BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES COMPANY
Suite 600 - 372 Bay Street, Toronto, ON Canada M5H 2W9
Telephone (416) 644-1216 Fax (416) 649-0335

# Project Memorandum

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| **To:** | **KGHM Ajax Mining Inc.** | **Doc. No.:** | **BGC-033** |
| **Attention:** | **Nicola Banton** | **cc:** | |
| **From:** | **C. Koenig** | **Date:** | **July 26, 2017** |
| **Subject:** | **Ajax Project EA/EIS - Summary of Contaminant Remediation Methods** | | |
| **Project No.:** | **1125011** | | |

## 1.0 INTRODUCTION

An *Application for an Environmental Assessment Certificate/Environmental Impact Statement for a Comprehensive Study* (the Application/EIS) was submitted in January 2016 (KAM 2016) for the Ajax Project (the Project). The Application/EIS is currently in the review phase, during which the BC Environmental Assessment Office (EAO) reviews all available information and seeks input from Aboriginal groups, all levels of government and the public to identify potential environmental impacts of the Project.

This memorandum has been prepared by BGC Engineering Inc. (BGC) on behalf of KGHM Ajax Mining Inc. (KAM) in response to a request from the Canadian Environmental Assessment Agency (the Agency) regarding potential groundwater remediation technologies that might be considered for the Project. The request was made during a phone call between the Agency, KAM and BGC and follow-up email from the Agency to KAM, both on July 18, 2017.

During the phone call, the Agency requested that KAM identify adaptive management options relating to the Edith Lake Fault Zone (ELFZ) and Jacko Lake, and provide a high level overview of the conditions under which they would be appropriate. Also during the phone call, KAM noted that a formal trigger-action-response plan for the ELFZ would be established as part of the permitting process. KAM emphasized that actions and responses would only be appropriate if monitoring indicated that seepage from the tailings impoundment and (west) mine rock storage areas was migrating within the ELFZ and that this seepage was occurring at quantities and concentrations that would be characterized as potentially harmful to the down gradient receiving environment (i.e., Jacko Lake). KAM further clarified that the actions and responses that would be considered in such a circumstance would be formulated based on the seepage conditions observed (i.e., based on the location, quantity, migration rate, chemical constituents concentrations of potential concern, anticipated receiving environment, etc.). In other words, it is premature to specify detailed actions and responses for situations that have not, and may not, occur.

The Agency acknowledged that KAM would not want to commit to adaptive management measures that may not be appropriate. The Agency expressed that it is interested in outlining mitigation options that would be available if conductivity of the ELFZ is higher than predicted (and if seepage quantities and concentrations potentially of concern to the downgradient receiving environment are encountered during monitoring), and understanding the conditions under which those options would be appropriate. The Agency would qualify any additions to the report outlining potential adaptive management options by noting that selection and implementation of appropriate options would depend on monitoring results (CEAA, 2017).

## 2.0 APPROACH TO REMEDIATING POTENTIAL GROUNDWATER CONTAMINATION AT AJAX

Specific actions undertaken to remediate groundwater at the Project would be designed and implemented in accordance with mine permit conditions. Where permit conditions do not designate requirements, remedial actions would be taken in accordance with applicable BC laws, regulations, standards, protocols, procedures and guidance as established in the BC Contaminated Sites Regulation (CSR) under the Environmental Management Act (B.C. Reg. 375/96 O.C. 1480/96). KAM is committed to future investigations and monitoring following the EA and throughout life of mine (LOM) to ensure that the Project adheres to Permit requirements and that measures are implemented to protect water quality in Jacko Lake during Project construction, operation, closure and post closure.

As indicated previously, KAM will submit a Surface Water and Groundwater Monitoring and Management Plan (SWGMMP) as part of the Mines Act and Environmental Management Act Permit Application process. A proposed Trigger Action Response Plan (TARP) for addressing any water quality issues identified by the monitoring plan would form part of the SWGMMP, or would be submitted as a separate document. Within the TARP, concentrations of the potential contaminants of concern (PCOCs) identified during the EA[1] for the Project would be proposed as triggers that would commence a certain action/response plan. Because large mining projects may need to monitor for water quality concerns from many potential sources, the TARP framework is often general to begin with, and is adapted based on the concerns encountered at a project, or specific location of a project. Such actions might include:

- Confirmation of trigger concentration (i.e., re-sample)
- Notifying the appropriate agencies that a trigger has been exceeded
- Risk assessment to evaluate if seepage loadings and migration rates pose a risk to receiving environment and an assessment of the time available during which a mitigation approach may be enacted (i.e., days, months or years)
- Selection and implementation of an appropriate mitigation strategy
- Additional monitoring to evaluate the effectiveness of the mitigation.

Where response times are short (e.g. hours to days) provisions are usually enacted under a spill response plan. For most groundwater contamination concerns, however, there is usually time (months to years) to evaluate the problem, then design and implement a suitable mitigation strategy.

[1] The PCOC list considered in the Permit Application would be based on the results of the EA and would be amended by findings from any additional studies and investigations that may be required as conditions on the EA Certificate.

Once a trigger is exceeded, an investigation into the extent of the concern would commence. There are numerous available frameworks for these studies, such as the levels of investigation specified under Sections 58 and 59 of the CSR which outline the requirements for preliminary and detailed site investigations required for contaminated sites in BC. The Stage 1 Preliminary Site Investigation (Stage 1 PSI) identifies the potential contaminants of concern that may be present at a site. The Stage 2 PSI is an intrusive investigation designed to confirm the presence/absence of the potential PCOCs. These two stages of investigation would be considered in the design and implementation of the SWGMMP and monitoring network. The next steps are:

- Delineating the contamination including an assessment of the contaminants of concern, concentrations, rates of migrations and anticipated receiving environment;
- Developing a remedial action plan;
- Remediating the concern;
- Confirmatory monitoring.

Remediation strategies that are implemented for groundwater contamination issues generally include:

- Source removal or treatment (e.g., in this case changes to the mineral extraction process or amendments added to the TSF pond water to lower concentrations of PCOCs in supernatant water)
- Quantitative risk assessment for the specific receiving environment at risk (i.e., evaluation of the receiving environment and biota at risk compared to the contaminant concentrations anticipated at that location, assessment of the exposure pathways)
- Source interception (e.g. seepage interception ponds, wells or trenches)
- Passive remediation approach (e.g. treatment wetland, PRB)
- Migration pathway control (e.g., grouting to reduce hydraulic conductivity and limit or eliminate migration potential).

A brief overview of some of these methods, all of which are conventional remediation approaches and technologies readily available in British Columbia, is provided below.

## 3.0 POTENTIAL REMEDIATION AND MITIGATION MEASURES AT AJAX

The following potential adaptive management measures were discussed during the July 18, 2017 phone call between the Agency, KAM and BGC as potential options that could be considered and potentially implemented at Ajax should exceedances in water quality trigger thresholds be identified in the surface water and/or groundwater monitoring network:

- Grouting
- Seepage interception wells
- Pressure relief wells
- Permeable reactive barriers (PRB)

A general overview of each of these methods, as well as a brief discussion of the circumstances under which they may be considered for mitigation at the Ajax Project is provided in Sections 3.1 through 3.5 below.

### 3.1. Grouting

Grouting fractures within bedrock (i.e., interface treatment) lowers the rockmass permeability and thus lowers seepage rates through groundwater systems. Various types of grout can be injected into fractures to fill void space, depending on site conditions. As the permeability of grouted rock is lower, this reduces the magnitude of seepage through the grouted areas (USACE 2017). There are several case studies where grouting of fracture zones has been successful in decreasing seepage rates, although appropriate field investigations are necessary to plan the grouting program and assess whether the grout has filled the fractures as desired (USACE 1993). The utility of this approach depends on the ability to identify the fracture zones of interest, and on the degree of success of the grouting program to fill them. A schematic of the construction sequence for interface treatment is shown on Figure 3-1. Grouting can be used to reduce rockmass hydraulic conductivity to values to as low as $10^{-7}$ m/s or, with use of ultrafine grinds of cements, to $10^{-8}$ m/s or lower. Grouting is a potentially feasible method for reducing rockmass hydraulic conductivity to depths of up to 60 m below grade and is a common mitigation applied at water storage and hydroelectric projects to limit seepage water losses from reservoirs.

At the Ajax Project, targeted grouting might be considered in areas of high fracture density (e.g., within or adjacent to the ELFZ downgradient of the TSF and WMRSF and upgradient from Jacko Lake, if identified from drilling investigations to address EA Certificate conditions). The decision to grout would be made in conjunction with results from groundwater monitoring (e.g., if results of laboratory analyses indicate exceedances of parameters of concern within the monitoring network designed around the TSF, and/or high flux rates with loadings of potential concern to the receiving environment).

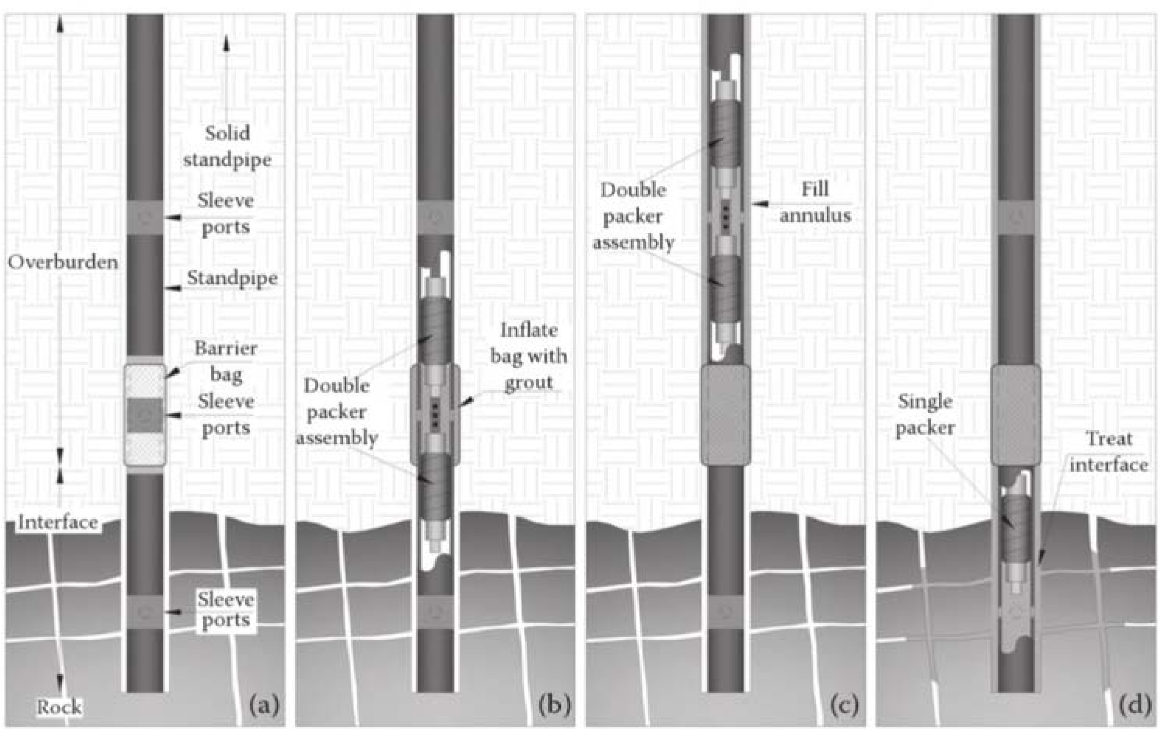


**Figure 3-1. Construction sequence for interface treatment within bedrock (from Bruce (2013)).**

### 3.2. Seepage Interception Wells

Seepage interception wells are often used to capture contaminated groundwater and limit its migration to an area of concern located downgradient of mining operations (e.g., lakes, streams, well fields, etc.). Seepage interception wells are generally equipped with a pumping system, which can be operated continuously or intermittently depending on the predicted migration rate of the contaminant(s). An example of a seepage interception system is shown on Figure 3-2 after Ministry of Environment, Lands and Parks (MOELP). Note that the design of such a system requires delineation of a groundwater capture zone (Figure 3-2 (a)) to limit drawdowns and groundwater pattern changes while effectively containing the zone of concern.

Seepage interception using wells is generally feasible at aquifer (rock or soil) hydraulic conductivity greater than $10^{-6}$ m/s and may be possible at lower hydraulic conductivity in some rockmasses. The wells require a pumping out facility to be available over a long period and even in perpetuity in extreme cases.

Investigations (i.e., pumping tests) planned for the ELFZ and Jacko Lake area in support of Project permitting would be used to characterize the larger scale hydraulic conductivity of the rockmass between the TSF and Jacko Lake/Peterson Creek. The results of these investigations will be useful in evaluating both the potential for seepage in the rockmass and the feasibility of seepage pumpback and grouting mitigation options. Additional investigations may also be carried out to better delineate the seepage zones and to determine the spacing of wells.

**(a)** **(b)**

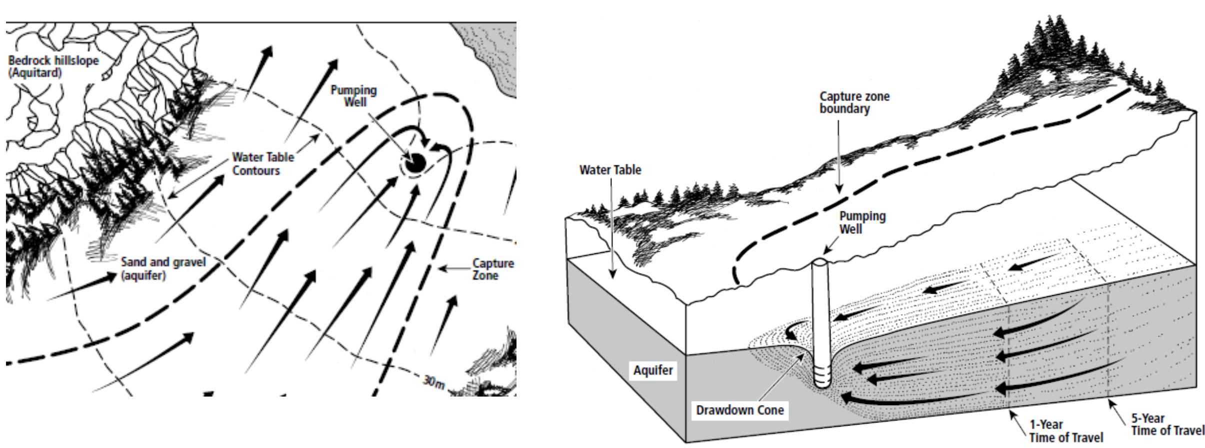


**Figure 3-2. Schematic diagram of a well capture zone for a seepage interception in (a) plan and (b) section view (from MOELP *et al.* 2006).**

### 3.3. Pressure Relief Wells

Relief wells are designed to intercept seepage and lower pore pressures, and are generally installed along a downstream toe of a dam to prevent excessive uplift pressures and piping through foundations. The application at Ajax would be for seepage interception[2]. Relief wells are typically installed vertically such that the water level within reaches the height of a collector pipe or trench, which will cause seepage water to naturally flow up and out of the well where it may be diverted to be treated or discharged (USACE 1992). An advantage of relief wells is that they can provide seepage control at greater depths than is typically practical for some methods such as cutoffs. Relief wells must be appropriately spaced in order to capture the desired amount of seepage, similar to seepage interception wells. A schematic for the design of a typical pressure relief well is provided in Figure 3-3.

At the Ajax Project, a potential application of pressure relief wells would be immediately adjacent to the downstream toe of the TSF. Such wells might be used to intercept seepage migrating within the ELFZ (if the ELFZ is determined to be a potential migration pathway by additional investigations and monitoring) and divert it into the drainage collection ponds proposed for the TSF.

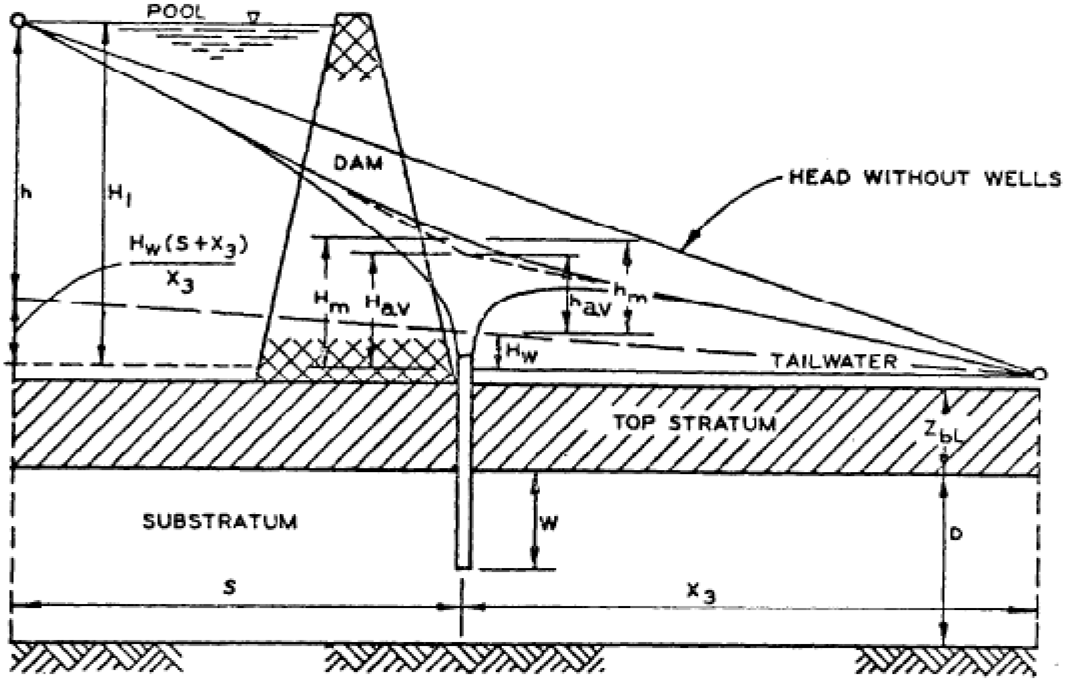


**Figure 3-3. Design of Pressure Relief Well (from USACE (1993)).**

[2] It is BGC's understanding that there are no concerns related to dam stability that would necessitate the use of pressure relief wells, rather, this is a mechanism that can be used to take advantage of the hydraulics of the groundwater flow system to intercept and collect seepage without active pumping (i.e. mitigation with pressure relief wells represents a passive approach rather than the active approach with pumping indicated in Section 3.2)

### 3.4. Permeable Reactive Barrier (PRB)

A PRB is a passive, *in situ*, technology that, in certain conditions, has a high potential to treat shallow [typically non lithified] aquifers (Blowes *et al.* 2000). In these systems, a permeable barrier is constructed to intercept a contaminated groundwater plume, with the barrier amended with one or more materials to create a reactive media for contaminant removal (Figure 3-4). The PRB is designed to be more permeable than the surrounding aquifer media so that groundwater can easily flow through the reactive material selected without significantly altering a groundwater flow system. PRBs have been used successfully to treat organic and inorganic contaminants using zero-valent iron ($Fe^0$) and/or carbon-based organic material as a reductant (USEPA 2005). Zero-valent iron PRB systems have been installed at the field scale for the treatment of arsenic, molybdenum, selenium, technetium and uranium (Smyth et al., 2004 and references therein).

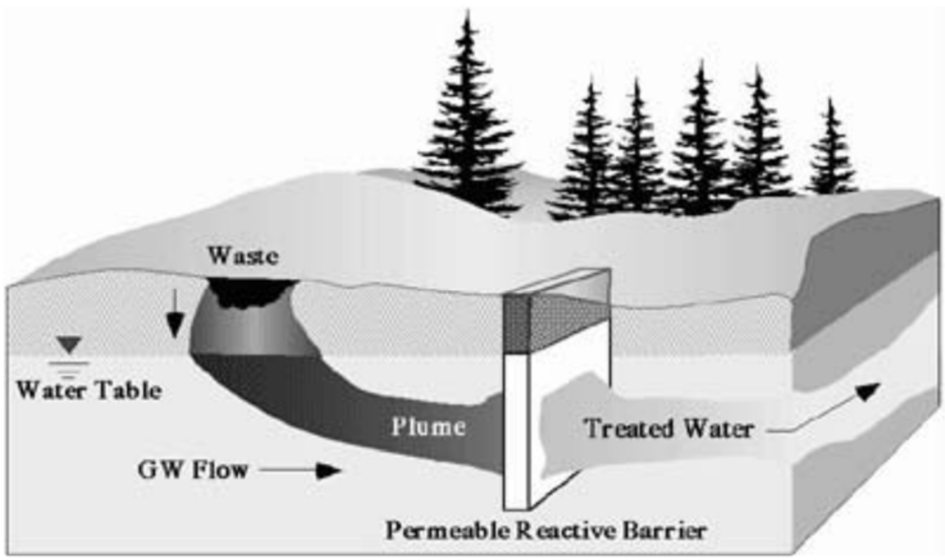


**Figure 3-4. Example of a Permeable Reactive Barrier (from USEPA 2005).**

Specific considerations dictate the selection of a PRB as a treatment option, and comprehensive understanding of site hydrogeochemistry is required for barrier design, placement configuration, and selection of reactive materials to effectively treat groundwater contaminant plumes. If results from groundwater investigations and monitoring to be completed at Ajax during permitting and throughout LOM suggest that treatment of groundwater for mine drainage and/or dissolved metals is necessary, and that observed conditions may be effectively treated with PRB technology, the Project could consider this as a mitigation option for potential seepage from mine infrastructure to Jacko Lake or the Peterson Creek aquifer by installation of a barrier across seepage pathways. However, actual placement location(s) and PRB materials would need to be informed by observation (i.e., water quality monitoring results at permitting and throughout LOM) as well as updated flow modelling with the final mine plan.

## 4.0 CLOSURE

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Yours sincerely,

**BGC ENGINEERING INC.**
**per:**


Cassandra Koenig, M.Sc., P.Geo.
Senior Hydrogeologist

Reviewed by:

Trevor Crozier, M.Eng., P.Eng.
Principal Hydrogeological Engineer

CK/TC/vg/mm

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