CIMARRON CORPORATION
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January 30, 2009

Mr. Kenneth Kalman
Office of Nuclear Materials Safety & Safeguards
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Re: Docket No. 70-925; License No. SNM-928
Addendum to June 2, 2008 License Amendment Request

Dear Mr. Kalman:

Cimarron Corporation (Cimarron) met with NRC and DEQ at the Cimarron site on July 16, 2008. During that meeting, Cimarron provided NRC management an overview of the status of decommissioning at the Cimarron site, and provided information related to the above-referenced license amendment request (LAR). NRC also desired to address Cimarron's proposal to implement a two-phased effort, beginning with "initial treatment" and progressing to "full-scale", when NRC had requested a pilot test prior to approving full-scale remediation.

Cimarron maintained that the initial treatment process proposed by ARCADIS in the LAR should satisfy NRC's concerns, and explained that monitoring provided in the plan would generate the required information. Cimarron acknowledged that the work plan did not clearly specify conditions which must be demonstrated during initial testing to justify proceeding to full-scale remediation.

In a follow-up July 30 teleconference with NRC technical staff, Cimarron described four sets of conditions which must be demonstrated to assert that groundwater remediation is successful. Therefore a letter was prepared to specify the criteria which must be met to proceed with the design and implementation of the full-scale remediation system. This letter was submitted on September 4, 2008 as an addendum to the June 2, 2008 LAR and included the four success criteria for the initial treatment areas as well as an attached description of the revised column testing procedure.

A subsequent teleconference was held on October 23, 2008 to discuss the NRC's comments on the September 4, 2008 addendum submittal. Based on that discussion, on November 24, 2008, Cimarron submitted a revised Bioremediation Implementation Process Figure (Figure 5-1 from the June 2, 2008 LAR) to address changes to the process as discussed in the teleconference on October 23, 2008. A teleconference was then held on December 12, 2008 to discuss four additional issues needing resolution prior to the NRC's acceptance of the LAR and addendum in the Acceptability Review. An additional technical discussion was held between Cimarron and NRC technical staff (Tom Nicholson and Mark Fuhrmann) on January 7, 2009.

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As a result of the teleconferences and discussions between the NRC and Cimarron, it was agreed that Cimarron would provide this addendum to the June 2, 2008 LAR. This addendum supersedes the September 4 and November 24 submittals, and represents the sole addendum to the June 2, 2008 license amendment request.

A revised Bioremediation Implementation Process Figure (Figure 5-1) is attached, summarizing the agreed-upon steps in the bioremediation process. Figure 5-1 also includes Table 5-1 which summarizes all of the data to be collected during the bioremediation process. This figure is intended to replace Figure 5-1 in the June 2, 2008 license amendment request.

The conditions that must be met prior to advancing from the initial treatment area implementation to full-scale implementation are discussed in detail below, and a revised column testing procedure is included as Attachment 1.

Condition #1 –Reactant Must be Distributed Throughout the Impacted Area
ARCADIS must demonstrate that amendments can be distributed throughout each of the impacted areas, including the alluvial areas, the finer-grained materials present in the transition zones of both Burial Area #1 and the Western Alluvial Area, and the sandstone of both Burial Area #1 and the Western Upland Area. ARCADIS will establish six initial treatment systems in the three areas of concern as described in Section 5.2.1 and depicted in Figure 5-2 of the LAR. ARCADIS will demonstrate that amendments are being distributed in the hydrogeological environments present in all of these areas. The amendments most likely to be injected are TOC and ferrous sulfate. However, both TOC and ferrous sulfate are consumed as they move through the water-bearing zone, so it is impractical to use TOC or sulfate to measure success in distributing amendments.

ARCADIS proposed to inject a tracer (e.g., fluorescein dye) in the injection system and to monitor groundwater for the specified tracer at locations between and/or downgradient of the injection wells. The tracer will move through the water-bearing zone in a manner similar to the amendments, but is not susceptible to degradation as are the TOC and ferrous sulfate.

As described in Section 5.2.1 of the LAR, extraction and injection will continue for at least seven days, or until monitoring yields steady-state conditions for the tracer. The injections will then be discontinued, and monitoring will continue through declining concentrations to evaluate the stability of the tracer.

Success criteria – ARCADIS must demonstrate delivery of the tracer to monitoring locations in all six areas. In monitoring wells, both the attainment of a steady-state tracer concentration and subsequent decline in tracer concentration after shutting down the injection system must be determined prior to moving on to full-scale remediation.

Condition #2 – Uranium Concentrations Must be Reduced to Below Release Criteria
Section 5.2.1 of the LAR states that amendment (organic carbon solution) injection will be initiated after completing the tracer testing. ARCADIS will monitor groundwater during amendment injection for those parameters for which results can be obtained quickly and

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economically. Figure 5-1 shows this as a step preceding full-scale remediation, but Table 5-1 does not make this clear.

ARCADIS will monitor groundwater for field parameters including water level, pH, temperature, conductivity, ferrous iron, and dissolved oxygen. In addition, uranium activity will be analyzed with a short turn-around time. Evaluation of these parameters will provide the information needed to determine when to collect groundwater samples for laboratory analysis of TDS, sulfate, sulfide, nitrate, nitrite, total iron (unfiltered and acid preserved) and dissolved iron (0.45 micron-filtered and acid preserved), alkalinity, and uranium mass concentration. Collectively, the field parameters (including pH, dissolved oxygen, and ferrous iron) and groundwater parameters analyzed in the laboratory are groundwater "performance indicators," whereas the solid phase mineralogical analyses are soil performance indicators.

ARCADIS must be able to demonstrate that uranium concentrations are statistically significantly decreasing while reducing conditions are being established. ARCADIS will demonstrate that uranium concentration reduction corresponds with the establishment of reducing conditions. The iron sulfide and uranium data will undergo statistical analysis using the software ProUCL version 4.0 (EPA's statistical analysis software). This software can calculate the significance of the decline in concentration of uranium in groundwater in monitoring wells across the initial treatment areas as compared to the baseline (pre-treatment) data set.

Groundwater sampling during operation of the initial treatment system will proceed according to a prescribed sampling frequency in order to assess the progress of groundwater treatment, (sampling for performance indicators will be performed at an optimal frequency). However, the sampling program will be flexible when seeking to accommodate extremes in seasonal fluctuations in the water table or after extreme rain events. Event-driven groundwater performance indicator sampling will be performed when seasonal precipitation or river stage is outside of the norm (as described in the Hydrology Addendum to the LAR). Event-driven sampling will also be performed during the full-scale remediation phase as noted on Figure 5-1.

Success criteria – Statistically significant reduction in uranium concentration is observed in all six initial treatment zones as reducing conditions are achieved, as demonstrated by DO, iron, nitrate, and sulfate monitoring results.

Condition #3 – A "Bank" of Iron Sulfide Must be Created in the Soil to Prevent Remobilization

To demonstrate longevity of the remediation effort, ARCADIS must establish a bank of iron sulfide sufficient to yield an iron sulfide to uranium ratio of no less than 80:1. However, it is neither practical nor necessary to develop this ratio during the initial treatment phase. In fact, it is not necessary that this ratio be developed at each and every spot; this ratio must be averaged volumetrically in each material type throughout the areas of impact. ARCADIS must demonstrate that a bank of iron sulfide is being built up in both low- and high-permeability material in each of the initial treatment system areas.

Figure 5-1 of the LAR shows that soil sampling will be performed at the end of the initial treatment system operation. Groundwater data (groundwater performance indicators) obtained during the operation of the initial treatment system are expected to provide assurance that the required geochemical conditions have been established in soil. Consequently, it was assumed that soil sampling will only need to be performed one time – at the conclusion of operation of the initial treatment system. Of course, if the success criteria are not demonstrated in a single soil sampling event, initial treatment will continue and the sampling will be repeated.

Table 5-1 of the LAR states that samples will be collected from three borings in each area of impact, with two samples taken from different depths from each boring. This would yield a total of 18 soil samples site-wide. Based on conversations with NRC, this has been revised so that, for each of the six initial treatment areas, soil samples will be collected from one boring near one injection well and one near one monitoring well. Sampling techniques will be used to minimize the disturbance to the area adjacent to the wells; the volume of soil that is retrieved will be minimized to prevent large void volumes. If a boring yields two different types of material within the saturated zone (e.g., clay from 10 – 12 feet and sand from 14 – 16 feet), more than one sample may be collected from a boring. This determination will be made based on the boring log generated during installation of the wells, or the logs of existing wells. A maximum of two samples will be collected from each boring, for a maximum of 24 total soil samples.

Soil samples will be analyzed for the parameters listed in Table 5-1 of the LAR (soil performance indicators). Analytical results will be evaluated to determine that iron sulfide is being developed in all material types at all locations. In addition, analytical results need to demonstrate that iron sulfide concentrations are generated at multiples of uranium concentrations, such that a reduction in uranium concentration corresponds to an increase in iron sulfide concentration. The iron sulfide and uranium data will undergo statistical analysis using the software ProUCL version 4.0 (EPA's statistical analysis software). This software can compare two data sets to determine if the difference is significant and it also has the ability to handle "non-detect" data as well as non-parametric data sets.

Success Criteria - Iron sulfide concentrations must exhibit a statistically significantly increase in samples collected from borings relative to corresponding samples collected from borings at a similar location during baseline analysis prior to initiating treatment. Finally, it must be demonstrated that increases in iron sulfide concentrations correspond to reductions in uranium concentrations for associated wells.

<u>Condition #4 – Uranium Must not Remobilize if Water Bearing Zone Becomes Oxic</u>
NRC, DEQ, and Cimarron agree that uranium will remain immobilized as long as the water bearing zones maintain a reducing environment. NRC is less certain that, should the water bearing zone become oxidizing, uranium would not remobilize at concentrations exceeding the 180 pCi/l release criterion. ARCADIS will run column tests utilizing site soils and site groundwater to demonstrate that, even if infiltrating groundwater generates an oxidizing environment, the concentration of uranium in effluent will not exceed the release criterion.

ARCADIS will collect soil from borings located in impacted areas near each of the six initial treatment areas. The column tests can only be practically performed on samples of unconsolidated soils, so sandstone from Burial Area #1 and the Western Upland area will not be collected for column testing. This is reasonable because the fine-grained soil in the two transition zones and the cleaner sands of the deeper alluvium represent "ends of the spectrum",

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with the silty sandstone being in the middle of the spectrum. It is reasonable to presume that if the fine-grained soil and clean sands yield acceptable results in column tests, the silty sandstone would yield acceptable results.

Groundwater samples corresponding to the groundwater in each of these four soil samples will be collected from impacted and unimpacted wells yielding water quality similar to that of the corresponding soil sample (based on information presented in Conceptual Site Model, Rev. 01). For instance, referring to Figure 4-7 of this report, if a soil sample were collected for a column test near TMW-13, groundwater for this column test would be collected from this well and an unimpacted well yielding high sulfate (similar to Sandstone C) water. ARCADIS will ensure that site groundwater used in tests reflects the chemistry of groundwater associated with the soil sample used in the column test.

Reducing conditions will be created in each batch of soil sample and corresponding groundwater from an impacted well until the required ratio of iron sulfide to uranium is achieved. Once this ratio is achieved, the soil will be packed into columns for the column tests. Unimpacted site groundwater will be run through the column until oxidizing conditions are created within the column. In addition, the column tests will be conducted using Cimarron River water with water quality representative of river water at flood stage and rainwater to simulate oxidizing conditions produced by infiltration of either river water or rainwater. River water will be used because it potentially has a higher concentration of nitrate than groundwater; this will be verified through analysis. Both during leaching and after oxidizing conditions are established, samples of the effluent from each column will be analyzed for uranium to demonstrate that the iron sulfide has retarded the remobilization of uranium at concentrations exceeding the release criteria. ARCADIS' column test procedure, included as Attachment 1 to this letter, provides more description of the performance of these column tests.

Soil mineralogical analyses will be performed prior to starting the column test, and at the end of the establishment of oxidizing conditions in the column. These analyses will also be performed in the field during operation of the initial treatment system as described in Condition #3, above. The results of the mineralogical analyses of the soil used in the column tests can subsequently be compared with the field results to assess similarities and differences between field and laboratory conditions. In this manner, fingerprints in the soil mineralogy, indicative of longevity for uranium immobilization, will be established and then sought and tracked in the mineralogical analyses of soil samples collected from the field.

Success criteria – Uranium concentrations in leachate from all columns is less than 180 pCi/l total uranium in all samples collected after reducing conditions are established, through the attainment of oxidizing conditions in the column.

The above description of testing for all four conditions is intended to clarify and/or supersede the descriptions of the same tests in Section 5.2 of the June 2 LAR. For instance, Cimarron is replacing the column testing described in the LAR with the column testing described above, since it is our understanding that this more accurately reflects NRC's desire for a bench-scale demonstration of the process than what was proposed in the June 2 submittal. Cimarron recognizes that the above-listed success criteria must be demonstrated for each of the four above listed conditions before ARCADIS will be authorized to proceed with the design and implementation of full-scale remediation in all areas.

Revisions to Figure 5-1: In conversations with NRC subsequent to the submittal of the September 4 Addendum to the LAR, it was requested that additional opportunities be made available for the presentation to NRC of relevant field data. These are indicated on Figure 5-1 as "Discussion Check-Points". It should also be noted that upon initiation of the field work, baseline groundwater and soil sampling will be performed and the geochemical model will be updated in light of this data set. This information will be used to refine the design of the initial treatment area system installation, and the data and the model update will be shared with the NRC.

Additional clarification was provided on Figure 5-1 for the criteria that must be satisfied to achieve license termination. These include the following:

A. Eight quarters of groundwater monitoring results with U below 180 pCi/L and no increasing trends based on EPA statistical evaluation methods (Mann-Kendall test/Sen's estimate of slope).
B. A round of soil sampling to confirm the presence of iron to uranium ratio of at least 80:1 completed at the end of the Remedy Completion Demonstration Testing phase.
C. Geochemical modeling results updated with site-specific data to demonstrate the 1000-year stability of the remedy.
D. Column testing results that show that reoxidation of the aquifer will not result in remobilization of the uranium above the criteria (from column testing completed during the initial treatment area phase).

It should be noted that with respect to A, prior to the initiation of eight quarters of groundwater monitoring (during the formal "Remedy Completion Demonstration Testing" phase), two to three years of groundwater monitoring will have been conducted to confirm that all wells have U concentrations below 180 pCi/L prior to discontinuing active remediation. However, the eight quarters of sampling is consistent with EPA procedures for a robust groundwater data set to support decisions about remedy effectiveness. In addition, with respect to B., additional soil sampling will be performed prior to the final sampling as noted in Figure 5-1 and Table 5-1 (5-1g). The soil data set in its entirety, and changes in soil mineralogy that occur during and up to the final sampling phase, will be considered in the updated geochemical modeling described in C. Finally, as described in Condition #4, results of the analysis of soil mineralogy during the column testing will be compared to the tests of soil mineralogy in field collected samples so that markers of uranium immobilization longevity can be identified.

Final Dose Assessment: A final dose assessment will be performed at the completion of the remediation process in order to support license termination. Cimarron will demonstrate for scenarios such as a resident farmer that the remaining dose is below 25 mRem on average with no exceedence of the 100 mRem level. The dose assessment will be based upon uranium concentrations in groundwater as observed during the groundwater monitoring, specifically the results of the eight consecutive quarters of monitoring. In addition, the concentration of uranium in groundwater as predicted by the geochemical modeling, over the 1000-year period, will be used as the basis for the dose assessment.

If you have any questions regarding this proposed addendum to the June 2, 2008 license amendment request, please call me at 405-775-5194 (OKC) or 405-642-5152 (mobile).

Sincerely,

Jeff Lux

Jeff Lux
Senior Project Manager

Cc: Jack Whitten, NRC Region IV
David Cates, DEQ
Mike Broderick, DEQ

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Stage 1 – Development of Groundwater Decommissioning Plan/Conceptual Design

Groundwater Decommissioning Plan Approval (by the NRC and ODEQ)

Year 1

Stage 2 – Baseline Sampling and Initial Treatment System Installation

- Additional field characterization as needed in each of the three areas to advance the conceptual design to the initial treatment system design and baseline groundwater sampling (Table 5-1a); establish soils mineralogy baseline (Table 5-1b)
- Adjust site models and utilize outputs in initial treatment system design considerations
- Complete initial treatment system design for all 6 remediation systems
- Share new information with the NRC and ODEQ (estimated at 6 months from GDP approval)

Install and operate initial treatment system components in the forward, middle and rear portions of the groundwater areas of impact

Utilize initial system installation efforts to collect:

- Groundwater water quality and flow information (Table 5-1c)
- Soils - iron mineralogy information (Table 5-1d)

Collect soil samples from initial treatment areas and conduct column testing per procedure in September 2008 Addendum to GDP to demonstrate (Table 5-1e):

- FeS to U ratio of 80:1 is achievable
- Oxidation of column does not result in leaching of U above 180 pCi/L
- Projected long-term water quality remains below 180 pCi/L U (eliminates need for long-term monitoring)

Initial Treatment Area Testing Results achieve Success Criteria in September 2008 Addendum to the GDP?

No

Yes

Update/adjust site models as appropriate and share new information with the NRC and ODEQ

Discussion check-point: Meet with NRC to present data collected that support achievement of success criteria

Complete full-scale design

Year 2

Stage 3 – Full-scale Systems Operation/Active Treatment

- Expand treatment systems to complete functionality
- Initiate full-scale treatment throughout areas of elevated uranium impacts to groundwater

Continue to collect system operations and impacts data

Monthly Groundwater Data Collection (Table 5-1f)

- water quality sampling (full suite)
- flow information

Update/adjust site models as appropriate and share new information with the NRC and ODEQ

Discussion check-point: Meeting with NRC to discuss progress*

Make basic remediation system adjustments

* Minimum annual meetings with NRC to present data collected, review results to date, and provide assessment of bioremediation success and planned path forward.

Program Manager Erhardt Werth	ARCADIS	Bioremediation Implementation Process	Date: 01/29/2009
Project Manager Sara Handy			FIGURE
Task Manager Janis Lutrick	630 Plaza Drive, Suite 100 Highlands Ranch, Colorado 80129 Tel: 720-344-3500 Fax: 720-344-3535 www.arcadis-us.com	Cimarron Corporation Crescent, Oklahoma	5-1
Technical Review Jeff Gillow			Page 1 of 3

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Estimated Timeframe

- Year 3 — **Stage 3 Continued – Full-scale Systems Operation/Active Treatment**

Active Treatment: 1 to 3 years

Semi-Annual (Seasonal) Groundwater Monitoring (Table 5-1f)

- IRZ performance indicators
- Uranium concentrations

Soils Mineralogy Demonstration Testing (Table 5-1g)

- Iron mineralogy

Continued Systems Operation

Remedial Systems Optimization

- **Event driven (seasonal wet/dry) sampling**
- **Information reporting (2 events annually) to the NRC and ODEQ**

Uranium concentrations > 180 piC/L in some wells

Uranium concentrations < 180 piC/L in all 32 wells across BA#1, WAA, WUA

Perform 2nd Set of Mineralogy Tests (Table 5-1g)

Termination of Radiation Protection Program

Adequate Iron Mineralogy In Place? - presence of mass ratio of 1 part uranium to 80 parts iron in all twelve soil samples tested as per Table 5-1g

No

Yes

Discussion check-point: Meet with NRC to present data collected that support achievement of soil and groundwater criteria for initiating Remedy Completion Demonstration Testing Phase *

2 years

Stage 4 – Remedy Completion Demonstration and License Termination

Start of Remedy Completion Demonstration Testing

- **Groundwater:**
  - Collection of uranium concentration information and statistical trend analysis over 8 quarters (Table 5-1h)

Successful Remediation Demonstrations = License Termination

License termination shall be granted upon the successful demonstration that:

A. 16 demonstration wells across BA#1, WAA and WUA do not show statistically significant positive trend in uranium concentrations in 8 quarters of data using USEPA-approved statistical methods (Mann-Kendall Test/Sen's Estimate of Slope).

B. Results of soil analyses for iron mineralogy demonstrate that iron sulfide mass has accumulated to the required mass ratio of 1 part uranium to at least 80 parts iron (Table 5-1i).

C. Geochemical modeling results updated with site-specific data demonstrate 1,000-year stability for the remedy.

D. Column testing results demonstrated that reoxidation of the aquifer will not remobilize U above 180 pCi/L (from column testing completed during initial treatment area phase).

License Termination Process:

- Submit license termination request including final dose assessment based on modeled long-term U concentrations (estimated submission at the start of year 7 or earlier based upon remedial performance)
- Achieve license termination (no later than one year from submission of the final dose assessment).

* Minimum annual meetings with NRC to present data collected, review results to date, and provide assessment of bioremediation success and planned path forward.

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Program Manager Erhardt Werth Project Manager Sara Handy Task Manager Janis Lutrick Technical Review Jeff Gillow	ARCADIS 630 Plaza Drive, Suite 100 Highlands Ranch, Colorado 80129 Tel: 720-344-3500 Fax: 720-344-3535 www.arcadis-us.com	Bioremediation Implementation Process Cimarron Corporation Crescent, Oklahoma	Date: 01/29/2009 FIGURE 5-1 Page 2 of 3

Table 5-1. Summary of Baseline, Performance, and Remedy Completion Demonstration Monitoring

# of Sampling Locations	Sampling Frequency	Analyses to be Conducted (See Appendix C of GDP for Data Quality Objectives for each analysis) [b]
Stage 2: Baseline Monitoring		
5-1a: Groundwater Monitoring:		

32 wells across all 3 areas: BA#1, WAA , WUA	One-time sampling event	• Water levels
		• Uranium – total activity, isotopic, mass concentration
		• Performance indicators:
		  o Field parameters (pH, temperature, dissolved oxygen, specific conductivity)
		  o Total organic carbon
		  o Total dissolved solids
		  o Alkalinity
		  o Sulfate/sulfide
		  o Nitrate/nitrite
		  o Dissolved/ferrous iron

5-1b: Soil Monitoring:		

3 borings installed within each alluvial area of impact with 2 soil samples from different depth intervals in each boring (total of 6 samples from each area of impact)[a]	One-time sampling event	• Uranium – total activity, isotopic, mass concentration
		• Performance indicators:
		  o Bulk iron mineralogy including:
		    ▪ Selective chemical extraction
		    ▪ X-ray diffraction
		  o Iron sulfide content quantification
		  o Induced mineralogy changes including microprobe methods to examine soil mineralogy changes induced by TOC additional and anaerobic microbial processes using:
		    ▪ SEM with EDS
		    ▪ μ-XRF
		    ▪ μ-XANES

Stage 2: Initial Treatment System Installation		
5-1c: Groundwater Monitoring:		

12 wells – 2 wells within each of the 6 Initial Treatment Areas	Initially daily, then weekly for tracer, water levels, and field parameters for first month; monthly for other parameters during estimated 3-4 month Initial Treatment System Installation testing phase.	• Water levels
		• Tracer
		• Uranium – total activity, isotopic, mass concentration
		• Performance indicators:
		  o Field parameters (pH, temperature, dissolved oxygen, specific conductivity)
		  o Total organic carbon
		  o Total dissolved solids
		  o Alkalinity
		  o Sulfate/sulfide
		  o Nitrate/nitrite
		  o Dissolved/ferrous iron

5-1d: Soil Monitoring:		

One soil boring installed within each of the 6 Initial Treatment Areas (total of 6 samples)	Minimum of one sampling event based on observed results.	• Uranium – total activity, isotopic, mass concentration
		• Performance indicators:
		  o Bulk iron mineralogy including:
		    ▪ Selective chemical extraction
		    ▪ X-ray diffraction
		  o Iron sulfide content quantification
		  o Induced mineralogy changes including microprobe methods to examine soil mineralogy changes induced by TOC additional and anaerobic microbial processes using:
		    ▪ SEM with EDS
		    ▪ μ-XRF
		    ▪ μ-XANES

5-1e: Soil Oxidative Aging Testing:		
Laboratory Column Studies	During Initial Treatment System Installation testing phase	Column testing to asses: • Oxygen consumption • Iron oxidation Oxidative aging testing to be conducted using a PNNL methodology (Thornton et al 2007) as described in Attachment A to the September 2008 GDP Addendum
Stage 3: Performance Monitoring:		
5-1f: Groundwater Monitoring:		

32 wells across all 3 areas: BA#1, WAA , WUA	Monthly for the first 6 months of IRZ operation
	
	Semi-annually starting 12 months after start of IRZ operation and continuing until the start of remedy completion demonstration testing for groundwater
		• Water levels
		• Uranium – total activity, isotopic, mass concentration
		• Performance indicators:
		  o Field parameters (pH, temperature, dissolved oxygen, specific conductivity)
		  o Total organic carbon
		  o Total dissolved solids
		  o Alkalinity
		  o Sulfate/sulfide
		  o Nitrate/nitrite
		  o Dissolved/ferrous iron

5-1g: Soil Monitoring:		

3 borings installed within each alluvial area of impact with 2 soil samples from different depth intervals in each boring (total of 6 samples from each area of impact)a	Minimum of two sampling events based on observed results	• Uranium – total activity, isotopic, mass concentration
		• Performance indicators:
		  o Bulk iron mineralogy including:
		    ▪ Selective chemical extraction
		    ▪ X-ray diffraction
		  o Iron sulfide content quantification
		  o Induced mineralogy changes including microprobe methods to examine soil mineralogy changes induced by TOC additional and anaerobic microbial processes using:
		    ▪ SEM with EDS
		    ▪ μ-XRF
		    ▪ μ-XANES

Stage 4: Remedy Completion Demonstration Monitoring:		
5-1h: Groundwater Monitoring:		
16 wells across all 3 areas: BA#1, WAA, WUA	Quarterly for 8 quarters	• Water levels • Uranium – total activity, isotopic, mass concentration • Performance indicators: o Field parameters (pH, temperature, dissolved oxygen, specific conductivity)
5-1i: Soil Monitoring:		

3 borings installed within each alluvial area of impact with 2 soil samples from different depth intervals in each boring (total of 6 samples from each area of impact)[a]	Minimum of two sampling events based on observed results	• Uranium – total activity, isotopic, mass concentration
		• Performance indicators:
		  o Bulk iron mineralogy including:
		    ▪ Selective chemical extraction
		    ▪ X-ray diffraction
		  o Iron sulfide content quantification
		  o Induced mineralogy changes including microprobe methods to examine soil mineralogy changes induced by TOC additional and anaerobic microbial processes using:
		    ▪ SEM with EDS
		    ▪ μ-XRF
		    ▪ μ-XANES

a - Locations for sampling will be selected so that soil is retrieved from 1) within the areas of the highest concentration of uranium in groundwater at the start of remediation, 2) within the leading edge of the area of uranium impacts, and 3) within the area of uranium impacts upgradient from the highest concentration location. The selection of locations for sampling will be refined as the groundwater remediation progresses.

b - Sampling and analyses to be performed in accordance with Cimarron's Quality System Manual and the Data Quality Objectives (DQOs) established for this project as included in Appendix C of the June 2008 GDP.

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Attachment 1: Column Testing to Demonstrate the Protective Role of Iron Sulfide Relative to Uranium Immobilization

Jeff Gillow, Ph.D. and Boyce Clark, Ph.D.
ARCADIS, U.S., Inc.

January 30, 2009

1.0 INTRODUCTION

The NRC has requested a bench-scale test to examine the potential remobilization of uranium from soil after in situ treatment. This test will provide data to satisfy one of the four NRC acceptance criteria prior to proceeding to full-scale in situ groundwater treatment. This test replaces the final oxidative aging test proposed in the June 2, 2008 in-situ bioremediation work plan. This attachment presents a conceptual summary of the column test procedure as illustrated in the attached Figure 1.

2.0 CONCEPTUAL SUMMARY OF COLUMN TESTS

Column testing will be performed on soil collected from within areas of uranium impact at the Cimarron site, and within the areas to be treated by the full-scale in situ reactive zone (IRZ) treatment program. The soil, and corresponding groundwater, however will be obtained outside of the zone of influence of the initial treatment areas to ensure that:

1) The injection well system will not be affected by creation of void volumes in the aquifer due to removal of soil cores near the injection well.

2) The soil will be representative of the geochemical conditions within the area of uranium impact.

The column experiment will proceed through a "reducing phase," and an "oxidizing phase." The reducing phase will involve a batch incubation and the oxidizing phase will be a column test. First the untreated soil will be placed into glass bottles and site groundwater containing uranium will be added to the bottle along with amendment (organic carbon) and reagents (ferrous sulfate) to simulate the field treatment protocol. The bottle will be purged with nitrogen to remove air from the headspace, and reducing conditions will be established (through the introduction of organic carbon to stimulate microbial activity [identical to the process used in the field]) to promote the precipitation of uranium in the soil, and to create iron sulfide. The batch incubation method for the reducing phase of the test will provide the opportunity to remove samples of groundwater and soil. Analysis of samples that are periodically removed from the bottles will provide a means to track the progress of uranium reduction as well as the production of iron sulfide. After an appropriate mass of iron sulfide is created and uranium is precipitated, the reduced soil will be packed into a column. Site groundwater (collected from an area outside of the uranium impact) will then be introduced into the column. This groundwater will have dissolved oxygen at an ambient site concentration (~3 mg/L) as well as background concentrations of nitrate, and represents future groundwater entering the areas of impact from upgradient. Dissolved oxygen and sulfate will be monitored in the column effluent, and the uranium concentration will be measured during the establishment of oxidizing conditions in the groundwater.

Figure 5-2 of the June 2008 Groundwater Decommissioning Plan (GDP) defines the initial treatment areas. The soil samples that will be collected for column tests will come from the following four areas:

1) The downgradient portion of the area of impact in the sandy alluvium in Burial Area #1 (BA#1) (near well TMW-13).
2) The transitional alluvium in BA#1 in the middle of the uranium area of impact (near well TMW-9).
3) The downgradient portion of the area of impact in the sandy alluvium in the Western Alluvial Area (WAA) (near wellT-77).
4) The transitional alluvium in WAA in the middle of the uranium area of impact near the bedrock escarpment (nearT-64).

Therefore soil will be collected from locations dominated by sand (1 and 3, above) and dominated by finer-grained lithology (2 and 4, above). The column tests will therefore employ samples that are chosen to represent the end-members of soil types encountered within the areas of uranium impact.

3.0 COLUMN TESTING PROCEDURE

3.1 Soil Sampling

A sample of soil will be retrieved from BA#1 and from the WAA, within the area planned for full-scale treatment, and near but outside of the radius-of-influence of the initial treatment program, as described above. The untreated soil samples will be taken with an acetate-lined steel core sampling sleeve of the appropriate diameter (~1.5 inches) and length (~3-4 feet, or multiple 1-foot cores). Upon removal from the subsurface, the core(s) will be capped with plastic and wrapped with parafilm and vinyl tape and placed in a cooler on dry-ice. The sample will be shipped to a University laboratory (Colorado School of Mines or equivalent lab that maintains a license to handle radioactive material [specifically enriched uranium]).

3.2 Soil Mineralogical Testing

Prior to commencing column testing, the core sample will be analyzed for baseline mineralogy. The core will be extruded, homogenized by mixing, and subsamples will be removed (at 4 locations along a 1-ft core) for analysis of the following:

1) Total uranium and iron content by acid digestion and ICP-MS.
2) Extractable iron by dilute hydrochloric acid extraction (for amorphous iron)
3) Extractable iron by citrate-bicarbonate-dithionite extraction (for total iron oxyhydroxide).
4) Acid-volatile sulfide and simultaneously extractable metal analysis (AVS-SEM) to determine the iron sulfide content.

5) Acid-base accounting analysis (ABA) to determine the amount of sulfide-sulfur present in the soil.

The results of this analysis will constitute baseline soil mineralogical testing.

3.3 Column Testing

The baseline geochemical modeling work, presented in the June 2008 GDP, specifies that the concentration of reactive iron required for protection of the immobilized uranium, relative to re-oxidation over 1000 years, is 0.03 wt % (300 mg Fe/kg soil). In addition, the 80:1 Fe:U mass ratio is also specified by the baseline geochemical modeling to provide enough total sorptive capacity to immobilize any uranium that may be oxidized. Treatment is complete when these two criteria are met. Therefore, batch incubations with the samples described above will be treated with organic carbon and ferrous sulfate to establish these conditions in the laboratory. Multiple batches will be prepared so that adequate material is available for the column test, and the batches will be analyzed for the appropriate mineralogy. Details of the treatment procedure are provided here.

After baseline soil mineralogy sampling the soil will be placed into thick-walled, wide-mouthed screw-top glass bottles with Teflon-lined plastic closures. This will be done inside of an anaerobic (nitrogen-filled) gloved-box. Site groundwater will be added (after purging with nitrogen gas) and molasses and ferrous sulfate will also be added to stimulate microbial activity and provide a substrate for the formation of iron sulfide. Reducing conditions will be established and confirmed through the analysis of dissolved uranium, iron, and sulfate. A subsample of soil will be removed to assay for iron sulfide and uranium in the solid phase. Once appropriate conditions are met (specified above), the liquid will be decanted and the soil will be removed with a stainless-steel spatula and wet-packed (using the liquid decant from the batch incubation) into the column. Once filled with soil, the 2-foot, approximately 4-inch diameter thick-walled clear PVC column will be capped at either end and mounted vertically inside of an anaerobic glove box. The end-caps will consist of in-line 1 micron filters to prevent soil particles from exiting the columns. The weight of the soil added to the column will be recorded. Column testing will proceed as follows:

1) Anoxic site groundwater (prepared by purging site groundwater with nitrogen to remove dissolved oxygen) will be allowed to flow through the column, in an upflow direction, until it is fully saturated. The flow of anoxic site groundwater through the column will continue for 1-2 days at which point the pH, dissolved oxygen, iron, uranium, and sulfate concentration in the water will be measured. This will establish baseline effluent parameters.

2) Site background groundwater at ambient oxygen concentration, along with a conservative tracer (fluorescein or rhodamine) will be introduced into the column. The dissolved oxygen content of the influent water will be measured, as well as pH, sulfate, and nitrate concentration in the influent water. The conservative tracer will be used to determine column pore volume and to examine the retardation of dissolved oxygen through the column.

3) Samples will be collected at each pore volume (flow will be established so that replacement of one pore volume requires approximately 1-2 days) and measured for tracer concentration, pH, dissolved oxygen (using an in-line dissolved oxygen probe), dissolved iron, and dissolved uranium, and sulfate and nitrate.

4) The column experiment will be terminated when any one of the following criteria are met:

   - 5 days after dissolved oxygen breaks through the column
   - Uranium breaks through the column at >180 pCi/L

We will frequently monitor for dissolved oxygen breakthrough, and once observed, we will collect samples to determine the trend in uranium concentration. If, for example at approximately 60 days of operation at a flowrate of 1 pore volume every 2 days, we observe dissolved oxygen breakthrough, then we will have simulated ~125 years of groundwater flow. This duration of simulated flow is based upon the 1-D geochemical modeling (Section 3.4.3.3 of the GDP) where we prepared the model so that one pore volume represents 4.2 years of flushing with groundwater. Based upon the data that we obtain up to this point where oxygen breaks through, and 5 days past it, we will extrapolate to performance over 1,000 years. This extrapolation will be based upon the results of the concentration of uranium in the column effluent, the rate of uranium leaching (if any), and the remaining mass of uranium in the column (determined by mass balance calculation).

A reoxidation column test will be performed using BA#1 soil and Cimarron river water. The river water will be substituted for site background groundwater (step 2 described above). The river water will be analyzed prior to use to determine the concentration of dissolved oxygen, nitrate, and other constituents. If possible, Cimarron river water will be collected at flood stage and used in the reoxidation column test. In addition, a reoxidation column test will be performed using WA soil and rain water. The rain water will be collected during the time of the year with the highest average precipitation; the collected water will be analyzed for baseline chemistry prior to use. Additional tests, of BA#1 soil with rain water, and WA soil with river water, may be performed in batch tests if the results of the column tests yield different results than the tests with baseline site groundwater. Batch tests will involve the addition of the oxic water to the reduced sediments in a serum bottle and measurement of loss of dissolved oxygen, nitrate, and other oxidants from the water and corresponding measurement of dissolved sulfate and uranium. The batch tests will be simpler to perform than column tests and they will provide information about the potential reoxidation of uranium with the other sources of oxic water, however extrapolation over the 1,000-year period will be more difficult as compared to the advective groundwater flow column experiments.

4.0 SUMMARY

The column test described above has been developed in specific response to an NRC request. It is one of four acceptance criteria specified by the NRC in order to obtain the approval necessary to allow the in-situ, bio-remediation program to advance to full-scale. The column test is intended to demonstrate that the iron sulfide geochemistry necessary to sequester uranium in soils, thereby preventing uranium concentrations in groundwater from ever exceeding a threshold value of 180 pCi/L, can be established. Specifically, results obtained from the column test will be used to demonstrate that 1) uranium in groundwater in Burial Area #1 and the Western Alluvial Area can be reduced to and maintained at concentrations below the 180 pCi/L treatment level after ambient (oxygenated) conditions return (following completion of active remediation) and that 2) post-treatment, uranium concentrations in groundwater will permanently remain below the 180 pCi/L treatment level. Accordingly, the results of the column test will pre-empt the need for long-term monitoring at the site once basic (two to three year) remedy performance monitoring has been concluded. In addition to providing the requested demonstration, information obtained from the column study will be used to optimize the amendment applications performed in the field to create the widespread geochemical conditions required to achieve lasting treatment of the groundwater impacted by uranium.