Heap Leach Recovery of Uranium in the Western US

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Background and History

- Heap leaching dates to 1500's
  - *De Re Metallica* (Agricola, 1556)

- New References
  - Heap Leaching, T. J. Manning and D. W. Kappes, SME Mining Engineering Handbook, 2011.
  - Surface Techniques of Solution Mining, W. J. Schlitt, SME Mining Engineering Handbook, 2011.

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US Uranium Mines and Prospects

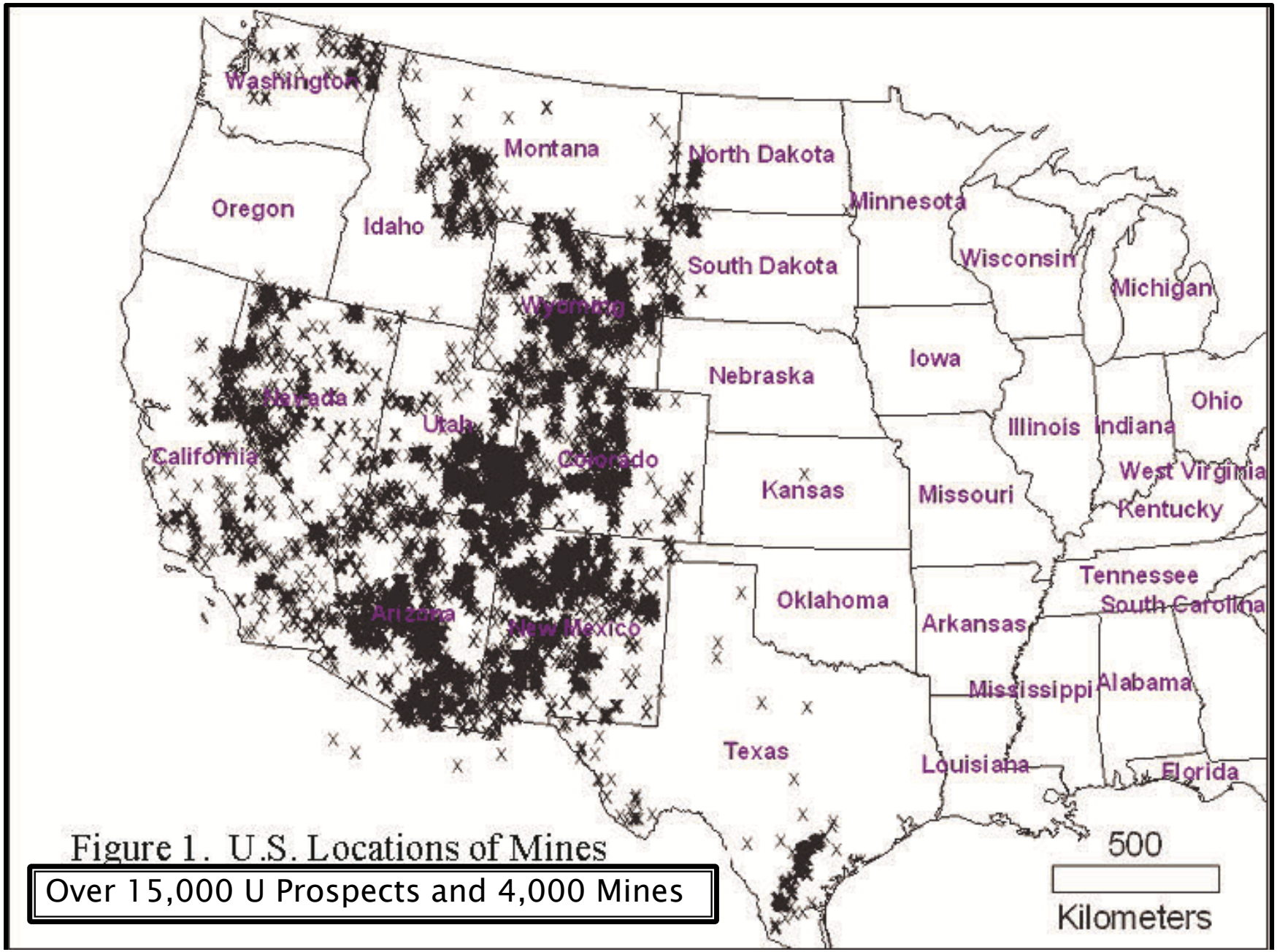
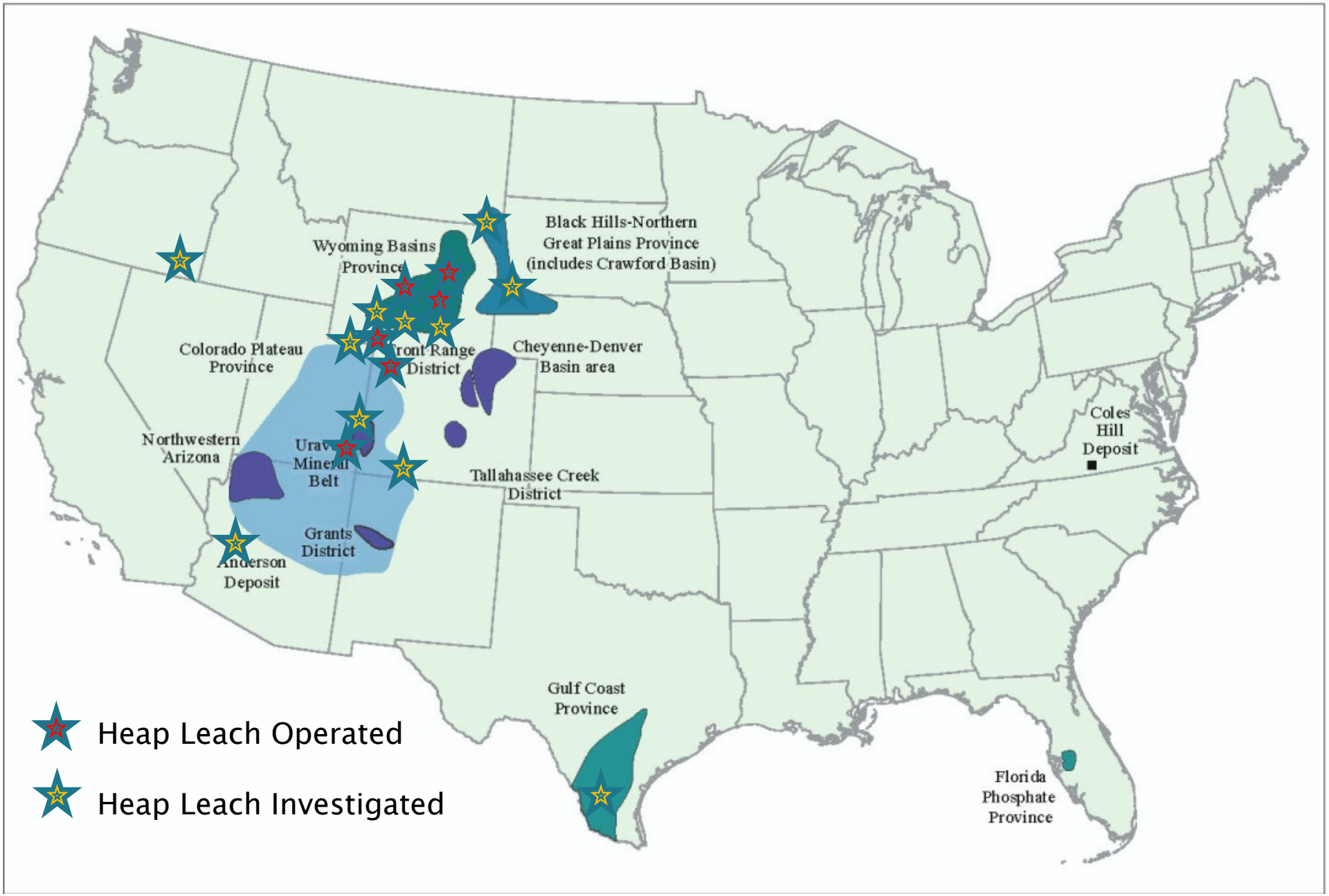


Figure 1. U.S. Locations of Mines

Over 15,000 U Prospects and 4,000 Mines

US Uranium Provinces and Heap Leach



Evolution of Regulations
Heap Leach Operations for Uranium (US)

- Early US Uranium Industry Regulated by AEC (1954)
  - Source Material defined as ores that contain by weight 0.05 percent (500 ppm) or more of uranium, thorium, or any combination thereof.
  - Processes which upgraded ore less than 500 ppm, including small heaps were generally considered (by miners) as mining operations.
- Regulatory Transition to NRC 1974 to 1975
  - Defined byproduct materials or tailings under Section 11e.(2) as the tailings or wastes produced by the extraction or concentration of uranium or thorium from any ore processed primarily for its source material content.

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Upgrading Operations (US)
1950's and 1960's

- Limited Number AEC Buying Stations
- Less Efficient Transportation
- Ore Upgrading
  - Sorting
  - Sizing
- Uranium Heap leaching
  - Common in the US in the1950's and early 1960's
  - Small operations
  - Low grade (<0.05 %U_3O_8)
- Prior to Modern Permitting Requirements

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Ore Sorting

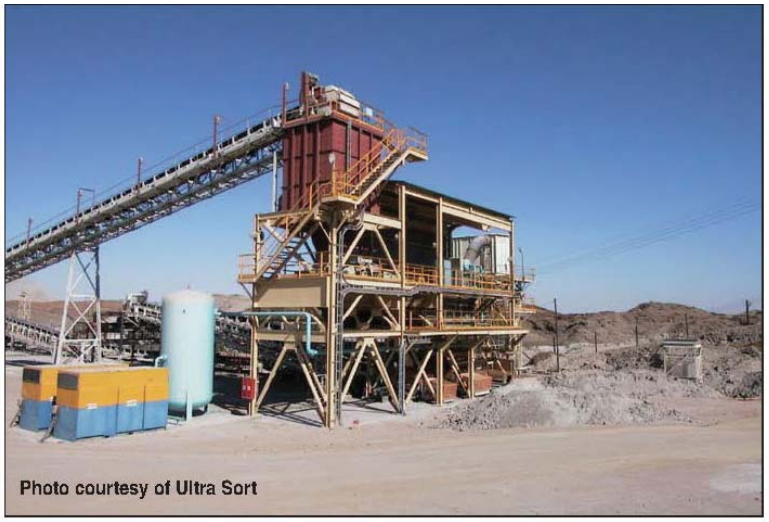

Figure 2—Rössing radiometric sorting plant

- Pre-1964 Hand Ore Sorting Station Little Mountain, Wyoming (Below)
- Radiometric Ore Sorter (Left)

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Ore Concentration by Size Classification

Ore Classification (Above)

- Pre-1964
- Little Mountain, WY
- Vibratory Screening
- Concentrate shipped
  AEC Buying Station
  Riverton, WY

Ore Classification (Below)

- Pre-1964
- Pumpkin Buttes, WY
- Sand/Slime Separation
- Concentrate shipped
  AEC Buying Station
  Edgemont, SD

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Uranium Heap Pre-1964
Powder River Basin, Wyoming

- Small Heap <10,000 tons (Left)
- Excavated During Mine Reclamation
  - Note: Liner Bottom Left
  - Single 4 mil Plastic Liner
  - Pipe and Gravel Bedding

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Uranium Heap Leach Operations (US) 1970s and 1980's – Larger Scale

- Western Nuclear Corporation
  - Day Loma Heap Leach, Gas Hills, WY
  - Spook Vat Leach, Powder River Basin, WY
- Ranchers Uranium
  - Naturita Tailings Uranium and Vanadium Heap Leach (500,000 tons)
- Union Carbide Mining and Metals
  - East Gas Hills Heap, WY (650,000 tons initial)
  - Maybell Heap, CO (Tributary to Gas Hills Mill)
  - Planned: Black Hills, SD; Great Divide Basin, WY; West Gas Hills; and Others

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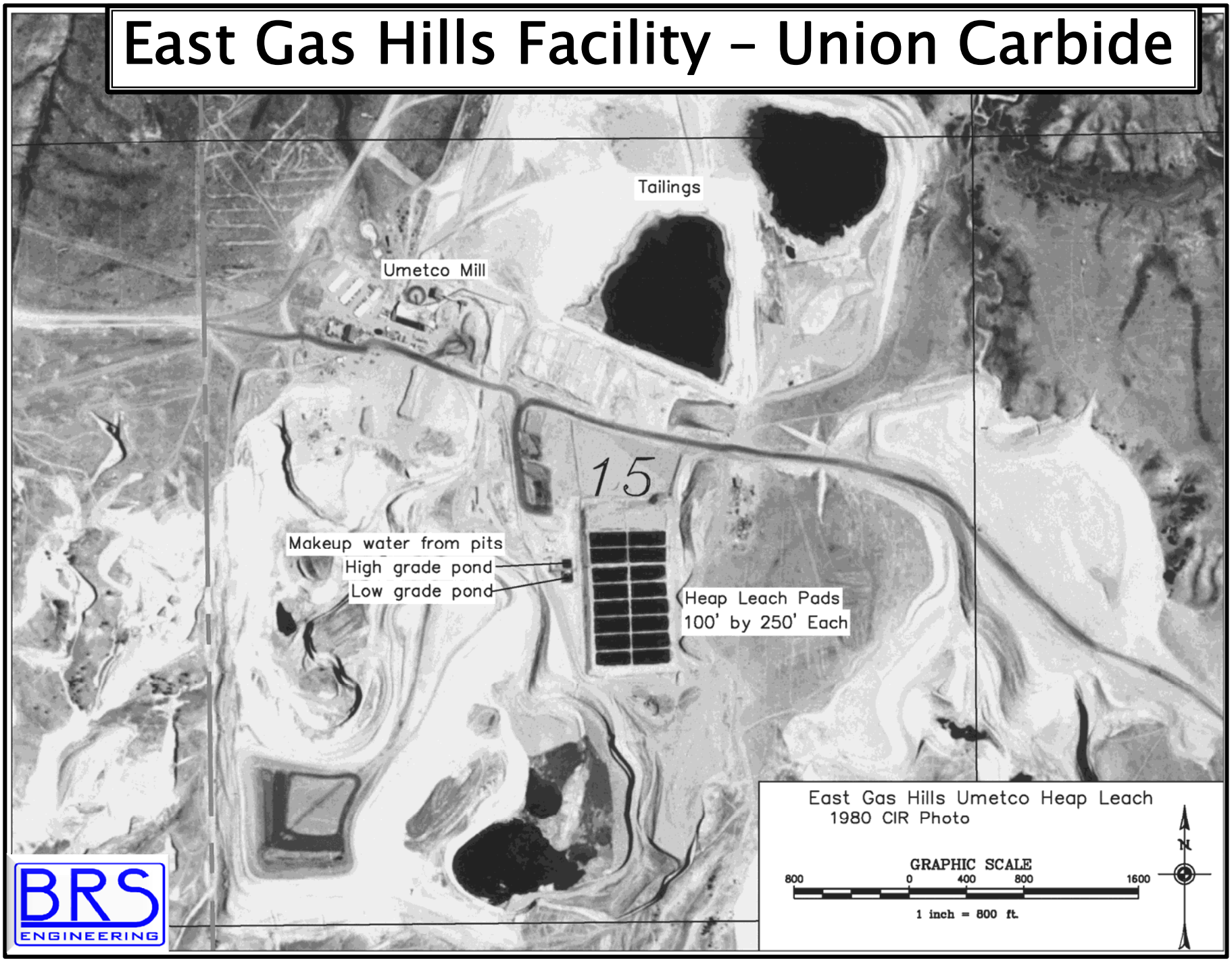
Naturita Facility – Ranchers Uranium

From Scheffel, 2010

East Gas Hills Facility – Union Carbide



Heap Operating Parameters
Gas Hills

- Average Grade 0.044 %U_3O_8
- Final Tails < 0.008 %U_3O_8
  - 0.004 %U_3O_8 Heap Interior
  - Average Loss includes Wetted Perimeter Losses
  - 82 % recovery
- Average liquor grade 0.54 g/l
  - 540 ppm or 4.5 lbs U_3O_8 per 1,000 gal
- Acid consumption 45 lbs/ton
- Run of Mine construction
- Pond application

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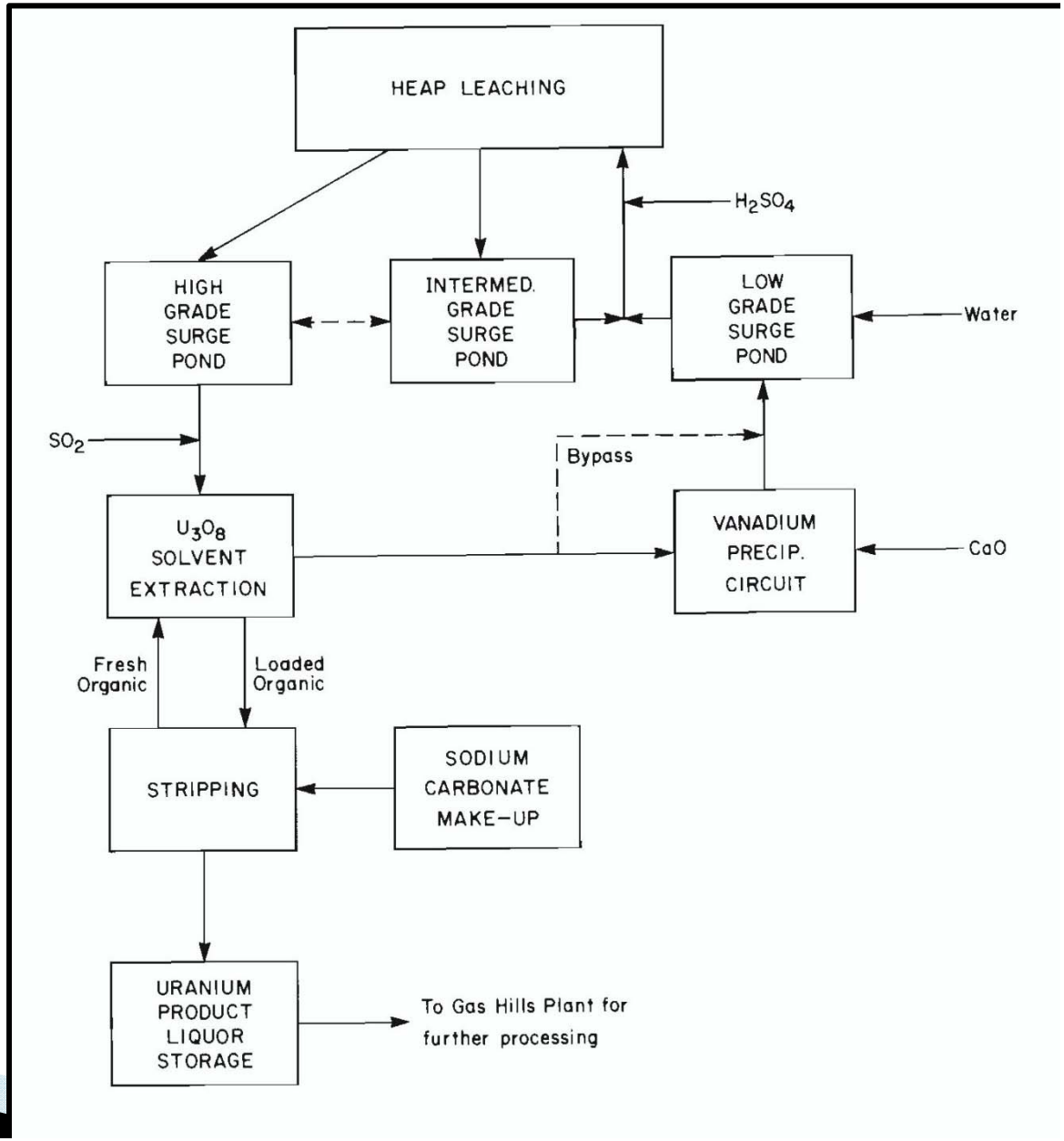
Edgemont, South Dakota

Edgemont Heap Flow Chart

Satellite Operation to Gas Hills



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Heap Design Parameters Edgemont, South Dakota

- Average Grade 0.1 %U_3O_8
- Final Tails Testing
  - 0.003 %U_3O_8 Heap Interior
  - 95 % recovery
- Design Recovery 87%
  - Soluble Losses
  - Wetted Perimeter
- Average liquor grade 0.74 g/l
  - 740 ppm or 3.2 lbs U_3O_8 per 1,000 gal
- Acid consumption 30 lbs/ton
- Uranium and Vanadium Recovery
  - Vanadium 60% recovery as sludge

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Current Example
Sheep Mountain Project – EFR

- **PROJECT OVERVIEW**
- Site Location
  - Fremont County, Wyoming
  - 8–10 Miles South of Jeffrey City
  - Approximately 3,600 Acres Federal, State and Fee Lands
- Existing Uranium Mine Permit WDEQ/LQD 381C
  - Mined 1956 – 1988
  - Milling at Split Rock Mill
- Planned Operation
  - Open Pit and Underground Mining
  - Heap Leach Processing

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Heap Design Parameters
Sheep Mountain

- Sheep Mountain Heap Design Parameters
  - Average Grade 0.111 %U_3O_8
  - Assumed Final Tails < 0.01 %U_3O_8 (includes soluble loss)
  - Overall Recovery 91%
  - Average liquor grade > 500 ppm column testing
  - Acid consumption 50 lbs/ton
  - Conveyor loading
  - Spray application
- Bench Scale Column Tests – 0.002 %U_3O_8 tails
- Additional testing is being planned

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Column Testing Schematic Edgemont, South Dakota

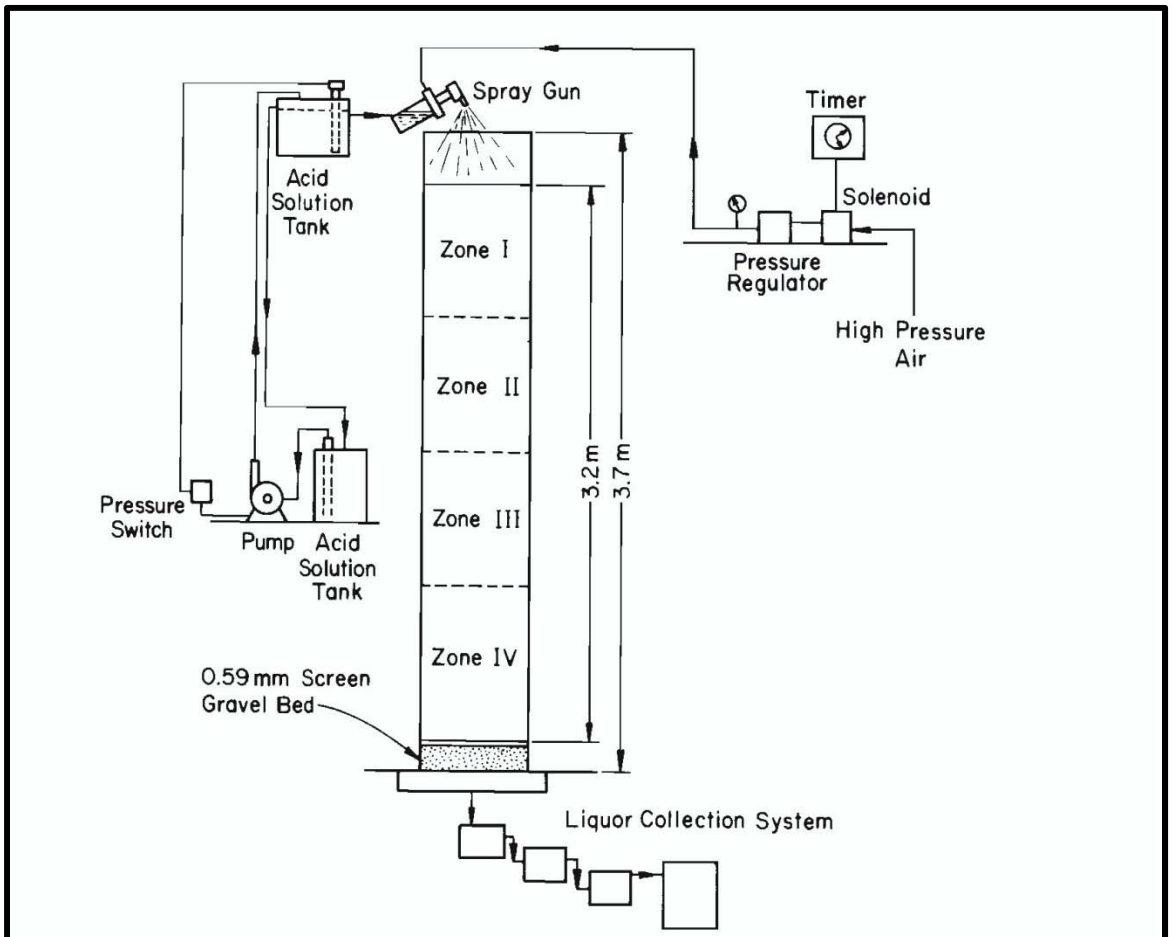

Figure 1. Arrangement of equipment in the pilot column leach test.

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Sheep Mountain
Column Leach Testing

Close-up of Column

Testwork Competed in Wyoming

- 15 foot (5m) columns
- 0.5 foot (0.15 m) diameter


Loaded Columns

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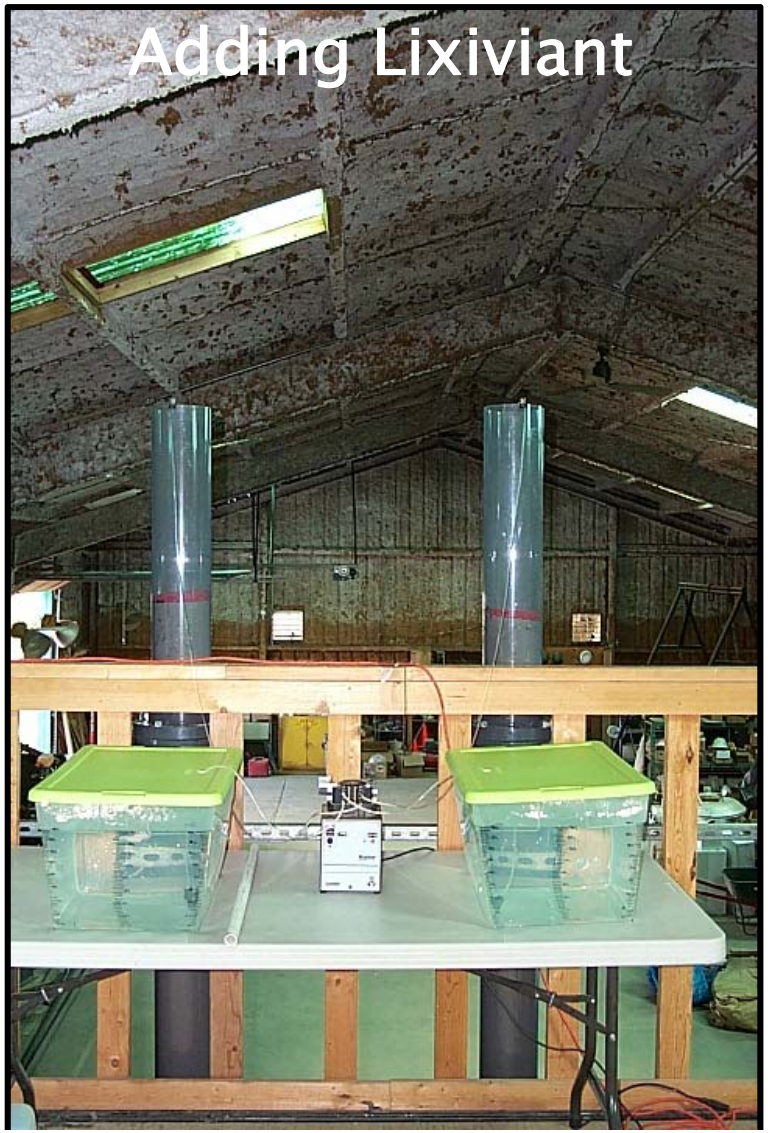
Sheep Mountain
Column Leach Testing



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Sheep Mountain
Column Leach Testing

Ion eXchange (IX) Columns (Left)

Uranium Rich Solution (Below)

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Column Leach Results Edgemont, South Dakota

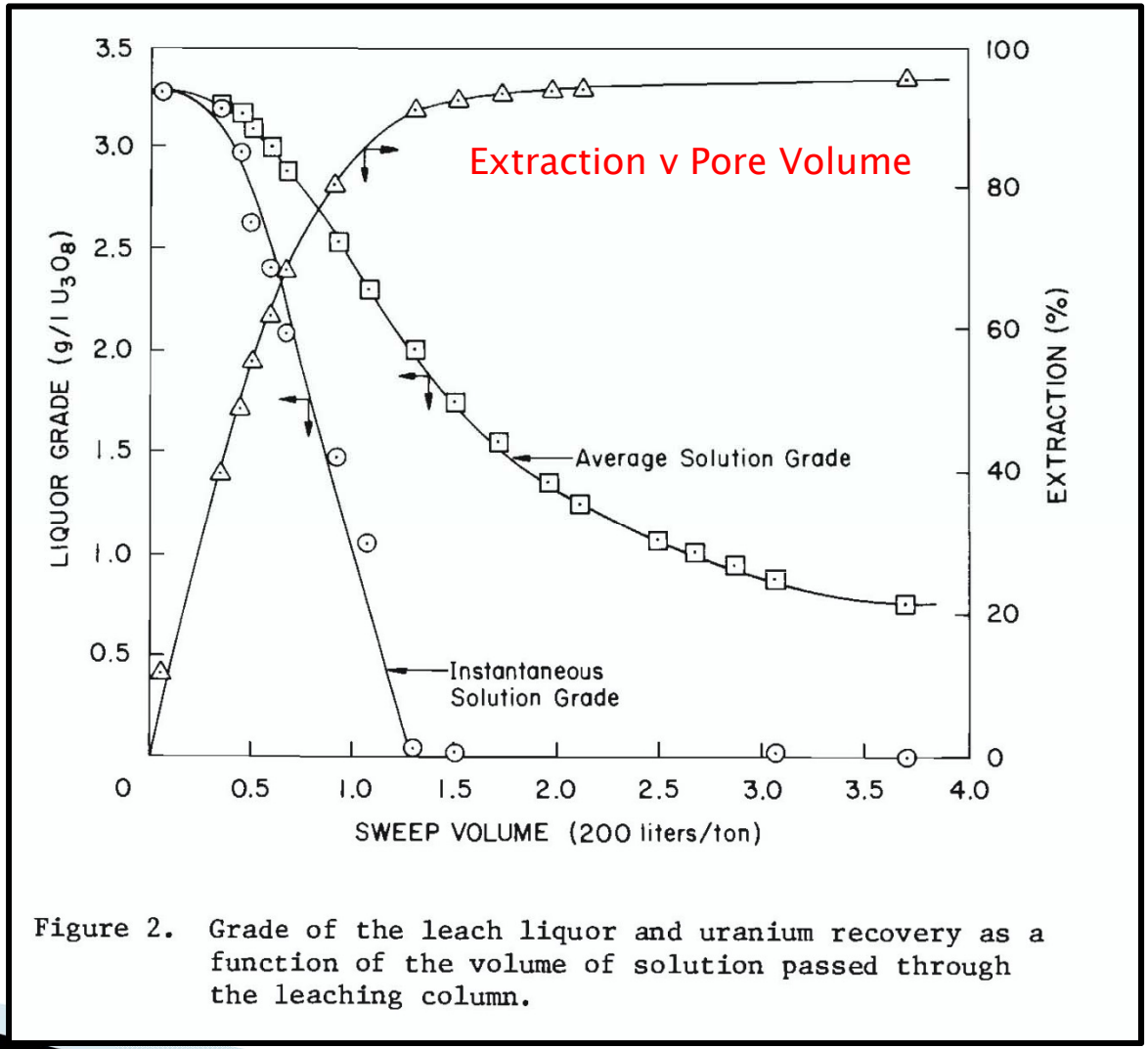

Figure 2. Grade of the leach liquor and uranium recovery as a function of the volume of solution passed through the leaching column.

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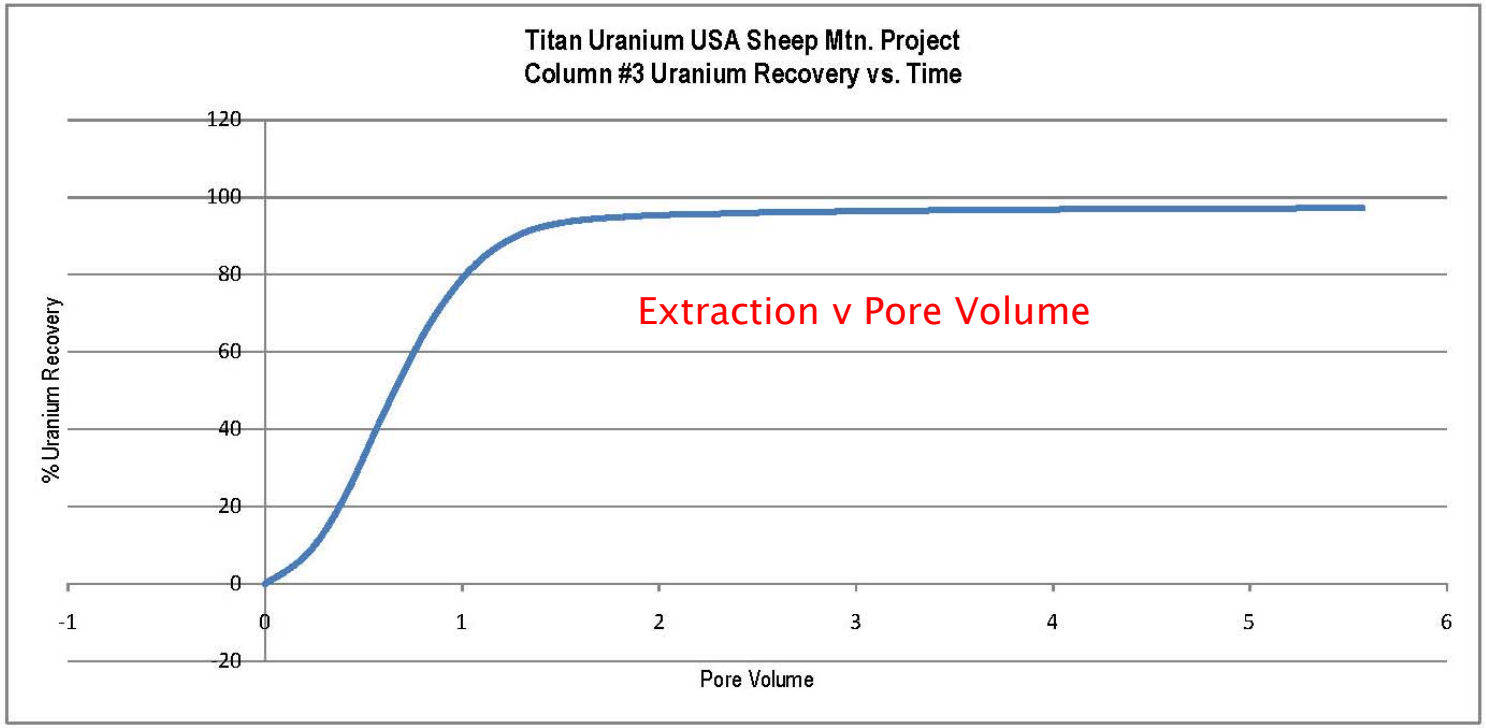
Column Leach Results
Sheep Mountain



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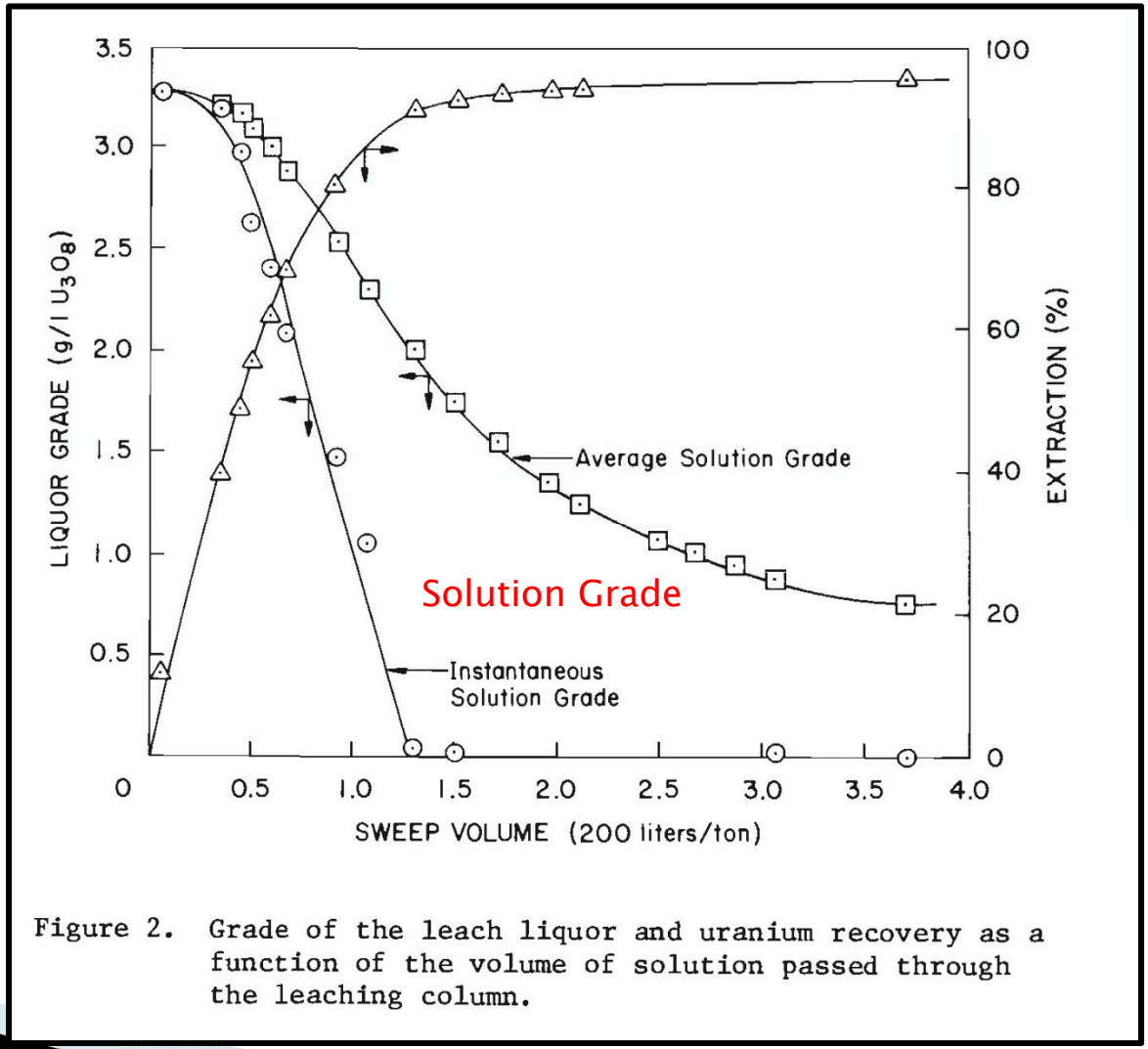
Column Leach Results Edgemont, South Dakota



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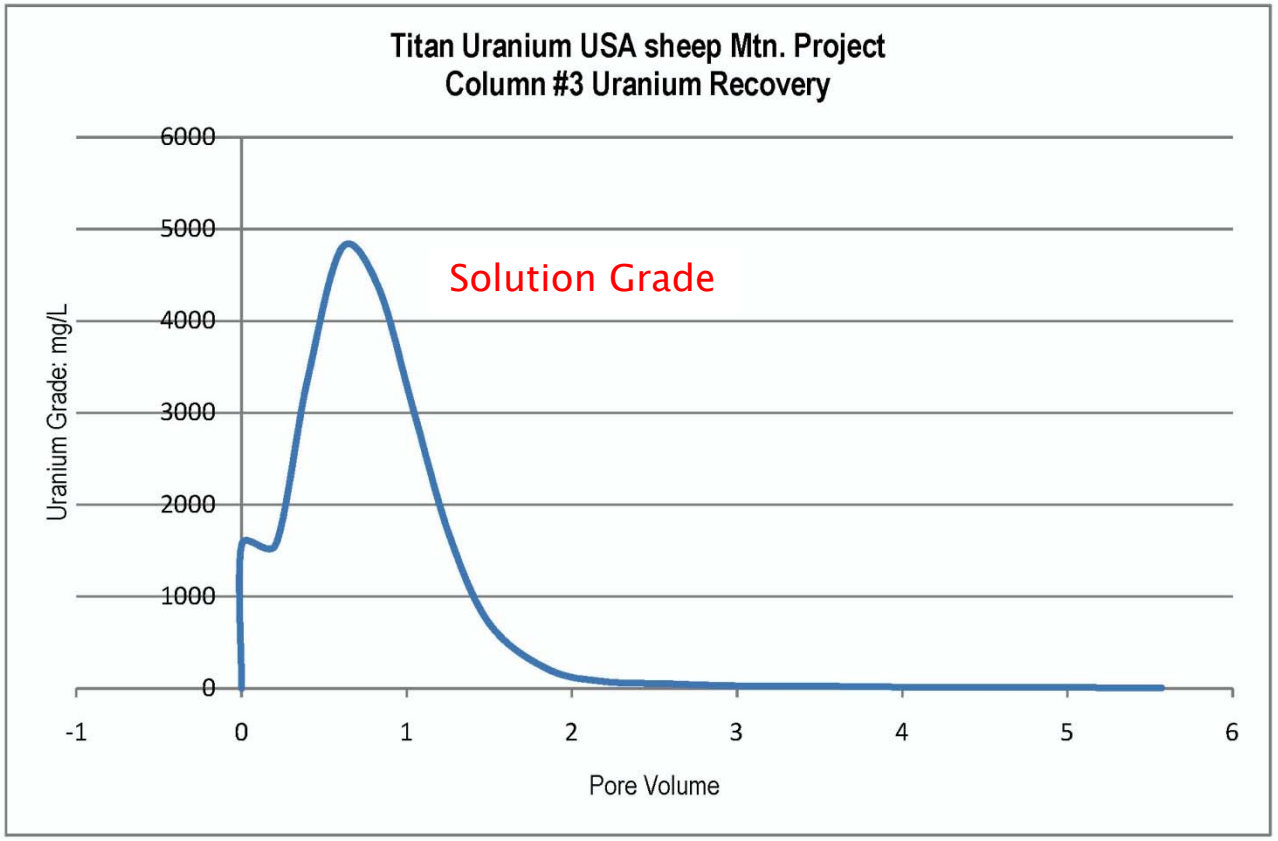
Column Leach Results
Sheep Mountain



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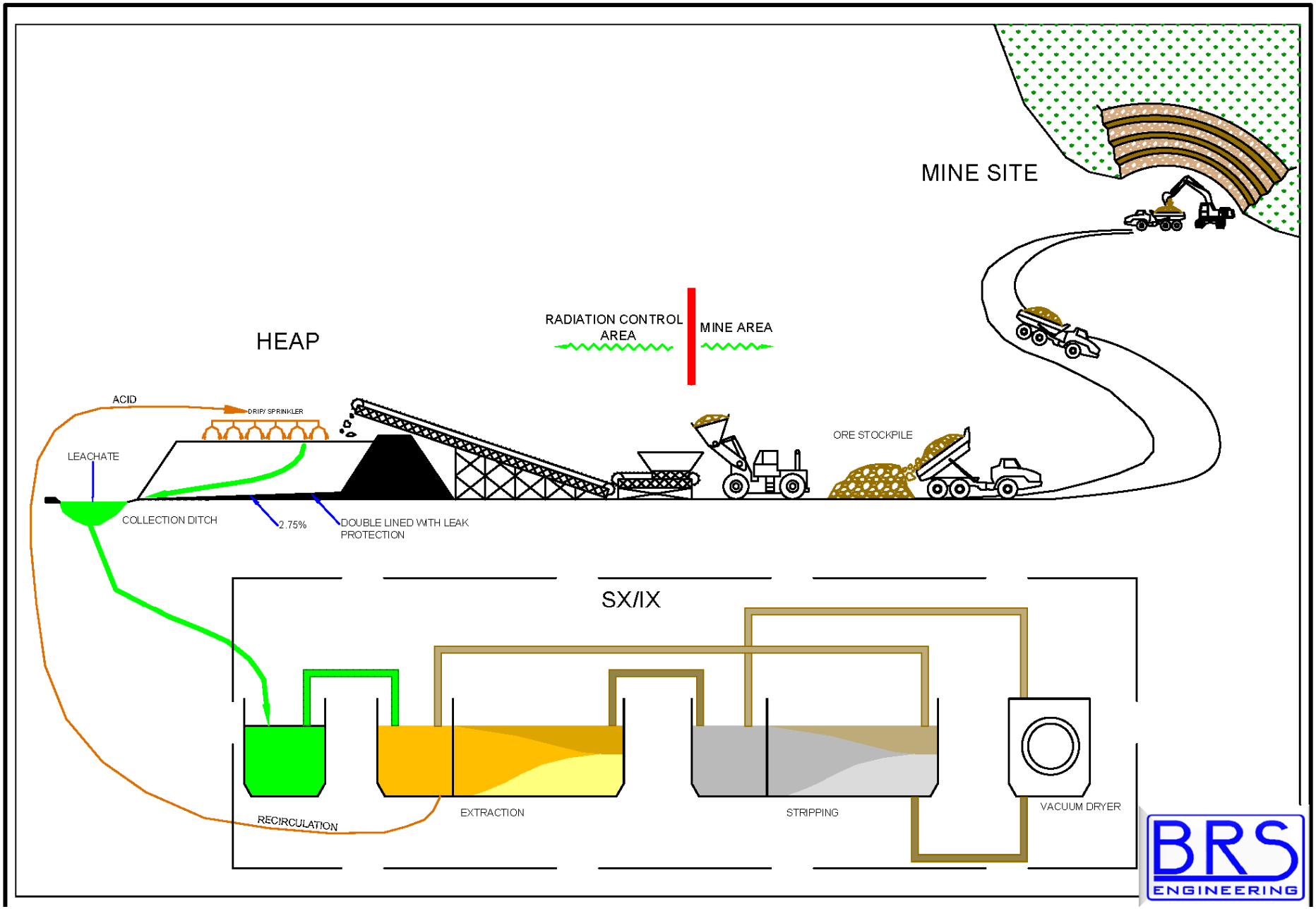
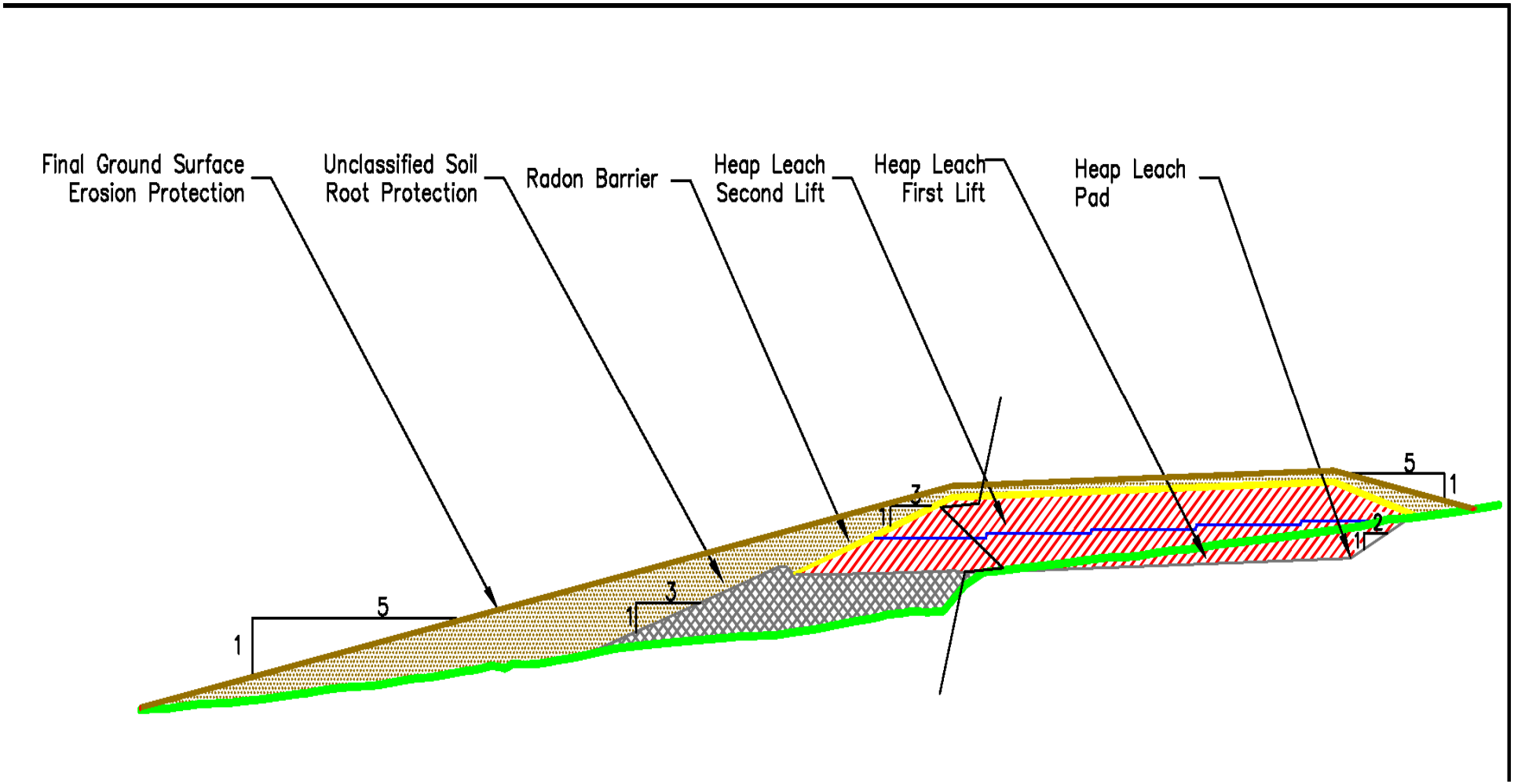
Heap Leach Process Overview

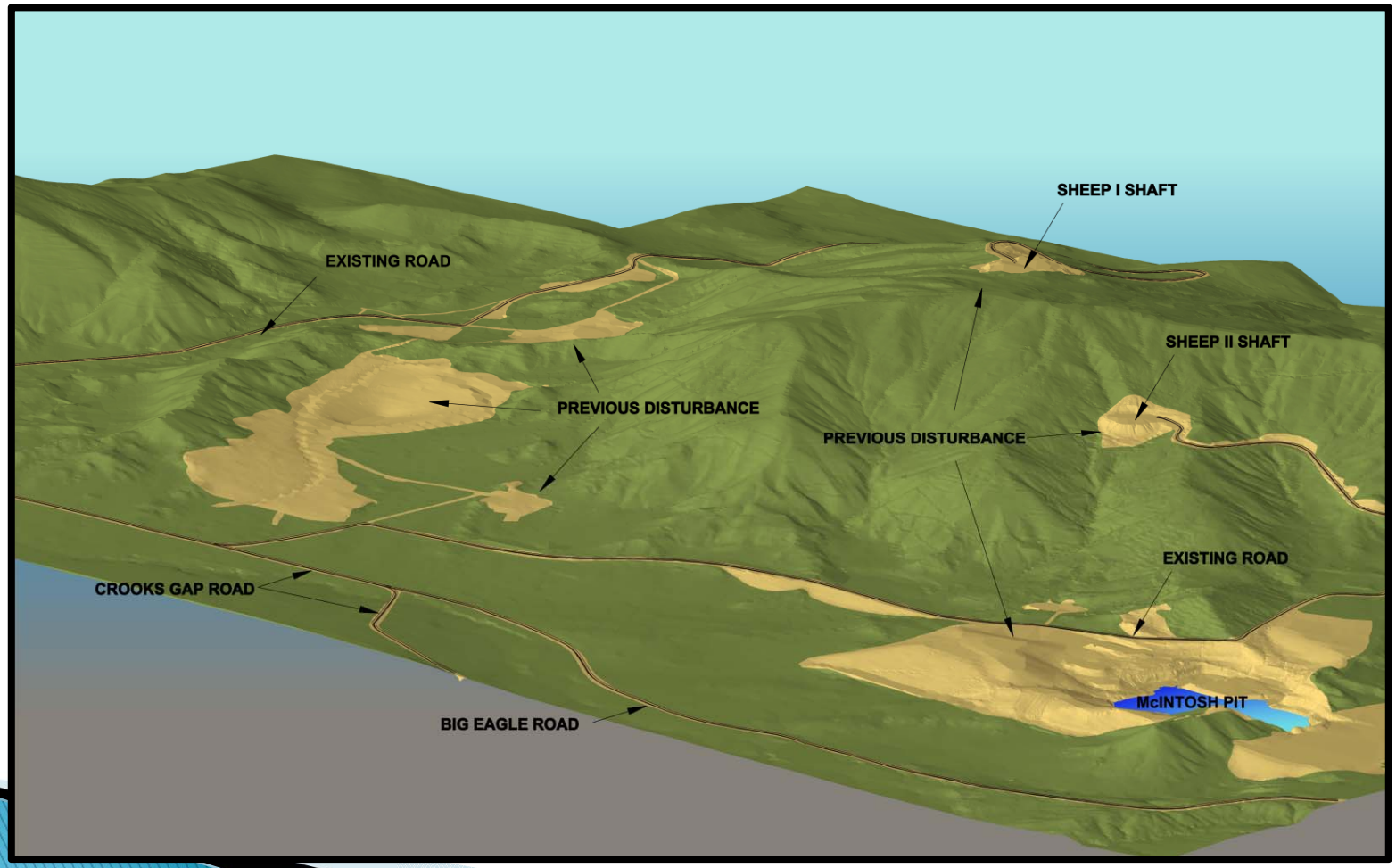


Typical Heap Design Details

Heap Leach Sectional View Reclaim in Place



Current Example
Sheep Mountain Project – EFR
Existing Site Conditions



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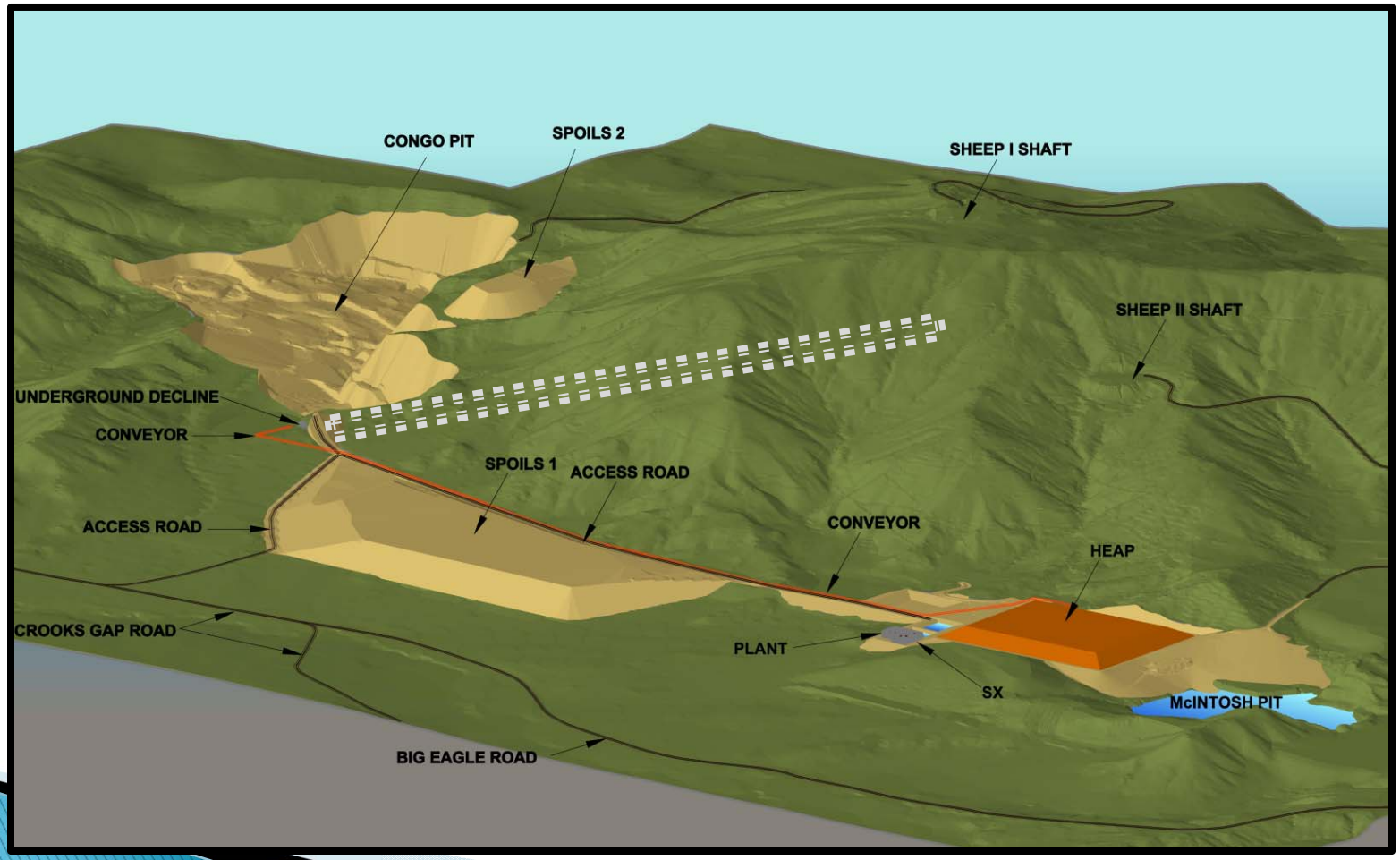
Current Example
Sheep Mountain Project – EFR Site During Operations



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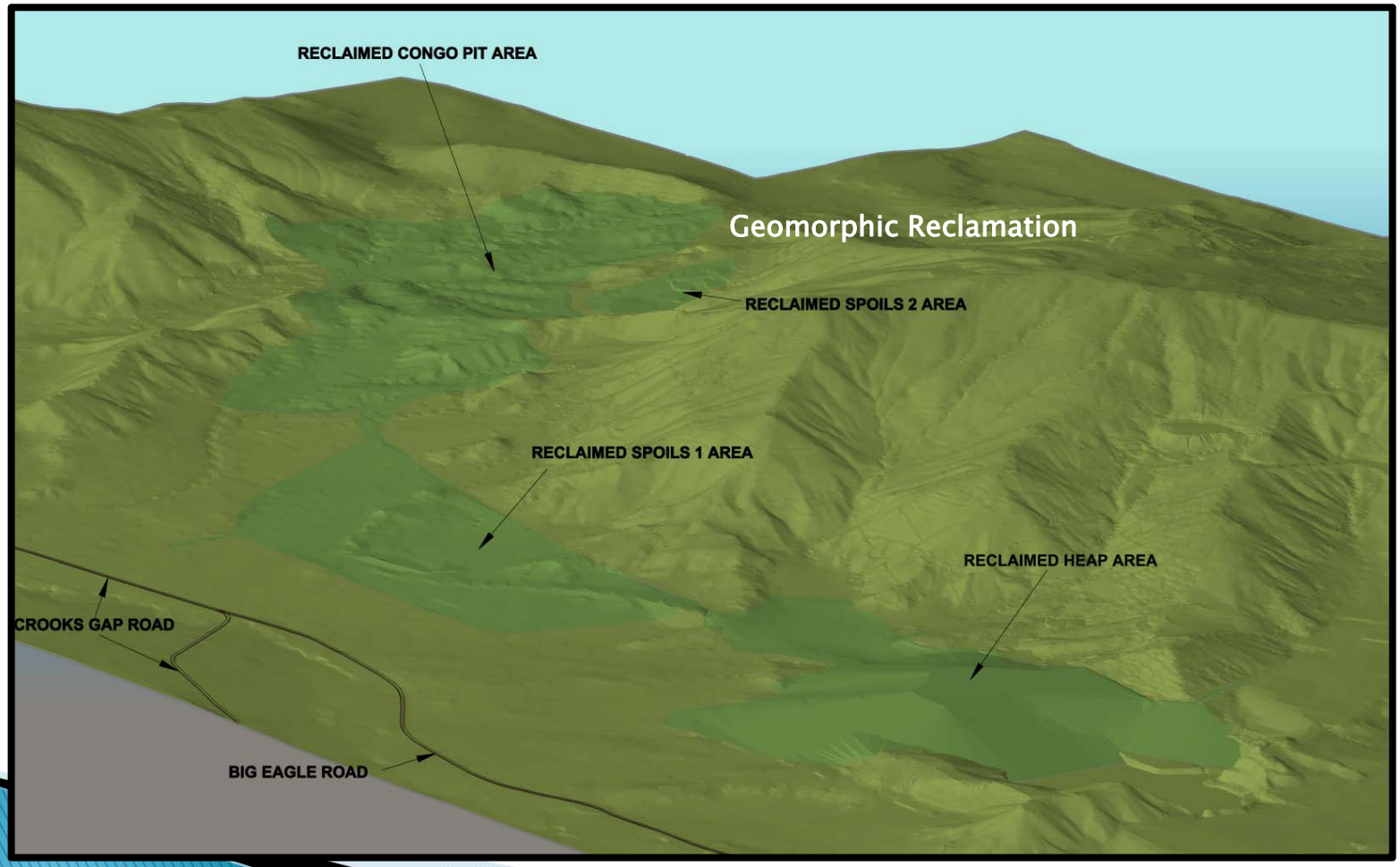
Current Example
Sheep Mountain Project – EFR
Reclaimed Site



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Geomoprhic
Mine Land Reclamation

Geomorphic Design

- Emulates Natural Topography
- Computer Aided Design
- GPS Machine Control
- Promotes Vegetative Diversity
- Erosionally Stable
- Sustainable

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Heap Leach Perspective

Processing Plant Considerations

- CONVENTIONAL MILL
  - Tons Department – Crushing, Grinding, Leaching
  - Tailings – Slurry, Sand/Slime Separation or Filtration
- IN SITU RECOVERY
  - Flow rates 3,500 – 7,000 gpm
  - Solution head grade less than 100 ppm
- HEAP LEACH (SHEEP MTN.)
  - Flow Rate @ Sheep Mtn. 350 gpm or less
  - Solution head grades 500 ppm or greater
  - Ore Sizing for Conveyor Loading

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Heap Leach Perspective

"TAILINGS" CHARACTERISTICS
HEAP LEACH DOES NOT PHYSICALLY ALTER ORE

- 98% of Radium remains in the Heap not circulated through plant
- Fewer pathways for exposures
- Heap remains comingled
  - No Grinding;
  - No Sand Slime separation;
  - No Concentration of Radium
  - No Head – Heap is Drained

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Conclusion – Why Heap Leach

- Low Capital Costs
- High Percentage Resource Recovery
- Low Operating Costs
- Environmental considerations
  - Low water demand
  - Closed Hydraulic System
  - Built on a liner with a positive drain
  - No Concentration of Slimes
  - Reclamation can proceed efficiently

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Conclusion – Why Heap Leach

- No Single Approach to Mining and Mineral Processing fits ALL Mineral Deposits or ALL Portions of a Deposit
- Quote from Woolery,1978

  "This application is now the prime consideration within UCC for all uranium projects that are either to small or too low grade to justify conventional processing. Its significance to the uranium producer is becoming ever more important as the demand for uranium increases and the discovery of major uranium deposits dwindles."

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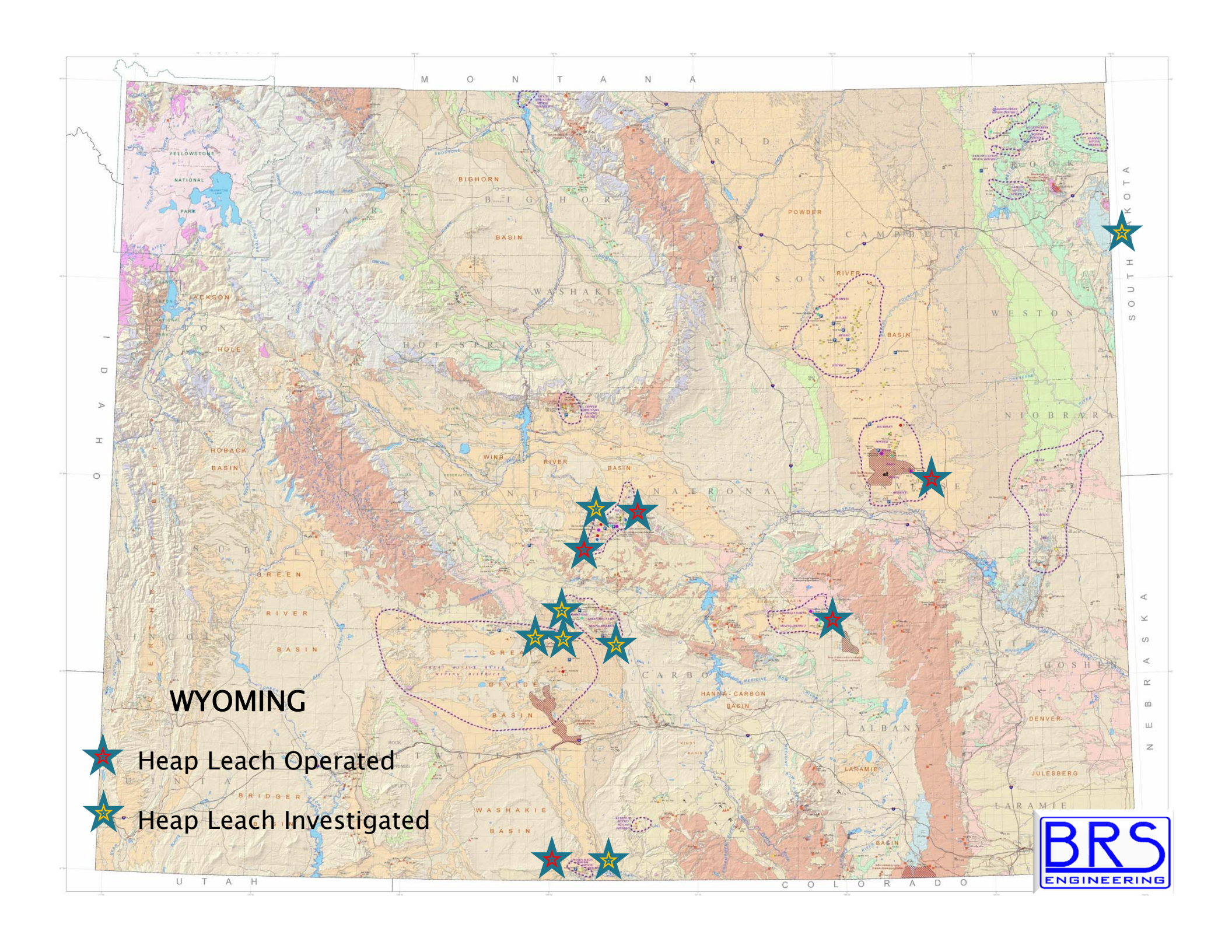
WYOMING
Heap Leach Operated
Heap Leach Investigated
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IN CLOSING

- Complementary flash drives are available from BRS containing a copy of this presentation.
- The flash drive also contains information about BRS and some of our recent and/or current projects
- Thank You for your time and consideration.