UNM METALS Superfund Research Center

Metal Exposure and Toxicity Assessment on tribal Lands in the Southwest

Current Issues in Uranium Remediation Policy on the Navajo Nation

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COLLEGE OF PHARMACY
METAL EXPOSURE AND TOXICITY ASSESSMENT ON TRIBAL LANDS IN THE SOUTHWEST

Superfund Research Program

SOUTHWEST RESEARCH AND INFORMATION CENTER

PUEBLO OF LAGUNA

INDIGENOUS EDUCATION INSTITUTE I.E.I

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- **Approvals:** Human research is approved and monitored by the UNM Human Research Protections Office and Navajo Nation Human Research Review Board: DiNEH Project, NNR-04-145; NBCS, NNR-11.323; NBCS-ECHO+, NNR-19.360; Thinking Zinc, NNR-18.330T.

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Communities: We recognize and honor the communities and community organizations that are partners in the UNM METALS Superfund Research Center:

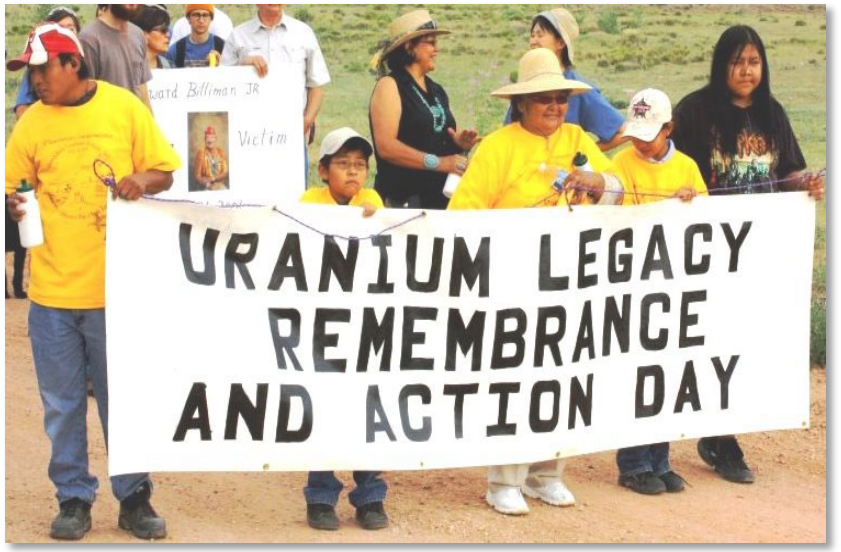
- Blue Gap-Tachee Chapter
- Cameron Farm Enterprise
- Indigenous Education Institute
- Pueblo of Laguna
- Red Water Pond Road Community Association

Land Acknowledgement Statement: *The University of New Mexico sits on the traditional homelands of the Pueblo of Sandia. The original peoples of New Mexico have deep connections to the land and have made significant contributions to the broader community statewide. We honor the land itself and those who remain stewards of this land and acknowledge our committed relationship to Indigenous peoples.*

Grass-roots Diné Uranium Agenda, 2003: Progress so far

~500 people attended Diné Bidziil Coalition Uranium Gathering at Shiprock High School, July 19, 2003. Four principal policy objectives were adopted:

- ***Ban new uranium mining and processing***
  - ✓ Diné Natural Resources Protection Act adopted April 2005
- ***Clean up 500+ abandoned uranium mines***
  - ✓ Radiological assessments, remediation of contaminated structures
    - 0 mines remediated as of January 2021
    - 8 remediation plans issued for public comment by 2023-2024
- ***Fully compensate uranium workers and their families thru RECA***
  - ✓ 9,331 approved awards (65%) totaling $932.7 million for U workers, 1949-1971
  - S. 3853 pending in the U.S. House; extends RECA 6 years, extends eligibility to Post-'71 workers, adds NM, other states as "downwinders"
  - Still no compensation for people living in mining areas
- ***Conduct health studies to determine effects of uranium exposures***
  - ✓ DiNEH Project, 20 chapters ENA, 2002-2012
  - ✓ Navajo Birth Cohort Study, Navajo Nation-wide, 2010-present
  - ✓ Thinking Zinc Clinical Intervention, 2018-present
  - METALS Superfund Research Center – bioprojects pending
  - Cancer reports by NNDOH/Epi Center recommend investigating causation



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Environmental Health Studies Can Inform Uranium Mine Remediation on the Navajo Nation

Navajo Nation Human Research Review Board Biennial Conference

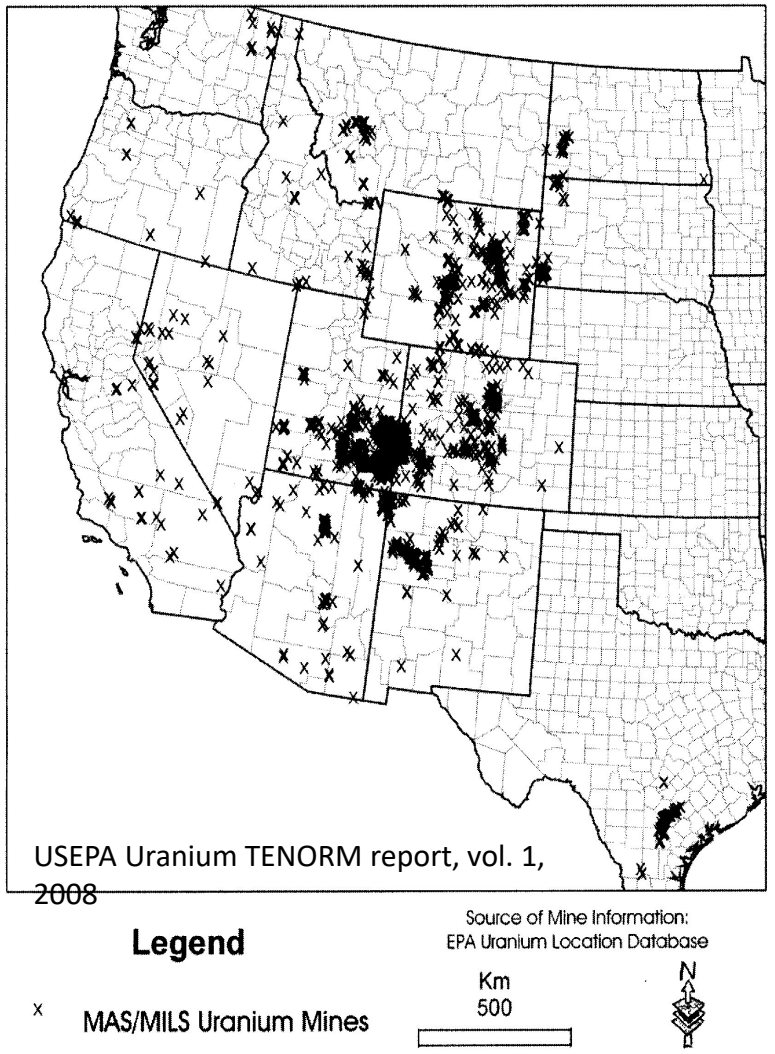
Chris Shuey, MPH[1], Esther Erdei, Ph.D., MPH[2], and Donald A. Molony, MD[3]

Twin Arrows Resort, Flagstaff, AZ
October 19, 2023
(revised Feb. 2024, May 2024)

1 SOUTHWEST RESEARCH AND INFORMATION CENTER
2 COLLEGE OF PHARMACY
3 UTHealth Houston McGovern Medical School
4 Iiná Nizhóní

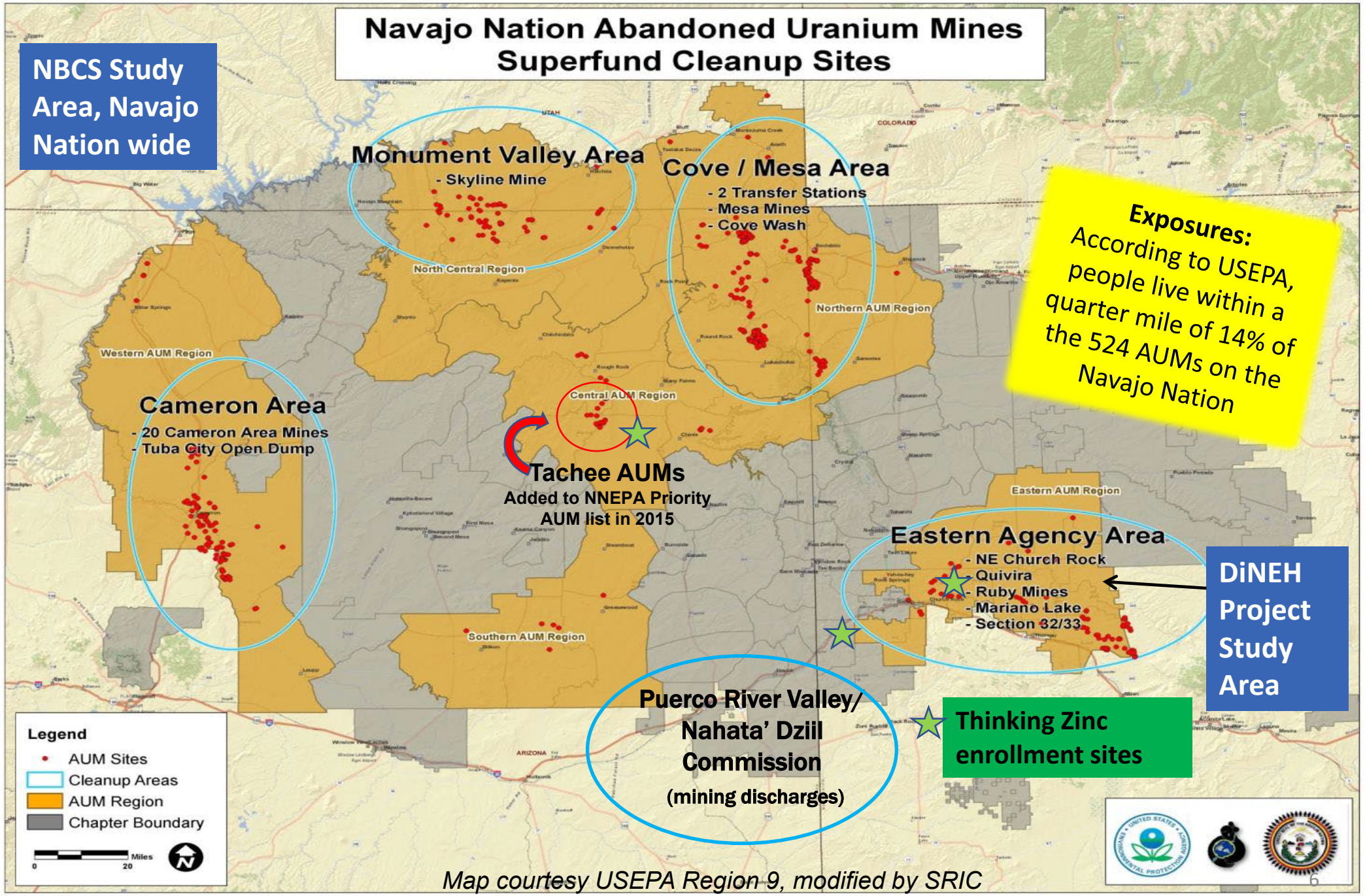
Bradley Henio photo

The Uranium Legacy – a technological disaster 80+ years in the making



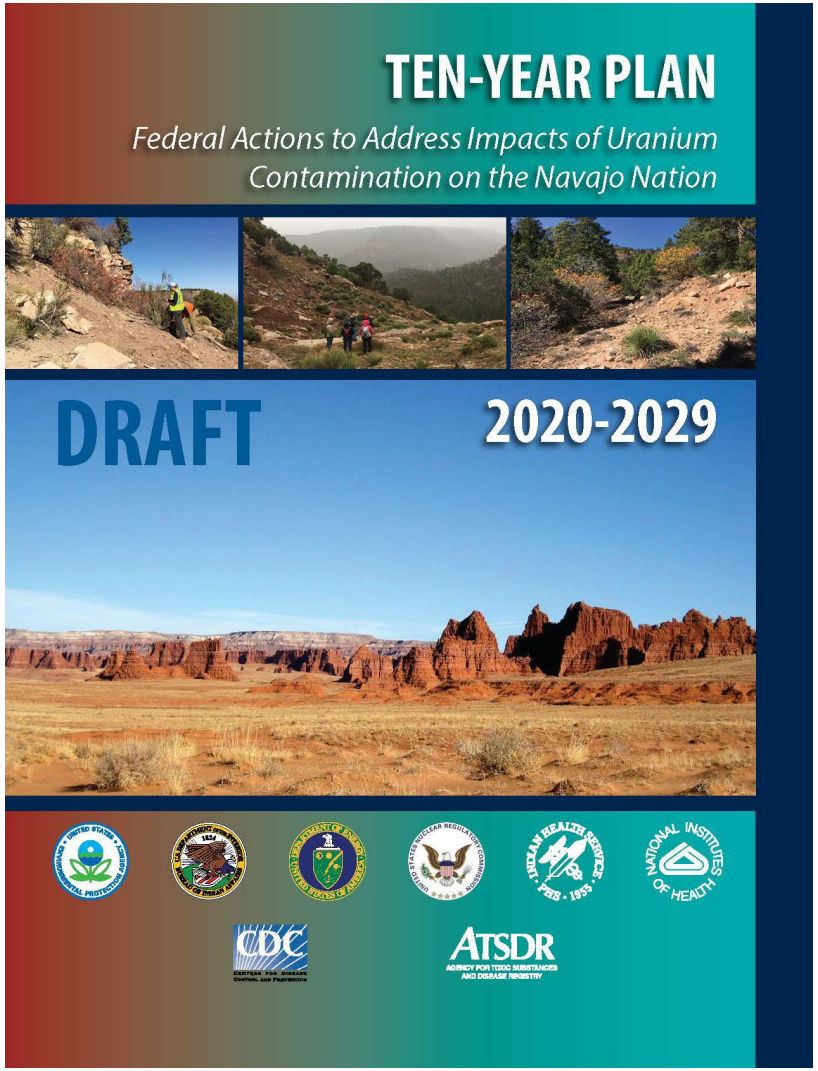
USEPA Uranium TENORM report, vol. 1, 2008

- The field of disaster research study has noted distinctions among natural disasters, technological accidents, and sudden episodes of mass violence (McFarlane et al., 2006).
- Since the first mining of uranium in Monument Valley AZ-UT in 1942, more than 10,000 uranium mines and more than 50 uranium mills were operated in 15 Western states, leaving hundreds of millions of tons of toxic and radioactive wastes
- While the "Uranium Legacy" has received attention under the federal Superfund Law, it has not been seen as a technological disaster with long-term environmental impacts and ongoing exposures to local populations



Map courtesy USEPA Region 9, modified by SRIC

Navajo Uranium Legacy: By the Numbers



Cover of USEPA Ten-Year Plan, Jan. 2021

524	Abandoned uranium mines (AUMs), plus >1,100 mine "features"
0	***Fully remediated AUMs***
4	Interim AUM remedial actions to contain wastes
96	AUM site radiation screening reports
130	Site assessments (RSEs) expected to be completed by end of 2022
10-15	EE/CAs* expected to be completed by end of 2022
$1.7 billion	Money USEPA says it has available for remediating **~40% AUMs** through Tronox bankruptcy, settlements with mining companies, federal contributions
3	Congressional hearings: 1979, 1993, 2007
3	Federal response plans: 2008, 2014, 2021
57	Navajo Chapters w/ 1-3 uranium exposure sources (AUMs, water sources, contaminated structures)

*EE/CA = Engineering Evaluation/Cost Analysis

Community Concern: *What is mine waste?*

- Mine waste **IS**:
  - Mine waste rock – broken rocks, sand, soils, protore
  - Contaminated with natural radioactive and non-radioactive metals at levels *higher than background* in surface soils.
  - Waste left by the miners that had too little uranium to be transported to mills for processing
- Mine waste **IS NOT**:
  - Uranium mill tailings, which are processed ore that has been altered from its natural state by crushing and acidifying
  - Chemically reactive, explosive or acutely toxic because the milling process uses acids and solvents
  - Hazardous waste, as defined in Resource Conservation and Recovery Act (RCRA)
- Mine waste from Quivira and Section 32/33 mines is *not regulated* by the NRC because of low radiation levels, unlike uranium mill tailings

***Modified by SRIC, RWPRCA and MASE from USEPA presentation, 1/26/24, 3/13/24, 4/18/24**

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Radiation Intensities of Various Nuclear Wastes, Compared with Background

Increasing doses of gamma radiation

(A) Normal soils: naturally occurring radiation
(B) Mine wastes: elevated radiation, heavy metals; dry dirt, rocks
(C) Uranium ore: elevated radiation, heavy metals
(D) Uranium mill tailings: high chemical toxcity, high radiation
(E) Transuranic wastes: high radiation, remote-hand
(F) Spent fuel: deadly, remote handled

"Background," or natural conditions

Mine waste (Quivira CR1 Mine)

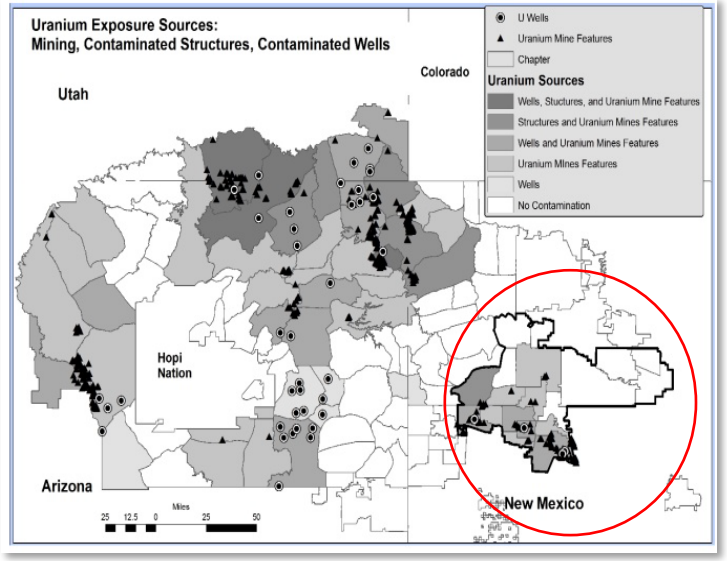
Uranium ore hauling on AZ Strip

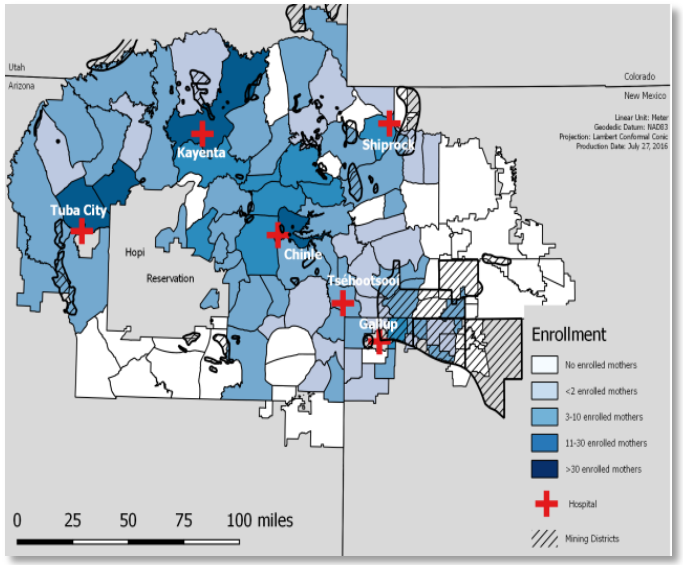
Uranium mill tailings (UNC, Churchrock)

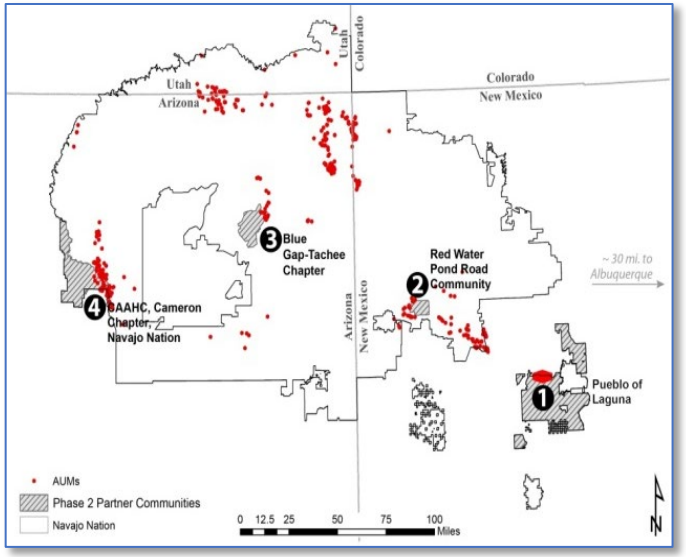
Transuranic wastes (WIPP)

Spent nuclear fuel (Palo Verde NGS)

Community questions about exposures have driven UNM environmental health research







DiNEH Project, 2002-2012

- Does U in drinking water increase risk of kidney disease?
- Do multi-pathway exposures to metals in mine wastes increase risks of chronic disease?
- *Community-based trainings to develop study design, implementation methods, consents*

Navajo Birth Cohort Study, 2010-present

- Do exposures to U mine waste affect child health, development?
- Do exposures to metals in mine wastes increase chronic disease?
- *Extensive trainings to develop EH capacity among community members hired by UNM, SRIC and NNDOH*

METALS SRP, 2014-present

- Do mixed-metal U mine wastes contribute to air, water and farmland contamination?
- Do exposures to U wastes result in immunologic, cardiovascular, pulmonary effects?
- Status of remediation?
- *Community defines research*

UNM Population-based EH studies to ascertain exposures and health outcomes

Study	Design	Population	Target Health Outcomes
DiNEH Project, Navajo Uranium Assessment and Kidney Health	Cross-sectional; iterative, multi-pathway analysis	Phase I – 1,304 participants in 20 chapters of ENA; Phase II – 267 participants in blood and urine collections	▪ Chronic kidney disease ▪ Cardiovascular disease ▪ Autoimmunity
Navajo Birth Cohort Study	Longitudinal cohort	More than 1,800 mothers, fathers, babies in 3 phases across Navajo Nation	▪ Child development ▪ Metals and pre-term births ▪ Upper airway effects
Thinking Zinc	Clinical trial	52 volunteers from Churchrock and Blue Gap-Tachee communities	▪ Zn supplementation to repair metals-induced damage to DNA repair mechanisms
METALS Superfund Research Center	Laboratory animals	Community members exposed to dust from AUMs	▪ Cardiopulmonary effects of exposure to metals-laden “nanoparticles”





Common methods to ascertain exposures, health outcomes

Method	DiNEH Project	NBCS-ECHO+	Thinking Zinc	UNM METALS
Surveys administered Navajo-speaking researchers	●	●	●	
Geospatial analyses (locations of homes, AUMs)	●	●	●	●
Water quality in public water systems, unregulated wells	●	●		●
Home assessments, including radiation surveys, indoor radon, indoor dusts		●		
Assessments of biomarkers of effects	●		●	
Biomonitoring (detection of metals in human tissues, including urine, blood, hair, toenails)	●	●	●	
Child developmental assessments		●		
Laboratory animal studies of environmental exposures to mine dust				●
Administration of zinc supplements to repair damage from metals exposures			●	

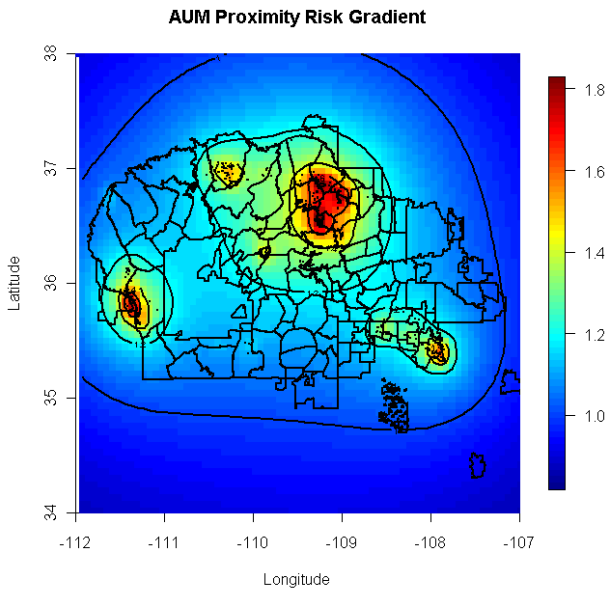
Summary of *Significant* Exposure Variables and Key Findings across UNM Environmental Health Studies (see complete chart at end)

AID = autoimmune disease; CKD = chronic kidney disease; CVD = cardiovascular disease

Exposure variables	Studies	Selected results
Promixity to AUM sites	Hund et al, 2015; Harmon et al, 2017; Erdei et al, 2019; Erdei et al, 2023	▪ CKD: Doubling risk in active mining era, 1950-1986 (10% of participants were U workers) ▪ CVD: 62%-81% increase in the risk of hypertension during legacy period (after 1986); ▪ CVD: Increased inflammatory potential measured by endothelial transcriptional responses ▪ AID: Proximity predicted autoantibody responses for women (p=0.01), all participants (p=0.0065); AuAbs markers associated with U in drinking water *below* MCL ▪ AID: Twofold increase in ANA positivity; proximity associated with clinically defined ANA response (OR*=3.07, p=0.025)
Environmental metals from biomonitoring	Erdei et al, 2022 (NBCS, N=52); Dashner-Titus et al, 2022 (Thinking Zinc N=52); Hoover et al, 2020 (NBCS, N=783); Harmon et al, 2018 (N=252)	▪ CVD: 92% of babies with detectable urine U at birth born to mothers who had urine-U levels greater than national norms; As exposure increased oxidative stress, a contributor to CVD ▪ 4-fold increase in U levels among Thinking Zinc participants ▪ AID: 7 cytokines indicative of immune dysfunction were higher than U.S. U levels (OR = 2.21 (1.08–4.52)) ▪ Pregnant Navajo women have higher U exposures than all U.S. women
Metals in drinking water	Erdei et al, 2019 (N=239); Harmon et al, 2018 (N=252); Erdei et al, 2023 (N=239) Hoover et al, 2017	▪ CVD: Consumption of U correlated with increased C-reactive protein ▪ AID: Elevated autoantibody biomarkers associated with U at levels <MCL of 30 ug/L ▪ AID: As (OR=1.79; p=0.012) and Ra (OR=1.04, p=0.001) associated with anti-dsDNA serum response for ANA positivity ▪ AID: Hg consumption associated with increased ANA response (OR=2.34; p=0.008); Ni consumption predicts increased serum anti-U1-RNP ▪ CVD: As (15.1%), U (12.5%) most frequently measured metals exceeding their drinking water standards in nearly 500 unregulated water sources on the Navajo Nation, including ~100 in Eastern Agency
Age	Erdei et al, 2023 Erdei et al, 2019	▪ Associated with increased serum ANA response (OR*=1.07, p=0.018) ▪ Associated with increased antibodies to denatured DNA

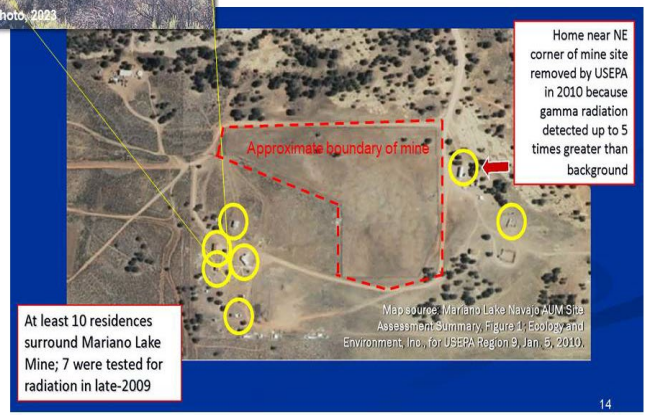
This is what "proximity" looks like

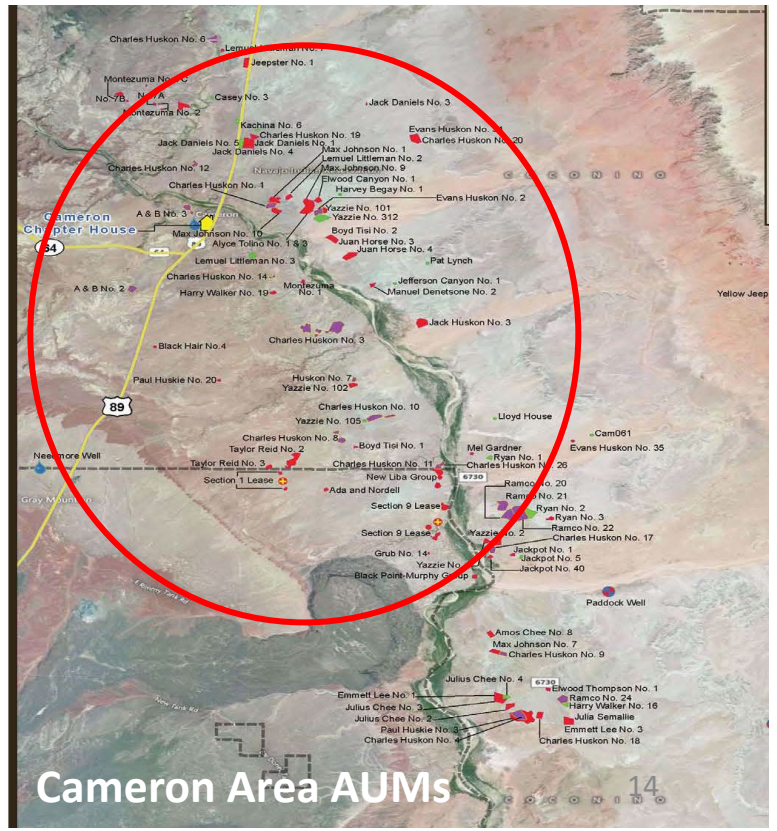
Claim 28 Mine in Blue Gap-Tachee



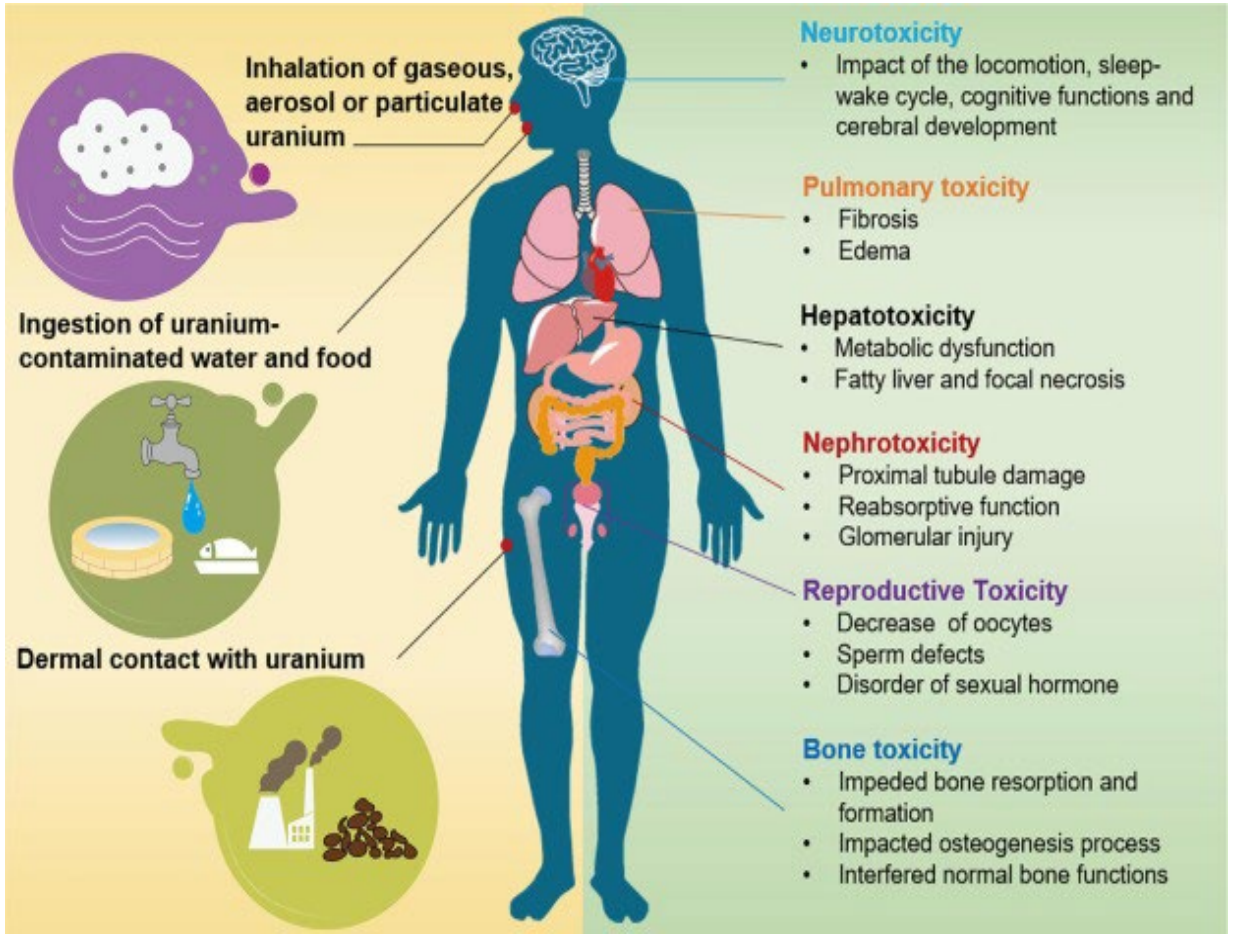
Example: Mariano Lake Mine

- Operated by Gulf Mineral Resources 1977-1982; closed 1986; Chevron current responsible party
- Interim actions: buildings removed, site graded and fenced; one home abandoned
- 10 to 15 residences surround the mine site





Uranium exposure and nephrotoxicity – damage to the kidney, our current focus of study

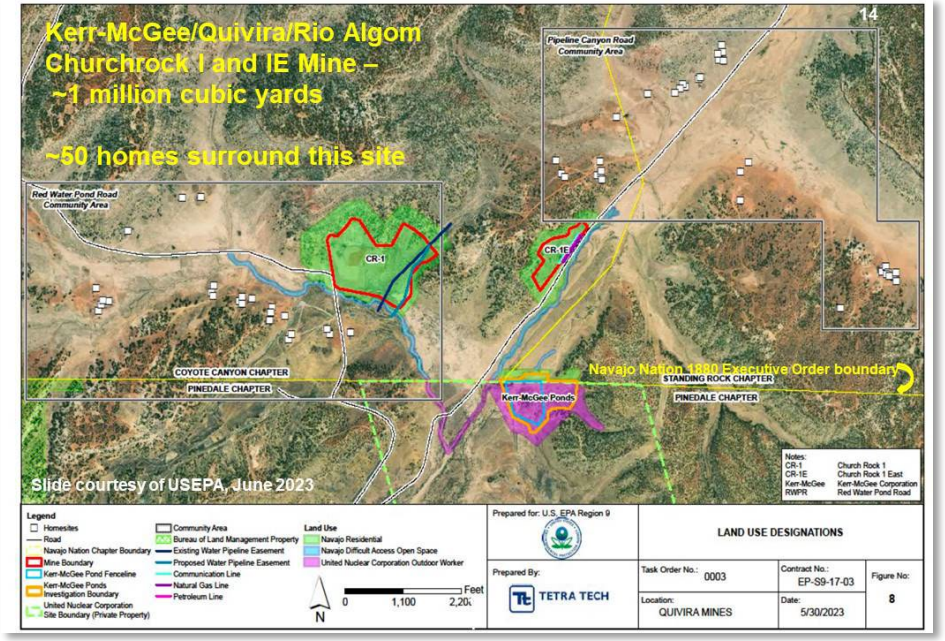


From Ma et al., Environment International, 2020

- Prior "evidence" from dozens of epidemiological and animal studies on the possible role of uranium in causing kidney disease
- **DiNEH Project:** Urine analyses of biomarkers to characterize kidney injury associated with uranium exposure
- Identify multiple kidney sites of injury with kidney biomarkers panel
- Exploring impact of U exposure on cardiovascular health occurring together with kidney disease
- Implications for understanding the burden of kidney disease on the health of individuals and families and for measuring the success of mine remediation

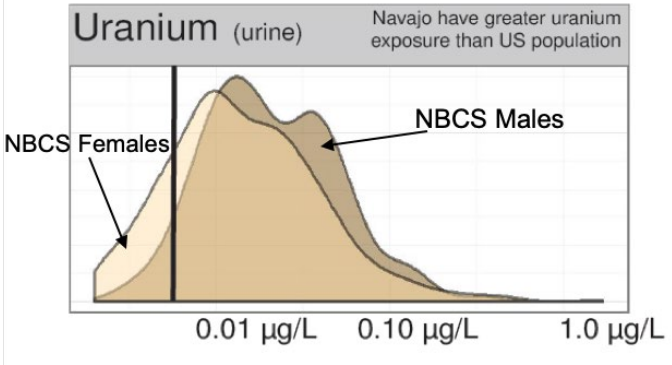
Implications for remediation

- Recognize “proximity” as a risk factor — prioritize remediation of AUM waste sites located near where people live
- Consider synergism between kidney disease and cardiovascular disease in the Navajo population – increased risks of both from U exposures!
- Consider cultural practices that tie *Diné* people to their homelands — resist the practice of relocating people unless exposures cannot be mitigated
- Use biomonitoring — assessment of contaminants in bodily fluids — as companion to regulatory risk assessment that depends on environmental data only
- Embrace environmental health findings in remediation decision making
- Consolidate wastes into fewer sites to reduce exposures; e.g., Cameron, Churchrock, Smith Lake, Mariano Lake, Lukachukai Mountains



Conclusions

- **DiNEH Project** – Largest cross-sectional study of exposure to uranium on the Navajo Nation
- **Navajo Birth Cohort Study** – Largest cohort study of mothers, fathers and babies



- **Thinking Zinc** – First-ever community-based clinical trial showing elevated concentrations of metals in blood and urine, exceeding national norms
- Studies developed in partnership with community members, designed to answer community questions about effects of exposures to uranium wastes

- Exposure to mine wastes, contaminants in drinking water, and metals in blood and urine associated with increased risks of chronic, metabolic diseases
- Proximity to uranium wastes consistent significant relationship to disease outcomes
- Metal contaminants in drinking water – As, Ra, Hg, Ni, U – at levels less than MCLs associated with biomarkers of cardiovascular disease, autoimmunity
- More complete understanding of the magnitude and effects of exposures on cardiovascular and kidney health best characterized through continuation of long-term cross-sectional and longitudinal studies

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Abigail Sanders

Navajo Team Members
Other Native Team Members
Bold indicates Current Team
Non-bold are former team members

The people of the Navajo Nation:
- > 1000 participating Navajo families
- Many supporting chapters
- HEHSC, Tribal and Agency Councils, Executive Branch, NNEPA, GIB
- NAIHS & PL-638 hospital laboratory staff, leadership, and health boards

And many others who have contributed to and supported this work!

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NBCS Navajo Birth Cohort Study

ECHO Environmental influences on Child Health Outcomes
A program supported by the NIH

NM HEALTH SCIENCES

SOUTHWEST RESEARCH AND INFORMATION CENTER

INDIAN COMMUNITY HEALTH REPRESENTATIVE

UCSF

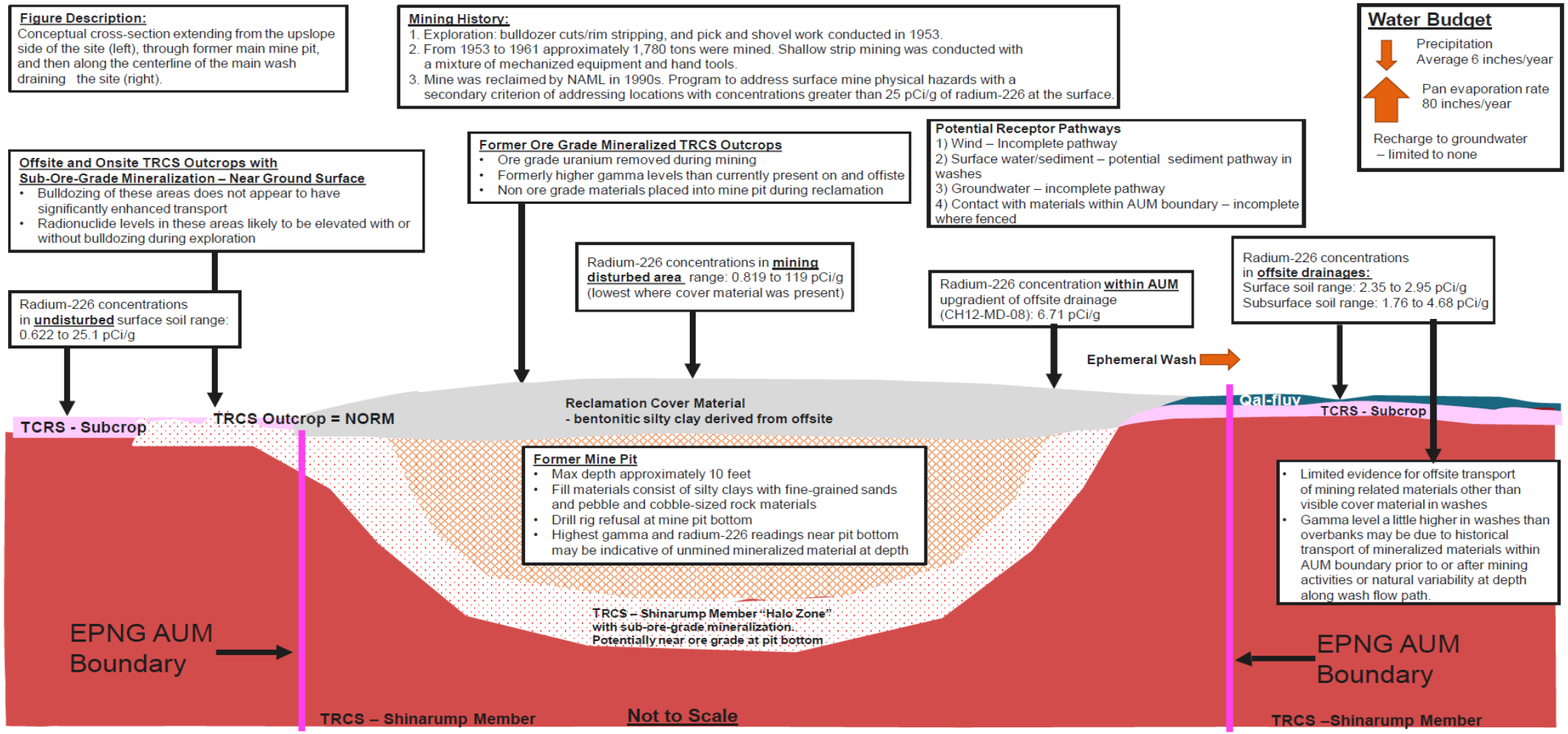
Current as of June 2023

Current Topics in Uranium Remediation

- **Cap-in-place/evapotranspiration covers:** Survey of EPA diagrams in five EE/CAs
  - "Conceptual" models belie claim of "engineered" containment covers
  - Radon, biointrusion barriers not addressed
  - Full engineering cover designs deferred until AFTER preferrded Iternative selected in Action Memo
- **Regional Disposal Facilities**
  - Crescent Junction
  - Red Rock Landfill property
  - Ambrosia Lake
  - Cameron area
- **"Buffer" zones** in USEPA AUM Atlas (2007) misinterpreted as exclusion areas

"Conceptual" Cover on Charles Huskon No. 12, Cameron Chapter

(from EE/CA, Feb. 2023)



Notes:
1. AUM = abandoned uranium mine
2. CH12 = Charles Huskon No. 12
3. COIs = constituents of interest: uranium, arsenic, molybdenum, selenium, vanadium, and mercury
4. EPNG = El Paso Natural Gas Company, L.L.C.
5. NAML = Navajo Abandoned Mine Land
6. NORM = naturally occurring radioactive material
7. pCi/g = picocuries per gram
8. Surface soil samples collected from 0-6 inches, subsurface soil collected from 6-12 inches.

Stratigraphy:
Qal-fluv: Quaternary channel alluvium
TRCS (Triassic Chinle Formation Shinarump Member): Mineralized and mottled mudstone-siltstone
• TRCS – Outcrop: Shinarump Member sandstones and mud stone-siltstones
• TRCS - Subcrop: Thinly eroded cover over Shinarump Member sandstones and mud stone-siltstones

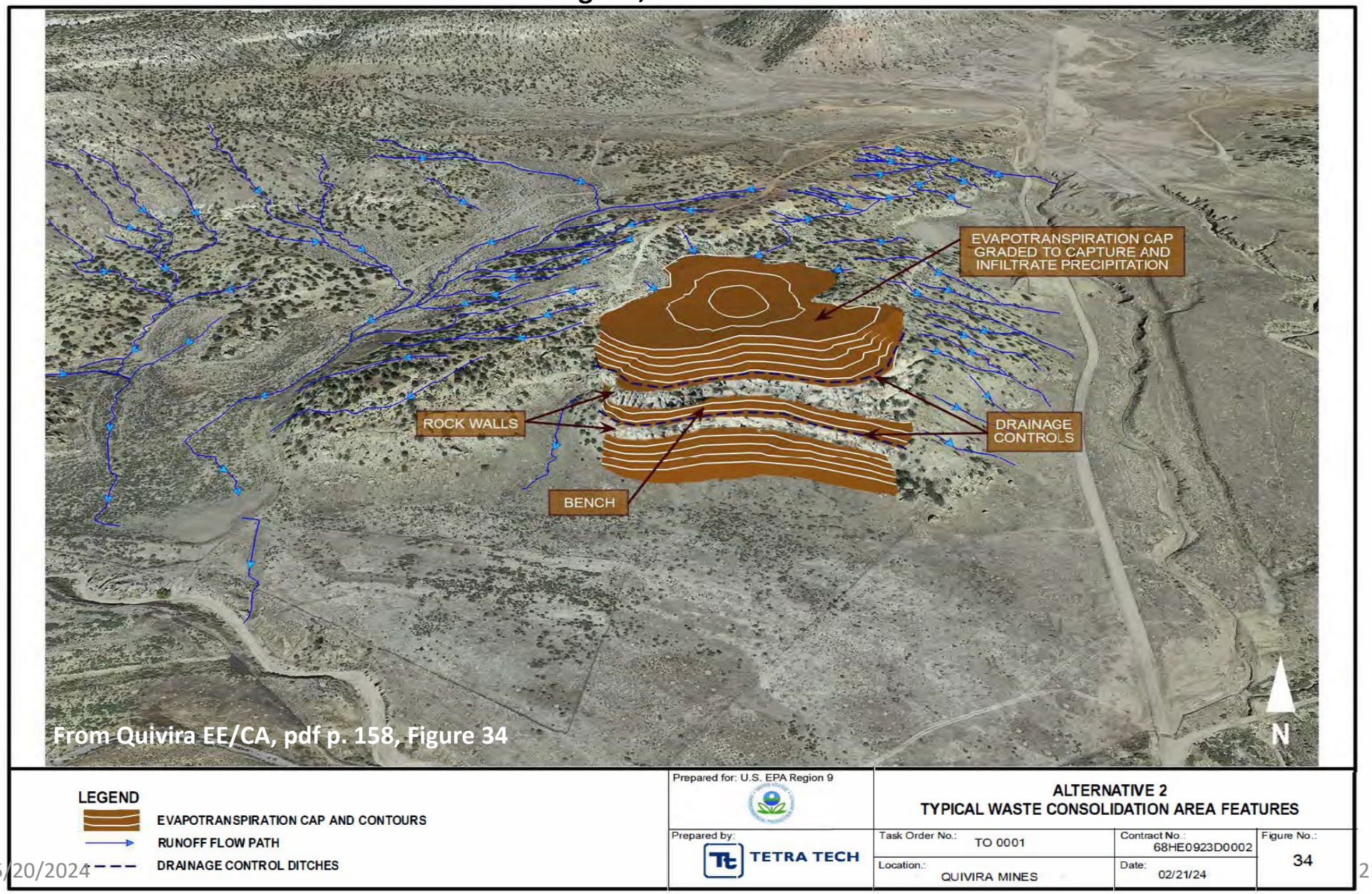
Charles Huskon No. 12
Cameron Chapter, Navajo Nation
Coconino County, Arizona
ENGINEERING EVALUATION/COST ANALYSIS

GENERALIZED CONCEPTUAL SITE MODEL FOR CH12

ARCADIS 20 | FIGURE 2-8

11/15/2021 4:52:45 PM

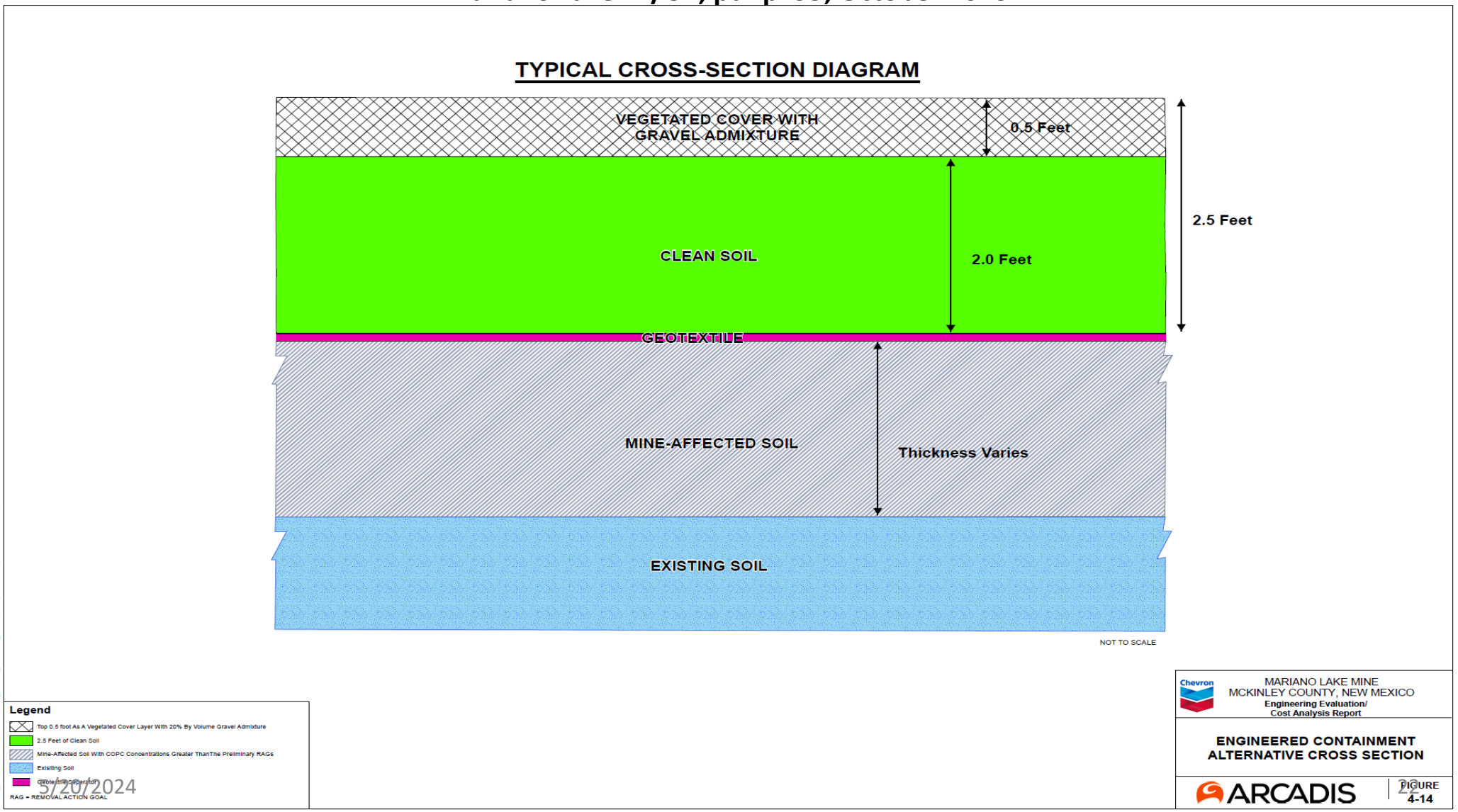
“Typical” cover design for Alternative 2 (cap-in-place), Quivira Churchrock Mine, EE/CA, Fig. 34, March 2024



Containment Cap (Cover) Cross Section for Mine Waste Repositories at Mac 1 and Black Jack 1

Mariano Lake and Smith Lake Chapters

Mariano Lake EE/CA, pdf p. 99, October 2023



5/20/2024

UNM METALS Superfund Center

“Typical Cap” (Cover) Cross Section, Ruby Mines, Smith Lake Chapter

EPA EE/CA for Ruby Mines, pdf p. 128, September 2023

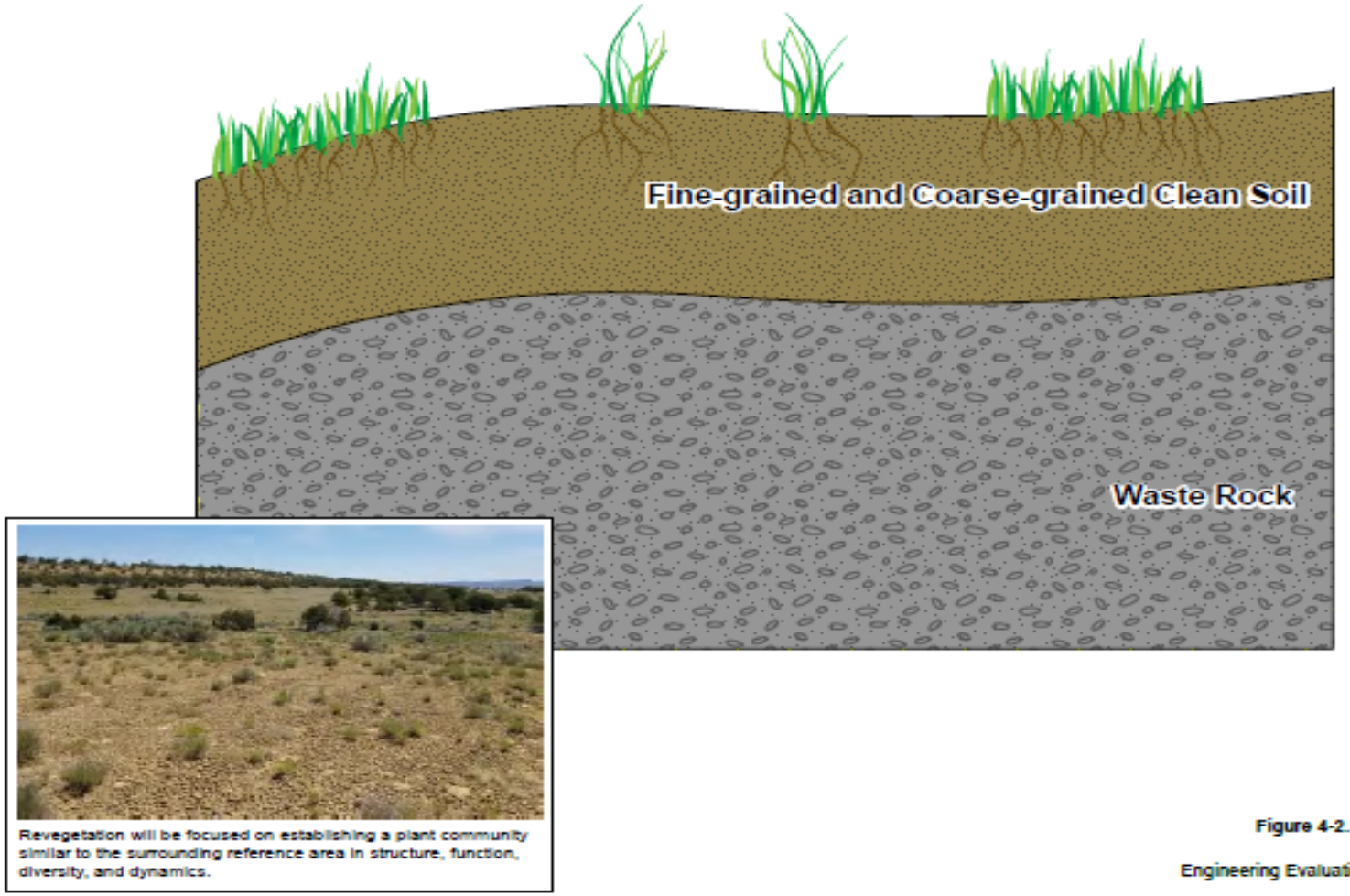
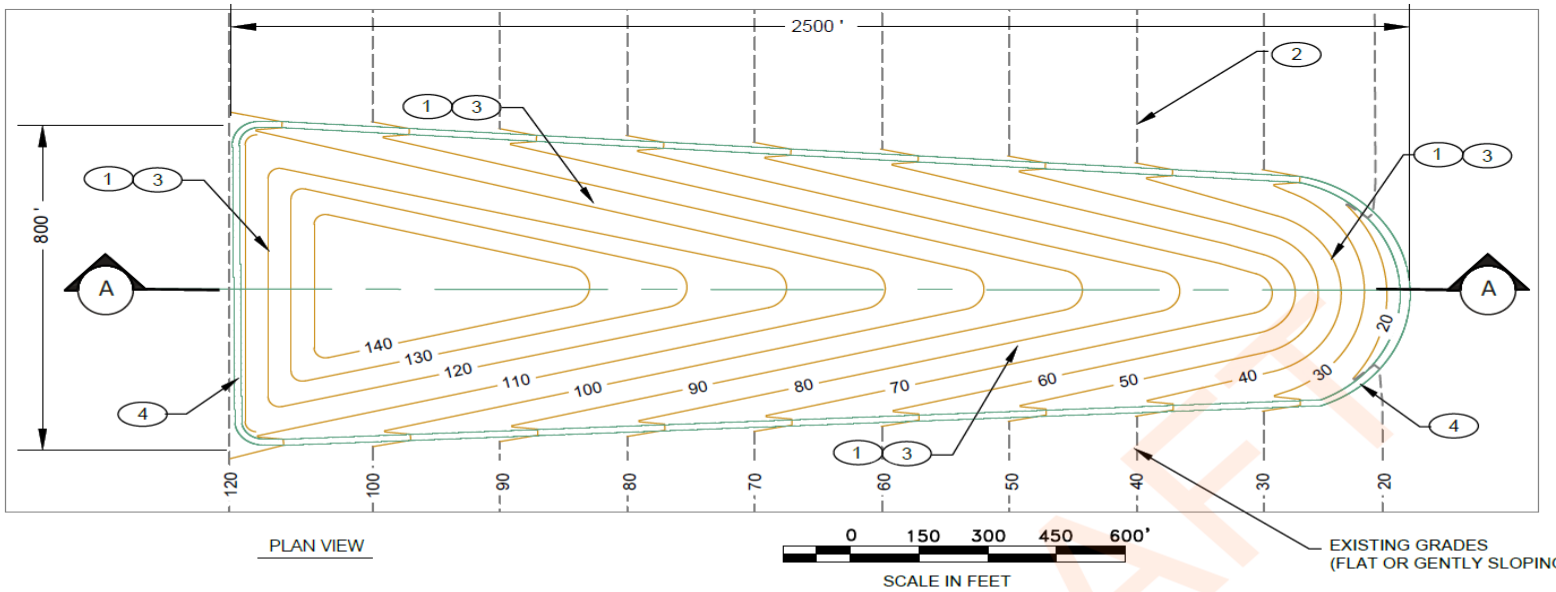


Figure 4-2. Typical Cap Design
Ruby Mines
Engineering Evaluation and Cost Analysis

Jacobs

Conceptual model for Smith Lake/Mariano Lake Uranium Mine Waste Repository

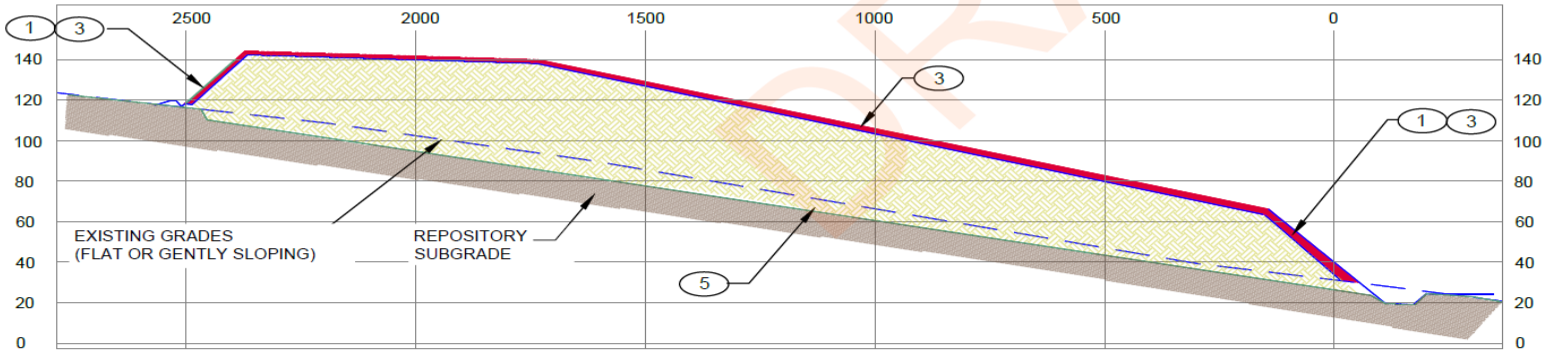
EPA EE/CA for Mariano Lake Mine, Attachment 1, pdf p. 813, October 2023



PLAN VIEW

REPOSITORY NOTES

1. REPOSITORY SLOPES = 5H:1V
2. GRADE REPOSITORY FOR POSITIVE DRAINAGE AWAY FROM SLOPES.
3. CLEAN COVER SOILS OVER ALL REPOSITORY SURFACES.
4. SERVICE ROAD BERM DESIGNED TO DEFLECT NATURAL SURFACE DRAINAGE FLOWS AWAY FROM REPOSITORY.
5. EXCAVATE CLEAN SOILS UNDER REPOSITORY FOR COVER SOIL. VARY EXCAVATION DEPTH TO OBTAIN THE VOLUME OF COVER SOILS NEEDED



SECTION AA - LONGITUDINAL SECTION
AS SHOWN

VERTICAL SCALE = 5X HORIZONTAL

REPOSITORY DATA

1. CAPACITY OF FULL BUILDOUT = 1.25 MILLION CY
2. TOTAL AREA DISTURBED - 44.1 ACRES
3. HEIGHT ABOVE EXISTING GRADES AT UPSTREAM END = 30'
4. HEIGHT ABOVE EXISTING GRADES AT DOWNSTREAM END = 50'
5. OVERALL WIDTH = 800' OVERALL LENGTH = 2500'
6. WIDTH AND LENGTH DIMENSIONS TO BE ADJUSTED TO THE PARTICULAR SITE CONDITIONS.

Prepared By: Alan Kuhn Associates LLC

Smith Lake/ Mariano Lake Regional Uranium Mine Waste Repository

FIGURE 1 REPOSITORY CONCEPTUAL MODEL #1 *(GENTLY SLOPING OR FLAT SUBGRADE)*

Regional Uranium Waste Disposal Facilities

Atlas Corp. Uranium Mill Tailings, Moab UT → Shipped by train 30 miles to Crescent Junction Disposal Cell

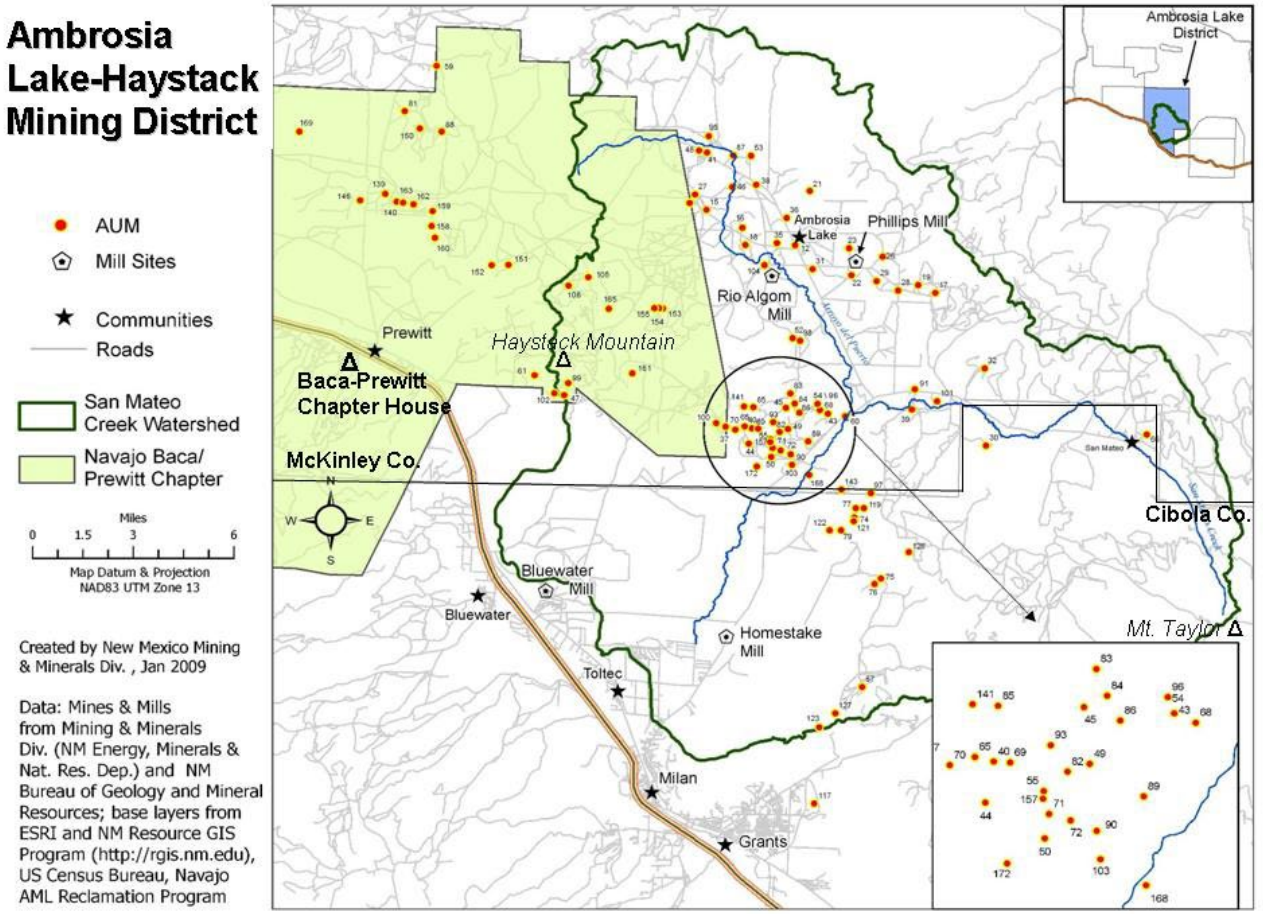
- Existing facilities are hundreds of miles way, including Crescent Junction, UT
- New Mexico opposing any plan to bring uranium mine waste from Navajo sites to Ambrosia Lake
- EPA says BLM has looked for **federal lands** on the periphery of the Navajo Nation, but to no avail

Advantages of Red Rock Landfill (RRL)

- Will provide permanent, safe place to dispose of mine wastes from Eastern Agency AUMs
- The site has many advantages:
  - ✓ Away from people; few homes within 1 mile of the site
  - ✓ On private land, owned by Northwest New Mexico Regional Solid Waste Authority
  - ✓ Permitted by N.M. Environment Dept.
  - ✓ Serves trash collection needs of Cibola and McKinley counties and *the entire Navajo Nation*
  - ✓ Has plenty of room to construct an engineered disposal "cell" based on NRC's "prime option" – below-grade disposal in lined cells – for uranium mill tailings
  - ✓ Mine wastes would not be mixed with municipal wastes
  - ✓ Topography minimizes erosion from wind and water
  - ✓ Groundwater is more than 350 feet from surface

Why not Ambrosia Lake Region?

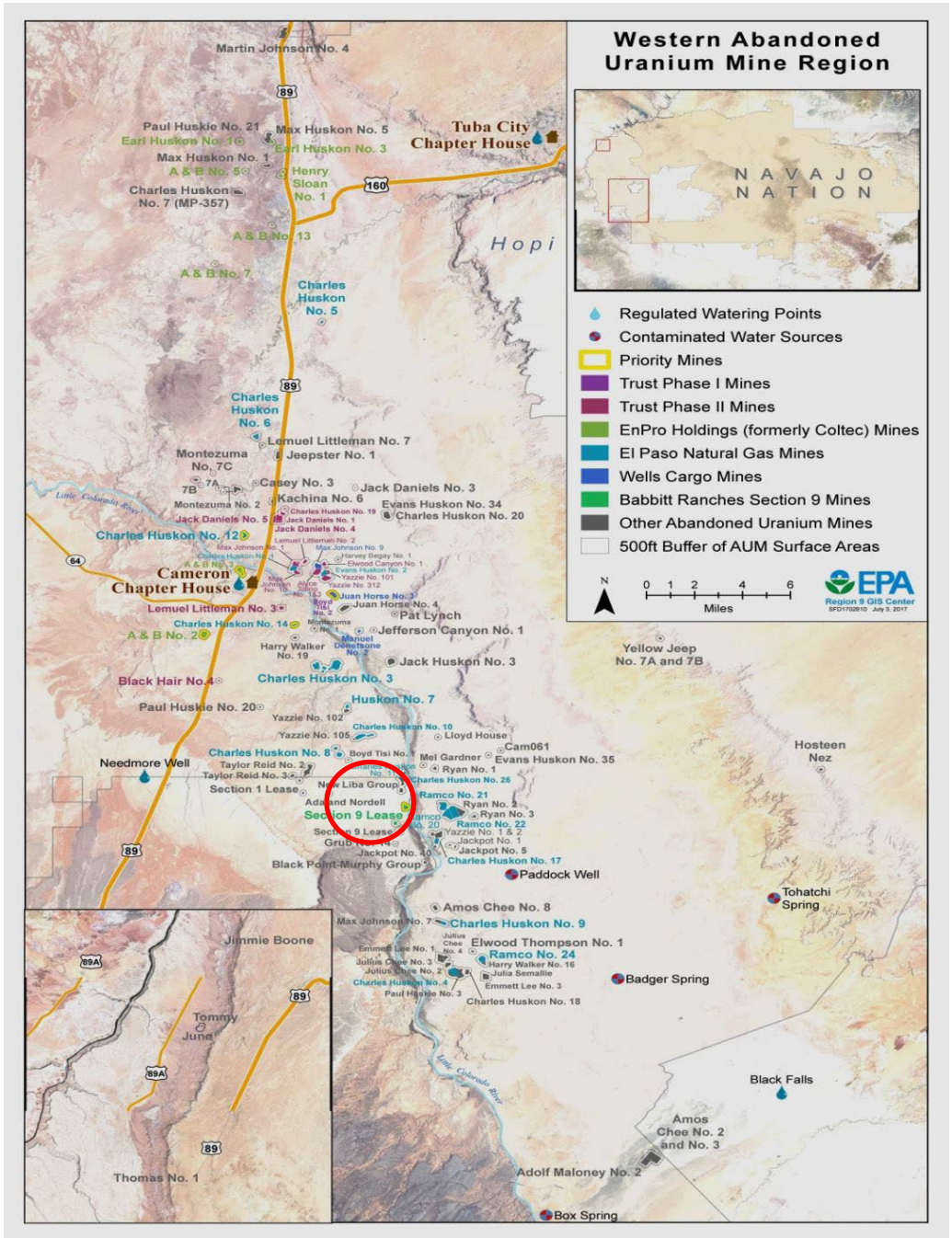
It's already a National Sacrifice Area!



- New Mexico opposes disposal of wastes from other jurisdictions, including the Navajo Nation
- Cannot co-dispose of mine wastes on 2 closed mill tailings piles without federal legislation
- Would take 10 years to find and construct a disposal site
- Would not eliminate need to haul wastes by truck or rail
- Opportunities:
  - Lobby NM Governor to change NM's position
  - Multi-jurisdiction cooperation with representation by frontline communities
  - NM State Land Office has at least 2 AUMs to remediate

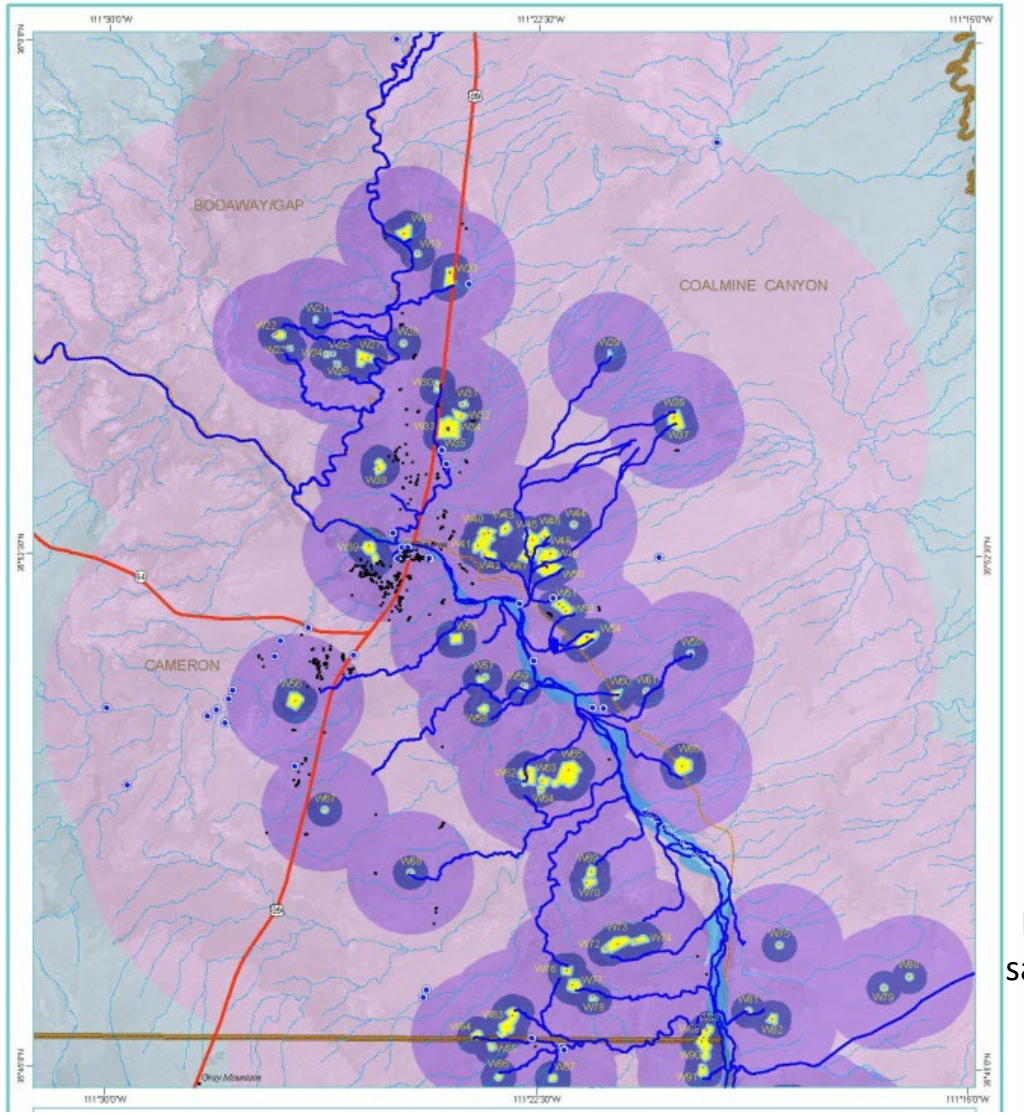
Regional disposal facility needed in Cameron area?

- Nearly 300,000 tons of ore extracted from 100 uranium properties in Cameron area between 1951-1963
- About 30 discrete AUMs surround Cameron (map)
- Occupied residences are close to AUMs, NORM outcrops, contributing to human exposures
- Four major community concerns:
  - *Are the AUMs polluting the soils of agricultural lands adjacent to the Little Colorado River?*
  - *Will crops grown there be safe to eat?*
  - *What are effects of radiation from AUM sites on human and livestock health*
  - *How is mine radiation distinguished from natural radiation?*
- Possible site for disposal facility: Federal or state public lands south of the Grey Mountain Navajo boundary (red circle)?



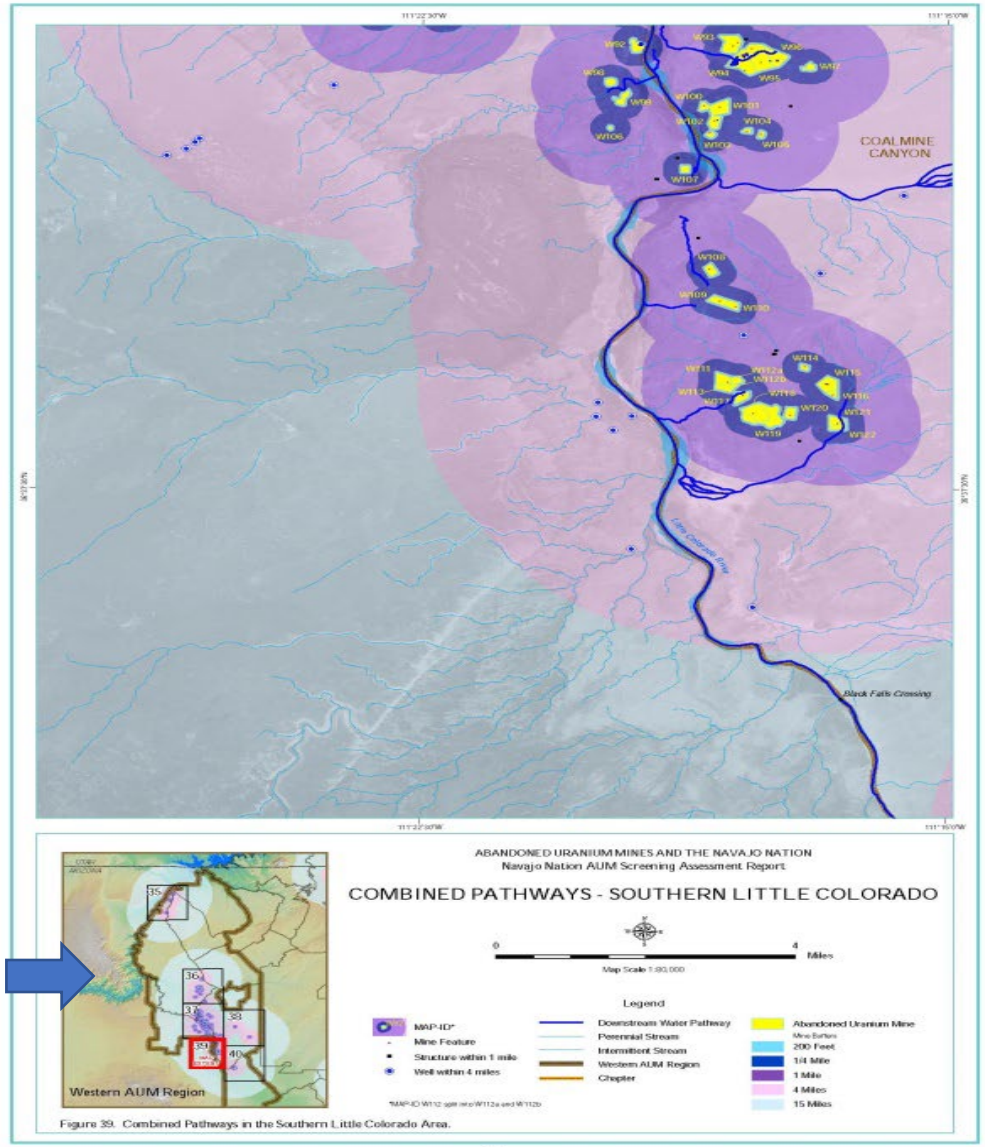
USEPA-USACE AUM Atlas (2007)

Fig. 37: Cameron (close-up)



Key is the same for all maps

Fig. 39: Southern Little Colorado



What are the purposes of the purple-shaded circles around AUMs in the 2007 Atlas?

"*Potential* contamination" (p. 6)

…[A]rea shown in Figure 4,… with the locations of the AUMs and *buffers* out to 15 miles. The modeled results for aquifer sensitivity may prove useful for *further assessments of potential contamination from AUMs* through ground water pathways. [emphasis added]

Calculating "pathway scores" (p. 14)

The scores for each ***buffer zone*** were tabulated and presented in a table for each AUM. The "Soil Pathway and Air Pathway Score" tables presented the counts of structures that are within the 200 foot, 1/4 mile, and 1 mile ***buffers*** as well as the total number of structures within 1 mile of each AUM.

Purple circles on AUM maps do not indicate documented contamination or imply an exclusion zone. They are for estimating potential risk to air, land, surface water and ground water from AUMs.


Ahéhee'! Questions?