Long-term Water Management of Saline Groundwater at the Ekati Diamond Mine

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Abstract

Deep groundwater in much of northern Canada is characterized by high concentrations of total dissolved solids (TDS) that can increase by orders of magnitude with depth. Mining in this region can result in upwelling of saline groundwater that needs to be managed during pit development during operations and in the mine closure/post-closure phases. Due to the pristine nature of the downstream receiving environment in northern Canada, direct discharge of high TDS water may not be acceptable and the remote location of the mine often makes water treatment not economically feasible. Therefore, alternate water management strategies often need to be developed to manage this water.

The proposed Jay open pit Project at the Ekati Mine in the Northwest Territories, Canada is expected to result in upwelling of high TDS groundwater that will have to be managed during mine operations. A water management strategy was developed to minimize TDS loads in the mine discharge through using an existing mined out pit (Misery Pit) to store mine water produced during the development of the Jay Pit. Water balance modelling indicates discharge to the receiving environment will be required during mining of Jay Pit for a period of time. To preclude discharge of peak TDS concentrations, which are predicted to increase through operations, water will be pumped to the bottom of Misery Pit allowing surface water in Misery Pit that meets regulatory criteria to be discharged. At closure, mine water will be pumped back from Misery Pit to Jay Pit, and Misery and Jay Pits will be capped with freshwater from a nearby lake to establish permanent meromictic conditions.

Evaluating the feasibility of the proposed water management strategy required the development and integration of several models that were linked at key times and nodes. These included a three-dimensional hydrogeological model to predict groundwater inflow rates and TDS loads to Jay Pit during operations, and a site mass balance water quality model and downstream lake hydrodynamic models to evaluate if the proposed water management strategy would result in an acceptable discharge water quality. For closure, the stability of meromixis was evaluated using pit lake hydrodynamic models.

This paper presents a case study of the Jay Project water management plan and an overview of modelling that is required to evaluate water management options for high TDS water.

Keywords: saline water, mine water management, pit lake water quality

Introduction

Groundwater in much of the Canadian Shield is characterized by high salinity that increases by orders of magnitude with depth (Fritz and Frape 1987). Mining in these areas has the potential to cause upwelling of deep seated groundwater containing elevated concentrations of total dissolved solids (TDS). This poses a challenge for developers since the pristine nature of the downstream receiving environment, which is characterized by very low (e.g., less than 20 milligrams per litre [mg/L]) concentrations of TDS (Vandenberg et. al, 2015), can preclude direct discharge of groundwater produced during mining.

Dominion Diamond ULC (Dominion Diamond) is currently constructing the Jay Project at the Ekati Mine, located in the Northwest Territories (Figure 1). The proposed Jay Pit is located below Lac du Sauvage, which contains an open talik. Hydrogeological modelling (Dominion Diamond 2014; Golder 2016) indicates that groundwater inflows and TDS concentrations will increase as mining progresses. To minimize the discharge volume of water containing high TDS, Dominion Diamond proposes to store saline mine water during operations and subsequently use this water to develop meromictic pit lakes, permanently isolating mine water from mixing with surface water during post-closure.

A detailed modelling evaluation of operational and post-closure water quality was completed for the Jay Project as part of the Developer's Assessment Report (DAR) (Dominion Diamond 2014) and the subsequent Water Licence Application (Golder 2016). There are several influences on water quality at the Jay Project (e.g., geochemical, hydrogeological, etc.) and accounting for all of these processes required several models to evaluate if the proposed water management strategy would be protective of downstream receptors.

This paper presents a summary of the modelling that was completed to validate the feasibility of the proposed saline water management strategy. A focus is given to the pit lake hydrodynamic modelling as the water management strategy takes advantage of the development of meromictic pit lakes during post-closure.

Project description

The Jay kimberlite pipe is located below Lac du Sauvage. Access to the pipe will require construction of a dyke around, and dewatering of, a small area of Lac du Sauvage (Figure 2). During mining of Jay Pit, mine water will be pumped to Misery Pit and subsequently discharged to Lac du Sauvage after the Misery Pit storage capacity is exceeded. Hydrogeological modelling indicates that TDS concentrations will increase as mining advances in Jay Pit. Dominion Diamond proposes to pump mine water from Jay Pit to the bottom of Misery Pit. This approach conceptually displaces water containing lower TDS concentrations vertically through the water column, precluding the discharge of water containing the highest concentrations of TDS that are produced later in the mine life.

At closure, mine water stored in the upper 50 m of Misery Pit will be pumped to the bottom of Jay Pit. Residual mine water in the Jay and Misery Pits will be covered with water pumped from Lac du Sauvage, catchment runoff and groundwater inflows. This approach will create a low-density, freshwater cap over the residual mine water and meromictic lakes in Misery and Jay pits. Following back-flooding, and after water quality monitoring confirms that water quality is suitable for discharge, the Jay dyke will be breached and the pit lake will be reconnected to Lac du Sauvage. Misery Pit lake will drain naturally to Lac de Gras.

Methods

To test the validity of the proposed water management strategy, several models (e.g., hydrogeological, water balance, site water quality, etc.) were developed that were linked at key times and nodes. This paper focuses on the pit lake hydrodynamic model developed in CE-QUAL-W2 (Cole and Wells 2008) to evaluate the vertical stratification potential within the pits during the first 200 years of the post-closure period (i.e., after the mined-out pits are entirely back-flooded). Initial conditions in the mixolimnion (upper layer) and monimolimnion (lower layer) of the pit lake were simulated using the site water quality model.

As part of the Water Licence Application, the stability of meromixis in Jay and Misery pits was evaluated for different density gradients between the mixolimnion and monimolimnion. These were referred to as the 1xTDS (low density gradient) and 2xTDS (high density gradient) scenarios. The reader is referred to Golder (2016) for additional details on the model scenarios as well as additional details on the pit lake model configuration and calibration.

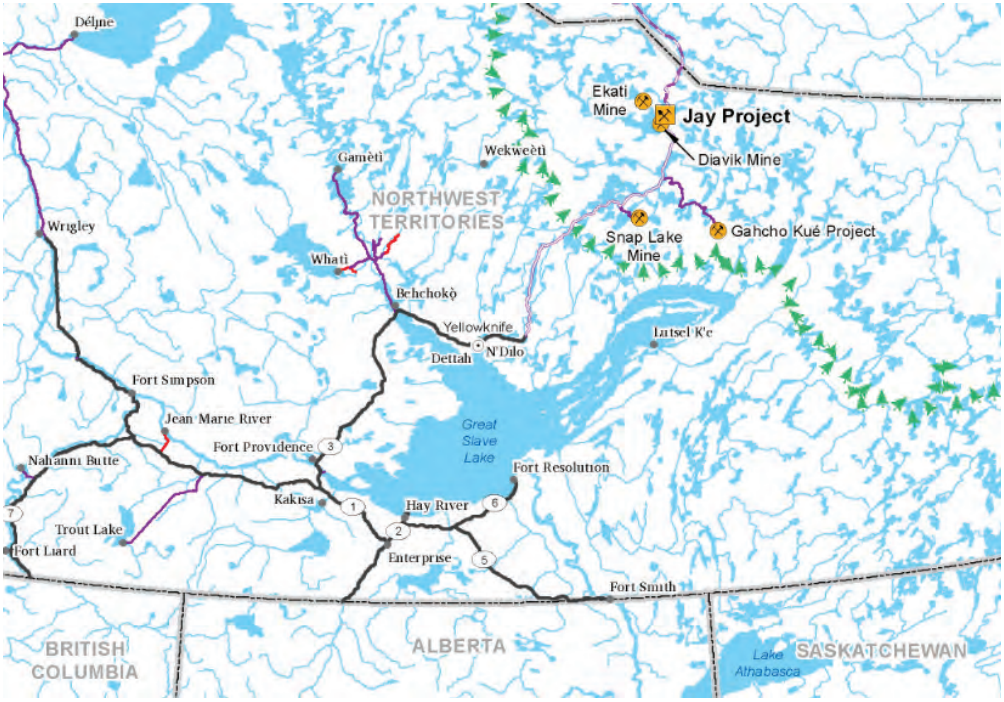

Figure 1 Location of the Jay Project

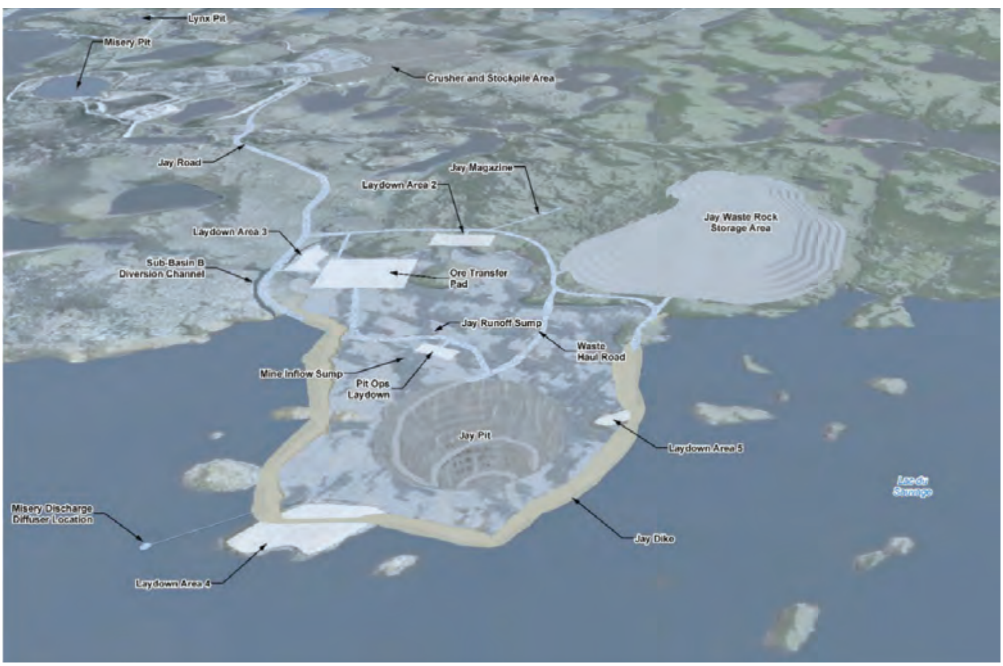

Figure 2 Proposed Jay Project Infrastructure

Results

Projected pit lake TDS profiles for the Jay and Misery Pit are presented in Figures 3 and 4, respectively. Predicted TDS concentrations for the Jay Pit indicated meromixis will be stable during the 200 year post-closure period. Concentrations of TDS in the mixolimnion increase to just over 100 mg/L for the 1xTDS and 2xTDS scenarios. For both scenarios, the transition layer gets thicker over time and the pycnocline migrates deeper into the pit lake creating a thicker freshwater cap.

Projected TDS concentrations for Misery Pit (Figure 4) also indicate this pit lake will remain meromictic throughout the 200 year modelled post-closure period for the 1xTDS and 2xTDS scenarios. For both scenarios, concentrations were predicted to increase in the mixolimnion until about 150 years into post-closure. This increase is mainly attributed to runoff from the high wall and other surface inflows. The model shows that the transition layer between the mixolimnion and monimolimnion will thicken over time but the elevation of the pycnocline is not expected to notably change. Concentrations in the monimolimnion remain unchanged because Misery Pit is developed in permafrost, which acts as a barrier to groundwater inflows. Similar to Jay Pit, there is a higher density difference in the long-term for the 2xTDS scenario in comparison to the 1xTDS scenario (Figure 4).

Discussion

The detailed water quality modelling completed as part of the Jay Project indicates that development of meromictic pit lakes is a viable solution for saline water management at the Ekati Mine. This saline water management strategy is considered feasible for the Jay Project for the following reasons;

- There is a location available (i.e., Misery Pit) to store saline water containing elevated TDS during mining of Jay Pit;
- There is an abundant source of water (e.g., Lac du Sauvage) available to develop a freshwater cap during closure;
- The pit geometry is favourable (e.g., low surface area to depth ratio) for the development of meromictic conditions (Pieters and Lawrence 2014); and
- The Jay dyke will act as a wave barrier, limiting the effective fetch and therefore limiting mixing in the Jay pit lake.

Use of mined out pit lakes as a viable saline water management strategy is therefore site specific and the above considerations would need to be evaluated as part of saline water management at other mine sites.

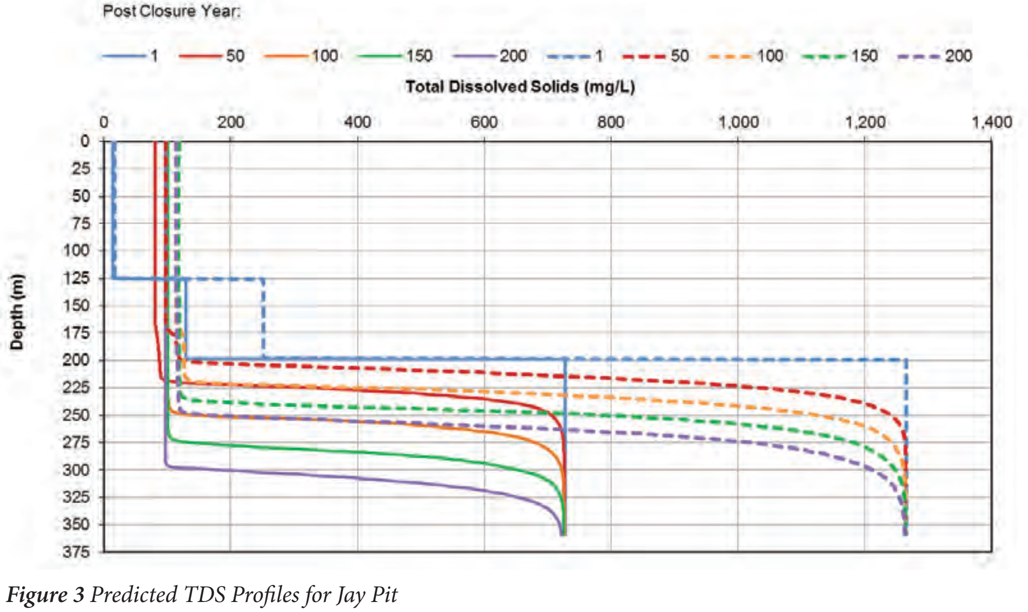

Figure 3 Predicted TDS Profiles for Jay Pit

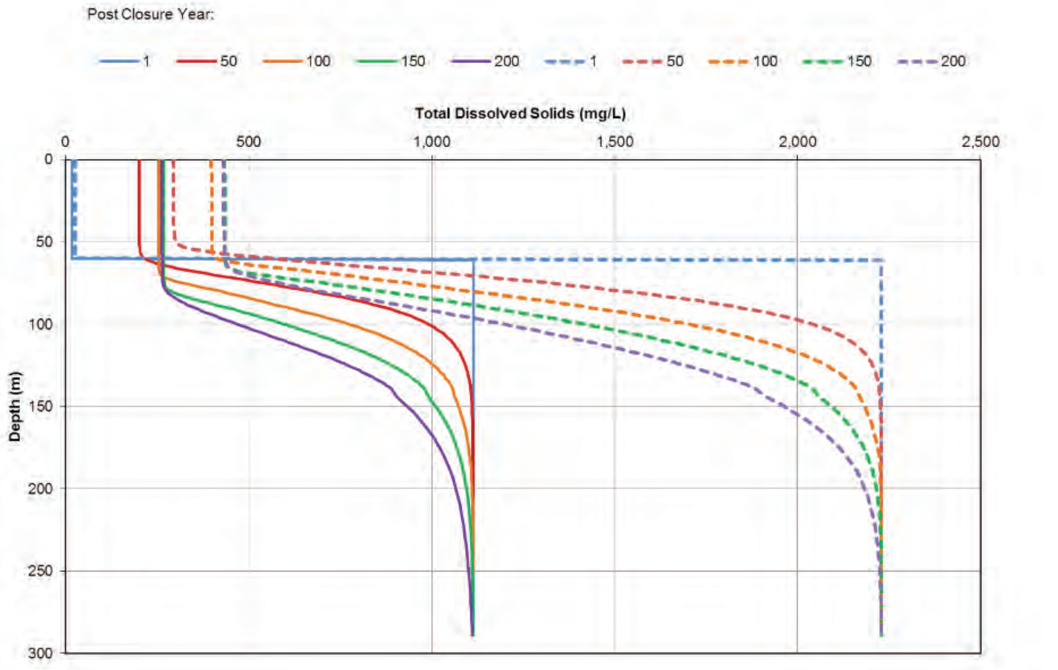

Figure 4 *Predicted TDS Profiles for Misery Pit*

As part of the Regulatory and Public review process, several other pit lake modelling scenarios were completed to evaluate the risk of a Jay Pit lake overturn in post-closure. These included a lower bound TDS scenario (Golder 2015a) and an extreme wind scenario (Golder 2015b). In all scenarios modelled, the Jay Pit was predicted to remain meromictic indicating there is a very low probability of a lake overturn. The additional model scenarios provided confidence to the Regulators and Public that use of mined out pit lakes the store minewater under established meromictic conditions was a viable saline water management strategy at the Jay Project, and the project was approved to proceed.

The Regulatory and Public review process was also valuable in "setting the bar" for the level of modelling that could be expected if use of pit lakes as a saline water management strategy were to be considered in Northern Canada. The feedback received clearly demonstrated the need to evaluate several model scenarios, included scenarios for upset conditions, to confirm the validity of using pit lakes as a proposed water management strategy.

Conclusions

Mining in Northern Canada poses several challenges. The baseline groundwater quality is characterized by high concentrations of TDS and mining in this region can produce saline water, which may not be able to be discharged due to the pristine nature of downstream receptors. In addition, the remote nature of the sites can make conventional treatment options impractical.

Use of mined out pit lakes to cap saline water with freshwater can produce meromictic pit lakes. These lakes contain a monimolimnion that is permanently isolated from mixing with the overlying mixolimnion, with the exception of a small amount of upward dispersion. If conditions indicate this is a feasible mine water management solution, it needs to be tested through a site-specific modelling exercise that accounts for all conditions, including upset conditions, that may be encountered.

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