Pacific Northwest
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GENII Training:

Uranium Mining and Milling

April 16th, 2021

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U.S. DEPARTMENT OF ENERGY BATTELLE

PNNL - SA - 161291

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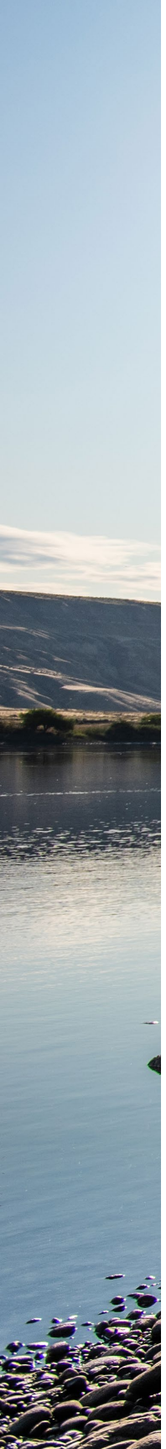

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Environmental Radiation Dosimetry Software

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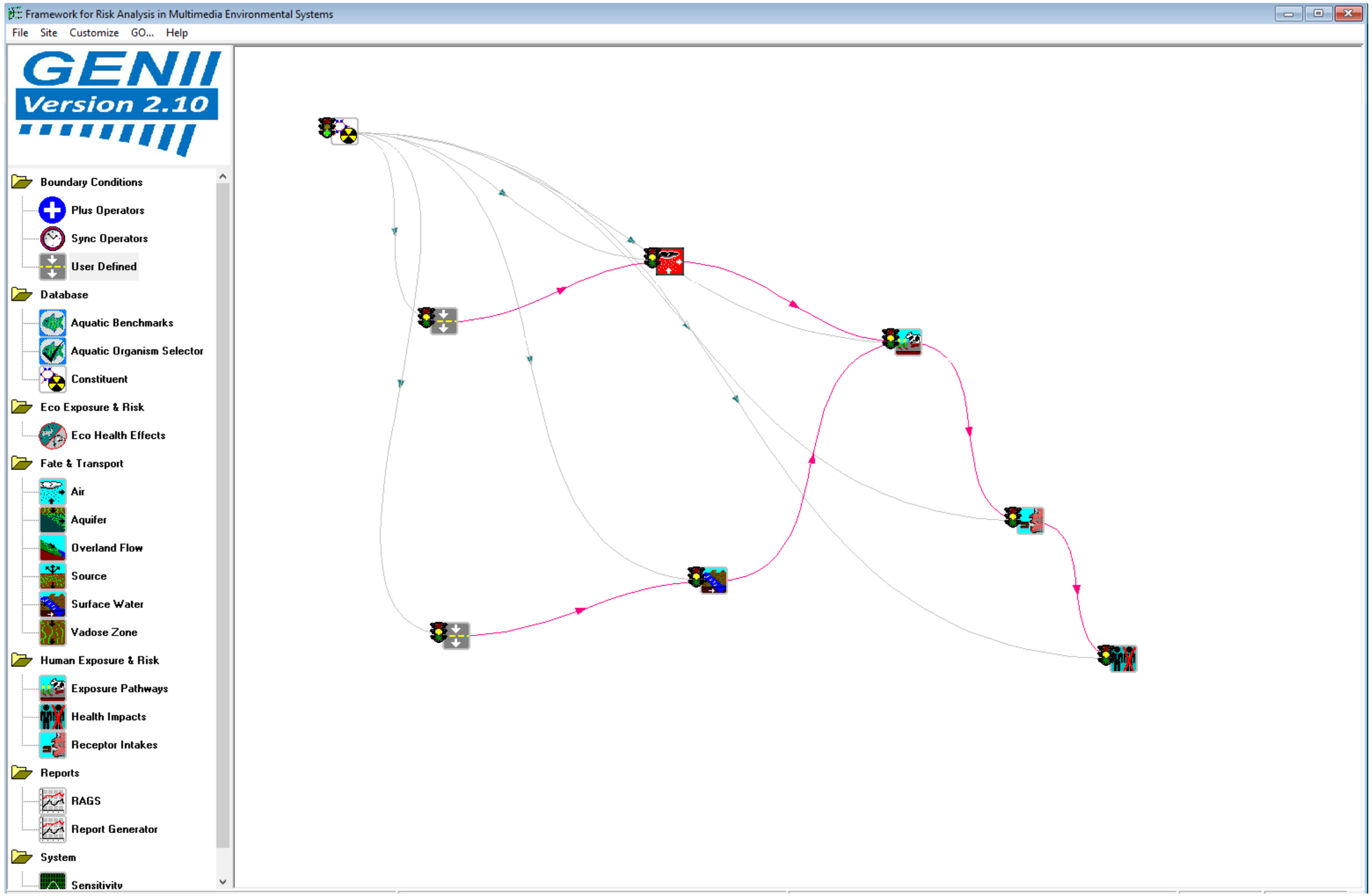
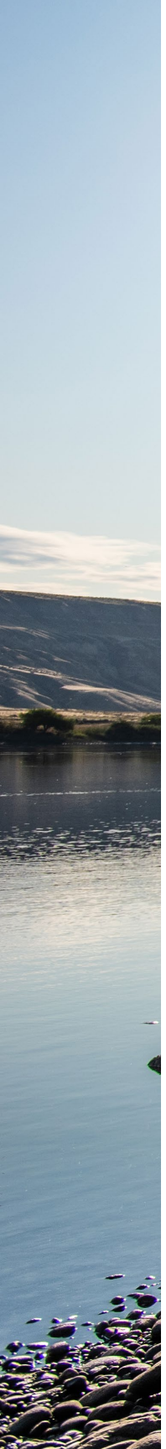
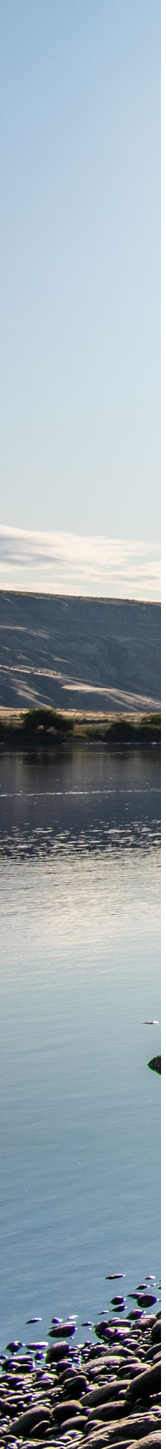




What is the Assessment Question?

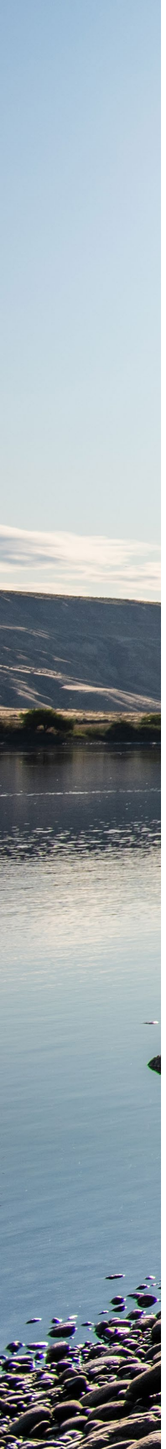
- Are we compliant?
  - Often, regulatory requirements of facility operations are posed in terms of radiation dose limits
- Design requirements
  - How much material may be released and still meet the criteria?
- Safety Analyses
  - How much redundancy is necessary to prevent this event?
- Accident Planning
  - How bad could this event be?



Scenarios

- A *scenario* is a conceptual model that describes patterns of human activity, events, and processes that result in radiation exposure to people.

- GENII is designed to allow flexible application to most scenarios of interest in a regulatory setting at an appropriate level of detail.



Scenario Analyses

- All of these questions can be answered through the analysis of a *scenario* that considers
  - Radionuclide inventories,
  - Radionuclide releases,
  - Environmental transport,
  - Environmental accumulation and dilution,
  - Subsequent human exposure.

Human Exposure Pathways

- External
  - Transported air
  - Soil
  - Swimming/Boating
  - Shoreline
- Inhalation
  - Transported air
  - Resuspended soil
  - Volatilized indoor air pollutants from water

Human Exposure Pathways

- Ingestion
  - Leafy vegetables
  - Other vegetables
  - Fruit
  - Grain
  - Meat
  - Milk
  - Poultry
  - Eggs
  - Fish
  - Crustaceans
  - Mollusks
  - Aquatic plants
  - Drinking water
  - Shower water
  - Swimming water
  - Soil

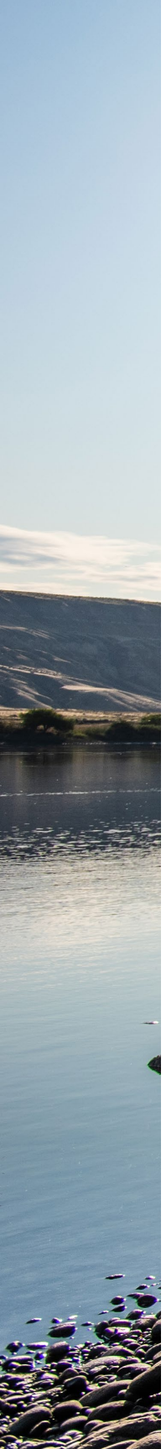
GENII V.2 Acute-Deposition Food Pathways

- GENII V.2 presents results for 4 seasons (Winter/spring/summer/autumn)
- “Seasons” are surrogates for complex sets of underlying assumptions about plant growth, weathering, uptake, and time-to-harvest
- Selection of season depends on meteorological input (this is related to the uncertainty capability)
- *Seasons below the equator are reversed! A minor change in an external file to adjust…*

GENII V.2 Human Exposure

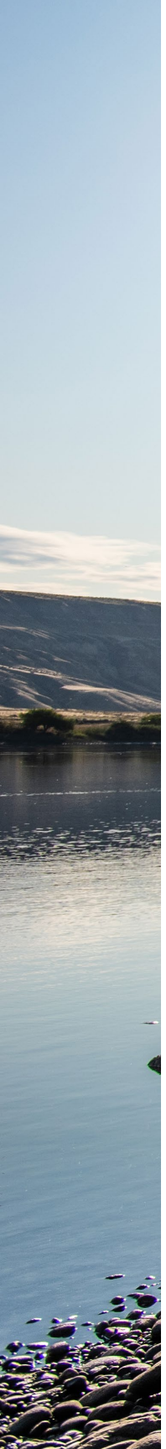
- Up to 6 age groups allowed, following ICRP-56,67,69

3 months	0-1 year
1 year	1-2 year
5 year	2-7 year
10 year	8-12 year
15 year	13-17 year
20 + year	17- 110 year



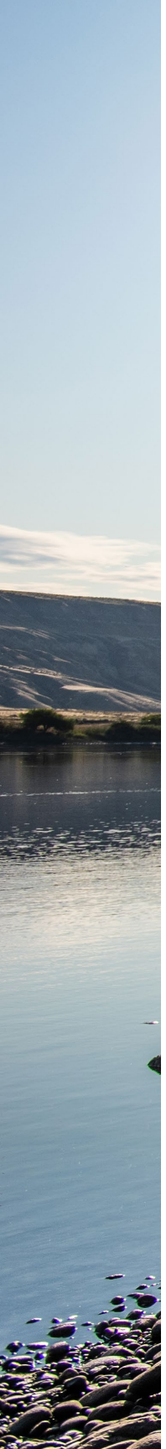
External Exposure - Doses

- Dose rate conversion factors from Federal Guidance Report 12, provided by Keith Eckerman, ORNL
  - Air Submersion
  - Water Immersion
  - Soil Plane
  - Soil Volume



Internal Exposure - Doses

- Effective dose equivalent: ICRP-30
  - Adult only
- Effective dose: ICRP-72
  - 6 age groups
  - 24 organs/tissues
  - Inhalation classes F, M, S

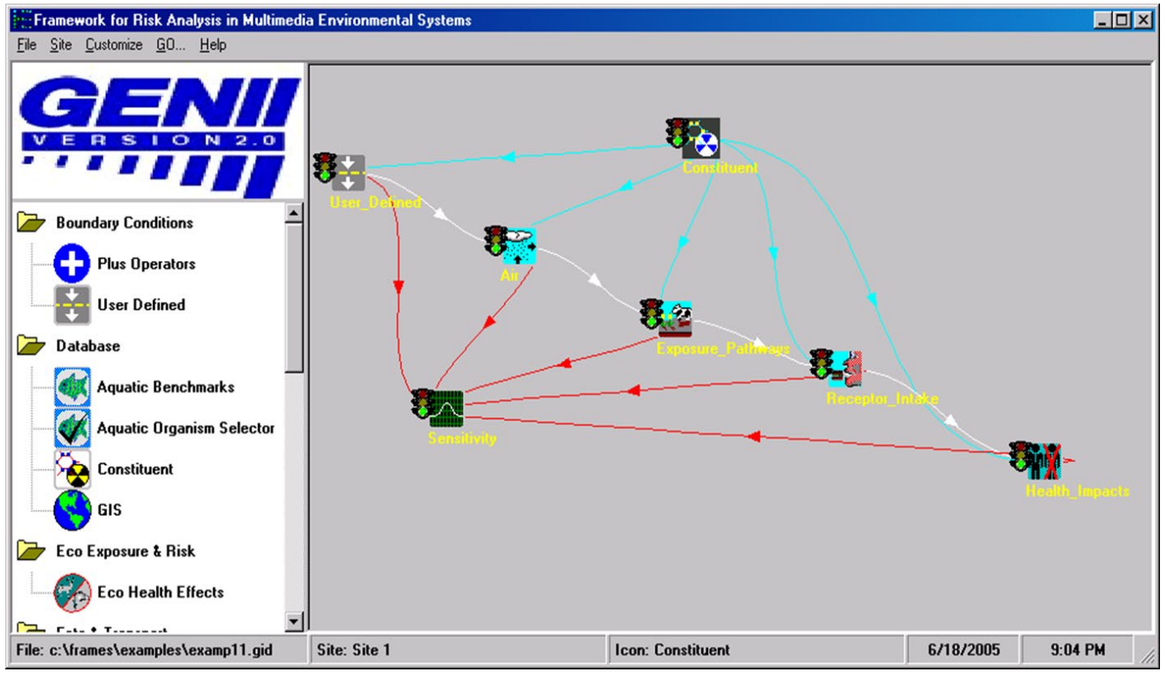


Risk Calculations - FGR 13

- US Federal Guidance Report 13 provides coefficients for 15 cancer sites
  - Inhalation (risk/Bq)
    - ✓Inhalation classes F, M, S
  - Ingestion (risk/Bq)
    - ✓Accounts for different consumption patterns with age
      - Drinking water
      - Food crops

GENII V.2 Uncertainty Analysis

- Parameter uncertainty and sensitivity may be addressed using the SUM^3 processor in FRAMES.
- All non-control parameters are allowed to be varied, using description files to define ‘available’ parameters
- Acute atmospheric releases are an important subset. SUM^3 is used to vary start times, creating distribution functions of dose.



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Uranium Milling and Mining

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Background

Uranium Minerals		
Select Primary Uranium Minerals		
Mineral Name	**Mineral Formula**	**%U**
Uraninite (Pitchblend)	UO_2	88.15
Coffinite	$U(SiO_4)_{1-x}(OH)_{4x}$	72.63
Brannerite	UTi_2O_6	33.54
Davidite	$(La,Ce,Ca)(Y,U)(Ti,Fe^{3+})_{20}O_{38}$	3.2
Select Secondary Uranium Minerals		
Mineral Name	**Mineral Formula**	**%U**
Schoepite	$(UO_2)_8O_2(OH)_{12}\cdot 12(H_2O)$	72.89
Sharpite	$Ca(UO_2)_6(CO_3)_5(OH_4)\cdot 6(H_2O)$	66.85
Carnotite	$K_2(UO_2)_2(VO_4)_2\cdot 1\text{-}3(H_2O)$	52.77
Tyuyamunite	$Ca_2(UO_2)_2(VO_4)_2\cdot 5\text{-}8(H_2O)$	51.85
Autunite	$Ca(UO_2)(PO_4)_2\cdot 12(H_2O)$	48.27
Uranophane	$Ca(UO_2)_2(HSiO_4)_2\cdot 5(H_2O)$	40.59
Mourite	$UMo_5O_{12}(OH)_{10}$	22.04

- ~250 uranium minerals
- Primary and secondary minerals
- Percent Uranium (%U) ranges from 88% to 0.1%
  - Uranium dioxide (UO_2)

Source: webmineral.com/

Background

- Uranium Ore
- Ore Grades
  - Very High-Grade = 20% U
  - High-Grade = 2% U
  - Low-Grade = 0.1% U
- Most U deposits contain 0.05-0.5% U
- Radioactive daughter products
- Other important metals

Schnell, 2009

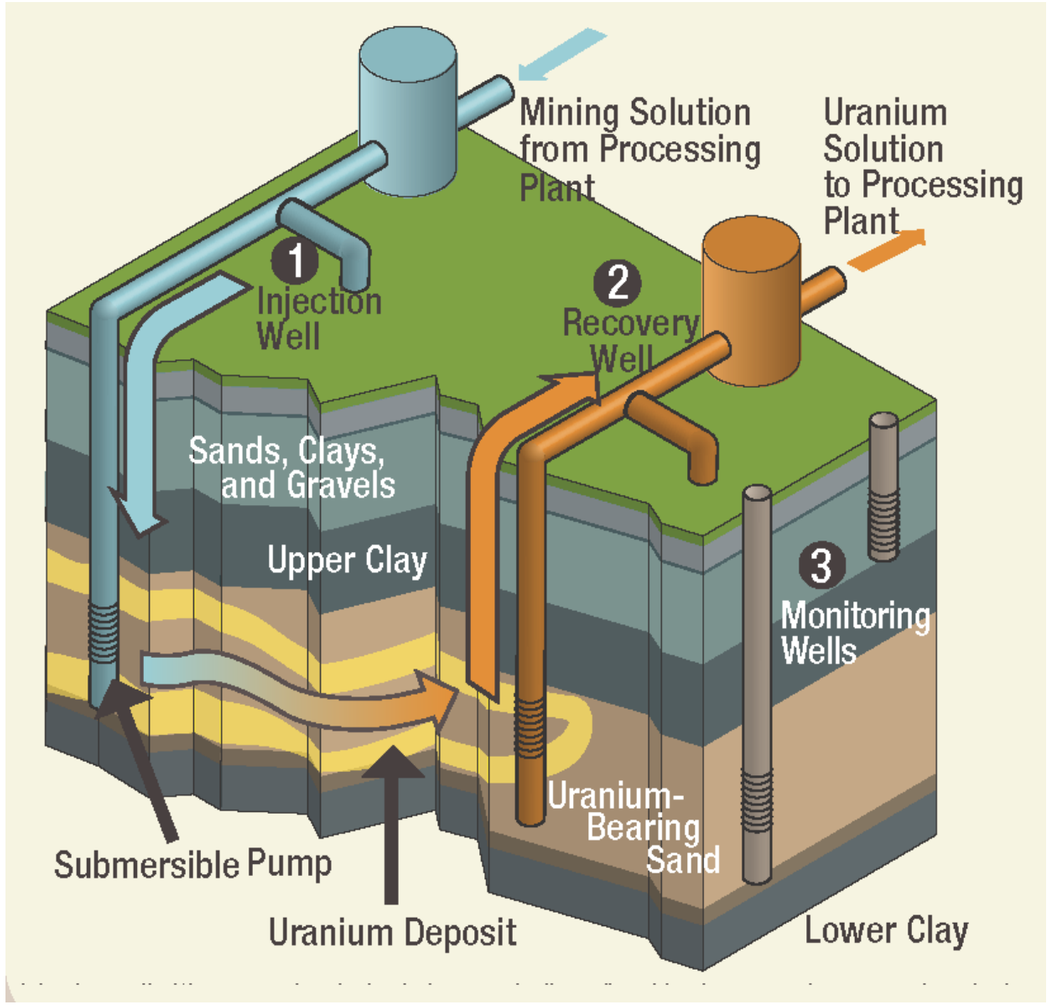
Uranium Ore Mining

https://www.atomicheritage.org/history/uranium-mining

https://www.mindat.org/photo-939017.html

- Surface operations: rim strips, open pits, cut and fill, trenches
- Underground excavation

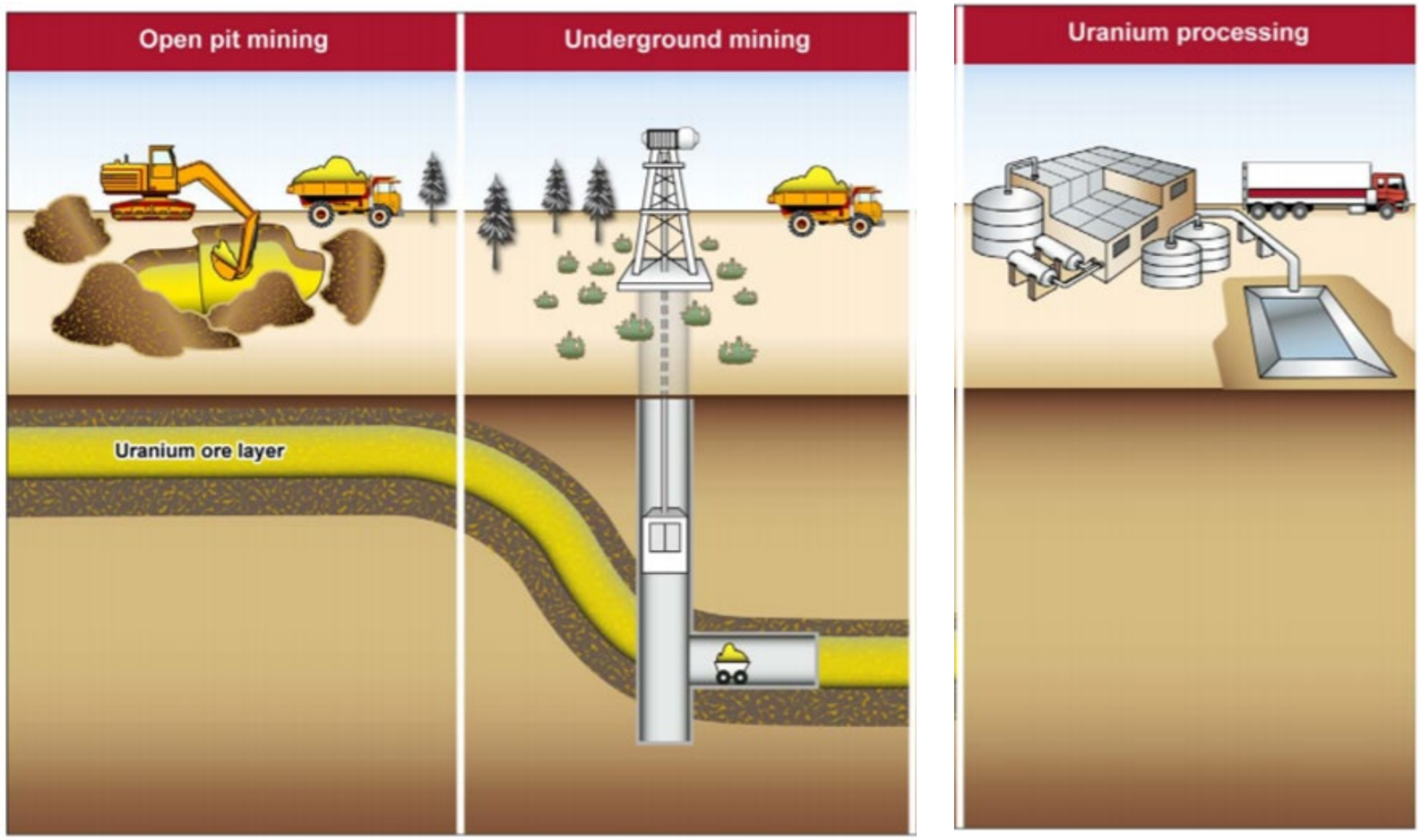
Uranium Mining: In-Situ Recovery (ISR)



Source: Courtesy of NRC

- Inject acidic solution to dissolve uranium minerals from mineralized target
- Extract solution with dissolved uranium
- Daughter products or other radioactive metals are also mobilized into solution
- Process solution to isolate uranium and dispose of remaining hazardous materials

Uranium Milling



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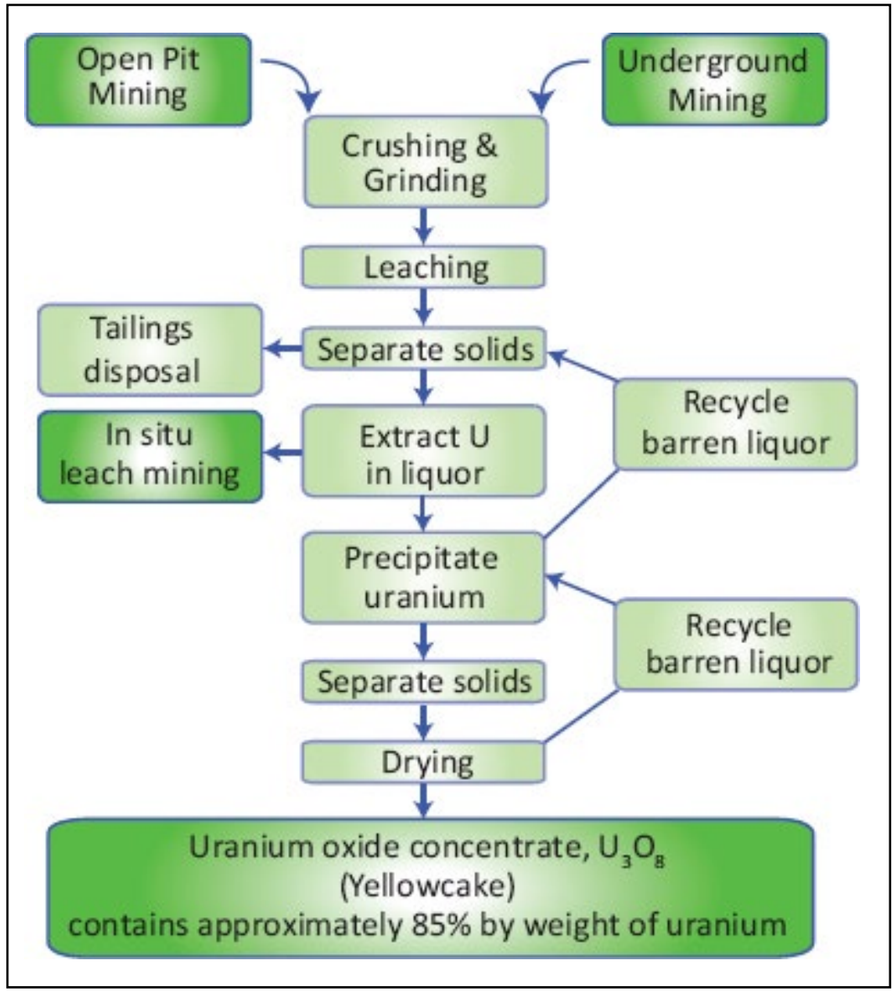
Uranium Milling



https://www.nap.edu/read/13266/chapter/7#107

Grand Junction, Colorado Uranium Mill

https://www.dol.gov/sites/dolgov/files/owcp/energy/regs/compliance/public_reading_room/deeoic_training/DOE_Info_Sessions/PDFs/GrandJunction.pdf

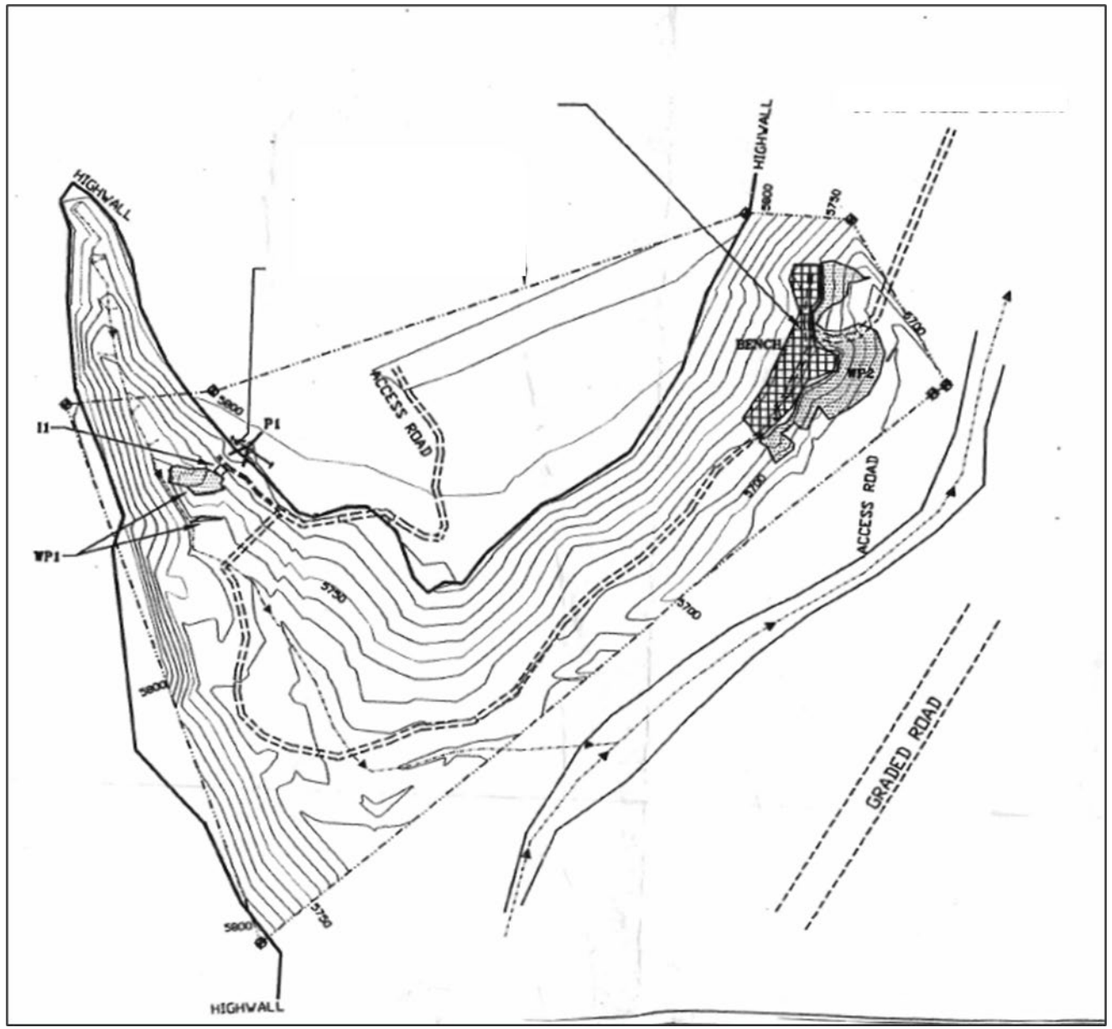
- Extract uranium from ore and process into uranium oxide concentrate (Yellowcake)
- Residual waste rock (tailings) collected into tailings ponds and piles

Uranium Mining and Milling Waste

https://www.moabsunnews.com/news/article_6005cca8-b743-11e2-a81e-001a4bcf6878.html

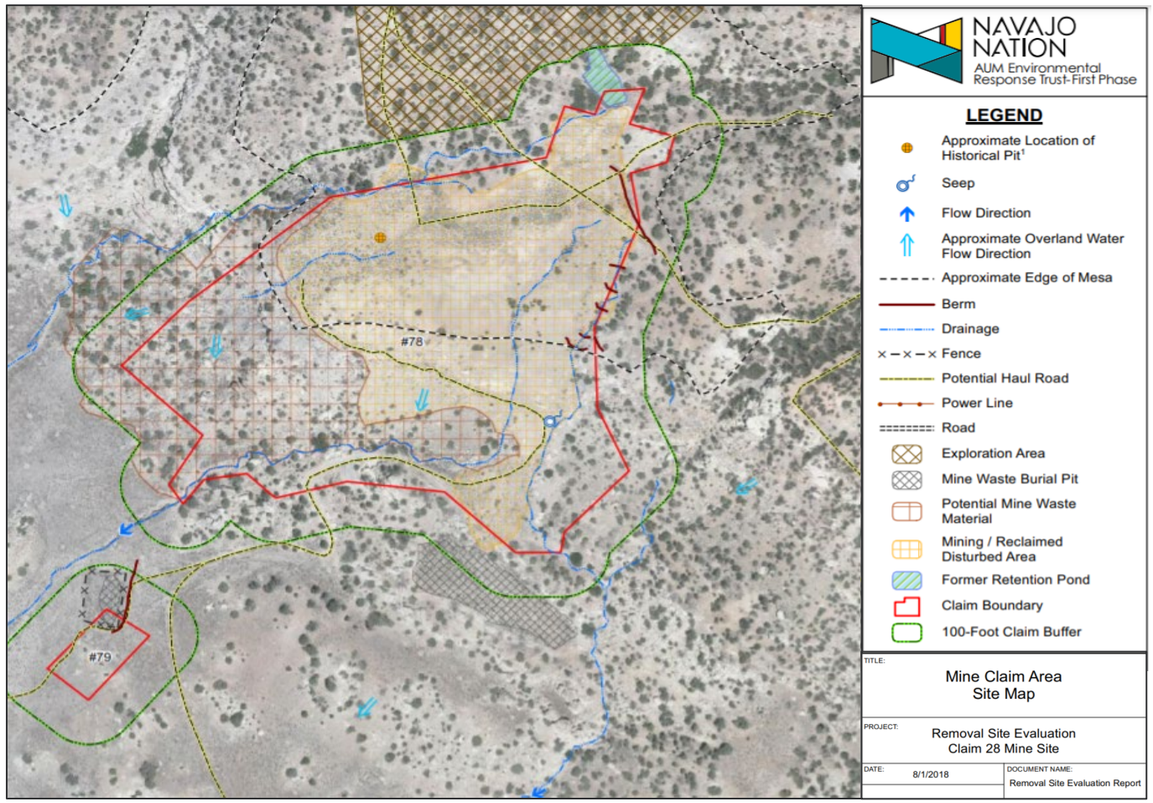
Modified from: https://www.gao.gov/assets/gao-14-323.pdf

Early Reclamation Efforts in the Navajo Nation



Modified from: Navajo Abandoned Mine Land Reclamation Program (NAMLRP), 1999 Historical Site Drawing, Tse Tah 3 Reclamation Project
Google Earth Imagery; July 2019

Recent Remedial Efforts in Navajo Nation



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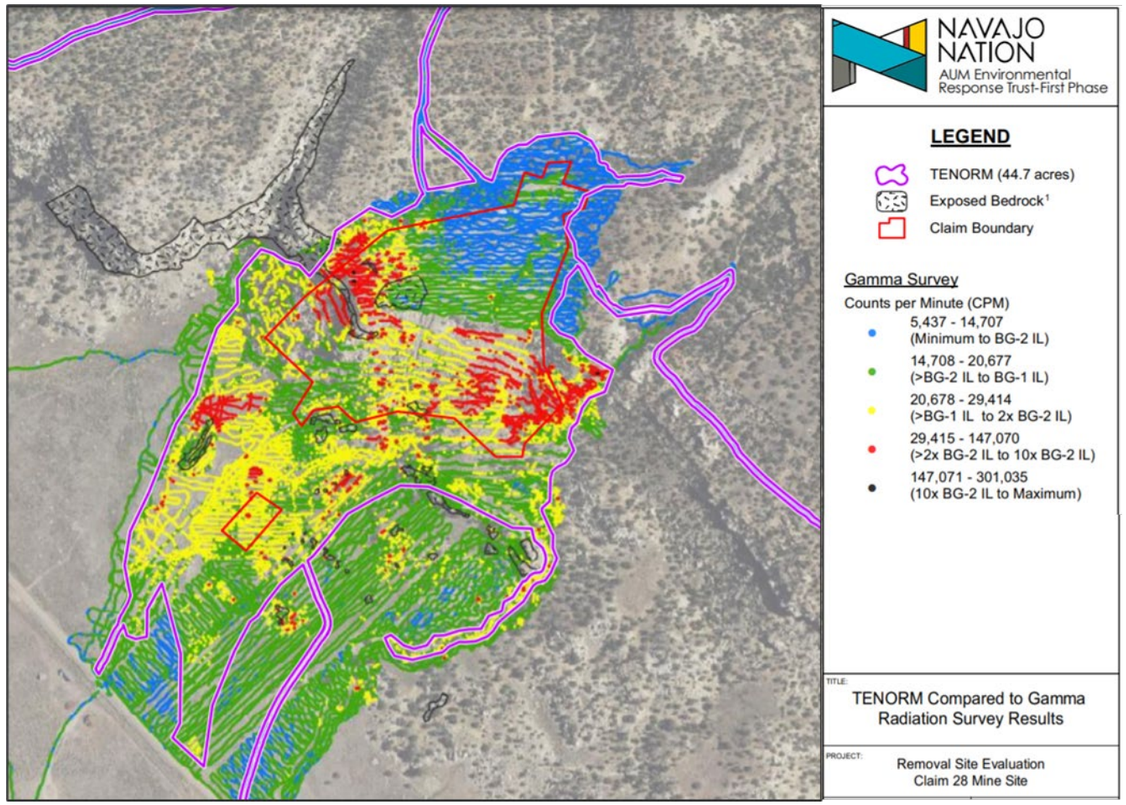

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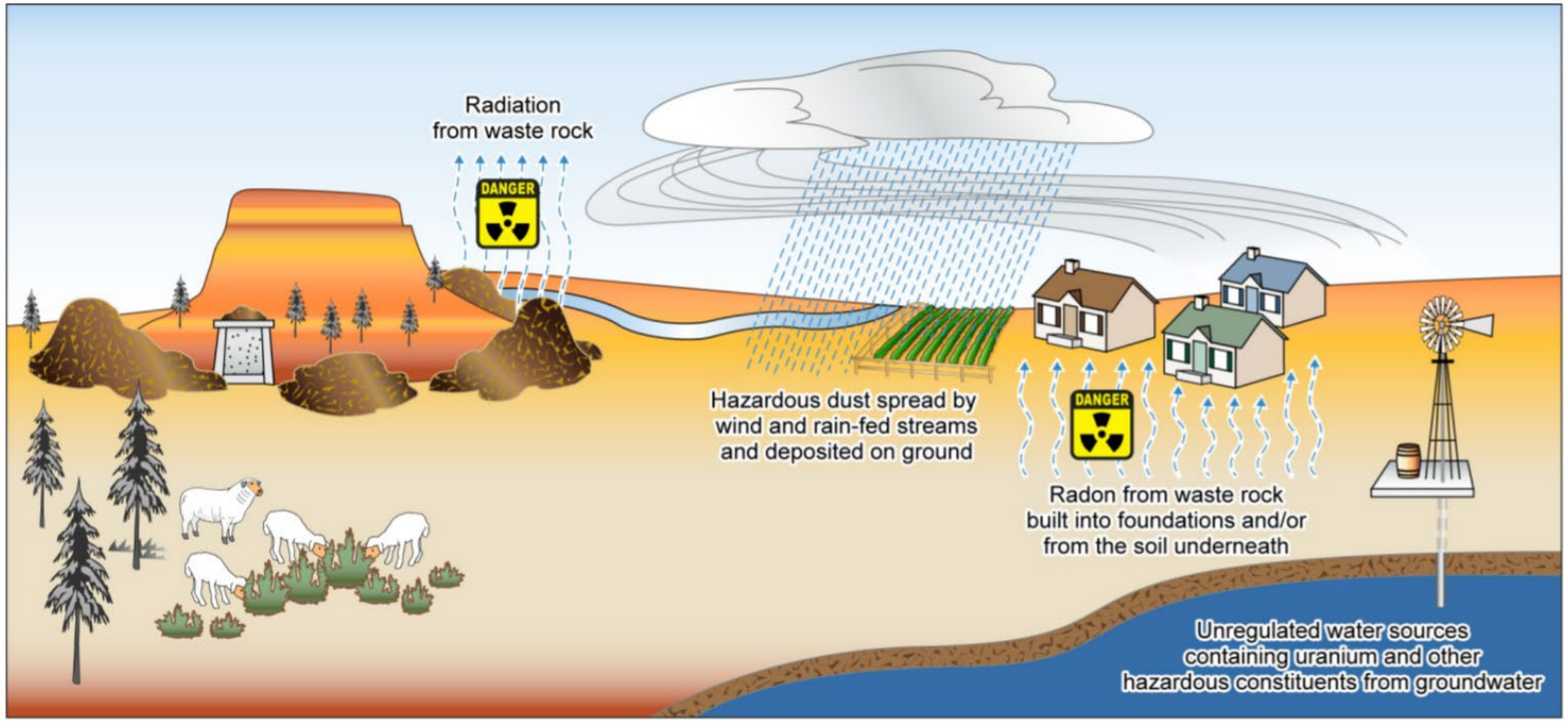
- Identify and delineate NORM and TENORM
- Characterize nature and extent of impacts
- Identify and design corrective actions protective of human health and ecology

Uranium Mine/Mill Radiological Exposure Pathways



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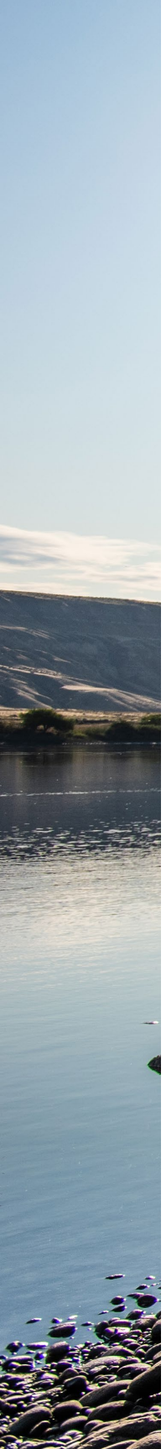

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