Uranium Development & Water in New Mexico: Lessons from the Past & Strategies for the future

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Introduction

- Historically NM produced ~50% of U.S. domestic production
- Should understand past successes and challenges to establish basis for evaluating future development
- Objective:
  - Summarize history of U mining & milling in NM
  - Discuss mining & milling technologies used in the past
  - Consider environmental challenges
  - A few strategies for dealing with future issues

A Bit of History and Irony

1938/1939 – Discovery of fission: Hahn, Strassmann, Meitner, Frisch

1942 – First reactor, Chicago Pile-1: Fermi

U from Belgian Congo

1942 – 1946 – Manhattan District, IL, NM, WA, KY, etc.

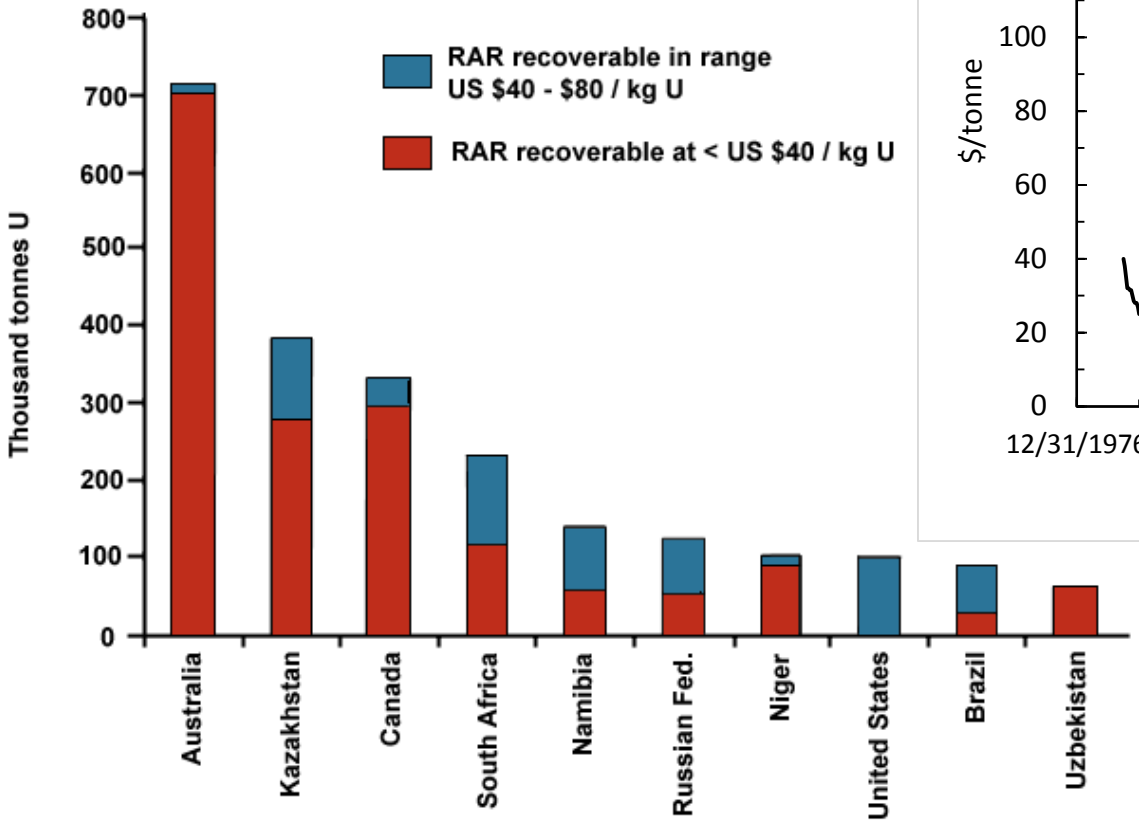
1945 – Atomic bomb, Trinity Site, Alamogordo, NM

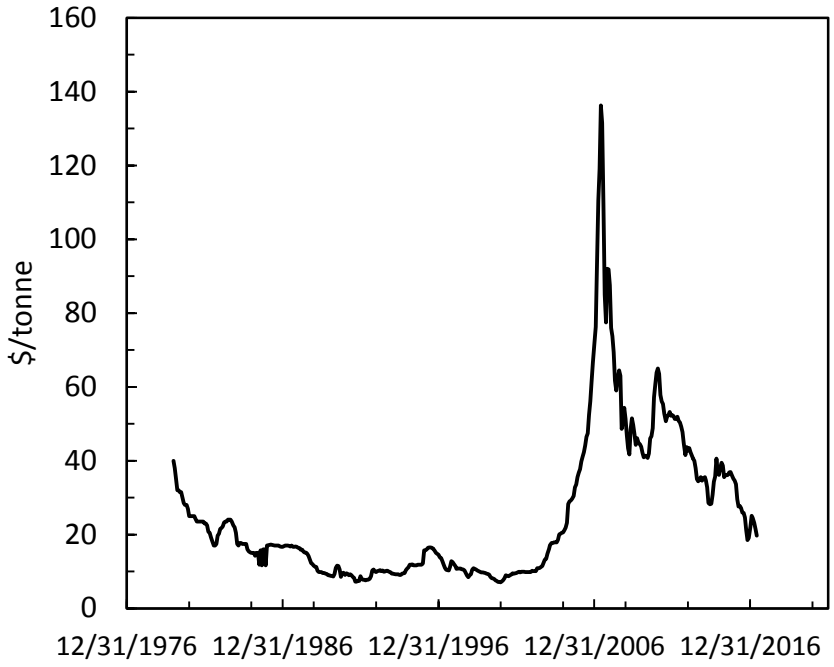
U from Belgian Congo

1950 – Discovery of major U reserves in NM, Grants Mineral Belt, NM

World U Resources

- NM has ~350 M lbs @ $50/lb
- 38% of US supply, 2nd to WY



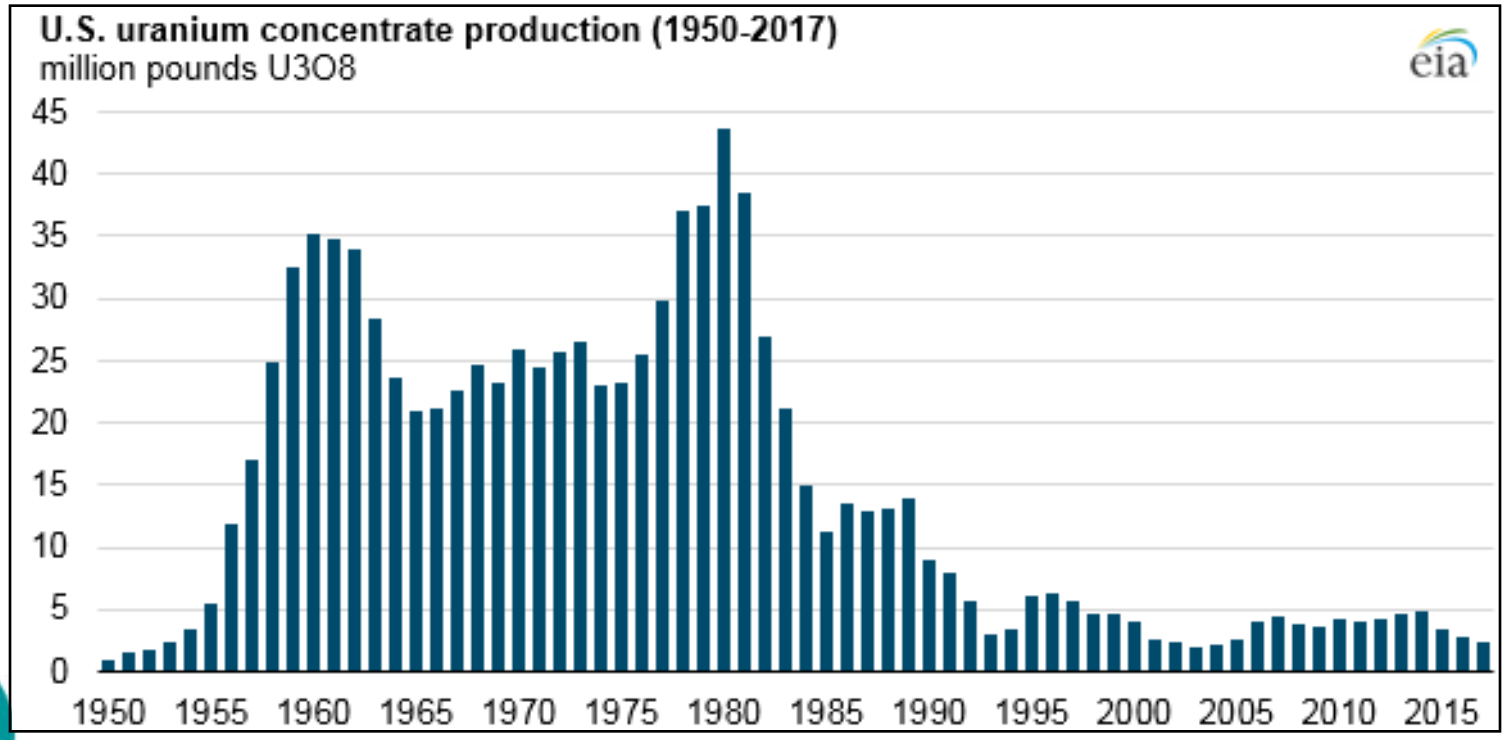


https://fred.stlouisfed.org

Domestic U Production

(https://www.eia.gov/todayinenergy/detail.php?id=35092)

- Current US operations: 1 underground mine, 5 ISL mines, 1 “other” (mine water circulation)
  - Lowest production since 2004
  - 11% of U deliveries



Uranium Resources in NM

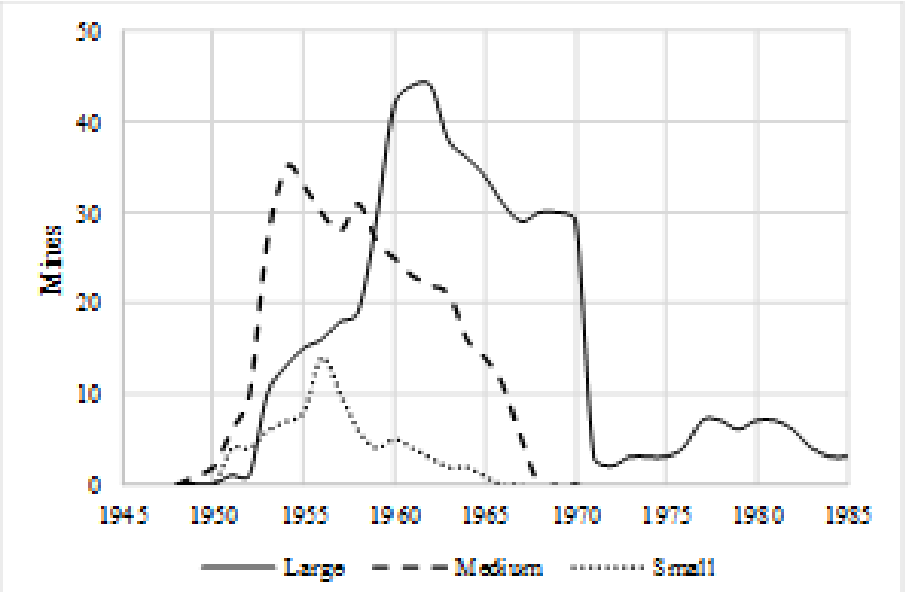
(SJBRUS, 1980)

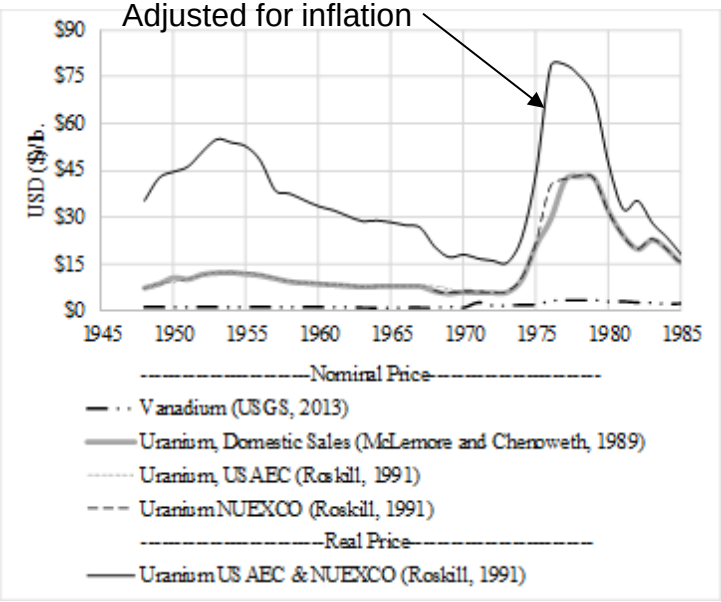
- Discovered in 1950 by Navajo sheepherder - Paddy Martinez
- In 1979 NM produced ~50% of nation's supply of U
  - 38 mines
  - 6 mills
  - ~7,000 employees
  - Then:
    - Three Mile Island (3/28/79)
    - Churchrock tailings dam failure (8/16/79)
      - 370,000 m^3 of tailings solution
      - 1,000 tonnes of tailings
      - Contaminated 110 km of Rio Puerco of the west
    - Price of U plummeted
  - Now:
    - No mines or mills operating in NM

Relationship Between U Mines & Price

(Zemlick et al., 2018)

- Production originally dominated by small mines. Out competed by large mines due to increasing mining costs & economies of scale

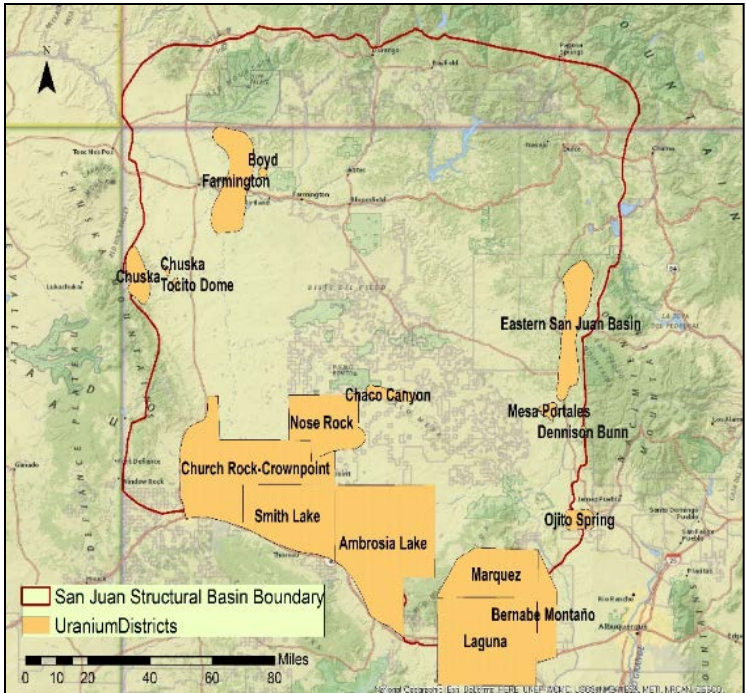




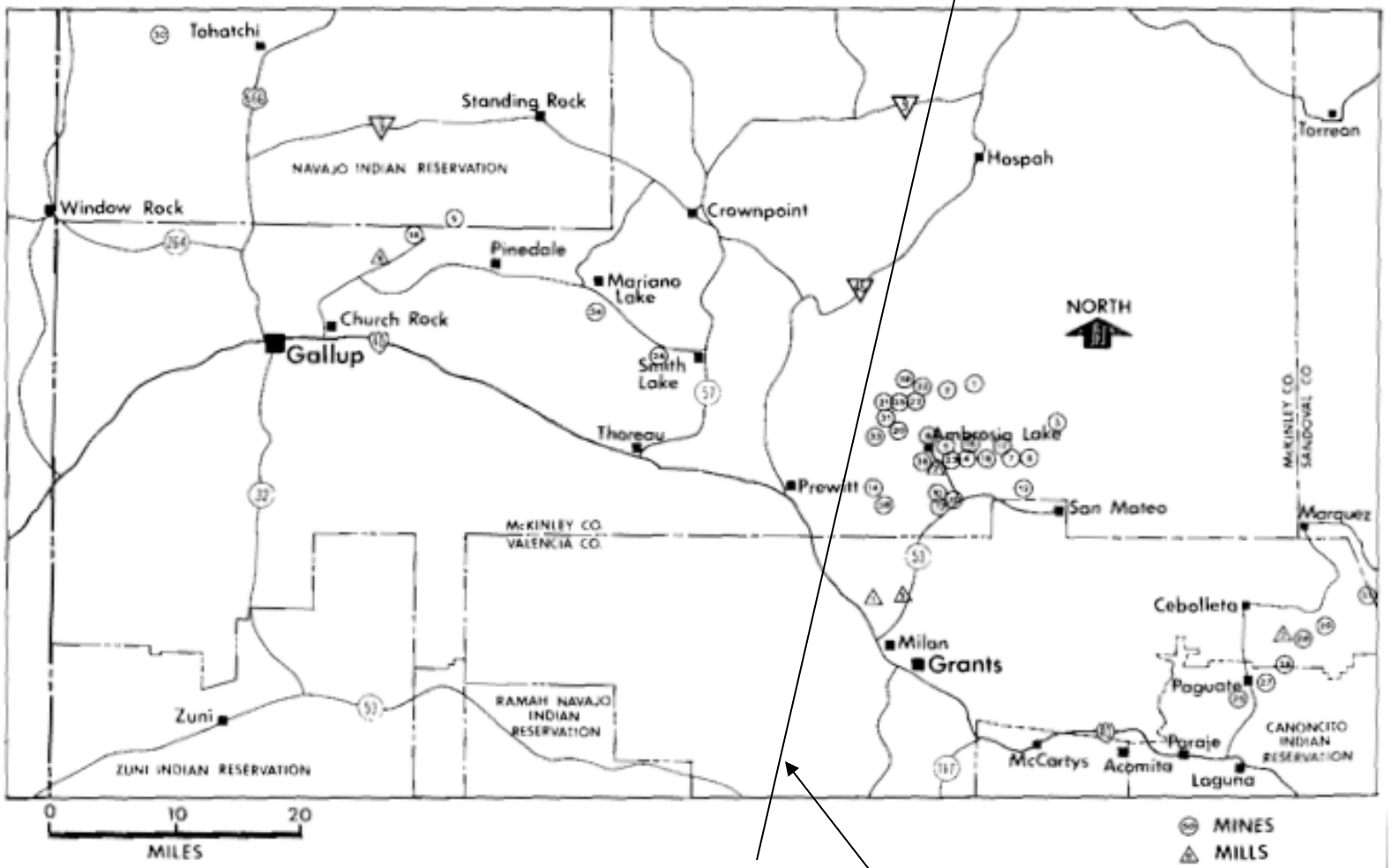
San Juan Basin U Mining Districts

(NMBGMR, 2015)

- Prior to the early 1980s, mines in the Grants Mineral Belt of the San Juan Basin supplied nearly half of domestic demand:
  - 236 mines and 5 mills produced more than 350 million pounds of U3O8
  - $5 billion dollars
- It is estimated that nearly 600 million pounds of uranium (U_3O_8) are present in the basin
- Potential for ~$60 billion in direct revenues



Mines & Mills in 1980 (SJBRUS, 1980)

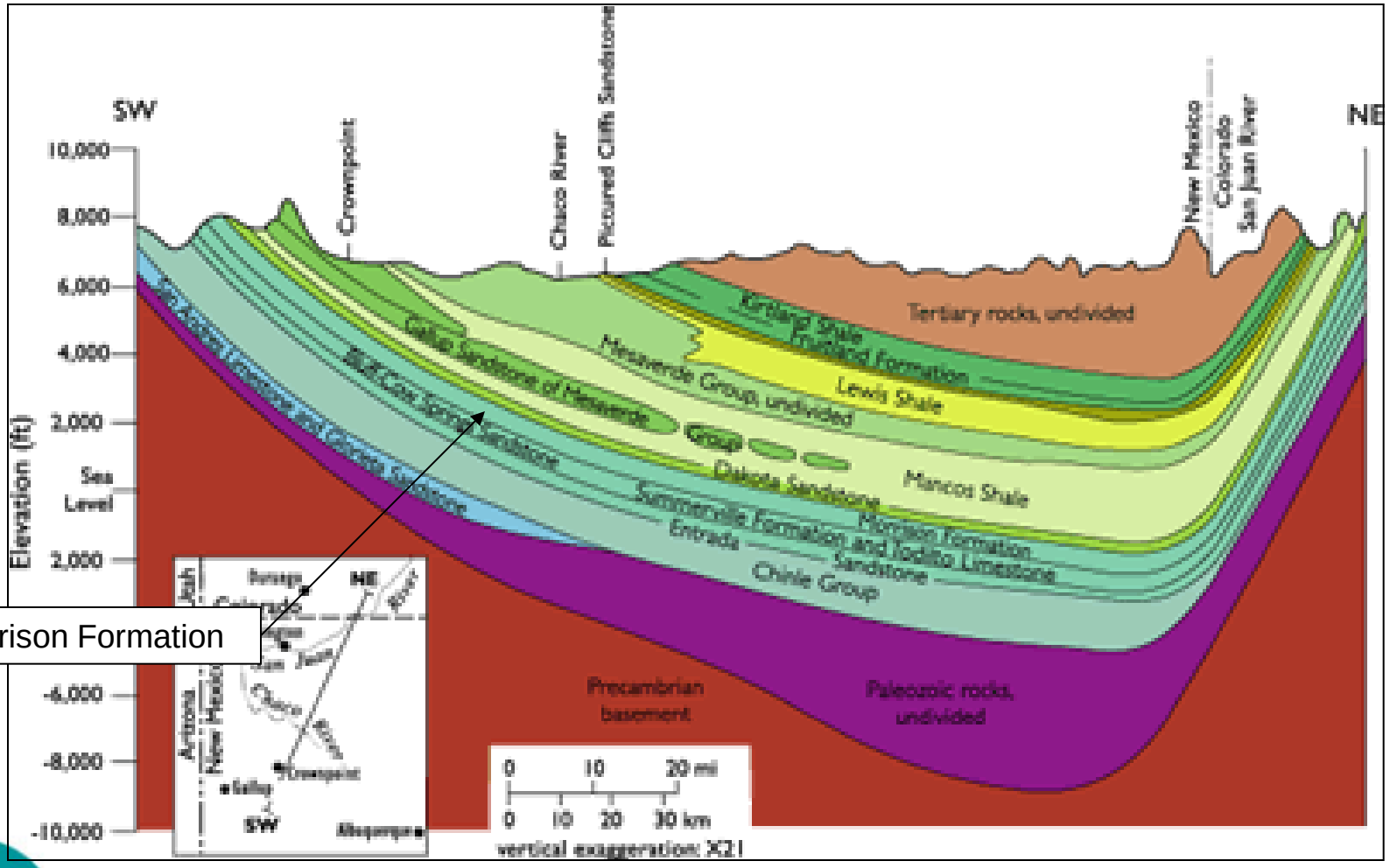


Cross section on next slide

EXISTING MILLS & MINES

General Cross Section of San Juan Basin

(NMBGMR, 2014)



Morrison Formation

U Mining

- Conventional mining
  - Open pit mine - Laguna Jackpile Paguate Mine
  - Underground mining
    - Requires mine dewatering - up to 3,000 gal/min
    - Large power requirements for ventilation (Palo Verde nuclear generating station)

- In situ leach (ISL) mining
  - Practiced in So. TX, NB, & WY – currently (2017) only 5 operating mines
  - Less impact on ground water resources
  - Little surface disturbance
  - Difficult to restore aquifer quality

1980 NM Mine Dewatering Act

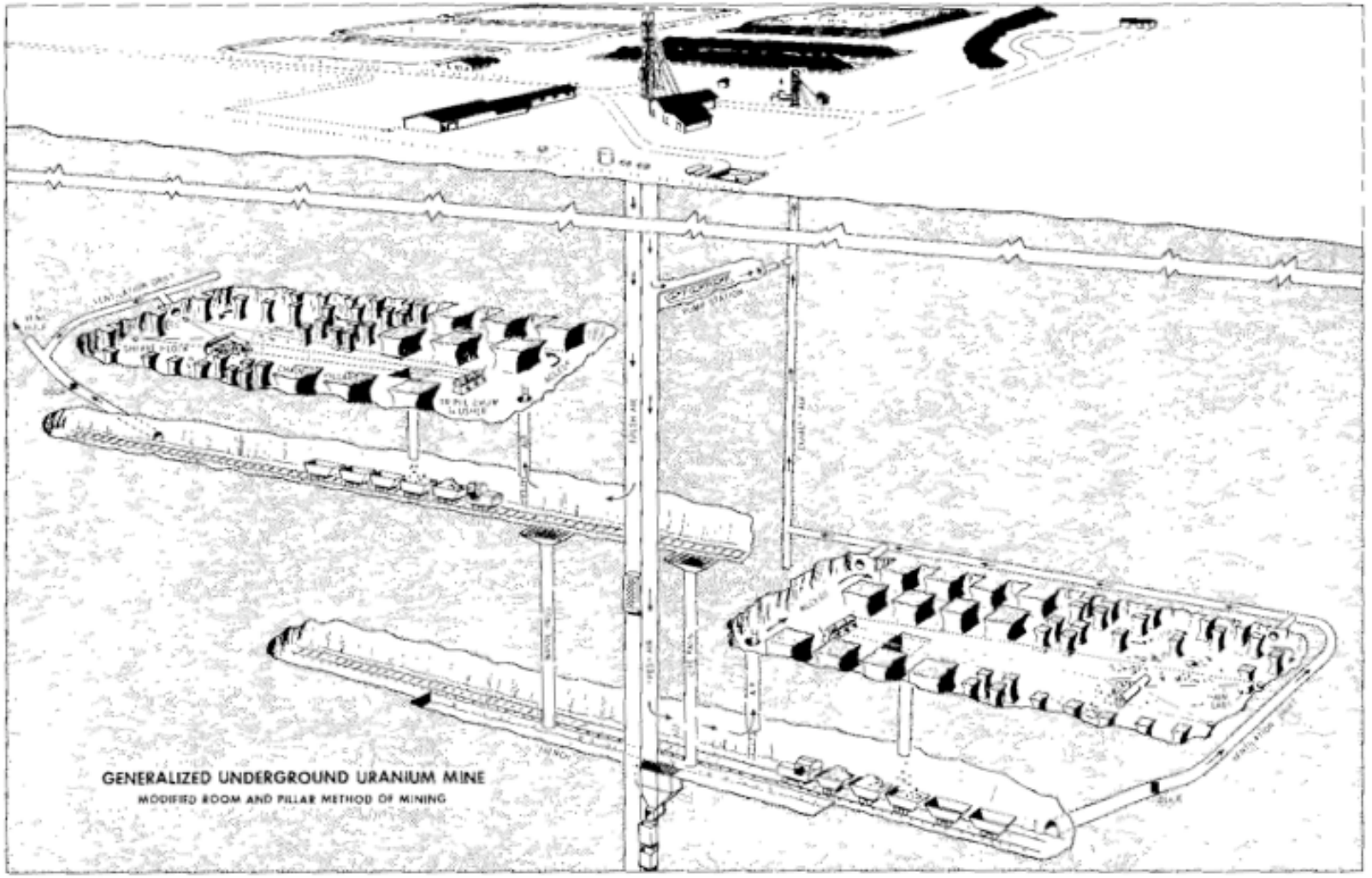
(New Mexico Statutes 72-12A)

- Assigns jurisdiction to State Engineer – Mines must obtain permit to dewater
  - Must show non impairment to existing water rights
- Right of replacement – If mining impairs water resource, mine can replace the water right (“cure the impairment”)
  - Deepen existing wells or drill new wells
  - Provide alternate source of supply
  - Applicant has right of condemnation, subject to OSE jurisdiction, in order to cure impairment
- No water rights may be established solely by mine dewatering
- Replacement may use reclaimed mine water, but must posses a water right for this water.
- Responsibility extends beyond life of mine for as long as impairment exists

Jackpile Mine
(Laguna Pueblo)

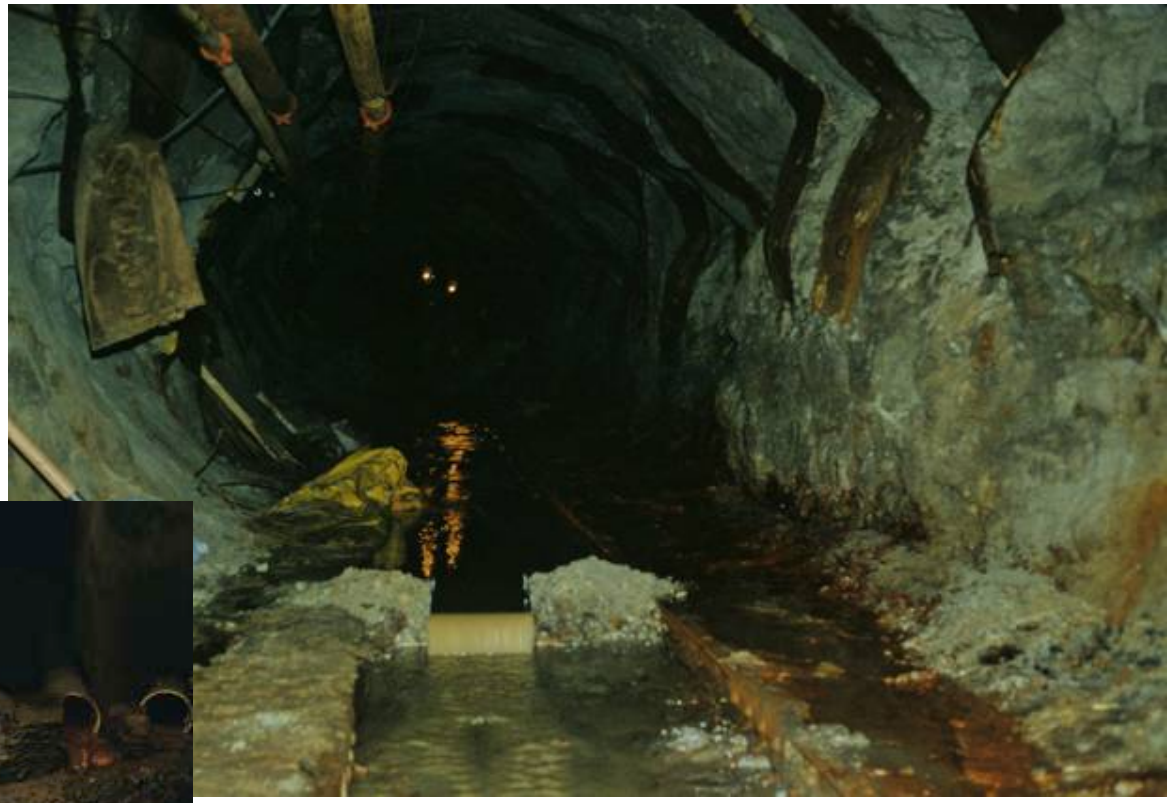
- Largest open pit U mine in world
  - 1953 – 1982
  - ~7,868 acres in 3 pits
  - ~400 Mtons or ore
  - Deepest pit excavated to depth of 625 ft
  - Reclamation from 1989-1994
  - Recent Superfund site

Method of Underground Mining (SJBRUS, 1981)



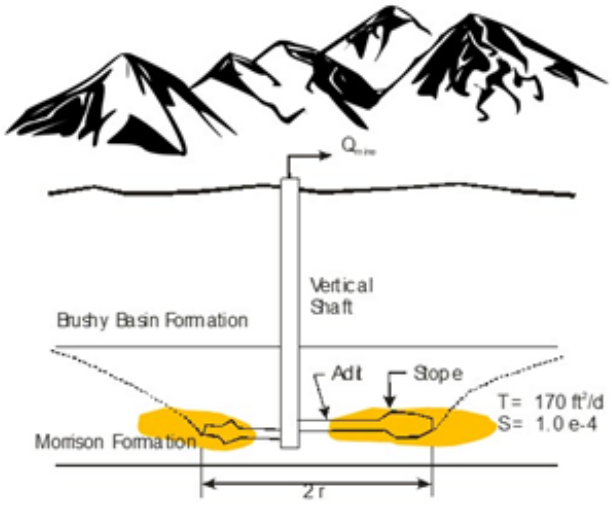
Underground Images

- It’s dark & wet (inside an aquifer



Underground Mining Requires Mine Dewatering

- By late 1970's >30,000 AF/yr of water pumped to surface & discharged
  - Consumptive use by ABQ ~40,000 AF/yr
- Water produced by mining does not require water right according to NM law
  - Produced water could not be put to beneficial use



Average Water Quality of the Puerco River

(EID Data, 1983)

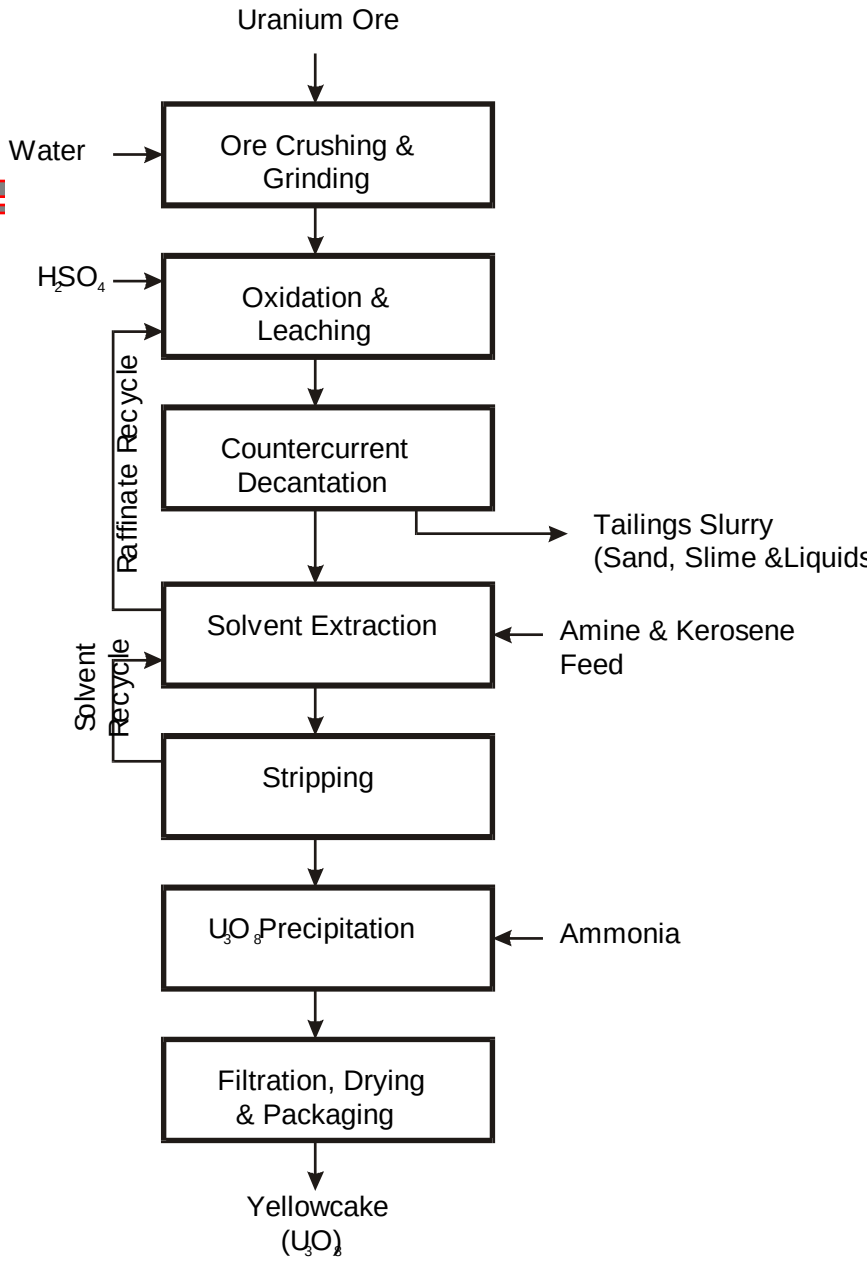
	Concentration (mg/L)		
Constituent	**1978**	**1979**	**SDWA Std.**
Ba	0.16	0.125	2.0
NO_2^- & NO_3^-	2.0	6.6	10.0
Se	.025	.010	.05
SO_4^{2-}	204.	201.5	250*
TDS	627	609	500*
U	.63	.40	1.0#

Notes:

* = Recommended standard
# = Current standard is 0.03 mg/L

U Milling Uses Strong Acids or Bases (Merritt, 1971)

- Acid (or alkaline) leach process
  - Oxidize U(IV) to U(VI)
  - Dissolve in acid (or base)
  - Recover by solvent extraction or IX
  - Precipitate as U_3O_8
- Acid leach - low Ca in ore (leach at pH < 2)
- Alkaline leach - high Ca in ore (leach at pH > 10)



Uranium Mills in NM

Name	Years of Operation
Anaconda Bluewater	1953-1982
Bokum Mill	-
Foote Mineral Company, Shiprock	1954 - 1963
Homestake Partners	1958 - 1990
Kerr McGee/Rio Algom Ambrosia Lake	1958 – 2002
L-Bar Mill (Laguna)	1977 - 1981
Phillips Ambrosia Lake	1958 – 1982
UNC Ambrosia Lake	1957 – 1963
UNC Churchrock	1967- 1982

Sources:

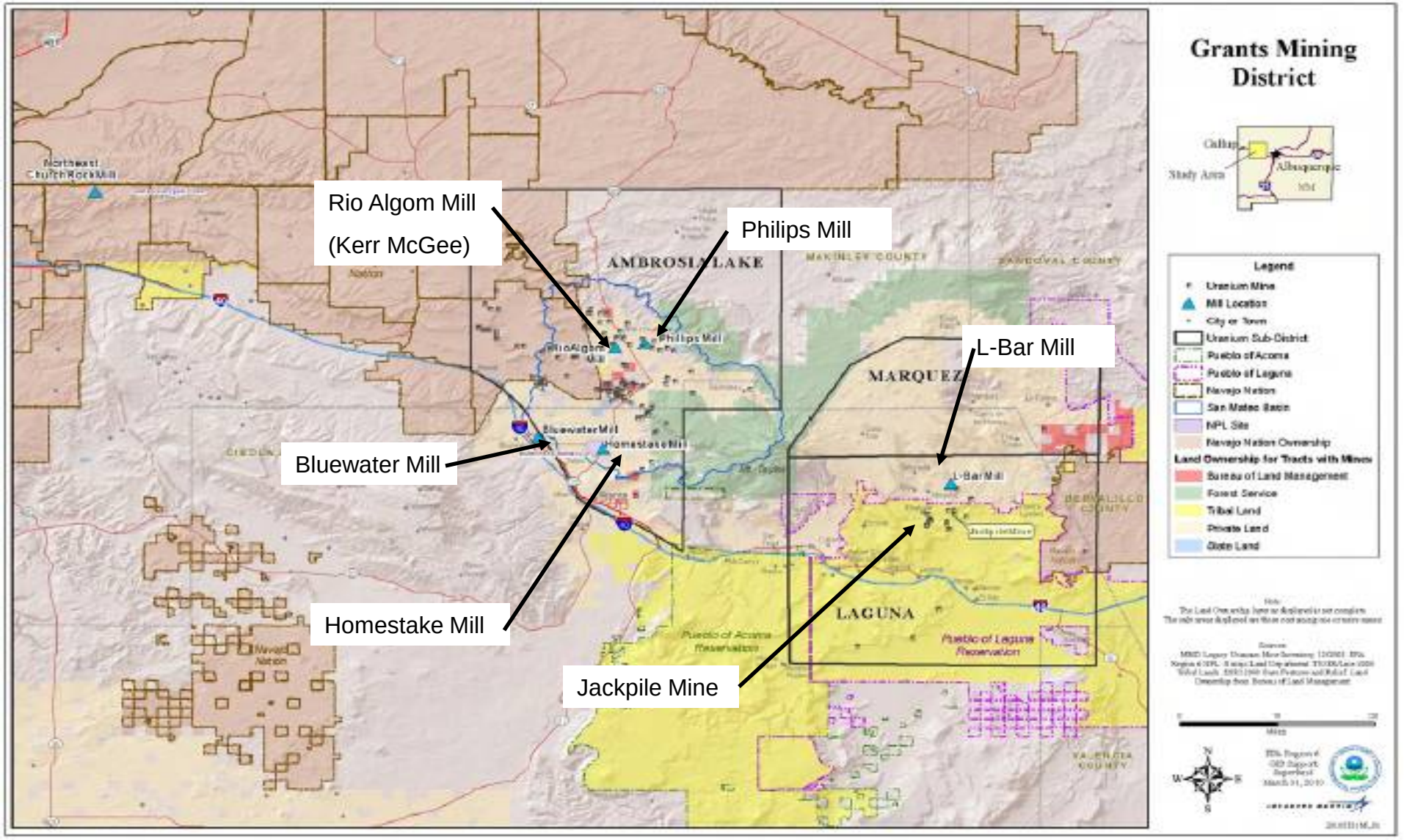
- Merritt (1971). The Extractive Metallurgy of Uranium
- EPA, Region VI Legacy Study https://www.epa.gov/sites/production/files/2015-08/documents/uranium-mine-brochure.pdf

Mill Tailings Decant Water Quality

(Thomson & Heggen, 1983)

Constituent	SDWA MCL (mg/L)	4 Acid Mills in NM	1 Alkaline Mill in NM
As	.010	1.3	5.0
Mo		0.9	98.0
NH_3 (as N)		400.0	16.0
Se	.050	29,700.	8,400.
U	.030	74.0	14.0
TDS	500.	39,800.	25,400.
pH		1.05	10.1
Ra-226 (pCi/L)	5.	70.0	58.0
Gross-α (pCi/L)	15.0	38,000.	6,700.

Grants Mining District



U Mill Tailings – Homestake

(1980)

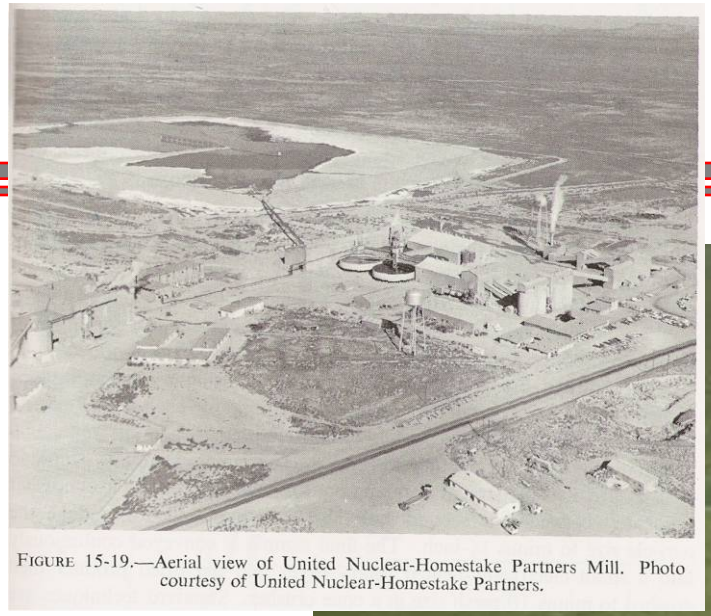


FIGURE 15-19.—Aerial view of United Nuclear-Homestake Partners Mill. Photo courtesy of United Nuclear-Homestake Partners.

Homestake Mill Tailings Pile

(Oct. 2012)

Kerr McGee
U Mill Tailings
(1980)

The University of New Mexico

Kerr McGee/Quivira/Rio Algom

(Oct.2012)

Churchrock Tailings
Dam Failure

- 7/16/79 tailings dam failure released 1,100 tons of tailings & 93 Mgal of wastewater to Puerco River of the west (flows through Gallup)
- pH = 1.2, Gross α = 128,000 pCi/L
- Total release ~46 Ci
- Initial cleanup was performed by hand (shovels & 55 gal drums)
- Superfund designation 1983
- Cleanup continues to date

Church Rock Tailings Dam Failure

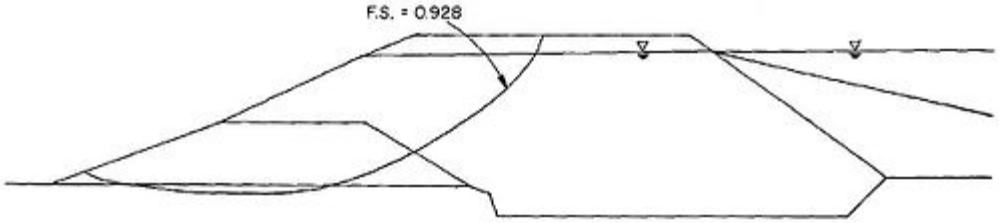


FIGURE 1. CRITICAL CIRCLE FOR HIGH PHREATIC SURFACE, CHURCH ROCK TAILINGS DAM.

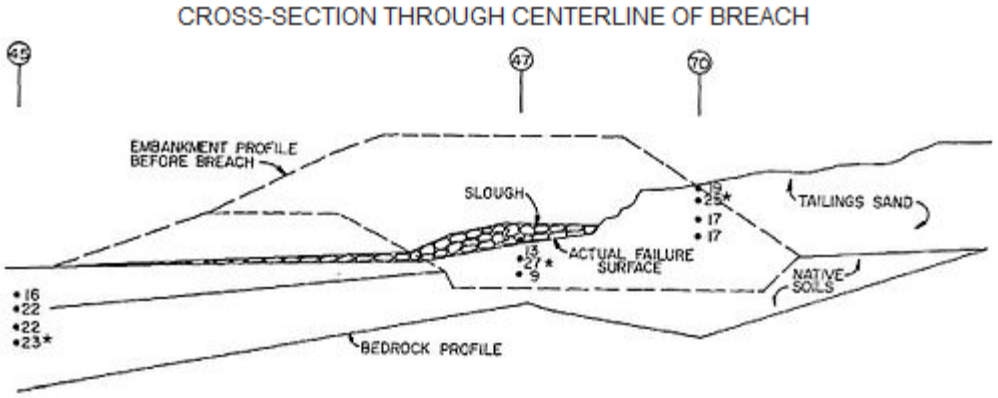
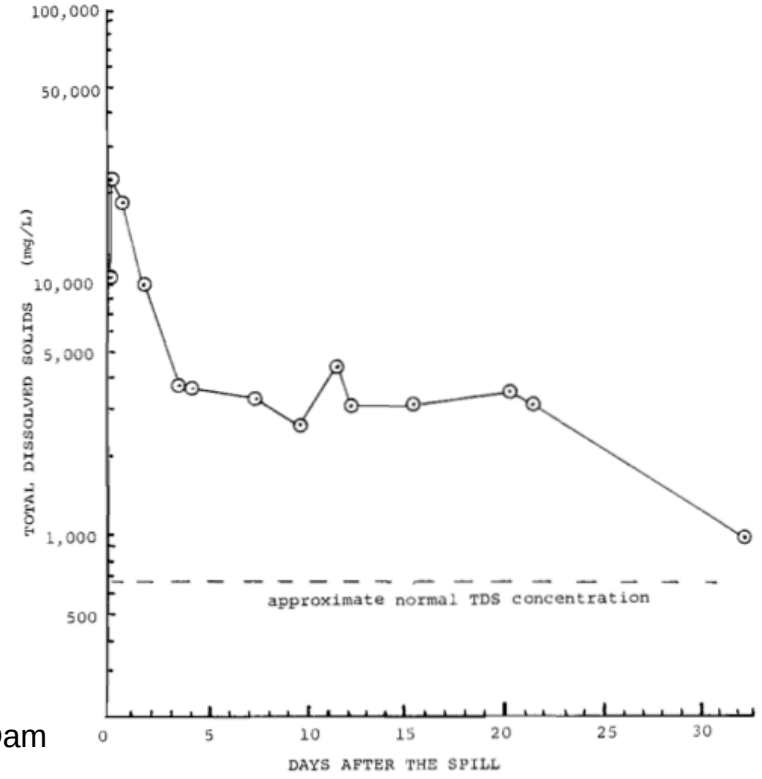


FIGURE 2. ACTUAL FAILURE SURFACE AFTER BREACH (AFTER SERGENT, HAUSKINS AND BECKWITH)



Nelson, et al. (1980)
https://en.wikisource.org/wiki/The_Failure_of_the_Church_Rock_Tailings_Dam

Future Considerations

Major Proposed U Mine Projects in NM

(http://www.wise-uranium.org/uousanm.html)

Name	Principal Company	Resources (tones U_3O_8)
Cebolleta Project	Neutron Energy, Inc.	8,023[b]
Churchrock – Strathmore	Strathmore Minerals Corp.	3,313[a]
Churchrock – HRI	Hydro Resources, Inc.	7,154[b]
Crownpoint – ISL	Hydro Resources, Inc.	5,885[a]
Crownpoint Section 19/29	Tigris U Corp	4,373[a]
Hosta Butte	Tigris U Corp	4,030[a]
La Jara Mesa	Laramide Resources Ltd.	2,791[a]
Marquez Project	Strathmore Minerals Corp	2,545[a]
Mt. Taylor Mine	Rio Grande Resources	38,500[c]
Roca Honda	Energy Fuels, Inc.	5,591[a]

Notes:
a – Indicated reserves
b – Probable reserves
c – Not specified

Challenges of Renewed U Development in NM

- Ryan Flynn (Secretary of NMED) identified legacy of U mining & milling as highest priority facing NMED (NM First, Water Town Hall meeting, 4/15/14)
- San Mateo Creek watershed is potential Superfund site
- Concerns regarding San Mateo Creek watershed
  - Major threats to human health & the environment
  - Site is relatively accessible
  - Leverage on-going work by EPA, NMED, Homestake, etc.
  - Interesting & challenging technical issues that are relevant to future U development in NM
- Prioritized public issues for Roca Honda mine DEIS: **Water**, vegetation, wildlife, culture, socioeconomic, health, safety, environmental justice, etc.

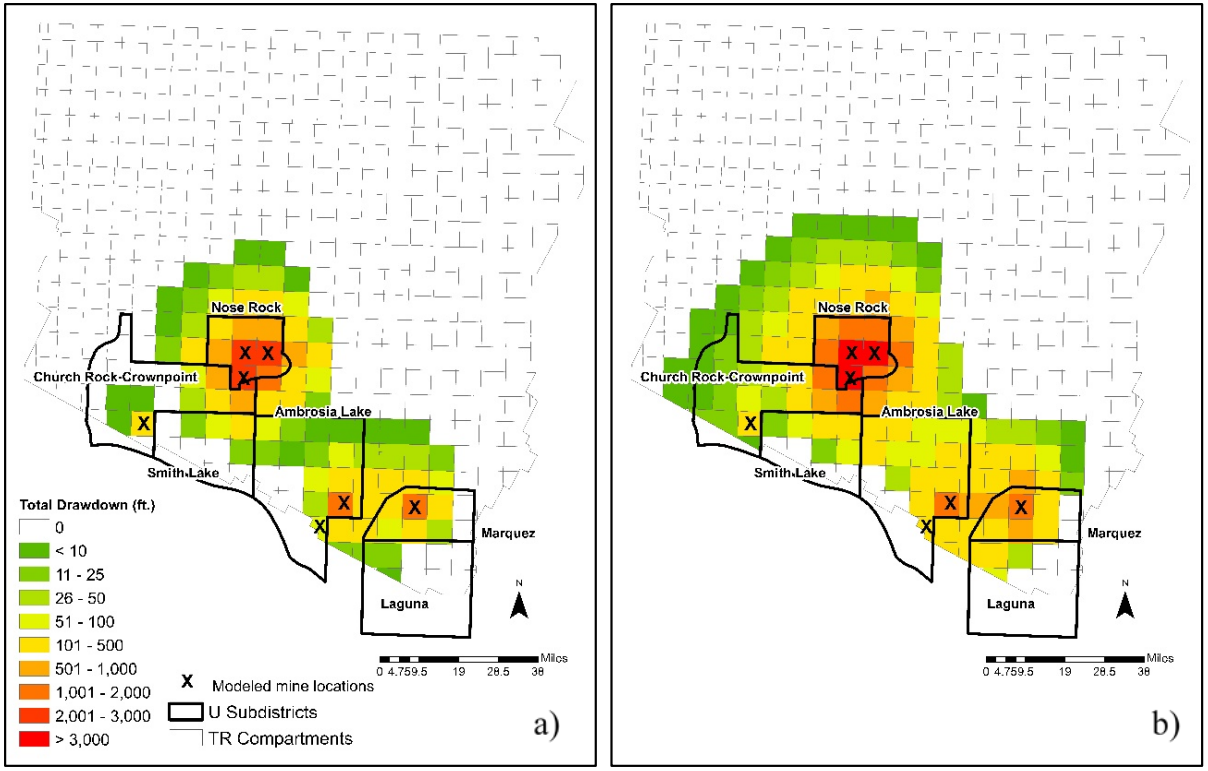
Strategies for Mine Water Management

- Minimize amount of water produced
- Treat water to remove contaminants
- Allow beneficial use of mine water

Ground Water Impacts for Different Mining Scenarios

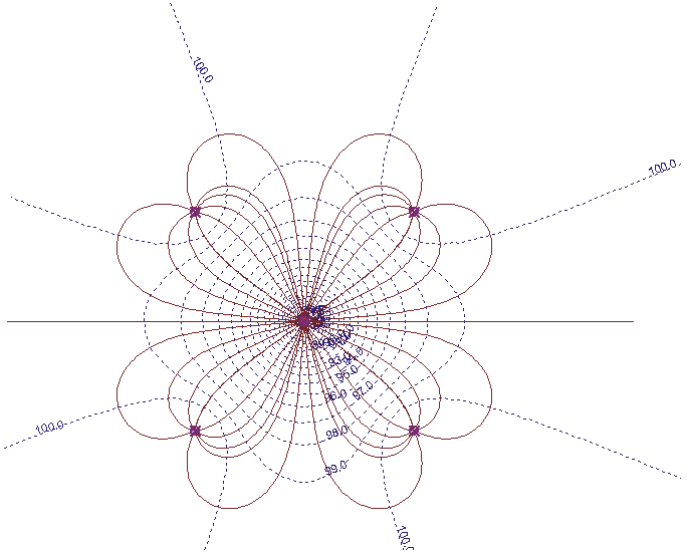
(Zemlick, 2018)

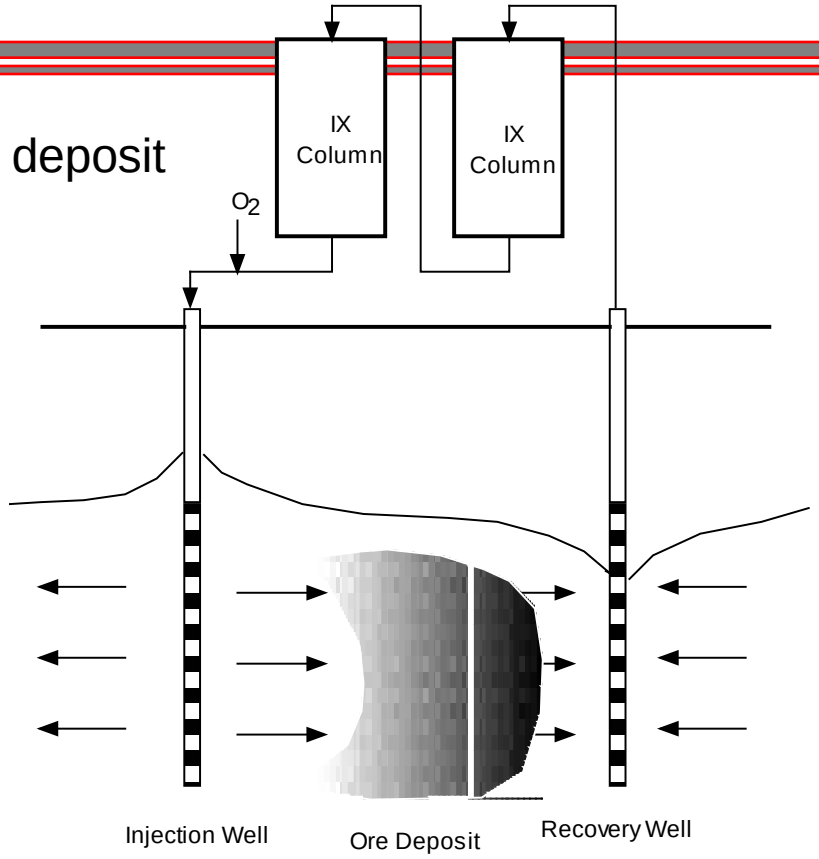
- Alternate mining scenarios for 7 future mines
- Dewatering ranges from <30 KAF/yr to >50 KAF/yr



ISL/ISR Technology

- Circulate oxidizing solution through ore deposit





- Recover $UO_2(CO_3)_2^{2-}$ using IX
- Recycle leachate
- ISR accounts for ~30% of world U production
- Major challenge is restoring aquifer & ground water quality after mining

Crownpoint ISL Pilot Test

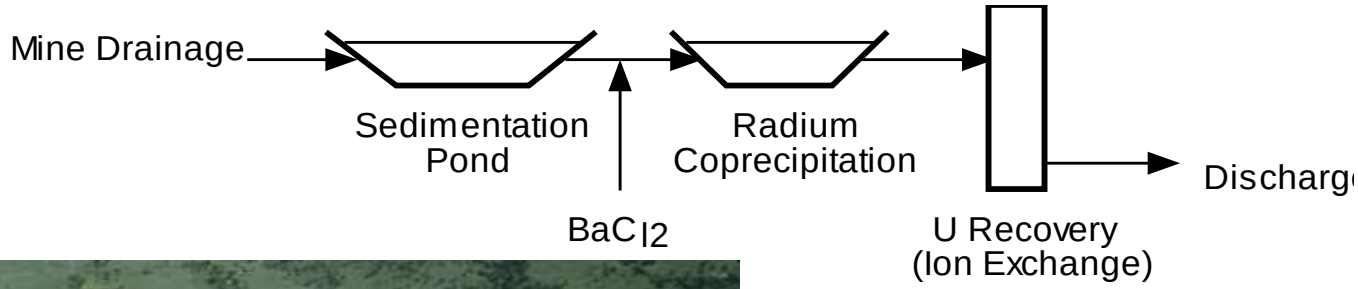
(UPA, from NMED Files)

- Pilot test initiated in 1979 by Mobil to:
  - Test ISL at depths ~2,000 ft
  - Test H_2O_2 (>1500 mg/L) & HCO_3^- (>1500 mg/L), pH = 8.3 lixiviant
  - Test hydraulic controls
  - Evaluate above ground U recovery
  - Test restoration
- 5 spot well pattern at 100 ft spacing
- Excellent initial GW quality: TDS = 373 mg/L, U = .013 mg/L, etc.
- Recovered ~15% of U in 3 months
- After 12 months of restoration met ground water standards except for pH, Mo, Ra, and U. (But were close to standards)

Mine Water Treatment & Reuse

- Generally water quality from U mines in NM was very good
  - Low TDS
  - High Ra & U
  - Few other contaminants
- Can easily & inexpensively treat to drinking water quality
  - Remove Ra by co-precipitation with $BaSO_4$ (barite)
  - Remove U by IX

Mine Water Treatment



Mine Water Reuse

- Recently the Office of the State Engineer determined that water from mine dewatering can be put to beneficial use. But does not constitute a water right and reuse ends when mining stops.

Thoughts

- Very large U reserves in NM
- Historic mining caused major health problems and significant environmental impacts
  - Legacy impacts
  - Most of mill tailings piles have been stabilized
- Future U development must be safe and with little/no threat to health or the environment:
  - Health issues
  - Water quantity impacts
  - Water quality impacts
  - (And soil & air quality)
- New knowledge & technology can support responsible mining

Selected References

EPA (2011). Region VI Legacy Study https://www.epa.gov/sites/production/files/2015-08/documents/uranium-mine-brochure.pdf

Merritt, R.C. (1971). The Extractive Metallurgy of Uranium, Colorado School of Mines Research Institute, Fort Collins, CO

Ruiz, Omar, Thomson, Bruce M., Cerrato, Jose M. (2016). Investigation of In Situ Leach (ISL) Mining of Uranium in New Mexico and Post-Mining Reclamation, New Mexico Geology, vol. 38, no. 4, pp. 77-85.

SJBRUS [San Juan Basin Regional Uranium Study]. (1980). Uranium Development in the San Juan Basin Region: A Report on Environmental Issues: Albuquerque, NM, US Department of the Interior, 573 p.

Thomson, B.M., Heggen, R.J., "Uranium and water: Managing common resources," Chemtech, vol. 13, no. 5, pp. 294-299, (1983).

Zemlick, K., Thomson, B. M., Chermak, J., & Tidwell, V. C. (2017). Modeled Impacts of Economics and Policy on Historic Uranium Mining Operations in New Mexico. *New Mexico Geology*, 39(1).

Zemlick, K. (2018). Modeling the Interdependencies of Energy and Water in New Mexico: Historic Drivers, Hydrologic Impacts, and Energy Requirements, Ph.D. dissertation, Civil Engineering, University of New Mexico