# FLORENCE COPPER, INC.

# UIC PERMIT APPLICATION

# FLORENCE COPPER PROJECT – PRODUCTION TEST FACILITY

## ATTACHMENT H – OPERATING DATA

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## H.1 Introduction

This Attachment H has been prepared in support of an Application by Florence Copper, Inc. (Florence Copper) to the United States Environmental Protection Agency (USEPA) for issuance of an Underground Injection Control Class III (Area) Permit (UIC Permit) for the planned Production Test Facility (PTF), to be located at the Florence Copper Project (FCP) property in Pinal County, Arizona. As required for Attachment H under USEPA Form 7520-6, this Attachment includes information regarding proposed operating data for all injection and recovery wells at the PTF. This Attachment provides background information and data in the order that it is requested in the instructions for Attachment H. The requested information includes:

- Average and maximum daily rate and volume of fluids to be injected;
- Average and maximum injection pressures;
- Nature of the annulus fluid; and
- A qualitative analysis and ranges in concentrations of all constituents of injected fluids.

## H.2 Background

Florence Copper is proposing to operate the PTF to demonstrate the feasibility of developing an in-situ copper recovery (ISCR) facility at the FCP property that will consist, in part, of a closely spaced array of Class III injection wells and recovery wells. The proposed PTF area is approximately 13.8 acres in size.

The UIC Permit is requested to authorize injection and recovery operations in the oxide zone, the upper portion of the bedrock underlying the PTF. The top of the oxide zone is at approximately 450 feet below ground surface at the PTF well field. It has an average thickness of approximately 750 feet beneath the PTF well field. To prevent vertical excursion of injected fluids, the uppermost 40 feet of the oxide zone will be excluded from injection. Consequently, the injection wells constructed at the PTF will have a typical injection interval of 700 feet. Florence Copper has chosen to divide the injection interval for the PTF wells into multiple intervals to focus injection into targeted areas of the oxide zone.

## H.3 Rate and Volume of Fluids to be Injected

Aggregate injection and recovery rates in the PTF well field will be carefully balanced to ensure that hydraulic control will be maintained throughout the portions of the oxide zone in which injection and recovery is occurring from the time that injection begins until the PTF well field is closed in accordance with the requirements of the UIC Permit.

For each well, the rate and daily volume of fluids injected may vary based on the length of the injection interval and the capacity of the oxide zone to transmit fluids at each well site. Because the oxide zone varies in thickness and packers will be used to focus injection, the length of the injection interval in each well will vary accordingly. The rate of fluid injection in wells with longer injection intervals will need to be greater than the rate in wells with shorter injection intervals to maintain a consistent rate of flow through the oxide zone on a per-foot of thickness basis to achieve a target pregnant leach solution (PLS) grade. To maintain PLS grade, injection rates in all wells must be proportionate to the length of the injection interval. Florence Copper proposes an average injection rate of approximately 0.15 gallons per minute per foot (gpm/ft) of injection interval, and a maximum injection rate of approximately 0.20 gpm/ft of injection interval. Injection rates may be lower than the proposed average based on the length of the final injection interval used and the location of packer placement. Typical injection rates may be as low as 0.10 gpm/ft of injection interval depending on formation properties and resulting final packer configuration in each well.

The maximum aggregate injection rate proposed for PTF operations is 240 gpm, and the maximum extraction rate is limited by the capacity of the planned SX/EW plant to 300 gpm. At the maximum injection rate and maximum recovery rate, extraction will exceed injection by 25 percent. The minimum ratio between injection and recovery will be 110 percent. This means that extraction will always be greater than injection by at least 10 percent and as much as 25 percent.

Given the relatively small area of the PTF well field, it is anticipated that the thickness of the oxide zone and the resulting screened interval from well to well will be approximately uniform.

The PTF wells will be constructed with multiple injection intervals separated by sections of blank well casing that will allow packer assemblies to be used to focus injection into targeted intervals of the injection zone.

Table H-1 lists example injection rates and the resulting daily total fluid volumes derived using these rates. The planned aggregate injection rate for the PTF is limited to 240 gpm regardless of well configuration or well performance. If formation performance is uniform, each of the four injection wells will be limited to an injection rate of 60 gpm. Variation in formation performance may require some wells to be operated at rates lower or higher than 60 gpm. In all cases, the aggregate injection rate will be balanced between the four injection wells to ensure that no more than 240 gpm is injected. The values presented in Table H-1 reflect potential injection rates for a variety of well configurations which may be applied to compensate for formation performance. Depending on formation performance, planned injection rates may be less than 0.15 gpm/ft of injection interval.

## H.4 Average and Maximum Injection Pressure

Each of the proposed injection and recovery wells will be completed to Class III injection well standards and individually adjusted for the depth, thickness, and hydraulic characteristics of the portion of the oxide zone penetrated by the well. Because injection pressures are calculated based on the distance from the top of the well casing to the top of the injection interval, variations in well construction depth may in turn result in variation of the average and maximum injection pressures at each well. The calculated average and maximum injection pressures, therefore, will be specific to each of the planned wells. Each well will be constructed to ensure that the injection interval is at least 40 feet below the top of the oxide zone, but spans the remainder of the oxide zone below. Based on available formation thickness data, injection pressures have been calculated for the proposed PTF injection wells and are presented in Table H-2.

Typical wells may include one or more injection intervals ranging in length between 190 and 700 feet. The injection pressures presented herein are calculated by multiplying the depth from the top of well casing to top of the injection interval by a pre-determined factor that is designed to moderate injection pressures and prevent hydraulic fracturing of the formation.

### *H.4.1 Average Injection Pressure*

Average injection pressures are calculated as a function of the dynamic elevation of the column of lixiviant standing above the top of the injection interval during PTF well field operations. For the purposes of estimating the average injection pressure, it is assumed that the dynamic elevation of the injected fluid is equal to the elevation of the well head, and that no additional mechanical pressure is applied.

Typical groundwater will exert a pressure equivalent to 0.43 pounds per square inch per foot (psi/ft) of depth. Although composed primarily of water, lixiviant also includes sulfuric acid and dissolved minerals that will increase the density by an estimated 5 percent. Thus, the lixiviant solution is estimated to exert a pressure equal to approximately 0.45 psi/ft of depth. This is the value used to calculate the average injection pressures at the top of each injection interval.

Average injection pressures are calculated by multiplying the depth to the top of the injection interval from the top of well casing by 0.45 psi/ft. This method reflects a well head pressure that is equal to atmospheric pressure, while the well casing is flooded with lixiviant. The pressure generated at the top of the injection interval results solely from the weight of the column of lixiviant with no additional mechanical pressure applied. Examples of average injection pressure at the anticipated depth of the top of the PTF injection intervals are included in Table H-2.

### *H.4.2 Maximum Injection Pressure*

Formation testing conducted in 1995 by BHP Copper Inc. (BHP Copper) determined a minimum fracture gradient of approximately 0.71 psi/ft for rock within the oxide zone. To ensure that injection pressures did not induce additional fracturing of the oxide zone, UIC Permit No. AZ396000001 issued to BHP Copper for the FCP in 1997 established a fracture gradient limit of 0.65 psi/ft. The fracture gradient packer testing data are included in Attachment I of this Application. Florence Copper proposes to use the 0.65 psi/ft fracture gradient to determine the maximum injection pressure for each injection interval.

Maximum injection pressures are determined by multiplying the fracture gradient limit (0.65 psi/ft) by the depth from the top of well casing to the top of the injection interval. This method of calculating maximum injection pressures reflects the pressure generated by the weight of the column of raffinate and an additional pressure applied by mechanical means to achieve the maximum allowable injection pressure at depth.

As described above, packer assemblies may be used to focus injection in targeted areas of the broader injection zone. Because operational injection pressures are calculated to the top of each injection interval, the length of the interval does not affect the calculated injection pressures. Consequently, if multiple injection intervals are used, the injection pressure will be calculated at the top of the each interval.

Example average and maximum injection pressures at selected depths representing the top of potential injection intervals and the corresponding maximum well head pressures are included in Table H-2.

## H.5 Nature of the Annulus Fluid

Annulus fluid is the fluid that exists between the injection pipe and the interior of the well casing. Over the operational life of a Class III injection well at the FCP site, the nature of the annulus fluid in a given well will vary between native groundwater from the oxide zone, lixiviant solution, and PLS. The estimated composition of native groundwater and the forecast compositions of lixiviant solution are presented in Exhibit H-1. Exhibit H-1 is discussed further in Section H.6.

### *H.5.1 Injection*

The proposed Class III injection wells may be operated in one of two modes: pressurized at the well head with an injection pipe and packer assembly, or under atmospheric well head pressures with only an injection pipe. The nature of the annulus fluid under each of these injection conditions is described below.

#### H.5.1.1 Pressurized Injection

Under pressurized operation, an injection pipe and packer assembly will be used to isolate and focus injection into a targeted injection interval. The packer assembly will include packer(s) placed at the top and bottom (if required) of the injection interval. For new wells, the well will contain only native groundwater and when the packer assembly is inflated, native groundwater will be trapped in the annulus above the uppermost packer.

After operations have commenced, the packer assembly may periodically be deflated so the assembly can be moved between injection intervals within the injection zone. Deflation and moving of the packer assembly will result in incidental mixing of the native groundwater from the oxide zone, initially trapped above the uppermost packer with the lixiviant solution until eventually the composition of the annulus fluid reflects lixiviant solution.

#### H.5.1.2 Injection at Atmospheric Well Head Pressures

Under atmospheric well head pressure, lixiviant solution will be introduced with an injection pipe that discharges below the static fluid level in the well. Groundwater will not be isolated above a packer assembly. Operation under atmospheric well head pressure will flood the annulus with lixiviant solution for the entire length of the well at the commencement of operations and will maintain that condition throughout the period of injection.

### *H.5.2 Recovery*

All wells used for recovering PLS will be constructed to Class III well standards. Annulus fluid within new recovery wells will initially be oxide zone groundwater. As injection begins and fluids are recovered from the injection zone and pumped back to the surface, the annulus of the recovery wells will be flooded with PLS at atmospheric pressure.

## H.6 Qualitative Analysis of Constituents in Injected Fluid

Monitoring of injected fluid is required by 40 Code of Federal Regulations (CFR) 146.33(b)(1) at a sufficient frequency to yield representative data describing fluid characteristics. Permittees are required by 40 CFR 146.34(a)(7)(iii) to provide a qualitative analysis and ranges of concentrations of all constituents in the injected fluids. A new analysis is required by 40 CFR 146.33(b)(1) whenever the injected fluid is modified to the extent that the existing data is incomplete or incorrect, and the new data must be submitted pursuant to 40 CFR 146.34(a)(7)(iii).

Florence Copper requests that the UIC Permit authorize the injection of fresh water, solutions of sodium carbonate or other neutralizing agents, and lixiviant used to dissolve copper. The lixiviant solution will be generated on site starting with the commencement of PTF operations. The initial lixiviant solution will be composed of water and sulfuric acid, and can be considered an "immature" solution. Once this solution has been circulated through the oxide zone and recovered as PLS, and the copper has been recovered from the solution by the solvent extraction/electrowinning (SX/EW) process, the solution will be re-acidified and re-injected.

At the outset of PTF operations, the solution may be re-acidified and re-injected without recovering the copper by SX/EW until the copper concentration is sufficiently high to begin SX/EW recovery. With each injection and recovery cycle, the solution will accumulate constituents dissolved from the oxide zone. A "mature" lixiviant solution is one that has been acidified and circulated through the oxide zone and SX/EW process a sufficient number of times to reach equilibrium concentrations of dissolved constituents. The lixiviant solution will be recycled for the duration of PTF operations.

The typical concentrations of dissolved constituents that will occur in the mature lixiviant solution during PTF operations can only be estimated at this time because actual constituent concentrations can only be measured during the injection and recovery of an acidified solution though the oxide zone at a scale and duration representative of PTF operations, and no injection and recovery has yet been conducted at that scale or duration.

### *H.6.1 Injectate (Lixiviant) Solution Composition*

Florence Copper proposes that "lixiviant" be used to refer to the solution prepared for injection and "raffinate" be used to refer to PLS after it has been processed in the SX/EW plant. The composition and constituent concentrations of PLS and raffinate are similar except that the SX/EW process removes approximately 90 percent of the copper from the PLS and causes a downward shift in pH. Florence Copper bases its proposal on the recognition that the "barren" PLS (or raffinate) exiting the SX/EW plant may need to be treated before it is ready for re-injection. Thus, "lixiviant" is proposed to distinguish between the solution that is ready for re-injection and the barren PLS solution, or raffinate, that has exited the SX/EW plant but has not been prepared for re-injection.

Organic constituents in in-situ solutions result from the contact of PLS with organic process chemicals in the SX/EW plant. Florence Copper proposes to limit the total concentration of organic constituents in the lixiviant solution to 10 milligrams per liter (mg/L). The organic constituents include polynuclear aromatic hydrocarbons (PAHs) derived from the kerosene type fluid used in the SX process. The composition of the organic compounds in the lixiviant solution can be controlled by specifying the quality of process chemicals purchased. Their concentrations can be controlled by the equipment process controls and the protocols for the SX/EW plant and mixing facilities.

Inorganic constituents in the in-situ solutions are a product of both process chemicals as well as chemical reactions resulting from the interaction of lixiviant solution with the host rock of the oxide zone during PTF well field operations. They will be variable in both composition and concentration. Some constituents are relatively predictable because their sources are the inorganic chemicals (such as sulfuric acid and calcium carbonate that will be mixed to acidify or neutralize solutions) which are controlled and measurable; however, other constituents are a function of the interaction between the injection fluids, pH of injection fluids, existing groundwater, and the solubility of minerals present in the oxide zone. Their composition and concentration will be difficult to validate until the injection and recovery process has continued for enough time to develop a mature PLS, and sufficient operational data are available. Therefore, a qualitative analysis of constituents in lixiviant solution cannot be definitively provided at this time until a mature PLS solution is produced from PTF operations.

### *H.6.2 Previous Studies*

Two studies have been conducted in an effort to forecast the character and range of constituent concentrations in in-situ solutions that will be produced during ISCR operations at the FCP site. One study was conducted in 1995 and reported in Section 3 of Volume IV of the Aquifer Protection Permit (APP) application that BHP Copper submitted to the Arizona Department of Environmental Quality (ADEQ) in January 1996 (1996 Application), concurrent with its application to USEPA for UIC Permit No. AZ396000001. A summary of the results of that study was included in Table 4.3-1 of Volume 1 of the 1996 Application (included as Exhibit H-2 of this Attachment), and made part of the UIC Permit and of APP No. 101704 that ADEQ subsequently issued to BHP Copper in 1997. Solution compositions were re-evaluated by Daniel B Stephens and Associates in April 2014 on behalf of Florence Copper, to update and expand on the information in Table 4.3-1. Both studies are briefly discussed below.

As explained in Section 3, Volume 4 of the 1996 Application, forecast compositions of in-situ solutions were developed from geochemical models that were based on column tests of core samples collected from the FCP site. The core samples were collected from a number of locations within the oxide zone of the bedrock underlying the FCP site; this is the same bedrock oxide zone proposed for PTF operations. Some of the forecast compositions shown in Table 4.3-1 (Exhibit H-2) were developed from those models; however, the compositions of PLS and lixiviant solution (referred to as raffinate in Table 4.3-1) were based on actual process data from BHP Copper's copper leach in-situ operation at San Manuel, Arizona. The solution data from San Manuel were preferred because those solutions had been in contact with more copper oxide ore for a longer period of time and were therefore more mature than the solutions used in the column tests, and were likely to show more representative mineral concentrations than the less mature solutions from the BHP column tests.

Florence Copper retained the services of Daniel B Stephens & Associates (DBS&A) to use PTF site specific data and current geochemical modeling software to evaluate and refine the composition forecasts reported previously by BHP Copper in Table 4.3-1. As discussed in Exhibit H-1 of this Attachment, DBS&A used data generated by long term leaching test conducted by METCON laboratories of Tucson Arizona, using core samples collected from the oxide zone at the PTF well field site, and groundwater collected from the oxide zone near the PTF well field site. The DBS&A modeling results are presented in Exhibit H-1, and the forecast compositions produced by the modeling results are summarized in Table 3.1 of Exhibit H-1.

The DBS&A model did not use the PLS and raffinate data reported by BHP in Table 4.3-1 (Exhibit H-2) because those data were based on PLS and raffinate produced at BHP Copper's San Manuel deposit, which might have been significantly different geochemically than the oxide zone beneath the FCP site. The hydraulic control test conducted by BHP Copper at the FCP site was too short to produce solutions that could approximate equilibrium conditions of the minerals dissolved in solutions at the FCP. Accordingly, the estimated constituent concentrations derived by DBS&A do not represent anticipated maximum concentrations, or a range of concentrations. Rather, the concentrations provided in Table 3.1 of Exhibit H-1 represent potential typical constituent concentrations that must be validated by field-scale testing.

Florence Copper proposes to construct and operate the PTF to produce process solutions that are representative of commercial scale copper production. The PTF will produce in-situ solutions sufficiently mature to evaluate and fine-tune process treatment technologies and identify opportunities for groundwater conservation. Florence Copper estimates that mature PLS can be produced within 12 months after commencing PTF operations, and that the resulting data can then be used in geochemical models to accurately forecast the range of inorganic constituents in lixiviant solutions and PLS that can be reasonably expected over the life of operations at the FCP. At the conclusion of PTF operations, Table 3.1 will be amended to reflect solution compositions generated during PTF operations.

### *H.6.3 Forecast Composition of Raffinate*

The fourth column form the left of Table 3.1 of Exhibit H-1 shows the estimated forecast composition of raffinate. The composition is based on the assumption that the solution after processing in the SX/EW plant may have a composition similar to the PLS composition (fourth column from the left of Table 3.1), with the exception that it will have lower copper concentrations and lower pH. Raffinate will exit the SX/EW plant and be directed to the raffinate pond before it is piped to the PTF well field and acidified, as needed, prior to injection as lixiviant.

### *H.6.4 Forecast Composition of Pre-Stacked PLS*

No solution stacking is proposed for PTF operations. Solution stacking refers to the practice of staging and re-injecting intermediate grade solutions to manage overall PLS grade during commercial copper recovery.

At PTF startup, recovered solution will be re-acidified and re-injected until copper concentrations reach a level sufficient to achieve SX/EW copper recovery. Once SX/EW operations begin, solutions will only be re-injected following SX/EW copper recovery. Consequently, no pre-stacked solution composition is included in Table 3.1 of Exhibit H-1.

### *H.6.5 Estimated Composition of 98 Percent $H_2SO_4$*

The third column from the left of Table 3.1 of Exhibit H-1 shows the estimated composition of 98 percent sulfuric acid. Sulfuric acid is typically produced from the recovery of sulfur dioxide at a smelter facility. The composition shown is representative of the sulfuric acid generated at the ASARCO Hayden smelter, and is typical of acid that will be delivered to the PTF for acidifying raffinate during PTF operations.

### *H.6.6 Estimated Composition of Make-up Water*

The extreme right hand column of Table 3.1 of Exhibit H-1 shows the estimated composition of groundwater that would be used as make-up water during PTF operations. Make-up water will be obtained from an existing well named PW2-1, located east of the PTF well field and outside of the AOR.

Table H-1. Injection Rates and Volumes

| | Injection Interval Length (Feet) | Typical Injection Rate at 0.15 gpm/ft (gpm) | Typical Injection Rate at 0.20 gpm/ft (gpm) | Daily Injection Volume at 0.15 gpm/ft (gallons) | Daily Injection Volume at 0.20 gpm/ft (gallons) |
|---|---|---|---|---|---|
| Well with Shortest Injection Interval | 190 | 29 | 38 | 41,760 | 54,720 |
| Well with Typical Length Injection Interval | 400 | 60* | 80* | 86,400* | 115,200* |
| Well with Longest Injection Interval | 700 | 105* | 140* | 151,200* | 201,600* |

*gpm = gallons per minute*
*gpm/ft = gallons per minute per foot*
**The values provided in this Table are for a single injection well using a variety of injection interval lengths and injection rates. The maximum aggregate injection rate for the four injection wells planned for PTF operations is limited to 240 gpm regardless of well configuration or formation performance. It is anticipated that well performance may be variable, and that some of the four injection wells may accept less than 25% of the aggregate injection rate, and that some wells may accept more than 25% of the aggregate injection rate. The upper range of potential injection rates for a single well is reflected in the range of values provided in this Table. The lower range of injection rates will not be defined until the planned injection wells are drilled and the formation exposed to those wells characterized. In all cases, the injection rates at each of the four injection wells will be balanced to ensure that the aggregate injection rate of 240 gpm is not exceeded.*

Table H-2. Example Calculated Average and Maximum Injection Pressures for Selected Injection Intervals

| Depth to top of Injection Interval (Feet) | Average Injection Pressure at Top of Injection Interval (psi) | Average Well Head Pressure (psi) | Maximum Injection Pressure at Top of Injection Zone (psi) | Maximum Well Head Pressure (psi) |
|---|---|---|---|---|
| 500 | 225 | Atmospheric | 325 | 100 |
| 690 | 311 | Atmospheric | 449 | 138 |
| 880 | 396 | Atmospheric | 572 | 176 |

*psi = pounds per square inch*

# Exhibit H-1

## Geochemical Evaluation of Forecast Process Solutions at Florence Copper Project

# Geochemical Evaluation to Forecast Composition of Process Solutions for In-Situ Copper Recovery Pilot Test Facility at Florence Copper, Florence, Arizona

**Prepared for** **Florence Copper, Inc.**
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# Geochemical Evaluation to Forecast Composition of Process Solutions for In-Situ Copper Recovery Pilot Test Facility at Florence Copper, Florence, Arizona

Florence Copper, Inc. requested Daniel B. Stephens & Associates, Inc. (DBS&A) to evaluate the geochemistry of process solutions for their in-situ copper recovery (ISCR) pilot test facility near Florence, Arizona. Schlumberger (2012) provides an overview of the project, as well as a description of this previous geochemical investigation that forecasts chemistry of various process solutions. The calculations and methods presented within this report continue the efforts of Schlumberger (2012) in order to forecast water quality of the various process solutions. The current work uses new data available from metallurgical laboratory and water quality testing.

The values shown in Table 3.1 represent estimated forecasted solution compositions derived from best available data that include both laboratory analyses and geochemical model simulations. The values shown in Table 3.1 represent solution compositions that may reasonably be expected to occur during pilot test facility operations. Solution compositions observed during pilot test facility operations may vary from those shown in Table 3.1 based on natural mineralogical and chemistry variations existing in the formation.

## 1. Data Sources

In addition to Schlumberger (2012), sources of data include two laboratory analytical reports that provide results of ongoing metallurgical testing that evaluated leaching characteristics of samples from the site and also for an onsite supply well. Metallurgical testing consisting of unpressurized leach boxes and pressurized leach pipes (simulating in situ pressure), has been ongoing since 2011 at SGS/METCON in Tucson, Arizona. This work has recycled process solutions and developed site-specific mature pregnant leach solution (PLS) and raffinate. PLS generated in the SGS laboratory was run at Turner Laboratories in Tucson, Arizona (Turner, 2014a; laboratory sample ID 14C0293-01) and was used to forecast composition of mature PLS, raffinate, lime-neutralized raffinate sent to the evaporation impoundment, and sediments in the impoundment that form during evaporation. Water quality data for the makeup solution is

represented by groundwater supply well PW2-1 (Turner, 2014b, laboratory sample ID 14C0493-01). Forecasted composition of pregnant electrolyte solution from Schlumberger (2012) was deemed to be within normal solution extraction (SX) process solution ranges and was carried over from the Schlumberger (2012) document. Composition of concentrated sulfuric acid from a regional ASARCO smelter was provided by a vendor.

## 2. Geochemical Modeling of Process Solutions

Two geochemical modeling programs were used to forecast the composition of these solutions. PHREEQC (Parkhurst and Appelo, 1999) was used for equilibrium modeling, addition of amendments, and evaporation calculations. Geochemist's Workbench (Bethke and Yeakel, 2012a and 2012b) was used for reactive transport simulations to determine water quality during the block rinsing phase of the project.

The forecasted composition of PLS is based on composite data for metallurgical testing experiments performed at SGS/METCON in Tucson, Arizona on samples of oxide copper ore from the Florence Copper site. The PLS sample (Turner laboratory sample ID 14C0293-01) with a total copper concentration of 1,900 milligrams per liter (mg/L) was scaled up by a factor of 1.053 to match the copper grade in PLS of 2,000 mg/L expected during operations. Sulfate concentrations were altered in PHREEQC to charge balance the sample and maintain electrical neutrality.

The results forecasted for the PLS were used to calculate the composition of raffinate, which is the term used to designate PLS after the copper has been removed by the SX process. Copper concentrations were reduced to approximately 208 mg/L, and the subsequent water quality was charge balanced and equilibrated with sulfuric acid to a pH of 1.4 in PHREEQC.

The raffinate solution composition determined in PHRREQC was used to forecast the chemistry of a neutralized raffinate solution discharged to a surface impoundment. The raffinate was amended with lime (CaO) at a rate of 9 grams per liter (g/L) to bring the pH to a value of 6.2.

The amended raffinate was evaporated in PHREEQC to approximately 5 percent of its original volume to predict the chemistry of solids precipitating out of solution in the impoundment.

Minerals precipitating out of solution were dominated by gypsum ($CaSO_4 \cdot 2H_2O$) and sulfate salts due to the high initial concentration of sulfate in the raffinate.

Block rinsing following ISCR was modeled in Geochemist's Workbench. Injection of a 6 g/L sodium carbonate solution ($Na_2CO_3$), known as amended rinse solution, was run until sulfate concentrations were below the closure goal of 750 mg/L sulfate and pH raised to a value of 7. The amended solution was run for 6 pore volumes to allow for neutralization of residual acidity and reduce the total dissolved solids.

## References

Bethke, C.M. and S. Yeakel. 2012a. *The Geochemist's Workbench, Release 9.0: Reaction modeling guide*. Aqueous Solutions LLC, Champaign, Illinois.

Bethke, C.M. and S. Yeakel. 2012b. *The Geochemist's Workbench, Release 9.0: Reactive transport modeling guide*. Aqueous Solutions LLC, Champaign, Illinois.

Parkhurst, D.L. and A.A.J. Appelo. 1999. *User's guide to PHREEQC (version 2): A computer program for speciation, batch-reaction, one dimensional transport, and inverse geochemical modeling*. U.S. Geological Survey Water-Resources Investigation Report 99-4259.

Schlumberger Water Services Inc. (Schlumberger). 2012. Technical memorandum from Drummond Early to Daniel Johnson, Curis Resources Ltd., regarding Geochemical evaluation of forecast process solutions at Florence Copper project for pilot testing of in-situ copper recovery. February 22, 2012.

Turner Laboratories Inc. (Turner). 2014a. Water testing laboratory report. Work Order No.: 14C0293. Prepared for R.R. Carnerio, SGS Metcon. April 3, 2014.

Turner. 2014b. Water testing laboratory report. Work Order No.: 14C0493. Prepared for I. Ream, Florence Copper Inc. April 9, 2014.

## Table 3.1. Estimated Composition of Pilot Test Facility Process Solutions


| Analyte | Arizona Water Quality Standard (mg/L) | Forecasted Concentration (mg/L [a]) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Composition of 98% $H_2SO_4$ | PLS | Raffinate | Pregnant Electrolyte (SX Solution) | Water Impoundment Solution with 9 g/L Lime Treatment | Water Impoundment After Evaporation (mg/kg) | Groundwater After Block Rinsing | Makeup Water [b] |
| *Metals* | | | | | | | | | |
| Aluminum | None | — | 1,642 | 1,639 | 110 | 1,569 | 63,380 | 0.30 | <2.0 |
| Antimony | 0.006 | 0.05–0.15 | — | — | 0.10 | — | — | <0.2 | <0.2 |
| Arsenic | 0.05 | 0.1–0.4 | 1.32 | 1.32 | 0.06 | 1.33 | 53.58 | <0.0005 | <0.0005 |
| Barium | 2 | — | 0.55 | 0.55 | < 0.2 | 0.55 | 22.14 | <0.05 | <0.05 |
| Beryllium | 0.004 | — | 0.09 | 0.09 | — | 0.09 | 3.59 | <0.002 | <0.002 |
| Cadmium | 0.005 | — | 0.24 | 0.24 | 25.0 | 0.24 | 9.74 | <0.002 | <0.002 |
| Calcium | None | — | 449 | 448 | 90 | 4,180 | 168,740 | 11.8 | 61 |
| Chromium | 0.1 | — | 0.74 | 0.73 | 15 | 0.74 | 29.8 | <0.03 | <0.03 |
| Cobalt | None | — | 1.1 | 1.09 | 15 | 1.1 | 44.27 | <0.1 | <0.1 |
| Copper | None | 0.2–0.5 | 2,080 | 208 | 51,000 | 208 | 8,410 | 1.44 | 0.044 |
| Iron | None | 7–14 | 1,314 | 1,310 | 1,650 | 1 | 26.41 | <0.001 | 0.34 |
| Lead | 0.05 | 0.1–0.7 | 0.44 | 0.44 | < 1.0 | 0.44 | 17.7 | <0.04 | <0.04 |
| Magnesium | None | — | 1,204 | 1,202 | 160 | 1,198 | 48,430 | 24.40 | 14 |
| Manganese | None | 0.05–0.15 | 15.3 | 15.3 | 0.014 | 15.3 | 620 | 0.05 | <0.02 |
| Mercury | 0.002 | — | — | — | < 0.01 | — | — | <0.001 | <0.001 |
| Nickel | 0.1 | 0.07–0.2 | 2.3 | 2.3 | 35 | 2.3 | 93 | <0.05 | <0.05 |
| Potassium | None | — | 372 | 372 | < 0.01 | 344 | 13,900 | 55.0 | 6.2 |

[a] Unless otherwise noted
[b] Makeup water results from well PW2-1 sampled March 12, 2014 (Turner Laboratories [Tucson] work order 14C0493)
[c] Turner Laboratories result

mg/L = Milligrams per liter
$H_2SO_4$ = Sulfuric acid
PLS = Pregnant leach solution
g/L = Grams per liter
mg/kg = Milligrams per kilogram
— = Not estimated

## Table 3.1. Estimated Composition of Pilot Test Facility Process Solutions


| Analyte | Arizona Water Quality Standard (mg/L) | Forecasted Concentration (mg/L [a]) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Composition of 98% $H_2SO_4$ | PLS | Raffinate | Pregnant Electrolyte (SX Solution) | Water Impoundment Solution with 9 g/L Lime Treatment | Water Impoundment After Evaporation (mg/kg) | Groundwater After Block Rinsing | Makeup Water [b] |
| *Metals (cont.)* | | | | | | | | | |
| Selenium | 0.05 | — | 0.44 | 0.4 | < 0.1 | 0.4 | 18 | <0.04 | <0.04 |
| Silver | None | — | 0.11 | 0.11 | < 0.01 | 0.11 | 1.09 | <0.1 | <0.1 |
| Sodium | None | — | 164.2 | 163.9 | 110 | 164.4 | 6,640 | 1,203 | 120 |
| Thallium | 0.002 | — | 0.55 | 0.6 | 0.1 | 0.6 | 22 | <0.05 | <0.05 |
| Zinc | None | 0.05–0.75 | 7.6 | 7.5 | 0.06 | 7.6 | 305 | — | 0.095 |
| *Anions* | | | | | | | | | |
| Bicarbonate | None | — | — | <1 | <1 | 1.86 | 75 | 3,180 | 160 |
| Chloride | None | <1 | 296 | 295 | 25 | 296 | 11,950 | 159 | 160 |
| Fluoride | 4 | — | 230 | 230 | <1 | 230 | 9,300 | 1 | <0.5 |
| Nitrate | None | <5 | 24 | 24 | — | 24 | 974 | 1.9 | 1.9 |
| Phosphate | None | — | — | — | <0.5 | — | — | <0.5 | <0.5 |
| Sulfate | None | 954,000 | 24,226 | 23,055 | 214,000 | 16,780 | 678,280 | 507 | 76 |
| *Field Parameters* | | | | | | | | | |
| TDS | None | — | 32,410 | 29,350 | 267,483 | 25,146 | — | 5,150 | 550 [c] |
| pH | None | — | 1.57 | 1.4 | 0.01 | 6.2 | — | 7.0 | 7.2 |
| *Radiochemicals* | | | | | | | | | |
| Uranium | None | — | 4.1 | 4.1 | — | 4.1 | 163 | — | 0.013 |

[a] Unless otherwise noted
[b] Makeup water results from well PW2-1 sampled March 12, 2014 (Turner Laboratories [Tucson] work order 14C0493)
[c] Turner Laboratories result

mg/L = Milligrams per liter
$H_2SO_4$ = Sulfuric acid
PLS = Pregnant leach solution
g/L = Grams per liter
mg/kg = Milligrams per kilogram
— = Not estimated

# Exhibit H-2

## Characteristics of Process Fluids and Waste Streams (Table 4.3-1)

# EXHIBIT H-2

**Table 4.3-1. Characteristics of Process Fluids and Waste Streams in Milligrams per Liter (mg/L)**

| Analyte | Composition of 93 Percent $H_2S04$ | Forecast Composition of PLS | Forecast Composition of Raffinate | Estimated Pregnant Electrolyte (SX solution) | Estimated Evaporation Pond Solution | Estimated Tailings/ Evaporate Salts | Estimated Composition of Solution During Block Wash | Estimated Composition of Solution During Natural Attenuation After Block Wash | Make-up Water |
|---|---|---|---|---|---|---|---|---|---|
| Aluminum | 0.012 | 8,950 | 9,700 | 110 | 35,000 | 3.45 percent | 41.26 | < 1.0 | < 0.10 |
| Antimony | 0.012 | < 0.1 | < 0.1 | 0.10 | 0.2 | < 0.1 | < 0.01 | < 0.02 | < 0.005 |
| Arsenic | 0.13 | 5.10 | 6.60 | 0.06 | 30.00 | 23.0 | < 0.05 | < 0.05 | < 0.002 |
| Barium | < 0.01 | < 0.2 | < 0.2 | < 0.2 | 1.0 | 0.05 | < 0.02 | < 0.1 | 0.08 |
| Cadmium | 0.039 | < 5.0 | < 5.0 | 25.0 | 5 | < 5 | < 5 | < 5 | < 0.005 |
| Calcium | 8.5 | 610 | 560 | 90 | 560 | 400 | 159 | 152 | 192 |
| Chromium | 0.045 | 9 | 4 | 15 | 120 | 400 | < 1 | < 1 | < 0.005 |
| Cobalt | < 0.01 | 21 | 22 | 15 | 22 | 100 | < 0.1 | < 0.001 | < 0.04 |
| Copper | 0.15 | 2,000 | 200 | 51,000 | 3,600 | 1,000 | 3.3 | < 0.5 | < 0.02 |
| Iron | 16.0 | 2,000 | 1,500 | 1,650 | 8,000 | 5,800 | < 0.005 | < 0.001 | < 0.04 |
| Lead | 0.19 | < 1.0 | < 1.0 | < 1.0 | < 1.0 | < 10.0 | < 0.002 | < 0.002 | < 0.002 |
| Magnesium | NA | 10,000 | 9,900 | 160 | 9,900 | 3.65 percent | 63 | 121 | 5.5 |
| Manganese | 0.045 | 1.15 | 1.20 | 0.014 | 4.550 | 4,600 | < 0.01 | < 0.01 | < 0.01 |
| Mercury | 0.013 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.1 | < 0.002 | < 0.002 | < 0.0002 |
| Nickel | 0.06 | 26 | 24 | 35 | 60 | 250 | < 0.001 | < 0.01 | < 0.04 |
| Potassium | 0.8 | 80 | 70 | < 0.01 | 250 | 500 | 7 | 147 | 7.5 |
| Selenium | < 0.02 | < 0.1 | < 0.1 | < 0.1 | < 0.1 | < 0.1 | < 0.1 | < 0.1 | < 0.004 |
| Silver | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.1 | < 0.01 | < 0.01 | < 0.01 |

**Table 4.3-1. Characteristics of Process Fluids and Waste Streams in Milligrams per Liter (mg/L)**

| Analyte | Composition of 93 Percent $H_2S04$ | Forecast Composition of PLS | Forecast Composition of Raffinate | Estimated Pregnant Electrolyte (SX solution) | Estimated Evaporation Pond Solution | Estimated Tailings/ Evaporate Salts | Estimated Composition of Solution During Block Wash | Estimated Composition of Solution During Natural Attenuation After Block Wash | Make-up Water |
|---|---|---|---|---|---|---|---|---|---|
| Sodium | 11.0 | 320 | 320 | 110 | 1,700 | 1,300 | 181 | 246 | 200 |
| Thallium | < 0.01 | < .003 | < 0.003 | < .003 | < .01 | < .01 | < 0.003 | < 0.003 | < 0.003 |
| Zinc | 0.27 | 105 | 100 | 245 | 395 | 310 | < 0.5 | < 1 | < 0.01 |
| Bicarbonate | < 1 | < 1 | < 1 | < 1 | NA | NA | 0.65 | 0.65 | 270 |
| Chloride | < 1.0 | 115 | 115 | 25 | NA | 3,700 | 387 | 393 | 320 |
| Fluoride | NA | 87 | 87 | < 1 | NA | NA | < 1.0 | < 1.0 | 0.69 |
| Nitrate | NA | NA | NA | NA | NA | NA | NA | NA | 110.00 |
| Phosphate | 0.13 | < .5 | < .5 | < .5 | 40 | < 10 | < 0.5 | < 0.5 | < 0.20 |
| TDS | 184,000 | 116,000 | 111,000 | 108 | 415 | NA | 1,000 | 1,000 | 1,500 |
| Sulfate | 93 percent $H_2S04$ | 93,700 | 96,600 | 214,000 | 41,000 | 33.2 percent | 750 | 750 | 350 |
| pH | | 1.82 | 1.83 | < 0.01 | 7.21 | 7.2 | 3.3 | 7.6 | 7.30 |

[a] Examples of solution composition during natural attenuation process.

NA - Not included in analyses
TDS - Total Dissolved Solids