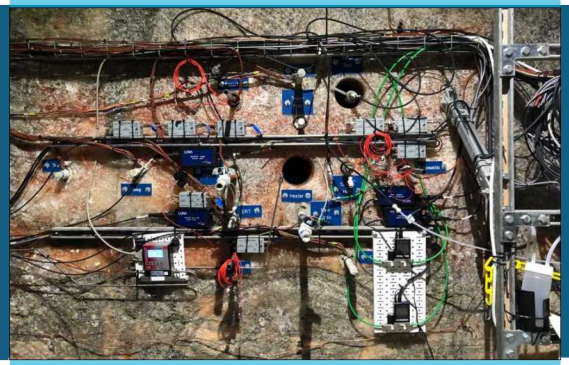
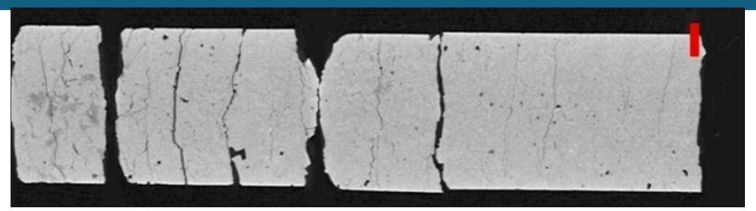
SAND2020-8228PE

Human Intrusion Scenarios for WIPP and YMP





Emily Stein

Sandia National Laboratories

Salt Scenarios Workshop, August 11, 2020

SAND2020-xxxx

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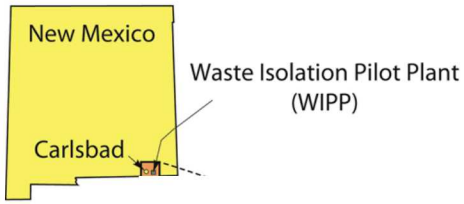
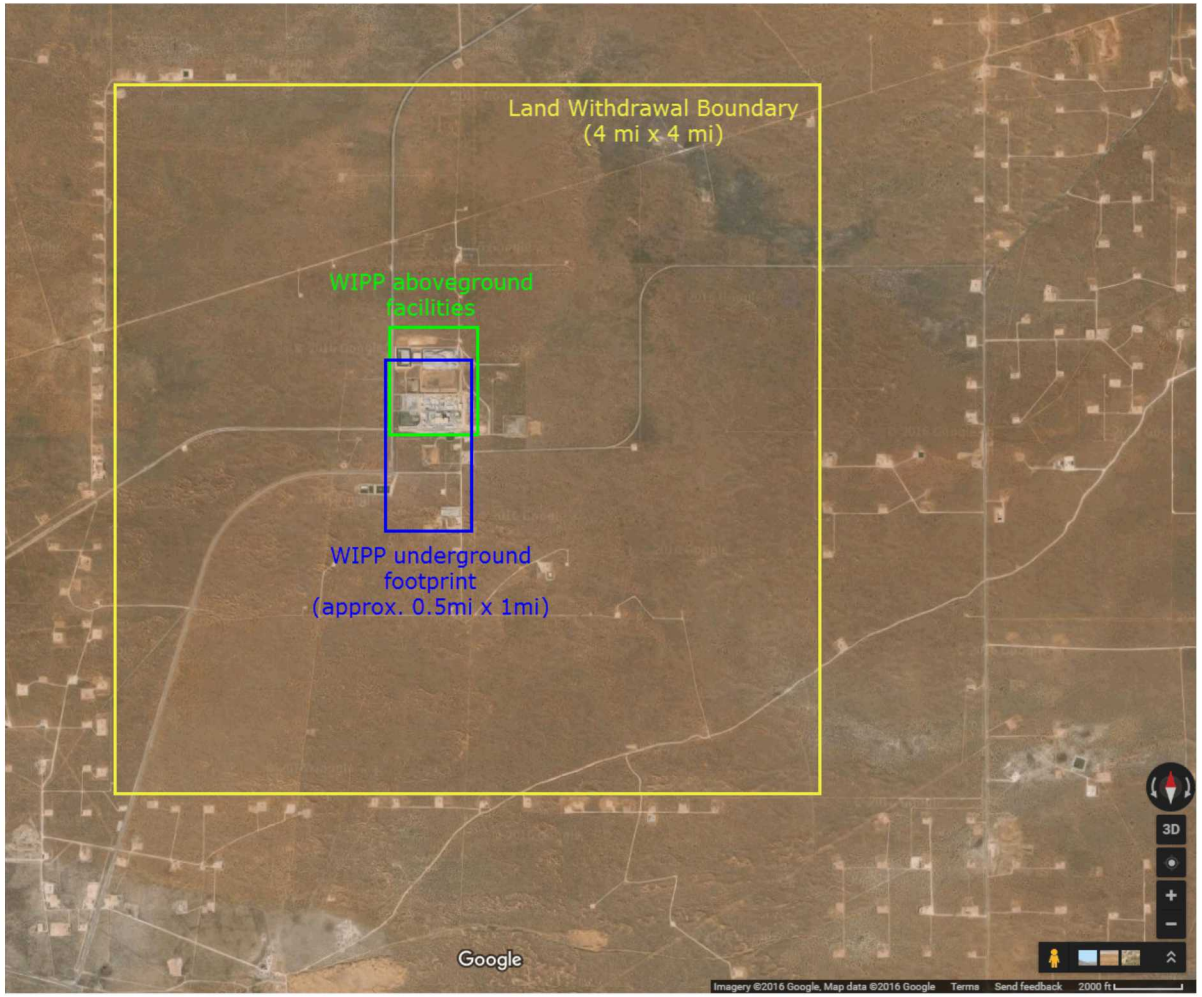
Waste Isolation Pilot Plant & Yucca Mountain Project





https://www.yuccamountain.org/mapnv.gif

https://commons.wikimedia.org/w/index.php?curid=1026543

Waste Isolation Pilot Plant (WIPP) Post-closure Performance

Regulatory time period = 10,000 y

Containment requirements **(40 CFR §§ 194.31 - 194.34)**

- Addressed with probabilistic performance assessment
- Human intrusion is primary radionuclide release pathway (inadvertent)
- Regulatory criteria are probabilities of exceeding normalized cumulative release limits

Individual and groundwater protection requirements **(40 CFR §§ 194.51 - 194.55)**

- Addressed through conservative calculations
- Undisturbed case (no human intrusion)
- Regulatory criteria are dose (<15 millirem = 150 microsieverts) and various groundwater concentration criteria

40 CFR § 194.33 Consideration of drilling events in performance assessments

Specifies the assumptions about inadvertent human intrusion to be used in PA:

Drilling events will occur in the Delaware Basin at random intervals in time and space during the regulatory time frame.

The drilling rate will be equal to the drilling rate over the past 100 years prior to preparation of the compliance application.

Future drilling practices and technology will remain consistent with practices in the Delaware Basin at the time a compliance application is prepared (e.g., drilling fluids; borehole depths, diameters, and seals; and the fraction of such boreholes that are sealed by humans).

Natural processes will degrade or otherwise affect the capability of boreholes to transmit fluids.

https://www.law.cornell.edu/cfr/text/40/194.33

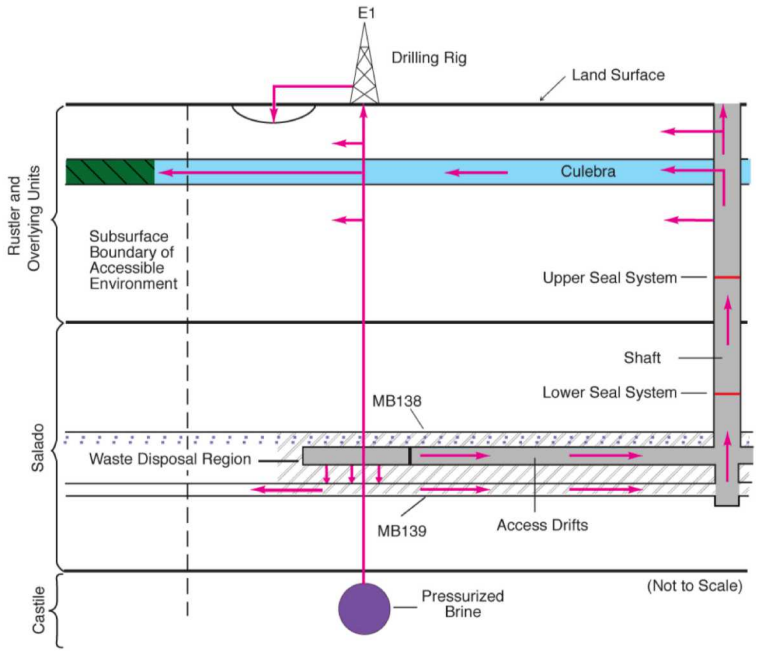
WIPP Human Intrusion Scenarios

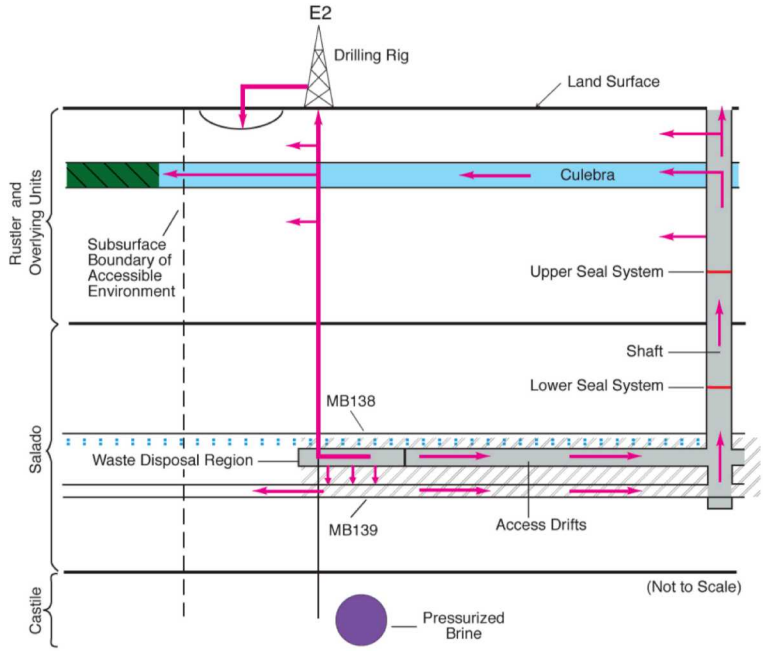
E0 – No intrusion

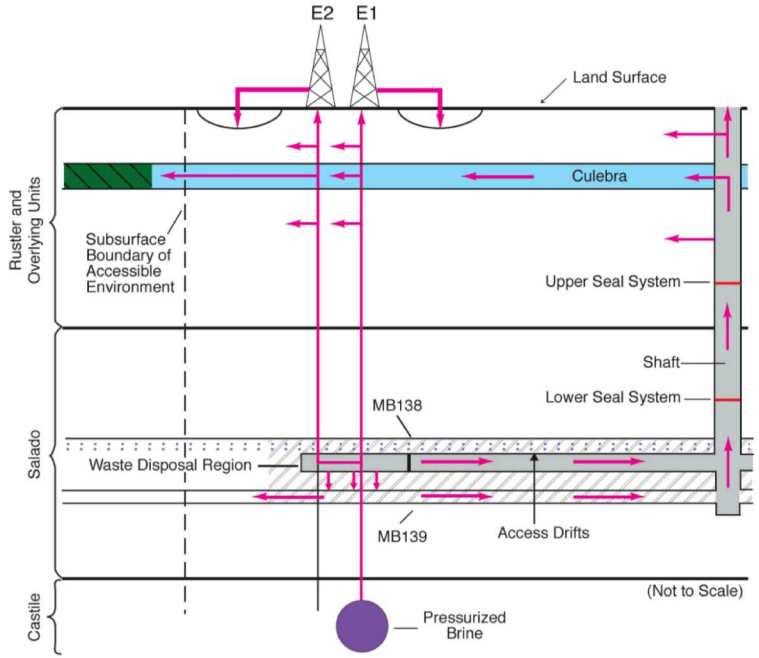
E1 – Borehole intersects pressurized brine pocket beneath the repository

E2 – Borehole does not intersect brine pocket

E2-E1 – Multiple boreholes







Calculation of Releases

Aleatory uncertainty (random; irreducible)

- Time and location of intrusions
- Whether a brine pocket is intersected
- Borehole plugging method

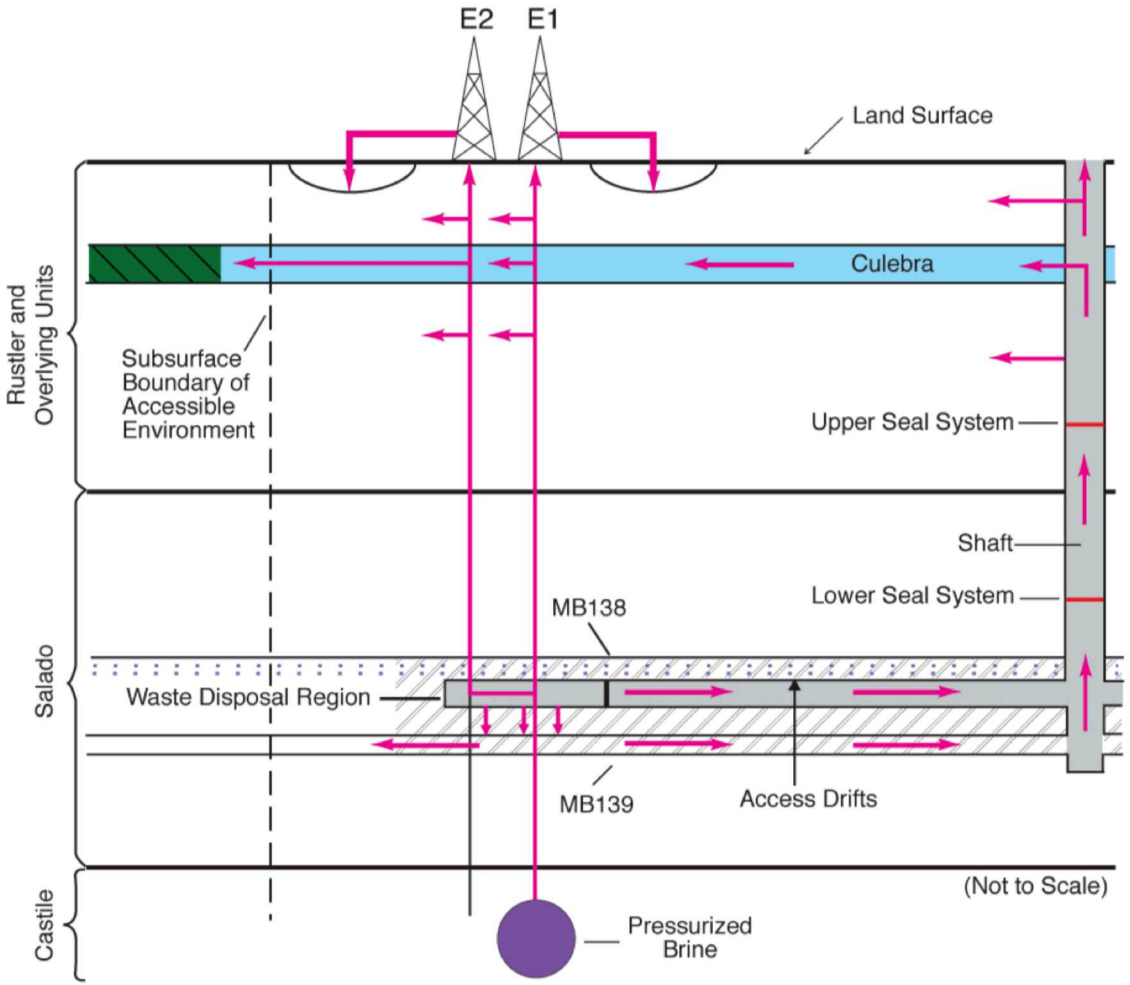
Epistemic uncertainty (state of knowledge; reducible)

- Permeability, porosity, solubility, etc.

10,000 futures (aleatory) for each of 300 vectors (epistemic)

Cumulative releases

- Cuttings, cavings and spallings
- Direct brine release
- Transport in the Culebra across land withdrawal boundary



Complementary Cumulative Distribution Functions

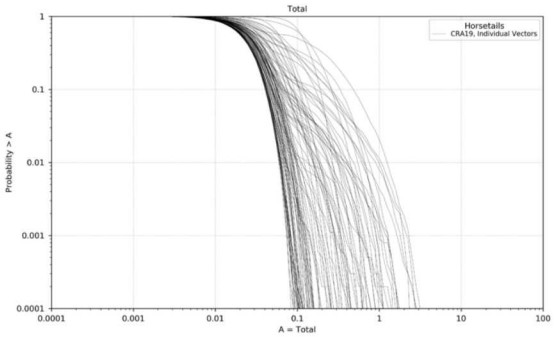


Figure PA-69. Total Normalized Releases, Replicate R1, CRA19

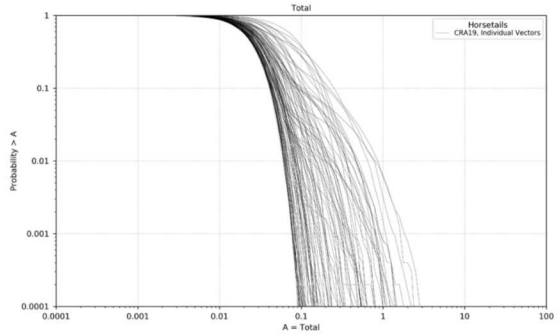


Figure PA-70. Total Normalized Releases, Replicate R2, CRA19

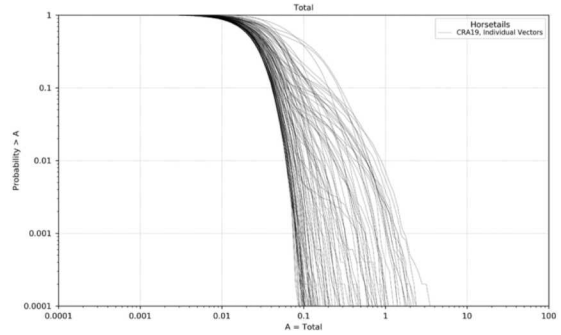
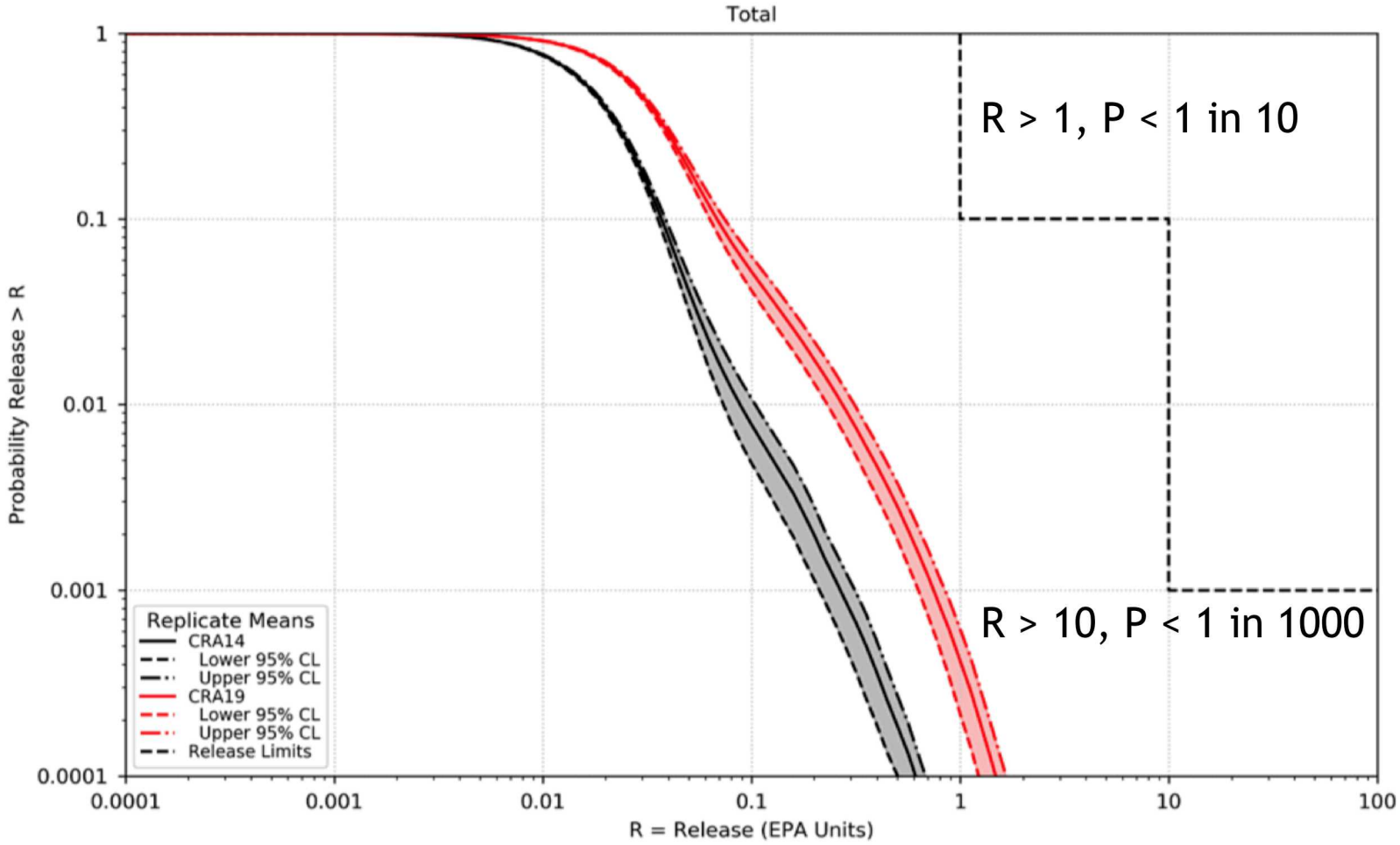


Figure PA-71. Total Normalized Releases, Replicate R3, CRA19



Normalized cumulative release

https://wipp.energy.gov/library/CRA/CRA-2019/CRA-15315-v2-CRA-2019_Appendix_PA_Final.pdf

Yucca Mountain Scenario Classes

10 CFR § 63.2 excludes human intrusion from performance assessment.

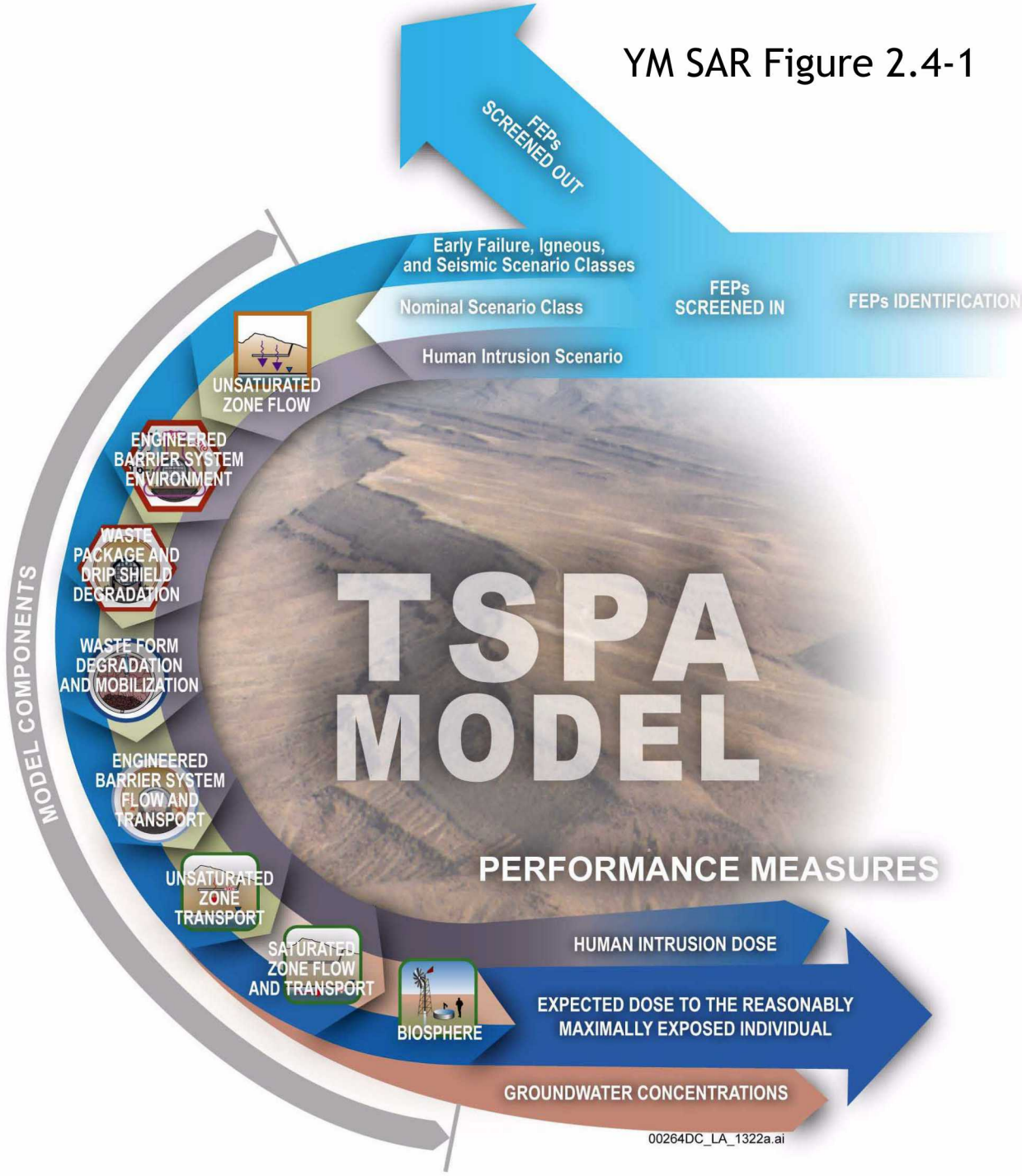
10 CFR § 63.102 explains why:

(k) *Institutional controls.* Active and passive institutional controls will be maintained over the Yucca Mountain site, and are expected to reduce significantly, but not eliminate, the potential for human activity that could inadvertently cause or accelerate the release of radioactive material. However, because **it is not possible to make scientifically sound forecasts of the long-term reliability of institutional controls, it is not appropriate to include consideration of human intrusion into a fully risk-based performance assessment** for purposes of evaluating the ability of the geologic repository to achieve the performance objective at § 63.113(b). Hence, human intrusion is addressed in a stylized manner as described in paragraph (l) of this section.

(l) *Human intrusion.* In contrast to events unrelated to human activity, the **probability and characteristics of human intrusion occurring many hundreds or thousands of years into the future cannot be estimated** by examining either the historic or geologic record. Rather than speculating on the nature and probability of future intrusion, **it is more useful to assess how resilient the geologic repository would be against a human intrusion event**. Although the consequences of an assumed intrusion event would be a separate analysis, the analysis is similar to the performance assessment required by § 63.113(b) but subject to specific requirements for evaluation of human intrusion specified at §§ 63.321, 63.322 and 63.342 of subpart L of this part.

https://www.nrc.gov/reading-rm/doc-collections/cfr/part063/full-text.html#part063-0102

YM SAR Figure 2.4-1



10 CFR § 63.321 Individual protection standard for human intrusion

(a) DOE must determine **the earliest time after disposal that the waste package would degrade** sufficiently that a human intrusion (see § 63.322) could occur without recognition by the drillers.

200,000 y

(b) DOE must demonstrate that there is a reasonable expectation that the **reasonably maximally exposed individual** receives, as a result of the human intrusion, no more than the following **annual dose**:

(1) 0.15 mSv (15 mrem) for 10,000 years following disposal; and

(2) 1.0 mSv (100 mrem) after 10,000 years, but within the period of geologic stability.

(c) DOE's analysis must include all potential environmental pathways of radionuclide transport and exposure, subject to the requirements of § 63.322.

https://www.nrc.gov/reading-rm/doc-collections/cfr/part063/full-text.html#part063-0321

10 CFR § 63.322 Human Intrusion Scenario

For the purposes of the analysis of human intrusion, DOE must make the following assumptions:

(a) There is a **single human intrusion** as a result of exploratory drilling for groundwater;

(b) The intruders drill a borehole directly through a degraded waste package into the uppermost aquifer underlying the Yucca Mountain repository;

(c) The drillers use the common techniques and practices that are currently employed in exploratory drilling for ground water in the region surrounding Yucca Mountain;

(d) Careful sealing of the borehole does not occur, instead natural degradation processes gradually modify the borehole;

(e) No particulate waste material falls into the borehole;

(f) The **exposure scenario includes only those radionuclides transported to the saturated zone by water** (e.g., water enters the waste package, releases radionuclides, and transports radionuclides by way of the borehole to the saturated zone); and

(g) No releases are included which are caused by unlikely natural processes and events.

https://www.nrc.gov/reading-rm/doc-collections/cfr/part063/full-text.html#part063-0322

9000 Human Intrusion Dose Histories (YM SAR 2.4.3.1)

9,000 realizations (i.e., 9,000 annual dose histories)

- Latin hypercube sample of 30 over 3 aleatory parameters
- Latin hypercube sample of 300 over 300 epistemically uncertain parameters

Dose histories are averaged in groups of 30 (corresponding to the aleatory samples) to produce 300 expected dose histories.

300 expected dose histories are averaged at each τ to produce the overall mean annual dose history, and

50th percentile value is computed at each time τ to produce the median annual dose history.

Aleatory uncertainties

- Type of waste package (SNF (0.7) or co-disposal (0.3))
- Percolation flux
- Entry point into the saturated zone

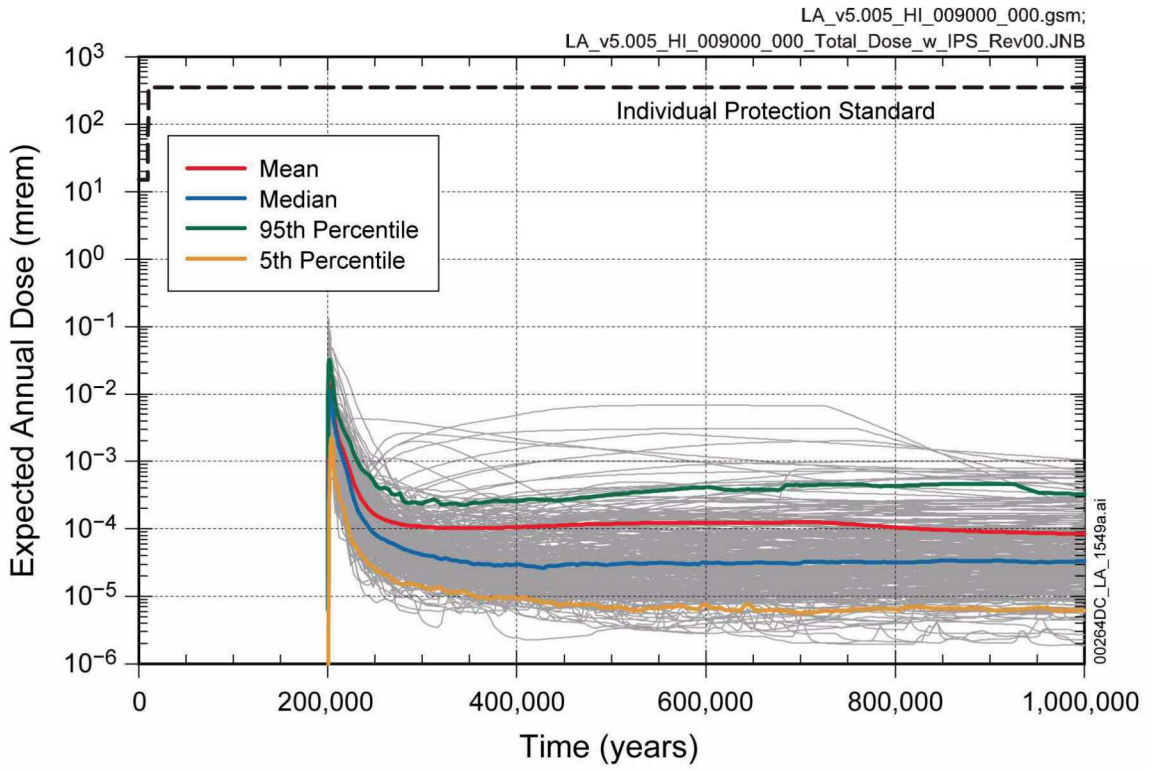


Figure 2.4-11. Distribution of Expected Annual Dose for the Human Intrusion Modeling Case for the Post-10,000 Year Period after Permanent Closure, with Drilling Intrusion Event at 200,000 Years
NOTE: The individual protection standard in this figure is based on proposed 10 CFR 63.321.

References

U.S. Department of Energy 2019. *Title 40 CFR Part 191 Subparts B and C Compliance Recertification Application 2019 for the Waste Isolation Pilot Plant*. U.S. Department of Energy, Carlsbad Field Office, Carlsbad, NM.

U.S. Department of Energy 2008. *Yucca Mountain Repository License Application Safety Analysis Report*. U.S. Department of Energy, Office of Civilian Radioactive Waste Management, Las Vegas, NV.