Overview of Operation of In-Situ Uranium Recovery

Uranium Extraction Workshop
- Identifying the Challenges and Opportunities for Research

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What is “IN-SITU” Recovery?

In-situ recovery (ISR) is the “In-Place” extraction of mineral from an ore-body. Uranium is removed from sandstone deposits by reversing the natural chemical process which deposited it.

Uranium is recovered without bringing the ore to the surface by conventional open pit or underground methods.
Advantages of ISR Technology

- No tailings, waste dumps or mill facilities
- Unit costs are reduced allowing lower grade deposits to be mined
- Minimal airborne emissions
- Significantly reduced workforce (90 vs. 600)
- Surface disturbances are temporary
- At conclusion of operation, affected ground water is restored to pre-mining conditions
ISR: Multi-Disciplinary Technology

- Geology
- Hydrology
- Drilling Engineering
- Chemical/Process Engineering
- Radiation Health Physics
- Environmental Engineering
- Metallurgy
- Energy Engineer?
Introduction to In Situ Recovery (ISR) Mining

- Uranium Deposition
- In Situ Recovery Method
- Progressive Stages of In Situ Mining

PRI - Highlands, F-Wellfield, 2nd year in operation. 7/98, Quarterly Inspection.
**Major Types of Uranium Deposits**

*North America*

**SEDIMENTARY**
- **TABULAR**
  - New Mexico, Colorado Plateau
- **ROLLFRONT**
  - Wyoming, Texas, Nebraska, Colorado
- **BASAL CONGLOMERATE / UNCONFORMITY**
  - Canada
- **COLLAPSE BRECCIA PIPES**
  - Arizona
- **EVAPORITES - Phosphates**
  - Florida

**IGNEOUS / METAMORPHIC**
- **VEIN TYPE**
  - Colorado, Washington
- **VOLCANICS**
  - Mexico, Arizona, Nevada
- **PLUTONIC**
  - Alaska, Washington
Redox Relationship

- A fundamental concept for sandstone uranium deposits
- U is mobile in OXIDIZING (Eh+) environment as U\(^{+6}\)
- U precipitates in REDUCING (Eh -) environment as U\(^{+4}\)
Uranium occurs in ‘roll front’ deposits in sandstone layers within sandstone/shale sequences in the major geologic basins (e.g. the Powder River Basin & the Great Divide Basin). Uranium weathered from basement source rocks and/or overlying volcanic ash is transported into sedimentary basins by ground water.
Uranium Roll Front Deposition

Deposition mode results in long, narrow sinuous roll front deposits in sandstones, which are generally separated by shale.

There may be uranium deposits at different depths at the same surface location.
**In Situ Mining Method**

The ore is mined by injecting a fluid (lixiviant) into the ore zone to ‘remobilize’ the uranium (the reverse of the deposition process). The uranium enriched fluid is then pumped to a facility for uranium recovery. In Wyoming, the most effective lixiviant is generally a carbonate-based solution (carbonated ground water).

As outlined on the following slides, the injection and production wells are completed in the ore zone and surrounded by a monitor well ring in that zone, as well as overlying and underlying monitor wells.

Lost Creek Drilling, Summer 2007.
3-D Schematic of a Five-Spot Pattern & Idealized Flow Lines
Modern Mining

• Environmentally sound (No tailings or pit)
• Understood by State and Federal regulators
• Cost effective
Production Zones (economically recoverable ore)

- Exploration
- Delineation
- Permitting
- Mine Unit Development
- Production Operations
- Restoration /Reclamation
- Release to Unrestricted Use
Progressive Stages of In Situ Mining

☑ Exploration

Lost Creek Ore Trend

Ore Trend

1 mile
Exploration: Typical 1500 Drill Rig
Identifying economically recoverable ore

Delineation

Period of More Intensive Drilling

Progressive Stages of In Situ Mining
Delineation: Geophysical Logging
Progressive Stages of In Situ Mining

✓ Permitting
✓ Baseline Data Collection
  (in Permit Area & Adjoining Lands)
  Land Use (present & historic),
  Archeology, Climate, Geology,
  Hydrology (quantity, quality, & water rights),
  Soils, Vegetation, Wildlife, Wetlands, Radiology

Gamma Survey at Lost Creek, September 2006
Progressive Stages of In Situ Mining

✓ Initial Operations Permitting
   Baseline Evaluation
   Mine (Operations) Plan
   Reclamation Plan

Production Zones (economically recoverable ore)

Mine Unit 1
Monitor Well Ring

Mine Unit 2
Monitor Well Ring

Ore Trend
Progressive Stages of In Situ Mining

 ✓ Development

 Period of Most Intensive Activity

 Production Zones (economically recoverable ore)

 Ore Trend

 Permit Area
**Production Operations**

**Reporting** (Wildlife, Annual Reports, 5 Year Mechanical Integrity Testing, etc)

PRI - Highlands,
Sage Hens in H Wellfield, July 2000
Production: ISR Plant Facilities

Christensen Ranch Satellite Plant - Wyoming

Smith Ranch Plant - Wyoming
**Progressive Stages of In Situ Mining**

✓ **Restoration /Reclamation**
  (groundwater restoration, well abandonment, facilities removal, reseeding, ...)

Reverse Osmosis Units

Production Zones

Mine Unit 1
Monitor Well Ring

Mine Unit 2
Monitor Well Ring

Ore Trend

Permit Area
Reclamation: Once recovery operations are complete in a given Mine Unit, ground water restoration and then final reclamation of the surface facilities are required. The land is returned to original use without restrictions.
Progressive Stages of In Situ Mining

✓ Bond Release Packages

Lost Creek ISR, Bond Calculation, Table 1/2, Page 17/17.

Worksheet 8
Miscellaneous Reclamation

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<th>Quantity (Feet)</th>
<th>Cost of Removal/Disposal ($/Foot)</th>
<th>Cost of Removal/Disposal ($)</th>
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Total Miscellaneous Cost: $73,347

Lost Creek ISR, LLC
TABLE RP-4 Restoration and Reclamation Costs
ISR Locations in Wyoming
Producing Wyoming Uranium ISR Operation