July 12, 2016

Mr. Ken Kalman
U.S. Nuclear Regulatory Commission
11555 Rockville Pike
Rockville, MD 20852-2738

Re: Docket No. 70-925; License No. SNM-928
Distribution Coefficient Determination for the Cimarron Site

Dear Mr. Kalman:

During recent meetings conducted in Oklahoma City, the Nuclear Regulatory Commission (NRC) requested that Environmental Properties Management (EPM) provide additional details regarding the methods and assumptions used in deriving distribution coefficient ($K_d$) values for various water-bearing aquifer units at the Cimarron site. EPM understands that $K_d$ is a critical parameter in estimating the rate at which contaminant concentrations in an aquifer can be reduced, and the assignment of $K_d$ values must be reasonable and defensible.

2002 Hazen Research, Inc. Evaluation

The initial determination of $K_d$ for site-specific soils was performed by Hazen Research, Inc. (Hazen) in 2002. Soil with a high clay content was obtained from boring 02W02, located in the Transition Zone within Burial Area #1. Sandy soil was obtained from boring 02W08, located within the alluvium in Burial Area #1. Groundwater was obtained from Monitor Well 02W04, located within Burial Area #1 alluvial material in an area of relatively high uranium concentration. Analysis of the water recovered from 02W04 yielded an average uranium concentration of 3,600 micrograms per liter (µg/L).

For each laboratory soil $K_d$ assessment experiment, approximately 25 grams (g) of soil was placed in a 250-milliliter (mL) centrifuge tube. An amount of contaminated water equal to four times the weight of soil (approximately 100 mL) was added to the tube and the tube was capped. Samples were gently shaken for three hours on Day 1 and three hours on Day 2, and then were allowed to settle. After the samples had settled, the samples were centrifuged for about 20 minutes before sampling. The centrifuged liquid was collected, acidified to a pH of < 2 standard units with nitric acid, and analyzed for uranium concentration.

Samples were analyzed 3 days, 6 days, 9 days, and 15 days following laboratory sample preparation. The laboratory also analyzed samples collected from headspace liquid and laboratory blanks. Concentrations reported after 3, 6, 9, and 15 days were compared to the headspace samples to account for potential absorption by solids or plating onto the sample container. The sample headspace concentrations were subsequently compared to the laboratory blanks to account for potential loss due to sample container wall plating. The amount of uranium absorbed by the solids was the difference between the sample headspace concentration and the concentration at 3, 6, 9, and 15 days, using the sample blank concentration to correct for plating. The uranium content absorbed by solids was then converted to a uranium value in milligrams per kilogram (mg/kg). Dividing this value by the uranium concentration in the residual solution yielded (mg/kg)/micrograms per liter (mg/L) – also written as milliliters per gram (mL/g) – which represents the value for $K_d$

After 15 days, the calculated $K_d$ values for the clayey soil ranged from 1.9 to 4.7 mL/g, averaging 3.0 mL/g. The calculated $K_d$ values for the sandy soil ranged from 1.6 to 4.0 mL/g, averaging 3.0 mL/g.

Hazen documented the results of this testing in *Determination of Distribution Coefficients ($K_d$) for Uranium in Soils* (Hazen Research, Inc., 2002). A copy of the 2002 Hazen report is provided on the enclosed compact disc (CD).

<u>2006 Hazen Research, Inc. Evaluation</u>
In the process of preparing *Conceptual Site Model (Revision – 01)* (ENSR, October 2016), ENSR Corporation (ENSR) retained Hazen to perform dynamic elution tests using soil and groundwater samples collected from Burial Area #1 at the Cimarron site.

The 2006 Hazen tests were conducted on soil samples SC-01 through SC-05. Soil sample SC-01 consisted of silty fine sand collected from the Transition Zone northwest of Monitor Well 02W29. Soil sample SC-02 was coarse sand collected from alluvial material north of Monitor Well 02W05. Soil sample SC-03 was Transition Zone clay south of Monitor Well TMW-09. Soil sample SC-04 contained sandstone from the top 5 feet of Sandstone B northwest of Monitor Well TMW-08. Soil sample SC-05 was soil directly above Sandstone A near Monitor Well 1325, upgradient of any impacted areas.

Water samples were collected from various monitor wells located in Burial Area #1. Water samples were collected from Monitor Wells 02W04 (alluvium), 02W33 (alluvium), TMW-02 (Sandstone B), and TMW-09 (Transition Zone).

Six 3-inch diameter by 12-inch long polyvinyl chloride (PVC) columns were each filled with between 1,949 and 2,450 g of soil collected from the locations described above. Water from Monitor Well TMW-02 was run through Columns 1, 2, 4, and 5, containing soils collected from locations SC-01, SC-02, SC-03, and SC-04, respectively. Water from Monitor Well 02W33 was run through Column 3, containing soil collected from SC-02. Synthetic rainwater was run through Column 6, containing a mixture of soils collected from locations SC-02 and SC-05.

The purpose of the column study was to evaluate the leachability of uranium into groundwater under dynamic conditions, simulating the extraction of uranium from the formation via groundwater extraction. Hazen submitted *Dynamic Column (Elution) and Adsorption Studies on Soil and Water Samples from the Cimarron Corporation Site in Crescent, Oklahoma*, (Hazen Research, Inc., 2006) to ENSR in June, 2006. ENSR described the results of the test on pages 5-2 and 5-3 of *Conceptual Site Model (Revision – 01).* ENSR summarized the Hazen study's results as yielding $K_d$ values of 0.5 for the sandy soil, 2.0 for the silty soil, and 3.4 for the clayey soil. Copies of both the ENSR and Hazen reports are provided on the enclosed CD.

<u>2016 EPM Evaluation of Previous LNST Study</u>

Prior to the submittal of *Groundwater Decommissioning Plan* (ARCADIS U.S., Inc., March 2009), Lucas Newman Science & Technologies, Inc. (LNST) conducted an evaluation of data provided by soil and groundwater sampling and analysis conducted during 2002 Burial Area #1 monitor well installations (monitor wells with a well identifier bearing the prefix "02W"). The intent of this study was to evaluate uranium concentrations in soil samples, obtained from soil borings, and in groundwater samples collected from monitor wells installed in the aforementioned borings. All concentration data were reported in units of picoCuries per gram (pCi/g) or picoCuries per liter (pCi/L), meaning the results represent the ***activity concentration*** of the sample.

EPM was unable to locate any original documentation related to the LNST study. Consequently, EPM duplicated the evaluation for this submittal in *2016 $K_d$ Evaluation Using 2002 Data*, (Environmental Properties Management LLC, 2016). A copy of this document is provided on the enclosed CD in both .pdf and Microsoft Excel® formats. All uranium concentration data obtained from the analysis of soil and groundwater samples collected in 2002 is presented in tab "All 02W Data" in the spreadsheet entitled *2016 $K_d$ Evaluation Using 2002 Data*; all samples collected within the saturated zones are highlighted. The depth to water at each sample location (monitor well) was obtained from field parameter forms generated during the site-wide groundwater sampling event performed in 2015. Depth to water calculations were performed under the assumption that the top of casing for all monitor wells is three feet above ground surface. The formation (transition zone, alluvium, sandstone) corresponding to the screened interval and saturated zone material type (clay, silt, sand, sandstone) are also identified.

Tabs within the spreadsheet *2016 $K_d$ Evaluation Using 2002 Data* labeled "Sandstone B," "Transition Zone," and "Alluvium" include saturated soil and groundwater sample data collected from monitor wells located in each distinct Burial Area #1 "formation." The $K_d$ for each location was calculated by dividing the ***average*** uranium activity for soil samples in the saturated zone at that location by the activity of uranium in the corresponding groundwater location.

The average $K_d$ calculated for various ranges of soil and groundwater concentration is listed at the bottom of the spreadsheet on the tab for each formation (i.e., Sandstone B, Transition Zone, and Alluvium). The solids concentrations remain consistent as the dissolved concentrations go up and down by orders of magnitude, indicating there is little sorption or desorption occurring. It is likely that most of the uranium in the solid phase is not "sorbed" uranium, but is natural uranium that is part of the mineralogical composition of the soil. Consequently, at low dissolved uranium concentrations, $K_d$ values reflect the solubility of the mineralogical natural uranium, and as high dissolved uranium concentrations, $K_d$ values reflect the solubility/desorption of sorbed anthropogenic uranium.

The wide range of $K_d$ values are calculated because as the solids concentrations remain relatively constant, the $K_d$ is driven solely by the dissolved concentrations (i.e., as dissolved concentrations increase the $K_d$ values decrease). $K_d$ values for samples obtained from borings with comparatively high concentrations of dissolved uranium were similar to the values calculated by Hazen.

The $K_d$ values calculated for locations where the concentration of enriched uranium exceeds 1,000 pCi/L, are 1.4 mL/g in Alluvium, 1.5 mL/g in Sandstone B, and 2.4 mL/g in Transition Zone. All these values are lower than the $K_d$ values used in *Facility Decommissioning Plan* (EPM, December 2015) to estimate the mass of uranium removed with each pore volume of extracted groundwater and the corresponding duration of remediation.

Comparison of $K_d$ Values with RESidual RADioactive (RESRAD) Model Default Values

RESRAD is a computer model used to estimate dose from residual radioactive materials. RESRAD is the widely accepted standard used by the U.S. Department of Energy, the NRC, and the licensed community to assess the dose consequences associated with radioactive materials left on site after license termination.

RESRAD Version 6 is the latest version that includes calculation of dose for offsite material or to offsite members of the public. RESRAD Version 6 provides default $K_d$ values for uranium in clay soil in units of cubic centimeters per gram ($cm^3/g$). Based on the pH of the soil, the default values for $K_d$ vary from 270 – 2,000 $cm^3/g$. These values are significantly higher than the $K_d$ values assigned to even the lowest permeability material (clay) at the Cimarron site. Appendix H of *User's Manual for RESRAD Version 6*, "Distribution Coefficients" addresses alternatives to the use of default values, stating,

> *"The value of $K_d$ for a given radionuclide can be quite variable, depending strongly on soil type, the pH and Eh of the soil, and the presence of other ions. Therefore,*

> *considerable uncertainty can be caused by using the default value for the distribution coefficient, especially when the water-dependent pathways are the dominant pathways for radiation exposure. Because of the wide range of $K_d$ values,* ***site-specific values should always be used whenever they are available.***
>
> *… RESRAD provides four optional methods for deriving the distribution coefficient. The first method requires inputting a value greater than zero for the elapsed time since material placement (TI) and* ***providing the groundwater concentration of the radionuclide, which is measured at the same time as the radionuclide soil concentration****."* [emphasis added]

In order to prevent the use of a potentially erroneous $K_d$ value in RESRAD, the first $K_d$ derivation alternative requires the input of a site-specific value for $K_d$ calculated using groundwater and soil concentrations ***measured at the same time*** since material placement. The time since material placement is important to ensure that equilibrium has been established when the soil and groundwater concentrations are determined. Since material placement occurred decades ago at the Cimarron site, it is reasonable to assume that equilibrium has been established.

Conclusion

The collection and analysis of additional soil and groundwater samples during future remediation construction activities, for the purpose of re-evaluating $K_d$ estimates was discussed during the meetings conducted in Oklahoma City in June 2016. Additional soil samples could be obtained from borings advanced during groundwater extraction well installation. Groundwater samples could then be collected from the newly installed extraction wells, providing results for co-located soil and groundwater samples.

Batch tests performed by Hazen in 2002, dynamic elution tests conducted by Hazen in 2006, and the 2016 evaluation of data for co-located 2002 soil and groundwater samples all yielded similar values for $K_d$ in site-specific soil and groundwater. The 2006 and 2016 work utilized samples obtained from alluvial, transition zone, and sandstone formations located in Burial Area #1. Consequently, both the primary groundwater geochemistry regimes (calcium-sulfate and calcium- carbonate/bicarbonate) and the primary aquifer material compositions were considered in previous $K_d$ determinations.

While it would be possible to perform additional sampling, analysis, and $K_d$ determinations, most if not all of the work would be conducted outside of Burial Area #1, in areas of low total uranium concentration in groundwater (i.e., closer to 30 µg/L than 300 µg/L). Due to the observed increase in $K_d$ with a decrease in dissolved uranium concentration, the value of such an evaluation would be very limited. A higher value for $K_d$ would be expected, because the concentration of natural uranium in the soil is far greater than the concentration of sorbed uranium.

The primary application of $K_d$ is the calculation of groundwater remediation duration estimates, upon which remediation schedule and cost are heavily dependent. Once groundwater remediation begins, the rate of decline in uranium and nitrate groundwater concentrations, based on laboratory analytical groundwater results provided by periodic in-process remediation sampling events, will provide more definitive duration estimates than any $K_d$ calculation could provide. Consequently, EPM does not believe the collection and analysis of additional soil and groundwater samples for the purpose of re-evaluating $K_d$ provides a benefit commensurate with the cost that would be incurred. Further, the information provided by this effort would be far less useful than data that will be generated during in-process remediation monitoring.

Please call me at (405) 642-5152, or e-mail me at jlux@envpm.com if you desire clarification or additional information regarding the determination and assignment of $K_d$ values for the Cimarron site.

Sincerely,

Jeff Lux, P.E.
Project Manager

Enclosure: One CD containing the following documents:

- *Determination of Distribution Coefficients ($K_d$) for Uranium in Soils* (Hazen Research, Inc., 2002)
- *Dynamic Column (Elution) and Adsorption Studies on Soil and Water Samples from the Cimarron Corporation Site in Crescent, Oklahoma*, (Hazen Research, Inc., 2006)
- *Conceptual Site Model (Revision – 01)*, (ENSR Corporation, 2006)
- *2016 Kd Evaluation Using 2002 Data*, (Environmental Properties Management LLC, 2016)

Cc: Mr. Paul Davis, Oklahoma Department of Environmental Quality
Dr. Gerald Schlapper, U.S. Nuclear Regulatory Commission