Waste Management at Hanford and the Savannah River Site

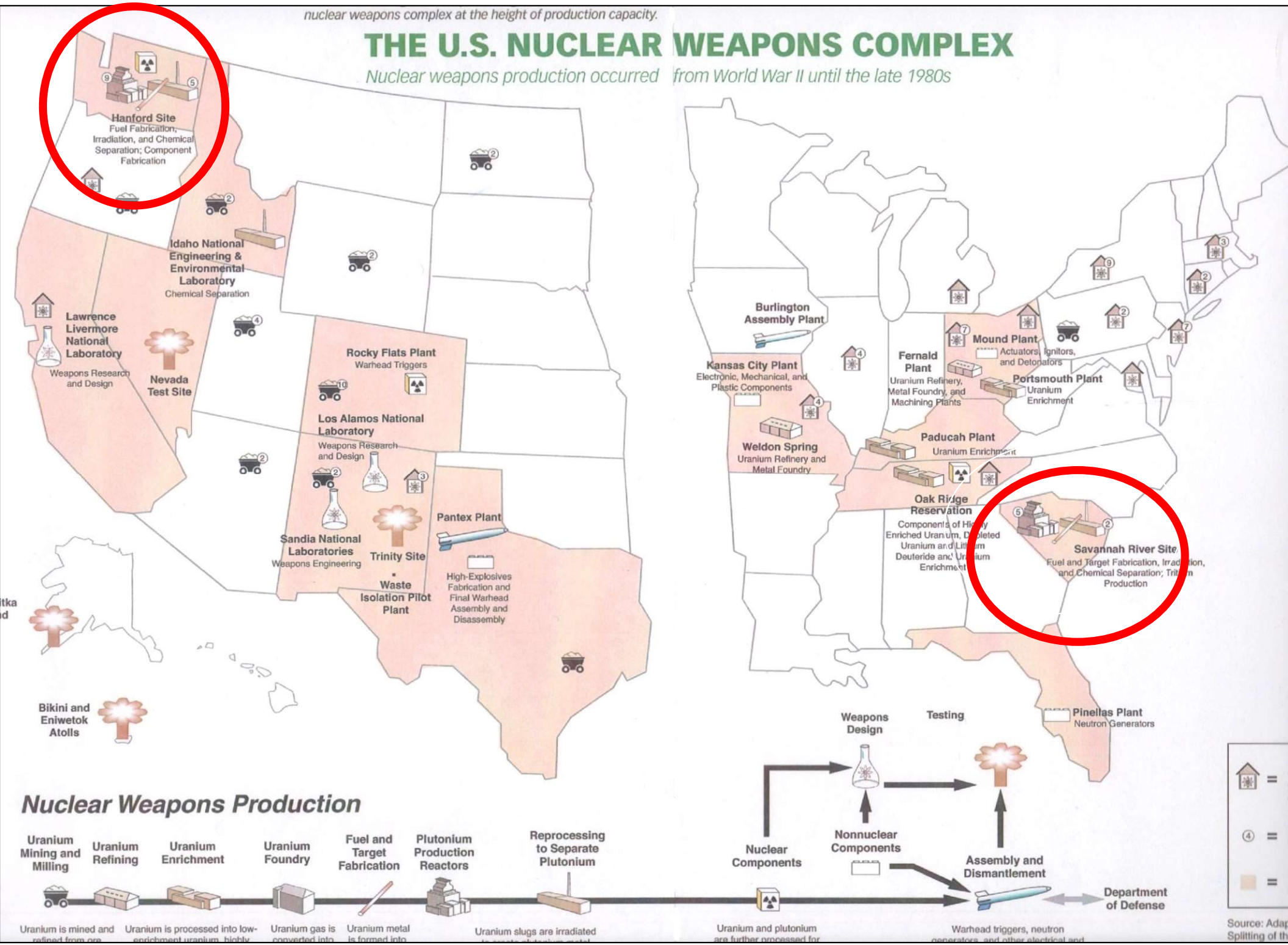
"I had a notion, more from intuition than anything else, that he said to me, 'we are lost.'"

—Henry Lawson in "Journey to the Center of the Earth" by Jules Verne.

nuclear weapons complex at the height of production capacity.

THE U.S. NUCLEAR WEAPONS COMPLEX

Nuclear weapons production occurred from World War II until the late 1980s



Nuclear Weapons Production

Source: Adap
Splitting of th

Hanford Site in Washington

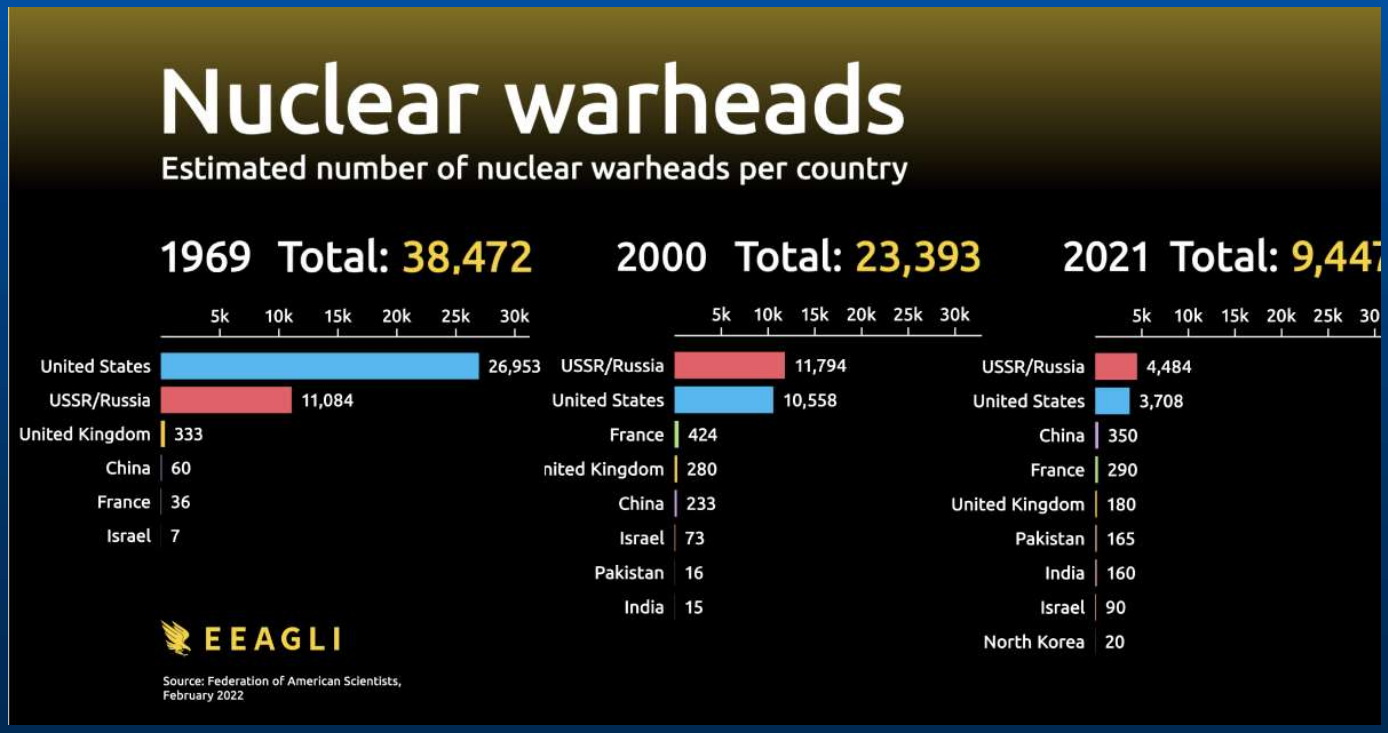
https://www.hanford.gov/

First established in 1943 as part of the Manhattan Project to produce the first nuclear weapons for World War 2.

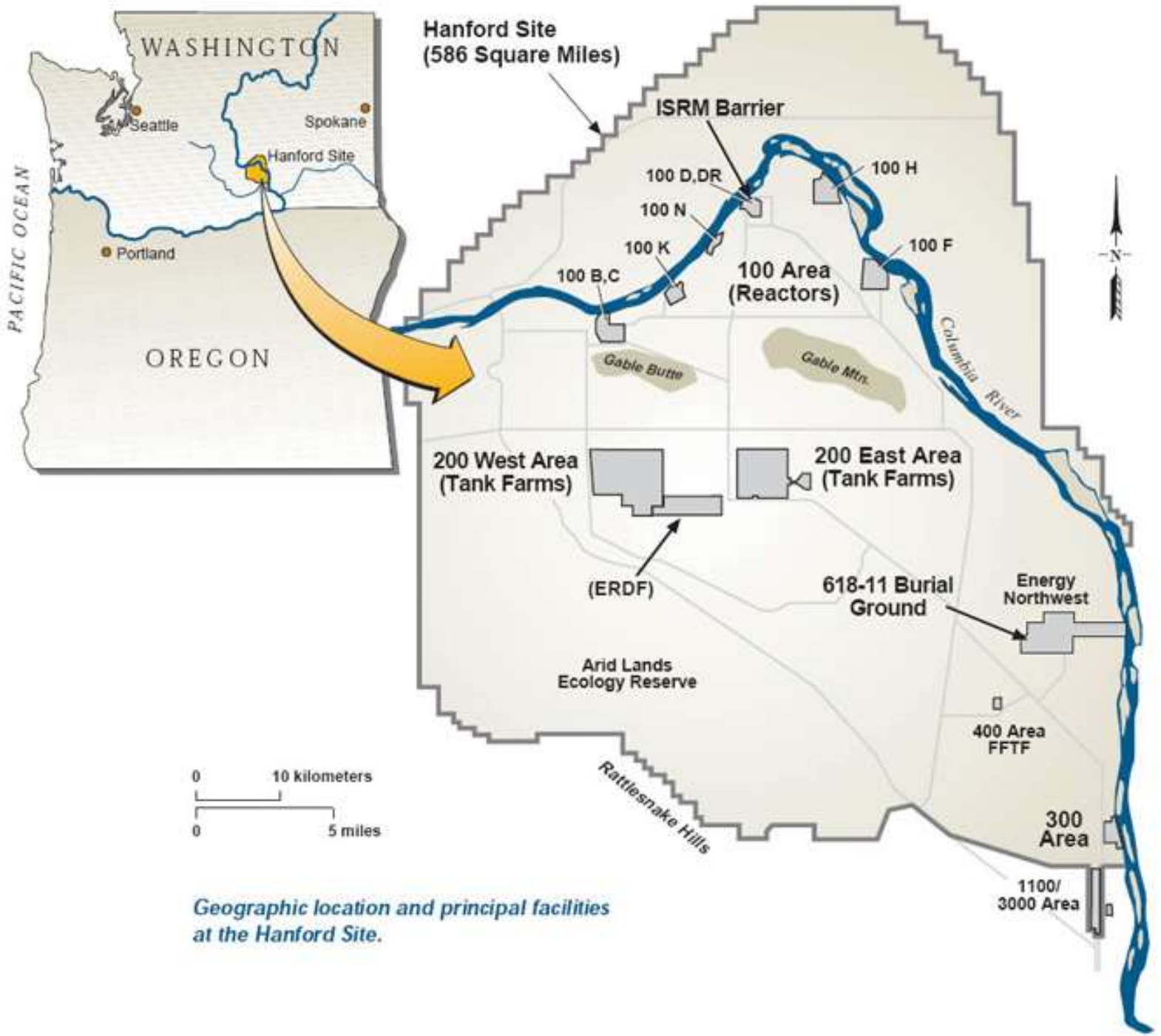
By 1963, nine nuclear reactors and five reprocessing plants to produce plutonium for the Cold War.

Hanford Site in Washington

Peak production from 1956 to 1965. Produced about 63 short tons (57 tonnes) of plutonium, supplying the majority of the weapons in the U.S. arsenal.



Hanford in 1960



Geographic location and principal facilities at the Hanford Site.

Hanford background

The only purpose of the Hanford facility was to produce plutonium for warheads.

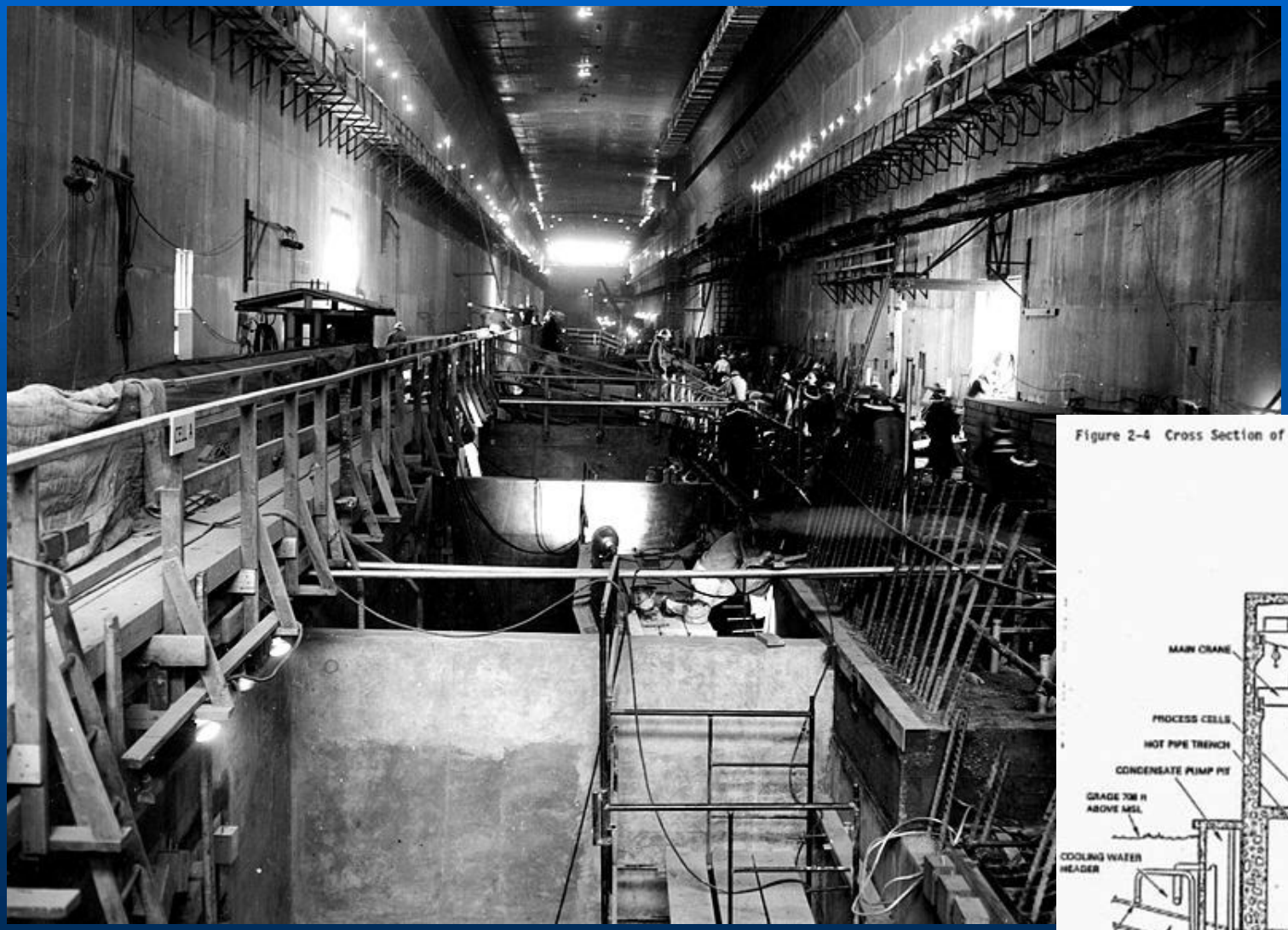
^{238}U was feed to up to 9 reactors. The plutonium was extracted from the irradiated fuel using the Purex process. The raffinate produced was pumped in underground storage tanks.

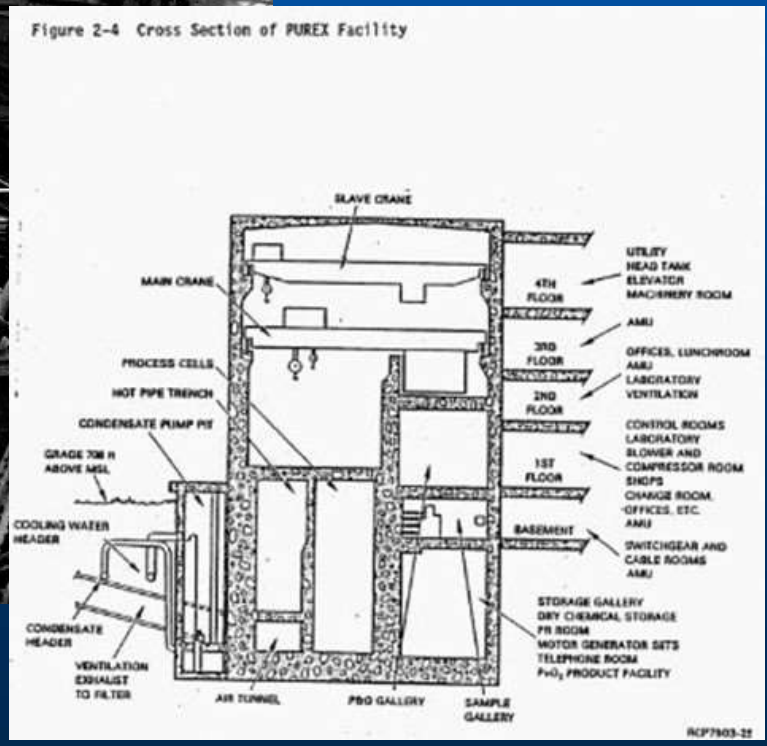
The Plutonium Uranium Extraction Plant

The Purex Plant operated from 1956 to 1972 and from 1983 to 1988.

The main part of the plant in 1,005 feet long. The major part was called "the canyons" that contained 11 extraction cells.

The Purex Plant



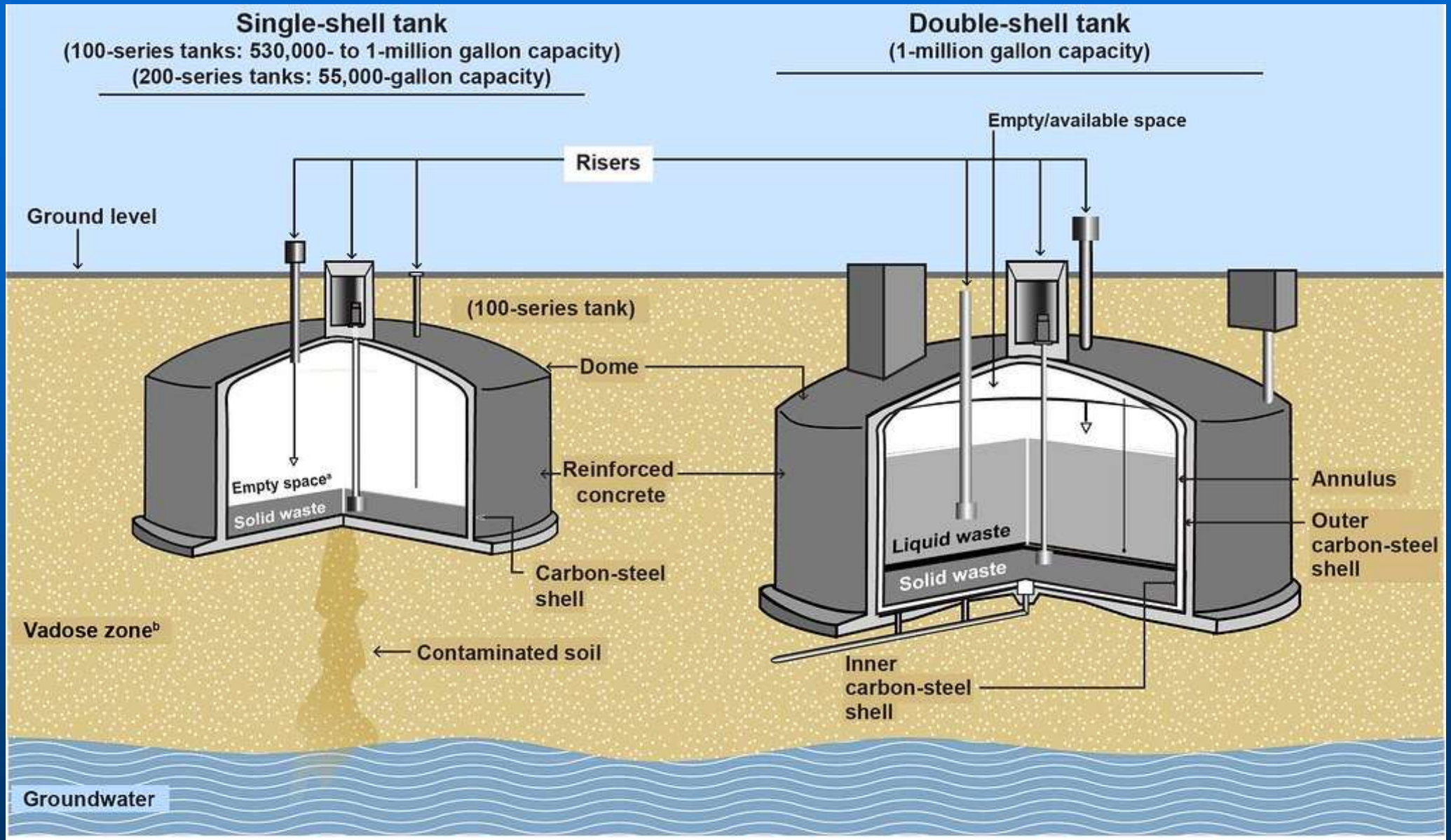


Mixed wastes in tanks

177 underground storage tanks were built to contain about 55 million gallons (2.1×10^8 L) of waste at pH 9 to 14. The wastes contained dissolved cladding, raffinate with fission products, organic solvents, all mixed with NaOH to neutralize the nitric acid.

12 of the 177 waste tanks during construction


The Tank Farms
A 200 Area Aerial Overview
200 West Area
200 East Area
SX
S
U
TX
TY
T
SY
BX
BY
B
C
AW
A
AY
AX
AZ
AN
AP
Waste Treatment and Immobilization Plant
Single-Shell Tank Farm
Double-Shell Tank Farm

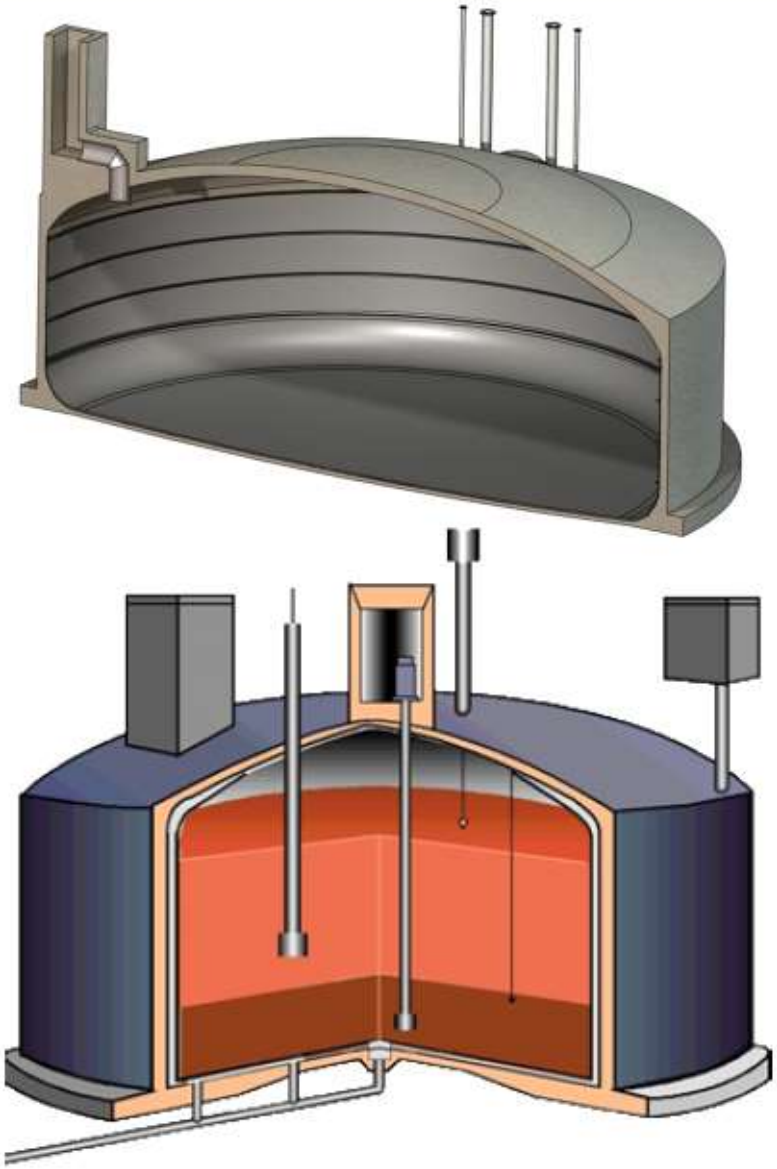


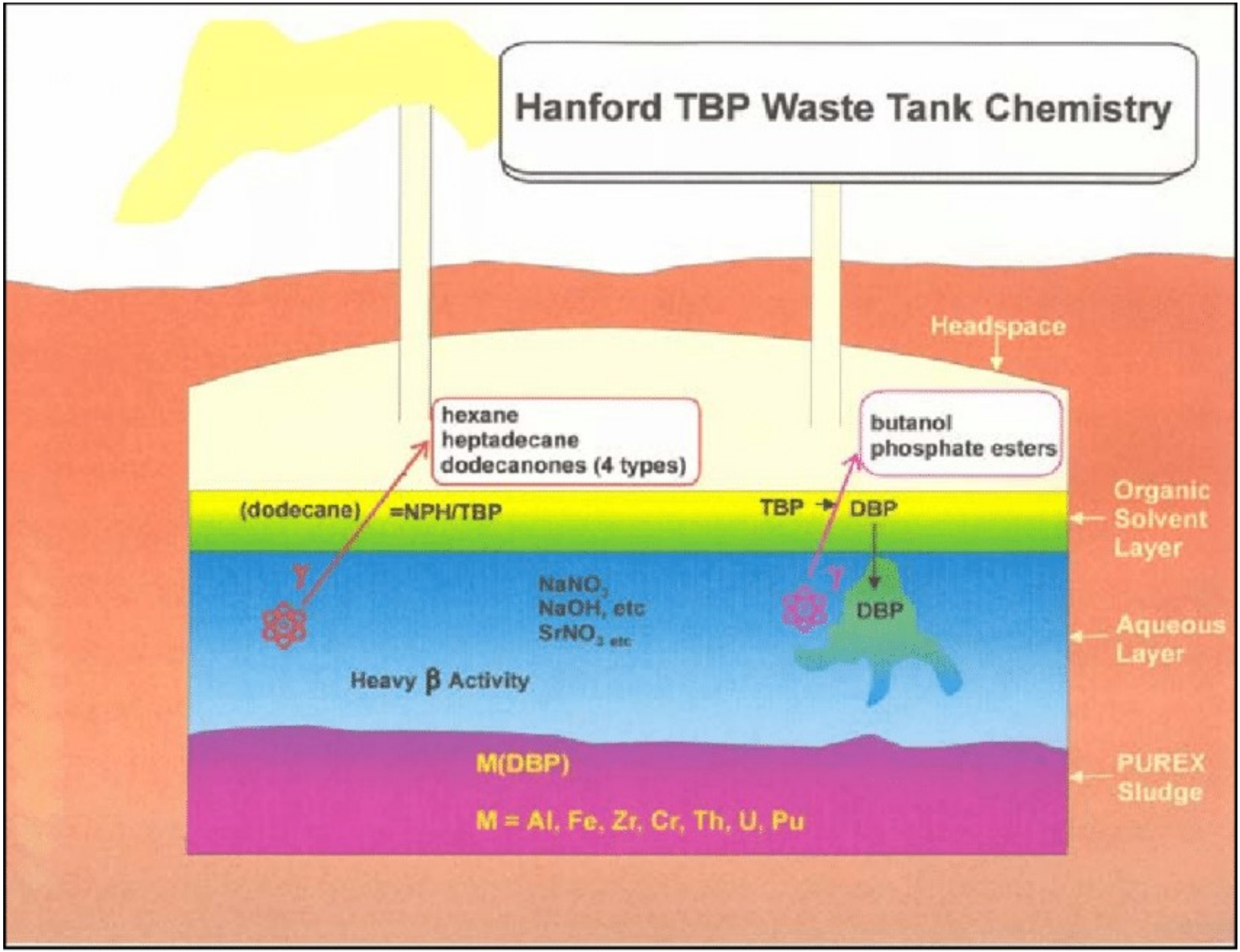
Source: GAO analysis of Department of Energy documents. | GAO-21-73

The Tanks

Two types of tanks:

- **Single-shell tanks (SST)**
  - 149 tanks
  - Constructed 1943–1964
  - 55,000 to 1 million gallons
  - 58 of the 149 SSTs are suspected “leakers”
- **Double-shell tanks (DST)**
  - 28 tanks
  - Constructed 1968–1986
  - 1 to 1.26 million gallons




Hanford TBP Waste Tank Chemistry
Headspace
hexane
heptadecane
dodecanones (4 types)
butanol
phosphate esters
(dodecane)
=NPH/TBP
TBP
DBP
Organic
Solvent
Layer
NaNO3
NaOH, etc
SrNO3 etc
DBP
Aqueous
Layer
Heavy β Activity
M(DBP)
PUREX
Sludge
M = Al, Fe, Zr, Cr, Th, U, Pu

The Waste in the Tanks

56 million gallons of waste

Saltcake

23 Mgal

Mostly water-soluable salts; small amount of interstitial liquid

Supernate

21 Mgal

Any non-intersitial liquid in the tanks - similar to saltcake in composition

Sludge

12 Mgal

Water-insoluable metal oxides, significant amount of interstitial liquid - texture similar to peanut butter

Chemical composition of the tanks

Example: estimated that the tanks hold

pH 11.9, 4.0 M Na^+, 3.2 M NO_3^-

11 mCi/L (407 MBq/L) of ^3H

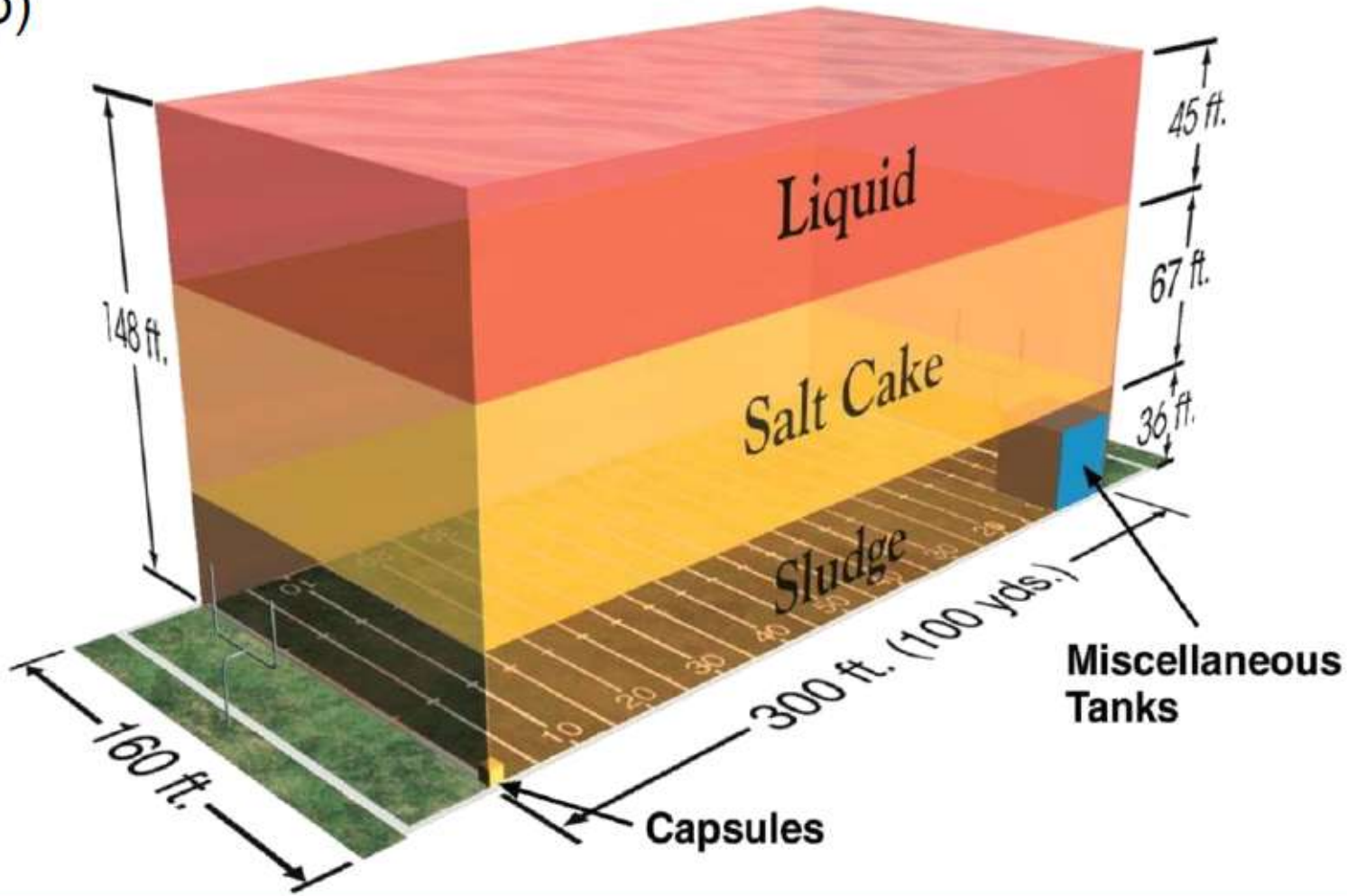
98 mCi/L (3.6 MBq/L) ^{90}Sr

115 mCi/L (4,250 MBq/L) of ^{137}Cs

0.114 µCi/L (4,203 Bq/L) of ^{239}Pu and others.

How to Quantify Tank Waste

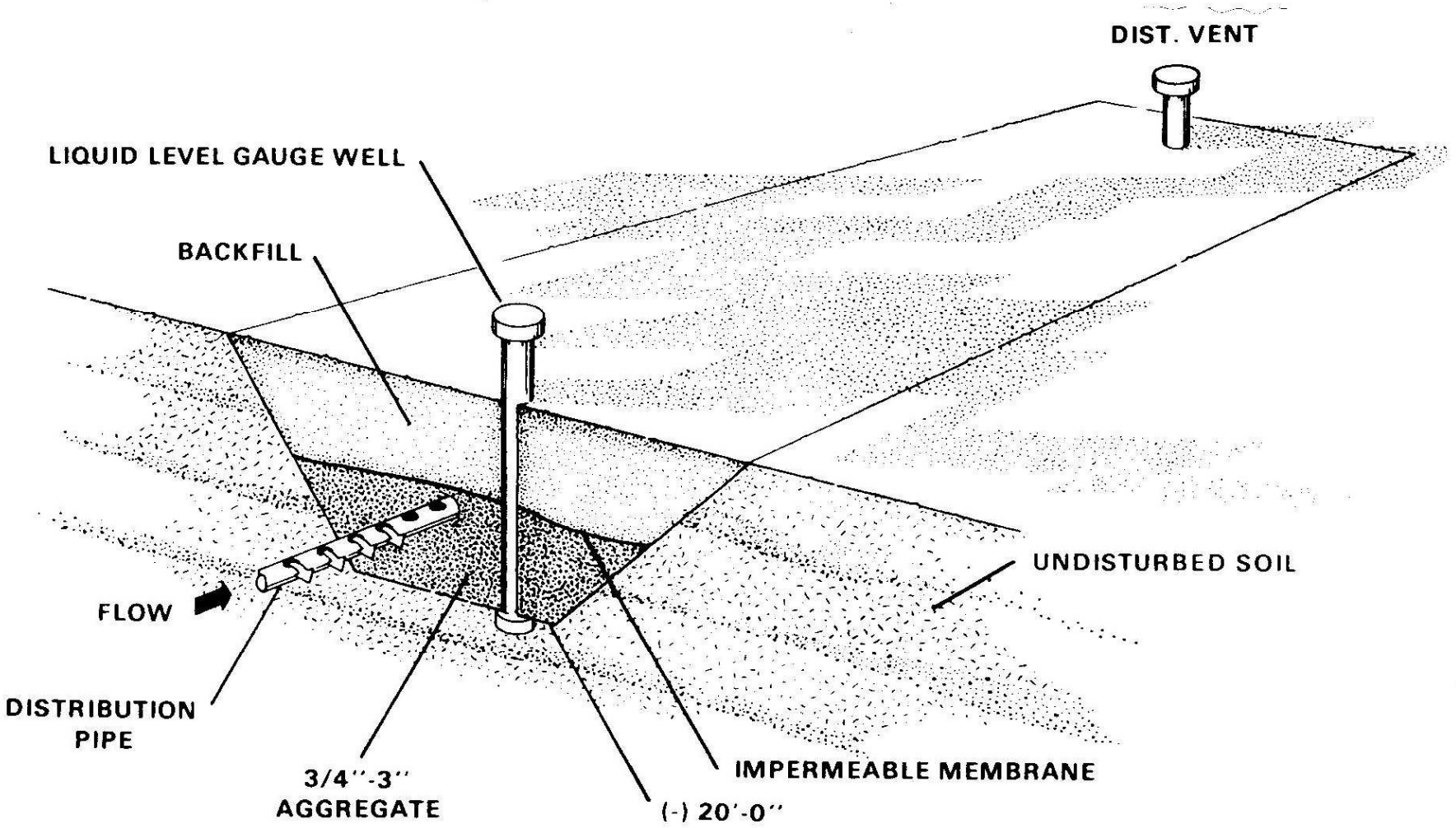
Approximately 56 million gallons of waste contained in 177 underground storage tanks (enough to cover a football field 148 feet deep)



From c. 1944 to 1973

When the tanks became full, it was decided that there was no more room to build new ones, so the tanks were allowed to settle, and the liquid phase was deliberately discharged to the ground into "cribs."

A crib was a ditch, 20 ft (6.1 m) deep and up to 1,400 ft (427 m) long, backfilled with gravel


DIST. VENT
LIQUID LEVEL GAUGE WELL
BACKFILL
UNDISTURBED SOIL
FLOW
DISTRIBUTION PIPE
3/4"-3" AGGREGATE
(-) 20'-0"
IMPERMEABLE MEMBRANE

Flawed assumptions

The depth to groundwater was between 150 to 300 ft (46 to 91 m).

It was assumed that the radionuclides would be adsorbed by ion exchange associated with the clay minerals. Ion exchange can be a reversible reaction! The radionuclides can continue to migrate.

It was acknowledged that tritium, ruthium, and nitrate would not be retained, and could "flow to groundwater" but "be rapidly diluted."

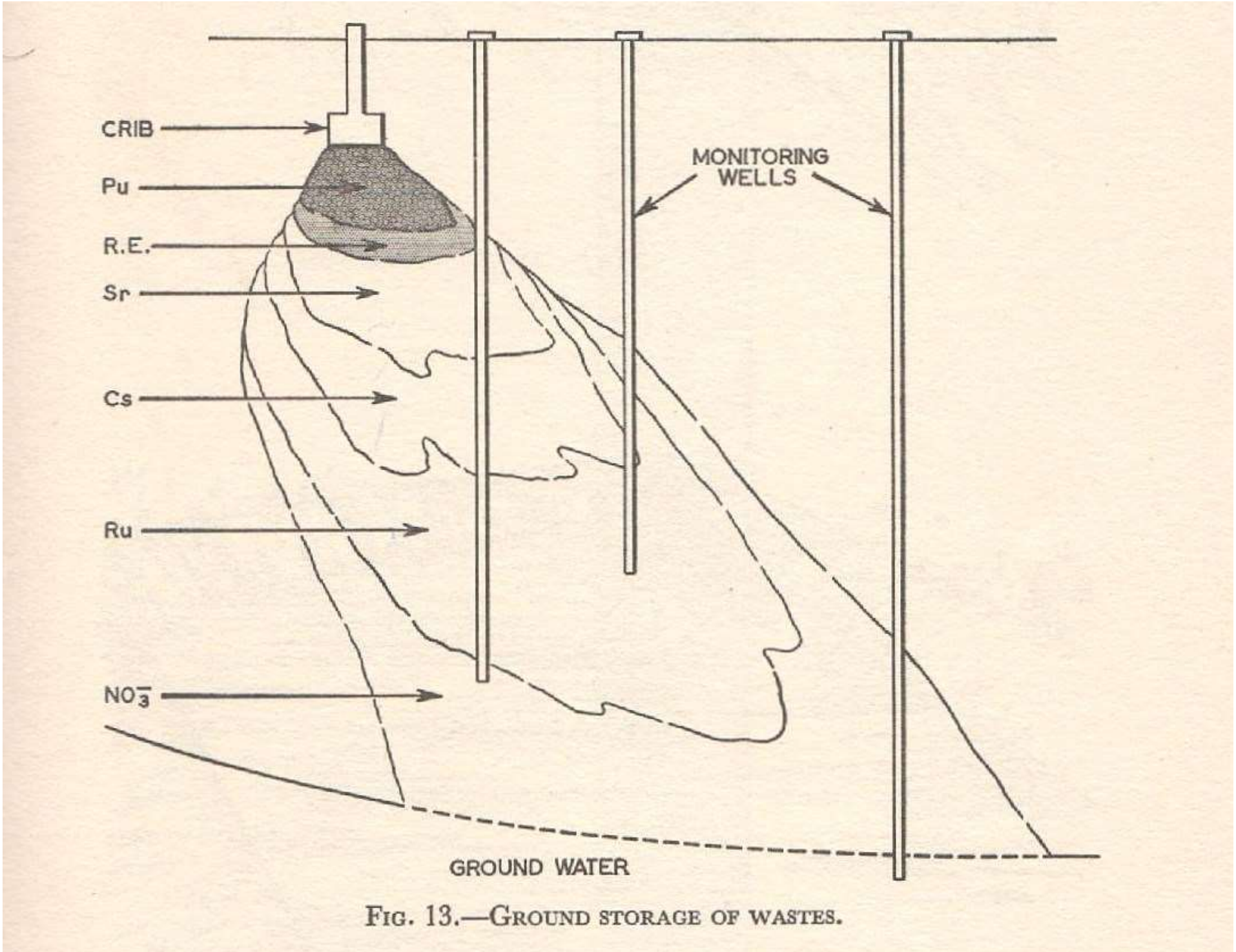


FIG. 13.—GROUND STORAGE OF WASTES.

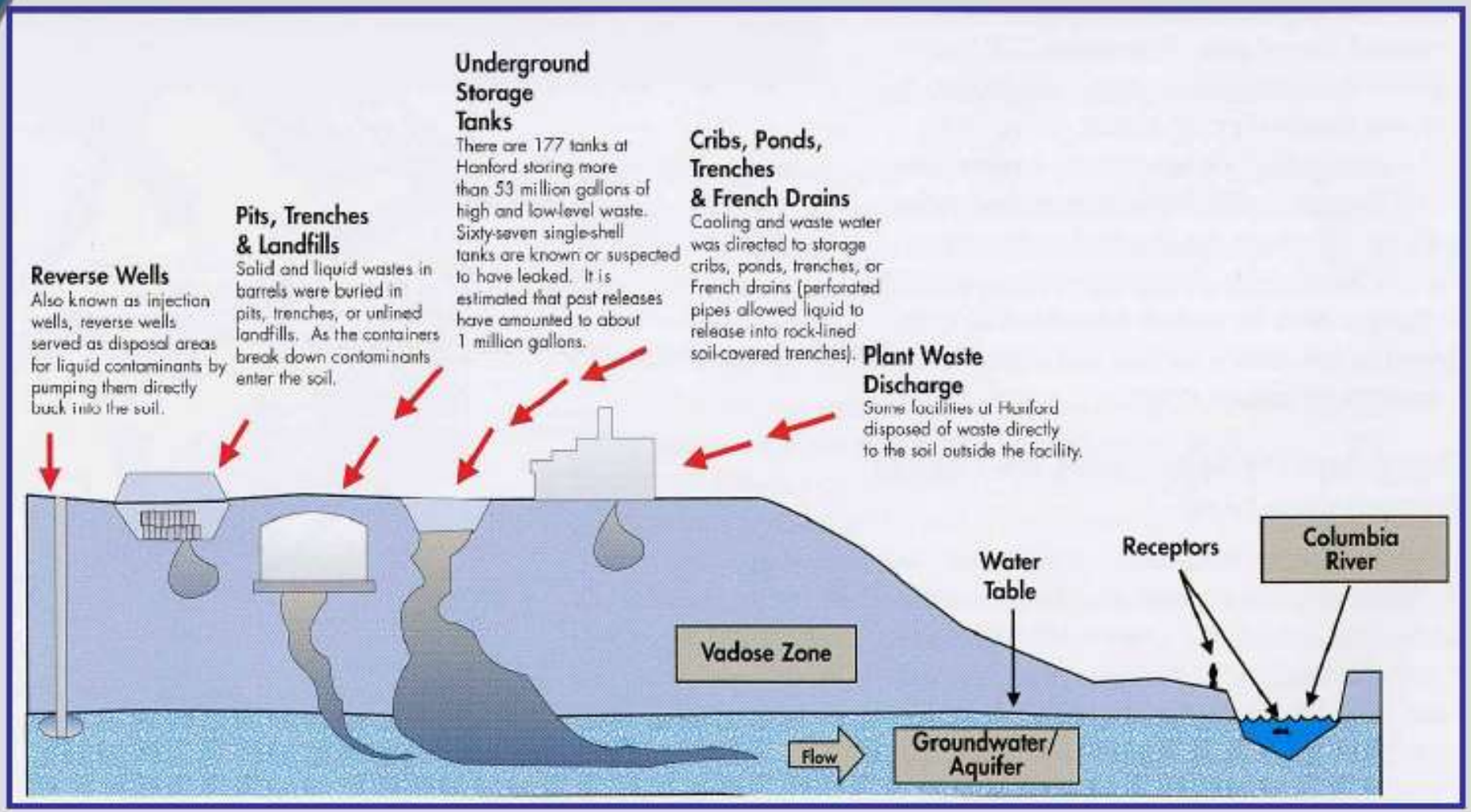
More releases at Hanford

450 billion gallons (1.7×10^{12} L) of liquid wastes released from 1944 to 1996.

150-mile^2 (389 km^2) plume of contaminated groundwater.

Fate of radionuclides in soil unknown. Ion exchange is a reversible reaction. Will be a source of contamination for years.

Sources of Hanford Groundwater Contamination

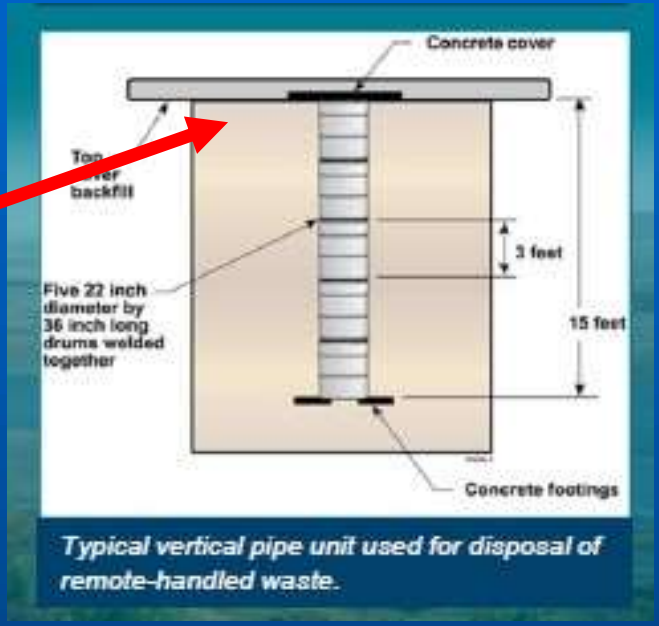


The Burial Grounds

The Burial Grounds were disposal areas with trenches, vertical-well units, and concrete vaults. The well units were 55-gallon drums that were welded together to a depth of 15 feet. They were used to dispose "low- and high-activity wastes" from 1954 to 1967.

The Burial Grounds

The burial ground during operations (1964), showing the trenches on the left and vertical pipe units on the right.



Typical vertical pipe unit used for disposal of remote-handled waste.

The 618-11 Burial Ground, 2012.

The Burial Grounds

Burial Ground 618-11 contaminated the groundwater. It will be remediated in 2030 (no details).

Burial Ground 618-10 was decommissioned and remediated from 2010 to 2017 at a cost of $284 million. The wastes were moved to the on-site Environmental Restoration Disposal Facility.

The Environmental Restoration Disposal Facility consists of multiple cells for receiving cleanup waste from across the Hanford Site.

The U.S. Department of Energy and contractor Central Plateau Cleanup Company are safely and compliantly operating the Environmental Restoration Disposal Facility (ERDF) at the Hanford Site in southeastern Washington state.

Background

The ERDF is a large engineered landfill located in the center of the Hanford Site. The facility is used for the disposal of low-level radioactive, hazardous and mixed wastes generated from demolition, remediation and other cleanup activities across the Site. The facility began operating in 1996 and is regulated by the U.S. Environmental Protection Agency under the federal *Comprehensive Environmental Response, Compensation, and Liability Act*. The ERDF contains double-lined disposal cells with a drainage system that collects potentially contaminated water from rain and dust-suppression activities, which has come in contact with the waste. The facility covers an area of approximately 107 acres and its size provides tremendous flexibility in disposing of different waste forms, ranging from soils to large pieces of contaminated equipment.

Site remediation/restoration

The budget for site remediation is currently $2.4 billion per year.

The completion date has been estimated as 2064 to 2095!

Approaches use in site remediation and environmental restoration of the contaminated land and groundwater will be covered in NPRE 498 D.

Returning to the solid wastes in the tanks . . .

Retrieval: Not an Easy Task

- **Risk**

  Waste is highly radioactive and must be handled remotely

- **Variation**

  Tanks contain multiple forms of waste: liquid, sludge, solids

- **Accessibility**

  Tanks are buried underground and have a limited number of small access pipes

Waste Treatment

- Building world's largest radioactive-waste treatment plant
- Waste will be immobilized in glass using a vitrification process that secures the waste for permanent storage
- The Waste Treatment and Immobilization Plant plays an essential role in reducing the environmental risk posed by Hanford's tank waste

The Savannah River Site (SRS)

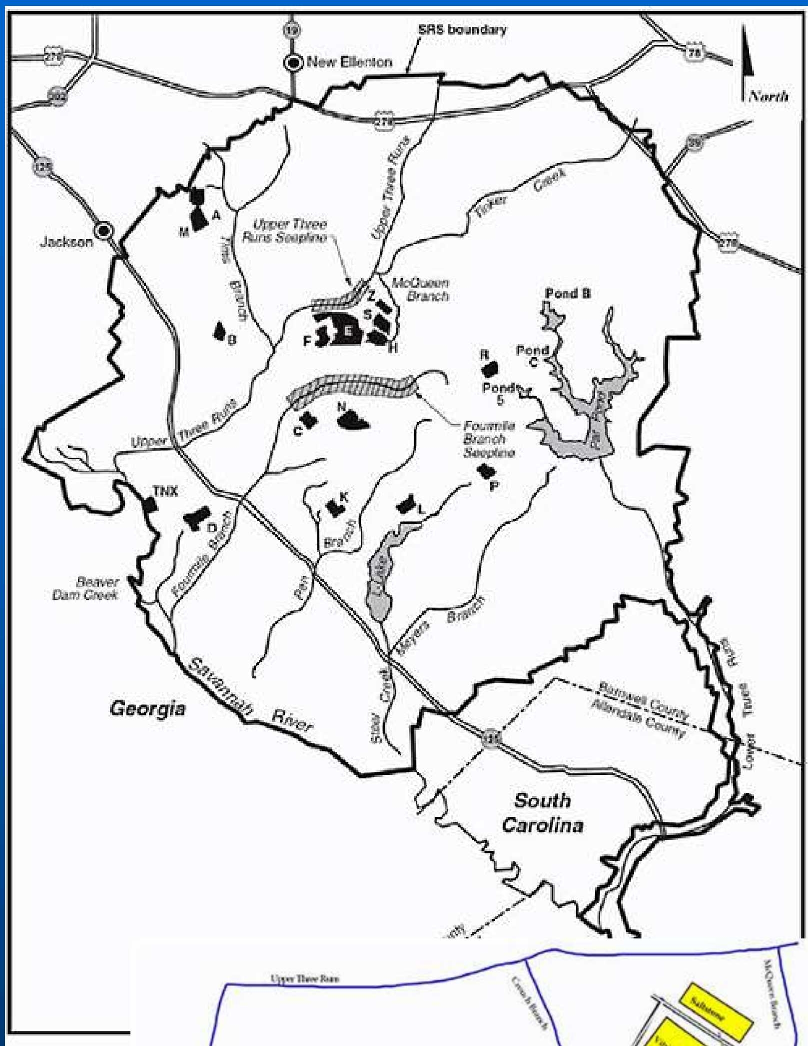
A "nuclear reservation" in South Carolina. A Cold-War Era government facility built to operate five reactors, then separate plutonium for nuclear weapons. Covers an area of 310 mile^2 (803 km^2).

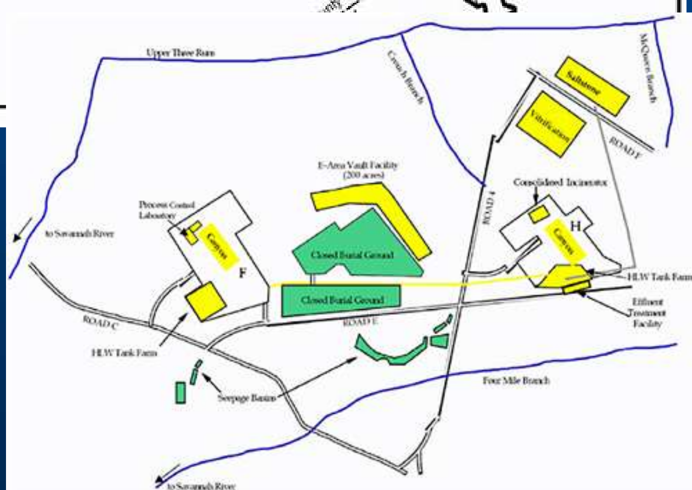
Early history of SRS

1950-1951. Built by E. I. Du Pont. Managed by the US Atomic Energy Commission.

1952-1955. Reactors R, P, L, K and C went critical.

Canyon F became the world's first full-scale Purex separation plant.


SRS boundary
New Ellenton
North
Jackson
Upper Three Runs Seepline
Upper Three Runs
Tinker Creek
McQueen Branch
Pond B
Pond C
Pond 5
Fourmile Branch Seepline
Upper Three Runs
TNX
Beaver Dam Creek
Fourmile Branch
Pen Branch
L Lake
Meyers Branch
Steel Creek
Savannah River
Georgia
Barnwell County
Allendale County
Lower Three Runs
South Carolina


Upper Three Runs
Crouch Branch
McQueen Branch
Saltstone
Vitrification
ROAD F
E-Area Vault Facility
(200 acres)
Consolidated Incinerator
Process Control Laboratory
to Savannah River
Canyon
F
Closed Burial Ground
Closed Burial Ground
ROAD 4
Canyon
H
HLW Tank Farm
Effluent Treatment Facility
ROAD C
ROAD E
HLW Tank Farm
Seepage Basins
Four Mile Branch
to Savannah River

Later history of SRS

Produced about 36 tonnes of plutonium from 1953 to 1988.

Cold War ended in ca. 1991

The last reactor was turned off in 1992.

From 1953 to about 1996, all wastes were stored on-site without much thought. SRS became the major facility to "manage" all Legacy radioactive wastes.

Prior to 1996

36 million gallons (1.36×10^8 L) of reprocessing liquids and sludge stored in 49 underground tanks.

Tens of thousands of UNF assemblies

"Interim storage" of all Legacy-DOE Pu.

Prior to 1996

Stockpiles of enriched U
Stockpiles of depleted U
TRU wastes were stored in drums and buried in mounds.
LLRW placed in the "Low Level Burial Grounds"

Site cleanup and waste reduction

From 1997 to 1999, 8,500 TRU waste drums were uncovered then stored above ground.

10,000+ sent to WIPP since 2001

Fig. 4. TR Waste Drums Before Retrieval

Fig. 5. TRU Waste Drums After Retrieval

Engineered Trench 1

Operational in 2001. Capacity until 2024.

B-25 boxes (90 ft^3 [2.6 m^3]), aluminum, steel) are stacked 4 high then covered with soil.

Boxes assumed to fail via corrosion in 200 to 300 years after burial.

Fig. 2. Engineered Trench

The Defense Waste Processing Facility

- Largest vitrification plant in the world.
- In operation since 1996.
- Since 1996, 7 million gallons (1.8 million L) of radioactive sludge have been vitrified.
- Glass frit + sludge heated to 2,100° F (1,150° C)
- Placed in stainless steel canisters.

The Defense Waste Processing Facility

Each canister is 10 feet (3.1 m) tall, 2 feet (0.6 m) diameter and when filled, weighs 5,000 pounds (2,270 kg).

Currently placed in the Glass Waste Storage Buildings.

"The canisters will be temporarily stored at SRS until a federal repository is established" (they were expecting Yucca Mountain).

The Savannah River Site

SRS Overview 2021. Websites

https://www.youtube.com/watch?v=rRBqdP-yC8I (6:50)

Websites

https://www.srs.gov/general/srs-home.html

https://www.energy.gov/srs/savannah-river-site

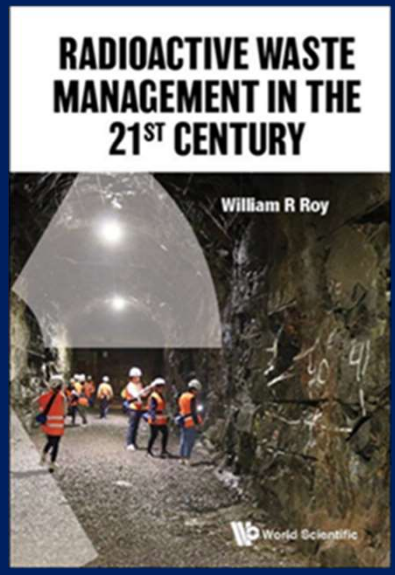
"DWPF Safely Dispositioning Liquid Waste"

https://www.youtube.com/watch?v=rESXUcSeQYU

(4:50)

Class Assignment 8

Read Chapter 9
Answer Review Question 6.
Rubric:
The assignment is worth 20 points.
There are 8 questions. Each is worth 2 points.
Figures and tables are worth 1 point each.



Questions?

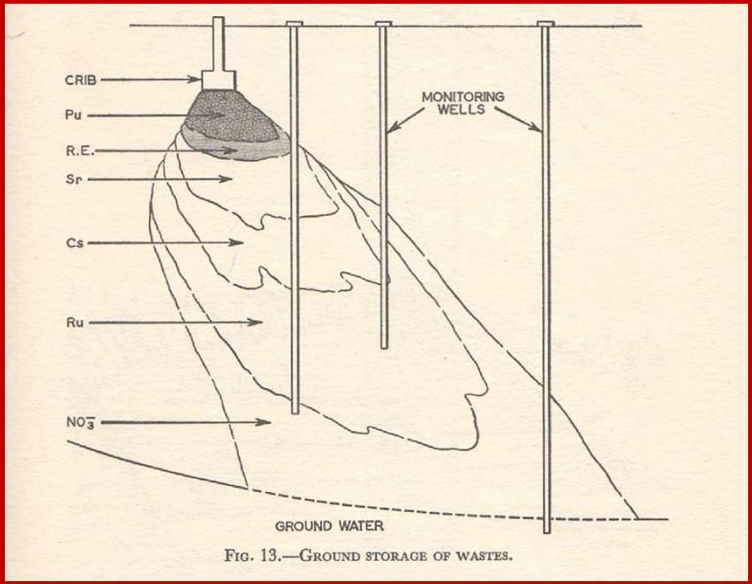


FIG. 13.—GROUND STORAGE OF WASTES.