



TECHNICAL MEMORANDUM

To: Lindsay Dehart
Yukon Government

Date: April 25, 2007

From: David Flather

Project #: 487-1

Subject: Carmacks Copper Project: Technical Review of Closure Plan and Additional Information

Western Copper Corporation (WCC) is planning to develop the Carmacks Copper Project, which will recover copper as cathode using an acid heap leach and SX/EW process. WCC have focused on a number of environmental issues, both from an operations as well as closure perspective. Particular attention has been afforded addressing those issues associated with the water chemistry emanating from the spent leached ore. To address these issues, WCC commissioned rinsing and detoxification studies on representative ore material, bench-scale water treatment testing of heap solutions and have developed a Conceptual Closure and Reclamation Plan that has included the findings from much of this work.

In early 2006, the Yukon Government commissioned Lorax Environmental Services Ltd. (Lorax) to perform a technical review of WCC's proposed heap detoxification process and relevant closure strategies. A number of documents available at that time were reviewed including:

- Project Description and Environmental Assessment Report for the Carmacks Copper Project (2005) and associated Appendices;
- Conceptual Closure and Reclamation Report (Appendix F; 2005);
- Beattie Consulting Ltd. (2001) Report on Leaching and Decommissioning of Samples from Carmacks Oxide Copper Project (Appendix E);
- Detoxification and Rinsing Testwork Report (Alexco Resource Corp. 2006);
- Clearwater Consultants Ltd. memorandum CCL-CC6 and CCL-CC7 (2006).

The 2006 review identified the following primary issues:

Rinse Time and Expected Chemistry

- The review suggested that rinse times proposed for the project of approximately 3 to 4.5 years may be optimistic and that rinsing and detoxification could take upwards of 9 years based on a scale-up approach using solution:ore ratios.
- Water chemistry from the column neutralization and rinse testing performed in 2005 indicated that elevated levels of selenium (Se) could be expected at

Carmacks, particularly in the early phases of rinsing; Se was not, however specifically addressed in the Conceptual Closure Plan.

- The review suggested that the proposal would benefit from bench-scale water treatment testing of actual column rinse draindown waters, which currently represent the best estimate of future rinsate quality. The data could then be used to better demonstrate the efficacy of the proposed water treatment scheme to treat rinse solutions that are not economical for copper recovery. The treatment scheme outlined in the Conceptual Closure Plan indicated that treatment would be accomplished through pH adjustment using NaOH, soda ash or lime. The review noted that lime neutralization alone is not generally successful at reducing Se concentrations to acceptable concentrations for discharge.

Water Quality Predictions and Development of Site Specific Discharge Criteria

- The baseline water quality data for the receiving environment (*i.e.* Williams Creek) was limited and suffered from historically high detection limits for key environmental parameters. This resulted in the assimilative capacity of Williams Creek being poorly constrained. The review suggested that the proposal could be strengthened by updating and improving the water quality database for surface water and groundwater, with improved analytical detection limits. Parameters of focus should be Se and Cd.
- In concert with improved baseline water quality characterization, the review indicated that the proponent should develop site-specific discharge limits for discharge water into Williams Creek utilizing the rinsing phase and closure water balances and expected water treatment performance.

Since early 2006, WCC and their consultants have completed additional work on the Carmacks Copper Project with the view towards advancement of the project as well as to address issues raised by the Yukon Government as part of the external technical reviews of the program. The present review by Lorax has focused on recent documents/supplemental information provided by WCC to the Yukon Government throughout 2006 and early 2007 including:

- Conceptual Closure and Reclamation Report – Revision No. 1 (August 2006);
- Leach Residue Fine Fraction ABA Testing (Western Silver Corporation, September 2006);
- Heap Rinsing Additional Information Memorandum (Alexco Resource Corp. June 15, 2006);
- Lawrence Consulting Ltd. Memorandum (May 13, 2006);

- Rinse Column Mineralogy (Canmet, July 2006);
- 2006 Water Quality Database (provided by Access Consulting Ltd); and
- Process Water Treatability Study Report – Neutralization Testwork on Process Solutions (CEMI; March 2007).

The additional information and reports provided by the proponent have largely addressed the outstanding issues identified in the original review. The present memorandum discusses the rationale supporting this view. There are some minor issues remaining; however, the reviewer is of the opinion that these items can be readily addressed during the process of submitting and reviewing a Type A Water Use Application. The most salient findings are discussed below.

Conceptual Closure and Reclamation Plan

The revised Conceptual Closure and Reclamation has been updated to incorporate the most recent information and conceptual thinking including:

- Full description of detoxification testwork results from Alexco Resource Corp. (January 2006);
- Long-term passive treatment contingency options for metals in heap draindown “outside” of the heap rather than metal stabilization “within the heap” as originally proposed;
- Proper acknowledgement that heap seepage will likely continue to occur in the long-term even following placement of a soil cover. The revised plan proposes contingency measures to address this potential.
- Discussion of most recent data regarding metal leaching and acid generation potential of the rinsed heap pile. Acid base accounting results indicate very low levels of residual sulphide-S and support the original posit that the acid generation potential of the closed heap facility is very low.

With respect to the potential for acid generation from the heap facility, Canmet was commissioned by Environment Canada to conduct detailed mineralogical analysis of spent heap material from column detoxification testwork (Canmet 2006). The program focused on the fines fraction of material and revealed the presence of residual elemental sulphur and jarosite. The report suggested two potential sources for long-term acid generation from the heap pile at closure:

1. oxidation of Fe^{2+} to Fe^{3+} and concomitant generation of $\text{Fe}(\text{OH})_3$ and H^+ (acidity);
2. Slow weathering of elemental sulphur and jarosite.

With respect to the potential for acidity from oxidation of ferrous iron, it is likely that most residual ferrous iron will be oxidized to ferric iron during the alkaline rinsing phase and the associated acidity produced would be neutralized during the rinsing. The Canmet report postulated this process, but did not actually measure residual ferrous iron concentrations to substantiate or refute the likelihood. With regards to sulphur and jarosite weathering, the Canmet report acknowledges these processes to be slow and the rate at which protons are produced is highly relevant. Therefore, while theoretically the above processes are possible, the reviewer is not of the opinion that their manifestation would be significant and result in depressed pH conditions over the long term.

As a general comment to the Conceptual Closure and Reclamation Plan, it is noted that the proposed water treatment plan is largely non-specific, with options presented for lime treatment, caustic treatment or treatment with soda ash. While this non-specificity is not considered problematic, it would appear that testwork completed by CEMI in 2006 and 2007 would allow for the presentation of a preferred plan. Specifically, water treatment testwork of process solutions has suggested successful treatment can be achieved through ferric iron addition in concert with lime precipitation. As previously mentioned, the details of this plan will, in all likelihood, need to be described as part of the A License application.

Time Required for Rinsing-Detoxification of Heap

The original review by Lorax suggested that heap rinse times may be longer than the 4.5 years proposed by the proponent for planning purposes. Lorax used the approach of solution:ore ratios to calculate a rinse period of roughly 9 years. In response to the Lorax review comments, the proponent provided their rationale for calculation of heap rinse-detoxification times in a memorandum (June 2006). While acknowledging that alternate methodologies exist for determining rinse periods, the proponents states:

“For assessment and planning purposes, a heap rinsing period between the two methodologies is a reasonable approach. A rinse time of 4.5 years, as described in the previous report, is still a reasonable time estimate based on the currently available information. Re-evaluation of the estimated rinse times will be made after rinse tests are complete on the large scale column.”

The reviewer concurs with this synopsis. In addition, differences in rinse time estimates do not appear to have a material effect on closure planning or closure cost analysis. For example, using water balance estimates for closure provided by Clearwater Consultants Ltd. (CCL-CC7, 2006), and reasonable estimates of incremental water treatment costs, a comparison of the financial impact of longer rinse times can be provided. For this analysis the following assumptions were made:

- Annual rinse volumes requiring treatment during detoxification phase of approximately 150,000 m³/year (see Table CC7-I.12);
- Starting unit water treatment cost of \$0.40/m³ and increasing by 3% each year.

Based on these assumptions, and a relatively conservative unit treatment cost, the difference in total water treatment liability costs between a 4.5-year and 9-year rinse/detoxification period is only on the order of \$335,000.

Water Quality Predictions and Development of Site Specific Discharge Criteria

In the 2006 review, it was suggested that site-specific discharge criteria be developed for the Carmacks Copper project based on best estimates of the assimilative capacity of Williams Creek at the designated compliance point. Most projects require that, at least as a starting point, CCME water quality objectives be met at a designated compliance point in the receiving environment. By knowing the background chemistry in the receiving environment, the hydrological regime of the receiving environment and the water balance driving effluent discharge requirements, a proponent is capable of back-calculating the threshold concentration(s) in the effluent necessary to meet CCME at the compliance point. In this way, the applicability of MMER standards can be more accurately assessed. The 2006 review suggested that the largest limitation to developing site-specific effluent discharge criteria for Carmacks was the baseline water quality database.

Throughout 2006, (*i.e.*, March, June, July, August, September and October) the proponent has collected water quality data from the Williams Creek watershed; these data are considered to be of high quality with low detection limits achieved. As such, all the necessary components of an assimilative capacity assessment are available including:

- Baseline water quality data;
- Operational and closure water balance for the operation (CCL-CC7; Tables CCL-I.12 and CCL-I.13);
- Estimates of monthly treatment discharge volumes; (CCL-CC7; same tables as above)
- Estimates of mean flow throughout Williams Creek (CCL-CC7; same tables as above)

To date the proponent has not established effluent discharge criteria for the project, although numerous references exist to meeting MMER standards. While MMER standards may in fact be adequate for the project, the exercise described above would demonstrate the applicability of these effluent limits. However, the reviewer is still of the position that a broader range of environmental parameters (e.g. Cd, Se) need to be covered in the effluent standards than stipulated by MMER. It is assumed that the setting of effluent standards will, at any rate, be a necessary component of the Carmacks Copper project Type A Water Use License Application (see requirements of Section D 38 (i) of Water Use Application).

As part of the present review, an initial assimilative capacity assessment was performed to determine appropriate effluent discharge concentrations during heap pile rinsing and closure. These calculated limits were then compared to MMER limits as well as the most recent water treatment results (CEMI 2007) to evaluate the overall efficacy of the

proposed water management and treatment scheme. As mentioned, the proponent will need to complete a similar exercise for the Type A Water Use Application.

Assimilative Capacity and Site Specific Effluent Limits

In determining the assimilative capacity of Williams Creek to Carmacks Copper effluent discharges a compliance point at W10 was assumed. When comparing baseline water quality in Williams Creek to CCME water quality objectives, the hardness of Williams Creek must be factored for Cd, Cu, Ni and Pb objectives. Table 1 below provides a summary of baseline quality and associated water quality objectives for key parameters at the compliance point W10.

**Table 1:
 Summary of Baseline Water Quality (mg/L) and Water Quality Objectives (CCME) for Key Parameters at Station W10 in Williams Creek**

	<i>Williams Ck. Background</i>	<i>WQ Objective</i>
Cd	0.00001	0.000054
Cu	0.001	0.003
Se	0.0002	0.002
Zn	0.004	0.03
As	0.00050	0.005
Ni	0.001	0.11
Pb	0.0002	0.004

Note: Criteria for Cd, Cu, Ni and Pb are all hardness dependent. For Williams Creek, a hardness value of 175 mg/L has been used (range of ~140 to 220).

The BC objective for Se has been used in place of the CCME guideline. The rationale for this is that it is widely acknowledged that Se in well-oxygenated receiving waters is not toxic to organisms. The CCME guideline for Se is 0.001 mg/L. In contrast, the BC guideline maximum is higher at 0.002 mg/L (Nagpal, 2001) and based on considerable Provincial experience with selenium issues, particularly downstream of coal mines. As such, the review has considered the BC guideline here in place of CCME.

Using the baseline data and the receiving water quality guidelines for the protection of aquatic life, in concert with the hydrological conditions of Williams Creek (CCL-CC7), and the estimated treatment volumes during the intensive rinsing phase of the project (Year 2 to Year 10 following completion of mining) it is possible to evaluate treatment/discharge standards for Carmacks.

Table 2 below illustrates the expected peak treated discharge volumes from the heap rinsing/detox phase and varies from roughly 20 L/s during freshet to a low of 5 L/s. The calculated treatment limits for each month is based on predicted flows in Williams Creek at W10 (CCL-CC7), the existing background concentration and the discharge volume. The method used the receiving water quality objectives for each parameter to back-calculate what the concentration had to be in the treated discharge to meet aquatic life objectives at W10.

**Table 2:
 Calculation of Treatment Limits for Carmacks Effluent**

	Daily Excess Water Discharge (L/s) Yr 10					
	May	June	July	August	Sept	Oct
m ³ /month	50,000	23,719	24,000	20,000	18,000	14,000
L/s	19	9	9	8	7	5
Calculated Treatment Limits to Meet WQ Objectives (mg/L)						
Cd	0.00205	0.00314	0.00211	0.00222	0.00252	0.00200
Cu	0.09360	0.14306	0.09635	0.10165	0.11512	0.09146
Se	0.08354	0.12805	0.08602	0.09078	0.10290	0.08162
Zn	1.20786	1.85078	1.24360	1.31239	1.48750	1.18001
As	0.20886	0.32014	0.21505	0.22695	0.25726	0.20404
Ni	5.04796	7.74328	5.19779	5.48616	6.22030	4.93122
Pb	0.17615	0.27011	0.18137	0.19143	0.21702	0.17208

A summary of the treatment limits can then be determined from the most sensitive period and are provided below and compared to MMER effluent limits (Table 3).

**Table 3:
 Comparison of Calculated Treatment Limits to
 MMER Authorized Effluent Limits**

Parameter	Calculated Treatment Limit (mg/L)	MMER Maximum Authorized Monthly Mean (mg/L)
Cd	0.002	Non proposed
Cu	0.09	0.3
Se	0.08	Non proposed
Zn	0.5	0.5
As	0.2	0.5
Ni	0.5	0.5
Pb	0.17	0.2

As illustrated, it does not appear that during the heap rinse/detoxification phase that MMER limits for Cu, As and Pb would be sufficient to ensure water quality objectives at the compliance point in Williams Creek and more stringent limits would be required. However, when comparing the proposed effluent limits to the most recent water treatment testwork (Table 4) results suggests that the proposed water treatment plan can achieve these limits and the project should be capable of operating without water quality impacts.

**Table 4:
 Comparison of Calculated Treatment Limits to
 Most Recent Water Treatment Results**

Parameter	Calculated Treatment Limit (mg/L)	Most Recent Water Treatment Test Results¹ (mg/L)
Cd	0.002	0.0007
Cu	0.09	0.069
Se	0.08	0.07
Zn	0.5	0.005
As	0.2	0.003
Ni	0.5	0.008
Pb	0.17	0.0005

1: Results for Raffinate Neutralization to pH 9.5 (CEMI 2007)

In summary, information is currently available to establish site-specific discharge standards for the Carmacks Copper project for operations and closure phases. To determine if MMER limits were indeed universally appropriate for the project, an initial assimilative capacity evaluation was performed using improved baseline water quality for Williams Creek, estimates of monthly discharge volumes of effluent and Williams Creek hydrological estimates. The analysis indicated that while MMER limits were appropriate for Ni and Zn, more stringent limits would likely be required for Cu, As and Pb.

Comparison of these proposed limits to water treatment testwork results suggests that a viable water treatment scheme is available for the project.