Taseko Prosperity Gold-Copper Project

Appendix 5-2-C

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Memo

To:	Rod Bell-Irving, Taseko Mines Ltd.	**Date:**	June 12, 2007
cc:	Karen Munro, Jacques Whitford AXYS Ltd. Greg Smyth, Knight Piesold Ltd.	**From:**	Dylan MacGregor, SRK
Subject:	Prosperity Project: Information to support a significance determination relating to mine discharge water quality	**Project #:**	1CT013.000

1 Introduction

One of the key inputs to the Environmental Assessment for the Prosperity Project is the prediction of discharge water quality from the mine site to the receiving environment. In order to arrive at a determination that the project will not have a significant environmental impact, a defensible demonstration that the project will produce acceptable discharge water quality is required.

There has been considerable work undertaken to date by the project team in this regard- this memo summarizes the main technical points that demonstrate that this requirement can be met.

2 Background

The present layout of the project has all major project elements, including infrastructure and waste disposal facilities, situated within the upper Fish Creek valley. The lowest element of the mine site will be the open pit situated at the northwest end of the site. During the post-closure period, all surface water will be routed through the open pit prior to discharge to lower Fish Creek. As such, the pit forms a logical 'last point of control' for water management prior to discharge.

There will be two main sources of surface water entering the pit- the surface water discharge from TSF Lake, and the combined Main Embankment seepage and Non-PAG Stockpile runoff (hereafter referenced as 'the seepage'). These and other minor sources are projected to flood the open pit and cause surface discharge to lower Fish Creek to occur in Year 44 of the project schedule. It is at this point that Taseko needs to demonstrate that the discharge will not have significant environmental impact on the receiving environment.

3 Water Quality Prediction

3.1 Method

A prediction of discharge water chemistry has been developed by SRK with significant input from other members of the project team. The prediction is based on a chemical mass balance spreadsheet model, with the main inputs being the site water balance (developed by Knight Piesold) and an estimate of annual chemical loading from all the components of the mine site.

For certain parameters such as sulphate, the mass balance approach has been modified to reflect well-understood controls on dissolved concentrations (primarily mineral precipitation and dissolution, with gypsum being the controlling mineral in the case of sulphate).

There are a number of technical limitations in developing a precise water chemistry prediction. Generally, these limitations (or uncertainties) are related to the supporting geochemical laboratory test work that provides the basis for estimating rates of contaminant release from the planned mine elements, and to uncertainty about actual site conditions after mine construction. In the face of these uncertainties, there are technical and legislative requirements that force the adoption of reasonable but conservative inputs at all steps in the modeling process. The result is a water quality model that predicts discharge concentrations of parameters that are likely to be higher than the actual discharge concentrations.

The following points summarize some of the main sources of conservatism inherent to the Prosperity water quality prediction.

- Where laboratory testing indicated a range of contaminant release rates, the highest release rates were typically incorporated into the model.
- Where initial predictions of copper concentrations in tailings seepage were below saturation with common copper oxide minerals, copper concentrations were increased to equilibrium concentrations.
- The model does not estimate contaminant removal that might occur via attenuation of dissolved species (either through adsorption or through secondary precipitation) along flow paths. These processes are generally accepted as providing important controls on contaminant mobility, but quantitative prediction of attenuation is not realistic at this stage given the various uncertainties.

3.2 Key Results

Despite a predictive model that is intended to estimate the upper limits of expected discharge concentrations, the predicted concentrations of most parameters in Year 44 pit discharge are below or only slightly above provincial and federal water quality guidelines (WQG).

Parameters that are predicted to exceed guidelines and have been identified for further discussion include sulphate, cadmium, and selenium. Sulphate concentrations in the initial pit discharge are predicted to be around 500 mg/L, compared to a current BC WQG of 100 mg/L. Cadmium is predicted to be around 0.0005 mg/L (BC WQG of 0.00001 mg/L), and selenium is predicted to be around 0.009 mg/L (BC WQG of 0.002 mg/L). These concentrations will be diluted somewhat before reaching the proposed compliance point at the waterfall, but will remain sufficiently elevated that further consideration is required.

4 Significance determination

4.1 Preamble

The water quality prediction has indicated that sulphate, cadmium and selenium are the parameters that most exceed the respective WQG. There is precedent for discharge of elevated sulphate concentrations from mines elsewhere in BC, and discussions within the project team have concluded that elevated sulphate concentrations are best addressed in the EA with a discussion of potential impacts and a reference to precedents. However, the project team has felt that a more detailed discussion is necessary with respect to cadmium and selenium.

4.2 Summary of Facts in Support of a Significance Determination

- Water quality prediction indicates that, without additional mitigation measures, there is a chance that discharge to Lower Fish Creek will not meet published provincial/ federal water quality guidelines for selected criteria (sulphate, Cd, Cu, Se).
- Water quality prediction indicates that discharge from the project to the Taseko River will not cause any exceedances of published provincial/ federal water quality guidelines. For those parameters which are above guidelines in the Taseko River baseline (e.g. cadmium), the increase in concentration will be minor.
- The planned configuration of the mine, with the pit being the most downstream element, provides for a very reliable system of water management in that no surface water can leave the project without passing through the open pit. This feature is a very robust measure of controlling discharge to Lower Fish Creek.
- The long period required for the pit to fill to the discharge elevation will provide an opportunity for decades of water quality monitoring to ensure that water quality is acceptable for discharge.
- During the operating and post-closure periods prior to discharge, monitoring of the actual geochemical performance of the project will allow the water quality prediction to be calibrated to site data, and will remove a large amount of the uncertainty that is present in the current prediction and that is manifested in the conservative nature of assumptions about chemical loads generated by the different waste facilities.
- There are current water treatment technologies that are capable of achieving the necessary load reductions to meet existing provincial and federal water quality standards. Details of some full scale water treatment operations currently removing selenium and cadmium from mine discharge are discussed in Attachment 1.
- Taseko is not applying for a permit to discharge at present. Discharge will not occur for decades.

4.3 Considerations for Significance Determination

If discharge from the project turns out to have concentrations of selenium and cadmium as high as those estimated in the water quality prediction, the project team has determined that there will be a local, high magnitude effect in lower Fish Creek.

However, there are management options (up to and including a variety of water treatment alternatives) that are currently being used to remove selenium and cadmium from mine discharges elsewhere in North America, to sufficiently low concentrations that Prosperity water quality objectives could be achieved at present using these methods. The Prosperity site layout, with its open pit down gradient of all mine sources, appears to be well suited for implementation of water treatment as a mitigation measure of last resort, should it be necessary.

5 Summary of Main Considerations

5.1 Significance Determination

If selenium and cadmium concentrations in project discharge do not exceed the regulatory water quality objectives (either current or site specific), the 'high magnitude' nature of the local effect in Lower Fish Creek will be reduced. It follows that a determination of 'no significant effects' in Lower Fish Creek can be put forward if Taseko commits to mitigation. The following points summarize the main project features that support this determination.

1. Conservative water quality prediction
2. Minor predicted exceedances of water quality guidelines for select parameters
3. Long time period to initial discharge, with decades-long opportunity to monitor evolution of pit water quality prior to discharge.
4. Reliable mechanism for controlling surface water discharge to Lower Fish Creek
5. Mitigation to be implemented as required to achieve water quality objectives in Lower Fish Creek

5.2 Mitigation

Other recently permitted mines in BC have proposed monitoring as a mitigation, and have been permitted on that basis. The following three points summarize the mitigation options that the project team has identified as appropriate.

A. Water quality monitoring within mine footprint, as well as in the ultimate receiving environment
B. Environmental effects assessment to be carried out in the receiving environment
C. Commitment to achieve either published water quality guidelines <u>or</u> such site specific water quality objectives as deemed appropriate prior to discharge, including through implementation of water treatment if necessary.

Attachment 1

Prosperity Project:

Methods for removal of selenium and cadmium from discharge water

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Memo

To:	File	**Date:**	12 June 2008
cc:	Dylan MacGregor	**From:**	Stephen Schultz
Subject:	Prosperity Project - Methods for removal of selenium and cadmium from discharge water	**Project #:**	1CT013.000.0999

Estimates of long-term discharge water quality indicate that, under the worst case scenario, concentrations of selenium and cadmium in the site discharge could result in receiving water concentrations above government guidelines for protection of aquatic life (i.e. BC or CCME guidelines). A contingency plan for managing this scenario could be based on the application of water treatment. This memo provides a preliminary review of the treatment options available.

For the purpose of this review, the treatment task was described as continuous, year-round treatment and discharge of 115 m^3/hour (32 L/s), for an annual discharge of one million cubic metres. This would be seepage from the tailings dam combined with drainage from the non-PAG waste rock storage area. Treatment influent (feed) concentrations could be 70 micrograms per litre (µg/L) selenium and 4 µg/L cadmium. Desirable effluent concentrations would be 10 to 20 µg/L selenium and <0.2 µg/L cadmium. Clean site water sources could be used to dilute the effluent before discharge to the receiving environment. With dilution by a factor of ten, which appears achievable, these effluent qualities would maintain downstream water quality within BC or CCME guidelines.

The contaminants of concern are discussed separately in the following sections, although some treatment systems could reduce the concentrations of both contaminants.

Selenium

Many different processes have been evaluated for the removal of selenium from contaminated waters, but few have been successfully applied on a large scale. The following sections describe technologies currently in use on a large scale.

Iron Co-precipitation

Until recently, chemical co-precipitation with iron was the only widely applied method and this is still considered the Best Available Technology (BAT) for selenium removal from water by the US EPA. In this process, ferrihydrite is precipitated from the water, with concurrent adsorption of selenium onto the ferrihydrite surface. For the co-precipitation to occur, ferric iron (Fe3+) must be present in the water, either from site sources or added in the form of ferric chloride or ferric sulphate. The process is effective in removal of selenite ions (Se4+) but not very effective for selenate (Se6+), and waters with elevated selenate require pre-treatment to reduce the ions before co-precipitation with iron.

At Barrick's Richmond Hill Mine (SD) a selenium treatment system was developed in 1994. Elemental iron is used to reduce selenate ions to selenite, followed by ferrihydrite precipitation from a ferric sulphate solution. The selenium-iron precipitate is separated from the water in a clarifier and stored in a sludge pond. After three years of optimization work, the effluent selenium concentrations were 12 to 22 µg/L. In the case of this mine, those concentrations were unacceptable for discharge and a reverse osmosis process was added to the treatment train (discussed later). Other mining industry examples of iron co-precipitation for selenium removal are Agrium's Dry Valley phosphate mine (ID) and Homestake gold mine (SD).

Biological Reduction

Biological methods have been investigated extensively since the 1990s and several full-scale processes are now operating. Bacterially mediated volatilization and precipitation can both be exploited for water treatment. Bacteria can reduce soluble, oxidized selenium forms to volatile organic forms (selenide Se2-), which can then be volatilized by aquatic plants. This is one of the mechanisms by which ponds and wetlands can remove selenium from water. A more important process is bacterial reduction of oxidised forms (both Se6+ and Se4+) to insoluble, elemental selenium which is precipitated. This process can occur in wetlands, but also in controlled environments (i.e. treatment plants).

Full-scale active biological treatment systems have been operating for several years at Goldcorp's Wharf Resources Mine (SD) and the former Zortman-Landusky gold mine (MT). The Wharf Resources plant treats seasonally variable flows of 40 to 300 gpm (9 to 68 m^3/hour) and reduces selenium concentrations from an average of 15 µg/L to <5 µg/L. The influent water is treated at ambient temperatures, as low as 1.5^oC in winter. The plant is simple, with low maintenance and operating costs.

The Zortman-Landusky treatment plant has much higher selenium loadings. The feed flow rate varies from 75 to 300 gpm (17 to 68 m^3/hour) and feed selenium concentrations are 500 to 700 µg/L. The average effluent concentration is 100 µg/L Se. While this is above the regulated discharge criterion, it is low enough to allow disposal by land application. The plant treats very cold water in winter. As at the Wharf mine, the plant is simple and operating costs are low.

While information on operating active treatment systems is hard to obtain, there is extensive literature on pilot scale testing of biological processes. As an example of potential performance, a comprehensive test of active treatment was completed at Kennecott Utah Copper Corporation's Garfield Wetlands-Kessler Springs site in 2000. The process treated 1 gpm (227 L/hr), reducing selenium concentrations from several thousand micrograms per litre down to <2 µg/L. Although the treatment scale was small, the tests indicate potential for exceptional performance from this technology.

As well as active systems, so-called passive treatment systems for selenium removal have been tested extensively. The first of these to consider are constructed, enclosed cells in which bacteria reduce dissolved selenium to form elemental selenium precipitate, which stays inside the cell. An example is the Biopass System developed in the mid-1990s at Homestake's Santa Fe Mine (NV), which consists of a sub-excavated basin lined with geomembrane and filled with a substrate of decaying organic matter. The influent is introduced by gravity flow at the bottom of the cell. The water flows upwards, through the organic layer, into a collection zone and then overflows the cell. In its first year of operation the cell treated an average flow rate of 7 gpm (1.6 m^3/hr), removing 82% of the selenium and achieving the regulated discharge criterion. The Biopass cell was designed for a 20-year life and continues to operate successfully. For eventual closure, the cell will have to remain isolated from the environment, with a low-oxygen environment.

There are several examples of natural wetlands and ponds removing selenium from water. The most successful example of constructed wetlands treating selenium containing waters is the Chevron Richmond Oil Refinery (CA). A very large wetland has been created, consisting of three 300 acre cells, which receives flows of 1000 gpm (227 m^3/hr) containing 10 to 30 µg/L selenium, and reduces the concentration to <5µg/L. Most of the selenium is precipitated in the wetland sediments as elemental selenium, although volatilization through wetland plants is also a significant mechanism for removal. One concern with this and other open passive treatment systems is the potential for uptake of selenium by wildlife, particularly aquatic birds. To address this concern at Richmond, the wetland was modified to make it less attractive to nesting birds. Another issue to consider with respect to wetlands treatment is the site-specific set of conditions that develop over time. It is difficult to design constructed wetlands to a specific performance target.

Membrane Filtration

Dissolved selenium responds well to membrane filtration processes, including reverse osmosis (RO) and nanofiltration. However, additional pre-treatment (softening, salt removal) could be required to achieve effluent selenium concentrations below 10 µg/L. These processes have very high capital and operating costs. Nanofiltration is potentially less expensive than RO, but there are no examples of its current use for selenium treatment.

There is one North American example of RO being used to remove selenium from mine water, in combination with iron reduction and co-precipitation. At the Richmond Hill Mine (SD) an RO process takes the effluent from the iron precipitation process (12 to 22 µg/L Se) and reduces the selenium down to approximately 2 µg/L.

Cadmium

There is just one type of treatment process used at mines to specifically target cadmium; which is sulphide precipitation. Membrane filtration processes (RO and nanofiltration) would certainly remove cadmium to low levels, but capital and operating costs are very high and this process would not be used to manage the cadmium concern under consideration in connection with this project.

Sulphide precipitation is used fairly extensively to remove cadmium and other metals, often in combination with a lower cost process, such as lime (metal hydroxide) precipitation. There are examples of sulphide precipitation being applied before and after lime precipitation. A good example is Teck Cominco's Red Dog Mine (AK), where sodium sulphide solution is added to the influent immediately before the lime precipitation stage. The maximum treatment rate is 14,500 gpm (3,300 m^3/hr) and the influent cadmium concentration is up to about 5,000 µg/L. After the lime is added, the water is given 20 minutes residence time in a stirred tank reactor, and then the sludge is removed in a clarifier. The final treatment stage is filtration through a sand bed. The final effluent contains 0.5 to 0.7 µg/L (on average), and the permit limit is 2 µg/L. The performance of sulphide precipitation for cadmium removal at Red Dog is considered to be very good.

Cadmium will be removed in wetlands and other biological treatment systems, typically being reduced and precipitated as a sulphide. Although there are natural and constructed wetlands being used for treatment of mine effluents containing a variety of metal contaminants, we could not find examples of treatment specifically targeting cadmium. As noted in connection with selenium removal, wetland performance is difficult to predict with certainty based on results at other sites.

References

The following information sources were consulted as part of this review, in addition to personal communications with water treatment specialists.

"Evaluation of Treatment Options to Reduce Water-Borne Selenium at Coal Mines in West-Central Alberta". Prepared for Alberta Environment. Microbial Technologies Inc. Dr. Andre Sobolewski. 2006.

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