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"Technical Support for Grassroots Public Interest Groups"

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Date: April 28, 2008
Ref: Review of Carmacks Copper Heap Closure Plan

This review of heap closure plans was completed at the request of the Little Salmon Carmacks First Nation. The list of documents reviewed is provided as an attachment. The Center for Science in Public Participation (CSP2) provides technical advice to public interest groups, non-governmental organizations, regulatory agencies, mining companies, and indigenous communities on the environmental impacts of mining. CSP2 specializes in mining, especially with those issues related to water quality impacts and reclamation bonding.

One of the most troubling issues for closure of this project is the potential for metal leaching from the heap over the long term. We concur that the heap is unlikely to be acid generating, however, acid is not required for mobilization of metals. The concentration of metals and metalloids in effluent after closure is a function of the mass and speciation of metals remaining in the heap, the volume of water flowing through the heap, and the accessibility of infiltration water to sequestered metals. Copper is the primary metal of concern due to the high concentrations remaining after leaching, but other contaminants will also need to be addressed, based on the expected post-mining use of the area. Four important aspects of heap closure are addressed in this correspondence.

1. Copper concentrations

The first aspect is the copper released over the long term from heaps after closure. It is estimated that at least 15% of the copper in the ore will remain after leaching (WCC, 2008b; Beattie, 2001 pg 1, pg 24, Appendix 2). Although raising the pH of the leaching solution indeed reduces the effluent concentration of copper, it still remains unacceptably high, and the remaining copper in the heap presents a clear risk to aquatic resources. Lab column simulations demonstrated near 5000 mg/L copper remaining in effluent at the end of the leach period (Alexco, 2006); after further rinsing with raffinate, 100 mg/L remained(WCC, 2008b).

Regardless of the concentration of copper in effluent after leaching is complete, a significant mass of copper can be expected to remain, and a portion of this will flush out of the heap over time. The proposed plan to reduce copper is a series of rinses and neutralization. If the heap can be maintained at greater than pH 10, low copper concentrations can be maintained in the discharge solution, and the copper sequestered in the heap, however, this pH will cause other contaminants to mobilize, particularly selenium, arsenic, molybdenum, and aluminum.

Column testing has not shown good draindown chemistry even under controlled conditions

Column testing has not shown that material subjected to the proposed rinsing and neutralization methods will meet the Metal Mining Effluent Regulations (MMER) for copper. MMER and Canadian Council of Ministers of the Environment (CCME) provide guidance for setting effluent limits. Molybdenum, selenium, and cadmium do not have MMER guidelines, but effluent discharge limits will likely be set during the Water Use License Application process.

- In testing by Alexco, 2006, the MMER for copper was not met in 3 of the 4 columns, despite being held at a pH of 9.5 or higher, which is unlikely to be sustained in a heap over the long term (see subsection below). Concentrations just below MMER have been met with one column (#9) in Alexco's testing and in preliminary results of recent copper column rinse testing (WCC, 2008b). However, rebound to near the copper MMER was observed after draindown two out of three times in the 2007-2008 column test, and copper hovered near the MMER for the entire period of the last rinse; no data is available to determine if a rebound above MMER occurred during draindown after the final rinse (WCC, 2008b).
- No effluent standards have been set for selenium, but the draindown chemistry provided is not encouraging. Some selenium guidelines are 2 ug/L (British Columbia) or 1 ug/L (CCME). Laboratory testing indicates that selenium levels can be expected to be elevated in heap effluent: "rested columns" were over 250 ug/L at the end of treatment, efficacy in "unrested" columns is difficult to ascertain with limits of detection varying from 20-200 ug/L (Alexco, 2006b). The most recent column testing set a limit of detection of 50 ug/L (WCC, 2008b), despite the recommendation for setting it at 0.5-1.0 ug/L (Lorax, 2006).
- There are no MMER for molybdenum and cadmium. CCME for molybdenum for protection of freshwater aquatic life is 0.073 ug/L, with toxicity observed at 0.73 ug/L; British Columbia has a less stringent standard of 1 mg/L for a 30 day average. Effluent may not be able to reach even the British Columbia standard. In columns rinsed with raffinate and neutralized, molybdenum increased when pH decreased from alkaline to neutral, with rinsed samples generally ranging from 200-500 ug/L (WCC, 2008b). In columns which did not receive a long-time raffinate rinse, molybdenum was quite high, at 1742-5320 ppb in columns rinsed immediately after leaching, and 23,835-30490 ppb in columns rested between leaching and rinsing (Alexco, 2006b).
- Column testing does not indicate if protective levels for cadmium can be achieved; the data from the latest rinse testing does not include cadmium concentrations, and testing in 2006 used limits of detection that varied between 2-20 ug/L; the Lorax review recommended a limit of detection of 0.015 to 0.02 ug/L (Lorax, 2006). Discharge of neutralized process solution water was only able to reach 2 ug/L (the US criteria for freshwater) at pH 9.5 (CEMI, 2006 Tables 2.2 and 2.3; CEMI, 2007 Tables 2 and 3). CCME standards for protection of aquatic life are 0.017 ug/L.

The pH of the heap will decrease over time, causing copper to mobilize.

The solubility of copper is a function of pH, and solubility goes up as pH goes down; copper will leach appreciably below pH of 10. Copper removal testing has been done on process solutions in simulated emergency water treatment, and in rinsed and neutralized columns. Testing of pregnant leach solution (PLS) neutralized to pH 7.5, 8.5, and 9.5 with hydrated lime demonstrated copper above or near the MMER (CEMI, 2006). The data presented is suspect. In treated effluent, copper will have been lowest at pH 9.5 and increase with decreasing pH; the results provided by CEMI (Table 2.2) indicate that a fast filtration method was utilized, and the slight variation in concentrations (0.24 to 0.66 mg/L) are likely essentially scatter of the same number due to particulates. Testing neutralized raffinate provide more consistent results, with copper increasing at decreasing pH , but still indicate copper near or above the MMER when pH is below 8.5 (Table 2.3, CEMI 2006; Table 2, CEMI 2007).

High-density sludge (HDS) treatment of raffinate represents the best case scenario of copper removal. Metals flushed from the heap after closure will not have the benefit of lime treatment. It is clear from column tests that the effluent will contain copper either above or very close to the MMER of 0.3 mg/L (see subsection above). The current plan for long term management of the heap does not include long term active neutralization of heap effluent. Even though the heap can be neutralized or left basic, carbon dioxide from the atmosphere will ultimately reduce the discharge pH to at least 8.5, and it may go lower depending on the specific characteristics of the heap. Copper concentrations in effluent held at pH 9 or 10 will increase as the pH of the heap decreases over time with atmospheric influence; potential cadmium mobilization is also a concern.

The heap will be heterogeneous.

Heaps are heterogeneous, not homogenous. This is likely to be the case even if a conveyor system is utilized for stacking (Ecometrix, 2008). Examination of leached material in both copper oxide and gold cyanide heap leaches has shown that preferential pathways develop during leaching (Catalan, 2008a,b; O'Kane et al., 1999); Dr. Catalan's report is provided as Attachment A. Development of low flow zones has been addressed at the Gold Quarry mine in Nevada by determining areas of high conductance and re-applying a leach to specific areas for more complete extraction (Bell, 2008). Channeling has also been observed in column tests related to the Carmacks Copper Project (Beattie, 2001).

The issue of low flow zones has been addressed in the Conceptual Closure and Reclamation Plan (WCC, 2006a) and in Ecometrix (2008). Suggestions have been made to improve flow through the heap, which will optimize both copper recovery and rinse solution contact with ore. These include adding additional collection piping on lifts, placing drip emitters at 40 cm apart, instead of 60 cm; stacking ore with a conveyor system rather than bulldozer; and rinsing for ten years, with rest periods in between to allow for sequestered solution to drain into main paths. However, none of these remedies is likely to provide a heap drainage system that is effectively modeled by a simple column study. Differential settling, preferential flow paths and ore type differences render *every* heap heterogeneous and complicate the rinsing beyond anything that can be accurately modeled or the drainage water quality predicted. Copper and some of the other contaminants will be draining from the heap for a very long time.

It has not been demonstrated in a heap leach operation that copper can be completely removed from a heap by rinsing. As mentioned above, even controlled laboratory tests have rarely demonstrated good removal of copper. If copper remains, despite either 4.5 to 10 years of rinsing, the testing of "rested" columns (Alexco, 2006) becomes relevant. After closure is complete, the covered heap will "rest" from approximately October to March, when no precipitation is expected to infiltrate, and then be flushed with snowmelt. During the rest period, the main pathways will drain; entrained solution and dissolved copper will migrate from more sequestered areas into the main pathways over time, and can be expected to flush out with spring melt and precipitation.

This rebound, detailed in Dr. Catalan's report of the Gaspe mines testing (Catalan, 2008b) has been observed in Carmacks column tests. Some examples of rebound in neutralized, rinsed columns include:

In WCC 2008b

- Copper increase from 0.01 mg/L to 0.38 mg/L after the 1st rinse and increase from <0.01 mg/L to 0.28 mg/L after the 3rd rinse (Dec 2007 and Feb 2008)
- Selenium increase from <0.05 mg/L to 0.42 mg/L after the 3rd rinse (Feb 2008)
- Aluminum increase from <0.05 mg/L to 1.86 mg/L after the 3rd rinse (Feb 2008)

In Alexco, 2006b:

- Copper increase from 18 mg/L to 502 mg/L after the 1st alkali rinse and draindown (Column 8)
- Copper increase from 43 mg/L to 313 mg/L after the 1st alkali rinse and draindown (Column 5)
- Copper increase from 4.2 mg/L to 7.1 mg/L after the 2nd alkali rinse and draindown (Column 5)
- Increase in sulfate (236 to 884 mg/L), calcium (<11 to 34 mg/L) and sodium (231 to 574 mg/L) during freshwater pulsing (day 188 to day 272, column 9); no draindown information provided.

Therefore there cannot be certainty that the heap, even after rinsing, will not experience frequent rebound.

2. Volume of water in heap

A second aspect to be considered is the volume of water that will move through the heap annually, in perpetuity. This can be estimated from the acreage covered by the heap (330,000 m^2) accepting an average of 375 mm of precipitation a year (120 million liters) or by using the water balance developed by CCL of approximately 100,000 m^3 (100 million liters) of water expected to flow annually through the heap, primarily in April and May (CCL, 2006). Using 100 to 120 million liters of water annually provides 190-235 liters per minute of average flow through the heap. A previous review estimated 120-240 liters per minute seepage during peak periods (Lorax, 2006). The assumption of 20,000 m^3/yr as a long-term infiltration rate, yielding 38 liters per minute (WCC, 2006a pg 3-17), is highly optimistic.

Heap cover is not intended to reduce infiltration (WCC, 2007c), despite a review that recommends exactly this (Lorax, 2006); it is unclear why it is assumed that only 25% of average precipitation is expected to infiltrate. Proposed cover estimates have ranged from 0.3 m to 1 m (WCC, 2007c). The pan evaporation is likely to be quite low during most months in the northern climate, therefore relying on evapotranspiration is optimistic (WCC, 2006a pgs 3-13, 3-16). It is critical to determine the expected monthly and annual flow through the heap based on precipitation in order to size long term treatment systems. The current long term management plan is vague, but presumes passive treatment through utilization of some combination of limestone drains, a biocell, and/or an infiltration gallery (WCC, 2006a). There are no passive treatment systems that have demonstrated success over the long term for volumes of water greater than 50 liters per minute, and certainly not passive biocells. Active treatment will be required during spring and summer due to the volume of water that will move through the heap.

3. Water quality standards

The third and last aspect to be considered for long term water treatment is the discharge limits that will be required. Currently MMER standards have been proposed for arsenic, copper, lead, nickel and zinc; effluent limits have not yet been set for the Water Use License Application. Site specific discharge limits are currently being considered for copper; it is known that copper is toxic to fish at 10 ug/L. Removal of selenium and molybdenum in process solutions by HDS treatment has been discussed (WCC, 2008a), but potential mobilization after heap closure has not been addressed. If post-mining use requires a vibrant aquatic life community in Williams Creek or other parts of the watershed, stringent discharge limits should be considered for other contaminants toxic to aquatic life, particularly selenium, molybdenum, and cadmium. Removing these metals, in addition to copper, is problematic due to solubilities that vary with pH and alkalinity. Copper and cadmium are less soluble as pH increases, but selenium, molybdenum, and aluminum become more soluble; addition of alkaline material to the heap will result in sequestration of some metals and mobilization of others. As heap pH changes on exposure to meteoric water and atmosphere, metal mobilities will be altered.

Issues with mobilization of arsenic and selenium, and toxicity of selenium, have been discussed in a previous review (Lorax, 2006). Selenium is toxic to fish and birds at very low concentrations. Criteria for protection of aquatic life range from 1 ug/L (CCME) to 2 ug/L (British Columbia) to 5 ug/L (US) (Ecometrix, 2007). Aquatic plants accumulate selenium, which re-mobilizes when plants decay. The fate and transport is complicated, and dependent on retention time, physical characteristics of a water body, the type of sediment, and interactions with other elements and organic material. Primary toxic impacts include deformities and reduced growth and survival in both fish and birds, weight loss in birds, and reduced hatching success in birds. Fish and birds have similar toxicity thresholds.

Molybdenum and cadmium are also toxic to aquatic organisms. CCME criteria for molybdenum is 0.073 ug/L for protection of freshwater aquatic life; British Columbia uses 1 mg/L monthly average. Cadmium has a CCME freshwater protective standard of 0.017 ug/L and the US National Recommended Water Quality Criteria is 0.25 ug/L (CCC, chronic criteria) or 2 ug/L (CMC, maximum criteria) (EPA, 2004).

This drainage system should be considered a direct discharge to the creek and then to the Yukon River. Despite the proposal to utilize an infiltration system, the distance to the creek is sufficiently short that the fluids infiltrating into the soil will discharge to the surface water in the near future, depending on the type of soils present in the area. Thus, the discharge limits should be those of a surface water discharge permit, rather than a soil application.

4. Sludge

Briefly, the application of sludge on top of the rinsed heap is not recommended. As discussed, the pH of the heap will change over time, allowing some metals to mobilize. Infiltration of meteoric water through the heap while it maintains an alkaline pH will result in mobilization of selenium and molybdenum, while infiltration as heap pH decreases will result in mobilization of copper and cadmium. Implementation of one of the other alternative sludge storage options, such as mixing with cement, would ensure containment (WCC, 2006a pg 3-6).

Conclusions

To date, studies related to the Carmacks Copper project have examined efficacy of leaching protocols for best extraction of copper (Beattie, 2001), efficacy of fresh water and alkali-amended rinse water protocols (Beattie, 2001; Alexco, 2006a,b; WCC, 2007b; WCC, 2008b), and contaminant concentrations after treating PLS and raffinate process solution with lime or simulate HDS protocols (CEMI, 2006; CEMI, 2007). Lorax (2007) concludes that treated process solution discharge is unlikely to meet proposed effluent limits at the compliance point in Williams Creek, except under the best scenario of HDS treatment of raffinate at pH 9.5. Recent testing of neutralized columns, in which repeated freshwater rinses were applied, has not indicated that contaminants will remain low when flushed out of the heap over the long term (WCC, 2008b).

The issues that will remain after closure are primarily

1) the mass of copper and other contaminants remaining in the heap
2) the volume of water that will infiltrate the heap and flush remaining contaminants and
3) the concentration of contaminants that will reach Williams Creek at the compliance point.

In my opinion, given the information provided thus far, the Carmacks Copper project does not ensure protection of the environment or flora and fauna within the nearby environs over the long term after closure of the proposed copper heap leach. It has not been demonstrated that the heap will remain neutralized over the long term, nor that neutralization will stabilize metals within the heap. Long term management plans to constrain contaminants outside the heap remain vague, and depend on passive treatment systems, as yet un-designed, to handle in perpetuity seepage. This is the most troubling aspect of closure as presented to date. Passive treatment will not handle the quantity of water calculated to flow from the heap after closure, and copper and other contaminants can be expected to drain from the heap for many years to come. A sensitive location near the Yukon River, in a cold climate with moderate precipitation will not provide ideal conditions for an unproven experiment in heap neutralization as the basis for a long term closure plan.

Sincerely,

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Documents reviewed from the Carmacks Copper Project, with most pertinent in bold:

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- WCC, 2008a. Response to YESAB Supplementary Information Request. Western Copper Corporation. March 31.
- **Ecometrix, 2008**. YESAB Commissioned Technical Review of Heap Closure and Detoxification Issues, Revision 2. Dr. Ron Nicholson, Ecometrix Inc. March 20.
- **WCC, 2008b**. Copper Column Rinse Test Update – Letter report from Paul West-Sells to J. Clegg. Western Copper Corporation. March 12.
- Slater, B. 2008. Letter report to Little Salmon Carmacks FN. February 5.
- **Catalan, L. 2008b**. Dr. Lionel Catalan – Report to Yukon Conservation Society. February 1.
- WCC, 2007a. “YESAB Response – Water Treatment” memo from Paul West-Sells (WCC) to Travis Ritchie (YESAB). August 30.
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- WCC, 2007c. “Heap Cover Responses to YESAA”. Response from WCC to YESAB July 25, 2007 questions.
- **Lorax, 2007**. Carmacks Copper Project: Technical Review of Closure Plan and Additional Information. Lorax Environmental. April 25.
- Slater, 2007. Letter report to Little Salmon Carmacks First Nation. April 2.
- **CEMI, 2007.** Process Water Treatability Study Report on Process Solutions. Canadian Environmental and Metallurgical Inc. March.
- **WCC, 2006a**. Project Proposal, Appendix F, Conceptual Closure and Reclamation Plan – Revision No. 2 and Appendix A, Description of Water Treatment Process for Reclamation Duty. Western Copper Corporation. October.
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- **Alexco, 2006b**. Project Proposal, Appendix E3, Detoxification and Rinsing Testwork Report. Alexco Resource Corporation. January.

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- Beattie, 1998. Waste Neutralization Testwork. Beattie Consulting. May.

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