Conceptual Water Management Model for Zeehan Zinc Ltd, Comstock Mine - Update

27 August 2007

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A Report to Zeehan Zinc Ltd

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Executive summary

Zeehan Zinc plans to source its process water from the Comstock Adit, with water surplus to requirement being discharged from the polishing pond to the environment. A process water management plan has been developed, and Zeehan Zinc has requested that the acidic water management plan developed in March 2006 be updated to reflect these changes. The company also recognises that once the mine becomes operational, discharges from the polishing pond will have to be consistent with Best Practice Environmental Management rather than the ‘1-pH unit deviation from upstream background levels’ presently in the environmental permit.

Because of the elevated concentrations of zinc in the adit water, neutralisation to a minimum of pH 8 will be required to produce discharge water of acceptable environmental quality. The high levels of ferrous zinc in the adit discharge will require aeration after pH adjustment, and the treated water will require days to weeks to settle to ensure efficient removal of the metal hydroxides upstream of the polishing pond.

A quicklime neutralisation system is proposed for installation in the Comstock valley with dosing occurring near the mouth of the adit. There is potential for aeration of the treated water to occur as it flows down the valley towards a settling pond (or series of ponds) upstream of the polishing pond. Minimum capital costs associated with a dosing system are ~$250,000, with reagent costs for treating the adit alone estimated to be approximately $75,000 per year.

Identifying suitable locations for settling ponds, and suitable long-term storage locations for the generated sludges present the biggest challenges in implementing the system.

Diffuse acid sources on the site, including leachate from waste rock dumps, ore stock piles and storm water should be directed towards the Comstock treatment plant so that the Stage 1 tailings storage facility can remain a dry facility. Waters which cannot be directed via gravity should be collected in sumps and pumped to the Comstock treatment plant.

It is recommended that discussions begin as soon as possible with DTAE to establish the required discharge criteria for the polishing pond, that the design of future waste storage facilities include secure areas for metalliferous sludges, and that additional water flow and water quality information be collected to facilitate the design of the neutralisation circuit.

1 Introduction

In March 2006 *Technical Advice on Water* prepared a draft conceptual water management plan for Zeehan Zinc based on available information. Since that time, the process water management scheme has been advanced and it is timely to update the conceptual water management plan for acidic waters based on environmental considerations. The brief for this update also includes suggesting options for the treatment of diffuse acid drainage sources on the lease site.

Since the 1996 report, a few additional water quality samples have been collected, and in July 2007 a continuous flow and water quality monitoring site was installed at the Comstock adit discharge point. The limited flow results are insufficient to be used as the basis for flow analysis so flow estimates provided in the process water management plan (GHD) are used in this report. Average water quality results from Comstock Adit obtained since 2002 are used in the calculation of acidity loads.

2 Assumptions of water management plan

The following information was derived from the process water management plan and discussions with Zeehan Zinc, and underpins the updated acidic water management plan:

- Zeehan Zinc will recycle process water and source any make-up water from the Comstock adit;
- Mining in the Alison open pit affects water quality in the Comstock adit, so Zeehan Zinc plans on collecting and treating all water flowing from the adit to acceptable environmental standards;
- The Comstock Creek is to be diverted upstream of where the adit discharge enters the river;
- The polishing pond is to discharge into the Comstock Creek downstream of the diversion;
- Although present permit conditions require the discharge of water 'within 1 pH unit of background', Zeehan Zinc recognises that DTAE will alter those discharge conditions prior to issuing an operating permit. 'Best Practice' treatment of the water requires neutralisation to pH 7-8, followed by settling to remove zinc, lead, aluminium, iron and other metal hydroxides. It is assumed that discharge requirements issued by DTAE will be consistent with Best Practice.
- Zinc, iron and aluminium are the main contributors to acidity in the Comstock Adit water. The drop in pH of water samples following collection strongly suggests that ferrous iron is present in the adit water, which will require oxidation during water treatment;
- The tailings storage facility is a 'dry' facility which does not have the capacity to store metal-hydroxides;

- The proposed polishing pond is not to be used as a settling pond for metal hydroxides, as residence time is low and water is to be re-circulated back to the mill;
- The area between the mouth of Comstock adit and the entrance to the polishing pond (approximately 250 m in length) is available for water treatment and the temporary storage of metal hydroxide sludges; and,
- The present life of the tailings storage facility is only a couple of years. A long-term tailings storage facility is presently being designed which could have the capacity to store metal hydroxides as well as tailings and waste rock (need to consult design engineers).

3 Requirements for water treatment

Table 1 contains a summary of water quality in the Comstock Adit based on data collected over the past 5 years (March 2002 – present), showing high total suspended solids, low pH, and elevated concentrations of aluminium, iron, manganese, lead and zinc.

Table 1. Summary of water qualityy results collected from Comstock Adit March 2002 - May 2007. All metals are dissolved (<0.45µm) component.

	TSS	Alk	Acidity	pH	Al	As	Cd	Co	Cu	Fe	Mn
	mg/l	mg/l $CaCO_3$	mg/l $CaCO_3$		mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Max	1020	<1	288	5.3	9.6	0.06	1.36	0.08	1.4	58.2	10.6
Med	937	<1	146	3.3	2.55	<0.01	0.027	0.06	0.004	2.74	9.35
Avg	914	<1	157	3.4	3.15	0.02	0.094	0.06	0.07	10.06	9.38
n=	22	22	22	22	22	12	22	22	22	22	22

	Ni	Pb	Zn
	mg/l	mg/l	mg/l
Max	0.17	0.56	44.8
Med	0.11	0.09	28.0
Avg	0.11	0.16	28.9
n=	22	22	22

The steps which are required to treat the adit water to acceptable standards for discharge include:

- Increasing pH levels to promote the oxidation of iron and precipitation of metal hydroxides;
- Aeration to promote the oxidation of iron and formation of iron-hydroxides;
- Storage and settling to ensure the neutralisation reaction goes to completion and metal hydroxides are removed from the water column.

Each of these steps is discussed in the following section.

4 Conceptual design of water treatment system

The components of the water treatment plan need to be completed in sequence to achieve the best environmental outcome. A conceptual design for the process includes a lime dosing plant near the Comstock Adit which doses the discharge either directly in the river channel, or in a separate mixer into which part or all of the flow is diverted. Following dosing, the water requires aeration, which may be able to be achieved by cascading the flow down an irregular surface.. Finally the dosed and aerated water requires storage in a low energy settling pond to promote the precipitation and settlement of iron hydroxides.

4.1 Neutralisation to pH 8

The high concentration of zinc present in the Comstock Adit water necessitates neutralising the water to a pH of 8 to promote the precipitation of zinc hydroxide. The 'Best Practice' approach is to use quicklime or hydrated lime as it is an efficient and relatively inexpensive neutralising reagent which produces a stable sludge and results in low dissolved solids in the water relative to sodium based neutralising reagents. The negatives of using quicklime are that a suitable storage and mixing (slaker) system must be installed which increase upfront capital costs.

Presently, Zeehan Zinc is proposing to use sodium hydroxide to maintain discharge pH within 1 pH unit of 'background'. This is an efficient neutralisation reagent which is easy to handle (except for high freezing point), but more expensive than quicklime or hydrated lime, and results in the formation of gelatinous sludges. The use of sodium hydroxide as proposed for small pH adjustments is suitable, however, the neutralisation of all flow from the Comstock Adit using sodium hydroxide would be an expensive approach and generate higher volume sludges. The integration of a sodium hydroxide system into a lime-dosing system are discussed in Section 4.6

Capital costs associated with installation of a lime-dosing system are substantial, and can only be determined following refinement of flow estimates, acidity loads and level of mechanisation (will dosing occur in a mixer or will the river channel be used, etc). As a rough guide, a minimum of $250,000 should be assumed.

Based on the estimated average flow of 45 l/s and the average water quality shown in Table 1, it is estimated that 240 tonnes of hydrated lime per year would be required on average. At an estimated cost of $300/tonne delivered to site, average reagent costs would be ~$72,000 per year for treatment of adit water.

Actual lime reagent costs will be determined by the actual flow from the adit, the actual acidity load (which is strongly dependent on the amount of ferrous iron and zinc) and cost of lime reagent. Additional flow and water quality information, including sulphate and ferrous iron concentrations, are required to refine these estimates. The above estimate does not take into consideration the treatment of leachate or storm water from other areas of the lease site.

4.2 Aeration of dosed water

Oxidising the ferrous iron in the adit discharge is important so that the neutralisation reactions can be completed as rapidly as possible, and there is not a continual decrease in pH with time resulting in the re-release of other metals. If it is assumed that all of the total iron in the adit water is ferrous upon discharge from the adit, then 8 – 10 mg/l of oxygen is required to oxidise the average concentration of 53 mg/l. An aeration 'run' can be developed between the dosing point and the entrance to the settling pond which will provide at least some of the required aeration. To maximise aeration, a serpentine water course should be established with a rough bed to enhance turbulence and air entrainment. If this is insufficient to introduce the required oxygen, an aeration system may need to be integrated in the system at an additional cost.

As presently planned, the Comstock adit water is to be piped from the dosing plant to the diversion dam. This will reduce aeration, and should be modified to take advantage of the gradient in the valley to promote oxidation. Alternatively, the adit water could be dosed with an oxidising agent during or following dosing, or an aeration tank could be incorporated in the system.

4.3 Settlement of metal hydroxides

The precipitation and settlement of metal hydroxides requires an extended residence time within a settling pond due to the small size of the metal hydroxides. The largest holding pond feasible should be established within the Comstock valley between the adit and polishing pond. To achieve a high rate of capture of metal hydroxides, a residence time of 1-2 weeks should be designed for, although the actual settlement time required needs to be refined through test work. Maximising the residence time of treated water in a settlement pond will reduce the risk of precipitating metal hydroxides in the polishing pond and improve discharge water quality.

Achieving retention times of this order during the winter months will be a challenge given the limited space available, and consideration should be given during the planning of the stage 2 tailings storage facility for the inclusion of a large settling pond.

If the polishing pond could be used for the settling of metal hydroxides, the volume of upstream storages could be reduced. However, this would require the identification of a long-term sludge storage facility (as the volume of the polishing pond would be insufficient to store sludges over the long-term), and the low-density sludge would need to be moved, which is an added cost.

Based on the average water quality in Table 1, and assuming a sludge density of 10% solids, a rough estimate of the sludge volume to be generated is 1,500 m^3/year to 2,000 m^3/year. This estimate assumes complete removal of iron and zinc, no removal of manganese, and does not include any gypsum formation which cannot be estimated as no sulphate analyses of the adit water are available.

4.4 Long-term storage of metal hydroxide sludges

The metal hydroxides precipitated during neutralisation need to be permanently stored in a secure environment with a pH in excess of 6.5. The Stage 1 tailings storage facility is unsuitable for long-term sludge storage as it is a dry facility. In the short term (~2 years), the sludges may be stored in the settling pond if there is sufficient volume. Longer-term, a permanent storage facility will need to be established as part of the stage 2 tailings storage facility. The identification of a suitable long-term repository for the sludges is very important and should be addressed as soon as possible.

4.5 Alternative neutralisation system

If it is found that there is insufficient space for settling ponds in the Comstock valley, a high-density sludge lime treatment system could be investigated. In these systems, lime-dosing takes place in a mixer, with the slurry reporting to a clarifier. A large portion of the lime-rich underflow from the clarifier is recirculated back to the mixer. The recirculated sludge provides surface area for the precipitation of additional metal hydroxides resulting in larger particles which settle more readily. The capital cost associated with these systems is higher than a lime dosing plant ($2,000,000+ depending on size) but the sludge that is produced settles rapidly to a higher density which makes handling and storage easier.

4.6 Integration with sodium hydroxide dosing system

In the short-term, a sodium hydroxide dosing plant will be installed near the mouth of the adit. Following diversion of Comstock Creek, the dosed water will be transported via a pipeline to aeration ponds in the Comstock Creek valley. As described in the process water management plan, the objective of this system is to adjust pH levels in the adit water to within 1-pH unit of ‘background’ levels. There is no consideration of the oxidation of iron or the capture and storage of any resulting metal hydroxides. Given the small size and hence short residence time of the weir ponds, it is likely that sludges will accumulate in the polishing pond, which is undesirable from a waste management perspective.

This approach may satisfy the environmental permit requirements of Zeehan Zinc as long as only 1 pH unit of adjustment is required, and the accumulation of sludges in the polishing pond is acceptable. If/when discharge criteria require neutralisation to ‘Best Practice’ standards (eg. pH 7-8) this system will not be suitable as:

- There is insufficient retention time in the system to allow for the neutralisation reactions and settling of metal hydroxides;
- There is insufficient holding capacity upstream of the polishing pond for the generated metal hydroxide sludges; and,
- The pipeline inhibits oxidation of ferrous iron which needs to be accomplished rapidly to ensure complete neutralisation is achieved.

Changes to the proposed sodium hydroxide dosing system which would make the system more compatible with future needs include:

- Excavating / constructing a large volume settling pond or ponds in the Comstock Creek valley rather than cascading weirs which can be used to settle and capture metal hydroxides now and into the future. This requires identification of a suitable site; and ,
- Promoting oxidation of iron immediately following dosing. This requires a re-think of the pipeline. A turbulent open flume which promoted aeration would be preferable to maximise aeration potential as the water flows down the valley (let gravity provide the energy for aeration). Alternatively, an aeration tank could be incorporated in the system.

If the system is changed to a lime-dosing plant in the future, test-work should be completed to ascertain how the two sludges will interact with respect to settling and long-term stability.

5 Treatment of diffuse acid drainage sources

There are a number of diffuse acid drainage sources on the Zeehan Zinc lease site and some point sources which are not presently being collected and treated. No detailed investigations have been completed related to these sources, but the following dot points provide some guiding principles for the management of diffuse and isolated point sources.

- The production of acid drainage should be minimised on site by not using Potentially Acid Forming rock for any construction purposes (roads, dams, etc) and all PAF rock should be encapsulated in clay lined waste rock dumps;
- Stormwater diversion drains should direct clean water away from the active mine site;
- Ore stock pile volumes should be minimised and used as soon as practicable. Guidelines for acceptable storage times should be established based on geochemical testing. If ore is to be stored for extended periods, limestone or lime should be placed over and within the stockpile to reduce acid creation. All stockpiles should be created on clay-lined and bunded pads with leachate collected and treated;
- Where possible acidic drainage originating from stock piles or waste rock dumps should be directed into limestone lined drains which report to the Comstock water treatment facility. If drainage cannot be gravity fed to the Comstock, then lined sumps should be established which are periodically pumped to the treatment facility;
- Acidic drainage should be directed away from the tailings storage facility as this is a ‘dry’ facility with no capacity to treat acidic waters;
- The Alison open pit drains into Comstock Adit, so acidic drainage water could be directed into the pit for eventual treatment. This approach may increase metal loads as the acid water percolates through the mine workings. It is preferable to maintain acidic drainages in lined surface drains and sumps.

6 Recommendations

The implementation of a lime dosing system in the Comstock valley between the adit and the polishing pond will fulfil the requirements of Zeehan Zinc and is consistent with Best Practice Environmental Management. To progress the implementation of such a system, the following steps are recommended:

1. Discussions should be held with DTAE as soon as possible to establish the pH and metal discharge criteria for the polishing pond. This is of utmost importance as it will establish the operating parameters for the water treatment system. Until or unless these criteria are agreed upon, it is difficult to progress

planning of a water treatment system. This discussion paper has assumed that 'Best Practice Environmental Management' will be required to minimise the release of metals into the environment. This assumption underpins the shift from a sodium hydroxide to quicklime based dosing system, and has major operational and financial implications for Zeehan Zinc. This issue needs to be resolved as soon as possible;

2. The conceptual design for the lime dosing plant should be advanced by identifying potential sites for a settling pond or ponds and determining the potential volume of each pond, and identifying a suitable site for the lime dosing plant. The length and location of the aeration run between the dosing plant and settling pond should be a secondary consideration compared to the size of the settling pond;
3. The engineers designing the present and future tailings storage facility should be consulted regarding potential secure storage locations for metal hydroxide sludges in the short- and long-term;
4. Water quality analyses should include sulphate to evaluate the potential for gypsum formation during neutralisation. Ideally, ferrous iron analyses of the adit discharge should be completed to refine neutralisation reagent requirements;
5. A detailed analysis of flow from the adit should be completed to assist with the sizing of the settlement pond and estimates of reagent usage.