SAND2010-7900P

1. Overview of WIPP Performance Assessment

KAERI Hydrology Short Course

November, 2010

Kris Kuhlman
Sandia National Laboratories

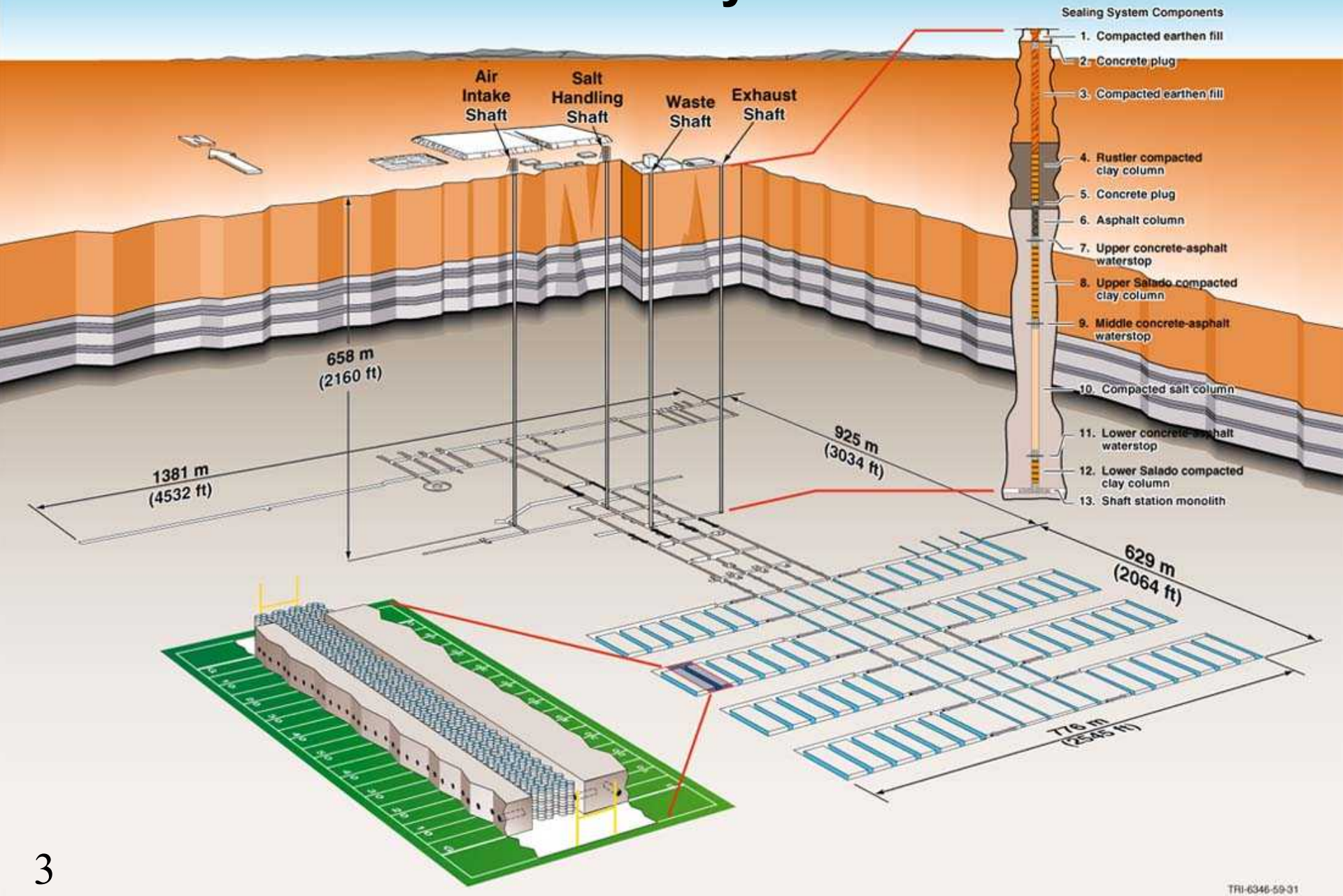
Sandia National Laboratories is a multi-program laboratory operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000. .

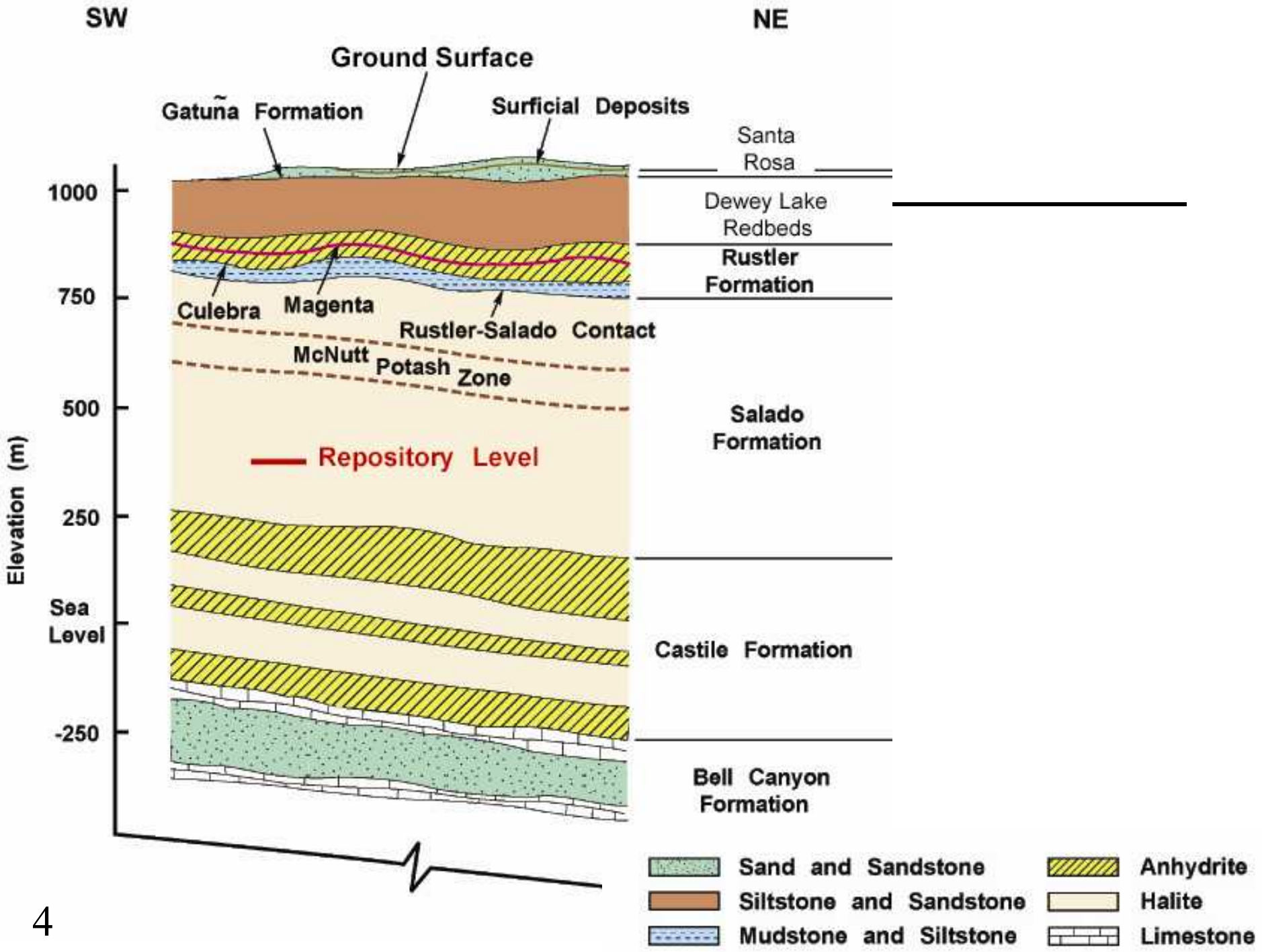
Sandia National Laboratories

Outline

- WIPP Repository System
- Brief Tour of WIPP PA
  - Regulatory Basis
  - Conceptual Basis
  - Release Mechanisms and Pathways
  - Scenarios
  - Treatment of Uncertainty
  - Calculation of Total Releases
  - Culebra Contribution to Total Releases

WIPP Layout


Air Intake Shaft
Salt Handling Shaft
Waste Shaft
Exhaust Shaft
658 m (2160 ft)
1381 m (4532 ft)
925 m (3034 ft)
629 m (2064 ft)
776 m (2545 ft)
Sealing System Components
1. Compacted earthen fill
2. Concrete plug
3. Compacted earthen fill
4. Rustler compacted clay column
5. Concrete plug
6. Asphalt column
7. Upper concrete-asphalt waterstop
8. Upper Salado compacted clay column
9. Middle concrete-asphalt waterstop
10. Compacted salt column
11. Lower concrete-asphalt waterstop
12. Lower Salado compacted clay column
13. Shaft station monolith
TRI-6346-59-31


SW
NE
Ground Surface
Gatuña Formation
Surficial Deposits
Santa Rosa
Dewey Lake Redbeds
Rustler Formation
Culebra
Magenta
Rustler-Salado Contact
McNutt Potash Zone
Salado Formation
Repository Level
Castile Formation
Bell Canyon Formation
Elevation (m)
1000
750
500
250
Sea Level
-250
Sand and Sandstone
Siltstone and Sandstone
Mudstone and Siltstone
Anhydrite
Halite
Limestone

Regulatory Basis

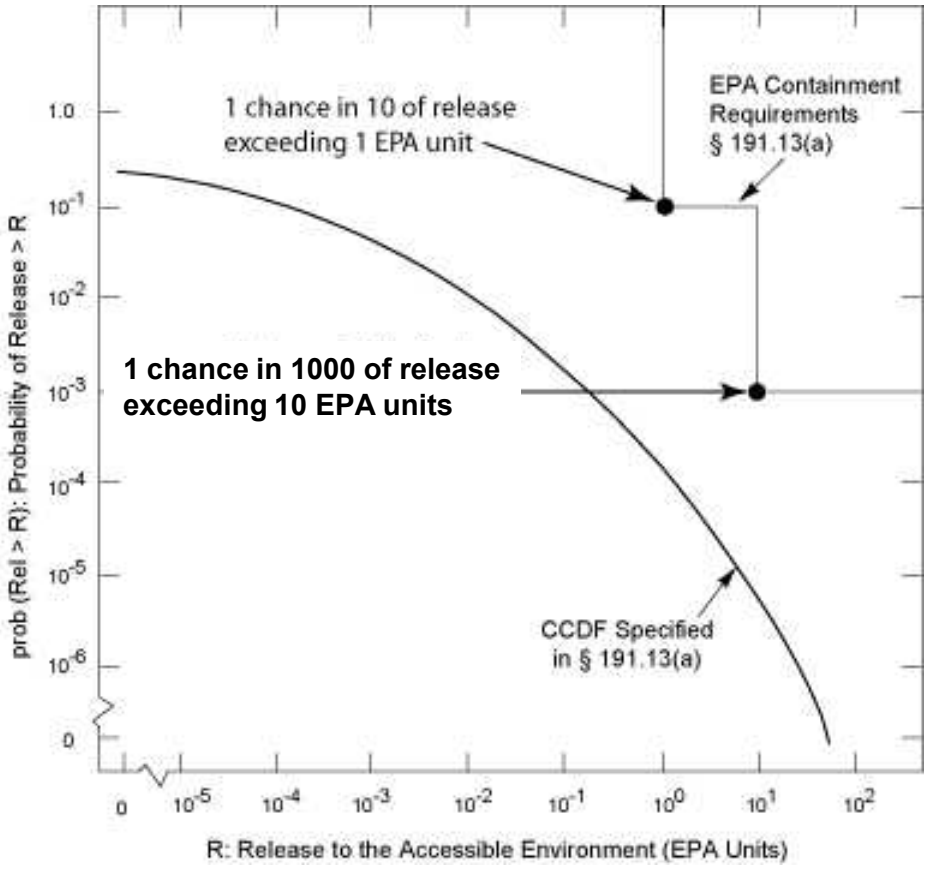
- WIPP Land Withdrawal Act (*PL 102-579*)
  - WIPP must comply with EPA disposal standards
- EPA Regulations
  - 40CFR Part 191
    - Standards of performance
    - Assurance measures
  - 40CFR Part 194
    - Content of compliance certification/recertification application
    - Requirements/standards for performance assessments

40CFR Part 191

- Establishes standards of long-term performance
  - Containment requirements (isolation)
  - Protection of individuals from radiation exposures
  - Protection of groundwater from radioactive contamination
- Requires assurance measures
  - Active and passive institutional controls
  - Multiple (natural and engineered) barriers
  - Other measures to enhance confidence in the disposal system performance

Containment Requirements

Probability distributions of cumulative releases - CCDFs



Normalized EPA unit:

$$R = \frac{1}{W}\sum_i \frac{Q_i}{L_i}$$

where

W = 10^6 Ci of TRU radionuclides in WIPP

Q_i = Amount released

L_i = Release limit

Sandia National Laboratories

Individual and Groundwater Protection

- Individual
  - Annual committed effective dose by all potential pathways < 15 millirem
- Groundwater – in any underground source of drinking water
  - combined ^{226}Ra and ^{228}Ra < 5 picocuries per liter
  - gross alpha particle activity, including ^{226}Ra but excluding Uranium and other Radon isotopes < 15 picocuries per liter
  - annual dose equivalent to the total body or any internal organ from the average annual concentration of beta particle and photon radioactivity from man-made radionuclides < 4 millirem per year

40CFR Part 194

- Requirements for conceptual model peer reviews
  - NUREG-1297
- Scope of performance assessments
  - Threshold probability: 1 in 10,000 over 10,000 years
  - Impacts due to natural processes and events
    - Groundwater flow and solute transport
    - Climate change
  - Impacts due to resource extraction
    - Oil and gas exploration/production (drilling)
    - Potash mining

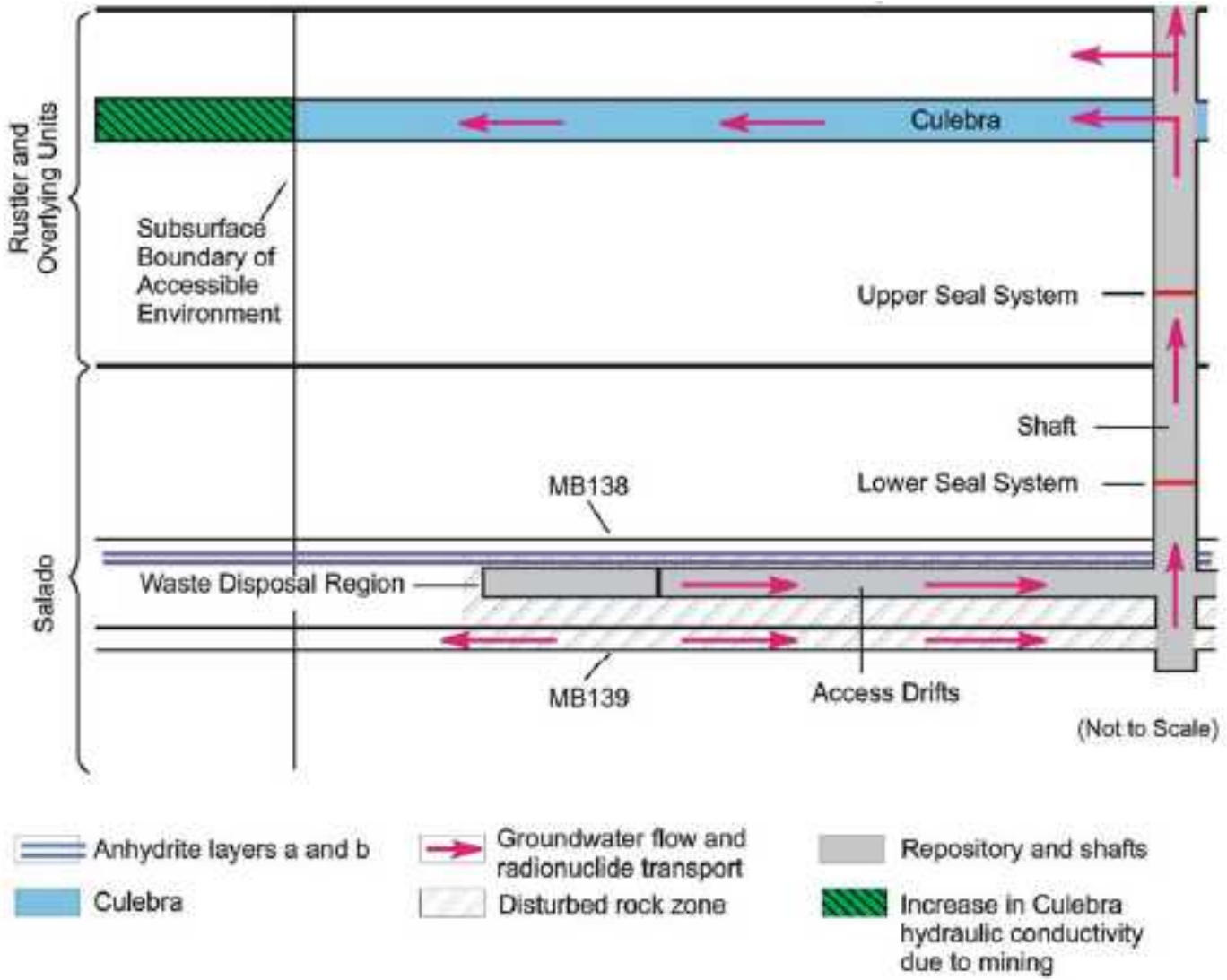
Conceptual Basis of WIPP PA

- Quantitative, probabilistic estimate of the future performance of repository system
  - Based upon probabilistic risk assessment (PRA) methodologies for nuclear reactors
- WIPP PA answers three questions about 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
  1. What level of confidence can be placed on the estimate? (uncertainty in analysis)

Release Mechanisms/Pathways

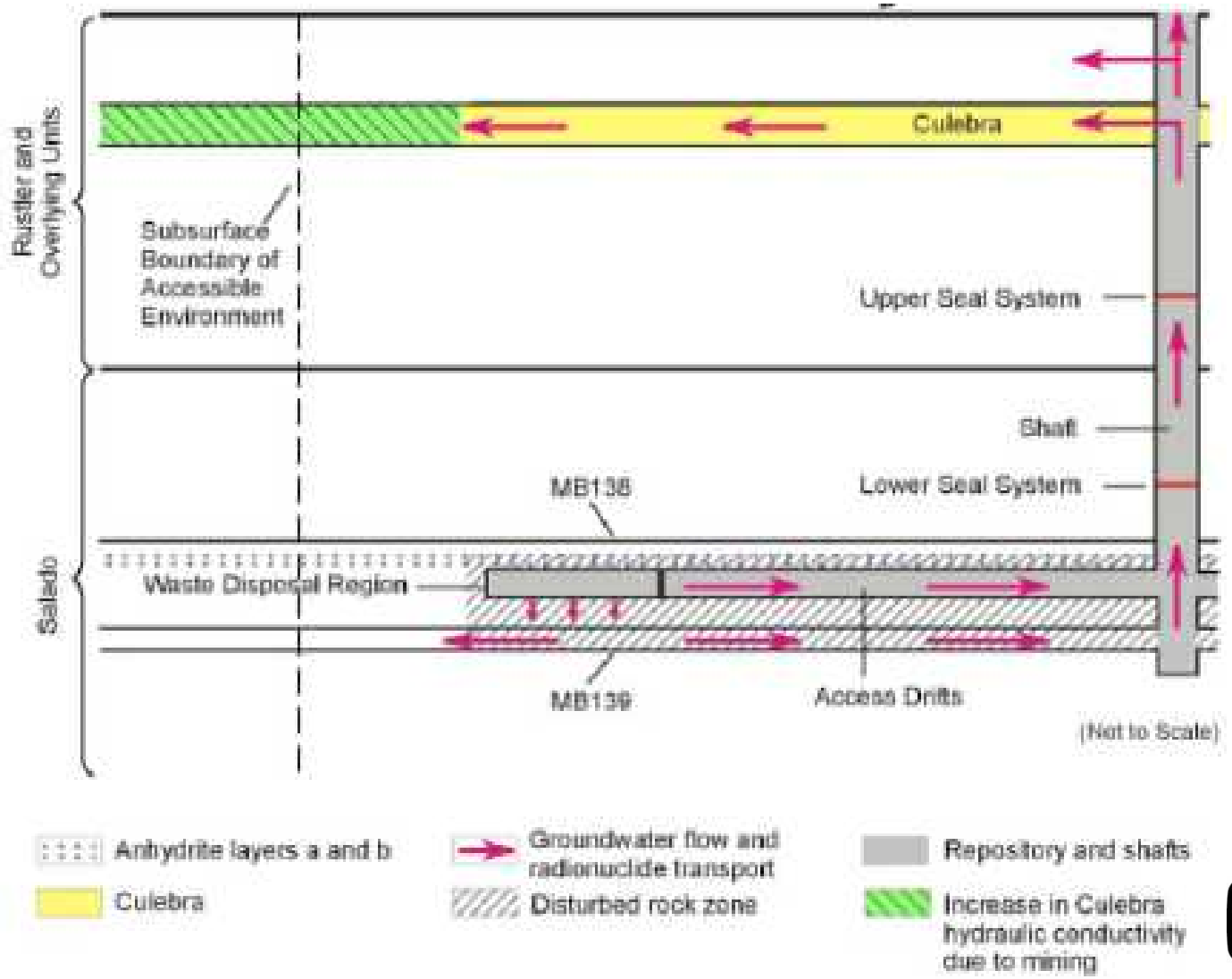
- Direct Releases (at time of drilling)
  - Cuttings: material intersected by the rotary drilling bit
  - Cavings: material eroded from the borehole wall during drilling
  - Spallings: solid material carried into the borehole during rapid depressurization of the waste-disposal region
  - Direct brine release: contaminated brine that may flow to the surface during drilling
- Long-Term Releases
  - Dissolved/sorbed radionuclides move with brine flows
    - Through Salado marker beds
    - Up boreholes/shaft to Culebra, through Culebra

Undisturbed Performance Scenario



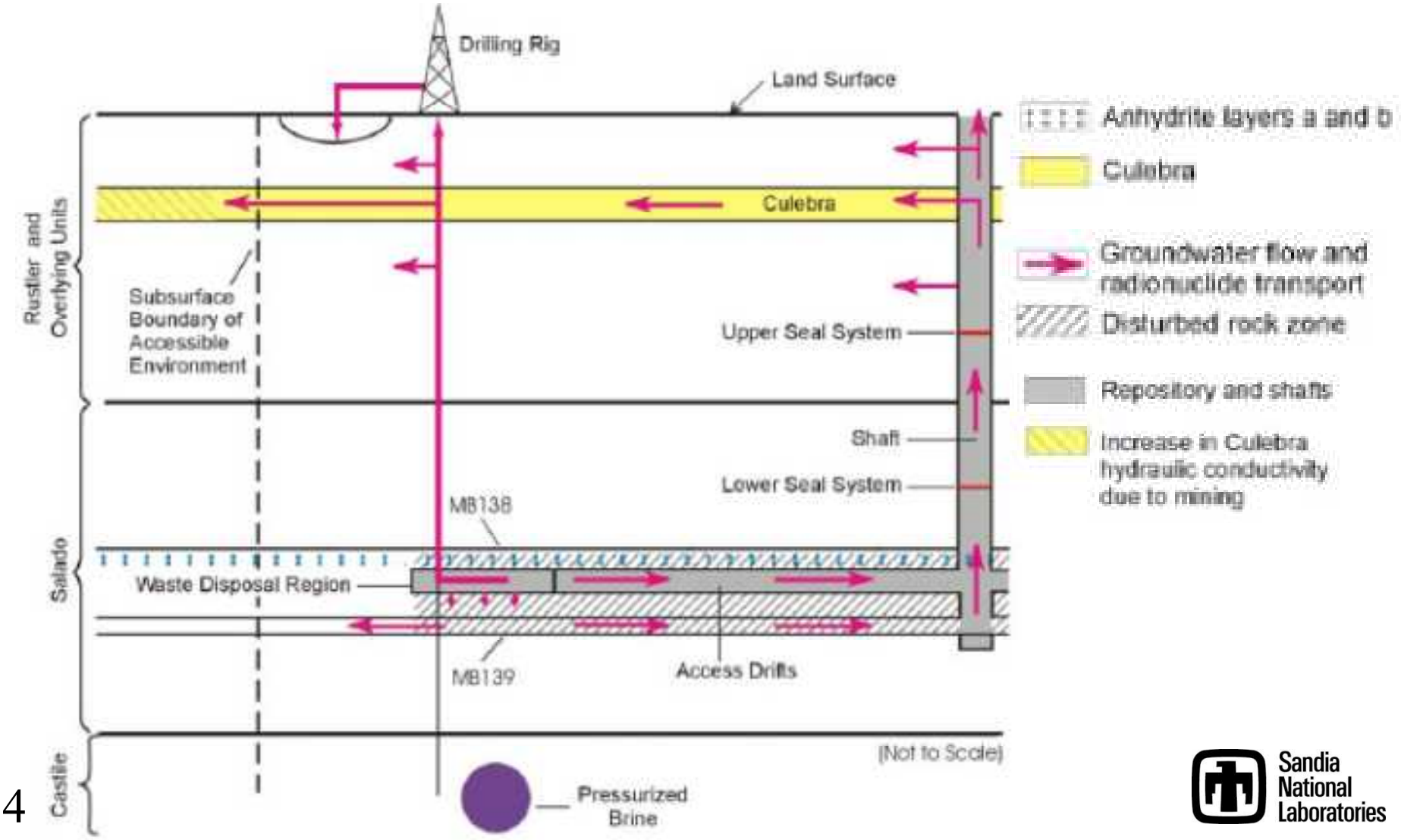
Sandia National Laboratories

Disturbed Performance (Mining)



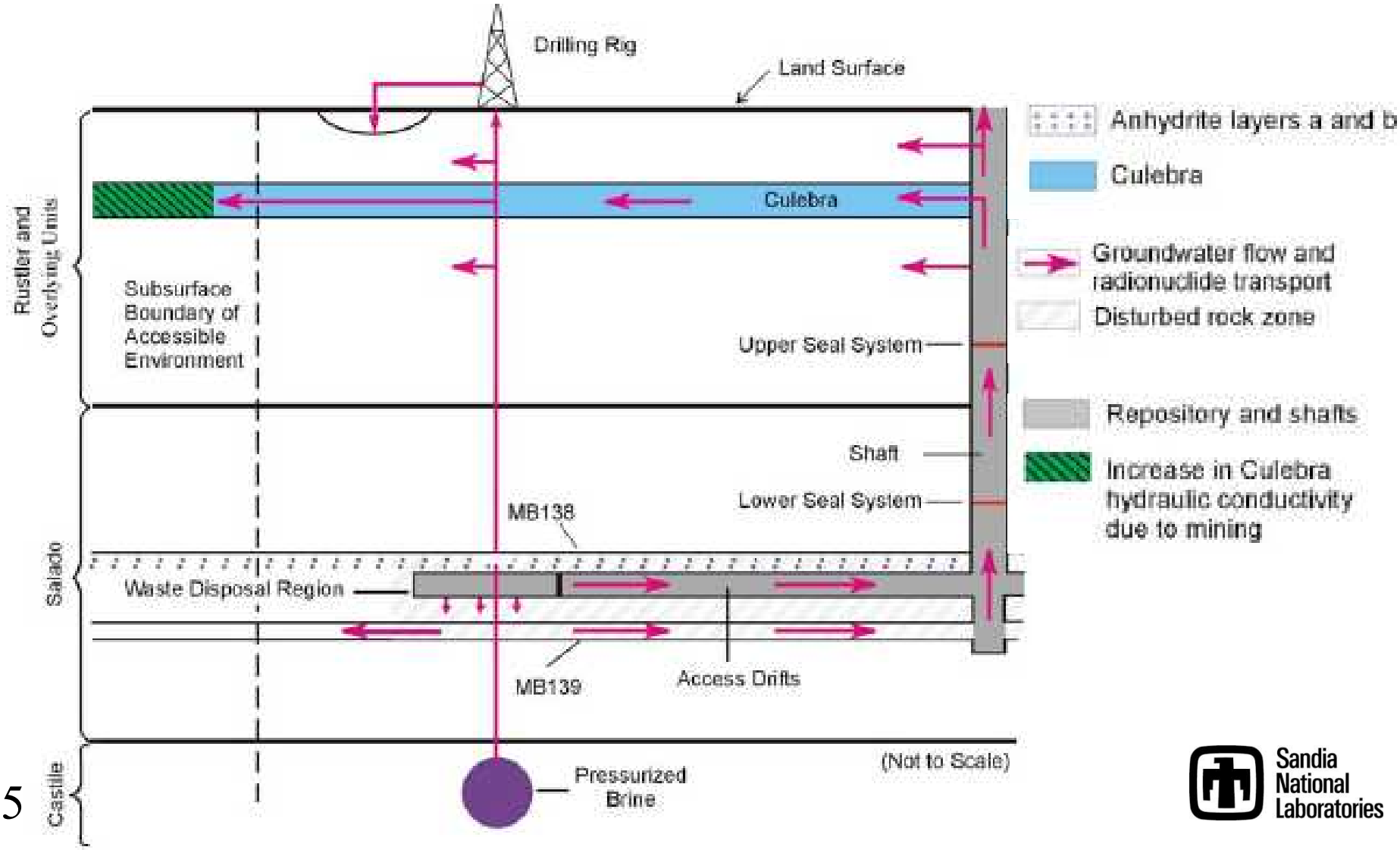
Sandia National Laboratories

Disturbed Performance (Drilling-E2)



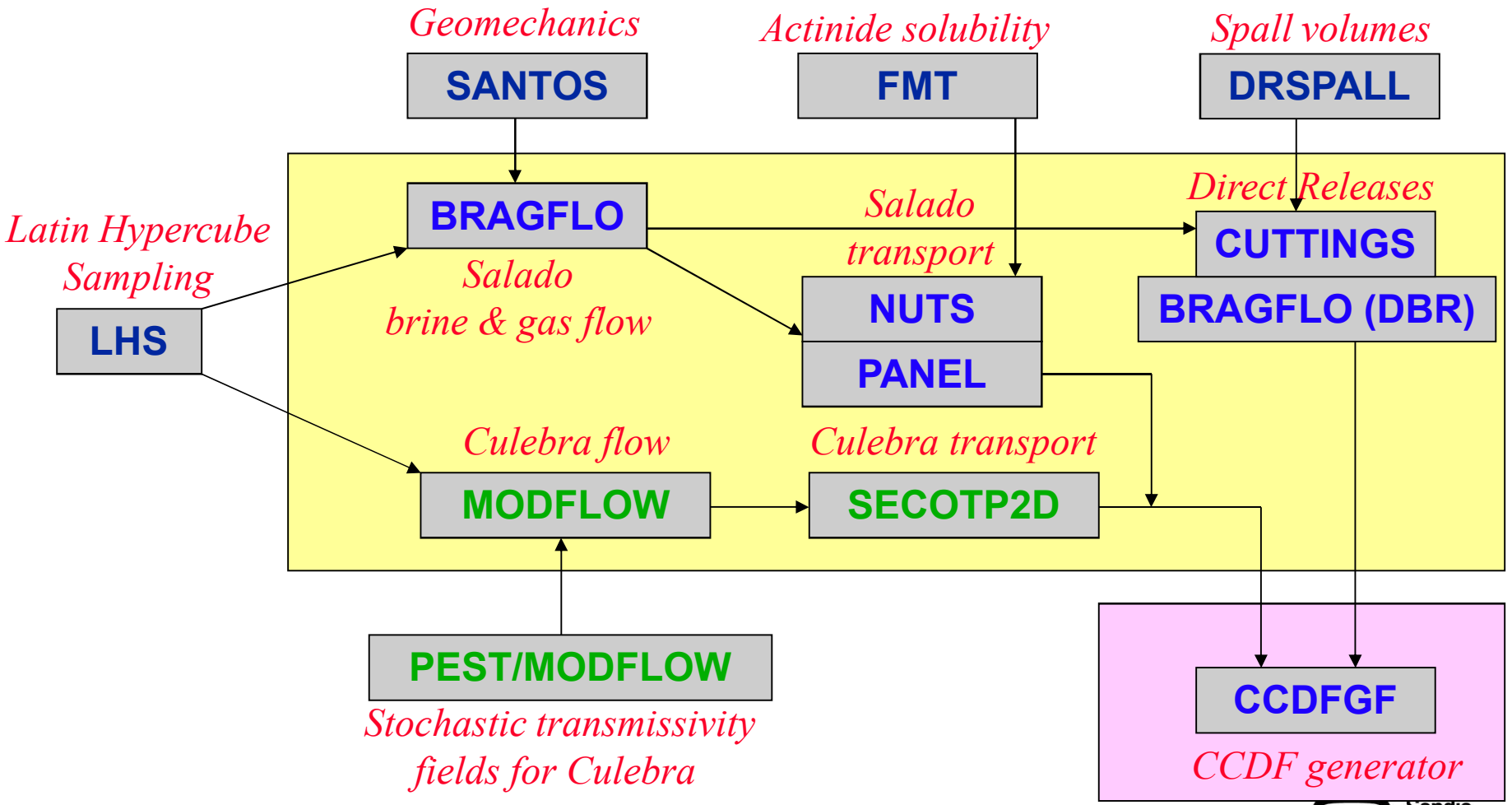
Sandia National Laboratories

Disturbed Performance (Drilling-E1)



Sandia National Laboratories

Scenario Consequence Estimation



Sandia National Laboratories

Role of Uncertainty in WIPP PA

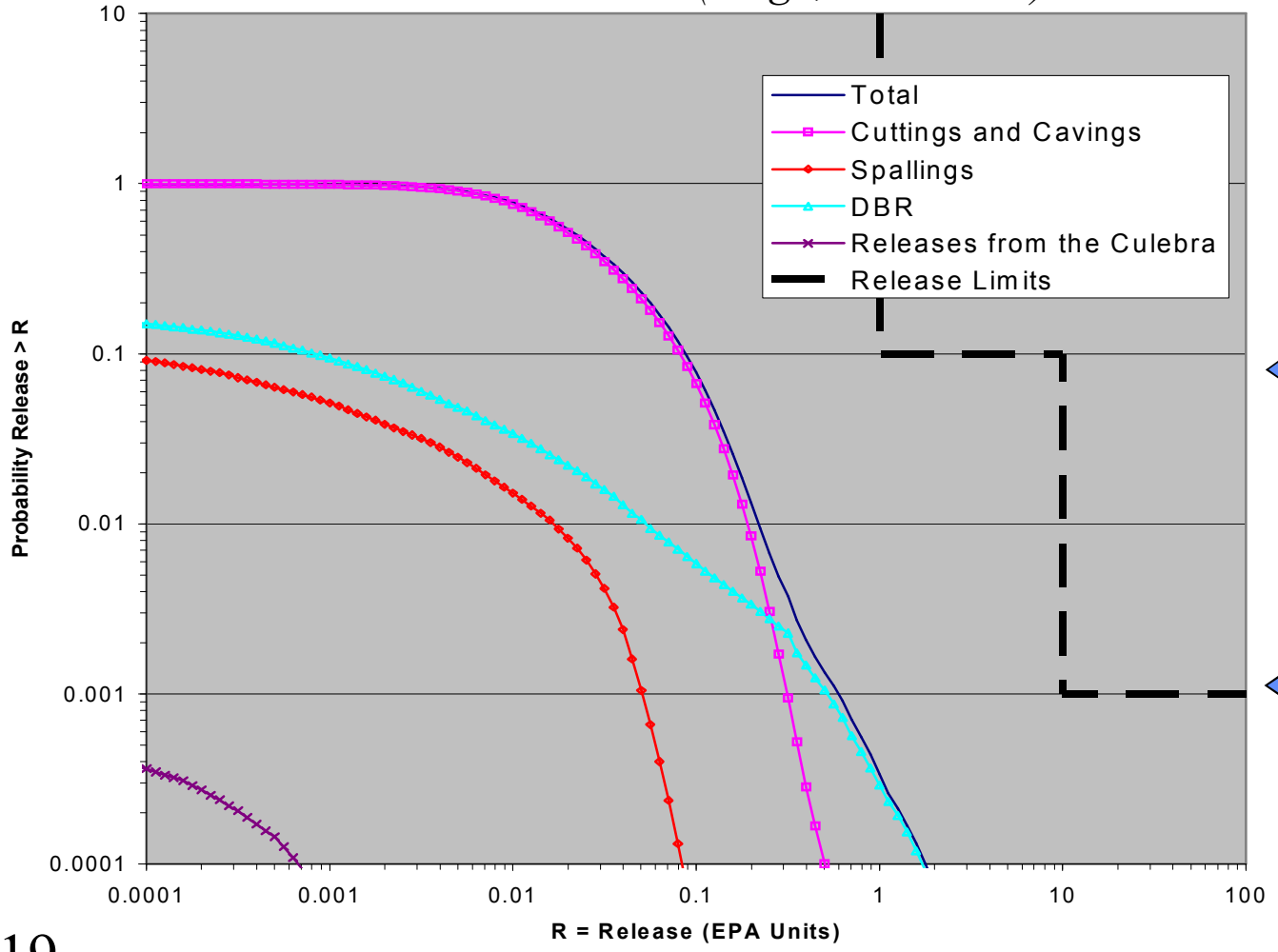
- Two principal types of uncertainty
  - Subjective (epistemic) uncertainty
    - Permeability of geologic media
    - Microbial degradation rates
    - Characteristics of degraded waste
  - Stochastic (aleatory) uncertainty
    - Time and location of drilling events
    - Potash mining in overlying strata

Construction of CCDFs

- Fix a vector of parameter values.
  - Random sampling used to construct possible futures (sequences of events)
    - 10,000 futures
    - For each future F_i, compute the release R_i.
    - Set of (F_i, 1/NF, R_i) quantifies the risk
  - Set of releases (R_i) estimate a probability distribution of releases (CCDF)
  - Shape of CCDF determined by stochastic uncertainty
- Repeat process for each parameter vector
  - Obtain family of CCDFs
  - Difference among CCDFs results from subjective uncertainty

Culebra Contribution to Total Releases

Results from CRA-2004 PABC (Leigh, et al. 2005)

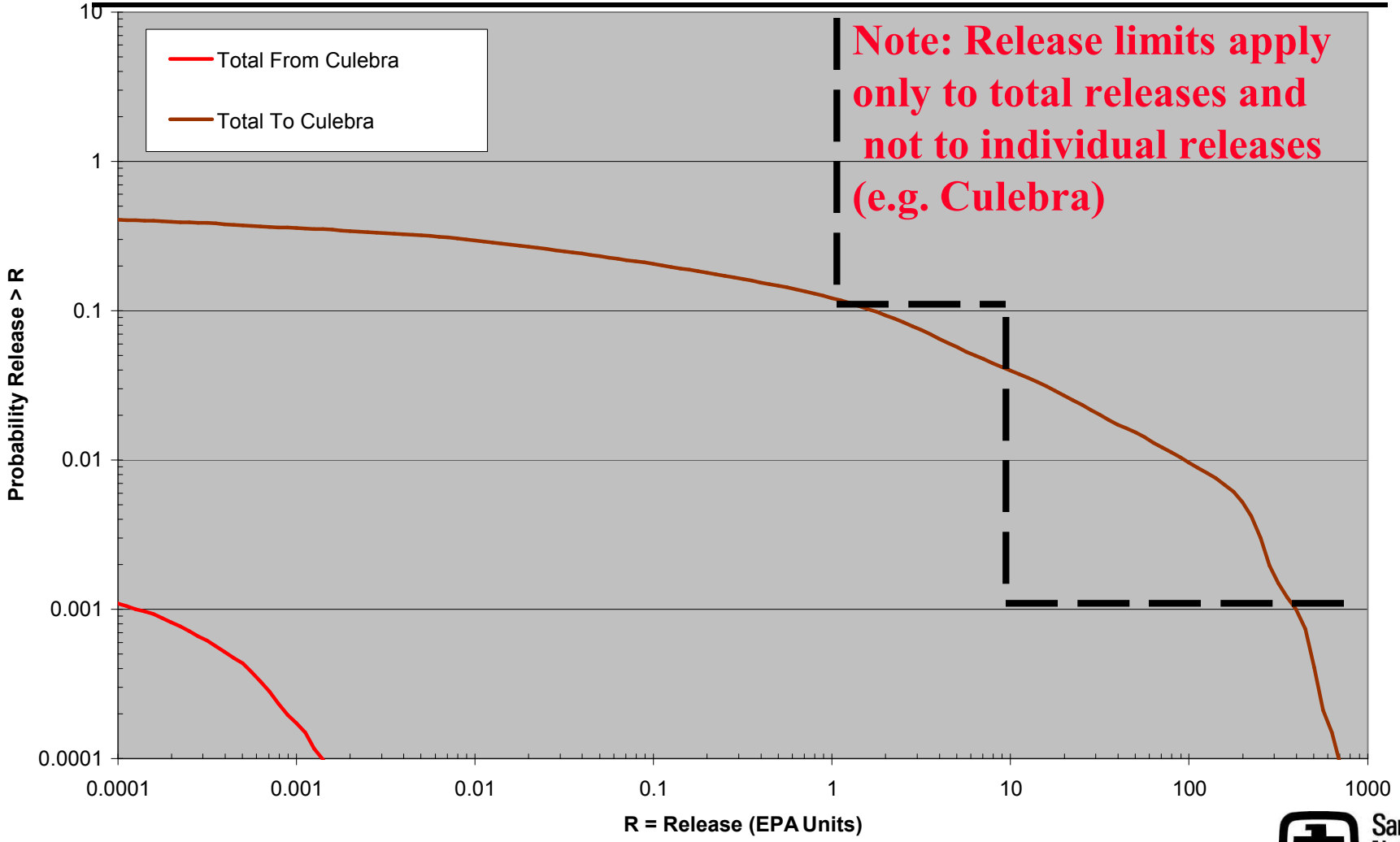


Less than 1 chance in 10 of exceeding 1 EPA unit

Less than 1 chance in 1000 of exceeding 10 EPA units

Sandia National Laboratories

Releases to Culebra vs. Releases From Culebra



Results from 2004 PABC (Replicate 2)

Sandia National Laboratories

References

- Leigh, C. D., J. F. Kanney, L. H. Brush, J. W. Garner, G. R. Kirkes, T. Lowry, M. B. Nemer, J. S. Stein, E. D. Vugrin, S. Wagner, and T. B. Kirchner. (2005). *2004 Compliance Recertification Application Performance Assessment Baseline Calculation, Revision 0*. Sandia National Laboratories, Carlsbad, NM. ERMS 541521.

Sandia National Laboratories