# Appendix A

# Phoenix Copper Heap Leach E-Pond Solid Chemistry

GEOMEGA
Visionary Environmental Consulting
2525 28th Street, Suite 200, Boulder, CO 80301 ▪ Tel: (303) 443.9117 Fax: (303) 938.8123 ▪ www.geomega.com

# Memorandum

**TO:** Meg Burt and Adam House, Newmont Mining Corporation

**FROM:** Andy Davis and Maggy Lengke, Geomega

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**RE:** **Newmont Phoenix Copper Heap Leach E-Pond Solid Chemistry Following Complete Evaporation**

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## 1. Introduction

Geomega has conducted a geochemical modeling study to predict mineral solubility in evaporating draindown solution from Duval-era Phoenix HLF, also known as C4 or the Philadelphia Canyon WRF, (April 9, 1997) and estimated trace metal concentrations in the solution at up to 80% evaporation (Geomega 2011). The geochemical modeling was conducted using the reaction path code EQ3/6 version 8.0 with the modified Pitzer (ypf) database (Wolery 2002) which specifically accounts for high ionic strength solutions.

As part of the proposed Phoenix Copper Leach Project, Geomega was asked by Newmont Mining Corporation (Newmont) to develop an approach to assess evaporation pond (E-pond) solid chemistry including uranium during complete evaporation (100% evaporation). The results will be used as a predictor for solid chemistry for future operation and facility closure.

To accomplish this objective, the following scope of work was undertaken:

- Estimate uranium concentration as the starting chemistry using the average column pregnant leach solution ( PLS) concentration; and
- Determine the target solid chemistry evaporated at 100% using the Duval-era Phoenix HLF data as the starting point.

## 2. Methods and Results

### *2.1. Uranium Concentration*

The Duval-era Phoenix HLF data (April 9, 1997) were selected as a starting point to determine solution chemistry during evaporation at up to 80% (Geomega 2011). However, the data collected from C-4 during the 13 year history of draindown (1993 to 2006 in Table 4-5 of Geomega 2010) lacked any U concentrations.

Uranium incorporated into the evaporated solid is an important piece of information required to select an applicable solid management plan. Uranium in the starting solution was estimated using the average solution chemistry from the PLS column tests conducted by McClelland (2008a, 2008b; Table 2-1; Appendix A) using ore samples from the proposed Phoenix copper heap leach facility (HLF). The average PLS chemistry was calculated based on the proportion of ore formations in the proposed Phoenix HLF (Table 2-1). In decreasing order, the ore formations for the proposed Phoenix HLF (A. House 2010, pers. Comm.; Table 4-6 and Figure 4-8 of Geomega 2010) comprise the Tertiary Intrusive (38%), Permian Pumpernickel arkosic sandstone (27%), Cambrian Harmony arkosic sandstone (18.3%), Virgin fault zone (7.6%), Permian Battle Mountain lower conglomerate (4%), Permian Antler Peak limestone (1.8%), Battle Mountain upper conglomerate (1.7%), Battle Mountain middle siltstone (1.4%), and Permian Edna Mountain sandstone (0.1%).

The ratio of uranium to sulfate from the average column test PLS was used to determine uranium in the starting solution of the Duval-era Phoenix HLF (April 9, 1997). Sulfate in both the PLS and the starting solution is much higher than other possible U-complexing anions (e.g., fluoride, chloride, and nitrate), and therefore, it is more likely that a uranium-sulfate complex [e.g., $UO_2(SO_4)_3^{4-}$] would be more stable in solution than other anionic complexes. For comparison, sulfate is approximately 1,000 and 115,450 times higher than chloride and nitrate, respectively.

The ratio of uranium to sulfate in the PLS is 0.000038, so using this ratio, uranium as the starting solution ($U_{C-4}$) can be calculated using the following equation:

$$U_{C-4} = \left(\frac{U}{SO_4}\right)_{PLS} \times \left(SO_4\right)_{C-4} \qquad (2.1)$$

Sulfate as the starting solution [$(SO_4)_{C-4}$] is 142,000 mg/L resulting in a U concentration of 5.5 mg/L. Using the ratios of uranium to fluoride (0.03) and uranium to nitrate (0.6), the calculated uranium in the starting solution would be less conservative (at 3.4 and 0.8 mg/L, respectively), so the U-sulfate complex was adopted for the ensuing analysis.

## *2.2. E-pond Solid Chemistry*

The E-pond solid chemistry at 100% evaporation was determined using the Duval-era Phoenix HLF C-4 solution chemistry data (April 9, 1997) with the estimated U of 5.5 mg/L (Table 2-2). The evaporated solid chemistry composition (mg/kg) was calculated by dividing the solution concentration (mg/L) with the total dissolved solids (TDS) in mg/L, as follows:

$$[\frac{mg}{kg}]_{Solid} = \frac{\left[\frac{mg}{L}\right]_{Solution}}{\left[\frac{mg}{L}\right]_{TDS}} \times \left[10^6 \frac{mg}{kg}\right] \qquad (2.2)$$

Using equation (2.2), $SO_4$, Mg and Al represent the highest solid composition fraction at ~927,000; 21,500; and 18,700 mg/kg in the E-pond evaporated solid (Table 2-2). Copper, Zn and U will comprise ~16,500; 6,450; and 36 mg/kg, respectively. The other Profile 2 metal solid concentrations are also provided in Table 2-2.

# 3. Conclusions

Selection of the highest sulfate and TDS from the Duval-era Phoenix HLF at C-4 during 13 years of sampling was purposefully designed to provide a conservative estimate of the E-pond solid chemistry following complete evaporation.

This study demonstrated that:

- The U concentration in the starting solution of Duval-era Phoenix HLF from C-4 (April 9, 1997) was estimated to be ~5.5 mg/L. This value was calculated using uranium-sulfate ratio from the average McClelland column test data.
- The E-pond evapoconcentrated solid will contain sulfate (927,000 mg/kg solid), magnesium (21,500 mg/kg), and aluminum (18,700 mg/kg). Uranium will comprise ~36 mg/kg of the solid phase.



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## References

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McClelland. 2008a. Environmental characterization testing conducted on samples generated during the Phoenix Phase I pilot column leach testing program. June 4, 2008. Spark, NV: McClelland Laboratories, Inc.

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Wolery, T.J. 2002. EQ3/6 - Software for Geochemical Modeling, Version 8.0, UCRL-ODE-2003-009, Lawrence Livermore National Laboratory, Livermore, California.

## Table 2-1. Phoenix and Reona average column leach PLS chemistry based on ore distribution.

| Parameters | Harmony (18.3%)* | Pumpernickel (27.1%)* | Intrusive (TAG) (38%)* | VFZ (16.6%)* | Average |
|---|---|---|---|---|---|
| Acidity ($CaCO_3$) | 39,333 | 40,667 | 39,000 | 41,500 | 39,928 |
| Aluminum | 4,533 | 5,200 | 4,233 | 5,550 | 4,769 |
| Antimony | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| Arsenic | 44.3 | 177.3 | 87.0 | 130.5 | 110.9 |
| Barium | 0.42 | 0.50 | 0.42 | 0.38 | 0.43 |
| Beryllium | 0.64 | 0.66 | 0.82 | 0.75 | 0.73 |
| Bismuth | 4.17 | 5 | 5 | 3.75 | 4.64 |
| Boron | 5.47 | 5 | 5 | 3.75 | 4.88 |
| Cadmium | 28 | 44.3 | 30.7 | 26.5 | 33.2 |
| Calcium | 537 | 553 | 567 | 545 | 554 |
| Chloride | 78.7 | 97 | 120 | 95 | 102 |
| Chromium | 8.0 | 11.7 | 10.6 | 15.2 | 11.2 |
| Cobalt | 56.67 | 72 | 56 | 48 | 59 |
| Copper | 470 | 1,070 | 480 | 395 | 624 |
| Fluoride | 172 | 157 | 120 | 130 | 141 |
| Gallium | 4.17 | 5.00 | 4.17 | 3.75 | 4.32 |
| Iron | 4,833 | 4,100 | 5,633 | 5,200 | 4,999 |
| Lead | 0.52 | 0.82 | 0.46 | 0.53 | 0.58 |
| Lithium | 4.17 | 5.00 | 4.17 | 3.75 | 4.32 |
| Magnesium | 3,067 | 4,033 | 2,833 | 3,700 | 3,345 |
| Manganese | 363 | 510 | 683 | 1,070 | 642 |
| Mercury | 0.002 | 0.001 | 0.001 | 0.001 | 0.001 |
| Molybdenum | 0.7 | 0.5 | 1.1 | 1.2 | 0.9 |
| Nickel | 80 | 115 | 68 | 69 | 83 |
| Nitrate (N) | 9.2 | 5.4 | 6.0 | 7.8 | 6.7 |
| Nitrite (N) | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| pH (su) | 1.8 | 1.8 | 1.7 | 1.7 | 1.8 |
| Phosphorus | 430 | 620 | 450 | 560 | 511 |
| Potassium | 207 | 320 | 313 | 290 | 292 |
| Scandium | 4.17 | 5.00 | 4.17 | 3.75 | 4.32 |
| Selenium | 0.48 | 0.65 | 0.27 | 0.89 | 0.52 |
| Silver | 0.21 | 0.25 | 0.21 | 0.19 | 0.22 |
| Sodium | 2,467 | 2,533 | 4,700 | 2,215 | 3,292 |
| Strontium | 5.9 | 5.0 | 7.0 | 7.4 | 6.3 |
| Sulfate | 99,667 | 99,000 | 110,000 | 120,000 | 106,788 |
| Thallium | 0.02 | 0.02 | 0.04 | 0.02 | 0.03 |
| Tin | 4.2 | 5.0 | 4.2 | 3.8 | 4.3 |
| Titanium | 4.2 | 8.3 | 4.2 | 3.8 | 5.2 |
| Uranium | 2.3 | 4.9 | 5.1 | 2.5 | 4.1 |
| Vanadium | 4.9 | 5.8 | 7.9 | 5.0 | 6.3 |
| Zinc | 750 | 1,023 | 703 | 1,225 | 885 |
| Total dissolved solids | 63,333 | 72,000 | 72,000 | 76,000 | 71,078 |
| Calculated total dissolved solids | 117,849 | 119,702 | 131,152 | 141,318 | 127,302 |

All units are in mg/L, except for pH.

*Percentage of ore formation.

The VFZ percent includes VFZ, the Battle Mountain, the Antler Peak, and the Edna Mountain formations.

## Table 2-2. Starting solution chemistry and E-cell solid chemistry.

| Parameters | Solution 4/9/1997 (mg/L) | Solid (mg/kg) |
|---|---|---|
| Aluminum | 2,870 | 18,729 |
| Antimony | 0.14 | 0.9 |
| Arsenic | 0.145 | 0.9 |
| Barium | 0.013 | 0.1 |
| Beryllium | 0.19 | 1.2 |
| Boron | 1.7 | 11 |
| Cadmium | 32.5 | 212 |
| Calcium | 444 | 2,897 |
| Chloride | 137 | 894 |
| Chromium | 0.383 | 2.5 |
| Cobalt | 76.2 | 497 |
| Copper | 2,540 | 16,576 |
| Fluoride | 116 | 757 |
| Iron | 61.1 | 398.7 |
| Lead | 1.0 | 6.5 |
| Magnesium | 3,300 | 21,535 |
| Manganese | 202 | 1,318 |
| Mercury | 0.006 | 0.04 |
| Molybdenum | 0.1 | 0.7 |
| Nickel | 96.3 | 628.4 |
| Nitrate | 1.23 | 8.0 |
| Nitrate and nitrite (N) | 1.25 | 8.2 |
| pH (su) | 3 | |
| Phosphorus | 87 | 567.7 |
| Potassium | 7.2 | 47.0 |
| Scandium | 0.2 | 1.3 |
| Selenium | 0.25 | 1.6 |
| Silver | 0.6 | 3.9 |
| Sodium | 264 | 1,723 |
| Strontium | 0.8 | 5.2 |
| Sulfate | 142,000 | 926,663 |
| Thallium | 0.6 | 3.9 |
| Tin | 2 | 13.1 |
| Titanium | 0.1 | 0.7 |
| Uranium* | 5.5 | 35.9 |
| Vanadium | 0.5 | 3.3 |
| Zinc | 988 | 6,447 |
| Total Dissolved Solids | 153,238 | |

*Calculated concentration

## Table A-1. Summary of the column leach chemistry results (McClelland 2008a, 2008b).

| | AC-1 | | | AC-34 | | | AC-66 | | |
|---|---|---|---|---|---|---|---|---|---|
| | Harmony Oxide | | | Harmony Partial Leach | | | Harmony Partial Leach | | |
| **Parameters** | **PLS** | **PV # 1** | **PV # 3** | **PLS** | **PV # 1** | **PV # 3** | **PLS** | **PV # 1** | **PV # 3** |
| Acidity ($CaCO_3$) | 44,000 | 11,000 | 3,800 | 37,000 | 25,000 | 3,900 | 37,000 | 24,000 | 7,000 |
| Aluminum | 4,900 | 980 | 120 | 4,600 | 2,400 | 520 | 4,100 | 2,400 | 600 |
| Antimony | 0.0098 | <0.0025 | <0.0025 | 0.0071 | 0.0037 | <0.0025 | <0.0025 | <0.0025 | <0.0025 |
| Arsenic | 40 | 7.9 | 0.92 | 66 | 11 | 0.73 | 27 | 15 | 2 |
| Barium | <1 | <0.1 | 0.024 | <1 | <0.1 | <0.1 | <0.5 | <0.5 | <0.1 |
| Beryllium | 0.55 | 0.12 | 0.019 | 0.71 | 0.29 | 0.086 | 0.66 | 0.48 | 0.14 |
| Bismuth | <10 | <1 | <0.1 | <10 | <1 | <1 | <5 | <5 | <1 |
| Boron | <10 | <1 | <0.1 | <10 | <1 | <1 | 6.4 | <5 | <1 |
| Cadmium | 44 | 7.3 | 0.94 | 23 | 8.2 | 2.3 | 17 | 9.8 | 2.6 |
| Calcium | 570 | 690 | 330 | 600 | 710 | 420 | 440 | 450 | 420 |
| Chloride | 110 | <100 | 19 | <100 | <100 | 16 | 76 | 53 | 56 |
| Chromium | 7.1 | 1.9 | 0.21 | 7 | 2.2 | 0.68 | 9.8 | 6.2 | 1.5 |
| Cobalt | 88 | 14 | 2 | 46 | 1.6 | 4.5 | 36 | 21 | 5.8 |
| Copper | 570 | 100 | 62 | 570 | 11 | 62 | 270 | 100 | 57 |
| Fluoride | 280 | <50 | 14 | 87 | <50 | 13 | 150 | 68 | 12 |
| Gallium | <10 | <1 | <0.1 | <10 | <1 | <2 | <5 | <5 | <1 |
| Iron | 5,700 | 890 | 66 | 5,100 | 1,600 | 220 | 3,700 | 2,200 | 440 |
| Lead | 0.26 | <0.2 | <0.01 | 0.1 | 0.037 | <0.1 | 1.2 | 0.55 | <0.1 |
| Lithium | <10 | 1 | 0.19 | <10 | 1.4 | <1 | <5 | <5 | <1 |
| Magnesium | 4,200 | 790 | 130 | 2,400 | 1,300 | 270 | 2,600 | 1,600 | 460 |
| Manganese | 470 | 110 | 15 | 260 | 110 | 29 | 360 | 340 | 93 |
| Mercury | 0.0013 | 0.0003 | 0.0003 | 0.0016 | 0.0024 | 0.0015 | 0.0024 | 0.0011 | <0.001 |
| Molybdenum | 1.4 | <0.2 | <0.01 | <1 | <0.2 | <0.1 | 0.5 | <0.5 | <0.1 |
| Nickel | 130 | 21 | 3 | 67 | 25 | 7 | 42 | 27 | 7.3 |
| Nitrate (N) | 7.6 | 3.7 | <1 | 2.9 | 4.6 | <1 | 17 | 11 | 6 |
| Nitrite (N) | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| pH (su) | 1.8 | 2.31 | 2.53 | 1.79 | 2.27 | 2.65 | 1.77 | 1.94 | 2.2 |
| Phosphorus | 400 | 58 | 1.9 | 650 | 210 | 13 | 240 | 140 | 19 |
| Potassium | 180 | 84 | 28 | 250 | 160 | 70 | 190 | 160 | 75 |
| Scandium | <10 | <1 | <0.1 | <10 | <1 | <1 | <5 | <5 | <1 |
| Selenium | 0.57 | 0.14 | 0.024 | 0.22 | <0.25 | 0.018 | 0.65 | 0.34 | 0.092 |
| Silver | <0.5 | <0.05 | <0.005 | <0.5 | <0.05 | <0.05 | <0.25 | <0.25 | <0.05 |
| Sodium | 3,500 | 930 | 160 | 2,700 | 1,100 | 290 | 1,200 | 680 | 210 |
| Strontium | <10 | 1.2 | 0.78 | <10 | 2.7 | 3.4 | 7.7 | 6.2 | 3.2 |
| Sulfate | 99,000 | 25,000 | 5,600 | 90,000 | 48,000 | 10,000 | 110,000 | 84,000 | 23,000 |
| Thallium | 0.034 | 0.018 | 0.0073 | 0.02 | 0.02 | 0.0061 | 0.019 | 0.018 | 0.008 |
| Tin | <10 | <1 | <0.1 | <10 | <1 | <1 | <5 | <5 | <1 |
| Titanium | <10 | <1 | <0.1 | <10 | <1 | <1 | <5 | <5 | <1 |
| Uranium | 3.1 | 0.92 | 0.14 | 3.7 | <0.01 | 0.45 | <0.01 | <0.01 | 0.67 |
| Vanadium | 5.7 | 1.2 | 0.032 | 5.3 | 0.58 | <0.1 | 3.8 | 1.9 | 0.25 |
| Zinc | 1,200 | 180 | 23 | 660 | 210 | 65 | 390 | 320 | 88 |
| Total dissolved solids | 64,000 | 21,000 | 5,600 | 60,000 | 43,000 | 8,000 | 66,000 | 39,000 | 13,000 |
| Calculated total dissolved solids | 121,410 | 29,875 | 6,580 | 108,101 | 55,871 | 12,010 | 123,888 | 92,612 | 25,562 |

## Table A-1. Summary of the column leach chemistry results (McClelland 2008a, 2008b).

| | AC-7 | | | AC 61 | | | AC-42 | | |
|---|---|---|---|---|---|---|---|---|---|
| | Pumpernickel Partial Leach | | | Pumpernickel Oxide (1st) | | | Pumpernickel Oxide (2nd) | | |
| **Parameters** | **PLS** | **PV # 1** | **PV # 3** | **PLS** | **PV # 1** | **PV # 3** | **PLS** | **PV # 1** | **PV # 3** |
| Acidity ($CaCO_3$) | 41,000 | 20,000 | 7,100 | 48,000 | 18,000 | 2,700 | 33,000 | 16,000 | 2,200 |
| Aluminum | 4,900 | 1,700 | 690 | 6,900 | 1,800 | 340 | 3,800 | 1,300 | 230 |
| Antimony | 0.0082 | <0.0025 | <0.0025 | 0.0027 | <0.0025 | <0.0025 | 0.012 | <0.0025 | <0.0025 |
| Arsenic | 22 | 15 | 3.1 | 260 | 67 | 0.88 | 250 | 71 | 1 |
| Barium | <1 | <0.1 | <0.1 | <1 | <0.1 | <0.1 | <1 | <0.1 | <0.1 |
| Beryllium | 0.55 | 0.2 | 0.1 | 0.84 | 0.22 | 0.054 | 0.6 | 0.19 | 0.043 |
| Bismuth | <10 | <1 | <1 | <10 | <1 | <1 | <10 | <1 | <1 |
| Boron | <10 | <1 | <1 | <10 | <1 | <1 | <10 | <1 | <1 |
| Cadmium | 61 | 14 | 7.4 | 44 | 9.2 | 2.5 | 28 | 6.7 | 1.7 |
| Calcium | 560 | 720 | 430 | 550 | 710 | 510 | 550 | 680 | 290 |
| Chloride | 110 | <100 | 46 | 130 | <100 | 16 | <100 | <100 | 15 |
| Chromium | 11 | 5 | 2.2 | 14 | 4.5 | 0.78 | 10 | 3.8 | 0.68 |
| Cobalt | 110 | 26 | 12 | 62 | 12 | 3.2 | 44 | 11 | 2.5 |
| Copper | 510 | 73 | 86 | 1,500 | 290 | 200 | 1,200 | 140 | 67 |
| Fluoride | 260 | <50 | 66 | 110 | <50 | 6.1 | 100 | <50 | 7.3 |
| Gallium | <10 | <1 | <1 | <10 | <1 | <2 | <10 | <1 | <2 |
| Iron | 4,400 | 1,500 | 490 | 3,300 | 590 | 50 | 4,600 | 1,100 | 120 |
| Lead | 1.7 | 0.94 | 0.29 | 0.29 | 0.044 | <0.1 | 0.48 | 0.15 | <0.1 |
| Lithium | <10 | 1.7 | <1 | <10 | 1.9 | <1 | <10 | 1.1 | <1 |
| Magnesium | 4,700 | 1,400 | 680 | 4,600 | 1,300 | 330 | 2,800 | 930 | 220 |
| Manganese | 820 | 240 | 110 | 470 | 100 | 24 | 240 | 75 | 17 |
| Mercury | 0.0012 | 0.0006 | 0.0007 | 0.0016 | 0.0041 | 0.013 | 0.0011 | 0.0009 | 0.0014 |
| Molybdenum | <1 | <0.2 | <0.1 | <1 | <0.1 | <0.1 | <1 | <0.2 | <0.1 |
| Nickel | 150 | 35 | 17 | 120 | 26 | 6.8 | 74 | 20 | 4.5 |
| Nitrate (N) | 6 | 4.9 | 3.2 | 6.4 | 4.3 | <1 | 3.7 | 3.2 | <1 |
| Nitrite (N) | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| pH (su) | 1.82 | 2.19 | 2.38 | 1.99 | 2.38 | 3.06 | 1.75 | 2.25 | 2.73 |
| Phosphorus | 650 | 190 | 54 | 440 | 58 | <5 | 770 | 140 | 5.6 |
| Potassium | 200 | 140 | 82 | 310 | 130 | 78 | 450 | 250 | 81 |
| Scandium | <10 | <1 | <1 | <10 | <1 | <1 | <10 | <1 | <1 |
| Selenium | 0.27 | 0.13 | 0.036 | 1.3 | 0.27 | 0.044 | 0.38 | 0.082 | 0.016 |
| Silver | <0.5 | <0.05 | <0.05 | <0.5 | 0.055 | <0.05 | <0.5 | <0.05 | <0.05 |
| Sodium | 1,600 | 980 | 470 | 2,600 | 650 | 190 | 3,400 | 870 | 190 |
| Strontium | <10 | 1.8 | 2.3 | <10 | 1.1 | 2.9 | <10 | 2.2 | 1.5 |
| Sulfate | 98,000 | 44,000 | 17,000 | 110,000 | 39,000 | 8,300 | 89,000 | 34,000 | 5,400 |
| Thallium | 0.023 | 0.03 | 0.017 | 0.0088 | 0.01 | 0.0061 | 0.026 | 0.017 | 0.0065 |
| Tin | <10 | <1 | <1 | <10 | <1 | <1 | <10 | <1 | <1 |
| Titanium | <10 | 1.1 | <1 | <10 | <1 | <1 | 15 | 1.4 | <1 |
| Uranium | 3.1 | 1.8 | 0.8 | 9.2 | 3.8 | 0.56 | 2.5 | 1.2 | 0.2 |
| Vanadium | 7.3 | 4.1 | 0.23 | <5 | <0.1 | <0.1 | 7.6 | 0.36 | <0.1 |
| Zinc | 1,600 | 320 | 180 | 810 | 160 | 47 | 660 | 150 | 42 |
| Total dissolved solids | 75,000 | 40,000 | 16,000 | 83,000 | 34,000 | 6,600 | 58,000 | 28,000 | 4,700 |
| Calculated total dissolved solids | 118,685 | 51,377 | 20,435 | 132,240 | 44,921 | 10,112 | 108,008 | 39,760 | 6,700 |

## Table A-1. Summary of the column leach chemistry results (McClelland 2008a, 2008b).

| | AC-20 | | | AC-26 | | | AC-72 | | |
|---|---|---|---|---|---|---|---|---|---|
| | TAG Oxide | | | TAG Partial Leach | | | Replacement TAG Partial Leach | | |
| **Parameters** | **PLS** | **PV # 1** | **PV # 3** | **PLS** | **PV # 1** | **PV # 3** | **PLS** | **PV # 1** | **PV # 3** |
| Acidity ($CaCO_3$) | 40,000 | 15,000 | 1,400 | 44,000 | 18,000 | 3,900 | 33,000 | 29,000 | 4,500 |
| Aluminum | 4,600 | 1,600 | 200 | 5,100 | 1,800 | 420 | 3,000 | 2,400 | 380 |
| Antimony | 0.011 | <0.0025 | <0.0025 | 0.0034 | <0.0025 | <0.0025 | 0.0025 | <0.0025 | <0.0025 |
| Arsenic | 120 | 14 | 0.37 | 50 | 14 | 0.7 | 91 | 0.16 | 3.6 |
| Barium | <1 | <0.1 | <0.1 | <1 | <0.1 | <0.1 | <0.5 | <0.5 | <0.1 |
| Beryllium | 0.74 | 0.22 | 0.042 | 0.87 | 0.25 | 0.079 | 0.85 | 0.64 | 0.14 |
| Bismuth | <10 | <1 | <1 | <10 | <1 | <1 | <5 | <5 | <1 |
| Boron | <10 | <1 | <1 | <10 | <1 | <1 | <5 | <5 | <1 |
| Cadmium | 34 | 7.8 | 1.6 | 40 | 8.9 | 2.8 | 18 | 12 | 2.4 |
| Calcium | 630 | 210 | 350 | 610 | 770 | 450 | 460 | 460 | 470 |
| Chloride | 120 | <100 | 14 | 170 | <100 | 26 | 71 | 51 | 46 |
| Chromium | 11 | 3.8 | 0.46 | 12 | 4.1 | 0.94 | 8.8 | 8.2 | 1.3 |
| Cobalt | 54 | 13 | 2.6 | 77 | 15 | 4.6 | 38 | 30 | 6.2 |
| Copper | 820 | 170 | 78 | 430 | 48 | 33 | 190 | 74 | 35 |
| Fluoride | 100 | <50 | 4.3 | 120 | <50 | 25 | 140 | 81 | <10 |
| Gallium | <10 | <1 | <2 | <10 | <1 | <2 | <5 | <5 | <1 |
| Iron | 6,200 | 790 | 36 | 7,000 | 1,300 | 160 | 3,700 | 2,600 | 260 |
| Lead | 0.2 | 0.01 | <0.1 | 0.21 | 0.011 | <0.1 | 0.98 | 0.74 | <0.1 |
| Lithium | <10 | 1.7 | <1 | <10 | 1.9 | <1 | <5 | <5 | <1 |
| Magnesium | 2,800 | 990 | 200 | 3,400 | 1,100 | 340 | 2,300 | 2,000 | 430 |
| Manganese | 460 | 130 | 25 | 840 | 170 | 48 | 750 | 850 | 170 |
| Mercury | 0.0013 | 0.0016 | 0.0003 | 0.001 | 0.0017 | 0.001 | 0.0019 | 0.0011 | <0.001 |
| Molybdenum | <5 | <0.2 | <0.1 | <1 | <0.2 | <0.1 | 0.5 | <0.5 | <0.1 |
| Nickel | 77 | 20 | 4.1 | 82 | 21 | 6.3 | 46 | 35 | 7.3 |
| Nitrate (N) | <1 | 3.4 | <1 | 4.6 | 3.8 | <1 | 13 | 8.4 | 3.5 |
| Nitrite (N) | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| pH (su) | 1.73 | 2.31 | 2.69 | 1.75 | 2.19 | 2.47 | 1.77 | 1.93 | 2.32 |
| Phosphorus | 520 | 61 | <5 | 510 | 82 | 6.3 | 320 | 190 | 12 |
| Potassium | 260 | 75 | 20 | 530 | 180 | 66 | 150 | 160 | 61 |
| Scandium | <10 | <1 | <1 | <10 | <1 | <1 | <5 | <5 | <1 |
| Selenium | 0.28 | <0.25 | <0.01 | 0.15 | <0.25 | <0.020 | 0.39 | 0.4 | 0.52 |
| Silver | <0.5 | 0.065 | <0.05 | <0.5 | <0.05 | <0.05 | <0.25 | <0.25 | <0.05 |
| Sodium | 8,100 | 1,400 | 300 | 4,900 | 1,500 | 510 | 1,100 | 700 | 170 |
| Strontium | <10 | 1.4 | 1.3 | <10 | 2.2 | 2.6 | 11 | 7 | 3.8 |
| Sulfate | 110,000 | 35,000 | 5,900 | 110,000 | 42,000 | 11,000 | 110,000 | 88,000 | 17,000 |
| Thallium | 0.076 | 0.032 | 0.0071 | 0.037 | 0.026 | 0.008 | 0.0016 | 0.0015 | <0.001 |
| Tin | <10 | <1 | <1 | <10 | <1 | <1 | <5 | <5 | <1 |
| Titanium | <10 | <1 | <1 | <10 | 1.5 | <1 | <5 | <5 | <1 |
| Uranium | 8.8 | 0.01 | 0.32 | 6.6 | 0.011 | 0.5 | 0.01 | <0.01 | 0.43 |
| Vanadium | 10.0 | 0.3 | <0.1 | 12 | 0.2 | <0.1 | 1.8 | 1.7 | 0.23 |
| Zinc | 680 | 160 | 36 | 820 | 180 | 60 | 610 | 680 | 140 |
| Total dissolved solids | 81,000 | 29,000 | 4,700 | 74,000 | 37,000 | 8,200 | 61,000 | 44,000 | 8,800 |
| Calculated total dissolved solids | 135,608 | 40,654 | 7,177 | 134,717 | 49,205 | 13,165 | 123,023 | 98,352 | 19,206 |

## Table A-1. Summary of the column leach chemistry results (McClelland 2008a, 2008b).

| | AC 48 | | | AC-75 | | |
|---|---|---|---|---|---|---|
| | VFZ | | | VFZ | | |
| **Parameters** | **PLS** | **PV # 1** | **PV # 3** | **PLS** | **PV # 1** | **PV # 3** |
| Acidity ($CaCO_3$) | 58,000 | 18,000 | 9,200 | 25,000 | 21,000 | 6,100 |
| Aluminum | 8,400 | 2,100 | 1,200 | 2,700 | 1,600 | 480 |
| Antimony | 0.019 | <0.0025 | <0.0025 | 0.0025 | <0.0025 | <0.0025 |
| Arsenic | 250 | 52 | 11 | 11 | 4.9 | 0.27 |
| Barium | <1 | <0.1 | <0.1 | <0.5 | <0.5 | <0.1 |
| Beryllium | 0.91 | 0.2 | 0.13 | 0.59 | 0.4 | 0.14 |
| Bismuth | <10 | <1 | <1 | <5 | <5 | <1 |
| Boron | <10 | <1 | <1 | <5 | <5 | <1 |
| Cadmium | 40 | 7.1 | 4.7 | 13 | 8.1 | 2.7 |
| Calcium | 590 | 790 | 630 | 500 | 460 | 410 |
| Chloride | 120 | <100 | 29 | 69 | 44 | 58 |
| Chromium | 24 | 5.5 | 3.2 | 6.4 | 3.7 | 0.87 |
| Cobalt | 64 | 10 | 6.8 | 31 | 22 | 7.8 |
| Copper | 620 | 46 | 25 | 170 | 150 | 100 |
| Fluoride | 150 | <50 | 50 | 110 | 66 | <10 |
| Gallium | <10 | <1 | <2 | <5 | <5 | <1 |
| Iron | 7,000 | 800 | 290 | 3,400 | 1,600 | 300 |
| Lead | 0.064 | 0.013 | <0.1 | 1 | <0.5 | <0.1 |
| Lithium | <10 | 1.6 | 1 | <5 | <5 | <1 |
| Magnesium | 4,900 | 1,200 | 800 | 2,500 | 1,600 | 580 |
| Manganese | 640 | 110 | 68 | 1,500 | 1,300 | 540 |
| Mercury | 0.0012 | 0.0004 | 0.0003 | 0.0016 | <0.001 | <0.001 |
| Molybdenum | 1.8 | <0.2 | <0.1 | 0.5 | <0.5 | <0.1 |
| Nickel | 92 | 18 | 12 | 46 | 31 | 11 |
| Nitrate (N) | 5.6 | 3.6 | <1 | 9.9 | 6.4 | 3.9 |
| Nitrite (N) | <1 | <1 | <1 | <1 | <1 | <1 |
| pH (su) | 1.88 | 2.32 | 2.42 | 1.65 | 1.9 | 2.49 |
| Phosphorus | 900 | 110 | 25 | 220 | 86 | 6.4 |
| Potassium | 460 | 150 | 160 | 120 | 70 | 22 |
| Scandium | <10 | <1 | <1 | <5 | <5 | <1 |
| Selenium | 0.89 | 0.028 | 0.058 | 0.89 | 0.46 | 0.16 |
| Silver | <0.5 | <0.05 | <0.05 | <0.25 | <0.25 | <0.05 |
| Sodium | 3,500 | 600 | 390 | 930 | 540 | 180 |
| Strontium | <10 | <1 | 1.1 | 9.8 | 5.6 | 2.6 |
| Sulfate | 130,000 | 40,000 | 19,000 | 110,000 | 66,000 | 21,000 |
| Thallium | 0.026 | 0.0083 | 0.011 | 0.016 | 0.011 | 0.0044 |
| Tin | <10 | <1 | <1 | <5 | <5 | <1 |
| Titanium | <10 | 2.2 | <1 | <5 | <5 | <1 |
| Uranium | 5 | 0.99 | 0.93 | 0.01 | 1.5 | 0.44 |
| Vanadium | 7.9 | 0.21 | <0.2 | 2.1 | 1.4 | 0.2 |
| Zinc | 850 | 140 | 98 | 1600 | 1200 | 450 |
| Total dissolved solids | 96,000 | 31,000 | 16,000 | 56,000 | 37,000 | 13,000 |
| Calculated total dissolved solids | 158,624 | 46,150 | 22,808 | 123,953 | 74,803 | 24,159 |

All units are in mg/L, except for pH.

Sulfate was determined using ion chromatographic (IC) method.