mass movement and snow avalanching, resulting in the formation of parallel and sub-parallel long, narrow ravines (Howes and Kenk, 1997). The gullying process has been applied to terrain units (polygons) that exhibit such morphology to an extent that distinguishes them from surrounding, more uniform slopes (e.g., **Photo 4-2**). Gullies occur in all surficial materials and on bedrock slopes, typically elevating the potential for instability. Most gullies are formed through fluvial incision over millennia and, in some cases, may be subject to debris flows. The most conspicuous gullies are delineated on the maps with line symbols.

4.2.7 Solifluction (-S)

Solifluction is the slow (mm/yr to cm/yr, Price, 1991; Matsuoka, 2001; Kinnard, 2003), downslope movement of saturated, non-frozen overburden across a frozen or otherwise impermeable substrate. More accurately, in this study area, gelifluction is the form of solifluction that has generally been mapped due to the movement of material within the active layer on the permafrost table. Solifluction occurs most commonly on convex northerly slopes veneered or blanketed in colluvium in subalpine or alpine environments within the study area. Both solifluction lobes and terraces are present and active within the study area, particularly on northerly aspects (**Photo 4-6**). The solifluction lobes that typify this form of mass movement may comprise silty to fine sandy material rich in organics or clast-rich material bound together by ground ice. Solifluction slopes have generally been mapped as having ice-poor or ice-moderate, shallow permafrost.

Photo 4-6. Solifluction (-S) lobes and terraces on gentle slope above the Class C Storage Facility

4.2.8 Thaw flow slides (-Xf)

An active-layer detachment, referred to more generically for mapping purposes by Howes and Kenk (1997) as a "thaw flow slide", is a shallow form of debris slide that occurs within the active layer on top of the permafrost table (**Photo 4-7**). Active-layer detachments typically occur in response to intense or prolonged rainfall or snowmelt, high air temperatures, or surface disturbances (e.g., wildfire, windthrow, abnormal drainage concentration, anthropogenic ground disturbance). Active-layer detachments exhibit widespread occurrence throughout the study area, but are restricted to initiation on slopes underlain by permafrost. They initiate on gentle to steep slopes, commonly just above a convex roll much like a snow avalanche. They have runout distances of up to a few hundreds of metres and can transport woody vegetation and underlying colluvial material from ridge shoulders to slope-toe aprons. Following their initial occurrence, permafrost exposed on, or directly beneath, their sliding surface begins to thaw, and the active layer thickens. Continued slides, flows and gullying are common, until active layer thickening ceases. The headscarps of active-layer detachments may migrate retrogressively upslope through gradual thawing and sloughing. The paths of former active-layer detachments are commonly recognized by the anomalous stripe of deciduous trees (e.g., alder, birch) that colonize above the locally depressed permafrost table.

Terrain units (polygons) that exhibit a history of active-layer detachments are assigned this process label (-Xf); discrete failures are also delineated with line symbols. Retrogressive thaw slumps are commonly initiated by small active-layer detachments and have not been separately distinguished due to their small size within the study area.

Photo 4-7. Recent thaw flow slide (active-layer detachment) (-Xf) on mountainside above Finlayson Creek

4.2.9 Thermokarst Subsidence (-Xt)

Thermokarst subsidence is the formation of ground-surface depressions created by the thawing of ice-rich permafrost and associated soil subsidence (Howes and Kenk, 1997). Terrain units (polygons) inferred to have ice-rich permafrost are generally susceptible to thermokarst, although the form and severity of such thermokarst also depends on material properties, depth to permafrost and the form of ground ice. The melting of massive ice bodies produces the most conspicuous thermokarst depressions, which may or may not contain standing water. Thermokarst occurs naturally, such as in response to windthrow or wildfire, but is accelerated through anthropogenic disturbance to surface organic cover and drainage patterns. Thermokarst subsidence is most common in valley bottoms and on benches on gentle valley sides. **Photo 4-8** reveals thermokarst slumping along the shoreline of a pond adjacent to the access road near KM 5.5. Discrete thermokarst subsidence features, whether or not filled with water, are mapped using point symbols.

Photo 4-8. Leaning trees and collapsing bank indicative of thermokarst subsidence (-Xt) along shoreline of pond adjacent to access road near KM 5.5

4.2.10 Thermal Erosion (-Xe)

Thermal erosion is the process of gully formation initiated by heat transfer from water bodies, typically flowing streams, to underlying permafrost. Thermal erosion can also occur due to heat transfer along the shorelines of standing water bodies. Thermokarst gullies are commonly distinguished by anomalously low width-to-depth ratios, indicative of relatively rapid incision into ice-rich permafrost, and tension cracks along the crests of their side walls. Trees growing along the edges of such gullies gradually tilt inward toward the gully; straight trunks that have not had an opportunity to adjust their growth habitat upward are indicative of relatively rapid gully enlargement (**Photo 4-9**). Retrogressive erosion of thermokarst gullies is common and can lengthen gullies that initiate on over-steepened slope toes by orders of magnitude upslope.

Within the study area, thermal erosion is most commonly associated with ice-rich, thick deposits of till with or without a mantle of glaciofluvial material. Natural and anthropogenic alterations in surface runoff patterns, especially where surface runoff becomes concentrated, can trigger thermal erosion. Significant thermal erosion, forming gullies, was mapped using line symbols. **Photo 4-9** shows a remarkable case of thermal erosion along a thermokarst gully that crosses the access road near KM 5.8. Surface runoff concentrated along the gully bottom has formed a cavernous entrance to a 40 m-long tunnel up to a few metres in diameter beneath the ground surface.

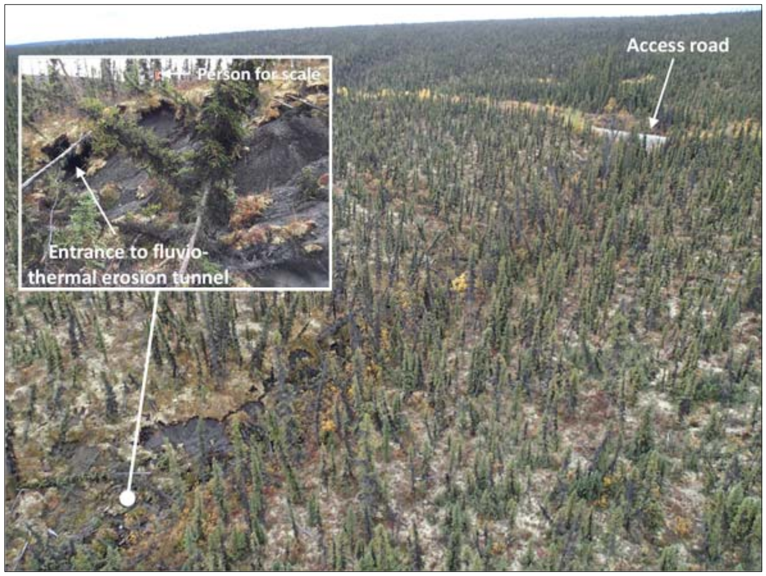


Photo 4-9. Severe thermal erosion and gullying (-Xe) along a stream crossed by the access road at KM 5.8

4.2.11 Slopewash (-Xs)

Slopewash, sometimes referred to as sheetwash, is the mobilization and redistribution of fine material by water flowing down the surface or within the shallow subsurface of smooth slopes that are typically underlain by permafrost. Slopewash exhibits widespread occurrence in permafrost terrain, but is most prevalent on slopes demarcated by downslope, parallel to sub-parallel runnels also known as water tracks (**Photo 4-10**). Such slopes that are distinguishable on the basis of these runnels have been mapped with this process label (-Xs). The runnels are readily distinguished by the growth of dwarf willows, which contrast with surrounding dominance of dwarf birch. The concentration of surface runoff in slopewash runnels leads to local depression of the permafrost table, which in some cases can trigger thermal erosion. Slopewash runnels require consideration in drainage management strategies along roadways, as their thicker active layer allows seepage to continue well into winter, when icing ("glaciation") can develop and block culverts.

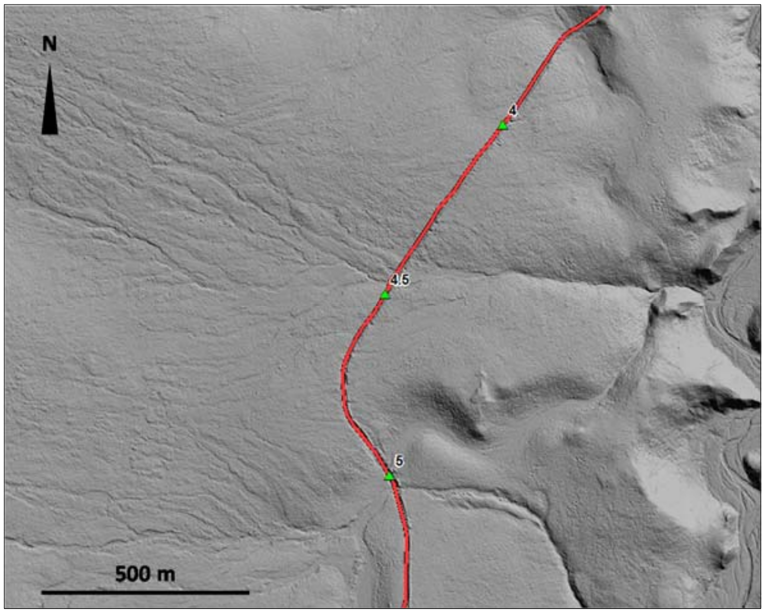


Photo 4-10. LiDAR-derived bare earth hillshade of slopewash (sheetwash) (-Xs) runnels on gentle till slope with permafrost between KM 4 and 5 of the access road

4.2.12 Meander Migration (-M) and Irregularly Sinuous Channels (-I)

Much of the existing access road parallels Finlayson Creek, which exhibits meander migration (-M) and irregularly sinuous channels (-I) along the bottom of its deeply incised valley (**Photo 4-11**). Finlayson Creek is crossed once before the final ascent toward the proposed mine area. Stream channels adjust their planform geometry naturally through bank erosion and meander processes including loop extension, down-valley migration and cut-off (avulsion). Meander migration must be accounted for when sections of road are proposed to cross or encroach alongside sizable creeks, or where mine infrastructure footprints on or immediately adjacent to valley bottoms may be exposed to such a hazard. Anthropogenic disturbances can accelerate bank erosion through perturbations to natural channel patterns.

Photo 4-11. Floodplain of Finlayson Creek exposed to meander migration (-M)

5. Terrain Stability and Hazards

5.1 Terrain Stability

As discussed in Section 3.3.2, each polygon was attributed with an 'existing' or 'disturbed' stability class. The terrain stability mapping (Map 2) in **Appendix B** reveals that the majority (68%) of the study area has an existing terrain stability class of 'generally stable' (Class II) (**Figure 5-1**). This is expected given the gentle slopes that predominate on lower valley sides and in upland areas. Approximately 4% of the study area is considered 'potentially unstable' (Class IV, <1%) or 'unstable' (Class V, 4%), mostly represented by moderately steep, gullied, valley wall scarps and areas of permafrost already exhibiting thermokarst activity.

The disturbed terrain stability class is defined in terms of the worst case scenario of ground disturbances in association with conventional cut-and-fill road construction, without any mitigation measures to address potential instabilities related to permafrost or sidecast on steep slopes. This allows for the establishment of improved baseline references, and better highlights areas that warrant special design consideration. This approach for communicating terrain hazard conditions enables engineers responsible for designing the mine facilities and access road to make more informed and site-specific decisions about appropriate construction techniques. Furthermore, it allows project risk assessments to be specifically tailored to different circumstances.

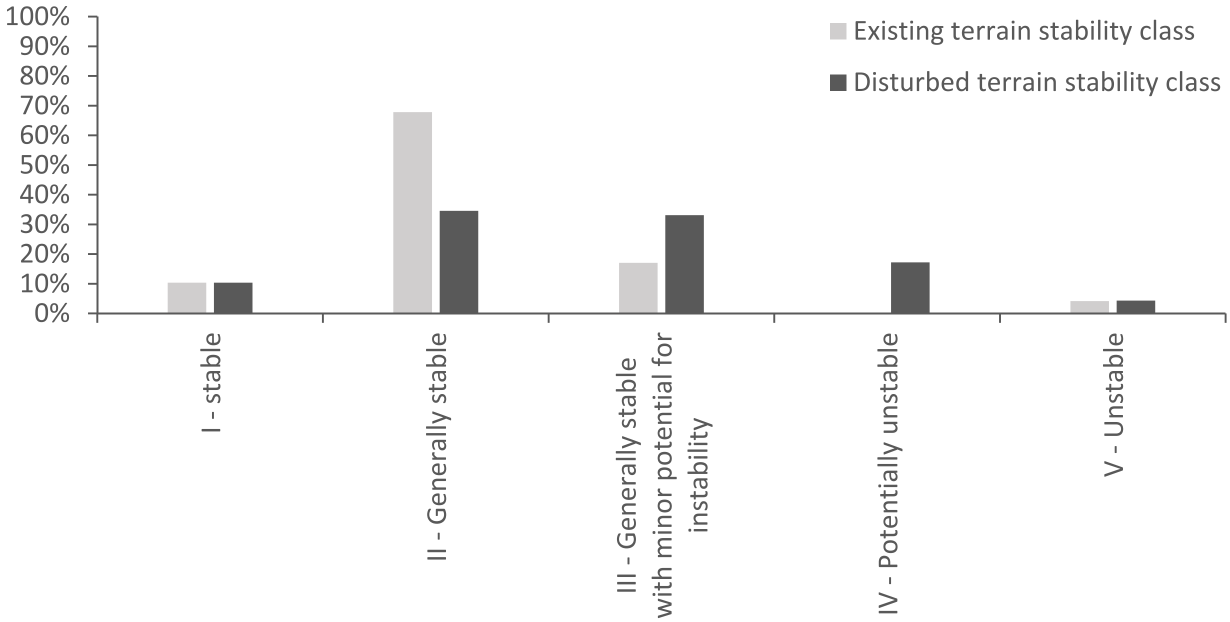


Figure 5-1. Histogram of proportional areal coverage of existing and disturbed terrain stability classifications in the study area

According to the disturbed terrain stability class, the proportion of terrain stability polygons with a 'generally stable' (Class II) rating drops from 67% (existing) to 35% (disturbed) (**Figure 5-1**). Many of these polygons become 'generally stable with minor potential for instability' (Class III, 33%) or 'potentially unstable' (Class IV, 17%) if disturbed without mitigation. This notable increase in terrain stability class reflects the sensitivity of permafrost terrain to disturbance, which can initiate or exacerbate active-layer detachments and thermokarst.

The distinction between existing and disturbed terrain stability classes allows accurate representation of potential upslope (e.g., active-layer detachments) or downslope (e.g., thermal erosion) hazards that are unaffected by proposed infrastructure footprints. This format of mapping distinguishes natural hazards, which may be triggered by occurrences such as wildfire, from those potentially exacerbated or initiated by project-related disturbance. For example, a particular polygon crossed by the proposed road may have a disturbed terrain stability class of IV (potentially unstable). Its existing terrain stability class, however, may only be II (generally stable). Therefore, the potential hazard posed by terrain conditions within this polygon could be recognized as being appreciably lower if the road passes beneath it than if it crosses it.

Each disturbed terrain stability class was qualified according to the main influential types of disturbance. Project-related construction, without mitigation, is projected to be the main driver of terrain instability in approximately 54% of the study area. Approximately 45% of the study area is sensitive to both project-related construction and climate change. Waterbodies comprise the remaining 1% of the study area. Identification of disturbance type does not necessarily indicate that this disturbance is projected to increase the terrain stability class from the existing to the disturbed condition, as the projected responses of many map units are minor (within a given stability class). No map units were classified as only being sensitive to climate change.

5.2 Hazards Overview

The mapping of terrain (Map 1, **Appendix A**) and terrain stability and hazards (Maps 2 (**Appendix B**) and 3 (**Appendix C**)) collectively identifies various forms of hazards through the assignment of geomorphological process codes (polygon-scale) and discrete geomorphological processes (point or linear features), in addition to the actual terrain stability classes. **Table 5-1** outlines the likelihood and potential magnitude of hazard occurrence over the mine life, generalized according to each of the identified hazards within the study area. Project considerations are also included in order to better communicate the implications of different processes for infrastructure design and future maintenance requirements. Site-specific hazards with the potential to affect each of the proposed components of mine infrastructure are characterized below in association with the risk assessment (Section 6).

5.3 Slope Failure and Thermokarst

As discussed in Section 3.4, each polygon was more broadly categorized according to its dominant potential hazard – slope failure, thermokarst or both – in order to highlight those areas where thermokarst activity is possible in addition to the default instability related to slope failure. This hazard category is not intended to represent the existence or imminence of thermokarst (or slope failure); its aim is to rule out certain areas from the possibility of thermokarst activity. ‘Thermokarst potential’ dominates the applicable hazard category within approximately 34.8% of the study area (**Figure 5-2**). Such areas are generally characterized by gentle or moderate slopes with ice-moderate or ice-rich permafrost. The potential for thermokarst outweighs the much lower possibility of slope failure in these areas. Approximately 10.6% of the study area has been categorized co-dominantly with ‘slope failure and thermokarst potential’. Such areas are distinguished from those dominated only by thermokarst potential by their slope class of moderate (class 3) or higher. A category of ‘slope failure potential dominant’ applies to all other areas (54.2%), except anthropogenic and open water areas (not applicable, 0.4%), irrespective of the possibility of slope failure (e.g., fluvial plains).

Hazards may affect the footprints locally (e.g., thermokarst subsidence), upslope (e.g., active-layer detachment running out into or across footprint) or downslope (e.g., retrogressive erosion of thermokarst gullies) of the footprints. The distribution of terrain hazards within and immediately surrounding the footprints of proposed project infrastructure is characterized below in association with the facility-specific risk assessment (Section 6).

Table 5-1. Generalized characteristics and considerations for hazards within the study area

Hazard	Likelihood (over mine life)	Magnitude	Project considerations
Rockfall	Typically recurrent and frequent, where present; freshness of talus at base of bluff indicative of recency	Generally small in volume, but rapid and dense	Plan for rockfall below bluffs, especially in areas of fresh deposits (avoid or mitigate), and on steep slopes with small bedrock outcrops
Debris slide	Most likely to occur on steep slopes exhibiting history of debris sliding, especially within or adjacent to recent scars	Generally small to moderate in volume, but rapid and moderately dense	Avoid debris slide slopes and runout zones, or otherwise manage trajectories
Debris flow	Most likely to occur on steep and/or gullied slopes exhibiting history of debris flows, especially adjacent to recent deposits	Generally small to moderate in volume, but rapid and moderately dense	Avoid debris flow paths and runout zones, or otherwise manage trajectories
Debris flood	Most likely to occur along narrowly confined watercourses with high sediment inputs from adjacent slopes	Generally moderate to large in volume, rapid and moderately dense	Avoid development within the paths or runouts (fans) of debris floods, or otherwise manage trajectories
Rock creep	Periodic movement expected; freshness of patches of rock debris indicative of recency	Small volume, short distance, slow movements of angular rock debris	Expect increased maintenance and allow for minor settlement and shifting of rock debris
Gullying	Periodic and localized gully erosion processes (e.g., fluvial incision, side wall mass wastage)	Generally incremental and localized incision, and minor surface sloughing	Minimize crossings of gullied slopes, especially where underlain by permafrost, and expect increased maintenance
Solifluction	Near-continuous, incremental movement	Small volume, short distance, slow (mm/yr to cm/yr) movements of silt-rich debris	Expect increased maintenance and allow for minor settlement and shifting of surficial material
Thaw flow slide	Most likely to occur on recently disturbed or burned slopes, slopes with previous failures (including within existing scars), or in steep and/or gullied terrain especially downslope of any sites of newly concentrated surface runoff	Small to moderate in volume; generally rapidly transports organic-rich surficial material tens to hundreds of metres downslope	Avoid slopes that exhibit a history of active-layer detachments, or otherwise accommodate their possible occurrence, minimize disturbance to surface organics and drainage, and expect increased maintenance for debris removal
Thermokarst subsidence	Gradual or periodic settlement, especially in areas of ice-rich permafrost	Isolated, slow deepening of ground surface depressions, formation and expansion of ringing tension cracks, and possible slow, inward slumping	Minimize disturbance to surface organics and drainage in areas of ice-moderate to ice-rich permafrost through appropriate gravel embankments/pads and water management, and expect increased maintenance that could involve localized road reconstruction; consider monitoring settlement
Thermal erosion	Gradual or periodic incision, especially in areas of ice-rich permafrost	Localized, slow, commonly retrogressive incision of rills or gullies, formation and expansion of adjacent tension cracks, and possible slow, inward slumping	Avoid or minimize concentrating surface runoff in areas of ice-moderate to ice-rich permafrost, especially into pre-existing gullies, and expect increased maintenance that could involve localized road reconstruction; consider monitoring incision
Slopewash	Seasonal slopewash and transport of fine sediments within runnels; near-continuous seepage	Localized, slow transport of fine sediments, and seepage and icing especially in runnels	Accommodate seepage-induced icing accumulation especially within intercepted runnels, expect increased maintenance due to fine sediment delivery adjacent to road, and manage downslope drainage
Meander migration & irregularly sinuous channels	Episodic erosion of banks, mainly along the outside of meanders, in association with high flow events	Destabilization of road or crossing structures by incremental erosion or undercutting and slumping	Accommodate natural meander migration processes, where possible, by maintaining setbacks appropriate to the site; otherwise, proactively protect the road from erosion using appropriately sized riprap or alternative measures

Note: Mapped geomorphological processes that are inactive (e.g., meltwater channelled) or do not represent hazards (e.g., cryoturbation) are not included.

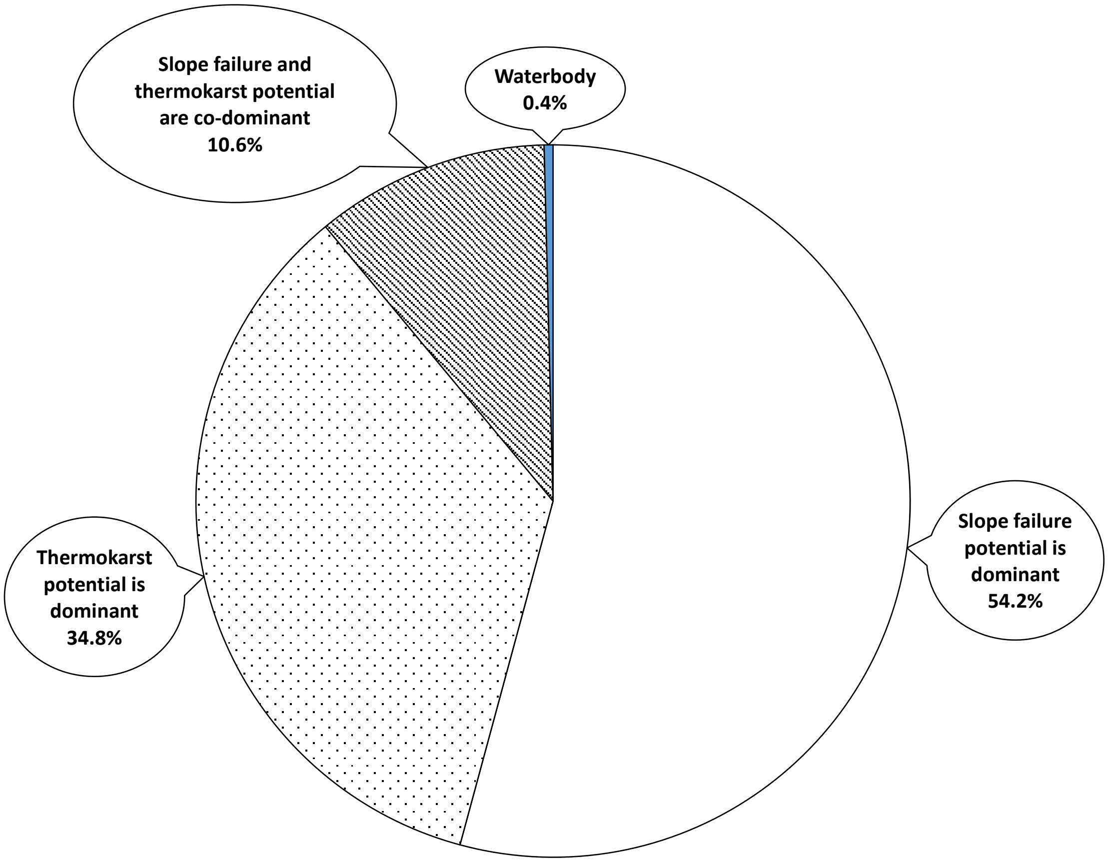


Figure 5-2. Areal proportion (%) of applicable hazard categories in the study area (symbolization matches overlays on terrain stability/hazards maps)

5.4 Other Hazard Considerations

Several other processes were noted as potential hazards through the mapping process, but delineation of their limits requires site-specific investigation and analysis of detailed hydrological and topographic data beyond the scope of this assessment:

- **Icing** – Icing, commonly referred to as ‘glaciation’, is the accumulation of ice (aufeis) during winter along streams and large slopewash runnels that receive near-continuous groundwater seepage from unfrozen portions of active layers or adjacent permafrost-free ground (**Photo 5-1**). Icings form through the accretion of layers of ice, attaining thicknesses of up to several metres and widths of several tens of metres, depending on site topography. Icings within the study area likely initiate mid-autumn and may persist well into spring where thickest and most shaded. Staff at the KZK Project camp report having to break up or melt ice that accumulates within, and blocks, a few culverts along the existing access road. Large accumulations of aufeis along stream beds and low-lying areas of floodplains can also increase the width (and height) of flooding if intense rainfall or snowmelt occurs before the ice has thinned and broken up. Allowances should be made in the design of crossings of icing-prone drainages for both the formation and failure of aufeis, as well as potential flooding in excess of that predicted by regular hydrological analysis.

Photo 5-1. Example of icing spanning the bottom of a headwater drainage in central Yukon

- **Flooding and Beaver Dam Effects** – Sections of road that cross or follow low-lying areas alongside modern streams may be subject to temporary flooding (inundation) during intense or prolonged rainfall or snowmelt. Small ice jams, which can also significantly raise water levels, could exacerbate flooding. Riparian vegetation patterns and soil profiles provide indicators of the approximate limits and frequency of flooding. In general, map units attributed with "meander migration" (-M) or "irregularly sinuous channels" (-I) geomorphological processes exhibit broad floodplains prone to flooding. As alluded above in Section 3.1, consideration should also be given to the possibility of flooding from beaver dams, both upstream within areas of potential inundation and downstream following a sudden breach and outburst. Geona Creek exhibits a history of beaver activity, including along its headwater reaches such as in the vicinity of the proposed water management ponds (**Photo 5-2**). Evidence includes (i) breached beaver dams (woody debris and mud exposed in creek banks); (ii) floodplain-spanning, arcuate patterns in vegetation (e.g., willows) elevated slightly from the surrounding, poorly drained ground; and (iii) anomalous clearings supporting wet meadow vegetation of similar species and age, indicative of areas formerly inundated behind beaver dams.
- **Creek Bed Degradation and Aggradation** – Degradation, also known as channel down-cutting, is the lowering of stream bed elevation due to erosion overwhelming deposition at a reach scale. Aggradation, or channel infilling, is the raising of stream bed elevation due to deposition outpacing erosion at a reach scale. Both degradation and aggradation along streams may pose hazards to crossing structures (e.g., culverts or bridges) if not recognized and accommodated in the design. Degradation can lead to undermining of abutments, potentially destabilizing crossing structures, and perching of culverts. Aggradation can reduce the hydraulic capacity of the channel or crossing structures by partial infilling, which in turn can increase the frequency of overbank flooding and the potential for road overtopping.

Photo 5-2. Cascade over breached beaver dam near proposed water management ponds

6. Risk Evaluation and Mitigation Measures

An evaluation of the credible risks posed to the Project by specific hazards was completed according to the procedure described above in Section 3.5. The term, credible risk, is used to distinguish scenarios that warrant special consideration due to the nature of the associated hazard(s) in a particular area, from scenarios that should be satisfactorily addressed through planned construction methods and related best management practices. For example, risks related to road upgrades or realignment in permafrost-free areas (commonly terrain stability classes of I, II or III) or in areas of ice-poor or ice-moderate permafrost (commonly disturbed terrain stability classes of II, III or IV) can be addressed through standardized construction techniques expressed in typical cross-sections prepared for the Project by OEL (2016). Risks associated with ice-rich permafrost (commonly a disturbed stability class of IV) warrant additional attention and were preliminarily identified as credible and prioritized for evaluation.

Based on the project-specific risk evaluation matrix (**Table 3-2**), **Table 6-1** presents the systematic risk evaluation applied to each credible hazard posed to the main proposed mine infrastructure footprints. **Table 6-2** presents the same evaluation for the existing/proposed access road. The risks reported in both tables represent an *unmitigated* condition. Opportunities to mitigate the risks, which are either recommended or already planned in association with mine development and operations (noted, where applicable), provide a means of reducing risks to acceptable, residual levels.

Table 6-1. Evaluation of risks posed by terrain hazards to proposed mine infrastructure

Facility	Hazard	Hazard Description	Likelihood (unmitigated)	Consequence (unmitigated)	Risk (unmitigated)	Mitigation Opportunities	Likelihood (mitigated)	Consequence (mitigated)	Residual Risk (mitigated)
Open Pit The two-part open pit is proposed in the centre of the valley at the headwaters of Geona Creek. The pit walls will extend upward until they meet the existing ground surface within the valley bottom or on either valley side. It is assumed that any existing hazards within the footprint of the open pit do not pose any risks, given that the ground on which they occur will be fully stripped and then removed during mining operations. The focus is on hazards adjacent to the open pit that could pose risks to mining operations within or immediately adjacent to the pit. NOTE: There are no notable risks to (1) the adjacent paste plant, which is proposed to be situated in a gentle draw with thin (<1 m) overburden without permafrost (and well beyond the maximum runouts of small debris flows observed at the head of the draw); (2) the pit rim pond, which is proposed to be situated on the valley bottom on an alluvial plain punctuated by a remnant glaciofluvial terrace; or (3) the spur roads that access the pit entrance.	Active-layer detachments & retrogressive thaw slumping (-Xf)	The eastern portions of both portions of the open pit extend up the eastern valley side, crossing map units where active-layer detachments have recently occurred (Poly_IDs 426 and 499). One of the active-layer detachments initiated immediately above an exploration road cut. As mining operations proceed and the pit limits expand outward, there is a potential for similar active-layer detachments to occur naturally or in response to exposure of permafrost and the implicit alteration of drainage patterns that follows. More broadly, there is potential for retrogressive thaw slumping of ice-moderate till and colluvium freshly exposed along the eastern and western rims of the pit (Poly_IDs 403, 409, 426 and 499). *Active-layer detachments and retrogressive thaw slumping could transport material over the rim of the pit, thereby posing a risk to mining operations immediately within or adjacent to the pit rim.*	Moderate	Moderate	Moderate	Construct a berm along the upslope perimeter of the open pit in order to divert or accommodate localized mass movements, or extend the area of stripping slightly beyond the rim of the open pit, so that any localized mass movements terminate before entry.	Moderate	Negligible	Negligible
	Solifluction (-S)	Two small edges of the westernmost portion of the open pit footprint extend onto a moderate slope blanketed in till that exhibits solifluction (Poly_ID 403). Ongoing solifluction could deposit material inside the rim of the pit, albeit at a rate that <u>does not constitute a risk</u>.	High	Negligible	Negligible	N/A	High	Negligible	Negligible
	Debris floods (-Rt)	The southern portion of the open pit extends well into the map unit representing the large, active alluvial fan at the mouth of Fault Creek (Poly_ID 461), which drains a mountainous basin west of Geona Creek. In addition to being prone to normal (clearwater) floods, Fault Creek also exhibits a history of recurrent debris floods. A debris flood that transported and deposited gravels to the maximum limits of the alluvial fan along two distributary channels occurred between 1986 and 1992, based on comparison between historical aerial photographs. This is consistent with a minimum age of 21 years derived dendrochronologically from the tallest willow in the cleared path of the flood event. Earlier events appear to have occurred along similar paths prior to 1949 (the earliest available aerial photograph). Debris floods likely occur during intense/prolonged rainfall events following saturation and sudden mobilization of in-channel debris that has accumulated from frequent debris slides originating along the steep gully sidewalls. *Debris floods (and normal floods) pose a risk to operations within the open pit, given their potential to deposit large volumes of water and sediment in the pit within a short timeframe.*	Moderate	High	High	Construct a diversion ditch and berm (as planned, Drawing C560, KP, 2016b), beginning at the apex of the fan, to divert floods/sediment into the abandoned channel west of the current channel, thereby minimizing cut/fill requirements. Sufficient cross-sectional area must be available in the excavated diversion channel to accommodate floodwaters and rapid aggradation along the bed.	Moderate	Negligible	Negligible

Facility	Hazard	Hazard Description	Likelihood (unmitigated)	Consequence (unmitigated)	Risk (unmitigated)	Mitigation Opportunities	Likelihood (mitigated)	Consequence (mitigated)	Residual Risk (mitigated)
Class A Storage Facility The facility is proposed with its upper limit near treeline.on the middle to upper slope of the western valley side of upper Geona Creek. NOTE: There are no notable risks to the collection pond at the base of the facility, or to the spur roads accessing it.	Solifluction (-S)	All of the map units encompassing the facility footprint exhibit veneers of till and/or colluvium on gentle to moderate slopes. One map unit along the upper edge of the facility, south of the meltwater channel, exhibits evidence of minor solifluction over ice-poor permafrost or bedrock (Poly_ID 331). The gradual build-up of material against or on top of the western perimeter of the facility is less of a concern than the potential for mine waste placed on the soliflucting till to eventually creep downslope. *Continued solifluction at the base of the mine waste poses a long-term (post-closure) risk to the integrity and surface form of the facility, due to the potential for slow creep of mine waste within portions of the facility.*	Moderate	Low	Low	Pre-strip overburden (as planned, AEG, 2017) at least within the areas of minor solifluction and/or be prepared to monitor and maintain the facility surface such that any localized creep does not impact the management of surface runoff. Ensure upslope surface and near-surface runoff (active layer or to bedrock) are diverted around the facility (as planned, AEG, 2017), in order to inhibit water entry.	Negligible	Low	Negligible
Class B Storage Facility The facility is proposed with its upper limit near treeline on the middle to lower slope of the western valley side of upper Geona Creek. NOTE: There are no notable risks to the Mill Site or collection pond at the base of the facility, or to the spur roads accessing it.	Thermokarst subsidence (unmapped; potential only)	Two map units within the upper third of the facility footprint are blanketed in till inferred to have a moderate ice content (Poly_IDs 403 and 409). Till containing seams or small lenses of ground ice has the potential to settle irregularly, albeit likely only modest (<1 m) amounts, if the ground thermal regime changes and the ice thaws. *Potential differential settlement following degradation of ice-moderate permafrost at the base of the mine waste poses a risk to the surface form of the facility.*	Moderate	Low	Low	Pre-strip overburden (as planned, AEG, 2017) at least within the areas of ice-moderate permafrost and/or be prepared to monitor and maintain the facility surface such that surface runoff is managed. Ensure upslope surface and near-surface runoff (active layer or to bedrock) are diverted around the facility (as planned, AEG, 2017), in order to inhibit water entry and retention.	Negligible	Low	Negligible

Facility	Hazard	Hazard Description	Likelihood (unmitigated)	Consequence (unmitigated)	Risk (unmitigated)	Mitigation Opportunities	Likelihood (mitigated)	Consequence (mitigated)	Residual Risk (mitigated)
	Solifluction (-S)	Two map units within the upper third of the facility footprint that are veneered by colluvium (Poly_ID 405) or blanketed by till (Poly_ID 403) exhibit solifluction. The gradual build-up of material against or on top of the western perimeter of the facility is less of a concern than the potential for mine waste placed on the soliflucting material to eventually creep downslope. *Continued solifluction at the base of the mine waste poses a long-term (post-closure) risk to the integrity and surface form of the facility, due to the potential for slow creep of mine waste within portions of the facility.*	High	Low	Moderate	Pre-strip overburden (as planned, AEG, 2017) at least within the areas of solifluction and/or be prepared to monitor and maintain the facility surface such that any localized creep does not impact the management of surface runoff. Ensure upslope surface and near-surface runoff (active layer or to bedrock) are diverted around the facility (as planned, AEG, 2017), in order to inhibit water entry.	Negligible	Low	Negligible
Class C Storage Facility The facility is proposed within a hanging valley that enters the Geona Creek valley from the east. NOTE: There are no notable risks to the collection pond at the base of the facility, or to the spur roads accessing it.	Solifluction (-S)	The northern and central thirds of the footprint are underlain by well drained till veneers to blankets and glaciofluvial landforms with no notable hazards. Conspicuous solifluction slopes, exhibiting both lobe and terrace forms, descend the north-facing valley side into the southern portion of the footprint (Poly_IDs 427, 428 and 432). The gradual build-up of material against or on top of the southern perimeter of the facility is less of a concern than the potential for waste rock placed on the soliflucting till to eventually creep downslope. *Continued solifluction at the base of the placed waste rock poses a long-term (post-closure) risk to the integrity and surface form of the facility, due to the potential for slow creep of waste rock within portions of the facility.*	High	Low	Moderate	Pre-strip overburden containing permafrost with excess ice and/or design the facility such that it anticipates and accommodates minor solifluction, depending on the results of site-specific investigations to support engineering design. Maintain positive surface drainage to discourage infiltration and water retention. Ensure upslope surface and near-surface runoff (active layer or to bedrock) are diverted around the facility (as planned, AEG, 2017), in order to inhibit water entry.	Negligible	Low	Negligible

Facility	Hazard	Hazard Description	Likelihood (unmitigated)	Consequence (unmitigated)	Risk (unmitigated)	Mitigation Opportunities	Likelihood (mitigated)	Consequence (mitigated)	Residual Risk (mitigated)
Upper Water Management Pond The pond is situated on the valley bottom of upper Geona Creek. NOTE: The spur road paralleling the eastern shoreline of the pond traverses the same map units and thus is exposed to the same hazards.	Active-layer detachments & retrogressive thaw slumping (-Xf)	The proposed shoreline traverses the base of the eastern valley side, which is covered by a veneer of colluvium overlying moderately sloping till inferred to contain ice-moderate permafrost (Poly_IDs 304 and 309). Inundating the lower valley sides will saturate unfrozen surficial materials (e.g., active layer), and initiate or accelerate permafrost degradation, both of which promote mass movement. Several, small active-layer detachments have occurred near the base of the eastern valley side, within and immediately up-valley of the proposed dam footprint. Although all the active-layer detachments were short-travelled, having maximum runouts of <10 m, they were up to 40 m wide and have locally triggered degradation of ice-moderate permafrost. This degradation has resulted in thickening of the active layer and minor upslope retrogression of the headscarp through thaw slumping. *This existing combination of active-layer detachments and retrogressive thaw slumping, which could be exacerbated following inundation, poses a risk to the stability of the dam through its effects on foundation materials and the possibility of overtopping by a displacement wave generated by a small mass movement (although any displacement waves from typical permafrost-related failures are likely to be small, rapidly attenuated and readily accommodated by the much larger pond). Excessive sedimentation could occur in the pond due to gradual thawing and erosion of shoreline materials, necessitating increased maintenance.*	High	Moderate	High	Pre-strip all overburden with permafrost (to bedrock or competent, ice-free material) within the pond and dam footprints, and extend stripping along the pond perimeter/berm, including the immediate upslope area. Ensure the dam foundation is keyed into competent, ice-free material. Monitor and manage (as required) the stripped areas above the pond perimeter/berm for deposition of localized mass movements. Where required, implement spur road construction techniques specifically designed for ice-rich permafrost (as per OEL, 2016). All mitigations identified above are planned by BMC (pers. comm., 2017).	Negligible	Moderate	Negligible

Facility	Hazard	Hazard Description	Likelihood (unmitigated)	Consequence (unmitigated)	Risk (unmitigated)	Mitigation Opportunities	Likelihood (mitigated)	Consequence (mitigated)	Residual Risk (mitigated)
Lower Water Management Pond The pond is situated on the valley bottom of upper Geona Creek. NOTE: The spur road paralleling the eastern shoreline of the pond traverses the same map units and thus is exposed to the same hazards.	Active-layer detachments & retrogressive thaw slumping (-Xf)	The proposed shoreline traverses the base of the eastern valley side, which is covered by a veneer of colluvium overlying moderately sloping till inferred to contain ice-moderate permafrost (Poly_IDs 304 and 309), and the base of the western valley side, which is covered by a blanket of till also inferred to have moderate ice content (Poly_ID 290). Inundating the lower valley sides will saturate unfrozen surficial materials (e.g., active layer) and initiate or accelerate permafrost degradation, both of which promote mass movement. Several, small active-layer detachments have occurred along the base of both valley sides, below and along the proposed shoreline. Although all the active-layer detachments were short-travelled, having maximum runouts of <20 m, they were up to 70 m wide and have locally triggered degradation of ice-moderate permafrost. This degradation has resulted in thickening of the active layer and minor upslope retrogression of the headscarp through thaw slumping. *This existing potential for active-layer detachments and retrogressive thaw slumping, which could be exacerbated following inundation, poses a risk to the stability of the dam through its effects on foundation materials and the possibility of overtopping by a displacement wave generated by a small mass movement (although any displacement waves from typical permafrost-related failures are likely to be small, rapidly attenuated and readily accommodated by the much larger pond). Excessive sedimentation could occur in the pond due to gradual thawing and erosion of shoreline materials, necessitating increased maintenance.*	High	Moderate	High	Pre-strip all overburden with permafrost (to bedrock or competent, ice-free material) within the pond and dam footprints, and extend stripping along pond perimeter/berm, including the immediate upslope area. Ensure the dam foundation is keyed into competent, ice-free material. Monitor and manage (as required) the stripped areas above the pond perimeter/berm for deposition of localized mass movements. Where required, implement spur road construction techniques specifically designed for ice-rich permafrost (as per OEL, 2016). All mitigations identified above are planned by BMC (pers. comm., 2017).	Negligible	Moderate	Negligible
Overburden Stockpile The stockpile is proposed midslope on the gentle, southwest-facing valley side of upper Geona Creek. NOTE: There are no notable risks to spur roads accessing the facility.	Thermokarst subsidence (unmapped; potential only)	One map unit encompassing most of the collection pond and a topsoil stockpile immediately downslope, and extending to the base of the facility, exhibits a colluvial veneer overlying a blanket of till inferred to have a moderate ice content (Poly_ID 334). Till containing seams or small lenses of ground ice has the potential to settle irregularly, albeit likely only modest (<1 m) amounts, if the ground thermal regime changes and the ice thaws. *Potential differential settlement following degradation of ice-moderate permafrost at the base of the stockpiled topsoil/overburden and the collection pond poses a risk to the surface form of the facilities.*	Moderate	Low	Low	Pre-strip overburden containing permafrost with excess ice and/or be prepared to monitor and maintain the facility surface such that surface runoff is managed as anticipated. Ensure upslope surface and near-surface runoff (active layer or to bedrock) are diverted around the facility (as planned, AEG, 2017), in order to inhibit water entry and retention.	Negligible	Low	Negligible

Facility	Hazard	Hazard Description	Likelihood (unmitigated)	Consequence (unmitigated)	Risk (unmitigated)	Mitigation Opportunities	Likelihood (mitigated)	Consequence (mitigated)	Residual Risk (mitigated)
Process Plant, Water Treatment Facility and Mill Site The facility is proposed on the gentle, lower slope of the western valley side of upper Geona Creek, between the bases of the Class A and B Storage Facilities. NOTE: There are no notable risks to spur roads accessing the facility.	Thermokarst subsidence (unmapped; potential only)	Most of the facility is encompassed by map units characterized as relatively thin till blankets inferred to have moderate ice contents (Poly_IDs 332, 353, 361 and 366). Till containing seams or small lenses of ground ice has the potential to settle irregularly, albeit the materials are so thin in this case that potential settlement <u>does not constitute a risk</u>.	Moderate	Negligible	Negligible	N/A	Moderate	Negligible	Negligible

Table 6-2. Evaluation of risks posed by terrain hazards to the proposed access road (including existing sections)

Kilometre Range	Hazard	Hazard Description	Likelihood	Consequence	Risk (unmitigated)	Mitigation Opportunities	Likelihood (mitigated)	Consequence (mitigated)	Residual Risk (mitigated)
1.24-1.26	Thermokarst subsidence (-Xt)	The existing/proposed road crosses a narrow portion of a map unit characterized by a thin veneer of fluvial sediments overlying an ice-rich blanket of till (Poly_ID 10). There is already evidence of thermokarst subsidence within the map unit. *The short segment of road is at risk of differential settlement in response to potential degradation of ice-rich permafrost.*	Moderate	Moderate	Moderate	Implement road upgrades with a thick gravel prism (and include an allowance for additional material placement and maintenance), minimal disturbance to adjacent ground, and minimal to no concentration of drainage (e.g., as per the typical cross-section for ice-rich permafrost, OEL, 2016).	Negligible	Moderate	Negligible
3.37-3.41	Thermal erosion (-Xe)	The existing/proposed road crosses the head of a large gully incised through a glaciofluvial cap into a thick blanket of ice-rich till (Poly_ID 46). There is no obvious evidence of active thermokarst gullying within the map unit, but the road crosses the gully at a prominent knickpoint, increasing its susceptibility to impact from possible upstream migration and associated down-cutting of the stream bed. *The short segment of road is at risk of differential settlement and down-cutting through knickpoint migration in response to potential degradation of ice-rich permafrost.*	Low	High	Moderate	Monitor knickpoint position and implement road upgrades with a thick gravel prism (and include an allowance for additional material placement and maintenance), minimal disturbance to adjacent ground, and minimal to no concentration of drainage (e.g., as per the typical cross-section for ice-rich permafrost, OEL, 2016).	Low	Negligible	Negligible
4.37-4.61	Thermal erosion (-Xe)	The existing/proposed road crosses a narrow portion of a map unit characterized by a thick, ice-rich till blanket that exhibits active slopewash and thermokarst gullying (Poly_ID 51). Ponding along the road edge is contributing to permafrost degradation. *The short segment of road is at risk of differential settlement in response to potential degradation of ice-rich permafrost.*	Moderate	Moderate	Moderate	Implement road upgrades with a thick gravel prism (and include an allowance for additional material placement and maintenance), minimal disturbance to adjacent ground, and minimal to no concentration of drainage (e.g., as per the typical cross-section for ice-rich permafrost, OEL, 2016).	Negligible	Moderate	Negligible
4.95-5.04	Thermal erosion (-Xe)	The existing/proposed road crosses a narrow map unit characterized by a thin veneer of fluvial sediments overlying an ice-rich blanket of till. There is already evidence of active thermokarst gullying within the map unit (Poly_ID 59) and an immediately adjacent one (Poly_ID 67), and a road sign approaching the crossing warns of icy conditions (seasonally), which KZK Project camp staff confirmed relates to prolonged seepage onto the road surface. *The short segment of road is at risk of differential settlement in response to potential degradation of ice-rich permafrost.*	Moderate	Moderate	Moderate	Implement road upgrades with a thick gravel prism (and include an allowance for additional material placement and maintenance), minimal disturbance to adjacent ground, and minimal to no concentration of drainage (e.g., as per the typical cross-section for ice-rich permafrost, OEL, 2016).	Negligible	Moderate	Negligible
5.76-5.81	Thermal erosion (-Xe)	The existing/proposed road crosses a thermokarst gully that has incised into the underlying thick, ice-rich till blanket. The gully exhibits active thermokarst gullying, especially downslope of the road crossing where vertical scarps of ice-rich permafrost are exposed and the stream now flows subsurface through a 2 m-diameter 'tunnel' before emerging 40 m farther downslope (Poly_ID 67). *The short segment of road is at risk of differential settlement in response to potential degradation of ice-rich permafrost.*	Moderate	High	High	Implement road upgrades with a thick gravel prism (and include an allowance for additional material placement and maintenance), minimal disturbance to adjacent ground, and minimal to no concentration of drainage (e.g., as per the typical cross-section for ice-rich permafrost, OEL, 2016). As an additional contingency, be prepared to realign the road slightly westward.	Negligible	High	Negligible

Kilometre Range	Hazard	Hazard Description	Likelihood	Consequence	Risk (unmitigated)	Mitigation Opportunities	Likelihood (mitigated)	Consequence (mitigated)	Residual Risk (mitigated)
6.52-7.13	Thermal erosion (-Xe)	The existing/proposed road crosses several contiguous map units characterized by thick deposits of ice-moderate to ice-rich till (Poly_IDs 82, 83 and 88), which locally exhibits thermokarst gullying, particularly downslope of the road where bank collapses are widespread (Poly_ID 83). *The short segment of road is at risk of differential settlement in response to potential degradation of ice-rich permafrost.*	Moderate	Moderate	Moderate	Implement road upgrades with a thick gravel prism (and include an allowance for additional material placement and maintenance), minimal disturbance to adjacent ground, and minimal to no concentration of drainage (e.g., as per the typical cross-section for ice-rich permafrost, OEL, 2016).	Negligible	Moderate	Negligible
7.51-7.56	Thermal erosion (-Xe) (unmapped; potential only)	The existing/proposed road crosses a narrow portion of a map unit characterized by a thick, ice-rich till blanket (Poly_ID 92) that exhibits slopewash and thermokarst gullying a short distance downslope (Poly_ID 93). *The short segment of road is at risk of differential settlement in response to potential degradation of ice-rich permafrost.*	Low	Moderate	Low	Implement road upgrades with a thick gravel prism (and include an allowance for additional material placement and maintenance), minimal disturbance to adjacent ground, and minimal to no concentration of drainage (e.g., as per the typical cross-section for ice-rich permafrost, OEL, 2016).	Negligible	Moderate	Negligible
7.56-7.69	Thermal erosion (-Xe)	The existing/proposed road traverses a gently sloping, thick blanket of till, discontinuously veneered by glaciofluvial sediments (Poly_ID 93). The crest of the scarp that forms the wall of the main incised valley is within 55 m of the road. Several thermokarst gullies descend the valley wall to the floodplain of Finlayson Creek. One of the thermokarst gullies has formed recently and is actively deepening, widening and retrogressing upslope. More than 1 m of ice-rich till, with a visually estimated volumetric ice content of >50%, is exposed in the vertical sidescarp of the gully. The gully has grown from approximately 2 m deep and 20 m wide in the summer of 2016 to approximately 6 m deep and 35 m wide in September 2017. Its headscarp is 55 m from a small CSP culvert that concentrates upslope drainage beneath the road, possibly including active-layer throughflow from the adjacent slopewash polygon. Rapidly thawing permafrost is producing debris flows that have entered Finlayson Creek (Poly_ID 64). *The continued retrogression of this or an adjacent 'dormant' thermokarst gully, or the formation and extension of a new one, poses a risk to the stability of the road.*	Low	High	Moderate	Install additional culverts beneath the road and/or use permeable subgrade material, in order to diffuse the drainage and avoid unnatural concentrations of surface runoff that can initiate or exacerbate thermokarst gullying. Monitor the rate of retrogression of the headscarp toward the road, and, as a contingency, be prepared to realign the road slightly westward (upslope) if necessary. Implement road upgrades with a thick gravel prism (and include an allowance for additional material placement and maintenance), minimal disturbance to adjacent ground, and minimal to no concentration of drainage (e.g., as per the typical cross-section for ice-rich permafrost, OEL, 2016).	Negligible	High	Negligible
8.22-8.30	Thermal erosion (-Xe)	The existing/proposed road crosses a narrow map unit characterized by a thin veneer of fluvial sediments overlying an ice-rich blanket of till (Poly_ID 107). There is possible evidence of thermokarst gullying (bank collapses) downstream of the road, within the better defined gully (Poly_ID 97). *The short segment of road is at risk of differential settlement in response to potential degradation of ice-rich permafrost.*	Low	Moderate	Low	Implement road upgrades with a thick gravel prism (and include an allowance for additional material placement and maintenance), minimal disturbance to adjacent ground, and minimal to no concentration of drainage (e.g., as per the typical cross-section for ice-rich permafrost, OEL, 2016).	Negligible	Moderate	Negligible

Kilometre Range	Hazard	Hazard Description	Likelihood	Consequence	Risk (unmitigated)	Mitigation Opportunities	Likelihood (mitigated)	Consequence (mitigated)	Residual Risk (mitigated)
8.30-8.70	Thermokarst subsidence (-Xt)	The existing/proposed road crosses a map unit characterized by an ice-rich blanket of till, possibly exhibiting the subtle surface expression of ice-wedge polygons (Poly_ID 105). There is early evidence of thermokarst subsidence in the immediate vicinity of the road: tilted, straight trees; hummocky micro-topography; and small ponded areas. *The short segment of road is at risk of differential settlement in response to potential degradation of ice-rich permafrost.*	Moderate	Moderate	Moderate	Implement road upgrades with a thick gravel prism (and include an allowance for additional material placement and maintenance), minimal disturbance to adjacent ground, and minimal to no concentration of drainage (e.g., as per the typical cross-section for ice-rich permafrost, OEL, 2016).	Negligible	Moderate	Negligible
9.05-9.11	Thermokarst subsidence (-Xt) & retrogressive thaw slumping (-Xf)	The existing/proposed road crosses a narrow portion of a map unit characterized by a thin veneer of fluvial sediments overlying an ice-rich blanket of till (Poly_ID 111). There is already evidence of active thermokarst subsidence, four thaw ponds, within the map unit. The 1-3 m-high vertical headscarp of a small retrogressive thaw slump that formed shortly before 2016 is within 0.8 m of the downslope road edge (September 11, 2017), which is at immediate risk of being undercut and collapsing without intervention. Ponded water at the base of the headscarp has at least partly accumulated from the thawing of underlying ice-rich permafrost, an occurrence that promotes further thaw through the positive feedback cycle that develops. *The short segment of road is at immediate risk of at least partial collapse and differential settlement in response to continued degradation of ice-rich permafrost.*	High	High	Very High	Consider realigning the road slightly westward such that it is set-back from the adjacent valley wall while not encroaching on the actively subsiding ground around the thaw ponds. Attempts to stabilize the road by placing rock against the headscarp may be ineffective, as this cannot fully address the thawing that has begun. Implement road upgrades with a thick gravel prism (and include an allowance for additional material placement and maintenance), minimal disturbance to adjacent ground, and minimal to no concentration of drainage (e.g., as per the typical cross-section for ice-rich permafrost, OEL, 2016).	High	Negligible	Negligible
9.68-9.79	Thermal erosion (-Xe)	The existing/proposed road crosses a narrow map unit characterized by a thin veneer of fluvial sediments overlying an ice-rich blanket of till (Poly_ID 122). There is already evidence of active thermokarst gullying within the map unit, albeit not in the immediate vicinity of the road crossing. *The short segment of road is at risk of differential settlement in response to potential degradation of ice-rich permafrost.*	Low	Moderate	Low	Implement road upgrades with a thick gravel prism (and include an allowance for additional material placement and maintenance), minimal disturbance to adjacent ground, and minimal to no concentration of drainage (e.g., as per the typical cross-section for ice-rich permafrost, OEL, 2016).	Negligible	Moderate	Negligible
11.20-11.44	Thermokarst subsidence (-Xt)	The existing/proposed road crosses a map unit characterized by an irregular mantle of glaciofluvial sediments overlying an ice-rich blanket of till (Poly_ID 145). There are already two identified thaw ponds indicating active thermokarst subsidence within the map unit. One of these ponds is within 35 m of the road. *The short segment of road is at risk of differential settlement in response to potential degradation of ice-rich permafrost.*	Moderate	Moderate	Moderate	Implement road upgrades with a thick gravel prism (and include an allowance for additional material placement and maintenance), minimal disturbance to adjacent ground, and minimal to no concentration of drainage (e.g., as per the typical cross-section for ice-rich permafrost, OEL, 2016).	Negligible	Moderate	Negligible

Kilometre Range	Hazard	Hazard Description	Likelihood	Consequence	Risk (unmitigated)	Mitigation Opportunities	Likelihood (mitigated)	Consequence (mitigated)	Residual Risk (mitigated)
11.44-11.79	Thermokarst subsidence (-Xt) (unmapped; potential only)	The existing/proposed road crosses a map unit characterized by a thick, ice-rich till blanket (Poly_ID 150). Although there is no evidence of active thermokarst subsidence, it could initiate given its occurrence in the immediately adjacent, similar map unit (Poly_ID 145). *The short segment of road is at risk of differential settlement in response to potential degradation of ice-rich permafrost.*	Low	Moderate	Low	Implement road upgrades with a thick gravel prism (and include an allowance for additional material placement and maintenance), minimal disturbance to adjacent ground, and minimal to no concentration of drainage (e.g., as per the typical cross-section for ice-rich permafrost, OEL, 2016).	Negligible	Moderate	Negligible
23.61-23.66	Solifluction (-S)	The proposed road crosses a narrow portion of a map unit characterized by a relatively thin blanket of till, exhibiting solifluction and inferred to have a moderate ice content (Poly_ID 403). The short segment of road is prone to minor downslope creep, although at typical solifluction rates of mm/yr to cm/yr it does not constitute a credible risk over the anticipated 10-year mine life. Furthermore, differential settlement in response to potential degradation of ice-moderate permafrost within a relatively thin till blanket will likely be minimal and not constitute a credible risk.	High	Negligible	Negligible	N/A	High	Negligible	Negligible
23.75-23.85	Solifluction (-S)	The proposed road crosses a narrow portion of a map unit characterized by a relatively thin blanket of till, exhibiting solifluction and inferred to have a moderate ice content (Poly_ID 403). The short segment of road is prone to minor downslope creep, although at typical solifluction rates of mm/yr to cm/yr it does not constitute a credible risk over the anticipated 10-year mine life. Furthermore, differential settlement in response to potential degradation of ice-moderate permafrost within a relatively thin till blanket will likely be minimal and not constitute a credible risk.	High	Negligible	Negligible	N/A	High	Negligible	Negligible
23.94-24.04	Solifluction (-S)	The proposed road crosses a narrow portion of a map unit characterized by a relatively thin blanket of till, exhibiting solifluction and inferred to have a moderate ice content (Poly_ID 403). The short segment of road is prone to minor downslope creep, although at typical solifluction rates of mm/yr to cm/yr it does not constitute a credible risk over the anticipated 10-year mine life. Furthermore, differential settlement in response to potential degradation of ice-moderate permafrost within a relatively thin till blanket will likely be minimal and not constitute a credible risk.	High	Negligible	Negligible	N/A	High	Negligible	Negligible
24.34-24.61	Solifluction (-S) & active-layer detachments (-Xf)	The proposed road crosses map units characterized by a relatively thin blanket of colluvium (Poly_IDs 402 and 405), exhibiting solifluction and localized tension cracks within the solifluction material, indicative of minor active-layer detachment. The short segment of road is prone to minor downslope creep, although at typical solifluction rates of mm/yr to cm/yr it does not constitute a credible risk over the anticipated 10-year mine life. *Very localized and short-travelled active-layer detachments pose a risk primarily for road maintenance.*	Moderate	Moderate	Moderate	Ensure road cuts are gentle (at least 2H:1V), avoid unnecessary concentration of drainage, and be prepared for periodic ditch maintenance.	Moderate	Negligible	Negligible

Kilometre Range	Hazard	Hazard Description	Likelihood	Consequence	Risk (unmitigated)	Mitigation Opportunities	Likelihood (mitigated)	Consequence (mitigated)	Residual Risk (mitigated)
24.61-25.33	Solifluction (-S)	The proposed road crosses a map unit characterized by a relatively thin blanket of till, exhibiting solifluction and inferred to have a moderate ice content (Poly_ID 403). The short segment of road is prone to minor downslope creep, although at typical solifluction rates of mm/yr to cm/yr it does not constitute a credible risk over the anticipated 10-year mine life. Furthermore, differential settlement in response to potential degradation of ice-moderate permafrost within the relatively thin till blanket does not pose a credible risk.	High	Negligible	Negligible	N/A	High	Negligible	Negligible
26.33-26.36	Debris slides & rockfall	The proposed road crosses a narrow map unit characterized by a densely-gullied, steep scarp that exposes a thick blanket of till overlying bedrock (Poly_ID 465). Shallow debris slides and rockfall occur on the erosional scarp alongside lower Fault Creek, immediately upstream of its alluvial fan apex, although the alignment is proposed at the lowermost, gentler end of the scarp. *The short segment of road is at risk from periodic debris slides and rockfall.*	Moderate	Moderate	Moderate	Consider realigning the road slightly downslope to avoid descending the low scarp, or ensure re-grading alleviates the over-steepened sections of scarp that produce debris slides and rockfall.	Moderate	Negligible	Negligible
26.36-26.76	Debris floods	The proposed road crosses the large, active alluvial fan at the mouth of Fault Creek (Poly_ID 461), which drains a mountainous basin west of Geona Creek. In addition to being prone to normal (clearwater) floods, Fault Creek also exhibits a history of recurrent debris floods. A debris flood that transported and deposited gravels to the maximum limits of the alluvial fan along two distributary channels occurred between 1986 and 1992, based on comparison between historical aerial photographs, which is consistent with a minimum age of 21 years derived dendrochronologically from the tallest willow in the cleared path of the flood event. Earlier events appear to have occurred along similar paths prior to 1949 (the earliest available aerial photograph). Debris floods likely occur during intense/prolonged rainfall events following saturation and sudden mobilization of in-channel debris that has accumulated from frequent debris slides originating along the steep gully sidewalls. *Debris floods (and normal floods) pose a risk to the road, given their potential to overtop and rapidly erode its embankment, or deposit large volumes of sediment on its surface within a short timeframe.*	Moderate	High	High	Construct a diversion ditch and berm (as planned, Drawing C560, KP, 2016b), beginning at the apex of the fan, to divert floods/sediment into the abandoned channel west of the current channel, thereby minimizing cut/fill requirements. Sufficient cross-sectional area must be available in the excavated diversion channel to accommodate floodwaters and rapid aggradation along the bed.	Moderate	Negligible	Negligible

7. Conclusion

Terrain stability and hazard mapping completed for the KZK Project presents the distribution and characteristics of terrain units, geomorphological processes and hazards within a 64 km^2 study area that encompasses the proposed mine site and its access road from the Robert Campbell Highway. This report and its accompanying maps support project planning and a response to YESAB's IR R162. A disturbed terrain stability class, representing projected conditions in the absence of planned mitigation measures, was distinguished from the existing stability class in order to highlight areas that warrant attention. The assessment of credible risks to the Project indicates how planned mitigations can be incorporated to address the site-specific hazards. Several key results warrant highlighting:

- Morainal (till) deposits are the most widespread surficial material within the study area, ranging in thickness from <0.5 m on ridges and upper slopes in the mine site area to more than 10 m in lower slope and valley bottom settings along the northern portion of the access road corridor.
- The primary mass movement hazards that may affect the footprints of the proposed mine facilities and access road, where not avoided or mitigated, are active-layer detachments, thermokarst subsidence, thermal erosion, solifluction and debris floods.
- Several actively incising thermal erosion gullies that cross or begin downslope of the access road reveal ice-rich permafrost within till. Road upgrades in areas of ice-rich permafrost should minimize the concentration of surface- and near-surface drainage in ditches and culverts in order to avoid or minimize thermokarst activity. Potential upslope migration of gully-bottom knickpoints currently situated downslope of the road should also be anticipated and accommodated.
- Glaciofluvial sand and gravel mantles extensive portions of the ice-rich till along the central to northern portion of the access corridor, giving the appearance at surface of stable, permafrost-free ground, but it cannot fully buffer the effects of ground disturbance. Such areas should be managed with consideration for the underlying ice-rich permafrost.
- The southern portion of the Open Pit is proposed to extend well into the area currently occupied by the active alluvial fan at the mouth of Fault Creek. Recurrent debris floods necessitate diversion of the channel to safely convey floodwater and sediment away from the Open Pit, with a channel design that accommodates rapid aggradation (infilling) during the cessation of a debris flood.
- Solifluction is widespread and active on the valley sides and in the upper basins above the proposed mine site. Solifluction transports material slowly downslope at rates of a few millimetres to centimetres per year, so it does not represent a credible risk to the proposed access road over a ten-year mine life. However, placement of mine waste or waste rock directly on soliflucting materials with excess ice is not advisable within the Class A, B or C Storage Facilities, given the increased potential for creep-related instabilities to develop during operations and continue post-closure.
- The Upper and Lower Water Management Ponds are proposed to be constructed along a section of Geona Creek valley that exhibits numerous, short-travelled, active-layer detachments and related retrogressive thawing along the base of the valley sides. Care should be taken to pre-strip all overburden containing permafrost with excess ice, at least in the footprint of the proposed dams, such that they can be keyed into competent, ice-free material.

- This study has demonstrated where and how project-related construction and/or climate change may affect terrain stability and hazards over the ten-year mine life. All credible risks posed to project infrastructure by the hazards can be reduced to acceptable, residual levels through the implementation of planned and additional recommended mitigation measures.

8. Statement of Limitations

This report (including its appended maps) has been prepared by the Consultant (Coregeo and Associates) for the benefit of the Client (BMC Minerals (No. 1) LTD) in accordance with the agreement between Consultant and Client, including the scope of work detailed therein (the "Agreement"). The report and the information it provides may be used and relied upon only by Client, except (1) as agreed to in writing by Consultant and Client, (2) as required by-law, or (3) to the extent used by governmental reviewing agencies for the purpose of obtaining permits or approvals.

The extent of this study was limited to the specific scope of work for which we were retained and that is described in this report. Coregeo and Associates has assumed that the information and data provided by the client or any secondary sources of information are factual and accurate. Coregeo and Associates accepts no responsibility for any deficiency, misstatement or inaccuracy contained in this report as a result of omissions, misinterpretations or negligent acts from relied-upon data. Judgment has been used by Coregeo and Associates in interpreting terrain stability and hazards based on desktop-based interpretation calibrated by field observations at sites representative of the diversity of conditions within the study area. Ground conditions may differ from those interpreted at a polygon scale, even where investigated in the field, due to inherent variability in terrain characteristics.

Coregeo and Associates is not a guarantor of the terrain, permafrost or hazard conditions within each of the mapped polygons, or of the related risk classifications (where applicable), but warrants only that its work was undertaken and its report prepared in a manner consistent with the level of skill and diligence normally exercised by competent geoscience professionals practicing in Yukon. Our findings, conclusions and recommendations should be evaluated in light of the limited scope of our work.

9. Certification

This report was prepared by:

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Appendix R2-H, Part 2

Terrain Stability and Hazard Mapping for the KZK Project

Appendix A

Map 1 – Terrain

A1. Map 1A – Mine Site Area
A2. Map 1B – Access Road Corridor

MAP 1A

TERRAIN - MINE SITE AREA

KUDZ ZE KAYAH PROJECT

Scale 1:10,000

0.25 0 0.25 0.5 0.75 1
kilometres

Universal Transverse Mercator Projection Zone 9 N
North American Datum 1983

Bare earth hillshade generated from LiDAR-derived DEM provided by BMC Minerals.

Base mapping from Geomatics Yukon and Natural Resources Canada

Original Page Size 27" x 49.25" (Includes 0.5" Margins)

October 2017

N

BMC MINERALS

Terrain mapping completed by D. Sacco and R. McKillop using softcopy photo-interpretation systems at a view (zoom) scale of 1:10,000, following field reconnaissance conducted in September 2017. Terrain codes are from the Yukon Geological Survey's adaptation of the Terrain Classification System for British Columbia (Howes and Kenk, 1997). Typical textures inferred based on observed landform associations.

Digital Cartography by B.Elder

CORE GEOSCIENCE SERVICES

PALMER ENVIRONMENTAL CONSULTING GROUP INC.

LEGEND

- Thermokarst pond
- Kettle hole
- Active layer detachment
- Debris flow
- Esker; dir. unknown
- Esker; dir. known
- Gully
- Meltwater channel; dir, known
- Meltwater channel; dir. unknown
- Thermokarst gully/erosion
- km marker — Proposed Road

Dominant surficial material

O	Organic	F^G	Glaciofluvial
F	Fluvial	M	Morainal (till)
C	Colluvial	R	Bedrock
	Waterbody		

- Mine Site Area (1:10,000 Mapping)
- Access Road Corridor (1:20,000 Mapping)
- Proposed Mine Building or Ancillary Facility
- Proposed Mine Facility Footprint

LABEL FORMAT

123
zsdCb / sdFv - Xe
2;i-p;m

Terrain component delimiter
Surficial material
Surface expression
Unique polygon identifier
Texture (increasing order of dominance)
Geomorphological process & subclass (whole polygon)
Component 1
Component 2
Slope class
Drainage class(es)
Permafrost relative ice content

TERRAIN CODE DEFINITIONS*

TEXTURE
- s sand
- z silt
- c clay
- d mixed fragments
- g gravel
- x angular fragments
- e fibric
- u mesic

SURFACE EXPRESSION
- a moderate slope (apron for colluvium)
- b blanket
- f fan
- h hummocky
- j gentle slope
- k moderately steep slope
- p plain
- r ridged
- s steep slope
- t terraced
- u undulating
- v veneer
- w mantle of variable thickness
- x thin veneer

GEOMORPHOLOGICAL PROCESS
- C cryoturbation
- E channeled by meltwater
- F slow mass movements
- I irregularly sinuous channels
- L surface steepage
- M meandering channels
- N nivation
- R rapid mass movements
- S solifluction
- U inundation
- V gully erosion
- X permafrost

DELIMITER AND MATERIAL SUBTYPE
- / the component in front of this symbol is more extensive than the component that follows
- // the component in front this symbol is much more extensive than the component that follows
- \ the component in front of this symbol overlies the component that follows

GEOMORPHOLOGICAL PROCESS SUBCLASS
- " initiation zone

PERMAFROST PROCESSES
- e thermal erosion
- f thaw flow slides
- s sheetwash
- t thermokarst subsidence

MASS MOVEMENT PROCESSES
- b rockfall
- d debris flow
- g rock creep
- s debris slide
- t debris flood

SLOPE CLASS
- 1 planar
- 2 gentle
- 3 moderate
- 4 moderately steep
- 5 steep

DRAINAGE CLASS
- x very rapidly drained
- r rapidly drained
- w well drained
- m moderately well drained
- i imperfectly drained
- p poorly drained
- v very poorly drained

RELATIVE ICE CONTENT OF PERMAFROST WITHIN SURFICIAL MATERIAL
- n no permafrost
- p ice-poor
- m ice-moderate
- r ice-rich

* Refer to "Terrain Codes Definitions" cover pages for definitions of all terminology.


MAP 1B
TERRAIN - ACCESS ROAD CORRIDOR
KUDZ ZE KAYAH PROJECT
Scale 1:20,000
0.5 0 0.5 1 1.5 2
kilometres
N
Universal Transverse Mercator Projection Zone 9 N
North American Datum 1983
Bare earth hillshade generated from LiDAR-derived DEM provided by BMC Minerals.
Base mapping from Geomatics Yukon and Natural Resources Canada
Original Page Size 19.5" x 38" (Includes 0.5" Margins)
October 2017
Terrain mapping completed by D. Sacco and R. McKillop using softcopy photo-interpretation systems at a view (zoom) scale of 1:20,000, following field reconnaissance conducted in September 2017. Terrain codes are from the Yukon Geological Survey's adaptation of the Terrain Classification System for British Columbia (Howes and Kenk, 1997). Typical textures inferred based on observed landform associations.
Digital Cartography by B.Elder
CORE GEOSCIENCE SERVICES
PALMER ENVIRONMENTAL CONSULTING GROUP INC.
BMC MINERALS
LEGEND
Thermokarst pond
Kettle hole
Active layer detachment
Debris flow
Esker; dir. unknown
Esker; dir. known
Gully
Meltwater channel; dir, known
Meltwater channel; dir. unknown
Thermokarst gully/erosion
Dominant surficial material
O Organic
F Fluvial
C Colluvial
F^G Glaciofluvial
M Morainal (till)
R Bedrock
Waterbody
Mine Site Area (1:10,000 Mapping)
Access Road Corridor (1:20,000 Mapping)
Proposed Mine Building or Ancillary Facility
Proposed Mine Facility Footprint
km marker
Proposed Road
LABEL FORMAT
Terrain component delimiter
Surficial material
Surface expression
Unique polygon identifier
Texture (increasing order of dominance)
Geomorphological process & subclass (whole polygon)
123
zsdCb / sdFv - Xe
Component 1
2;i-p;m
Component 2
Slope class
Drainage class(es)
Permafrost relative ice content
TERRAIN CODE DEFINITIONS*
TEXTURE
s sand
z silt
c clay
d mixed fragments
g gravel
x angular fragments
e fibric
u mesic
SURFACE EXPRESSION
a moderate slope (apron for colluvium)
b blanket
f fan
h hummocky
j gentle slope
k moderately steep slope
p plain
r ridged
s steep slope
t terraced
u undulating
v veneer
w mantle of variable thickness
x thin veneer
GEOMORPHOLOGICAL PROCESS
C cryoturbation
E channeled by meltwater
F slow mass movements
I irregularly sinuous channels
L surface steepage
M meandering channels
N nivation
R rapid mass movements
S solifluction
U inundation
V gully erosion
X permafrost
DELIMITER AND MATERIAL SUBTYPE
/ the component in front of this symbol is more extensive than the component that follows
// the component in front this symbol is much more extensive than the component that follows
\ the component in front of this symbol overlies the component that follows
GEOMORPHOLOGICAL PROCESS SUBCLASS
" initiation zone
PERMAFROST PROCESSES
e thermal erosion
f thaw flow slides
s sheetwash
t thermokarst subsidence
MASS MOVEMENT PROCESSES
b rockfall
d debris flow
g rock creep
s debris slide
t debris flood
SLOPE CLASS
1 planar
2 gentle
3 moderate
4 moderately steep
5 steep
DRAINAGE CLASS
x very rapidly drained
r rapidly drained
w well drained
m moderately well drained
i imperfectly drained
p poorly drained
v very poorly drained
RELATIVE ICE CONTENT OF PERMAFROST WITHIN SURFICIAL MATERIAL
n no permafrost
p ice-poor
m ice-moderate
r ice-rich
* Refer to "Terrain Codes Definitions" cover pages for definitions of all terminology.
Dawson
YUKON
Ross River
SITE LOCATION
Whitehorse
Watson Lake
Robert Campbell Highway
4
412000
414000
416000
418000
420000
6836000
6834000
6832000
6830000
6828000
6826000
6824000
6822000
6820000

Appendix R2-H, Part 3

Terrain Stability and Hazard Mapping for the KZK Project

Appendix B

Map 2 – Existing Terrain Stability and Hazards

B1. Map 2A – Mine Site Area
B2. Map 2B – Access Road Corridor

MAP 2A

EXISTING TERRAIN STABILITY AND HAZARDS - MINE SITE AREA

KUDZ ZE KAYAH PROJECT

Scale 1:10,000

0.25 0 0.25 0.5

kilometres

Universal Transverse Mercator Projection Zone 9 N
North American Datum 1983

Bare earth hillshade generated from LiDAR-derived DEM provided by BMC Minerals.

Base mapping from Geomatics Yukon and Natural Resources Canada

Original Page Size 27" x 48" (Includes 0.5" Margins)

October 2017

BMC MINERALS

Terrain stability and hazard mapping completed by D. Sacco and R. McKillop using softcopy photo-interpretation systems at a view (zoom) scale of 1:10,000, following field reconnaissance conducted in September 2017.

Digital Cartography by B.Elder

CORE GEOSCIENCE SERVICES

PALMER ENVIRONMENTAL CONSULTING GROUP INC.

LEGEND

- 123 Unique polygon ID
- Thermokarst pond
- Active layer detachment
- Debris flow
- Gully
- Thermokarst gully/erosion
- Mine Site Area (1:10,000 Mapping)
- Access Road Corridor (1:20,000 Mapping)
- Proposed Mine Building or Ancillary Facility
- Proposed Mine Facility Footprint
- km marker Proposed Road

EXISTING TERRAIN STABILITY CLASS

I	Stable
II	Generally stable
III	Generally stable with minor potential for instability
IV	Potentially unstable
V	Unstable

APPLICABLE HAZARD CATEGORY (OVERLAY)

- (no fill) Slope failure potential is dominant
- Thermokarst potential is dominant
- Slope failure and thermokarst potential are co-dominant

NOTES:
1. Refer to "Terrain Stability, Hazards and Risk Code Definitions" cover pages for definitions of all terminology, and refer to Terrain Map for complete terrain polygon labels (including slope class, drainage and relative ice content of permafrost).
2. Existing terrain stability class represents current (baseline) conditions.


MAP 2B
EXISTING TERRAIN STABILITY AND HAZARDS - ACCESS ROAD CORRIDOR
KUDZ ZE KAYAH PROJECT
Scale 1:20,000
0.5 0 0.5 1 1.5 2
kilometres
N
Universal Transverse Mercator Projection Zone 9 N
North American Datum 1983
Bare earth hillshade generated from LiDAR-derived DEM provided by BMC Minerals.
Base mapping from Geomatics Yukon and Natural Resources Canada
Original Page Size 19.5" x 38" (Includes 0.5" Margins)
October 2017
Terrain stability and hazard mapping completed by D. Sacco and R. McKillop using softcopy photo-interpretation systems at a view (zoom) scale of 1:20,000, following field reconnaissance conducted in September 2017.
Digital Cartography by B.Elder
CORE GEOSCIENCE SERVICES
PALMER ENVIRONMENTAL CONSULTING GROUP INC.
BMC MINERALS
LEGEND
EXISTING TERRAIN STABILITY CLASS
I Stable
II Generally stable
III Generally stable with minor potential for instability
IV Potentially unstable
V Unstable
123 Unique polygon ID
Thermokarst pond
Active layer detachment
Debris flow
Gully
Thermokarst gully/erosion
Mine Site Area (1:10,000 Mapping)
Access Road Corridor (1:20,000 Mapping)
Proposed Mine Facility Footprint
km marker Proposed Road
APPLICABLE HAZARD CATEGORY (OVERLAY)
(no fill) Slope failure potential is dominant
Thermokarst potential is dominant
Slope failure and thermokarst potential are co-dominant
NOTES:
1. Refer to "Terrain Stability, Hazards and Risk Code Definitions" cover pages for definitions of all terminology, and refer to Terrain Map for complete terrain polygon labels (including slope class, drainage and relative ice content of permafrost).
2. Existing terrain stability class represents current (baseline) conditions.
Dawson
YUKON
Ross River
SITE LOCATION
Whitehorse
Watson Lake
Robert Campbell Highway
4
Finlayson Creek
412000
414000
416000
418000
420000
6836000
6834000
6832000
6830000
6828000
6826000
6824000
6822000
6820000

Appendix R2-H, Part 4

Terrain Stability and Hazard Mapping for the KZK Project

Appendix C

Map 3 – Disturbed Terrain Stability, Hazards and Risk

MAP 3A

DISTURBED TERRAIN STABILITY, HAZARDS AND RISKS - MINE SITE AREA

KUDZ ZE KAYAH PROJECT

Scale 1:10,000

0.25 0 0.25 0.5
kilometres

Universal Transverse Mercator Projection Zone 9 N
North American Datum 1983

Bare earth hillshade generated from LiDAR-derived DEM provided by BMC Minerals.

Base mapping from Geomatics Yukon and Natural Resources Canada

Original Page Size 27" x 48" (Includes 0.5" Margins)

October 2017

BMC MINERALS

Terrain stability, hazard and risk mapping completed by D. Sacco and R. McKillop using softcopy photo-interpretation systems at a view (zoom) scale of 1:10,000, following field reconnaissance conducted in September 2017.

Digital Cartography by B.Elder

CORE GEOSCIENCE SERVICES

PALMER ENVIRONMENTAL CONSULTING GROUP INC.

LEGEND

123 Unique polygon ID

Thermokarst pond

Active layer detachment

Debris flow

Gully

Thermokarst gully/erosion

km marker — Proposed Road

Mine Site Area (1:10,000 Mapping)

Access Road Corridor (1:20,000 Mapping)

EVALUATED RISK BEFORE MITIGATION

Negligible, Low, Moderate, High, Very High — TO PROPOSED MINE INFRASTRUCTURE

TO EXISTING/PROPOSED ACCESS ROAD

DISTURBED TERRAIN STABILITY CLASS

I	Stable
II	Generally stable
III	Generally stable with minor potential for instability
IV	Potentially unstable
V	Unstable

COMBINATION OF INFLUENTIAL DISTURBANCE AND APPLICABLE HAZARD CATEGORY (OVERLAY)*

(no fill) "Construction-related disturbance influence" and "Slope failure potential is dominant"

Both "Construction- and climate change-related disturbance influence" and "Thermokarst potential is dominant"

Both "Construction- and climate change-related disturbance influence" and "Slope failure and thermokarst potential are co-dominant"

*Overlays distinguish whether construction, climate change or both are likely to affect terrain stability, and whether the changes are likely to be associated with an increase in the potential for slope failure, thermokarst or both. Despite consideration of all possible combinations of influential disturbances and applicable hazard categories, only the three identified above apply to this study area.

NOTES:
1. Refer to "Terrain Stability, Hazards and Risk Code Definitions" cover pages for definitions of all terminology, and refer to Terrain Map for complete terrain polygon labels (including slope class, drainage and relative ice content of permafrost).
2. Disturbed terrain stability class represents projected conditions following disturbance to ground conditions from climate change and/or from project-related facility or road construction without mitigation.
3. Risk classifications depicted for the proposed infrastructure/facility footprints reflect the highest (most conservative) risk posed by one or more hazards. Refer to accompanying report for a full breakdown of the hazard-specific risks.

MAP 3B

DISTURBED TERRAIN STABILITY, HAZARDS AND RISKS - ACCESS ROAD CORRIDOR

KUDZ ZE KAYAH PROJECT

Scale 1:20,000

Universal Transverse Mercator Projection Zone 9 N
North American Datum 1983

Bare earth hillshade generated from LiDAR-derived DEM provided by BMC Minerals.

Base mapping from Geomatics Yukon and Natural Resources Canada

Original Page Size 19.5" x 38" (Includes 0.5" Margins)

October 2017

Terrain stability, hazard and risk mapping completed by D. Sacco and R. McKillop using softcopy photo-interpretation systems at a view (zoom) scale of 1:20,000, following field reconnaissance conducted in September 2017.

Digital Cartography by B.Elder

Appendix R2-I

Permafrost Distribution Mapping for the KZK Project

CORE GEOSCIENCE SERVICES | PALMER ENVIRONMENTAL CONSULTING GROUP INC.

Coregeo and Associates

Memorandum

Date: October 30, 2017

Project #: BMC-17-02/170341

To: Name Redacted
(BMC Minerals (No. 1) Ltd.)

From: Name Redacted

Re: Permafrost Distribution Mapping for the Kudz Ze Kayah Project, Yukon

Introduction

Coregeo and Associates, a collaboration of Core Geoscience Services Inc. (Coregeo) and Palmer Environmental Consulting Group Inc. (PECG) with Dr. Derek Turner in the role of a senior technical advisor, is pleased to provide BMC Minerals (No. 1) Ltd. (BMC) with the results of our team's permafrost distribution mapping (**Appendix A**) for the Kudz Ze Kayah (KZK) Project (the Project), in southeastern Yukon. The mapping and this accompanying memorandum were completed to address information request (IR) R167/R2-79 made by YESAB in association with its review of the adequacy of the Project Proposal and subsequent responses from BMC:

> *"Provide a comprehensive permafrost study, including mapping and related analysis indicating permafrost distribution within the mine footprint and access road area. Indicate the magnitude and extent of soil erosion potential within this area that is attributed to thermal erosion of permafrost."*

Permafrost distribution mapping was completed within a 100 m buffer of all proposed mine infrastructure footprints and the access road centre line to fully encompass all potential disturbance. This mapping is based on a synthesis of data from (i) multiple years of geotechnical field investigations and (ii) recently completed detailed terrain stability and hazards mapping and related field reconnaissance (Coregeo and Associates, 2017). This memorandum explains the mapping methods and the permafrost distribution classifications and legend. The mapping and memorandum address the first part (first sentence) of R167/R2-79.

The magnitude and extent of soil erosion potential within the study area that is attributed to thermal erosion of permafrost (i.e., the second part (second sentence) of R167/R2-79) can be inferred based on the terrain stability and hazards mapping recently completed for the KZK Project (Coregeo and Associates, 2017). This mapping package depicts evidence of existing thermal erosion (thermokarst gullies) and thermokarst subsidence (thaw ponds), using line or point symbols, and represents the polygon-scale magnitude and extent of thermal erosion potential through the interpretations of the relative ice content of permafrost within surficial material. *Ice-rich* permafrost is susceptible to the greatest magnitude of thermal erosion following disturbance (whether from anthropogenic activity or climate change). *Ice-moderate* permafrost is susceptible to a lower magnitude of thermal erosion, and *ice-poor* permafrost exhibits little to no susceptibility to thermal erosion, given its lack of excess ground ice[1].

Readers interested in further background information and a comprehensive review of the physical setting and terrain units comprising the study area are referred to the project-specific terrain stability and hazards mapping report (Coregeo and Associates, 2017).

Study Area

Permafrost distribution mapping was produced to encompass proposed footprints of mine infrastructure with a minimum buffer of 100 m. Buffers around discrete mine site infrastructure (e.g., open pit, storage facilities, seepage collection ponds) were smoothed and dissolved to create a single mapping boundary. A mapping corridor with a conservative minimum width of 200 m was delineated along the centreline of the proposed/existing access road to ensure a 50 m buffer of the road surface, embankments (cuts and fills), and cleared right-of-way. Where necessary, the corridor was locally widened to encompass proposed borrow sources and spoil identified in a set of geometric road design sheets prepared in association with the access upgrade construction management plan by Onsite Engineering Ltd. (OEL, 2017).

Methods

Permafrost distribution mapping was derived through the integration of relevant data captured in the terrain stability and hazards mapping and associated fieldwork (Coregeo and Associates, 2017), and through interpretation of geotechnical observations from previous studies on the property (**Table 1**).

The focus of this study and mapping was to identify permafrost within a few metres of the ground surface in the surficial material (whether within a single-material or stratigraphic surficial unit). Explicit consideration was not given to permafrost below a few metres of ground surface or in underlying bedrock, due to its relative insensitivity to surface activities and the unreliability of its interpretation based primarily on surface diagnostics.

[1] *Full definitions and bases for the interpreted relative ice contents of permafrost within surficial material are detailed by Coregeo and Associates (2017).*

Table 1. Data sources used to support permafrost distribution mapping for the KZK Project.

Author(s)	Data source	Pertinent Information	Comment
Coregeo and Associates, 2017	Terrain stability and hazard mapping for the KZK Project	Terrain units (polygons), periglacial features/processes, relative ice content of permafrost	Provided a foundation for permafrost-focused reclassification
OEL, 2017	Access road upgrade construction management plan for the KZK Project	Generalized “permafrost sections” along road, proposed road footprint (cut/fill, right-of-way and borrow pits/spoil)	Unspecified locations and results of test pitting used to establish the “permafrost sections” along road
Alexco Environmental Group (AEG), 2017	Terrain and soils chapter of the Project Proposal submission to YESAB	Summary mapping of presence and depth of permafrost in previous test pitting	Some references to the test pits excavated by Golder Associates Ltd. (Golder, 1996) cannot be traced back to original report
BMC, 2017	High-resolution (30 cm) stereo-aerial photography encompassing the study area	Basis for interpretation of surficial geology, drainage and permafrost conditions	
KP, 2016a	Terrain analysis report and accompanying maps for the KZK Project	Sites of possible thermal erosion and thaw ponds	Exclusively desktop-based interpretations, so considered preliminary and superseded by subsequent field-calibrated interpretations
Knight Piésold (KP), 2016b,c,d, 2017	Geotechnical site investigation data reports for the KZK Project	Permafrost and ground ice notes in test pit logs, thermistor data, borehole data	All test pitting conducted in May, at which time seasonal frost persists and active layers are thin, inhibiting conclusive determinations of permafrost
BMC, 2016a	High-resolution (30 cm) orthophotography encompassing the study area	Base mapping and recent temporal comparison	
BMC, 2016b	High-resolution (<50 cm) LiDAR-derived digital elevation model (DEM)	Basis for derivation of bare earth hillshade and slope classification models, which informed interpretations	
Bonnaventure et al., 2012	30 m-resolution permafrost probability model for southern Yukon	Regional classification and drivers of permafrost probability	Based primarily on DEM data and a network of basal snow temperature records, with no consideration for site-scale surficial material, drainage, surface organic cover, vegetation characteristics, snowpack, etc.
Golder Associates Ltd. (Golder), 1996	Feasibility-level geotechnical and hydrogeological site investigation for the KZK Project	Permafrost and ground ice notes in test pit logs, thermistor data, borehole data, approx. line separating permafrost and permafrost-free test pits	Overall May-to-September date range for test pitting inhibits conclusive determinations of permafrost due to possibility of persistent seasonal frost
Heginbottom et al., 1995	Permafrost map of Canada	Regional expectation for the areal extent, contiguity and ground ice conditions of permafrost	Only broadly applicable as regional context

Note: Data sources listed in reverse-chronological order.

The terrain units (polygons) from the terrain stability and hazards mapping for the KZK Project (Coregeo and Associates, 2017) were used as a base, and each polygon was assigned one of four classes representing the certainty with which it contains permafrost within surficial material[2]:

- **Confirmed** (dark blue) – Confirmed presence of permafrost within the terrain polygon, based on definitive evidence of permafrost from geotechnical data (e.g., test pits, boreholes, thermistors) and/or the identification of permafrost features or processes (e.g., thermal erosion, thermokarst subsidence, active-layer detachment, slopewash) within the terrain polygon.
- **Probable** (light blue) – Probable presence of permafrost within the terrain polygon, based on strong evidence of permafrost from geotechnical data and/or its strong similarity in characteristics (landform association) to adjacent or nearby terrain polygons with confirmed permafrost.
- **Possible** (green) – Possible presence of permafrost within the terrain polygon, based on weak to moderate evidence of permafrost from geotechnical data and/or its weak to moderate similarity in characteristics to adjacent or nearby terrain polygons with confirmed permafrost.
- **Unlikely** (yellow) – Unlikely presence of permafrost within the terrain polygon, based on strong evidence of no permafrost from geotechnical data and/or its lack of similarity in characteristics to adjacent or nearby terrain polygons with confirmed permafrost.

The mention of ground ice in the geotechnical data (e.g., test pit logs), in itself, was not considered *definitive* evidence of permafrost. Many of the test pits were excavated in May (KP, 2016a,b) or at an unspecified time between May and September (Golder, 1996), such that ground ice occurrences within a metre or two below surface could be explained by persistent seasonal frost. Definitive evidence generally required specific records of frozen ground and/or ice at depths that could not possibly be from seasonal frost.

In order to help substantiate the polygon-scale interpretations of permafrost distribution within the study area, the Permafrost Distribution Maps identify field sites with “definitive” evidence of permafrost. Data sources providing definitive evidence of permafrost include select test pits logs, borehole logs and ground temperature records from down-hole thermistors from Golder (1996) and KP (2016a,b), and a number of site-specific, near-surface observations of ground ice, active layer thickness or permafrost features or processes (Coregeo and Associates, 2017). KP’s (2016c) desktop-mapped sites of thermal erosion and thaw ponds were uncorroborated by field evidence and thus not identified. Geotechnical data sources that mention ground ice (or frozen) near surface, but remain ambiguous at depth, were deemed “inconclusive” of permafrost presence due to the possibility of springtime or unspecified spring-summer observations encountering seasonal frost. Data sources without indication of ground ice or permafrost were identified as having permafrost “not indicated”. Permafrost was conservatively not considered to be altogether absent from surficial material within terrain polygons encompassing geotechnical investigation sites without explicit record of ground ice or permafrost for two reasons: (i) permafrost may be present only within portions of the polygon, which is commonplace in this region of discontinuous permafrost; and (ii) inconsistencies in the format, content and seasonal timing of different records inhibited definitive determinations of permafrost

[2] *Some terrain polygons that were attributed in the terrain stability and hazards mapping as having no permafrost within the surficial material (which typically corresponds to an “unlikely” classification in this mapping) received an updated classification of “possible” based on increased scrutiny of geotechnical data and/or landform associations, as well as the option to use additional, more precise classifications.*

absence. The distribution and characteristics of all geotechnical records, including those with and without indications of permafrost, are available in the respective original reports (i.e., Golder, 1996; KP, 2016a,b,c). Field-based observations made by Coregeo and Associates (2017) of active-layer thickness were identified as definitive evidence of permafrost.

Certification

This memorandum and the appended mapping were prepared by:

Name and Signature Redacted

Principal, Geomorphologist
Palmer Environmental Consulting Group Inc.

Name and Signature Redacted

Terrain Mapping Specialist
Palmer Environmental Consulting Group Inc.

This memorandum and the appended mapping were reviewed by:

Name and Signature Redacted

Quaternary Geologist

Name and Signature Redacted

Principal, Geoscientist
Core Geoscience Services Inc.

Name and Signature Redacted

Principal, Environmental Geoscientist
Core Geoscience Services Inc.

References

Alexco Environmental Group, 2017. Kudz Ze Kayah Project: Project proposal for YESAB Executive Committee Screening. Report submitted to BMC Minerals (No.1) Ltd., Vancouver, BC.

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Knight Piésold Ltd., 2016b. Prefeasibility Design Report, Kudz Ze Kayah Project. Report submitted to BMC Minerals (No.1) LTD, Vancouver, BC, 26 p. plus appendices.

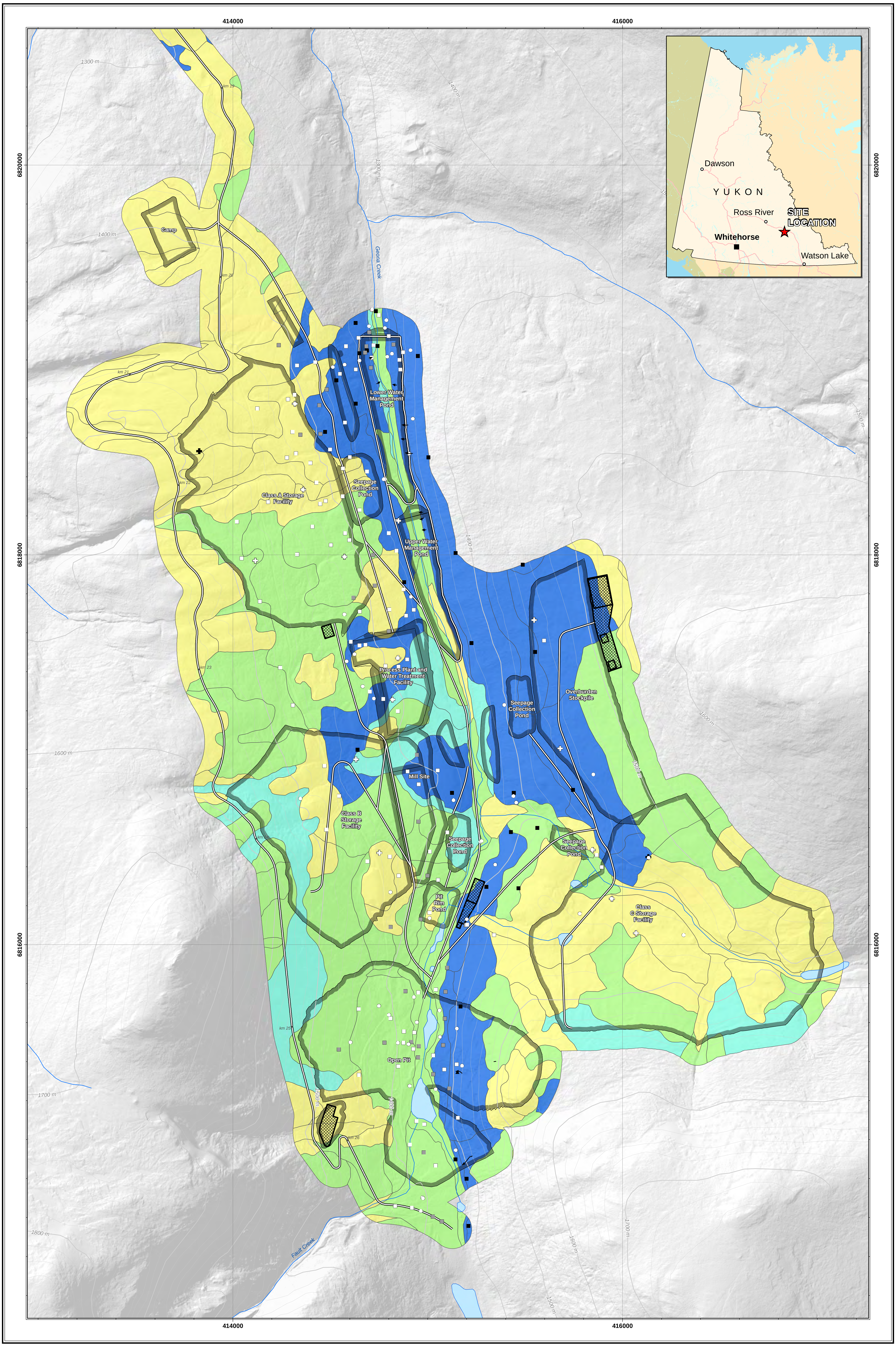
Knight Piésold Ltd., 2016c. 2015 Geotechnical Site Investigation Data Report for Kudz Ze Kayah Project. Report submitted to BMC Minerals (No. 1) LTD, Vancouver, BC, 25 p. plus appendices.

Knight Piésold Ltd., 2016d. 2016 Geotechnical Site Investigation Data Report for Kudz Ze Kayah Project. Report submitted to BMC Minerals (No. 1) LTD, Vancouver, BC, 48 p. plus appendices.

Knight Piésold Ltd., 2017. 2017 Site Investigation – Preliminary Thermistor Data. Memorandum submitted to BMC Minerals (No.1) LTD, Vancouver, BC, 16 p. incl. appendices.

Onsite Engineering Ltd, 2017. Kudz Ze Kayak Access Upgrade Construction Management Plan. Report submitted to BMC Minerals (No.1) Ltd, Vancouver, BC, 44 p.

Appendix A
Permafrost Distribution Map for the Kudz Ze Kayah Project



PERMAFROST DISTRIBUTION - MINE SITE AREA

KUDZ ZE KAYAH PROJECT

Scale 1:10,000

0.25 0 0.25 0.5 0.75 1

kilometres

Universal Transverse Mercator Projection Zone 9 N
North American Datum 1983

Bare earth hillshade generated from LiDAR-derived DEM provided by BMC Minerals.
Base mapping from Geomatics Yukon and Natural Resources Canada
Original Page Size 20" x 32" (Includes 0.5" Margins)
October 2017

N

D. Sacco and R. McKillop completed the original terrain mapping (Coregeo and Associates, 2017) from which this permafrost distribution mapping was derived through re-classification of polygons. Refer to accompanying memorandum for list of data sources used to support the re-classification.

Digital Cartography by B.Elder

LEGEND

Permafrost presence within surficial material

Confirmed - Confirmed presence of permafrost, based on definitive evidence from geotechnical data and/or permafrost features or processes.

Probable - Probable presence of permafrost, based on strong evidence from geotechnical data and/or strong similarity in characteristics to polygons with confirmed permafrost.

Possible - Probable presence of permafrost, based on weak to moderate evidence from geotechnical data and/or weak to moderate similarity in characteristics to polygons with confirmed permafrost.

Unlikely- Unlikely presence of permafrost, based on strong evidence of no permafrost from geotechnical data and/or a lack of similarity in characteristics to polygons with confirmed permafrost.

- Definitive - Ground Observation
- Definitive - Thermistor
- Definitive - Test Pit
- Inconclusive - Test Pit
- Not Indicated - Borehole
- Not Indicated - Thermistor
- Not Indicated - Test Pit

- Active Layer Detachment
- Thermokarst Gully/Erosion
- km marker — Proposed Road
- Proposed Mine Facility Footprint
- Proposed Mine Building or Ancillary Facility
- Waterbody

NOTES
1. Geotechnical data sources with indications of permafrost include test pits, boreholes and thermistors from Golder (1996) and KP (2016a,c,d, 2017); ground observations and permafrost features/processes include thermal erosion, thermokarst subsidence, slopewash and active-layer detachments from Coregeo and Associates (2017).
2. On-site symbols for linear permafrost processes/features clipped to study area boundary.
3. Permafrost classifications are defined conservatively at the polygon scale, based on site-specific indicators, but do not necessarily indicate the presence of continuous permafrost within the polygon.

PERMAFROST DISTRIBUTION - ACCESS ROAD CORRIDOR
KUDZ ZE KAYAH PROJECT
Scale 1:20,000
0.5 0 0.5 1 1.5 2
kilometres
N
Universal Transverse Mercator Projection Zone 9 N
North American Datum 1983
Bare earth hillshade generated from LiDAR-derived DEM provided by BMC Minerals.
Base mapping from Geomatics Yukon and Natural Resources Canada
Original Page Size 19.5" x 34.5" (Includes 0.5" Margins)
October 2017
D. Sacco and R. McKillop completed the original terrain mapping (Coregeo and Associates, 2017) from which this permafrost distribution mapping was derived through re-classification of polygons. Refer to accompanying memorandum for list of data sources used to support the re-classification.
Digital Cartography by B.Elder
CORE GEOSCIENCE SERVICES
PALMER ENVIRONMENTAL CONSULTING GROUP INC.
BMC MINERALS
LEGEND
Permafrost presence within surficial material
Confirmed - Confirmed presence of permafrost, based on definitive evidence from geotechnical data and/or permafrost features or processes.
Probable - Probable presence of permafrost, based on strong evidence from geotechnical data and/or strong similarity in characteristics to polygons with confirmed permafrost.
Possible - Probable presence of permafrost, based on weak to moderate evidence from geotechnical data and/or weak to moderate similarity in characteristics to polygons with confirmed permafrost.
Unlikely- Unlikely presence of permafrost, based on strong evidence of no permafrost from geotechnical data and/or a lack of similarity in characteristics to polygons with confirmed permafrost.
Definitive - Thermokarst Pond
Definitive - Ground Observation
Definitive - Thermistor
Definitive - Test Pit
Inconclusive - Test Pit
Not Indicated - Borehole
Not Indicated - Thermistor
Not Indicated - Test Pit
Active Layer Detachment
Thermokarst Gully/Erosion
km marker
Proposed Road
Proposed Mine Facility Footprint
Proposed Mine Building or Ancillary Facility
Waterbody
NOTES
1. Geotechnical data sources with indications of permafrost include test pits, boreholes and thermistors from Golder (1996) and KP (2016a,c,d, 2017); ground observations and permafrost features/processes include thermal erosion, thermokarst subsidence, slopewash and active-layer detachments from Coregeo and Associates (2017).
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Dawson
YUKON
Ross River
SITE LOCATION
Whitehorse
Watson Lake
412000
414000
416000
418000
420000
6836000
6834000
6832000
6830000
6828000
6826000
6824000
6822000
Robert Campbell Highway
4
km 0
km 1
km 2
km 3
km 4
km 8
km 10
km 11
km 12
km 14
km 15
km 16
km 17
km 18
Finlayson Creek
Geona Creek
1000 m
1100 m
1200 m
1300 m
1400 m
1500 m
1600 m

Appendix R2-J
Draft Wildlife Protection Plan

BMC MINERALS (NO.1) LTD

KUDZ ZE KAYAH PROJECT

WILDLIFE PROTECTION PLAN - FOR MINE CONSTRUCTION, OPERATIONS, AND CLOSURE

Draft

November 2017

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LIST OF FIGURES

APPENDICES

LIST OF ACRONYMS

Acronym	Definition
ABM	A. B. Mawer
AEG	Alexco Environmental Group
BBS	Breeding Bird Survey
CCME	Canadian Council of Ministers of the Environment
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
CRCP	Conceptual Reclamation and Closure Plan
CWTS	Constructed Wetland Treatment Systems
DEM	Digital elevation model
DFO	Fisheries and Oceans Canada
ECCC	Environment and Climate Change Canada
EMR	Energy, Mines and Resources
FCH	Finlayson Caribou Herd
GIS	Geographical Information System
GPS	Global Positioning System
HDPE	High Density Polyethylene
HPW	Government of the Yukon Highways and Public Works
HSERP	Health, Safety and Emergency Response Plan
HSI	Habitat Suitability Index
INAC	Indigenous and Northern Affairs Canada
IUCN	International Union for Conservation of Nature
KZK	Kudz Ze Kayah
LFN	Liard First Nation
LMB	Land Management Branch.
LNG	Liquified Natural Gas
LSA	Local Study Area
LWMP	Lower Water Management Pond
MOE	Ministry of Environment
MRB	Mineral Resources Branch
PEM	Predictive Ecosystem Map
PFS	Pre-feasibility Study
QML	Quartz Mining Licence
RCH	Robert Campbell Highway
RCP	Reclamation and Closure Plan
RRDC	Ross River Dena Council
RSA	Regional Study Area
SARA	Species at Risk Act
SEPA	Socio-economic Participation Agreement
SSE	Senior Site Executive
SWMP	Surface Water Management Plan
TEM	Terrestrial Ecosystem Map

Acronym	Definition
UTM	Universal Transverse Mercator
VEC	Valued Ecosystem Component
WKA	Wildlife Key Areas
WMP	Water Management Plan
WPP	Wildlife Protection Plan
WSF	Waste Rock Storage Facility
WTP	Water Treatment Plant
WUL	Water Use Licence
YG	Yukon Government
YBGO	Yukon Big Game Outfitters
YCDC	Yukon Conservation Data Centre
YESAA	Yukon Environmental and Socio-economic Assessment Act
YESAB	Yukon Environmental and Socio-economic Assessment Board
ZOI	Zone of Influence

1 INTRODUCTION

This draft Wildlife Protection Plan (WPP) was requested by the Yukon Environmental and Socioeconomic Assessment Board (YESAB) during their adequacy review of BMC's Project Proposal to develop the Kudz Ze Kayah (KZK) Project (via email dated August 31, 2017). The specific request was in relation to information requests R241, R244, R246 and R248 (YESAB, 2017). For further context YESAB indicated the conceptual WPP included in the Project Proposal:

> "*…is short on detail. There are general mitigation measures provided, but details on how monitoring will take place, who is responsible, and the actions that will be taken if effects to wildlife are noticed are lacking. The WPP is cited multiple times as a key mitigation measure for wildlife; without details the Executive Committee cannot have confidence that it will be effective. The absence of these details may lead to additional conditions for the protection of wildlife beyond what BMC has provided in the WPP".*

This draft WPP will be revised following consultation with Kaska (Ross River Dena Council and Liard First Nation) and other interested parties (i.e. Yukon Government (YG), Environment Canada, Communities etc.), likely during the Seeking Views and Information stage of the environmental assessment process and/or during the subsequent permitting processes.

1.1 PURPOSE AND OBJECTIVES OF THE WILDLIFE PROTECTION PLAN

1.1.1 Purpose

The purpose of this WPP is to describe BMC's procedures for minimizing and managing impacts to wildlife and their habitat, provide a framework for the development and implementation of wildlife monitoring programs, and outline the adaptive management approach if the management and mitigation measures are not sufficiently minimizing effects to wildlife and their habitat.

The WPP builds on the wildlife management which is described in the KZK Exploration Environmental Management Plan that has been effectively implemented over the past three years of exploration at the Project. The WPP also draws on the most recent wildlife surveys completed by BMC between March of 2105 and the fall of 2017, the Initial Environmental Evaluation (IEE) completed by Cominco Ltd. (1996), the effects assessment and mitigation measures proposed in the Project Proposal, the conceptual WPP presented in the Project Proposal, and input from the YG biologists for baseline studies, technical experts, and consultants. Input from Kaska will also be incorporated during WPP revisions, and will ensure that the wildlife protection measures meet Kaska land stewardship requirements (following the agreements between BMC and Kaska).

Mitigation and management measures described in this WPP are designed to comply with BMC's policies, legal requirements, the commitments made during Project approval through the Yukon Environmental and Socio-economic Assessment Act (YESAA) process, commitments made in agreements between Kaska and BMC, and BMC's management commitment to continual improvement.

1.1.2 Objectives

In recognition of the potential disturbances and effects that construction, operation and closure of the Project may have on wildlife and habitat, BMC will implement mitigation measures to eliminate or reduce such effects. Some mitigation actions may be general in nature and applicable to all species, areas and phases of the Project. Other mitigations may be specific to Project phase, species, or area, or may be time-specific. Mitigations are subject to monitoring and modification or adaptive management as necessary to ensure ongoing efficacy.

The objective of this WPP is to avoid and/or minimize the potential impacts of Project activities to wildlife and their habitat. To meet this objective, the plan has the following goals:

- Minimize interactions with wildlife;
- Reduce potential wildlife disturbance;
- Reduce and mitigate habitat disturbance; and
- Prevent wildlife mortalities.

1.2 LEGAL REQUIREMENTS, PERMIT CONDITIONS, AND COMMITMENTS CONCORDANCE

1.2.1 Regulatory Context

The following legislation, regulations and existing wildlife management policies were reviewed and integrated into the development of this WPP.

CANADA MIGRATORY BIRDS CONVENTION ACT (1994)

Federal migratory bird protection under section 6 of the *Migratory Birds Convention Act*, 1994 states that "subject to subsection 5(9), no person shall:

- *disturb, destroy or take a nest, egg, nest shelter, eider duck shelter or duck box of a migratory bird; or*
- *have in his possession a live migratory bird, or a carcass, skin, nest or egg of a migratory bird except under authority of a permit. SOR/80-577, s. 4*" (Government of Canada 1994).

The *Migratory Birds Convention Act* also prohibits deposition of deleterious substances in waters used by migratory birds.

CANADA *SPECIES AT RISK ACT* (SARA) (2002)

The *Species at Risk Act* (SARA) (Government of Canada, 2002) identifies wildlife species considered at risk, categorizing them as Threatened, Endangered, Extirpated, or of Special Concern. The *Species at Risk Act* prohibits destruction, harassment, capture, or removal of habitations of extirpated, endangered, or threatened species. The *Act* also restricts development in designated critical habitat.

The protections in the SARA currently apply throughout Canada to all aquatic species and migratory birds (as listed in the *Migratory Birds Convention Act*, 1994 [Government of Canada, 1994]), regardless of whether the species are resident on federal, provincial, public, or private land. This means that if a species is listed in the SARA and is either an aquatic species or a migratory bird, there is a prohibition against harming it or its residence.

YUKON *WILDLIFE ACT* (2002)

Environment Yukon manages wildlife under the *Yukon Wildlife Act* (2002) and in accordance with First Nation Final Agreements.

The *Yukon Wildlife Act* (2002) prohibits disturbance of nests, dens, and beaver dams, unauthorized hunting, trapping, and harassment of wildlife. Note that harassment includes feeding and interfering with wildlife movement across roads or waterways. The *Wildlife Act* also requires proper attractant management to prevent dangerous wildlife interactions.

The *Yukon Wildlife Act* (Regulations Section 5) lists several species as "specially protected" including: Cougar, Gyrfalcon, Peregrine Falcon, Trumpeter Swan, and Chisana Caribou Herd. Only Gyrfalcon, Peregrine Falcon and Trumpeter Swan are known to potentially occur in the Project area.

YUKON MANAGEMENT PRACTICE GUIDELINES AND INDUSTRY STANDARDS

Management practice guidelines, industry standards and other documents used to develop this WPP include (but are not limited to):

- *Yukon Wildlife Act* (Yukon Government, 2002), and *Quartz Mining Act* (Yukon Government, 2003);
- Yukon Chamber of Mines' Yukon Mineral and Coal Exploration Best Management Practices and Regulatory Guide (Yukon Chamber of Mines, 2010);
- Management Plan for the Northern Mountain Population of Woodland Caribou (*Rangifer tarandus caribou*) in Canada (Environment Canada, 2012);
- Yukon Forest Resources Act Operational Standards (Yukon EMR, 2011; Yukon EMR, 2014);
- Guidelines for Industrial Activity in Bear Country (MPERG, 2008a);
- How to Stay Safe in Bear Country (Yukon Government, 2016);
- Flying in Caribou Country (MPERG, 2008b);
- Flying in Sheep Country (MPERG, 2008c);
- Proponent's Guide: Assessing and Mitigating the Risk of Human-Bear Encounters (Yukon Government, 2012); and
- Kaska Dena Land Use Framework and Management Practices (Dena Kayeh Institute, 2010) (Although not endorsed by RRDC, some of the management practises in the Kaska Dena Land Use document have been incorporated into the draft WPP, pending additional input from RRDC, which will be added as part of the revised WPP).

1.2.2 BMC Policies

BMC has established Environmental, No Hunting / No Fishing, No Firearms, No Recreational Use of ATVs and Snowmobiles, and No Feeding of Animals policies. These are presented below.

ENVIRONMENTAL POLICY

The KZK Project will be undertaken in accordance with BMC's Environmental Policy which states the Company is committed to:

- Minimizing the environmental footprint of our operations as far as is practicable (Lease Agreement 105G07-001, Schedule 2, 4.5; LQ00424b, Appendix C, 2017-0002, p.8);
- Establishing environmental programs based upon risk assessments that set and review environmental targets and objectives;
- Developing and implementing sound management systems that are designed to minimize pollution while supporting the Company in meeting or exceeding the specified environmental targets and objectives for each Project;
- Ensuring that stakeholders are considered when developing Project systems;
- Ensuring that heritage sites are recognized, managed and protected as a fundamental part of our environmental culture;
- Integration of environmental issues into site inductions, training and ongoing workplace communication processes and procedures;
- Regularly evaluating and reviewing subcontractor and supplier environmental performance;
- Promoting the efficient use of energy and continually improving our processes to minimize waste so as to conserve natural resources;
- Encouraging continual improvement in environmental performance through establishment of planning, training, monitoring, inspection and reporting systems; and
- Ensuring that exploration rehabilitation outcomes target the establishment of self-sustaining ecosystems.

BMC is committed to conducting its activities in a manner that supports environment, social, economic, health and heritage values. To meet these objectives BMC requires its employees and contractors to:

- Comply with Project environmental conditions as communicated through the induction and ongoing communications;
- Support continual improvement of Project environmental performance; and
- Communicate environmental incidents and actively participate in rectification.

It is noted that the Environmental Policy will be updated to account for Project phases beyond exploration. This will be updated prior to submission of the QML Application.

NO HUNTING / NO FISHING

A "no hunting/no fishing" policy will be enforced for all personnel in all Project areas (LQ00424b, Appendix C, 2017-0002, p.8). This policy will be communicated to all employees and contractors during the site orientation.

NO FIREARMS POLICY

All firearms are prohibited at the BMC Minerals (No. 1) Ltd, Kudz Ze Kayah site unless otherwise authorized by BMC Management (LQ00424b, Appendix C, 2015-0028, p.1). Firearms are to only be used for the protection of personnel and property in the event of dangerous wildlife. All authorized firearms at the Kudz Ze Kayah Project site are under direct control of the BMC Management or an employee(s) designated by BMC Management. As described in the Yukon Occupational Health and Safety Regulations "*any worker who is required to use, handle or otherwise have control of a firearm shall:*

- *have successfully completed the Canadian Firearms Safety Course, given by an instructor who is designated by a chief firearms officer, and*
- *have demonstrated proficiency with that firearm to the employer.*"

Every designated employee who handles firearms in the course of their duties, must hold a valid Federal Firearms Possession License with non-restricted acquisition privileges.

All firearms must be handled and stored in accordance with the federal Firearms Act. This includes, but is not limited to, locking mechanisms on all firearms when not in use and proper storage of ammunition.

NO RECREATIONAL USE OF ATVS AND SNOWMOBILES

Recreational use of all-terrain vehicles (ATVs) and snowmobiles is prohibited on BMC Project sites (Lease Agreement 105G07-001, Schedule 2, 1.1(iii)). Use of the road to access recreational areas for ATVing and snowmobiling is strictly prohibited.

NO FEEDING OF ANIMALS

A "no feeding of animals" policy will be enforced for all personnel in all Project areas (LQ00424b, Appendix C, 2015-0028, p.1). This policy will be communicated to all employees and contractors during the site orientation. Contractors will also be required to adhere to this policy as part of their contractual agreements with BMC.

1.3 BMC'S EXPLORATION LICENCE/LEASE REQUIREMENTS

Extensive wildlife protection conditions are included in the existing Tote Road Lease Agreement 105G07-001 (Government of Yukon, 2015) and in the Class 3 Quartz exploration permit LQ00424b (Yukon Energy, Mines and Resources, 2017). These conditions, commitments and requirements will continue to be implemented throughout the proposed phases of the Project. These are grouped by topic in the sections below. These conditions have been integrated and cross-referenced in the mitigation measures of this WPP starting for mine construction as presented in Sections 5 and 6.

1.3.1 General Measures

- *Firearms will not be allowed on the exploration site. A "no hunting/no fishing" policy will be enforced for all personnel in all exploration areas (including access roads). This policy will be communicated to all employees and contractors during the site orientation. Contractors will also be required to adhere to this policy as part of their contractual agreements with BMC Minerals (No. 1) Ltd. (LQ00424b, Appendix C, 2015-0028, p.1);*
- *A "no feeding of animals" policy will be enforced for all personnel in all exploration areas. This policy will be communicated to all employees and contractors during the site orientation. Contractors will also be required to adhere to this policy as part of their contractual agreements with BMC Minerals (No. 1) Ltd. (LQ00424b, Appendix C, 2015-0028, p.1).*
- *The Wildlife Protection Policies shall include ... a "No hunting / No Fishing Policy" applicable to all mine employees and contractors. The objective of this policy will be to prohibit hunting and fishing in the general vicinity of the project mine site or haul road to the Robert Campbell Highway. This policy shall be in effect throughout the life of the project from construction through to closure and reclamation and shall apply to all mine employees and contractors. The lessee shall notify the lessor of any reported infringement of this policy (Lease Agreement 105G07-001, Schedule 2, 1.1(ii)); LQ00424b, Appendix C, 2017-0002, p.8);*
- *The Lessee during the term of this lease, shall carry out the wildlife protection, monitoring, facilities, management, and consultation provisions as set out in Schedule 2 [of lease Agreement 105G07-001], attached hereto and in accordance with the provision of the letter agreement, dated July 29, 1999 entered into between the Lessee and Yukon Government, Department of Renewable Resources (Lease Agreement 105G07-001, Condition 29B);*
- *Prior to commencement of construction of the project, the lessee shall establish Wildlife Protection Policies to encourage wildlife awareness and avoid disturbance effects (Lease Agreement 105G07-001, Schedule 2, 1.1)*
- *Attached (Appendix C [of LQ00424b]) are the commitments that form part of this operating plan (LQ00424b, Condition 87).*

1.3.2 Management of Wildlife-Human Interactions

- *Encounters with wildlife are to be avoided. If ungulates, bears or wolverines, are encountered while carrying out project activities, the activities shall stop, as long as it is safe to do so, until the animal(s) has left the area. Wildlife shall be given the right of way (LQ00424b, Condition 66; Lease Agreement 105G07-001, Condition 29A(ii));*
- *If conditions are warranted, the camp shall be enclosed with electric fencing with attention given to camp design (as outlined in the Guideline for Industrial Activity in Bear Country for the Mineral Exploration, Placer Mining and Oil and Gas Industries) in order to avoid attracting bears. Warranted conditions are developed in consultation with the Conservation Officer and include site-specific bear activity (LQ00424b, Condition 73);*

- *As part of safety training, all personnel and contractors will be provided wildlife safety and awareness training, including bear awareness and how to avoid disturbing sensitive species such as caribou (LQ00424b, Appendix C, 2015-0028, p.1);*

- *Personnel and contractors will not attempt to handle nuisance or problem wildlife without specific direction from the Conservation Officer (LQ00424b, Appendix C, 2015-0028, p.1);*

- *All field personnel will carry bear repellent spray with them at all times, as well as functioning radios, with scheduled check-in times to ensure worker safety (LQ00424b, Appendix C, 2015-0028, p.1);*

- *Harassment of wildlife will not be tolerated. This includes attempts to chase, catch, divert, follow, or otherwise harass wildlife by on- or off-road vehicles, aircraft, or on foot [excluding situations where diversion for human safety is required] (LQ00424b, Appendix C, 2015-0028, p.1);*

- *All work areas will be kept free of garbage and spills. All uncontained garbage or spills will be cleaned up immediately. Improperly disposed garbage, especially food or camp wastes, will be cleaned up and reported to the Project Geologist as soon as possible. With proper waste management, bears will be less likely to be attracted to the camp and work areas (LQ00424b, Appendix C, 2015-0028, p.1);*

- *All chemicals (i.e. glycols etc) that may be wildlife attractants will be sealed and stored on site in a building/shed to minimize the potential for attracting the wildlife to the site (LQ00424b, Appendix C, 2015-0028, p. 2);*

- *The construction of new roads and exploration trails will be avoided to the extent possible (LQ00424b, Appendix C, 2015-0028, p. 2 and 2017-0002, p.8);*

- *Drill site cuts will be sloped to allow for personnel and wildlife to exit safely (LQ00424b, Appendix C, 2015-0028, p. 2);*

- *Wildlife logs will be maintained to provide information regarding presence of wildlife and potential changes in use of areas over time (LQ00424b, Appendix C, 2015-0028, p. 2); and*

- *Wildlife interactions (e.g., traffic accidents) and nuisance or problem animals will be reported to the Project Geologist immediately. Observations of wildlife behaving abnormally will be reported within 24 hours (LQ00424b, Appendix C, 2015-0028, p. 2).*

1.3.3 Sensitive Species and Areas

- *The Lessee will minimize the potential for disturbance to caribou during sensitive life cycle activities by avoiding those areas that are used for calving, post-calving and rutting, and by ensuring the access road does not conflict with such areas used by caribou and other migratory wildlife (i.e. moose) (Lease Agreement 105G07-001, Condition 29A(i));*

- *The operator shall contact the Watson Lake Regional Biologist for information on appropriate set back distances if nests, dens or mineral licks are encountered. These site-specific features shall not be disturbed (LQ00424b, Condition 67; LQ00424b, Appendix C, 2017-0002, p.8);*

- *The operator shall contact YG, Environment for detailed information on the exact location of mineral licks within the polygon on the Wildlife Key Area maps (note: mineral licks are not situated in the centre of the 5 km diameter circular polygons) and for information on techniques/methodologies related to monitoring mineral licks (LQ00424b, Condition 68);*

- *Den and nest sites: if discovered during work, locations must be recorded and avoided until no longer in use by wildlife (LQ00424b, Appendix C, 2017-0002, p.8);*

- *Any new mineral licks found by the operator shall be reported to the Watson Lake Regional Biologist (LQ00424b, Condition 69; LQ00424b, Appendix C, 2017-0002, p.8);*

- *Avoid worksites where sensitive species have been seen until the wildlife moves away (LQ00424b, Appendix C, 2017-0002, p.8);*

- *Additional mitigation measures for bears will include pre-denning monitoring in the areas of planned exploration activities each year. If bear activity indicates they may be preparing to den in an area that could be disturbed by exploration activities, the YG conservation officer and RRDC Land Stewards will be consulted to determine measures to mitigate potential human-bear interactions (LQ00424b, Appendix C, 2017-0002, p.8);*

- *The lessee, in consultation with the Regional Biologist, shall establish appropriate measures to prevent bear attraction into the project area, including the mine, camp, and Mine Haul Road, and elimination of problem wildlife incidents for all species. Bear avoidance measures shall include fencing the dump and kitchen areas with electric fences, storage of waste in bear-proof containers, and daily incineration of waste in a Canadian Standards Association approved fuel-fired incinerator. All bear incidents are to be reported to the local Conservation Officer within 24 hours of the incident or as directed by a Conservation Officer in writing (Lease Agreement 105G07-001, Schedule 2, 4.4);*

- *When the timing of exploration activities cannot avoid the nesting period, BMC's qualified environmental monitor conducts pre-clearing surveys and in the event a nest is discovered the area is flagged as a work avoidance area until the birds have left the nest. These procedures will continue to be followed at KZK (LQ00424b, Appendix C, 2017-0002, p.8); and*

- *Conduct pre-exploration surveys for presence of nesting birds (as required) (LQ00424b, Appendix C, 2017-0002, p.8).*

1.3.4 Waste Management

- *Implementing a Bear Awareness Program (LQ000424b, Appendix C, 2015-0028, p. 2);*

- *The operator shall keep all garbage, including kitchen waste, in a container that prevents access by bears and other wildlife, until properly disposed of in accordance with the Solid Waste Regulations (LQ00424b, Condition 33; LQ00424b, Appendix C, 2015-0028, p. 2);*

- *The garbage disposal area will be kept at least 100 m from sleeping quarters (LQ00424b, Appendix C, 2015-0028, p. 2);*

- *All food and cooking supplies should be either stored securely in metal bear-proof containers or removed from site during times when the camp is closed (LQ00424b, Condition 74);*

- *Food and kitchen waste will be managed as follows:*

    - *Frozen food will be kept in freezers, with fresh food kept in refrigerators (LQ00424b, Appendix C, 2015-0028, p. 2);*

    - *The camp and kitchen areas will be kept clean, and free of refuse (LQ00424b, Appendix C, 2015-0028, p. 2);*

    - *When burning kitchen waste on site it must be burned regularly to reduce odours that might attract wildlife and be burned to ash by forced air or fuel fired incineration (LQ00424b, Condition 34); Garbage will be burned in an incinerator daily whenever possible, to prevent the accumulation of waste (LQ00424b, Appendix C, 2015-0028, p. 2; Lease Agreement 105G07-001, Schedule 2, 4.4);*

    - *Combustible garbage is stored in an area surrounded by an electric fence, in a lockable bin and burned in an incinerator on a daily basis to prevent its accumulation. The incinerator is a "SmartAsh" model Cyclonic Barrel Burner which can be used as fuelfired or forced-air depending on the type of garbage being burned. Ash from the incinerator is buried in pits > 1 m deep (and covered as per the waste management permit). (Lease Agreement 105G07-001, Condition 76; LQ00424b, Appendix C, 2017-0002, p.11 replaces commitment in 2015-0028, p. 2);*

    - *Non-combustible garbage (e.g. cans, metal, recyclable containers) is stored in lockable bins and then periodically (approximately once a week) trucked off site and disposed of in the Whitehorse Landfill and/or a recycling centre (e.g., Raven Recycling in Whitehorse). (Lease Agreement 105G07-001, Condition 76; LQ00424b, Appendix C, 2017-0002, p.11 replaces commitment in 2015-0028, p. 2);*

- *If food is taken out into the field (i.e., in lunches) field crews will bring all garbage back with them for disposal (LQ00424b, Appendix C, 2015-0028, p. 2);*

- *Grey water (i.e., from showers and the kitchen) will be disposed of through a sewage disposal system including septic tanks and an absorption bed (LQ00424b, Appendix C, 2017-0002, p.11 replaces commitment in 2015-0028, p. 2);*

- *The operator shall remove any flagging tape used to carry out project activities once the activities are completed unless bio-degradable tape is utilized (LQ00424b, Condition 77); and*

- *[In Final Decommissioning] Debris, equipment, fuel barrels, scrap metal and other waste at the work site shall be completely disposed of, so as not to attract wildlife, by removal to an authorized disposal site as often as is practicable throughout the mining season and completely at the cessation of the operation (LQ00424b, Condition 81).*

1.3.5 Habitat Management

- *Cut brush must not be piled so that it blocks movement of wildlife or people (LQ00424b, Condition 45);*

- *All reasonable efforts must be made when drilling to minimize the impact on wildlife and the public (LQ00424b, Condition 49);*

- *Trail routes must be reconnoitered and must be used in a way that minimizes ground disturbance, including damage to permafrost and sensitive wildlife habitat (LQ00424b, Condition 59);*

- *The KZK camp location will be chosen for its proximity to the desired exploration areas, and also so as to minimize proximity to natural wildlife habitats (the camp location will avoid critical caribou habitat such as rutting areas). In addition, the camp will be greater than 30 m from the high water mark of any water body (LQ00424b, Appendix C, 2015-0028, p.2);*

- *Drill sites built near the gravel tote road will be re-vegetated with non-palatable plants to avoid attracting wildlife to the roadside (LQ00424b, Appendix C, 2015-0028, p.3);*

- *The lessee shall implement progressive reclamation plans with the objective of minimizing impacts and duration of habitat loss associated with disturbed areas that are no longer required for mine-related activities. The lessee shall report annually on the extent of surface disturbances and reclaimed areas (Lease Agreement 105G07-001, Schedule 2, 4.5; LQ00424b, Appendix C, 2017-0002, p.8);*

- *The operator shall ensure that annual reclamation efforts are successful in reestablishing the vegetative mat and community. A variety of sloping, contouring, scarifying and spreading of fines, silt and/or vegetative mat would prepare the ground to achieve these ends and encourage natural re-vegetation (LQ00424b, Condition 21). Ongoing reclamation from all exploration activities will be undertaken (LQ00424b, Appendix C, 2015-0028, p.3);*

- *Only biodegradable synthetic drilling fluids will be utilised at the drill (LQ00424b, Appendix C, 2015-0028, p.3);*

- *Bulk fuel systems, sub-caches of smaller containers (e.g. 205 L drums) and other fuel or waste fuel storage areas will be on stable ground and set back greater than 30 metres from the high water mark of any water body. Bladder bulk fuel systems and all sub-caches will be placed in synthetic berms. Earthen berms will act as a third containment barrier for double-walled fuel tanks (LQ00424b, Appendix C, 2015-0028, p.3); and*

- *Where construction of trails cannot be avoided, the Contractor shall construct trails as narrow as possible and avoid straight lines where possible (LQ00424b, Appendix C, 2017-0002, p.8).*

1.3.6 Aircraft Operation

- *The operator shall plan to avoid carrying out their helicopter exploration activities during the critical periods for caribou (critical periods for this area are May to July for calving and post-calving and mid-September to mid-October for rutting.) If caribou are present within 1 km of* *the active work area during these times, helicopter exploration activities shall cease until the caribou have left the area (LQ00424b, Condition 71);*

- *Flight paths have been and will continue to be designed to reasonably avoid disturbing wildlife and active hunting areas (LQ00424b, Appendix C, 2017-0002, p.9);*

- *The guidelines developed by the Mining and Petroleum Environmental Research Group (MPERG) have been adapted to minimize potential wildlife harassment from aircraft and helicopter over flights. All personnel, pilots and contractors will be asked to follow the guidelines as set out in "Flying in Caribou Country: How to minimize disturbance from aircraft" (MPERG, 2008b) and "Flying in Sheep Country: How to minimize disturbance from aircraft" (MPERG, 2008c). These guidelines will be provided to aircraft and helicopter service providers (LQ00424b, Appendix C, 2015-0028, p.3 and 2017-0002, p.9; Lease Agreement 105G07-001, Schedule 2, 4.2);*

- *Helicopter operations during the winter months will adhere to the measures outlined in the guidance document for Flying in Caribou Country. (YOR 2017-0002-022-1, p.3) (LQ00424b, Appendix C, 2017-0002, p.9);*

- *Flight timing windows as described in Quartz Mining Land Use Approval LQ00424 will also be adhered to (LQ00424b, Appendix C, 2017-0002, p.9);*

- *Key mitigation measures will include the following:*

    - *Flight path routes will be determined to best avoid disturbing wildlife and active hunting areas. Consultation with the Kaska Nation and Outfitters will be ongoing throughout the field season to aid in avoiding sensitive areas (LQ00424b, Appendix C, 2015-0028, p.3 and 2017-0002, p.9);*

    - *Flying will be avoided over areas where wildlife has been observed in past seasons (based on publicly available information from the Yukon Zinc Studies in the vicinity of the Project and Yukon Government data), and areas sensitive to wildlife at certain times will be avoided (LQ00424b, Appendix C, 2015-0028, p.3 and 2017-0002, p.9);*

    - *Flights will be conducted at minimum of 300 m (1000 ft.) above ground level elevations to minimize disturbance to wildlife, except where required for work, safe landing approaches/ flight path, etc. (LQ00424b, Appendix C, 2015-0028, p.3 and 2017-0002, p.9);*

    - *Flying height for airborne geophysical surveys will likely be below 300 m, but the surveys will be timed so as to not interfere with caribou rutting/calving seasons etc. (LQ00424b, Appendix C, 2015-0028, p.3 and 2017-0002, p.9);*

    - *All reasonable efforts will be made to avoid sensitive habitats during key seasonal periods (LQ00424b, Appendix C, 2015-0028, p.3);*

    - *When sensitive habitats cannot be avoided, a minimum over flight altitude of 600 m (or 2000 ft) will be maintained to the extent possible (LQ00424b, Appendix C, 2015-0028, p.3);*

- o *Whenever possible, aircraft will avoid sheep ranges by 3.5 km or a ridge will be placed between the aircraft and sheep range, and aircraft will fly at altitudes below sheep if they are encountered (LQ00424b, Appendix C, 2015-0028, p.3);*
- o *Purposefully flying towards, hovering and circling wildlife will not be permitted (LQ00424b, Appendix C, 2015-0028, p.3);*

- *BMC will plan to avoid carrying out the airborne geophysics program during critical periods for caribou, which is May to July for calving and post-calving and mid-September to mid-October for rutting. Ideally, the airborne geophysics program will be conducted during late August. If, despite planning to avoid these times, the surveys must be completed during the critical time periods BMC's Project Manager will contact EMR for approval (LQ00424b, Condition 70 and Appendix C, 2017-0002, p.9);*
- *Purposefully flying towards, hovering and circling wildlife will not be permitted (LQ00424b, Appendix C, 2017-0002, p.9);*
- *It is noted that the proposed flight frequency would be low during the winter months between Whitehorse and the airstrip (i.e. once or twice per week) and if the road is opened during the winter then the air traffic between the airstrip and the exploration site would be limited to an emergency or monthly water sampling, as personnel and supplies would be transported to the exploration site via vehicle rather than aircraft (LQ00424b, Appendix C, 2017-0002, p.9); and*
- *Aircraft use shall be carried out to minimize non-essential flight activities and to avoid wildlife calving and rutting areas during sensitive lifecycle periods. Avoidance periods are subject to change from time to time in accordance with results from wildlife survey and Wildlife Log observations and consultation with the Regional Biologist (Lease Agreement 105G07-001, Schedule 2, 4.2).*

1.3.7 Access Management

- *The Wildlife Protection Policies shall include … a policy prohibiting recreational use by employees and contractors of all-terrain vehicles and snowmobiles. The lessee shall prohibit access and use of ATVs and snowmobiles for recreational purposes on the mine haul road and the mine site (Lease Agreement 105G07-001, Schedule 2, 1.1(iii));*
- *In addition to any remedial action required in relation to re-establishment of the vegetative mat, temporary trails must be blocked to prevent further vehicular access (LQ00424b, Condition 63);*
- *Where the construction of trails cannot be avoided, the operator shall construct trails as narrow as possible and avoid straight lines where possible. This will limit use of trails as 'wolf highways' which can increase predation of ungulates by wolves (LQ00424b, Condition 64);*
- *Increased access to the traditional range of the Finlayson caribou herd, especially along their migration route to winter range, has been identified as the primary concern by Yukon Government and the Ross River Kaska Dena (Cominco, 1996). The security station and gate at the access to the tote road from the Robert Campbell Highway has been seasonally manned and maintained by a member of the Ross River community since 1995, and only authorized vehicles*

are allowed on the tote road. Over the winter period the gate is locked. Access along the tote road will continue to be managed in this fashion (LQ00424b, Appendix C, 2015-0028, p.3);

- *The use of the tote road in the winter will be dependent on the exploration activities required through the winter. If the tote road is to be used in the winter, BMC will continue to prevent unauthorized use of the road through the use of a manned station at the entrance of the tote road and/or a locked gate (LQ00424b, Appendix C, 2017-0002, p.9);*

- *Mitigation measures to minimize the potential effects to caribou/moose are outlined in the [Exploration] EMP and will be adhered to when the road is being used during the winter months. It is noted that many of the management measures listed in the EMP are from the existing class 3 exploration permit and the tote road lease conditions. These mitigation measures/permit conditions will be adhered to during the winter months (LQ00424b, Appendix C, 2017-0002, p.9);*

- *Minimum traffic levels will be maintained to the extent possible (LQ00424b, Appendix C, 2015-0028, p.3);*

- *A site vehicle access register will be maintained at the gatehouse (LQ00424b, Appendix C, 2015-0028, p.3);*

- *Wildlife will have the right-of-way along the entire tote road (LQ00424b, Appendix C, 2015-0028, p.3);*

- *If caribou or moose are encountered on the tote road, the equipment and/or activity is to be halted until the wildlife has left the immediate area (LQ00424b, Appendix C, 2015-0028, p.3);*

- *The authorized use of on-road and off-road vehicles will be restricted to established roads and designated trails at the exploration site except to access monitoring sites and remote communications equipment. Use of private and recreational vehicles will be prohibited at all times (LQ00424b, Appendix C, 2015-0028, p.3);*

- *All wildlife observations on access corridors will be reported to the Project Geologist and recorded in the Wildlife Log (LQ00424b, Appendix C, 2015-0028, p.3);*

- *Additional mitigation measures that will be implemented during the winter months along the tote road, when it's being used (that are not included in the exiting EMP or permits) include:*

    - *Radio communication among road users will be required to communicate information such as sightings of large animal species (LQ00424b, Appendix C, 2017-0002, p.9);*

    - *The road will be plowed so that snow banks are less than 1 m in height (LQ00424b, Appendix C, 2017-0002, p.9);*

    - *Breaks in snow banks will be placed every 50 to 100 m on both sides of the road to enable passage of large mammals (LQ00424b, Appendix C, 2017-0002, p.10); and*

    - *Gravel and/or sand will be used on compacted snow or ice to improve road safety. Salt will not be used as it is a wildlife attractant (LQ00424b, Appendix C, 2017-0002, p.10);*

1.3.8 Facilities Management

- *Commencing upon construction of the project, the lessee shall manage company-directed activities and transportation along the Mine Haul Road to avoid wildlife mortality and to eliminate movement barriers from wildlife access routes. Areas of concern shall include the Mine Haul Road and portions of Robert Campbell Highway and other highway routes used, if applicable. The lessee shall consult with the YTG, RRDC and Department of Transportation to implement appropriate wildlife protection measures, which may include, but are not limited to maintenance guidelines for winter, speed reduction zones, signs at crossings, radio equipped tucks, reporting of wildlife on roads (Lease Agreement 105G07-001, Schedule 2, 4.1); and*

- *The lessee, in consultation with the Regional Biologist, shall establish appropriate measures to carry out blasting activities at the mine in a manner that avoids disturbance of wildlife during critical lifecycle activities, particularly caribou calving and sheep lambing periods (Lease Agreement 105G07-001, Schedule 2, 4.3).*

1.3.9 Wildlife Reporting Procedures

- *The Wildlife Protection Policies shall include … a wildlife and incident reporting log in accordance with Section 2.0, Wildlife Monitoring (Lease Agreement 105G07-001, Schedule 2, 1.1(iv)).*

- *Reporting procedures for wildlife-human interactions, wildlife observations and wildlife features (i.e. nest, den, mineral lick, species at risk etc.) will be included in employee and contactor orientations (LQ00424b, Appendix C, 2015-0028, p.4).*

- *All incidents with wildlife shall be reported to the District Conservation Officer in Watson Lake (Liard Region) at (867) 536-3210, as well as any other communication regarding wildlife (LQ00424b, Condition 14; Lease Agreement 105G07-001, Schedule 2, 4.5; Lease Agreement 105G07-001, Schedule 2, 4.5).*

- *The operator shall maintain a wildlife log which shall be provided to the Chief, Mining Lands annually. The log shall include the following: date and time of sighting, a detailed location description (coordinates are preferable), species and number of animals, age and sex if possible, activity of the animals, and any other comments. The Wildlife Log shall be maintained for the life of the mine until there are no longer employees on site. The area definition should include the mine property and access road, as well as relevant portions of the Robert Campbell Highway. The Wildlife Log shall be in written form, including maps. The Wildlife Log shall be reviewed annually each January with the Regional Biologist for the area. (LQ00424b, Condition 15; Lease Agreement 105G07-001, Schedule 2, 2.3).*

- *Wildlife observations, monitoring programs, and incidents may be required to be followed up with additional mitigation as determined by the lessor, in consultation with the lessee, YTG RR and affected First Nations (Lease Agreement 105G07-001, Schedule 2, 2.4).*

- *Reporting procedures will also include reporting wildlife incidents (i.e. close or aggressive encounters, unusual or erratic behaviour, traffic accidents or near misses, and dead or injured wildlife) (LQ00424b, Appendix C, 2015-0028, p.4).*

- *Records will be managed by the Project Geologist and will be used to provide an indication of the effectiveness of wildlife mitigation measures and to allow an adaptive management approach to improve performance (LQ00424b, Appendix C, 2015-0028, p.4).*

- *A reporting mechanism will be developed with the Yukon Government for the reporting of wildlife fatalities that occur along the access road (although such an incident is not expected to occur) ((LQ00424b, Appendix C, 2015-0028, p.4 and Lease Agreement 105G07-001, Condition 29A(iii)).*

- *Species at Risk (YOR 2015-0028-003) Species of Concern Fact Sheet for Kudz Ze Kayah Project - If these species are observed during exploration activities, they will be recorded in the project wildlife-siting log:*

    - *Bank Swallow, Caribou (Northern Mountain), Collared Pika, Common Nighthawk, Grizzly Bear, Little Brown Myotis, Northern Myotis, Olive-sided Flycatcher, Red-necked Phalarope, Rusty Blackbird, Short-eared Owl, Western Bumble Bee (mackayi ssp), Wolverine, and Woodchuck (LQ00424b, Appendix C, 2015-0028, p.4).*

- *The lessee shall provide opportunities to meet at least once each year with Interested Parties to report on and review the wildlife protection and monitoring provisions contemplated in this schedule. A primary objective of the annual meetings shall be to provide advance notice of anticipated project activities and plans for the upcoming year and to avoid unnecessary conflicts with other resource users (Lease Agreement 105G07-001, Schedule 2, 5.1).*

1.3.10 Wildlife Monitoring

- *Wildlife activities in the project area are to be monitored to identify changes in wildlife migration, distribution, abundance, to evaluate causal relationships between observed changes and project-related activities and to obtain information for the planning of mitigation. Monitoring of caribou and moose shall be used as indicators for the Valued Ecosystem Components. Monitoring shall be used to detect changes beyond baseline conditions or specific values for Valued Ecosystem Components (Lease Agreement 105G07-001, Schedule 2, 2.2).*

  The parameters for Valued Ecosystem Components monitoring shall be as follows:

  (i) frequency of surveys should be established in two year periods, commencing upon mine construction, subject to review at annual meetings of the Lessor, the Lessee, YTG, RRDC, affected First Nations, and other resource users in the area, including, but not limited to representatives of outfitters and trappers groups (the "Interested Parties"). The period for which surveys are required should be for the life of the mine, unless otherwise determined by the parties (Lease Agreement 105G07-001, Schedule 2, 2.2);

  (ii) survey area definition should be as completed in accordance with the original baseline survey for the project as shown in the map attached as Schedule 3 [see appendix 5 of IEE] (Lease Agreement 105G07-001, Schedule 2, 2.2);

  (iii) survey methodology shall include participation in annual YTG post-calving and rut surveys for caribou in conjunction with YTG RR survey schedules. Moose

observations for the project area should be in the surveys. Methodology, including participation, should be determined annually through discussions with the YTG RR regional biologist (the "Regional Biologist") (Lease Agreement 105G07-001, Schedule 2, 2.2);

(iv) survey reporting shall be made by December 31 of each year for review in an annual meeting of the Interested Parties (Lease Agreement 105G07-001, Schedule 2, 2.2).

(v) survey follow-up should include review and discussion with Interested Parties of survey data in conjunction with YTG as well as additional mitigation based on the findings of effects monitoring. Reformatting of the wildlife monitoring design may also be required to reflect changing conditions (Lease Agreement 105G07-001, Schedule 2, 2.2).

1.3.11 Employee and Contractor Training

- *Employee and contractor orientation will include the following topics of relevance to wildlife management:*
    - *Access road use protocols;*
    - *A "no hunting/no fishing" policy;*
    - *Bear Awareness;*
    - *Waste management procedures;*
    - *Wildlife observation and interaction reporting procedures;*
    - *Wildlife sensitive locations/timing, as applicable;*
    - *Helicopter management practises; and*
    - *Access management practises (LQ00424b, Appendix C, 2015-0028, p.1).*
- *The operator shall supply the camp with bear deterrent devices such as bear bangers, cracker shells, bear spray, etc. The bear awareness training provided to personnel and contractors shall include use of these deterrent devices (LQ00424b, Condition 72).*
- *The Wildlife Protection Policies shall include … environmental training for all mine employees and contractors, pursuant to which the lessee will implement an education and awareness program with respect to wildlife and habitat protection needs of wildlife. One objective of this program will be to educate mine employees and contractors about potential wildlife issues and the commitments made by the lessee regarding wildlife mitigation This program shall be presented in conjunction with site orientation and training and shall be made available in written form as part of the overall environmental program at the mine. Upon request by the lessee, the Yukon Territorial Government Renewable Resources (YTG RR) will provide assistance*

in reviewing program materials and making related presentations to mine personnel (Lease Agreement 105G07-001, Schedule 2, 1.1(i))

1.4 ENGAGEMENT

1.4.1 Kaska Requirements

Through agreements, BMC and Kaska will cooperatively manage environmental components of the mine (including wildlife). BMC will collaborate with Kaska to monitor wildlife, utilizing Ross River Dena Council (RRDC) and Liard First Nation (LFN) personnel. BMC is also committed through agreements to obtain Kaska input to this WPP.

1.4.2 Other Engagement

BMC recognizes the importance of consultation with all interested parties for positive management of wildlife populations. BMC will participate in wildlife management and monitoring programs with other stakeholders and interested parties where there are mutual interests and where feasible.

1.5 PLAN STRUCTURE

1.5.1 Outline

BMC's wildlife protection, management, and monitoring programs for the KZK Project have been developed to protect and monitor wildlife activity in the Project area, to assess potential changes to wildlife and habitat resources, and to evaluate whether mitigation measures outlined in this document are effective in managing Project effects on wildlife.

The WPP is the primary document that BMC will use to implement wildlife and habitat protection. The WPP is a "living document" that will undergo review on an annual basis and be adjusted to ensure an appropriate level of wildlife protection is achieved. As more information is gathered through monitoring the presence and behaviour of wildlife interaction with the KZK Project and personnel, additional mitigation measures may be developed and integrated into the WPP.

This document is structured into the following sections:

- Section 1: Introduction – presents background information, BMC policies, regulatory requirements, and Kaska requirements;
- Section 2: Implementation - presents how the plan will continue on from exploration into construction including roles and responsibilities, key lines of communication, and the plan structure;
- Section 3: Kudz Ze Kayah Project Description – provides a brief summary of the Project activities and layout;
- Section 4: Potential Impacts – provides a summary of the potential impacts, wildlife species that occur in the Project area, specific species with conservation status, and traditionally important species;

- Section 5: Wildlife Protection and Mitigation Measures – presents requirements for training, sensitive times and locations, species-specific mitigations, mine and infrastructure design and operations, approaches to attractants management, traffic and access management, and procedures for problem wildlife management;
- Section 6: Wildlife Monitoring Program – provides the ongoing wildlife monitoring program to track effects, and the wildlife records program; and
- Section 7: Adaptive Management – describes the evolving nature of the WPP with regular updates and includes changes in the monitoring results that trigger adaptive management and potential initial corrective measures.

1.5.2 Associated Management Plans

The WPP is part of BMC's Environmental Management System which consists of the overarching policies, management plans, auditing program, and adaptive management program. Environmental management plans that are tied to the WPP include the following:

- Environmental Management Plan, Kudz Ze Kayah Exploration Project, 2017 includes wildlife protection measures that are in place until this WPP comes into effect for construction;
- Waste Management Plan includes measures to collect, store, and incinerate putrescible waste to minimize wildlife attractants, defines waste storage requirements that minimize the Project footprint and prevent contaminant release to the receiving environment;
- Hazardous Materials Management Plan includes measures to prevent contaminant release to the receiving environment, and minimize wildlife attractants;
- Surface Water Management Plan includes measures to prevent contaminant release to the receiving environment;
- Spill Contingency Plan includes measures to prevent contaminant release to the receiving environment, and minimize wildlife attractants;
- Vegetation Management Plan includes measures to control invasive plants to protect native wildlife habitat and protect any rare habitats that may be encountered;
- Noise Management Plan includes measures to minimize noise that could disturb surrounding wildlife;
- Air Quality Management Plan includes measures to minimize contaminant release to the receiving environment that could affect wildlife forage habitat or health;
- Traffic and Access Management Plan includes measures to minimize vehicle collisions with wildlife, minimize disturbance of wildlife in surrounding habitat, and prevent hunter access via the Access Road; and

- Closure and Reclamation Plan includes measures to restore wildlife habitat progressively during construction and operations and fully at closure.

1.5.3 Living Document

This WPP is a "living document" that will undergo review on an annual basis and be adjusted to ensure an appropriate level of wildlife protection is achieved during construction, operation, and closure. As more information is gathered through monitoring the presence and behaviour of wildlife interactions with the KZK Project and personnel, additional mitigation measures may be developed and integrated into the WPP through adaptive management as described in Chapter 7.

1.5.4 Review

Management will review information related to wildlife management at least annually and make any necessary revisions to the WPP where the monitoring and records indicate the objectives of the WPP are not being met. Review will be completed earlier if a situation warrants more immediate corrective action. Management may call upon outside experts to assist with review and changes to the WPP. Relevant information for review includes the following:

- Wildlife monitoring data and reports;
- Related environmental monitoring data and reports;
- Wildlife incidents;
- Inspector and Conservation Officer correspondence and reports;
- Grievances from staff, contractors, community members, trapline holders, Kaska Nation guide outfitters, NGOs, and/or the public; and
- Observations made by staff and contractors.

2 IMPLEMENTATION

Implementation of the WPP for construction, operations, and closure will carry forward the already implemented wildlife protection measures from the exploration Environmental Management Plan. This section defines the roles and responsibilities, key lines of communication, training programs, and plan structure including review and adaptive management framework, which will be implemented during the construction phase. Note that the roles are separated between corporate BMC staff and the KZK Project site staff. As is common practice at other mines, KZK Project staff will manage day-to-day operations with oversight such as reviews and auditing conducted at the corporate level. Titles and organization will likely change as BMC develops its Safety, Health and Environmental Management Program for construction and then operations. Such updates will likely be included as part of the more advanced WPP that will be submitted as part of QML licence application.

2.1 ROLES AND RESPONSIBILITIES

2.1.1 BMC Senior Management Team

Roles and responsibilities of the BMC Senior Management Team include the following:

- Manage media relations as required on WPP performance and any wildlife incidents;
- Provide the resources to ensure the implementation and control of the WPP;
- Delegate authority necessary to carry out the elements of the WPP;
- Support action required to correct any non-conformances; and
- Participate in the annual management review which will address the need for changes to the WPP in light of compliance and performance records, site specific conditions, changing circumstances, monitoring results, and the commitment to continuous improvement. The BMC Senior Management Team may delegate this review to an Environment, Health and Safety Review Committee or similar.

2.1.2 BMC Environmental / Sustainability Manager

BMC's Environmental / Sustainability Manager (or similar title) will participate as part of BMC's Senior Management Team. Roles and responsibilities of the Environmental / Sustainability Manager include the following:

- Review and approve updates to the WPP;
- Assist in emergency situations to minimize adverse environmental effects;
- Communicate WPP-related concerns to BMC senior management;
- Conduct at least one site inspection per quarter during construction and closure, at least once every quarter during operations, and as needed post-closure;
- Manage environmental management system audit program (including WPP components); and
- Participate in the annual management review which will address the need for changes to the WPP in light of compliance and performance records, site specific conditions, changing circumstances, monitoring results, and the commitment to continuous improvement.

2.1.3 KZK General Manager

Roles and responsibilities of the KZK General Manager include the following:

- Provide the resources to ensure the implementations and control of the WPP;
- Delegate authority necessary to carry out the elements of the WPP effectively;

- Support action required to correct any non-conformances; and
- Participate in the annual management review which will address the need for changes to the WPP in light of compliance and performance records, site specific conditions, changing circumstances, monitoring results, and the commitment to continuous improvement.

2.1.4 KZK Environmental Site Coordinator

Roles and responsibilities of the KZK Environmental Coordinator include the following:

- Manage and conduct Project activities in a manner that complies with all permit, legal and Kaska requirements, minimizes wildlife impacts, and reduces the likelihood of wildlife incidents;
- Provide updates when required to the WPP;
- Provide on-site training to the Environmental Monitors;
- Communicate the WPP to the KZK General Manager, BMC Environmental Manager, KZK Environmental Monitors, and other relevant parties (i.e. personnel on site) through site orientation meetings, tailgate meetings etc.;
- Ensure staff and contractor activities comply with the WPP;
- Prepare compliance and management reports and/or review the reports provided by the KZK Environmental Monitors;
- Liaise with Kaska and Yukon Government agencies as needed;
- Lead and manage WPP-related emergency situations on-site including communication with Conservation Officers and designated Kaska land stewards;
- Identify sensitive environmental areas;
- Provide notification to applicable environmental regulators, related to wildlife aspects of the Project, if required;
- Manage monitoring programs; and
- Participate in the annual management review which will address the need for changes to the WPP in light of compliance and performance records, site specific conditions, changing circumstances, monitoring results, and the commitment to continuous improvement.

2.1.5 KZK Environmental Monitors

Roles and responsibilities of KZK Environmental Monitors include the following:

- Participate in Health Safety and Environment (HSE) meetings, as necessary;
- Monitor the efficacy of the mitigation and management practises being undertaken by the contractor (described in Section 2.1.6);
- Provide recommendations for modifying and/or improving environmental mitigation measures, as necessary;
- Notify the KZK General Manager and KZK Environmental Coordinator on environmental incidents (including wildlife);
- Prepare environmental documentation, including weekly environmental reports on environmental measures that are being undertaken at the Site including wildlife-related measures;
- Liaise with and report to the KZK General Manager and KZK Environmental Coordinator with respect to issues that may require communication with regulatory agencies, Kaska Nation and other key stakeholders; and
- Assist in emergency situations to minimize adverse effects on wildlife.

2.1.6 KZK Contractors and Employees

All contractors and employees working on the KZK Project will be responsible for conducting their work in a manner which will achieve the required level of wildlife protection including: complying with all wildlife protection policies and procedures, conducting themselves in a responsible and polite manner at all times, respecting the community life, their values, rules, customs, and local traditions. BMC contractors and employees will be required to follow the requirements of this WPP (as part of their contractual or employment agreements).

2.2 KEY LINES OF COMMUNICATION

Key lines of communication for effective operation of the WPP are presented in Figure 2-1.

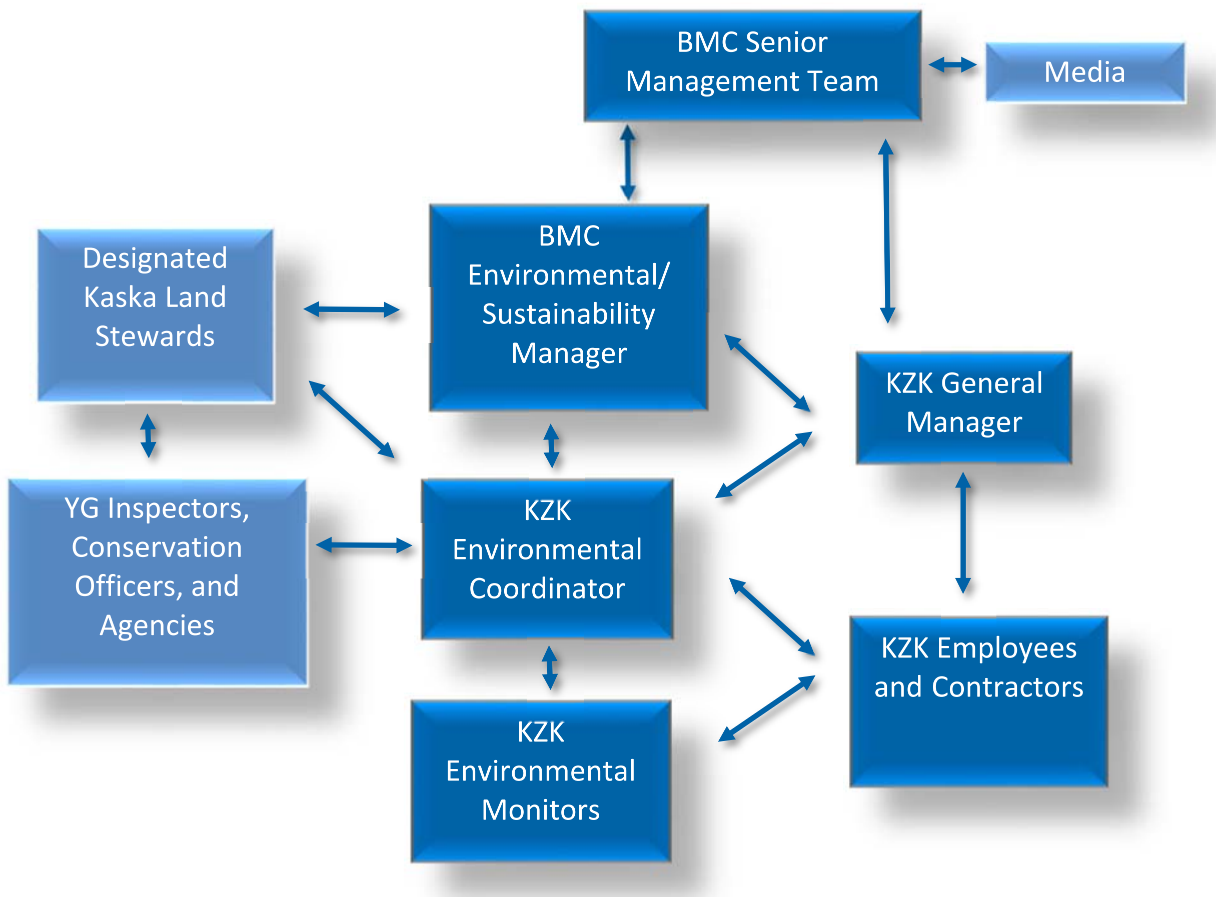


Figure 2-1: Key Lines of Communication for Managing the WPP

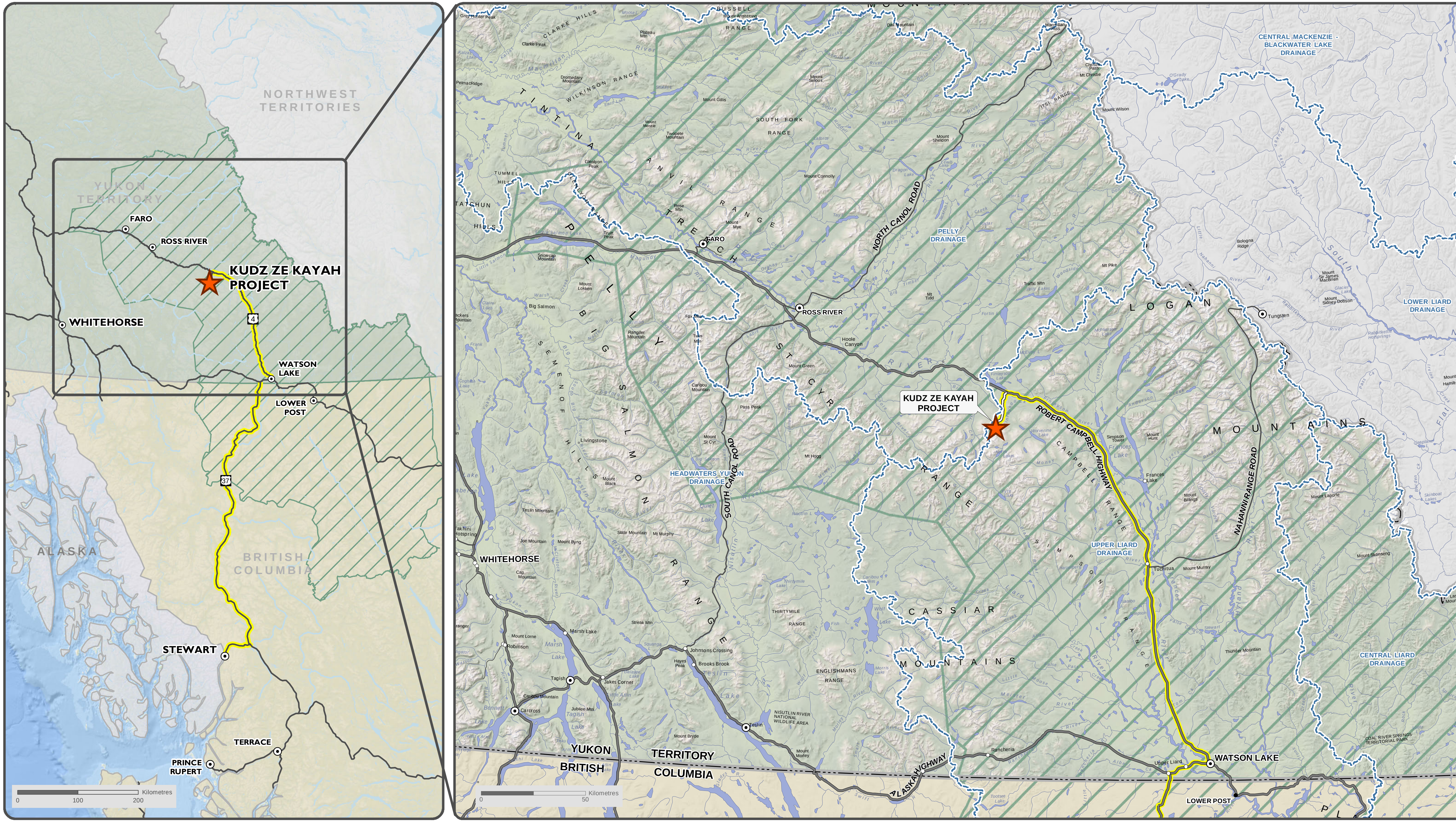
3 KUDZ ZE KAYAH PROJECT DESCRIPTION

The Project is within the traditional territory of the Kaska Nation. The Kaska Nation in the Yukon is comprised of the Ross River Dena Council (RRDC) and the Liard First Nation (LFN).

The KZK Project is a zinc-copper-gold-silver-lead development located 260 km northwest of Watson Lake, 110 km southeast of Ross River, and 24 km south west of the Robert Campbell Highway (RCH) near Finlayson Lake, Yukon as shown in Figure 3-1. The KZK Project includes the construction and operation of an open pit and underground mine, concentrator, and infrastructure to support a production rate of approximately 5,500 tonnes per day. There is a two-year construction period employing approximately 350 people followed by a ten-year mine life operating 24-hours per day, 365 days per year, employing approximately 300 full-time workers.

In addition to the mine and ore concentrator, there is supporting infrastructure including a widened access road, a temporary overburden storage area, two permanent rock storage facilities, a permanent combined tailings and rock storage facility, water collection and storage facilities, water treatment plant, camp, laydown area, maintenance shops, and administration offices. The layout of BMC's proposed Project is presented in Figure 3-2.

Equipment and supplies will be trucked in via the Robert Campbell Highway through Watson Lake and concentrate will be trucked out via the same route and then along Highway 37 in British Columbia to the port at Stewart. Employees will be flown in and out using an upgraded Finlayson airstrip and then by vehicle to and from site. Traffic on the Access Road includes only Project-related vehicles with access controlled by KZK Project staff at a gate near the Robert Campbell Highway.



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AEG

Kudz Ze Kayah Project

Proposed Concentrate Transport Route

Kaska Dena First Nation (Ross River Dena Council and Liard) Traditional Territory

BMC MINERALS

KUDZ ZE KAYAH PROJECT

FIGURE 3-1
LOCATION OF KUDZ ZE KAYAH PROJECT

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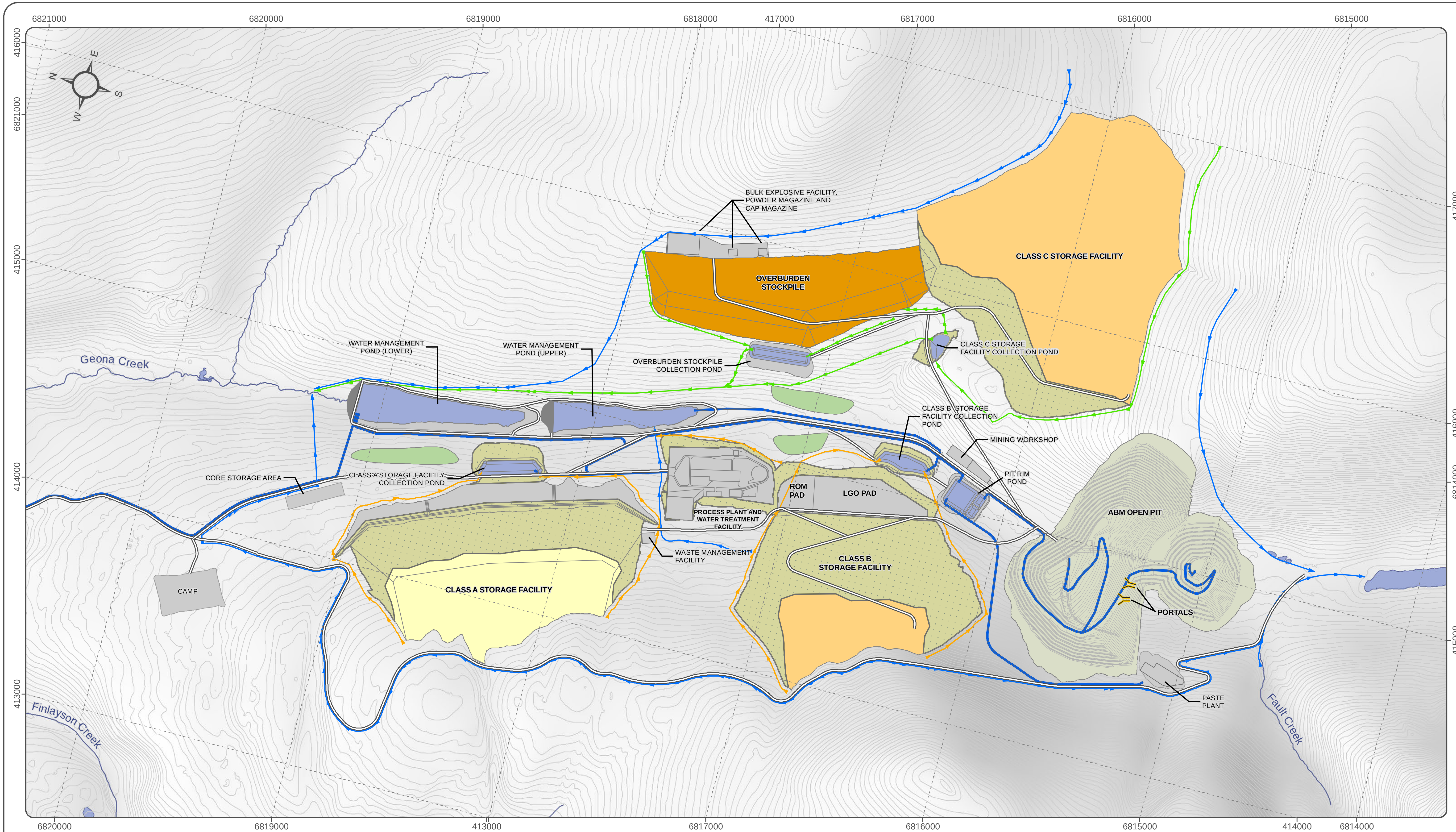

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0 250 500 750 Metres

- Class A Storage Facility
- Class B and C Storage Facility
- Overburden Stockpile
- Topsoil Stockpile
- Progressive Reclamation
- Pond/Water
- Non Contact Diversion
- Contact Class A & B Diversion
- Contact Class C Diversion
- Pipeline
- Proposed Mine Road

KUDZ ZE KAYAH PROJECT

FIGURE 3-2
PROJECT MINE LAYOUT

OCTOBER 2017

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4 POTENTIAL IMPACTS

4.1 POTENTIAL PROJECT EFFECTS

Potential effects from the KZK construction, operations, and closure period activities were described and assessed in detail in the Kudz Ze Kayah Project Proposal (BMC, 2017). A brief summary of the effects is presented in this section.

In general, mining activity can potentially affect wildlife directly through direct habitat loss and sensory disturbances where certain species will avoid industrial sites due to loud noises, the presence of humans, removal of vegetation and obstructions to movement such as buildings and active roads. Some wildlife species are more sensitive to sensory disturbance than others and will avoid the source of agitation by detouring around it. This can result in some wildlife avoiding or not utilizing habitat beyond the actual Project footprint. This area of potential interaction is known as the Zone of Influence (ZOI). Conversely, other wildlife species can become habituated to Project activities and humans, particularly if food and other attractants are accessible or if the area provides escape from other hazards such as predators or hunters. This may lead to increased interactions between humans and wildlife.

The main infrastructure components associated with the KZK Project are shown on Figure 3-2. Table 4-1 below relates mine infrastructure and activities with potential impacts on wildlife. Mitigation strategies for reducing these impacts are presented in Section 5.

Table 4-1: Potential Effects from Project Activities

Project Activity	Potential Effects	Species and Habitats of Concern
Construction		
Tote Road upgrade to Access Road	Direct habitat loss in footprint Sensory disturbance of surrounding habitat	All species using boreal habitat around road
Finlayson Lake airstrip upgrade	Direct habitat loss in footprint Sensory disturbance of surrounding habitat	All species using boreal habitat around airstrip; In particular, the Finlayson Caribou Herd wintering range around the airstrip
Site preparation and clearing	Direct habitat loss in footprint Sensory disturbance of surrounding habitat	All species using subalpine and alpine habitat around the mine
Site grading, including soil and overburden removal and stockpiling	Direct habitat loss in footprint Sensory disturbance of surrounding habitat	All species using subalpine and alpine habitat around the mine
Off site traffic (construction equipment and materials delivery)	Sensory disturbance of surrounding habitat Harm and potential mortality of wildlife from collisions with vehicles	Finlayson Caribou Herd wintering range along Robert Campbell Highway; Little Rancheria and Horseranch Caribou Herds wintering range on Highway 37 and the Alaska Highway surrounding the junction of these two highways
On site traffic	Sensory disturbance of surrounding habitat Harm and potential mortality of wildlife from collisions with vehicles	All species using subalpine and alpine habitat around the mine

Project Activity	Potential Effects	Species and Habitats of Concern
ABM open pit development (including dewatering and Fault Creek diversion)	Direct habitat loss in footprint Sensory disturbance of surrounding habitat (from noise, vibration, and activity, including blasting)	All species using subalpine and alpine habitat around the mine; In particular, caribou post-calving, rut habitat and early winter and spring movement periods, collared pika, and grizzly bear denning
Infrastructure construction	Sensory disturbance of surrounding habitat Increased risk of human-wildlife interaction from habitat creation in buildings Entanglements with wires and cables	All species around the mine
Waste handling	Sensory disturbance of surrounding habitat Increased risk of human-wildlife interaction and conflict from garbage and chemicals attracting wildlife	All species around the mine; In particular, grizzly bear, black bear, rodents
Water use and management	Sensory disturbance of surrounding habitat Attraction of wildlife to water management ponds with potential for entrapment or exposure to contaminants	All species around the mine; waterfowl in particular
Power generation	Sensory disturbance of surrounding habitat	All species around the mine
Worker transport	Sensory disturbance of surrounding habitat	All species around the mine, Access Road, and Finlayson airstrip; In particular the Finlayson Caribou Herd wintering range around the airstrip
Construction camp operation	Sensory disturbance of surrounding habitat Increased risk of human-wildlife interaction and conflict from garbage and chemicals attracting wildlife	All species around the mine; In particular, grizzly bear, black bear, rodents
Workforce, procurement and hiring	None	
Operations		
ABM open pit operations (including blasting and dewatering)	Direct habitat loss in footprint as the pit expands Sensory disturbance of surrounding habitat (from noise, vibration, and activity, including blasting)	All species using subalpine and alpine habitat around the mine; In particular, caribou post-calving and rut habitat, collared pika, and grizzly bear denning
Underground operations	Sensory disturbance of surrounding habitat (from noise, vibration, and activity, including blasting)	All species using subalpine and alpine habitat around the mine; In particular, caribou post-calving and rut habitat, and grizzly bear denning
Ore processing and mine infrastructure operations	Sensory disturbance of surrounding habitat Increased risk of human-wildlife interaction from habitat creation in buildings Entanglement with wires and cables	All species around the mine
On site traffic	Sensory disturbance of surrounding habitat Harm and potential mortality of wildlife from collisions with vehicles	All species using subalpine and alpine habitat around the mine

Project Activity	Potential Effects	Species and Habitats of Concern
Off site traffic (highway)	Sensory disturbance of surrounding habitat Harm and potential mortality of wildlife from collisions with vehicles	Finlayson Caribou Herd wintering range along Robert Campbell Highway; Little Rancheria and Horseranch Caribou Herds wintering range on Highway 37 and the Alaska Highway surrounding the junction of these two highways
Finlayson Lake airstrip operations	Sensory disturbance of surrounding habitat	All species using boreal habitat around airstrip; In particular, the Finlayson Caribou Herd wintering range around the airstrip
Storage facilities management (Class A, B, and C)	Sensory disturbance of surrounding habitat	All species using subalpine and alpine habitat around the mine
Progressive reclamation of storage facilities	Sensory disturbance of surrounding habitat Habitat restoration	All species using subalpine and alpine habitat around the mine
Water use (potable and non-potable)	Negligible	
Water management, treatment and discharge	Sensory disturbance of surrounding habitat Attraction of wildlife to water management ponds with potential for entrapment or exposure to contaminants	All species around the mine; waterfowl in particular
Waste management	Sensory disturbance of surrounding habitat Increased risk of human-wildlife interaction and conflict from garbage and chemicals attracting wildlife	All species around the mine; In particular, grizzly bear, black bear, rodents
Power generation	Sensory disturbance of surrounding habitat	All species using subalpine and alpine habitat around the mine
Worker transport	Sensory disturbance of surrounding habitat	All species around the mine, Access Road, and Finlayson airstrip; In particular the Finlayson Caribou Herd wintering range around the airstrip
Camp operation	Sensory disturbance of surrounding habitat Increased risk of human-wildlife interaction and conflict from garbage and chemicals attracting wildlife	All species around the mine; In particular, grizzly bear, black bear, rodents
Workforce, procurement and hiring	None	
Closure		
Processing plant decommissioning and site reclamation	Sensory disturbance of surrounding habitat Habitat increase over time	All species using subalpine and alpine habitat around the mine
ABM lake filling	Sensory disturbance of surrounding habitat Attraction of wildlife to ABM lake with potential for entrapment or exposure to contaminants	All species around the mine; waterfowl in particular
Final storage facilities reclamation	Sensory disturbance of surrounding habitat Habitat increase over time	All species using subalpine and alpine habitat around the mine
Support infrastructure removal and site reclamation	Sensory disturbance of surrounding habitat Habitat increase over time Entanglement with wires and cables	All species using subalpine and alpine habitat around the mine

Project Activity	Potential Effects	Species and Habitats of Concern
Water management, treatment and discharge	Sensory disturbance of surrounding habitat Attraction of wildlife to water management ponds with potential for entrapment or exposure to contaminants	All species around the mine; waterfowl in particular
On site traffic	Sensory disturbance of surrounding habitat Harm and potential mortality of wildlife from collisions with vehicles	All species using subalpine and alpine habitat around the mine
Off site traffic	Sensory disturbance of surrounding habitat Harm and potential mortality of wildlife from collisions with vehicles	Finlayson Caribou Herd wintering range along Robert Campbell Highway; Little Rancheria and Horseranch Caribou Herds wintering range on Highway 37 and the Alaska Highway surrounding the junction of these two highways
Access Road reclamation	Sensory disturbance of surrounding habitat Habitat increase over time	All species using subalpine and alpine habitat around the mine
Workforce, procurement and hiring	None	

4.2 WILDLIFE SPECIES IN THE KZK AREA

To protect wildlife and their associated habitat, it is important to understand the species that exist within the KZK Project area and their survival requirements. Wildlife, vegetation and ecosystem baseline studies have been conducted in the Project area to establish a bench mark to measure changes in subsequent years. Information gathered through the previous IEE, Yukon Government studies and the current 2015 through 2017 wildlife survey program shows that the area is utilized by a diverse number of wildlife species supported by a complex landscape.

This section lists the wildlife species known to exist and those species which potentially exist in the area. In addition, wildlife species that are identified under the *Species at Risk Act* (SARA) or by Yukon Government as being at some level of risk are detailed in Section 4.2.1.

Notable wildlife species in the KZK Project area include; the Finlayson Caribou Herd (FCH), moose, black bear, grizzly bear, wolf, red fox, wolverine, marten, mink, hoary marmot, collared pika, muskrat, river otter, beaver, several raptor species, ptarmigan, various waterfowl, and a variety of other birds. The lakes and small ponds/wetlands within or in proximity to the Project area provide breeding and migratory habitats for waterfowl and shorebirds. The Finlayson Lake/River area and the east slope of the Pelly Mountains (part of the Tintina Trench flyway) are recognized as a major flightpath for migratory birds.

A summary of the wildlife resources that are known to occur, or have the potential to occur in the KZK Project area is shown in on the following Table 4-2.

Table 4-2: Wildlife Species Occurring or Having Potential to Occur in the KZK Project Area

Ungulates	**Rodents**
Moose (*Alces alces*)	River Otter (*Lutra canadensis*)
Woodland Caribou (*Rangifer tarandus caribou*)	Beaver (*Castor canadensis*)
Mule Deer (*Odocoileus hemionus*)*	Hoary Marmot (*Marmota caligata*)
Stone Sheep (*Ovis dalli stonei*)	Muskrat (*Ondatra zibethicus*)
Carnivores	North American Porcupine (*Erethizon dorsatum*)
American Marten (*Martes americana*)	Arctic Ground Squirrel (*Spermophilis parryii*)
Black Bear (*Ursus americanus*)	Brown Lemming (*Lemmus sibiricus*)
Coyote (*Canis latrans*)	Bushy-tailed Woodrat (*Neotama albigula*)
Cougar (*Puma concolour*)*	Deer Mouse (*Peromyscus maniculatus*)
Ermine (*Mustela ermine*)	Least Chipmunk (*Tamias minimus*)
Gray Wolf (*Canis lupus*)	Long-tailed Vole (*Microtus longicandus*)
Grizzly Bear (*Ursus arctos*)	Meadow Jumping Mouse (*Zapus princeps*)
Lynx (*Lynx canadensis*)	Meadow Vole (*Microtus pennsylvanicus*)
Least Weasel (*Mustela nivalis*)	Northern Bog Lemming (*Synaptomys borealis*)
Mink (*Mustela vison*)	Northern Flying Squirrel (*Claucomys sabrinus*)
Red Fox (*Vulpes vulpes*)	Northern Red-backed Vole (*Clethrionomys rutilus*)
Wolverine (*Gulo gulo*)	Red Squirrel (*Tamiasciurus hudsonicus*)
Lagomorphs	Singing Vole (*Microtus miurus*)
Collared Pika (*Ochotona collaris*)	Taiga Vole (*Microtus xanthognathus*)
Snowshoe Hare (*Lepus americanus*)	Tundra Vole (*Microtus oeconomus*)
Bats	**Insectivores**
Little Brown Bat (*Myotis lucifugus)*	Black backed Shrew (*Sorex arcticus)*
Northern Myotis (*Myotis septentrionalis)**	Common Shrew (*Sorex cinereus)*
	Dusky Shrew (*Sorex monticolus)*
**Currently undocumented in area, but ranges are expanding northwards with one confirmed occurrence near Watson Lake.*	Pygmy Shrew (*Sorex hoyi)*
	Water Shrew (*Sorex palustris)*
Birds	
Alder Flycatcher (*Epidonax alnorum)*	Lesser Scaup (*Aythya affinis*)
American Kestrel (*Falco sparverius*)	Lesser Yellowlegs (*Tringa flavipes*)
Bank Swallow (*Riparia riparia*)	Northern Shrike (*Lanius excubitor*)
Barn Swallow (*Hirundo rustica*)	Mew Gull (*Larus canus*)
Barrow's Goldeneye (*Bucephala islandica*)	Olive-sided Flycatcher (*Contopus cooperi*).
Blackpoll Warbler (*Setophaga striata*)	Peregrine Falcon (*Falco peregrinus anatum-tundrius*)
Canada Warbler (*Cardellina canadensis*)	Red-necked Phalarope *(Phalaropus lobatus*)
Common Loon (*Gavia immer*)	Rusty Blackbird (*Euphagus carolinus*)
Common Nighthawk (*Chordeiles minor*)	Sandhill Crane (*Grus canadensis*)
Golden-crowned Sparrow (*Zonotrichia atricapilla*)	Short-Eared Owl (*Asio flammeus*)
Golden Eagle (*Aquila chrysaetos*)	Spotted Sandpiper (*Actitis macularia*)

Gray Jay (*Perisoreus canadensis*)	Trumpeter Swan (*Cygnus buccinator*)
Gyrfalcon (Falco r*usticolus*)	White-crowned Sparrow (*Zonotrichia leucophrys*)
Horned Grebe (*Podiceps auritus*)	Wilson's Warbler (*Cardellina pusilla*)
Amphibians	
Wood Frog (*Rana sylvatica*)	

4.2.1 Species of Conservation Status

Wildlife species that are designated as endangered, threatened or of special concern listed under SARA and occur or are likely to occur in the Project area are presented in Table 4-3. *The Yukon Wildlife Act* has five species designated as specially protected, two of these have the potential to occur at KZK and are also included in Table 4-3. . Designated wildlife species include woodland caribou, grizzly bear, wolverine, collared pika and a number of migratory bird species.

Table 4-3: Yukon Wildlife Species of Conservation Concern in the KZK Area

Species	Status	Source
Woodland Caribou *(Rangifer tarandus caribou)* - Northern mountain population	Special Concern	COSEWIC (2014a), SARA
Grizzly Bear (*Ursus arctos)*	Special Concern	COSEWIC (2012)
Wolverine *(Gulo gulo)*	Special Concern – western population	COSEWIC (2014b)
Woodchuck (*Marmota monax*)	Vulnerable	Yukon CDC (2015)
Collared Pika *(Ochotona collaris)*	Special Concern	COSEWIC (2011)
Little Brown Bat *(Myotis lucifugus)*	Endangered	COSEWIC (2013b), SARA
Northern Bat *(Myotis septentrionalis)*	Endangered	COSEWIC (2013b), SARA
American Kestrel *(Falco sparverius)*	Candidate for assessment	COSEWIC (2017)
Bank Swallow *(Riparia riparia)*	Threatened	COSEWIC (2013a)
Barn Swallow (*Hirundo rustica*)	Threatened	COSEWIC (2011)
Common Nighthawk *(Chordeiles minor)*	Threatened	COSEWIC (2007c)
Gyrfalcon *(Falco rusticolus)*	Specially Protected	Yukon Wildlife Act
Horned Grebe *(Podiceps auritus)*	Special Concern	COSEWIC (2009)
Lesser Yellowlegs *(Tringa flavipes)*	Candidate for Assessment (2016)	COSEWIC (2017)
Olive-sided Flycatcher *(Contopus cooperi)*	Threatened (2007)	COSEWIC (2007a)
Peregrine Falcon *(Falco peregrinus anatum-tundrius)*	Special Concern (2007), Spec. protected	COSEWIC (2007b), *Yukon Wildlife Act*
Red-necked Phalarope *(Phalaropus lobatus)*	Special Concern (2014)	COSEWIC (2014)
Rusty Blackbird *(Euphagus carolinus)*	Special Concern (2006)	COSEWIC (2006)
Short-Eared Owl *(Asio flammeus)*	Special Concern (2008)	COSEWIC (2008)
Trumpeter Swan *(Cygnus buccinator*)	Specially Protected	*Yukon Wildlife Act*

4.2.2 Traditionally Important Species

Employees and contractors are required to respect that the Project is located on Kaska traditional lands and there are many wildlife species that are traditionally important for sustenance and/or spiritual reasons and require consideration and respect. Table 4-4 presents a preliminary list of traditionally important species to Kaska based on engagement to date. This list will be updated with further input from Kaska.

Table 4-4: Traditionally Important Wildlife Species

Traditionally Important Species	Comments on Importance
Caribou	
Moose	
Grizzly bear	
Wolverine	
Wolf	
Snowshoe Hare	
Marten	
Beaver	
Groundhog / Hoary Marmot	
Raven	
Willow Ptarmigan	

5 WILDLIFE PROTECTION AND MITIGATION MEASURES

5.1 TRAINING AND EDUCATION

As part of safety training, all personnel and contractors will be provided wildlife safety and awareness training, including bear awareness and how to avoid disturbing sensitive species such as caribou (LQ00424b, Appendix C, 2015-0028, p.1). This training will include a background on the wildlife species around the Project, sensitive areas and sensitive timings of the year, requirements for employee and contractor conduct, as well as mitigation measures discussed further in this document. All concentrate haul drivers will also have appropriate training (which will be a contractual requirement). Monitoring and auditing will be conducted to ensure that policies and procedures are being followed to protect wildlife and that employee and contractor training is current.

Environmental training for all mine employees and contractors is required, and BMC will implement an education and awareness program with respect to wildlife and habitat protection needs of wildlife. One objective of this program will be to educate mine employees and contractors about potential wildlife issues and the commitments made by BMC regarding wildlife mitigation. This program will be presented in conjunction with site orientation and training and will be made available in written form as part of the overall environmental program at the mine. Upon request by BMC, the Yukon Territorial Government Renewable Resources (YTG RR) will provide assistance in reviewing program materials and making related presentations to mine personnel (Lease Agreement 105G07-001, Schedule 2, 1.1(i)).

5.1.1 Employee and Contractor Conduct

The following are existing permit conditions and BMC policies.

- No hunting or fishing will be permitted by mine personnel or contractors at the mine site or on BMC's mining claims and leases at any time (Lease Agreement 105G07-001, Schedule 2, 1.1(ii)); LQ00424b, Appendix C, 2017-0002, p.8);
- Harassment of wildlife will not be tolerated. This includes attempts to chase, catch, divert, follow, or otherwise harass wildlife by on- or off-road vehicles, aircraft, or on foot excluding situations where diversion for human safety is required (LQ00424b, Appendix C, 2015-0028, p.1). The harassment of wildlife is also prohibited under the *Yukon Wildlife Act*.;
- Personal wildlife deterrents to defend persons and property against threats from large carnivores (e.g., air horns, bear spray, bear bangers) will be issued and carried by field crews (e.g., environment staff, geologists). These are not to be used on ungulates. BMC will supply the camp with bear deterrent devices such as bear bangers, cracker shells, bear spray, etc. The bear awareness training provided to personnel and contractors will include use of these deterrent devices (LQ00424b, Condition 72).;
- Personal firearms will not be permitted at the mine site at any time (LQ00424b, Appendix C, 2015-0028, p.1). This includes the transport, storage and use of firearms. If required, only designated personnel will use a firearm to manage dangerous human-wildlife conflicts;
- For exploration activities, all field personnel will carry bear repellent spray with them at all times, as well as functioning radios, with scheduled check-in times to ensure worker safety (LQ00424b, Appendix C, 2015-0028, p.1);

- Mine personnel and contractors will not attempt to handle nuisance or problem wildlife on their own (LQ00424b, Appendix C, 2015-0028, p.1). Site Management will be notified as soon as possible or within the shift that it occurred if any significant wildlife is encountered while working at site;
- Feeding wildlife is prohibited at all times, including during travel to and from the mine site (LQ00424b, Appendix C, 2015-0028, p.1);
- Personal pets are not allowed on site;
- All work areas will be kept free of garbage and spills. All uncontained garbage or spills will be cleaned up immediately. Improperly disposed garbage, especially food or kitchen wastes, will be reported to Site Management as soon as possible (LQ00424b, Appendix C, 2015-0028, p.1); and
- Staff and contractors are required to report wildlife sightings and observations in the wildlife log and communicate wildlife incidents immediately to the KZK Environmental Coordinator and/or KZK General Manager (LQ00424b, Appendix C, 2015-0028, p.2).

5.1.2 Employee and Contractor Orientation

Employee and contractor orientation will be an important element of the Project. Orientation will include the following topics of relevance to wildlife management (LQ00424b, Appendix C, 2015-0028, p.1):

- Access Road use protocols;
- BMC's policies and permit/lease requirements;
- Bear awareness;
- Waste management procedures;
- Wildlife observation and interaction reporting procedures;
- Wildlife sensitive locations/timing, as applicable;
- Helicopter management practises; and
- Transportation and access management practises.

5.1.3 Training, Awareness and Competence

BMC is aware all personnel on the Project have the potential to create an impact on the environment and as such require appropriate training. All staff and contractors will attend a Site Orientation before being allowed to commence work. The KZK General Manager, KZK Environmental Coordinator or designate will conduct a training assessment based on the job tasks to determine training requirements.

As part of safety training, all personnel and contractors will be provided wildlife safety and awareness training, including bear awareness and how to avoid disturbing sensitive species such as caribou (LQ00424b, Appendix C, 2015-0028, p.1).

Pre-job environmental meetings and toolbox talks will be held to brief staff before the start of each new job, or before working in a new area or when the job scope changes.

General toolbox talks will be held on a regular basis to communicate general and task-specific environmental requirements. Emphasis will be placed during toolbox training on:

- Conformance with the procedures and requirements presented in the WPP and other applicable plans and procedures;
- The significant environmental impacts (actual or potential) of work activities and the environmental benefits of improved personal performance;
- The roles and responsibilities in achieving conformance with the procedures and requirements of the plans and procedures including emergency preparedness and response;
- The potential consequences of not following the procedures; and
- Spill notification and clean-up procedures.

Any changes to the WPP will be communicated to all Project staff and contractors through postings on site and during orientation and tailgate meetings.

5.1.4 Bear Awareness Training

Training will orient employees to correct waste disposal procedures and reporting guidelines. All employees and contractors will be given Bear awareness training (both in-house training and watching the educational video "Staying Safe in Bear Country") (LQ00424b, Appendix C, 2015-0028, p.1). The training will have the following objectives:

- Eliminating bear deaths and relocations as a result of them being attracted into the area due to garbage, fruit, compost, and other human-generated attractants;
- Increasing worker understanding of the negative implications on bears and humans when bears become habituated to camps for food;
- How to use the bear deterrent devices (i.e. bear spray); and
- Maintaining domestic areas as litter-free as possible.

5.1.5 Driver Training

All authorized drivers on site including employees, contractors, and transportation contractors will be trained so they are fully familiar with the Traffic and Access Management mitigation measures presented in Section 5.6. During construction, operations and closure the gatehouse attendant will provide a road safety orientation and truck orientation to all personnel who are approved to pass through the gate. All drivers must have the required licences and be Fit for Work.

5.2 SENSITIVE TIMES AND LOCATIONS

5.2.1 High Value and Sensitive Habitats and Seasons

Due to the wide range of topographic relief and landscape features in the KZK Project area, there are a variety of vegetation communities that support local wildlife species. Certain habitat is considered high value for wildlife where it is important for certain seasonal functions; breeding, rearing, growing, and over-wintering. In particular, at the KZK Project the following are high value habitats that have particular mitigation measures and where special attention should be given to minimize unnecessary disturbance:

- Caribou post-calving, rut, and wintering habitat;
- Grizzly bear denning;
- Migratory bird nesting; and
- Wetlands and riparian zones adjacent to creeks and ponds.

No rare ecosystems or habitats have been found in the Project area. Sensitive timings for construction and operation are presented in Table 5-1.

Table 5-1: Sensitive Species and Periods

Species	Approximate Dates	Sensitivity	Mitigations or Activities to Avoid	Reference
Ungulates	January 1 – March 31	Late-winter conditions	Give ungulates right of way; where practicable do not block movement corridors; minimize disturbance to animals during this time of year; keep snow banks less than 1 m and create passages in banks where trails and tracks are evident on a regular basis. Particular attention will be given for transportation activities around the Finlayson Herd caribou around Finlayson Lake and Pelly River lowlands and the Little Rancheria and Horseranch Herds caribou around the Alaska Highway and Highway 37 (Figure 5-4).	Adamczewski et al., 2010. Farnell, 2009
Caribou	May 1 – May 31	Calving period	Minimize working in alpine areas during this period to the extent practicable.	Chisana Caribou Recovery Team, 2010. Environment Canada. 2012.
Raptors	May 1 – July 31	Nesting period	Blasting to be restricted to the active mine. Minor blasting outside the mine may be needed for construction and will be scheduled to avoid nesting periods. .	McIntyre, C.L., and Schmidt, J.H. 2012
Breeding Birds	June 1 – July 31 is peak nesting however, various species nesting ranges from early May to late August	Nesting period	Conduct breeding bird surveys prior to clearing during the nesting period; if indications of nesting, establish nominal 15 m buffers around active nests (buffer distances to be set by qualified person based on local conditions and bird species) (see Section 5.3.3).	Zone B8 - Environment and Climate Change Canada. 2017. General nesting periods of migratory birds in Canada. Available at: http://www.ec.gc.ca/paom-itmb/default.asp?lang=En&n=4F39A78F-1#_03
Caribou	September 25 – October 31	Rutting period	Minimize working in alpine and subalpine areas during this period to the extent practicable.	Environment Canada. 2012 Adamczewski et al., 2010

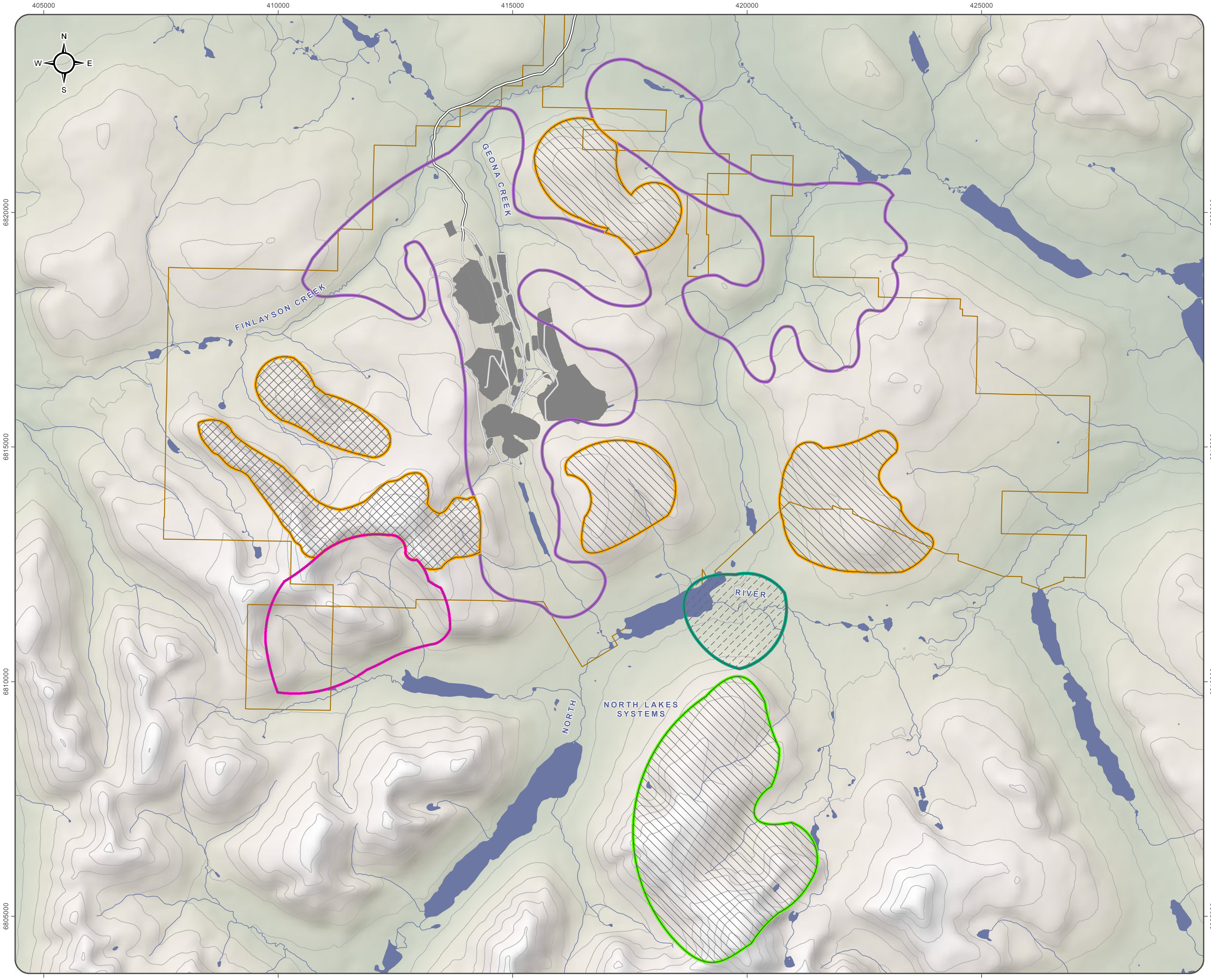
Species	Approximate Dates	Sensitivity	Mitigations or Activities to Avoid	Reference
Bears	1 Nov – 15 April	Denning period	There are bear dens located approximately 4.5 km from site. A preconstruction survey will be undertaken for bear dens and appropriate set back distances from the construction area will be applied until the bears leave the den, if bear dens are observed. During operations, the area will be monitored. Periodic checks will be conducted around the ABM open pit perimeter during the pre-denning period. If bears are observed in the vicinity of the ABM open pit, the conservation officer and RRDC will be contacted to discuss deterrence measures to prevent bears from denning in close proximity to the work areas.	MPERG (Mining and Petroleum Environmental Research Group). 2008a

5.2.2 Locations of Sensitive and High Use Habitat

For exploration, the operator shall contact the Watson Lake Regional Biologist for information on appropriate set back distances if nests, dens or mineral licks are encountered. These site-specific features shall not be disturbed (LQ00424b, Condition 67; LQ00424b, Appendix C, 2017-0002, p.8).

High value and sensitive habitats around the Project require protection during all phases of the Project to minimize impacts. Sensitive habitat is often high-value wildlife habitat that is easily damaged by anthropogenic disturbance. Areas such as wetlands, riparian zones and rocky outcrops have limited distribution within the Project area. Plant communities that exist in these types of habitats are unique due to specific growth conditions. Other areas considered sensitive are microsites that provide specific habitat features for wildlife species. (e.g., dens, mineral licks, rub trees, raptor nests, wallows, etc.). These microsites have not been found in the Geona watershed other than raptor nests, but should be watched for during clearing. If found, these areas should not be cleared until communicated to the KZK Environmental Coordinator and any management and/or mitigation measures implemented.

The locations of high value wildlife habitat in the Project area are shown in Figure 5-1 and areas with higher likelihood of wildlife crossings are shown in Figure 5-2.



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KUDZ ZE KAYAH PROJECT

FIGURE 5-1

KEY WILDLIFE AREAS BASED ON BASELINE SURVEYS 2015-17 AND YUKON GOVERNMENT MAPS

NOVEMBER 2017

- Grizzly Bear Den Area
- Moose Late Winter Season Habitat
- Caribou Post Calving Season Habitat
- Caribou Rut Season Habitat
- Sheep and Caribou Rut Season Habitat
- Mineral Lick Area
- BMC Minerals (No.1) Ltd. Mineral Claim Areas
- Location of Proposed Infrastructure
- Tote Road/Proposed Access Road
- Proposed Project Site Road
- Contour (100 m interval)

ALEXCO ENVIRONMENTAL GROUP

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.

Datum: NAD 83; Projection UTM Zone 9N

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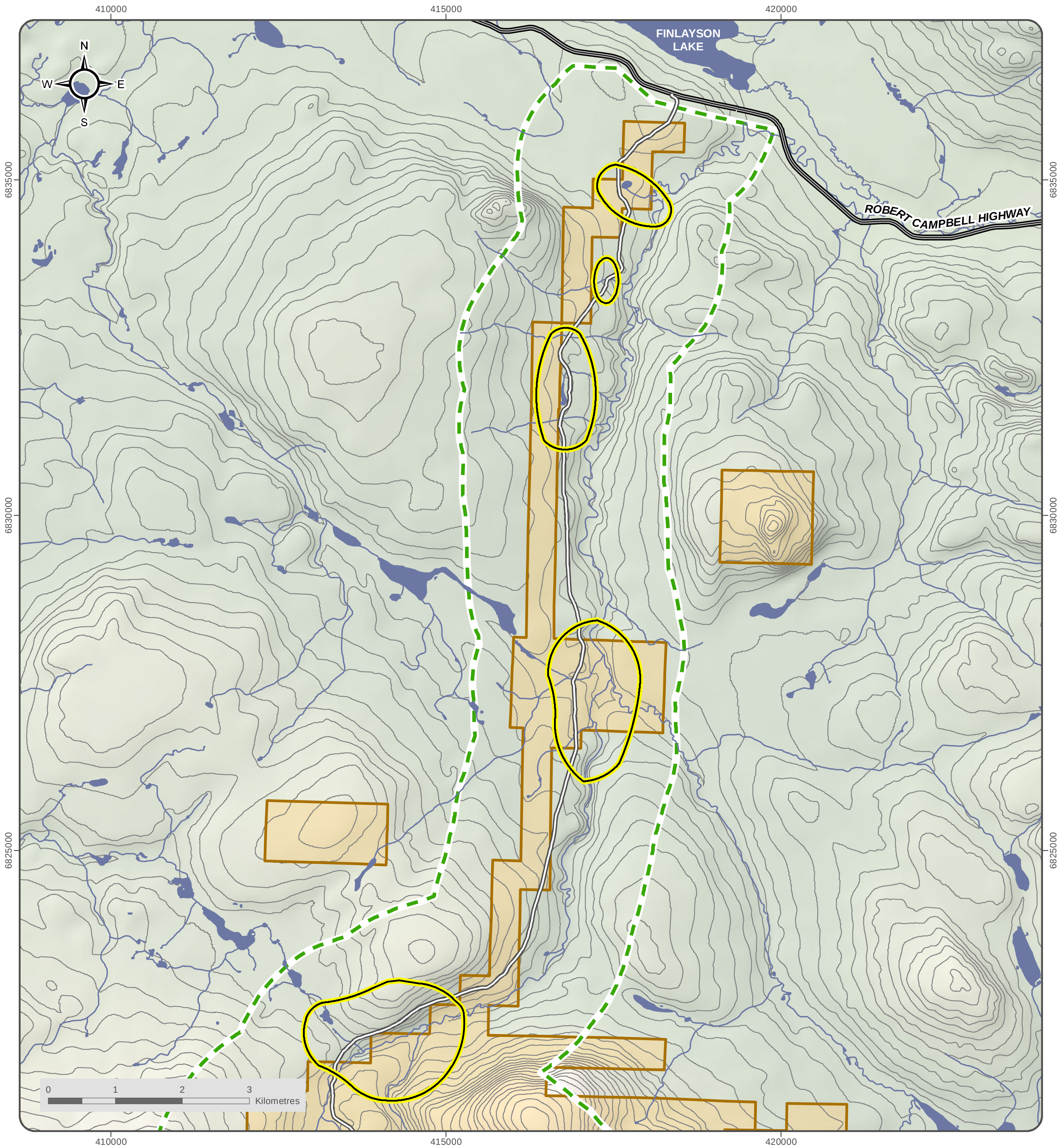

Potential Wildlife Crossing

Local Study

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

Waterbody

Watercourse

Tote Road/Proposed Access Road

Contour (20 m interval)

KUDZ ZE KAYAH PROJECT

FIGURE 5-2

ACCESS ROAD POTENTIAL WILDLIFE CROSSINGS

OCTOBER 2017

Datum: NAD 83; Projection: UTM Zone 9N

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5.3 SPECIES-SPECIFIC MITIGATIONS

Some species are of higher concern for potential impacts including caribou, grizzly bear, and migratory birds. Species-specific measures are presented in the following sections.

5.3.1 Caribou (Special Concern)

FINLAYSON CARIBOU HERD

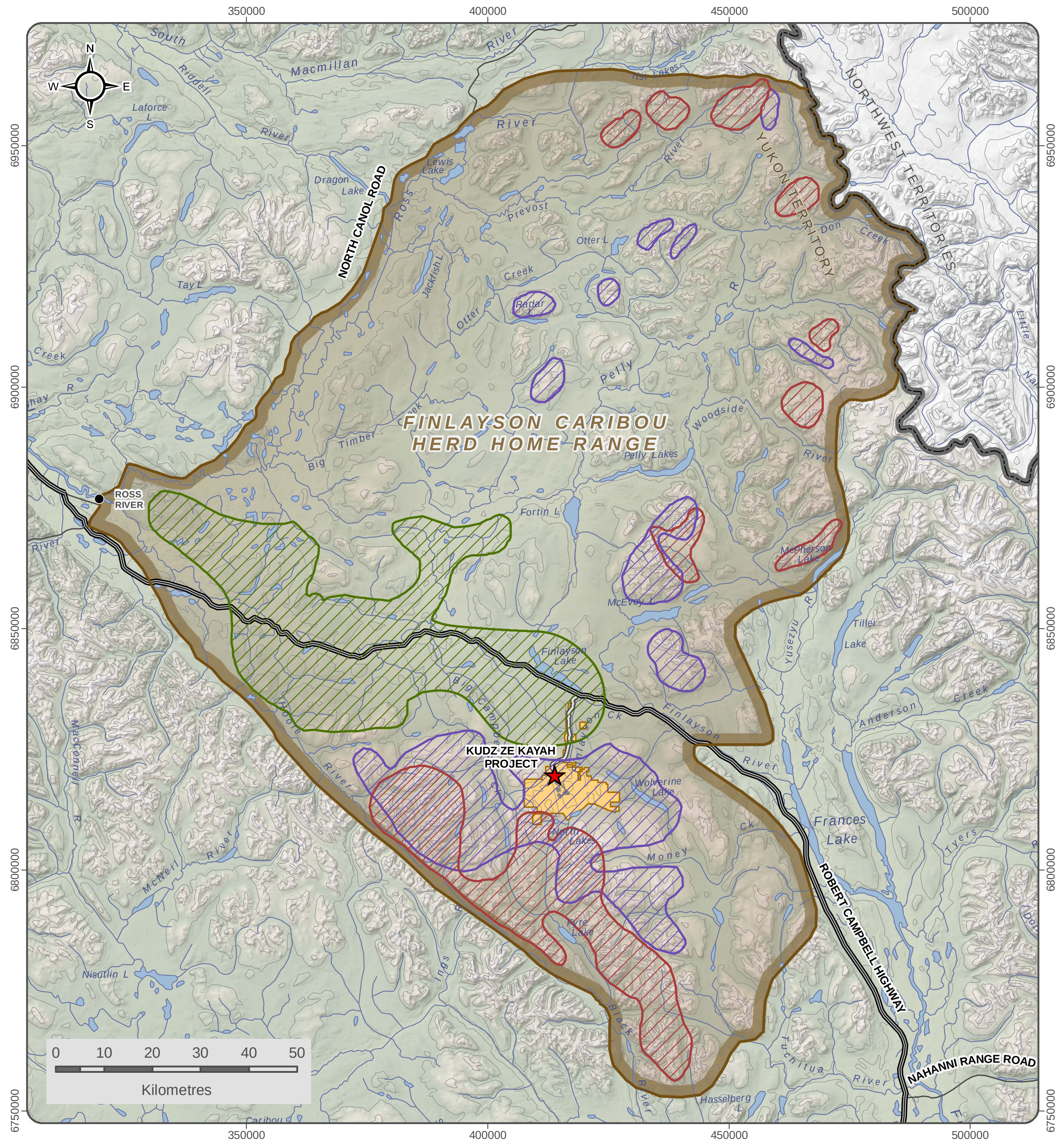
The Project is located in core habitat for part of the Finlayson Caribou Herd (FCH). This Northern Mountain Population of woodland caribou is noted as Special Concern by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and the *Species at Risk Act*. Approximately two thirds of the FCH utilize the Pelly Mountains south of the Robert Campbell Highway for calving, post-calving, and rutting life stages and then move north to the Pelly River lowlands by late winter.

The KZK Project lies in core rutting habitat (used from October to mid-December) and on the northeastern edge of core post-calving habitat (used from June to September) of the FCH as shown in Figure 5-3. In addition, the Finlayson airstrip and part of the Robert Campbell Highway are located in wintering habitat of the FCH. Calving likely occurs from early May to early June in the highlands east, west, and south of the Project, but surveys have not been definitive during this period since the caribou hide well during calving. Nonetheless, activity in alpine areas will be avoided (where practicable) from May 1 to May 31 to minimize effects on calving. Through BMC's wildlife orientation, employees and contractors will also be made aware of the location of caribou post-calving and rutting habitat around the Project (Figure 5-1) and will try to minimize activity in these areas (where practicable) when caribou are likely to be present. In particular, activity near rutting areas will be minimized from September 25 to October 31 (where practicable).

From January 1 to March 31, flight paths at the Finlayson airstrip will be optimized where possible and vehicle transportation minimized around Finlayson Lake and Pelly River lowlands to minimize disturbance of caribou in their wintering grounds. The existing mitigation measures for aircraft operations required under the exploration permits as presented in Section 1.3.6 will continue to be followed during construction and operations to minimize impacts on caribou.

LITTLE RANCHERIA AND HORSERANCH CARIBOU HERDS

The transportation haul route goes through the range of the Little Rancheria and Horseranch caribou herds in southeast Yukon and northern BC near Watson Lake, Alaska Highway, and the north end of the Stewart-Cassiar Highway (Highway 37; Figure 5-4). The highways go through the core winter range of the Little Rancheria herd which has resulted in vehicle mortalities mainly occurring in the fall and winter (EDI, 2015; Florkiewicz et al., 2004). Mitigation measures are already in place in high collision areas and include cautionary signage at high incidence areas along the road that ask motorists to slow down and stay alert during key seasons of caribou use (EDI, 2015). Transport contractors and drivers for the Project will be made aware of the higher potential for caribou along these sections of highway and to maintain slower speeds in winter in these key areas.



Kudz Ze Kayah Project	Community	Watercourse
Core Post Calving Range	Tote Road/Proposed Access Road	Waterbody
Core Rut Range	Highway	Location of Proposed Infrastructure
Core Winter Range	Secondary Road	BMC Minerals (No.1) Ltd. Mineral Claim Areas

KUDZ ZE KAYAH PROJECT

FIGURE 5-3

FINLAYSON CARIBOU HERD RUTTING, POST-CALVING RANGES

OCTOBER 2017

National topographic Data Base (NTDB) compiled by Natural Resources Canada at a scale of 1:50,000. Reproduced under license from Her Majesty the Queen, as represented by the Minister of Natural Resources Canada. All rights reserved.
Wildlife Key Area data compiled by the Yukon Department of Environment. Publication Date: May 2009
Obtained from Geomatics Yukon. Datum: NAD 83; Projection: UTM Zone 9N

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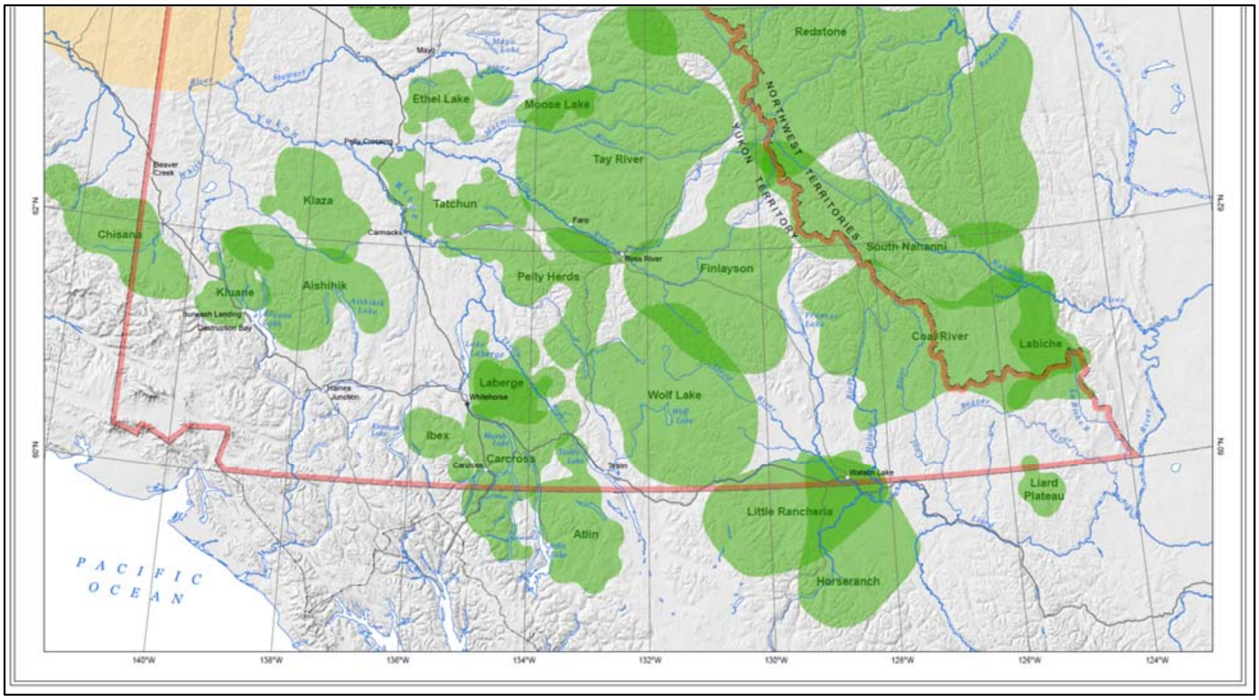


Figure 5-4: Location of Caribou Herds in Yukon (Source: Environment Yukon, 2012)

5.3.2 Grizzly Bear (Special Concern)

Mitigation measures are included throughout Section 5 to reduce the chances of grizzly bear being attracted to the site and to minimize the risk of human-bear conflicts. These include bear awareness training in Section 5.1.4, wildlife access controls in Section 5.4.3, attractants management in Section 5.5, and problem wildlife management in Section 5.7.

Grizzly bear dens were found in 2015 and 2016 surveys located approximately 4.5 km southwest from site. Grizzly bear denning occurs from approximately November 1 to April 15. Grizzly bears denning in closer proximity to the open pit could be disturbed by noise and blasting vibrations from the open pit.

For exploration, mitigation measures for bears will include pre-denning monitoring in the areas of planned exploration activities each year. If bear activity indicates they may be preparing to den in an area that could be disturbed by exploration activities, the YG conservation officer and RRDC Land Stewards will be consulted to determine measures to mitigate potential human-bear interactions (LQ00424b, Appendix C, 2017-0002, p.8). These mitigation measures will carry over into construction and operations.

5.3.3 Birds

The main mitigation for birds pertains to requirements not to destroy migratory bird nests under the *Migratory Birds Convention Act* (1994). The regional nesting period of birds in the Yukon is early May to late August (Environment Canada and Climate Change Canada, 2017).

As a first measure, where practicable, clearing will be scheduled to avoid nesting periods. Should it be required that clearing occur during the breeding bird nesting season, BMC will undertake breeding bird surveys in nesting areas prior to clearing. This is to ensure compliance with the *Migratory Birds Convention Act* 1994 which prohibits the disturbance or destruction of migratory bird nests and eggs in Canada (Government of Canada, 1994). The following will be observed:

- When the timing of exploration activities cannot avoid the nesting period, BMC's qualified environmental monitor conducts pre-clearing surveys and in the event a nest is discovered the area is flagged as a work avoidance area until the birds have left the nest. These procedures will continue to be followed at KZK during construction, operations and closure (LQ00424b, Appendix C, 2017-0002, p.8);

- Conduct pre-exploration surveys for presence of nesting birds (as required) (LQ00424b, Appendix C, 2017-0002, p.8). This will be followed for pre-construction periods;

- Surveys will be led by qualified and experienced individuals. Instead of trying to directly locate nests, a non-intrusive search method will be applied. This method searches for evidence of nesting by observing the presence of birds, alarm calls, distraction displays, ideal nesting habitat, etc. to determine whether there are likely nesting birds in the area;

- The operator will contact the Watson Lake Regional Biologist for information on appropriate set back distances if nests, dens or mineral licks are encountered. These site-specific features shall not be disturbed (LQ00424b, Condition 67; LQ00424b, Appendix C, 2017-0002, p.8);

- Any nest suspected or found will be protected with a buffer zone determined by a setback distance appropriate to the species, the level of the disturbance and the landscape context as set by the qualified surveyors in conjunction with the Regional Biologist (some examples of buffer distances are described below), until the young have permanently left the vicinity of the nest; and

- If no nests are found, clearing activities will be completed within a 7-day window of survey conclusion and continue until completed. If clearing works are unable to be completed on a continual basis and there is a stoppage in works, another survey would be completed before recommencing clearing;

- If a suitable buffer zone is unable to be established or followed, activities will be postponed until birds have left the nests; and

- For non-migratory birds, if the buffer zone is unable to be followed, written permission may be obtained from Environment Yukon to disturb nests.

A few published recommended buffers for specific species are as follows:

- The recommended buffer for the olive-sided flycatcher is 300 m at high disturbance, 150 m at medium disturbance, and 50 m at low disturbance (Environment Canada, 2009);
- For the trumpeter swan, the recommended buffer is 800 m at all disturbance levels set by the Alberta Sustainable Resource Development (ARSD, 2011);
- The Yukon standard for the no disturbance buffer for raptor nests on cliffs is 300 m (Yukon Forest Resources Act, 2014); and
- The Yukon forest standards for no disturbance buffer for raptor tree or stick nests is 50 m (Yukon Forest Resources Act, 2014).

Additional consideration will be given to the variety of bird habitats around the Project area. Table 5-2 presents habitats, risks, and mitigation or avoidance measures for specific species or groups of species.

Table 5-2: Specific Bird Species Potential Effects and Mitigations

Bird Grouping or Species	Species-Specific Habitat and Behaviours	Species-Specific Potential Effects or Risks	Mitigations or Activities to Avoid
Cliff-Nesting Raptors Bald Eagles and Golden Eagles are cliff-nesting raptors in the Project area. Gyrfalcon (specially protected) not found, but potentially occur.	Cliff-nesting raptors occupy nests around the 15th of March – the 31st of April (Hayes and Reid, 2014)	Disturbance and accidental removal of nests in cliff habitat. Accidental nesting in tall inactive equipment.	Checks for cliff nesting activity and nests prior to clearing and blasting and appropriate buffers cordoned off during nesting. The Yukon standard for the no disturbance buffer for cliff-nesting is 300 m (Yukon Forest Resources Act, 2014). Nesting checks will also be conducted in any tall inactive equipment (e.g. cranes) in March and April.
Tree-Nesting Raptors Bald Eagles in the Project area (bird surveys at Finlayson Lake also observed red-tailed hawk, American kestrel, and sharp-shinned hawk)	Typically nest in trees with good visibility or proximity to prey	Disturbance and accidental removal of nests in trees. Accidental nesting in tall inactive equipment.	Checks for tree nesting activity and nests prior to clearing and blasting and appropriate buffers of 50 m cordoned off during nesting (Yukon Forest Resources Act, 2011). Nesting checks will also be conducted in any tall inactive equipment in March and April.
Short-eared Owl (Special Concern)	Ground nesters in large grassland habitat with some low shrubs	Disturbance of nesting habitat during progressive clearing	Surveys during twilight in potential habitat to check for short-eared owl activity that could indicate nesting (when clearing is scheduled during nesting periods). If activity present, clearing in the area should be postponed until mid-August.

Bird Grouping or Species	Species-Specific Habitat and Behaviours	Species-Specific Potential Effects or Risks	Mitigations or Activities to Avoid
Common Nighthawk (Threatened)	Ground nesters. Nests can be constructed on disturbed sand and gravel areas	Disturbance of nesting habitat during progressive clearing or potential creation of nesting habitat in cleared borrow areas.	Revegetate disturbed areas as soon as practicable. Surveys during twilight in old disturbed areas prior to any new land clearing (when clearing is scheduled during nesting periods). If activity present, clearing in the area should be postponed until mid-July.
Sandhill Cranes and Trumpeter Swan (Specially Protected)	From the 2015 through 2017 wildlife logs, sandhill cranes and trumpeter swans have been seen flying over, but rarely stopping or staging in the Project area	If behaviours change and more individuals stop around the Project on their migration route they may become disturbed by mining activities or may be at risk of entrapment or exposure to contaminants in water management ponds.	If birds are observed, install bird netting or bird deterrents on any water management ponds expected that do not meet the site water quality objectives.
Willow ptarmigan and Grouse	Ground nesters in open forests and shrub meadows mainly in the subalpine and alpine	Disturbance of nests	Avoid clearing during nesting periods, where practicable If clearing coincides with nesting periods, pre-clearing nesting survey will be conducted and buffers set around any nests.
Barn Swallows (Threatened)	Nest in cup shaped mud nests in man-made structures	Swallows may nest in rafters and eaves of buildings	Design buildings and install deterrents to prevent nesting in buildings if and where needed
Bank Swallows (Threatened)	Nest in burrows in sandy embankments such as along streams	May nest in embankments of borrow or cleared areas	Revegetate disturbed areas as soon as practicable. Surveys in old embankment areas prior to any new land clearing during nesting periods. If activity present, clearing in the area should be postponed.
Perching Birds (Olive-sided Flycatcher and Rusty Blackbird are threatened)	Perching birds in the Project area are mostly migratory. They nest in a variety of areas including grasses, low bushes, or trees.	Potential to disturb nests during clearing.	Avoid clearing during nesting periods. Complete pre-clearance nesting surveys if clearing during nesting periods and establish buffers around nests or potential nests.

Bird Grouping or Species	Species-Specific Habitat and Behaviours	Species-Specific Potential Effects or Risks	Mitigations or Activities to Avoid
Waterfowl and Shorebirds (Horned Grebe and Red-necked Phalarope are Special Concern; Lesser Yellowlegs is candidate for assessment)	Nesting around ponds and creeks	Lost wetland habitat. Potential to disturb nests during clearing. Potentially may try and utilize water management ponds, pit lake, or constructed wetlands.	Lost habitat is partially offset by creation of the Fish Offset Ponds and reclaimed wetlands post-closure. Avoid clearing during nesting periods. Complete pre-clearance nesting surveys if clearing during nesting periods and establish buffers around nests or potential nests. If birds observed, install bird deterrents for any ponds expected to have contaminants. Treat pit water when filling after closure to maintain water quality at acceptable concentrations to protect wildlife.

5.4 MINE AND INFRASTRUCTURE DESIGN AND CONTROL MEASURES

Wildlife habitat considerations have been, and will continue to be, integrated into the Project design as the Project moves forward into detailed design and construction. The following wildlife habitat protection measures have been, or will be, incorporated in the Project.

Overall, the Project footprint was designed to cover as little area as practicable to minimize habitat loss and disturbance. Clearing during construction will be kept to a minimum and only include areas needed to safely and efficiently construct and operate the Project. Project operations will continue many of the mitigation measures since there will be progressive clearing and reclamation on many facilities. Through construction and operations the following mitigation measures will be implemented to minimize potential effects on wildlife.

5.4.1 Access Roads

The Tote Road will be upgraded prior to mine development, to accommodate increased traffic and concentrate transport vehicles. Parts of the road will be expanded to include pull out areas to facilitate two-way traffic and passing. Traffic will consist primarily of concentrate haul trucks, freight trucks and crew transport vehicles.

The following design and procedures will be implemented:

- The Tote Road will be upgraded to avoid blind spots and reduce potential for wildlife collisions;
- Each kilometre will be marked with a marker visible in both directions of travel to allow road users to identify locations of wildlife observations, and other incidences;
- Where embankments are necessary and where practicable, they will be graded to a low slope (1:5) and have fine fill that replicates natural trail conditions. Surfaces will be smooth, compact and constructed with finer fill (<100 mm) to avoid leg entrapment; and

- Equipment laydown areas will be distant from known wildlife trails or wildlife road crossings; and

- For exploration activities outside the development footprint, construction of new roads will be minimized (e.g., Tote Road will be upgraded to Access Road largely in the existing alignment). The construction of new roads and exploration trails will be avoided to the extent possible (LQ00424b, Appendix C, 2015-0028, p. 2 and 2017-0002, p.8).

- For exploration activities outside the development footprint, where the construction of trails cannot be avoided, the operator shall construct trails as narrow as possible and avoid straight lines where possible. This will limit use of trails as 'wolf highways' which can increase predation of ungulates by wolves (LQ00424b, Condition 64).

5.4.2 Clearing

- High value wildlife areas (e.g. nest sites, dens) and sensitive vegetation areas (e.g. alpine tundra, wetlands) have been identified and will be indicated on detailed design plans;

- Clearing of the Overburden Stockpile, Class A, B, and C Facilities will be progressive, to minimize total area of disturbance at any given time;

- Clearing will be scheduled to minimize disturbance to bird nesting as much as practicable;

- Cut brush will not be piled so that it blocks movement of wildlife or people (LQ00424b, Condition 45);

- Where construction of trails cannot be avoided, BMC and it's contractors will construct trails as narrow as possible and avoid straight lines where possible (LQ00424b, Appendix C, 2017-0002, p.8)

- Activities will be planned to avoid sensitive habitat areas and times for focal species, where practicable (Table 5-1); and

- Avoid disturbance to riparian vegetation wherever possible (i.e. not including the water management ponds) and, if required out of necessity, riparian vegetation will only be cut to ground level so as not to damage rootstock and promote rapid regeneration (LQ00424b, Condition 17);

- BMC will not construct any facilities within thirty point four eight (30.48) metres of the ordinary high water mark of any body of water without the written approval of Yukon (Lease Agreement 105G07-001, Condition 30).

- Protective buffer zones around riparian areas (i.e., creeks) will be established to prevent sedimentation of aquatic habitats and minimize disturbance to movement corridors including 30 m adjacent to fish bearing waterbodies and 15 m adjacent to non-fish bearing waterbodies (Yukon EMR, 2011), where practicable.

5.4.3 Wildlife Access Controls

- If conditions are warranted, the camp will be enclosed with electric fencing with attention given to camp design (as outlined in the Guideline for Industrial Activity in Bear Country for the Mineral Exploration, Placer Mining and Oil and Gas Industries) in order to avoid attracting bears. Warranted conditions will be developed in consultation with the Conservation Officer and include site-specific bear activity (LQ00424b, Condition 73);

- Ancillary facilities including waste management facility, Upper and Lower Water Management Ponds, and all water collection ponds with engineered liners will be surrounded by wildlife proof fences;

- Fencing will be designed to avoid harming or entangling wildlife (i.e. including small mesh size);

- The operating areas will be monitored daily for wildlife, particularly areas where animals may become entrapped (e.g., storage facilities, ponds, and open buildings); and

- Snowbanks will be kept less than one-metre high, and provide wildlife passageways through banks along the Access Road and around site.

5.4.4 General Practices

- Avoid construction and operations in and around sensitive areas, such as caribou calving and rutting grounds, raptor nesting sites, and den sites during the seasonal periods outlined in Table 5-1 (where practicable);

- Follow Yukon flying guidelines including no-fly and flight height restrictions, especially for focal species, as presented further in Section 5.6.3;

- Follow the waste and materials management measures presented in Section 5.5 to minimize wildlife attractants;

- Follow traffic and access management measures presented in Section 5.6 to minimize harm to wildlife;

- Use water spray or approved dust suppressant (environmentally-friendly that does not contain salts that would attract wildlife) to control dust generation from construction and operational activities, storage piles, and exposed soils/surfaces as presented in Section 5.6;

- Untreated, non-attractant gravels will be used for traction surfacing of roads in winter as presented in Section 5.6;

- Surface runoff from site will be controlled and directed away from natural areas to reduce potential contamination, sedimentation, and smothering of vegetation (refer to the Water Management Plan for details and see provisions in LQ00424b and Type B Water Licence QZ16-085);

- Machinery and personnel will be required to remain in the defined Project area and along defined roads;
- If work is required in the backcountry, personnel will be expected to minimize disturbance (e.g., no littering, retain natural vegetation, address any spills immediately, shut off equipment/vehicles when not in use, report all wildlife observations and incidents to management);
- Use of new or well-maintained heavy equipment and machinery with mandatory fully functional emission control systems/ muffler/ exhaust system baffles, engine covers;
- Implement a regular vehicle and equipment maintenance program to minimize noise and emissions (LQ00424b, Condition 44);
- Discourage and limit on site vehicle and equipment idling (where practicable); and
- Exploration drill site cuts will be sloped to allow for personnel and wildlife to exit safely (LQ00424b, Appendix C, 2015-0028, p. 2).

5.4.5 Progressive Reclamation

Reclamation requirements will take forward the exploration permit requirements as indicated below into construction, operations, and closure.

- BMC will implement progressive reclamation plans with the objective of minimizing impacts and duration of habitat loss associated with disturbed areas that are no longer required for mine-related activities. BMC will report annually on the extent of surface disturbances and reclaimed areas (Lease Agreement 105G07-001, Schedule 2, 4.5; LQ00424b, Appendix C, 2017-0002, p.8);
- If adequate seed or root stock is not naturally available, re-seeding or transplanting of vegetation will be required. Only non-invasive species will be used for re-seeding or transplanting. If seeding is required, BMC will contact Government of Yukon, Compliance, Monitoring and Inspections for further information on appropriate seed mixes or collection of local seed (LQ00424b, Condition 20);
- Areas near roads will be re-vegetated with non-palatable plants to avoid attracting wildlife to the roadside (LQ00424b, Appendix C, 2015-0028, p.3);
- The operator will ensure that annual reclamation efforts are successful in re-establishing the vegetative mat and community. A variety of sloping, contouring, scarifying and spreading of fines, silt and/or vegetative mat would prepare the ground to achieve these ends and encourage natural re-vegetation (LQ00424b, Condition 21). Ongoing reclamation from all exploration activities will be undertaken (LQ00424b, Appendix C, 2015-0028, p.3);
- In addition to any remedial action required in relation to re-establishment of the vegetative mat, temporary trails will be blocked to prevent further vehicular access (LQ00424b, Condition 63);

- Lost wetland habitat will be partially offset by creation of the Fish Offset Ponds and by restoration of wetland habitat post-closure; and

- Wildlife habitat enhancement will be considered in site rehabilitation and restoration planning.

5.5 ATTRACTANTS MANAGEMENT

To mitigate potential effects of attractants (i.e., food, waste, fuel, and other attractants), BMC will implement the measures in the following section. In addition, employees and contractors will have bear awareness training as presented in Section 5.1.4.

5.5.1 Food Management

Food at the camp and around site is managed with the following provisions:

- Employees and contractors must adhere to BMC's no feeding wildlife policy (LQ00424b, Appendix C, 2015-0028, p.1);

- Frozen food will be kept in freezers, with fresh food kept in refrigerators (LQ00424b, Appendix C, 2015-0028, p. 2);

- The camp and kitchen areas will be kept clean, and free of refuse (LQ00424b, Appendix C, 2015-0028, p. 2);

- If food is taken out into the field (i.e., in lunches) field crews will bring all garbage back with them for disposal (LQ00424b, Appendix C, 2015-0028, p. 2);

- All food and cooking supplies will be either stored securely in metal bear-proof containers or removed from site during times when the camp is closed (LQ00424b, Condition 74); and

- Camp kitchens will contain stack scrubbers in the venting system to reduce cooking odours.

5.5.2 Waste Management

Waste management around site includes the following provisions:

- The Waste Management Facility (details presented in the Waste Management Plan) will be enclosed by an electrified fence (LQ00424b, Condition 73);

- The camp and kitchen areas will be kept clean, and free of refuse (LQ00424b, Appendix C, 2015-0028, p. 2);

- BMC will remove any flagging tape used to carry out project activities once the activities are completed unless bio-degradable tape is utilized (LQ00424b, Condition 77);

- While waiting to be burned, garbage will be kept in a bear proof container so that bears will not be able to access it;

- When burning kitchen waste on site it will be burned regularly to reduce odours that might attract wildlife and be burned to ash by forced air or fuel fired incineration (LQ00424b, Condition 34). Garbage will be burned in an incinerator daily whenever possible, to prevent the accumulation of waste (LQ00424b, Appendix C, 2015-0028, p. 2; Lease Agreement 105G07-001, Schedule 2, 4.4);

- Combustible garbage will be stored in an area surrounded by an electric fence, in a lockable bin and burned in an incinerator on a daily basis to prevent its accumulation.. Ash from the incinerator will be buried in pits > 1 m deep (and covered as per the waste management permit). (LQ00424b, Appendix C, 2017-0002, p.11 replaces commitment in 2015-0028, p. 2; Lease Agreement 105G07-001, Condition 76);

- Non-combustible garbage (e.g. cans, metal, recyclable containers) will be stored in lockable bins and then periodically (approximately once a week) trucked off site and disposed of in the Whitehorse Landfill and/or a recycling centre (e.g., Raven Recycling in Whitehorse). (LQ00424b, Appendix C, 2017-0002, p.11 replaces commitment in 2015-0028, p. 2). The garbage disposal area will be kept at least 100m from sleeping quarters (LQ00424b, Appendix C, 2015-0028, p. 2).; and

- Signs will be posted around to remind personnel not to litter.

5.5.3 Fuel Management

Fuel management around site includes the following provisions:

- Gasoline, diesel, lubricants, oils and other petrochemicals may act as animal attractants (particularly bear), therefore, will be stored in appropriate facilities (further details are provided in the Waste Management Plan) (Lease Agreement 105G07-001, Condition 42);

- Fueling of vehicles will be limited to designated areas, to control odours and minor spills (Type B Water Licence QZ16-085, Condition 31);

- Vehicle maintenance will be conducted in designated areas (i.e., maintenance shop). Vehicles with fuel or oil leaks will be identified and repaired within 24 hrs of the leak being identified (where practicable) (LQ00424b, Condition 44). If maintenance is required outside of designated areas (e.g., the pit), supplies will be used to contain and clean up any grease and fluids (e.g. tarps, collection pans, absorbents, etc.);

- Fuel spills will be reported promptly and will be managed following procedures in the Spill Contingency Plan (LQ00424b, Condition 43; Type B Water Licence QZ16-085, Conditions 24 to 30); and

- Despite clean-up efforts, odours will remain at spill areas, which will be treated as ‘high-risk’ bear encounter areas following the spill incident.

5.5.4 Other Attractants

Other wastes and materials around site will include the following provisions:

- Grey water (i.e., from showers and the kitchen) will be disposed of through a sewage disposal system including septic tanks and an absorption bed (LQ00424b, Appendix C, 2017-0002, p.11 replaces commitment in 2015-0028, p. 2);
- All chemicals (i.e. glycols etc) that may be wildlife attractants will be sealed and stored on site in a building/shed to minimize the potential for attracting the wildlife to the site (LQ00424b, Appendix C, 2015-0028, p. 2);
- Solid wastes not incinerated on site will be stored securely and removed to an approved facility on a regular basis; and
- Waste disposal or storage sites will be inspected regularly to ensure anti-wildlife measures are effective.

5.6 TRAFFIC AND ACCESS MANAGEMENT

5.6.1 Access Road

ROAD CONTROL GATE

Increased access to the traditional range of the Finlayson caribou herd, especially along their migration route to winter range, has been identified as the primary concern by Yukon Government and the Ross River Kaska Dena (Cominco, 1996). The security station and gate at the access point to the Access Road from the Robert Campbell Highway has been seasonally manned and controlled by the Project owners since 1995 by employing a member of the Ross River community. Only authorized vehicles are allowed on the Access Road in accordance with lease conditions imposed by the Yukon Government. Over the winter period the gate is locked. Access along the tote road will continue to be managed in this fashion (LQ00424b, Appendix C, 2015-0028, p.3);

The use of the tote road in the winter will be dependent on the exploration activities required through the winter. If the tote road is to be used in the winter, BMC will continue to prevent unauthorized use of the road through the use of a manned station at the entrance of the tote road and/or a locked gate (LQ00424b, Appendix C, 2017-0002, p.9);

A site vehicle access register will be maintained at the gatehouse (LQ00424b, Appendix C, 2015-0028, p.3);

A guard at the gatehouse on the Access Road will continue to restrict hunter and other unauthorized access to the Project area. The Access Road is a private road with required access control. The Mines Inspector and lands department will be contacted if any conflicts occur over access. Signage will be placed at the entrance of the Access Road to inform drivers of safety and responsibilities. Signage includes:

- Public access restriction;
- Warning of narrow road and large vehicle use;
- Functional two-way radio requirement with channel frequencies;
- List of road use conditions: lights on, maximum speed limit, wildlife area, obey all signs, etc.; and
- Condition to report all wildlife sightings and a supply of wildlife observation card (WOC) and wildlife incident form (WIF) cards.

ROAD OPERATION

Commencing upon construction of the Project, BMC will manage company-directed activities and transportation along the Mine Haul Road to avoid wildlife mortality and to eliminate movement barriers from wildlife access routes. Areas of concern include the Mine Haul Road and portions of Robert Campbell Highway and other highway routes used, if applicable. BMC will consult with the YTG, RR and Department of Transportation to implement appropriate wildlife protection measures, which may include, but are not limited to maintenance guidelines for winter, speed reduction zones, signs at crossings, radio equipped tucks, reporting of wildlife on roads (Lease Agreement 105G07-001, Schedule 2, 4.1).

BMC will minimize the potential for disturbance to caribou during sensitive life cycle activities by avoiding those areas that are used for calving, post-calving and rutting, and by ensuring the access road does not conflict with such areas used by caribou and other migratory wildlife (i.e. moose) (Lease Agreement 105G07-001, Condition 29A(i)).

Wildlife are expected to be allowed to cross the Access Road to access habitat on either side. Certain sections of the road intercept trails that have been used by generations of caribou, moose and bears. These trails often coincide with riparian corridors and easy access to Finlayson Creek. During the spring (April to May) caribou migrate from wintering grounds to calving areas south of the Project and in the fall move back to their wintering grounds. Drivers will be instructed at all times to be alert for the presence of wildlife on the Access Road and site roads to avoid collisions that could cause serious injury or death. Areas along the Access Road with higher likelihood of wildlife crossings are shown on Figure 5-2.

The following are required for operating vehicles along the BMC Access Road:

- Wildlife will have the right-of-way along the entire tote road (LQ00424b, Appendix C, 2015-0028, p.3);
- If caribou or moose are encountered on the tote/access road, the equipment and/or activity is to be halted until the wildlife has left the immediate area (LQ00424b, Appendix C, 2015-0028, p.3);
- The authorized use of on-road and off-road vehicles will be restricted to established roads and designated trails at the exploration site except to access monitoring sites and remote communications equipment. Use of private and recreational vehicles will be prohibited at all times (LQ00424b, Appendix C, 2015-0028, p.3);

- All wildlife observations on access corridors will be recorded in the Wildlife Log (LQ00424b, Appendix C, 2015-0028, p.3);
- Travel speeds along the roadway will be restricted to a maximum of 50 km/hr for daytime travel, and reduced during nighttime or hazardous weather conditions (as appropriate);
- Signage will be posted in high collision risk areas (e.g., blind or obstructed turns, water and wildlife crossings) and speeds will not exceed 30 km/hr in these road portions. These signs will instruct drivers to reduce speed, remain alert, stop for wildlife, and wait for wildlife to move away;
- Radio communication among road users will be required to communicate information such as sightings of large animal species, dust, hazards etc.;
- Any spills on roadways will be handled as per the Spill Contingency Plan;
- Carrying over from exploration, minimum traffic levels will be maintained to the extent practical (LQ00424b, Appendix C, 2015-0028, p.3). Convoys of 2 or 3 vehicles will travel along Transportation Route together when practical to reduce periods of sensory disturbance; and
- Regular vehicle and equipment maintenance will be conducted to minimize noise and emissions.

The following procedures are meant to ensure human and wildlife safety while operating vehicles and equipment on the Access Road and site. (LQ00424b, Condition 66):

- Wildlife has the "Right-of-Way" to avoid potential collisions and disturbance between wildlife and vehicles. Vehicle operators will adhere to the conditions set out in Figure 5-5;
- Stop when wildlife is observed on or moving towards the road;
- Allow individual or groups of animals standing on the road to move off the road unalarmed;
- Wildlife incidents (e.g., traffic accidents) will be reported to Site Management as soon as possible;
- Wildlife near misses and collisions will be investigated to identify the cause and possible future remedial actions; and
- Any observations of wildlife will be recorded on wildlife observation card (WOC) and incidences, such as collisions, will be reported to Site Management as soon as possible and a wildlife incident form (WIF) completed.

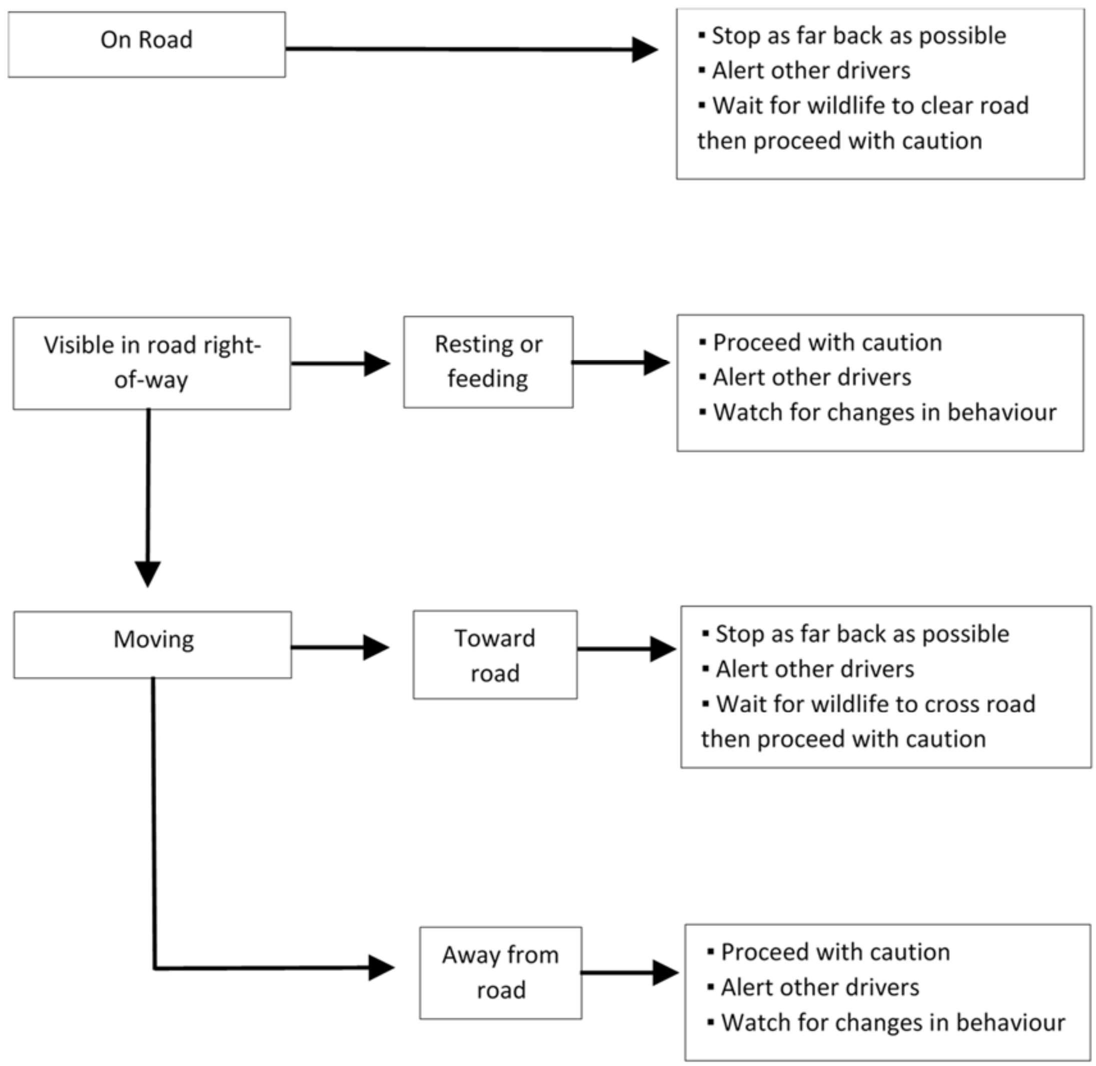


Figure 5-5: Wildlife and Road Operation Decision Matrix

ROAD MAINTENANCE

Road maintenance will incorporate strategies to reduce barriers to wildlife so there is safe passage across roads. The following mitigation measures will be implemented to increase wildlife safety around the Access Road and site haul roads:

- In summer, vegetation along roads will be cleared to remove browse and forage, and improve visibility. Clearing will be done early in the season and will be completed manually as BMC has a policy of no herbicide use;
- Debris, such as fallen trees, will be removed from roadways as soon as practicable;

- Fugitive dust will be controlled using water sprays or approved dust suppressant (environmentally-sound that do not contain salts that would attract wildlife) to minimize the Project's zone of influence over the surrounding landscape;
- Road embankments will be low profile to prevent the road acting as a barrier to, or channel for, wildlife movement; and
- Native seed mixtures will be used to prevent erosion along roadsides. Seed mixtures will contain minimal attractive/palatable vegetation to bears and ungulates (such as legumes).

- In winter, measures will include:
    - Radio communication among road users will be required to communicate information such as sightings of large animal species (LQ00424b, Appendix C, 2017-0002, p.9);
    - The road will be plowed so that snow banks are less than 1 m in height (LQ00424b, Appendix C, 2017-0002, p.9);
    - Breaks in snow banks will be placed (as required in key crossing areas) on both sides of the road to enable passage of large mammals (LQ00424b, Appendix C, 2017-0002, p.10);
    - Gravel and/or sand will be used on compacted snow or ice to improve road safety. Salt will not be used as it is a wildlife attractant (LQ00424b, Appendix C, 2017-0002, p.10); and
    - Snow plowing of access and Project roads will be limited to only those required for current operations, maintenance and/or emergency access.

Various native seed mixtures will be studied as part of reclamation research, which will be undertaken in collaboration with Ross River Dena Council (RRDC). The results of the studies will be discussed with YG to confirm seed mixes to be used for reclamation.

5.6.2 Highway Transport

Transportation contractors will be required to be oriented in and adhere to KZK policies and procedures to protect wildlife along the transportation routes. Applicable requirements to protect wildlife for highway transportation include the following:

- Comply with no hunting policy;
- Carry and maintain appropriate spill kits on all vehicles;
- Adhere to speed limits and reduce speeds in adverse driving conditions;
- Adhere to wildlife encounter protocols on the highway as presented in Figure 5-5;
- All drivers will be informed of high risk areas for wildlife encounters where they will be more alert and follow any posted speed reduction requirements.

High risk times and areas are where the highways go through caribou core wintering grounds which include: (1) the Robert Campbell Highway east and west of the KZK Access Road junction from approximately January 1 to March 31 in the Finlayson caribou herd wintering grounds; and (2) the northern end of Highway 37 and the Alaska Highway around the Highway 37 junction from approximately January 1 to March 31 in the Little Rancheria and Horseranch caribou herds wintering grounds.

5.6.3 Air Transport

The nearest airstrip servicing the KZK camp is at Finlayson Lake, approximately 30 km NW of the Project site which will be used for servicing of the Project, primarily for transporting crews. There is also the potential to use helicopters during ongoing exploration and construction work, and if this is required the following will be implemented:

- BMC will plan to avoid carrying out helicopter activities during the critical periods for caribou (critical periods for this area are May to July for calving and post-calving and mid-September to mid-October for rutting.) If caribou are present within 1 km of the active work area during these times, helicopter activities will cease until the caribou have left the area (LQ00424b, Condition 71);

- Flight paths have been and will continue to be designed to reasonably avoid disturbing wildlife and active hunting areas (LQ00424b, Appendix C, 2017-0002, p.9);

- The guidelines developed by the Mining and Petroleum Environmental Research Group (MPERG) have been adapted to minimize potential wildlife harassment from aircraft and helicopter over flights. All personnel, pilots and contractors will be required to follow the guidelines as set out in "Flying in Caribou Country: How to minimize disturbance from aircraft" (MPERG, 2008b) and "Flying in Sheep Country: How to minimize disturbance from aircraft" (MPERG, 2008c). These guidelines will be provided to aircraft and helicopter service providers (LQ00424b, Appendix C, 2015-0028, p.3 and 2017-0002, p.9; Lease Agreement 105G07-001, Schedule 2, 4.2);

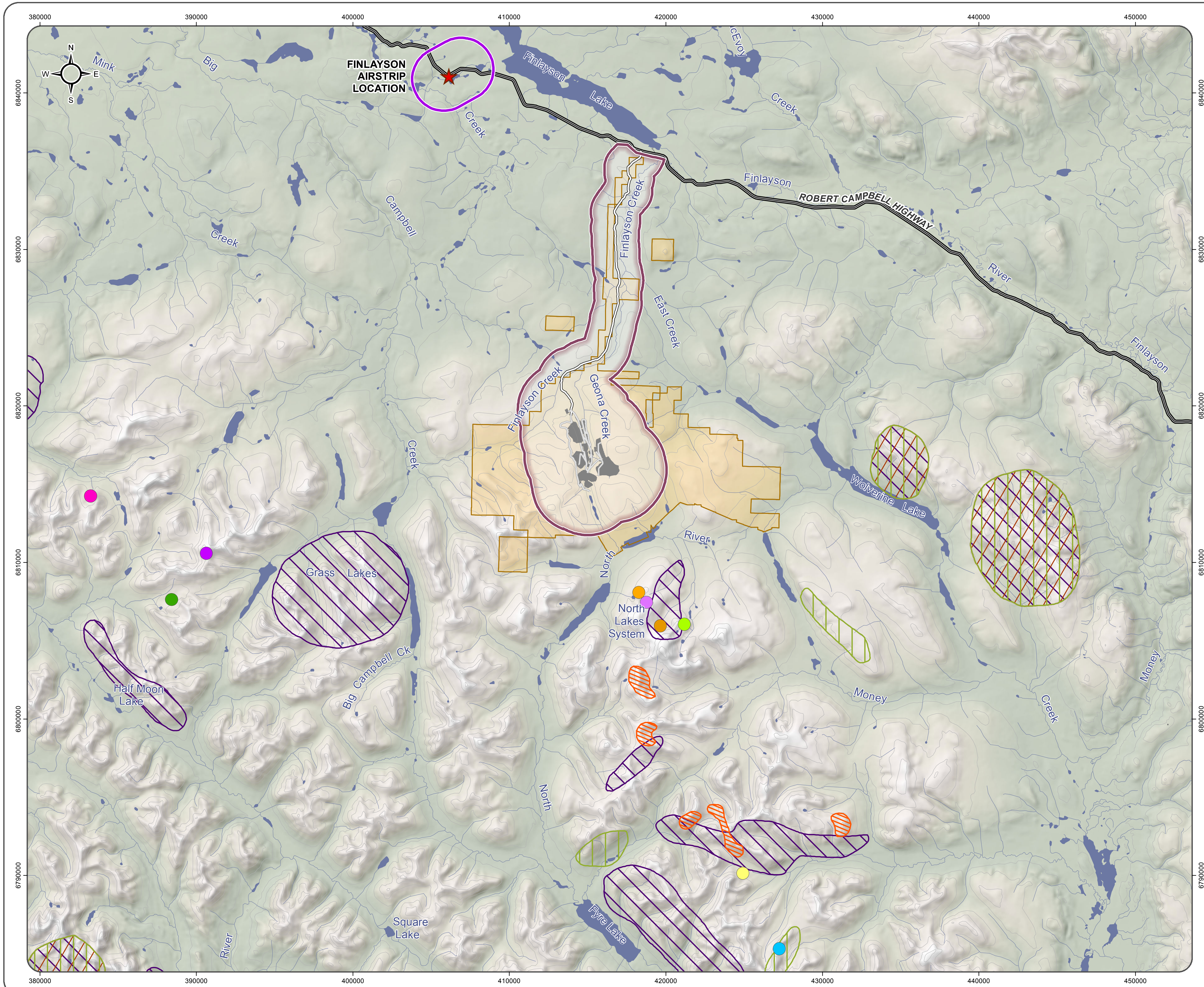
- Helicopter operations during the winter months will adhere to the measures outlined in the guidance document for Flying in Caribou Country. (YOR 2017-0002-022-1, p.3) (LQ00424b, Appendix C, 2017-0002, p.9);

Key mitigation measures include the following:

- Flight path routes will be determined to best avoid disturbing wildlife and active hunting areas. Consultation with the Kaska Nation and Outfitters will be ongoing throughout the field season to aid in avoiding sensitive areas (LQ00424b, Appendix C, 2015-0028, p.3 and 2017-0002, p.9). In particular, the area around the Finlayson airstrip is in core late winter habitat for caribou;
- Flying will be avoided over areas where wildlife has been observed in past seasons (based on publicly available information from the Yukon Zinc Studies in the vicinity of the Project and Yukon Government data), and areas sensitive to wildlife at certain times will be avoided (LQ00424b, Appendix C, 2015-0028, p.3 and 2017-0002, p.9);
- Flights will be conducted at a minimum of 300 m (1000 ft.) above ground level elevations to minimize disturbance to wildlife, except where required for work, safe landing approaches/ flight path, etc. (LQ00424b, Appendix C, 2015-0028, p.3 and 2017-0002, p.9);

- Flying height for airborne geophysical surveys will likely be below 300 m, but the surveys will be timed so as to not interfere with caribou rutting/calving seasons etc. (LQ00424b, Appendix C, 2015-0028, p.3 and 2017-0002, p.9);
- All reasonable efforts will be made to avoid sensitive habitats during key seasonal periods (LQ00424b, Appendix C, 2015-0028, p.3);
- When sensitive habitats cannot be avoided, a minimum over flight altitude of 600 m (or 2000 ft) will be maintained to the extent possible (LQ00424b, Appendix C, 2015-0028, p.3);
- Whenever possible, aircraft will avoid sheep ranges by 3.5 km or a ridge will be placed between the aircraft and sheep range, and aircraft will fly at altitudes below sheep if they are encountered (LQ00424b, Appendix C, 2015-0028, p.3);
- Purposefully flying towards, hovering and circling wildlife will not be permitted (LQ00424b, Appendix C, 2015-0028, p.3);
- If flying height is required below 300 m, flights will be timed so as to not interfere with sensitive species and seasons (refer to Table 5-1) especially caribou rutting/calving seasons; and
- The closest known Dall sheep area is 6 km southeast of the Project area, which is a nursery site and a mineral lick is situated at the east end of North Lake. Air traffic coming from the south, will avoid these two areas by approaching Project area from southwest.

Sensitive wildlife habitat areas and flight timing restrictions are presented in Figure 5-1 and Figure 5-6. These maps will be updated annually and provided to air service contractors.



BMC MINERALS

KUDZ ZE KAYAH PROJECT

FIGURE 5-6
WILDLIFE KEY AREAS FOR FLIGHTS

OCTOBER 2017

SHEEP OBSERVED DURING:

- 2015 Bear Den Survey # 1 (6)
- 2015 Caribou Post Calving Survey (6)
- 2015 Caribou Rut Survey (5)
- 2015 Caribou Rut Survey (7)
- 2015 Post Rut Moose Survey (12)
- 2016 Caribou Post Calving Survey (7)
- 2016 Caribou Rut Survey (14)
- 2016 Caribou Rut Survey (2)
- 2016 Caribou Rut Survey (4)
- Thinhorn Sheep Spring Lambing
- Thinhorn Sheep Early Winter Rut
- Thinhorn Sheep Winter Range
- Thinhorn Sheep Winter Range

OTHER MAP FEATURES:

- Finlayson Lake Airstrip Location
- Finlayson Airstrip 2km Buffer Zone
- Local Study Area
- Location of Proposed Infrastructure
- Tote Road/Proposed Access Road
- Proposed Mine Road
- BMC Minerals (No.1) Ltd. Mineral Claim Areas

* Numbers in brackets represent the number of individual sighted.

ALEXCO ENVIRONMENTAL GROUP

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.

Datum: NAD 83; Projection UTM Zone 9N

1:235,000 when printed on 11 x 17 inch paper

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Kilometres

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(*Last edited by: amatlashevska; 13/10/2017/10:16 AM*)

5.7 PROBLEM WILDLIFE MANAGEMENT

Encounters with wildlife are to be avoided. If ungulates, bears or wolverines, are encountered while carrying out project activities, the activities shall stop, as long as it is safe to do so, until the animal(s) has left the area. Wildlife shall be given the right of way (LQ00424b, Condition 66; Lease Agreement 105G07-001, Condition 29A(ii)).

Through the use of this WPP, BMC aims to reduce the occurrence of human-wildlife interactions. However, even with mitigation and management measures in place, human-wildlife interactions may occur. The following protocol is intended to maintain personnel safety and minimize human and animal injury or mortality:

- Trained personnel will be identified to monitor, manage and evaluate human-wildlife conflicts onsite;
- All personnel and contractors are required to report wildlife sights on the WOC;
- When a human wildlife confrontation occurs, management will be informed and WIF will be completed followed by an investigation;
- The investigation will include recording date, time and incident details from employee interview and scene investigation. Photographs of any visual evidence will be taken;
- Warnings signs will be erected in locations where frequent wildlife sightings occur. These will be altered seasonally or as necessary;
- Personnel and contractors will not attempt to handle nuisance or problem wildlife without specific direction from the Conservation Officer district office in Faro 867-994-2862 or Watson Lake 867- 536-3210 (LQ00424b, Appendix C, 2015-0028, p.1); and
- With approval from the Conservation Officer, adverse conditioning actions will be used with problem wildlife to negate human habituation.

Problem wildlife issues will first be prevented by implementing the mitigation and management measures included in this document. There may be occasions when these measures are not fully effective. BMC will use the initial risk and probability decision matrix shown in the following Table 5-3 to assess and manage problem wildlife encounters.

Table 5-3: Decision Matrix for Managing Problem Wildlife

Interaction	Actions and Management Response					
	Monitor	***Post Warnings***	***Area Closure***	***Contact CO***	***Aversive Conditioning to Change Behaviour***	***Relocate***
Sighting reported (low risk)	x					
Animal behaves normally (i.e., feeding) but could come in conflict with humans (moderately low risk)	x	x				
Animal reacts defensively and could come in conflict with humans (moderate risk)	x	x	x			
Animal tolerates human disturbance, ignores people/facilities but could come in conflict with humans (moderate risk)	x	x	x			
Animal displays repeated active interest in people/facilities and could come in conflict with humans (moderately high risk)	x	x	x		x	
Animal is clearly habituated to people/facilities and could come in conflict with human (high risk)	x	x	x	x	x	x
Animal displays aggressive behaviour and is a threat to safety (high risk)			x	x		x

6 WILDLIFE MONITORING PROGRAM

6.1 MONITORING PROGRAM

BMC's wildlife monitoring program is intended to track the effectiveness of mitigation and management measures. A summary of BMC's wildlife survey frequency and schedule for each monitoring program component is provided in Table 6-1.

Note that monitoring methods will be based on baseline surveys and will be appended as standard procedures to the WPP prior to construction.

The wildlife monitoring program requirements for caribou and moose (the Valued Ecosystem Component indicators) under the road Lease Agreement 105G07-001 are as follows:

- *Wildlife activities in the project area are to be monitored to identify changes in wildlife migration, distribution, abundance, to evaluate causal relationships between observed changes and project-related activities and to obtain information for the planning of mitigation. Monitoring of caribou and moose shall be used as indicators for the Valued Ecosystem Components. Monitoring shall be used to detect changes beyond baseline conditions or specific values for Valued Ecosystem Components (Lease Agreement 105G07-001, Schedule 2, 2.2).*

  The parameters for Valued Ecosystem Components monitoring shall be as follows:

  (i) frequency of surveys should be established in two year periods, commencing upon mine construction, subject to review at annual meetings of the Lessor, the Lessee, YTG R.R, affected First Nations, and other resource users in the area, including, but not limited to representatives of outfitters and trappers groups (the "Interested Parties"). The period for which surveys are required should be for the life of the mine, unless otherwise determined by the parties (Lease Agreement 105G07-001, Schedule 2, 2.2);

  (ii) survey area definition should be as completed in accordance with the original baseline survey for the project as shown in the map attached as Schedule 3 [see appendix 5 of IEE] (Lease Agreement 105G07-001, Schedule 2, 2.2);

  (iii) survey methodology shall include participation in annual YTG post-calving and rut surveys for caribou in conjunction with YTG RR survey schedules. Moose observations for the project area should be in the surveys. Methodology, including participation, should be determined annually through discussions with the YTG RR regional biologist (the "Regional Biologist") (Lease Agreement 105G07-001, Schedule 2, 2.2);

  (iv) survey reporting shall be made by December 31 of each year for review in annual meetings of the Interested Parties (Lease Agreement 105G07-001, Schedule 2, 2.2); and

  (v) survey follow-up should include review and discussion with Interested Parties of survey data in conjunction with YTG as well as additional mitigation based on the findings of effects monitoring. Reformatting of the wildlife monitoring design may also be required to reflect changing conditions (Lease Agreement 105G07-001, Schedule 2, 2.2).

Table 6-1: Wildlife Monitoring Program Summary

Monitoring Program Component	Project Phase*	Methods and Objective	Timing	Duration	Frequency	Location	Personnel Responsible for Conducting Survey
Wildlife Records Program	C,O,D,PC	Observations and locations reported by employees and contractors on site and along access road recorded in onsite log. Information will be used to determine wildlife movement corridors, potentially identify any changes in wildlife health, track wildlife species using the area, and identify high risk areas and any unexpected effects.	Ongoing, reported annually.	Ongoing	Ongoing	Project site and access road	All employees and contractors for the Project. Assistance with species recognition will be provided by onsite environmental staff.
Winter Wildlife Monitoring	C,O,D	Surveys will include snow track surveys shortly after fresh snow fall. This will provide information on presence and use of Project areas by small and medium sized furbearers as well as larger mammals.	Each month where there is snow cover. Survey to be conducted approximately between October to April each year that the survey is scheduled (dependent on weather and snow conditions).	2 days, once per month (~Oct-Apr)	Surveys will be carried out every three years depending on the results following the adaptive management plan.	Project site and access road at or adjacent to baseline transect sites	Onsite qualified environmental staff, First Nation members, and/or external experts.
Finlayson Caribou Herd Fall Composition Counts	C,O,D	Aerial helicopter surveys during the fall rut period. Survey will be consistent with the methods and area surveyed in 2015 and 2016. Late winter ungulate surveys consistent with baseline surveys. Information will be used to track actual effects on the herd habitat use, status, and potentially identify changes to herd health.	During the fall rut period (from late-September to early October) and late winter (March - April)	2 days	Annual for rut. Every three years for late winter.	Survey areas as per baseline surveys. Late winter habitat in GMS 10-07.	Onsite environmental staff, YG, First Nation members, and/or external experts.
Moose Late Winter Survey	C,O,D	Aerial helicopter surveys in conjunction with the fall caribou rut period. Aerial surveys of ungulates in late winter in the study area to locate critical late winter habitat. Survey will be consistent with the methods and area surveyed in 2015 and 2016. Information will be used to track effects on habitat use and avoidance from the Project.	Survey to be conducted in late winter (March - April).	2 days	Annual in conjunction with caribou rut. Late winter surveys will be carried out every three years depending on the results following the adaptive management plan.	Late winter habitat in GMS 10-07 around site, in particular east and west of the Access Road	Onsite environmental staff, First Nation members, and/or external experts.
Grizzly bear denning monitoring	C,O	The main purpose of the grizzly bear monitoring program is to prevent the disturbance of mining on hibernating bears. The area surrounding the open pit will be monitored during the pre-denning period to determine if there are any bears that show indications of preparing to den near the open pit.	Conducted in conjunction with the caribou fall rut survey (from late September to early October)	Weekly during pre-denning period	Annual	Area around open pit	Onsite environmental staff.
Breeding Bird Counts	C,O,D	Point count surveys to determine trends in nesting bird species and relative abundance in local study areas. Control sites established outside of Zone of Influence.	Survey to be conducted from Spring May – June.	2 days	Surveys will be carried out every three years depending on the results following the adaptive management plan.	At or adjacent to baseline survey sites at the Project site and along the Access Road	Onsite qualified environmental staff, First Nation members, and/or external experts.
Facility Monitoring	C,O,D	Routine checking for wildlife issues on the site. Include checks to remove/prevent potential nesting locations during the pre-nesting period. Regular checks of wildlife species use of water management ponds. Regular inspections of beaver dams to ensure culverts and creeks are flowing and not inhibiting correct operation of water management facilities. Information will be used to ensure that Project activities are not harming wildlife.	Emphasis on bird migration periods spring (~April - June). Checks will be carried out regularly during the spring, summer and fall.	Ongoing	Ongoing	Project infrastructure	Onsite environmental staff

* Project phase: C=construction; O=operations; D=decommissioning; PC=post-closure

6.2 WILDLIFE RECORDS PROGRAM

Reporting procedures for wildlife-human interactions, wildlife observations (including condition), and wildlife features (i.e. nest, den, mineral lick, species at risk etc.) will be included in employee and contactor orientations. Reporting procedures will also include reporting wildlife incidents (i.e. close or aggressive encounters, unusual or erratic behaviour, traffic accidents or near misses, and dead or injured wildlife). Records will be managed by the KZK Environmental Coordinator.

Wildlife logs will be maintained to provide information regarding presence of wildlife and potential changes in use of areas over time (LQ00424b, Appendix C, 2015-0028, p. 2). All wildlife encounters will be entered on the BMC Wildlife Observation Card (WOC) and Wildlife Incident Forms (WIF) (templates are included in Appendix 1). Information generated by these forms will be summarized in a wildlife observation log (Lease Agreement 105G07-001, Schedule 2, 1.1(iv); LQ00424b, Condition 15; Lease Agreement 105G07-001, Schedule 2, 2.3). The wildlife observation log will be compiled annually and will be provided to the Chief, Mining Lands. The log will include: date and time of sighting, a detailed location description (coordinates are preferable), species and number of animals, age and sex if possible, activity of the animals, and any other comments. The log will also be distributed to Ross River Dena Council, YG Regional Biologist, and Regional Conservation Officer. Any documented sightings of SARA-listed species will be reported to the Yukon Conservation Data Centre (LQ00424b, Appendix C, 2015-0028, p.4).

In the unlikely event that wildlife fatalities (i.e. caribou, moose, bear, or species at risk) occur along the Access Road or at the mine site the incident will be reported to the Conservation Officer (district office in Faro 867-994-2862 or Watson Lake 867- 536-3210) (LQ00424b, Appendix C, 2015-0028, p.4 and Lease Agreement 105G07-001, Condition 29A(iii)). Reporting procedures will also include reporting wildlife incidents (i.e. close or aggressive encounters, unusual or erratic behaviour, traffic accidents or near misses, and dead or injured wildlife) (LQ00424b, Appendix C, 2015-0028, p.4). Wildlife observations, monitoring programs, and incidents may be required to be followed up with additional mitigation as determined by the lessor, in consultation with the lessee, YTG RR and affected First Nations (Lease Agreement 105G07-001, Schedule 2, 2.4).Wildlife log data will be used in the Adaptive Management Program to help assess the efficacy of mitigation measures implemented to reduce Project effects on wildlife and habitat.

Grievances and comments from Kaska, Conservation Officers, trapline holders, NGO's, guide outfitters, community members, and public will be recorded as part of the Wildlife Records Program.

6.3 WILDLIFE HEALTH MONITORING

It is acknowledged that observing health conditions of individual animals is difficult. Indirect measures to monitor health will include the air quality, soil quality, and water quality monitoring programs that will be implemented to ensure air quality and water quality protection measures are working effectively and contaminants are not entering the receiving environment in concentrations that would be a risk to wildlife health. In addition, the programs to monitor wildlife use of the Project site will be used as indirect measures of the health of the wildlife.

Direct measures (i.e. capturing mammals and analysing their tissues) are not proposed to monitor wildlife health because, as the invasive measures necessary (i.e. mortality) to monitor health in one location over time is considered to be an unacceptable Project effect to wildlife and would not be supported by the Kaska Nation. However, from experience on mine sites, personnel often see the same wildlife frequenting the Project area, and notes on animal health in the wildlife logs can be used to help identify changes to an animal's condition over time. The wildlife observation cards currently used in exploration and that will continue to be used for construction and operations include a space to record the condition and behaviour of the animals. Yukon Government also monitors parasites and infection diseases of Yukon caribou herds (Hegel, 2013), which may be a source of reference during the implementation of the Wildlife Management Plan. Other sources that can be used to identify changes to wildlife condition can come from trappers, guide outfitters, and First Nations carrying out traditional activities around the Project.

7 ADAPTIVE MANAGEMENT

Under the exploration permit, records are used to provide an indication of the effectiveness of wildlife mitigation measures and to allow an adaptive management approach to improve performance (LQ00424b, Appendix C, 2015-0028, p.4). This will carry on to construction and operations.

BMC will provide opportunities to meet at least once each year with Interested Parties to report on and review the wildlife protection and monitoring provisions contemplated in this schedule. A primary objective of the annual meetings is to provide advance notice of anticipated project activities and plans for the upcoming year and to avoid unnecessary conflicts with other resource users (Lease Agreement 105G07-001, Schedule 2, 5.1).

BMC will use adaptive management methods to revise and refine the environmental management strategy. Adaptive management will consider a wide range of factors, including:

- Results of environmental audits or other evaluation activities;
- Results of wildlife and habitat monitoring;
- Results of monitoring of the performance or condition of environmental infrastructure, such as containment structures, water management systems or treatment facilities;
- Technological developments;
- Grievances and comments from, Kaska, Conservation Officers, Mine Inspectors, trapline holders, NGO’s, outfitters, staff, contractors, and the public; and
- Changing environmental conditions.

As development at KZK progresses, and as the results of further studies become available, the wildlife protection procedures and mitigations presented in this document will be revised as necessary to reflect changing site conditions, activity levels to ensure continued to mitigation of potential effects on wildlife.

A key factor in making changes to the WPP will be the results from the wildlife monitoring program. Table 7-1 provides a summary of the monitoring program triggers for corrective action and the proposed initial and potential corrective actions. The program and triggers are a result of the effects assessment in the YESAA Project Proposal (BMC, 2017) and will be updated through ongoing discussions with Kaska, commitments made during the Seeking Views and Information stage of the EA process and eventually the requirements from the YESAA Decision Document.

In addition, the following actions will be taken to facilitate adaptive management of wildlife:

- The BMC Environmental / Sustainability Manager will make recommendations to the management team about additional procedures, measures to implement, or changes to existing protocols or measures that may assist in further mitigating potential effects on wildlife;

- Recommendations gathered by the KZK Environmental Coordinator by liaising with the Kaska, Environment Yukon, and communities will be incorporated as appropriate; and

- The local Conservation Officer will be notified about wildlife incidences at site and the KZK Environmental Coordinator will work to implement the Conservation Officer's recommendations into site practices and update the WPP accordingly.

Table 7-1: Wildlife Subcomponents, Monitoring Parameters, Triggers, Corrective Action

Subcomponents	Monitoring Parameters	Triggers	Initial Corrective Action
Finlayson Caribou Herd	Habitat - Fall rut survey and post-calving survey distribution and numbers.	Caribou not using areas more than 3 km from Project. Reported avoidance greater than 3 km from Project.	Review mine activities potentially causing more disturbance than anticipated, identify potential options. Also discuss with Conservation Officers and Kaska as to whether any additional mitigation measures are needed.
	Movement - Aerial surveys	Changes in ungulate distribution from aerial surveys.	Check if reduction of sightings is due to reduced reporting and strengthen records program. If the root cause is traffic then modify traffic patterns to allow for longer periods without traffic during movement periods.
	Mortality - Wildlife records program; facility monitoring	Caribou injury or mortality recorded.	Investigate root cause (including discussions with Conservation Officers and Kaska) and make adjustment to access controls, egress structures, signage, speed, training, and/or enforcement.
	Health condition - Wildlife records program	Reports of poor condition of caribou that appear to have a connection to the Project, based on aerial surveys, outfitters, trappers, staff or contractors	Investigate root cause by reviewing soil, water and air quality emission data, other activities not related to the Project. Mitigate the source of the problem.
Moose	Habitat - Moose distribution from fall and late winter aerial ungulate surveys	Moose not using areas more than 3 km from Project. Reported avoidance greater than 3 km from Project.	Review mine activities potentially causing more disturbance than anticipated, identify potential options. Also discuss with Conservation Officers and Kaska as to whether any additional mitigation measures are needed.
	Movement - Aerial surveys	Changes in ungulate distribution from aerial surveys.	Check if reduction of sightings is due to reduced reporting and strengthen records program. If not from reporting then modify traffic patterns to allow for longer periods without traffic during movement periods.
	Mortality - Wildlife records program; facility monitoring	Moose injury or mortality recorded.	Investigate root cause (including discussions with Conservation Officers and Kaska) and make adjustment to access controls, egress structures, signage, speed, training, and/or enforcement.
	Health condition - Wildlife records program	Reports of poor condition of moose from aerial surveys, outfitters, trappers, staff or contractors that appear to have a connection to the Project.	Investigate root cause by reviewing water and air quality emission data, external activities. Mitigate root cause.
Grizzly Bear (and Black Bear)	Habitat - Wildlife records program; Incidental sightings during aerial surveys.	Changes in bear distribution from incidental observations during aerial surveys.	Investigate root cause (including discussions with Conservation Officers and Kaska) and make modifications to mitigation measures if Project is the cause and if necessary.
	Movement - Wildlife records program	Reduced bear sightings on road over time. Changes in bear distribution from incidental observations during aerial surveys.	Check if reduction of sightings is due to reduced reporting and strengthen records program. If not from reporting then modify traffic patterns to allow for longer periods without traffic during movement periods.
	Mortality - Wildlife incidents reports in wildlife records program; facility monitoring	Grizzly bear - human conflict reported or mortality recorded	Investigate root cause and carry out corrective action which could include measures such as better enforcement of waste or hazardous materials management, better training, better control structures, etc.
	Health condition	Qualitative - no barriers to seasonal movement patterns	Investigate root cause by reviewing water and air quality emission data, external activities. If information and data indicate a need, cooperate with regional health tracking programs with government or Northern Contaminants Program or similar.

Subcomponents	Monitoring Parameters	Triggers	Initial Corrective Action
Grey Wolf	Prey availability - ungulate aerial surveys; Wildlife records program	Ungulate's distributions have changed. Wolf missing from incidental observations during aerial surveys. Grievances or comments from trapline holders or Kaska community members	Investigate root cause and discuss with Conservation Officers and Kaska as to whether any additional mitigation measures are needed. Check for wolf more intensively during next scheduled aerial survey.
	Mortality - Wildlife records program; facility monitoring	Recorded incidents of injuries or fatalities	Investigate root cause and carry out corrective action which could include measures such as better enforcement of waste or hazardous materials management, better training, better control structures, etc.
	Health condition - Wildlife records program	Grievances or comments from trapline holders or Kaska community members	Investigate root cause by reviewing water and air quality emission data, external activities. If information and data indicate a need, cooperate with regional health tracking programs with government or Northern Contaminants Program or similar.
Wolverine and other Small Mammals	Habitat disturbance - incidental observations during aerial surveys; tracking surveys; Wildlife records program	Expected species missing from incidental observations during aerial surveys or in records. Species noted during baseline is not recorded in snow tracking survey. Grievances or comments from trapline holders or Kaska community members	Check for missing species more intensively during next scheduled aerial survey. Expand snow tracking survey lengths and frequency to determine extent of change in relative abundance. If actual change is suspected, investigate root cause and determine if and what remedial measures are required. Depending on the cause, measures could include changes to the reclamation program revegetation species or methods, improved emission controls, changes in mine activity patterns or timing, etc.
	Mortality - Wildlife records program; facility monitoring	Recorded incidents of injuries or fatalities	Investigate root cause and carry out corrective action which could include measures such as better enforcement of waste or hazardous materials management, better training, better control structures, etc.
	Health condition - Wildlife records program	Grievances or comments from trapline holders or Kaska community members	Investigate root cause by reviewing water and air quality emission data, external activities. If information and data indicate a need, cooperate with regional health tracking programs with government or Northern Contaminants Program or similar.
Birds	Habitat - breeding birds survey	Relative abundance reduced from baseline in survey areas	Investigate root cause. Potential corrective actions could include adjusting activity locations and schedules, adjusting the reclamation program, etc.
	Mortality - Wildlife records program; facility monitoring	Reported injuries or fatalities	Investigate root cause of mortality and determine corrective action if necessary. Additional measures could include changing access controls, adding deterrents, changing the reclamation program, etc.
	Health - breeding bird surveys; wildlife records program	Qualitative - no observable deterioration of physical condition	Investigate root cause by reviewing water and air quality emission data.
Waterfowl	Habitat - Waterfowl surveys of total counts from standardized locations	Relative abundance lower than baseline around Fish Offset Ponds and post-closure wetland habitat	Adjust monitoring frequency and locations to more fully assess use. Make adjustments to the restoration program vegetation species and habitat complexity to improve abundance and diversity.
	Mortality - Wildlife records program; facility monitoring	Noted injuries or fatalities (unless required for human safety) directly attributed to mine activity	Investigate root cause and determine corrective action if necessary. Additional measures could include changing access controls, adding deterrents, changing the reclamation program, etc.
	Health - waterfowl surveys; wildlife records program	Qualitative - no observable deterioration of physical condition	Investigate root cause by reviewing water and air quality emission data.

8 REPORTING

An annual environmental report for compliance with the Quartz Mining Licence will include the following information related to this WPP:

- Wildlife log;
- Wildlife management issues including incidence reports;
- Methods and results and discussions from the wildlife monitoring program; and
- Comments on the effectiveness of the WPP and any significant changes to the WPP (i.e. additional adaptive management measures, based on the results of the monitoring program).

BMC will maintain a wildlife log which will be provided to the Chief, Mining Lands annually. The log will include the following: date and time of sighting, a detailed location description (coordinates are preferable), species and number of animals, age and sex if possible, activity of the animals, and any other comments. The Wildlife Log will be maintained for the life of the mine until there are no longer employees on site. The area definition will include the mine property and access road, as well as relevant portions of the Robert Campbell Highway. The Wildlife Log will be in written form, including maps. The Wildlife Log will be reviewed annually each January with the Regional Biologist for the area. (LQ00424b, Condition 15; Lease Agreement 105G07-001, Schedule 2, 2.3).

Under the road lease agreement, survey reporting will be made by December 31 of each year for review in an annual meetings of the Interested Parties (Lease Agreement 105G07-001, Schedule 2, 2.2).

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APPENDIX 1.

Templates for Wildlife Observation Card and Wildlife Incident Form

BMC Minerals (No. 1) Ltd.

530-1130 West Pender Street, Vancouver, BC V6E 4A4

WILDLIFE INCIDENT REPORT

Each time a wildlife incident is observed by BMC personnel or contractors, it must be reported to the Environmental Coordinator immediately or at the end of the shift. An incident report will be completed by the Environmental Coordinator within 24 hrs of the incident occurring.

INCIDENT REPORT FORM
GENERAL INFORMATION
Employee/Contractor Name:
Date/Time of Incident:
Reported Incident to (Project Geologist Name):
Date of Report:
DETAILS OF INCIDENT
Wildlife Species:
Number of Species:
Incident Type (i.e. vehicle collision, near miss, encounter nuisance/problem interaction, or other). If vehicle involved specify type (truck, ATV, side-by-side, heavy equipment, aircraft or helicopter):
Location (i.e. GPS location, road km, camp etc):
Incident Outcome (i.e. injury, mortality, defensive behaviour, no injury, management action or other):
Description of Incident and Outcome:
Activity of wildlife before incident:
Type of Habitat (i.e. road, camp welands etc):
Could the incident have been prevented? (yes, no, uncertain):
If yes, describe how:

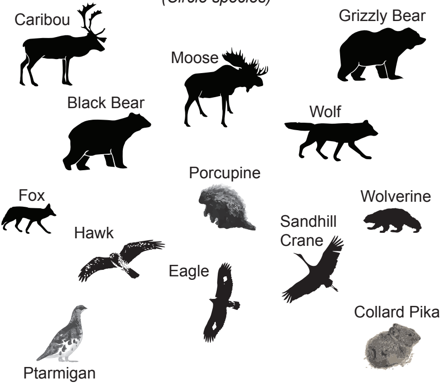
MANAGEMENT REVIEW AND REPORT DISTRIBUTION FORM
MANAGEMENT REVIEW
Completed By:
Signature:
Date:
COPIES OF REPORT SENT TO (YES OR NO)
Yukon Environment:
Yukon EMR:
Conservation Officer:
Ross River Dena Council:
Liard First Nation:

Note: If a wildlife mortality occurs along the access road, it must be reported to Yukon Environment (as per the Access Road Lease (Number 105G07-001). Wildlife interactions (e.g., traffic accidents) and nuisance or problem animals will be reported to the Project Geologist immediately. Observations of wildlife behaving abnormally will be reported within 24 hours (LQ00424b, Appendix C, 2015-0028, p. 2).

BMC Minerals

WILDLIFE OBSERVATION CARD

(Circle species)



☐ Other species: ______________________

Location *(specific)* : ______________________

Time: __________ AM / PM Date: ______________

☐ Male ☐ Female ☐ Unknown

Weather *(temp, precip)* ● Habitat *(river bank, slopes, ...)*

____

Herd *(numbers, ...)* ● Activity *(feeding, running)*:

____

Condition *(healthy,not healthy)*: ______________________

Behavioral Notes: ______________________

Name *(print)*: ______________________

Date:

Site observations and additional notes:

APPENDIX 2.

WPP Revisions Tracking Table

KUDZ ZE KAYAH PROJECT

WILDLIFE PROTECTION PLAN - FOR MINE CONSTRUCTION, OPERATIONS, AND CLOSURE

REVISIONS TRACKING

Revision	Date	Notes / Revisions
Rev0	November 2017	Draft prepared for YESAB Executive Committee review.

Appendix R2-K

2017 Nighthawk and Short Eared Owl Survey Results

2017 NIGHTHAWK AND SHORT-EARED OWL SURVEY RESULTS

KUDZ ZE KAYAH PROJECT

August 31, 2017

BMC MINERALS (NO. 1) LTD.

DISTRIBUTION LIST

# of copies	Company/Agency name
1	BMC Minerals (No.1) Ltd.

Name and Signature Redacted

Report prepared by: ________________

BMC Senior Biologist

Name and Signature Redacted

Report reviewed by: ____________

BMC Environmental Manager

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1 INTRODUCTION

This report summarizes the results of surveys completed in June 2017 for the Common Nighthawk (*Chordeiles minor*) and Short-eared Owl (*Asio flammeus*). This survey provides additional data on the status of these species of Special Concern for BMC Minerals (No. 1) Ltd.'s (BMC), Kudz Ze Kayah (KZK) Project (the Project), located in Yukon Territory, Canada. The purpose of the survey was to determine presence/absence and obtain an indication of relative abundance in the Project area.

There were three survey protocols identified for Common Nighthawk that could have been used for the surveys including the British Columbia inventory methods for Nighthawk and Poorwill (BC RIC, 1998), the Saskatchewan Common Nighthawk Survey Protocols (Saskatchewan MOE, 2015a), and the draft Canadian Nightjar Survey Protocol (Knight, 2016). Nightjars include nighthawks and poorwills that feed on insects during twilight. The Canadian Nightjar Survey Protocol was chosen for this study since it is the most recent and takes into consideration the most recent research and habitats used by nightjars throughout Canada.

The Saskatchewan Short-eared Owl survey protocol (Saskatchewan MOE, 2015b) is a most recent protocol and follows a three-minute point count survey method during twilight along the road. This is very similar to the Nighthawk survey protocol and the Short-eared Owls also actively feed around twilight in similar dry grassland habitats as Nighthawk (Environment Canada, 2016). Therefore, for efficiency, the Nighthawk survey protocol was followed for detection of Short-eared Owl.

Common Nighthawks are found almost everywhere in Canada, except Newfoundland and the far north. These birds are one of last birds to arrive from migration, showing up across the country in late May and early June. Common Nighthawks are generally found in open-area habitat such as grasslands, clearcuts, sandy areas, peatlands, rocky bluffs, open forests, and even urban areas (COSEWIC, 2007). Nighthawks use large areas of space and males are thought to defend territories for mating and nesting, but forage and roost outside those territories up to several kilometres away. Common Nighthawks are listed as Threatened due to steep population declines based on existing Breeding Bird Survey data (Knight, 2016).

Common Nighthawks become active approximately 30 minutes before sunset, and remain active until 60 or 90 minutes after sunset (twilight). Nighthawks forage for insect prey during sustained-flight, much like swallows and swifts. Their bright white wing bars are a tell-tale way to identify this species in flight.

Common Nighthawks can be identified by two different sounds. The first is a vocal "peent" or "beerb" call that is frequently made while the birds are in flight. The second is mechanical wing-boom, made by wind rushing through the down-curved wing tips of the male at the bottom of a steep vertical dive. Wing-booms are thought to be for territorial defense and mate attraction, much like the songs of male songbirds.

Due to their nocturnal habits, nighthawks and other nocturnal birds are understudied, but there is concern about their declining populations. Common Nighthawks are listed as Threatened under the federal *Species at Risk Act*.

2 METHODS

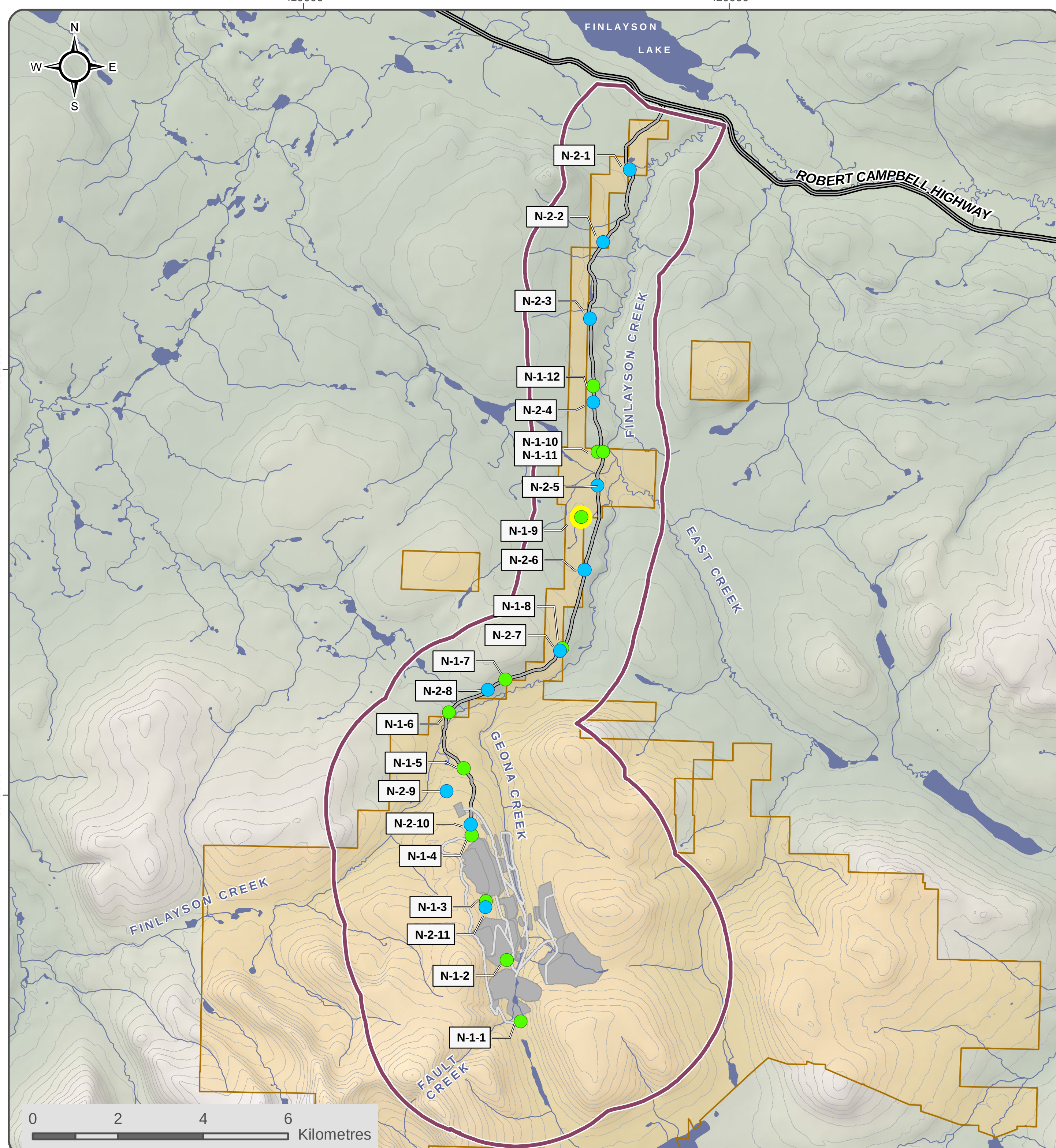
Surveys for Common Nighthawk and other incidental nocturnal birds was conducted during twilight from June 21 - 24, 2017 along the main north-south access road (Tote road) and through the Project (Figures 2-1 and 2-2) to capture all elevations of habitat throughout the Project area. Weather conditions were conducive for the survey (Table 2-1). Although there was intermittent light drizzle on the June 22nd moths, caddisflies and other flying insects were observed to be active. At this latitude twilight periods were considered to last from sunset to sunrise at the time of the survey.

The survey locations were chosen to maximize the distribution across the study area, while maintaining a spacing of at least approximately 1.6 km to reduce the chance of hearing nighthawks from more than one station. Four surveys were completed from June 21 to 24 during twilight. Surveys on June 22 and 23 followed the Canadian Nightjar Survey Protocol, Draft – April 2016 (Knight, 2016) and consisted of 23, 6-minute point counts located at approximately 1.6 to 2 km increments along the road. Surveys on June 21 and 24 followed a similar distribution but extended each count period to 20 minutes and focused on preferred habitat including open meadows with sandy soils along the Tote Road. Survey timing was increased for the purpose of increasing the chance of detection. Survey locations are shown on Figure 2-1 and Figure 2-2, and timing and survey conditions are presented in Table 2-1 below. It should be noted that twilight extends throughout the night at this latitude around the summer solstice.

All wildlife species observed or heard during the survey periods were recorded.

Table 2-1: Common Nighthawk Survey Conditions

Date of Survey	Sunset	Twilight	Temperature (C°)	Wind	Precipitation	Sky
June 21, 2017	11:36pm	Rest of night	5	light	Sporadic light mist	overcast
June 22, 2017	11:36pm	Rest of night	6	light	none	clear
June 23, 2017	11:36pm	Rest of night	4	light	none	clear
June 24, 2017	11:36pm	Rest of night	7	light	none	overcast



BASED ON 6-MINUTE POINT COUNTS

- Survey 1, No Observations
- Survey 1, Short-Eared Owl Observation
- Survey 2, No Observations

- Local Study Area
- Location of Proposed Infrastructure
- BMC Minerals (No.1) Ltd. Claim Areas
- Tote Road/Proposed Access Road
- Proposed Mine Road

Datum: NAD 83; Projection: UTM Zone 9N

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KUDZ ZE KAYAH PROJECT

FIGURE 2-1

KZK COMMON NIGHTHAWK SURVEY MONITORING LOCATIONS (JUNE 22 AND 23, 2017)

OCTOBER 2017

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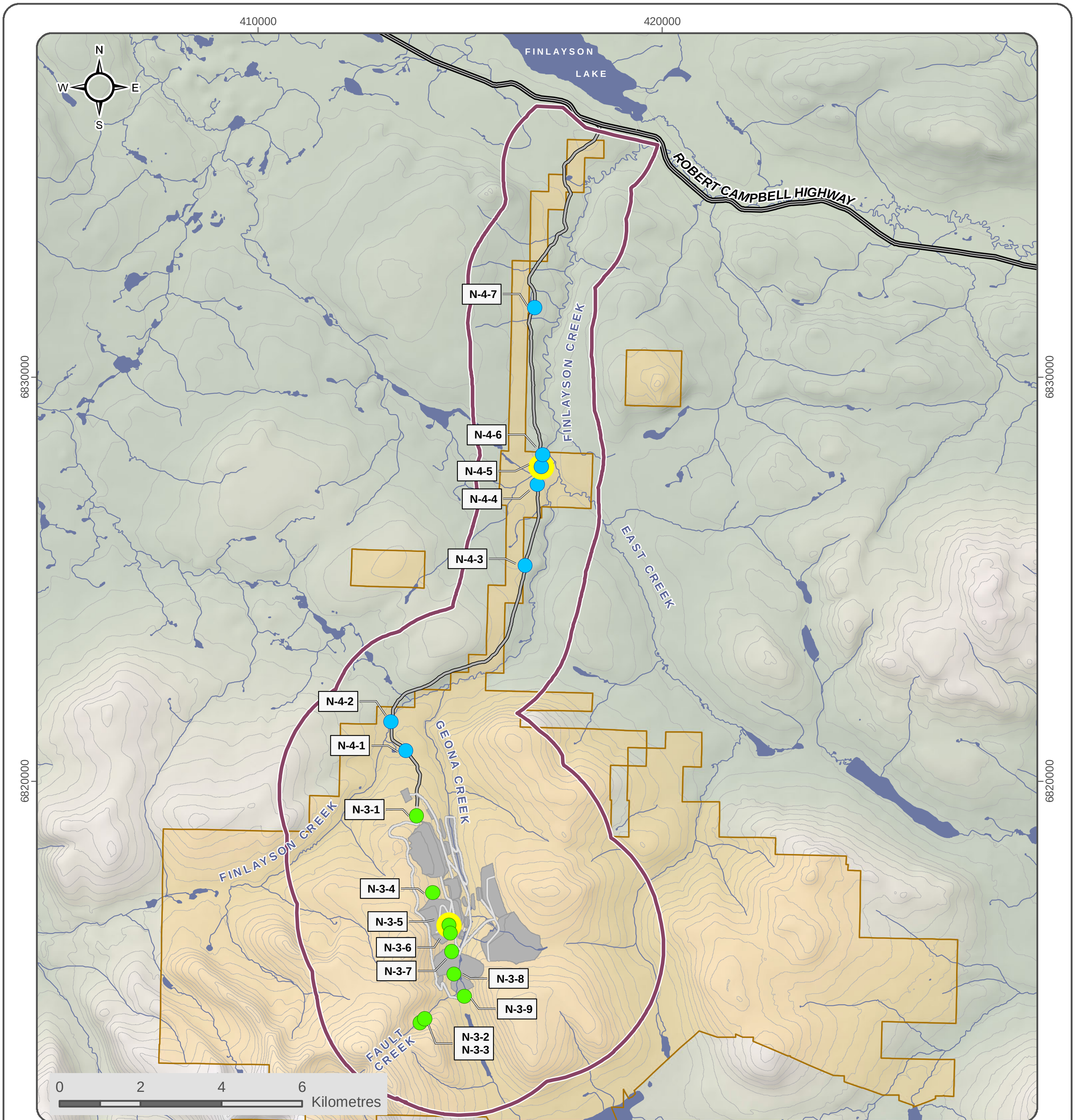

BASED ON 20-MINUTE POINT COUNTS

- Survey 3, No Observations
- Survey 3, Ptarmigan Observation
- Survey 4, No Observations
- Survey 4, Moose Cow and Calf Observation

- Local Study Area
- Location of Proposed Infrastructure
- BMC Minerals (No.1) Ltd. Claim Areas
- Tote Road/Proposed Access Road
- Proposed Mine Road

Datum: NAD 83; Projection: UTM Zone 9N

AEG

BMC MINERALS

KUDZ ZE KAYAH PROJECT

FIGURE 2-2

KZK COMMON NIGHTHAWK SURVEY MONITORING LOCATIONS (JUNE 21 AND 24, 2017)

OCTOBER 2017

D:\Project\AllProjects\Kudz_Ze_Kayah\Maps\03_Study\Wildlife\Small_Mammals_Birds\05-Post_Field\2017\Nighthawk_PF_Survey3_4_20170822.mxd
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3 RESULTS AND DISCUSSION

Total survey time was 7 hours and 38 minutes over four nights and 39 survey locations (Table 3-1 and Appendix A). Despite suitable timing and conditions, no Common Nighthawks were detected during the four field surveys, nor were any incidental observations of the species made along the road while travelling between stations (Appendix A). An incidental observation of one nocturnal species, a Short-eared owl, was observed at site 1-9 on June 22nd (Figure 2-1 and Table 3-1).

As no Common Nighthawk and only one Short-eared Owl were observed during the four days of study, it can be concluded that abundance is very low for these two species of Special Concern and no further species-specific mitigation are proposed. The potential effects from the Kudz Ze Kayah Project on these two species is therefore considered to be of low magnitude, local, and continuous for the life of the Project which results in a finding of not significant effects for these birds.

Table 3-1: Nighthawk Survey Times and Results

Survey #	Survey Start Date	Survey Time	Point Count Length	Number of Survey Points	Observations
1	22-Jun-17	23:16 - 01:32	6-minute	12	Short-eared Owl at site N_1-9
2	23-Jun-17	22:40 - 01:42	6-minute	11	No birds observed
3	21-Jun-17	23:40 - 03:11	20-minute	9	Several ptarmigan flying at site N_3-5
4	24-Jun-17	23:15 - 01:57	20-minute	7	Cow and calf moose at site N_4-5

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Appendix A

Monitoring data from KZK Nighthawk Survey June 21 to 24, 2017

Monitoring data from KZK Nighthawk Survey June 21 to 24, 2017

Survey Number	Date	UTM E	UTM N	time start	time end	Observations
1/1	06-22	415113	6814674	23:16	23:22	
1/2	06-22	414776	6816112	23:30	23:36	
1/3	06-22	414298	6817507	23:41	23:47	
1/4	06-22	413959	6819052	23:54	0:00	
1/5	06-22	413764	6820626	0:07	0:13	
1/6	06-22	413428	6821942	0:17	0:23	
1/7	06-22	414744	6822711	0:29	0:35	
1/8	06-22	416084	6823447	0:40	0:46	
1/9	06-22	416533	6826532	0:51	0:57	short-eared owl
1/10	06-22	416920	6828057	1:02	1:08	
1/11	06-22	417052	6828057	1:14	1:20	
1/12	06-22	416814	6829613	1:26	1:32	
2/1	06-23	417669	6834693	22:40	22:46	
2/2	06-23	417052	6832989	22:50	22:56	
2/3	06-23	416740	6831200	23:02	23:08	
2/4	06-23	416818	6829225	23:10	23:16	
2/5	06-23	416916	6827266	23:22	23:28	
2/6	06-23	416610	6825284	23:33	23:39	
2/7	06-23	416035	6823398	23:44	23:50	
2/8	06-23	414341	6822465	23:56	0:02	
2/9	06-23	413369	6820096	0:07	0:13	
2/10	06-23	413929	6819307	0:16	0:22	
2/11	06-23	414287	6817356	0:27	1:32	
3/1	06-21	413931	6819152	23:40	0:00	
3/2	06-21	414025	6814025	0:03	0:23	
3/3	06-21	414130	6814130	0:25	0:50	
3/4	06-21	414332	6817239	0:53	1:13	
3/5	06-21	414735	6816441	1:17	1:37	Several Ptarmigan flying
3/6	06-21	414774	6816244	1:40	2:00	
3/7	06-21	414799	6815793	2:04	2:24	
3/8	06-21	414863	6815227	2:28	2:48	

	3/9	06-21	415108	6814676	2:51	3:11	
	4/1	06-24	413664	6820753	23:15	23:25	
	4/2	06-24	413300	6821467	23:28	23:48	
	4/3	06-24	416624	6825334	23:58	0:18	
	4/4	06-24	416917	6827340	12:25	12:45	
	4/5	06-24	417010	6827778	0:48	1:08	cow and calf moose
	4/6	06-24	417043	6828078	1:10	1:30	
	4/7	06-24	416855	6831722	1:37	1:57	

Appendix R2-L

<u>Caribou Summary – KZK Project</u>

3 Calcite Business Centre, 151 Industrial Road
Whitehorse, Yukon Y1A 2V3
Phone (867) 668-6463 Fax (867) 633-4882
www.alexcoenv.com

Memorandum

To: Name Redacted

From: Name Name Redacted

CC:

Date: 12 October, 2017

Re: Caribou Summary – Kudz Ze Kayah Project

1 Introduction

This summary is provided to clarify the importance and ecology of the Finlayson Caribou Herd (FCH) with respect to the Kudz Ze Kayah (KZK) Project area. This clarification is in response specifically to R2-85 and R2-86 of YESAB's Adequacy Review Report – Information Request No.2 (YESAB, 2017). Of key interest is how the caribou use the Project area through all life stages, how they move throughout their range, and the importance of snow patches. In addition, a summary of known information is provided on caribou health including body condition to support the assertion that there is sufficient suitable habitat and vegetation availability throughout the range. As requested, extensive literature is included which supports this summary.

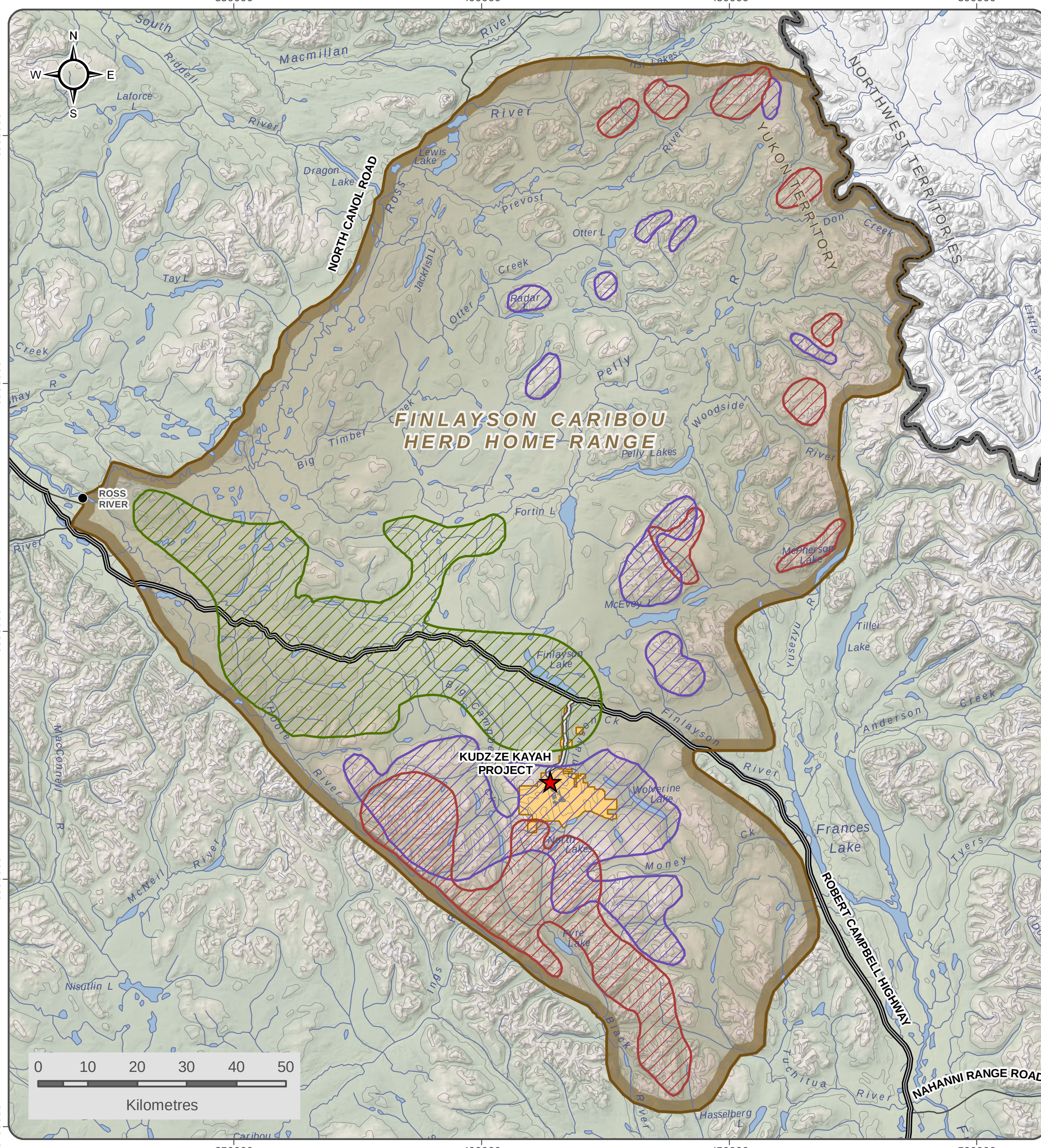
It should be noted that this summary is a supplement in response to adequacy review information requests. More information on the baseline surveys, habitat modelling, effects assessment, and mitigation and management plans are presented in the Wildlife Baseline Report in Appendix E-8, as well as Chapter 13 and 18 of the Project Proposal (BMC, 2017).

2 FCH Importance, Life History, and Ecology

2.1 Importance

Kudz Ze Kayah (KZK) Project area is very important to the Finlayson Caribou Herd (FCH) as it is part of their seasonal distribution and habitat, as noted by government agencies and the Kaska. Caribou are a Kaska cultural keystone species for hunting and cultural purposes (Dena Kayeh Institute, 2010). This Northern Mountain Population of woodland caribou is noted as Special Concern under the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and the *Species at Risk Act*. Species designated as special concern are those that may become threatened or endangered because of a combination of biological characteristics and identified threats (SARA; Government of Canada, 2002). As a species of special concern, these caribou require more intensive management of the species by the responsible jurisdictions. The ecological importance of woodland caribou changes throughout the seasons; however, they are an important food source for predators such as wolf and grizzly bear and scavengers such as wolverine (Environment Canada, 2011).

The Project is located in the FCH rutting and post-calving core ranges. Caribou move from their wintering grounds in the Pelly River and Finlayson River valleys to the Pelly mountains around the Project area for spring calving and through to early winter after the rut when they then move back to the River valleys where their food is more accessible. The existing Tote Road is on the eastern border of late winter core habitat for the FCH as seen in Figure 1.



Kudz Ze Kayah Project	Community	Watercourse
Core Post Calving Range	Tote Road/Proposed Access Road	Waterbody
Core Rut Range	Highway	Location of Proposed Infrastructure
Core Winter Range	Secondary Road	BMC Minerals (No.1) Ltd. Mineral Claim Areas

KUDZ ZE KAYAH PROJECT

FIGURE 1

FINLAYSON CARIBOU HERD RUTTING, POST-CALVING RANGES

OCTOBER 2017

Wildlife Key Area data compiled by the Yukon Department of Environment. Publication Date: May 2009
Obtained from Geomatics Yukon. Datum: NAD 83; Projection: UTM Zone 9N

AEG

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2.2 CALVING PERIOD

The calving period for the FCH is from May 7 to June 8 with a median peak of calving from 16 to 20 May (Chisana Caribou Recovery Team, 2010). Northern mountain caribou disperse into the mountains where they seek out solitary calving sites that are distant from alternate prey species such as moose, and spaces them away from predators (Bergerud et al., 1984; Bergerud and Page, 1987; Bergerud, 1992, Fenger et al., 1986). The woodland caribou anti-predation tactics make it problematic for biologists to make meaningful quantitative measure of their sensitivities during this life cycle period. Nonetheless, it can be inferred that the FCH likely calve in the Pelly mountains around the post-calving grounds (and around the Project area) based on the FCH distributions during other seasonal surveys.

2.3 POST-CALVING PERIOD

Instead of the calving period, a greater focus of caribou surveys has been directed at the post-calving period in July when caribou aggregate in large numbers in the alpine, which yields better insight into use of the area. Caribou have a limited time span during the summer for growth and building new fat reserves for the coming winter (White et al., 1975; Roby, 1978; Downes et al., 1986; Messier et al., 1988; Nixon, 1991). Constraints on the ability of caribou to feed optimally during this period of high forage quality and availability could have a negative effect on their body condition (White et al., 1975). Post-calving surveys were carried out by BMC from 2015 to 2017 to determine relative abundance and distribution of caribou and were combined with previous survey results from eight surveys conducted between 1982 and 1998 (Yukon Department of Environment, unpublished data). Survey results clearly show that caribou are present in and adjacent to the KZK Project area during the post-calving period. During post-calving surveys, up to 90% of caribou observations are made on snow patches where the animals congregate to avoid the heat and insects making them important habitats (Ion and Kershaw 1989). This habitat use is a known behaviour spanning at least 8000 years (Farnell et al. 2004).

2.4 RUTTING PERIOD

Caribou are highly segregated in distribution by sex and age classes during all life cycle periods except the rut (Begerud 1978). In fall (about Sept 28th to Oct. 10th) caribou aggregate into breeding groups on alpine plateaus (Figure 2) where they become homogeneously mixed. Calf mortality studies have found that five-month-old calf mortality equals that of adults in fall. Therefore, calves observed during the fall rut are considered recruits into the population at this time (Adams et al. 1995; Chisana Caribou Recovery Team, 2010). This provides an opportunity for biologists to conduct unbiased surveys in high observability habitats to acquire large sample size data on annual patterns of survival. Caribou rut counts are a conventional survey strategy carried out by wildlife managers across North America (Farnell, pers.comm.). Additionally, these data provide baseline information on the relative abundance, group dynamics, and population characteristics of caribou inhabiting the KZK Project area during the fall rut season. Rut counts were carried out from 2015 to 2017 and combined with previous annual Yukon Government survey data over a 32-year period from 1982 to 2014. From these studies, we expect that the highest level of interaction of the KZK Project with caribou will be during the rutting period when disturbance created by development and operation of the Project would result in a shift of distribution away from the mine site.

To better understand potential impacts, BMC conducted an analysis centered on the KZK footprint area of about 6.5 km² using 5 km, 10 km, and 15 km concentric circles around the proposed mine site. Using 35 years of rut survey data including that from the Yukon Department of Environment that recorded the location, number and sex/age composition in each group observed, there were 2,189 group observations of caribou that comprised 41,275 individual animal locations in all years within the survey block. These data indicate that there could be an overall reduction in the number of caribou within the 5-km radius (153.5 km^2) representing a direct and indirect functional loss of range during the rutting period and perhaps other seasonal periods.

Figure 2: Kudz Ze Kayah Project Area Looking Northeast Across Geona Creek Valley and onto Alpine Plateaus

2.5 EARLY WINTER

In 2015 and 2016, early winter (November/December) post-rut surveys for ungulate distribution and abundance surveys were carried out by BMC. The surveys found that the FCH distribution had largely shifted northward and were interacting with the Project area (until as late as mid-December). This life cycle period has not been well studied and remains an area where there could be significant local interaction with caribou moving through the area. More information will become available during Project construction and additional mitigations can be implemented to minimize effects through the adaptive management program.

2.6 LATE WINTER

Late winter ungulate surveys were carried out from 2015 to 2017. Additionally, there are data from comprehensive population estimate surveys performed in 1986, 1990, 1996, 1999, 2007 and 2017 (Yukon Department of Environment, unpublished data). The distribution of the FCH during late winter extends from the lower Genoa Creek-Finlayson Lake area across the Pelly River lowlands to just east of Ross River. The FCH winter range corresponds to a 'rain/snow shadow' region on the lee side of the Pelly Mountains, which forms an orographic barrier to precipitation originating in the Gulf of Alaska (Wahl et al., 1987). There is marked variation in precipitation across the range of the FCH. The winter range typically receives 40-50 cm of precipitation annually, while the foothills of the Logan Range receive approximately 75 cm or more annually. The long-established use of this area by caribou indicates an obligatory response to snow depth patterns relative to abundant lichen making it a key habitat in the herd's ecology (Figure 3).

Figure 3: Finlayson Caribou on a Lake and in Mature, Open Spruce Forest in the Finlayson Valley

2.7 MOVEMENT AND MIGRATION

Long-term studies of the FCH seasonal movements and distribution have been carried out for over 30 years. Additional studies on body conditions and contaminants studies were also conducted in the 1990s. Approximately two thirds of the herd utilize the Pelly Mountains south of the Robert Campbell Highway for calving, post-calving, and rutting life stages and then move north to the Pelly River lowlands by late winter (Figure 1). Woodland caribou are relatively sedentary and do not make large linear movements characteristic of arctic caribou but make elevational shifts from boreal forest rich in lichens to rolling mountains and high plateaus to browse on herbaceous vegetation (Bergerud, 1978; Thomas and Grey, 2002). There is no evidence that Yukon woodland caribou ranges expand and contract relative to population size changes ('recurrent fluctuation') over time (Yukon Department of Environment, unpublished data). Regardless, the Project is located well within the herds 'center of habitation'-- the central area in which all habitat needs are met to support the population as theorized by Skoog (1968). Body conditions, food habits, and contaminants could also affect the FCH population size but do not appear to be limiting factors for the current population as presented in Section 3 below.

2.8 POPULATION DYNAMICS

A review of the demography of the FCH is informative to place the potential effects of the KZK Project in the context of the ongoing caribou population trend. Wolf control from 1983 to 1989 (when wolf numbers were kept at about 15% of pre-control numbers) was successful in increasing Finlayson caribou calf and adult survival and overall numbers from less than 2,000 in 1982 to about 6,000 in 1991 (Farnell and

McDonald, 1989; Yukon Department of Environment, unpublished data). When the wolf control ended, wolf numbers and pack territories rebounded within about four years to pre-control numbers and distribution (Hayes et al., 2000 and 2000a). Caribou calf survival dropped within two years to pre-wolf control levels. The herd began to decline in about 1991 and has been declining slowly since then.

Annual fall calf recruitment data (calves/100 cows) and population estimate data are available for the FCH (Adamczewski et al., 2007; Yukon Department of Environment, unpublished data). During the wolf control years of 1986 to 1990, calf recruitment was very high at a mean 50.4 calves/100 cows (SD=7.53) resulting in an exponential annual rate of growth of ř=17% to 5959+17.7% caribou, indicating that wolf predation was the central driving force in the Finlayson herd's population dynamics. However, between 1991 and 1996, as wolves recovered on the herd's range, calf recruitment declined to a mean 27.1 calves/100 cows (SD=4.22) combined with excessive hunting this resulted in an annual rate of decline of ř= -4.6%. The declining trend continued between the population estimate years of 1996 to 1999 (4,537+11.9% to 4,130 +16.9%; mean recruitment 22.3 calves/100 cows with SD=5.34; ř= -9.4%) and 2000 to 2007 (mean recruitment 17.0 calves/100 cows with SD=6.63; ř= -3.7%) when the population was estimated at 3,077+5.6% caribou. Consequently, the herd has been in decline for 20 years since its high in 1990. This existing, natural trend needs to be considered when assessing potential effects from the KZK Project.

3 FCH HEALTH

3.1 FOOD HABITS

The late-winter diet of FCH caribou was determined by fecal analysis from samples collected at various locations on the herds' winter range between 1982 and 1999 (Yukon Department of Environment, unpublished data). The composition of the late winter diet can provide a crude evaluation of range condition when combined with food availability as determined by snow depth (Russell et al., 1993). Results showed the FCH caribou winter diet is comprised of 74% highly digestible terrestrial lichens and 2% moss (Figure 4). Moss has poor digestibility and is picked up incidentally when foraging for lichens. Low moss in the winter diet indicates that range condition is very good. Graminoids comprised approximately 6% of the diet and was mainly *Carex* which is found around lake edges. Graminoids are considered highly digestible compared to other vascular plants, and are rich in protein and phosphorous. High protein and mineral intake during late pregnancy leads to higher milk yield in cows and subsequent increased birth weight and growth of calves (Klein, 1982).

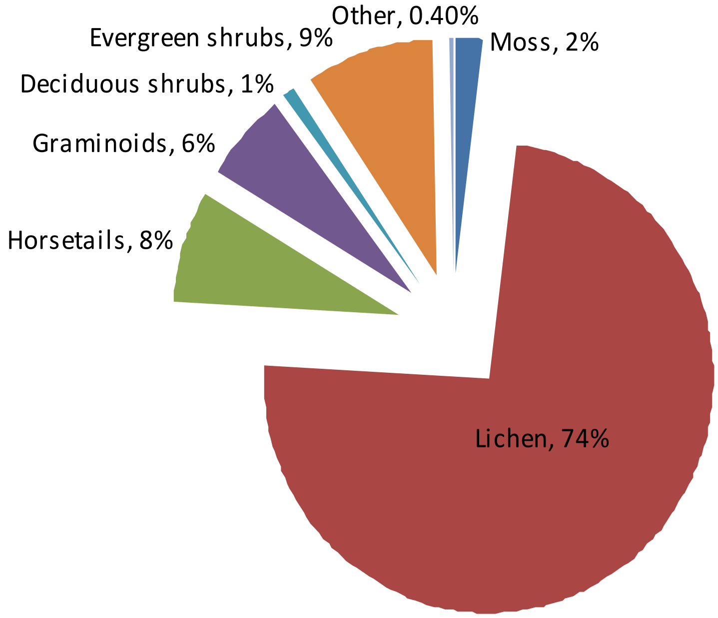

Figure 4: Average Winter Diet of the FCH Determined by Fecal Plant Material, 1982-1999

3.2 Body Condition

Body weight and composition are important determinants of population growth potential in caribou, affecting ovulation and conception rates (Dauphiné, 1976; Klein and White, 1978; Thomas, 1982), age of first reproduction (Leader-Williams and Rosser 1983), potential reproductive success (Clutton-Brock et al., 1982), and survival (Thomas et al., 1976). Monitoring body weight and composition is important for assessing changes in demographic vitality. Particularly if depressed weights and body reserves are associated with habitat degradation from overpopulation (Klein, 1968; Reimers et al., 1983; Skogland, 1983 and 1984) or human caused factors.

The need to monitor body weight and composition became important for the FCH during the 1980s wolf control program because steady population growth had substantially altered the population density. It was uncertain whether the population was approaching carrying capacity, and there was concern that an unsustainable density could lead to a population crash. It was also seen that these data can set baseline indices of herd physical condition for future comparisons (Farnell, pers. comm.).

Controlled hunts were carried out by the Yukon Department of Environment to collect 31 adult female caribou from the FCH during February and March 1992 and 20 adult females in March 1993 (Table 1). For comparison 20 and 18 adult female caribou were taken from the neighbouring Bonnet Plume Herd and Tay River Herd (BPH and TRH; Table 1), respectively, in March 1993 to provide control data. Results from pregnancy rate, body weight, back fat, kidney fat, and fetus weight indices taken from these caribou during late winter (i.e., when they should be most stressed) found that average values for the FCH exceeded or were comparable to the control herds with stable populations (Table 1) suggesting that forage and nutrition factors were not debilitating physical condition and therefore not limiting the herd.

These findings were supported by Kaska First Nation elders with long time experience in the area, who commented that caribou numbers were well below the forage resource carrying capacity (Regional Wildlife Management Planning Meeting, Ross River, June 1998).

Table 1: Average Body Condition Indices from Hunter Killed Caribou in the Finlayson, Bonnet Plume and Tay River Caribou Herds in Late Winter 1992 and 1993

Herd*	Cementum Age (Years)*	Pregnancy Rate	Total Weight (kg)	Back Fat (cm)	Kidney Fat (g)	Fetus Weight (g)	Sample Size
FCH 1992	4.4	100%	129.7	10.1	50.4	1743.7	n=31
FCH 1993	4.4	90%	136.4	10.2	53.9	2386.8	n=20
BPH 1993	5.3	85%	102.6	0.6	38.4	2324.1	n=20
TRH 1993	4.2	80%	139.8	6.4	52.9	1669.6	n=18

* Age determined from growth layers of cementum on the teeth.
Finlayson Caribou Herd = FCH; Bonnet Plume Herd = BPH; Tay River Herd = TRH

3.3 CONTAMINANTS STUDIES

Environmental contamination is a concern in the north as these ecosystems receive atmospheric deposition of contaminants from other industrial parts of North America. Caribou are of particular concern because lichens, their primary food source, absorb contaminants from the atmosphere and accumulate them over time. In addition, caribou are also an important food source for subsistence hunters. In 1993, a study was initiated to acquire baseline data on a variety of metals and other potential hazardous substances in woodland caribou (Gamberg, 1993). Caribou bone, muscle, liver and kidney tissue from 31 caribou harvested from the FCH were submitted to various laboratories for analysis. Of 26 metals analyzed, only high levels of cadmium in kidney and liver samples were of concern. Cadmium levels were positively correlated with age, and cadmium levels in kidney tended to be higher than in liver. High total mercury was found in kidneys, but in the relatively non-toxic inorganic form. Cessium^{137} in muscle and organochlorines in fat tissue were considered normal for sub-arctic caribou. An unusual pattern of dioxin and furan deposition in caribou fat was observed. Although not well understood, the presence of some of these substances may indicate a combustion source (e.g., from fossil fuels, municipal waste incineration, sewage treatment, forest fires, mining activity, pesticides, and herbicides) and transfer through atmospheric deposition to lichens.

The high levels of cadmium found in Finlayson caribou may be indicative of a local source of contamination, which is likely entering the food chain through natural mineralization in this part of the Yukon (Gamberg, 2000). Analysis of stream sediments and water by the National Geologic Survey of Canada (Hornbrook and Friske, 1988) shows the prevalence of a geologic formation known as the 'Earn Group' which includes black shale's known to be rich in cadmium and barium. Cretaceous outcroppings are also common and associated with elevated levels of mercury. These metals may be introduced into the environment through natural erosion forces, which are then absorbed into the soil and plants, and subsequently into foraging herbivores. Mineral licks are another possible source. Cesium^{137} levels found in Finlayson caribou were well within the range of levels found for other caribou herds in North America and do not indicate a health problem for the animals (Gamberg, 1993).

Radioactive fall-out in the north exists as a result of atmospheric nuclear weapons testing in the early 1960s and these levels have been declining since that time. On-going monitoring of contaminants in the Yukon through hunter submissions has continued since 1992 and provides background data to assess trends in these substances and test mitigation and reclamation measures (Gamberg, 1993; Gamberg et al, 2005). Health Canada recommends limiting consumption of caribou and moose liver and kidneys as result of these background levels.

4 POTENTIAL PROJECT EFFECTS AND MITIGATIONS

Overall, the KZK Project footprint and disturbance from the mine activities will potentially displace caribou from 5 to 6% of the FCH core rutting and post-calving habitat in the Pelly Mountains. However, it is expected that the caribou will use alternate, nearby rutting and post-calving habitat. There will also be disturbance by traffic and planes on the eastern extent of the FCH late winter range.

Reduction in the abundance of caribou in the vicinity of disturbed areas has been documented repeatedly, often with an avoidance zone (zone of influence) of 1 to 5 km (Cameron et al., 1992, 2005; Smith et al., 2000; Wolf et al., 2000; Dyer et al., 2001, 2000; Nelleman et al., 2001, 2003; Vistnes and Nellemann, 2001; Mahoney and Schaefer, 2002; Johnson et al., 2005; Florkiewicz et al., 2007; Weir et al., 2007; Polfus et al., 2011; Fortin et al., 2013; Johnson et al., 2015). Females with calves are less tolerant and more likely to avoid disturbance than other caribou (Roby, 1978; Cameron et al., 1979, Smith and Cameron, 1983; Dau and Cameron, 1986; Chubbs et al. 1993; Nellemann and Cameron, 1998; Nellemann et al., 2001). Large groups usually avoid disturbed areas more than smaller groups (Cameron et al., 1979; Cameron et al., 1992; Dyer et al., 2001; Nelleman et al., 2001). The timing and direction of migration may also be altered by disturbance (Cameron and Whitten, 1980; Curatolo and Murphy, 1986; Johnson and Russell, 2014; Johnson et al., 2015; Wilson et al., 2016). Additionally, greater access to caribou by linear corridors, such as roads and seismic lines, has led to increased harvest by humans (Bergerud, 1974; Edmonds, 1991; Rettie and Messier, 1998) and predation by wolves (James, 1999; James and Stuart-Smith, 2000; James et al., 2004; Kuzyk, 2002). However, it is also alleged that human caused physical features and associated disturbance have not affected caribou numbers and productivity (Bergerud et al. 1994).

The KZK Project is designed and will be operated to minimize effects on caribou as much as practicable. Designs to minimize effects include (but not limited to) minimizing the footprint of disturbance, putting fencing around water management ponds, using fencing with small mesh to avoid entanglements, providing ramps that allow escape routes out of lined water storage ponds, signage along the Access Road at wildlife crossing areas, and a tended guardhouse to prevent hunters from using the road. Management measures to minimize effects include minimizing unnecessary activity in alpine areas during the post-calving and rut as much as practicable, implementing and enforcing company no hunting, no harassment, and no feeding policies, convoying two to three vehicles on the Access Road, and worker and contractor wildlife education during induction presentations. In addition, adaptive management will be used to make any changes if data from the annual herd surveys and wildlife records indicate that the effects on the herd are not as expected or where opportunities arise to further minimize effects.

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Appendix R2-M

Resume of [Name Redacted]

Name Redacted

Service line		Management/ Research Consulting
Industry Focus		Wildlife Management Environmental Assessment Public Sector
Profile		Name Redacted is a Wildlife Biologist. Name Redacted key focus is to work with industry and government regulatory processes to help insure a sustainable economy as well as healthy wildlife populations. He has over 30 years experience in wildlife research and management as a senior biologist and project manager. His important accomplishments over the last three decades include co-implementing five caribou population recovery programs employing adaptable and innovative recovery strategies. Name Redacted was also responsible for initial and long-term inventory and monitoring of Yukon's woodland caribou herds through radio-collaring programs, routine population surveys, habitat quality, range condition and caribou body condition assessments. This information provided the baseline information required to adequately mitigate human activity affects on caribou as well provide the information base to develop and adapt management plans. The technical challenges encountered while carrying out these activities lead to research development into improved caribou management methods and procedures as well as insight into wildlife ecological processes. After graduating from the University of Eastern Michigan in 1972, Name Redacted gained a variety of experience coordinating and implementing wildlife research programs, completing surveys and analyzing data for various wildlife populations across the Yukon with an emphasis on caribou. In addition, Name Redacted has completed numerous environmental assessments and has written or co-authored over thirty articles, papers, technical reports, and was an editor of the proceedings of the 8th North American caribou Workshop. In addition to supervisory skills, Name Redacted has a broad consulting skill set and interacts with a variety of audiences including inter-jurisdictional governments, First Nations communities, interest groups, private industry, the public and the media. When Name Redacted retired from the Yukon Department of Environment in 2006 he received the Premier's Award of Excellence for his devoted work on caribou.
Selected Assignments:		
Industry	**Service Line**	
Land Use and Planning	**Habitat Suitability Modeling**	Peel River Land Use Planning Board – Habitat suitability modeling to assist the information base needed in developing a management plan for the Peel River basin of Yukon.
Environment	**Environmental Assessment Screening** **Report Development**	Yukon Environmental and Socioeconomic Assessment Board – Environmental assessment screening report reviews including specific assessments of wildfire affects on key caribou ranges.
Energy and Natural Resources **Wildlife Services**	**Wildlife Surveys** **Community Affairs**	Yukon Zinc Inc. – Wildlife surveys and advice to assess potential affects on wildlife from construction and operation of the Wolverine Mine Project. This included pre-development community consultations for input into engineering and design plans for the project.
Energy and Natural Resources **Wildlife**	**Baseline Studies** **Environmental Assessment**	Selwyn Resources – Senior advisor and field biologist for large mammal baseline and environmental assessment studies in relation to the Selwyn Project. This included researching and incorporating a large body of existing information into baseline reports, carrying out wildlife surveys in relation to the project area during important seasonal periods, literature reviews, cumulative effects assessments and

Name Redacted

Services Environmental Assessment	**Public Hearings**	management plans, establishing a long-term wildlife monitoring program, meetings with regulators, public hearings, research permits, annual work plans, and community consultation meetings over a ten year period.
Wildlife Services	**Wildlife Management Plans**	Canadian Wildlife Service – Technical support, inter-jurisdictional work shopping and co-authorship of the Northern Mountain Population Caribou Management plan as required under the Species at Risk Act. The goal of the plan is to provide adequate conservation strategies for 38 herds in BC, Yukon and NWT so that they do not become designated 'Threatened'.
Environment	**Publication Reviews** **Training and Facilitation**	Yukon Department of Environment – Authorship of peer review publications of past research. Firstly, a monograph on 28 years of intensive research into caribou predator/prey relationships, population dynamics, range use, climate effects, and body condition assessments. Secondly, case history analyses of a paradigm shift in caribou population recovery strategies over the past three decades. Also orientation of staff and training on community based wildlife management and aerial survey procedures.
Energy and Natural Resources **Wildlife Services**	**Best Practices Guidelines**	Yukon Energy Mines and Resources – Development of best practices guidelines for caribou in relation to oil and gas exploration activities in the northern Yukon a reference resource for industry.
Energy and Natural Resources **Wildlife Services**	**Wildlife Surveys**	EBA Engineering – Wildlife surveys for environmental assessment of the Ketza Mine in Yukon.
Environment	**Wildlife Surveys and Management** **Environmental Assessments**	Wildlife Biologist (Caribou) Yukon Department of Environment Whitehorse, Yukon Advanced professional biological work with responsibility to coordinate and implement caribou research and management programs throughout Yukon over a 28 year period. This required completion of surveys and data analysis for caribou populations, capture and handling caribou, maintenance of records, collecting and analyzing laboratory field specimens, comment on land use issues and numerous environmental assessment reviews, completion of reports and scientific papers, tracking caribou harvest, interaction with public advisory groups and individuals, providing input to legislation and policy processes, purchase and maintenance of field equipment, staff training, facilitating meetings and workshops, office administrative and budgetary duties and various other activities as were delegated. These duties required forming close ties with all Yukon communities and stakeholders. It also necessitated carrying out caribou recovery and conservation plans that necessitated effective co-management inter-jurisdictionally with Alaska, BC, and NWT. Budgetary responsibility at times exceeded $400K to implement intensive projects.
Energy and Natural Resources **Wildlife Services**	**Baseline Studies** **Environmental Assessment** **Public Hearings**	Gladstone Hydroelectric project overview - Ungulate baseline data delivery for initial feasibility assessment of possible hydro development in southwest Yukon.
Energy and Natural	**Baseline Studies**	Alaska Highway Pipeline Project – Caribou baseline data analysis for populations potentially interacting with a proposed gas pipeline bisecting the southern Yukon.

Name Redacted		
Resources **Wildlife Services**		
Energy and Natural Resources **Wildlife Services**	**Baseline Studies** **Environmental Assessment** **Public Hearings**	Casino Mining Project – Caribou baseline studies, environmental assessment review, and public meetings in development of and implementation of licensing through regulatory process.
Wildlife Management	**Meetings & Field Work**	Revelstoke Caribou Recovery Project – Advisory and implementation services for initiation of captive rearing project to recover the endangered North Columbia caribou herd in southern British Columbia.
Energy and Natural Resources **Wildlife Services**	**Baseline Studies** **Environmental Assessment** **Public Hearings**	Kutza Ze Kaya Mining Project – Large mammal baseline studies and environmental assessment reporting. Mitigation planning.
Education		• Eastern Michigan University, B.Sc. granted 1972
Employment History		• 2007-Present, Environmental Consulting Professional Services, Whitehorse, Yukon. • 1978-2006, Yukon Department of Environment, Whitehorse, Yukon • 1974-1976, Howard Paish & Associates, Vancouver, BC • 1973, 1976 British Columbia Fish and Wildlife, Nanaimo, BC • 1974-1976 Spatsizi Wilderness Safaris, Vancouver, BC • 1973 Canadian Forest Products, Woss Lake Division, Vancouver Island, BC

Appendix R2-N

Revised Preliminary Quantitative Risk Assessment

BMC MINERALS (NO.1) LTD

KUDZ ZE KAYAH PROJECT

PRELIMINARY QUANTITATIVE RISK ASSESSMENT

November 2017

EXECUTIVE SUMMARY

At the request of the Yukon Environmental and Socio-economic Assessment Board, BMC Minerals (No.1) Ltd. (BMC) has completed a multi-media exposure human health risk assessment (HHRA) of environmental conditions of at the proposed Kudz Ze Kayah Mine Project (the Project). The objective of the HHRA was to determine if the potential risks to human health from Contaminants of Potential Concern (COPCs) under the various Project phases.

The HHRA was completed using Health Canada risk assessment guidance, environmental concentrations predicted by other disciplines and the assumption that the mitigation and management measures (as outlined in BMC's Project Proposal for Executive Committee Screening) will be followed. Briefly, Health Canada Preliminary Quantitative Risk Assessment (PQRA) guidance was used as the key basis of the risk assessment methods. Although not specifically developed by Health Canada for use in environmental assessment, Health Canada PQRA guidance was applied to provide upper bound estimates of human health risks.

The HHRA was conducted for arsenic, cadmium, copper, fluoride, lead, selenium and zinc. The risk assessment found that risks will be acceptable provided the key elements of the mitigation and management measures are followed (including the adaptive management and monitoring programs that will be finalized during permitting).

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1. INTRODUCTION

BMC Minerals (No.1) Ltd. (BMC) completed a Preliminary Quantitative Human Health Risk Assessment (PQRA) of predicted environmental conditions at the proposed Kudz Ze Kayah Mine Project (the Project) in response to Yukon Environmental and Socio-economic Board's (YESAB) adequacy review of BMC's Project Proposal to develop the Kudz Ze Kayh (KZK) Project (Information Request R267). The initial PQRA was included as Appendix 3 of the Initial Response Report (BMC, 2017a). The conclusions of the initial PQRA indicated that risks from single exposure pathways were not predicted to have unacceptable risks. This conclusion was largely based on no predicted changes in environmental media concentrations or no exposure pathway. Following YESAB's review of the initial PQRA they have indicated that although risks from single exposure pathways are not predicted to have unacceptable risks, the assessment should consider multi-media risks and present how the combined risks are predicted to change from baseline due to Project development. Subsequently, this PQRA builds on the risk assessment in the initial PQRA and includes risks calculated from multi-media exposure pathways.

This PQRA was completed using Health Canada risk assessment guidance, environmental concentrations predicted by other disciplines and the assumption that the mitigation and management measures as described in the Kudz Ze Kayah Project Proposal (Project Proposal) (BMC, 2017b) will be followed. Briefly, PQRA guidance was used as the key basis of the risk assessment methods, at the request of YESAB. Although not specifically developed by Health Canada for use in environmental assessment, Health Canada PQRA guidance was applied to provide upper bound estimates of human health risks.

This report outlines the methods, results, conclusions and recommendations of the PQRA and is organized as follows:

- Section 2 summarizes the site setting and relevant documents that provide information cited in the PQRA;
- Section 3 provides methods used to complete the PQRA;
- Section 4 provides the results of the PQRA;
- Section 5 provides the uncertainty analysis for the PQRA;
- Section 6 provides the conclusions of the PQRA; and
- Section 7 provides the references.

1.1 SCOPE OF WORK

The PQRA was based on the measured and predicted concentrations various of substances that have been reported by other disciplines. The measured and predicted concentration data (where available) are presented in the Project Proposal as follows: Air quality (Chapter 6), Water quality (Chapter 8), Soil (Chapter 11) and Vegetation (Chapter 12). Noise has also been included in the PQRA. Baseline and predicted noise levels are presented in Chapter 7 of the Project Proposal. The PQRA was also based on the proposed mitigation and management measures and that are presented throughout the Project Proposal chapters (which are summarized in Chapter 18).

The methods used are based on guidance provided by Health Canada and the World Health Organization; however, the PQRA also incorporates the scientific literature to the extent reasonable.

2. SUMMARY OF SITE SETTING AND BACKGROUND INFORMATION

BMC proposes the development of the KZK Project in southeast Yukon which is within the Kaska traditional territory. The Project is a proposed open pit/underground copper, lead, and zinc mine located approximately 115 km southeast of Ross River, Yukon.

The Project lies within the Pelly River and Pelly Mountain ecoregions and is within the northern foothills of the Pelly Mountains of the Yukon Plateau. The elevations around Project area generally vary 800 to 1,800 metres above sea level. The Project is located on the east side of the divide between the Pelly River and the Liard River drainage basin, in the Upper Liard Drainage. The Project is located in the Geona Creek watershed which drains to Finlayson Creek. Finlayson Creek meets the outflow of Finlayson Lake north of the Robert Campbell Highway and flows east to eventually join the Frances River, and ultimately, the Mackenzie River.

The Project encompasses the A.B. Mawer (ABM) Deposit of which there are two zones; 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 nominal 2 million tonnes per year processing plant. Dry stack tailings will be deposited in the Class A Storage Facility on the western slope of the Geona Creek Valley while waste rock will be stored according to acid generation and metal leaching potential.

The mine is planned to operate for ten years, producing up to 180,000 tonne (t) zinc, 60,000 t copper, and 35,000 t lead concentrates annually. Concentrate will be transported to the port of Stewart for sale to market via Highway 4 south (Robert Campbell Highway) to Watson Lake and Highway 37 south to Stewart, British Columbia (a distance of 911 km).

The scope of the Project includes developing on site and off site surface infrastructure to support open pit and underground mining activities required to extract mineral reserves from the ABM Deposit. The Project will have a nominal 5,500 tonne per day throughput over an approximate 10-year mine life.

More detailed information on the proposed Project (including the environmental setting) is presented in the Project Proposal (BMC, 2017b).

3. METHODS

3.1 INTRODUCTION

This section of the report presents the methods used to complete the PQRA. As noted earlier, the PQRA was completed using Health Canada risk assessment guidance, environmental concentrations predicted by other disciplines and the assumption that mitigation and management measures as described in the Kudz Ze Kayah Project Proposal (Project Proposal) (BMC, 2017b) will be followed. Briefly, Health Canada Preliminary Quantitative Risk Assessment guidance was used as the key basis of the risk assessment methods. Although not specifically developed by Health Canada for use in environmental assessment, Health Canada PQRA guidance was applied to provide upper bound estimates of human health risks.

Important documents that were used to estimate risks include the following:

- Health Canada (2012): Federal Contaminated Site Risk Assessment in Canada – Part I: Guidance on Human Health Preliminary Quantitative Risk Assessment (PQRA); and
- Health Canada (2010a): Federal Contaminated Site Risk Assessment in Canada –Part II: Health Canada Toxicological Reference Values (TRVs) and Chemical-Specific Factors.

The details on the methods are provided in the sections below.

3.2 PROBLEM FORMULATION

In order for a potential risk to occur, there must be an interaction between all three of the following components:

- Contaminants of Potential Concern (COPC) that might pose a toxicological hazard;
- The presence of a human receptor who might come into contact with the COPC; and
- A pathway by which the person may be exposed to the COPC (i.e. inhalation, ingestion, skin contact, etc.).

Without the presence of all three components there is no potential for a risk to occur. Therefore, the first step in the PQRA was to develop a problem formulation and conceptual model for the risk assessment in order to determine if all three components exist at the Project. The problem formulation is presented in the following sections for air quality, noise, water quality, and other environmental media (i.e. country foods).

3.2.1 Air Quality

An air quality effects assessment is presented in Chapter 6 of the Project Proposal. The air quality model predicted changes to air quality based on two study areas:

- The local study area (5 km by 5 km, centred on the mine footprint); and
- The regional study area (40 km by 40 km and encompasses the mine footprint and the entire Tote Road/Proposed Access Road).

The closest receptors to the mine site in the modelling domains are the mine employees living in the camp. Employees on shift will be protected from any health effects as BMC will be required to meet the WCB regulations for air quality at an industrial site. However, there may be exposure to off-shift workers staying at the camp during their rotation. The potential exposure pathway would be inhalation. However, the modelled air quality generally meets the air quality objectives at the camp (for construction, operations and closure). As discussed in Chapter 6 of the Project Proposal, a few small exceedances are predicted under the worst case meteorological conditions, which if they occurred would be less than 1% of the time over a 24-hour period (based on conservative modelling assumptions) during the operations Phase. No exceedances are predicted during construction and closure. Subsequently, all three components required for a risk assessment are not met as the modelled COPCs do not pose a toxicological hazard. Subsequently, no further risk assessment is required. Since the closest receptor is not at risk, it follows that there would be no risk from incidental exposure due to Project related changes in air quality (i.e., to people using the regional areas for hunting, fishing or trapping at farther distances from the site).

Mitigation measures to minimize air emissions are presented in Section 6.4.2 of the Project Proposal and the conceptual Air Quality Management Plan is presented in Section 18.11 of the Project Proposal.

3.2.2 Noise

A noise levels effects assessment is presented in Chapter 7 of the Project Proposal. The noise model predicted changes in noise over the following study areas:

- The local study area (4.6 km by 6.0 km, centred on the Project Footprint, and includes camp as a sensitive receptor).
- The regional study area (32 km by 36 km and encompasses the Project Footprint and the entire Tote Road/proposed Access Road).

The closest receptor to the mine site in the modelling domain are the mine employees living in the camp. Employees on shift would be protected from any health effects as BMC will be required to meet the WCB regulations for noise at an industrial site. However, there may be exposure to off-shift works staying at the camp during their rotation. The potential exposure pathway would be acoustic. However, the noise model meets the noise objectives at the camp (for construction, operations and closure). Therefore, all three components required for quantitative risk assessment are not met as the modelled changes in noise levels do not pose a human health hazard. Subsequently no further risk assessment is required. Since the closest receptor is not at risk then there would be no risk from incidental exposure due to Project related changes in noise (i.e. to people using the regional areas for hunting, fishing or trapping at farther distances from the site).

Mitigation measures to reduce noise presented in Section 7.4.2 of the Project Proposal. Due to the low levels of noise predicted at the camp receptor, no specific monitoring is proposed. However, if off-shift workers were to complain about noise at the camp, then additional mitigation measures would be applied.

3.2.3 Water Quality

A water quality effects assessment is presented in Chapter 8 of the Project Proposal. This assessment did consider potential impacts on human health. However, for clarity the results are summarized in the following paragraphs. Appendix A of this PQRA presents the modelled COPC concentrations compared to the drinking water guidelines. Note that the surface water model has been updated in response to YESAB's information requests and therefore the results presented in Appendix A have been updated from those presented in the initial PQRA (BMC, 2017a). The water quality model has been revised with updated kinetic test results and associated source terms along with additional baseline information. These updates to the water quality model no longer identify antimony, uranium and nitrite as COPCs. YESAB has requested that the surface water model be updated again prior to them preparing the Screening Report; therefore, this PQRA will also be updated using the revised model results once they are available.

The water quality assessment included waterbodies in the local study area (Geona Creek, South Creek and upper Finlayson Creek) and the regional study area (Lower Finlayson Creek and North River). The only creek in the Project area that was specifically identified by First Nations as being used for drinking water purposes is Fault Creek. However, other creeks in the study areas may also be used for drinking water purposes when people are hunting or fishing in the area. It is unlikely that Geona Creek is used for drinking water purposes as it is a slow flowing stream that visibly does not look potable. The water quality in Fault Creek is not predicted to change as it is upgradient of the Project activities. Therefore, a further risk assessment of Fault Creek is not warranted as there are no Project related "COPCs that might pose a toxicological hazard".

During the construction, operations, and decommissioning, reclamation and active closure phases, there will be no public access to the creeks in the local study area (i.e., Fault Creek, Geona Creek, and upper Finlayson Creek). As per the requirements of the Tote Road license, the road will be gated and will be manned 24 hours a day 365 days per year. Therefore, there will be no "presence of a human receptor who might come into contact with a COPC" during these Project phases. Thus, further human health risk assessment is not required.

The only potential for exposure to these particular creeks would be during the post-closure scenario. Therefore, the water quality model results during post-closure within Finlayson Creek were compared to the maximum acceptable concentration drinking water guidelines (as provided by Health Canada, 2014) (Appendix A). Finlayson Creek was selected for comparison because of the creeks in the Project area it has the potential to be used for drinking water purposes and has the potential to be impacted by the Project. However, no COPCs were estimated to exceed the drinking water quality guidelines during the post closure period. Therefore, there are no "COPCs that might pose a toxicological hazard" and thus no further risk assessment is required. Note that the model results for all Project phases have been included in Appendix A (although only the post-closure phase results apply to this evaluation).

During all Project phases, people could access the creeks in the regional study area (i.e. lower Finlayson Creek, South Creek and North River). Therefore, the water quality model results were compared to the maximum acceptable concentration guidelines (Health Canada, 2014) during each of these Project phases (see Chapter 8 of the Project Proposal).

No COPCs assessed were estimated to exceed Canadian drinking water guidelines in the publicly accessible lower Finlayson Creek during the construction, operations or closure/post closure phases. Similarly, no COPCs were estimated to exceed drinking water guidelines in South Creek during all Project phases. Since South Creek ultimately flows into North River, North River would also not be expected to exceed the applicable guidelines.

3.2.4 Other Environmental Media

Country foods are animals, plants, or fungi used by people for medicinal or nutritional purposes that are harvested through hunting, gathering, or fishing. Country foods take up chemicals from the environmental media (i.e., water, soil, and vegetation). Thus, their concentrations (i.e., quality of the food) are directly related to the concentrations in the environmental media. Subsequently, any Project activity that could affect the quality of water, soil, and vegetation could also affect the quality of country foods. To determine the potential effects to country foods, predicted changes to the environmental media were reviewed from other relevant sections of the Project Proposal.

Soil

During construction, operations and closure, soil quality could be affected by minor fuel spills. These minor spills will be remediated as per the Spill Contingency Plan (Section 18.5 of the Project Proposal). Because the spills and all associated affected soils will be cleaned up, there is no potential for such spills to affect the quality of country foods (i.e., vegetation or wildlife) during all Project phases.

During construction, operations and closure, soil quality could be affected by dust containing metals. Potential sources of atmospheric metals are from residual ore dust from blasting, open haul trucks going to the crusher, the live ore stockpile, tailings dust from the Class A Storage Facility where the material has dried but is not yet covered, and earthmoving activities in an area with naturally higher mineralization. However, given the low levels of particulate that are predicted in the Air Quality Model (Chapter 6 of the Project Proposal). It is unlikely that concentrations in soils (from dust from the Project facilities) will increase. As such, there is low potential for changes in soil quality to affect the quality of country foods (i.e. vegetation or wildlife) during all Project phases.

In order to confirm this prediction, a monitoring program will initially collect soil samples at exposure and control sites. The sampling program will be conducted prior to construction, after development, and once every three years through to closure with data tracked over time to determine if there are any changes in metal concentrations resulting from the Project. An adaptive management plan will be developed during permitting, which will identify threshold values for additional mitigation or monitoring. If the soil concentrations trigger the threshold values (the lowest of which will be set as 'early warning' indicators, at levels below expected effects concentrations), additional mitigation measures would be implemented and a more intrusive monitoring program would be implemented (i.e., vegetation monitoring program).

Vegetation

Potential sources of COPC uptake into (or deposition onto) plants are from either air, soil or water.

Since the soil is not predicted to be impacted, then there would be no subsequent change to the vegetation concentrations. In order to confirm this prediction a monitoring program will initially collect soil samples at exposure and control sites. The sampling program will be conducted prior to construction, after development and once every three years through to closure with data tracked over time to determine if there are any changes in metal concentrations resulting from the Project. An adaptive management plan will be developed during permitting, which will identify trigger values for additional mitigation or monitoring. If the soil concentrations are approaching the trigger values, then additional mitigation measures would be implemented and a more intrusive monitoring program would be implemented (i.e. vegetation monitoring program).

Potential sources of COPCs in vegetation from water sources are limited to the closure period for constructed wetlands. The water management program will control and treat any contact water prior to release to the environment during operations and closure. A soil and vegetation metal monitoring program will commence with installation of constructed wetlands in order to monitor the efficacy of the constructed wetland at treating water as well as to ensure that metals are not accumulating to any significant degree in vegetative matter of any species. For wetlands, soils will be tested for nutrients, metals, and microbes. The wetlands are designed to create metal compounds in the soil and root systems that are not bioavailable. The monitoring program will be used to ensure that metals are not accumulating significantly in the vegetative matter as planned and expected. If there is significant increase in vegetation metal concentrations beyond background, then the wetland system will be modified to minimize wildlife access.

Terrestrial vegetation on Project facilities during the closure period will not be affected due to the thickness of the covers between the vegetation and waste rock/tailings.

Based on the above, the quality of edible vegetation (by people and wildlife) in the vicinity of the Project is not predicted to be affected during any of the Project phases. In addition, the general public will not be permitted to access the Project area during construction, operations and active closure, as per the Tote Road licence requirements.

Water

An effects assessment for water quality was presented in Chapter 8 of the Project Proposal. The following presents a summary of the water quality predictions during each of the Project phases as they relate to potential changes in the quality of country foods (i.e., fish and wildlife that may drink the water). This summary is qualitative, rather than quantitative due to the lack of reliable models for predicting fish and animal tissue concentrations for the COPCs.

Construction

During construction, no COPCs were estimated to exceed their respective water quality objectives. The exception is concentrations of fluoride (during March under the mean scenario and February and March under the wet scenario) in Genoa Creek. Since these concentrations are only predicted to be reached intermittently throughout operations the likelihood of fluoride concentrations increasing in country foods (i.e., fish or wildlife from drinking the water) is low.

It is noted that the only fish in this system that could be harvested for consumption is Arctic grayling. However, this system has an extremely low abundance of Arctic grayling (this is likely due to the fish barrier at the culverts where Finlayson Creek crosses the Robert Campbell Highway) and subsequently the waterbodies upgradient of the barrier (i.e. Finlayson and Geona Creeks) are not a source of fish for consumption. In addition, during construction, the general public will not be permitted to use Geona Creek for fishing due to the Tote Road licence requirements. Therefore, there will be no exposure to people from the consumption of fish from Geona Creek.

Operations

During operations, COPC concentrations were estimated to be higher than baseline but lower than preliminary Water Quality Objectives (pWQO) for the majority of COPCs. The exception is fluoride which was estimated to marginally exceed its pWQO in Geona Creek and Finlayson Creek for some months of the calendar year during operations. Currently, the abundance of Arctic grayling in these systems is extremely low and subsequently these creeks are not a source of fish for consumption. In addition, during operations there will be no public access to the site for fishing purposes, as per the requirements of the Tote Road Licence.

During operations, some COPCs were estimated to be higher than baseline in the South Creek. Although COPC concentrations were predicted to be higher than baseline in South Creek due to the diversion of Fault Creek, no pWQO exceedances were predicted from the modelling.

Closure

The following provides a summary of the revised model results for KZ-37 (which is located in Geona creek). Note that Geona Creek is not likely to be used for drinking water by people due to it not appearing potable, visually. However, wildlife in the post closure phase may use this waterbody for drinking water purposes. For the 1/10 dry year model:

- Arsenic concentrations were calculated to be below its preliminary water quality (pWQO) for ten months of the year; however, CWTS treatment is required to meet the arsenic pWQO in May and fractional exceedances were calculated in February and March when CWTS treatment was assumed to be negligible;
- Cadmium concentrations were calculated to be below its pWQO for nine months of the year with CWTS treatment exceeding the pWQO May to July (1.2 to 1.8 times the pWQO). Without

CWTS treatment, cadmium concentrations were calculated to be below its pWQO for seven months of the year and exceed May through September (1.4 to 2.2 times the pWQO);

- Copper concentrations were calculated to be below the pWQO for 11 months of the year with CWTS treatment (exceeding only marginally in June) and, without CWTS treatment, only fractionally exceed the pWQO in May and June by 20 to 30% over pWQO;
- Lead concentrations were calculated to be below the pWQO for ten months of the year with CWTS treatment (fractionally exceeding the pWQO during May and June by a maximum 1.3 times) and for five months of the year without CWTS treatment (exceeding the pWQO in May through September by a maximum 1.7 times);
- Selenium concentrations were calculated to be below the pWQO year-round both with and without CWTS treatment; and
- Zinc concentrations were calculated to exceed the pWQO by a maximum of 1.9-fold for three months of the year (May through July) with CWTS treatment and by a maximum of twice the pWQO for four months of the year without CWTS treatment.

It is noted that these intermittent exceedances are predicted to only occur in a very small area of Geona Creek prior to the confluence of Finlayson Creek. These model results and the PQRA will be updated prior to YESAB preparing the Screening Report.

Summary of Potential Risks

Due to the lack of reliable models for predicting fish and terrestrial wildlife tissue concentrations from exposure to these intermittent pWQO exceedances, it is not possible to quantify human health risks. No water quality guideline in Canada or elsewhere has been identified that reliably predicts the complex movement of these metals from water into fish/animal tissue and so there is no value for comparison. In particular, the federal guidelines and objectives do not address this pathway and, thus, a water quality exceedance should not be considered to be an indicator of potential human health risks. In addition, there is no generally accepted manner identified to predict fish or wildlife tissue concentrations for these substances. Consequently, there is little likelihood of completing a scientifically rigorous quantitative human health risk assessment of these substances.

Notwithstanding the above, there is a high degree of certainty that no unacceptable risks would occur from fish/wildlife consumption and that people will be adequately protected for a variety qualitative reasons discussed in part above and in more detail below. Firstly, a key principle of risk assessment guidance is that in order for risk to occur, there must first be exposure. During construction, operations and active closure, access to the creeks (for harvesting fish) would not be permitted (via the Tote Road). Thus, there will essentially be no exposure and, therefore, no risks during the period that the elevations in fluoride concentrations could occur.

A second factor that suggests a very low likelihood of unacceptable risks is that the predicted water exceedances are relatively short term in duration whereas the concerns for metals update into fish and wildlife would be due to longer term, chronic exposure.

However, the most important consideration that suggests low likelihood of unacceptable risks is the rigorous fish tissue monitoring plan that will be in place. Due to the lack of reliable models for predicting fish tissue concentrations, the most accurate method of assessment of risks is monitoring of fish tissue concentrations. A very substantial database of baseline fish (sculpin) concentrations has been collected that will be used to compare against the monitoring that will take place during the mine operation and post-closure periods (which will be required under MMER and the Type A Water Licence). This baseline data set includes fish tissue sampling every other year since 2000. Following the implementation of the Fish Offsetting Plan, the monitoring program will also include Arctic grayling (if the population sufficiently increases due to the removal of the fish barrier at the Robert Campbell Highway). If fish concentrations do not appreciably change from baseline concentrations, it will be clear that no incremental human health risks from fish consumption will be associated with the Project. In the event that fish tissue concentrations start to trend higher, there will be ample time to complete a human health risk assessment to evaluate any concern during the period that fish consumption from the creeks is not occurring. Consequently, there will be essentially no opportunity for persons to consume fish with elevated concentrations without a human health risk assessment and, if required, additional mitigation measures having first been completed and implemented.

Overall, there is no information that suggest that the minor water quality exceedances will result in unacceptable human health risks from fish/wildlife consumption. Note that these water quality objectives were not developed for protection of the fish/wildlife consumption pathway and, thus, do not actually indicate concern levels. Although there are no suitable models to accurately predict fish tissue concentrations, other factors are suggestive of low likelihood of risks. Most importantly, a rigorous monitoring plan will be in place that will detect any increases in fish tissues concentrations well in advance of any opportunity for persons to collect and consume fish from the creeks.

Wildlife Exposure to Mine Site Water

Potential exposure pathways to terrestrial wildlife include ingesting water from the Operations Water Management Ponds, treatment ponds, or ABM Lake at closure, or from ingesting plants that may have increased metal concentrations from accumulation or deposition. The likelihood for metals to transfer from water will be limited due to wildlife access barriers and water control and treatment programs. Wildlife is unlikely to access the water collection ponds or water management ponds as they will be fenced. In addition, the water quality of the ponds is predicted to meet the livestock drinking water guidelines with the exception of the Class A and Class B Storage Facilities collection ponds, which may have some elevated metals. But with limited access this is not a concern. The ABM Lake will be batch treated if necessary after closure to maintain water quality within acceptable guidelines for wildlife protection.

Based on the above, the quality of country foods (i.e. terrestrial wildlife) is not predicted to be affected due to on-site water storage and management facilities.

Additional mitigation and monitoring measures to prevent birds from entering site waterbodies are Presented in the Draft Wildlife Protection Plan (submitted to YESAB as Appendix R2-J of the Response #2 to YESAB Executive Committee Adequacy Review).

Summary

To determine the potential effects to country foods, predicted changes to environmental media were reviewed from other relevant sections of the Project Proposal. Based on this review, changes in air, soil, water and vegetation are not likely to result in a change in the quality of country foods. Therefore, it is concluded that a quantitative risk assessment on country foods is not required as there are no "COPCs that might pose a toxicological hazard". Monitoring programs for the environmental media will confirm this and an adaptive management program will be implemented (threshold values will be developed during the preparation of the application materials to support the permitting of the Project).

3.2.5 Receptors of Concern

Under PQRA guidance, the key receptors of concern were considered to be toddlers for non-carcinogens and adult/composite receptor for carcinogens. For these age groups, two receptors of primary concern were:

- Nearest residents: The closest permanent residents to the Project Site are the residents of Ross River (approximately 115 km from the site).
- Nearest recreational receptors: Kaska citizens (Ross River Dena Council and Liard First Nations) are known to conduct traditional activities (i.e. hunt, trap, fish, gather plants) in the regional area. In addition, Yukon Big Game Outfitters guides and outfits in the regional area on a seasonal basis.

Workers on-shift at the site were not addressed in the PQRA since they will be protected by a separate worker health and safety plan. However, workers off-shift staying in the camp were considered in the PQRA.

3.2.6 Conceptual Model

Based on the information provided in the previous sections and application of guidance from Health Canada, conceptual models were developed to illustrate the receptors and exposure pathways identified for evaluation of risks to nearest residential receptors (see Table 3-1) and nearest recreational receptors. These conceptual models assume that the mitigation and management measures presented in the Project Proposal will be in place.

Table 3-1: Conceptual Model for Nearest Residents

Critical receptor	Exposure pathways	
Toddler/ Adult	NPC	Soil Ingestion
	NPC	Soil dermal absorption
	NPC	Particulate inhalation
	NPC	Vapour inhalation
	NPC	Water dermal exposure

	NPC	Water ingestion
	NPC	Berry ingestion
	NPC	Fish ingestion
	NPC	Wild game ingestion

√ – Requires evaluation in the human health risk assessment

NPC - No pathway due to the lack of predicted contamination

Table 3-2: Conceptual Model for Nearest Recreational Receptor

Critical receptor	Exposure pathways	
Toddler/Adult	NPC	Soil Ingestion
	NPC	Soil dermal absorption
	NPC	Particulate inhalation
	NPC	Vapour inhalation
	NPC	Water dermal exposure
	NPC	Water ingestion
	NPC	Berry ingestion
	NPC	Fish ingestion
	NPC	Wild game ingestion

X – Requires evaluation in the human health risk assessment

NPC - No pathway due to the lack of predicted contamination

Based on these tables it is clear that there are no risks to further evaluate, based on single exposure pathways. However, at the request of YESAB the assessment will consider multi-media risks and will present how the combined risks are predicted to change from baseline due to Project development.

3.3 EXPOSURE ASSESSMENT

As noted in the problem formulation section, aside from surface water concentrations of certain metals and minor air quality changes of particulate matter at the camp, the media concentrations of Project-related substances are not expected to change. Nevertheless, at the request of YASEB, Project related substances from multi-media exposure will be assessed. Since the only substances with multimedia exposure is metals, the remainder of this PQRA will assess potential human health risks from metals. The only environmental media that is predicted to have changes in metals concentrations is surface water. Therefore, the COPCs identified in the water quality model were selected as COPCs for the human health risk assessment (Table 3-3).

Due to the lack of public access to the Project Area during the construction, operations and active closure periods and given the general lack of predicted changes in environmental media during these Project phases, the focus of the PQRA is baseline risks and post-closure risks. The post closure phase is the Project phase when people will be able to resume their traditional activities in the Project Area. It is also noted that there are no cabins in the vicinity of the Project Area that overlap with the modelling domains presented in the various discipline-specific effects assessments of the Project Proposal.

3.3.1 Environmental Media Assessed

Table 3-3 provides the metals evaluated in the PQRA and the concentrations for the media (where concentrations were available). References for these values can be provided as follows:

- Soil concentrations: Appendix E-6 of the Project Proposal (Section 7) presents the concentrations that we measured in soil within the Project area. Figure 7-1 presents the locations where soil samples were collected. Table 7-7 presents a summary of the soil results.
- Surface water concentrations: Finlayson Creek is the only water body in the Project areas that could be used for drinking water purposes and is predicted to change from baseline at post closure. During all other Project phases there will be no access to the waterbodies and only fluoride concentrations are predicted to change from baseline during operations. For the purposes of this PQRA the baseline concentrations at monitoring station KZ-15 (Finlayson Creek) were used to calculate baseline risks and the predicted changes in concentrations (at KZ-15) for post-closure were used for the post-closure risk calculations. Baseline concentrations used in the assessment were based on data collected between April 2015 and October 2017 (unpublished). The modelled concentrations used in the assessment were based on the updated water quality model dated November 4, 2017 (unpublished). At the request of YESAB additional modelling will be provided prior to them preparing the Screening Report. Therefore, this PQRA will be updated with the new model results and additional baseline data once it becomes available. However, it is noted that only minor changes are expected in the new model and baseline reports and are unlikely to change the results of the PQRA, given the low levels of metals observed in the baseline and the low-level changes predicted.
- Berry concentrations: Appendix E-6 of the Project Proposal (Section 7) presents the concentrations that we measured in berries within the Project area. Figure 7-1 presents the locations where vegetation samples were collected. Note that berries comprised only a small portion of the vegetation samples (6 samples in total). Berries sampled included lowbush cranberry (*Vaccinium vitis-idaea*) and bog blueberry (*Vaccinium uliginosum*). Appendix D of Appendix E-6 of the Project Proposal presents the analytical results of the berry samples.

Table 3-3: Substances Evaluated in the PRQA

Substance	Media		
	Soil (mg/kg)	**Surface Water (mg/L)**	**Berries (mg/kg; wet weight)**
Baseline Concentrations			
Arsenic	Mean =17 95th %ile =71 Maximum = 96	Mean = 0.000584 95th %ile =0.0021 Maximum =0.00318	Mean = 0.0025* Maximum = 0.0025*
Cadmium	Mean = 0.91 95th %ile =4.89 Maximum = 7.84	Mean = 0.0000573 95th %ile =0.00020 Maximum =0.00081	Mean = 0.0481 Maximum = 0.136
Copper	Mean = 40 95th %ile =145 Maximum = 192	Mean = 0.000736 95th %ile =0.0022 Maximum =0.00342	Mean = 0.859 Maximum = 1.83
Fluoride	Mean =N/A 95th %ile =N/A Maximum = N/A	Mean = 0.0791 95th %ile =0.12 Maximum = 0.12	Mean = N/A Maximum = N/A
Lead	Mean = 28 95th %ile = 70 Maximum = 72	Mean = 0.000166 95th %ile = 0.00070 Maximum =0.00223	Mean = 0.00298 Maximum = 0.0086
Selenium	Mean = 0.86 95th %ile =4.0 Maximum =6.52	Mean = 0.000738 95th %ile =0.0016 Maximum =0.00157	Mean = 0.005* Maximum = 0.005*
Zinc	Mean = 161 95th %ile =593 Maximum =784	Mean = 0.00610 95th %ile = 0.0188 Maximum = 0.055	Mean = 2.94 Maximum = 4.46
Estimated Post-Closure Concentrations			
Arsenic	No change from baseline predicted	**Mean = 0.00244** **95th %ile =0.0043** **Maximum = 0.0043**	No change from baseline predicted
Cadmium	No change from baseline predicted	No measurable increase vs baseline predicted	No change from baseline predicted
Copper	No change from baseline predicted	**Mean = 0.00031** **95th %ile =0.0070** **Maximum = 0.0070**	No change from baseline predicted
Fluoride	No change from baseline predicted	**Mean = 0.089** **95th %ile =0.123** **Maximum = 0.123**	No change from baseline predicted
Lead	No change from baseline predicted	**Mean = 0.0014** **95th %ile =0.0031** **Maximum = 0.0031**	No change from baseline predicted
Selenium	No change from baseline predicted	No measurable increase vs baseline predicted	No change from baseline predicted
Zinc	No change from baseline predicted	**Mean = 0.018** **95th %ile =0.0374** **Maximum = 0.0374**	No change from baseline predicted

N/A = not available
* = all values were less than the method detection limit (MDL) and, consequently, a value equal to one-half of the MDL was assumed for PQRA purposes
Bold values are concentrations that are predicted to increase under post-closure conditions

Other media that were not evaluated in the PQRA include air, fish and wild game. In the case of air, the substances evaluated in the PQRA were not numerically modelled in the air quality effects assessment of the Project Proposal. However, inhalation of air from resuspension of soil as dust was assessed and is considered sufficient to address this pathway.

Intake of substances from fish was not quantified under either baseline or post-closure conditions but was considered to be low and unlikely to contribute to substantial amounts of intake. The creeks in the area are not used for fishing due (most likely) to the extremely low abundance of fish in the Geona/Finlayson system. Baseline sculpin data is available (Appendix E-3 of the Project Proposal) which showed very low concentrations of the substances, but these fish are not consumed by people. Under post-closure conditions, there could be edible-sized fish due to the proposed Fish Offsetting Plan, but predicting the concentrations that would occur in these fish is extremely difficult and not very reliable (particularly since baseline concentrations are not known). Nevertheless, the amount of fish that could be consumed under post-closure conditions is considered to be low given the small size of the creeks. In addition, it would be not expected that the site would have a significant influence on fish tissue concentrations (based on the low-level changes in predicted water). Consequently, although it was not possible to quantify, it would be expected that very little if any increased intake of the substances of concern would occur from fish under post-closure conditions. Note that fish tissue monitoring and associated adaptive management strategies will assist in ensuring the safety of potential fish consumption in the future.

Similarly, intake of substances from wild game was not quantified. Soil and vegetation concentrations are not expected to change and, consequently, the only media that wild game (i.e. caribou) may be exposed to are the surface water concentrations. In addition, for wild game such as caribou, their home much larger than the size of the site and as a result it is unlikely that site conditions could contribute substantially to the intake by caribou. In the case of wild game with smaller ranges, the number of meals that a person would consume from animals dwelling at the site under post-closure conditions would be expected to be small. Finally, there is no expectation of changes in soil concentrations (and thus this would extend to berries and other vegetation) whereas the magnitude of changes intake from surface water concentration changes is expected to be very minimal. Therefore, although quantitative estimates of caribou and other wild game were not predicted, changes in tissue concentrations are expected to be small.

As a result, the PQRA was based on baseline and post-closure concentrations of soil, surface water and berries. Table 3-3 provides the assumed concentrations in these media that were used to evaluate risks in the PQRA.

3.3.2 Receptor Characteristics

The receptors evaluated in the PQRA were the toddler (for evaluation of non-cancer risks) and adult (for cancer risks) using the site for traditional or recreational purposes under baseline and post-closure conditions. Since a person of any age could be present under post-closure conditions, it was considered important to evaluate both of these receptors. It is noted that because all workers will be covered under the worker health and safety plan and associated WBC regulations, it was not considered necessary to evaluate such workers.

Receptor characteristics were similar to the PQRA guidance except that for the cancer risk evaluation where 1 week per year was assumed to be the time present at the site. In the case of berry consumption, the food ingestion rate for "other vegetables" was assumed (67 g/d for toddlers and 137 g/d for adults). For surface water ingestion, 0.6 L/d for toddlers and 1.5 L/d for adults was assumed. For soil ingestion, 80 mg/d for toddlers and 20 mg/d for adults were the PQRA default intake rates and used in the current assessment. Other characteristics are provided in the PQRA spreadsheet tool documentation (Appendix B).

Based primarily on the recommendations of Health Canada (2012), the assumed characteristics for key parameters are provided in the sections below.

Body Weight

Consistent with Health Canada (2012) guidance, the following values were selected as receptor characteristics in the current assessment:

Toddler (ages 0.5-4 y):	16.5 kg
Adult (ages > 20 y):	70.7 kg

Inhalation Rate

Consistent with Health Canada (2012) guidance, the following values were selected as receptor characteristics in the current assessment:

Toddler (ages 0.5-4 y):	8.3 m^3/day
Adult (ages > 20 y):	16.6 m^3/day

Soil Ingestion Rate

Consistent with Health Canada (2012) guidance, the following values were selected as receptor characteristics in the current assessment as the soil ingestion estimates:

Toddler (ages 0.5-4 y):	80 mg/day
Adult (ages > 20 y):	20 mg/day

Skin Surface Area for Dermal Contact with Soil

Consistent with Health Canada (2012) guidance, the following values were then selected as the surface areas available for dermal contact with soil:

Toddler (ages 0.5-4 y):	0.043 m^2 (hands)
	0.26 m^2 (arms and legs)
Adult (ages > 20 y):	0.089 m^2 (hands)
	0.82 m^2 (arms and legs)

Soil to Skin Adherence Factor

With respect to soil to skin adherence factor, Health Canada (2012) recommended the following values for all receptors.

Hands:	1 g/m^2/day
Rest of body:	0.1 g/m^2/day

Drinking Water Ingestion Rate

Consistent with Health Canada (2012) guidance, the following values were selected as receptor characteristics in the current assessment as the drinking water ingestion estimates:

Toddler (ages 0.5-4 y):	0.6 L/day
Adult (ages > 20 y):	1.5 L/day

It is noted that surface water ingestion may also occur from recreational use of creeks; however, as discussed in Wilson et al. (2015) (a paper with Health Canada co-authors), these rates are much lower than drinking water rates (i.e., typically in the range of 0.003 to 0.05 L/h of recreational contact with surface water) and so should not pose an appreciable source of exposure provided that risks from use of surface water as a drinking water source are considered to be acceptable.

Berry Consumption Rate

For berry consumption, the consumption rate recommended by Health Canada (2012) guidance and the PQRA spreadsheet tool for non-root vegetables was used. These amounts are equivalent to approximately 1.25 cups of berries per day for adults (and half that for toddlers). Consequently, the following values were selected as receptor characteristics in the current assessment as the berry consumption rate estimates:

Toddler (ages 0.5-4 y):	67 g/day
Adult (ages > 20 y):	137/day

Time Spent at the Site

Consistent with Health Canada (2012) guidance, user defined values were selected for use in the PQRA. Based on professional judgment and local knowledge, it was considered unlikely that any individual would spend more than 1 week per year at the site. Consequently, the following values were selected as the time spent at the site:

- Residential land use: 24 hours per day, 7 days per week, 1 week per years for 80 years.

It is stressed that this assumption of 1 week per year was only used to adjust cancer risk estimates and was not adopted for non-cancer risk estimates (i.e., owing to issues regarding exposure amortization of non-cancer risks, it was effectively assumed that exposures occurred 52 weeks per year for evaluation of non-cancer risks from all media even though risks would be anticipated to be substantially lower).

3.3.3 Exposure Pathways

The exposure pathways that were evaluated in the PQRA were as follows:

- Soil contact: incidental soil ingestion, dermal contact and inhalation of soil dusts were estimated using the Health Canada receptors assumptions provided in the PQRA spreadsheet tool;
- Surface water contact: use of the surface water of Finlayson Creek as a drinking water source using the Health Canada receptors assumptions provided in the PQRA spreadsheet tool; and
- Consumption of berries on a daily basis.

3.3.4 Estimation Exposure Rates

The PQRA spreadsheet tool was used to estimate exposures that would occur from the baseline and post-closure concentrations. Because time spent at the site was not expected to be greater than 1 week per year, a “user defined” receptor was evaluated; however, due to concerns regarding unjustified exposure amortization of non-carcinogens, it is stressed that the assumption of 1 week per year only affects the cancer risk estimates (i.e., non-cancer risks from all media were estimated assuming the equivalent of 52 weeks per year).

The equations used to estimate exposures including a worked example are provided in Appendix B.

3.4 TOXICITY ASSESSMENT

3.4.1 Description of Terms Used in Toxicity Assessment

For this assessment, toxicity reference values (TRVs) were expressed as follows:

- Tolerable Daily Intakes were used for the assessment of non-cancer endpoints via the oral and dermal routes (and in some cases the inhalation route);
- Tolerable Concentrations were used for the assessment of non-cancer endpoints via the inhalation route;
- Cancer Slope Factors were used for the assessment of cancer endpoints via the oral and dermal routes (and in some cases the inhalation route); and
- Unit Risk Factors were used for the assessment of cancer endpoints via the inhalation route.

Tolerable Daily Intake (TDI) is a term used by Health Canada that represents a daily dose of a chemical (typically expressed in units of "µg/kg bw/day") that a person can be exposed to without experiencing appreciable risk of developing adverse effects. The term "Tolerable Daily Intake" is similar in concept to the terms "Acceptable Daily Intake" (used by the WHO) and "Reference Dose" or RfD (used by the US EPA).

Tolerable Concentration (TC) is a term used by Health Canada that represents a 24-hour daily air concentration of a chemical (typically expressed in units of "$\mu g/m^3$") that a person can be exposed to without experiencing appreciable risk of developing adverse effects from the chemical. The term "Tolerable Concentration" is similar in concept to the term "Reference Concentration" or RfC (used by the US EPA). None of the substances evaluated in the PQRA had TRVs expressed in these units.

For oral and dermal cancer endpoints, Slope Factors (SFs) were used to estimate risks from exposures expressed in units of "$(\mu g/kg\ bw/day)^{-1}$". An oral SF represents the estimated cancer risk for a chemical at a certain dose rate (i.e., units of $[\mu g/kg\ bw/day]^{-1}$). More specifically, the oral SF expressed in units of $(\mu g/kg\ bw/day)^{-1}$ represents the Incremental Lifetime Cancer Risk (ILCR) that would be estimated if a person were exposed to a dose rate of 1 µg/kg bw/day of that chemical for every day of their life.

Finally, inhalation Unit Risk (UR) were used to estimate risks from inhalation exposures expressed in units of "$\mu g/m^3$". An inhalation UR represents the estimated cancer risk for a chemical at a specified dose rate (i.e., units of $[\mu g/m^3]^{-1}$). More specifically, the inhalation UR expressed in units of $(\mu g/m^3)^{-1}$ represents the Incremental Lifetime Cancer Risk that would be estimated if a person were exposed to an air concentration of 1 $\mu g/m^3$ of that chemical for 24 hours per day for every day of their lifetime.

3.4.2 TRVs Selected for Use in the PQRA

Table 3-4 provides the TRVs that were assumed and Appendix B provides additional details. Briefly, TRVs for all substances were identified from Health Canada, US EPA or WHO. For arsenic (cancer effects), cadmium, fluoride, selenium and zinc, the toxicity reference values provided in the Health Canada (2011) PQRA spreadsheet tool and these values were subsequently used. For arsenic (non-cancer effects), a TRV was not provided in the PQRA spreadsheet tool and, as a result, the US EPA (2017) IRIS database was used as the source for the TRV.

Table 3-4: Toxicity Reference Values for Substances Evaluated in the PRQA

Substance	Toxicity Reference Value		
	Tolerable Daily Intake or Reference Dose	Oral Slope Factor	Inhalation Unit Risk
Arsenic	0.3 µg/kg bw/d (US EPA, 2017)	1.8 x 10^{-3} $(\mu g/kg\ bw/d)^{-1}$ (Health Canada, 2010; 2011)	6.4 x 10^{-3} $(\mu g/m^3)^{-1}$ (Health Canada, 2010; 2011)
Cadmium	1.0 µg/kg bw/d (Health Canada, 2011)	Not considered to be a carcinogen via the oral route	9.8 x 10^{-3} $(\mu g/m^3)^{-1}$ (Health Canada, 2010; 2011)
Copper	90 µg/kg bw/d for toddlers (Health Canada, 2011)	Not considered to be a carcinogen	Not considered to be a carcinogen
Fluoride	105 µg/kg bw/d (Health Canada, 2010)	Not considered to be a carcinogen	Not considered to be a carcinogen
Lead	0.6 µg/kg bw/d for toddlers for 1 IQ point decrement (WHO, 2011)	Not considered to be a carcinogen	Not considered to be a carcinogen
Selenium	6.2 µg/kg bw/d (Health Canada, 2010; 2011)	Not considered to be a carcinogen	Not considered to be a carcinogen
Zinc	500 µg/kg bw/d (Health Canada, 2010; 2011)	Not considered to be a carcinogen	Not considered to be a carcinogen

3.4.3 Risk Characterization

The Health Canada (2011) spreadsheet tool was used to generate risk estimates. The equations used in the spreadsheet involved a comparison of the multimedia exposure estimates to the TRVs as shown below.

3.4.4 Estimation of Non-Cancer Risks

For the oral, inhalation and dermal exposures (i.e., in cases where non-cancer TRVs are expressed as dose rates rather than as air concentrations), non-cancer risks were estimated as Hazard Quotient values according to the following formula:

$$\text{Hazard Quotient} = \frac{\text{Estimated Exposure } (\mu g/kg \text{ body weight/day})}{\text{Tolerable Daily Intake } (\mu g/kg \text{ body weight/day})}$$

According to Health Canada (2012), a Hazard Quotient of less than 0.2 is normally considered to be acceptable. More specifically, a Hazard Quotient value of 0.2 or less means that exposures are not predicted to exceed the Tolerable Daily Intakes or Tolerable Concentrations. On the other hand, a Hazard Quotient value that is greater than 0.2 generally indicates that there is the potential for risk that might prompt a form of risk reduction/management or further analysis. However, in all cases, interpretation of risk estimates requires consideration of the overall risk assessment process, including all assumptions and uncertainties.

3.4.5 Estimation of Cancer Risks

In the case of the carcinogenic chemicals with cancer potency factors expressed in units of "(µg/kg body weight/day)$^{-1}$", cancer risks were calculated as Incremental Lifetime Cancer Risk (ILCR) estimates according to the following formula:

$$\text{ILCR} = \text{Lifetime Daily Exposure } (\mu g/kg \text{ bw/day}) \times \text{Cancer Potency Factor } (\mu g/kg \text{ bw/day})^{-1}$$

In the case of the carcinogenic metals with potency estimates expressed as unit risk factors in units of (µg/m^3)$^{-1}$, cancer risks were estimated according to the following formula:

$$\text{ILCR} = \text{Air Concentration } (\mu g/m^3) \times \text{Fraction of Lifetime at the Site} \times \text{Unit Risk } (\mu g/m^3)^{-1}$$

Total Incremental Lifetime Cancer Risks were then estimated as the sum of the inhalation ILCR and the oral/dermal ILCR estimates as follows:

$$\text{ILCR total} = \text{ILCR inhalation} + \text{ILCR oral/dermal}$$

In most parts of Canada, an Incremental Lifetime Cancer Risk which is less than 1 x 10^{-5} (i.e., 1 in 100,000) is normally considered to be acceptable, while an Incremental Lifetime Cancer Risk greater than this value generally indicates that remediation (i.e., clean-up) or some other form of risk reduction/management is required; however, in all cases, interpretation of Incremental Lifetime Cancer Risk estimates requires consideration of the overall risk assessment process and assumptions.

4. RESULTS

The results of the PQRA are provided in the sections below for baseline and post-closure concentrations. Appendix I provides a worked example of the risk calculation approach.

4.1 RISKS FROM BASELINE CONCENTRATIONS

The results of the PQRA of baseline conditions are presented in Table 3 (when mean and maximum concentrations are assumed). For all substances other than arsenic, cadmium and lead, the baseline risk estimates indicate Hazard Quotient values less than 0.2 and in all cases the Incremental Lifetime Cancer Risk estimates were less than 1 x 10^{-5}.

Table 3: Risk Estimates Under Baseline Conditions

Substance	Hazard Quotient	Incremental Lifetime Cancer Risk
Arsenic	0.39 (arithmetic mean) 2.0 (maximum)	8.1 x 10^{-7} (arithmetic mean) 3.7 x 10^{-6} (maximum)
Cadmium	0.20 (arithmetic mean) 0.62 (maximum)	6.8 x 10^{-9} (arithmetic mean)* 5.8 x 10^{-8} (maximum)*
Copper	0.041 (arithmetic mean) 0.095 (maximum)	Not a carcinogen
Fluoride	0.027 (arithmetic mean) 0.042 (maximum)	Not a carcinogen
Lead	0.26 (arithmetic mean) 0.78 (maximum)	Not a carcinogen
Selenium	0.0083 (arithmetic mean) 0.016 (maximum)	Not a carcinogen
Zinc	0.026 (arithmetic mean) 0.044 (maximum)	Not a carcinogen

* ILCR estimates for cadmium were calculated using the information from the PQRA particulate concentration multiplied by the unit risk (PQRA output erroneously does not provide the inhalation route output)

4.1.1 Arsenic

In the case of non-cancer risks from arsenic, it is unlikely that risks are unacceptable even though Hazard Quotient values are greater than 0.2 under baseline conditions. Arithmetic mean and maximum Hazard Quotients from arsenic were estimated to be 0.386 and 2.01, respectively. As shown in the worksheets provided in Appendix B, most (i.e., in range of 75%) of the Hazard Quotient values for non-cancer arsenic arises from soil ingestion by the toddler. It is noted that the baseline soil concentration of arsenic (arithmetic mean of 17 mg/kg and maximum of 96 mg/kg) is considered to be within the higher range of Canadian background soils (see Dodd et al., 2017); however, this is a mineralogical area and as noted in Dodd et al. (2017) background concentrations as high as 228 mg/kg have been reported in pristine areas of Canada. In addition, it is noted that the PQRA approach does not account for the high likelihood that the bioaccessibility of arsenic is much lower in soil than it was in the toxicity studies (i.e., drinking water). As noted by Dodd et al. (2017), the mean bioaccessibility of arsenic in Canadian soil samples is in the range of 11 to 16% which if applied in the PQRA would result in substantially lower Hazard Quotient estimates (mean Hazard Quotients would be equal to or less than 0.2 if such bioaccessibility values were considered). It is also noted that for non-cancer risks from arsenic, the PQRA approach does not account for a person being present for only one week per year.

Although there is not an accepted default amortization for estimation of non-cancer risks from arsenic, it would seem that risks for one week per year would be much less than 52 weeks per year. Overall, there seems to be no unacceptable non-cancer risks from arsenic under baseline conditions as the concentrations as the PQRA approach does not account for the reduced bioaccessibility and time spent at the site. Perhaps most importantly, arsenic concentrations are due to background and arguably since the arsenic soil concentrations will not be affected by the proposed mine activities, it is unnecessary to further evaluate risks from arsenic (i.e., according to Health Canada (2012), only substances existing at concentrations greater than background are required to be evaluated in a PQRA).

4.1.2 Cadmium

In the case of non-cancer risks from cadmium, it is also unlikely that unacceptable risks exist under baseline conditions. Although the Hazard Quotient values were near and/or exceeded the generally acceptable value of 0.2 (i.e., HQ = 0.187 and 0.62 for the mean and maximum concentrations, respectively), these risk estimates should be considered to be acceptable. Most (89%) of the maximum Hazard Quotient value arises consumption of berries with the maximum concentrations of cadmium (i.e., 013 mg/kg) whereas mean concentrations (i.e., 0.0481 mg/kg) would be more representative of typical intake (Health Canada often uses mean values for estimation of risks from food). In providing a Provision Tolerable Monthly Intake, WHO (2011) indicates that cadmium exposures can be amortized on a monthly basis and, consequently, if berries were only consumed daily for 1 week per year, Hazard Quotient values from the food pathway would be reduced by a factor of 7/30 and risks from even maximum concentrations would be less than 0.2. In addition, it is noted that with no change from background concentrations, further evaluation of cadmium seems unwarranted under Health Canada (2012) guidance. Thus, there is reasonable confidence that there are no unacceptable non-cancer risks from cadmium under baseline conditions.

4.1.3 Lead

It is also unlikely that unacceptable risks exist under baseline conditions from lead (Pb). Although the Hazard Quotient values from Pb exceeded the generally acceptable value of 0.2 (i.e., HQ = 0.26 and 0.78 for the mean and maximum concentrations, respectively), these risk estimates are considered acceptable, for reasons discussed following. As discussed in Wilson and Richardson (2013) which has been cited as part of the basis of the BC Ministry of Environment (2017) guidance for evaluation of lead, a HQ of 1 is considered to be acceptable for Pb since the TRV is more accurately termed a Risk Specific Dose rather than a Tolerable Daily Intake. In addition, it is noted that there is a strong case that the Pb toxicokinetics are indicative that exposures can be amortized on a monthly basis and, consequently, if exposure occurs daily for 1 week per year, Hazard Quotient values would be reduced by a factor of 7/30 and risks from even maximum concentrations would be less than 0.2. Finally, it is noted that most of the risk occurs from Pb in soil and the assumed concentrations (i.e., mean of 28 mg/kg and maximum of 72 mg/kg) are quite low concentration that no health agency in Canada has ever indicated to be a health concern.

Overall, baseline concentrations of the various substances are low and indicative of acceptable risks for the media evaluated in the PQRA.

4.2 RISKS FROM POST-CLOSURE CONCENTRATIONS

The results of the PQRA of post-closure conditions are presented in Table 4. As indicated earlier, the only substances with predicted increased concentrations during post closure were arsenic, copper, fluoride, lead and zinc in surface water. For all other substances and media, no change in concentrations were estimated and, consistent with Health Canada (2012) PQRA guidance, no estimates of risk were required.

Table 4: Risk Estimates Under Post-Closure Conditions

Substance	Hazard Quotient	Incremental Lifetime Cancer Risk
Arsenic	0.61 (arithmetic mean) 2.2 (maximum)	2.2×10^{-6} (arithmetic mean) 4.5×10^{-6} (maximum)
Copper	0.041 (arithmetic mean) 0.096 (maximum)	Not a carcinogen
Fluoride	0.031 (arithmetic mean) 0.0461 (maximum)	Not a carcinogen
Lead	0.33 (arithmetic mean) 0.83 (maximum)	Not a carcinogen
Zinc	0.027 (arithmetic mean) 0.047 (maximum)	Not a carcinogen

4.2.1 Arsenic

In the case of arsenic, the Incremental Lifetime Cancer Risk has remained substantially less than 1 x 10^{-5} and as a result there is no appreciable cancer risk contributed. In the case of non-cancer risks from arsenic, the Hazard Quotient values are greater than 0.2 from all media; however, this finding is almost entirely due to background conditions. The Hazard Quotient values are increased by about 0.2 due to the surface water changes; however, even this is likely an overestimate as the non-cancer risk estimates assume that persons are consuming water on a daily basis all year long whereas in reality persons would likely only consume daily for one week per year as a reasonable worst-case assumption. In addition, it is stressed that the maximum predicted surface water concentration of 0.0043 mg/L meets the Canadian Drinking Water Guideline of 0.010 mg/L for arsenic (developed for daily exposure for a lifetime). Consequently, it can be reasonably concluded that one week per year exposure to arsenic at concentrations that do not exceed the Canadian Drinking Water guidelines do not result in unacceptable risks.

4.2.2 Lead

In the case of lead (Pb), the Hazard Quotient values remain less than 1 and, thus, do not represent an unacceptable risk. As discussed in Section 4.1., a Hazard Quotient value of 1 remains a more reasonable endpoint for evaluation of Pb. In addition, it is noted that monthly amortization of Pb is reasonable and, thus, all Hazard Quotient values would be reduced by a factor of 7/30 if applied and Hazard Quotient values would be less than 0.2 under such an approach. Finally, it is noted that the only media greater than baseline is Pb in surface water where a maximum concentration of 0.0031 mg/L for post-closure versus 0.0022 mg/L under baseline; however, neither of these concentrations exceed the Canadian Drinking Water Guideline of 0.010 mg/L for Pb. Consequently, it can be reasonably concluded that one week per year exposure to Pb at concentrations that meet the Canadian Drinking Water guidelines do not result in unacceptable risks.

4.2.3 Other Substances

For copper, fluoride and zinc, the post-closure risk estimates indicate Hazard Quotient values less than 0.2 while none of these substances were considered to be carcinogens (i.e., Incremental Lifetime Cancer Risks were not estimated). As a result, no unacceptable risks are predicted for these substances under post-closure conditions.

Overall, post-closure concentrations of the various substances are low and indicative of acceptable risks for the media evaluated in the PQRA.

5. UNCERTAINTY ANALYSIS

The PQRA was completed using a series of upper-bound assumptions intended to overestimate human health risks and thereby ensure a conservative assessment. Given the conservative assumptions used in this assessment, it is quite possible that actual risks may be substantially lower than estimated herein. Nevertheless, certain assumptions were key determinants in the acceptability of risks. The following analysis discusses some of the most important assumptions that had key influences on the results and conclusions of the PQRA.

Chemical Concentrations in the Environment

One source of uncertainty is the concentrations of the chemicals in soil that a person may be exposed to through their typical daily activities. The HHRA was based on both mean and maximum estimates of concentrations. In the case of the latter, it is likely that concentrations will be lower than assumed in the PQRA.

Toxicity Reference Values

The approach that health agencies use to estimate acceptable or "safe" levels of exposure are typically very conservative and employ considerable safety factors to ensure protection to the general population. In most cases, Health Canada values were used as the primary source of information when available. In some cases, Health Canada did not have TRVs available (i.e., antimony, arsenic for non-cancer effects and nitrite) and in such cases alternate values recommended by major agencies were used. It is considered unlikely that such regulatory agency-derived TRVs would underestimate health risks. Overall, the TRVs used in this assessment represent dose rates that are unlikely to present unacceptable health risks and may overestimate health risks.

Time Spent at Site

For evaluation of carcinogens, it was assumed that receptors spend one week per year for an entire lifetime at the site. In the case of non-carcinogens, it was effectively assumed that persons spend all of their time at the site (in order to ensure exposure amortization was consistent with Health Canada guidance). It is considered unlikely that this approach for either non-carcinogens or carcinogens underestimate health risks.

Age Groups Evaluated

The key age groups evaluated were toddlers for non-cancer risks and adult receptors for cancer risks. These are the defaults in the PQRA spreadsheet tool and are consistent with the development of CCME soil quality guidelines. It is noted that Health Canada (2010; 2012) risk assessment guidance also discusses the composite receptor representing all age groups for evaluation of carcinogens; however, this was not an option in the PQRA spreadsheet tool. It is further stressed that none of the substances that will have increased post-closure concentrations (i.e., antimony, fluoride or nitrite) were considered to be carcinogens and, consequently, not using a composite receptor was considered to be an insensitive decision.

Soil Ingestion Rate

Health Canada guidance was the primary source of information used to characterize receptors at the site. One of the most important input parameter was soil ingestion rate of toddlers. For toddlers, a soil ingestion rate of 80 mg/day was assumed which is recommended by Health Canada (2012) and used in the Health Canada (2011) PQRA spreadsheet tool. As noted by Wilson et al. (2013) (a paper with Health Canada co-authors), it would seem the assumed values are greater than 95th percentile for toddlers. Consequently, the selected soil ingestion rate is considered to be likely to substantially overestimate intakes.

Implementation of the Mitigation and Management Measures

The HHRA was based on the mitigation and management measures presented in the Project Proposal as being implemented to ensure the key elements remain in place. If certain elements are not in place, it is possible that greater risks will exists than estimated in the current HHRA. Consequently, it is considered extremely important that the mitigation and management measures are implemented and monitored throughout the life of the Project (as per the permit requirements that will be in place prior to construction and operations).

Overall Uncertainty in the Risk Assessment

Overall, it is unlikely that human health risks have been underestimated in the risk assessment and it is quite possible that risks have been overestimated due to the conservativness in the assumptions made in the risk calculations. With this noted, it is still possible (but not likely) that risks may have been underestimated for certain receptors in some cases. The two main conditions where risks may have been underestimated would include:

- Any situation where environmental modelling has underestimated concentrations; and
- Any situation where people are not accurately represented by the assumed receptor assumptions.

Monitoring will be undertaken to ensure that neither of the conditions described above occur. If such conditions do occur, additional risk analysis would be recommended to address potential increases in human health risks.

6. CONCLUSIONS

Overall, the PQRA has indicated acceptable risks when the mitigation and management measures are implemented and maintained. The mitigation and management measures that will be protective of human health are summarized in Chapter 18 (Conceptual Management Plans) of the Project Proposal and include the following plans (but are not limited to):

- Waste Management Plan;
- Hazardous Materials Management Plan;
- Surface Water Management Plan;
- Spill Contingency Plan;
- Sediment and Erosion Control Plan;
- Wildlife Protection Plan;
- Vegetation Management Plan;
- Fish and Aquatic Habitat Management Plan;
- Noise Management Plan;
- Air Quality Management Plan; and
- Health, Safety and Emergency Response Plan.

When these plans are implemented (along the with the adaptive management and monitoring program that will be finalized during the development of application materials to support the permitting process), acceptable human health risks are estimated.

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APPENDIX A.
Summary of Model Results Compared to Drinking Water Guidelines

BMC MINERALS (NO.1) LTD

KUDZ ZE KAYAH PROJECT

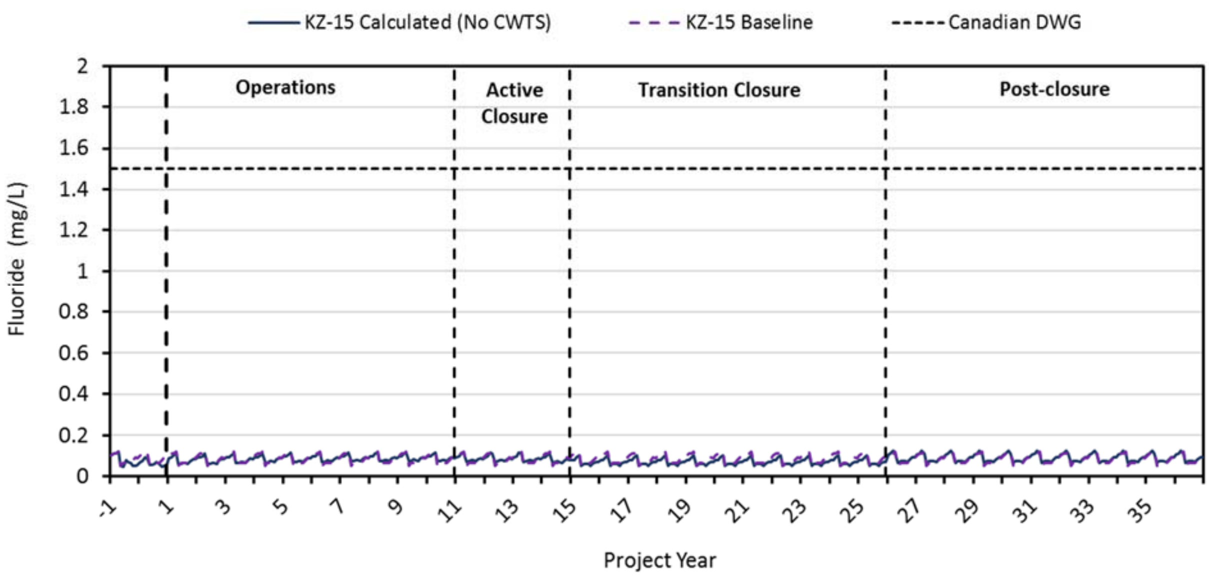
PRELIMINARY QUANTITATIVE RISK ASSESSMENT: APPENDIX A

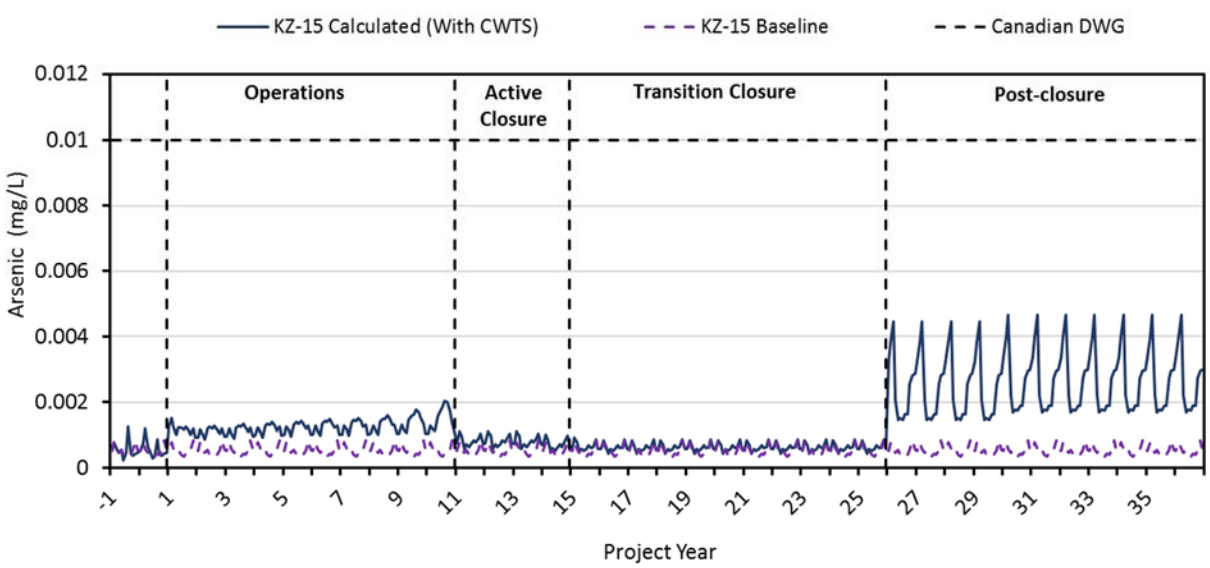
November 2017

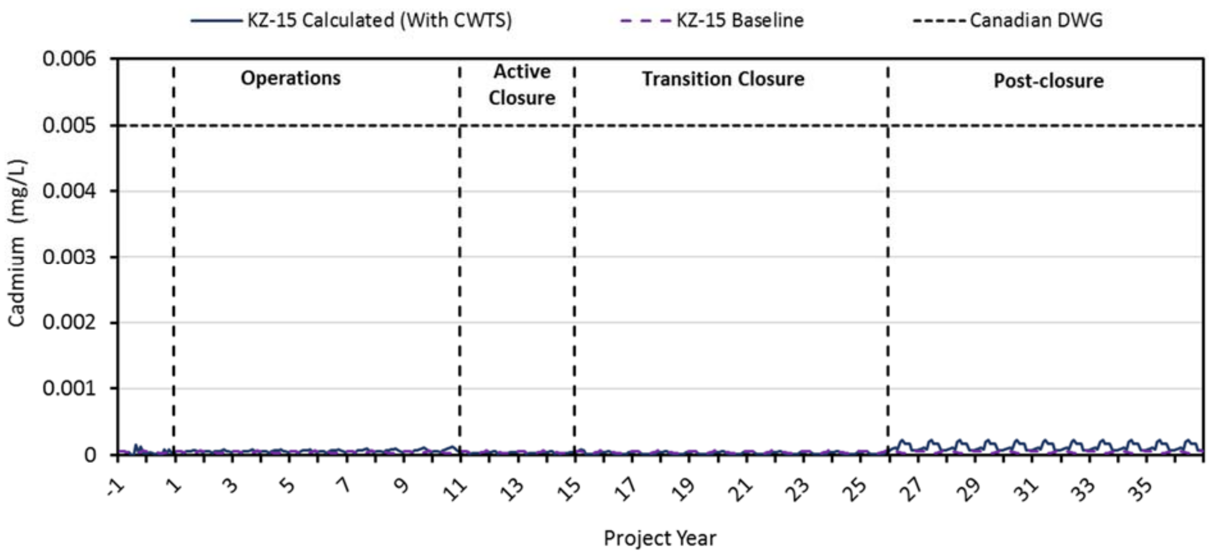
Summary of Model Results for COPCs Compared to Drinking Water Guidelines

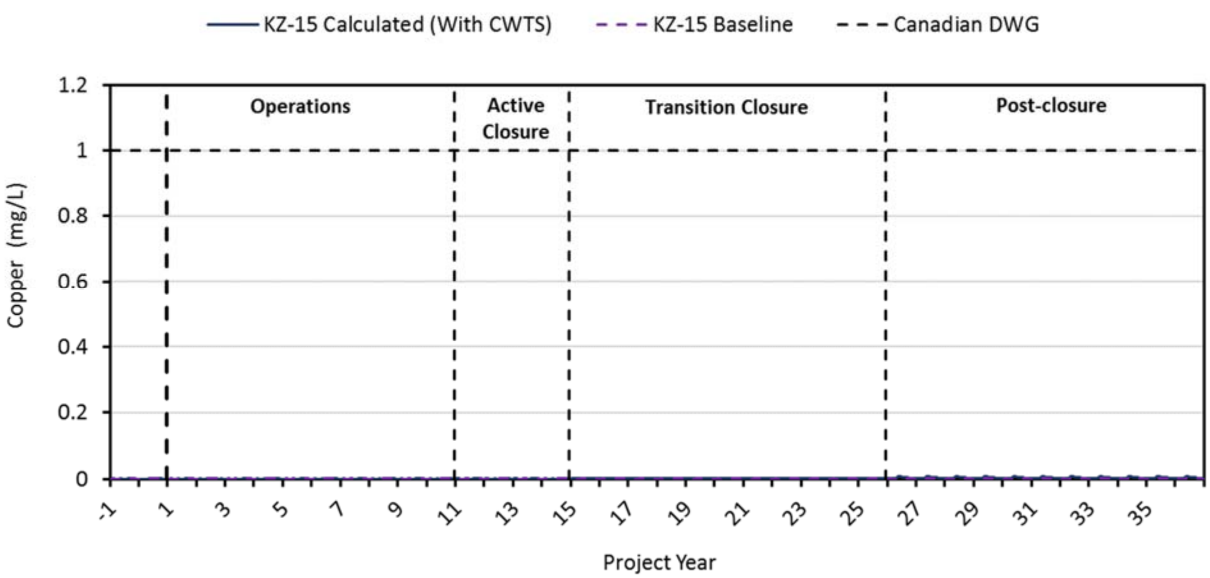
COPC	Guidelines for Canadian Drinking Water Guideline (mg/L)
Fluoride	1.5
Arsenic	0.01
Cadmium	0.005
Copper	1
Lead	0.01
Selenium	0.05
Zinc	5

KZ-15 – 1/10 Dry Year Model Results






KZ-15 Calculated (With CWTS)
KZ-15 Baseline
Canadian DWG
Operations
Active Closure
Transition Closure
Post-closure
Cadmium (mg/L)
0.006
0.005
0.004
0.003
0.002
0.001
0
-1
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
Project Year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KZ-15 Baseline
Canadian DWG
Operations
Active Closure
Transition Closure
Post-closure
Copper (mg/L)
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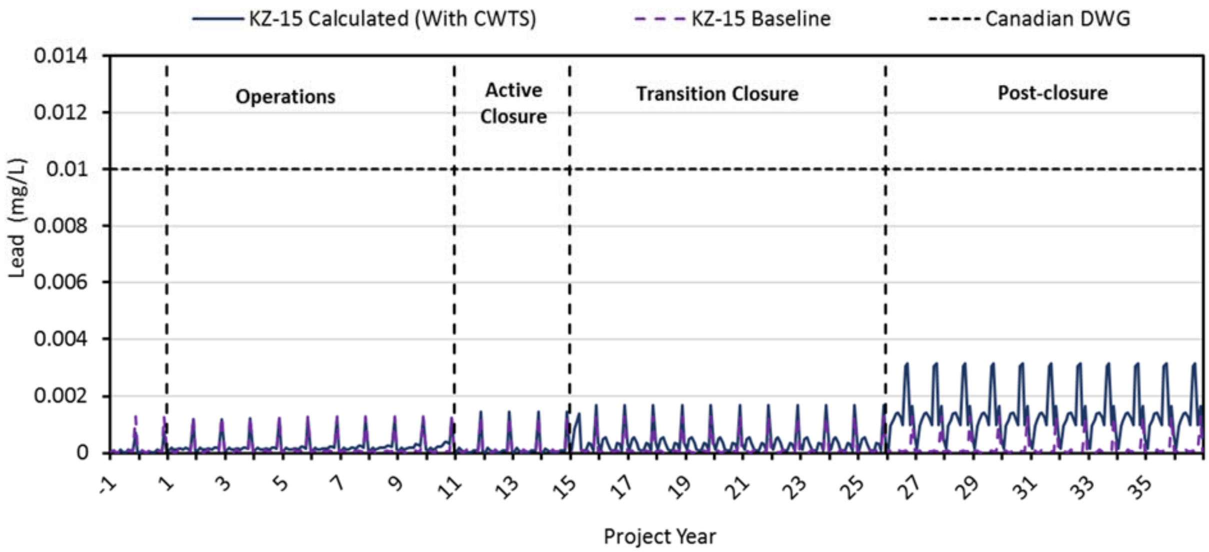
1
0.8
0.6
0.4
0.2
0
-1
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
Project Year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KZ-15 Baseline
Canadian DWG
Operations
Active Closure
Transition Closure
Post-closure
Lead (mg/L)
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0.012
0.01
0.008
0.006
0.004
0.002
0
-1
1
3
5
7
9
11
13
15
17
19
21
23
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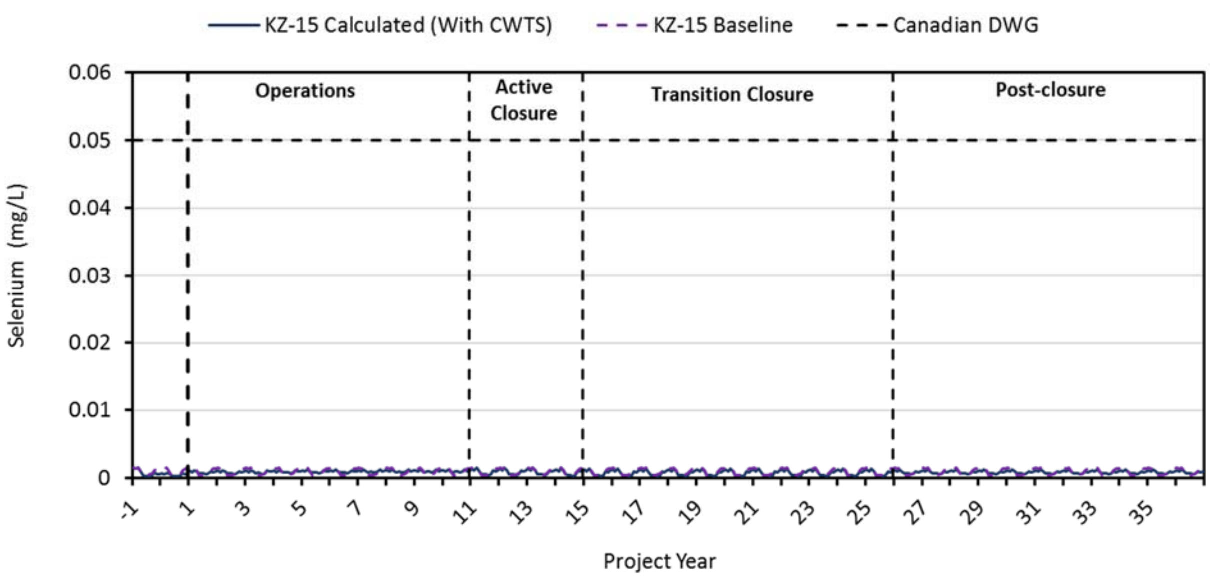
29
31
33
35
Project Year


KZ-15 Calculated (With CWTS)
KZ-15 Baseline
Canadian DWG
Operations
Active Closure
Transition Closure
Post-closure
Selenium (mg/L)
0.06
0.05
0.04
0.03
0.02
0.01
0
-1
1
3
5
7
9
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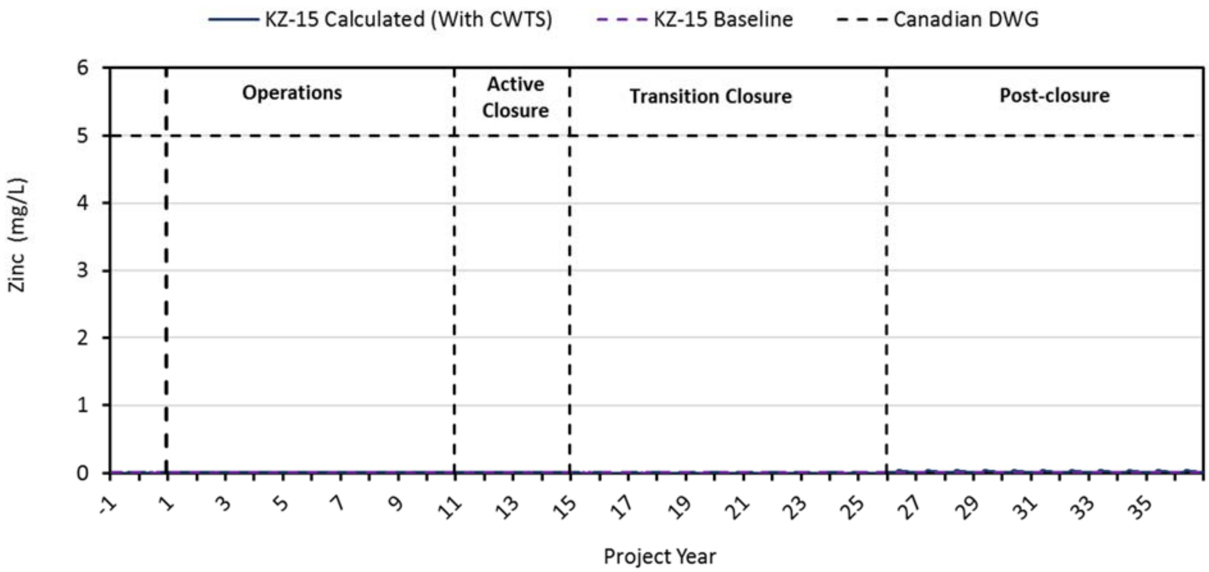
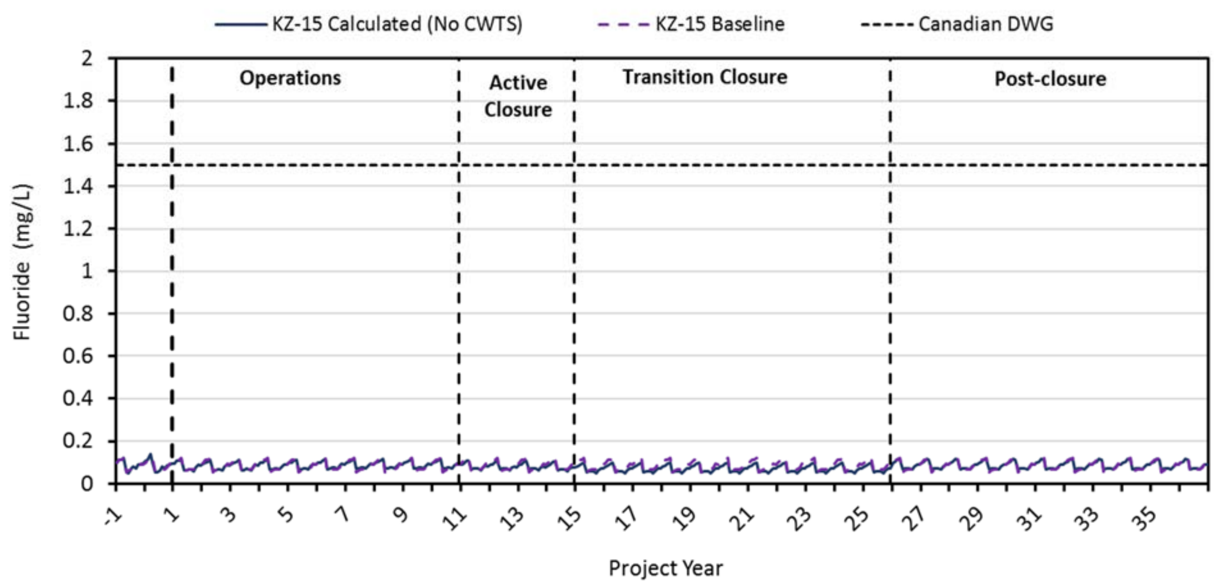
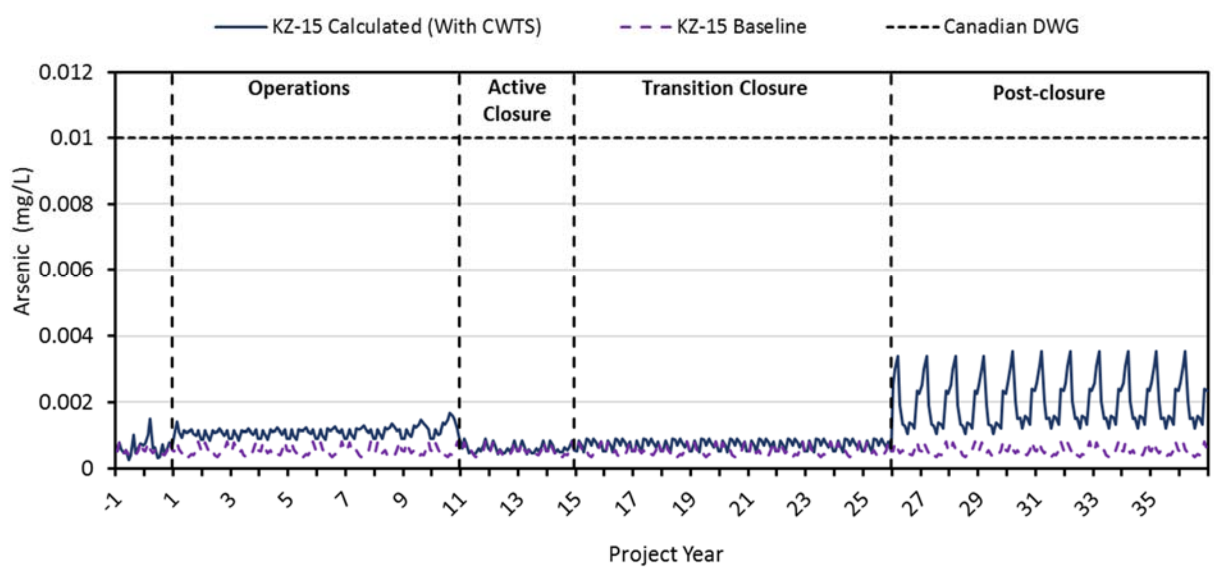
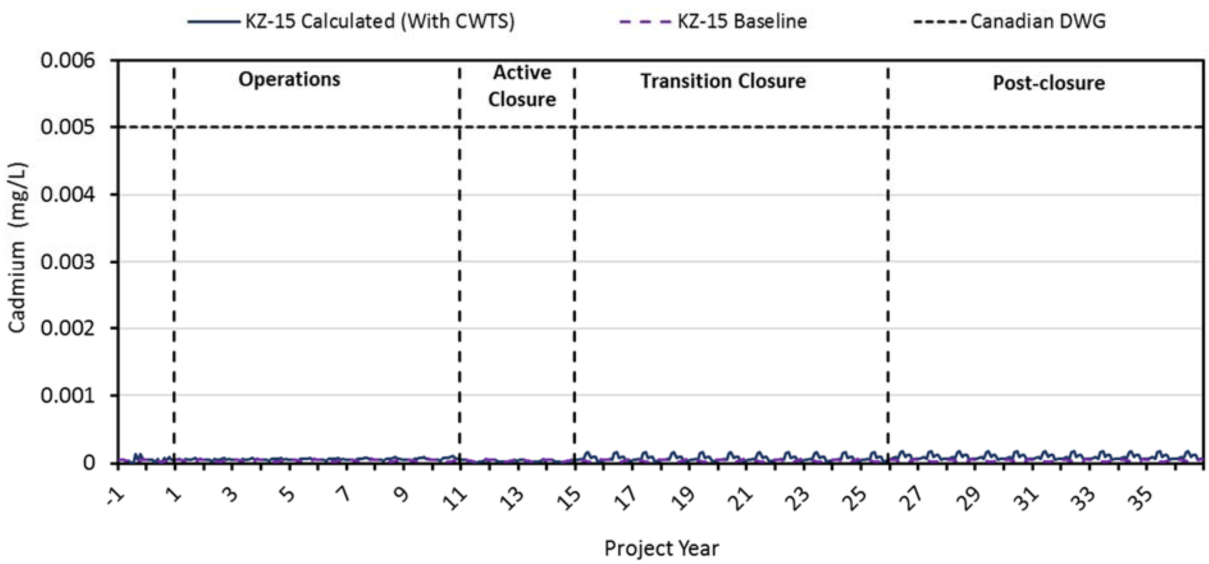
29
31
33
35
Project Year


KZ-15 Calculated (With CWTS)
KZ-15 Baseline
Canadian DWG
Operations
Active Closure
Transition Closure
Post-closure
Zinc (mg/L)
0
1
2
3
4
5
6
-1
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
Project Year

KZ-15 – Mean Precipitation Model Results






KZ-15 Calculated (With CWTS)
KZ-15 Baseline
Canadian DWG
Operations
Active Closure
Transition Closure
Post-closure
Cadmium (mg/L)
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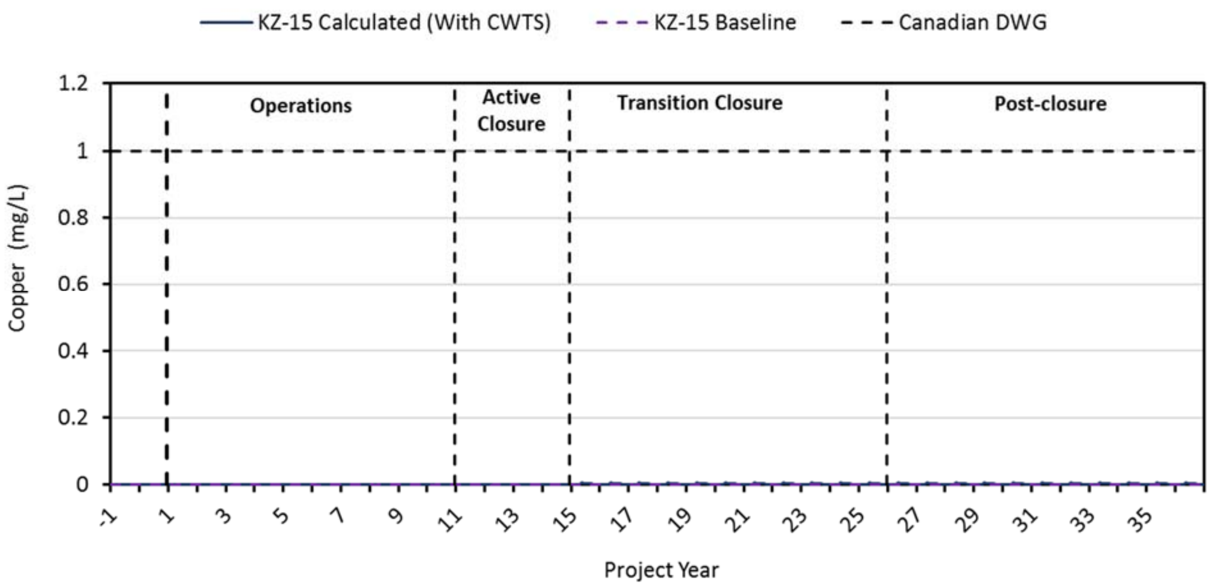
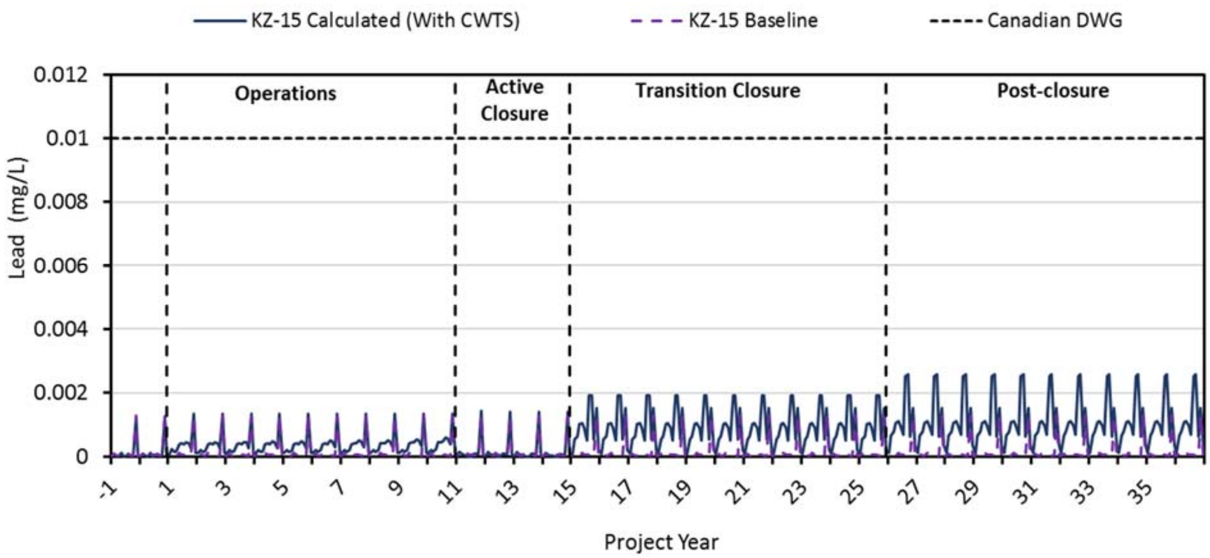
0.005
0.004
0.003
0.002
0.001
0
-1 1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35
Project Year


KZ-15 Calculated (With CWTS)
KZ-15 Baseline
Canadian DWG
Operations
Active Closure
Transition Closure
Post-closure
Copper (mg/L)
1.2
1
0.8
0.6
0.4
0.2
0
-1 1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35
Project Year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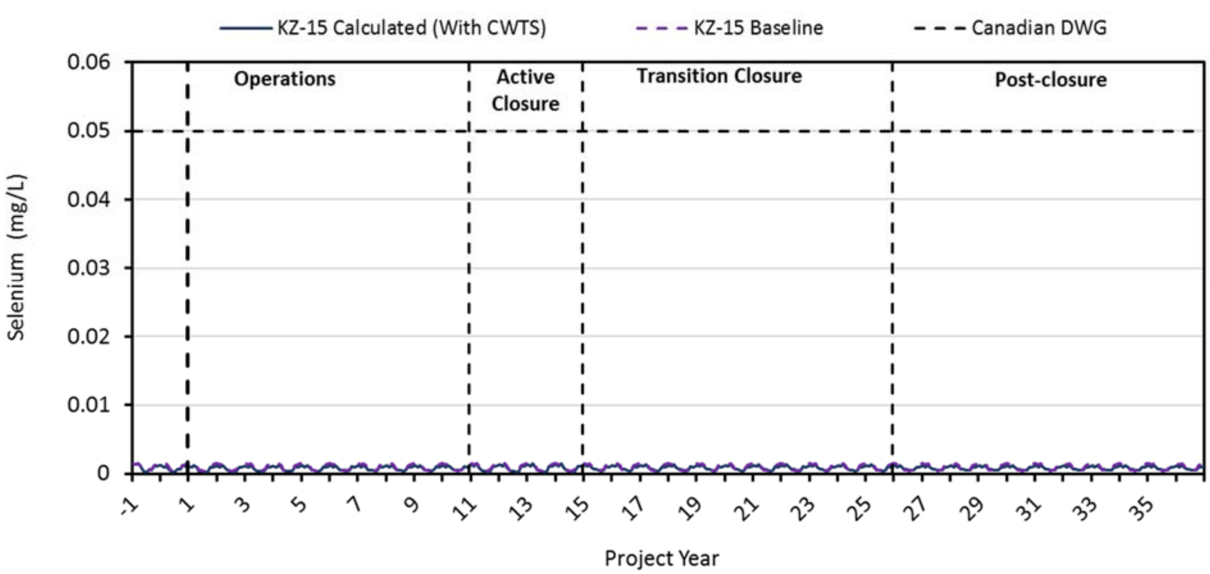
KZ-15 Baseline
Canadian DWG
Operations
Active Closure
Transition Closure
Post-closure
Lead (mg/L)
Project Year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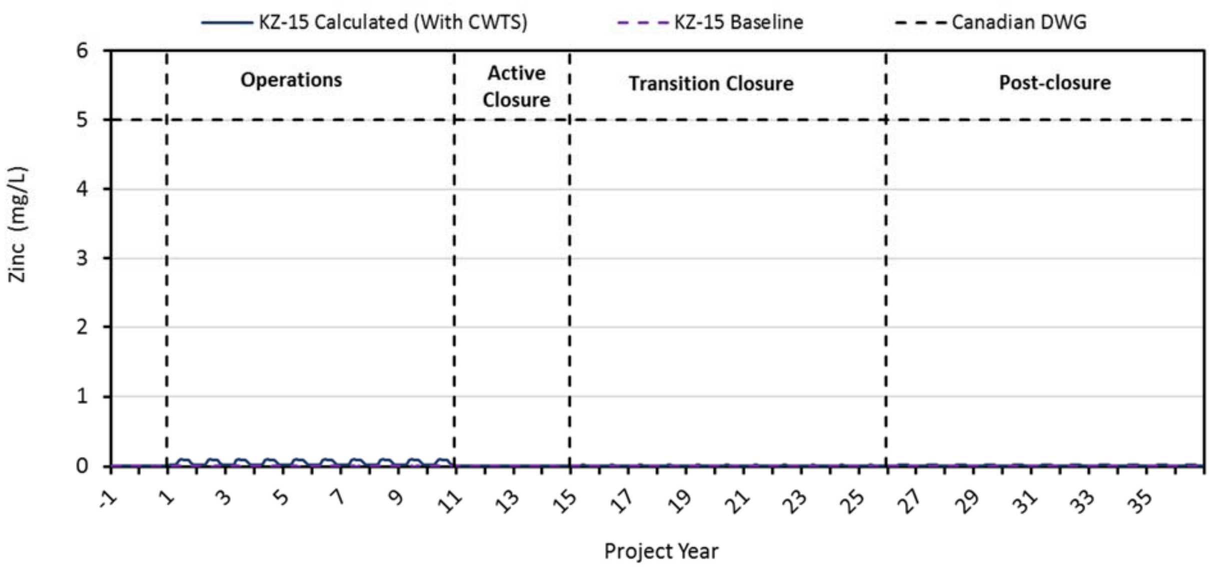
KZ-15 Baseline
Canadian DWG
Operations
Active Closure
Transition Closure
Post-closure
Selenium (mg/L)
Project Year


KZ-15 Calculated (With CWTS)
KZ-15 Baseline
Canadian DWG
Operations
Active Closure
Transition Closure
Post-closure
Zinc (mg/L)
Project Year

APPENDIX B.

Detailed Technical Information, Worked Example Risk Calculations and Detailed Risk Estimates

BMC MINERALS (NO.1) LTD

KUDZ ZE KAYAH PROJECT

PRELIMINARY QUANTITATIVE RISK ASSESSMENT: APPENDIX B

November 2017

DETAILED TECHNICAL INFORMATION, WORKED EXAMPLE RISK CALCULATIONS AND DETAILED RISK ESTIMATES

B-1 Introduction

This appendix provides detailed technical information on the PQRA. The appendix includes the following:

- Section B-2 provides the mathematical equations used to estimate exposures;
- Section B-3 provides worked examples of the risk calculations for various scenarios;
- Section B-4 provides information on the toxicological reference values selected for the various chemicals; and
- Section B-5 provides the detailed results of the HHRA (results expressed on an exposure pathway basis).

B-2 Mathematical Equations Used to Estimate Exposures

As discussed earlier, the exposures that receptors may receive were estimated for the following pathways:

- Incidental ingestion of soils
- Dermal contact with soils
- Inhalation of dusts originating from soils
- Ingestion of surface water as a drinking water source
- Ingestion of berries

The mathematical equations used to estimate exposures from these pathways are discussed in greater detail below.

ESTIMATION OF EXPOSURE FROM INGESTION OF SOIL

It is possible that receptors may unintentionally ingest soil from the site. In order to estimate exposure from soil ingestion, the following Health Canada (2012) equation was applied:

$$EIG = \frac{C_S \times IR_S \times RAF_{Oral} \times D_2 \times D_3 \times D_4}{BW \times LE}$$

where:

EIG = exposure from the soil ingestion pathway (μg/kg body weight/day)

C_S = soil chemical concentration (μg/g)

IR_S = soil ingestion rate of person (g/day)

RAF_{Oral} = relative bioavailability fraction via the ingestion route (chemical specific but assumed to be 1.0 for all chemicals in the current PQRA)

D_2 = days per week exposed/7 days (unitless)

D_3 = weeks per year exposed/52 weeks (unitless)

D_4 = total years exposed to site (only used for carcinogens)

BW = body weight of person (kg)

LE = life expectancy (years) (only used for assessment of carcinogens)

ESTIMATION OF EXPOSURE FROM DERMAL CONTACT WITH SOIL

Dermal contact with soil was another pathway of exposure that was quantitatively evaluated in the HHRA. Dermal exposure was estimated according to the following Health Canada (2012) equation:

$$EDS = \frac{[(C_S \times SA_H \times SL_H) + (C_S \times SA_O \times SL_O)] \times RAF_{Derm} \times D_2 \times D_3 \times D_4}{BW \times LE}$$

where:

EDS = exposure from the dermal pathway for soils (μg/kg/day)

C_S = soil chemical concentration (μg/g)

SA_H = surface area of hands exposed for soil loading (m^2)

SA_H = surface area exposed other than hands (m^2)

SL_H = soil loading rate to exposed skin of hands (m^2)

SL_O = soil loading rate to exposed skin other than hands (m^2)

RAF_{Dermal}= relative bioavailability fraction via the dermal route (chemical specific)

D_2 = days per week exposed/7 days (unitless)

D_3 = weeks per year exposed/52 weeks (unitless)

D_4 = total years exposed to site (only used for carcinogens)

BW = body weight of person (kg)

LE = life expectancy (years) (only used for assessment of carcinogens)

ESTIMATION OF EXPOSURE FROM INHALATION OF DUSTS

For chemicals with toxicity reference values for the inhalation route expressed in units of "µg/kg bw/day", it was necessary to estimate exposures in the same units. For these chemicals, exposures via dust inhalation were estimated as per the following Health Canada (2012) equation:

$$EID = \frac{C_S \times P_{Air} \times IR \times D_1 \times D_2 \times D_3 \times D_4}{BW \times LE}$$

where:

EID = exposure from the dust inhalation pathway (µg/kg bw/day)

C_S = soil chemical concentration (µg/g)

P_{Air} = particulate concentration in air (assumed to be 7.6×10^{-7} g/m^3 based on Health Canada and assuming no appreciable vehicle contact with impacted soils)

IR = inhalation rate (m^3/day)

D_1 = hours per day exposed/24 hours (unitless)

D_2 = days per week exposed/7 days (unitless)

D_3 = weeks per year exposed/52 weeks (unitless)

D_4 = total years exposed to site (only used for carcinogens)

BW = body weight of person (kg)

LE = life expectancy (years) (only used for assessment of carcinogens)

For chemicals with toxicity reference values for the inhalation route expressed in units of "µg/m^3", the above equation was not applied. Instead, the estimated air concentration from dust re-suspension was estimated according to the following formula:

$$DC = C_S \times P_{Air}$$

where:

DC = estimated dust concentration (µg/m^3)

C_S = soil chemical concentration (µg/g)

P_{Air} = particulate concentration in air

The estimated dust concentration was then used directly in risk calculations.

ESTIMATION OF EXPOSURE FROM INGESTION OF SURFACE WATER

It is possible that receptors may ingest surface water as their drinking water source while at the site. In order to estimate exposure from surface water ingestion, the following Health Canada (2012) equation was applied:

$$EIG = \frac{C_W \times IR_W \times D_2 \times D_3 \times D_4}{BW \times LE}$$

where:

EIG = exposure from the drinking water ingestion pathway (μg/kg body weight/day)

C_W = water chemical concentration (μg/g)

IR_W = water ingestion rate of person (g/day)

RAF_{Oral} = relative bioavailability fraction via the ingestion route (chemical specific but assumed to be 1.0 for all chemicals in the current PQRA)

D_2 = days per week exposed/7 days (unitless)

D_3 = weeks per year exposed/52 weeks (unitless)

D_4 = total years exposed to site (only used for carcinogens)

BW = body weight of person (kg)

LE = life expectancy (years) (only used for assessment of carcinogens)

ESTIMATION OF EXPOSURE FROM INGESTION OF BERRIES

It is possible that receptors may ingest surface water as their drinking water source while at the site. In order to estimate exposure from surface water ingestion, the following Health Canada (2012) equation was applied:

$$EIG = \frac{C_B \times IR_B \times D_2 \times D_3 \times D_4}{BW \times LE}$$

where:

EIG = exposure from the berry ingestion pathway (μg/kg body weight/day)

C_B = berry chemical concentration (μg/g)

IR_W = berry ingestion rate of person (g/day)

RAF_{Oral} = relative bioavailability fraction via the ingestion route (chemical specific but assumed to be 1.0 for all chemicals in the current PQRA)

D_2 = days per week exposed/7 days (unitless)

D_3 = weeks per year exposed/52 weeks (unitless)

D_4 = total years exposed to site (only used for carcinogens)

BW = body weight of person (kg)

LE = life expectancy (years) (only used for assessment of carcinogens)

B-3 Worked Example Risk Calculations

B-3.1 Child Exposed to Lead

In this worked example, risks posed by lead to a toddler with unrestricted soils, surface water and berries are estimated. To estimate exposures and risks, the following post-closure maximum environmental concentrations were assumed:

Maximum soil concentration of lead = 72 µg/g

Maximum surface water concentration of lead = 3.1 µg/L

Maximum berry concentration of lead = 0.0086 µg/g (wet weight)

ESTIMATION OF RISKS FROM INGESTION OF SOIL

Soil ingestion exposure to lead was estimated according to the following formula:

$$EIG = \frac{C_S \times IR_S \times RAF_{Oral} \times D_2 \times D_3}{BW}$$

where:

EIG = exposure from the soil ingestion pathway (μg/kg body weight/day)

C_S = soil chemical concentration (72 μg/g)

IR_S = soil ingestion rate of person (0.08 g/day)

RAF_{Oral} = relative bioavailability fraction via the ingestion route (1.0)

D_2 = fraction of week exposed/7 days (1; i.e., 7 days per week)

D_3 = fraction of per year exposed/52 weeks (1; i.e., even though site use is only 1 week per year, a value of 1 was used for evaluation of non-carcinogens due to amortization concerns)

BW = body weight of person (16.5 kg)

Under this scenario, the estimated exposure to lead from the soil ingestion route was estimated to be 0.349 μg/kg bw/day.

The Hazard Quotient from this route was then estimated as follows:

$$\text{Hazard Quotient} = \frac{\text{Estimated Exposure (0.349 μg/kg bw/day)}}{\text{Risk Specific Dose (0.6 μg/kg bw/day)}}$$

Thus, the Hazard Quotient value from the soil ingestion route was estimated to be 0.58.

ESTIMATION OF RISKS FROM DERMAL CONTACT WITH SOIL

Dermal contact with soil was estimated according to the following equation:

$$EDS = \frac{[(C_S \times SA_H \times SL_H) + (C_S \times SA_O \times SL_O)] \times RAF_{Derm} \times D_2 \times D_3}{BW}$$

where:

EDS = exposure from the dermal pathway for soils (μg/kg/day)

C_S = soil chemical concentration (72 μg/g)

SA_H = surface area of hands exposed for soil loading (0.043 m^2)

SA_H = surface area exposed other than hands (0.26 m^2)

SL_H = soil loading rate to exposed skin of hands (1 g/m^2)

SL_O = soil loading rate to exposed skin other than hands (0.1 g/m^2)

RAF_{Dermal}= relative bioavailability fraction via the dermal route (0.006)

D_2 = fraction of week exposed/7 days (1; i.e., 7 days per week)

D_3 = fraction of per year exposed/52 weeks (1; i.e., even though site use is only 1 week per year, a value of 1 was used for evaluation of non-carcinogens due to amortization concerns)

BW = body weight of person (16.5 kg)

Under this scenario, the estimated exposure to lead from dermal contact with soil was estimated to be 0.00744 μg/kg bw/day.

The Hazard Quotient from this route was then estimated as follows:

$$\text{Hazard Quotient} = \frac{\text{Estimated Exposure (0.00181 μg/kg bw/day)}}{\text{Risk Specific Dose (0.6 μg/kg bw/day)}}$$

Thus, the Hazard Quotient value from dermal contact with soil was estimated to be 0.0030.

ESTIMATION OF RISKS FROM INHALATION OF DUSTS

Exposures via dust inhalation were estimated as per the following Health Canada (2012) equation:

$$EID = \frac{C_S \times P_{Air} \times IR \times D_1 \times D_2 \times D_3}{BW}$$

where:

EID = exposure from the dust inhalation pathway (µg/kg bw/day)

C_S = soil chemical concentration (72 µg/g)

P_{Air} = particulate concentration in air (assumed to be 7.6×10^{-7} g/m^3 based on Health Canada [2009a])

IR = inhalation rate (8.3 m^3/day)

D_1 = fraction of day exposed/24 hours (24/24 = 1)

D_2 = fraction of week exposed/7 days (1; i.e., 7 days per week)

D_3 = fraction of per year exposed/52 weeks (1; i.e., even though site use is only 1 week per year, a value of 1 was used for evaluation of non-carcinogens due to amortization concerns)

BW = body weight of person (16.5 kg)

Under this scenario, the estimated exposure to lead was estimated to be 2.8×10^{-6} µg/kg bw/day.

The Hazard Quotient from this route was then estimated as follows:

$$\text{Hazard Quotient} = \frac{\text{Estimated Exposure } (2.8 \times 10^{-6}\ \mu g/kg\ bw/day)}{\text{Risk Specific Dose } (0.6\ \mu g/kg\ bw/day)}$$

Thus, the Hazard Quotient from the estimated dust concentration was 4.6×10^{-6}. It is noted that the PQRA spreadsheet tool calculates the intake but not the risk from dust inhalation; however, it is apparent, this level of intake is much smaller than other routes and does not influence overall risks.

ESTIMATION OF RISKS FROM INGESTION OF DRINKING WATER

Drinking water ingestion exposure to lead was estimated according to the following formula:

$$EIG = \frac{C_W \times IR_W \times RAF_{Oral} \times D_2 \times D_3}{BW}$$

where:

EIG = exposure from the drinking water ingestion pathway (µg/kg body weight/day)

C_W = drinking water chemical concentration (3.1 µg/L)

IR_W = drinking water ingestion rate of person (0.6 L/day)

RAF_{Oral} = relative bioavailability fraction via the ingestion route (1.0)

D_2 = fraction of week exposed/7 days (1; i.e., 7 days per week)

D_3 = fraction of per year exposed/52 weeks (1; i.e., even though site use is only 1 week per year, a value of 1 was used for evaluation of non-carcinogens due to amortization concerns)

BW = body weight of person (16.5 kg)

Under this scenario, the estimated exposure to lead from the drinking water ingestion route was estimated to be 0.113 µg/kg bw/day.

The Hazard Quotient from this route was then estimated as follows:

$$\text{Hazard Quotient} = \frac{\text{Estimated Exposure } (0.113\ \mu g/kg\ bw/day)}{\text{Risk Specific Dose } (0.6\ \mu g/kg\ bw/day)}$$

Thus, the Hazard Quotient value from the soil ingestion route was estimated to be 0.0172.

ESTIMATION OF RISKS FROM INGESTION OF BERRIES

Berry ingestion exposure to lead was estimated according to the following formula:

$$EIG = \frac{C_W \; x \; IR_W \; x \; RAF_{Oral} \; x \; D_2 \; x \; D_3}{BW}$$

where:

EIG = exposure from the berry ingestion pathway (µg/kg body weight/day)

C_B = berry chemical concentration (0.0086 µg/g; wet weight)

IR_B = berry ingestion rate of person (67 g/day)

RAF_{Oral} = relative bioavailability fraction via the ingestion route (1.0)

D_2 = fraction of week exposed/7 days (1; i.e., 7 days per week)

D_3 = fraction of per year exposed/52 weeks (1; i.e., even though site use is only 1 week per year, a value of 1 was used for evaluation of non-carcinogens due to amortization concerns)

BW = body weight of person (16.5 kg)

Under this scenario, the estimated exposure to lead from the drinking water ingestion route was estimated to be 0.0349 µg/kg bw/day.

The Hazard Quotient from this route was then estimated as follows:

$$\text{Hazard Quotient} = \frac{\text{Estimated Exposure } (0.0349 \; \mu g/kg \; bw/day)}{\text{Risk Specific Dose } (0.6 \; \mu g/kg \; bw/day)}$$

Thus, the Hazard Quotient value from the soil ingestion route was estimated to be 0.058.

Estimation of Risks from All Exposures

Summing the risks from all exposure routes for maximum concentrations of Pb, the following Hazard Quotient was estimated:

Hazard Quotient from soil ingestion	0.58
Hazard Quotient from dermal contact with soil	0.0030
Hazard Quotient from inhalation of dusts	0.0000046
Hazard Quotient from ingestion of drinking water	0.19
Hazard Quotient from ingestion of berries	0.058
Sum of all Hazard Quotients	0.83

B-3.2 Adult Exposed to Arsenic

In this worked example, cancer risks posed to the adult exposed to the maximum concentrations of arsenic are estimated. To estimate exposures and risks, the following post-closure maximum environmental concentrations were assumed:

Maximum soil concentration of arsenic = 96 µg/g

Maximum surface water concentration of arsenic = 3.18 µg/L

Maximum berry concentration of arsenic = 0.0025 µg/g (wet weight)

ESTIMATION OF RISKS FROM INGESTION OF SOIL

Soil ingestion exposure to arsenic was estimated according to the following formula:

$$EIG = \frac{C_S \times IR_S \times RAF_{Oral} \times D_2 \times D_3 \times D_4}{BW}$$

where:

EIG	=	exposure from the soil ingestion pathway (µg/kg body weight/day)
C_S	=	soil chemical concentration (96 µg/g)
IR_S	=	soil ingestion rate of person (0.02 g/day)
RAF_{Oral}	=	relative bioavailability fraction via the ingestion route (1.0)
D_2	=	fraction of week exposed/7 days (1; i.e., 7 days per week)
D_3	=	fraction of per year exposed/52 weeks (0.0192; i.e., 1 week per year)
D_4	=	fraction of lifetime exposed (1.0; i.e., return every year)
BW	=	body weight of person (70.7 kg)

Under this scenario, the estimated exposure to arsenic from the soil ingestion route was estimated to be 0.000522 µg/kg bw/day

The Incremental Lifetime Cancer Risk from this route was then estimated as follows:

ILCR = Exposure (0.000522 µg/kg bw/d) x Cancer Potency Factor (0.0018 $[\mu g/kg\ bw/d]^{-1}$)

Thus, the Incremental Lifetime Cancer Risk from arsenic via the soil ingestion route was estimated to be 9.40×10^{-7}.

ESTIMATION OF RISKS FROM DERMAL CONTACT WITH SOIL

Dermal contact with soil was estimated according to the following equation:

$$EDS = \frac{[(C_S \times SA_H \times SL_H) + (C_S \times SA_O \times SL_O)] \times RAF_{Derm} \times D_2 \times D_3 \times D_4}{BW}$$

where:

EDS	=	exposure from the dermal pathway for soils (μg/kg/day)
C_S	=	soil chemical concentration (96 μg/g)
SA_H	=	surface area of hands exposed for soil loading (0.089 m^2)
SA_H	=	surface area exposed other than hands (0.82 m^2)
SL_H	=	soil loading rate to exposed skin of hands (1 g/m^2)
SL_O	=	soil loading rate to exposed skin other than hands (0.1 g/m^2)
RAF_{Dermal}	=	relative bioavailability fraction via the dermal route (0.03)
D_2	=	fraction of week exposed/7 days (1; i.e., 7 days per week)
D_3	=	fraction of per year exposed/52 weeks (0.0192; i.e., 1 week per year)
D_4	=	fraction of lifetime exposed (1.0; i.e., return every year)
BW	=	body weight of person (70.7 kg)

Under this scenario, the estimated exposure to arsenic from dermal contact with soil was estimated to be 0.000134 μg/kg bw/day.

The Incremental Lifetime Cancer Risk from this route was then estimated as follows:

ILCR = Exposure (0.000134 μg/kg bw/d) x Cancer Potency Factor (0.0018 [μg/kg bw/d]$^{-1}$)

Thus, the Incremental Lifetime Cancer Risk from the dermal contact route was estimated to be 2.41 x 10^{-7}.

ESTIMATION OF RISKS FROM INHALATION OF DUSTS

Estimated air concentration from dust re-suspension was estimated according to the following formula:

$$DC = C_S \times P_{Air} \times D_1 \times D_2 \times D_3 \times D_4$$

where:

DC	=	estimated dust concentration (μg/m^3)
C_S	=	soil chemical concentration (96 μg/g)
P_{Air}	=	particulate concentration in air (7.6 x 10^{-7} μg/m^3)
D_1	=	fraction of day exposed/24 hours (1; i.e., 24 hours per day)
D_2	=	fraction of week exposed/7 days (1; i.e., 7 days per week)
D_3	=	fraction of per year exposed/52 weeks (0.0192; i.e., 1 week per year)
D_4	=	fraction of lifetime exposed (1.0; i.e., return every year)

As shown above, the dust concentration of arsenic was estimated to be 1.40 x 10^{-6} μg/m^3.

The Incremental Lifetime Cancer Risk from this route was then estimated as follows:

ILCR = Estimated Lifetime Air Conc. (1.40 x 10^{-6} μg/m^3) x Unit Risk (0.0064 [μg/m^3]$^{-1}$)

Thus, the Incremental Lifetime Cancer Risk from the dust inhalation route was estimated to be 8.98 x 10^{-9}. It is noted that the PQRA spreadsheet tool calculates the intake but not the risk from dust inhalation; however, it is apparent, this level of intake is much smaller than other routes and does not influence overall risks.

ESTIMATION OF RISKS FROM INGESTION OF DRINKING WATER

Drinking water ingestion exposure to arsenic was estimated according to the following formula:

$$EIG = \frac{C_W \times IR_W \times RAF_{Oral} \times D_2 \times D_3 \times D_4}{BW}$$

where:

EIG	=	exposure from the soil ingestion pathway (µg/kg body weight/day)
C_W	=	drinking water chemical concentration (3.18 µg/L)
IR_W	=	drinking water ingestion rate of person (1.5 L/day)
RAF_{Oral}	=	relative bioavailability fraction via the ingestion route (1.0)
D_2	=	fraction of week exposed/7 days (1; i.e., 7 days per week)
D_3	=	fraction of per year exposed/52 weeks (0.0192; i.e., 1 week per year)
D_4	=	fraction of lifetime exposed (1.0; i.e., return every year)
BW	=	body weight of person (70.7 kg)

Under this scenario, the estimated exposure to arsenic from the drinking water route was estimated to be 0.00130 µg/kg bw/day

The Incremental Lifetime Cancer Risk from this route was then estimated as follows:

ILCR = Exposure (0.00130 µg/kg bw/d) x Cancer Potency Factor (0.0018 [µg/kg bw/d]$^{-1}$)

Thus, the Incremental Lifetime Cancer Risk from arsenic via the soil ingestion route was estimated to be 2.34×10^{-6}.

ESTIMATION OF RISKS FROM INGESTION OF BERRIES

Drinking water ingestion exposure to arsenic was estimated according to the following formula:

$$EIG = \frac{C_B \times IR_B \times RAF_{Oral} \times D_2 \times D_3 \times D_4}{BW}$$

where:

EIG	=	exposure from the soil ingestion pathway (μg/kg body weight/day)
C_B	=	drinking water chemical concentration (0.0025 μg/g; wet weight)
IR_B	=	drinking water ingestion rate of person (137 g/day)
RAF_{Oral}	=	relative bioavailability fraction via the ingestion route (1.0)
D_2	=	fraction of week exposed/7 days (1; i.e., 7 days per week)
D_3	=	fraction of per year exposed/52 weeks (0.0192; i.e., 1 week per year)
D_4	=	fraction of lifetime exposed (1.0; i.e., return every year)
BW	=	body weight of person (70.7 kg)

Under this scenario, the estimated exposure to arsenic from the drinking water route was estimated to be 0.0000932 μg/kg bw/day.

The Incremental Lifetime Cancer Risk from this route was then estimated as follows:

ILCR = Exposure (0.0000932 μg/kg bw/d) x Cancer Potency Factor (0.0018 [μg/kg bw/d]$^{-1}$)

Thus, the Incremental Lifetime Cancer Risk from arsenic via the soil ingestion route was estimated to be 1.68 x 10^{-7}.

Estimation of Risks from All Exposures

Summing the risks from all exposure routes, the following ICLR was estimated:

ILCR from soil ingestion	9.40×10^{-7}
ILCR from dermal contact with soil	2.41×10^{-7}
ILCR from inhalation of dusts	8.98×10^{-9}
ILCR from drinking water ingestion	2.34×10^{-6}
ILCR from berry consumption	1.68×10^{-7}
Sum of all Hazard Quotients	3.69×10^{-6}

B-4 Toxicological Reference Values Used in the HHRA

As discussed in the Main Report, toxicological reference values were selected using Health Canada (2010; 201) guidance. In this guidance, Health Canada TRVs are given preference as the primary source of toxicological data except if more appropriate values are available from other recognized agencies (e.g., if other values are based on more recent data which may not have been available to Health Canada).

The rationale for the selected TRVs is provided for each of the metals of concern below.

Arsenic

Health Canada (2010) provided an inhalation unit risk value of 0.0064 $(\mu g/m^3)^{-1}$. This value was based on an epidemiological study of lung cancer in people occupationally exposed to arsenic whereby a tumorigenic concentration associated with a 5% increased incidence in lung cancer (TC_{05}) of 7.83 $\mu g/m^3$ was predicted. This unit risk was used for evaluation of risks from arsenic in air.

For evaluation of cancer risks from oral and dermal exposure, Health Canada (2010) provided an oral slope factor of 1.8 $x10^{-3}$ $(\mu g/kg\ bw/d)^{-1}$ based on epidemiological study of bladder, lung and liver cancer in people exposed to arsenic via drinking water. This slope factor was used to evaluate cancer risks from oral and dermal exposures to arsenic.

For evaluation of non-cancer risks, Health Canada did not provide a TRV. The US EPA IRIS RfD (last revised in 1993; http://www.epa.gov/iris/subst/0278.htm) of 0.3 µg/kg bw/d was based on a NOAEL of 0.8 µg/kg bw/d (skin and vascular effects in people exposed via drinking water) and application of a 3-fold uncertainty factor. For the purposes of HHSC development, the RfD of 0.3 µg/kg bw/d was used to evaluate the non-cancer risks from oral, inhalation and dermal exposure to arsenic.

Cadmium

Health Canada (2010; 2011) provided an inhalation unit risk value of 0.0098 $(\mu g/m^3)^{-1}$. This value was based on an inhalation rat study whereby a tumorigenic concentration associated with a 5% increased incidence in lung cancer (TC_{05}) of 5.1 $\mu g/m^3$ was predicted. This unit risk was used for evaluation of risks from cadmium in air.

For evaluation of non-cancer risks, Health Canada provided a TDI of 1 µg/kg bw/d was based on a NOAEL of 2.5 µg/g creatinine in urine for protection of renal tubular dysfunction. For the purposes of the PQRA, the RfD of 1.0 µg/kg bw/d was used to evaluate the non-cancer risks from oral, inhalation and dermal exposure to cadmium.

Copper

Health Canada (2011) provided TDIs of 90 µg/kg bw/d for toddlers and 100 µg/kg bw/d for adults for evaluation of risks from copper. The Health Canada TRVs were based on an Institute of Medicine analysis of chronic self-intoxication in people. From these studies, a NOAEL of 10 mg/d was estimated (critical effect was hepatotoxicity and gastrointestinal effects) by the Institute of Medicine. Health Canada used the Institute of Medicine's Upper Level intake rates and then adjusted for age group and body weight specific to Health Canada (2010) guidance to estimate TDIs of 91 μg/kg bw/d for toddlers and 141 μg/kg bw/d for adults; however, the Health Canada (2011) spreadsheet tool then adjusted these values to TDIs of 90 μg/kg bw/d for toddlers and 100 μg/kg bw/d for adults. Due to the similarities in TRVs, the Health Canada (2011) TDI was used to evaluate risks from copper via oral, inhalation and dermal routes of exposure.

Fluoride

Health Canada (2010) provided a TRV for evaluation of fluoride. Health Canada (2010) identified a MAC of 1.5 mg/L in drinking water for protection against moderate dental fluorosis in children. Health Canada converted this drinking water concentration into an intake rate of 0.105 mg/kg bw/d and then assigned an uncertainty factor of 1 to estimate a RfD of 105 μg/kg bw/d for evaluation of fluoride. As a result, a RfD of 105 μg/kg bw/d for evaluation of fluoride was used in the PQRA.

Lead

Neither Health Canada nor US EPA currently provide a TRV for lead. Consequently, other agencies were reviewed. Relying on the conclusions of WHO (2011), it was estimated that an intake rate of 0.6 μg/kg bw/d would be protective of a 1 IQ point decrement in children and 1.3 μg/kg bw/d would be protective of a 1 mmHg increase in systolic blood pressure in adults. EFSA (2013) has indicated a slightly more conservative value for the potency of lead associated with a 1 IQ point decrement. Using the same scientific dataset as WHO (2011), EFSA (2013) estimated that a dose rate of 0.5 μg/kg bw/day is associated with a 1 IQ point decrement (versus the WHO/JECFA value of 0.6 μg/kg bw/day for a 1 IQ point decrement). The differences in the potency estimate seem to mainly occur from: (1) EFSA (2013) using a 95% lower confidence level for its estimate of potency versus WHO (2011) using a central estimate; and (2) EFSA (2013) using less conservative toxicokinetics than WHO (2011) in back-calculating to an intake rate. Overall, these represent very similar estimates of potency of lead and at the present time, no other major health agencies have provided alternate potency estimates for protection of IQ effects as dose rates. For the current assessment, the WHO (2011) for a 1 IQ point decrement was used; however, no change in overall conclusions would have been noted if the EFSA (2013) value was used.

Selenium

Health Canada (2010) provided a TRV for evaluation of selenium. For protection against selenosis, Health Canada (2010) identified a NOAEL of 7 μg/kg bw/d in studies with infants and then estimated an Upper Level intake (equivalent to TDI) of 6.2 μg/kg bw/d for evaluation of toddlers exposed to selenium. As a result, a TDI of 6.2 μg/kg bw/d for evaluation of selenium was used in the PQRA.

Zinc

Health Canada (2011) provided TDIs of 480 μg/kg bw/d for toddlers and 570 μg/kg bw/d for adults for evaluation of risks from zinc. The Health Canada TRVs were based on an Institute of Medicine analysis of a subchronic study of dietary supplements provided to infants (supplementation via formula). From these studies, a NOAEL of 4.5 mg/d was estimated (critical effect was neurotoxicity) by the Institute of Medicine. Health Canada used the Institute of Medicine's Upper Level intake rates and then adjusted for age group and body weight specific to Health Canada guidance to estimate TDIs of 480 µg/kg bw/d for toddlers and 570 µg/kg bw/d for adults. On the other hand, Health Canada (2011) provided a TDI of 500 µg/kg bw/d for all age groups which is quite similar to the Health Canada (2010) values. Due to the similarities in TRVs, the Health Canada (2011) TDI was used to evaluate risks from zinc via oral, inhalation and dermal routes of exposure.

B-5 Detailed Risk Estimates

The risk estimates for each of the receptors of concern are provided as per the Health Canada (2011) spreadsheet tool input and output table.

Risk Estimates: Mean Concentrations at Baseline

HEALTH CANADA PQRA SPREADSHEET

USER INPUT SHEET

User Name:	KZK - BMC	Site:	
Proponent:	BMC	File #:	
Date:	October 16, 2017	Comment:	

PROBLEM FORMULATION

Potential Land Uses (Yes/No)		Default	*Operative Pathways (Yes/No)*		Default
Agricultural	No	Yes	Inadvertent ingestion of soil		Yes
Residential/urban parkland	No	Yes	Inhalation of fugitive dust		Yes
Commercial with daycare	No	Yes	Inhalation of indoor contaminant vapours	No	Yes
Commercial without daycare	No	Yes	Inhalation of outdoor contaminant vapours	No	Yes
Industrial	No	Yes	Ingestion of drinking water		Yes
Industrial - outdoors	No	Yes	Dermal contact with soil		Yes
Urban recreational	No	Yes	Dermal contact with water		Yes
Remote wild lands	No	Yes	Ingestion of contaminated food	Yes	No
Construction/utility work	No	Yes			
Other	Yes	No	*Vapour Transport Modelling*		
specify:	First Nations Traditional Land Use		Vapour source for exposure calculations		Most Conservative

Exposure Scenario		First Nations Traditional La	*Active Critical Receptors (Yes/No)*		Default
			Infant		Yes
			Toddler		Yes
Receptor Groups (Yes/No)		Default	Child		Yes
General public or residents	No	Yes	Teen		Yes
Employees	No	Yes	Adult		Yes
Canadian native communities	Yes	No	Construction/Utility Worker		No
Other	Yes	No	Other		No
specify:	First Nations Land Use - 1 Week Per		specify:		

Contaminant Concentrations

Chemical Name	required	Lead	Cadmium	Fluoride	Copper	Selenium	Zinc
Soil (mg/kg)	required	28	0.91	0	40	0.86	161
Groundwater - source (mg/L)	optional						
Drinking water (mg/L)	optional	0.000166	0.0000573	0.0791	0.000736	0.000738	0.0061
Bathing/swimming water (mg/L)	optional						
Indoor air - vapours (mg/m^3)	optional						
Outdoor air - vapours (mg/m^3)	optional						
Outdoor air - particulate (mg/m^3)	optional						
Root vegetables (mg/kg wet weight)	optional						
Other vegetables (mg/kg wet weight)	optional	0.00298	0.0481	0	0.859	0.005	2.94
Fish (mg/kg wet weight)	optional						
Wild game (mg/kg wet weight)	optional						
				#N/A			

Risk Assessment Endpoints		Default
Acceptable hazard index:		0.2
Acceptable cancer risk:		1.00E-05
Evaluate Early Lifestage Cancer Risks?		No

Precluding Conditions for Fate and Transport Models	**All precluding conditions questions should be answered**
Are non-aqueous phase liquids (NAPL) present?	
Is groundwater contamination present in fractured bedrock?	
Is groundwater contamination migrating through a confined aquifer?	
Is there active pumping or drawdown of groundwater at the site?	
Is contamination present within 1 m of building foundation?	
Do any buildings within 5 m of contamination have earthen foundations?	
Are any buildings constructed on very high permeability media?	
Are there preferential vapour flow pathways connecting contamination to a building?	

FATE AND TRANSPORT MODEL INPUT

	Value	Default	Models Affected
Soil Type		coarse-grained	PS, V-I, V-O, GW
Significant vehicle traffic on unpaved roads?		No	P-O
Site Characteristics			
Depth to Groundwater (m)		3	GW, V-O
Depth from Surface to Contamination (m)		0	GW, V-O
Distance - Contaminated Soil to Building (m)		1	V-I
Distance - Contaminated GW to Building (m)		1	V-I
Distance to potable water user (m)		0	GW
Distance to Bathing/Swimming Water (m)		0	GW
Particulate Concentration in Air (ug/m^3)		0.76	P-O
Apply biodegradation during GW transport?		No	GW
Building Type		Residential	V-I

OPTIONAL SECTIONS

NOTE: user-defined chemicals should be named in this section before being selected in the 'Contaminant Concentrations' table above

User-defined Chemicals

Enter all applicable and appropriate toxicity benchmarks; values must be referenced and justified in the PQRA report.

	Chemical 1	Chemical 2	Chemical 3
Name	Lead		
CAS Number			
Chemical class (organic/inorganic)			
Tolerable daily intake (mg/kg/d) - infant	0.0006		
Tolerable daily intake (mg/kg/d) - toddler	0.0006		
Tolerable daily intake (mg/kg/d) - child	0.0006		
Tolerable daily intake (mg/kg/d) - teen	0.0006		
Tolerable daily intake (mg/kg/d) - adult	0.0006		
Tolerable concentration (mg/m^3)			
Oral slope factor $(mg/kg/d)^{-1}$			
Dermal slope factor $(\mu g/cm^2/d)^{-1}$			
Inhalation slope factor $(mg/kg/d)^{-1}$			
Inhalation unit risk $(mg/m^3)^{-1}$			
Relative dermal absorption factor	0.006		
Relative retention factor from soil			
Viable epidermal thickness factor			
Test animal skin area (cm^2)			
Organic carbon partitioning coefficient (mL/g) - Koc			
Log Kow (unitless)			
Henry's Law constant at 25°C (unitless) - H'			
Henry's Law constant at 25°C (atm-m3/mol) - H			
Water Solubility at 25°C (mg/L)			
Molecular Weight (g/mol)			
Vapour Pressure at 25°C (atm)			

NOTE: values in grayed cells will not be used; Health Canada default values are applied.

User-defined Receptor

Name		Defaults
Age group	Toddler	Toddler
Lifestage duration (y)		4.5
Body weight (kg)		16.5
Soil ingestion rate (g/d)		0.08
Inhalation rate (m^3/d)		8.3
Water ingestion rate (L/d)		0.6
Time spent outdoors (h/d)		1.5
Skin surface area (cm^2)		
- hands		430
- arms		890
- legs		1690
- total		6130
Soil loading to exposed skin (g/cm^2/event)		
- hands		0.0001
- surfaces other than hands		0.00001
Soil monolayer loading rate (mg/cm^2)		5
Food ingestion (g/d)		
- root vegetables		105
- other vegetables		67
- fish		95
- wild game		85

User-defined Land-Use / Exposure Scenario

Scenario name	First Nations Traditional L	Defaults
Hours per day at site		24
Hours per day (outdoors)		
Days per week		7
Weeks per year	52	52
Dermal exposure events/day		1
Water contact events per day		1
Duration of water contact event (h)		1
Days/year contaminated food ingestion		365
Exposure duration (years)		60
Years for carcinogen amortization		60

HEALTH CANADA PQRA SPREADSHEET

Version: **July 13, 2011**

OUTPUT SHEET : Toddler

User Name:	KZK - BMC	Site:	
Proponent:	BMC	File #:	
Date:	October 16, 2017	Comment:	

Exposure Scenario: **First Nations Traditional La** **Exposure Duration (y):** **4.5**

Native population considered

Chemical Properties	Units	Lead	Cadmium	Fluoride	Copper	Selenium	Zinc
Tolerable daily intake	mg/kg/d	0.0006	0.001	NA	0.09	0.0062	0.5
Tolerable concentration	mg/m^3	NA	NA	NA	NA	NA	NA
Oral slope factor	$(mg/kg/d)^{-1}$	NA	NA	NA	NA	NA	NA
Inhalation slope factor	$(mg/kg/d)^{-1}$	NA	NA	NA	NA	NA	NA
Inhalation unit risk	$(mg/m^3)^{-1}$	NA	NA	NA	NA	NA	NA
Dermal slope factor	$(\mu g/cm^2/d)^{-1}$	NA	NA	NA	NA	NA	NA
Critical oral exposure benchmark		TDI	TDI	NA	TDI	TDI	TDI
Critical inhalation exposure benchmark		NA	NA	NA	NA	NA	NA
Critical dermal exposure benchmark		TDI	TDI	NA	TDI	TDI	TDI
Relative dermal absorption factor	unitless	0.006	0.01	1	0.06	0.01	0.1
Relative soil retention factor	unitless	NA	NA	NA	NA	NA	NA
Viable epidermal thickness factor	unitless	NA	NA	NA	NA	NA	NA
Test animal skin area	cm^{-2}	NA	NA	NA	NA	NA	NA

Chemical Concentrations	Units	Lead	Cadmium	Fluoride	Copper	Selenium	Zinc
Soil	mg/kg	2.80E+01	9.10E-01	0.00E+00	4.00E+01	8.60E-01	1.61E+02
Drinking water	mg/L	1.66E-04	5.73E-05	7.91E-02	7.36E-04	7.38E-04	6.10E-03
Bathing/swimming water	mg/L	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Indoor air vapours	mg/m^3	NA	NA	NA	NA	NA	NA
Outdoor air vapours	mg/m^3	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Outdoor air particulate	mg/m^3	2.13E-08	6.92E-10	0.00E+00	3.04E-08	6.54E-10	1.22E-07
Amortized total air concentration	mg/m^3	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Root vegetables	mg/kg wet wt	not evaluated	not evaluated	not evaluated	not evaluated	not evaluated	not evaluated
Other vegetables	mg/kg wet wt	2.98E-03	4.81E-02	0.00E+00	8.59E-01	5.00E-03	2.94E+00
Fish	mg/kg wet wt	not evaluated	not evaluated	not evaluated	not evaluated	not evaluated	not evaluated
Wild game	mg/kg wet wt	not evaluated	not evaluated	not evaluated	not evaluated	not evaluated	not evaluated

RESULTS

	Exposure (mg/kg/d unless otherwise noted)					
	Lead	Cadmium	Fluoride	Copper	Selenium	Zinc
Inadvertent ingestion of contaminated soil	1.36E-04	4.41E-06	0.00E+00	1.94E-04	4.17E-06	7.81E-04
Inhalation of fugitive dust	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Inhalation of contaminant vapours - indoor	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Inhalation of contaminant vapours - outdoor	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ingestion of contaminated drinking water	6.04E-06	2.08E-06	2.88E-03	2.68E-05	2.68E-05	2.22E-04
Dermal contact with contaminated soil	7.01E-07	3.79E-08	0.00E+00	1.00E-05	3.59E-08	6.71E-05
Dermal contact with contaminated soil ($\mu g/cm^2/d$)	not calculated	not calculated	not calculated	not calculated	not calculated	not calculated
Dermal contact with contaminated water	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Dermal contact with contaminated water ($\mu g/cm^2/d$)	not calculated	not calculated	not calculated	not calculated	not calculated	not calculated
Ingestion of contaminated food	1.21E-05	1.95E-04	0.00E+00	3.49E-03	2.03E-05	1.19E-02
Total ingestion exposure	1.54E-04	2.02E-04	2.88E-03	3.71E-03	5.13E-05	1.29E-02
Total dermal exposure	7.01E-07	3.79E-08	0.00E+00	1.00E-05	3.59E-08	6.71E-05
Total dermal exposure ($\mu g/cm^2/d$)	not calculated	not calculated	not calculated	not calculated	not calculated	not calculated
Ingestion + dermal exposure	1.55E-04	2.02E-04	2.88E-03	3.72E-03	5.13E-05	1.30E-02
Total inhalation exposure	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total Exposure (sum of all pathways)	1.55E-04	2.02E-04	2.88E-03	3.72E-03	5.13E-05	1.30E-02

		Hazard/Risk Estimates					
		Lead	Cadmium	Fluoride	Copper	Selenium	Zinc
Hazard Quotient - Oral/Dermal		2.58E-01	2.02E-01	NA	4.13E-02	8.28E-03	2.60E-02
Hazard Quotient - Inhalation		0.00E+00	0.00E+00	NA	0.00E+00	0.00E+00	0.00E+00
Hazard Index - Total		2.58E-01	2.02E-01	NA	4.13E-02	8.28E-03	2.60E-02
Target Hazard Index:	0.2	**Target Hazard Index Exceeded**	**Target Hazard Index Exceeded**				
Cancer Risk - Oral		NA	NA	NA	NA	NA	NA
Cancer Risk - Dermal		NA	NA	NA	NA	NA	NA
Cancer Risk - Oral + Dermal		NA	NA	NA	NA	NA	NA
Cancer Risk - Inhalation		NA	NA	NA	NA	NA	NA
Cancer Risk - Total		NA	NA	NA	NA	NA	NA
Target Cancer Risk:	1.00E-05						

HEALTH CANADA PQRA SPREADSHEET

USER INPUT SHEET

User Name:	KZK - BMC	Site:	
Proponent:	BMC	File #:	
Date:	October 16, 2017	Comment:	

PROBLEM FORMULATION

Potential Land Uses (Yes/No)		Default
Agricultural	No	Yes
Residential/urban parkland	No	Yes
Commercial with daycare	No	Yes
Commercial without daycare	No	Yes
Industrial	No	Yes
Industrial - outdoors	No	Yes
Urban recreational	No	Yes
Remote wild lands	No	Yes
Construction/utility work	No	Yes
Other	Yes	No
specify:	First Nations Traditional Land Use	

Operative Pathways (Yes/No)		Default
Inadvertent ingestion of soil		Yes
Inhalation of fugitive dust		Yes
Inhalation of indoor contaminant vapours	No	Yes
Inhalation of outdoor contaminant vapours	No	Yes
Ingestion of drinking water		Yes
Dermal contact with soil		Yes
Dermal contact with water		Yes
Ingestion of contaminated food	Yes	No

Vapour Transport Modelling

Vapour source for exposure calculations		Most Conservative

Exposure Scenario		First Nations Traditional La

Active Critical Receptors (Yes/No)		Default
Infant		Yes
Toddler		Yes
Child		Yes
Teen		Yes
Adult		Yes
Construction/Utility Worker		No
Other		No
specify:		

Receptor Groups (Yes/No)		Default
General public or residents	No	Yes
Employees	No	Yes
Canadian native communities	Yes	No
Other	Yes	No
specify:	First Nations Land Use - 1 Week Per	

Contaminant Concentrations

Chemical Name	required	Arsenic - non-cancer endpoint						
Soil (mg/kg)	required	17						
Groundwater - source (mg/L)	optional							
Drinking water (mg/L)	optional	0.000584						
Bathing/swimming water (mg/L)	optional							
Indoor air - vapours (mg/m^3)	optional							
Outdoor air - vapours (mg/m^3)	optional							
Outdoor air - particulate (mg/m^3)	optional							
Root vegetables (mg/kg wet weight)	optional							
Other vegetables (mg/kg wet weight)	optional	0.0025						
Fish (mg/kg wet weight)	optional							
Wild game (mg/kg wet weight)	optional							

Risk Assessment Endpoints		Default
Acceptable hazard index:		0.2
Acceptable cancer risk:		1.00E-05
Evaluate Early Lifestage Cancer Risks?		No

Precluding Conditions for Fate and Transport Models

All precluding conditions questions should be answered

Are non-aqueous phase liquids (NAPL) present?	
Is groundwater contamination present in fractured bedrock?	
Is groundwater contamination migrating through a confined aquifer?	
Is there active pumping or drawdown of groundwater at the site?	
Is contamination present within 1 m of building foundation?	
Do any buildings within 5 m of contamination have earthen foundations?	
Are any buildings constructed on very high permeability media?	
Are there preferential vapour flow pathways connecting contamination to a building?	

FATE AND TRANSPORT MODEL INPUT

	Value	Default	Models Affected
Soil Type		coarse-grained	PS, V-I, V-O, GW
Significant vehicle traffic on unpaved roads?		No	P-O
Site Characteristics			
Depth to Groundwater (m)		3	GW, V-O
Depth from Surface to Contamination (m)		0	GW, V-O
Distance - Contaminated Soil to Building (m)		1	V-I
Distance - Contaminated GW to Building (m)		1	V-I
Distance to potable water user (m)		0	GW
Distance to Bathing/Swimming Water (m)		0	GW
Particulate Concentration in Air (ug/m^3)		0.76	P-O
Apply biodegradation during GW transport?		No	GW
Building Type		Residential	V-I

OPTIONAL SECTIONS

NOTE: user-defined chemicals should be named in this section before being selected in the 'Contaminant Concentrations' table above

User-defined Chemicals

Enter all applicable and appropriate toxicity benchmarks; values must be referenced and justified in the PQRA report.

	Chemical 1	Chemical 2	Chemical 3
Name	Arsenic - non-cancer endpoint		
CAS Number			
Chemical class (organic/inorganic)			
Tolerable daily intake (mg/kg/d) - infant			
Tolerable daily intake (mg/kg/d) - toddler	0.0003		
Tolerable daily intake (mg/kg/d) - child			
Tolerable daily intake (mg/kg/d) - teen			
Tolerable daily intake (mg/kg/d) - adult			
Tolerable concentration (mg/m^3)			
Oral slope factor $(mg/kg/d)^{-1}$			
Dermal slope factor $(\mu g/cm^2/d)^{-1}$			
Inhalation slope factor $(mg/kg/d)^{-1}$			
Inhalation unit risk $(mg/m^3)^{-1}$			
Relative dermal absorption factor	0.03		
Relative retention factor from soil			
Viable epidermal thickness factor			
Test animal skin area (cm^2)			
Organic carbon partitioning coefficient (mL/g) - Koc			
Log Kow (unitless)			
Henry's Law constant at 25^{o}C (unitless) - H'			
Henry's Law constant at 25^{o}C (atm-m3/mol) - H			
Water Solubility at 25^{o}C (mg/L)			
Molecular Weight (g/mol)			
Vapour Pressure at 25^{o}C (atm)			

NOTE: values in grayed cells will not be used; Health Canada default values are applied.

User-defined Receptor

Name		Defaults
Age group	Toddler	Toddler
Lifestage duration (y)		4.5
Body weight (kg)		16.5
Soil ingestion rate (g/d)		0.08
Inhalation rate (m^3/d)		8.3
Water ingestion rate (L/d)		0.6
Time spent outdoors (h/d)		1.5
Skin surface area (cm^2)		
- hands		430
- arms		890
- legs		1690
- total		6130
Soil loading to exposed skin (g/cm^2/event)		
- hands		0.0001
- surfaces other than hands		0.00001
Soil monolayer loading rate (mg/cm^2)		5
Food ingestion (g/d)		
- root vegetables		105
- other vegetables		67
- fish		95
- wild game		85

User-defined Land-Use / Exposure Scenario

Scenario name	First Nations Traditional L	Defaults
Hours per day at site		24
Hours per day (outdoors)		
Days per week		7
Weeks per year	52	52
Dermal exposure events/day		1
Water contact events per day		1
Duration of water contact event (h)		1
Days/year contaminated food ingestion		365
Exposure duration (years)		60
Years for carcinogen amortization		60

HEALTH CANADA PQRA SPREADSHEET Version: **July 13, 2011**

OUTPUT SHEET : Toddler

User Name: KZK - BMC Site:
Proponent: BMC File #:
Date: October 16, 2017 Comment:

Exposure Scenario: **First Nations Traditional La** **Exposure Duration (y):** **4.5**
Native population considered

Chemical Properties	Units	Arsenic - non-cancer endpoint					
Tolerable daily intake	mg/kg/d	0.0003	NA	NA	NA	NA	NA
Tolerable concentration	mg/m3	NA	NA	NA	NA	NA	NA
Oral slope factor	$(mg/kg/d)^{-1}$	NA	NA	NA	NA	NA	NA
Inhalation slope factor	$(mg/kg/d)^{-1}$	NA	NA	NA	NA	NA	NA
Inhalation unit risk	$(mg/m^3)^{-1}$	NA	NA	NA	NA	NA	NA
Dermal slope factor	$(\mu g/cm^2/d)^{-1}$	NA	NA	NA	NA	NA	NA
Critical oral exposure benchmark		TDI	NA	NA	NA	NA	NA
Critical inhalation exposure benchmark		NA	NA	NA	NA	NA	NA
Critical dermal exposure benchmark		TDI	NA	NA	NA	NA	NA
Relative dermal absorption factor	unitless	0.03	1	1	1	1	1
Relative soil retention factor	unitless	NA	NA	NA	NA	NA	NA
Viable epidermal thickness factor	unitless	NA	NA	NA	NA	NA	NA
Test animal skin area	cm^{-2}	NA	NA	NA	NA	NA	NA

Chemical Concentrations	Units	Arsenic - non-cancer endpoint					
Soil	mg/kg	1.70E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Drinking water	mg/L	5.84E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Bathing/swimming water	mg/L	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Indoor air vapours	mg/m^3	NA	NA	NA	NA	NA	NA
Outdoor air vapours	mg/m^3	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Outdoor air particulate	mg/m^3	1.29E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Amortized total air concentration	mg/m^3	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Root vegetables	mg/kg wet wt	not evaluated	not evaluated	not evaluated	not evaluated	not evaluated	not evaluated
Other vegetables	mg/kg wet wt	2.50E-03	not evaluated	not evaluated	not evaluated	not evaluated	not evaluated
Fish	mg/kg wet wt	not evaluated	not evaluated	not evaluated	not evaluated	not evaluated	not evaluated
Wild game	mg/kg wet wt	not evaluated	not evaluated	not evaluated	not evaluated	not evaluated	not evaluated

RESULTS

	Exposure (mg/kg/d unless otherwise noted)					
	Arsenic - non-cancer endpoint					
Inadvertent ingestion of contaminated soil	8.24E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Inhalation of fugitive dust	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Inhalation of contaminant vapours - indoor	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Inhalation of contaminant vapours - outdoor	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ingestion of contaminated drinking water	2.12E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Dermal contact with contaminated soil	2.13E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Dermal contact with contaminated soil ($\mu g/cm^2/d$)	not calculated	not calculated	not calculated	not calculated	not calculated	not calculated
Dermal contact with contaminated water	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Dermal contact with contaminated water ($\mu g/cm^2/d$)	not calculated	not calculated	not calculated	not calculated	not calculated	not calculated
Ingestion of contaminated food	1.02E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total ingestion exposure	1.14E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total dermal exposure	2.13E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total dermal exposure ($\mu g/cm^2/d$)	not calculated	not calculated	not calculated	not calculated	not calculated	not calculated
Ingestion + dermal exposure	1.16E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total inhalation exposure	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total Exposure (sum of all pathways)	1.16E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

		Hazard/Risk Estimates					
		Arsenic - non-cancer endpoint					
Hazard Quotient - Oral/Dermal		3.86E-01	NA	NA	NA	NA	NA
Hazard Quotient - Inhalation		0.00E+00	NA	NA	NA	NA	NA
Hazard Index - Total		3.86E-01	NA	NA	NA	NA	NA
Target Hazard Index:	0.2	**Target Hazard Index Exceeded**					
Cancer Risk - Oral		NA	NA	NA	NA	NA	NA
Cancer Risk - Dermal		NA	NA	NA	NA	NA	NA
Cancer Risk - Oral + Dermal		NA	NA	NA	NA	NA	NA
Cancer Risk - Inhalation		NA	NA	NA	NA	NA	NA
Cancer Risk - Total		NA	NA	NA	NA	NA	NA
Target Cancer Risk:	1.00E-05						

HEALTH CANADA PQRA SPREADSHEET

USER INPUT SHEET

User Name:	KZK - BMC	Site:	
Proponent:	BMC	File #:	
Date:	October 16, 2017	Comment:	

PROBLEM FORMULATION

Potential Land Uses (Yes/No)		Default
Agricultural	No	Yes
Residential/urban parkland	No	Yes
Commercial with daycare	No	Yes
Commercial without daycare	No	Yes
Industrial	No	Yes
Industrial - outdoors	No	Yes
Urban recreational	No	Yes
Remote wild lands	No	Yes
Construction/utility work	No	Yes
Other	Yes	No
specify:	First Nations Traditional Land Use	

Operative Pathways (Yes/No)		Default
Inadvertent ingestion of soil		Yes
Inhalation of fugitive dust		Yes
Inhalation of indoor contaminant vapours	Yes	Yes
Inhalation of outdoor contaminant vapours	Yes	Yes
Ingestion of drinking water		Yes
Dermal contact with soil		Yes
Dermal contact with water		Yes
Ingestion of contaminated food	Yes	No

Vapour Transport Modelling

		Default
Vapour source for exposure calculations		Most Conservative

		Default
Exposure Scenario	First Nations Traditional Land Use	First Nations Traditional La

Active Critical Receptors (Yes/No)		Default
Infant		Yes
Toddler		Yes
Child		Yes
Teen		Yes
Adult		Yes
Construction/Utility Worker		No
Other		No
specify:		

Receptor Groups (Yes/No)		Default
General public or residents	No	Yes
Employees	No	Yes
Canadian native communities	Yes	No
Other	Yes	No
specify:	First Nations Land Use - 1 Week Per	

Contaminant Concentrations

Chemical Name	required	Arsenic	Cadmium				
Soil (mg/kg)	required	17	0.91				
Groundwater - source (mg/L)	optional						
Drinking water (mg/L)	optional	0.000584	0.0000573				
Bathing/swimming water (mg/L)	optional						
Indoor air - vapours (mg/m^3)	optional						
Outdoor air - vapours (mg/m^3)	optional						
Outdoor air - particulate (mg/m^3)	optional						
Root vegetables (mg/kg wet weight)	optional						
Other vegetables (mg/kg wet weight)	optional	0.0025	0.0481				
Fish (mg/kg wet weight)	optional						
Wild game (mg/kg wet weight)	optional						

Risk Assessment Endpoints		Default
Acceptable hazard index:		0.2
Acceptable cancer risk:		1.00E-05
Evaluate Early Lifestage Cancer Risks?		No

Precluding Conditions for Fate and Transport Models	
Are non-aqueous phase liquids (NAPL) present?	No
Is groundwater contamination present in fractured bedrock?	No
Is groundwater contamination migrating through a confined aquifer?	No
Is there active pumping or drawdown of groundwater at the site?	No
Is contamination present within 1 m of building foundation?	No
Do any buildings within 5 m of contamination have earthen foundations?	No
Are any buildings constructed on very high permeability media?	No
Are there preferential vapour flow pathways connecting contamination to a building?	No

FATE AND TRANSPORT MODEL INPUT

	Value	Default	Models Affected
Soil Type		coarse-grained	PS, V-I, V-O, GW
Significant vehicle traffic on unpaved roads?		No	P-O
Site Characteristics			
Depth to Groundwater (m)		3	GW, V-O
Depth from Surface to Contamination (m)		0	GW, V-O
Distance - Contaminated Soil to Building (m)		1	V-I
Distance - Contaminated GW to Building (m)		1	V-I
Distance to potable water user (m)		0	GW
Distance to Bathing/Swimming Water (m)		0	GW
Particulate Concentration in Air (ug/m^3)		0.76	P-O
Apply biodegradation during GW transport?		No	GW
Building Type		Residential	V-I

OPTIONAL SECTIONS

NOTE: user-defined chemicals should be named in this section before being selected in the 'Contaminant Concentrations' table above

User-defined Chemicals

Enter all applicable and appropriate toxicity benchmarks; values must be referenced and justified in the PQRA report.

	Chemical 1	Chemical 2	Chemical 3
Name			
CAS Number			
Chemical class (organic/inorganic)			
Tolerable daily intake (mg/kg/d) - infant			
Tolerable daily intake (mg/kg/d) - toddler			
Tolerable daily intake (mg/kg/d) - child			
Tolerable daily intake (mg/kg/d) - teen			
Tolerable daily intake (mg/kg/d) - adult			
Tolerable concentration (mg/m^3)			
Oral slope factor $(mg/kg/d)^{-1}$			
Dermal slope factor $(\mu g/cm^2/d)^{-1}$			
Inhalation slope factor $(mg/kg/d)^{-1}$			
Inhalation unit risk $(mg/m^3)^{-1}$			
Relative dermal absorption factor			
Relative retention factor from soil			
Viable epidermal thickness factor			
Test animal skin area (cm^2)			
Organic carbon partitioning coefficient (mL/g) - Koc			
Log Kow (unitless)			
Henry's Law constant at 25°C (unitless) - H'			
Henry's Law constant at 25°C (atm-m3/mol) - H			
Water Solubility at 25°C (mg/L)			
Molecular Weight (g/mol)			
Vapour Pressure at 25°C (atm)			

NOTE: values in grayed cells will not be used; Health Canada default values are applied.

User-defined Receptor

Name		Defaults
Age group	Adult	Toddler
Lifestage duration (y)		60
Body weight (kg)		70.7
Soil ingestion rate (g/d)		0.02
Inhalation rate (m^3/d)		16.6
Water ingestion rate (L/d)		1.5
Time spent outdoors (h/d)		1.5
Skin surface area (cm^2)		
- hands		890
- arms		2500
- legs		5720
- total		17640
Soil loading to exposed skin (g/cm^2/event)		
- hands		0.0001
- surfaces other than hands		0.00001
Soil monolayer loading rate (mg/cm^2)		5
Food ingestion (g/d)		
- root vegetables		188
- other vegetables	2.634615385	137
- fish		220
- wild game		270

User-defined Land-Use / Exposure Scenario

Scenario name	First Nations Traditional L	Defaults
Hours per day at site		24
Hours per day (outdoors)		
Days per week		7
Weeks per year	1	52
Dermal exposure events/day		1
Water contact events per day		1
Duration of water contact event (h)		1
Days/year contaminated food ingestion		365
Exposure duration (years)		60
Years for carcinogen amortization		60

HEALTH CANADA PQRA SPREADSHEET Version: **July 13, 2011**
OUTPUT SHEET - User-Defined Receptor **Adult** **RECEPTOR NOT ACTIVE**

User Name:	KZK - BMC	Site:	
Proponent:	BMC	File #:	
Date:	October 16, 2017	Comment:	
Exposure Scenario:	**First Nations Tr**		
Native population considered			
Lifestage for Cancer Risks	**Adult**		
Exposure Duration (y):	**60**		

User-Defined Receptor Characteristics	Skin surface area (cm2) - hands: 890	
Body weight (kg): 70.7	- arms: 2500	Food ingestion rates (g/d)
Soil ingestion rate (g/d): 0.02	- legs: 5720	Root vegetables: 188
Inhalation rate (m3/d): 16.6	- total: 17640	Other vegetables: 2.63461538461538
Water ingestion rate (L/d): 1.5	Soil loading (g/cm2-event) - hands: 0.0001	Fish: 220
	- other: 0.00001	Wild game: 270

Chemical Properties	Units	Arsenic	Cadmium				
Tolerable daily intake	mg/kg/d	NA	0.001	NA	NA	NA	NA
Tolerable concentration	mg/m^3	NA	NA	NA	NA	NA	NA
Oral slope factor	$(mg/kg/d)^{-1}$	1.8	NA	NA	NA	NA	NA
Inhalation slope factor	$(mg/kg/d)^{-1}$	28	42.9	NA	NA	NA	NA
Inhalation unit risk	$(mg/m^3)^{-1}$	6.4	9.8	NA	NA	NA	NA
Dermal slope factor	$(\mu g/cm^2/d)^{-1}$	NA	NA	NA	NA	NA	NA
Critical oral exposure benchmark		oral slope factor	TDI	NA	NA	NA	NA
Critical inhalation exposure benchmark		inhalation slope factor	inhalation slope factor	NA	NA	NA	NA
Critical dermal exposure benchmark		oral slope factor	TDI	NA	NA	NA	NA
Relative dermal absorption factor	unitless	0.03	0.01	1	1	1	1
Relative soil retention factor	unitless	NA	NA	NA	NA	NA	NA
Viable epidermal thickness factor	unitless	NA	NA	NA	NA	NA	NA
Test animal skin area	cm^{-2}	NA	NA	NA	NA	NA	NA

Chemical Concentrations	Units	Arsenic	Cadmium				
Soil	mg/kg	1.70E+01	9.10E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Drinking water	mg/L	5.84E-04	5.73E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Bathing/swimming water	mg/L	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Indoor air vapours	mg/m^3	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Outdoor air vapours	mg/m^3	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Outdoor air particulate	mg/m^3	1.29E-08	6.92E-10	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Amortized total air concentration	mg/m^3	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Root vegetables	mg/kg wet wt	not evaluated	not evaluated	not evaluated	not evaluated	not evaluated	not evaluated
Other vegetables	mg/kg wet wt	2.50E-03	4.81E-02	not evaluated	not evaluated	not evaluated	not evaluated
Fish	mg/kg wet wt	not evaluated	not evaluated	not evaluated	not evaluated	not evaluated	not evaluated
Wild game	mg/kg wet wt	not evaluated	not evaluated	not evaluated	not evaluated	not evaluated	not evaluated

RESULTS

	Exposure (mg/kg/d unless otherwise noted)					
	Arsenic	Cadmium				
Inadvertent ingestion of contaminated soil	9.25E-08	4.95E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Inhalation of fugitive dust	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Inhalation of contaminant vapours - indoor	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Inhalation of contaminant vapours - outdoor	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ingestion of contaminated drinking water	2.38E-07	2.34E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Dermal contact with contaminated soil	2.37E-08	4.24E-10	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Dermal contact with contaminated soil ($\mu g/cm^2/d$)	not calculated	not calculated	not calculated	not calculated	not calculated	not calculated
Dermal contact with contaminated water	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Dermal contact with contaminated water ($\mu g/cm^2/d$)	not calculated	not calculated	not calculated	not calculated	not calculated	not calculated
Ingestion of contaminated food	9.32E-08	1.79E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total ingestion exposure	4.24E-07	1.82E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total dermal exposure	2.37E-08	4.24E-10	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total dermal exposure ($\mu g/cm^2/d$)	not calculated	not calculated	not calculated	not calculated	not calculated	not calculated
Ingestion + dermal exposure	4.48E-07	1.82E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total inhalation exposure	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total Exposure (sum of all pathways)	4.48E-07	1.82E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00

		Hazard/Risk Estimates					
		Arsenic	Cadmium				
Hazard Quotient - Oral/Dermal		NA	1.82E-03	NA	NA	NA	NA
Hazard Quotient - Inhalation		NA	0.00E+00	NA	NA	NA	NA
Hazard Index - Total		NA	1.82E-03	NA	NA	NA	NA
Target Hazard Index:	0.2						
Cancer Risk - Oral		7.63E-07	NA	NA	NA	NA	NA
Cancer Risk - Dermal		4.27E-08	NA	NA	NA	NA	NA
Cancer Risk - Oral + Dermal		8.06E-07	NA	NA	NA	NA	NA
Cancer Risk - Inhalation		0.00E+00	0.00E+00	NA	NA	NA	NA
Cancer Risk - Total		8.06E-07	0.00E+00	NA	NA	NA	NA
Target Cancer Risk:	1.00E-05						

Risk Estimates: Maximum Concentrations at Baseline

HEALTH CANADA PQRA SPREADSHEET

USER INPUT SHEET

User Name:	KZK - BMC	Site:	
Proponent:	BMC	File #:	
Date:	October 16, 2017	Comment:	

PROBLEM FORMULATION

Potential Land Uses (Yes/No)

		Default
Agricultural	No	Yes
Residential/urban parkland	No	Yes
Commercial with daycare	No	Yes
Commercial without daycare	No	Yes
Industrial	No	Yes
Industrial - outdoors	No	Yes
Urban recreational	No	Yes
Remote wild lands	No	Yes
Construction/utility work	No	Yes
Other	Yes	No
specify:	First Nations Traditional Land Use	

Operative Pathways (Yes/No)

		Default
Inadvertent ingestion of soil		Yes
Inhalation of fugitive dust		Yes
Inhalation of indoor contaminant vapours	No	Yes
Inhalation of outdoor contaminant vapours	No	Yes
Ingestion of drinking water		Yes
Dermal contact with soil		Yes
Dermal contact with water		Yes
Ingestion of contaminated food	Yes	No

Vapour Transport Modelling

Vapour source for exposure calculations		Most Conservative

Exposure Scenario | | First Nations Traditional La

Active Critical Receptors (Yes/No)

		Default
Infant		Yes
Toddler		Yes
Child		Yes
Teen		Yes
Adult		Yes
Construction/Utility Worker		No
Other		No
specify:		

Receptor Groups (Yes/No)

		Default
General public or residents	No	Yes
Employees	No	Yes
Canadian native communities	Yes	No
Other	Yes	No
specify:	First Nations Land Use - 1 Week Per	

Contaminant Concentrations

Chemical Name	required	Lead	Cadmium	Fluoride	Copper	Selenium	Zinc
Soil (mg/kg)	required	72	7.84	0	192	6.52	784
Groundwater - source (mg/L)	optional						
Drinking water (mg/L)	optional	0.00223	0.00081	0.12	0.00342	0.00157	0.055
Bathing/swimming water (mg/L)	optional						
Indoor air - vapours (mg/m^3)	optional						
Outdoor air - vapours (mg/m^3)	optional						
Outdoor air - particulate (mg/m^3)	optional						
Root vegetables (mg/kg wet weight)	optional						
Other vegetables (mg/kg wet weight)	optional	0.0086	0.136	0	1.83	0.005	4.46
Fish (mg/kg wet weight)	optional						
Wild game (mg/kg wet weight)	optional						

Risk Assessment Endpoints

		Default
Acceptable hazard index:		0.2
Acceptable cancer risk:		1.00E-05
Evaluate Early Lifestage Cancer Risks?		No

Precluding Conditions for Fate and Transport Models

All precluding conditions questions should be answered

Are non-aqueous phase liquids (NAPL) present?	
Is groundwater contamination present in fractured bedrock?	
Is groundwater contamination migrating through a confined aquifer?	
Is there active pumping or drawdown of groundwater at the site?	
Is contamination present within 1 m of building foundation?	
Do any buildings within 5 m of contamination have earthen foundations?	
Are any buildings constructed on very high permeability media?	
Are there preferential vapour flow pathways connecting contamination to a building?	

FATE AND TRANSPORT MODEL INPUT

	Value	Default	Models Affected
Soil Type		coarse-grained	PS, V-I, V-O, GW
Significant vehicle traffic on unpaved roads?		No	P-O
Site Characteristics			
Depth to Groundwater (m)		3	GW, V-O
Depth from Surface to Contamination (m)		0	GW, V-O
Distance - Contaminated Soil to Building (m)		1	V-I
Distance - Contaminated GW to Building (m)		1	V-I
Distance to potable water user (m)		0	GW
Distance to Bathing/Swimming Water (m)		0	GW
Particulate Concentration in Air (ug/m^3)		0.76	P-O
Apply biodegradation during GW transport?		No	GW
Building Type		Residential	V-I

OPTIONAL SECTIONS

NOTE: user-defined chemicals should be named in this section before being selected in the 'Contaminant Concentrations' table above

User-defined Chemicals

	Chemical 1	Chemical 2	Chemical 3
Name	Lead	Fluoride	
CAS Number			
Chemical class (organic/inorganic)			
Tolerable daily intake (mg/kg/d) - infant	0.0006	0.105	
Tolerable daily intake (mg/kg/d) - toddler	0.0006	0.105	
Tolerable daily intake (mg/kg/d) - child	0.0006	0.105	
Tolerable daily intake (mg/kg/d) - teen	0.0006	0.105	
Tolerable daily intake (mg/kg/d) - adult	0.0006	0.105	
Tolerable concentration (mg/m^3)			
Oral slope factor $(mg/kg/d)^{-1}$			
Dermal slope factor $(\mu g/cm^2/d)^{-1}$			
Inhalation slope factor $(mg/kg/d)^{-1}$			
Inhalation unit risk $(mg/m^3)^{-1}$			
Relative dermal absorption factor	0.006		
Relative retention factor from soil			
Viable epidermal thickness factor			
Test animal skin area (cm^2)			
Organic carbon partitioning coefficient (mL/g) - Koc			
Log Kow (unitless)			
Henry's Law constant at 25°C (unitless) - H'			
Henry's Law constant at 25°C (atm-m3/mol) - H			
Water Solubility at 25°C (mg/L)			
Molecular Weight (g/mol)			
Vapour Pressure at 25°C (atm)			

Enter all applicable and appropriate toxicity benchmarks; values must be referenced and justified in the PQRA report.

NOTE: values in grayed cells will not be used; Health Canada default values are applied.

User-defined Receptor

Name		Defaults
Age group	Toddler	Toddler
Lifestage duration (y)		4.5
Body weight (kg)		16.5
Soil ingestion rate (g/d)		0.08
Inhalation rate (m^3/d)		8.3
Water ingestion rate (L/d)		0.6
Time spent outdoors (h/d)		1.5
Skin surface area (cm^2)		
- hands		430
- arms		890
- legs		1690
- total		6130
Soil loading to exposed skin (g/cm^2/event)		
- hands		0.0001
- surfaces other than hands		0.00001
Soil monolayer loading rate (mg/cm^2)		5
Food ingestion (g/d)		
- root vegetables		105
- other vegetables		67
- fish		95
- wild game		85

User-defined Land-Use / Exposure Scenario

Scenario name	First Nations Traditional L	Defaults
Hours per day at site		24
Hours per day (outdoors)		
Days per week		7
Weeks per year	52	52
Dermal exposure events/day		1
Water contact events per day		1
Duration of water contact event (h)		1
Days/year contaminated food ingestion		365
Exposure duration (years)		60
Years for carcinogen amortization		60

HEALTH CANADA PQRA SPREADSHEET Version: **July 13, 2011**

OUTPUT SHEET : Toddler

User Name:	KZK - BMC	Site:	
Proponent:	BMC	File #:	
Date:	October 16, 2017	Comment:	

Exposure Scenario: **First Nations Traditional La** **Exposure Duration (y):** **4.5**

Native population considered

Chemical Properties	Units	Lead	Cadmium	Fluoride	Copper	Selenium	Zinc
Tolerable daily intake	mg/kg/d	0.0006	0.001	0.105	0.09	0.0062	0.5
Tolerable concentration	mg/m^3	NA	NA	NA	NA	NA	NA
Oral slope factor	$(mg/kg/d)^{-1}$	NA	NA	NA	NA	NA	NA
Inhalation slope factor	$(mg/kg/d)^{-1}$	NA	NA	NA	NA	NA	NA
Inhalation unit risk	$(mg/m^3)^{-1}$	NA	NA	NA	NA	NA	NA
Dermal slope factor	$(\mu g/cm^2/d)^{-1}$	NA	NA	NA	NA	NA	NA
Critical oral exposure benchmark		TDI	TDI	TDI	TDI	TDI	TDI
Critical inhalation exposure benchmark		NA	NA	NA	NA	NA	NA
Critical dermal exposure benchmark		TDI	TDI	TDI	TDI	TDI	TDI
Relative dermal absorption factor	unitless	0.006	0.01	1	0.06	0.01	0.1
Relative soil retention factor	unitless	NA	NA	NA	NA	NA	NA
Viable epidermal thickness factor	unitless	NA	NA	NA	NA	NA	NA
Test animal skin area	cm^{-2}	NA	NA	NA	NA	NA	NA

Chemical Concentrations	Units	Lead	Cadmium	Fluoride	Copper	Selenium	Zinc
Soil	mg/kg	7.20E+01	7.84E+00	0.00E+00	1.92E+02	6.52E+00	7.84E+02
Drinking water	mg/L	2.23E-03	8.10E-04	1.20E-01	3.42E-03	1.57E-03	5.50E-02
Bathing/swimming water	mg/L	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Indoor air vapours	mg/m^3	NA	NA	NA	NA	NA	NA
Outdoor air vapours	mg/m^3	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Outdoor air particulate	mg/m^3	5.47E-08	5.96E-09	0.00E+00	1.46E-07	4.96E-09	5.96E-07
Amortized total air concentration	mg/m^3	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Root vegetables	mg/kg wet wt	not evaluated	not evaluated	not evaluated	not evaluated	not evaluated	not evaluated
Other vegetables	mg/kg wet wt	8.60E-03	1.36E-01	0.00E+00	1.83E+00	5.00E-03	4.46E+00
Fish	mg/kg wet wt	not evaluated	not evaluated	not evaluated	not evaluated	not evaluated	not evaluated
Wild game	mg/kg wet wt	not evaluated	not evaluated	not evaluated	not evaluated	not evaluated	not evaluated

RESULTS

	Exposure (mg/kg/d unless otherwise noted)					
	Lead	Cadmium	Fluoride	Copper	Selenium	Zinc
Inadvertent ingestion of contaminated soil	3.49E-04	3.80E-05	0.00E+00	9.31E-04	3.16E-05	3.80E-03
Inhalation of fugitive dust	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Inhalation of contaminant vapours - indoor	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Inhalation of contaminant vapours - outdoor	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ingestion of contaminated drinking water	8.11E-05	2.95E-05	4.36E-03	1.24E-04	5.71E-05	2.00E-03
Dermal contact with contaminated soil	1.80E-06	3.27E-07	0.00E+00	4.80E-05	2.72E-07	3.27E-04
Dermal contact with contaminated soil ($\mu g/cm^2/d$)	not calculated	not calculated	not calculated	not calculated	not calculated	not calculated
Dermal contact with contaminated water	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Dermal contact with contaminated water ($\mu g/cm^2/d$)	not calculated	not calculated	not calculated	not calculated	not calculated	not calculated
Ingestion of contaminated food	3.49E-05	5.52E-04	0.00E+00	7.43E-03	2.03E-05	1.81E-02
Total ingestion exposure	4.65E-04	6.20E-04	4.36E-03	8.49E-03	1.09E-04	2.39E-02
Total dermal exposure	1.80E-06	3.27E-07	0.00E+00	4.80E-05	2.72E-07	3.27E-04
Total dermal exposure ($\mu g/cm^2/d$)	not calculated	not calculated	not calculated	not calculated	not calculated	not calculated
Ingestion + dermal exposure	4.67E-04	6.20E-04	4.36E-03	8.53E-03	1.09E-04	2.42E-02
Total inhalation exposure	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total Exposure (sum of all pathways)	4.67E-04	6.20E-04	4.36E-03	8.53E-03	1.09E-04	2.42E-02

		Hazard/Risk Estimates					
		Lead	Cadmium	Fluoride	Copper	Selenium	Zinc
Hazard Quotient - Oral/Dermal		7.78E-01	6.20E-01	4.16E-02	9.48E-02	1.76E-02	4.85E-02
Hazard Quotient - Inhalation		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Hazard Index - Total		7.78E-01	6.20E-01	4.16E-02	9.48E-02	1.76E-02	4.85E-02
Target Hazard Index:	0.2	**Target Hazard Index Exceeded**	**Target Hazard Index Exceeded**				
Cancer Risk - Oral		NA	NA	NA	NA	NA	NA
Cancer Risk - Dermal		NA	NA	NA	NA	NA	NA
Cancer Risk - Oral + Dermal		NA	NA	NA	NA	NA	NA
Cancer Risk - Inhalation		NA	NA	NA	NA	NA	NA
Cancer Risk - Total		NA	NA	NA	NA	NA	NA
Target Cancer Risk:	1.00E-05						

HEALTH CANADA PQRA SPREADSHEET

USER INPUT SHEET

User Name:	KZK - BMC	Site:	
Proponent:	BMC	File #:	
Date:	October 16, 2017	Comment:	

PROBLEM FORMULATION

Potential Land Uses (Yes/No)		Default
Agricultural	No	Yes
Residential/urban parkland	No	Yes
Commercial with daycare	No	Yes
Commercial without daycare	No	Yes
Industrial	No	Yes
Industrial - outdoors	No	Yes
Urban recreational	No	Yes
Remote wild lands	No	Yes
Construction/utility work	No	Yes
Other	Yes	No
specify:	First Nations Traditional Land Use	

Operative Pathways (Yes/No)		Default
Inadvertent ingestion of soil		Yes
Inhalation of fugitive dust		Yes
Inhalation of indoor contaminant vapours	No	Yes
Inhalation of outdoor contaminant vapours	No	Yes
Ingestion of drinking water		Yes
Dermal contact with soil		Yes
Dermal contact with water		Yes
Ingestion of contaminated food	Yes	No

Vapour Transport Modelling		
Vapour source for exposure calculations		Most Conservative

Exposure Scenario | | First Nations Traditional La

Active Critical Receptors (Yes/No)		Default
Infant		Yes
Toddler		Yes
Child		Yes
Teen		Yes
Adult		Yes
Construction/Utility Worker		No
Other		No
specify:		

Receptor Groups (Yes/No)		Default
General public or residents	No	Yes
Employees	No	Yes
Canadian native communities	Yes	No
Other	Yes	No
specify:	First Nations Land Use - 1 Week Per	

Contaminant Concentrations								
Chemical Name	required	Arsenic - non-cancer endpoint						
Soil (mg/kg)	required	96						
Groundwater - source (mg/L)	optional							
Drinking water (mg/L)	optional	0.00318						
Bathing/swimming water (mg/L)	optional							
Indoor air - vapours (mg/m^3)	optional							
Outdoor air - vapours (mg/m^3)	optional							
Outdoor air - particulate (mg/m^3)	optional							
Root vegetables (mg/kg wet weight)	optional							
Other vegetables (mg/kg wet weight)	optional	0.0025						
Fish (mg/kg wet weight)	optional							
Wild game (mg/kg wet weight)	optional							

Risk Assessment Endpoints		Default
Acceptable hazard index:		0.2
Acceptable cancer risk:		1.00E-05
Evaluate Early Lifestage Cancer Risks?		No

Precluding Conditions for Fate and Transport Models

All precluding conditions questions should be answered

Are non-aqueous phase liquids (NAPL) present?	
Is groundwater contamination present in fractured bedrock?	
Is groundwater contamination migrating through a confined aquifer?	
Is there active pumping or drawdown of groundwater at the site?	
Is contamination present within 1 m of building foundation?	
Do any buildings within 5 m of contamination have earthen foundations?	
Are any buildings constructed on very high permeability media?	
Are there preferential vapour flow pathways connecting contamination to a building?	

FATE AND TRANSPORT MODEL INPUT

	Value	Default	Models Affected
Soil Type		coarse-grained	PS, V-I, V-O, GW
Significant vehicle traffic on unpaved roads?		No	P-O
Site Characteristics			
Depth to Groundwater (m)		3	GW, V-O
Depth from Surface to Contamination (m)		0	GW, V-O
Distance - Contaminated Soil to Building (m)		1	V-I
Distance - Contaminated GW to Building (m)		1	V-I
Distance to potable water user (m)		0	GW
Distance to Bathing/Swimming Water (m)		0	GW
Particulate Concentration in Air (ug/m^3)		0.76	P-O
Apply biodegradation during GW transport?		No	GW
Building Type		Residential	V-I

OPTIONAL SECTIONS

User-defined Chemicals

NOTE: user-defined chemicals should be named in this section before being selected in the 'Contaminant Concentrations' table above

Enter all applicable and appropriate toxicity benchmarks; values must be referenced and justified in the PQRA report.

	Chemical 1	Chemical 2	Chemical 3
Name	Arsenic - non-cancer endpoint		
CAS Number			
Chemical class (organic/inorganic)			
Tolerable daily intake (mg/kg/d) - infant			
Tolerable daily intake (mg/kg/d) - toddler	0.0003		
Tolerable daily intake (mg/kg/d) - child			
Tolerable daily intake (mg/kg/d) - teen			
Tolerable daily intake (mg/kg/d) - adult			
Tolerable concentration (mg/m^3)			
Oral slope factor $(mg/kg/d)^{-1}$			
Dermal slope factor $(\mu g/cm^2/d)^{-1}$			
Inhalation slope factor $(mg/kg/d)^{-1}$			
Inhalation unit risk $(mg/m^3)^{-1}$			
Relative dermal absorption factor	0.03		
Relative retention factor from soil			
Viable epidermal thickness factor			
Test animal skin area (cm^2)			
Organic carbon partitioning coefficient (mL/g) - Koc			
Log Kow (unitless)			
Henry's Law constant at 25°C (unitless) - H'			
Henry's Law constant at 25°C (atm-m3/mol) - H			
Water Solubility at 25°C (mg/L)			
Molecular Weight (g/mol)			
Vapour Pressure at 25°C (atm)			

NOTE: values in grayed cells will not be used; Health Canada default values are applied.

User-defined Receptor

Name		Defaults
Age group	Toddler	Toddler
Lifestage duration (y)		4.5
Body weight (kg)		16.5
Soil ingestion rate (g/d)		0.08
Inhalation rate (m^3/d)		8.3
Water ingestion rate (L/d)		0.6
Time spent outdoors (h/d)		1.5
Skin surface area (cm^2)		
- hands		430
- arms		890
- legs		1690
- total		6130
Soil loading to exposed skin (g/cm^2/event)		
- hands		0.0001
- surfaces other than hands		0.00001
Soil monolayer loading rate (mg/cm^2)		5
Food ingestion (g/d)		
- root vegetables		105
- other vegetables		67
- fish		95
- wild game		85

User-defined Land-Use / Exposure Scenario

Scenario name	First Nations Traditional L	Defaults
Hours per day at site		24
Hours per day (outdoors)		
Days per week		7
Weeks per year	52	52
Dermal exposure events/day		1
Water contact events per day		1
Duration of water contact event (h)		1
Days/year contaminated food ingestion		365
Exposure duration (years)		60
Years for carcinogen amortization		60

HEALTH CANADA PQRA SPREADSHEET Version: **July 13, 2011**

OUTPUT SHEET : Toddler

User Name:	KZK - BMC	Site:	
Proponent:	BMC	File #:	
Date:	October 16, 2017	Comment:	

Exposure Scenario: **First Nations Traditional La Exposure Duration (y):** **4.5**

Native population considered

Chemical Properties	Units	Arsenic - non-cancer endpoint					
Tolerable daily intake	mg/kg/d	0.0003	NA	NA	NA	NA	NA
Tolerable concentration	mg/m^3	NA	NA	NA	NA	NA	NA
Oral slope factor	$(mg/kg/d)^{-1}$	NA	NA	NA	NA	NA	NA
Inhalation slope factor	$(mg/kg/d)^{-1}$	NA	NA	NA	NA	NA	NA
Inhalation unit risk	$(mg/m^3)^{-1}$	NA	NA	NA	NA	NA	NA
Dermal slope factor	$(\mu g/cm^2/d)^{-1}$	NA	NA	NA	NA	NA	NA
Critical oral exposure benchmark		TDI	NA	NA	NA	NA	NA
Critical inhalation exposure benchmark		NA	NA	NA	NA	NA	NA
Critical dermal exposure benchmark		TDI	NA	NA	NA	NA	NA
Relative dermal absorption factor	unitless	0.03	1	1	1	1	1
Relative soil retention factor	unitless	NA	NA	NA	NA	NA	NA
Viable epidermal thickness factor	unitless	NA	NA	NA	NA	NA	NA
Test animal skin area	cm^{-2}	NA	NA	NA	NA	NA	NA

Chemical Concentrations	Units	Arsenic - non-cancer endpoint					
Soil	mg/kg	9.60E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Drinking water	mg/L	3.18E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Bathing/swimming water	mg/L	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Indoor air vapours	mg/m^3	NA	NA	NA	NA	NA	NA
Outdoor air vapours	mg/m^3	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Outdoor air particulate	mg/m^3	7.30E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Amortized total air concentration	mg/m^3	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Root vegetables	mg/kg wet wt	not evaluated	not evaluated	not evaluated	not evaluated	not evaluated	not evaluated
Other vegetables	mg/kg wet wt	2.50E-03	not evaluated	not evaluated	not evaluated	not evaluated	not evaluated
Fish	mg/kg wet wt	not evaluated	not evaluated	not evaluated	not evaluated	not evaluated	not evaluated
Wild game	mg/kg wet wt	not evaluated	not evaluated	not evaluated	not evaluated	not evaluated	not evaluated

RESULTS

	Exposure (mg/kg/d unless otherwise noted)					
	Arsenic - non-cancer endpoint					
Inadvertent ingestion of contaminated soil	4.65E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Inhalation of fugitive dust	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Inhalation of contaminant vapours - indoor	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Inhalation of contaminant vapours - outdoor	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ingestion of contaminated drinking water	1.16E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Dermal contact with contaminated soil	1.20E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Dermal contact with contaminated soil ($\mu g/cm^2/d$)	not calculated	not calculated	not calculated	not calculated	not calculated	not calculated
Dermal contact with contaminated water	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Dermal contact with contaminated water ($\mu g/cm^2/d$)	not calculated	not calculated	not calculated	not calculated	not calculated	not calculated
Ingestion of contaminated food	1.02E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total ingestion exposure	5.91E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total dermal exposure	1.20E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total dermal exposure ($\mu g/cm^2/d$)	not calculated	not calculated	not calculated	not calculated	not calculated	not calculated
Ingestion + dermal exposure	6.03E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total inhalation exposure	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total Exposure (sum of all pathways)	6.03E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

		Hazard/Risk Estimates					
		Arsenic - non-cancer endpoint					
Hazard Quotient - Oral/Dermal		2.01E+00	NA	NA	NA	NA	NA
Hazard Quotient - Inhalation		0.00E+00	NA	NA	NA	NA	NA
Hazard Index - Total		2.01E+00	NA	NA	NA	NA	NA
Target Hazard Index:	0.2	**Target Hazard Index Exceeded**					
Cancer Risk - Oral		NA	NA	NA	NA	NA	NA
Cancer Risk - Dermal		NA	NA	NA	NA	NA	NA
Cancer Risk - Oral + Dermal		NA	NA	NA	NA	NA	NA
Cancer Risk - Inhalation		NA	NA	NA	NA	NA	NA
Cancer Risk - Total		NA	NA	NA	NA	NA	NA
Target Cancer Risk:	1.00E-05						

HEALTH CANADA PQRA SPREADSHEET

USER INPUT SHEET

User Name:	KZK - BMC	Site:	
Proponent:	BMC	File #:	
Date:	October 16, 2017	Comment:	

PROBLEM FORMULATION

Potential Land Uses (Yes/No)		Default
Agricultural	No	Yes
Residential/urban parkland	No	Yes
Commercial with daycare	No	Yes
Commercial without daycare	No	Yes
Industrial	No	Yes
Industrial - outdoors	No	Yes
Urban recreational	No	Yes
Remote wild lands	No	Yes
Construction/utility work	No	Yes
Other	Yes	No
specify:	First Nations Traditional Land Use	

Operative Pathways (Yes/No)		Default
Inadvertent ingestion of soil		Yes
Inhalation of fugitive dust		Yes
Inhalation of indoor contaminant vapours	Yes	Yes
Inhalation of outdoor contaminant vapours	Yes	Yes
Ingestion of drinking water		Yes
Dermal contact with soil		Yes
Dermal contact with water		Yes
Ingestion of contaminated food	Yes	No

Vapour Transport Modelling		
Vapour source for exposure calculations		Most Conservative

Exposure Scenario	First Nations Traditional Land Use	First Nations Traditional La

Active Critical Receptors (Yes/No)		Default
Infant		Yes
Toddler		Yes
Child		Yes
Teen		Yes
Adult		Yes
Construction/Utility Worker		No
Other		No
specify:		

Receptor Groups (Yes/No)		Default
General public or residents	No	Yes
Employees	No	Yes
Canadian native communities	Yes	No
Other	Yes	No
specify:	First Nations Land Use - 1 Week Per	

Contaminant Concentrations								
Chemical Name	required	Arsenic	Cadmium					
Soil (mg/kg)	required	96	7.84					
Groundwater - source (mg/L)	optional							
Drinking water (mg/L)	optional	0.00318	0.00081					
Bathing/swimming water (mg/L)	optional							
Indoor air - vapours (mg/m^3)	optional							
Outdoor air - vapours (mg/m^3)	optional							
Outdoor air - particulate (mg/m^3)	optional							
Root vegetables (mg/kg wet weight)	optional							
Other vegetables (mg/kg wet weight)	optional	0.0025	0.136					
Fish (mg/kg wet weight)	optional							
Wild game (mg/kg wet weight)	optional							

Risk Assessment Endpoints		Default
Acceptable hazard index:		0.2
Acceptable cancer risk:		1.00E-05
Evaluate Early Lifestage Cancer Risks?		No

Precluding Conditions for Fate and Transport Models	
Are non-aqueous phase liquids (NAPL) present?	No
Is groundwater contamination present in fractured bedrock?	No
Is groundwater contamination migrating through a confined aquifer?	No
Is there active pumping or drawdown of groundwater at the site?	No
Is contamination present within 1 m of building foundation?	No
Do any buildings within 5 m of contamination have earthen foundations?	No
Are any buildings constructed on very high permeability media?	No
Are there preferential vapour flow pathways connecting contamination to a building?	No

FATE AND TRANSPORT MODEL INPUT

	Value	Default	Models Affected
Soil Type		coarse-grained	PS, V-I, V-O, GW
Significant vehicle traffic on unpaved roads?		No	P-O
Site Characteristics			
Depth to Groundwater (m)		3	GW, V-O
Depth from Surface to Contamination (m)		0	GW, V-O
Distance - Contaminated Soil to Building (m)		1	V-I
Distance - Contaminated GW to Building (m)		1	V-I
Distance to potable water user (m)		0	GW
Distance to Bathing/Swimming Water (m)		0	GW
Particulate Concentration in Air (ug/m^3)		0.76	P-O
Apply biodegradation during GW transport?		No	GW
Building Type		Residential	V-I

OPTIONAL SECTIONS

NOTE: user-defined chemicals should be named in this section before being selected in the 'Contaminant Concentrations' table above

User-defined Chemicals

Enter all applicable and appropriate toxicity benchmarks; values must be referenced and justified in the PQRA report.

	Chemical 1	Chemical 2	Chemical 3
Name			
CAS Number			
Chemical class (organic/inorganic)			
Tolerable daily intake (mg/kg/d) - infant			
Tolerable daily intake (mg/kg/d) - toddler			
Tolerable daily intake (mg/kg/d) - child			
Tolerable daily intake (mg/kg/d) - teen			
Tolerable daily intake (mg/kg/d) - adult			
Tolerable concentration (mg/m^3)			
Oral slope factor $(mg/kg/d)^{-1}$			
Dermal slope factor $(\mu g/cm^2/d)^{-1}$			
Inhalation slope factor $(mg/kg/d)^{-1}$			
Inhalation unit risk $(mg/m^3)^{-1}$			
Relative dermal absorption factor			
Relative retention factor from soil			
Viable epidermal thickness factor			
Test animal skin area (cm^2)			
Organic carbon partitioning coefficient (mL/g) - Koc			
Log Kow (unitless)			
Henry's Law constant at 25^oC (unitless) - H'			
Henry's Law constant at 25^oC (atm-m3/mol) - H			
Water Solubility at 25^oC (mg/L)			
Molecular Weight (g/mol)			
Vapour Pressure at 25^oC (atm)			

NOTE: values in grayed cells will not be used; Health Canada default values are applied.

User-defined Receptor

Name		Defaults
Age group	Adult	Toddler
Lifestage duration (y)		60
Body weight (kg)		70.7
Soil ingestion rate (g/d)		0.02
Inhalation rate (m^3/d)		16.6
Water ingestion rate (L/d)		1.5
Time spent outdoors (h/d)		1.5
Skin surface area (cm^2)		
- hands		890
- arms		2500
- legs		5720
- total		17640
Soil loading to exposed skin (g/cm^2/event)		
- hands		0.0001
- surfaces other than hands		0.00001
Soil monolayer loading rate (mg/cm^2)		5
Food ingestion (g/d)		
- root vegetables		188
- other vegetables	2.634615385	137
- fish		220
- wild game		270

User-defined Land-Use / Exposure Scenario

Scenario name	First Nations Traditional L	Defaults
Hours per day at site		24
Hours per day (outdoors)		
Days per week		7
Weeks per year	1	52
Dermal exposure events/day		1
Water contact events per day		1
Duration of water contact event (h)		1
Days/year contaminated food ingestion		365
Exposure duration (years)		60
Years for carcinogen amortization		60

HEALTH CANADA PQRA SPREADSHEET Version: **July 13, 2011**
OUTPUT SHEET - User-Defined Receptor **Adult** **RECEPTOR NOT ACTIVE**

User Name: KZK - BMC
Proponent: BMC
Date: October 16, 2017

Site:
File #:
Comment:

Exposure Scenario: **First Nations Tr**
Native population considered
Lifestage for Cancer Risks **Adult**
Exposure Duration (y): **60**

User-Defined Receptor Characteristics
Body weight (kg): 70.7
Soil ingestion rate (g/d): 0.02
Inhalation rate (m3/d): 16.6
Water ingestion rate (L/d): 1.5

Skin surface area (cm2) - hands: 890
- arms: 2500
- legs: 5720
- total: 17640
Soil loading (g/cm2-event) - hands: 0.0001
- other: 0.00001

Food ingestion rates (g/d)
Root vegetables: 188
Other vegetables: 2.63461538461538
Fish: 220
Wild game: 270

Chemical Properties	Units	Arsenic	Cadmium				
Tolerable daily intake	mg/kg/d	NA	0.001	NA	NA	NA	NA
Tolerable concentration	mg/m^3	NA	NA	NA	NA	NA	NA
Oral slope factor	$(mg/kg/d)^{-1}$	1.8	NA	NA	NA	NA	NA
Inhalation slope factor	$(mg/kg/d)^{-1}$	28	42.9	NA	NA	NA	NA
Inhalation unit risk	$(mg/m^3)^{-1}$	6.4	9.8	NA	NA	NA	NA
Dermal slope factor	$(\mu g/cm^2/d)^{-1}$	NA	NA	NA	NA	NA	NA
Critical oral exposure benchmark		oral slope factor	TDI	NA	NA	NA	NA
Critical inhalation exposure benchmark		inhalation slope factor	inhalation slope factor	NA	NA	NA	NA
Critical dermal exposure benchmark		oral slope factor	TDI	NA	NA	NA	NA
Relative dermal absorption factor	unitless	0.03	0.01	1	1	1	1
Relative soil retention factor	unitless	NA	NA	NA	NA	NA	NA
Viable epidermal thickness factor	unitless	NA	NA	NA	NA	NA	NA
Test animal skin area	cm^{-2}	NA	NA	NA	NA	NA	NA

Chemical Concentrations	Units	Arsenic	Cadmium				
Soil	mg/kg	9.60E+01	7.84E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Drinking water	mg/L	3.18E-03	8.10E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Bathing/swimming water	mg/L	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Indoor air vapours	mg/m^3	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Outdoor air vapours	mg/m^3	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Outdoor air particulate	mg/m^3	7.30E-08	5.96E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Amortized total air concentration	mg/m^3	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Root vegetables	mg/kg wet wt	not evaluated	not evaluated	not evaluated	not evaluated	not evaluated	not evaluated
Other vegetables	mg/kg wet wt	2.50E-03	1.36E-01	not evaluated	not evaluated	not evaluated	not evaluated
Fish	mg/kg wet wt	not evaluated	not evaluated	not evaluated	not evaluated	not evaluated	not evaluated
Wild game	mg/kg wet wt	not evaluated	not evaluated	not evaluated	not evaluated	not evaluated	not evaluated

RESULTS

	Exposure (mg/kg/d unless otherwise noted)					
	Arsenic	Cadmium				
Inadvertent ingestion of contaminated soil	5.22E-07	4.27E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Inhalation of fugitive dust	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Inhalation of contaminant vapours - indoor	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Inhalation of contaminant vapours - outdoor	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ingestion of contaminated drinking water	1.30E-06	3.30E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Dermal contact with contaminated soil	1.34E-07	3.65E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Dermal contact with contaminated soil ($\mu g/cm^2/d$)	not calculated	not calculated	not calculated	not calculated	not calculated	not calculated
Dermal contact with contaminated water	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Dermal contact with contaminated water ($\mu g/cm^2/d$)	not calculated	not calculated	not calculated	not calculated	not calculated	not calculated
Ingestion of contaminated food	9.32E-08	5.07E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total ingestion exposure	1.91E-06	5.44E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total dermal exposure	1.34E-07	3.65E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total dermal exposure ($\mu g/cm^2/d$)	not calculated	not calculated	not calculated	not calculated	not calculated	not calculated
Ingestion + dermal exposure	2.05E-06	5.44E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total inhalation exposure	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total Exposure (sum of all pathways)	2.05E-06	5.44E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00

		Hazard/Risk Estimates					
		Arsenic	Cadmium				
Hazard Quotient - Oral/Dermal		NA	5.44E-03	NA	NA	NA	NA
Hazard Quotient - Inhalation		NA	0.00E+00	NA	NA	NA	NA
Hazard Index - Total		NA	5.44E-03	NA	NA	NA	NA
Target Hazard Index:	0.2						
Cancer Risk - Oral		3.44E-06	NA	NA	NA	NA	NA
Cancer Risk - Dermal		2.41E-07	NA	NA	NA	NA	NA
Cancer Risk - Oral + Dermal		3.68E-06	NA	NA	NA	NA	NA
Cancer Risk - Inhalation		0.00E+00	0.00E+00	NA	NA	NA	NA
Cancer Risk - Total		3.68E-06	0.00E+00	NA	NA	NA	NA
Target Cancer Risk:	1.00E-05						

Risk Estimates: Mean Concentrations at Post Closure

HEALTH CANADA PQRA SPREADSHEET

USER INPUT SHEET

User Name:	KZK - BMC	Site:	
Proponent:	BMC	File #:	
Date:	October 16, 2017	Comment:	

PROBLEM FORMULATION

Potential Land Uses (Yes/No)

		Default
Agricultural	No	Yes
Residential/urban parkland	No	Yes
Commercial with daycare	No	Yes
Commercial without daycare	No	Yes
Industrial	No	Yes
Industrial - outdoors	No	Yes
Urban recreational	No	Yes
Remote wild lands	No	Yes
Construction/utility work	No	Yes
Other	Yes	No
specify:	First Nations Traditional Land Use	

Operative Pathways (Yes/No)

		Default
Inadvertent ingestion of soil		Yes
Inhalation of fugitive dust		Yes
Inhalation of indoor contaminant vapours	No	Yes
Inhalation of outdoor contaminant vapours	No	Yes
Ingestion of drinking water		Yes
Dermal contact with soil		Yes
Dermal contact with water		Yes
Ingestion of contaminated food	Yes	No

Vapour Transport Modelling

Vapour source for exposure calculations		Most Conservative

Exposure Scenario | | First Nations Traditional La

Active Critical Receptors (Yes/No)

		Default
Infant		Yes
Toddler		Yes
Child		Yes
Teen		Yes
Adult		Yes
Construction/Utility Worker		No
Other		No
specify:		

Receptor Groups (Yes/No)

		Default
General public or residents	No	Yes
Employees	No	Yes
Canadian native communities	Yes	No
Other	Yes	No
specify:	First Nations Land Use - 1 Week Per	

Contaminant Concentrations

Chemical Name	required	Lead	Arsenic (non-cancer)	Fluoride	Copper	Selenium	Zinc
Soil (mg/kg)	required	28	17	0	40		161
Groundwater - source (mg/L)	optional						
Drinking water (mg/L)	optional	0.0014	0.00244	0.089	0.00031		0.018
Bathing/swimming water (mg/L)	optional						
Indoor air - vapours (mg/m^3)	optional						
Outdoor air - vapours (mg/m^3)	optional						
Outdoor air - particulate (mg/m^3)	optional						
Root vegetables (mg/kg wet weight)	optional						
Other vegetables (mg/kg wet weight)	optional	0.00298	0.0025	0	0.859		2.94
Fish (mg/kg wet weight)	optional						
Wild game (mg/kg wet weight)	optional						
				#N/A			

Risk Assessment Endpoints

		Default
Acceptable hazard index:		0.2
Acceptable cancer risk:		1.00E-05
Evaluate Early Lifestage Cancer Risks?		No

Precluding Conditions for Fate and Transport Models

All precluding conditions questions should be answered

Are non-aqueous phase liquids (NAPL) present?	
Is groundwater contamination present in fractured bedrock?	
Is groundwater contamination migrating through a confined aquifer?	
Is there active pumping or drawdown of groundwater at the site?	
Is contamination present within 1 m of building foundation?	
Do any buildings within 5 m of contamination have earthen foundations?	
Are any buildings constructed on very high permeability media?	
Are there preferential vapour flow pathways connecting contamination to a building?	

FATE AND TRANSPORT MODEL INPUT

	Value	Default	Models Affected
Soil Type		coarse-grained	PS, V-I, V-O, GW
Significant vehicle traffic on unpaved roads?		No	P-O
Site Characteristics			
Depth to Groundwater (m)		3	GW, V-O
Depth from Surface to Contamination (m)		0	GW, V-O
Distance - Contaminated Soil to Building (m)		1	V-I
Distance - Contaminated GW to Building (m)		1	V-I
Distance to potable water user (m)		0	GW
Distance to Bathing/Swimming Water (m)		0	GW
Particulate Concentration in Air (ug/m^3)		0.76	P-O
Apply biodegradation during GW transport?		No	GW
Building Type		Residential	V-I

OPTIONAL SECTIONS

NOTE: user-defined chemicals should be named in this section before being selected in the 'Contaminant Concentrations' table above

User-defined Chemicals

	Chemical 1	Chemical 2	Chemical 3
Name	Lead	Arsenic (non-cancer)	
CAS Number			
Chemical class (organic/inorganic)			
Tolerable daily intake (mg/kg/d) - infant	0.0006	0.0003	
Tolerable daily intake (mg/kg/d) - toddler	0.0006	0.0003	
Tolerable daily intake (mg/kg/d) - child	0.0006	0.0003	
Tolerable daily intake (mg/kg/d) - teen	0.0006	0.0003	
Tolerable daily intake (mg/kg/d) - adult	0.0006	0.0003	
Tolerable concentration (mg/m^3)			
Oral slope factor $(mg/kg/d)^{-1}$			
Dermal slope factor $(\mu g/cm^2/d)^{-1}$			
Inhalation slope factor $(mg/kg/d)^{-1}$			
Inhalation unit risk $(mg/m^3)^{-1}$			
Relative dermal absorption factor	0.006	0.03	
Relative retention factor from soil			
Viable epidermal thickness factor			
Test animal skin area (cm^2)			
Organic carbon partitioning coefficient (mL/g) - Koc			
Log Kow (unitless)			
Henry's Law constant at 25°C (unitless) - H'			
Henry's Law constant at 25°C (atm-m3/mol) - H			
Water Solubility at 25°C (mg/L)			
Molecular Weight (g/mol)			
Vapour Pressure at 25°C (atm)			

Enter all applicable and appropriate toxicity benchmarks; values must be referenced and justified in the PQRA report.

NOTE: values in grayed cells will not be used; Health Canada default values are applied.

User-defined Receptor

Name		Defaults
Age group	Toddler	Toddler
Lifestage duration (y)		4.5
Body weight (kg)		16.5
Soil ingestion rate (g/d)		0.08
Inhalation rate (m^3/d)		8.3
Water ingestion rate (L/d)		0.6
Time spent outdoors (h/d)		1.5
Skin surface area (cm^2)		
- hands		430
- arms		890
- legs		1690
- total		6130
Soil loading to exposed skin (g/cm^2/event)		
- hands		0.0001
- surfaces other than hands		0.00001
Soil monolayer loading rate (mg/cm^2)		5
Food ingestion (g/d)		
- root vegetables		105
- other vegetables		67
- fish		95
- wild game		85

User-defined Land-Use / Exposure Scenario

Scenario name	First Nations Traditional L	Defaults
Hours per day at site		24
Hours per day (outdoors)		
Days per week		7
Weeks per year	52	52
Dermal exposure events/day		1
Water contact events per day		1
Duration of water contact event (h)		1
Days/year contaminated food ingestion		365
Exposure duration (years)		60
Years for carcinogen amortization		60

HEALTH CANADA PQRA SPREADSHEET Version: **July 13, 2011**

OUTPUT SHEET : Toddler

User Name:	KZK - BMC	Site:	
Proponent:	BMC	File #:	
Date:	October 16, 2017	Comment:	

Exposure Scenario: **First Nations Traditional La** **Exposure Duration (y):** **4.5**

Native population considered

Chemical Properties	Units	Lead	Arsenic (non-cancer)	Fluoride	Copper	Selenium	Zinc
Tolerable daily intake	mg/kg/d	0.0006	0.0003	NA	0.09	0.0062	0.5
Tolerable concentration	mg/m^3	NA	NA	NA	NA	NA	NA
Oral slope factor	$(mg/kg/d)^{-1}$	NA	NA	NA	NA	NA	NA
Inhalation slope factor	$(mg/kg/d)^{-1}$	NA	NA	NA	NA	NA	NA
Inhalation unit risk	$(mg/m^3)^{-1}$	NA	NA	NA	NA	NA	NA
Dermal slope factor	$(\mu g/cm^2/d)^{-1}$	NA	NA	NA	NA	NA	NA
Critical oral exposure benchmark		TDI	TDI	NA	TDI	TDI	TDI
Critical inhalation exposure benchmark		NA	NA	NA	NA	NA	NA
Critical dermal exposure benchmark		TDI	TDI	NA	TDI	TDI	TDI
Relative dermal absorption factor	unitless	0.006	0.03	1	0.06	0.01	0.1
Relative soil retention factor	unitless	NA	NA	NA	NA	NA	NA
Viable epidermal thickness factor	unitless	NA	NA	NA	NA	NA	NA
Test animal skin area	cm^{-2}	NA	NA	NA	NA	NA	NA

Chemical Concentrations	Units	Lead	Arsenic (non-cancer)	Fluoride	Copper	Selenium	Zinc
Soil	mg/kg	2.80E+01	1.70E+01	0.00E+00	4.00E+01	0.00E+00	1.61E+02
Drinking water	mg/L	1.40E-03	2.44E-03	8.90E-02	3.10E-04	0.00E+00	1.80E-02
Bathing/swimming water	mg/L	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Indoor air vapours	mg/m^3	NA	NA	NA	NA	NA	NA
Outdoor air vapours	mg/m^3	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Outdoor air particulate	mg/m^3	2.13E-08	1.29E-08	0.00E+00	3.04E-08	0.00E+00	1.22E-07
Amortized total air concentration	mg/m^3	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Root vegetables	mg/kg wet wt	not evaluated	not evaluated	not evaluated	not evaluated	not evaluated	not evaluated
Other vegetables	mg/kg wet wt	2.98E-03	2.50E-03	0.00E+00	8.59E-01	not evaluated	2.94E+00
Fish	mg/kg wet wt	not evaluated	not evaluated	not evaluated	not evaluated	not evaluated	not evaluated
Wild game	mg/kg wet wt	not evaluated	not evaluated	not evaluated	not evaluated	not evaluated	not evaluated

RESULTS

	Exposure (mg/kg/d unless otherwise noted)					
	Lead	**Arsenic (non-cancer)**	**Fluoride**	**Copper**	**Selenium**	**Zinc**
Inadvertent ingestion of contaminated soil	1.36E-04	8.24E-05	0.00E+00	1.94E-04	0.00E+00	7.81E-04
Inhalation of fugitive dust	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Inhalation of contaminant vapours - indoor	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Inhalation of contaminant vapours - outdoor	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ingestion of contaminated drinking water	5.09E-05	8.87E-05	3.24E-03	1.13E-05	0.00E+00	6.55E-04
Dermal contact with contaminated soil	7.01E-07	2.13E-06	0.00E+00	1.00E-05	0.00E+00	6.71E-05
Dermal contact with contaminated soil ($\mu g/cm^2/d$)	not calculated	not calculated	not calculated	not calculated	not calculated	not calculated
Dermal contact with contaminated water	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Dermal contact with contaminated water ($\mu g/cm^2/d$)	not calculated	not calculated	not calculated	not calculated	not calculated	not calculated
Ingestion of contaminated food	1.21E-05	1.02E-05	0.00E+00	3.49E-03	0.00E+00	1.19E-02
Total ingestion exposure	1.99E-04	1.81E-04	3.24E-03	3.69E-03	0.00E+00	1.34E-02
Total dermal exposure	7.01E-07	2.13E-06	0.00E+00	1.00E-05	0.00E+00	6.71E-05
Total dermal exposure ($\mu g/cm^2/d$)	not calculated	not calculated	not calculated	not calculated	not calculated	not calculated
Ingestion + dermal exposure	1.99E-04	1.83E-04	3.24E-03	3.70E-03	0.00E+00	1.34E-02
Total inhalation exposure	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total Exposure (sum of all pathways)	1.99E-04	1.83E-04	3.24E-03	3.70E-03	0.00E+00	1.34E-02

		Hazard/Risk Estimates					
		Lead	**Arsenic (non-cancer)**	**Fluoride**	**Copper**	**Selenium**	**Zinc**
Hazard Quotient - Oral/Dermal		3.32E-01	6.11E-01	NA	4.11E-02	0.00E+00	2.69E-02
Hazard Quotient - Inhalation		0.00E+00	0.00E+00	NA	0.00E+00	0.00E+00	0.00E+00
Hazard Index - Total		3.32E-01	6.11E-01	NA	4.11E-02	0.00E+00	2.69E-02
Target Hazard Index:	0.2	**Target Hazard Index Exceeded**	**Target Hazard Index Exceeded**				
Cancer Risk - Oral		NA	NA	NA	NA	NA	NA
Cancer Risk - Dermal		NA	NA	NA	NA	NA	NA
Cancer Risk - Oral + Dermal		NA	NA	NA	NA	NA	NA
Cancer Risk - Inhalation		NA	NA	NA	NA	NA	NA
Cancer Risk - Total		NA	NA	NA	NA	NA	NA
Target Cancer Risk:	1.00E-05						

HEALTH CANADA PQRA SPREADSHEET

USER INPUT SHEET

User Name:	KZK - BMC	Site:	
Proponent:	BMC	File #:	
Date:	October 16, 2017	Comment:	

PROBLEM FORMULATION

Potential Land Uses (Yes/No)		Default
Agricultural	No	Yes
Residential/urban parkland	No	Yes
Commercial with daycare	No	Yes
Commercial without daycare	No	Yes
Industrial	No	Yes
Industrial - outdoors	No	Yes
Urban recreational	No	Yes
Remote wild lands	No	Yes
Construction/utility work	No	Yes
Other	Yes	No
specify:	First Nations Traditional Land Use	

Operative Pathways (Yes/No)		Default
Inadvertent ingestion of soil		Yes
Inhalation of fugitive dust		Yes
Inhalation of indoor contaminant vapours	Yes	Yes
Inhalation of outdoor contaminant vapours	Yes	Yes
Ingestion of drinking water		Yes
Dermal contact with soil		Yes
Dermal contact with water		Yes
Ingestion of contaminated food	Yes	No

Vapour Transport Modelling		
Vapour source for exposure calculations		Most Conservative

Exposure Scenario	First Nations Traditional Land Use	First Nations Traditional La

Active Critical Receptors (Yes/No)		Default
Infant		Yes
Toddler		Yes
Child		Yes
Teen		Yes
Adult		Yes
Construction/Utility Worker		No
Other		No
specify:		

Receptor Groups (Yes/No)		Default
General public or residents	No	Yes
Employees	No	Yes
Canadian native communities	Yes	No
Other	Yes	No
specify:	First Nations Land Use - 1 Week Per	

Contaminant Concentrations								
Chemical Name	required	Arsenic						
Soil (mg/kg)	required	17						
Groundwater - source (mg/L)	optional							
Drinking water (mg/L)	optional	0.00244						
Bathing/swimming water (mg/L)	optional							
Indoor air - vapours (mg/m^3)	optional							
Outdoor air - vapours (mg/m^3)	optional							
Outdoor air - particulate (mg/m^3)	optional							
Root vegetables (mg/kg wet weight)	optional							
Other vegetables (mg/kg wet weight)	optional	0.0025						
Fish (mg/kg wet weight)	optional							
Wild game (mg/kg wet weight)	optional							

Risk Assessment Endpoints		Default
Acceptable hazard index:		0.2
Acceptable cancer risk:		1.00E-05
Evaluate Early Lifestage Cancer Risks?		No

Precluding Conditions for Fate and Transport Models	
Are non-aqueous phase liquids (NAPL) present?	No
Is groundwater contamination present in fractured bedrock?	No
Is groundwater contamination migrating through a confined aquifer?	No
Is there active pumping or drawdown of groundwater at the site?	No
Is contamination present within 1 m of building foundation?	No
Do any buildings within 5 m of contamination have earthen foundations?	No
Are any buildings constructed on very high permeability media?	No
Are there preferential vapour flow pathways connecting contamination to a building?	No

FATE AND TRANSPORT MODEL INPUT

	Value	Default	Models Affected
Soil Type		coarse-grained	PS, V-I, V-O, GW
Significant vehicle traffic on unpaved roads?		No	P-O
Site Characteristics			
Depth to Groundwater (m)		3	GW, V-O
Depth from Surface to Contamination (m)		0	GW, V-O
Distance - Contaminated Soil to Building (m)		1	V-I
Distance - Contaminated GW to Building (m)		1	V-I
Distance to potable water user (m)		0	GW
Distance to Bathing/Swimming Water (m)		0	GW
Particulate Concentration in Air (ug/m^3)		0.76	P-O
Apply biodegradation during GW transport?		No	GW
Building Type		Residential	V-I

OPTIONAL SECTIONS

NOTE: user-defined chemicals should be named in this section before being selected in the 'Contaminant Concentrations' table above

User-defined Chemicals

	Chemical 1	Chemical 2	Chemical 3
Name			
CAS Number			
Chemical class (organic/inorganic)			
Tolerable daily intake (mg/kg/d) - infant			
Tolerable daily intake (mg/kg/d) - toddler			
Tolerable daily intake (mg/kg/d) - child			
Tolerable daily intake (mg/kg/d) - teen			
Tolerable daily intake (mg/kg/d) - adult			
Tolerable concentration (mg/m^3)			
Oral slope factor (mg/kg/d)$^{-1}$			
Dermal slope factor (μg/cm^2/d)$^{-1}$			
Inhalation slope factor (mg/kg/d)$^{-1}$			
Inhalation unit risk (mg/m^3)$^{-1}$			
Relative dermal absorption factor			
Relative retention factor from soil			
Viable epidermal thickness factor			
Test animal skin area (cm^2)			
Organic carbon partitioning coefficient (mL/g) - Koc			
Log Kow (unitless)			
Henry's Law constant at 25^{o}C (unitless) - H'			
Henry's Law constant at 25^{o}C (atm-m3/mol) - H			
Water Solubility at 25^{o}C (mg/L)			
Molecular Weight (g/mol)			
Vapour Pressure at 25^{o}C (atm)			

Enter all applicable and appropriate toxicity benchmarks; values must be referenced and justified in the PQRA report.

NOTE: values in grayed cells will not be used; Health Canada default values are applied.

User-defined Receptor

Name		Defaults
Age group	Adult	Toddler
Lifestage duration (y)		60
Body weight (kg)		70.7
Soil ingestion rate (g/d)		0.02
Inhalation rate (m^3/d)		16.6
Water ingestion rate (L/d)		1.5
Time spent outdoors (h/d)		1.5
Skin surface area (cm^2)		
- hands		890
- arms		2500
- legs		5720
- total		17640
Soil loading to exposed skin (g/cm^2/event)		
- hands		0.0001
- surfaces other than hands		0.00001
Soil monolayer loading rate (mg/cm^2)		5
Food ingestion (g/d)		
- root vegetables		188
- other vegetables	2.634615385	137
- fish		220
- wild game		270

User-defined Land-Use / Exposure Scenario

Scenario name	First Nations Traditional L	Defaults
Hours per day at site		24
Hours per day (outdoors)		
Days per week		7
Weeks per year	1	52
Dermal exposure events/day		1
Water contact events per day		1
Duration of water contact event (h)		1
Days/year contaminated food ingestion		365
Exposure duration (years)		60
Years for carcinogen amortization		60

HEALTH CANADA PQRA SPREADSHEET Version: **July 13, 2011**

OUTPUT SHEET - User-Defined Receptor **Adult** **RECEPTOR NOT ACTIVE**

User Name: KZK - BMC
Proponent: BMC
Date: October 16, 2017
Site:
File #:
Comment:

Exposure Scenario: **First Nations Tr**
Native population considered
Lifestage for Cancer Risks **Adult**
Exposure Duration (y): **60**

User-Defined Receptor Characteristics
Body weight (kg): 70.7
Soil ingestion rate (g/d): 0.02
Inhalation rate (m3/d): 16.6
Water ingestion rate (L/d): 1.5

Skin surface area (cm2) - hands: 890
- arms: 2500
- legs: 5720
- total: 17640
Soil loading (g/cm2-event) - hands: 0.0001
- other: 0.00001

Food ingestion rates (g/d)
Root vegetables: 188
Other vegetables: 2.63461538461538
Fish: 220
Wild game: 270

Chemical Properties	Units	Arsenic					
Tolerable daily intake	mg/kg/d	NA	NA	NA	NA	NA	NA
Tolerable concentration	mg/m^3	NA	NA	NA	NA	NA	NA
Oral slope factor	(mg/kg/d)$^{-1}$	1.8	NA	NA	NA	NA	NA
Inhalation slope factor	(mg/kg/d)$^{-1}$	28	NA	NA	NA	NA	NA
Inhalation unit risk	(mg/m^3)$^{-1}$	6.4	NA	NA	NA	NA	NA
Dermal slope factor	(μg/cm^2/d)$^{-1}$	NA	NA	NA	NA	NA	NA
Critical oral exposure benchmark		oral slope factor	NA	NA	NA	NA	NA
Critical inhalation exposure benchmark		inhalation slope factor	NA	NA	NA	NA	NA
Critical dermal exposure benchmark		oral slope factor	NA	NA	NA	NA	NA
Relative dermal absorption factor	unitless	0.03	1	1	1	1	1
Relative soil retention factor	unitless	NA	NA	NA	NA	NA	NA
Viable epidermal thickness factor	unitless	NA	NA	NA	NA	NA	NA
Test animal skin area	cm^{-2}	NA	NA	NA	NA	NA	NA

Chemical Concentrations	Units	Arsenic					
Soil	mg/kg	1.70E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Drinking water	mg/L	2.44E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Bathing/swimming water	mg/L	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Indoor air vapours	mg/m^3	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Outdoor air vapours	mg/m^3	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Outdoor air particulate	mg/m^3	1.29E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Amortized total air concentration	mg/m^3	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Root vegetables	mg/kg wet wt	not evaluated	not evaluated	not evaluated	not evaluated	not evaluated	not evaluated
Other vegetables	mg/kg wet wt	2.50E-03	not evaluated	not evaluated	not evaluated	not evaluated	not evaluated
Fish	mg/kg wet wt	not evaluated	not evaluated	not evaluated	not evaluated	not evaluated	not evaluated
Wild game	mg/kg wet wt	not evaluated	not evaluated	not evaluated	not evaluated	not evaluated	not evaluated

RESULTS

	Exposure (mg/kg/d unless otherwise noted)					
	Arsenic					
Inadvertent ingestion of contaminated soil	9.25E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Inhalation of fugitive dust	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Inhalation of contaminant vapours - indoor	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Inhalation of contaminant vapours - outdoor	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ingestion of contaminated drinking water	9.96E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Dermal contact with contaminated soil	2.37E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Dermal contact with contaminated soil (μg/cm^2/d)	not calculated	not calculated	not calculated	not calculated	not calculated	not calculated
Dermal contact with contaminated water	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Dermal contact with contaminated water (μg/cm^2/d)	not calculated	not calculated	not calculated	not calculated	not calculated	not calculated
Ingestion of contaminated food	9.32E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total ingestion exposure	1.18E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total dermal exposure	2.37E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total dermal exposure (μg/cm^2/d)	not calculated	not calculated	not calculated	not calculated	not calculated	not calculated
Ingestion + dermal exposure	1.20E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total inhalation exposure	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total Exposure (sum of all pathways)	1.20E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

		Hazard/Risk Estimates					
		Arsenic					
Hazard Quotient - Oral/Dermal		NA	NA	NA	NA	NA	NA
Hazard Quotient - Inhalation		NA	NA	NA	NA	NA	NA
Hazard Index - Total		NA	NA	NA	NA	NA	NA
Target Hazard Index:	0.2						
Cancer Risk - Oral		2.13E-06	NA	NA	NA	NA	NA
Cancer Risk - Dermal		4.27E-08	NA	NA	NA	NA	NA
Cancer Risk - Oral + Dermal		2.17E-06	NA	NA	NA	NA	NA
Cancer Risk - Inhalation		0.00E+00	NA	NA	NA	NA	NA
Cancer Risk - Total		2.17E-06	NA	NA	NA	NA	NA
Target Cancer Risk:	1.00E-05						

Risk Estimates: Maximum Concentrations at Post Closure

HEALTH CANADA PQRA SPREADSHEET

USER INPUT SHEET

User Name:	KZK - BMC	Site:	
Proponent:	BMC	File #:	
Date:	October 16, 2017	Comment:	

PROBLEM FORMULATION

Potential Land Uses (Yes/No)		Default
Agricultural	No	Yes
Residential/urban parkland	No	Yes
Commercial with daycare	No	Yes
Commercial without daycare	No	Yes
Industrial	No	Yes
Industrial - outdoors	No	Yes
Urban recreational	No	Yes
Remote wild lands	No	Yes
Construction/utility work	No	Yes
Other	Yes	No
specify:	First Nations Traditional Land Use	

Operative Pathways (Yes/No)		Default
Inadvertent ingestion of soil		Yes
Inhalation of fugitive dust		Yes
Inhalation of indoor contaminant vapours	No	Yes
Inhalation of outdoor contaminant vapours	No	Yes
Ingestion of drinking water		Yes
Dermal contact with soil		Yes
Dermal contact with water		Yes
Ingestion of contaminated food	Yes	No

Vapour Transport Modelling		
Vapour source for exposure calculations		Most Conservative

Exposure Scenario		
		First Nations Traditional La

Active Critical Receptors (Yes/No)		Default
Infant		Yes
Toddler		Yes
Child		Yes
Teen		Yes
Adult		Yes
Construction/Utility Worker		No
Other		No
specify:		

Receptor Groups (Yes/No)		Default
General public or residents	No	Yes
Employees	No	Yes
Canadian native communities	Yes	No
Other	Yes	No
specify:	First Nations Land Use - 1 Week Per	

Contaminant Concentrations

Chemical Name	required	Lead	Arsenic (non-cancer)	Fluoride	Copper		Zinc
Soil (mg/kg)	required	72	96	0	192		784
Groundwater - source (mg/L)	optional						
Drinking water (mg/L)	optional	0.0031	0.0043	0.12	0.007		0.0374
Bathing/swimming water (mg/L)	optional						
Indoor air - vapours (mg/m^3)	optional						
Outdoor air - vapours (mg/m^3)	optional						
Outdoor air - particulate (mg/m^3)	optional						
Root vegetables (mg/kg wet weight)	optional						
Other vegetables (mg/kg wet weight)	optional	0.0086	0.0025	0	1.83		4.46
Fish (mg/kg wet weight)	optional						
Wild game (mg/kg wet weight)	optional						
				#N/A			

Risk Assessment Endpoints		Default
Acceptable hazard index:		0.2
Acceptable cancer risk:		1.00E-05
Evaluate Early Lifestage Cancer Risks?		No

Precluding Conditions for Fate and Transport Models

All precluding conditions questions should be answered

Are non-aqueous phase liquids (NAPL) present?	
Is groundwater contamination present in fractured bedrock?	
Is groundwater contamination migrating through a confined aquifer?	
Is there active pumping or drawdown of groundwater at the site?	
Is contamination present within 1 m of building foundation?	
Do any buildings within 5 m of contamination have earthen foundations?	
Are any buildings constructed on very high permeability media?	
Are there preferential vapour flow pathways connecting contamination to a building?	

FATE AND TRANSPORT MODEL INPUT

	Value	Default	Models Affected
Soil Type		coarse-grained	PS, V-I, V-O, GW
Significant vehicle traffic on unpaved roads?		No	P-O
Site Characteristics			
Depth to Groundwater (m)		3	GW, V-O
Depth from Surface to Contamination (m)		0	GW, V-O
Distance - Contaminated Soil to Building (m)		1	V-I
Distance - Contaminated GW to Building (m)		1	V-I
Distance to potable water user (m)		0	GW
Distance to Bathing/Swimming Water (m)		0	GW
Particulate Concentration in Air (ug/m^3)		0.76	P-O
Apply biodegradation during GW transport?		No	GW
Building Type		Residential	V-I

OPTIONAL SECTIONS

NOTE: user-defined chemicals should be named in this section before being selected in the 'Contaminant Concentrations' table above

User-defined Chemicals

Enter all applicable and appropriate toxicity benchmarks; values must be referenced and justified in the PQRA report.

	Chemical 1	Chemical 2	Chemical 3
Name	Lead	Arsenic (non-cancer)	
CAS Number			
Chemical class (organic/inorganic)			
Tolerable daily intake (mg/kg/d) - infant	0.0006	0.0003	
Tolerable daily intake (mg/kg/d) - toddler	0.0006	0.0003	
Tolerable daily intake (mg/kg/d) - child	0.0006	0.0003	
Tolerable daily intake (mg/kg/d) - teen	0.0006	0.0003	
Tolerable daily intake (mg/kg/d) - adult	0.0006	0.0003	
Tolerable concentration (mg/m^3)			
Oral slope factor $(mg/kg/d)^{-1}$			
Dermal slope factor $(\mu g/cm^2/d)^{-1}$			
Inhalation slope factor $(mg/kg/d)^{-1}$			
Inhalation unit risk $(mg/m^3)^{-1}$			
Relative dermal absorption factor	0.006	0.03	
Relative retention factor from soil			
Viable epidermal thickness factor			
Test animal skin area (cm^2)			
Organic carbon partitioning coefficient (mL/g) - Koc			
Log Kow (unitless)			
Henry's Law constant at 25°C (unitless) - H'			
Henry's Law constant at 25°C (atm-m3/mol) - H			
Water Solubility at 25°C (mg/L)			
Molecular Weight (g/mol)			
Vapour Pressure at 25°C (atm)			

NOTE: values in grayed cells will not be used; Health Canada default values are applied.

User-defined Receptor

Name		Defaults
Age group	Toddler	Toddler
Lifestage duration (y)		4.5
Body weight (kg)		16.5
Soil ingestion rate (g/d)		0.08
Inhalation rate (m^3/d)		8.3
Water ingestion rate (L/d)		0.6
Time spent outdoors (h/d)		1.5
Skin surface area (cm^2)		
- hands		430
- arms		890
- legs		1690
- total		6130
Soil loading to exposed skin (g/cm^2/event)		
- hands		0.0001
- surfaces other than hands		0.00001
Soil monolayer loading rate (mg/cm^2)		5
Food ingestion (g/d)		
- root vegetables		105
- other vegetables		67
- fish		95
- wild game		85

User-defined Land-Use / Exposure Scenario

Scenario name	First Nations Traditional L	Defaults
Hours per day at site		24
Hours per day (outdoors)		
Days per week		7
Weeks per year	52	52
Dermal exposure events/day		1
Water contact events per day		1
Duration of water contact event (h)		1
Days/year contaminated food ingestion		365
Exposure duration (years)		60
Years for carcinogen amortization		60

HEALTH CANADA PQRA SPREADSHEET Version: **July 13, 2011**

OUTPUT SHEET : Toddler

User Name:	KZK - BMC	Site:	
Proponent:	BMC	File #:	
Date:	October 16, 2017	Comment:	

Exposure Scenario: **First Nations Traditional La** **Exposure Duration (y):** **4.5**

Native population considered

Chemical Properties	Units	Lead	Arsenic (non-cancer)	Fluoride	Copper		Zinc
Tolerable daily intake	mg/kg/d	0.0006	0.0003	NA	0.09	NA	0.5
Tolerable concentration	mg/m^3	NA	NA	NA	NA	NA	NA
Oral slope factor	$(mg/kg/d)^{-1}$	NA	NA	NA	NA	NA	NA
Inhalation slope factor	$(mg/kg/d)^{-1}$	NA	NA	NA	NA	NA	NA
Inhalation unit risk	$(mg/m^3)^{-1}$	NA	NA	NA	NA	NA	NA
Dermal slope factor	$(\mu g/cm^2/d)^{-1}$	NA	NA	NA	NA	NA	NA
Critical oral exposure benchmark		TDI	TDI	NA	TDI	NA	TDI
Critical inhalation exposure benchmark		NA	NA	NA	NA	NA	NA
Critical dermal exposure benchmark		TDI	TDI	NA	TDI	NA	TDI
Relative dermal absorption factor	unitless	0.006	0.03	1	0.06	1	0.1
Relative soil retention factor	unitless	NA	NA	NA	NA	NA	NA
Viable epidermal thickness factor	unitless	NA	NA	NA	NA	NA	NA
Test animal skin area	cm^{-2}	NA	NA	NA	NA	NA	NA

Chemical Concentrations	Units	Lead	Arsenic (non-cancer)	Fluoride	Copper		Zinc
Soil	mg/kg	7.20E+01	9.60E+01	0.00E+00	1.92E+02	0.00E+00	7.84E+02
Drinking water	mg/L	3.10E-03	4.30E-03	1.20E-01	7.00E-03	0.00E+00	3.74E-02
Bathing/swimming water	mg/L	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Indoor air vapours	mg/m^3	NA	NA	NA	NA	NA	NA
Outdoor air vapours	mg/m^3	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Outdoor air particulate	mg/m^3	5.47E-08	7.30E-08	0.00E+00	1.46E-07	0.00E+00	5.96E-07
Amortized total air concentration	mg/m^3	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Root vegetables	mg/kg wet wt	not evaluated	not evaluated	not evaluated	not evaluated	not evaluated	not evaluated
Other vegetables	mg/kg wet wt	8.60E-03	2.50E-03	0.00E+00	1.83E+00	not evaluated	4.46E+00
Fish	mg/kg wet wt	not evaluated	not evaluated	not evaluated	not evaluated	not evaluated	not evaluated
Wild game	mg/kg wet wt	not evaluated	not evaluated	not evaluated	not evaluated	not evaluated	not evaluated

RESULTS

	Exposure (mg/kg/d unless otherwise noted)					
	Lead	Arsenic (non-cancer)	Fluoride	Copper		Zinc
Inadvertent ingestion of contaminated soil	3.49E-04	4.65E-04	0.00E+00	9.31E-04	0.00E+00	3.80E-03
Inhalation of fugitive dust	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Inhalation of contaminant vapours - indoor	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Inhalation of contaminant vapours - outdoor	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ingestion of contaminated drinking water	1.13E-04	1.56E-04	4.36E-03	2.55E-04	0.00E+00	1.36E-03
Dermal contact with contaminated soil	1.80E-06	1.20E-05	0.00E+00	4.80E-05	0.00E+00	3.27E-04
Dermal contact with contaminated soil ($\mu g/cm^2/d$)	not calculated	not calculated	not calculated	not calculated	not calculated	not calculated
Dermal contact with contaminated water	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Dermal contact with contaminated water ($\mu g/cm^2/d$)	not calculated	not calculated	not calculated	not calculated	not calculated	not calculated
Ingestion of contaminated food	3.49E-05	1.02E-05	0.00E+00	7.43E-03	0.00E+00	1.81E-02
Total ingestion exposure	4.97E-04	6.32E-04	4.36E-03	8.62E-03	0.00E+00	2.33E-02
Total dermal exposure	1.80E-06	1.20E-05	0.00E+00	4.80E-05	0.00E+00	3.27E-04
Total dermal exposure ($\mu g/cm^2/d$)	not calculated	not calculated	not calculated	not calculated	not calculated	not calculated
Ingestion + dermal exposure	4.99E-04	6.44E-04	4.36E-03	8.66E-03	0.00E+00	2.36E-02
Total inhalation exposure	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total Exposure (sum of all pathways)	4.99E-04	6.44E-04	4.36E-03	8.66E-03	0.00E+00	2.36E-02

		Hazard/Risk Estimates					
		Lead	Arsenic (non-cancer)	Fluoride	Copper		Zinc
Hazard Quotient - Oral/Dermal		8.31E-01	2.15E+00	NA	9.63E-02	NA	4.72E-02
Hazard Quotient - Inhalation		0.00E+00	0.00E+00	NA	0.00E+00	NA	0.00E+00
Hazard Index - Total		8.31E-01	2.15E+00	NA	9.63E-02	NA	4.72E-02
Target Hazard Index:	0.2	**Target Hazard Index Exceeded**	**Target Hazard Index Exceeded**				
Cancer Risk - Oral		NA	NA	NA	NA	NA	NA
Cancer Risk - Dermal		NA	NA	NA	NA	NA	NA
Cancer Risk - Oral + Dermal		NA	NA	NA	NA	NA	NA
Cancer Risk - Inhalation		NA	NA	NA	NA	NA	NA
Cancer Risk - Total		NA	NA	NA	NA	NA	NA
Target Cancer Risk:	1.00E-05						

HEALTH CANADA PQRA SPREADSHEET

USER INPUT SHEET

User Name:	KZK - BMC	Site:	
Proponent:	BMC	File #:	
Date:	October 16, 2017	Comment:	

PROBLEM FORMULATION

Potential Land Uses (Yes/No)		Default
Agricultural	No	Yes
Residential/urban parkland	No	Yes
Commercial with daycare	No	Yes
Commercial without daycare	No	Yes
Industrial	No	Yes
Industrial - outdoors	No	Yes
Urban recreational	No	Yes
Remote wild lands	No	Yes
Construction/utility work	No	Yes
Other	Yes	No
specify:	First Nations Traditional Land Use	

Operative Pathways (Yes/No)		Default
Inadvertent ingestion of soil		Yes
Inhalation of fugitive dust		Yes
Inhalation of indoor contaminant vapours	Yes	Yes
Inhalation of outdoor contaminant vapours	Yes	Yes
Ingestion of drinking water		Yes
Dermal contact with soil		Yes
Dermal contact with water		Yes
Ingestion of contaminated food	Yes	No

Vapour Transport Modelling		
Vapour source for exposure calculations		Most Conservative

Exposure Scenario	First Nations Traditional Land Use	First Nations Traditional La

Active Critical Receptors (Yes/No)		Default
Infant		Yes
Toddler		Yes
Child		Yes
Teen		Yes
Adult		Yes
Construction/Utility Worker		No
Other		No
specify:		

Receptor Groups (Yes/No)		Default
General public or residents	No	Yes
Employees	No	Yes
Canadian native communities	Yes	No
Other	Yes	No
specify:	First Nations Land Use - 1 Week Per	

Contaminant Concentrations

Chemical Name	required	Arsenic					
Soil (mg/kg)	required	96					
Groundwater - source (mg/L)	optional						
Drinking water (mg/L)	optional	0.0043					
Bathing/swimming water (mg/L)	optional						
Indoor air - vapours (mg/m^3)	optional						
Outdoor air - vapours (mg/m^3)	optional						
Outdoor air - particulate (mg/m^3)	optional						
Root vegetables (mg/kg wet weight)	optional						
Other vegetables (mg/kg wet weight)	optional	0.0025					
Fish (mg/kg wet weight)	optional						
Wild game (mg/kg wet weight)	optional						

Risk Assessment Endpoints		Default
Acceptable hazard index:		0.2
Acceptable cancer risk:		1.00E-05
Evaluate Early Lifestage Cancer Risks?		No

Precluding Conditions for Fate and Transport Models	
Are non-aqueous phase liquids (NAPL) present?	No
Is groundwater contamination present in fractured bedrock?	No
Is groundwater contamination migrating through a confined aquifer?	No
Is there active pumping or drawdown of groundwater at the site?	No
Is contamination present within 1 m of building foundation?	No
Do any buildings within 5 m of contamination have earthen foundations?	No
Are any buildings constructed on very high permeability media?	No
Are there preferential vapour flow pathways connecting contamination to a building?	No

FATE AND TRANSPORT MODEL INPUT

	Value	Default	Models Affected
Soil Type		coarse-grained	PS, V-I, V-O, GW
Significant vehicle traffic on unpaved roads?		No	P-O
Site Characteristics			
Depth to Groundwater (m)		3	GW, V-O
Depth from Surface to Contamination (m)		0	GW, V-O
Distance - Contaminated Soil to Building (m)		1	V-I
Distance - Contaminated GW to Building (m)		1	V-I
Distance to potable water user (m)		0	GW
Distance to Bathing/Swimming Water (m)		0	GW
Particulate Concentration in Air (ug/m^3)		0.76	P-O
Apply biodegradation during GW transport?		No	GW
Building Type		Residential	V-I

OPTIONAL SECTIONS

NOTE: user-defined chemicals should be named in this section before being selected in the 'Contaminant Concentrations' table above

User-defined Chemicals

Enter all applicable and appropriate toxicity benchmarks; values must be referenced and justified in the PQRA report.

	Chemical 1	Chemical 2	Chemical 3
Name			
CAS Number			
Chemical class (organic/inorganic)			
Tolerable daily intake (mg/kg/d) - infant			
Tolerable daily intake (mg/kg/d) - toddler			
Tolerable daily intake (mg/kg/d) - child			
Tolerable daily intake (mg/kg/d) - teen			
Tolerable daily intake (mg/kg/d) - adult			
Tolerable concentration (mg/m^3)			
Oral slope factor $(mg/kg/d)^{-1}$			
Dermal slope factor $(\mu g/cm^2/d)^{-1}$			
Inhalation slope factor $(mg/kg/d)^{-1}$			
Inhalation unit risk $(mg/m^3)^{-1}$			
Relative dermal absorption factor			
Relative retention factor from soil			
Viable epidermal thickness factor			
Test animal skin area (cm^2)			
Organic carbon partitioning coefficient (mL/g) - Koc			
Log Kow (unitless)			
Henry's Law constant at 25^oC (unitless) - H'			
Henry's Law constant at 25^oC (atm-m3/mol) - H			
Water Solubility at 25^oC (mg/L)			
Molecular Weight (g/mol)			
Vapour Pressure at 25^oC (atm)			

NOTE: values in grayed cells will not be used; Health Canada default values are applied.

User-defined Receptor

Name		Defaults
Age group	Adult	Toddler
Lifestage duration (y)		60
Body weight (kg)		70.7
Soil ingestion rate (g/d)		0.02
Inhalation rate (m^3/d)		16.6
Water ingestion rate (L/d)		1.5
Time spent outdoors (h/d)		1.5
Skin surface area (cm^2)		
- hands		890
- arms		2500
- legs		5720
- total		17640
Soil loading to exposed skin (g/cm^2/event)		
- hands		0.0001
- surfaces other than hands		0.00001
Soil monolayer loading rate (mg/cm^2)		5
Food ingestion (g/d)		
- root vegetables		188
- other vegetables	2.634615385	137
- fish		220
- wild game		270

User-defined Land-Use / Exposure Scenario

Scenario name	First Nations Traditional L	Defaults
Hours per day at site		24
Hours per day (outdoors)		
Days per week		7
Weeks per year	1	52
Dermal exposure events/day		1
Water contact events per day		1
Duration of water contact event (h)		1
Days/year contaminated food ingestion		365
Exposure duration (years)		60
Years for carcinogen amortization		60

HEALTH CANADA PQRA SPREADSHEET Version: **July 13, 2011**
OUTPUT SHEET - User-Defined Receptor **Adult** **RECEPTOR NOT ACTIVE**

User Name: KZK - BMC
Proponent: BMC
Date: October 16, 2017
Site:
File #:
Comment:

Exposure Scenario: **First Nations Tr**
Native population considered
Lifestage for Cancer Risks **Adult**
Exposure Duration (y): **60**

User-Defined Receptor Characteristics
Body weight (kg): 70.7
Soil ingestion rate (g/d): 0.02
Inhalation rate (m3/d): 16.6
Water ingestion rate (L/d): 1.5

Skin surface area (cm2) - hands: 890
- arms: 2500
- legs: 5720
- total: 17640
Soil loading (g/cm2-event) - hands: 0.0001
- other: 0.00001

Food ingestion rates (g/d)
Root vegetables: 188
Other vegetables: 2.63461538461538
Fish: 220
Wild game: 270

Chemical Properties	Units	Arsenic					
Tolerable daily intake	mg/kg/d	NA	NA	NA	NA	NA	NA
Tolerable concentration	mg/m^3	NA	NA	NA	NA	NA	NA
Oral slope factor	$(mg/kg/d)^{-1}$	1.8	NA	NA	NA	NA	NA
Inhalation slope factor	$(mg/kg/d)^{-1}$	28	NA	NA	NA	NA	NA
Inhalation unit risk	$(mg/m^3)^{-1}$	6.4	NA	NA	NA	NA	NA
Dermal slope factor	$(\mu g/cm^2/d)^{-1}$	NA	NA	NA	NA	NA	NA
Critical oral exposure benchmark		oral slope factor	NA	NA	NA	NA	NA
Critical inhalation exposure benchmark		inhalation slope factor	NA	NA	NA	NA	NA
Critical dermal exposure benchmark		oral slope factor	NA	NA	NA	NA	NA
Relative dermal absorption factor	unitless	0.03	1	1	1	1	1
Relative soil retention factor	unitless	NA	NA	NA	NA	NA	NA
Viable epidermal thickness factor	unitless	NA	NA	NA	NA	NA	NA
Test animal skin area	cm^{-2}	NA	NA	NA	NA	NA	NA

Chemical Concentrations	Units	Arsenic					
Soil	mg/kg	9.60E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Drinking water	mg/L	4.30E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Bathing/swimming water	mg/L	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Indoor air vapours	mg/m^3	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Outdoor air vapours	mg/m^3	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Outdoor air particulate	mg/m^3	7.30E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Amortized total air concentration	mg/m^3	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Root vegetables	mg/kg wet wt	not evaluated	not evaluated	not evaluated	not evaluated	not evaluated	not evaluated
Other vegetables	mg/kg wet wt	2.50E-03	not evaluated	not evaluated	not evaluated	not evaluated	not evaluated
Fish	mg/kg wet wt	not evaluated	not evaluated	not evaluated	not evaluated	not evaluated	not evaluated
Wild game	mg/kg wet wt	not evaluated	not evaluated	not evaluated	not evaluated	not evaluated	not evaluated

RESULTS

	Exposure (mg/kg/d unless otherwise noted)					
	Arsenic					
Inadvertent ingestion of contaminated soil	5.22E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Inhalation of fugitive dust	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Inhalation of contaminant vapours - indoor	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Inhalation of contaminant vapours - outdoor	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ingestion of contaminated drinking water	1.75E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Dermal contact with contaminated soil	1.34E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Dermal contact with contaminated soil ($\mu g/cm^2/d$)	not calculated	not calculated	not calculated	not calculated	not calculated	not calculated
Dermal contact with contaminated water	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Dermal contact with contaminated water ($\mu g/cm^2/d$)	not calculated	not calculated	not calculated	not calculated	not calculated	not calculated
Ingestion of contaminated food	9.32E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total ingestion exposure	2.37E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total dermal exposure	1.34E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total dermal exposure ($\mu g/cm^2/d$)	not calculated	not calculated	not calculated	not calculated	not calculated	not calculated
Ingestion + dermal exposure	2.50E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total inhalation exposure	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total Exposure (sum of all pathways)	2.50E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

		Hazard/Risk Estimates					
		Arsenic					
Hazard Quotient - Oral/Dermal		NA	NA	NA	NA	NA	NA
Hazard Quotient - Inhalation		NA	NA	NA	NA	NA	NA
Hazard Index - Total		NA	NA	NA	NA	NA	NA
Target Hazard Index:	0.2						
Cancer Risk - Oral		4.27E-06	NA	NA	NA	NA	NA
Cancer Risk - Dermal		2.41E-07	NA	NA	NA	NA	NA
Cancer Risk - Oral + Dermal		4.51E-06	NA	NA	NA	NA	NA
Cancer Risk - Inhalation		0.00E+00	NA	NA	NA	NA	NA
Cancer Risk - Total		4.51E-06	NA	NA	NA	NA	NA
Target Cancer Risk:	1.00E-05						

Appendix R2-O

Assessment of the Impact of a Hypothetical Catastrophic Failure of the Proposed Water Management Ponds

minnow environmental inc.
A Trinity Consultants Company

Technical Memo

Date: November 02, 2017

To: Name Redacted (BMC Minerals (No.1) Ltd.)

Cc: Name Redacted innow Environmental Inc.) and Name Redacted , B.Sc., EP (Alexco Environmental Group)

From: Name Redacted Ph.D. (Minnow Environmental Inc.), Name Redacted Ph.D. R.P.Bio (Minnow Environmental Inc.), and Name Redacted . (Alexco Environmental Group).

RE: Assessment of the Impact of a Hypothetical Catastrophic Failure of the Proposed Water Management Ponds at the Kudz Ze Kayah Mine Site on Fish and Fish Habitat in Geona Creek.

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1 INTRODUCTION

1.1 Background

BMC Minerals Ltd. (BMC) is proposing to develop the Kudz Ze Kayah (KZK) Project which is a copper-zinc-lead-gold mine located approximately 250 km northeast of Whitehorse, Yukon Territory, Canada. A prefeasibility study (PFS) design of tailings, waste rock and water management facilities for the site has been completed (KP 2016). According to the PFS design of water management facilities, two water management ponds (WMPs), the lower water management pond (LWMP) and the upper water management pond (UWMP), will be located within the current alignment of Geona Creek downstream of the Process Plant to manage contact runoff water and seepage during the operational phase of the mine (Figure 1.1, reproduced from the KZK PFS Report, Appendix B, Drawing C210). Site contact water will be routed to the UWMP for settling of sediments, and then decanted to the LWMP for additional storage prior to discharge to Geona Creek which then flows into Finlayson Creek. Both ponds have been designed to manage a 1-in-200 year, 24 hour storm event (including a 1 m freeboard allowance), and the dams of both ponds will be constructed with geosynthetic liners (Figure 1.2, reproduced from the KZK PFS Report, Appendix B, Drawing C500). The storage capacities of the UWMP and LWMP will be approximately 500,000 m^3 and 250,000 m^3 respectively. At closure, the UWMP will be removed, and the LWMP will be converted to a constructed wetland treatment system for site water discharge.

As part of Adequacy Review of the KZK Project by the Yukon Environmental and Socio-economic Assessment Board (YESAB), the board provided the following information request (IR):

> *R274: In Accidents and Malfunctions a discussion of the impacts on fish and fish habitat and the associated affects to Commercial, Recreational or Aboriginal (CRA) Fisheries that would result from a catastrophic breach of the water management ponds on Genoa Creek should be provided. The expectations for this analysis would be a robust assessment of potential impacts and risks to CRA Fisheries that would include modelling of wave inundation and erosional forces associated with an event that occurred during a dry or wet year in combination with a dry (piping) or wet (precipitation) event. This assessment would include discussion of how far the inundation wave would travel, how far erosional forces would extend, the range of potential effects.*

YESAB considered the response to the R274 to be insufficient, indicating that the Proponent provided a qualitative response focused on CRA fisheries. In addition to CRA fisheries, the IR requested an assessment of the potential impacts on fish and fish habitat from a hypothetical failure of the water management ponds. As part of the second Adequacy Review of the KZK Project, the YESAB provided the following IR (YESAB 2017):

> *R2-124: Provide an assessment of catastrophic failure of the water management ponds on Genoa Creek. This may be included in the response to R2-45 which requests an assessment of impacts associated with the Project on erosion, stream morphology, and riparian vegetation of all affected drainages from projected downstream flow changes during all Project phases.*
>
> *With respect to potential hydrologic/hydraulic impacts, there is potential, at least in Geona Creek, to result in an impact to stream morphology which could have a subsequent impact on fish and fish habitat. For instance, breach of the WMPs could result in (i) release of sediment downstream, (ii) erosion of sections of Geona Creek, (iii) sediment deposition in sections of Geona Creek, and (iv) change in stream morphology as a result of the erosion/sedimentation and alteration of natural erosion/sedimentation processes.*

This memorandum has been prepared in response to IR R2-124 and includes an assessment of the potential impact of a hypothetical catastrophic failure of the proposed UWMP and LWMP to downstream fish and fish habitat in Geona Creek. This memorandum outlines the approach, assumptions, and results of the assessment.

1.2 Scope of the Study

The following was approach was used for the hypothetical catastrophic failure of the proposed WMPs:

- Estimation of flow and sediment load from the failure, and resulting downstream flood flow attenuation;
- Identifying downstream (Geona Creek) sediment erosion and/or accumulation based on the flow from the failure, and existing (i.e., pre-failure) creek flow and morphological information; and
- Evaluate the fish and fish habitat implications associated with potential changes in the Geona Creek.

The mandate for Minnow Environmental was to complete these tasks within a spatial boundary extending approximately 25 km downstream of the WMPs from Geona Creek to Lower Finlayson Creek (see Alexco 2016a, Figure 3-3). This spatial extent is consistent with the Project local study area utilized in the baseline monitoring of aquatic resources (Alexco 2016a).

2 ASSESSMENT SCENARIO AND ASSUMPTIONS

2.1 Catastrophic Failure Scenario of the Proposed WMPs

The assessment was focused on a worst-case scenario representing a hypothetical catastrophic failure of the WMPs. It was assumed that the catastrophic failure of the proposed WMPs would occur through their respective dams, and henceforth, the term ‘dam failure’ is used to represent the failures of the WMPs. In this study, the worst-case scenario of the dam failure for the proposed WMPs was considered to occur under a rainy day failure as it would cause the most severe downstream inundation and sediment erosion and/or deposition. In addition, it was assumed that the overtopping failure of the upstream dam of the UWMP would cause a sequential overtopping failure of the downstream dam of the LWMP. As such, the combined volume of both the UWMP and LWMP was used for inundation analysis, where the volume of the UWMP was considered as inflow to the LWMP. Then, the impact assessment was focused on downstream Geona Creek and Finlayson Creek starting from the LWMP dam (elevation 1317 masl, at the toe of the dam) to station KZ-26 (elevation 950 masl), a water quality monitoring station in Lower Finlayson Creek, which is about 25.7 km from the LWMP dam and with a 367 m lower elevation. Furthermore, the failure was assumed to occur with a maximum possible height (from the dam crest to the toe) of the dams. It was also considered that the failure would occur when both WMPs are at the final year of their operation (i.e., year 10) which represents the time of greatest contained sediment volume. Furthermore, the downstream channel (Geona Creek) before the failure was considered to be flowing at the maximum possible level (i.e. flood flow). The likelihood of all these conditions co-occurring to cause the worst-case scenario considered here is *extremely low*, and the WMPs will be carefully managed so that such a failure does not occur at any point. Nevertheless, the inundation analysis was carried out for the above described worst-case scenario with the following assumptions:

- The initial water levels, volume and surface area of both water management ponds just before the failure was assumed to be at their dam crest elevations (Table 2.1);
- The volumes of deposited sediment contained just before the failure were about 100 m^3 in the LWMP, and 48 m^3 in the UWMP. The accumulated sediment was estimated for the end of mine operations (i.e., 10 years) based on the predicted annual runoff rates for both WMPs during a mean precipitation year as reported by the water balance model (Alexco 2017), and representative total suspended solids concentrations (10 mg/L) in the runoff (Alexco 2016c);
- The deposited sediment was assumed to be released at the end of water flow from the dam failure (i.e., after all the water is released); and
- The maximum flow in the downstream receiving water bodies (see Section 2.2) before the failure was assumed to be equal to the predicted discharge during a 1-in-50 wet precipitation year as reported in the receiving water balance model (Alexco 2017).

2.2 Downstream Receiving Environment

The waterbody immediately downstream of the dams is Geona Creek, which flows into upper Finlayson Creek and then Lower Finlayson Creek. Finlayson Creek discharges into the Finlayson River. There are a number of water quality monitoring stations (KZ-9, KZ-15, KZ-22 and KZ-26) in the immediate downstream receiving environment which are routinely monitored (see Alexco 2016a, Figure 3-3). The geometric dimensions and estimated bankfull discharge in these monitoring stations (Table 2.2) indicate that the conveyance capacity of the downstream receiving waterbodies increases as the discharge flows from Geona Creek to Upper Finlayson Creek, and then to Lower Finlayson Creek (as expected). The bankfull discharge is much higher than the predicted discharge during a 1-in-50 wet year suggesting that the conveyance capacity would be more than enough for carrying discharge during a 1-in-50 wet year (Table 2.2). The dominant size of the stream sediments in these stations is less than 2 mm in diameter (i.e., sand and finer; see Alexco 2016a, Figure 4-8).

3 METHODS

3.1 Inundation Analysis

In the first step of the inundation analysis, the breach dimension, peak discharge, and the flood hydrograph were estimated for the worst-case WMP failure scenario described in Section 2. A simplified methodology developed by the Washington State Department of Ecology (Schaefer 1992, updated in 2007) was adopted for this purpose. The methodology was developed based on an extensive literature review and the author's practical dam safety experience (Schaefer 1992, updated in 2007). In order to facilitate the accurate use of the methodology, the Washington State Department of Ecology has developed a detailed technical note (Schaefer 1992, updated in 2007), a number of Microsoft Excel spreadsheets, and a guidance document for spreadsheet use (Walther 2007). As such, the methodology has been widely used for a general assessment of dam break inundation analysis, and is recommended by a number of regulatory bodies, such as by the State of Colorado (Dam Safety Branch of the State of Colorado 2010) and the province of British Columbia (BC Dam Safety Program 2001). The basic principles and equations that were adopted in the methodology and were used in this analysis are provided below:

- The dam breach parameters such as geometric dimensions of the breach, time of breach development, and volume of embankment material eroded were estimated using empirical procedures developed by MacDonald and Langridge-Monopolis (1984). Assuming a trapezoidal breach shape, this empirical procedure allows the estimation of dam-breach parameters based on the volume of water stored in the reservoir at the water surface elevation under consideration, and the height of water over the base elevation of the breach. The Washington State methodology selected this empirical procedure based on an extensive review of historical breaches of earthfill dams (Wahl 1998);

- The dam breach peak discharge and time of the peak discharge were estimated from the breach dimensions calculated above using a modified weir equation proposed by Fread (1981). The volume of water available in the LWMP (500,000 m^3) and the inflows from the UWMP dam (250,000 m^3) were used to estimate the peak discharge; and

- The dam breach hydrograph was estimated from the estimated peak discharge and time of the peak discharge using dimensionless exponential equation proposed by Barfield et al. (1981).

In the second step, the attenuation of the dam breach peak discharge as the flood wave travels downstream was estimated based on a family of curves included in the British Columbia dam break inundation guidance document (BC Dam Safety Program 2001, updated in 2016). The guidance document was developed by the dam safety program of British Columbia Ministry of Forests, Lands, and Natural Resource Operations, and intended for small dams with height less than 15 m. The dams of both LWMP and UWMP will be less than 15 m in height, and hence the guidelines are applicable for the analysis. The attenuation curves depict the relationship of the percentage of peak flow reduction versus the distance downstream for various reservoir storage volumes ranging from 10 to 2,000 acre-feet and average channel slope ranging from 0.1% to 5%. The following tasks were completed in the second step:

- The attenuation of the peak discharge from the catastrophic failure of the WMPs in the downstream receiving environment was estimated from the attenuation curves mentioned above. The representative curve corresponding to 600 acre-feet (740,088 m^3) which is close to the combined volume (750,000 m^3, 608 acre-feet) of the LWMP and UWMP, and a 1% average channel slope which best represents the slope of the major part of the downstream channels (Table 2.2) was used for the purpose.
- The cross-sectional channel area required to pass the attenuated peak discharge was estimated by dividing the attenuated peak discharge (determined in the previous step) at the monitoring stations by a representative breach wave velocity for stream bed slope and overbank cover type at the cross-section, following the guidance document (BC Dam Safety Program 2001, updated in 2016). The same techniques were also suggested by the Washington State Department of Ecology (Schaefer 1992, updated in 2007). The representative breach wave velocity was obtained from the tabulated data for different slope and cover type in the guidance document.
- For illustration purposes, an estimate of the potential maximum flood depth corresponding to the cross-sectional area required to pass the peak flow (determined in the previous step) from the standard relationship of the area of a trapezoidal cross-section with its depth and width (top width and base width) was determined. This calculation assumes that the same trapezoidal shape is applicable until the maximum flood depth occurs, while in practice the shape will change when flood depth is more than the bankfull depth. As such, these estimates of the maximum flood depth can be taken as conservative estimate of the maximum flood depth.

3.2 Downstream Sediment Erosion/Deposition Potential Analysis

The potential geomorphological impacts of the dam breach peak flow discharge in downstream Geona Creek were analyzed. The analysis was based on the following two methods:

i. Applying a threshold velocity of erosion, deposition, and transportation from the Hjulström graph (Hjulström 1935) for the prevalent stream sediment size.

ii. Using the stream power as an indicator of the channel sensitivity to erosion and deposition processes, and major geomorphic work such as channel widening, elimination of roadway embankment, avulsions, and/or braiding.

The Hjulström graph (Hjulström 1935) provides the boundaries among erosion, transportation, and deposition in a plot of flow velocity versus particle size. Stream sediment sampling results from the downstream monitoring stations (KZ-9, KZ-15, KZ-22, and KZ-26) shows that the dominant size of the stream sediment in these stations is less than 2 mm in diameter (see Alexco 2016a, Figure 4-8). Using the Hjulström graph, the following threshold velocities for 2 mm sediment size were obtained and used in the analysis of sediment erosion and/or deposition:

- Deposition may start to occur for stream velocity < 0.18 m/s;
- Erosion may start to occur for stream velocity > 0.5 m/s; and
- Transportation of sediment may occur for stream velocity in the range 0.18 – 0.5 m/s.

The stream power of a flow indicates its ability to influence geomorphology, and is a measure of the main driving forces acting in the channel (i.e., joint effect of channel gradient and discharge) (Bizzi and Lerner 2015). Stream power has also been widely used to assess sediment transport and channel geomorphic pattern (e.g., Bagnold 1977; Chang 1979; Ferguson 2005). Total stream power (TSP) and specific stream power (SSP) at the selected monitoring stations in Geona Creek and Finlayson Creek were calculated as (Bagnold 1966, 1977):

$$TSP = \gamma QS, \;\; SSP = \frac{TSP}{W}$$

Where γ the unit weight of water (9,800 N/m^2), *Q* is the estimated attenuated peak discharge, *S* is energy slope which was approximated as bed slope, and *W* is the channel bankfull width. The calculated stream power was compared with a threshold stream power value (referred to as ‘critical stream power’) to analyze the likelihood of downstream sections experiencing major erosional processes. When stream power exceeds the critical stream power, erosion dominates (Bull 1979). There have been a range of values of critical specific stream power in the literature; the following thresholds of SSP suggested by the United States Department of Agriculture (Yochum and Scott 2017a; Yochum et al. 2017b) were applied in this study:

- Highly likely (90% potential) and likely (50% potential) of major geomorphic change with avulsions, braiding, and elimination of roadway embankments due to erosion-dominated processes for SSP > 2400 W/m^2 and SSP > 990 W/m^2 respectively.

- Highly likely (90% potential) and likely (50% potential) of substantially widened channel due to erosion-dominated processes for SSP > 2000 W/m^2 and SSP > 790 W/m^2 respectively.

4 RESULTS

4.1 Outflow and Downstream Inundation from the Hypothetical Failure of the WMPs

The inundation analysis for the worst-case scenario of the failure of the proposed KZK WMPs showed the following (summarized in Table 4.1 and Table 4.2):

- The prospective trapezoidal shaped breach is expected to fully form with a top width of 12 m and base width of 5.5 m. The maximum width (i.e. top width) of the breach is about 7% of dam crest length of LWMP. The height of the fully formed breach was considered as the height from the dam crest to its toe (13.2 m), a representative dam height for the worst-case scenario (Table 4.1).

- The hydrograph of the discharge through the breach suggests that the peak discharge would be 438 m^3/s, and would occur 44 minutes after the start of the failure (Figure 4.1). From the peak discharge of 438 m^3/s, the discharge is predicted to rapidly decrease to about 100 m^3/s at 60 minutes from the beginning of the failure, after which the discharge rate decreases at a slower rate (Figure 4.1). The outflow from the failure may continue for 1.5 hours before most of the stored water and sediment is released.

- The attenuation analysis of the peak discharge showed that the peak discharge is expected to attenuate from 438 m^3/s at the LWMP dam to about 315 m^3/s within 3.75 km (at KZ-15), 210 m^3/s within 11.75 km (at KZ-22), and 131 m^3/s within 25.7 km (at KZ-26) (Table 4.2).

- The peak flow and cross-sectional area needed to pass the peak flow at all the downstream stations are much higher than the bankfull discharge and cross-sectional area at bankfull depth respectively, indicating that the peak flow would cause overbank flooding (Table 4.2). The estimated potential maximum flood depth (Figure 4.2) corresponding to the peak flow is also expected to be much higher than the bankfull depth (Table 4.2).

- There is projected to be a total of 4,991 m^3 sediment released due to the WMP failure, of which the vast majority (4,843 m^3) would originate from the erosion of the embankment and the remainder (148 m^3) would be from the stored sediment in the two water management ponds.

This released sediment volume is expected to be much less than the total volume of water (750,000 m^3) that would be released during the breach. As such, the major downstream impact is expected to be caused by the water flow from the breach.

- The sediment from the dam materials would potentially be eroded during the initial breach development period and subsequently flow away due to continued water flow from the breach, while stored sediment would potentially be released after all the water was released (see Figure 4.1).

4.2 Potential Sediment Erosion/Deposition in the Downstream Waterbodies

The potential peak stream velocity in all monitoring locations (Table 4.2), which would occur when the peak discharge from the dam failure travels to the respective location, is expected to be much higher than the erosional threshold velocity (0.5 m/s) obtained from the Hjulström graph for the dominant sediment size present in those locations (see Section 3.2). The estimated specific stream power (Table 4.2) in a major part of the downstream waterbodies (from LWMP dam to 5 km upstream of KZ-26) would be much higher than the erosional threshold suggested by the United States Department of Agriculture (see Section 3.2). Consequently, the potential impact of dam breach peak discharge on downstream channel geomorphology would be the following:

- The downstream Geona Creek and Upper Finlayson Creek are expected to experience significant erosion when the peak flow travels through.
- The potential of substantially widened channel and major geomorphic change (e.g., avulsions, braiding, elimination of roadway embankments) is highly likely (90% potential) up to Station KZ-22.
- As SSP in KZ-26 is less than 790 W/m^2 (Table 4.2), KZ-26 and the stream section 5 km upstream of the KZ-26 may not experience major geomorphic change (e.g., avulsions, braiding, elimination of roadway embankments) caused by erosion-dominated processes. Deposition may not occur in these sections as the potential peak stream velocity in all monitoring stations is much higher than depositional threshold of Hjulström graph.
- As the dam breach peak flow would occur after the erosion of embankment sediment, most of the eroded embankment sediment would be carried away by the peak flow to beyond Station KZ-26.

The geomorphological impact summarized above was for the dam breach peak discharge, which is not expected to impact the fate of the stored sediment in the LWMP and UWMP as these deposited sediments would be released after the peak discharge ends, possibly at the end of the dam breach flow. Assuming that the entire 148 m^3 of deposited sediment would be released after all the water is released, it would flow downslope behaving like sediment-laden debris flows provided that there is a favorable condition of occurring such sediment-laden flows (Rickermann 1999). In general, debris flow does not occur as long as the downslope gradient is less than a certain critical value, and the critical gradient was reported to be more than 4% (Bathrust 1997, D'Agostino et al. 2010). The average slope from the LWMP dam toe to the immediate receiving environment (Geona Creek) is about 2.5% (Table 2.2). As such, it is highly likely that the stored sediment in the WMPs would not flow downslope at all, and rather stay in the LWMP. In the highly unlikely event of downslope sediment movement, the estimated runout distance for the stored sediment is about 80 m from the LWMP dam, with a maximum sediment depth of 0.84 m (Rickermann 1999).

4.3 Potential Impact on the Fish Habitat

4.3.1 Background Fish and Fish Habitat

The KZK Project area is located in the Geona Creek valley, and is characterized by a steep-sloped valley with discontinuous permafrost conditions and fine-grained glaciofluvial and morainal deposits (KP 2016). The valley drains to the north through Geona Creek into Finlayson Creek and Finlayson River, and to the south through South Creek into North River/Lakes system (Alexco 2016). Baseline environmental studies were completed in 1994-1995, and 2015-2016, and the results are outlined in Alexco (2016a). Full descriptions of the Fish and Fish Habitat in the Project area are also found in the Project Proposal submitted to YESAB, Chapter 10 – Aquatic Ecosystems and Resources, and Appendix E-4 – Fisheries Offsetting Plan. In summary, Geona Creek provides fish habitat, but at a low productivity level, and only to Arctic grayling (*Thymallus arcticus*). Most of the grayling found in the creek are fry and juveniles, with the highest numbers found in the headwater ponds (beaver ponds) of the creek. Very low numbers of adult grayling have been observed in the creek. Low numbers of grayling likely overwinter in the deepest pools of the creek, although this has not been confirmed.

Geona Creek was characterized into reaches as part of the baseline work (Alexco 2016a). Reach 1 is the downstream section that would be primarily affected by a failure of the WMPs. This reach was characterized as having an average channel width of 5.5 m, and average wetted width of 3.2 m. Both left and right banks are primarily undercut and composed of fines and gravels with intermittent cobbles. Riparian vegetation is dominated by shrubs and grasses, interspersed with some wetland species such as sedges. The reach is occasionally confined, with regular stream braiding with smaller channels branching off the main stem.

Historic and current beaver activity is the main driver of pond formation within the reach. The average pool depth is 0.8 m, and although investigations found that Geona Creek flowing water maintained dissolved oxygen concentrations high enough to sustain overwintering fish populations, the shallow ponds in the system freeze almost to the bottom. Therefore, Geona Creek provides marginal to no overwintering habitat, and possibly only for juveniles. Adult grayling likely move into Finlayson Creek, or even further downstream into Finlayson River, during the winter months. Beaver dams within the system have likely caused limited fish movement into and within the creek. Stream conditions within Reach 1 of Geona Creek, are therefore limited to providing suitable habitat for low-numbers of juvenile Arctic grayling rearing, and marginal habitat for spawning.

Finlayson Creek provides habitat for Arctic grayling, as well as slimy sculpin (*Cottus cognatus*). One burbot (*Lota lota*) was caught at KZ-26 in 2012, although this observation has not been replicated in any other fishing surveys, and may be an anomaly. Finlayson Creek flows through culverts under the Robert Campbell Highway. These culverts are barriers to fish passage, preventing fish from moving upstream. Any fish that move from Geona or Finlayson Creeks into the Finlayson River for overwintering are therefore currently unable to return to the upstream reaches. The baseline work concluded that no bull trout or Dolly Varden char (fall-spawners) are found in any of the creeks sampled. There are no resident salmonid species, other than Arctic grayling, in the creeks and beaver ponds within the Project area.

4.3.2 Potential Effects on Fish and Fish Habitat

As part of the KZK Project development, a Fisheries Offsetting Plan has been developed to enhance fisheries productivity in the system. A series of ponds will be developed in Reach 1 of Geona Creek, which will provide better overwintering habitat. Structural changes in Finlayson Creek at the Robert Campbell Highway are also proposed. This work will allow fish to migrate upstream into Lower Finlayson Creek, and ideally, facilitate a more typical seasonal movement pattern for Arctic grayling within the system. As these enhancements will be implemented at the same time as mine development, the hypothetical failure of the WMPs considers the potential effects on the system with these offsetting measures in place.

A summary of the predicted flood waves and effects on fish habitat are shown in Table 4.3. The modelling of the worse-case scenario of the failure of the WMP shows that the majority of the impacts would occur in Geona Creek, downstream of the LWMP. Peak flows would be immediate following a failure of the WMPs, with a peak flow of 416 m^3/s. This predicted flow is approximately 400 times the peak annual flood for Geona Creek (YESAB submission, Chapter 8, Surface Water Quality and Quantity). There would be no time for resident fish to move from the system, and a flood of this scale would flush the fish downstream, probably causing trauma and mortalities as the fish collide with substrate and debris in the system. Adult Arctic grayling have not been found in velocities greater than 1.5 m/s, which is significantly less than the predicted peak flows (Larocque et al. 2014). As the peak flow subsides, for surviving fish, there would be stranding of fish outside of the channel, or in isolated pools.

The additional pool habitat that will be created through offsetting measures may provide some refuge from the initial flood wave, particularly those that are created off the main channel. The inundation and sediment deposition following the initial flood wave would compromise the efficiency of some of this habitat, although some may still provide functional fish habitat. The proposed offsetting ponds will be approximately 2.0 ha in size with an average depth of about 2 m, providing a volume of 40,000 m^3. The inundation model indicates that less than 5,000 m^3 of sediment will be released due to the failure of the WMPs. Therefore, although the availability of the offsetting ponds would be reduced, not all would fill with sediment, and some deeper pools may still provide areas of refuge during the peak flow, and during the subsequent inundation.

The failure of the WMPs would result in a flood wave that would heavily scour Geona Creek where the channel is confined. Sediment deposition would be limited to the initial first approximately 80 m of Geona Creek downstream of the LWMP. The peak flow would result in major channel and bed erosion likely down to KZ-22 on Finlayson Creek. The suspended particles from this erosion have the potential to smother gills, as well as eggs and young of the year in spawning and rearing habitat.

The effects on fisheries productivity would depend on the timing of the WMP failure. Even with fully-functional offsetting measures, the immediate downstream reach of Geona Creek will likely not provide critical spawning habitat for grayling. A post-flood event inundation would therefore not remove large numbers of spawning adults from the population, and grayling would still be able to spawn in other watercourses, including Finlayson River and tributaries. A peak flood event during winter would likely have relatively greater impacts on the grayling population compared to the spring. Overwintering habitat is currently limited in the system, and offsetting measures will be in place that enhance pool habitat, and therefore, overwintering capacity. A peak flood event during the winter would displace fish during a season when overwintering habitat in neighbouring systems is also likely limited. Downstream movement to overwintering habitat primarily occurs in September (Craig and Poulin 1975), so a dam failure after September and before the spring, would have the greatest effect on the resident overwintering population. A failure of the WMP during the winter may therefore affect recruitment back into the population, until such time as overwintering habitat is functional again in the system. Although a dam failure after September and before the spring would have the greatest effect, the worst-case dam failure that was assumed to occur under a rainy day scenario (Section 2.1), and assessed here, is not likely to occur outside of the rainy season, and the WMPs and downstream waterbodies will be frozen in the winter.

As outlined in Table 4.3., the peak flow and erosion potential would be greatest in Geona Creek. As the flood moves down into Finlayson Creek, there would be some effects in this watercourse as well. The peak flow would be higher than the maximum sustained velocity for Arctic grayling, meaning that some fish mortalities and stranding may occur. Due to the closer proximity to Finlayson River, compared to Geona Creek, it is possible that fish would be flushed into the Finlayson River, where habitat would likely remain unaffected. Suspended sediments from the upstream channel scour and erosion may clog gills and smother spawning habitats. These effects would be temporary, and would not be a concern once the sediments settle out after the initial flood wave has passed through the system. The timing of the WMP failure would have the greatest influence on impacts to fisheries productivity. The offsetting measures are intended to facilitate fish upstream migration to spawning and rearing habitat in the spring and summer, and downstream migration to overwintering habitats in the fall (primarily September). A WMP failure and peak flood event during these critical life-cycles would have a greater influence on recruitment back into the population, than outside of the peak migration periods.

Arctic grayling are a widespread species in the north, and are found in most waters throughout the Yukon. Populations are generally secure, although some spring spawning runs have declined and monitoring is ongoing to determine the success of regulatory changes limiting harvest (Environment Yukon 2010). The Geona Creek system does not provide unique or specialized habitat that provides critical life-history function.

There are no commercial, recreational, or Aboriginal fisheries in Geona Creek, nor downstream in Finlayson Creek. This is likely due to low fisheries productivity throughout the system, as well as access restrictions. The implementation of the offsetting measures may enhance productivity within the system, although access to harvesting these fish is restricted as the Tote Road Lease does not permit public use to the road that runs parallel to the creek. This road will continue to have access restrictions during mine operations. For these reasons, the failure of the WMPs is not expected to affect CRA fisheries. Overall, Yukon fish populations are healthy and most fisheries are within sustainable limits (Environment Yukon 2010).

Geona Creek is an erosional creek system that is relatively straight in its alignment to Finlayson Creek. The flood wave would therefore not change the channel alignment substantially, and following inundation, it is expected that geomorphological processes would re-establish the creek to pre-inundation conditions. Riparian zones would be disturbed, however due to the low volume of sediment that would be mobilized, and the fact that peak sediment deposition would be limited to the immediate (<100 m) downstream section, this zone should recover within the short (months) to medium (<5 years) term. Even if the channel does not return to its exact pre-inundation conditions, it would return to a channel that provides fish habitat. Benthic drift from upstream, as well as fish colonization from adjacent watercourses (including from the Finlayson River), would help support natural restoration. Depending on the exact nature and location of sediment deposition and scour, restoration techniques could be used to facilitate a return to fish habitat. Although there would be impacts to the resident fish and fish habitat from the WMP inundation, a return to functional fish habitat within the Geona Creek is expected.

5 CONCLUSIONS

An assessment of the potential impact of a hypothetical catastrophic failure of the proposed water management ponds at the Kudz Ze Kayah site to downstream fish and fish habitat in Geona Creek was conducted. The hypothetical catastrophic failure of the WMPs was assumed to occur under a rainy day scenario through their dams with a sequential dam failure case, in which the failure of the upstream dam of the UWMP caused the subsequent failure of the downstream dam of the LWMP. The likelihood of this series of events co-occurring to produce this scenario is *extremely low*, and the consideration of the consequences and potential effects of this failure assessed herein should take this likelihood into account. The likelihood of a catastrophic failure of the WMPs during the most vulnerable overwintering period is even lower.

The major downstream impact of the failure of the proposed WMPs is expected to be caused mainly by the water flow from the breach, and sediment released by the failure would have minimal impact as there is projected to be less than 5,000 m^3 sediment released, compared to 750,000 m^3 water released due to the failure of the WMPs. The peak water discharge from the failure are expected to cause significant impact on the downstream channel morphology due to the erosional force from the discharge. Overall, the effects to the fish and fish habitat downstream of the WMPs are considered temporary, with a high restoration potential. Fish mortalities would be expected in Geona Creek in particular, with fish flushing and stranding. Recruitment back into the Arctic grayling population would be depressed until habitat becomes functional again. The downstream and adjacent waterbodies would still maintain viable populations, and the close proximity to Finlayson River, would facilitate a source of benthic macroinvertebrates and fish that would recolonize the system. Geona Creek, and to a lesser degree, Finlayson Creek, would likely experience scour of the channel and unstable channel banks and beds. Once the initial flood wave has passed, the system would start to stabilize, and restoration techniques could be used to speed-up the natural regeneration process. Overall, the failure of WMPs would be limited to temporary effects on up to two species, and no CRA fisheries.

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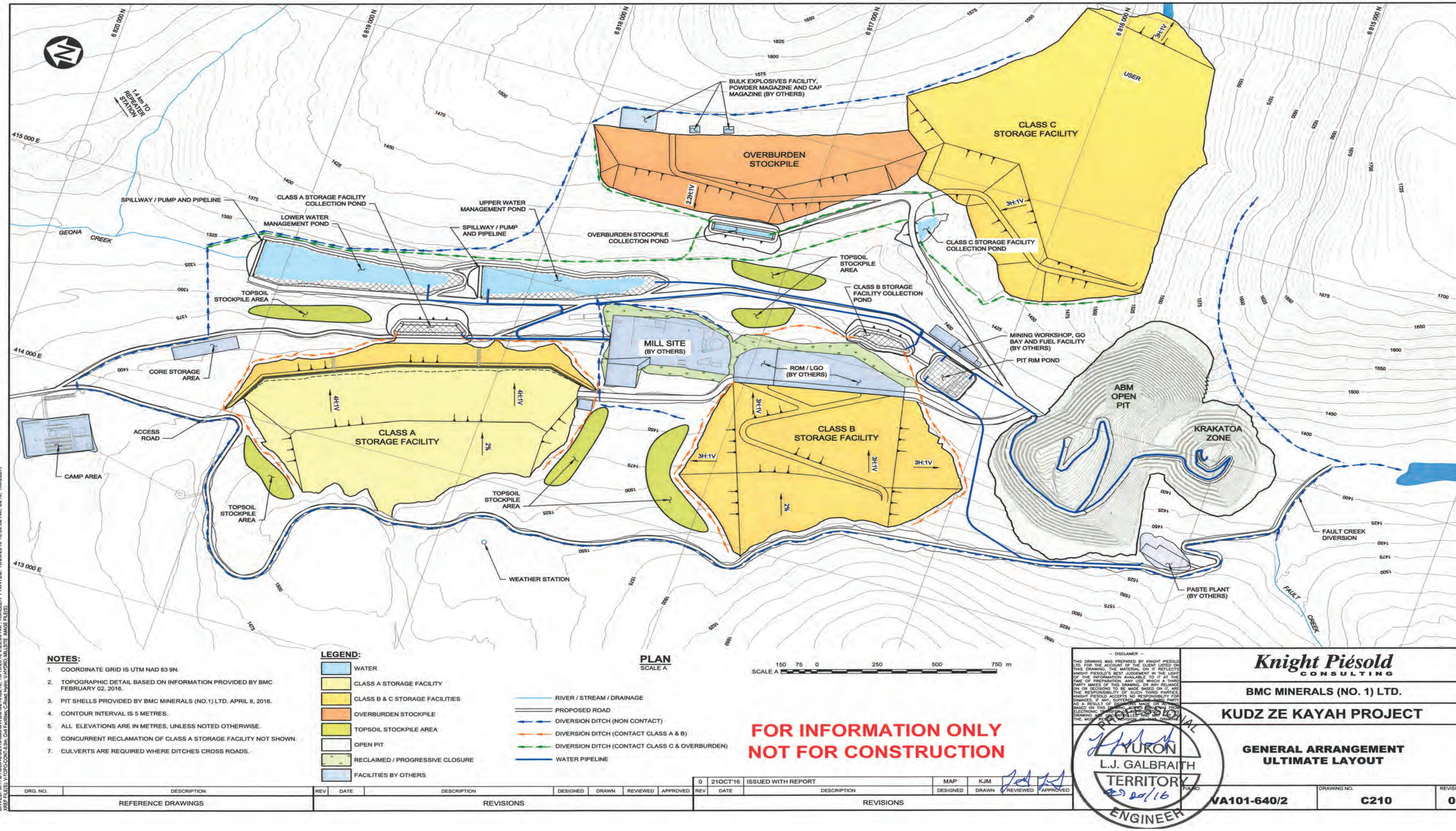

Layout of Kudz Ze Kayah Mine

Reproduced from the KZK PFS Report (KP,2016)

Date: October 2017
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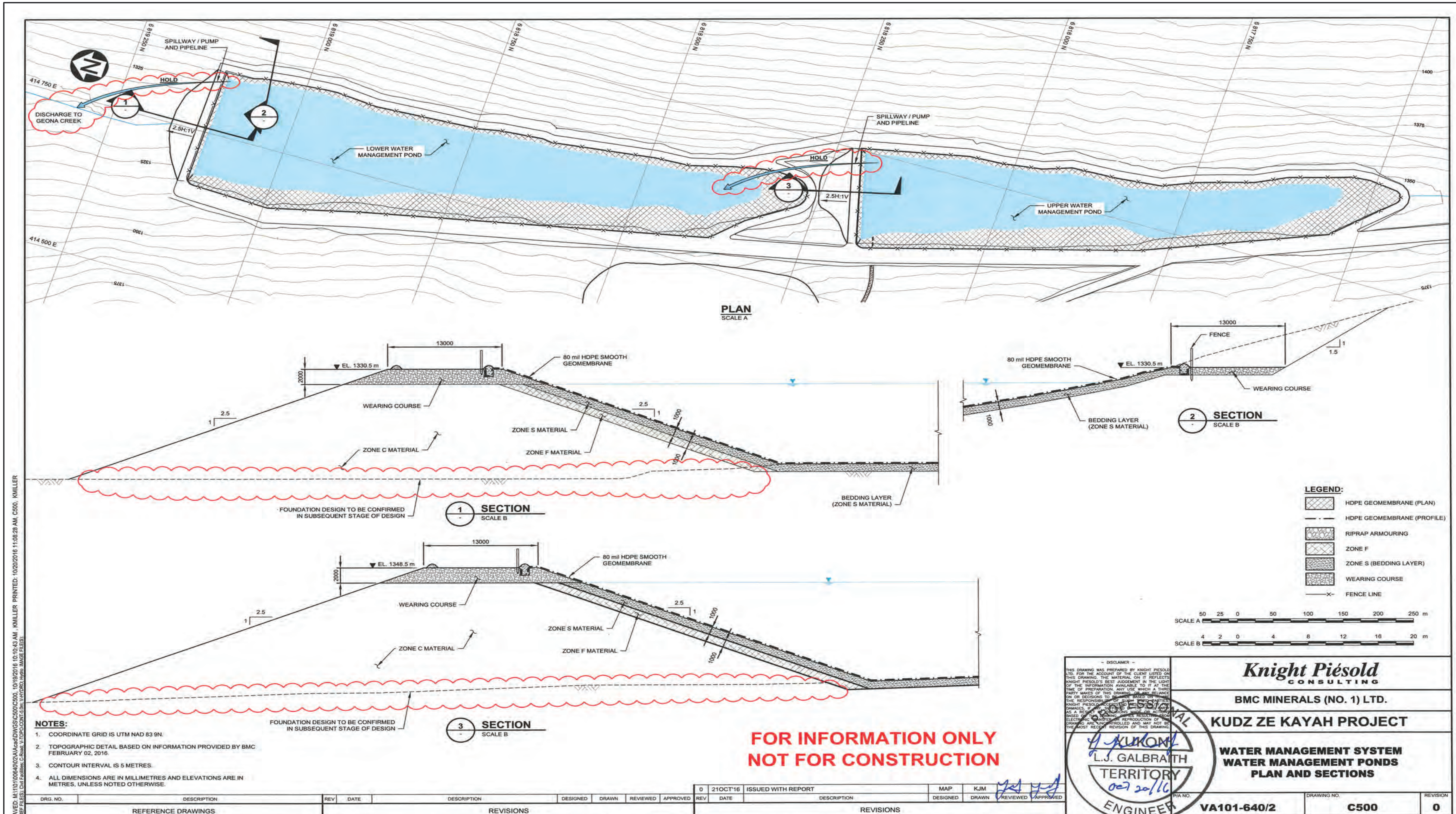
Figure 1.1



Layout of Proposed Water Management Ponds and Dams

Reproduced from the KZK PFS Report (KP,2016)

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Figure 1.2

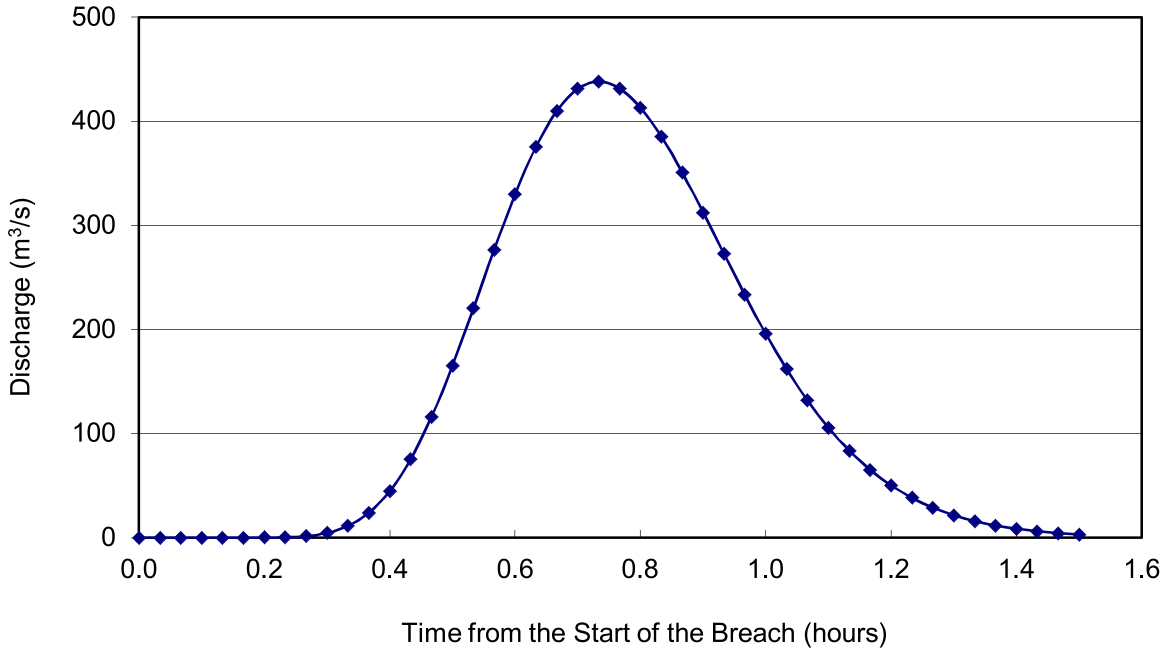
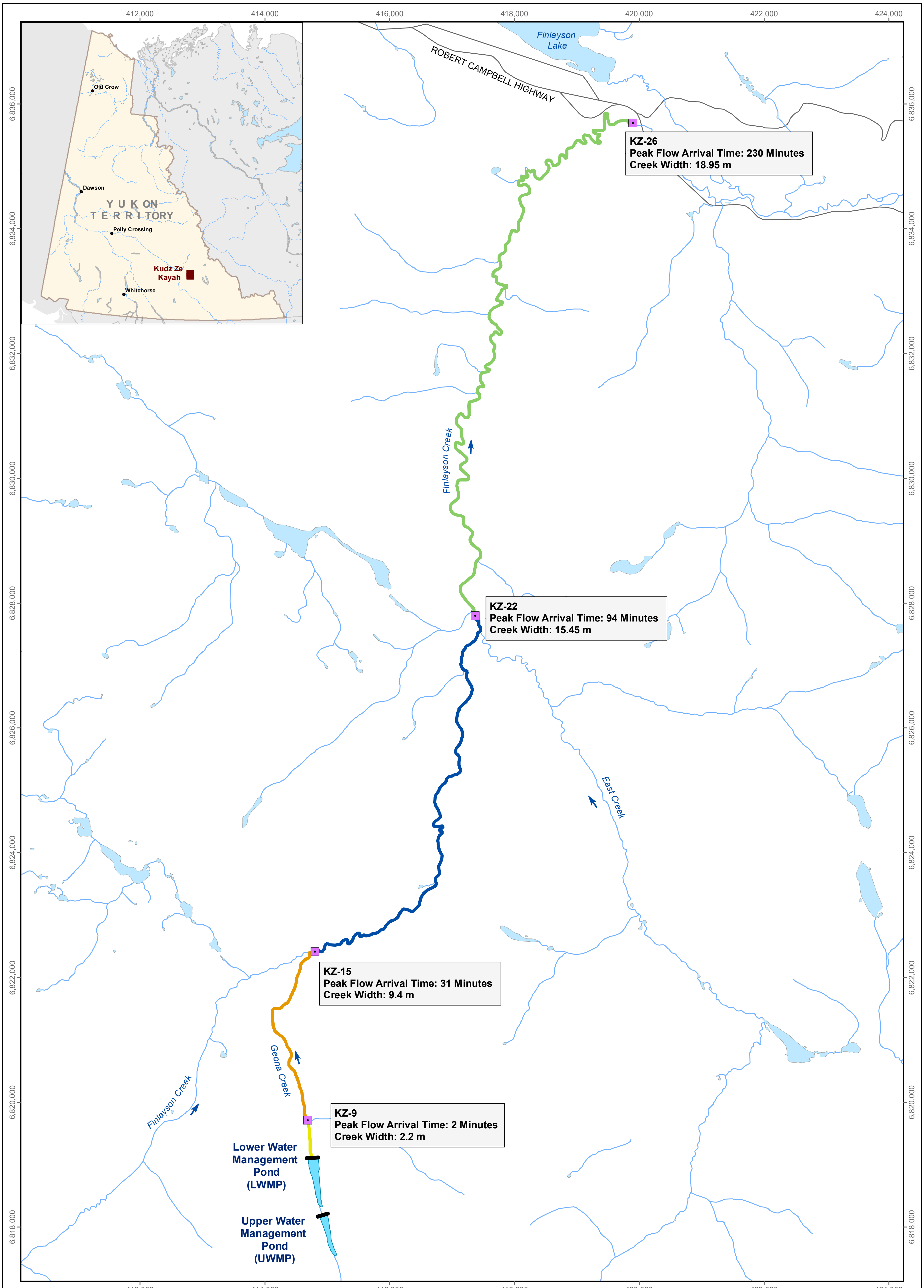


Figure 4.1: Discharge Hydrograph from the Hypothetical Catastrophic Failure of the Proposed WMPs



LEGEND

Water Quality Sampling Location

Maximum Channel Flood Depth (m)

- > 17
- 13 - 17
- 6 -13
- 4 - 6

Potential Maximum Channel Flood Depth for the Hypothetical Failure of the Proposed WMPs

0 1 2 4
km

N W E S

Map Projection: UTM Zone 9V NAD 1983
Data Source: Reproduced under licence from Her Majesty the Queen in Right of Canada, Department of Natural Resources Canada. All rights reserved.

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Figure 4.2

Document Path: S:\Projects\177202\177202.0041 - Kudz Ze Kayah Innundation Model\GIS Mapping\Flood mappin17-41 - Inundation Map.mxd

Table 2.1: Physical Characteristics of the Proposed Water Management Ponds

	Upper Water Management Pond	**Lower Water Management Pond**
Elevation at the Dam Crest	1,348.5 m	1,330.5 m
Volume at the Dam Crest	250,000 m^3	500,000 m^3
Elevation at Pond Bed	1,333.4 m	1,317.3 m
Maximum Depth	14.1 m	13.2 m
Surface Area at the Dam Crest	75,265 m^2	102,071 m^2
Dam Crest Length	151.5 m	178.8 m
Dam Crest Width	13 m	13 m
Downstream Dam Slope	2.5H:1V	2.5H:1V
Upstream Dam Slope	2.5H:1V	2.5H:1V
Accumulated Sediment	100 m^3	48 m^3

Table 2.2: Geometric Parameters and Discharge Capacity of the Downstream Receiving Waterbodies

Station	Description	Distance from the LWMP Dam (m)	Elevation (masl)	Average Slope (%)	Bankfull Parameters			During 1/50 Wet Year	
					Width (m)	Depth (m)	Discharge[a] (m^3/s)	Discharge[b] (m^3/s)	Depth[a] (m)
KZ-9	Geona Creek below the LWMP Dam	500	1,302	2.5	2.2	1.4	1.5	0.1	0.3
KZ-15	Finlayson Creek, 100 m downstream of the Confluence with Genoa Creek	3,754	1,203	1.0	9.4	1.1	7.1	1.1	0.3
KZ-22	Finlayson Creek below East Creek	11,755	1,091	1.0	15.5	1.4	9.8	2.7	0.7
KZ-26	Finlayson Creek just above the confluence with Finlayson River	25,689	950	1.0	19.0	1.9	14.7	3.3	0.7

[a]Estimated using calibrated stage-discharge rating curve (Alexco, 2016b).
[b]Discharge predicted by the water balance model (Alexco, 2017)

Table 4.1: Estimated WMP Failure Characteristics

Parameters	Results
Breach Shape	Trapezoidal
Breach Base Width	5.5 m
Breach Top Width	12 m
Breach Average Width	8.8 m
Breach Height	13.20 m
Time for Peak Discharge	44 min
Dam Breach Peak Discharge	438 m^3/s
Volume of Embankment Material Eroded	4,843 m^3

Table 4.2: Downstream Flow Characteristics caused by the Hypothetical Failure of the Proposed WMPs compared to the Pre-failure Condition

Parameters		Unit	KZ-9	KZ-15	KZ-22	KZ-26
Distance from the LWMP Dam		m	500	3,754	11,755	25,689
Pre-failure	Flow during 1/50 Wet Year	m^3/s	0.12	1.12	2.73	3.35
	Water Depth during 1/50 Wet Year	m	0.31	0.32	0.65	0.71
	Stream Velocity during 1/50 Wet Year	m/s	0.4	0.4	0.3	0.26
	Bankfull Depth	m	1.38	1.07	1.36	1.85
	Cross Sectional Area at Bankfull Depth	m^2	1.6	9.2	19.6	32.5
	Bankfull Discharge	m^3/s	1.52	7.12	9.8	14.7
During Failure	Peak Flow	m^3/s	416	315	210	131
	Peak Flow Arrival Time	minute	2	30	94	230
	Velocity corresponding to the Peak Flow	m/s	2.62	1.7	1.7	1.7
	Potential Maximum Flood Depth	m	17	13	6	4.22
	Cross-sectional Area needed to Pass the Peak Flow	m^2	159	185	100	77
	Stream Power corresponding to the Peak Flow	W/m	101,944	30,905	20,603	12,877
	Specific Stream Power corresponding to the Peak Flow	W/m^2	46,338	3,287	1,333	679

Table 4.3: Summary of the Predicted Flood Waves and Effects on the Downstream Fish Habitat

	Geona Creek	Finlayson Creek		
	KZ-9	KZ-15	KZ-22	KZ-26
Distance from LWMP Dam (km)	0.5	3.75	11.8	25.7
Physical Characteristics				
1-in-50 Wet Year Depth (m)	0.31	0.33	0.65	0.71
1-in-50 Wet Year Discharge (m^3/s) [1]	0.12	1.12	2.73	3.35
Bankfull Width (m)	2.2	9.4	15.5	19
Bankfull Depth (m)	1.38	1.07	1.36	1.85
Bankfull Discharge (m^3/s)	1.52	7.12	9.81	14.69
Flood Wave Impact				
Peak Flow Arrival (min)	2	30	94	230
Peak Flow (m^3/s)	416	315	210	131
Peak Flow / Bankfull Flow (ratio)	274 x	44 x	21 x	9 x
Peak Flow / 1-in-50 Wet Year Flow (ratio)	3467 x	281 x	77 x	39 x
Maximum Flood Depth (m)	17	13	6	4.2
Max / Bankful Depth (ratio)	12.3 x	12.1 x	4.4 x	2.3 x
Potential for Channel Widening by the Peak Flow[2]	Highly Likely	Highly Likely	Likely	Unlikely
Bed Sediment Erosion / Deposition by the Peak Flow[3]	Erosion - Very High, with scouring potential	Erosion - High	Erosion - High	Erosion - Moderate
Key Fish Habitat Notes	low productivity (but may expect more after barriers are removed as part of offsetting) low fish density very limited pool habitat, relatively straight run to Finlayson Creek	low productivity (but may expect more after barriers are removed as part of offsetting) low fish density very limited pool habitat	low productivity (but may expect more after barriers are removed as part of offsetting) low fish density very limited pool habitat	low productivity (but may expect more after barriers are removed as part of offsetting) low fish density very limited pool habitat
Key Fish Species Notes	Arctic Grayling. Juvenile grayling mainly present in headwater ponds. Low numbers of adults observed.	Arctic Grayling Slimy Sculpin		Arctic Grayling Slimy Sculpin Burbot (only 1 captured)
CRA Fisheries	None			
Seasonal Considerations	Limited over-wintering habitat. Marginal spawning habitat.	Over-wintering in Finlayson River - cannot return due to culvert barrier.		
Peak Flow Impact	Fish deaths, fish stranding, and temporary loss of fish habitat. Deeper pools may provide some refuge habitat.	Some fish deaths and stranding. Likely survival if fish are flushed to Finlayson River.		
Near-Term Impact [4]	eroded channel, short term food limitation, limited cover			sediment transport, seasonally elevated TSS, short term food limitation, limited cover
Long-Term Impact [5]	recovery expected - geomorphological, chemical, biological, riparian			

[1] mean annual discharge corresponding to the 1-in-50 wet year scenario

[2] Based on estimated specific stream power (SSP): SSP > 2000 W/m^2 (Highly likely), 790 W/m^2 < SSP < 2000 W/m^2 (Likely), and SSP < 790 W/m^2 (Unlikely)

[3] Based on estimated peak wave velocity (V_w) and SSP: SSP > 2000 W/m^2 and V_w > 2 m/s (Very High), 790 W/m^2 < SSP < 2000 W/m^2 and 1 m/s < V_w < 2 m/s (High), and SSP < 790 and 1 m/s < V_w < 2 m/s (Moderate).

[4] after failure-associated flow to 12 months post- failure

[5] 12 months post-failure to 10 years after failure