TECHNICAL MEMORANDUM

DATE: 19 April 2008

TO: **Craig Stevens (RT_OTX); Bruce Marsh (RCM)**

FROM: Mark J. Logsdon (Geochimica)

SUBJECT: **Draft Final Proposal for Geochemical Characterization of Resolution Copper Mining Block-Caving Zone**

BACKGROUND

Resolution Copper Mining Company (RCM), acting jointly with Rio Tinto (RT-OTX), asked Mark Logsdon (Geochimica, Inc, Aptos, CA) to prepare a plan to geochemically characterize the rock mass that may be subject to chemical weathering as a consequence of block-caving operations at The Resolution property near Superior, Arizona. Results from this study will be used by RCM and its contractors to develop a geochemical model of the block-cave zone as it affects operational and closure considerations. We assume that test work must meet (or at least be consistent with) requirements for material characterization under the Arizona Department of Environmental Quality's Aquifer Protection Permit Program (ADEQ-APP). In addition, the test work must be consistent with internal Rio Tinto standards and applicable guidance.

In preparing this proposal, we have:

- Consulted the relevant ADEQ guidance documents.
- Reviewed the geochemical characterization work conducted for the Shaft 10 Development-Rock study in 2006-2007.
- Reviewed prior communications between Geochimica, RT-TS, and RCM concerning geochemical test work.
- Reviewed the internal Rio Tinto ARD Risk-Review Protocols.
- Met with RCM Geology, RT_OTX project management, and geochemical-modeling contractor MWH to plan the approach, obtain borehole data for sample selection, and coordinate the testing plan with the modeling needs.

We have not evaluated current formal RCM mine plans in detail, but we understand that rock-mass strains, particularly fracturing, are expected to extend from the extraction zones upward through most, and probably all of the overlying geologic section. Most of the interval between ground surface and the ore horizons will be Tertiary Apache Leap Tuff and Whitetail Conglomerate that are much younger than and not associated with the target mineralization. [Traces of native copper have been observed in drill core from the basal portion of the Whitetail Conglomerate.] However, at depths greater than approximately

1000 m below ground surface (BGS), the fractured rock mass will be propylitically altered Cretaceous rocks, and below about 1750 m BGS, the fractured rock mass will be quartz-sericite-pyrite (QSP) alteration (with some zones perhaps including advanced argillic alteration) with sulfide-sulfur concentrations that exceed 0.5 wt% and zones in which skarns have developed in carbonate protoliths. In the Precambrian to Mississipian sequence and in any intrusive rocks in the cave-affected zone, sulfide-sulfur concentrations are expected to be far above 1%, particularly in skarnified carbonates.

Fracturing of the system and extraction of water at depth within the working zones is expected to substantially de-saturate the overlying fractured rock. Under unsaturated conditions, and with fractures – many of which can be anticipated to be interconnected – that are in communication with atmosphere (at both the surface and through the ventilated subsurface workings), much of the sulfide-bearing rock in the in-situ rubble of the cave zone and its fractured superstructure will be subject to oxidation, with potential for substantial geochemical reactivity, including generation of acid-rock drainage (ARD) and metals leaching. Whether and to what extent the rubble/fracture would constitute "waste rock" as described in the APP Guidance, its potential impacts on water resources must be considered in order to develop operational plans for water management and long-term plans for closure and post-closure conditions.

Because block-cave extraction is expected to take up to forty years of mining, based on the currently estimated reserve, there will be a substantial period of time over which ore-grade (nominally Cu> 1%) is exposed in the evolving cave. Therefore, although the long-term focus is on rock that would not be extracted, the characterization program includes evaluation of rock within the ore zone so that evolving water chemistry over life of mine can be assessed.

TECHNICAL APPROACH

General Approach

The proposed approach involves geochemical testing of samples obtained from 6 boreholes that penetrate the ore body, intersecting all recognized lithologies and their ranges of hydrothermal alteration. Based on advice from senior RCM geologists and mine planners, the geochemical characterization program includes five boreholes completed from within the target ore zone, and we consider rocks outside the ore zone by also using geochemical test work for borehole RES-08, the pilot hole for Shaft 10.

Geochimica proposes to adopt a two-phase approach to geochemical characterization that is described in detail in both the RT and the APP guidance documents. Tier #1 tests, simple static tests used to scope the general risk of acid-rock drainage and metals leaching, will be conducted on a broad suite of samples selected to provide adequate spatial and statistical characterization. Tier #2 tests will be performed on a subset (nominally, about 15% of Tier #1-tested samples) materials selected on the basis of available lithological, alteration, and geochemical data and RCM's developing plans for mining and evaluations of rock mechanics. In order to accelerate data collection that can be used for the geochemical modeling, we propose to select samples from mineralized rock to initiate Tier #2 testing at the beginning of the project, based on geological and mineralogical data (informed by the

testing results for RES-08). The Tier #2 testing, especially the kinetic testing, is a very long-term matter, encompassing at least 27 weeks (and probably 50 or more for many samples), so it is important to begin collecting data as soon as possible.

We propose to use general guidance of Rio Tinto's internal ARD Risk-Review Protocols for the geochemical test work to ensure that an adequate spatial as well as numeric sampling of lithologies is represented. In addition, there should be an evaluation of the environmental mineralogy of some portion of those materials. Based on experience with the Shaft 10 (RES-08) rocks, Geochimica considers that existing petrography by RCM staff is adequate for this at Tier #1 level, particularly when combined with data from the QEM-Scan program being conducted by other RT resources. If additional or supplemental work is required in either Tier #1 or Tier #2 studies, Geochimica, if requested, will propose specialists in environmental mineralogy who are qualified to work on porphyry-copper systems.

Because a geochemical characterization consistent with internal Rio Tinto guidance calls for comprehensive consideration of chemical parameters and because we understand that RCM Exploration already has initiated detailed chemical analyses, we will include the whole-rock solid chemistry in the Tier #1 program (although ADEQ does not require it until Tier #2). In addition, we propose to include in the Tier #1 program Net Acid Generation (NAG) testing. The purpose of this test at this time is to establish a database of the relationship of NAG tests to traditional ABA tests. The NAG tests can be executed in a time frame that is consistent with operational waste characterization, and is a recommended protocol in the Rio Tinto ARD protocols. Geochimica has shown for Shaft 10 that a combination of Sobek-type ABA and NAG tests provides additional assurance in planning waste management, and this has been confirmed in Rio Tinto ARD risk evaluations at, for example, the Kennecott Eagle Mining Project, Michigan.

The geochemical characterization work will be the responsibility of Mark J. Logsdon of Geochimica, Inc. Logsdon will be supported at Geochimica by a project geochemist who will assist with data management at our office. No QA/QC overlap will occur with MWH responsibilities, and thje official project database will be maintained by MWH under separate contract with RCM. The project-level support (at a rate of $40/hr) is entirely to provide cost-effective access by Logsdon to the ongoing data and routine communications with the laboratories so that he can make timely reports to RCM/RT_OTX and Dr. Mahoney's team at MWH.

<u>Special Considerations</u>

1. Unlike the development rock to be extracted from shafts, blasting residues should have no impacts on rock that remains in the cave.

2. Materials that must be characterized under Tier #2 may, to meet ADEQ direction, need evaluation for radiological characteristics of effluents. Although it is not a strict requirement of Tier #1, we suggest that some, and perhaps all the static leach tests for Tier #1 analysis include gross alpha testing, as preliminary data on this may allow a lesser program of radiological analysis in Tier #2, where obtaining solution volumes needed for radiological testing may be problematic. In particular, the combination of gross-alpha data with data on uranium and thorium will allow proper

qualification of apparently elevated gross-alpha data that actually are associated with species that are excluded from the water-quality criterion.

3. The APP program requires that geochemical test work be performed by laboratories certified by the State of Arizona. Test work to date has been performed by Kennecott Environmental Laboratory, and under the APP Guidance the data collected to date can be used as part of the formal submission. (This also is true for whole-rock chemistry developed as part of the exploration program.) Even if the work is not directly in support of an APP permit, Geochimica recommends that the project use an ADEQ-certified testing laboratory, specifically ACZ in Colorado. This will make any future discussions with ADEQ simpler, and ACZ already are familiar with the testing program we propose and also with RCM procurement. The Tier #2 kinetic-test work would be performed by Chemac Environmental Services (Englewood, Colorado), who would forward effluent solutions to ACZ for analytical chemistry, ACZ and Chemac have worked together on such projects many time over the past 15 years, and Geochimica has used both of them in this function on many prior projects. Our understanding is that MWH also has long-term relationships with both ACZ and Chemac, so there should be no problems in integrating testing results with MWH's subsequent modeling program.

4. Quality assurance/quality control (QA/QC) reviews of laboratory work would be conducted by MWH, reporting separately from Geochimica to RCM and RT-TX.

PROPOSED SCOPE OF WORK

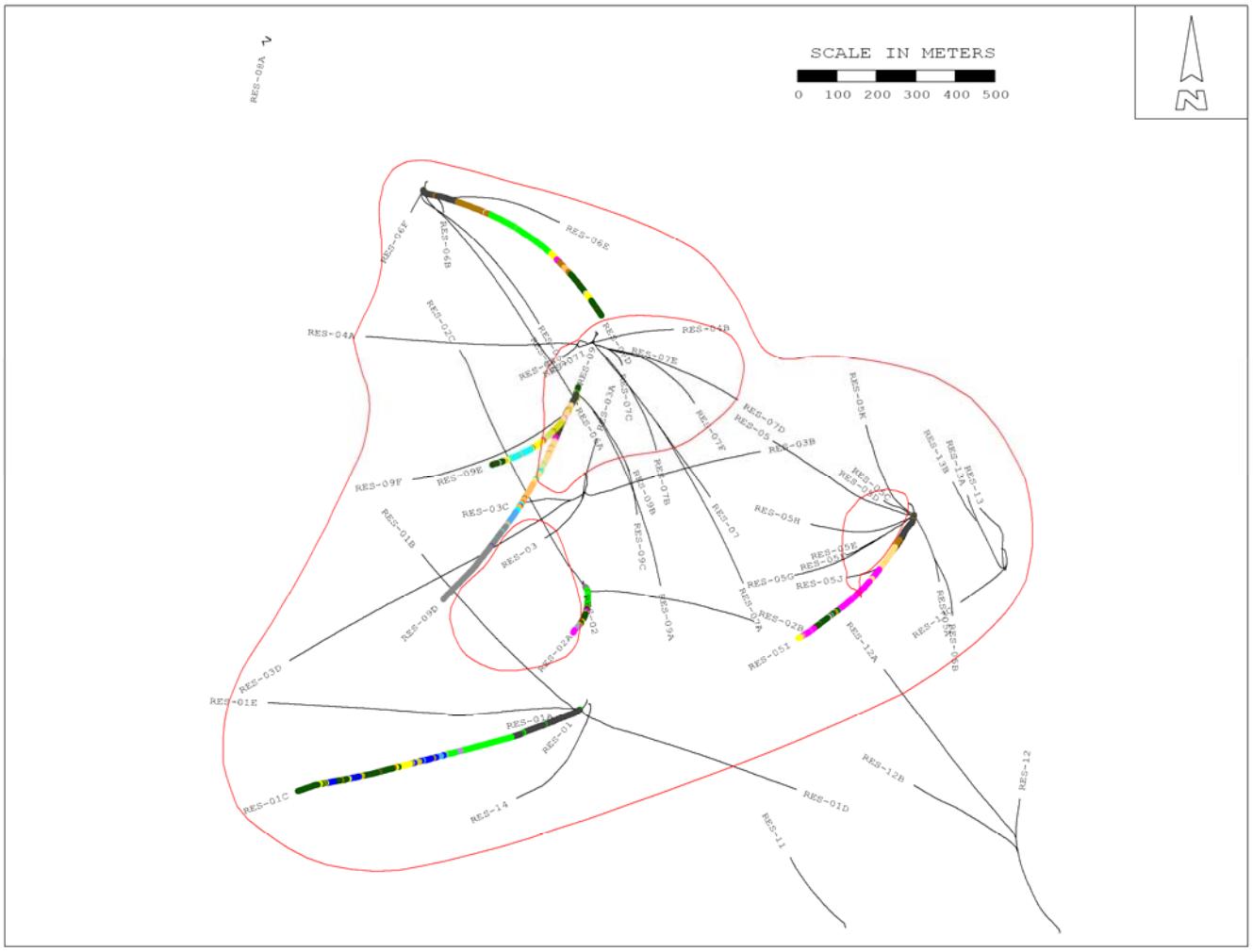
Task 1: Project Initiation and Sample Selection

Locations

We propose that the study be based on geochemical characterization of samples from six (6) RCM drill-hole clusters that already have been assayed and are important bases for the current RCM geologic block models.

- RES-08 already has a completed Tier #1 analysis. This hole will be used as a control for additional holes that are completed in the ore body (and overlying reaches) and also will be used to consider the potential behavior of rocks peripheral to the main caving zone, in the event that fracturing is more extensive than currently anticipated.
- RES-01C; 02A, 05I, -6D, and -09/9D/9E (see Figure 1). As shown in plan-view, these borehole clusters cover much of the lateral extent of the mineralized zone, and among the intervals also cover the full vertical extent of any rock that would remain in-situ due to the block caving. RES-9 is especially relevant as it is the hole that already has been tested hydrogeologically and for which some in-situ water-quality data are available. Boreholes RES-05I and -09D/E intersect the all major lithologies and the maximum thickness of the ore-grade zone.

Figure 1 Boreholes Locations in and adjacent to ore body. (Red outline is the ore-grade shell.) Note that the location of RES-08 also is shown, about 500 m northwest of the collar of RES-06.



General Sampling Strategy

Tier 1 Testing:

We recommend that two clusters, RES-05 and RES-09, be sampled intensively downhole, as was done for RES-08 as the pilot hole for Shaft 10. For that hole, the Tier#1 testing was done on 76 samples, plus 8 duplicates. For this study, the target sampling in each of those holes is 65 samples plus 7 duplicates for Tier #1. The remaining clusters (Res-01, -02, -06) would be sampled on a density of approximately 25 samples, or 40% of the intensive holes. In each new hole, approximately 60% of the samples (for both Tier #1 and Tier #2 testing) will be above the 1%-Copper shell, and 40% below. The goal of the sampling is to characterize rocks throughout the sequence so that the evolution of water quality both during mining and especially after mining is complete can be assessed. The 60% - 40% split

above and below the 1% ore shell is intended to allow RCM to understand both the 40 year life of mine and the post-mining rubble zone.

The sampling interval considered for each hole is from the uppermost retained interval to a total depth equivalent to a lower interval cutoff at -750 m amsl, because this is the RCM planning basis for the lowest elevation of mining.

The basic strategy for sampling in each new hole is stratified regular sampling. For each of the new boreholes there are two strata:

- Above and Below the elevation of the 1% Cu cutoff.
- Lithologies downhole that are proportioned according to the linear extent of each lithologic run. Each lithology that has a proportion > 0.5% is considered for sampling, with numbers rounded. Where the lithologic description and mineralogy suggest that a minor (0.3%-0.5% interval) may be geochemically important, some major lithologies are rounded downward, so that special samples can be added.

For RES-08, which is outside the ore zone, the division of strata is between upper, low-sulfur rocks that are "inert" under the APP classification and lower, high-sulfur rocks for which an APP must be obtained to handle deep development rock. The nominal depth in Shaft 10 for the distinction is 1633 m below ground surface, based on the Tier #1 testing results.

We use regular (i.e., evenly spaced) sampling in preference to random sampling in each unit to ensure that the full vertical extent of each sampled lithology is considered. When the regular sampling identified an interval that is too thin to sample for all the testing or in some way recorded on the log is anomalous (e.g., a sheared zone), then the sample was moved to the nearest interval (typically +/- 3 m vertically) that appears form the logs to suitable for testing.

For example, consider sampling down in borehole RES-IC. There are 133 lithologic sampling units logged from the uppermost sample to the 1% Cutoff depth. Five lithologies (one of which is intersected at two depths) comprise the full 133 intervals as follows [values in parenthesis are the number of intervals in the vertical run]:

- Kvs (Cretaceous volcaniclastic sediments) – [**77**]
- Andesite (a variation within the Kvs) – [**8**]
- Kvs – [**12**]
- Dm (Devonian Martin Limestone, now typically skarnified) – [**32**]
- Siltstone (a variation within Dm) – [**4**]

Because our target is 25 samples from RES-1C, we target 15 samples (60%) above the 1% Cutoff. Therefore we can determine the number of samples for each lithology by a proportion:

(Lithologic sample number : 133 intervals) :: (x : 15)

The proportioned values and sample numbers (in red) for each lithology in the stratum above the ore shell in borehole RES-01C, then, are:

- Kvs – [9.63; **9**]
- Andesite – [0.90; **1**]
- Kvs – [1.35; **1**]
- Dm – [3.61; **4**]
- Siltstone – [0.45; **1**]

In this example, we elected to round down the uppermost Kvs sampling in order to allow one sample for the Siltstone variation in the Dm sequence lower in the section. We also elected to keep the rounded up value of 4 for the Dm, even though this increased the total number of Tier #1 samples to 16 instead of 15. We made this judgment because it is important to have a sufficient number of skarn samples in the overall database that will be generated, and we judged that the advantages to RCM form having a wider selection of Martin Limestone samples outweigh the costs of one additional Tier #1 sample.

In summary, the Tier #1 program then would include (samples plus duplicates):

- (76 +8) samples from RES-08 (already available)
- (64+7) from RES-09/09D/09E.
- (65 +7) from RES-05I
- (25 +3) From RES-1C
- (26 +3) from Res-02A
- (25 +3) from Res-06D

Slightly different numbers of total samples (65 vs 64 and 26 vs 25) occur to honor the local variability in the holes. For simplicity in review, the sampling intervals are numbers in the figures of Attachments 1 to 6.

This yields an estimated total of 205 <u>new</u> samples plus 23 duplicates (228 total) for Tier #1 testing. When combined with the RES-08 data already available, this will provide 332 total Tier #1 samples from 6 different holes.

<u>Tier # 2 Testing:</u>

Based on RCM data for lithology, mineralogy and hydrothermal alteration, and allowing for samples across the full depth interval of each hole, we nominate 40 samples for Tier #2 (kinetic) testing, divided to maintain the 60% - 40% allocation between rocks above and below the 1% copper shell. To honor the density of static tests, we have identified 10 sample intervals in both RES-05I and RES-09/09D/09E (15%), and five samples (20%) each in Boreholes RES-01C, RES-02A, RES06D, and RES-08.

For the five new boreholes, the intervals for Tier #2 testing follow the sample two-strata sampling approach, with 60% above and 40% below the 1% Shell limit. Specific intervals were then selected to test the major lithologies and to provide reasonable vertical coverage,

while also representing the range of Sulfur concentrations (based on the ICP sulfur data in Attachment 1-6), with some additional judgment to include higher, rather than lower ranges of sulfur in each lithology. The intervals identified for static and kinetic testing in the new boreholes are shown in Attachments 1, 2, 3, 4, 5 (one for each borehole).

As discussed above, Tier #1 test work already is complete on RES-08. That borehole, which is the pilot hole for Shaft 10, is outside the economic zone. Therefore, instead of stratifying Tier #2 testing on a 1% Cu shell, we have stratified it on the depth at which RCM has proposed to ADEQ that we expect to encounter rock that is not classified as "Inert" under the APP regulations. Because only rock that needs an APP requires Tier #2 testing, one sample is a short distance above the Inert boundary, and the other four samples for Tier #2 testing from RES-08 are from the zone below the inert rock cutoff. Including Tier #2 testing of these samples with this program will allow RCM to complete the data collection for the APP permit for Shaft 10, and it also will provide additional data on mineralized lithologies that are relevant to the site-wide characterization.

The total sampling proposed is summarized by borehole in following Table 1. The specific sample locations are shown in Attachments 1 to 6.

Table 1 Sample Summary: Tier #1 and Tier #2 Testing, 2008. (Note that the elevation stratum for RES-08 is the cutoff for Inert versus Reactive APP designation, not the 1% Cu Shell elevation)

RES Borehole	1% Cu Cutoff Stratum*	Tier #1	Tier # 1 Duplicate	Tier # 2
01C	Above	15	2	3
	Below	10	1	2
02A	Above	16	2	3
	Below	10	1	2
05I	Above	40	4	6
	Below	25	3	4
06D	Above	15	2	3
	Below	10	1	2
08*	Above	33	3	1
	Below	43	4	4
09/9D/9E	Above	39	4	6
	Below	25	3	4

Level of Effort: Logsdon: 50 hours. Geochimica project geologist: 30 hours

Deliverable: Final sampling plan.

Schedule: 30 April 2008

Task 2: Implementation of Tier #1 Characterization Program

RCM geologists will obtain the samples described by the sampling plan as shown in Attachments 1 to 6. Note that the figures also identify intervals to be tested in duplicate. The RCM Geology Team may vary the sample intervals form those identified here in order to recognize intervals for which prior RCM testing or future testing and archival needs do not provide sufficient material in the nominated interval. In general, the alternative interval will be adjacent to that initially nominated, and a final sample-selection list will be prepared by RCM geology to identify all samples and explain variations.

Samples for Tier #2 testing are to be obtained form coarse-reject samples; Tier #1 samples may be pulps. Samples form the overburden units (Apache Leap Formation and Whitetail Conglomerate) may be sent to the lab as fractional core for crushing and preparation there. Based on prior experience with properly maintained samples in dry climates, Geochimica considers that incipient oxidation of the coarse rejects and pulps prior to testing would be a small effect, and one that can be assessed from the total sulfur speciation in the Tier #1 testing and the initial rinsate fram the kinetic tests.

We recommend that RCM Geology select and send the Tier #2 samples to the testing laboratory first, because the start-up period for the Tier #2 testing is much longer. The much more rapid Tier #1 tests will allow their results to be available months before the Tier #2 tests, even if they lag initiation.

Each Tier #1 sample will be tested as follows:

- Whole-rock major and trace metals.
- Acid-base account by modified Sobek procedures, including carbonate NP.
- Single additional Net Acid Generation procedure, reporting both NAG-P and NAG.
- Synthetic Precipitation Leaching Procedure (SPLP: EPA Method 1312).
- The effluents from both the NAG and SPLP tests should be analyzed for:
  - General parameters (pH, Conductivity, TDS, Alkalinity/Acidity, Hardness, Gross Alpha activity)
  - Major ions (Ca, Mg, Na, K, HCO_3/CO_3, SO_4, Cl and F)
  - Metals and metalloids including the Arizona designated metals (Sb, As, Ba, Be, Cd, Cr, Pb, Hg, Se, Tl, and Ni), plus eight site-specific metals (Al, B, Cu, Fe, Mn, Ag, U, and Zn).

The complete parameter list is recommended to ensure that planning and any potential permit application would be judged adequate, to allow standard quality-control evaluations of analytical data, and to support geochemical modeling of the evolution of water chemistry. For the Tier #1 evaluation, gross-beta activity (which addresses man-made radio-isotopes) is not necessary, and if gross alpha and U values are sufficiently low, it is possible that we can moot the need for radium and radon analyses in Tier #2. Fluoride (F) is not usually considered a major anion, but it often is significantly elevated in porphyry-copper systems and is both a water-quality parameter in its own right and am important complexing ligand (especially for aluminum). Uranium is commonly associated with porphyry copper systems and was identified in elevated concentrations in some tailing samples form the Superior West

Plant site. Boron (B) is a parameter of concern for agricultural water uses and commonly is required in Arizona evaluations. Given the now-standard use of ICP-based analyses, the extended list of metals and metalloids is a negligible contributor to total analytical costs.

The project also will develop a mineralogical and lithologic description of samples that is consistent with the APP Guidance. To the extent that this has been or can be done by RCM geologists, we will use that. If that not available or if supplementary description is required, we will identify this in the Task 1 work plan and submit a modified proposal.

Level of Effort: Logsdon: 80 hours. Geochimica project geologist: 40 hours

Deliverable: Data report and evaluation. Tier #1 Summary and Analysis.

Schedule: 30 days after receipt of all Tier #1 analytical reports from the laboratory.

Task 3: Implementation of Tier #2 Program

Geochimica has identified a suite of 40 samples for Tier #2 (kinetic) testing (see Attachments 1 to 6). The Tier #2 testing will be based on column weathering cells using a testing procedure equivalent to the ASTM standard for humidity cells. For the initial 27 week period, weekly effluents should be analyzed weekly for the same parameters as will be analyzed in the static testing program, except that gross alpha radiation does not need analysis. [There will not be sufficient solution for the gross alpha analysis]:

- General parameters (pH, Conductivity, TDS, Alkalinity/Acidity, Hardness)
- Major ions (Ca, Mg, Na, K, HCO_3/CO_3, SO_4, Cl and F)
- Metals and metalloids including the Arizona designated metals (Sb, As, Ba, Be, Cd, Cr, Pb, Hg, Se, Tl, and Ni), plus eight site-specific metals (Al, B, Cu, Fe, Mn, Ag, U, and Zn).

The general parameters except hardness, plus Fe and SO_4 will be analyzed at Chemac Environmental Services, with the solution then transported to ACZ for the full analytical suite, including general parameters, major ions, and trace metals.

At this time, we recommend that RCM plan on the Tier #2 testing taking at least 27 weeks. If review of the analytical results indicates that some of the initially designated parameters do not need continued analysis, Geochimica will prepare a recommendation to RCM and ADEQ for a modification of the analytical suite. At the end of 20 weeks, we will submit a report that recommends which, if any of the kinetic tests should be continued beyond 27 weeks, on what sampling and analysis interval (it may be possible to decrease the sampling and analytical intensity), and for how long. (Note: At the Eagle Project, kinetic tests have been ongoing for > 150 weeks in support of permitting that is currently being considered by the State of Michigan, and this is comparable to the kinetic testing basis for Rio Tinto's Diavik Project.)

The experimental work for Tier #2 will be performed at Chemac Environmental Services (Englewood, Colorado). ACZ does not conduct column-leaching experiments, nor do most

commercial laboratories that do large-volume analytical chemistry. Chemac will deliver effluent solutions to ACZ for analytical chemistry to meet ADEQ requirements for a qualified analytical lab.

Level of Effort: Logsdon 100 hours; Geochimica project geologist: 60 hours

Deliverable: Monthly progress report of Tier #2 Test. Technical memorandum after week 20 data on possible modifications to program. Interim technical report after 27 weeks, with plan for continuation (e.g., reducing testing interval). Final technical report at conclusion of program, nominally after 50 weeks of Tier #2 testing data.

Schedule: Monthly reports. Technical memorandum 2 weeks after receipt of Week 20 results. Interim report 2 weeks after receipt of 27-week laboratory results. Final report 30 days after receipt of final (week 50) results.

COSTS

This proposal assumes that all sampling and analytical costs would be contracted directly to RCM, and they therefore are not included. In addition MWH will contract its QA/QC reviews and formal database management separately with RCM.

Final costs for the Geochimica and supporting personnel will be estimated in a separate cost proposal after RCM and RT_OTX have reviewed this Draft Proposal.