Cameco

40-8964

July 24, 2017

CAMECO RESOURCES
Smith Ranch-Highland Operation
Mail:
P.O. Box 1210
Glenrock, WY
82637 USA

Tel: (307) 358-6541
Fax: (307) 358-4533
www.cameco.com

CERTIFIED MAIL # 7015 1520 0001 9364 3203

Ms. Andrea Kock, Deputy Director
Division of Decommissioning, Uranium Recovery, and Waste Program
Office of Nuclear Material Safety and Safeguards
U.S. Nuclear Regulatory Commission
Mailstop T8 F5
11545 Rockville Pike
Two White Flint North
Rockville, MD 20852-2738

Mine Unit 1 Stability Report, Smith Ranch-Highland Uranium Project, NRC License SUA-1548

Dear Ms. Kock:

Power Resources, Inc. d/b/a Cameco Resources (Cameco) is herein providing a Stability Report (Report) for Mine Unit 1 of the Smith Ranch-Highland Uranium Project to the U.S. Nuclear Regulatory Commission (NRC). The Report demonstrates the requisite stability of elements of concern and other parameters following groundwater restoration efforts in Mine Unit 1.

Cameco's demonstration of geochemical stability applies robust statistical methods using ProUCL, a 95% confidence level, and the Mann-Kendall stability analysis approach. The Mann-Kendall approach is one of the robust statistical methods suggested for use by the U.S. Environmental Protection Agency (EPA) in its 10 CFR Part 192 and its guidance on statistical analysis of groundwater monitoring data at RCRA facilities. The NRC concurred that this approach is acceptable at a Public Meeting held September 14, 2016, Docket Numbers 40-8965 and 40-8943.

In its forthcoming ACL application, Cameco is confident it will be able to demonstrate the restoration efforts in Mine Unit 1 are protective of the surrounding USDW's, human health, and the environment. Cameco agreed to submit a stability monitoring report for Mine Unit 1 in advance of and separate from that ACL application so that NRC could provide feedback on data requirements and analytical methodologies that may be helpful for other uranium recovery licensees preparing similar reports. While Cameco would welcome the NRC's views on the enclosed Report at any time, we would appreciate it if any feedback could be provided within 60

NMSS01

days so as to avoid unnecessary delay in submittal of the ACL application, which is currently planned for early September 2017.

Please contact me at 307-358-6541, ext. 438 or email to Lawrence_Reimann@cameco.com if you have questions.

Respectfully,

Larry Reimann
Manager of Compliance & Licensing

LR/kg

Attachments: Mine Unit 1 Stability Report and CD (containing data)

cc: File SR 4.6.4.1
Document Control Desk, NRC CERTIFIED MAIL # 7015 1520 0001 9364 3210
Robin Jones, WDEQ-LQD CERTIFIED MAIL # 7015 1520 0001 9364 3227

ec: Cameco Distribution

Stability Report for Mine Unit 1

June 24, 2017

INTRODUCTION

This report was requested by the Nuclear Regulatory Commission (NRC) during a meeting of Cameco Resources (CR) and NRC representatives held on September 14, 2016. The purpose of the meeting was to discuss the data and methods used to assess geochemical stability for Mine Unit 1 at the Smith Ranch-Highland mine.

Stability is a measure of the trend over time in dissolved concentrations of elements of concern (EOC) and other parameters (such as pH) included in the baseline sampling conducted at the onset of mining Mine Unit 1. All parameters were found to be stable for Mine Unit 1 (i.e., no statistically significant upward or downward trend were found using mine unit-wide averaging of individual well values).

The narrative here is confined to the restoration zone baseline monitor wells (B1 through B19). This report does not discuss Best Practicable Technology, Restoration Target Values, ring monitor wells, and other items of interest that will be addressed in an Alternate Concentration Limit (ACL) application for Mine Unit 1. The information and conclusions presented herein form the basis for the stability discussion in the forthcoming Mine Unit 1 ACL application.

STABILITY SAMPLING

The stability period for Mine Unit 1 began in September, 2014. There are 19 wells for monitoring and compliance purposes completed in the restoration zone of Mine Unit 1. All sampling used for trend analyses was completed after the circulation of water in the mine unit had ceased. The only pumping undertaken during stability testing was for the purpose of obtaining samples and consisted of approximately three casing volumes per sampled well. Furthermore, overlying and underlying monitor wells and the ring monitor wells were only pumped for compliance sampling at two-month intervals as prescribed by the NRC license and state permit for excursion monitoring.

The minimum stability period for Mine Unit 1 is defined as six months in the license issued by the NRC. The minimum stability period specified by the current state of Wyoming permit is one year. Therefore, for the purpose of this report, the minimum stability period is taken to be one year. This report assumes that one year encompasses five sampling rounds starting at time "zero" (the initial round) with further sampling rounds occurring in each of quarters one through four after time zero. However, eight full rounds of sampling were undertaken to improve the quality of the statistical analysis. Round eight was done one year after round seven to ensure there were no unexpected changes in wellfield chemistry during the intervening year.

RESULTS AND DISCUSSION

Mine Unit-wide stability as prescribed in the license

Included with this report are the following Excel workbooks that each contain Mine Unit 1 stability data in different formats: 1) ***MU-1 Groundwater Quality Summary.xlsx***; 2)

MineUnit1WorksheetsForMedianTrending; 3) ***MU-1 Distribution.xlsx***; 4) M***ineUnit1BaselineData.xls,*** and 5) ***Mine Unit 1 Field pH Measurements***. Also included with this report are the analytical reports from Inter-mountain Labs (IML) for each round of sampling.

Workbook 1) consolidates all of the Mine Unit 1 stability data and provides an historical perspective on the restoration of Mine Unit 1. The data in Workbook 2) distills trending results for Mine Unit 1 into a series of graphs with supporting statistical information. Workbook 3) contains the same data as Workbook 1) but arranges it in a column format amenable to ProUCL version 5.0 input for distribution testing and median determination. 95% confidence levels were used for all statistical tests. Workbook 4) contains all of the pre-mining baseline data for Mine Unit 1 for both the ring monitor wells (this data is not discussed here) and the restoration zone wells. It is provided so that reviewers can compare pre-mining restoration zone well data to the stability results. Workbook 5) contains all field pH data.

Not all components of the Wyoming Department of Environmental Quality (WDEQ) Land Quality Division (LQD) guideline 8 requirements are included in this stability report because visual inspection indicated that the concentrations of some chemical species were consistently below the detection limits of the methods of chemical analysis while others, though clearly detectable, did not show an upward trend.

Both the NRC license and the state permit specify that restoration goals be determined using "average" values for EOCs on a mine unit-wide basis (see paragraph 10.1.9a. of license SUA-1548, amendment 24). The appropriate average is the arithmetic mean for normally-distributed data, but for those cases where the data distribution is non-normal, the median is a better indicator of the average value of an array of numbers.[1] Data distributions were determined using the ProUCL goodness-of-fit (GOF) function.

Workbook 3) is formatted in a manner that allowed for easy use with ProUCL. Data in this work is grouped by sampling event. Each column of data contains only results for a single parameter and a single sampling round for all 19 wells. Thus, by specifying a single worksheet column for input to ProUCL, concentrations for specific EOCs can be tested to see if they are normally-distributed. The menu path for invoking this function is *Statistical Tests => Goodness-Of-Fit Tests => Full (w/o NDs) => Normal.* The Shapiro-Wilk test is used for determining whether the distribution is normally distributed, which is appropriate for the sample size (n = 19).

To illustrate how the GOF function was used, consider the round-by-round data distribution for dissolved sodium in Mine Unit 1. When all the wells were tested, each round of stability sampling resulted in an array of 19 dissolved sodium concentrations. This array was then input into ProUCL in column fashion from workbook 3). ProUCL indicated that each and every round of dissolved sodium data was normally distributed. As a consequence, trending for sodium was done using the arithmetic mean value of the 19 wells for each round of sampling. All other EOCs departed from a normal distribution for at least one round. In those cases, trending was done using the particular EOC's median value of the 19 wells for each round of sampling as determined using the "median" function from Excel. The distribution results can be found in workbook 2) in the worksheet "***Distribution Table***".

A table of median stability data are included in workbook 2) with a separate worksheet devoted to each EOC. These worksheets include tables and stability graphs determined from arithmetic means (for sodium) or median values (for all other EOCs/parameters). Stability graphs include a linear regression trend. In addition, each EOC other than pH has a "t-stat" worksheet that accompanies the table/graph

worksheet. T-stat worksheets include additional information of possible interest such as the t-statistic for each fit and tables of fitting residuals. The latter can easily be input into the ProUCL GOF function to determine whether the residuals are normally-distributed.

Mine Unit-wide trending was done for all EOCs/parameters using the Mann-Kendall routine included in ProUCL. At the September 2016 meeting, NRC staff recommended the use of the Mann-Kendall technique (MK) for stability trending. MK involves hypothesis testing with the null hypothesis being that there is no statistically significant trend in the data. Two other outcomes are possible: there is statistically significant increasing trend (an "SSI"); or there is a statistically significant decreasing trend (an "SSD"). The output file from a ProUCL MK trend test includes a sentence that states whether there is no trend, an SSI, or an SSD. See Table 1 below for a summary of stability findings using Mine Unit 1 averages.

Parameter	Normal Distribution?	Average used for trending	Stable?
Total Alkalinity	No	median	Yes
Chloride	No	median	Yes
Sodium	Yes	arithmetic mean	Yes
Sulphate	No	median	Yes
TDS	No	median	Yes
Arsenic	No	median	Yes
Uranium	No	median	Yes
Ra-226	No	median	Yes
Total Iron	No	median	Yes
Ca	No	median	Yes
Mn	No	median	Yes
pH	No	median	Yes

Table 1. The data for each parameter is treated as normally-distributed only if every round of sampling data for that parameter was found to obey a normal distribution. As discussed in this report, sodium is the only parameter for which this was found to be the case. As a consequence, sodium was trended using the arithmetic means of the 19 individual well values for each round of samples. For all other parameters, the medians for each found of sampling of the 19 individual wells were used. The results for pH actually involved the testing of the log-transformed data sets (to hydrogen ion activities). The "Stable?" column refers to mine unit-wide stability.

For the case of Ra-226, trending was also tested using the student's t-test in conjunction with linear regression to compare the fit values to the actual data since the regression slope was slightly positive.[2] Using a one-sided t-statistic of 2.447 (the probability of an upward trend only) for six degrees of freedom, the Excel regression analysis returns a t-statistic of 1.996 for the linear fit of Ra-226 data. The fit residuals were found to be normally distributed, so linear regression was deemed appropriate. Therefore both linear regression and Mann-Kendall detect no statistically significant upward trend for radium-226. In general, linear regression returned findings in agreement with the Mann-Kendall concerning trends for all EOCs. In most instances, the fit residuals were found to be normally-distributed.

pH data were handled differently than EOCs because of the logarithmic nature of this parameter. pH values were converted into hydrogen ion activities, and only field data was used for the analysis since lab measurements are often made days or weeks after samples are collected. Note that the dates of field pH measurements do not always align with those for other samples. Field measurements were made using a flow-cell and hand-held YSI model 556 meter that was pH-calibrated each day. The pH values shown in workbook 1) are laboratory data and were thus not used in the trending analysis. The data used for pH trending is in workbook 3).

Spatial analysis discussion

CR decided to also do a trending analysis for each individual B-well to provide a detailed look at the spatial distribution of EOCs/parameters (see Table 2). It should be noted that there are in certain cases more than eight data points for some EOCs and for some mine unit patterns. In these cases additional sampling was done to inform the closure monitoring plan that will be a part of the ACL application. The results of the individual B-well trending are reported in Workbook 2). Several of the parameters, such as calcium, chloride, sulfate, and alkalinity remain well below the drinking water standard.

Although the mine unit demonstrates stability as prescribed by the license, uranium is trending upwards in four wells: B1/3/5/19. The last round of sampling showed a dissolved uranium concentration of 0.0829 mg/L for B1, 0.901 mg/L for B3, 0.399 mg/L for B5 and 1.00 mg/L for B19. These wells are expected to stabilize during the closure monitoring period for this mine unit. In contrast, wells B2/6/9/16/18 are all trending down for uranium, with the last round of sampling resulting in concentrations of 0.852 mg/L, 0.361 mg/L, 0.902 mg/L, 0.272 mg/L, and 0.0742 mg/L respectively. Figure 1 shows the locations of these wells within Mine Unit 1 and the direction of groundwater flow in the restoration zone.

The situation where some wells trend upwards while others trend in the opposite direction illustrates the importance of using median values to give a more accurate picture of the overall `stability of the mine unit. See Table 2 for a summary of stability results for the individual B wells for every parameter of significance in the guideline 8 suite of analyses. Table 3 shows the dissolved uranium trend slopes for all nine B wells with an SSI or SSD as well as upper and lower confidence limits for those slopes (2.5% and 97.5% for an overall confidence of 95%). These slopes were computed using the Thiel-Sen method as implemented in ProUCL.[3] The upper and lower confidence limits show the relatively large uncertainties in these slope estimates, and all numbers in Table 3 are taken directly from ProUCL with no attempt to round to the appropriate number of significant digits. Despite the relatively large uncertainties, note that the sum of these nine slopes is negative (-1.66×10^{-3}).

Wells B4/10/11, with dissolved uranium concentrations of 4.65 mg/L, 2.24 mg/L and 2.66 mg/L respectively were all stable for dissolved uranium, but appeared to be possible statistical outliers. To test for outliers, a modified Dixon test using ProUCL was performed by discarding all but the least extreme suspected outlier (B10 at 2.24 mg/L uranium), thus avoiding the risk of masking caused by the B4 and B11 uranium concentrations.[4] B10 was found to be an outlier (and by inference B4 and B11). Uranium transport modelling that will be presented in the forthcoming ACL application that will show that the dissolved uranium concentrations are not a threat to water down-gradient of the aquifer exemption boundary.

Well	As	Ca	Cl	Fe	Alkalinity	Mn	Ra-226	Se	SO_4^{-2}	TDS	U	pH
B1	0	0	0	0	0	0	+1	0	0	0	+1	+1
B2	0	-1	-1	0	0	0	0	0	0	0	-1	0
B3	0	+1	0	0	+1	0	0	0	+1	+1	+1	0
B4	0	0	0	0	0	0	0	0	0	0	0	0
B5	0	+1	0	0	+1	0	+1	0	+1	0	+1	+1
B6	0	-1	-1	0	-1	-1	0	-1	-1	-1	-1	+1
B7	0	0	-1	0	0	0	0	0	0	0	0	0
B8	-1	0	-1	-1	0	0	0	0	0	0	0	0
B9	0	0	0	0	0	0	0	-1	0	0	-1	0
B10	-1	0	0	0	0	0	0	-1	0	0	0	+1
B11	0	+1	+1	0	+1	+1	+1	0	+1	+1	0	0
B12	0	+1	+1	0	0	+1	0	-1	+1	0	0	+1
B13	0	0	0	0	0	0	0	0	0	0	0	0
B14	0	0	0	+1	-1	0	0	0	-1	-1	0	0
B15	0	0	-1	0	-1	0	-1	0	0	0	0	0
B16	0	0	-1	-1	0	0	0	0	-1	-1	-1	0
B17	0	+1	+1	0	+1	+1	0	0	+1	+1	0	0
B18	0	0	-1	0	-1	-1	0	0	-1	-1	-1	0
B19	0	+1	0	0	+1	+1	0	0	0	+1	+1	+1

Table 2. Trends for parameters of importance on an individual B-well basis. +1 implies an upward trend (SSI), 0 implies no statistically significant trend, and -1 indicates a downward trend (SSD). All results include data through the March 7-8, 2017 sampling period and were determined using Mann-Kendall as implemented in ProUCL at 95% confidence. For the case of pH trending, hydrogen ion activity transforms were used (as activity trends decrease, pH trends increase and vice-versa).

Well	Thiel-Sen Slope (mg/L/day)	Upper Confidence Limit	Lower Confidence Limit
B1	+6.0959E-5	+9.8576E-5	+1.2159E-5
B2	-1.78E-3	-5.129E-4	-3.87E-3
B3	+8.8575E-4	+2.4176E-4	+1.7407E-4
B5	+1.5187E-4	+2.8739E-4	-5.768E-5
B6	-1.17E-3	-4.047E-4	-2.21E-3
B9	-3.880E-4	-3.971E-5	-1.86E-3
B16	-1.264E-4	-3.758E-6	-3.486E-4
B18	-1.859E-4	-7.638E-5	-5.154E-4
B19	+8.8960E-4	+1.24E-3	+3.3388E-4

Table 3. Dissolved uranium slopes for those wells showing an SSI or SSD for uranium.

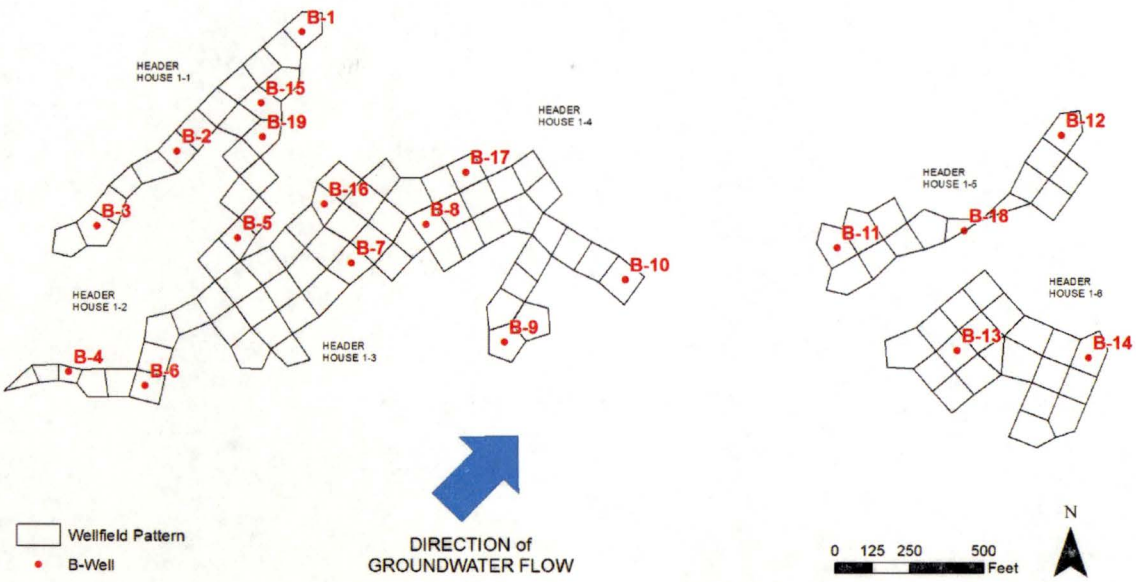

Figure 1. Mine Unit 1 showing the locations of the B wells discussed in this report. The direction of groundwater flow is inferred from monitor well water level measurements.

Much of the iron present is in the ferrous form, and is thus a reducing agent that can be taken to be a measure of restoration success.[5-6] Furthermore, it is a reducing agent that has only a secondary maximum concentration limit under current EPA regulations.

Total Dissolved Solids (TDS) values are also very stable over a mine unit-wide basis, but do show upward trends for four wells; though an additional four wells show decreasing trends for this parameter.

Radium has very low mobility under the geochemical conditions prevailing in Mine Unit 1.[7] Moreover, over the whole of Mine Unit 1 it is present at a median concentration that is approximately 62% as much as pre-mining (median of 578 pCi/L before mining, about 360 pCi/L as of the most recent stability sampling round).

Selenium is present at very low concentrations in Mine Unit 1, and appears to be trending downwards everywhere. Arsenic also represents no stability issues.

CONCLUSION

Mine Unit 1 is stable for all parameters as determined using the methods prescribed by the NRC license and state permit. An ACL application is planned for uranium, iron, and arsenic since these EOCs exceed both pre-mining concentrations and Environmental Protection Agency (EPA) drinking water standards though iron is a secondary standard only. As a part of the ACL application, a closure monitoring plan will be presented for each of these parameters.

FOOTNOTES

[1] "Statistical Analysis of groundwater monitoring data at RCRA Facilities" U.S.E.P.A. Unified Guidance, March, 2009, Page 3-11 has a brief general discussion of the use of the median for groundwater data. Page 5-12 of the Unified Guidance document also mentions using median values for non-normally distributed data in the context of looking for background trends.

[2] Linear regression coupled with the t-statistic was used to evaluate stability as described by NRC staff in "Technical Evaluation Report Christensen Ranch Mine Units 2 Through 6 Restoration Report Uranium One USA, Inc., Willow Creek Facility", 23 October 2012, Docket No. 040-08502.

[3]The use of Theil-Sen as a non-parametric test for estimating the slope of a trend is described on Page17-34 USEPA Unified Guidance cited in footnote 1.

[4]For a discussion of the modified Dixon's outlier test, see Page 12-8 USEPA Unified Guidance cited in footnote 1.

[5]"Effect of Amorphous Fe(III) Oxide Transformation on the Fe(II)-Mediated Reduction of U(VI)", Daniel D. Boland, *et al*, *Environmental Science & Technology* 45, pp. 1327-1333.

[6]"Reduction of U(VI) by Fe(II) during the Fe(II)-Accelerated Transformation of Ferrihydrite", Daniel D. Boland, *et al*, *Environmental Science & Technology* 48, pp.9086-9093.

[7]For a general discussion of factors influencing the mobility of radium in groundwater see the following: "Occurrence and geochemistry of radium in water from principal drinking-water aquifer systems of the United States", Zoltan Szabo, *et al*, *Applied Geochemistry* 27, pp. 729-752. Mine Unit 1 can be broadly characterized as having a low Total Dissolved Solid content (both pre-mining and post-restoration) with aquifer solids rich in clays. It is therefore not an environment conducive to high radium mobility, a fact that is made abundantly clear by the stark differences in radium activities in closely-spaced wells that are observed both before mining and after restoration.