In-Situ Recovery of Uranium:
EPA Region 8 & ORD Workshop for Government Staff

September 29, 2010
Denver, CO

Workshop Summary

CONTENTS

Section 1 – Introduction and Background

Workshop overview
This workshop provided a discussion platform for employees in Region 8 state and federal agencies regarding the mining practice of in-situ recovery (ISR) of uranium. EPA Region 8 states are Colorado, Utah, Wyoming, Montana, North Dakota, and South Dakota. Recent and near-future increases in ISR activities may result in environmental implications for groundwater and other environmental resources near ISR facilities. This workshop presented information on the following phases of the ISR process:

- Pre-operations and permitting considerations
- ISR operations
- Post-operations and aquifer restoration

The workshop allowed for discussion of technical aspects of uranium deposits and recovery operations, injection permitting issues, environmental and public health issues during ISR operations, and research on aquifer restoration methods and effectiveness, among other topics.

Purpose
The purpose of the workshop was to bring together federal and state agency staff involved in ISR permitting, regulation, and research to discuss the ISR mining process and analyze the potential environmental impacts. It was intended to provide a common understanding of ISR processes, to inform participants of new research related to ISR monitoring and restoration, and to discuss the potential implications of this research and ISR activities.

Date and Place
The workshop was held on Wednesday, September 29, 2010 from 8:00am to 5:00pm in EPA's Region 8 conference center at 1595 Wynkoop St. in Denver, CO 80202.

Introductory Remarks
Martin Hestmark, Deputy Assistant Regional Administrator, Office of Ecosystems, Protection, and Remediation, USEPA Region 8 (Denver, CO)

Mr. Hestmark provided some EPA perspective on the workshop, and congratulated participants for getting together to talk through the issues associated with in-situ recovery of uranium. He emphasized that this is "good government" in his view. He encouraged participants to interact. Additionally, Mr. Hestmark provided some perspective on the use and extraction of resources in our Region, including:

- Today's energy consumption world-wide is 17 terawatts. By 2050 it is anticipated to be 31 terawatts.
- There is no question that to avoid catastrophes of some sort we will need to become more efficient and develop energy sources to supply that need.
- Uranium and nuclear energy will be a part of this increased energy supply. There may be a couple of thousand nuclear power plants by 2050. Yet we have not permitted a nuclear power plant in the US in years. This is going to happen, and we are going to need this as a society.

- It would be great to see these nuclear and other energy related efforts occur in manner that does not result in a liability. For example, in this part of the world water is a real asset, and yet we are running short on it. We have six or seven reservoir projects to divert water from the Colorado River basin. Groundwater is a big deal. With respect to the ISR of uranium topic, we need to figure out how to do ISR without creating a liability and degrading our groundwater resources.
- We need to find a way to extract resources to fulfill our needs in a manner that works, and that doesn't cost more money down the road. We spend millions of dollars in efforts to address legacy mining (e.g., $300 million on the Libby, MT Superfund site). The cost of extracting resources needs to include all of those costs.
- Perhaps in cleaning up former mines, we have an opportunity as well. One example is the Schwartzwalder mine in Colorado. There are millions of gallons of uranium-pregnant water filling up the mine workings. This shouldn't be seen as just a liability, but also as an opportunity for someone to "mine" the water.

ISR: Uranium Ore to Yellowcake
Angelique Diaz, PhD, Environmental Engineer, Indoor Air Toxics and Transportation Unit, USEPA Region 8 (Denver, CO)

Dr. Diaz described the general processes used to extract uranium using the ISR method. She noted that U-235 is what is used for nuclear power, which is only <1% of natural uranium. The vast majority (~99%) of natural uranium is in the U-238 isotope.

To extract the uranium from a groundwater source, the uranium must be mobilized. To do this, a lixiviant with oxidative properties is injected underground into the groundwater. This oxidizes the U^{4+} (an insoluble form), which typically exists in a roll-front deposit within an aquifer, to U^{6+} (soluble form). Once mobile, the uranium-pregnant water can be extracted through wells to the surface. At the surface, the uranium is recovered via an ion exchanger and then further processed into yellowcake. Reverse osmosis or a similar process is often used to treat process water prior to reinjection. The brine from the reverse osmosis process goes to an evaporation pond and/or a disposal well.

ISR Operations and License Applications
Bill Von Till, Chief, Uranium Recovery Licensing Branch, Division of Waste Management and Environmental Protection, Nuclear Regulatory Commission (Rockville, MD)

Mr. Von Till discussed wellfield construction and well placement, as well as the number and location of licensed ISR facilities.

The NRC licenses facilities in non-agreement states, and oversees operations at existing facilities. Many NRC resources are spent on license renewals, and preparing for review of license applications based upon letters of intent. NRC updates its website (http://www.nrc.gov/materials/uranium-recovery.html) with information on letters of intent, applications, and site information for reviews monthly. Many licenses are approved with a large number of conditions. The NRC can approve with conditions, approve, or deny a license. The licensing process usually takes about three years.

Smith Ranch, WY is the largest production facility in the country, producing two million pounds of yellowcake per year. Mr. Von Till emphasized that ISR is really milling rather than mining because ISR chemically alters the rock below ground.

ISR wells are usually placed in a five-spot pattern with one production well in the middle of four surrounding injection wells. Gradient of the below-ground water is monitored to ensure flow to the production well. A monitoring well ring is installed ~500 feet outside the production wellfield to monitor for excursions.

Many underground uranium ore bodies associated with aquifers are not sources of drinking water prior to operations.

Hydrogeology of ISR Operations: ISR Wellfield Design and Characterization
Elise Striz, PhD, Hydrogeologist, Uranium Recovery Licensing Branch, Nuclear Regulatory Commission (Rockville, MD)

Dr. Striz expanded upon Mr. Von Till's discussion of wellfield design, and focused on the hydrogeology of an ISR operation. She emphasized that NRC's role is to ensure that the licensee operates, monitors, and restores ISR facility sites appropriately while protecting public health, safety, and the environment. Elements that must be characterized and evaluated at a potential site include aquitard layers, faults, groundwater flow and whether or not an aquifer is confined. Intensive pump tests are required for unconfined aquifers in particular to ensure the system is managed without expanding beyond the target region of the aquifer. Monitoring wells are installed both above and below the aquifer to be mined. Potential licensees must provide a considerable amount of characterization data to the NRC for consideration.

Section 2 – Pre-Operations and Permitting of In-Situ Recovery Facilities

Underground Injection Control Program Class III Injection Well Permitting
Valois Shea, Underground Injection Control Program, USEPA Region 8 (Denver, CO)
Angelique Diaz, PhD, Environmental Engineer, Indoor Air Toxics and Transportation Unit, USEPA Region 8 (Denver, CO)
Colleen Gillespie, Water Program, USEPA Region 8 (Denver, CO)
Wendy Cheung, PhD, Environmental Engineer, Underground Injection Control Program, USEPA Region 8 (Denver, CO)

These EPA staff members discussed the Underground Injection Control (UIC) program as it relates to Underground Sources of Drinking Water. There are different classes of injection wells depending upon their use. There are differing requirements for each type of well with respect to construction, monitoring, operation, reporting, and closure. The type of well required determines the type of permit for that well.

Dr. Diaz provided an update on the revision of 40 CFR §192. At the time when this was originally promulgated 25 years ago, conventional mining and milling dominated the industry. Standards for hazardous substances in groundwater and drinking water have changed since the standards were first developed. Therefore these standards are being reviewed and may be revised to better address ISR, which is anticipated to dominate the industry.

Regional Applied Research Effort
Valois Shea, Underground Injection Control Program, USEPA Region 8 (Denver, CO)

Ms. Shea discussed EPA's program to provide annual grants to each region for a specific research project. EPA's Region 8 selection for last year was a project to look at proposed Class III injection well permits for ISR activities to determine the aquifer exemption boundary for the area where injection of lixiviant will be occurring. The remainder of the aquifer must remain protected. Hydrologic and geochemical modeling of the uranium ore-bearing aquifers will provide information to support the development of effective EPA permit requirements and aquifer exemption delineations. The results of this research effort will ensure that permit requirements and aquifer exemption decisions are based on sound science and are protective of USDWs as mandated by the Safe Drinking Water Act.

Predictive Modeling Strategies at Proposed Uranium ISR Mines
Dr. Raymond H. Johnson, US Geological Survey (Denver, CO)

Dr. Johnson first discussed the context of uranium usage with respect to the amount of electricity that nuclear power provides in the US (20%), and the amount of uranium needed to fuel these nuclear operations (>55 million lbs./yr). He emphasized that uranium is a world market, and that it is sold to the highest bidder. Currently 80% of the uranium produced in the US is obtained via ISR.

Dr. Johnson has been working on modeling strategies to address groundwater issues including aquitard integrity, groundwater quality, and long-term restoration stability and natural attenuation. The modeling strategies include development of a conceptual hydrogeologic and geochemical system, a reactive transport model, modeling alternative design and closure plans, and evaluating uncertainty. These modeling strategies can be useful in evaluating operation and closure plans for ISR facilities, and will be used for the RARE collaboration with the EPA identified in the previous presentation by Valois Shea.

Section 3 –Operations of In-Situ Recovery Facilities

ISR Operations Monitoring – Excursions Detection and Correction
Elise Striz, PhD, Hydrogeologist, Uranium Recovery Licensing Branch, Nuclear Regulatory Commission (Rockville, MD)

Dr. Striz discussed ISR excursions, which is the movement of any fluid containing byproduct material from an ISR wellfield into surrounding groundwater. There are both vertical and horizontal monitoring wells that are typically installed 500 feet apart, and 500 feet outside of the production wellfield. Licensees must conduct ore zone aquifer pumping tests to demonstrate effectiveness of the monitoring well system and of the production and injection wells in containing the active ISR constituents. Dr. Striz discussed how unconfined aquifers pose challenges related to containing ISR operations. She discussed how excursion wells must be monitored twice a month during operations, and every six weeks during restoration. If an excursion does occur, it must be corrected within 60 days and the well must be monitored every week until the excursion is no longer detected. Placement of excursion monitoring wells, corrective actions for excursions, and complicating factors associated with a site's geology were discussed.

Recently, the NRC analyzed the environmental impacts from both horizontal and vertical excursions at three NRC licensed ISR facilities (NRC, 2009). In that analysis, which involved 60 events, the NRC staff found that, for most of the events, the licensees were able to control and reverse the excursions through pumping and extraction at nearby wells. Most excursions were short-lived, although a few continued for several years.

There was some discussion about surety bonds. The ISR facility proposes an amount for a surety bond and the NRC must approve the amount. If excursions are not mitigated within 60 days, a way to continue operating is to increase the surety bond, or the company can suspend injection until the excursion is no longer detected.

Protection of the Public and the Worker at ISR Sites
Bill Von Till, Chief, Uranium Recovery Licensing Branch, Division of Waste Management and Environmental Protection, Nuclear Regulatory Commission (Rockville, MD)

Mr. Von Till discussed various aspects related to NRC regulations and protections required at ISR operations. The NRC considers ISR to be a milling activity rather than a mining activity. He discussed regulatory requirements for public and worker exposure to radiation, as well as monitoring for these elements at ISR facilities.

Improving ISR Safety
Jim Krumhansl, Geochemistry Department, Geoscience, Climate, and Consequence Effects Center, Sandia National Laboratories (Albuquerque, NM)

Mr. Krumhansl presented some ideas that he and colleagues developed on methods to make ISR a safer process. They were restricted to modeling because Sandia does not have a program for studying ISR processes. One challenge with current ISR processes is that the lixiviant mobilizes other elements in addition to uranium, increases groundwater salinity, and introduces complex organic compounds into the groundwater. One idea for improving this is to develop a complexing agent that is specific to uranium, particularly if it is capable of complexing uranium in its tetravalent form. Isosaccarinic and gluconic acids or similar compounds may be capable of this and should be considered. Overall, Mr. Krumhansl emphasized that creative use of non-standard chemistry may provide new ways of targeting the extraction of uranium minerals while also providing environmentally friendly approaches that don't liberate oxy-anions or heavy metals.

Section 4 – Post-Operations and Aquifer Restoration at In-Situ Recovery Sites

Geochemical Processes Influencing Aquifer Remediation at In-Situ Recovery Uranium Sites
Patrick Longmire, PhD, Los Alamos National Laboratory (Los Alamos, NM)

Dr. Longmire discussed geochemical processes and mineralogy that influence aquifer remediation efforts following ISR activities. He emphasized that it is essential to know the mineralogy and water chemistry of the aquifer, including iron speciation and other constituents. To achieve aquifer restoration, you need to know the impact of reductants on mineralogy. It is challenging to restore an aquifer after it has been oxidized. We can use geochemical data to detect potential effectiveness of remediation tools, however. Reaction rates are important to know for this. Dr. Longmire discussed the use of PHREEQC data for actual wellfields in Texas and Wyoming. There are a number of different geochemical data needs for evaluating monitored natural attenuation at ISR uranium mining sites.

Overall, Dr. Longmire emphasized the following points:
- Geochemical, microbiological, and mineralogical characterization of redox-sensitive species are required for evaluating aquifer remediation at ISR uranium mining sites.
- Chemical characteristics of recharge water and kinetics of mineral precipitation control the long-term composition of post-remediated aquifer systems at ISR uranium mining sites.
- Prudent addition of oxidants and reductants during mining and aquifer restoration should enhance our ability to achieve pre-mining conditions at ISR uranium sites.
- Geochemical processes (adsorption/desorption and mineral precipitation/dissolution) influencing remediation are quantified through field data, experiments, and geochemical modeling.
- Achieving baseline conditions (groundwater chemistry-aquifer mineralogy) at ISR remediated sites is possible depending on site specific conditions and mining operations.

Groundwater Restoration at Uranium In-Situ Recovery Mines
Susan Hall, PhD, US Geological Survey, Central Energy Resources Science Center (Denver, CO)

Dr. Hall's research has focused on evaluating the baseline conditions at historical ISR operations to determine if they have been restored to these baseline conditions. Many restoration efforts use groundwater sweep, ion exchange and reinjection, and reverse osmosis systems.

Reverse osmosis is highly effective, but there is a considerable loss of water with each flush (~30%). Some operations attempt to recreate original conditions using bacteria – e.g., an in-situ bioreactor. It is important to determine how to get an aquifer back to reducing conditions. Dr. Hall used case studies from Texas, Wyoming, and Nebraska to illustrate efforts to restore post-ISR aquifers back to baseline conditions.

Establishing Baseline and Comparison to Restoration Values at Uranium In-Situ Recovery Sites

Ardyth Simmons, PhD, Los Alamos National Laboratory (Los Alamos, NM)

Dr. Simmons discussed monitored natural attenuation as one method of demonstrating restoration at ISR sites. Prior to demonstrating whether monitored natural attenuation has occurred at a site, however, it is first necessary to have a defensible groundwater baseline data set. To that end, LANL staff worked to establish a defensible baseline data set for two sites in New Mexico and Texas using methods approved by the New Mexico Environment Department and USEPA. Statistical tools, such as ProUCL (USEPA, 2009), were used to calculate upper tolerance limits (UTLs) for constituents in the aquifers. UTLs provide higher restoration values than means for most constituents. These results indicated that it may be unrealistic for ISR operations to restore aquifers to the mean, because in some cases, this means that there would have to be less uranium present than there was pre-mining. Pursuing more conservative concentrations results in a considerable amount of water usage, and many of these aquifers were not suitable for drinking water before mining initiated. There was some discussion at the end of Dr. Simmons' presentation about whether individual well data could be used as baseline, rather than using a mean for all wells. While this has some appeal, there would be a large amount of data required and that is not how the standard is currently set. NRC participants indicated that the NRC is considering adopting an alternative to restoration to mean values in its new rulemaking.

Enhanced Monitored Natural Attenuation

Jim Krumhansl, Geochemistry Department, Geoscience, Climate, and Consequence Effects Center, Sandia National Laboratories (Albuquerque, NM)

The key to monitored natural attenuation (MNA) is to better understand geohydrology and modeling. Mr. Krumhansl recommended looking for a better complexing agent that would degrade quickly, predictably, and would be innocuous. He suggested considering ISA and Citrate as potential complexing agents. He also recommended using sulfate reduction to enhance metal re-precipitation, and optimizing natural sorption with pH adjustment. Overall, Mr. Krumhansl suggested that there may be numerous strategies for enhancing MNA effectiveness. Many of the approaches he discussed were only in the modeling stages. Any selected enhancement to MNA would be very site specific.

ISR Restoration and Stability Monitoring

Elise Striz, PhD, Hydrogeologist, Uranium Recovery Licensing Branch, Nuclear Regulatory Commission (Rockville, MD)

Dr. Striz discussed NRC requirements for ISR facilities with respect to restoration post-operations. To ensure ISR wellfields do not contaminate surrounding groundwater after ISR operations are completed, the ISR wellfields must be fully restored to the groundwater protection standards (GWPS) and demonstrate that those standards will not be exceeded. She noted that licensees and applicants must demonstrate that they can achieve background levels for constituents or an alternate concentration limit (ACL), which can only be considered after the licensee has demonstrated that primary restoration goals are not practicably achievable. ACLs are not established prior to restoration.

Typical restoration methods include groundwater sweep, groundwater treatment (such as reverse osmosis), introduction of reductants, and groundwater circulation. She noted that groundwater sweep is starting to be abandoned because it is very water intensive and is not as effective as other strategies. Reverse osmosis is often effective and reduces total dissolved solids considerably.

Dr. Striz recommended a document, "Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities" published by the USEPA in March 2009, as a good resource. She noted that a large number of data points are needed – at least 8-10 points – and longer monitoring times to get good statistical data.

She emphasized that as a part of NRC's primary objective to protect public health, safety and the environment, the NRC regulates ISRs to ensure that the licensee restores ISR wellfields to approved groundwater protection standards (GWPS) to ensure no future contamination of surrounding groundwater.

NRC requires a licensee to:

- Show that the restoration achieved the GWPS for all contaminants of concern (COCs) on a wellfield average or well-by-well basis at the wellfield compliance wells
- Show that stability monitoring demonstrates that there are no statistically significant increasing trends in any COCs at compliance wells for four consecutive quarters (1 year).

An analysis of restoration field results from approved NRC restorations:

- Shows the COC GWPS standard can be met and has remained protective of surrounding groundwater
- Shows stability monitoring can indicate if there are statistically significant increasing trends to trigger more monitoring or if corrective action is needed.

Status of the NRC Proposed Rule on Groundwater Protection at ISR Sites
Bill Von Till, Chief, Uranium Recovery Licensing Branch, Division of Waste Management and Environmental Protection, Nuclear Regulatory Commission (Rockville, MD)

Mr. Von Till discussed NRC's direction to create a new, narrow rule making on ISR operations. With respect to long-term monitoring he noted that it is difficult to determine how long they should monitor. The EPA emphasized the benefits of a longer monitoring period. He also discussed three restoration regimes – baseline, based on use, and alternate concentration levels (ACLs). He noted that in NRC regulations there is not a good way to conduct monitored natural attenuation because operators want to clean up a facility and leave. Industry prefers an ACL. He suggested that perhaps the length of monitoring time should be site specific, once stabilization has been achieved within the aquifer. It is believed that at least three years is necessary to demonstrate stabilization. NRC is currently looking for an extension on this rule-making so that they can see what EPA's rulemaking does in 2011. There is also an issue that there are no real institutional controls because once operations are closed down, they are released by the NRC.

Section 5 – Wrap-Up Discussion

Group Discussion – General Issues for Each Phase of the ISR Process

What topics need to be discussed in greater depth?

- Issue of liability. At the end of the process, where does liability lie? We need to ensure that the taxpayers aren't paying for cleanup down the road.
- Issue of institutional controls and follow-up. If an aquifer is exempted, who is monitoring its water quality?
- NRC baseline that is established every two weeks is not a representative sample, according to one participant with the State of Colorado. You need a least 12 data points for each well for a year – that is likely what the Colorado standard will require. NRC does pre-operational testing for 4 quarters. If they are targeting the ore zone, that should be the focus. This could require more pre-operational testing. One participant mentioned that geochemically, the reductive capacity is the key. It is not too difficult to do a couple samples of redox for iron.
- Aquifer exemption boundary is an issue for states and the EPA (not in NRC's purview). The boundary is located somewhere outside the monitoring well ring, before it gets to underground sources of drinking water (USDWs).
- Bill VonTill indicated that we need more data upfront. Yet we need justification to get industry to provide it. If the additional data do not cost much more to obtain, then they will often agree. If not, they will want to see a technical basis for requiring more data. If you can demonstrate that you have a way to save industry money or reduce pore volume treatment, that would be appealing to companies.
- There are problems with inconsistency of data with really old or really new monitoring wells.
- Maybe EPA can write something into 40 CFR §192 to address some of these issues associated with uncertainty. EPA can't tell NRC how to implement the standard, but EPA could look at identifying important elements to measure, monitor, and test.
- Is the baseline set too low? Individual wells vs. average of the entire wellfield leads to different figures, which may make it impossible to establish certain levels at wells where the baseline was actually higher than the average.
- There is a lot of water used when restoring ISR-impacted aquifers. Maybe this needs to be evaluated to determine how effective this is at cleaning up operation sites beyond a certain point.

Appendix A: Workshop Agenda

FINAL AGENDA

In-Situ Recovery of Uranium: EPA Region 8 and ORD Workshop for Government Staff
September 29, 2010
EPA Region 8 Office: 1595 Wynkoop St., Denver, CO 80202

Overview/Introduction

8:00 Workshop overview and introduction
8:15 Overview of ISR process
- 8:15 Technically how the ISR process works – how lixiviant mobilizes uranium, how operations are designed (Angelique Diaz, EPA)
- 8:30 Wellfield design, location of current/future operations (Bill Von Till, NRC)

8:50 Overview of hydrogeology of ISR operations (Elise Striz, NRC)

Permitting/Pre-Operations

9:20 UIC issues
- o Permitting for Class 3 wells (Valois Shea, EPA)
- o Disposal permits (Wendy Cheung, EPA) & NPDES (Colleen Gillespie, EPA)
- o State roles in regulating (Valois Shea & Colleen Gillespie, EPA)
- o Update on 40 CFR 192 (Angelique Diaz, EPA)

9:55 *Break*
10:10 Role of Predictive Modeling
- 10:10 Overview of R8 RARE project for South Dakota ISR permit (Valois Shea, EPA)
- 10:20 Predictive modeling strategies at proposed uranium in-situ recovery mines (Ray Johnson, USGS)
- 10:40 Discussion of modeling requirements in permits

Operations

10:55 Operations Monitoring at ISR operations: Excursion detection and correction (Elise Striz, NRC)
11:25 Protection of the public and worker during ISR operations (Bill Von Till, NRC)
- o Regulatory requirements and guidance

12:00 Safer ISR methods – Sandia recommendations (Jim Krumhansl, Sandia)
12:30 *Lunch*

Restoration/Post-Operations

1:30 Geochemistry of restoration (Patrick Longmire, LANL)
2:00 The effectiveness of restoration techniques used in legacy US ISR deposits (Susan Hall, USGS) – assessments using real data, not models
2:30 Monitored Natural Attenuation / Post-Closure Monitoring
- 2:30 Establishing baseline and comparing it to restoration values (Ardyth Simmons, LANL)

3:00 *Break*
3:10 Enhanced MNA (Jim Krumhansl, Sandia)
3:25 ISR restoration and stability monitoring (Elise Striz, NRC)

4:00 Status of the NRC proposed rule on groundwater protection at ISR sites (Bill Von Till, NRC)
4:15 Discussion Session
5:00 Adjourn

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