March 2017

Ajax Mine Application for Environmental Assessment Certificate/
Environmental Impact Statement

Summary Assessment Memos
Ministry of Environment

This document contains summary assessment memos that the Ministry of Environment (MOE) provided following "round 2" of the review of the KGHM Ajax Mining Inc.'s (KAM's) Application for an Environmental Assessment Certificate / Environmental Impact Statement. These memos summarize MOE's assessment of air quality, water quality and hydrology for the Ajax Mine environmental assessment.

MEMORANDUM

Ministry of Environment

Environmental Protection Division
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To: **Brian Heron-Herbert**
Senior Project Manager
Environmental Protection Division
via email

File: KGHM-Ajax Mine
Date: March 17, 2017

From: Ralph Adams
Air Quality Meteorologist
Monitoring Assessment and Stewardship
Environmental Protection

RE: Review of Air Quality impacts of proposed Ajax Mine.

Dear Brian

The impact assessment for the proposed Ajax mine south of Kamloops relies on dispersion modelling to estimate maximum concentrations of air pollutants that would occur if the mine went into operation. The modelling used the Calmet and Calpuff models, which are the most suitable models for use in the complex topography and meteorological conditions experienced in the interior of BC. The results of the modelling have been used in the assessment of health effects due to inhalation and ingestion through the HHERA and Country foods assessments, as well as in the water quality models. Therefore, confidence in the model output is critical to the assessment of potential effects. However, despite considerable efforts by the proponent's consultants to characterise the effects of the methods used to apply emission factors through the year, and the effects of different mitigation efficiencies on active suppression of dust from the haul roads, there is still large uncertainty in the model output. I am unable to supply upper bounds for the uncertainty except to say that it is larger than the accepted factor of two that is used for the Calpuff model.

The uncertainty in model output can be divided into that due to how the models were run, and that due to the uncertainty in the emission factors used. The rest of this memo summarises the sources and implications of the uncertainty in model output, and summarises the likely effects of the proposed mine on the Kamloops airshed.

Scope of review

I have restricted my review to the dispersion modelling: I have not reviewed the emission factors. By that, I mean that as a meteorologist I do not have the expertise to determine if the various sources on the mine site have been correctly characterised, or if the correct methods of estimating emission factors have been used. However, I expended considerable effort on understanding how the emission factors are used in the modelling and how uncertainties in the emission factors effect model output. As this has been a subject of intense discussion over the last years, I will beleaguer the point with an example. The emission factors for the haul roads depend on a formula which includes silt content of the road surface and vehicle weight; the proponent used 5% as the silt content. It is outside my area of expertise to comment on the choice of 5%, but I have checked that the value was used correctly in the model and what effect errors in the value would have on model output.

Documents used in review

While I have reviewed a large number number of documents relating to the dispersion modelling and air quality component of the Ajax review, my final review over the last months has focussed on four:

1. *Ajax Project – Environmental Assessment Certificate Application / Environmental Impact Statement for a Comprehensive Study. Part B. Volume 5. Chapter 10, section 10.1 Air Quality and Appendix 10.1-A.* I have referred to this in my review as the *original proposal*. Much of this document has been superseded by the documents listed below, but it contains the modelling plan, detailed description of the model settings, and descriptions of the emission factors used.

2. *Additional Information Required to Support an Examination of the Air Dispersion Model Behaviour. Memo report from Peter Reid at Stantec to Nettie Ore at KGHM Ajax dated July 25th, 2016*. I have referred to this document as the *modelling addendum* in my review. The document contains results of the additional modelling of the TSF to examine the effect of time varying emission factors on model output, and the modelling of the haul roads with multiple mitigation efficiencies.

3. *Response to BC EAO / CEA Agency Letter of November 10th 2016 (part A). Memo report from Peter Reid at Stantec to Nettie Ore at KGHM dated December 7th, 2016.* I have referred to this document as the *restated modelling results* in my review. It contains the final model output including all changes and corrections since the original proposal.

4. *KGKM Ajax Mining Inc. Fugitive Dust Management Plan. December 2016.* I have referred to this document as the *dust monitoring and mitigation plan* in my review.

Uncertainty due to Calmet/Calpuff modelling

There is uncertainty in the output of the Calmet/Calpuff model due to the simplifications the models must make of complex physical processes, and the measurements of meteorology and surface properties required by the model. In general, model output from the Calmet/Calpuff system is expected to be within a factor of two. That is, the actual levels will be between half and twice the predicted values. However these bounds are for well defined stacks, in the case of the Ajax modelling, considerably greater uncertainty is expected due to the uncertainties in the emission factors for the many fugitive sources on the mine. In my opinion, the uncertainty in the model output for the Ajax is far larger due to the uncertainty in the emission factors than that due to the dispersion model.

Uncertainty due to emission factors

The uncertainty resulting from the emission factors can also be broken down. In my opinion, the two largest sources of uncertainty are due to the way in which the emission factors were calculated and applied, and the uncertainty resulting from the high mitigation efficiencies assumed for the haul roads. With the exception of the tailings storage facility (TSF)[1], the emission factors are calculated with formulas that supply an annual loading, the total amount of a particular pollutant produced in a year. This number is then reduced by multiplying by a factor that accounts for the number of days in the year that there is precipitation or snow-cover as it is assumed that dust is not produced on those days. In the case of the haul roads the value is also reduced to account for active mitigation of dust from the haul roads using techniques such as watering. The Calpuff dispersion model requires an emission rate for each hour of the years that are modelled. To calculate this the total amounts of each pollutant for each source (reduced to account for both natural and active mitigation) are distributed evenly across all hours of the year. This is clearly not realistic as there is a variation of dust production from the sources through the year, highest in the dry summer period and lowest in winter when there are extended periods of snow-cover.

Uncertainty due to use of constant emission factors

In order to investigate the effects of this simplification, the proponent was required to run the Calpuff model again. In these runs the TSF was the only source modelled and two types of emission factors were used. One set of emission factors used formulas which produced an emission rate for the TSF based on windspeed, precipitation and snow cover for each hour of the year modelled. These were then then summed up and divided to produce a second emission factor where the rate was constant for every hour in the year.

[1] In the original proposal constant emission factors were used for the TSF. However, after the work described in the modelling addendum was completed, the restated results use time varying emission factors for the TSF.

The results for the new modelling run were that the location of the maximum concentrations were, as expected, on the fence-line. Those for the hourly varying emission factors were on the Kamloops side of the facility, but for the constant emission factors they were to the West of the TSF. The values of all statistics were lower for the time-varying emission factors than the constant emission factors. The patterns of the maximums on the landscape also changed. In case of the constant emission factors, they were evenly distributed around the mine site and did not show a clear indication of a prevailing wind-direction. However, the time-varying emission factors showed a pattern indicating plumes carried dust away from the mine. There was a clear indication of the prevailing South West winds on the site.

In my opinion, the most plausible interpretation of these results is that the constant emission factors result in higher ambient values as the emission rates are too high during periods of calm winds and poor dispersion which are most frequent in winter. The time varying emission rates produce the most realistic distributions of maxima across the landscape indicating that the model is replicating periods of high winds during dry conditions and carrying the plumes longer distances. In the final restatement of the model output the values resulting from the time-varying values TSF were used. As the emissions from the TSF are small compared to those from the remaining sources, the effect on the final restated concentrations of using the values based on the time varying emissions was not large.

The comparison of constant and time varying emission factors using the TSF described above is important as it has a number of important implications that have to be considered when interpreting the uncertainty in the restated results from all sources. The TSF is not the only source where the actual emission would be expected to vary rather than be constant. The formulas which were used to calculate the emission factors for the waste rock storage piles are similar to those used for the tailing storage facility. Of more concern, while the emission factors for the haul roads do not include windspeed, similar effects can be expected if time varying emission factors were used as wind transports the dust entrained by the traffic on the haul road, and higher emissions will occur in summer during hot and dry conditions. It is likely that in summer there will be events when dust from all the sources is transported long distances during wind storms. These events have not been captured by the modelling due to the use of constant emission factors.

The modelling for the Ajax mine has concentrated on 24 hour and annual statistics as these are the averaging periods on which Ambient Air Quality Objectives (AAQOs) are based. The reason that the AAQOs are based on these averaging periods is because the the link between air quality and health effects is based on studies which use daily and annual averaging periods. There is currently not sufficient scientific evidence to support AAQOs for particulate matter based on shorter averaging periods. This does not mean that there is *not* a health effect due to shorter periods of high concentrations, but that scientific studies are not yet able to evaluate it.

It is possible for short wind events to produce very high PM_{10} concentrations for periods less than an hour. These may result in very high concentrations for short periods of time, but do not result in exceedances of the 24 hour objective[2]. In my opinion, if it was possible to model the Ajax mine with all emission factors varying realistically with changing weather conditions, and to examine sub-hourly output in detail[3], the model results would indicate the occurrence of short periods of elevated dust concentrations (less than an hour to several hours) that would be noticeable and objectionable to residents in the areas closest to the Ajax mine. In other words, the dispersion modelling does not realistically represent short term dust events.

Uncertainty due to use of mitigation factors

As I noted above, the haul road emission factors have active mitigation applied as well as the natural mitigation applied to other sources. The active mitigation level applied in the original proposal was 90%. Unlike the natural mitigation, active mitigation is applied to both the 24 hour and annual emission factors. In practice, this means that the assumption is made that the suppression of dust on the haul roads will never fall to less than 90%. This was raised as an issue right after the initial proposal was released. The proponent was asked to supply evidence that this level of suppression would be possible at the Ajax mine site. The proponent supplied a study conducted at two De Beers diamond mines in the North West Territories. As I have described in earlier correspondence, neither I nor my colleagues at Environment Canada agree that the study supplies adequate evidence that 90% dust mitigation can be maintained in the conditions expected at the proposed Ajax mine.

In April 2016 the EAO and CEAA requested additional modelling from the proponent to investigate the effect of varying haul road mitigation levels on model output. The haul roads were examined in isolation from the other sources. As well as the original 90%, the 24 hour and annual emission factors were mitigated at 80 and 70%. In addition hourly emission factors were modelled with 0% mitigation applied. The modelling showed that the when the haul roads were isolated, the increase in maximum ambient concentrations of all particulate size fractions was proportional to the changes in mitigation levels. Note that a reduction in mitigation from 90% to 80% results in a doubling of emissions. In addition, the modelling showed that as mitigation levels were decreased, the haul roads became the dominant source of particulate matter and therefore the resulting ambient concentrations. Even when all other sources were included in the final restatement of results, the maximum daily average PM_{10} concentrations due to the mine sources increased from 345 μgm^{-3} to 863 μgm^{-3} as mitigation changed form 90 to 70%. As expected, the maximums occur at the fence-line. In Upper Aberdeen the values were approximately [4] 50 and 150 μgm^{-3} respectively.

[2] I base this on the study currently underway East of Kamloops to characterise dusting events associated with the Blackwell Dairy Farm site where a number of fugitive dust sources, including gravel pits, are resulting in dust complaints from local residents.

[3] This is not possible in practice due to the large number and complexity of emission sources and the inherent limitations of the dispersion models and their inputs. Current dispersion models are not designed to be used to investigate short events that last less than an hour.

[4] These values were interpolated form the isopleth maps provided.

In the modelling addendum report and the final restatement of results the proponent refers to the results of the 0% mitigation as *hypothetical*. This is certainly correct for statistics based on the annual emission factors; it is impluasible that mitigation would fail for a substantial part of the year. However, as the averaging period decreases, the probability of mitigation being unavailable for that period increases. In the extreme, if mitigation were lost for 6 hours, the loss of mitigation occurred during a dry period, and a wind event then occurred, the *hypothetical* 0% event could occur. These events are likely to be rare as loss of mitigation, dry conditions and strong winds are required. Based on my experience, these events are also likely to be short lived; however, it must be taken into account that the modelling predicts hourly average PM_{10} values in Aberdeen area of 1000 μgm^{-3}. While such an event may not result in exceedances of air quality objectives, or result in adverse health effects, it would have significant local effects[5] including a reduction in visibility, noticeable dust deposition on surfaces, and eye irritation. Similar events do occur from local sources such as the Owl Head landfill, the Blackwell Dairy farm gravel pits, the Newgold mine tailings dam, the HVC tailings dam, and the Copper mountain tailings dam.

The uncertainty concerning the mitigation levels that can be achieved, and the frequency of periods when mitigation is not available, results in considerable uncertainty in the model output as the haul roads are a large contributor to the particulate matter emissions. In addition, the use of constant emission factors for the haul roads also increases the uncertainty in the model output.

Other sources of uncertainty related to emission factors

There are a number of additional issues relating to emission factors which increase uncertainty in the model output. In my opinion, the two most important are the ratio of $PM_{2.5}$ in the haul road dust emission factors, and the silt content used in the calculation of the haul road emission factors.

In both the modelling and regulatory community there is consensus that the equations used to predict $PM_{2.5}$ emissions from haul roads are overestimates. The origin of the overestimate is the instrumentation used in the studies on which the emission factor formulas developed by the US EPA are based. These instruments allow some of the coarse particles past the inlet and they are incorrectly measured as $PM_{2.5}$. This leads to a significant overestimate of the $PM_{2.5}$in the sample.

In the modelling of the proposed Ajax mine, part of the $PM_{2.5}$ emitted by the haul roads is due to the exhaust of the diesel engines in the haul trucks[6]. The modelling assumed

[5] I have never experienced a dusting event where measurements were available and showed an hourly average in the range of 1000,μgm^{-3}. However, I have experienced events in North Kamloops where PM_{10} concentrations reached these levels for periods of a few minutes. These events occur near the river in spring when dust is picked up by high winds from the exposed riverbed. Under these conditions visibility is limited, I experienced difficulty breathing and had to cover my eyes. Note that this event resulted in hourly average far less than 1000 μgm^{-3}.

[6] The proponent has stated in meetings with the regulatory agencies that in the original modelling at 90% mitigation of haul roads, about half of the $PM_{2.5}$ from the haul roads was from exhaust emissions.

the use of older diesel engines which are no longer produced. Newer Tier 4 engines have significantly lower $PM_{2.5}$ emissions. Therefore, if a significant proportion of the the haul trucks used the newer low emission engines, $PM_{2.5}$ levels are probably overestimated in the model output. This does not apply to PM_{10} or TSP emission factors.

As described above, the formulas used to calculate the haul road emission factors depend on the silt content of the road surface and the weight of the trucks. In the modelling for the proposed Ajax mine the silt content was set at 5%. This is the lowest value suggested in the guidance documents which describe the formulas. There has been lively discussion over the last year about the validity of this assumption. While we do not have measurements which would allow us to estimate the actual silt content that the roads would have, it is possible to estimate the effect of errors in the estimate on emission factors. The emission factor is approximately linearly related to the silt content. If the silt content increases from 5 to 10%, the emission rates of PM_{10} and $PM_{2.5}$ approximately double, that for TPM increases slightly less. Therefore, small errors in the silt content estimate could have significant effects on the emission factors; this is another source of uncertainty in the model output.

Effects of model uncertainty on the development of the dust monitoring and control plan.

It is clear that there is a great deal of uncertainty in the model output due to all of the factors I have described above. The uncertainty of the model output has an effect on the assessment of environmental and human health impacts. In light of the large uncertainty in the model output it has frequently been suggested over the past year that the uncertainty in the model output can be compensated for by developing a robust dust monitoring and mitigation plan. The logic is that safe ambient levels are selected and a monitoring and mitigation plan is developed that prevents ambient levels exceeding the selected thresholds. Note that it is not feasible to measure the mitigation levels on the haul roads directly. The proponent has developed a monitoring and mitigation plan; however, parts of the plan are based on model output and therefore the model uncertainty must be considered when reviewing the plan.

A key component of the proposed plan is the use of triggers based on the difference between the existing upwind station and a station to be built on the mine-site.[7]. This strategy has a great deal of merit; however, in my opinion, while it would be very effective during periods of poor dispersion and low windspeeds where there is a gradual increase in ambient levels, it will be less effective in dealing with the short-term dusting events that are likely to occur. The direction of the plume will depend on wind-direction and siting monitors that could detect such plumes across the large mine-site is not practical. Also, as the events are very short, there is little time to respond to trigger levels. Finally, there is little that can be done to rapidly reduce dust emissions from sources other than the haul roads and blasting (where slowing trucks, increased watering or

[7]Note this is in addition to the exiting air station located in Upper Aberdeen at the Pacific Way Elementary School.

completely halting truck traffic would have an immediate effect on emissions).

So what?

In discussions you have led for the Ministry of Environment Review team, you have often challenged as to answer the question, ”so what?”. This is my attempt to do so. I have tried to condense all the hundreds of documents and arguments that have been part of the review process (which has now been underway for almost 6 years) into the information that I believe the residents of Kamloops and the decision makers most need to be aware of in order to make decisions regarding the proposed mine.

- The Ajax mine review included one of the most comprehensive and complex dispersion modelling projects ever undertaken in BC, certainly the most complex for a proposed mine. However, even after all the efforts of the proponents and the review teams, there is still great uncertainty in the output of the dispersion models.
- The uncertainty arises from three areas: the uncertainty inherent in using a dispersion model which uses greatly simplified approximations of physical processes, the uncertainty in the amount of pollutants emitted from the various sources on a mine, and the the way in which the emission factors are applied. The last two sources of uncertainty are the likely much larger than the first.
- The use of constant emission factors rather than factors which change over time to reflect changing conditions are likely to result in overestimates during winter and underestimates in summer.
- The modelling is considered to be most accurate for longer averaging periods. In this case case the uncertainty is least for the magnitude and location of annual averages predicted by the model, higher for the daily statistics, and highest for the hourly.
- In the modelling and reporting, annual and daily (24 hour) values were emphasised as ecosystem health and human health objectives are based on these averaging periods. Short term dust events are likely to occur under dry summer conditions. These are common at other mines and similar facilities. It is unlikely that these events will have a significant effect on air quality statistics as they are so short-lived, but they will be noticeable and are considered a significant nuisance by the public.
- It is likely that the $PM_{2.5}$ emission factors and predicted ambient concentrations are overestimates. This is due to overestimates of the proportion of $PM_{2.5}$ in haul road dust in the formulas used to estimate the haul road emission factors. The modelling also used estimates of $PM_{2.5}$ in truck exhaust based on older diesel

engines. If newer tier 4 engines are used at the mine site this will reduce $PM_{2.5}$ levels[8]. This does not apply to the larger particulate size fractions PM_{10} and TSP.

- Much of the modelling is based on the assumption that watering and other mitigation measures applied to the haul roads will limit dust to 10% of the level without mitigation (this is equivalent to a 90% mitigation efficiency). The proponent has not been able to supply convincing evidence to show that this is possible in the dry environment at the site. The model was subsequently run at mitigation efficiencies of 80%, 70% and 0%. The 0% level was done to determine worst case results if all mitigation on haul roads was lost. The results showed that as mitigation efficiency dropped the predicted concentrations increased rapidly and the proportion of the dust from the haul roads increased dramatically. At 70% mitigation the model results showed that 24 hour average PM_{10} levels reached 150 μgm^{-3} in the Aberdeen area. This value compares to levels of 70 to 160 μgm^{-3}measured in North Kamloops at the Mayfair Street air station. Mitigation of haul roads is likely to be critical if the proposed mine goes into operation.

- The proponent has been clear that they consider the 0% mitigation scenario to be *hypothetical* and *not plausible*. This is based on the assumption that mitigation of the haul roads would never fail for long enough for the surface to dry (several hours) and either a wind-storm occur to entrain the dust and carry it towards Kamloops, or a period of calm winds and poor dispersion allow values to build up. If this did occur, the model predicts hourly average values in Aberdeen of 1000 μgm^{-3}. Again, this indicates that mitigation of haul road will be critical if the mine goes into operation.

- Given the large uncertainties in model output, a logical conclusion would be that, rather than rely on the model predictions, robust and reliable monitoring and mitigation plans be developed that can be relied on to prevent adverse effects due to the operation of the mine. I think it important to note that this strategy carries risk. This strategy is based on the assumption that any issues that arise during the life of the mine could be resolved with additional mitigation measures; however, there may be issues where no practical or economically feasible solution can be found. We must be aware that not all dusting events and exceedances can be fully mitigated, all of the time. If the mine goes ahead the development of the monitoring and mitigation plans will be critical and are likely to require the most comprehensive, complex and expensive monitoring and mitigation systems that have been attempted for any mine in BC.

[8]The policy recently adopted by the ministry for permitting new sources of $PM_{2.5}$ in airsheds where there are higher $PM_{2.5}$ levels is that all sources should use (or match the emissions of) Best Available Technology (BAT), regardless of current ambient $PM_{2.5}$ levels. If the proponent does not wish to use BAT, they should provide evidence that the use of non BAT sources will not have an adverse effect on ambient $PM_{2.5}$ levels.

Sincerely,

Ralph Adams
(250) 371-6279

cc:Lyudmilla Merkulova, Environmental Protection Officer, Environmental Protection Division, BC Ministry of Environment.

Ministry of Environment

Mining Operations
Environmental
Protection Division

MEMORANDUM

File: Ajax Mine - KGHM
March 16, 2017

To: Brian Heron-Herbert, Senior Project Manager – Mining Operations

From: Lyudmila Merkulova, Environmental Protection Technician – Mining Operations

Re: AJAX mine, KGHM Ajax Mining Inc. - Assessment of effects related to air quality

I have reviewed the Ajax Mine Project (the project) Environmental Assessment (EA) application submitted by KGHM Ajax Mining Inc. (KGHM). My review focused on emission factors (EFs) used in the air quality dispersion model. The review considered results of the modelling and contributed to the air dispersion modelling review.

Documents reviewed:
Appendix E – Project Case Construction and Operations Emission Inventory
Ch. 10. Assessment of Potential Health Effects
Memo 1207_KAM_ AQ Covering Letter-Summary "Response to Ajax Project 'Round 2' Air Quality Information Requests", December 7, 2016 by KGHM
Memo 1207_KAM_ AQ Mitigation Effectiveness "Response to BC EAO / CEA Agency Letter of November 10th 2016 (Part A)", December 7, 2016 by Stantec
Document 1207_Fugitive Dust Management Plan "KGHM Ajax Mining Inc. Fugitive Dust Management Plan, Rev 2" December 2016 by KGHM
Memo 1207_KAM_ HHERA Approach "Response to BC EAO / CEA Agency Letter of November 10th 2016 (Part C)", December 7, 2016 by Stantec
Memo 1207_KAM_VC Implications "Ajax Project – Round 2 Technical Working Group Comments and Responses – Air Quality and Health Point C", December 7, 2016 by ERM
Ajax Integrated Summary Memo – Air Quality "Ajax Project – Summary of Round 1 Technical Working Group Comments and Responses – Air Quality", July 27, 2016
Memo 0428_KAM_Fugitive Dust Management Plan "Management of Fugitive Dust", April 22, 2016
Memo 0705_KAM_Revised Project Alone Case Dispersion Modelling "Stantec Response to Request for Information MOE 083", July 5, 2016
Memo 0725_KAM_Combined Stantec Responses to EAO 001-006 "Combined Responses to 0428_Air Quality Information Request_EAO-001-006", July 6, 2016
Memo 0721_KAM_Model Sensitivity_EAO004 "Additional Information Required to Support an Examination of the Air Dispersion Model Behaviour", July 25, 2016

Short term event implications

BC ambient air quality objectives for particulate matter

In British Columbia BC impacts to air quality from proposed activities are assessed through comparison of modelled or measured concentrations with established ambient air quality criteria compiled from various provincial and national sources including BC Ambient Air Quality Objectives (BCAAQOs), the former Pollution Control Objectives (PCOs), National Ambient Air Quality Objectives (NAAQOs), and Canadian Ambient Air Quality Standards (CAAQS). The contaminants of concern for the Ajax mine are particulate matter of different size fractions, i.e. $PM_{2.5}$, PM_{10} and TSP. The criteria for PM have been established for averaging periods of 24 hr and annual, for which the results of modelling have demonstrated that no significant effects to air quality on the long-term basis are expected to occur. Nonetheless, no objectives for short-term impact (i.e. 1 hr) currently exist which complicates the process of assessment. It is particularly critical for a mine in the proximity of an urban area to take into account short-term events, as events of large magnitude that potentially might have nuisance (TSP) and adverse health effects ($PM_{2.5}$ and PM_{10}) are very likely to occur for the reasons presented below.

0% effectiveness mitigation

It's evident from the experience with existing mines that upset conditions occur from time to time as a result of many factors, including meteorology (high winds), dry conditions, incorrect forecasts, failed coordination, upset response systems etc. Thus, despite a KGHM statement that 0% mitigation effectiveness on the roads is a "non-credible scenario" (Memo 1207 part A) it's arguably realistic, even if it is rare. However, it's difficult to predict the frequency of such events as each site has a unique design, operating plan and geological and meteorological conditions. In terms of magnitude, modelling results on the plant boundary with 0% mitigation on the roads illustrate maximum 1 hr $PM_{2.5}$ concentrations reach 635 $\mu g/m^3$, whereas 24 hr $PM_{2.5}$ – 426 $\mu g/m^3$ (17 x BCAAQO). For PM_{10}, predicted exceedances are even more profound – 2,690 $\mu g/m^3$ averaging over 24 hours (54 x BCAAQO), while hourly concentration could reach 4,283 $\mu g/m^3$. Moreover, these numbers could increase if other sources simultaneously fail mitigation as well.   The duration of such events could vary from less than one to several hours.

Blasting

A large contributing component to hourly emissions is blasting that will take place regularly on a daily basis: reflecting this pattern, the model has used time–varying emission factors, which are accounted for only one hour and assumed to be zero for 23 hours each day. The predicted maximum hourly ambient concentrations on the plant boundary are estimated up to 60 $\mu g/m^3$ for $PM_{2.5}$ and 570 $\mu g/m^3$ for PM_{10} for the 90% road mitigation case[1].

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[1] Hourly PM predictions have been extrapolated from established relationship between daily and hourly values for 0% road mitigation data (Memo 1207, Part A, Dec 7, 2016). The data for 0% mitigation were available only for the plant boundary.

Uncertainty due to Use of Constant Emission Factors

In response to the EAO request for additional information to understand the sensitivity of the model to time-varying emission factors for the Tailing Storage Facility (TSF) it was illustrated that the changes from the initial case for daily statistics was minimal, while the hourly ambient concentrations are the ones that influenced by short-term infrequent high wind in combination with dry conditions. Moreover, changes in spatial distribution of the concentrations produced by time-varying and constant emission factors are noticeable, i.e. location of maximum PM concentration predictions based on hourly-varied EFs is predicted on the Northeast mine boundary (closer to receptor location), whereas constant EFs indicate that maximum PM concentrations are located on south and west of the mine. This could suggest that constant emission factors applied for the rest of the sources can misrepresent the location of the maximum predicted concentration, and consequently, frequency of poor air quality episodes in the city associated with PM exceedances may be underestimated. This ultimately confirms the importance of short-term PM predictions in terms of health and environmental effects assessment.

Uncertainty Due to Mitigation Level in Emission Factors

Daily PM Predictions

According to the information received from KGHM and their Qualified Professional there will be infrequent exceedances of the 24 hr $PM_{2.5}$ AAQO in Upper Aberdeen at all levels of mitigation on the roads, but the magnitude of exceedances largely depend upon the mitigation effectiveness, particularly, for the roads, which when mitigated to 90%, contribute roughly half the predicted concentration of PM depending on receptor location and size fraction.
Regarding the level of mitigation on the roads, the working group expressed concerns regarding credibility of the KGHM's commitment to maintain the roads in such a way that the dust is suppressed by 90% most of time. To alleviate these concerns, EAO requested additional information on the achievement of such high level of dust mitigation effectiveness including examples of existing mines. The information[2] supplied by Stantec in my opinion failed to demonstrate the performance of cited mines to be relevant to Ajax mine, both in terms of design and in meteorological settings. Furthermore, predictions for various road mitigation levels were also requested by EAO to test sensitivity of the model. The results demonstrated that the roads are major contributors to PM ambient concentrations with their increasing influence at the decreased level of mitigation. I note maximum predicted concentrations exceed BCAAQOs at any level of road dust mitigation, with greater exceedances for larger fractions.
Information on the number of days, when the ambient 24 hr objective will be exceeded has not been supplied. However, there is no doubt that the number of days with exceedances of

[2] Memo 0725_KAM_Combined Stantec Responses to EAO 001-006 "Combined Responses to 0428_Air Quality Information Request_EAO-001-006", July 6, 2016

objectives leading to poor air quality is expected to increase with the reduced effectiveness in mitigation. Thus, the dust mitigation on the roads will be a critical component if the mine proceeds to operations.

Annual PM Predictions

According to the modelling results annual PM predictions do not exceed the BCAAQOs. Notwithstanding, the method of calculation of annual EFs for the roads remains questionable due to an application of a natural mitigation factor of 0.45 in addition to mine mitigation measures (90%) meaning that 45% of a year the roads will not be emitting dust when precipitation is greater than 0.25 mm. The factor that accounts for precipitation on an annual average basis has been taken from USEPA AP-42[3]; the EPA methodology provides this estimate on the following basis:

- does not account for differences in the temporal distributions of the rain events. Thus, the modelling approach potentially overestimates winter emissions, and underestimates emissions in dry and high wind conditions.
- is intended to apply for uncontrolled conditions. In the case of Ajax mine, the factor has been applied in addition to routine watering (i.e. 90% mitigation – Application scenario).

Therefore, the PM annual predictions could be unrepresentative of the conclusion in terms of the magnitude of the emissions in specific season (particularly dry and high wind periods), location of poor air quality episodes and associated with them effects.

Uncertainty Due to Rating of Emission Factors

The PM emission rates from fugitive dust sources used for modelling PM ambient concentrations contribute substantial uncertainty in the results due to low rating of emission factors (D and E). These ratings indicate either high variability within the source population or could mean that characteristics of the source are unrepresentative of the industry[4]. Hence, the emission factors embedded in the model may not be reflective of the Ajax mine's sources reducing confidence the predicted results.

Fugitive Dust Management Plan

To address concerns of the Working Group regarding the achievement of high efficiency level of mitigation measures, particularly during the dust events at the mine site, KGHM developed a

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[3] USEPA. AP-42. 13.2.2 Unpaved Roads https://www3.epa.gov/ttn/chief/ap42/ch13/final/c13s0202.pdf

[4] AP 42 Frequent Questions https://www3.epa.gov/ttnchie1/faq/ap42faq.html

Fugitive Dust Management Plan[5]. The plan outlines strategic and operational measures to manage dust and is supported by PM monitoring on the mine site and beyond the plan boundary. While the approach is reasonable, additional detail on specifics to the preventative and reactive measures, and monitoring will be required in an *Environmental Management Act* permit application.

Implications to Water Quality Model

With respect to the source terms related to air emissions for the water quality (WQ) model, modelled dust deposition concentrations were incorporated in the WQ model based on the proposed 90% mitigation effectiveness on the roads, which remains the main Application case. Although the mitigation level can vary throughout operations, Ministry of Environment (MOE) considers the assumptions related to the area of dust deposition and the fraction of bioavailability to be sufficiently conservative to support the proponent's e water quality predictions. Notwithstanding, application of dust suppressants and surfactants, considered by KGHM for dust mitigation on the TSF tailings beach and haul roads [6] adds up to uncertainty in the effects of dust suppressants on water quality of the local water bodies.

Conclusion

The Proponent's predictions show that no significant air quality effects, which may be linked directly to long-term health impacts, are expected on regular basis. However, there is an indication of potential effects from short-term dust events of large magnitude and periodic frequency, subject to atmospheric conditions, operation activities and level of mine management. Furthermore, a substantial degree of uncertainty accompanies the modelled ambient air quality concentrations associated with emissions factors including application of mitigation factors, variation over time and poor rating.
Thus, in MOE's view, effective mitigation of fugitive dust and proactive approach of the mine will be key to successfully minimizing emissions from the operating mine to ensure that the company consistently meets the commitment to maintain high efficiency mitigation.
For the purpose of EA process, MOE considers the information presented by KGHM sufficient to support the effects assessment; however, further information including development of detailed trigger-response and adaptive management plans in collaboration with MOE will be required for the EMA permit application.

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[5] Document 1207_ Fugitive Dust Management Plan "KGHM Ajax Mining Inc. Fugitive Dust Management Plan, Rev 2" December 2016 by KGHM
[6] Document 1207_ Fugitive Dust Management Plan "KGHM Ajax Mining Inc. Fugitive Dust Management Plan, Rev 2" December 2016 by KGHM

BRITISH COLUMBIA **Ministry of Environment** Environmental Protection Division Mining Operations

MEMORANDUM

File: Ajax Project - KAM
Date: March 6, 2017

To: Brian Heron-Herbert, Senior Project Manager – Mining Operations

From: Gabi Matscha, RP Bio, Environmental Impact Assessment Section Head – Mining Operations

RE: Ajax Mine Project – Surface Water Quality Effects Assessment Review of the Environmental Assessment Application

INTRODUCTION

The purpose of this memo is to provide the Environmental Assessment Office with information to support the assessment of the Ajax Mine's potential impacts to water quality and water uses, such as aquatic and semiaquatic life, wildlife, livestock and irrigation.

For the protection of water quality and water uses, the Ministry of Environment (MOE) has to consider a range of potential flow, dilution and source term conditions that may potentially occur throughout the mine life.

As per Appendix 6.3, Section 3.5 in of the application, "*water quality predictions were generated at the model assessment notes under multiple scenarios. The Base Case water quality predictions were generated using median baseline water quality and average climate conditions as inputs to the water balance model. … The range of predicted downstream water chemistry was assessed by conducting 13 sensitivity scenarios.*"
While the Base Case can provide predictions of average receiving water quality, it does not account for expected natural variations in baseline water quality, precipitation and flow (which influences dilution), quality of source term material, and cover material. To ensure MOE has assessed the range of predicted potential water quality effects, our review included the Base Case as well as the Sensitivity Analyses. When determining the potential for effects, it was considered that Sensitivity Analyses scenarios included less frequent conditions, thus may not result in chronic toxicity but could lead to significant effects if resulting in acute toxicity.

In British Columbia (BC) effects on water quality, and with this impact on water uses from proposed activities, are being assessed through comparisons of model predicted or measured concentrations with established Approved and Working Water Quality Guidelines (WQGLs) as published at http://www2.gov.bc.ca/gov/content/environment/air-land-water/water/water-quality. However, in some cases, site specific benchmarks, such as Science Based Environmental Benchmarks (SBEBs) may be proposed at the waste discharge permit application phase. Information on SBEBs can be found at the following website:
http://www2.gov.bc.ca/assets/gov/environment/waste-management/industrial-waste/industrial-waste/mining-smelt-energy/guidance-documents/tg8_framework_for_sbebs.pdf.

The company has proposed a number of preliminary environmental benchmarks, some of which may be refined into SBEBs for the permitting phase. The rationale for acceptance or non-acceptance of these benchmarks is summarized in the review comments below and provided in more detail in the appendix.

The water quality effects assessment summarized in this document is based on the review by the MOE Contractor, Bruce Carmichael, RP Bio, of the water quality predictions contained in the Knight Piesold memo to KGHM of January 23, 2017 titled "*Responses to Follow-up Water Quality Comments Provided in the Canadian Environmental Assessment Agency Letter (December 5, 2016) Re: KGHM Ajax Mining Inc.'s responses to the Information Requests relating to the Environmental Impact Statement for the Ajax Mine – Water Quality*". This has been identified in an e-mail by Knight Piesold as the most up to date version of the Base Case predictions, Sensitivity Analyses, and Updated Residual Effects. The detailed review comments by Bruce Carmichael are included in the Appendix.

The review focused on water quality parameters identified as

- Category 1 = parameters which WQGL exceedances were predicted at multiple nodes, during multiple phases, under the Base Case water quality model scenario and
- Category 2A = parameters predicted to exceed an applicable WQGL in the Base Case at only one node and during a single mine phase, or under a sensitivity case and for which KGHM identified a residual effect.

These parameters are listed in Table 4.1 and 4.2 of the above document. Predictions were compared to WQGLs for the water uses that exist downstream of the mine: aquatic life, wildlife, livestock and irrigation.

SUMMARY OF ENVIRONMENTAL ASSESSMENT STAGE REVIEW

The potential effects of the project on surface water quality and water uses based on predicted water quality in Peterson Creek and its tributaries and Jacko Lake were assessed.

MOE partially agrees with the residual effects assessment determination by Knight Piesold; however, differs in the determination of the effect on aquatic life, livestock, wildlife and irrigation for predicted category 1 and 2A parameters as described below.

Based on this assessment, MOE has identified potential effects on aquatic life, livestock and irrigation water use from the Ajax Mine Project in Humphrey and Peterson and Creeks from the mine site to Long Lake Road.

Since the most recent water quality model for Jacko Lake does not predict parameters to exceed water quality guidelines as well as current background concentrations, the likelihood of the project effects to water uses in Jacko Lake is considered low.

In the following potential for effects from the mine are rated low, medium or high based on

- the magnitude of WQG or MOE accepted benchmark exceedances,
- the likelihood of an impact based on toxicity information the water quality guideline is based on,
- the likelihood of a scenario occurring (e.g. Sensitivity Analysis Scenarios based on 95^{th}percentile of source terms or 95^{th} percentile of baseline water quality occur less frequent than values around the median in the Base Case), and
- whether chronic or acute WQGs are exceeded during these scenarios.

Potential for key effects are **bolded** in the detailed review below for EAO to consider for the assessment report.

Nitrate:

MOE expects that the predicted nitrate concentrations for the Base Case condition represent a low potential for impact to Peterson or Humphrey Creek aquatic life. Under Sensitivity Analyses scenarios, specifically the water management pond seepage bypass scenario, nitrate is predicted to reach 5.8 mg/L during Post Closure. This value exceeds the chronic WQG for the protection of aquatic life and is close to the lowest observed effect level (in the literature) on larval weight in salmonid fish (including rainbow trout) (MOE: *Water Quality Guidelines for Nitrogen (Nitrate, Nitrite, and Ammonia) Addendum to Technical Appendix Water Stewardship Division Ministry of Environment Province of British Columbia,* 2009). Given the presence of rainbow trout in this stream section, **the seepage bypass scenario likely has a moderate potential for impact on fish reproduction in Peterson Creek**. Elevated nitrate in **Humphrey Creek under the same scenario (4.2 mg/L) likely represent a relatively low risk to amphibians** in the area, with the values below the known lowest effect value for chronic amphibian toxicity. Nitrate is not predicted to exceed WQGL in Peterson Creek near Hwy 5a (PC02) under Base Case or Sensitivity Analysis scenarios, so the potential for **cumulative effects into lower Peterson Creek is estimated to be low.**

Ammonia:

In reviewing baseline data for key receiving water sites, we noted frequent instances of higher temperatures and different pHs than was used by KGHM to calculate the applicable WQGL for the protection of aquatic life. Thus MOE has adjusted the guideline for their review, using 20^{o}C and a pH of 8.5, resulting in a WQGL for the site of 0.261 mg/L. This is anticipated to provide a reasonable worst case scenario, under which there **could be a high potential for chronic impact in Peterson Creek in fish habitats from above Humphrey to Long Lake Road**. **However, the ammonia predictions in the receiving water may have been overly conservative**. Ammonia from blasting residue in open pit mining is typically oxidized to nitrate prior to seepage or discharge into receiving streams. We also understand the sewage waste will be treated onsite or removed from site, thus reducing ammonia inputs. **Based on this, ammonia impacts to aquatic life may be reduced; however, it is uncertain, to what degree ammonia presence in receiving waters may have been underestimated.**

Chloride:

With the most recent model version based on removal of the Peterson Creek Downstream Pond (PCDP), chloride has become a potential issue in Peterson Creek from Humphrey Creek to Long Lake Road (PC02.5 and PC02.3). Base Case and Sensitivity Analysis chloride is predicted to regularly exceed the 100 mg/L irrigation and 150 aquatic life WQGL, ranging up to 189 mg/L during Post Closure in this stream section. While these represent a **relatively low impact potential for aquatic life protection**, the exceedance of the irrigation guideline may be of concern. As per the 2003 BC guideline for chloride (CCME (1999), water quality guidelines indicate that sensitive plants should not be irrigated with waters containing greater than 100 mg chloride/L. In contrast, chloride-tolerant plants can be irrigated with water up to 700 mg chloride/L. For the EA level, **we consider the current impact potential on irrigation to be moderate**.

Sulphate:

The BC Ambient Water Quality Guidelines for Sulphate Technical Appendix (MOE 2013) recommends "that additional toxicity testing on several species is required if natural background water hardness is greater than 250 mg/L." Nautilus conducted toxicity tests on invertebrates, algae and fish to determine a safe sulphate concentrations in the Peterson Creek watershed with background hardness of over 300 mg/L.

Based on the results, Nautilus recommends two benchmarks:

1. In areas and during times where rainbow trout spawning and egg development may occur, the average sulphate water quality guideline for water hardness of 181-250mg/L Calcium Carbonate of 429mg/L sulphate will be applied;
2. In all other areas of the receiving water, 730mg/L sulphate (less than one half of the level at which effects may occur for 20% of the invertebrate or algae organisms compared to Jacko Lake water).

While MOE agrees that the general approach taken by Nautilus is useful to set benchmarks, we recommend further discussions about the approaches with MOE and First Nations to finalize an SBEB at permitting. However, the use of the sulphate water quality guideline for the protection of aquatic life at hardness below 250mg/L (429mg/L sulphate) seems a reasonably conservative preliminary benchmark for the EA review in all fish bearing areas during spawning periods until an SBEB is accepted. At Peterson Creek below the Falls, whereas per KP (2016) the sulphate concentrations seem to have been historically above the WQGL, a concentration up to the 95th percentile of the natural concentration range may be applied as the benchmark.

The proposed value of 730 mg/L provides some conservatism in protecting these organisms in non-fish bearing waters. However, MOE (2016) indicates that SBEBs should not exceed drinking water guidelines for human health anywhere in the province, unless these are naturally exceeded. This restriction supports the intent of the Water Sustainability Act to protect BC's water for future drinking water use. It also needs to be considered that increasing sulphate concentrations have the potential to lead to rising phosphorus (nutrient) mobilization rates in riverine sediments and that higher sulphate levels in the sediment leads to higher rates of mercury methylation, making it more toxic (MOE, 2013). As a result a preliminary benchmark of 500mg/L (at the drinking water guideline level) is acceptable for the EA review for non-fish bearing areas and outside of the spawning period.

The entire Peterson Creek assessment area is considered fish habitat. Sulphate concentrations are **not predicted to exceed the WQGL of 429 mg/L during the period of rainbow trout spawning and egg rearing i**n predicted Base Case scenarios. However, exceedances of the recommended preliminary benchmark of 500mg/L are predicted and expected during the **remainder of the year, particularly during winter and summer low flows for the Base Case and Sensitivity Analysis scenarios, which may result in low to moderate (Base Case) and moderate to high (Sensitivity Analysis scenarios) potential for impact to aquatic life.** Given predicted concentrations in Peterson Creek near Hwy 5A (PC02), there is a **limited cumulative effects potential for the Base Case condition and most Sensitivity Analysis scenarios**. However, during **seasons with high baseline sulphate concentrations, sulphate may spike to 1229 mg/L, which translates into a high effects potent**ial. The potential for cumulative impacts in Peterson Creek downstream from Hwy 5A may require assessment during permitting at various stages through life of mine.

<u>Aluminum</u>

For the Base Case and Sensitivity Analysis conditions, the dissolved aluminum aquatic life guideline (50 µg/L) is predicted to be exceeded in **Peterson Creek between Humphrey Creek and Long Lake Road during mine Operations and Closure.** The maximum prediction is 75 µg/L. Given the small difference between the maximum expected dissolved aluminum concentration and the guideline for acute toxicity (100 µg/L); **MOE considers the chronic impact potential for aquatic life to be moderate.**

While dissolved aluminum in Humphrey Creek is predicted to exceed the acute guideline for a number of Sensitivity Analyses (122 µg/L), the creek is not considered fish habitat (FLNRO/DFO) and lacks surface contact with Peterson Creek. **Humphrey Creek is confirmed habitat for western toad,** however. The BC WQGL cites Birge (1978), indicating 50% mortality of embryos and larva of a sub-tropical toad at a 7-day exposure of 50 µg/L aluminum. **There is a potential impact of dissolved aluminum on amphibian chronic toxicity.**

Given lack of predicted exceedances of any WQGL at Peterson Creek at Hwy 5A, **cumulative effects from predicted aluminum concentrations are unlikely in lower Peterson Creek.**

<u>Arsenic:</u>

MOE does not support KGHM's approach for the proposed arsenic benchmark. A recalculation method can only be applied if no species of the most sensitive taxonomic group the WQGL is based on may be found within the receiving water system. We recommend application of the 5 µg/L WQGL instead. MOE notes that the green algae Scenedesmus sp. (Phylum Chlorophyta) was located in Goose and McConnell Lakes. Goose Lake is within the Peterson Creek drainage, with some degree of connection to Peterson Creek via Keynes

Creek, thus it can be expected that Scenedesmus sp. also be present in Peterson Creek at least to some degree. The 5 µg/L BC approved WQGL is based on the CCME (2001) WQGL which was derived from growth inhibition toxicity tests on the algae Scenedesmus obliquus as the most sensitive species. Given current water quality predictions for arsenic in Peterson Creek, we see a **low impact potential for Peterson Creek from Humphrey Creek to Long Lake Road** (PC02.5 and PC02.3) under Base Case condition. If any of a number of **Sensitivity Analyses are realized, a moderate impact potential exists in Peterson Creek from below Jacko Lake to Long Lake Road** (PC08 to PC02.3) **and near Hwy 5A (PC02), particularly during Post Closure.** C**umulative effects into lower Peterson Creek are not anticipated under the Base Case scenario**. **Under the lower hydraulic conductivity in groundwater upstream from PC02 cumulative effects assessment into lower Peterson Creek below Hwy 5A may be necessary.**

Copper:

KGHM (Stantec) proposed a water quality benchmark (WQB) based on organic copper complexing capacities. The median "baseline" hardness reported by Stantec of 381 mg/L is outside the test range used to develop the copper WQGL and the equation cannot be extrapolated past the highest concentration tested. While MOE acknowledges the potential benefits to copper complexing applied in the Biotic Ligand Model (BLM), the use of this model in BC water quality assessment is not currently approved and the proposed WQB of 25.6 µg/L dissolved copper cannot be supported. However, MOE is updating its hardness based guideline for copper and will be applying that guideline to the dissolved copper fraction once available. If required, acceptable approaches for the development of SBEBs may be discussed for permitting. For the purpose of the Environmental Assessment Review, MOE applied the guideline for aquatic life protection of 10 µg/L total copper. Under the e**xpected Base Case scenario and all mine phases, t**he predicted exceedance of the 10 µg/L (total) copper guideline is restricted to **Peterson Creek between Humphrey Creek and Long Lake Road** (PC02.5, PC02.3), with concentrations up to 15 µg/L. **MOE considers this a low impact potential to aquatic life given local baseline hardness. Under the Sensitivity Analyses, potential for impact is likely higher (moderate to high) in Peterson Creek from above Humphrey Creek to Long Lake Road (PC03 to PC02.3), particularly under the Lower Hydraulic Conductivity scenario (concentrations of 34 to 41 µg/L) during Post Closure.**

Birge and Black (1979) observed frequent mortality in the embryo to larval stage of northern leopard frogs (Rana pipiens) at copper levels of 5 to 10 µg/L in water with a hardness of 100 mg/L. While the Ajax local hardness is much greater than that used by Birge and Black, the predicted Base Case (up to 26 µg/L total) and Sensitivity scenarios (13 µg/L dissolved) are elevated and represents a **low to moderate impact potential to amphibian life in Humphrey Creek.** The Rana genus is present in the mine area.

With copper predicted to exceed the WQGL at Hwy 5A (PC02) under the **Base Case condition, cumulative effects potential into lower Peterson Creek is low**. However, in the event the **Low Hydraulic Conductivity scenario** occurs in groundwater upstream from PC02, c**umulative effects on lower Peterson Creek may need to be assessed.**

Iron:

MOE acknowledges some uncertainty related to the bioavailability of the total iron fraction, some of which are predicted to be elevated at Ajax. Based on this, **MOE considers the concentrations of iron predicted through the life of the mine will not likely result in an impact to the aquatic environment of the Peterson Creek drainage,** based on the fact, that the dissolved iron is not predicted to exceed the WQGL for the Base Case and most Sensitivity Analyses (Baseline Sensitivity Case). **Low potential for cumulative effects into lower Peterson Creel.** MOE considers this parameter to have been adequately assessed at the EA review level. Its predicted concentrations should be manageable under EMA permitting with BC WQGLs or science based environmental benchmarks.

Molybdenum:

KGHM (Stantec,) proposed a water quality benchmark for livestock watering of 180 µg/L based on a modification of the 1986 BC WQGL, claiming that local cattle are beef and that water consumption by beef cattle is up to 91 L/d of water in summer. This is lower than the maximum daily water consumption rate the guideline was based on for dairy cows (205 L). MOE notes that this position is supported in the literature (see details in the appendix) where it is indicated that the total daily water intake of beef cattle (drink and in food) at 32.2°C is a maximum of 78 L/day for herd bulls, feeders and replacements 12 months and older. Also, from Agriculture and Agri-Food Canada (August, 2014), lactating cows in summer require 95 L/day and finishing cattle in summer, 86 L/day. All other cattle and horses and sheep have lower summer requirements.

While MOE supports some of the rationale that a value above the livestock guideline could be protective of beef livestock, the following information also needs to be considered:

- BC WQGL (1986) states that ruminants (wild or domestic) are more sensitive than non-ruminants, with cattle the most sensitive. Ruminants include deer, moose, sheep, goats.
- BG WQGL (1986) does acknowledge the mobile nature of wildlife compared to livestock. They have the advantage over domesticated animals of not being confined to restricted areas of food.
- MOE understands that the Ministry of Forest, Lands, and Natural Resource Operations is pursuing riparian habitat improvements in the Peterson drainage, including setback fencing. These measures may benefit livestock protection by reducing access to surface water and thus molybdenum uptake.

In addition, SBEBs are restricted to aquatic life protection and are thus not suitable for livestock. Based on the above, we will not consider the proposed value as a preliminary benchmark.

Applying the livestock/wildlife guideline, predicted **molybdenum concentrations in Peterson Creek may have a low potential for impact during Operations, increasing to moderate by Closure and high during Post Closure in the event that scenarios predicted under Sensitivity Analyses occur**. The potential for **impact to livestock/wildlife in Humphrey Creek is likely low under the Base Case scenario, but moderate if Sensitivity Analyses are realized**. MOE considers this parameter to have been adequately assessed at the EA review level. Its predicted concentrations should be manageable under EMA permitting with BC water quality guidelines provided a number of potential management techniques are found to be applicable and effective. With molybdenum not predicted to exceed WQGL at PC02, the **potential cumulative effects into lower Peterson Creek is expected to be low under any Base Case scenarios**. **Under the Lower Hydraulic Conductivity scenario in groundwater during decommissioning, closure and post closure effects may occur**.

Selenium:

The review of the proposed selenium WQB is based on Lana Miller`s, (MOE) review of Application Appendix 6.3-D (Stantec proposed benchmarks, May 8, 2015) and resulting email correspondence from Lana Miller PhD (MOE) to Gabi Matscha (MOE) December 28, 2016 “2016-12-28 LLMiller Rev of Prop Ajax Se Benchmark” (included in the appendix under the selenium review chapter by the contractor).

KGHM has proposed Water Quality Benchmarks (WQBs) in receiving waters downstream of the Ajax Mine of 2.5 to 4.5 µg/L selenium for still (lentic) waters containing rainbow trout and for habitats with aquatic-feeding birds. For moving (lotic) waters, KGHM proposed a 5.0 µg/L WQB.

While the general benchmark derivation process identified for Se is reasonable, for the Ajax proposal it lacked site-specific details/information and made several assumptions that were not justified with site specific data. Until site specific Se data are overlaid with Orr et al’s (2012) bioaccumulation models to show that the assumption that a site-specific model for the Elk Valley is relevant to the Ajax area, application of the proposed WQB is pre-mature and the project should be assessed against BC WQGLs for selenium.

Predicted selenium in Peterson Creek between Humphrey Creek and Long Lake Road (PC02.5, PC02.3) during Post Closure has increased from less than 2 µg/L to 8 µg/L with the recent design changes (removing the Peterson Creek Downstream Pond (PCDP) (December, 2016). In comparing the “Residual Effects Characterization Criteria” with and without the PCDP, we note a “Significance of Adverse Residual Effects” change from “not significant (minor)” to “not significant (moderate)” for both sites. While we acknowledge that selenium is predicted to “only exceed the interim WQB in the winter low flow months, when productivity is very low and when surface flows are predicted to be very low at this assessment location”, **MOE questions why a change from 2 to 8 µg/L as Base Case is considered as “not significant”**. **Impact potential related**

to predicted selenium for Base Case and scenarios for the Sensitivity Analyses remains uncertain until the interim WQB can be supported with site specific data.

Selenium is predicted to exceed WQGLs in Peterson Creek near Hwy 5A (PC02) with up to 7 µg/L,; however, since, selenium has historically exceeded WQGLs in Lower Peterson Creek (up to 7 µg/L), **mine related selenium contributions may not necessarily lead to cumulative effects.**

Predicted **antimony and uranium exceed WQGL** for the protection of aquatic life slightly under various Sensitivity Analysis scenarios. The **likelihood for impact to aquatic life is considered to be low to moderate**.

MOE does not agree with the KGHM position to always assume that all measured chromium is CrIII and with a WQGL of 8.9 µg/L. Until such time as specific chromium forms can be analyzed or the measured total fraction can be confirmed to be from dust particles, MOE believes the CrVI guideline should be applied. This comment refers to Issue Tracking Table MOE-062.

ENVIRONMENTAL ASSESSMENT REVIEW CONCLUSION

MOE partially agrees with the residual effects assessment determination by Knight Piesold; however, differs in the determination of the effect on aquatic life, livestock, wildlife and irrigation for predicted category 1 and 2A parameters in Peterson Creek, particularly in the section from Humphrey Creek to Long Lake Road and in Humphrey Creek. This is partially based on the fact that MOE does not agree with some of the proposed benchmarks and thus applies WQGLs for the assessment instead.

Based on this assessment of the predicted receiving water quality, MOE has identified the following potential effects in Peterson Creek and Humphrey Creek:

Potential Effects in Peterson Creek Reach from Humphrey Creek to Long Lake Road Crossing on:	**Potential Effects in Humphrey Creek on:**
• **rainbow trout reproduction due to high nitrate levels,** • **chronic effect on the aquatic food chain in the Peterson Creek Watershed from high sulphate levels,** • **health, growth, and/or reproduction of aquatic life (fish and its food chain) due to high aluminum and copper values** • **mortality of a local green algae as part of the food chain due to high arsenic concentrations,** • **wildlife/livestock due to elevated molybdenum values,** • **irrigation water use due to predicted high chloride levels, and** • **uncertain effects from predicted selenium levels.**	• **mortality of western toad due to high aluminum values,** • **reproduction (egg-larval stage mortality) of local frog species of the genus (Rana), and** • **wildlife/livestock due to high molybdenum values.**

We recommend that further mitigation of elevated nitrate, sulphate, aluminum, copper, arsenic, molybdenum, and chloride levels be evaluated in the EMA permit application.

Items that are suitable to be dealt with at EMA Permitting rather than the EA Review are listed in Appendix C.

Should you have any questions about the above, please contact me at 250-371-6296 or at Gabriele.Matscha@gov.bc.ca.

Sincerely,

Gabi Matscha, R.P.Bio
Environmental Impact Assessment Section Head – Mining Operations, Ministry of Environment

REFERENCES

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MOE, 2016. Technical Guidance 8 Environmental Management Act Applications: A Framework for the Development and Use of Freshwater Science-Based Environmental Benchmarks for Aquatic Life in Environmental Management Act Permitting for Mines. March 2016

Knight Piesold (KP), 2013. Historical Surface Water Quality Data Report. June 30, 2016

File: Ajax Project - KAM
Date: March 17, 2017

To: Brian Heron-Herbert, Senior Project Manager – Mining Operations

From: Erin Rainey, Hydrologist – Mining Operations

RE: Ajax Mine Project – Surface Water Hydrology Review of the Environmental Assessment Application

INTRODUCTION

I have reviewed the Ajax Mine Project (the project) Environmental Assessment (EA) application submitted by KGHM Ajax Mining Inc. (KAM). My review focussed on the flow quantity aspects of the application (surface water hydrology), specifically related to the hydrology baseline data and water balance modelling. The comments/concerns that I raised during the EA were all been sufficiently addressed; therefore the objective of this memo is to summarize my final assessment of the EA and key issues that warrant further consideration should the project move into the permitting process.

SUMMARY OF EA REVIEW

The potential effects of the project on surface water hydrology, particularly monthly streamflow, were assessed in Peterson Creek (and its tributaries), Jacko Lake (lake levels) and Kamloops Lake. The changes to streamflow were estimated based on the water balance model developed for the EA. The water balance predicted that the mine site will be in a water deficit during operations; a deficit was defined as requiring additional makeup water from outside the Peterson Creek catchment to support mine activities. The main source of makeup water was proposed to be Kamloops Lake, which would be pumped to the project via a water pipeline. The additional design capacity of the proposed water pipeline was also considered to augment flow in Lower Peterson Creek during mine operations, as a preferred streamflow mitigation option. However, the flow augmentation option was only presented at a conceptual level for the EA and the EA water balance did not consider the addition water pumped to Lower Peterson Creek during operations.

I agree with the residual effects assessment determination of “not significant” for changes in streamflow in Jacko Lake, Lower Peterson Creek and Kamloops Lake due to the project. Furthermore in my opinion, the changes in streamflow predicted in Lower Peterson Creek can be considered conservative for water quantity given that the flow augmentation from Kamloops Lake was not included in the EA residual effects assessment.

While, I believe the hydrology baseline data collection and water balance model were adequate to characterize the project site and estimate changes to water quantity due to the project for the EA, the next section highlights key concerns and recommendations for the more detailed *Environmental Management Act* permitting requirements.

ISSUES FOR PERMITTING

The key issues I identified for permitting in terms of water quantity are:

1. **Standard of hydrology data collection –** limited benchmark surveys and data grade assessment
2. **Uncertainty in water balance model –** uncertainty in model calibration using limited site data

The following sections provide background information and rationale as to why I believe the above-mentioned issues require further consideration in permitting.

<u>Standard of Hydrology Data Collection</u>

In my opinion, the hydrology data collection presented in the EA application did not consistently meet the minimum standard of practice as outlined in Manual of British Columbia Hydrometric Standards – Version 1.0 (RISC, 2009). While some components of the program did meet expected RISC standards, others do not. For example, all data grades require at least 1 (or more) benchmark level surveys conducted per year; however, none of the project site stations met this minimum standard as no benchmark surveys were reported to be conducted in 2014, while only periodic surveys were reported between 2008-2011.

As such, the current data collection program will not be sufficient in the permitting phase for long-term monitoring at the project site. I recommend that ongoing data collection programs be designed and implemented with the intent of achieving at least the Grade B data grade. For the permit application, I recommend benchmark surveys be completed of the staff gauges relative to station benchmarks at least once per season. The hydrology reporting should also include a comprehensive summary of the data collected and the data grade assessment, which should include a discussion of data quality and accuracy.

<u>Uncertainty in Water Balance Model</u>

Updates to the water balance model for the project were completed in 2016, subsequent to submission of the EA application in 2015. The water balance updates were summarized in the supporting memos by BGC (2016a, 2016b) and KP (2017). In terms of flow quantity, the key model update was related to the recalibration of the predicted streamflow based on five years of measured streamflow at the inflow of Jacko Lake (JACINF hydrometric station) for the open water months of April to October for 2008-2011 and 2014. The measured streamflow for JACINF was updated based on a new rating curve developed by BGC to include the 2014 measurements. The 2014 rating curve increased the resulting measured flows slightly compared to the previous rating curve develop by KP (2013). As a result of the recalibration using the updated JACINF streamflow record and a correction of an error found in the original climate input data (BGC, 2016b), the updated water balance model predicted higher annual runoff (~30%) for the Peterson Creek watershed.

The EA water balance model in the 2015 application used the 50-year synthetic flow series developed for JACINF by KP (2013), which I felt provided a good representation of the expected long-term streamflow conditions, given the year-to-year and month-to-month variability available in the long-term record. Conversely, the five years of incomplete record for JACINF (open water months only) used to calibrate the updated model in 2016 represented a wetter than average period in the project area, as shown by comparing concurrent years from the 100-year streamflow record available for the nearby regional Water Survey of Canada (WSC) station at Deadman River above Criss Creek (08LF027). The streamflow at Deadman River above Criss Creek for 2008-2011 and 2014 indicated that those years, with the exception of 2009, were higher than average particularly in the freshet months, which represents 70% of the annual flow (KP, 2013).

Therefore, my concern is that the updated model calibration may have biased the model predictions towards higher than average streamflow/runoff in some months compared to what would be expected in the long-term. This could have implications to water quality model predictions in the receiving environment. I recommend that for permitting the water balance model be calibrated with additional high quality measured streamflow data in order to demonstrate that the model provides a robust characterization of long-term runoff conditions at the project site.

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Should you have any questions about the above, please contact me at 250-354-6358 or Erin.Rainey@gov.bc.ca.

Sincerely,

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