The Waste Isolation Pilot Plant: A Potential Solution for the Disposal of Transuranic Nuclear Waste

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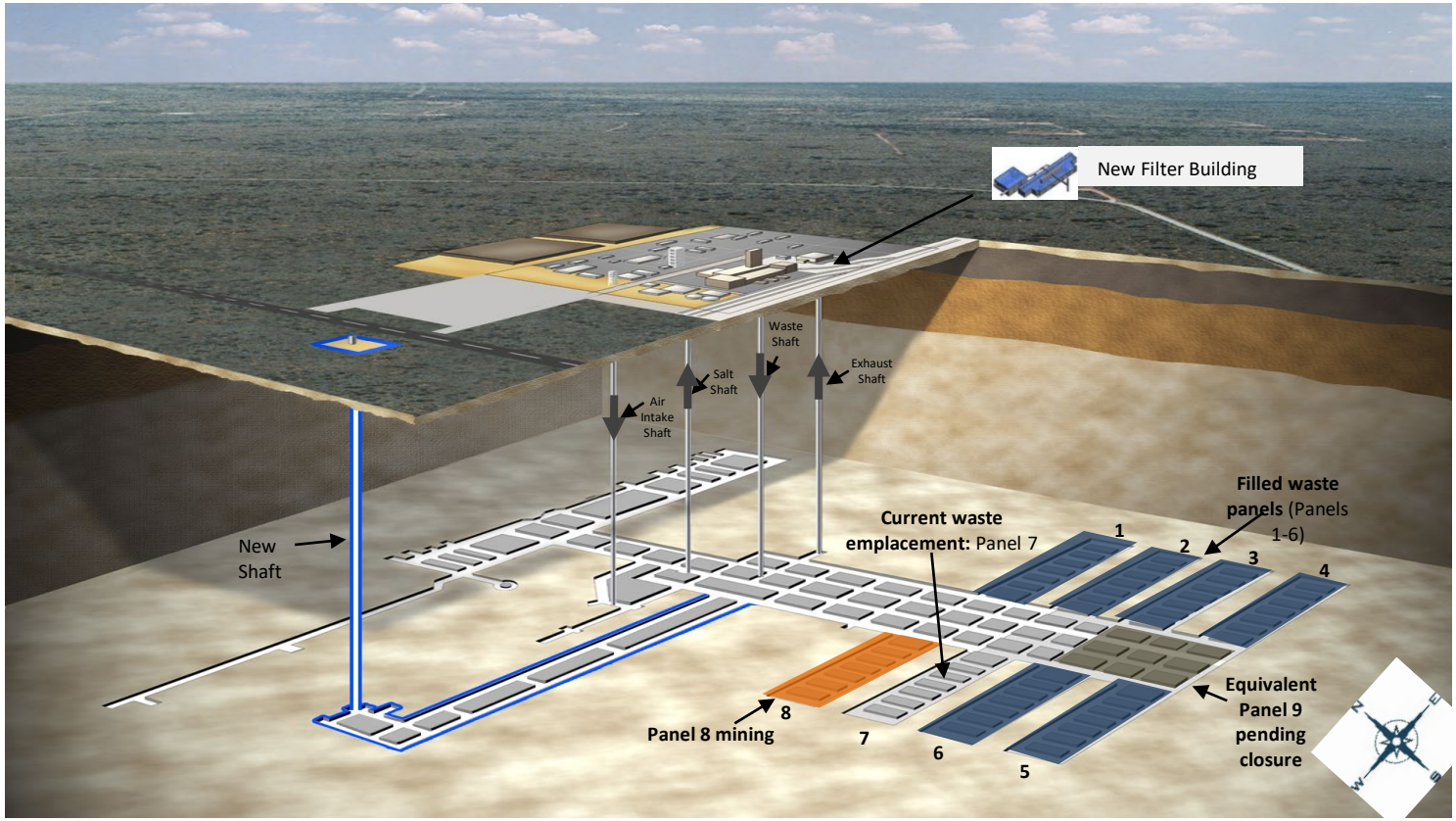
WIPP: A Working Repository

- 15 years of safe operations and permanent geological disposal of transuranic defense wastes [Intermediate-Level Long-Lived Waste by IAEA definition].
- Located in southeast New Mexico about 26 miles east of Carlsbad.
- TRU waste is man made radioactive elements that are heavier than uranium (Z>92).
- >100 nCi/g (>3700 Bq/g or ~1ppm) alpha emitting isotopes with $t_{1/2}$ > 20 years.
- WIPP is also the first to recover from an accident and resume operations.

WIPP Layout



Quick Facts: As of DEC 2020

- Opened March 26, 1999
- 12,827 shipments received
- 98,579 cubic meters of waste disposed
- 176,482 containers emplaced in the underground

WIPP Regulatory Framework

Public Law 102-579, WIPP Land Withdrawal Act (LWA), 102nd Congress

Withdraw certain public lands and to otherwise provide for the operation of WIPP

U.S. Department of Energy (DOE)

Worker Safety, Industrial Safety, Nuclear Safety, Radiological Safety, Security

U.S. Environmental Protection Agency (EPA)

Repository certification, TRU Waste Activity, PCB/TRU waste, air, ground water

New Mexico Environment Department (NMED)

RCRA hazardous constituents, air, water discharge, ground water

U.S. Nuclear Regulatory Commission (NRC)

Transportation Type B packages for nuclear materials

U.S. Department of Transportation (DOT)

Highway transportation, Type A containers

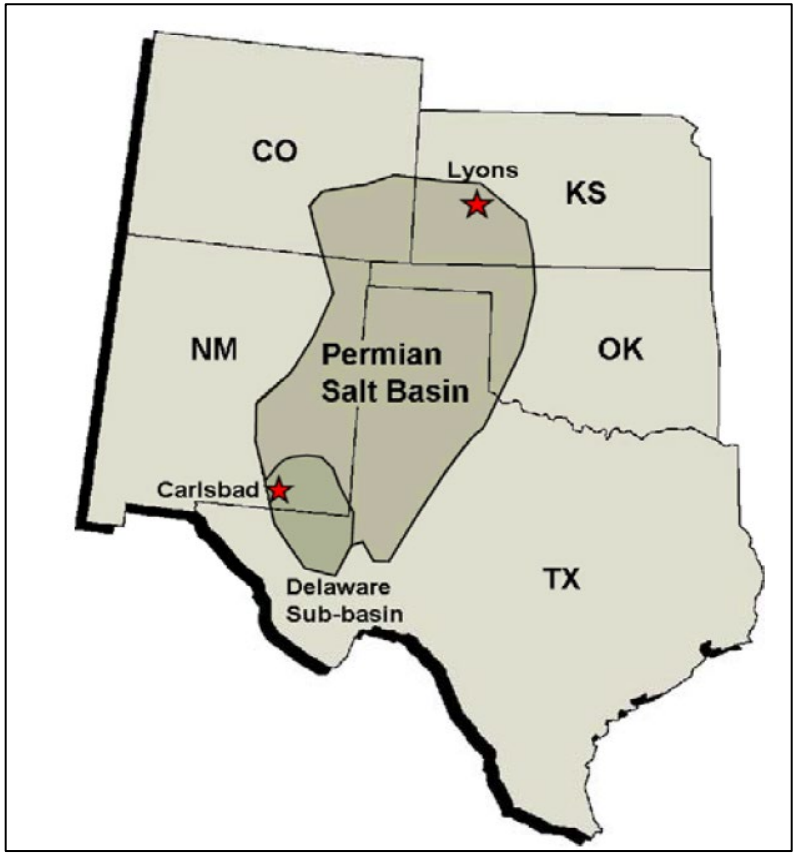
Salt is the reason for WIPP's location

National Academy of Sciences (NAS) concludes in 1957 that the most promising disposal option for all radioactive waste is in massive salt deposits

"Salt at great depth 'flows.' It will encapsulate any waste placed at depth and isolate it from the surface environment for eons." – NAS

"Salts are not all equal: Massive interbedded domed"

"The great advantage is that no water can pass through salt. Fractures are self healing.." - NAS



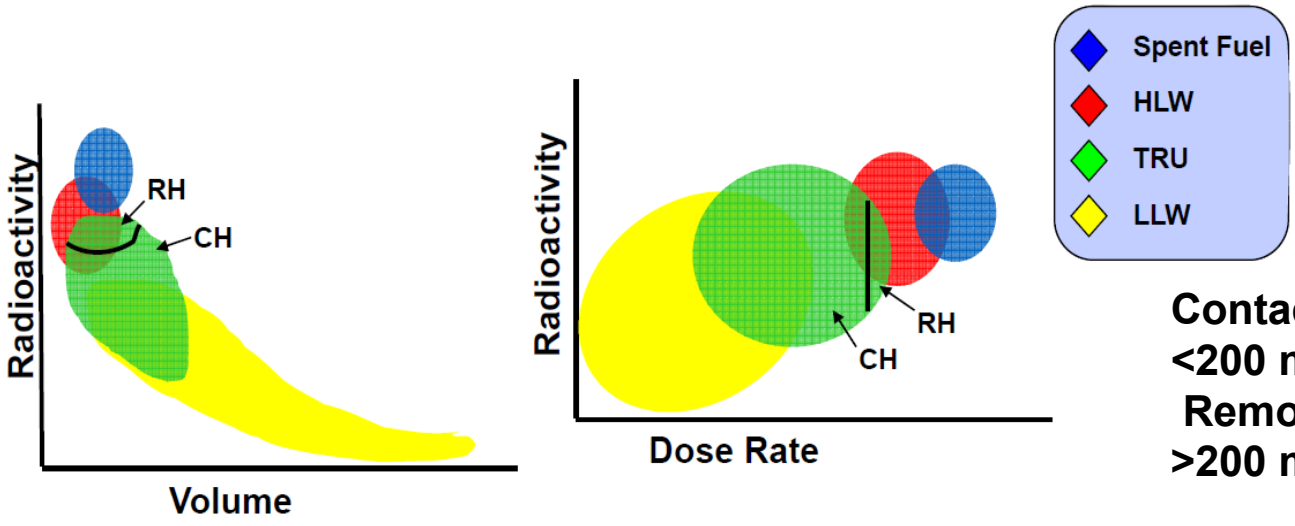
Nuclear waste Classifications in the US

In the meantime…..

….disposal options for waste from power production versus weapons production begins to diverge in the 1970's

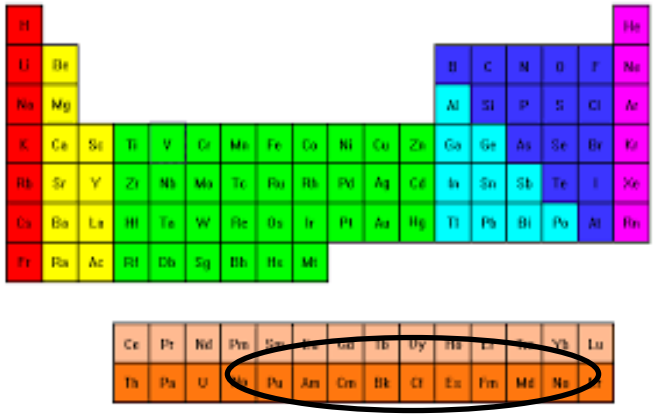
1970 - AEC establishes new category for transuranic waste, distinct from low-level radioactive waste.

1976 - Atwater convinces Ford/Carter to outlaw reprocessing of commercial spent fuel; retrievable storage concept is born.



Contact Handled (CH)
<200 mrem/hr
Remote Handled (RH)
>200 mrem/hr

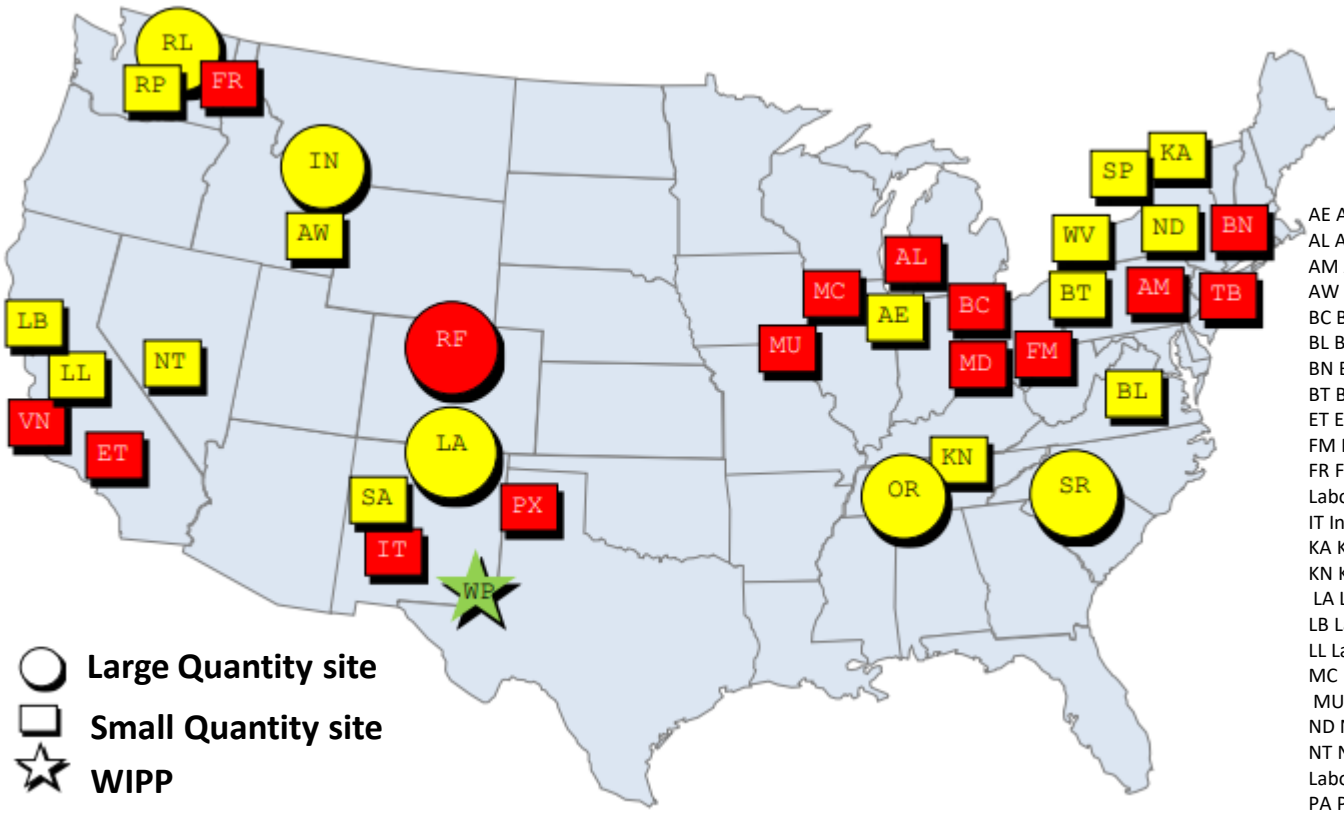
TRU waste Properties



- **Materials contaminated with man-made radioactive elements heavier than uranium**
  - Debris: clothing, tools, rags, containers, etc.
  - Soils
  - Homogeneous solids, residues
- >100 nCi/g (>3700 Bq/g ~1ppm):
  - alpha emitting isotopes
  - $t_{1/2}$ > 20 years
- Two types of TRU waste
  - Contact-handled (<2 m Sv/hr)
  - Remote-handled (>2 mSv/hr)
- Legacy inventory ~700,000 drum equivalents

Z > 92 (transuranic)

U.S. Department of Energy TRU Waste Generator Sites



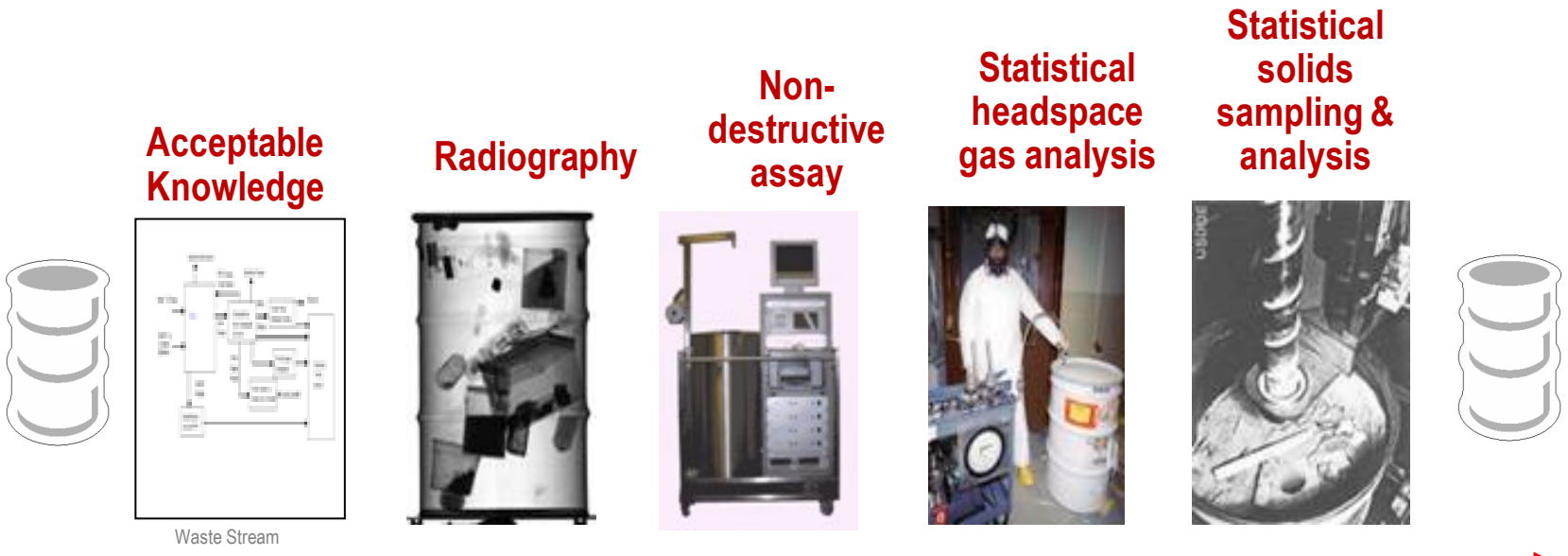
AE Argonne National Laboratory
AL Ames Laboratory
AM ARCO Medical Products
AW Material and Fuels Complex
BC Battelle Columbus Laboratories
BL Babcock and Wilcox Nuclear Energy Services
BN Brookhaven National Laboratory
BT Bettis Atomic Power Laboratory
ET Energy Technology Engineering Center
FM Fernald Environmental Management Project
FR Framatome (AREVA) IN Idaho National Laboratory
IT Inhalation Toxicology Research Institute
KA Knolls Atomic Power Laboratory
KN Knolls Atomic Power Laboratory-NFS
LA Los Alamos National Laboratory
LB Lawrence Berkeley Laboratory
LL Lawrence Livermore National Laboratory
MC U.S. Army Materiel Command MD Mound Plant
MU University of Missouri Research Reactor
ND Nuclear Radiation Development Site, Inc.
NT Nevada Test Site OR Oak Ridge National Laboratory
PA Paducah Gaseous Diffusion Plant
PX Pantex Plant
RF Rocky Flats Environmental Technology Site
RL Hanford Site (Richland Operations Office)
RP Hanford Site (Office of River Protection)
SA Sandia National Laboratories
SP Separations Process Research Unit
SR Savannah River Site
TB Teledyne Brown Engineering
VN General Electric Vallecitos Nuclear Center
WV West Valley Demonstration Project
WP Waste Isolation Pilot Plant

Red = De-inventoried of all TRU waste

Yellow = Active Sites

Characterization

Process to determine the physical, chemical and radiological contents of TRU waste containers to ensure that waste is acceptable for disposal at WIPP



Use documented waste stream knowledge to identify waste contents

Look for prohibited items, such as aerosol cans or liquids

Determine radiological contents

Determine volatile organic compound contents

Performed on samples of homogeneous waste to analyze for chemical hazards

Central Characterization Project

(deploying mobile waste characterization systems to sites around the complex

Mobile systems perform waste characterization at sites that lack equipment, and to supplement sites with their own facilities to keep 'pipeline' full

Systems currently deployed at:

- **Savannah River Site (SRS)**
- **Idaho National Laboratory (INL)**
- **Los Alamos National Laboratory (LANL)**
- **Oak Ridge National Laboratory (ORNL)**
- **Argonne National Laboratory (ANL) – RH only**

Mobile systems can characterize ~90-100 waste packages/week (~3 shipments/week)

Throughput limited by the rate that host site can supply compliant feed containers (highly dependent on remediation of prohibited items, e.g., liquids)

Eliminates need to build costly fixed facilities, saving taxpayers millions (cost still ~$2,500 per package)

Transportation

Waste containers are loaded into protective shipping containers (such as TRUPACT-II)

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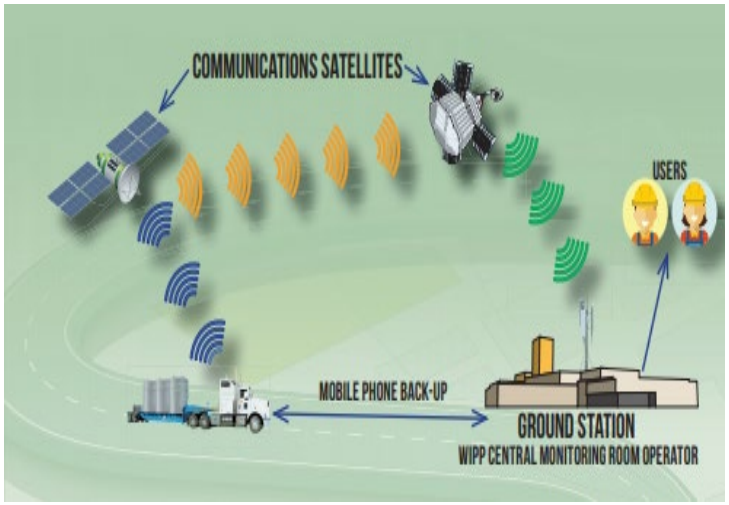
Drivers inspect their rigs and loads every 3 hours or 150 miles. Some states require additional inspections at their ports of entry

Shipment tracked by satellite



For safety and security reasons, shipments are tracked throughout their journey using a satellite system (TRANSCOM)

WIPP-trained state and local emergency responders (~30,000) along all shipping routes, with frequent exercises

WIPP's Shipping Containers

TRUPACT II

Half Pact

TRUPACT III

RH 72B

WIPP has a nationally recognized transportation safety program

WIPP Transportation Routes

Highway Legend

- Interstate Highway
- U.S. Highway
- Principal Highway

Every town and city along all WIPP transportation routes have been provided radiation and nuclear hazard response training (Over 30,000 fire, police and medical first responders

WASTE EMPLACEMENT

Mining the Salado is the easiest and safest mining operation in the world – a soft rock

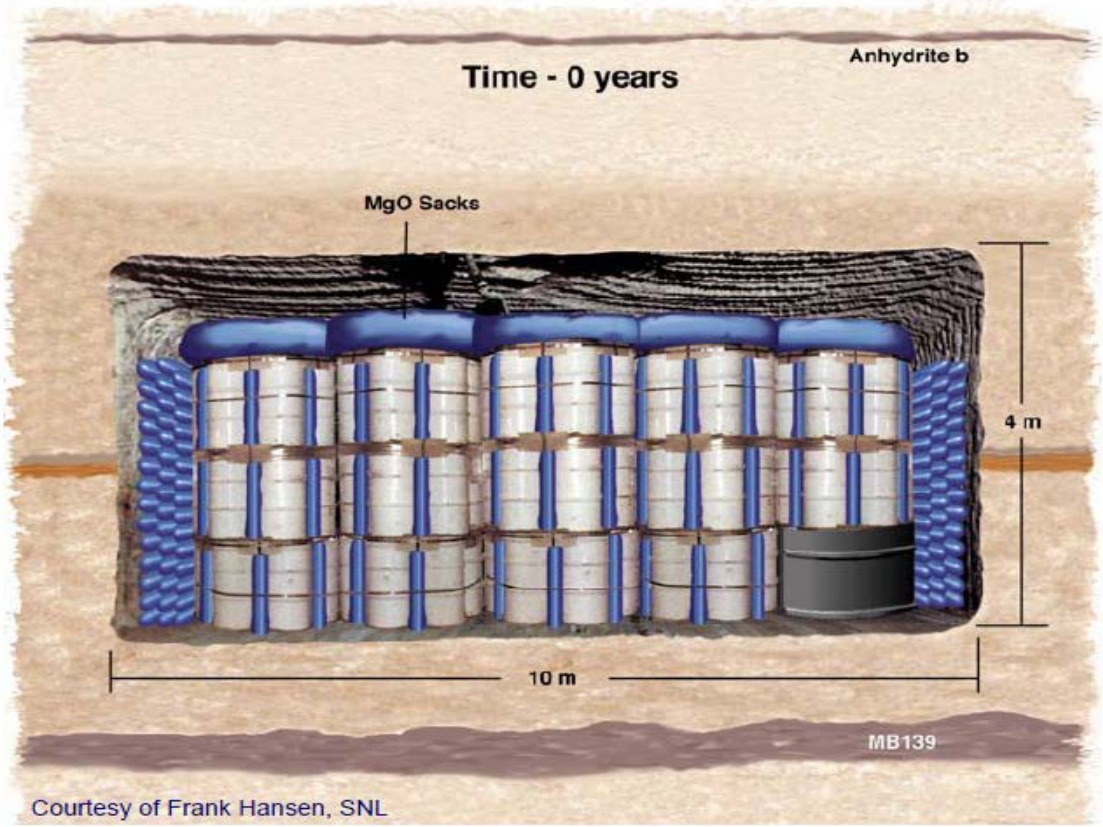
RH Waste Emplacement

The higher activity waste is remotely handled in shielded transport casks

The higher activity waste is remotely plunged into boreholes the room walls prior to filling with the lower activity waste

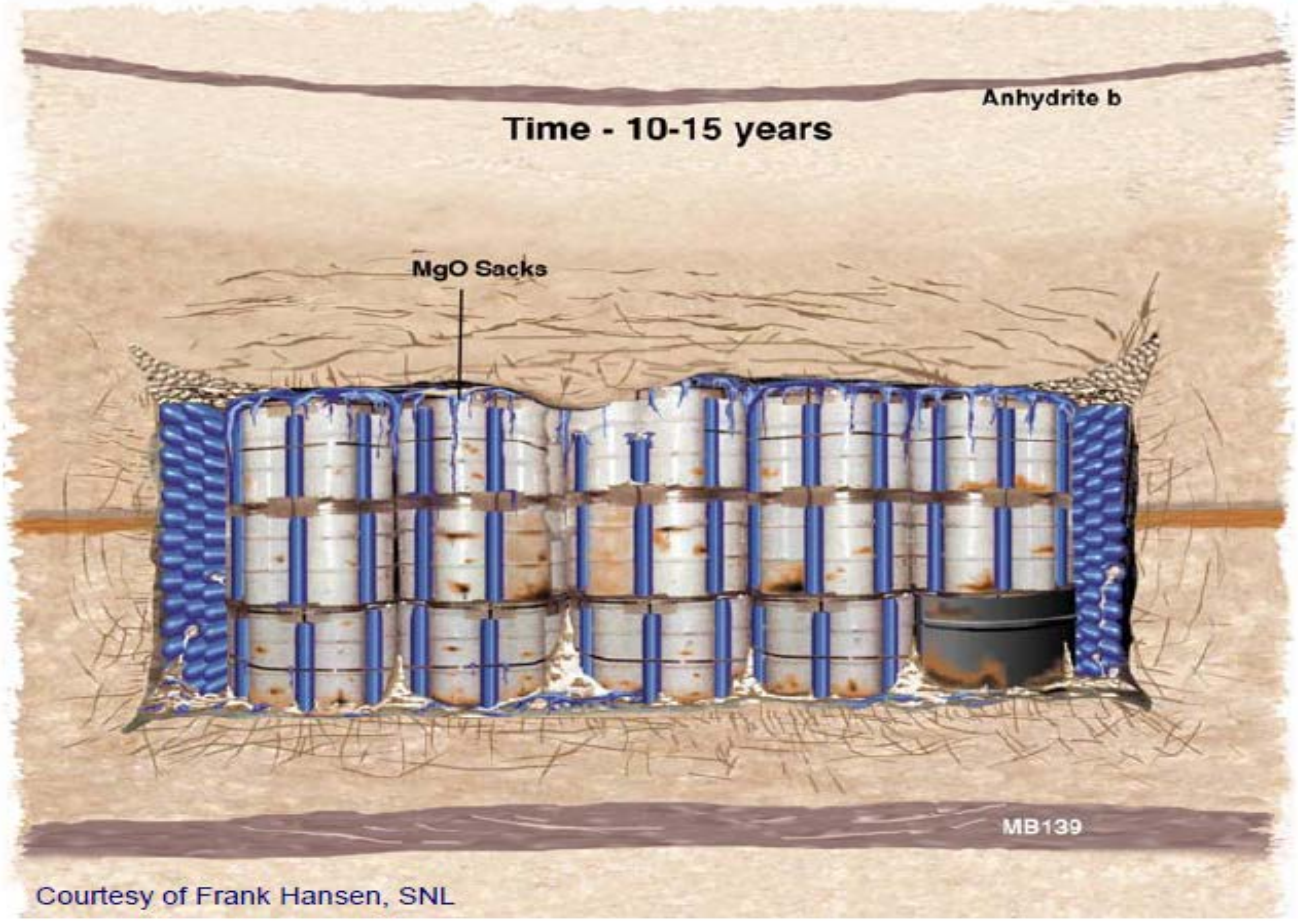
How salt encapsulates the Waste

Evolution of the WIPP Disposal Rooms (t = 0 yrs)



Courtesy of Frank Hansen, SNL

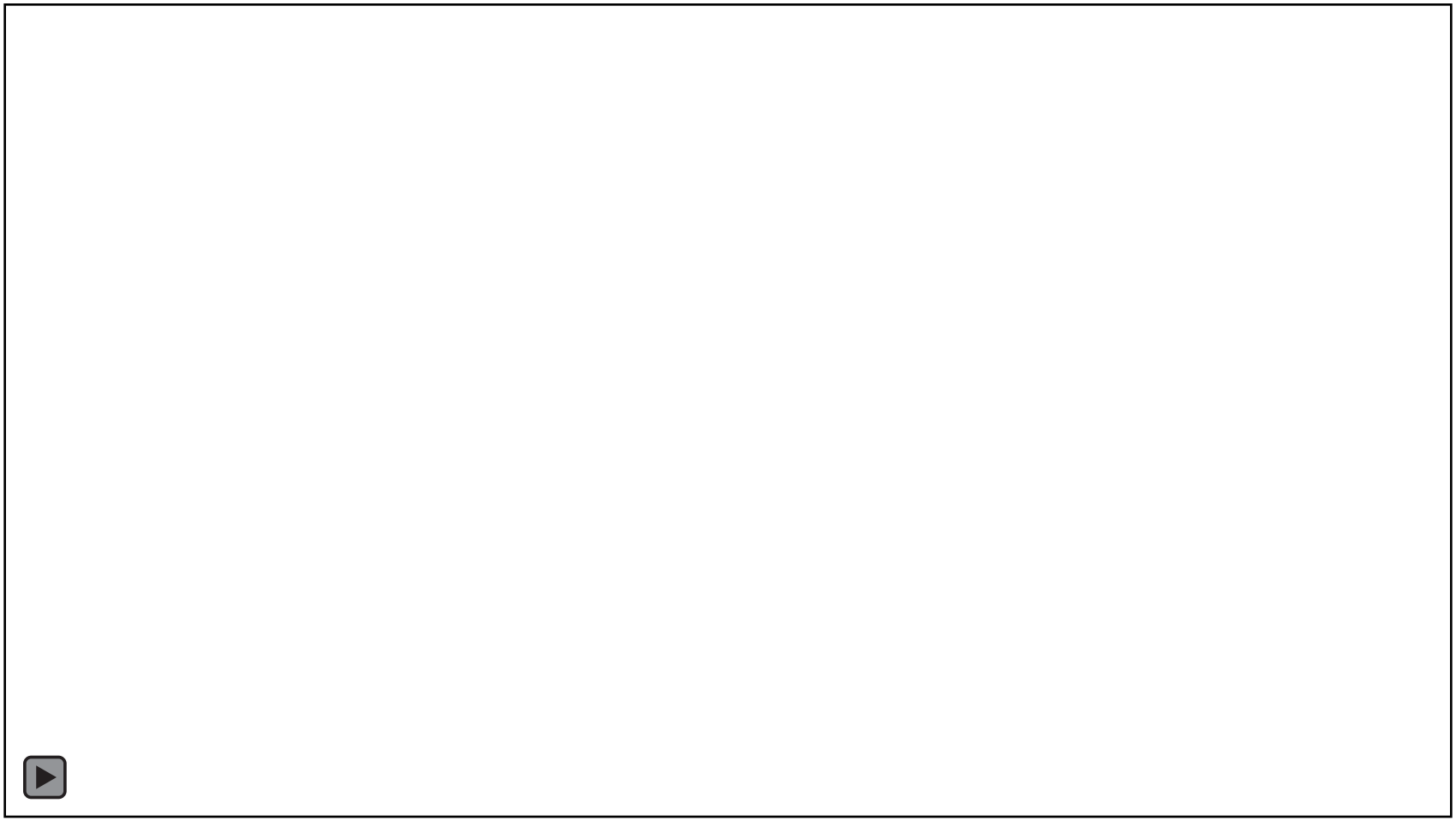
Evolution of the WIPP Disposal Rooms (10-15 yrs)



Courtesy of Frank Hansen, SNL

Evolution of the WIPP Disposal Rooms (1000 yrs)

WIPP experience (Video)



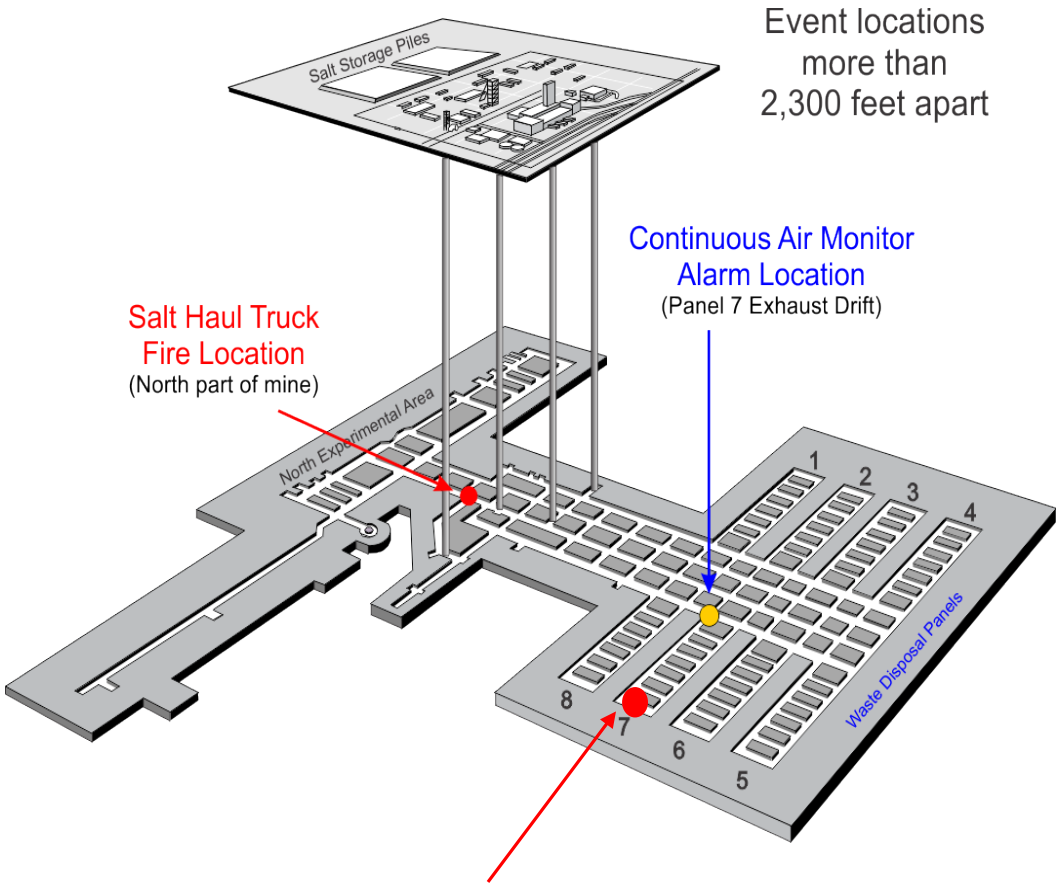
After 20 Years WIPP's merits and issues are still debated

The first transuranic waste shipment arrives at the Waste Isolation Pilot Plant in the early morning of March 26, 1999.

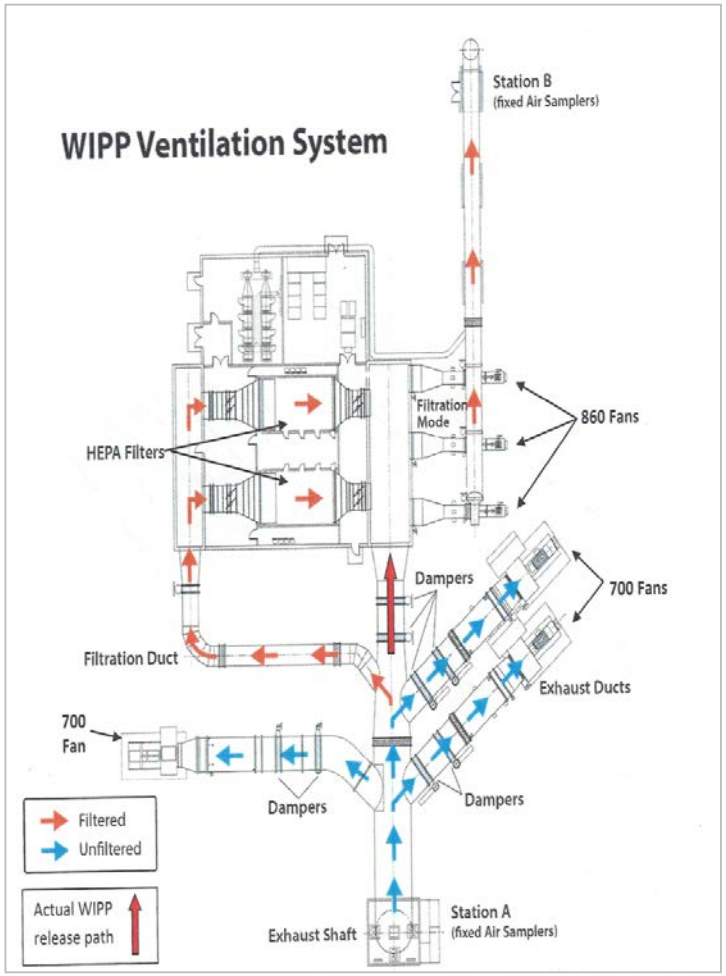
WIPP Incidents

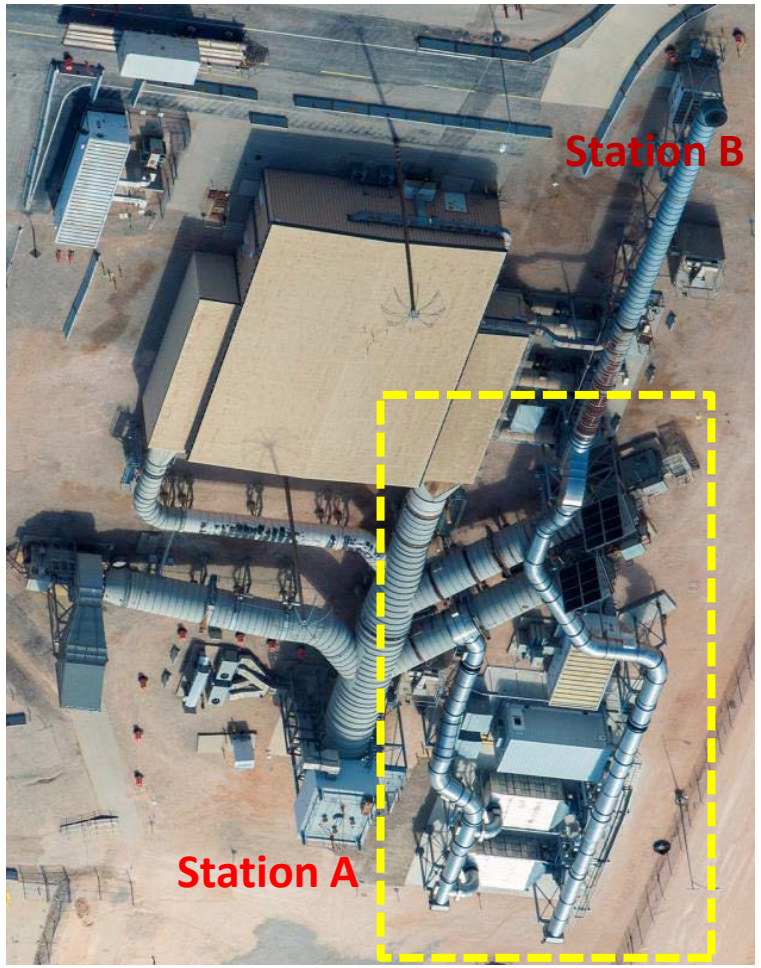
February 5, 2014 Underground Fire

February 14, 2014 Radiation Release



Filtration bypass allowed some (minor) external contamination





- **Two leaking dampers allowed some contamination to bypass the filtration system**

Underground Source Term Estimation

- The total radiological inventory in the drum was estimated to be around 9 Ci.
- It is estimated that between 5% and, at most, 20% of the drum inventory released into the WIPP underground.
- Source term estimation ~ 0.3-1.5 Ci of radioactivity released from the breached drum.
- The radiological constituents in the drum include: ^{241}Am, ^{243}Am, ^{237}Np, ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{241}Pu, and ^{242}Pu (>95% of activity).

Data source: CEMRC, NWP and Hunter & Viner 2015

Consequence Assessment

Environmental Monitoring and WIPP

- **Before site selection, DOE and local community leaders recognized the value of independent oversight for maintaining community support**

- **The purpose was to independently establish a baseline before operations began, and then evaluate the radiological fingerprint of the facility in its environmental setting throughout its operational lifetime.**

- **The Land Withdrawal Act (Public Law 104-201) established monitoring through the Environmental Evaluation Group (EEG).**

- **The New Mexico Environment Department (NMED)- DOE Oversight Bureau, established in 1989.**

- **The Carlsbad Environmental Monitoring and Research Center (CEMRC), established in 1991.**

CEMRC's -Independent Monitoring Program Overview

- Funded Primarily by the Department of Energy (DOE) through a grant (NOT a contract) that respects CEMRC independence
  - Current funding level $3m per year (~80% of total funding for CEMRC)
  - CEMRC monitoring and other work includes:
    - WIPP Underground Exhaust Air
    - Ambient Air
    - Drinking Water
    - Soil and sediment
    - Surface Water & Ground water
    - Whole Body Counting for Area Residents age 13+
    - R&D on monitoring methods and technologies

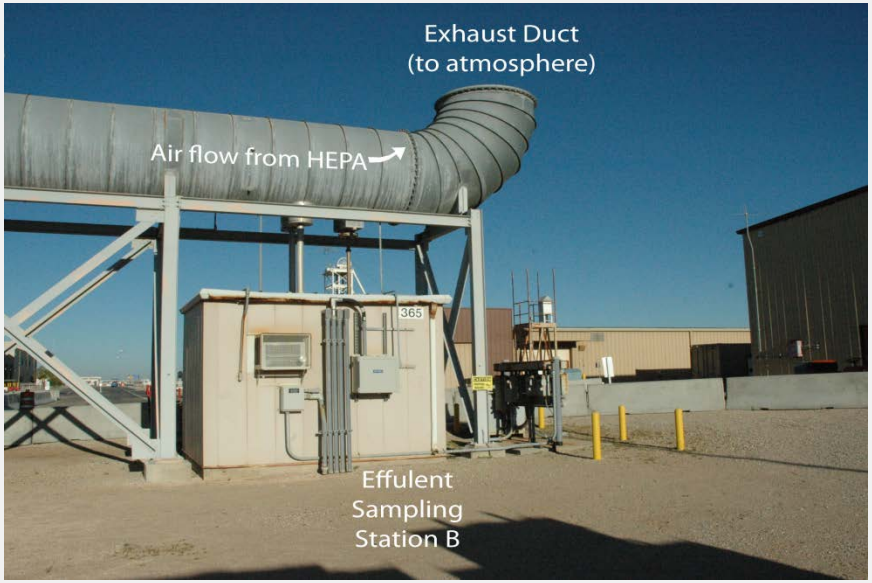
Role of Independent Environmental Monitoring

- CEMRC communicated all its monitoring results to the public through press releases and by posting on the CEMRC website *www.cemrc.org*
- Timely dissemination of independently measured and interpreted environmental monitoring data following the release event, through local newspaper and Town Hall type meetings, helped develop trust through transparency
- Public access to the monitoring data and their ability to directly participate in CEMRC's whole body counting program provided a sense of security to concerned citizens after the event
- Develop relationships with the host community – local and online
- Establish trust before an incident – during the incident is too late
- CEMRC helped alleviate fear in the local community and restored confidence <u>because it is independent</u>

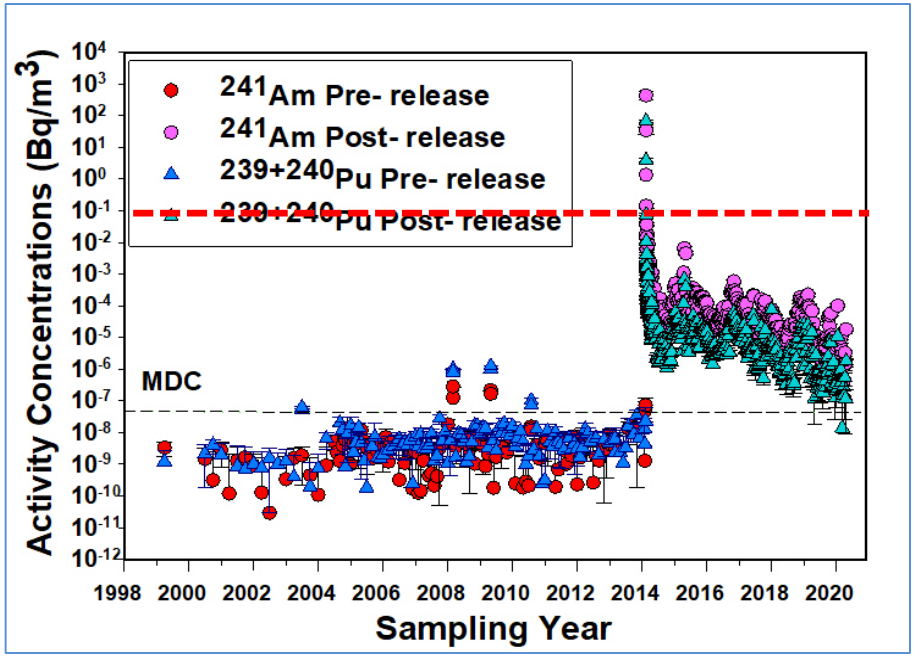
WIPP Underground Air Sampling Stations (A and B)

Station A, before filtration

Station B, at post-filtration outlet

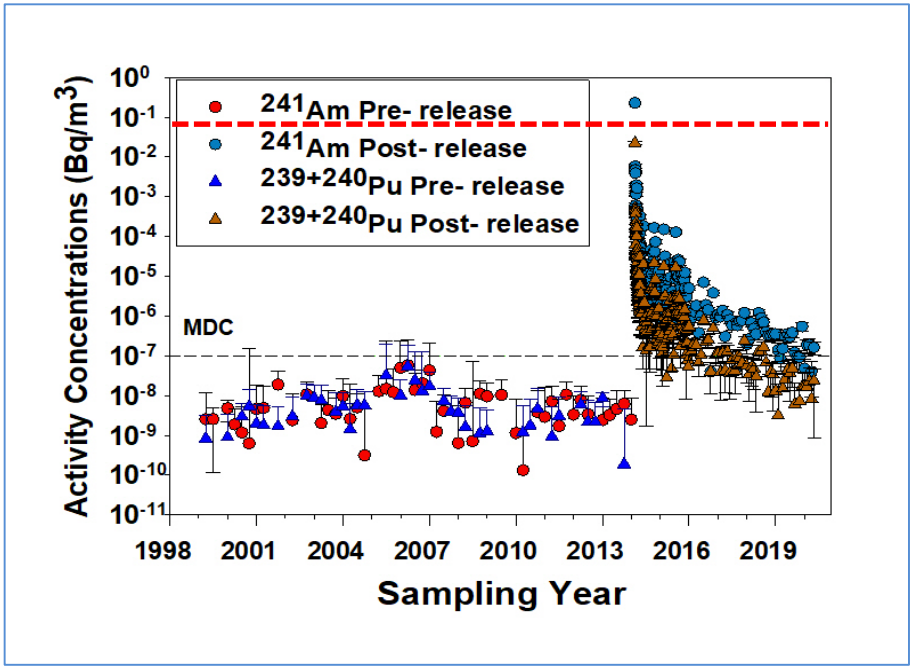


Current Radiation Levels in the WIPP Underground Air



Unfiltered (Pre-HEPA)
Exhaust air

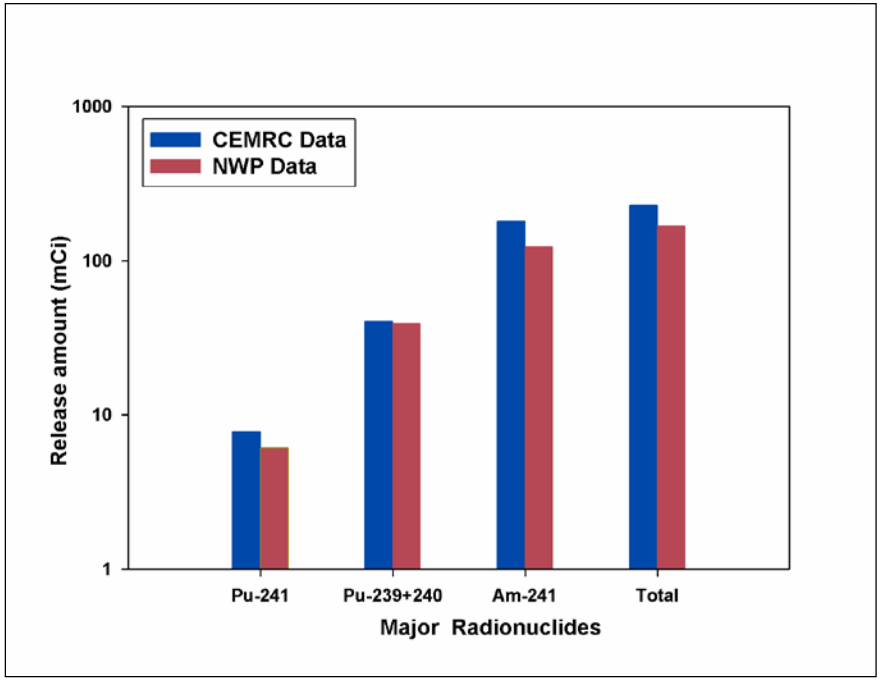
1 DAC Pu-239



Filtered (Post HEPA) Exhaust air

Source Term From Station A-Filter Analysis

Total Estimated Release of Radio-activity to Station A from the WIPP underground



CEMRC analyses:

- 180.1 mCi of ^{241}Am and
- 40.3 mCi of $^{239+240}$Pu

Total = (~228 mCi)

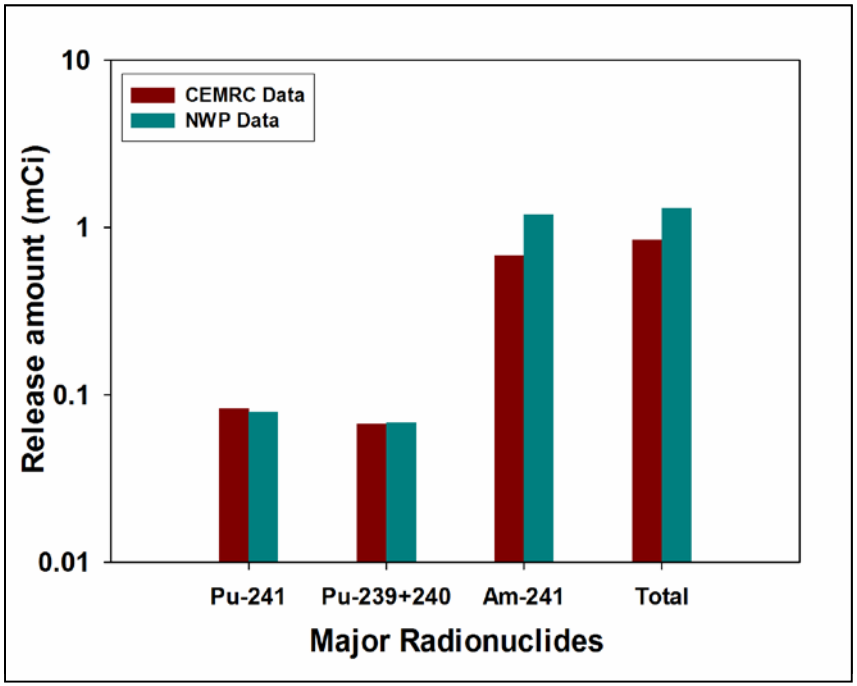
NWP analyses :

- 123.1 mCi of ^{241}Am and
- 39.1 mCi of $^{239+240}$Pu

Total = (~168 mCi).

Total Environmental Release

Total atmospheric Released



CEMRC analyses:

- 0.72 mCi of ^{241}Am and
- 0.067 mCi of $^{239+240}$Pu

Total = (~1 mCi).

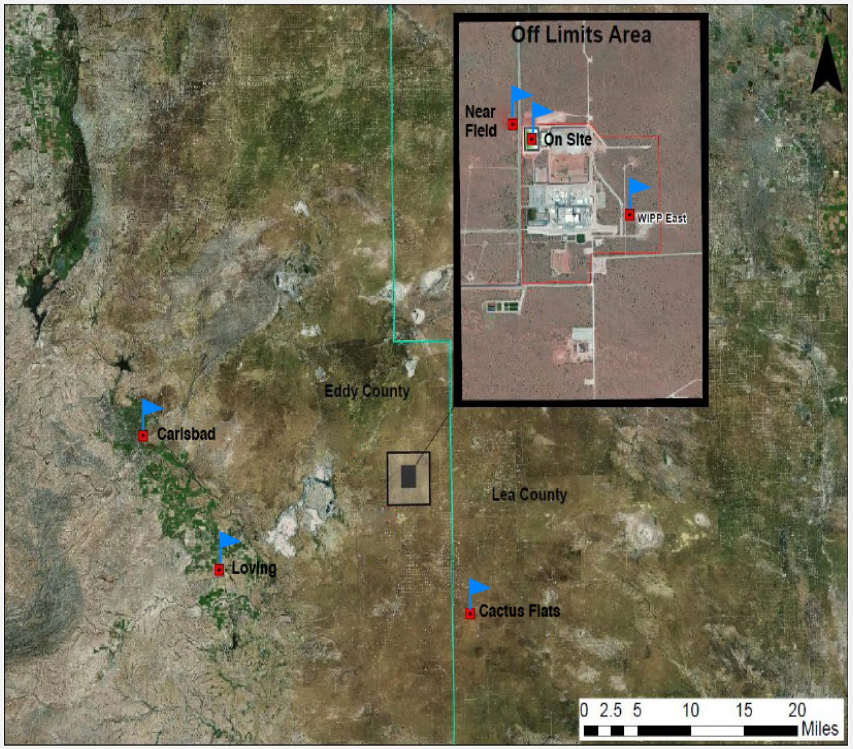
NWP analyses :

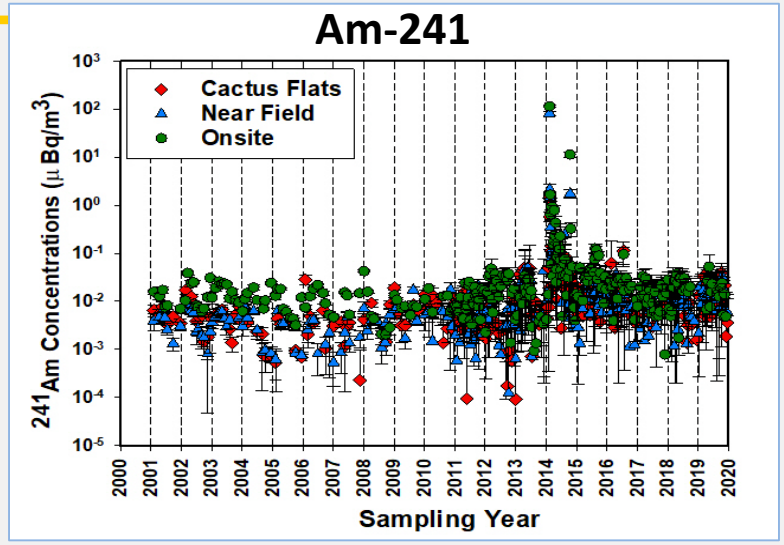
- 1.21 mCi of ^{241}Am and
- 0.068 mCi of $^{239+240}$Pu

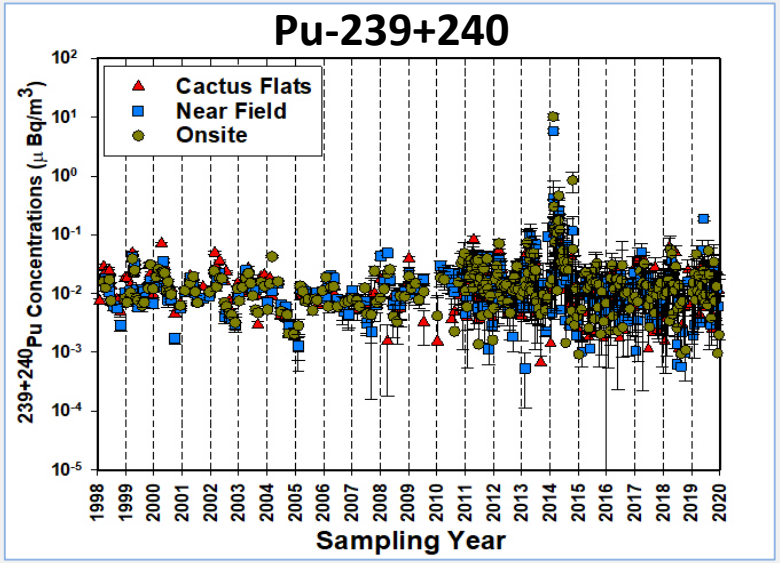
Total = (~1.3 mCi).

On Site and Off Site Radiation Levels

CEMRC Air sampling sites





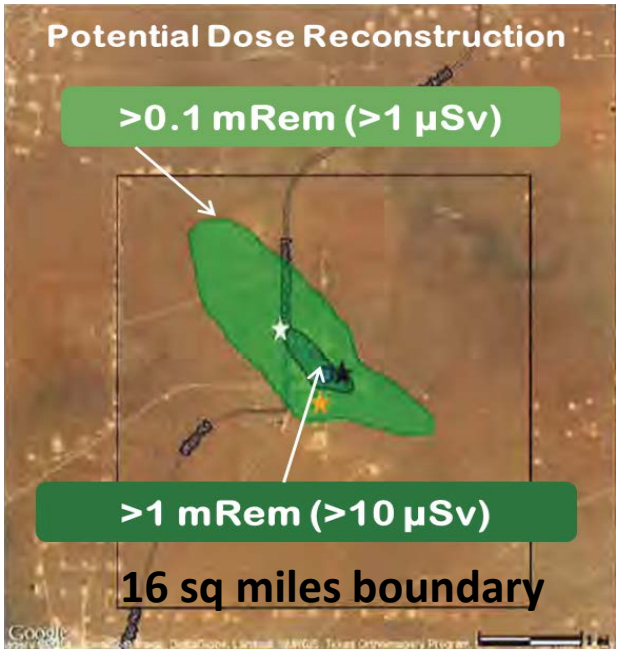


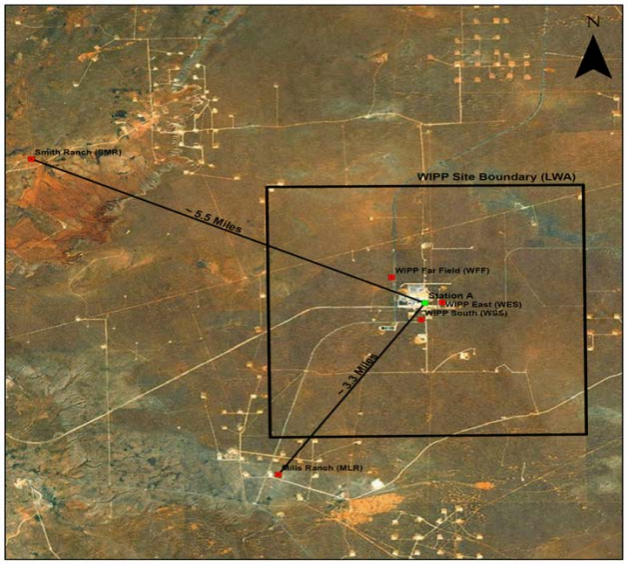
- Onsite detection: 115 µBq/m³ of ^{241}Am; 81.4 µBq/m³
- No off-site hi-volume sampler detections were positively attributable to the WIPP release event.

Modeling the atmospheric dispersion plume

14-15 February 2015 release was modeled based on measured filter values and wind data in 15-minute increments

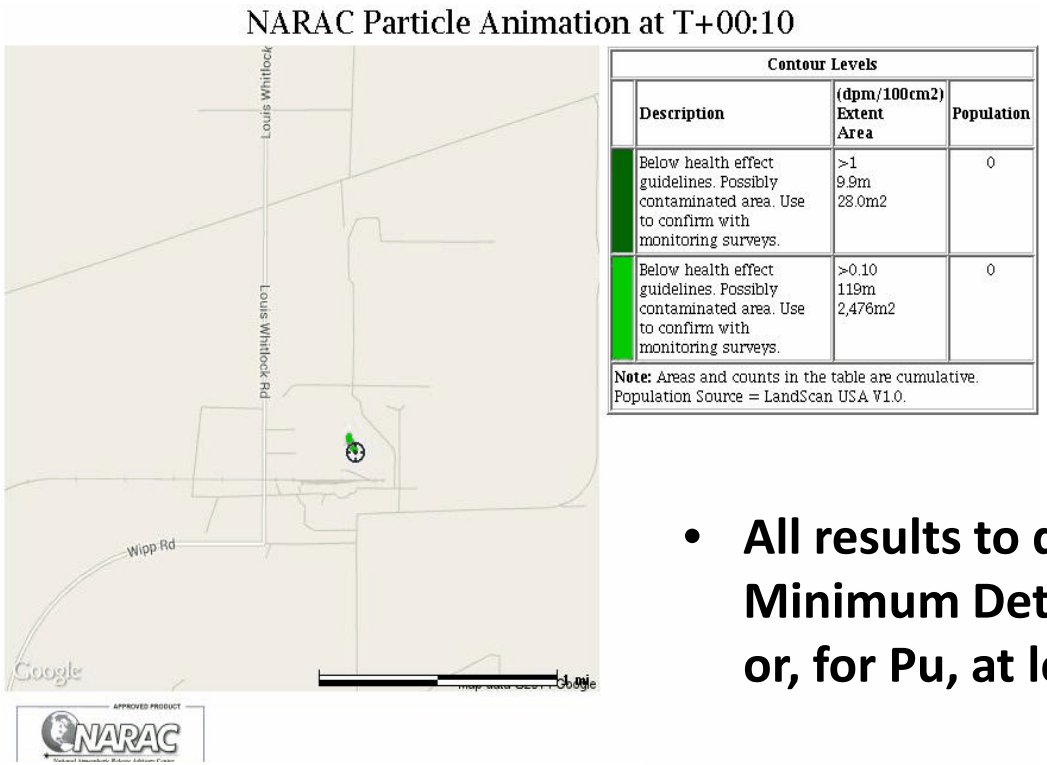
- **Inhalation doses constructed as if all alpha was only ^{239}Pu (conservative) and a hypothetical human breathed for entire duration of release.**
- **Inner darker green area >0.01 mSv**
- **Outer green area ranged from 0.01 to 0.001 mSv.**
- **Stars indicate sampling stations.**
- **Modeling of deposition in both green areas suggested none would be detectable on soil or vegetation (proven correct).**





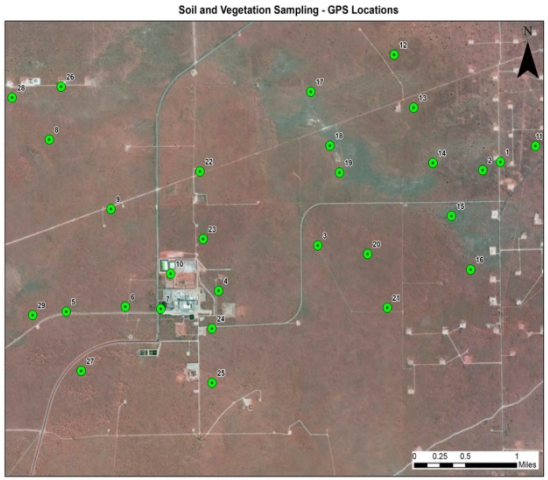
Ground Contamination in the WIPP Vicinity

Both predicted and measured values of ground contamination are below detectable levels



Contour Levels			
	Description	(dpm/100cm2) Extent Area	Population
	Below health effect guidelines. Possibly contaminated area. Use to confirm with monitoring surveys.	>1 9.9m 28.0m2	0
	Below health effect guidelines. Possibly contaminated area. Use to confirm with monitoring surveys.	>0.10 119m 2,476m2	0
Note: Areas and counts in the table are cumulative. Population Source = LandScan USA V1.0.			

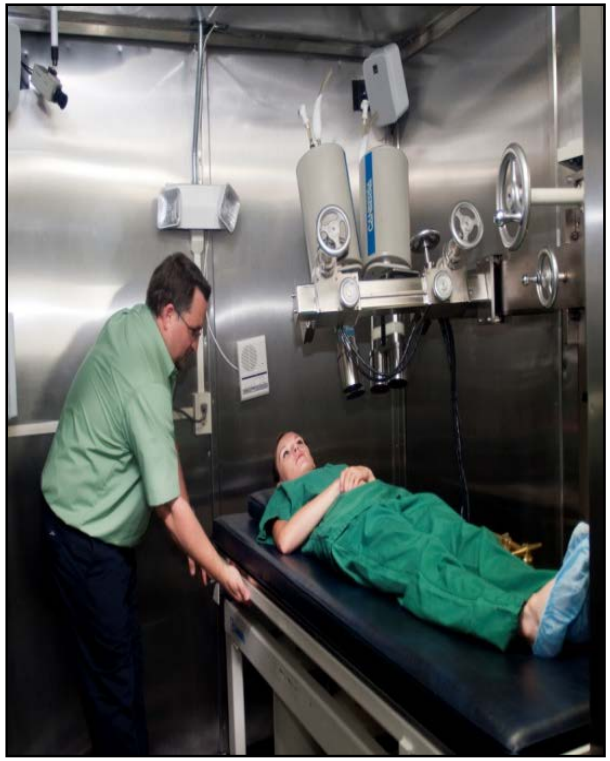
Accumulated Deposition During First 12 hours



Soil Location

- **All results to date were either below Minimum Detectable Concentrations (MDCs) or, for Pu, at levels seen prior to the event**
- **Positive Pu detections did not have detectable Am, suggesting a non-WIPP event source, perhaps the nearby Gnome test's atmospheric release (1961)**

Workers Exposer- Radio-bioassay



Fecal samples: 31

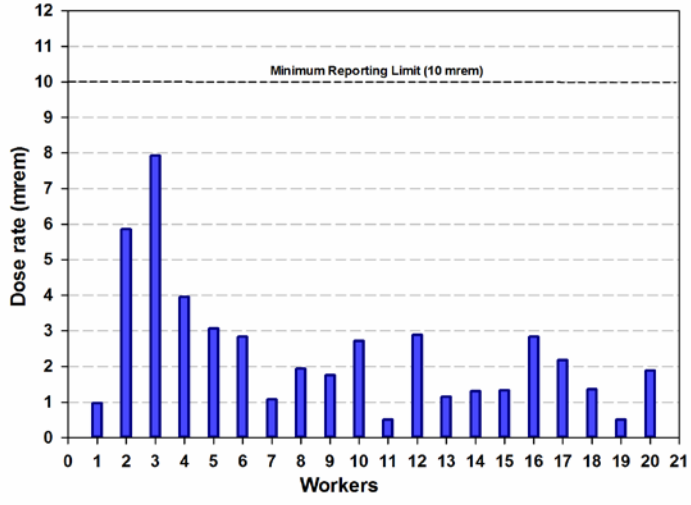
- 21 low-level positive
  - 21 positive for ^{241}Am
  - 7 positive for Pu
- 0.024 Bq (1.45 dpm) was highest total activity in a sample

Urine samples: 140

- 1 low-level ^{241}Am positive

- Between Feb-July, 2014, 144 WIPP workers and 42 local citizens were counted.
- 0.1 nCi MDA for ^{241}Am
- ^{241}Am not detected.

Dose to the Contaminated workers

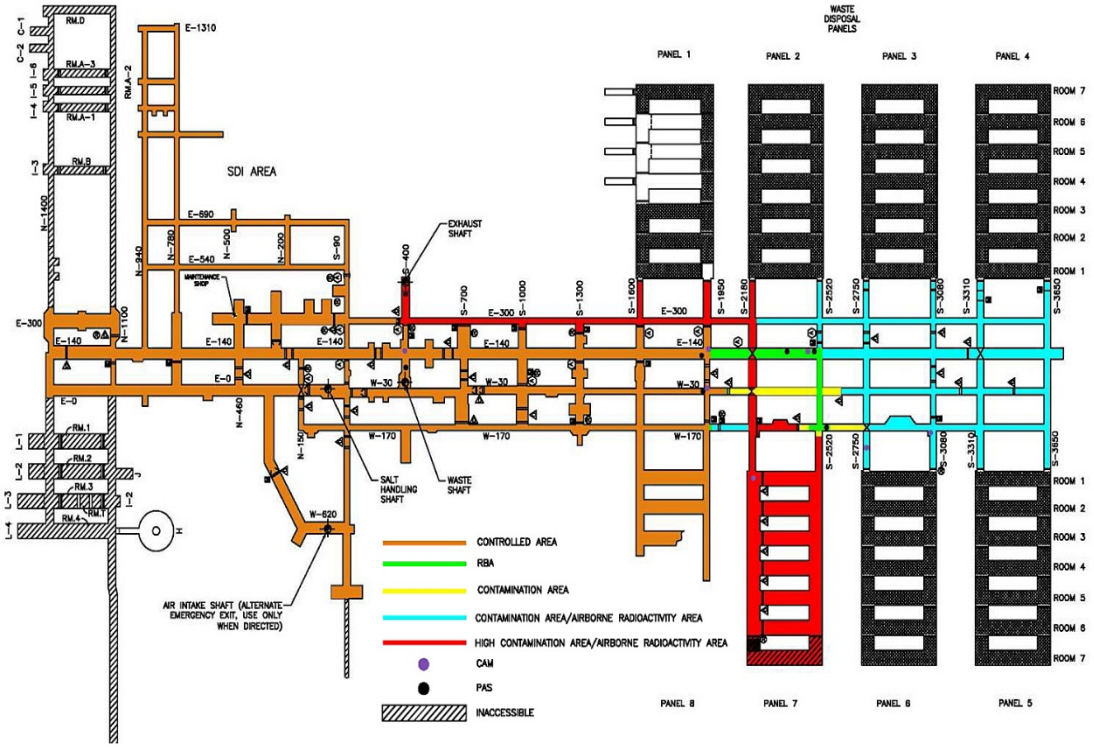


WIPP Underground –Contamination Status

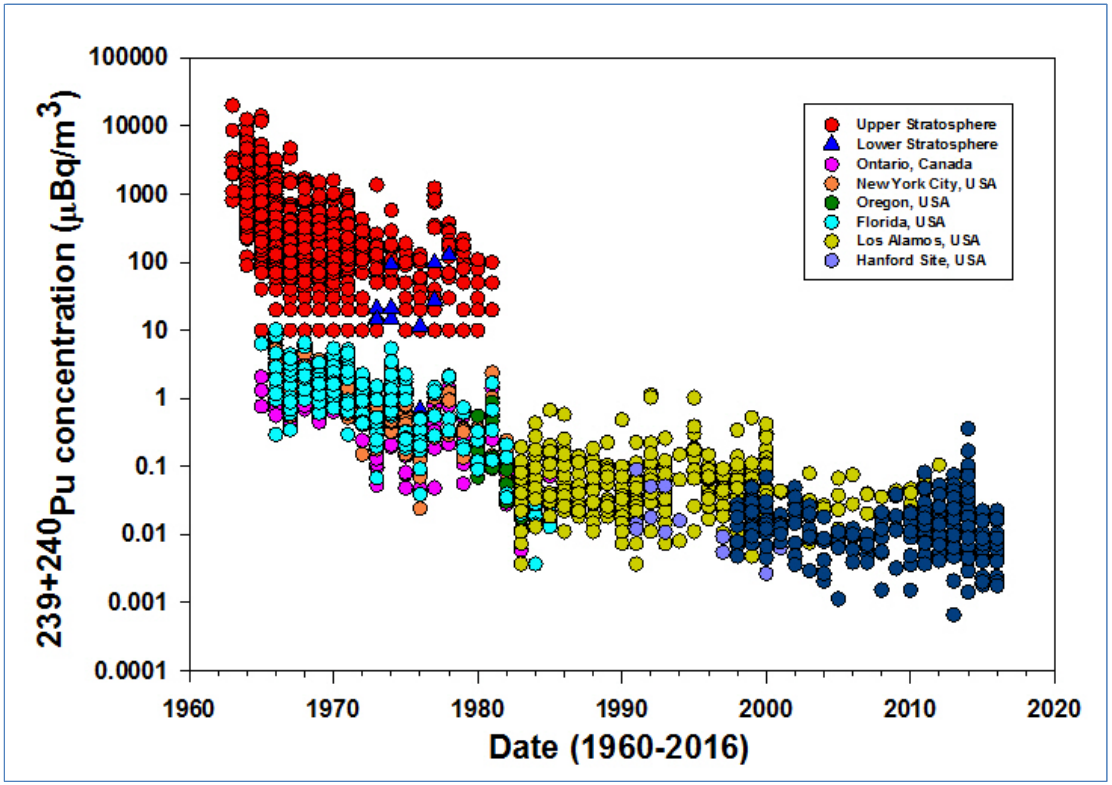
A water spray is being used to remove and "fix" contamination from walls and ceilings (ribs and backs).

When the salt recrystallizes, it encapsulates the contamination and prevents any resuspension of radioactive.

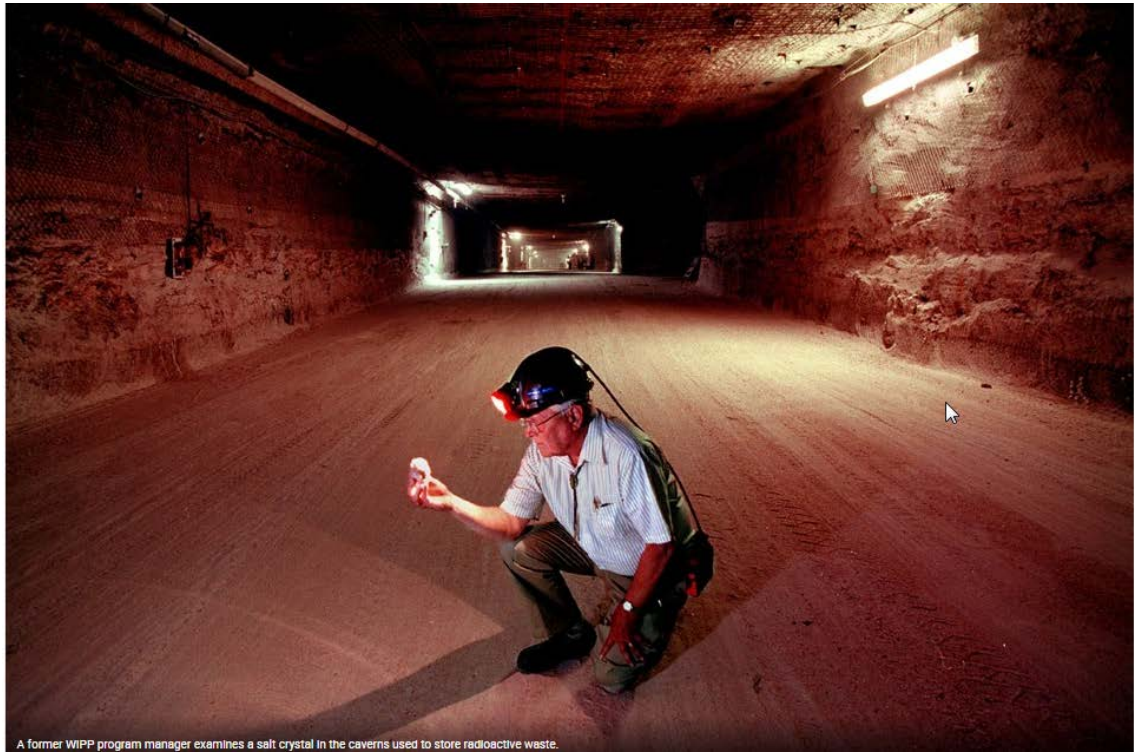
In some areas, Brattice cloth and a layer of uncontaminated salt on top of the cloth are used to further trap any contamination on the floor.



Plutonium Ambient Air Concentrations in the US



WIPP underground is a radiation-deprived environment


A former WIPP program manager examines a salt crystal in the caverns used to store radioactive waste.

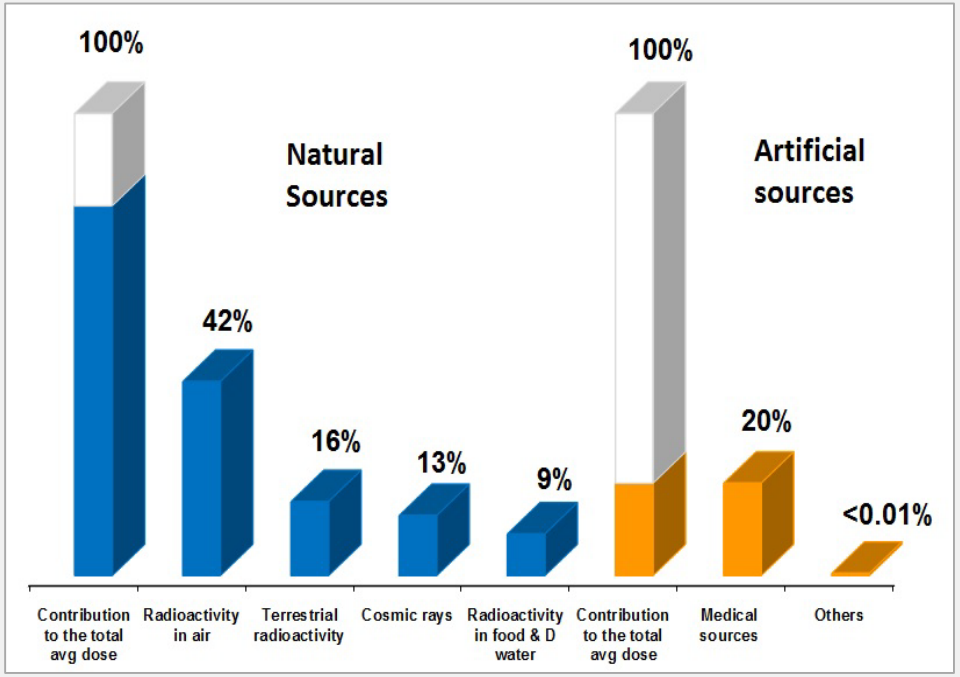
WIPP radiation levels average

- **0.031 µSv/h at the surface,**
- **0.006 µSv/h 655m underground or 2.2 µSv/year**

Source: G.B. Smith, et al., Health Physics,100: 263-265 (2011).

Why Are We So Afraid of Nuclear ?

- Radiation and the risk associated with it -is the sole reason why people fear and nuclear energy.
- General public often associates nuclear energy with radiation and radiation with cancer.
- Natural radiations are less scary- but radiation from nuclear facilities are dangerous.
- Just because we can measure radiation does not necessarily mean that it is dangerous.
- We live in a world that is full of natural radiation-yet our species thrives. Therefore we must have developed a mechanism to cope with the biological effects of radiation.



FEAR OF RADIATION: The Problem as it Stands Today

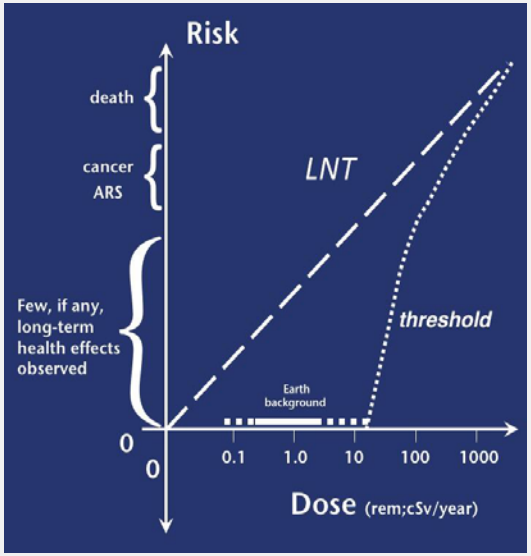
NMSU Low Background Radiation Experiments

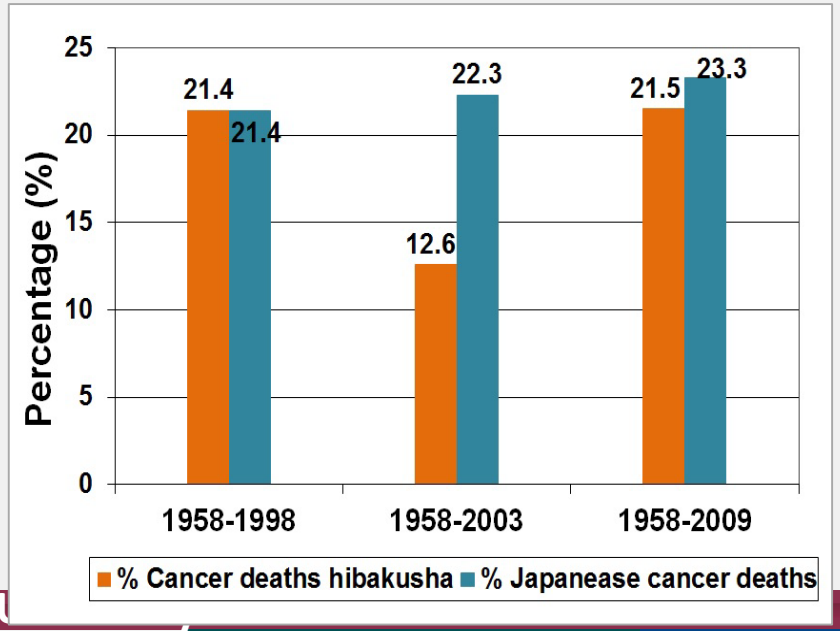
- **The fear of radiation originated around 1959, when the world adopted a hypothesis called the Linear No-Threshold (LNT).**

- **The LNT assumes that there is no amount of radiation is safe, even the earth's background.**
- **Scientific data show health effects only at high (>100 mSv) exposures**

  Leukemia incidence of 96,000 Hiroshima atomic bomb survivors is compelling evidence that the LNT model is wrong.

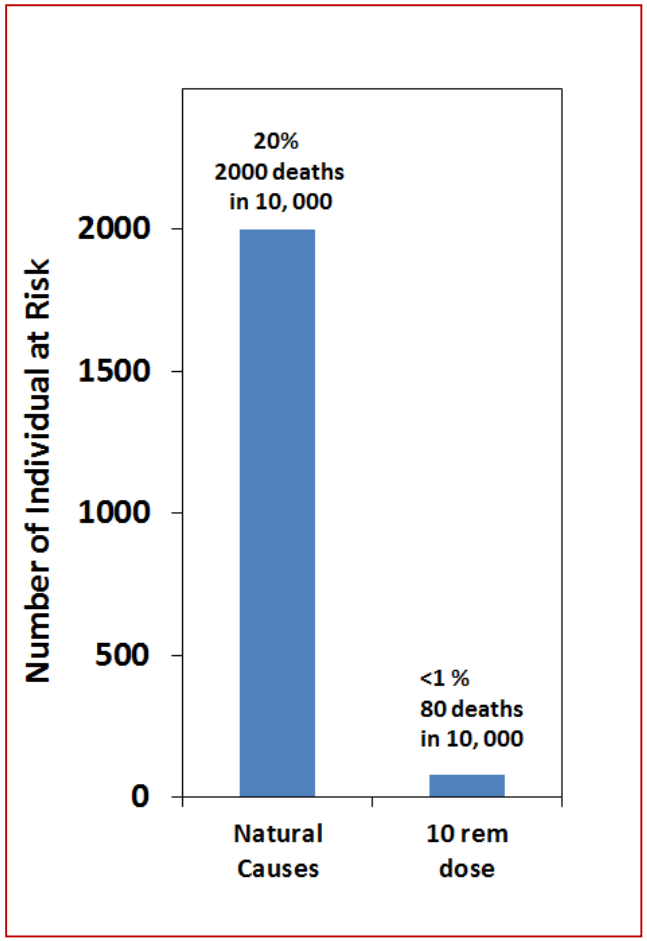
- **LBRE is showing that the LNT does not consider an organisms defense mechanisms, and that they may have evolved to thrive in the presence of non-zero background radiation.**





Underground Radiation and Risk

- The primary risk from occupational radiation exposure is an increased risk of cancer.
- The amount of risk depends on the amount of radiation dose received, and the body parts exposed.
- Although scientists assume low-level radiation exposure increases one's risk of cancer; medical studies have not demonstrated adverse health effects in individual exposed to small chronic radiation doses (up to 10 rem above background).
- If a person received a radiation dose of 10 rem to the entire body (above background), his or her chance of getting cancer would increase by 1%.



Estimated Cancer Risks to a population of 10,000

WIPP radiation Release Event in numbers

Accident	Type	Release of Radioactive materials	Populations Evacuated	Off-site dose	Estimated clean-up costs in million US$
Winscale 1957	Reactor fire	20,000 Ci, ^{131}I 594 Ci ^{137}Cs 0.02TBq Pu	No evacuation	10 time the Bkgd level	70,000 Complete by 2037
Three mile Island, 1979	Partial core melt	13-17 Ci ^{131}I 34,000 Ci ^{85}Kr	Voluntary short term evacuation of nearby communities due to misinformation.	0.08-1.0 mSv	~1000 12 years
Chernobyl, 1986	Runaway fission process destroying the reactor	1.4E+8 Ci	28, deaths, >300, 000 relocated	>20 mSv	250,000-500,000
Fukushima, 2011	Three reactor units severely damaged	1.2E+7 Ci	~160, 000 evacuated with prospects of return still unclear after 6 six years	~10 mSv	100,000-500,000
WIPP, 2014	Waste Drum breach	0.0013 Ci	No evacuation	1-10 µSv	500

Conclusions and Recommendations

- **The WIPP radioactive release event was serious:**
  - It stopped operations for almost three years
  - It cost up to a half billion dollars to recover the facility
- **The WIPP radiation release event was minor:**
  - In terms of exposures to workers (no doses assigned based on low and temporary bioassay results) and environmental contamination
  - There are no public health implications given such low off-site releases
- **The WIPP Underground air is relatively clean :**
  - The residual radioactivity levels in the underground no longer warrant HEPA filtration in order to meet either worker or environmental protection criteria
  - DOE should consider resumption of the unfiltered discharge of underground ventilation
- **Independent voice and communication extremely important**
  - With public and elected officials and also internally
  - Between site developer and regulator
  - Transparency; don't withhold information
- **Be Prepared**
  - Plan for a release, be able to measure it and mitigate it
  - Be able to tell public what the potential impact is-quickly and on a sustainable basis

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