Vertical Flume Testing of WIPP Surrogate Waste Materials (EP53B-0806)

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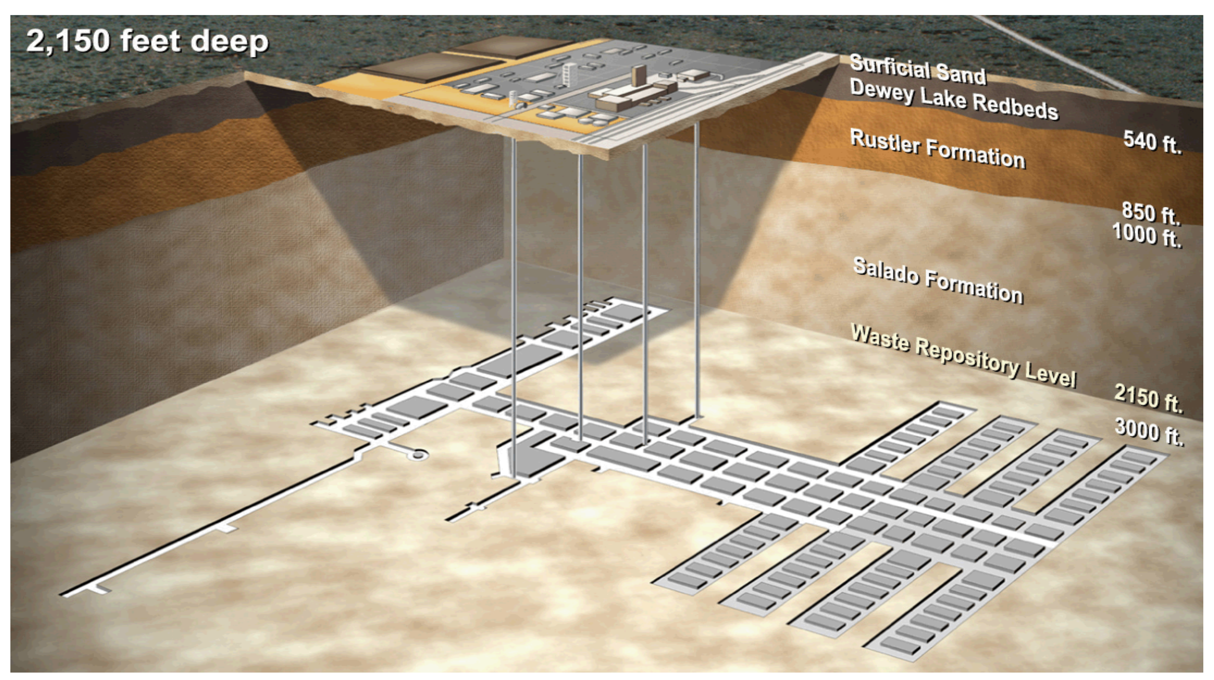
Sandia National Laboratories

Waste Isolation Pilot Plant

The **Waste Isolation Pilot Plant** (WIPP) is a disposal facility for transuranic (TRU) radioactive waste located in southeastern New Mexico and operated by the U.S. Department of Energy (DOE).

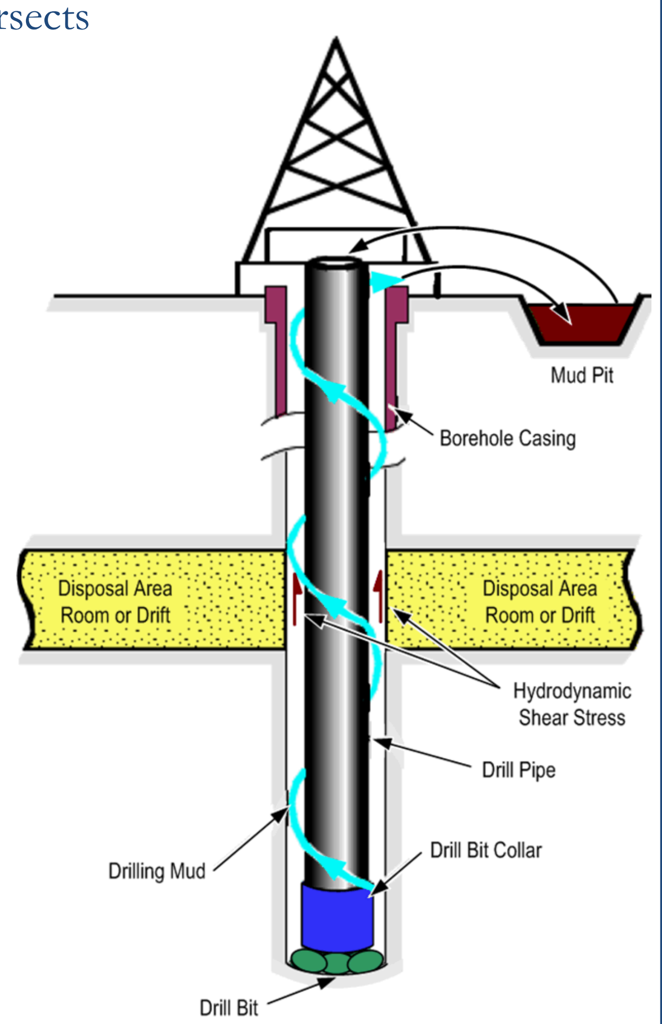
- The disposal facility is located 655 m (2,150 ft) underground in an ≈ 600 m (2,000 ft) thick bedded salt formation – the Salado Formation.
- Containment of TRU waste at WIPP is regulated by the U.S. Environmental Protection Agency (EPA). The DOE demonstrates compliance with the containment requirements by means of **performance assessment** (PA) calculations carried out by Sandia National Laboratories. WIPP PA calculations estimate the probability and consequences of radionuclide releases from the WIPP repository to the accessible environment for a regulatory period of 10,000 years.
- WIPP PA models support the repository recertification process that occurs at five-year intervals following the receipt of the first waste shipment in 1999. The current regulatory baseline was established by the 2009 Performance Assessment Baseline Calculation (PABC-2009).



The Cavings Model

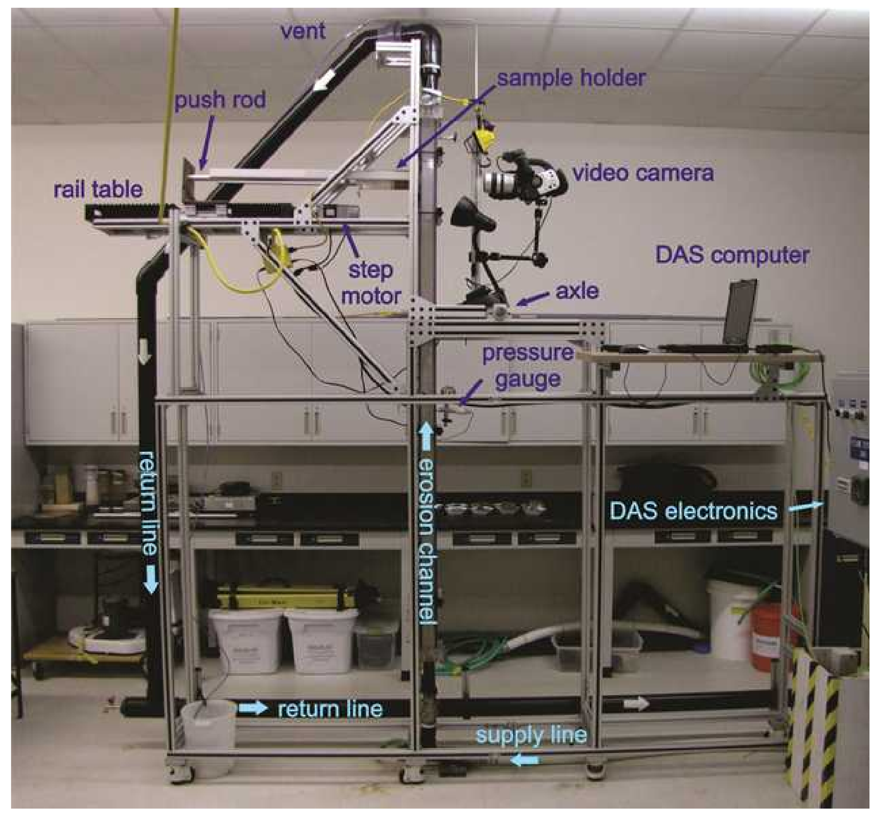
WIPP PA scenarios include cases of hypothetical human intrusion in which a future borehole intersects the waste in the repository.

- Drilling mud flowing up the borehole applies a hydrodynamic shear stress to the borehole wall which, if high enough, could result in erosion of the wall material – "**cavings**."
- Radionuclides may be carried up the borehole in the drilling mud.
- WIPP PA uses the parameter **TAUFAIL**, and its associated epistemic uncertainty, to represent the **hydrodynamic waste shear strength**.



Why Vertical Flume Testing

- The hydrodynamic shear strength can only be estimated in the laboratory by flume testing.
- To simulate mud flowing up a borehole, a flume was built in which the eroding fluid enters a vertical channel from the bottom and flows up past a specimen of an appropriate surrogate waste material.



Surrogate Waste Material

- The surrogate waste materials are comprised of a mixture of raw materials including iron, glass, cellulosics, rubber, plastic, degradation byproducts, solidified cements, soil, and WIPP salt.
- Materials represent 100, 75, and 50% levels of degradation, which correspond to theorized end states of the waste after 10,000 years in the repository.
- Degradation of every waste constituent is considered.
- Hansen et al. (1997) argued that the degraded waste material properties represented the lowest plausible realm of the future waste state because no strengthening processes were included.
- It is believed that the surrogate materials used during the testing reported herein represent an unobtainable degraded state of the waste far weaker than any conceivable future state, and thus are ideal for establishing the lower limit of the TAUFAIL uncertainly range.

Waste Category	Example Waste Simulants	Relative Weight Proportions of Surrogate Waste Constituents		
		100%	75%	50%
Iron-base metal, alloys; steel container material	Strips of steel sheet metal, small nails (cut up), scraps of steel or iron	0.0	0.9	1.9
Corroded iron-base metal, alloys; steel container material; corroded nonferrous metal and alloys	Scrapings from rusted steel or iron; supplement with Fe(III)O.OH (goethite or limonite rock samples) crushed sand- to silt-sized particles	7.3	6.0	4.6
Other inorganic materials: vitrified	Broken labware, broken glassware	1.0	1.0	1.0
Cellulosics; rubber; plastics; plastic container/liner material	Equal masses of finely shredded paper, snipped cotton balls, sawdust, shredded plastic grocery bags, o-rings, rubber gloves, rubber bands, polyethylene sheet and bottles, and peat (no vermiculite)	0.0	0.4	0.7
Solidification cement	Broken hydrated concrete and mortar, crumbled sheet-rock	1.2	1.2	1.2
Soils	Natural soil	0.5	0.5	0.5
Salt precipitate. corrosion induced		0.9	0.7	0.5
Total Batch Size		**10.9**	**10.7**	**10.4**

Determination of Shear Strength of the Material

- Three methods are used to determine surrogate waste shear strength from erosion rate versus shear stress data:
  - A bilinear fit in which the upper line, representing the bulk material, is extended back to an erosion rate of zero
  - Linear interpolation to a critical erosion rate of 10^{-4} cm/s
  - Power-law interpolation to a critical erosion rate of 10^{-4} cm/s.
- At least five samples of each material type were used.
- The surrogate waste samples were compacted to two different stresses – 2.3 and 5 MPa – representing the minimum stress the waste will be subjected to during the 10,000 year regulatory period.
- Only surrogate 50 and 75% degraded samples reported herein.
  - For the vast majority of the PA calculations, half or more of the initial iron and cellulosics, plastics, and rubber inventory remains.
  - Surrogate 100% degraded sample results are considered unreliable due to deformation of sample holders.

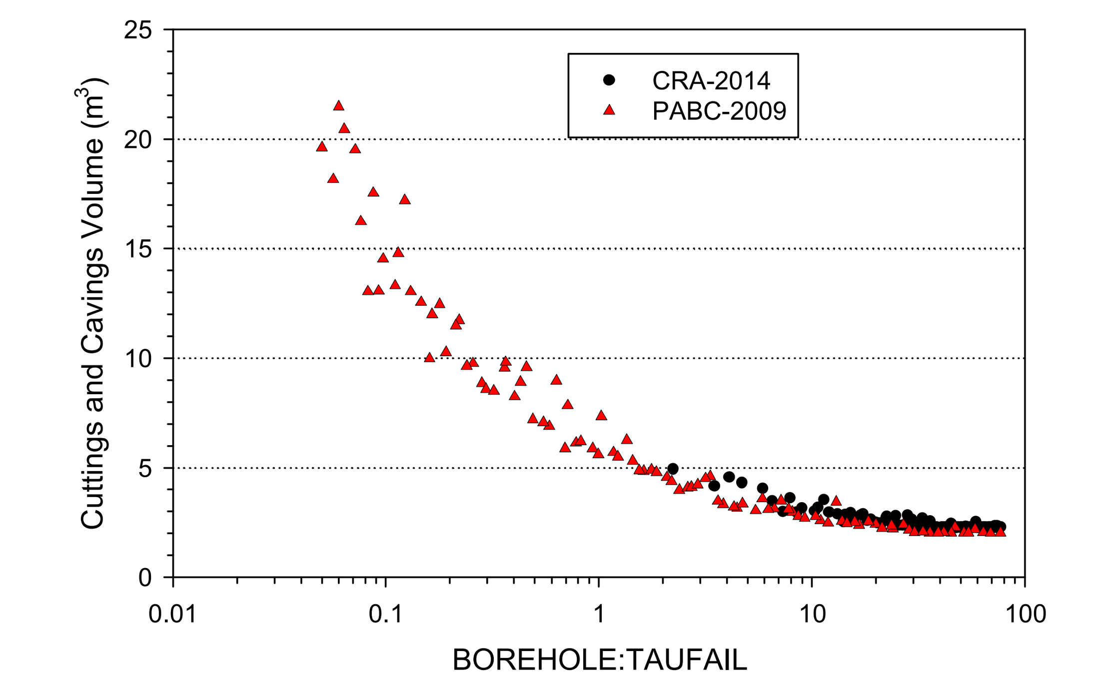
Surrogate Material	Surrogate Waste Shear Strength		
	Bilinear Fit	Linear Interpolation	Power-Law Interpolation
75% degraded waste, 2.3 MPa compaction pressure	1.53	1.38	1.49
75% degraded waste, 5.0 MPa compaction pressure	2.17	1.81	1.97
50% degraded waste, 2.3 MPa compaction pressure	2.22	2.58	2.85
50% degraded waste, 5.0 MPa compaction pressure	5.05	5.10	5.29

Recommendation for WIPP PA

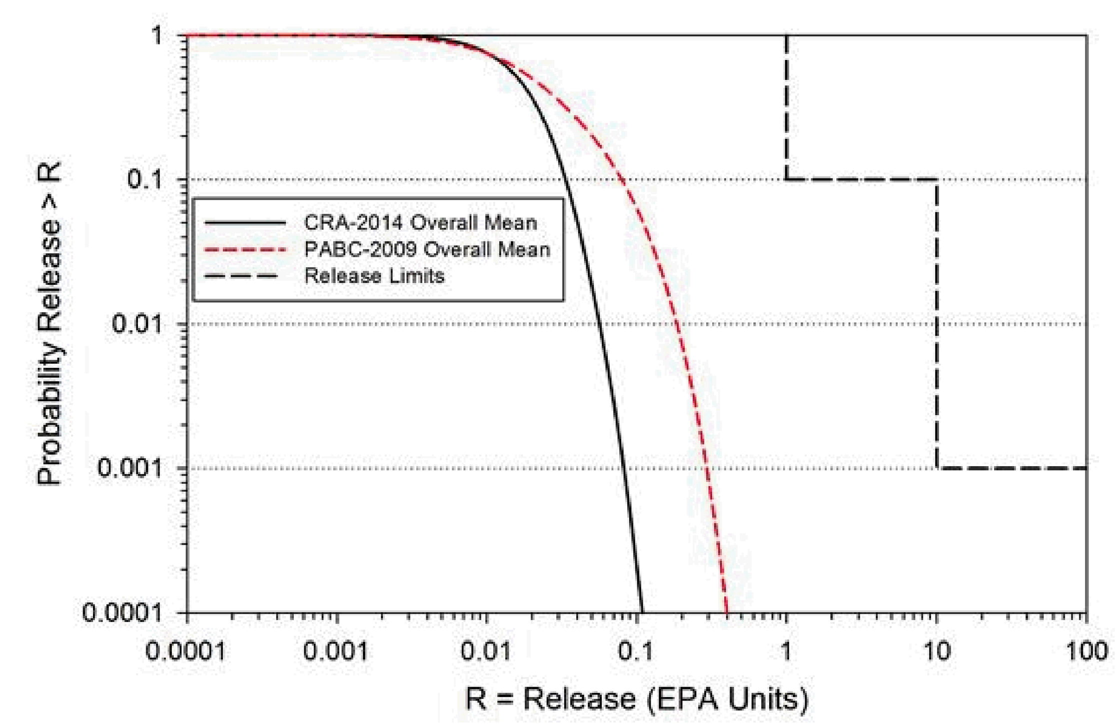
- The DOE recommends using the results from surrogate 50% degraded waste material compacted at 2.3 MPa using the bilinear fit method of data analysis for the lower limit of TAUFAIL.
- Surrogate 50% degraded waste was used to determine other PA model parameters.
  - Accepted by a peer review panel and the EPA.
- The bilinear analysis method fits the majority of experimental data extremely well and is the most conservative.
- Back-calculation of PA results indicates that the minimum compaction stress the waste is expected to be subjected to is 4.3 – 4.4 MPa.
  - Since shear strength is highly dependent on the compacting pressure, using the results of specimens subjected to 2.3 MPa is conservative and defendable.
- The recommended 2.22 Pa value is considerably higher than the presently accepted 0.05 Pa value based on one flume test of San Francisco Bay mud found in a literature review.
- Because the lower limit is changed to within two orders of magnitude of the upper limit, a uniform uncertainty distribution can be used for TAUFAIL in WIPP PA calculations.

Effect on WIPP PA

- The latest PA calculations will be documented in the 2014 Compliance Recertification Application (CRA-2014), which will be submitted by the DOE for EPA approval in March 2014.
- By changing the range and distribution of TAUFAIL the Cuttings (the material removed by the mechanical action of the drill bit, a constant) and Cavings volumes are reduced from the previous baseline amounts.



- The mean Cuttings and Cavings radionuclide release complementary cumulative distribution function (CCDF) moves away from the regulatory limit.



References

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