

# REPORT - MEETING No. 4

INDEPENDENT GEOTECHNICAL REVIEW BOARD (IGRB)

July 31 and August 1, 2018

## Review of Water Dam, Water Management and Tailings Storage Systems, KSM Project

British Columbia, Canada



# REPORT – MEETING NO. 4, INDEPENDENT GEOTECHNICAL REVIEW BOARD REVIEW OF WATER DAM, WATER MANAGEMENT AND TAILINGS STORAGE SYSTEMS, KSM PROJECT

## Table of Contents

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Table of Contents .....	i
List of Appendices .....	i
1. Introduction .....	1-1
2. Information Provided .....	2-1
2.1 Documents and Presentations .....	2-1
2.2 SG/FP Update .....	2-1
2.3 Future Fieldwork .....	2-2
3. Norway Site Inspections .....	3-1
4. Proposed Field Investigation Programme .....	4-1
4.1 Water Storage Dam .....	4-1
4.2 Tailings Management Facility .....	4-2
5. Hydrological Analyses Update .....	5-1
6. Proposed Pit Geotechnical Investigation Programme .....	6-1
7. Waste Geochemical Characterization Programme .....	7-1
7.1 Introduction .....	7-1
7.2 EcoMetrix .....	7-1
7.3 Golder Program .....	7-2
8. Closure .....	8-1

### List of Appendices

Appendix A	Agenda
Appendix B	Attendees

# 1. Introduction

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The fourth meeting of the KSM Independent Geotechnical Review Board (IGRB or Board) was convened by Seabridge Gold Inc. and on behalf of a future KSM Partner (SG/FP). The meeting was held from July 31<sup>st</sup> through August 1<sup>st</sup>, 2018. The Board is comprised of Dr. Andrew Robertson (Chairman), Mr. Anthony Rattue (Vice Chairman), Mr. Terry Eldridge, Dr. Gabriel Fernandez, Dr. Ian Hutchison, Mr. Jim Obermeyer, Dr. Leslie Smith, and Dr. Jean-Pierre Tournier. All Board members were present at the meeting which was conducted at the offices of Blake, Cassels and Graydon in Vancouver. The Agenda of the meeting is attached as Appendix A, and the list of attendees is in Appendix B.

The principal objectives of the meeting were to:

- Receive updates on corporate developments at SG/FP and work done at the site since the last IGRB meeting in August 2017;
- Discuss the implications of the recent inspection trip to the Engabreen Glacier in Norway on the investigations and design of the proposed Mitchell Glacier water intakes;
- Review and comment on the proposed foundation investigation programs for the Water Storage Dam (WSD), the Tailings Management Facility (TMF) and Mitchell Pit;
- Receive updates on the hydrological study programs; and
- Receive updates on the geochemical programs.

The Board's review scope includes the WSD and the associated Seepage Collection Dam (SCD), the Waste Rock Storage Facility (RSF), Surface Water Management, and the TMF including its seepage control facilities.

A range of topics were discussed during the meeting. These are listed below together with the section numbers of this report which contain the comments and recommendations of the Board.

- Project Updates (Section 2);
- Norway Site Inspection Trip (Section 3);
- Proposed Field Investigation Programs for the WSD and TMF (Section 4);
- Hydrological Analyses Update (Section 5);
- Proposed Pit Geotechnical Investigations (Section 6);
- Waste Geochemical Investigation Programme (Section 7); and
- Closure (Section 8).

As for prior meetings, the Board's review was carried out at "Discussion Level", in which the Board relies principally on information provided during meeting presentations, with support of KSM study reports where these have been provided.

In this report, the Board provides: observations made during the meeting, presents the outcomes of the discussions and gives recommendations for future work. *The recommendations are given in the body of the report in italics. The more significant recommendations are underlined.* The Board considers the Preliminary Feasibility Study Update (PFSU) to be complete (see Board Report No. 3) and the comments and recommendations provided in this report are applicable to the proposed future Feasibility Study (FS).

## 2. Information Provided

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### 2.1 DOCUMENTS AND PRESENTATIONS

Information provided to the Board, both prior to, and during the meetings, includes technical reports, drawings and tabular information dealing with the following topics:

- KSM Infrastructure Mapping (Geologic). Memorandum by Seabridge Gold, June 2018;
- Water Storage Dam (WSD) Area Drilling Plan. Drawing prepared by Klohn Crippen Berger (KCB), July 6, 2018;
- KSM Project - WSD Drilling Programme Objectives. Report by KCB, July 6, 2018;
- Proposed additional Drilling. Table prepared in 2018 by KCB;
- Preliminary Plan for additional Tailings Management Facility (TMF) Area Drilling and Site Investigation (on various base maps). Four drawings prepared by KCB, May 29, 2018;
- KSM Project - Proposed Preliminary Drilling Plan (for North Dam and the Splitter and Saddle Dam Areas). Two drawings prepared in 2018 by KCB;
- Proposed TMF Drilling. Tables prepared in 2018 by KCB; and
- Visit to Norway - Report by IGRB, March 2018.

Presentations given to the Board during the meetings included:

- Norway Trip, SG/FP and Board member Anthony Rattue;
- Glacial Inlet Design, KCB;
- WSD and TMF Site Investigations, KCB;
- Open Pit Geotechnical Update, SG/FP;
- Probable Maximum Precipitation (PMP) Estimation Methodology, Applied Weather Associates (AWA);
- Review of the Geochemical and Water Quality Assessment, EcoMetrix; and
- Geochemistry Data Review and Path Forward, Golder Associates.

### 2.2 SG/FP UPDATE

SG/FP provided the IGRB with an update on the Project activities and schedule. The IGRB was informed that SG is still in discussions with potential future partners and that, in the interim, a start is being made on certain FS activities including those discussed in this report. These include continued consideration of data and design needs for the glacial intakes, updates to hydrological studies, review of, and updates to, the geochemical evaluation work, and field investigations at the WSD, TMF and Mitchell Pit.

The IGRB was informed that SG/FP was transferring ownership of the Project to a separate subsidiary, KSM Mining ULC, which is a wholly owned subsidiary of Seabridge Gold. The Board is expected to continue its work in the future and will be retained by the ULC.

## 2.3 FUTURE FIELDWORK

The proposed additional fieldwork is described in Section 4.0 below. To facilitate the Board's review of this type of information in the future, it would be useful to have a clearer picture of the Project development. In particular, information on the means and extent of access to the various locations of the Project components, including the area of the Mitchell Glacier, is needed to better appreciate where and what types of field investigations are possible. This information would assist the Board in providing comments and recommendations on future fieldwork. It would also provide SG/FP and the Board better assurance that information needed for the future project phases is appropriately prioritized and obtained in a timely manner.

*The Board recommends the above information be provided. It would include tabulation of the various project phases, the associated information needs, anticipated means of access, and possible investigative methods. Supplementary plans of the areas and investigation points would also be helpful.*

*The proposed site investigation and information gathering could be categorized as:*

- *Required for demonstration of feasibility;*
- *Required for detail design; and*
- *Desirable for establishing the scope of work and site conditions for various construction contract packages.*

*This recommendation applies to all Project components.*

### 3. Norway Site Inspections

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#### Discussion

In March 2018, a fact-finding mission was carried out to learn more about the sub-glacial inlets beneath the Engabreen Glacier at the Svartisen Hydro-electric plant in Norway. The glacier research laboratory that is part of the installations was also visited. IGRB member Anthony Rattue participated in the visit.

The Svartisen site is one of five known examples of working sub-glacial water capture systems. All are operated for hydro-electric power production and the oldest, at the Tré-la-Tête glacier in France, dates back to 1943. The Engabreen Glacier Inlets at Svartisen have been in operation since 1990.

The five examples demonstrate there is precedence for the effective capture of sub-glacial water flow. The Engabreen Glacier experience highlights the extent of the seasonal variation in the subglacial water flow which is meteorologically driven. Characteristically, the low Winter flows facilitate plastic ice deformation that can substantially close-off the underlying water inlets. Spring thaw can re-open these inlets and increase water flows due to thawing of snow and ice. During Summer rainstorms, flows to the inlets can also increase significantly. Seasonal flow fluctuations of the magnitude experienced at Svartisen will make complete capture of subglacial flows at the KSM site by sub-glacial inlets alone challenging. Therefore, in order to enhance the capture rate surface inlets will be located downstream of the sub-glacial inlets and on the fringes of the glacier

Experience at Svartisen indicates that because of the inherent difficulties in exploring and characterizing the rock and ice conditions at the glacial-bedrock contact, it was necessary to use the observational approach to ultimately achieve an effective capture system. This approach involved iterative phases of installing exploration and pilot tunnels and water collection systems, data collection and analyses, and the design and installation of improvements and extensions to the collection system. A similar observational approach may be needed to improve the probability of success with KSM's glacial inlets. This will permit adaptation of the system to the site conditions as the operations mature.

At Svartisen, the systems are operated in a "passive" mode; i.e. the inlets collect water to the extent that their design physically allows for during the various seasons. Ice intrusion into the tunnels on occasion reduces the amount of water captured and effects access to the inlets. Attempts were made to "actively" manage the system by excavating and thawing the intruded ice, but this approach was abandoned and "passive" operation was continued.

Operational experience at Svartisen indicates that removal of glacial debris and sediment in the inlet facilities is an ongoing maintenance requirement. It is anticipated that the extent of any maintenance will be determined as the inlets are established and based on observations of their performance.

Providing for access to perform the necessary maintenance will be an important consideration at KSM and has been included in the plans.

Many of the issues discussed above are described in the literature and are now more clearly appreciated by the design team because of the visit.

#### Comments

The objectives of the KSM inlet system are to minimize the mixing of "non-contact" water from under the glacier with impacted "contact" water immediately downstream of the glacier and in the Mitchell Pit area, and in conjunction with the downgradient surface water collection system, minimize any glacial inflows to

Mitchell Pit. These objectives have been established to both minimize the amount of inflow that has to be managed in Mitchell Pit as well as reduce water treatment requirements. These objectives aim to capture flow in both winter, if present, and summer, and up to a specified extreme wet event. Consequently, a system capable of being adapted to conditions over the life of the mine is the intent.

Considering the similarities and differences between the Svartisen hydro-power and KSM inlet system operations, the Board believes the following useful comparisons can continue to be evaluated in order to guide the design of the KSM system:

- For glaciers of similar size, comparisons of glacier behaviour and dynamics through the seasons;
- Intake and tunnel geometry and dimensions;
- Glacial hydrology and water balance; and
- Water capture efficiency.

Compared to the hydro-power case histories, a more advanced design will be needed at KSM to achieve a suitable capture efficiency. It is likely that “active” capture systems will need to be considered as well as means to deal with extreme high glacial water flows. Actively opening and/or maintaining water inlets so they are ready to accept spring flow would differentiate the “active” system from a “passive” one that uses whatever capture capacity is available at a given moment during the year. Designing the system for a specified extreme high-flow condition may require additional capacity to be provided in surface capture and diversion systems immediately downstream of the toe of the glacier. While short-term surge storage on or below the surface could also be considered it would need to be approached with caution to ensure it does not occur for periods long enough to result in any hydraulic pressure buildup in the pit walls or to risk avoidable spill into the pit.

### Recommendations

*KSM design concepts need to be further developed using the lessons learned from the precedent hydro-power sites and with additional field data collection including various approaches for “active” water capture management, collecting and diverting extreme high-flows, and debris and sediment management.*

*The Board supports KSM’s intention to continue communication and cooperation with the entities operating glacial inlets at Svartisen and other sites to document experiences and information on glacial conceptual models, hydrology, water and ice pressures, and ice kinetics, and to determine the similarities and differences to KSM. In comparing the two systems it will be important to account for any differences that there may be in the rock quality. Information relating to the experiences at other sites with different rock conditions would be useful to widen the database. It will be important to analyze at least one other project in the Alps to see if the results and lessons learned are similar to those at Svartisen. Furthermore, the historic data collection period for the glacier, Mer de Glace, is certainly much longer and may provide more insight into long-term behaviour and seasonal extremes.*

The Board understands that KCB has been requested to further develop concepts for the glacier toe/surface flow collection and diversion system. *This should include further defining the relative flow rates of “contact” and “non-contact” water requiring capture to meet the design criteria of capturing the 1:200 year and 1:1000 year inflow floods into the open pit and underground works, respectively.*

*Sufficient data collection and analyses will be required to develop a glacial water balance including, amongst other components, precipitation input, temperature-flow correlations, and separation of land-based runoff from glacial melt, etc. There will be a need to include the capacity to store and or divert the relatively large observed difference between the instantaneous peak and the average 24-hour maximum flow values in the design of the capture system.*

The need for geophysics and surface drilling in the area of the proposed collection system (east of Brucejack fault) has been identified by the SG/FP team. *In addition to these proposed investigations, the Board sees a need for an investigation adit or adits in the same location as the inlets to gain early access below the glacier and permit the collection of information listed below. This adit (or these adits) should, to the extent practicable, also serve as elements of the ultimate inlet system.*

- *Rock quality and the requirements for tunnel excavation and support;*
- *Required minimum rock cover thickness;*
- *Selection of technique for inlet boring;*
- *Anticipated flow capacity of inlets;*
- *Optimal location and orientation of inlets;*
- *Distinction between sub-glacial flow and surface flow (only the total combined flow can be observed at the toe of the glacier);*
- *Inherent resistance of tunnel invert rock to erosion and the need for concrete lining;*
- *Required maintenance of the inlets and tunnels;*
- *Access for maintenance;*
- *Ice movement;*
- *Ice pressure; and*
- *Water pressure and flow in the glacier.*

*There will also be a need to evaluate the debris and sediment load at the toe of the glacier. It is understood that currently there is little or no information on the quantity and grain size distribution of the glacial debris load.*

*From discussions, it was learned that SG/FP would consider the inclusion of exploration adits in the pre-construction planning activities and the Board supports this early activity.*

## 4. Proposed Field Investigation Programme

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### 4.1 WATER STORAGE DAM

#### Discussion

The objectives and the proposed investigation programme and associated geotechnical and hydrogeological testing for the next stage of drilling for the WSD foundation were presented. The objectives presented include:

- Confirmation of the extent and nature of the calcareous unit in the WSD centerline area;
- Confirmation of the current local hydrogeological model that covers the WSD site to provide a better understanding of the water level variations observed between existing adjacent drill holes;
- Assessment of fracture patterns and potential dissolution features; and
- Confirmation of rock quality and excavation requirements along the spillway alignment.

The investigation programme includes drilling inclined drill holes within the WSD footprint, at the Seepage Collection Dam (SCD) downstream of the WSD, at the portals of the diversion tunnel for constructing the WSD, as well as along the spillway alignment. The holes are inclined to intercept the westward dipping calcareous unit in the WSD centerline area. Packer testing, televiwer logging, oriented core and the installation of multiple level vibrating wire piezometers in the drill holes are planned to assess rock fracture patterns and potential dissolution features, and to verify previously measured piezometric elevations. Also included in the programme is the installation of two vertical pumping wells: one on each flank of the valley.

#### Comments

Given that low pH water that will be impounded behind the WSD, there is the potential to create solution cavities in the calcareous unit which may be detrimental if this is exposed in the WSD foundation and particularly in the footprint of the central core plinth of the WSD. The Board considers that cavity dissolution may be difficult to mitigate by conventional means such as bedrock grouting. Furthermore, the presence of weathered, graphitic layers in the right flank of the valley might require extensive excavation and treatment in the abutment area.

Due to the potential issues described above, and the nominal leakage rate permitted downstream of the SCD, the Board considers a key objective of the investigation programme should be the confirmation and/or optimization of the location of the dam axis to avoid localized, karstic foundation features. The Board considers avoidance of the avalanche chute is of lesser importance in deciding on the location of the dam axis. Optimization of the location is a normal process in dam design to achieve the most favorable dam axis and overall footprint. The potential adjustments at KSM might involve only a rotation of the dam axis by swinging the right abutment slightly upstream.

Staging of the proposed drilling programme while concurrently expanding geological mapping in the exposed canyon area would allow for the potential optimization of the dam axis and the collection of data to support a revised location. Geologic mapping can be enhanced using high resolution drones to identify advantageous, homogeneous, siltstone and shale zones for the dam foundations. This information would provide valuable support to revising the dam axis location if deemed necessary.

Given the nominal leakage rate permitted, it will be important to develop a robust grouting programme for the various types of bedrock in the dam foundation. This requires both a knowledge of the groutability of

the rock as well as the temperature of the rock. Rock temperature affects the ability to grout, the time period during which grouting can occur, the grout set time, and also the composition of the grout to be used. As discussed in the recommendations below, and as noted in an earlier Board report, installation of thermistors should be considered.

It is also the view of the Board that given the complex geological environment and the need to achieve an effective grout curtain, placement of a concrete block at the base of the dam incorporating a grouting / drainage gallery would facilitate achievement of the design goals. Such a gallery would allow for the implementation of an effective grouting programme and reduce interference with rockfill placement, would provide for the installation of a row of closely spaced drain holes to collect and monitor leakage, and would permit future reinforcement of the grout curtain if required. Consideration of this design concept will also influence the location of future drill hole locations.

### Recommendations

Based on the considerations outlined above, the IGRB recommends that SG/FP:

- Make a key objective of the investigation programme the confirmation and/or optimization of the location of the Water Storage Dam axis to avoid localized, karstic foundation features;
- Give priority to installing drill holes aimed at characterizing the calcareous zone. It is noted that while one of the drill holes, WSD-18P intersects the entire layer thickness, others such as WSD-18C, WSD-18F, WSD-18G and WSD-18H only intersect the upstream part. It is suggested that the initial drill holes intersect the entire layer thickness;
- Implement the proposed canyon area geological reconnaissance programme concurrently with the drilling programme to optimize the dam axis location, and adjust the remaining drill hole locations in a timely manner if required;
- Adjust the spillway drill hole locations using data collected from the geological reconnaissance of the canyon area emphasizing rock quality and excavation requirements, and facilitating the optimization of the spillway axis location;
- Add vertical drill holes in the area of the upstream and downstream portals of the WSD diversion tunnel, so as to identify joints and other geological features with unfavorable orientation;
- As part of the investigation programme install several thermistor strings in selected drill holes to provide rock temperature data to assess climatic constraints to grouting. This needs to be accomplished as soon as possible to provide for a sufficient period of record; and
- Consider a groundwater pumping test at an accessible location in the vicinity of the SCD to confirm that piezometric levels and the rate of seepage beneath the SCD can be controlled to the extent necessary to meet the seepage control objectives.

## 4.2 TAILINGS MANAGEMENT FACILITY

### Discussion

KCB and SG/FP presented a high level description of the geotechnical investigation programs proposed for the TMF area anticipated for FS level design. Preliminary seismic lines have been identified to define the extent of the till borrow sources and identify locations for borrow area drilling. To further assess foundation seepage, sites for drilling and cone penetration testing (CPT) of the Splitter and Saddle Dam foundations have been identified. Thirty four (34) drill holes and 6 CPT soundings are proposed.

Recommendations

The IGRB makes the following suggestions and recommendations based on the information presented.

The IGRB review of the information presented concluded that additional information is required on:

- Till borrow resources; inside and outside the proposed tailings impoundments;
- Seepage mapping and characterization of groundwater conditions in the impoundment areas and more intensively in the Carbon-in-Leach (CIL) cell area to collect sufficient information to properly design the liner underdrainage system to mitigate against the potential for liner uplift;
- Foundation characteristics for the Splitter and Saddle Dams (including depth of organics and alluvial materials, extent of any buried channel, liquefaction potential, and differential settlement); and
- Foundation and cut-off extent for the North and South Seepage Collection Dam (SCD) locations, since these were moved during the Environmental Assessment process to locations that have not yet been characterized by drilling.

The planning for borrow material investigations should include:

- Developing a list of the estimated volumes of all construction materials including core, filter and drain materials;
- Identifying potential borrow areas for investigations of the various construction materials;
- Developing an investigation plan to identify at least 1.5 times the material quantities for each construction material. This planning must consider construction sequence since borrow cannot be obtained from areas after inundation (e.g. by the TMF impoundments); and
- If feasible, it would be beneficial to add test pits to supplement the drill hole and geophysical investigation methods.

Other Board suggestions include:

- *The Board was previously informed that alluvial soils in the foundation of the Saddle dam may be liquefiable during an earthquake. Therefore, the investigation may need to be expanded in this area to be sufficient to characterize liquefaction potential of these materials and to enable evaluation of methods to mitigate liquefaction;*
- *The proposed investigation programme includes a total of only six CPT soundings. This is a small amount of subsurface investigation work considering the cost to mobilize the CPT equipment to the site. The Board suggests that the number of CPT soundings be increased to take better advantage of this investigation equipment once it is at the site; and*
- *Consider whether the single vertical drill hole proposed for the east abutment of the North SCD will adequately characterize the foundation conditions for this portion of the dam given the potential for a steeply dipping fault along the axis of the valley in this location, and augment the drill programme as necessary.*

## 5. Hydrological Analyses Update

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### Discussion

SG/FP informed the Board about the updates to the 2012 hydrometeorology report, which provides refinements to the statistically based storm precipitation estimates (such as the 100-year, and 200-year 24-hour precipitation, for example). The updated report will be issued in due course. The design flood peak statistical analyses (such as the 100-year, 200-year, etc.) of peak streamflow are also being updated in anticipation of the FS level engineering to be performed. These parameters are used in the design of hydraulic structures such as diversion ditches and tunnels, and the Board looks forward to reviewing the results when they become available.

In addition to updating the statistically based precipitation and streamflow data discussed above, SG/FP is also considering updating estimates of the Probable Maximum Precipitation (PMP) which is defined as the theoretically greatest depth of precipitation for a given duration (e.g. 24 hours) that is physically possible. It is used to calculate corresponding Probable Maximum Flood (PMF) peak flows and volumes which in turn are used in the design of the more critical hydraulic structures such as the spillway for the WSD and the water management system for the TMF.

The Environmental Assessment in 2012 included a Probable Maximum Precipitation (PMP) estimate which was based on the statistical Hershfield method using data from the nearby Unuk River Eskay Creek Climate Station. Local adjustments to the rainfall totals were then applied to account for orographic effects at the site. The Hershfield method is generally used for initial estimates of the PMP event. As discussed further below, SG/FP is planning to update the PMP estimates as well.

SG/FP invited Applied Weather Associates (AWA) to provide an overview of the various current methodologies used for estimation of PMP events and describe a potential approach for updating the KSM PMP values. AWA suggested that a deterministic storm-based method be considered that incorporates the latest methods for data processing in PMP estimation. In this method, a number of extreme storms that have occurred in areas that experience similar climatic and storm conditions to KSM would be identified and transposed to the KSM site. The factors causing precipitation, such as atmospheric moisture conditions and temperature, would then be maximized to estimate the PMP.

The above PMP approach can be combined with frequency distributions of precipitation (using L-moments) and an expanded data base on annual extreme precipitation measurements derived from stochastic storm transposition methods. Combining these two approaches has the benefit of improving the accuracy of the statistical precipitation estimates discussed above but also provides a comparison and check on the PMP values which are expected to have “theoretical” annual exceedance probabilities of more than 100,000 to 1,000,000 years.

### Comments

The Board appreciates the insights provided by AWA on leading-edge technologies for PMP estimation using the storm-based approach and in the determination of annual exceedance probabilities for rainfall totals.

### Recommendations

*The IGRB recommends that in preparation for the next design phase, a storm-based method of PMP estimation and annual exceedance probabilities using stochastic storm transposition be commissioned for the mine and TMF sites. The results of these analyses and the updated hydrometeorological and streamflow studies mentioned above, can then be used by SG/FP to select design storm and flood criteria and parameters for the FS with the knowledge that the underlying analyses are the most comprehensive available and the data bases used are extensive.*

## 6. Proposed Pit Geotechnical Investigation Programme

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### Discussion

The proposed geotechnical investigation for the Mitchell and Sulphurets pits was provided to the IGRB. This presentation was primarily to give the Board an understanding of the extent of investigations proposed to enhance the data base for assessing both physical and geochemical waste rock characteristics. The presentation also included a discussion of an additional borings to better define the extent of the monzonite (P8) in Mitchell Pit, as this unit is expected to provide competent Non-Acid Generating (NAG) rockfill for the WSD construction.

The Board appreciates the update and has no comments or recommendations on the information presented.

## **7. Waste Geochemical Characterization Programme**

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### **7.1 INTRODUCTION**

The KSM waste characterization programme is aimed at characterizing the geochemical properties of the waste rock in order to assess the quality of any seepage or runoff water emanating from this material over the short- and long-term. This information is needed for predicting the water quality in the WSD and TMF, in assessing the treatment needs, and evaluating the receiving water quality in the surface water bodies downstream of these facilities. While this work is not being reviewed by the Board, the Board needs to understand the results and the uncertainties associated with the estimates of water quality in the WSD and the TMF since these estimates affect the water management and design of the facilities that the Board is reviewing.

The Board appreciated SG/FP arranging for presentations by both EcoMetrix, who reviewed the prior work, and Golder Associates who have taken over the programme and will be continuing the studies for input to the next design stage. The Board's views on these presentations are discussed below.

### **7.2 ECOMETRIX**

#### Discussion

EcoMetrix Inc. provided a presentation on the following tasks they had been commissioned to address by SG/FP:

- Review of the KSM geochemical data base to identify gaps and opportunities for future data collection;
- Review of the lime requirements for the proposed water treatment plant (WTP) immediately downstream of the WSD;
- Review of the previous water quality assessments that had been performed; and
- Provide suggestions for the management of potentially acid generation (PAG) waste rock.

The presentation by EcoMetrix generally corroborated the previous investigations and analyses and indicated that these followed good practice and produced appropriate assessments of the amount of waste rock and tailings expected to be PAG and the projected receiving water quality for the operational and closure phases of the mine. Aspects EcoMetrix believes should be further refined include:

- The ultimate amount of the neutralization potential (NP) in the waste rock that would be available in the waste rock dump. While refinement of this aspect of the work does not affect the overall characterization of the waste rock or the proposed management of this material, it could affect the lime demands of the treatment plant and/or the timing of this demand; and
- More detail should be paid in future to the testing and evaluation of the geochemical characteristics of the construction materials expected to be excavated from the pit areas; particularly the monzonite that is intended for construction of the WSD.

EcoMetrix also provided an estimate for the potential lime demands for the WTP based on a simplistic model and provided a list of measures that could be considered in the next level of design for management of the waste rock in ways that reduce the amount of Acid Rock Drainage (ARD) produced and the amount of Metal Leaching (ML) that would occur. Finally, they provided recommendations on the spatial resolution

for future geochemical sampling and approaches for improving the estimation of selenium levels that would occur in the leachate from the waste rock.

#### Comments

The Board considers the proposed refinements provided by EcoMetrix to be well considered and expects these to be addressed in the future programs by the Golder team. The Board has no comment on the recommendation for sample density because it does not have the necessary rock type distribution information for the materials contained within the proposed pit shells and would expect the Golder team to determine these requirements in any event.

The Board did not have sufficient information to evaluate the internal workings of the model used to estimate the future lime demands. Based on the explanation of how this modeling was completed, and reviewing the results, the Board believes these are likely over-estimates and that the demand over time will not increase or fluctuate as rapidly as indicated by the model results. One of the main deficiencies in the modeling was that it assumes a ready supply of oxygen to the waste and does not account for the reduced amount of oxygen that would actually enter the waste rock dump over time.

The list of proposed PAG management measures proposed by EcoMetrix are generic, frequently theoretical and often not practical.

#### Recommendations

*The Board recommends that the Golder team consider and address the EcoMetrix recommendations and that the determination of the PAG management approaches be developed by the engineering design teams, and the mine planning team with input from the Golder team. It is important that the mine planning team play a role in assessing what methods and controls can actually be implemented during mining.*

*The Board considers there is value in using the EcoMetrix team from time to time to independently review the details of the sampling and geochemical analyses performed by Golder.*

### **7.3 GOLDER PROGRAM**

#### Discussion

Golder provided a presentation outlining a proposed geochemical programme going forward. Key goals of their programme are to perform a more detailed characterization of the ARD/ML potential to establish robust and appropriate design criteria and to establish site-specific ARD/ML management plans aimed at minimizing acid and selenium loads since these require treatment in separate WTPs.

The next steps Golder envisages include additional field sampling to further characterize the various rock and mineral types encountered in the pits, additional laboratory testing, predictions of ARD/ML potential including selenium leaching potential, and an update to the overall site-wide water balance and quality model. Extensive use is to be made of the large exploration data bases available (including whole metal analyses) using “machine learning” to correlate this information with the ARD data and thereby expand the ARD/ML data base.

#### Comments

The proposed Golder approach is comprehensive and is focussed mainly on characterizing the wastes. It is anticipated that the data will be sufficient for assessing suitable ARD/ML management approaches for the waste rock. In defining the scope and frequency of sampling and testing needed it will be important to not only consider general characterization of the materials, but also what the management approach will

likely be and its specific requirements for measurements that need to be undertaken, the parameters (both field and laboratory) needed, any sampling and testing needed, and what the trigger values may be that determine what actions should be taken in the event these are exceeded.

### Recommendations

*In order to provide for a more focussed and cost-effective geochemical programme going forward, the Board recommends the following:*

- *Before initiating the program, use an updated version of the existing waste block model to estimate the volumes of rock with differing ARD/ML potentials and the schedule of these over time;*
- *Use the above information to select a range of potentially feasible methods of managing the waste rock to meet the objectives of minimizing ARD/ML. As discussed under the EcoMetrix review recommendations above, involve the design engineering and mine planning groups to develop these selective loading and strategic placement methods aimed at minimizing oxygen infusion and water infiltration, not only on an overall design basis but also for daily/seasonal adjustment of the process;*
- *Based on the knowledge of the types of management approaches that may be feasible, identify the data needs to refine these approaches and establish their feasibility. This includes defining the number of sampling points required for each rock/mineral type and also the need for physical characterization data such as weatherability or durability, potential amount of fines, etc. or other data needs;*
- *Incorporate the above data needs in the proposed program;*
- *Execute the proposed programme in a phased manner, and on a regular basis update and refine the proposed management approaches. While samples need to be collected when the exploration borings are carried out, the testing of these can be phased to allow for the data needed to perform the evaluations.*
- *Reject those management approaches that are determined to be infeasible; and*
- *Complete the programme and the assessment of the feasible management approach or approaches.*

## **8. Closure**

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The IGRB appreciates the update on the KSM Project and the opportunity to review the information provided.

The Board expects the design of the glacial inlets will continue to be challenging and require a significant exploration and analytical effort, including obtaining more information on the various operating hydro-power glacial intake systems in Europe.

While the site investigations at the WSD and the TMF reflect more routine activities, the focus should be on resolving the potential design complications identified by the Board and others.

The geochemical programme should be run in parallel with the establishment and evaluation of alternative waste rock management approaches to allow for a more effective characterization programme to be executed.

**REPORT – MEETING NO. 4,  
INDEPENDENT GEOTECHNICAL REVIEW BOARD**

**Review of Water Dam, Water Management and  
Tailings Storage Systems, KSM Project**

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## **Appendix A**

Agenda

# Agenda

## IGRB Board Meeting No. 4 KSM Project

July 31 to August 1, 2018 (morning of August 2 may be used if required)

Location: Blake, Cassels & Graydon LLP  
Board Room  
595 Burrard Street, Suite 2600, Vancouver BC V7X 1L3  
Tel: 604-631-3300 Fax: 604-631-3309  
blakes.com

**July 31, 2018**

### 1. Greetings and Introductions (8:30-8:45AM)

- 1.1 Safety Share
- 1.2 Project Update ..... *Peter Williams/Brent Murphy*

### 2. Summary Reports from Norway Trip (8:45-10:00AM)

- 2.1 Klohn ..... *Graham Parkinson/Harvey Mcleod*
- 2.2 IGRB ..... *Anthony Rattue*
- 2.3 Discussion

**Coffee Break (10:00-10:15AM)**

### 3. Water Management with a Focus on Glacier Water (10:15-11:30AM)

- 3.1 Review existing concept design ..... *Mike Skurski/Graham Parkinson*
  - 3.1.1 Two Phases of Investigation Planned
    - 3.1.1.1 Initial Phase
    - 3.1.1.2 Follow up Phase
  - 3.1.2 Discussion - Design Requirements for Large Projects ..... *All*

### 4. Initial Foundation Drilling- Programme Update (11:30AM-2:00PM)

- 4.1 WSD ..... *Mike Skurski/Klohn*
- 4.2 TMF ..... *Mike Skurski/Klohn*

**Lunch (12:30-1:00PM)**

### 5. Hydrological Analysis Update (2:00-4:00PM)

- 5.1 Draft HydroMet Report Update ..... *Brent Murphy/Mike Skurski*

**Coffee Break (3:00-3:15PM)**

- 5.2 Storm Frequency Analysis – *Presentation by Bill Kappel, Applied Weather Associates*
- 5.3 Discussion

**6. Other Topics (4:00-4:30PM)**

- 6.1 Pit Geotechnical Drilling Programme (for future FS)..... *Mike Skurski*

**End of Day 1 Meetings**

**August 1, 2018**

**6. Other Topics (continued; 8:30-11:00AM)**

- 6.2 Waste Characterization Program..... *Mike Skurski/Brent Murphy*
  - 6.2.1 Independent Review of Existing KSM  
Geochemical Database..... *Presentation by Ecometrix*
  - 6.2.2 2018 Drilling Program ..... *Mike Skurski/Brent Murphy*
  - 6.2.3 Change of Consultants..... *Brent Murphy*
- 6.3 Date of Next Meeting

**End of Day 2 Meetings**

**REPORT – MEETING NO. 4,  
INDEPENDENT GEOTECHNICAL REVIEW BOARD**

**Review of Water Dam, Water Management and  
Tailings Storage Systems, KSM Project**

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## **Appendix B**

Attendees

# Attendees

IGRB Meeting			
Date: July 31, 2018		Blake, Cassels & Graydon	
Location:		595 Burrard Street, Suite 2600	
		Vancouver, BC, V7X 1L3	
		Tel: 604-631-3300 Fax: 604-631-3309	
Name	Firm	Name	Firm
1 Peter Williams	Seabridge Gold	26	
2 MJ Piggott	KCB	27	
3 Jessy Chaplin	Seabridge Gold	28	
4 BRENT MURPHY	SEA GOLD	29	
5 Ambika Maita	PR Associates	30	
6 Terry Eldridge	Golden Associates	31	
7 Mike Skurda	Seabridge	32	
8 Graham Parkinson	KCB	33	
9 Leslie Smith	self	34	
10 Harvey McLeod	KCB	35	
11 JPTOURNIER	HQ	36	
12 A. ROBERTSON	RGC	37	
13 A. RATTUE	Rattue Consultant	38	
14 I HUTCHISON	RGC	39	
15 Jim Obermayer	Stantec	40	
16 Gehriel Fernandez	Consultant	41	
17 Bill KAPPEL	AWA	42	
18 Garry Stevenson	KCB	43	
19 Sarah Burabash	EcoMatrix	44	
20		45	
21		46	
22		47	
23		48	
24		49	
25		50	

Date: Aug 1, 2018  
 Location:

IGRB Meeting

Blake, Cassels & Graydon  
 595 Burrard Street, Suite 2600  
 Vancouver, BC, V7X 1L3  
 Tel: 604-631-3300 Fax: 604-631-3309

	Name	Firm		Name	Firm
1	Harvey McLeod	KCB	26		
2	MO Piggott	KCB	27		
3	Barah Parabrah	EnviroMetric	28		
4	Mike Skurski	Seabridge	29		
5	Bill KAPPEL	AWA	30		
6	BREN MURRAY	SEA	31		
7	Ambika Mehta	PR Associates	32		
8	IAN HUTCHISON	RGC	33		
9	Anthony RATTVE	RATTVE CONSULTANTS INC	34		
10	Terry Eldridge	Golder	35		
11	Kristin Salesauler	Golder	36		
12	Tom Marulcar	Golder	37		
13	ROSS HAMMERT	Golder	38		
14	Andy Robertson	RGC	39		
15	Graham Parkinson	KCB	40		
16	Leslie Smith	self	41		
17	Gabriel Fernandez	Independent Consultant	42		
18	Jim Obermeyer	Spence	43		
19	JP TOURNIER	HQ	44		
20	Peter Williams	Seabridge Gold	45		
21			46		
22			47		
23			48		
24			49		
25			50		