Uranium In-Situ Leach Mining Overview

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Rapid City, South Dakota

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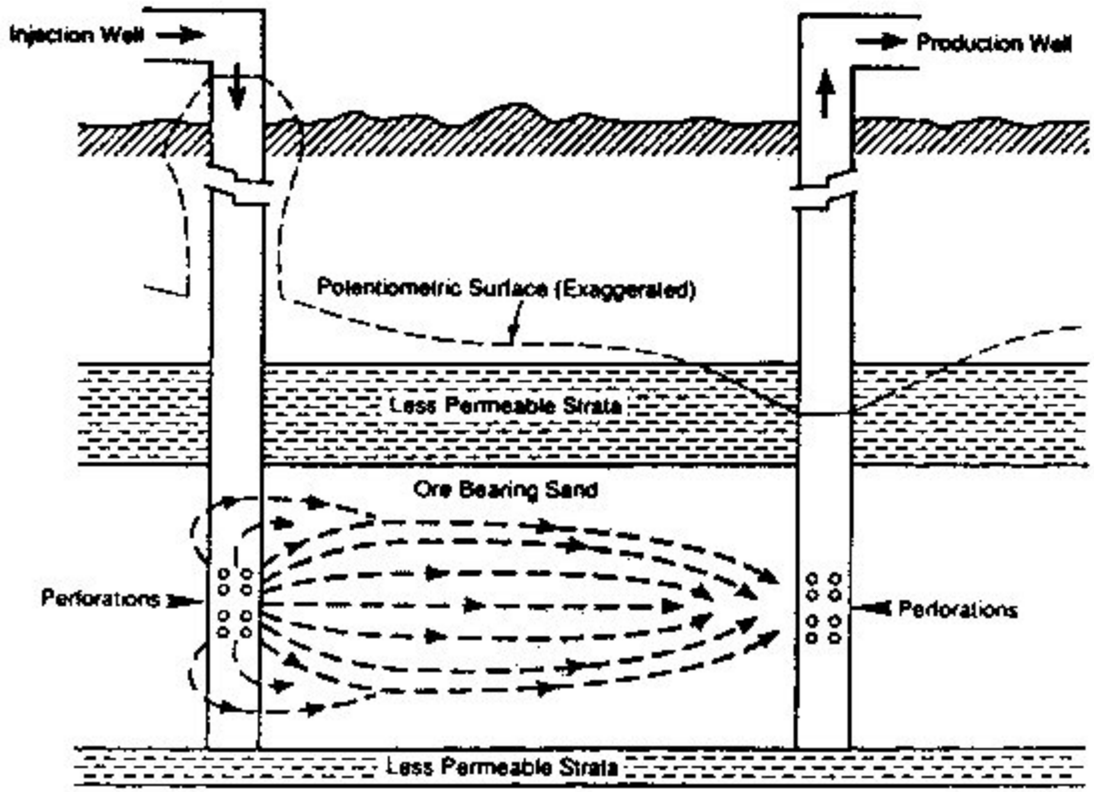


Advantages
- cheaper infrastructure requirements
- no large-scale tailings dams
- no large open cut or underground mine to rehabilitate
- lower occupational health and safety : accidents, dust and radiation
- reduced workforce requirements

http://www.sea-us.org.au/isl/islnotgood.html

Disadvantages
- significant risks of contaminating groundwater systems outside the mining zone
- inherent difficulties in the hydraulic and geochemical behavior of the deposit
- difficult to restore groundwater to pre -mining quality
- large volumes of waste water and solutions to dispose of

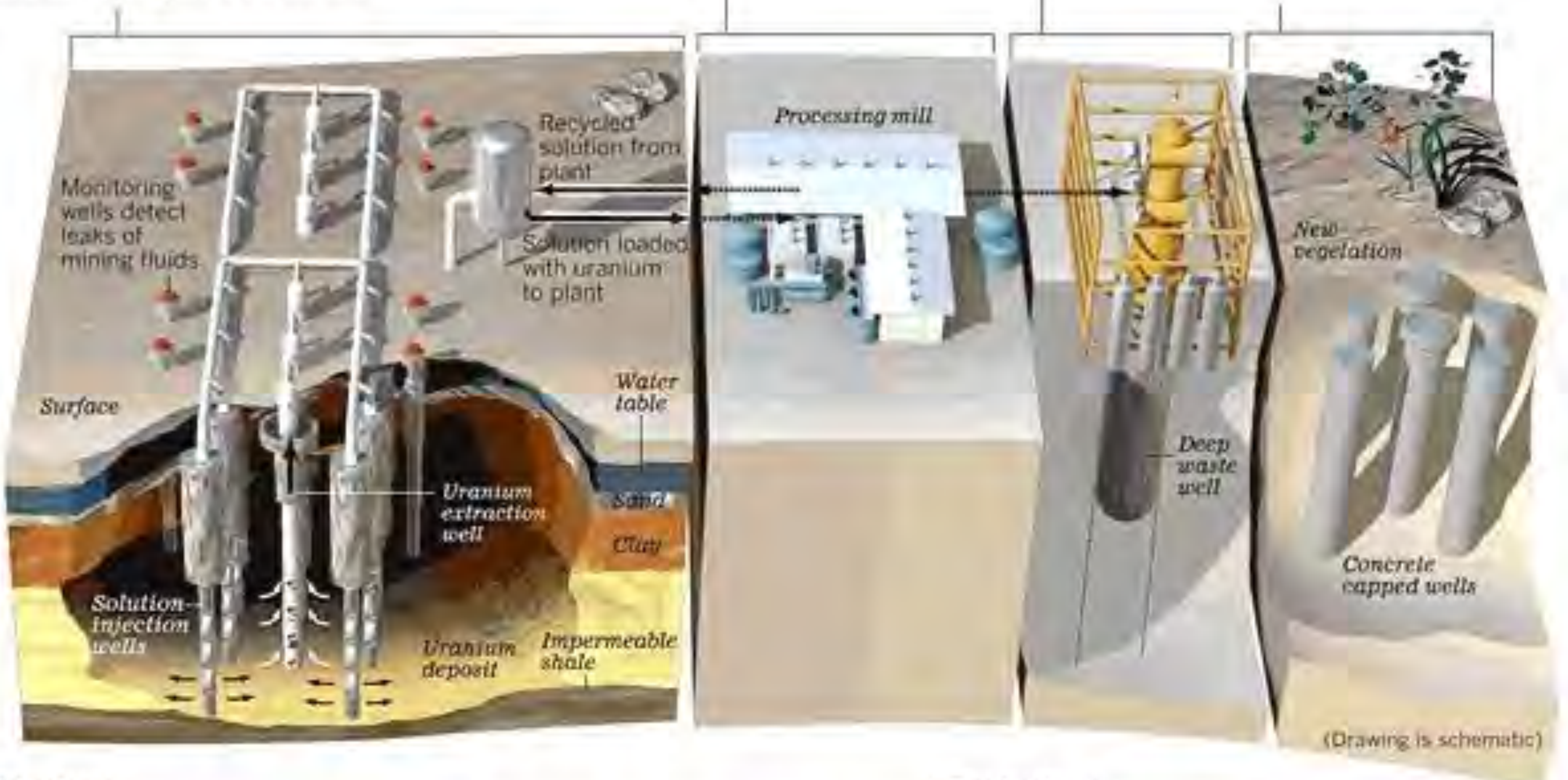
Solution mining

Extraction
A solution of groundwater and oxygen is pumped into injection wells drilled through layers of sandstone. Oxygen rusts uranium in the sandstone. Uranium dissolves in the water, and the solution is pumped to the surface.

Processing
The solution is pumped to a plant, where uranium is removed. Water is reoxygenated and pumped back down injection wells. It recirculates until uranium in the deposit is depleted.

Waste management
Wastewater is treated and pumped into disposal wells, evaporated or sprinkled into the soil at the surface. Solids are sent to a waste disposal site.

Restoration
Water is purified and reinjected into the well field. Wells are later filled with concrete and capped below the surface. Surface soil is decontaminated if necessary.



Advantages
- Minimal surface disturbance.
- No mine to rehabilitate.
- Does not create excess rock piles or tailings from processing.
- Can be used for small deposits that are not economical for conventional mining.
- Uranium can be processed on site.
- Less time is needed for establishing and maintaining mining facilities.

Disadvantages
- Cannot be used at sites without the necessary geological layering.
- Requires water in the uranium deposit.
- Rock being mined must be permeable.
- Restoring water to an acceptable level of purity can be difficult.

Sources: Uranium Producers of America, Environmental Protection Agency, National Energy Institute, Bureau of Land Management, Utah Geological Survey, Uranium Resources, Inc.
Graphics reporting by TOM REINKEN; *Graphic by* LORENA IÑIGUEZ *Los Angeles Times*

Table 4. U.S. Uranium Mills by Owner, Capacity, and Operating Status at End of the Year, 2003-2008

Mill Owner(s)	Mill Name	Milling Capacity [1] (short tons of ore per day)	Operating Status at End of the Year 2003	2004	2005	2006	2007	2008
Cotter Corporation	Canon City Mill	400	Standby	Operating	Operating	Standby	Standby	Standby
Denison White Mesa L.L.C.	White Mesa Mill	2,000	Standby	Standby	Operating-Processing Alternate Feed	Operating-Processing Alternate Feed	Operating-Processing Alternate Feed	Operating
Energy Fuels Resources Corp.	Piñon Ridge Mill	1,000	-	-	-	-	-	Developing
Kennecott Uranium Company/Wyoming Coal Resource Company	Sweetwater Uranium Project	3,000	Standby	Standby	Standby	Standby	Standby	Standby
Uranium One Utah, Inc.	Shootaring Canyon Uranium Mill	750	Reclamation	Reclamation	Reclamation	Standby	Changing License To Operational	Changing License To Operational
Total Milling Capacity:		**7,150**						

Licensed US Conventional Production Capacity - 7,150 tons per year (at 0.2% U ore grade)

Table 5. U.S. Uranium In-Situ-Leach Plants by Owner, Capacity, and Operating Status at End of the Year, 2003-2008

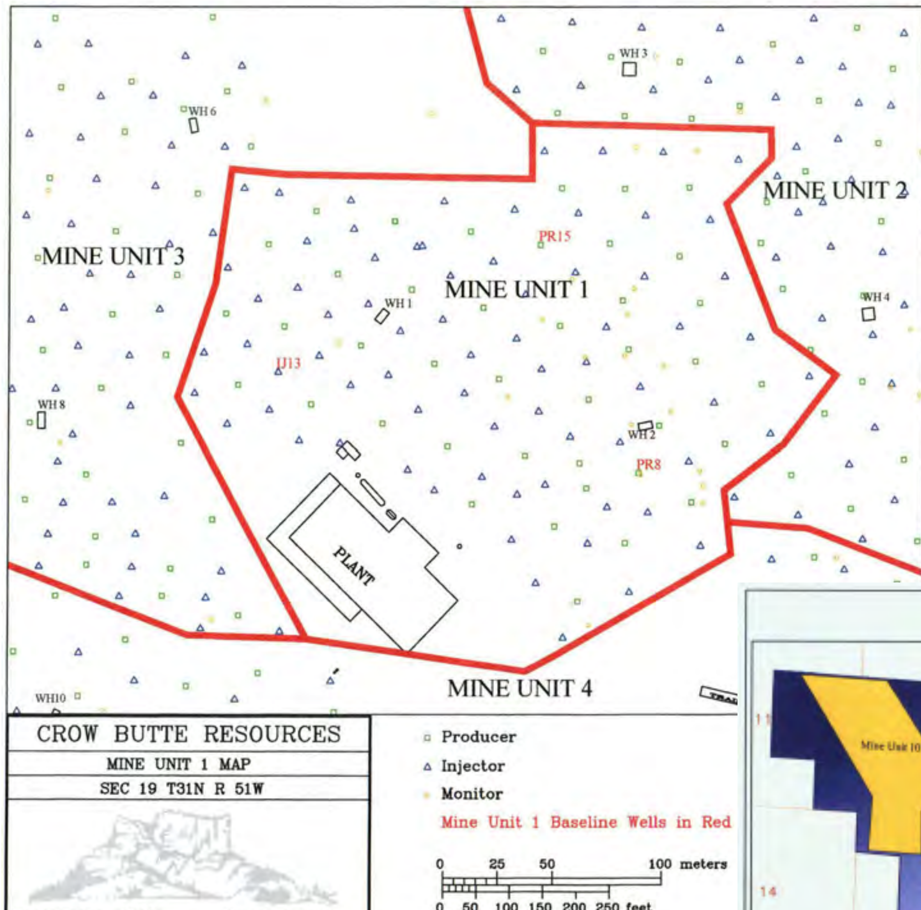
In-Situ-Leach Plant Owner	In-Situ-Leach Plant Name	Production Capacity [1] (pounds U_3O_8 per year)	Operating Status at End of the Year 2003	2004	2005	2006	2007	2008
COGEMA Mining, Inc.	Christensen Ranch	650,000	Reclamation	Reclamation	Reclamation	Reclamation	Changing License To Operational	Standby
COGEMA Mining, Inc.	Irigaray Ranch	-	Reclamation	Reclamation	Reclamation	Reclamation	Inactive	Standby
COGEMA Mining, Inc.	Texas Operations	-	Reclamation	Reclamation	Reclamation	Reclamation	Reclamation	Reclamation
Cameco Corporation	Crow Butte Operation	1,000,000	Producing	Producing	Operating	Operating	Operating	Operating
HRI, Inc.	Church Rock	1,000,000	Permitted And Licensed	Permitted And Licensed	Permitted And Licensed	Partially Permitted And Licensed	Partially Permitted And Licensed	Partially Permitted And Licensed
HRI, Inc.	Crownpoint	1,000,000	Partially Permitted And Licensed	Partially Permitted And Licensed	Partially Permitted And Licensed	Partially Permitted And Licensed	Partially Permitted And Licensed	Partially Permitted And Licensed
Lost Creek ISR LLC	Lost Creek Project	2,000,000	-	-	-	-	-	Developing
Mestena Uranium LLC	Alta Mesa Project	1,000,000	Development	Pending	Operational	Operational	Producing	Producing
Power Resources, Inc. dba Cameco Resources	Smith Ranch-Highland Operation	5,500,000	Producing	Producing	Operating	Operating	Operating	Operating
Powertech Uranium Corp.	Centennial Project	-	-	-	-	-	-	Undeveloped
Powertech Uranium Corp.	Dewey Burdock Project	-	-	-	-	-	-	Undeveloped
South Texas Mining Venture, LLP	Hobson ISR Plant	1,000,000	Close Indefinitely	Close Indefinitely	Standby	Standby	Under Construction	Permitted And Licensed
South Texas Mining Venture, LLP	La Palangana	1,000,000	-	-	-	Developing	Partially Permitted And Licensed	Partially Permitted And Licensed
URI, Inc.	Kingsville Dome	1,000,000	Standby	Standby	Standby	Operational	Producing	Producing
URI, Inc.	Rosita	1,000,000	Depleted	Depleted	Standby	Standby	Standby	Standby
URI, Inc.	Vasquez	800,000	Partially Developed	Producing	Producing	Producing	Producing	Restoration
Uranerz Energy Corporation	Nichols Ranch ISR Project	-	-	-	-	-	-	Developing
Uranium Energy Corporation	Goliad ISR Uranium Project	-	-	-	-	-	-	Partially Permitted And Licensed
Uranium Energy Corporation	Nichols Project	-	-	-	-	-	-	Developing
Uranium One, Inc.	Jab and Antelope	2,000,000	-	-	-	-	-	Developing
Uranium One, Inc.	Moore Ranch	2,000,000	-	-	-	-	-	Developing
Total Production Capacity:		**20,950,000**						

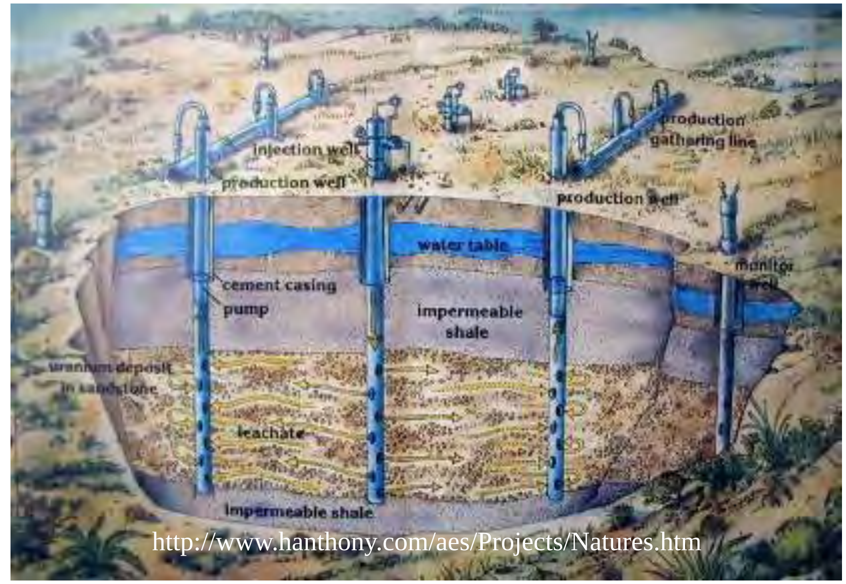
Licensed US ISL Production Capacity - 10,000 tons per year

- http://www.eia.doe.gov/cneaf/nuclear/dupr/dupr.html

Expected Uranium Recovery Facility Applications / Restarts / Expansions					
Company	**Site**	**Design type**	**Estimated Application Date**	**State**	**Letter of Intent**
Fiscal 2007 Applications					
Cogema	Christensen Ranch	ISL - Restart	Rec. 4/07, Comp. 9/08	WY	None
Cameco (Crow Butte Resources, Inc.)	North Trend	ISL - Expansion	Received June 2007	NE	None
Cameco (Crow Butte Resources, Inc.)	Plant Upgrade	ISL - Expansion	Rec. 10/06, Comp. 12/07	NE	None
Fiscal 2008 Applications					
Lost Creek ISR, LLC	Lost Creek	ISL - New	Resubmitted Mar 2008	WY	*05/23/07*
Uranerz Energy Corp.	Hank and Nichols	ISL - New	Received December 2007	WY	*06/27/07*
Uranium One (Energy Metals Corporation)	Moore Ranch	ISL - New	Received October 2007	WY	*05/31/07*
Uranium One (Energy Metals Corporation)	Jab and Antelope	ISL - New	Received September 2008	WY	*05/31/07*
Fiscal 2009 Applications					
Powertech Uranium Corporation	Dewey Burdock	ISL - New	Received 2/27/09	SD	*01/26/07*
Uranium One (Energy Metals Corporation)	Ludeman	ISL - New	Sep-09	WY	*02/26/09*
Fiscal 2010 Applications					
Lost Creek ISR, LLC	Lost Creek	ISL - Expansion	Apr-10	WY	*03/21/08*
UR-Energy Corp.	Lost Soldier	ISL - Expansion	Apr-10	WY	*03/02/09*
Uranium One (Energy Metals)	Allemand-Ross	ISL-Expansion	Dec-09	WY	*02/26/09*
Neutron Energy	Marquez	Conv. - New	Mar-10	NM	*03/25/08*
Cameco (Crow Butte Resources, Inc.)	Three Crow	ISL - Expansion	Mar-10	NE	*03/04/09*
Rio Grande Resources	Mt. Taylor	Conv. - New	Apr-10	NM	*03/21/08*
Fiscal 2011 Applications					
Concentric	Yavapai County	Conv. - New	Oct-10	AZ	*03/20/08*
Strathmore Minerals Corporation	Reno Creek	ISL - New	Mar-11	WY	*03/18/09*
Cameco (Power Resources, Inc.)	Smith Ranch/Highland CPP	ISL - Expansion	FY 2011	WY	*03/20/08*
Wildhorse Energy	West Alkali Creek	ISL - New	Dec-10	WY	*03/20/08*
Uranium Energy Corporation	Grants Ridge	Heap Leach - New	Jan-11	NM	*02/22/08*
Wildhorse Energy	Sweetwater	ISL and Conv. - New	May-11	WY	-
Fiscal 2012 Applications					
Cameco (Power Resources, Inc.)	Ruby Ranch	ISL-Expansion	Oct-11	WY	*03/20/08*
Strathmore Minerals Corporation	Gas Hills	Conv. - New	Oct-11	WY	*03/18/09*
Strathmore Minerals Corporation	Roca Honda	Conv. - New	Dec-11	NM	*03/18/09*
Cameco (Crow Butte Resources, Inc.)	Marsland	ISL - Expansion	Sep-12	NE	*03/04/09*
Uranium King Corporation	Apex Mill	Conv. - New	To Be Determined	NV	*09/27/08*
			6 year projected total reviews = 26		
			Total Uranium Recovery Applications Received = 8		
			Total New Uranium Recovery Applications = 17		
			Total Restart/Expansion Uranium Recovery Applications = 9		

- http://www.nrc.gov/info-finder/materials/uranium/ur-projects-list-public.pdf


MINE UNIT 3
MINE UNIT 1
MINE UNIT 2
MINE UNIT 4
PLANT
WH 1
WH 2
WH 3
WH 4
WH 6
WH 8
WH10
PR15
PR8
IJ13
CROW BUTTE RESOURCES
MINE UNIT 1 MAP
SEC 19 T31N R 51W
Producer
Injector
Monitor
Mine Unit 1 Baseline Wells in Red
0 25 50 100 meters
0 50 100 150 200 250 feet


injection well
production well
production gathering line
production well
water table
monitor well
cement casing
pump
impermeable shale
uranium deposit in sandstone
leachate
impermeable shale
http://www.hanthony.com/aes/Projects/Natures.htm


Kingsville Dome ISL Mine, Texas http://www.hanthony.com/aes/Projects/KVD.htm

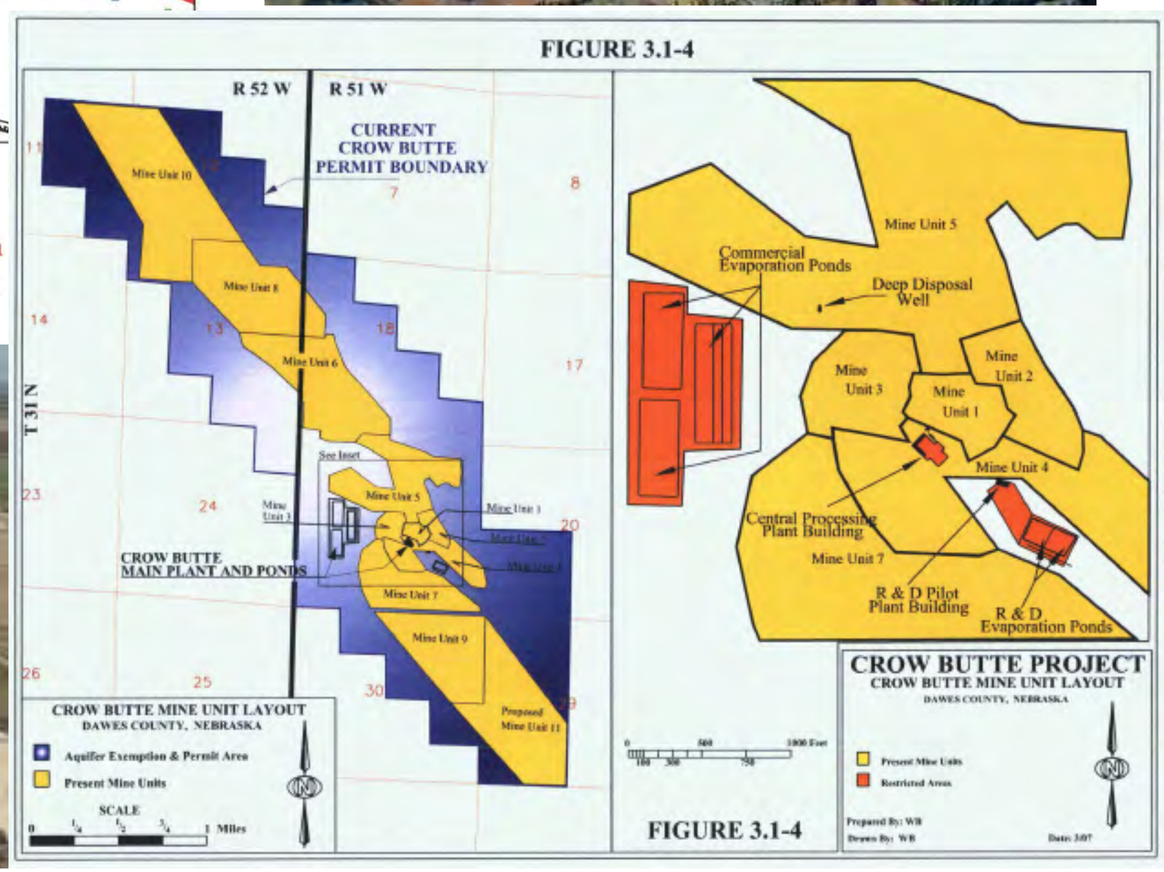
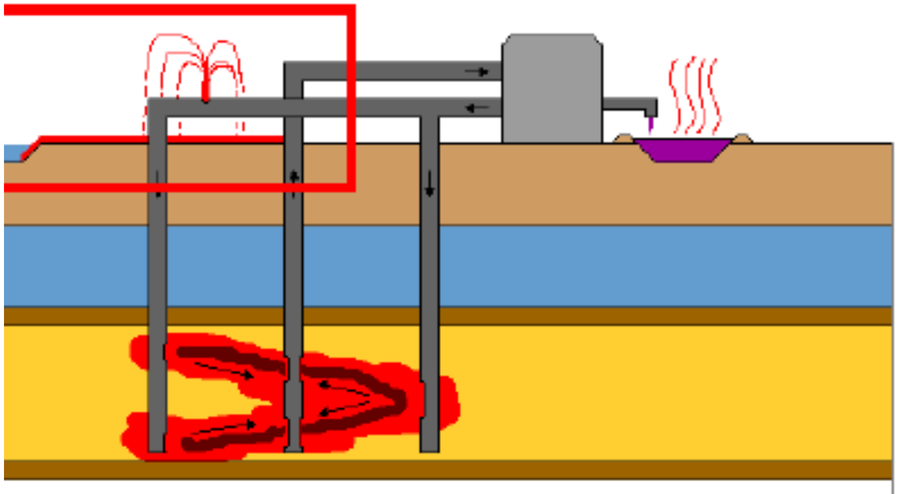


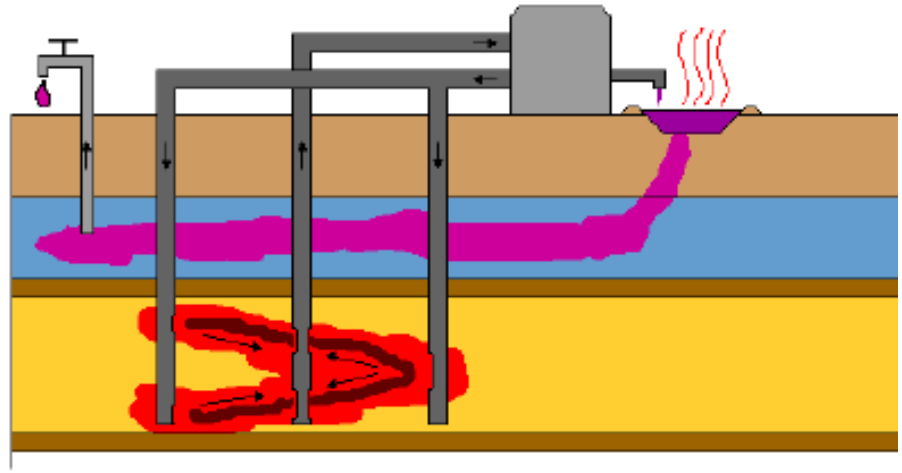
FIGURE 3.1-4
R 52 W
R 51 W
CURRENT CROW BUTTE PERMIT BOUNDARY
T 31 N
Mine Unit 10
Mine Unit 8
Mine Unit 6
Mine Unit 5
Mine Unit 7
Mine Unit 9
Proposed Mine Unit 11
See Inset
CROW BUTTE MAIN PLANT AND PONDS
CROW BUTTE MINE UNIT LAYOUT
DAWES COUNTY, NEBRASKA
Aquifer Exemption & Permit Area
Present Mine Units
SCALE
1 Miles
Commercial Evaporation Ponds
Deep Disposal Well
Mine Unit 5
Mine Unit 3
Mine Unit 1
Mine Unit 2
Mine Unit 4
Central Processing Plant Building
Mine Unit 7
R & D Pilot Plant Building
R & D Evaporation Ponds
FIGURE 3.1-4
CROW BUTTE PROJECT
CROW BUTTE MINE UNIT LAYOUT
DAWES COUNTY, NEBRASKA
Present Mine Units
Restricted Areas

In Situ Uranium Mine Failure Mechanisms

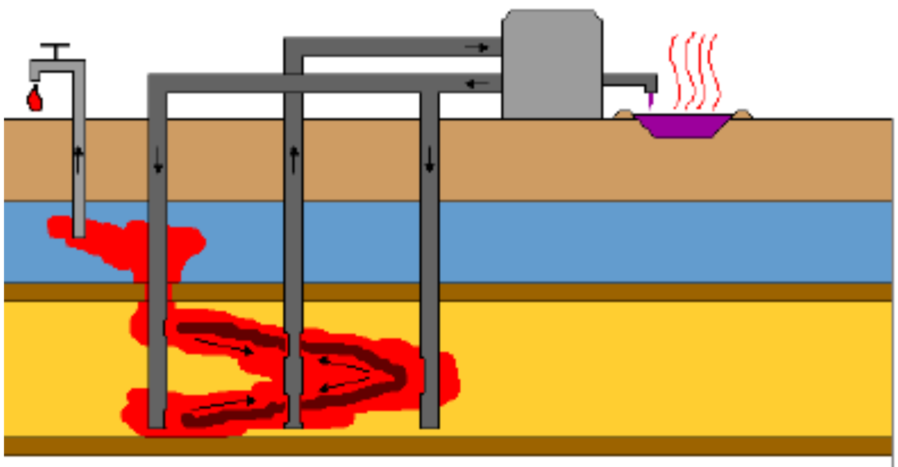
- graphics from www.wise-uranium.org



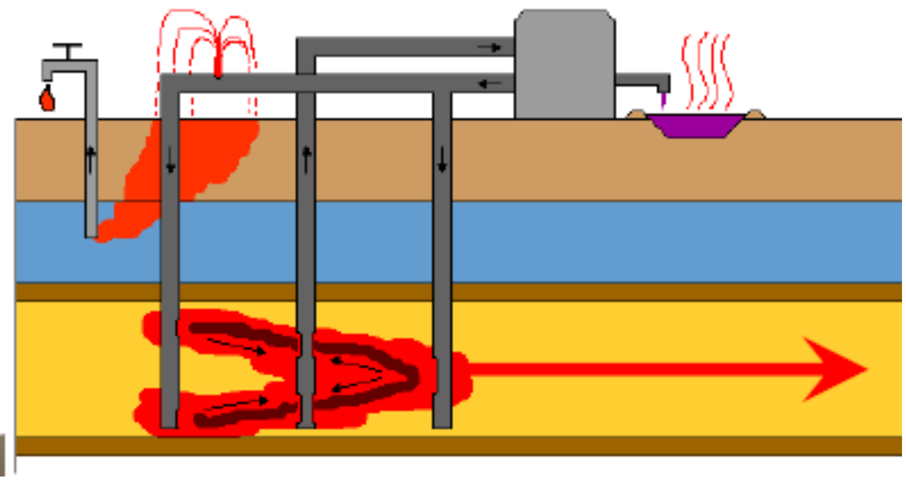
Surface Pipeline Break



Pond Liner Failure

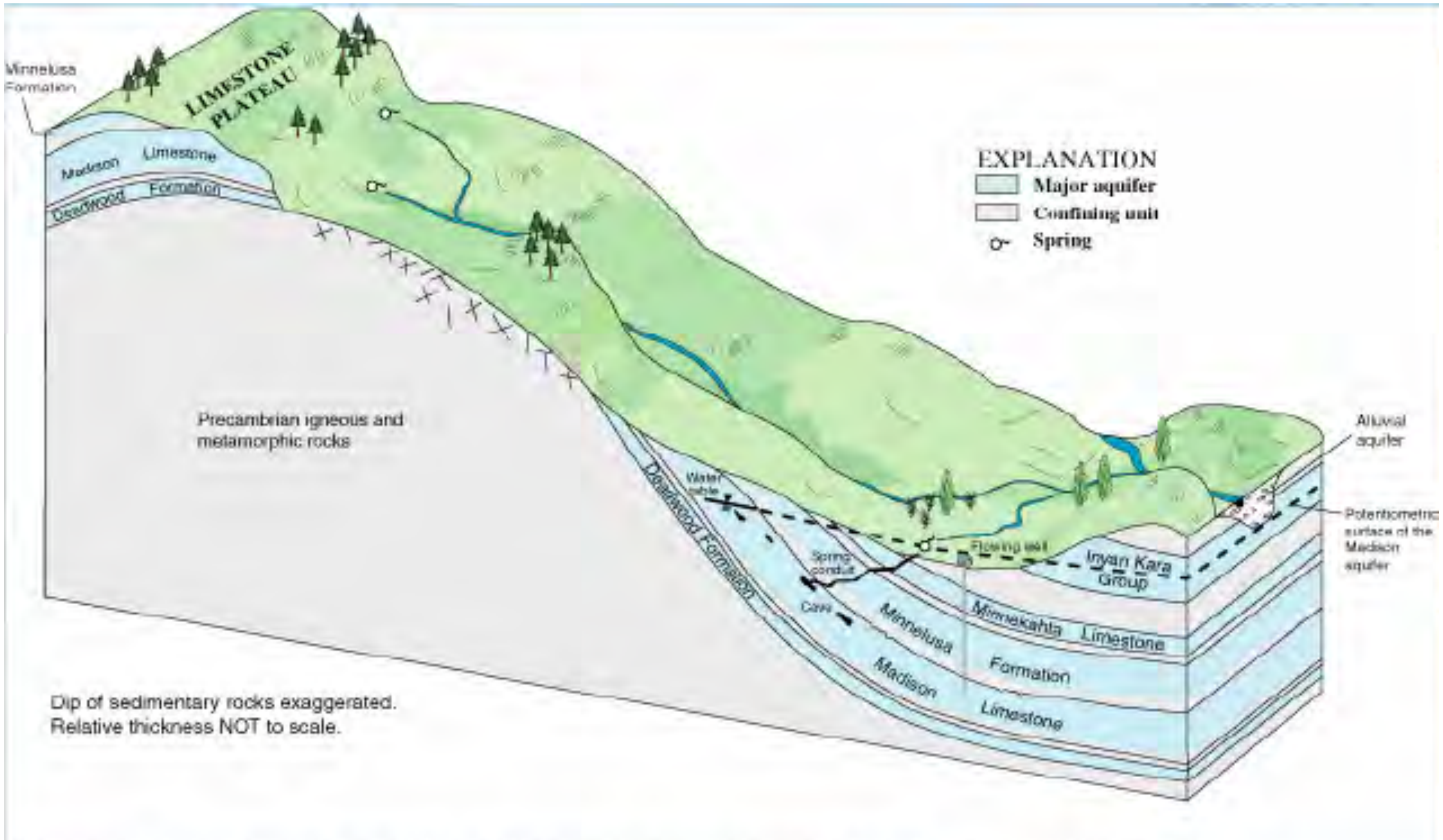


Vertical Release from Ore Zone -
“Vertical Excursion”



Horizontal Release from Ore Zone -
“Horizontal Excursion”

Cameco-Owned Crow Butte In Situ Uranium Mine, Nebraska

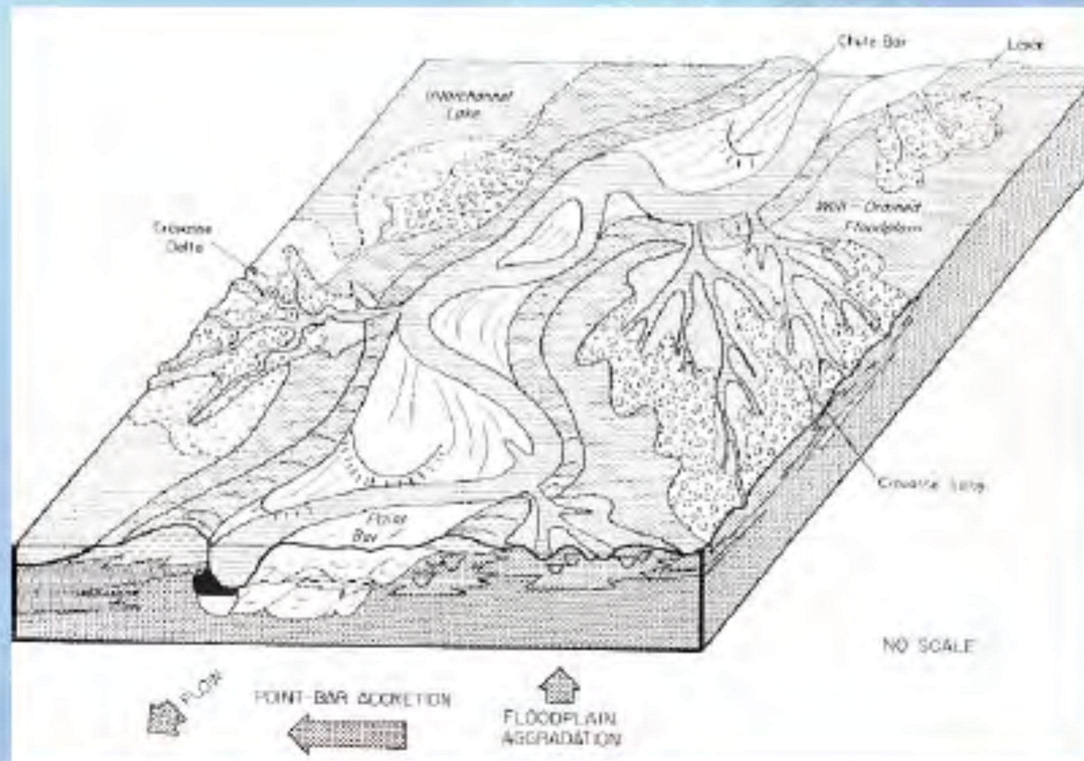


Schematic diagram showing simplified hydrologic setting of the Black Hills area. Schematic diagram generally corresponds with geologic cross section shown in figure 5.

Dan Hoyer, Dewey-Burdock Uranium In Situ Recovery Project, 2007 Eastern SD Water Conference and the 52nd Annual Midwest Groundwater Conference,
RESPEC at http://www.sdgs.usd.edu/esdwc/hoyer.pdf

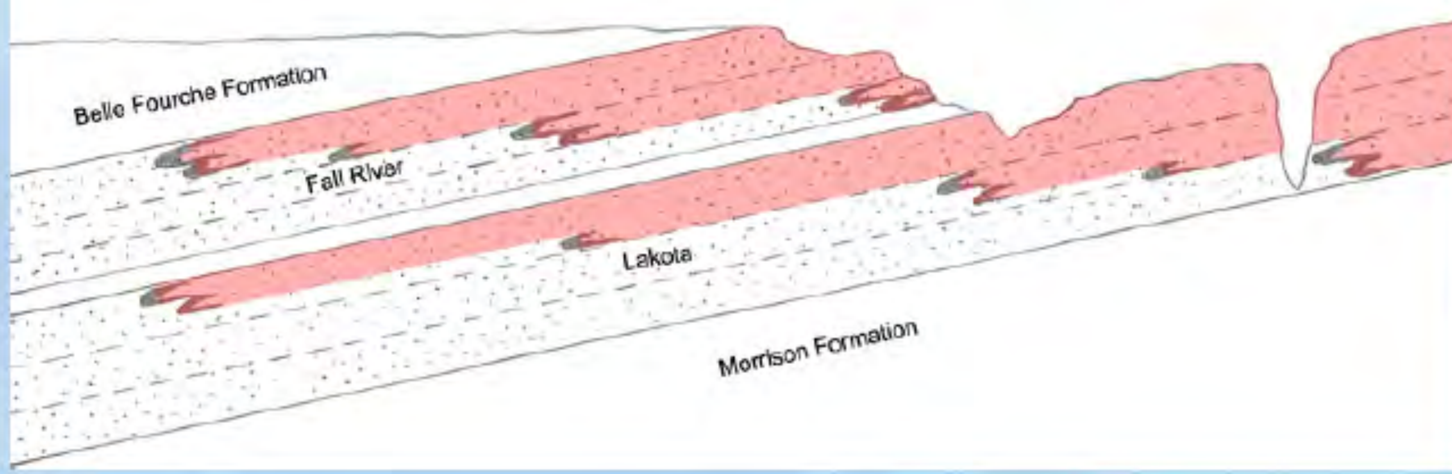
Inyan Kara Group

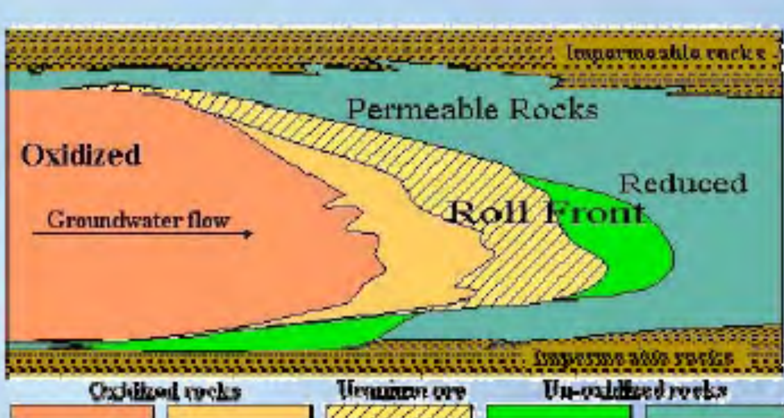
- *Fall River, Fuson, Lakota members*
- *Interbedded sandstone, siltstone, and mudstone*
- *Alluvial, deltaic, marginal marine*
- *Dips 5-10 degrees, SW*
- *Depth 0 to >500 ft*
- *Overlain by Cretaceous Shales (0-500+ ft)*
- *Underlain by Morrison Fm Shale (50-100 ft)*



In "Groundwater Characterization, Pump Tests, and Modeling of the Dewey-Burdock Uranium Project, Fall River and Custer Counties, South Dakota": Crystal Hocking, RESPEC, Rapid City, at SD.http://denr.sd.gov/des/gw/GWQConference/2009/GWQ_Conference_2009.aspx

CROSS-SECTION OF URANIUM OCCURANCES
BLACK HILLS URANIUM DISTRICT





RESPEC
WATER & NATURAL RESOURCES

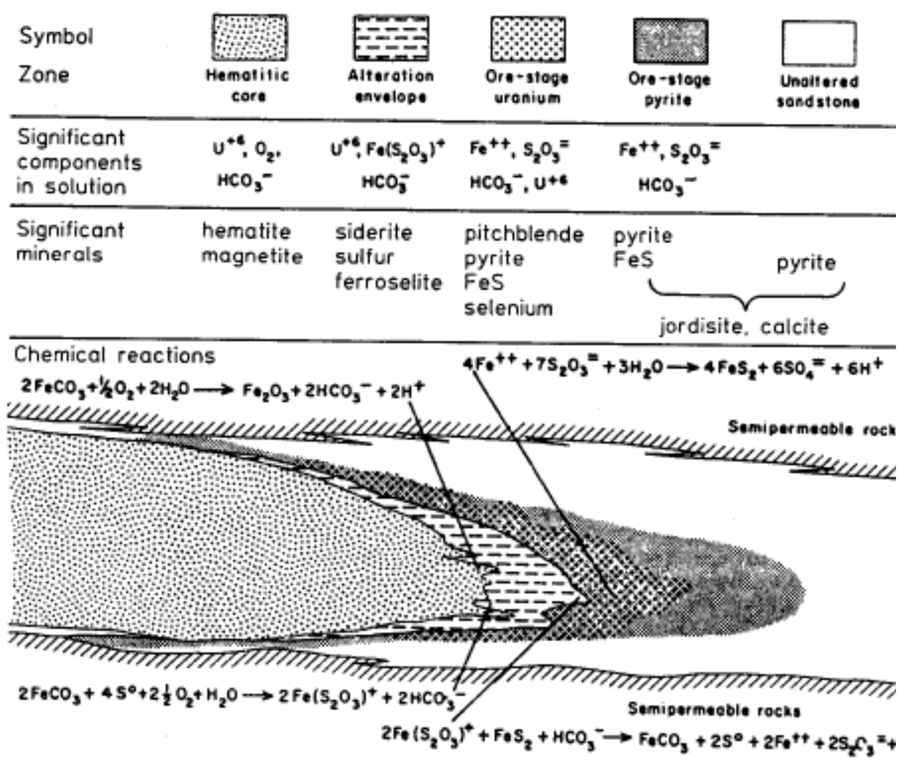


Figure 3. Schematic of idealized Wyoming Basin uranium roll front deposit showing alteration zones, related mineral components, solution components, and important aqueous chemical reactions for Fe, S, O, and CO_2 (after Granger and Warren, 1974).

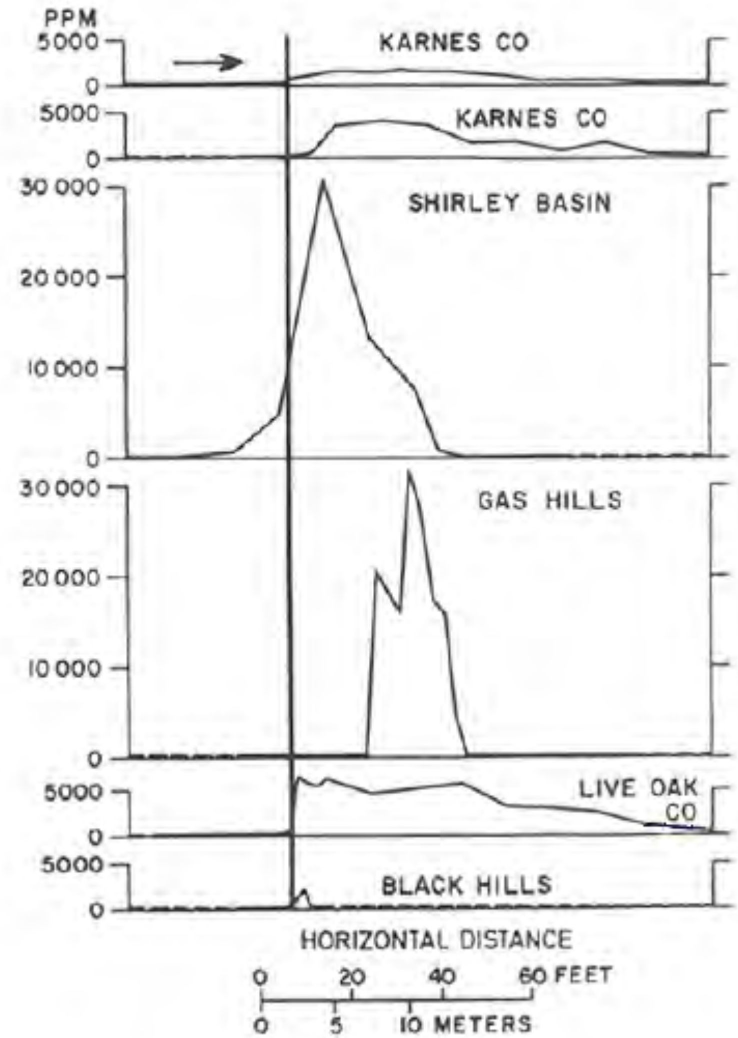


Figure 5. Concentration and distribution of uranium in various roll front deposits (after Harshman, 1974).

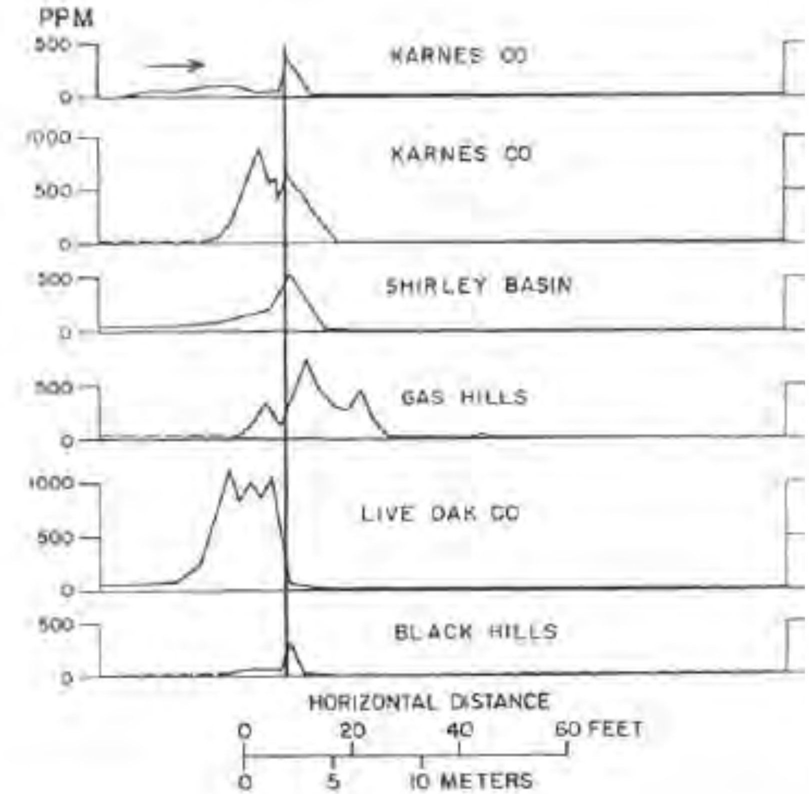


Figure 6. Concentration and distribution of selenium in various uranium roll fro deposits (after Harshman, 1974).

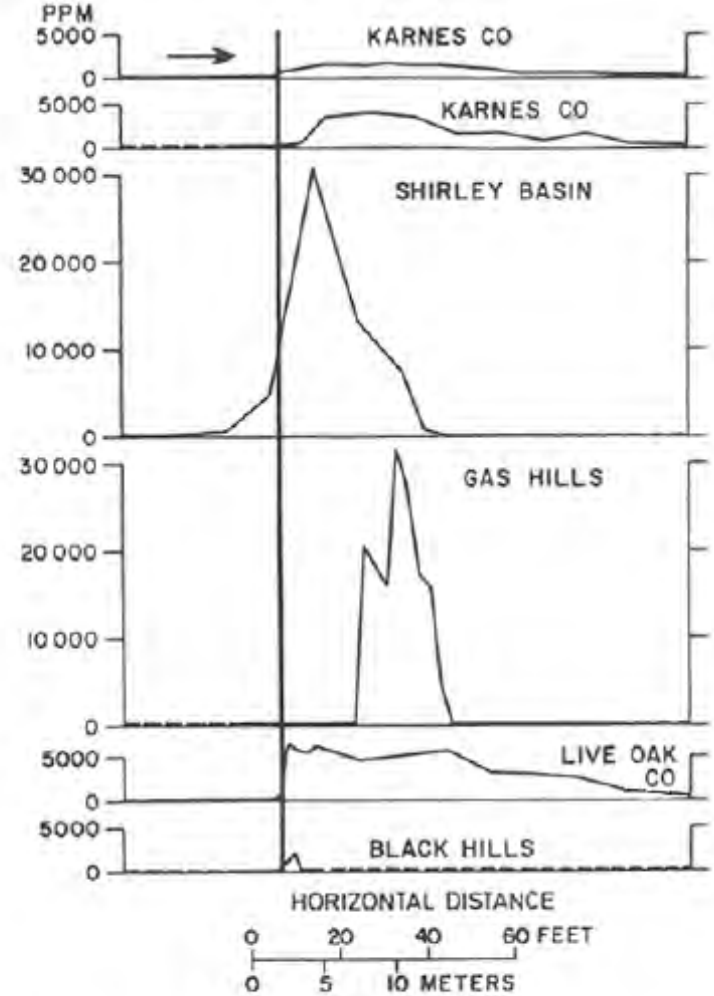


Figure 8. Concentration and distribution of arsenic in various uranium roll front deposits (after Harshman, 1974).

Consideration of Geochemical Issues in Groundwater Restoration at Uranium In Situ Leach Mining Facilities,NUREG/CR-6870, January 2007
Prepared by USGS for NRC,
http://www.nrc.gov/reading-rm/doc-collections/nuregs/contract/cr6870/

…Because of heterogeneities in the aquifers, the fresh groundwater that is brought into the ore zone does not completely displace the residual lixiviant….

…groundwater sweep may cause oxic groundwater from upgradient of the deposit to enter into the mined area, making it more difficult to re-establish chemically reducing conditions...

…it is difficult to predict how much time is required or even if the reducing conditions will return via natural processes. The mining disturbance introduces a considerable amount of oxidant to the mined region.....

Injection of lixiviant - leaching fluid - destroys water quality

oxidizes & mobilizes contaminants

changes the redox potential of the rock

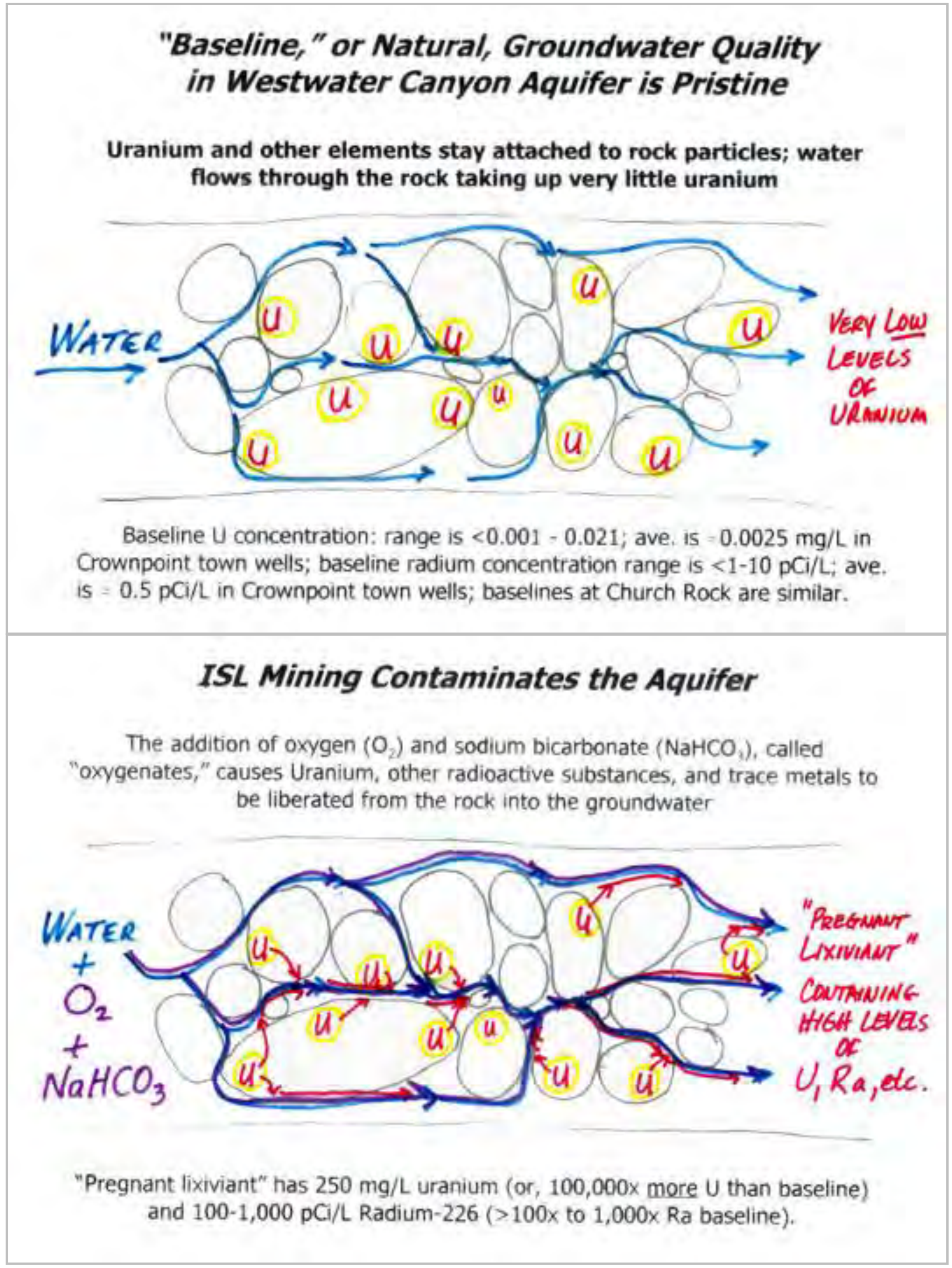
Restoration to baseline is not possible as contaminants continue to bleed with time

‘Restored’ water migrates downgradient and follows paleochannel flow paths carrying elevated levels of U, Ra, SO_4, O_2

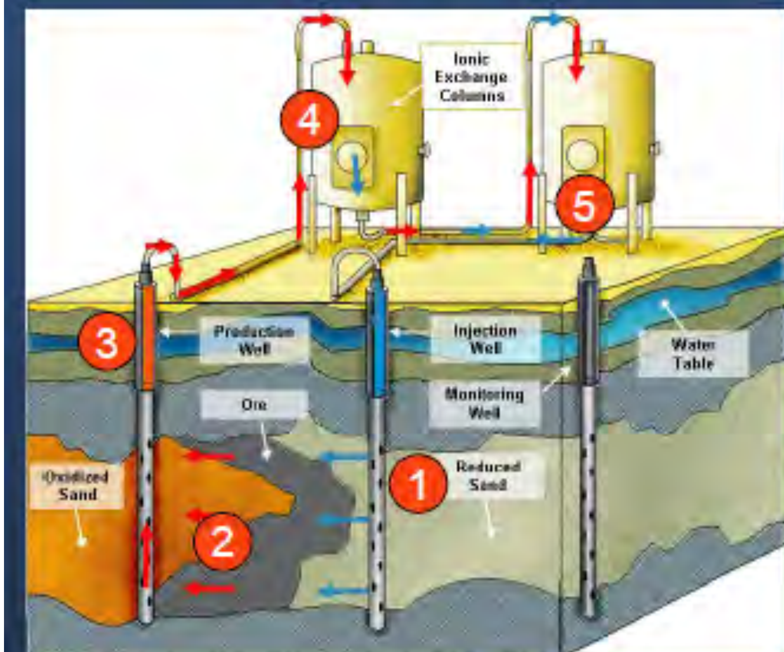
Natural attenuation is unlikely because the net charge on rock particles is negative therefore anions will not adsorb to rock particle contamination plume grows with time

Lixiviant injection destroys water quality

- Under normal conditions (top R), very little uranium is dissolved in the groundwater; it's stuck to sand grains in the rocks
- ISL mining frees uranium from the rocks, contaminating the groundwater (bottom R)



In-Situ Recovery Process – Description

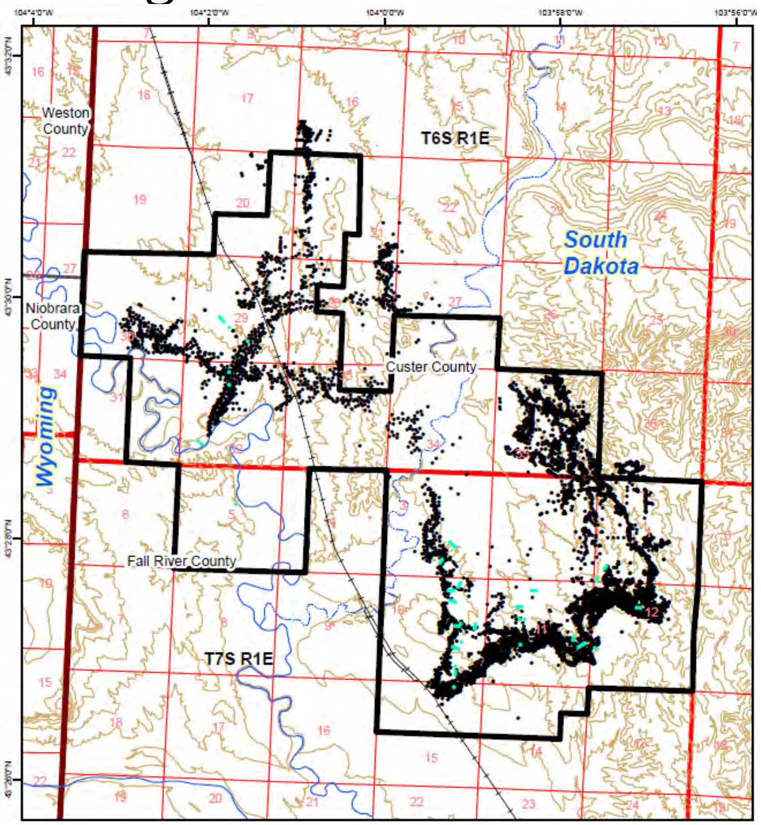


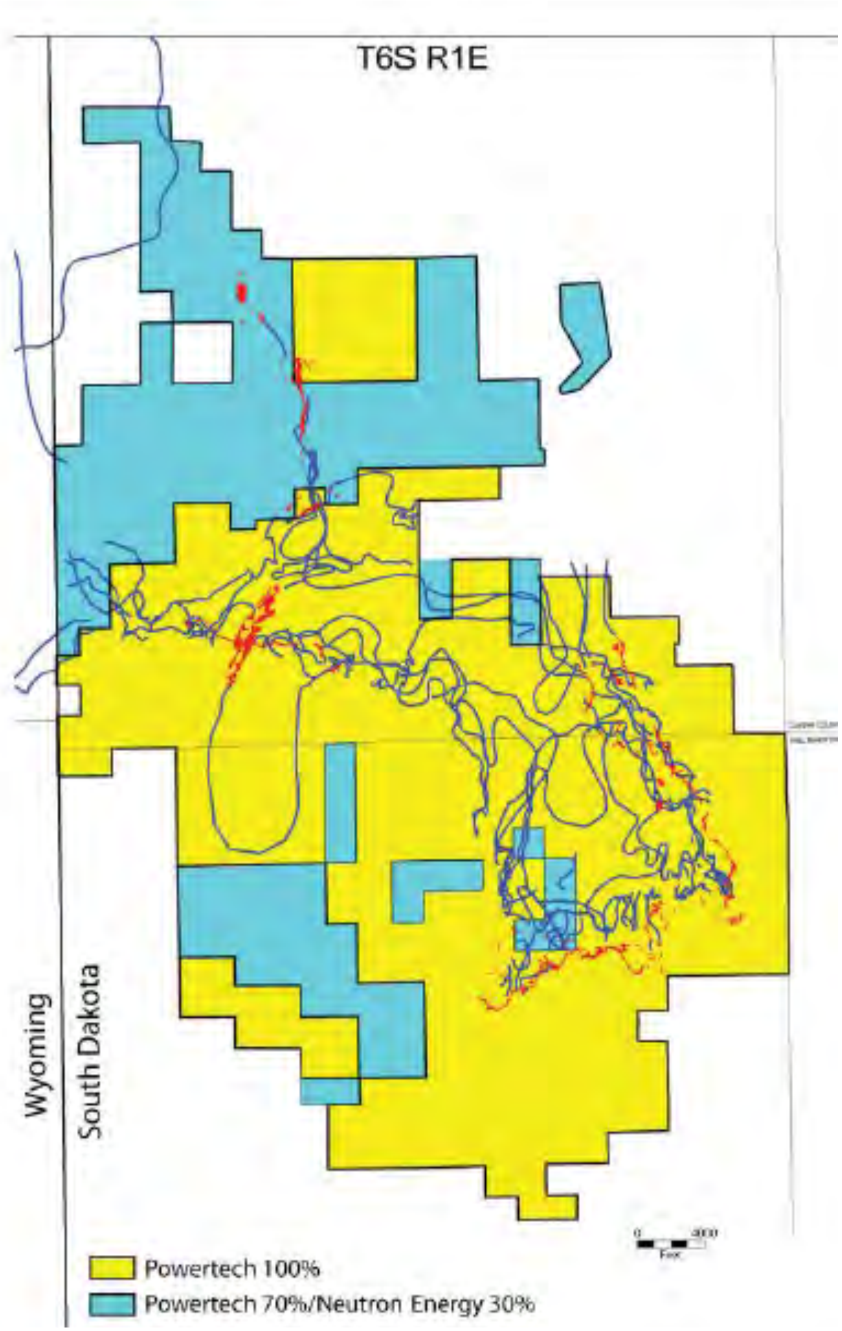
1. Oxygenated groundwater injected into ore-bearing sandstone.
2. Fluids dissolve uranium as they pass through the ore zone.
3. Pregnant solutions brought to surface by production wells.
4. Uranium is extracted in Ion exchange columns.
5. Stripped fluids re-oxygenated and re-injected into the wellfield.

Recycling fluids through the wellfield is an efficient, non-consumptive use of groundwater. Up to 90% of in-place uranium is recovered.

From www.powertech.com August 10, 2009 Presentation at http://www.powertechuranium.com/s/Presentations.as

Locations of Main Oxidation Fronts and areas of dense drilling



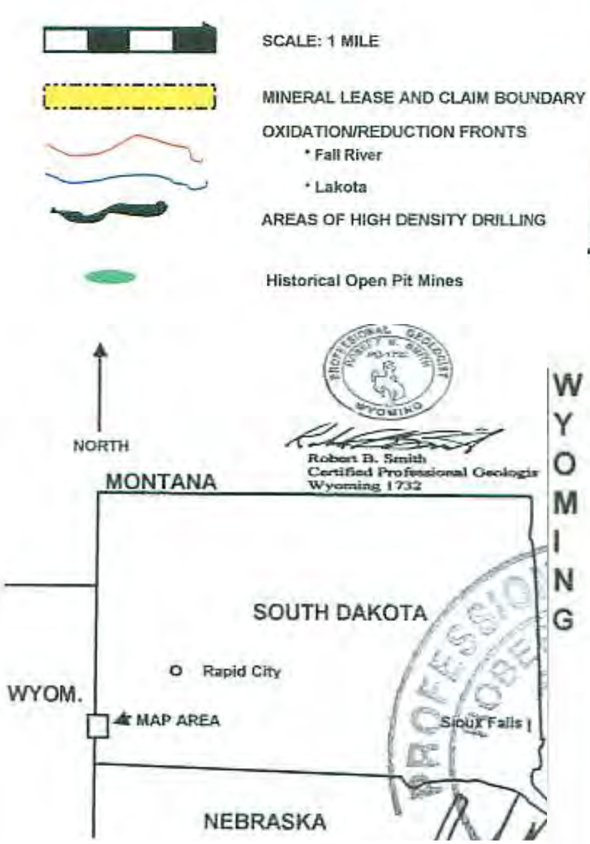


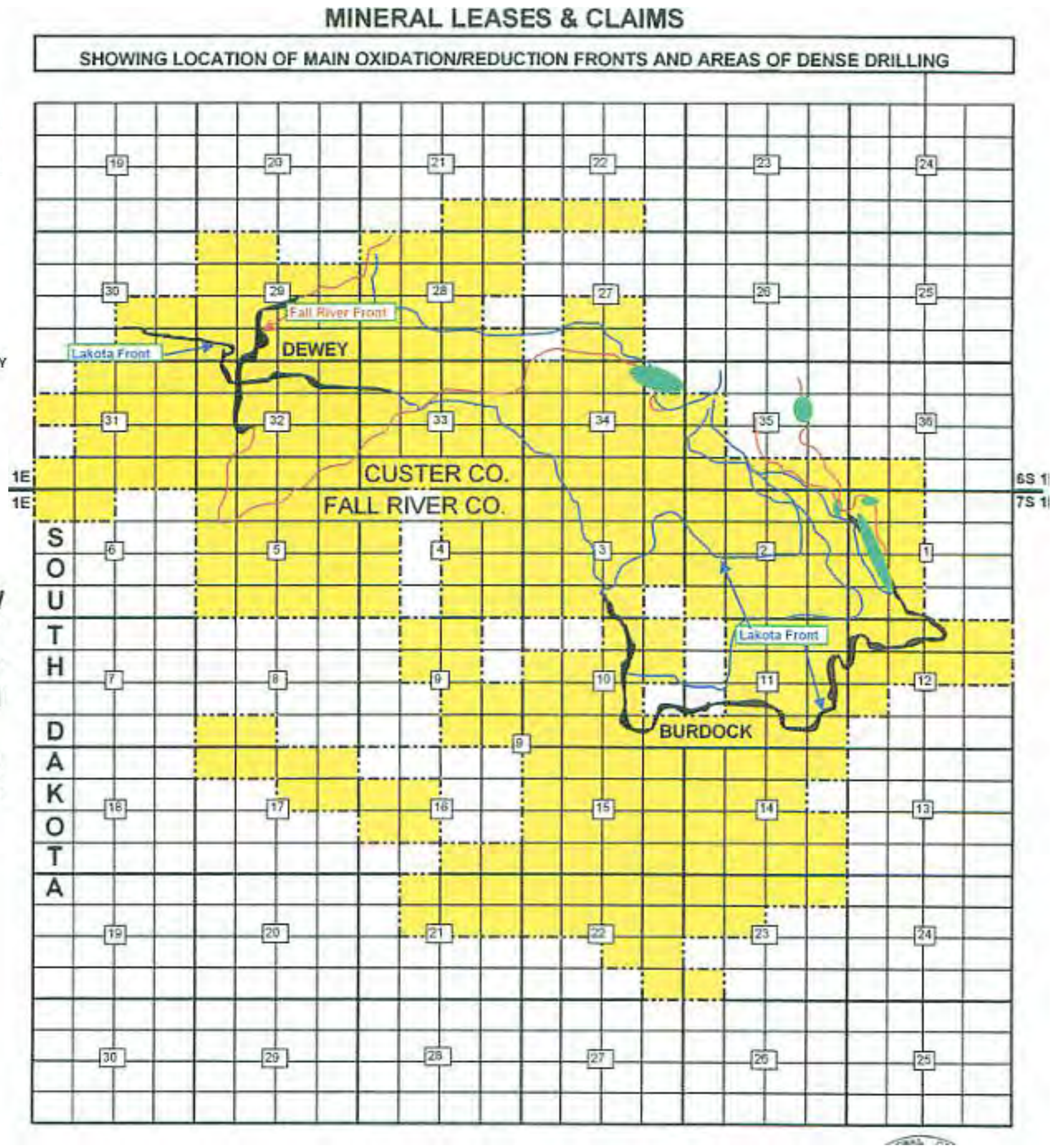
Dewey-Burdock Project

Edgemont Uranium District

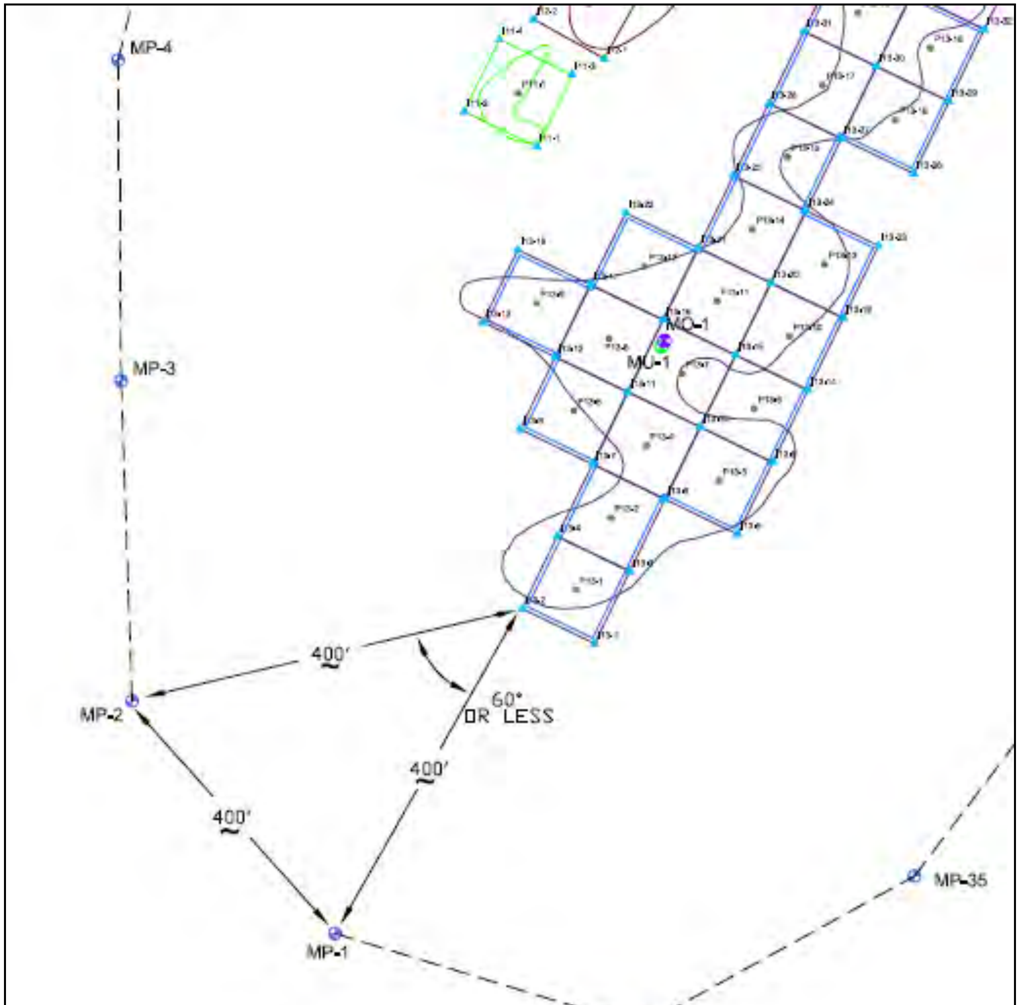
Custer and Fall River Counties, South Dakota

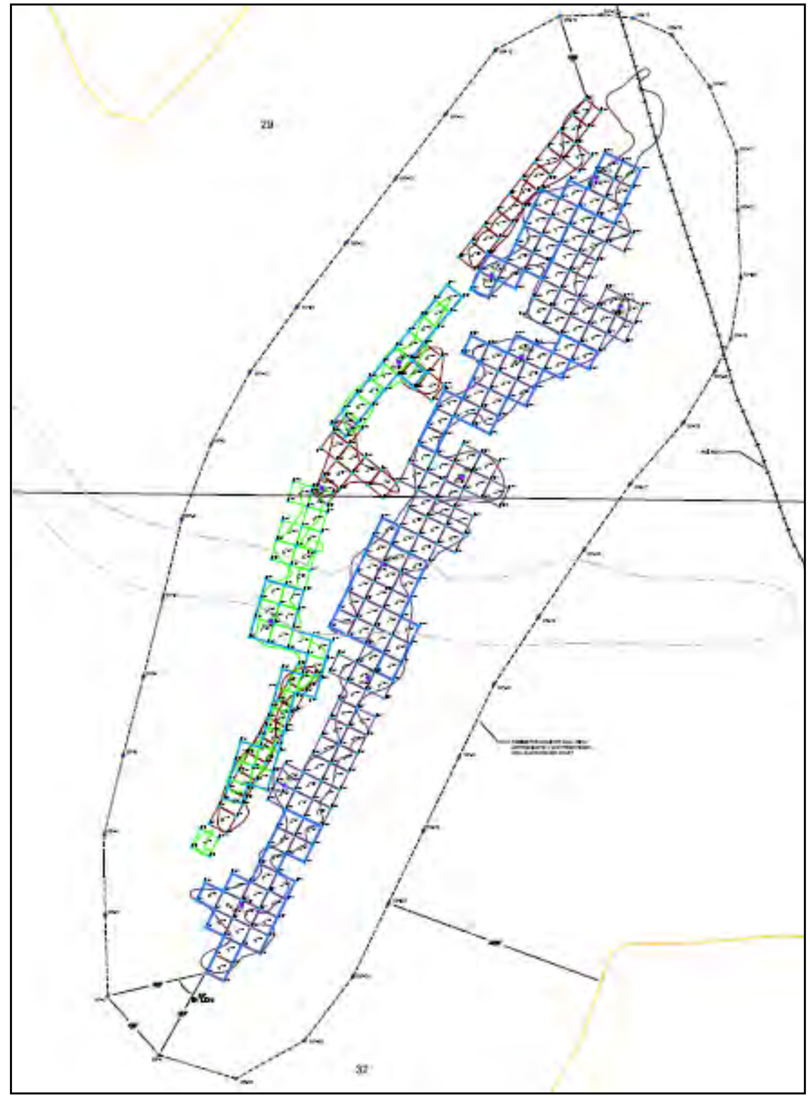
MINERAL LEASES & CLAIMS





FROM; Powertech Dewey-Burdock Project NI43-101 Report, December 2005





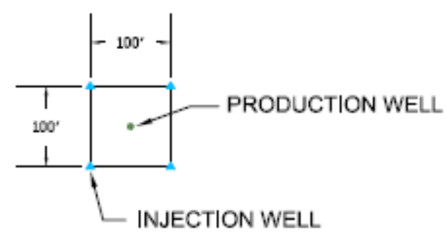
POWERTECH (USA) INC.

Plate 7.1

Map #2 Typical Layout-Mining Unit (100' Grid)

Fall River Well Detail, T1E-R6S, Sections 29 & 32

ONSITE WELLS	
TYPE	QTY
INJECTION (IXX-XXX)	355
PRODUCTION (PXX-XXX)	200
OVERLYING MONITORING (MO-X) 1 EVERY 4 ACRES	12
UNDERLYING MONITORING (MU-X) 1 EVERY 4 ACRES	12
PERIMITER MONITORING (MP-XX)	35



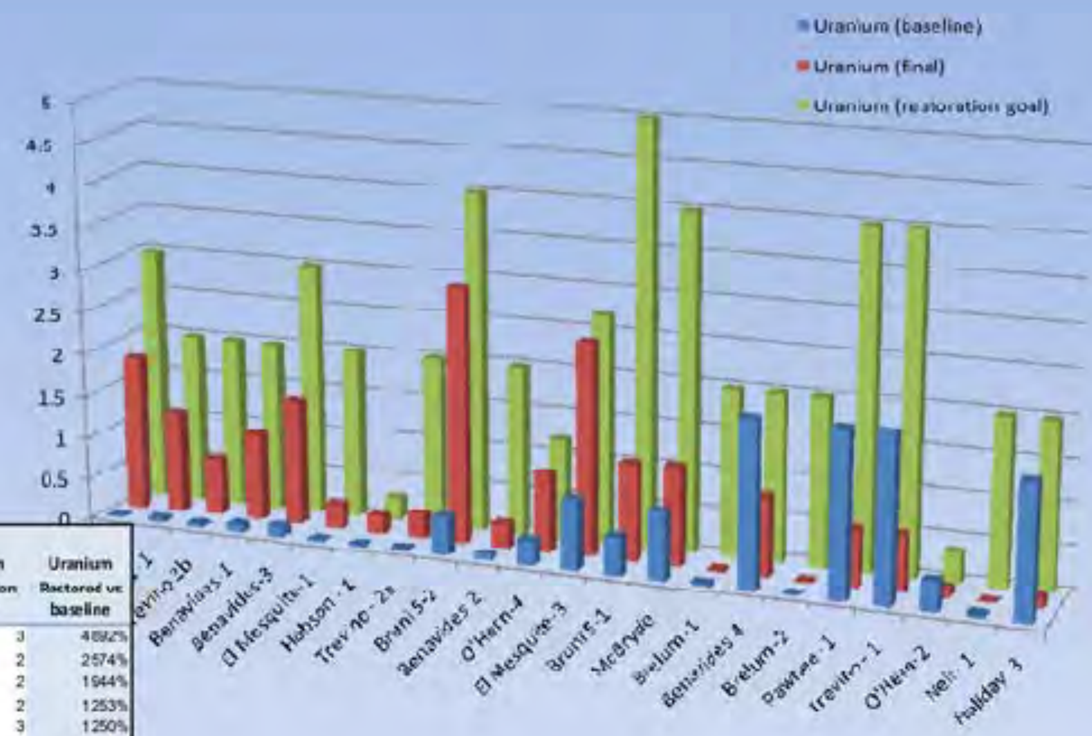
“To date, no remediation of an ISR operation in the United States has successfully returned the aquifer to baseline conditions. Often at the end of monitoring, contaminants continue to increase by

- reoxidation and resolubilization of species reduced during remediation;

- slow contamination movement from low to high permeability zones; and

- slow desorption of contaminants adsorbed to various mineral phases”

- from Otten, J. K., and Hall, S., USGS, “In-situ recovery uranium mining in the United States: Overview of production and remediation issues”, IAEA-CN-175/87 at: http://www-pub.iaea.org/MTCD/Meetings/PDFplus/2009/cn175/URAM2009/Session%204/08_56_Otton_USA.pdf



PAA	Uranium (baseline)	Uranium (final)	Uranium (restoration goal)	Uranium Restored vs baseline
Longoria - 2	0.037	1.81	3	4892%
Longoria -1	0.047	1.21	2	2574%
Trevino 2b	0.036	0.7	2	1944%
Benavides-1	0.083	1.04	2	1253%
Benavides-3	0.12	1.5	3	1250%
El Mesquite-1	[illegible]	[illegible]	[illegible]	[illegible]
Hobson -1	0.025	0.206	0.29	824%
Trevino -2a	0.036	[illegible]	2	[illegible]
Bruni 5-2	0.461	3.02	4	655%
Benavides-2	0.078	[illegible]	2	[illegible]
O'Hern-4	0.307	0.96	1.2	313%
El Mesquite-3	0.84	2.53	2.7	301%
Bruni 5-1	0.461	1.185	5	257%
McBryde	0.831	1.2	4	144%
Brelum 1	[illegible]	[illegible]	2	[illegible]
Benavides-4	2	0.95	2	48%
Brelum -2	[illegible]	[illegible]	2	[illegible]
Pawnee -1	2	0.672	4	34%
Trevino -1	2	0.672	4	34%
O'Hern-2	0.371	0.124	0.371	33%
Nell - 1	0.041	0.013	2	32%
Holiday -3	1.6	0.134	2	8%

Uranium (mg/L)

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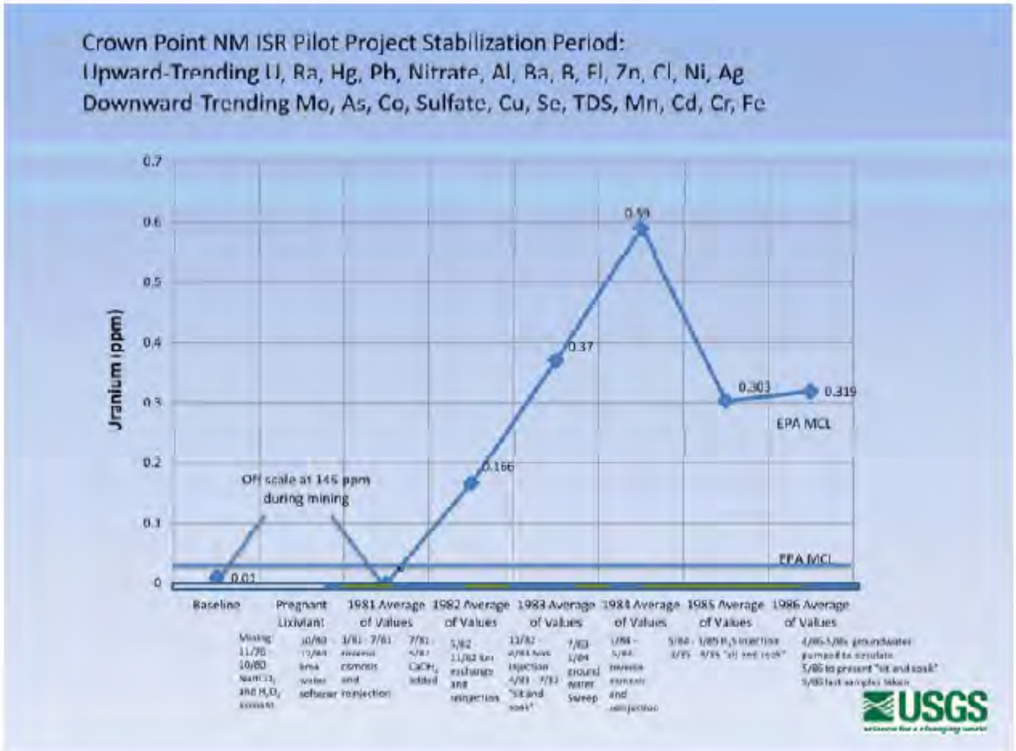
- Hall, Susan, 2009, Groundwater restoration at uranium in-situ recovery mines, south Texas coastal plain: U.S. Geological Survey Open-File Report 2009–1143, 32 p. - http://pubs.usgs.gov/of/2009/1143/



During the one-year stabilization period that followed restoration at Mobil's Crown Point, New Mexico ISR pilot project, both upward and downward trends in various chemical constituents were noted (Mobil, 1981). The Crown Point data are not detailed enough to analyze these trends, but the data indicate that groundwater may not have stabilized when the final samples were collected, similar to the Grover, Colorado, project.

Examples from Grover, Colorado, Crown Point, New Mexico, and ISR pilot projects in Wyoming indicate that the 6-month stability period mandated by Texas ISR rules may not have been long enough to adequately determine if groundwater in well fields had stabilized. Recent rule changes in Texas allow for longer term monitoring and could yield valuable data about the chemical stability of groundwater after ISR mining.

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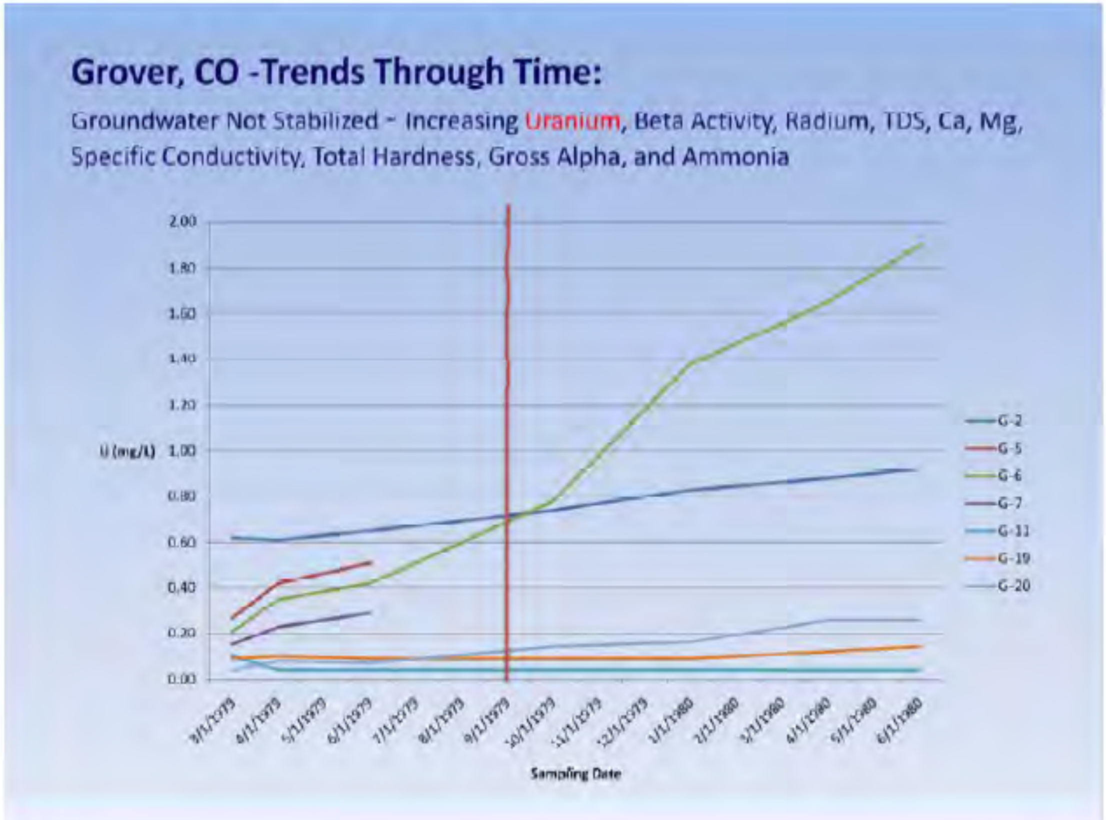

At the Grover, Colorado, pilot test site, pump and treat technologies did not return groundwater to baseline. Analysis of data collected by Colorado State regulators showed upward-trending uranium, beta activity, radium, TDS, calcium, magnesium, specific conductivity, total hardness, gross alpha, and ammonia. Results from individual wells differentiated using solid colored lines are shown above in the time series plot of uranium concentration. Note that the vertical red line indicates the end of the 6-month stabilization period required for Texas PAAs. These increasing concentrations of analytes indicate groundwater may not have stabilized when the Grover well field was released.

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Has any ISR Mine in the United States Returned Post-mining Groundwater to Baseline?

	More than half of PAAs were lower than baseline after mining and reclamation	More than half of PAAs were higher than baseline after mining and reclamation
MCLs	As, Cd, Fl, Pb, Hg, Nitrate, Ra	U, Se
Secondary Standards	Cl, TDS, Fe, Mn	Sulfate
Other Chemical Constituents	Na, K, Si, Mo	Ca, Mg, Bicarbonate, Conductivity, Alkalinity, Ammonia-N

Can we answer the question: "Has any ISR mine in the United States returned post-mining groundwater to baseline?"

Answer: Not based upon analysis of the Texas database because "final value" records were found for only 22 of 77 PAAs (13 of 36 mines).

We can conclude that in Texas, ISR mines are characterized by high baseline arsenic, cadmium lead selenium radium and uranium After mining and restoration for those well fields that reported "final values" in TCEQ records, more than half of the PAAs had lowered levels of many elements, including some that dropped below MCL.

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