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Development of Modern Performance Assessment Tools and Capabilities for Underground Disposal of Transuranic Waste at WIPP

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Waste Isolation Pilot Plant—WIPP

WIPP is the nation's only deep geologic repository for nuclear waste:
- Permanent disposal site for defense-generated transuranic (TRU) waste
- 2,150 feet deep
- 6.2 million cubic feet of disposal area

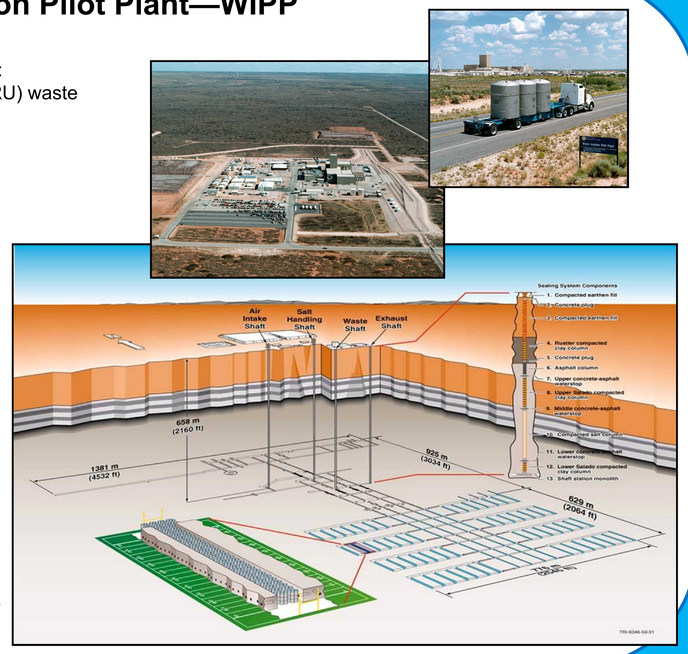
Located in southeast New Mexico:
- Semiarid region, little potable water, no significant aquifers
- Geology and hydrology provide primary isolation

Bedded salt host rock:
- Extremely low permeability
- Creeping behavior
- Geologically stable for more than 200 million years
- Plastic-like quality and self-healing ability to encapsulate waste

Defense-generated TRU waste:
- Contaminated radioactive and hazardous elements
- Clothing, tools, rags, debris, residues, disposable items
- Less than one percent liquid by volume

Operated by U. S. Department of Energy (DOE)

Regulated by U. S. Environmental Protection Agency (EPA)
- Requires periodic performance assessment analysis from DOE



Performance Assessment Calculations

WIPP PA is a probabilistic framework to estimate the future performance of the repository system that:
- calculates releases to the accessible environment over 10,000 years.
- uses a collection of site-specific conceptual models, process models, and scenarios.
- explicitly includes both epistemic and aleatory uncertainty.

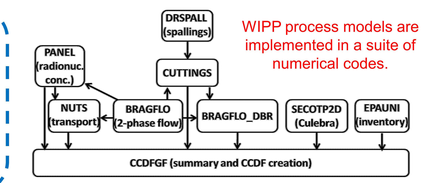
CCDF for mean total releases is the measure of WIPP compliance with EPA release limits.

PA continues to be refined and enhanced to ensure longevity into the future.

Keys to PA

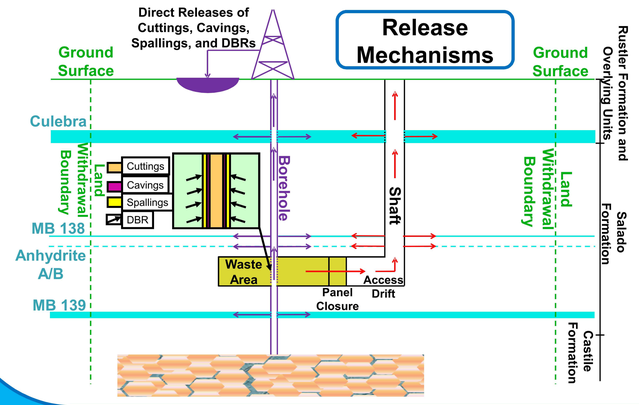
PA answers three questions about a repository system:
1. What can happen after permanent closure?
2. How likely is it to happen?
3. What can result if it does happen?

And one question about the analysis:
What level of confidence can be placed on the estimate? (uncertainty in analysis)



WIPP process models are implemented in a suite of numerical codes.

Release Mechanisms



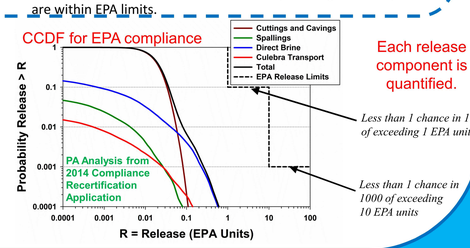
Releases of Interest

Direct Releases (occur during or immediately after drilling)
- Cuttings (Solids from drilling)
- Cavings (Solids from drilling)
- Spallings (Solids from pressure release)
- Direct Brine Release (Brine from pressure release)

Long-term Releases
- Groundwater Transport in Culebra
- Groundwater Transport in Salado

Numerical modeling of the behavior of the system shows essentially no 10,000-yr releases from undisturbed performance.

Releases that might result from human intrusion (a drilling intrusion) are within EPA limits.



Each release component is quantified.

Performance Assessment Modernization Effort

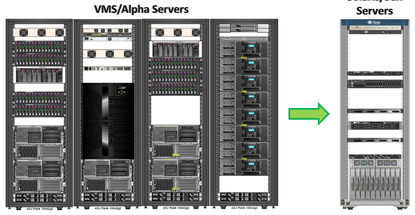
1. Hardware and Operating System Update

The principal hardware update is a change from an Open VMS/Alpha processor platform to a modern UNIX (Solaris)/Intel processor platform.

Open VMS/Alpha
- used for PA calculations since 1996
- increasingly limited OS and hardware support
- HP Alpha systems no longer in production

UNIX (Solaris)/Intel
- low cost hardware and OS support
- easily expandable
- widely-used in academia and industry

VMS/Alpha Servers → Solaris/Sun Servers



Transition to the new platform necessitates the migration of PA computer codes and verification of their functionality.

2. Code Migration from VMS to Solaris

The quality assurance (QA) process intrinsic to PA work requires that each code be "requalified" following any change to the source code, or any significant change to the operating system or hardware system.

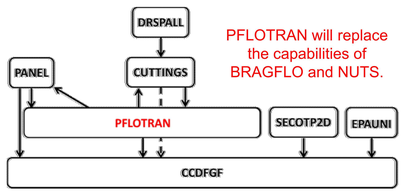
Requalification requires recompiling each code and submitting each code to a series of test problems intended to confirm that the code implements requirements specified in its Requirements Document as quantified by criteria specified in its Verification and Validation Plan.

The code migration process is complete following documentation of all test case results, as well as updates to user's manuals.

3. Implementation of PFLOTRAN[1] for Subsurface Flow and Transport Calculations

Subsurface two-phase flow and transport codes will be replaced by the open-source code PFLOTRAN.

PFLOTRAN has capabilities that are new to WIPP PA, including:
- 3-D spatial gridding
- parallel processing
- 2-phase miscible flow
- heat transfer



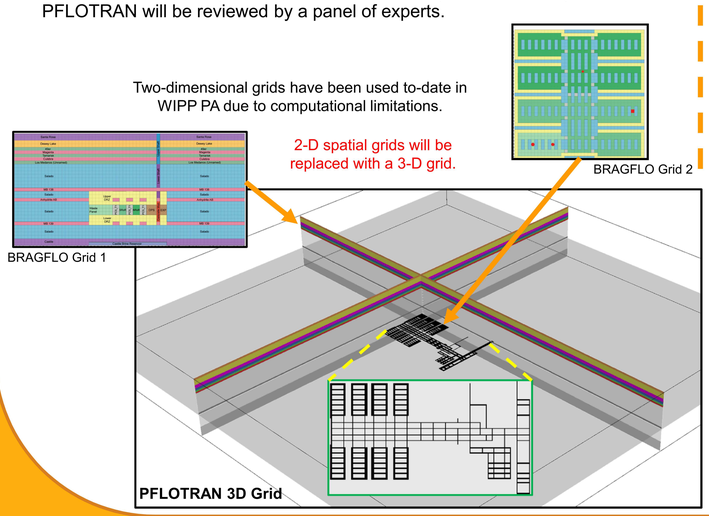
PFLOTRAN will replace the capabilities of BRAGFLO and NUTS.

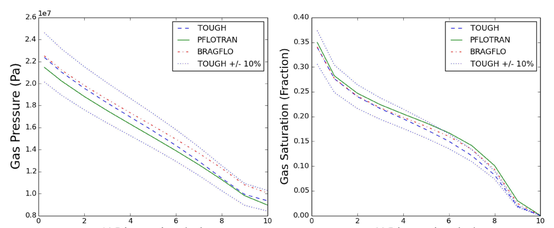
In order to add PFLOTRAN to the list of approved codes for WIPP PA calculations, it must go through the QA process of qualification.

A final critical step to the qualification of PFLOTRAN will be submission of the code to a peer review process, in which the conceptual models implemented in PFLOTRAN will be reviewed by a panel of experts.

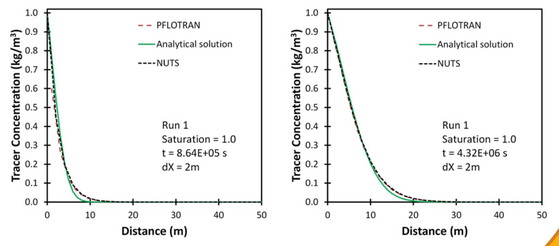
Two-dimensional grids have been used to-date in WIPP PA due to computational limitations.

2-D spatial grids will be replaced with a 3-D grid.





A set of initial tests have been conducted early in the development phase to show that PFLOTRAN can mirror BRAGFLO (above) and NUTS (below) results.



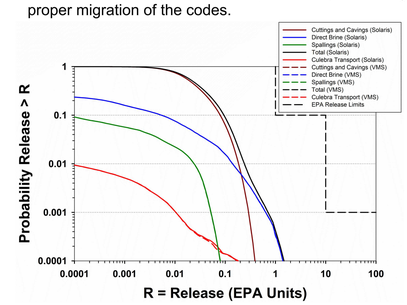
[1]Hammond, G. E.; P. C. Lichtner, and R. T. Mills. Evaluating the Performance of Parallel Subsurface Simulators: An Illustrative Example with PFLOTRAN. Water Resources Research, 50 (1), 208-228 (2014).

Summary

The WIPP PA program is currently driving a modernization effort in three principal areas:

Hardware and OS update
- Have successfully switched from Open VMS/Alpha platform to UNIX (Solaris)/Intel platform.
- New system has lower costs and is more easily expanded.

Code Migration from VMS to Solaris
- Computational codes have been recompiled and tested on the new platform.
- A complete PA analysis has been performed, confirming the proper migration of the codes.



Implementation of PFLOTRAN for Subsurface Flow and Transport Calculations
- PFLOTRAN offers a number of new capabilities for WIPP PA, including 3-D spatial gridding, parallel processing, and heat transfer.
- Currently testing capabilities of PFLOTRAN and comparing results with current PA codes for confirmation.

The result of the modernization effort will be a state-of-the-art subsurface flow and transport capability that will serve WIPP PA into the future.

Acknowledgement

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