United States Nuclear Regulatory Commission

Performance Assessment Perspective on the Behavior of Engineered Barriers

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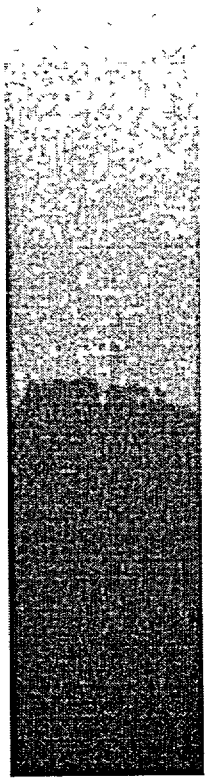
NMSS07
WM-11
6/19/02
Rec: Bret/NMSS

Outline

- Overall repository risk – current knowledge
- Insights on system behavior (waste package as a barrier)
- Conservatism and 'risk'
- Performance Assessment (PA) perspective – waste package key issues

Performance Assessment Perspective

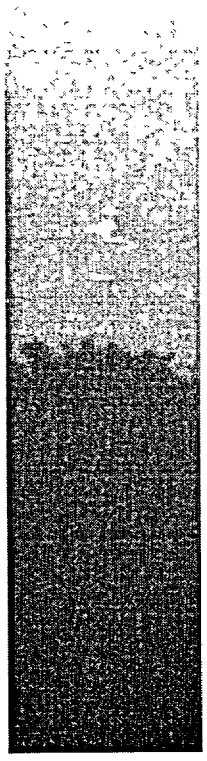


- Performance assessment perspective is a result of:
  - Independent analyses by NRC and CNWRA (TPA code, uncertainty and sensitivity analyses, barrier evaluation, other)
  - Review of DOE and others (e.g. EPRI)
  - Comments of review committees (e.g. ACNW, NWTRB, peer reviews)
- Performance assessment involves understanding why the results are what they are

Repository Risk (role of waste package)

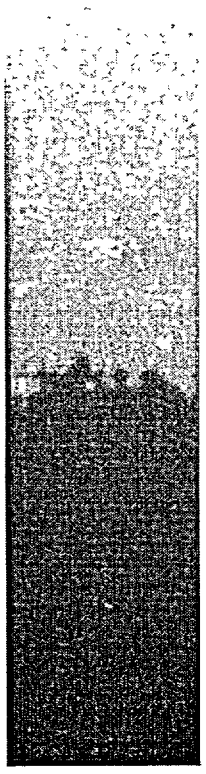
Scenario	Time Period	Nominal (mrem/yr)/# Failures		Igneous (mrem/yr)
DOE, TSPA-SR	10k	0	0	0.1
DOE, FEIS	10k	0.00002	0.3	0.1
DOE, TSPA-SR	100k	70	6000	NA
DOE, FEIS	100k	0.1	900	NA
DOE, TSPA-SR	peak	500	12000	NA
DOE, FEIS	peak	200	12000	NA

Overall Repository Risk – Current Understanding



- 10k model risks are small (assuming current models appropriately represent uncertainties)
- 100k and longer model risks are comparable to background radiation
- Igneous activity model risks are larger than nominal risks in 10k, but small compared to the radiological standard
- Why continue to study this problem?

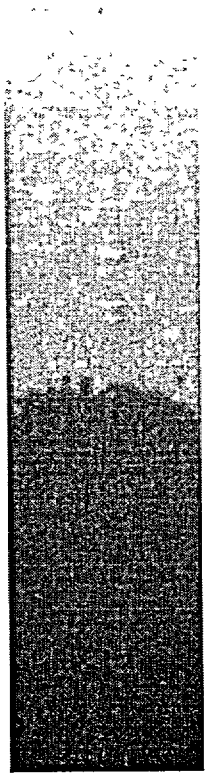
Overall Repository Risk – Current Understanding



- We continue to evaluate this problem to understand the impact of key uncertainties on:

  1) Timing and magnitude of the doses in the nominal scenario
  2) Magnitude of the disruptive scenario doses (reasonably bounded by current estimates).
  3) The capabilities of the barriers

Insights on System Behavior

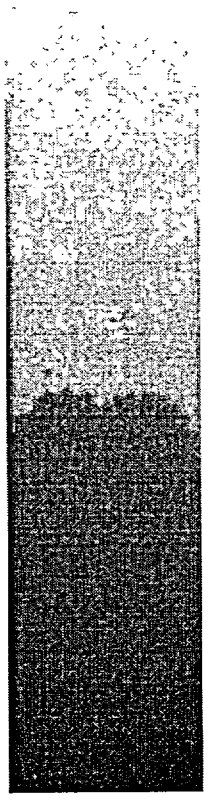


- Repository system comprised of many components
- Not all components are created equal (from a risk perspective)
- Both NRC and DOE analyses suggest that the waste package performance is significant contributor to limiting future risk
- Simple calculations can provide insights into repository behavior
- Is the waste package the only contributor that limits future risk?

Waste Package as a Barrier

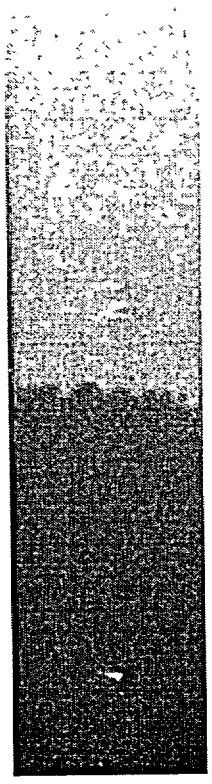
- Take inventory of ^{129}I (0.3 Ci) and ^{99}Tc (130 Ci) in a single commercial spent nuclear fuel waste package (readily transported species)
- Assume the spreading/dilution function of the rest of the system is only equivalent to 500 years
- Dilute the concentrations in the regulatory defined water volume (3,000 acre-ft/yr)
- Dose from a single package ~ 0.5 mrem/yr
- TPA 4.1 result from 40 initial failures is 0.02 mrem/yr, a factor of 1000 *lower*
- Other components of the repository system contribute to the limitation of future risks

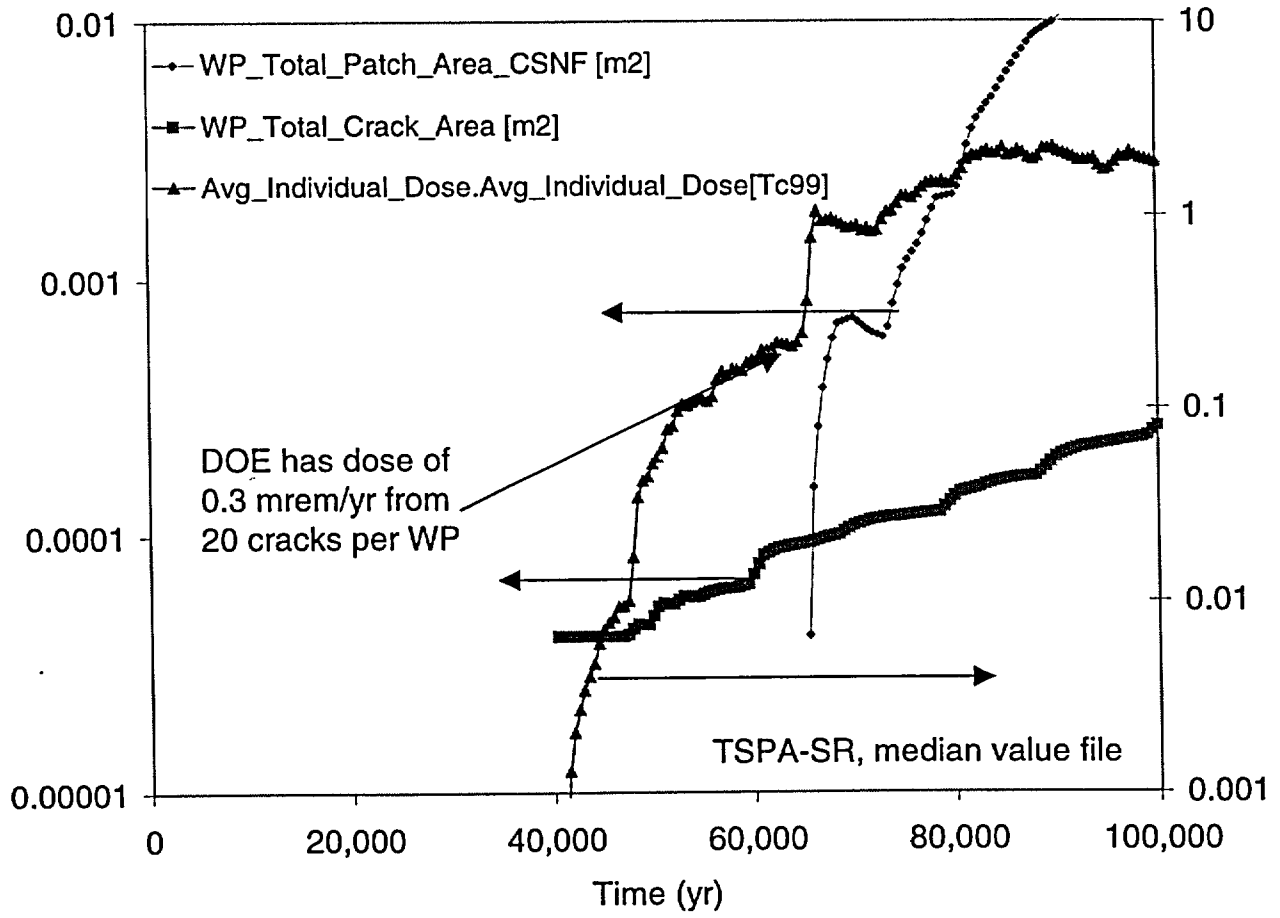
Risk and Surface Area Failed



- Diffusive releases are directly proportional to the surface area of the failures
- Early advective releases are strongly correlated with surface area failed
- Does the type of failure have a strong influence on risk?

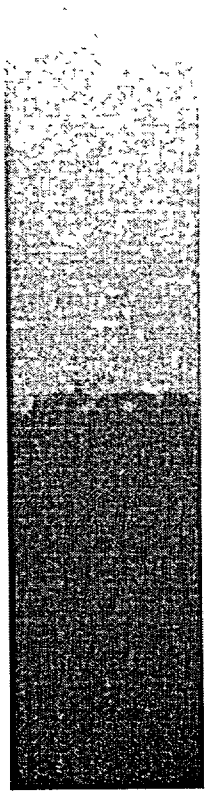
Risk and Surface Area Failed





In TSPA-SR, only 13% of packages experience advective conditions

Simple Models to Evaluate Diffusive Risks - SCC



Conservative representation (only diffusion through the end caps):

~300 mrem/yr from ^{129}I, ^{99}Tc, and ^{237}Np (300 cracks per package, 1000 packages cracked)

Less conservative representation (adding diffusion from waste to end caps through water film):

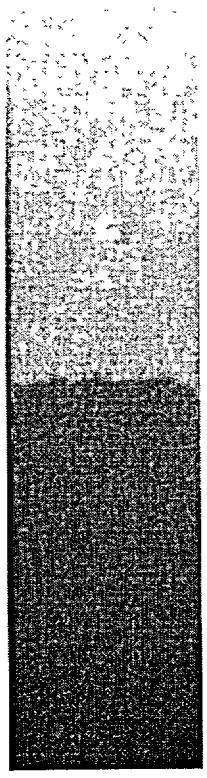
Reduces dose to 0.1 mrem/yr (no performance benefit from rest of repository)

Conclusion – Caution is needed in interpreting the results of highly conservative models

Risk and Surface Area Failed - Summary

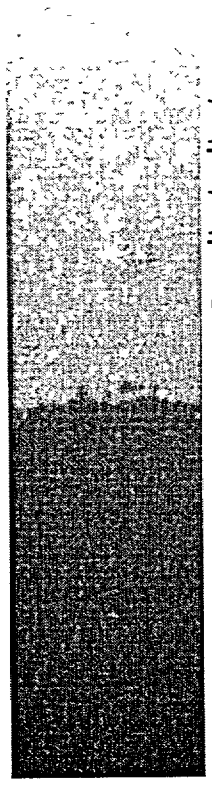
- Caution is needed in employing conservatism in mass transfer representations for radionuclide release
- Waste package failure mechanisms that result in numerous small openings or a few catastrophic failures are not likely to be risk-significant
- PA staff are most concerned with mechanisms that may result in numerous moderate to large openings that experience advective conditions

Issue Resolution in Waste Package and Drip Shield Performance



- Environmental Conditions
- Uniform Corrosion/Passivity
- Localized Corrosion
- Stress Corrosion Cracking (SCC)
- Drip Shield Performance
- Materials Aging
- Mechanical Failure
- Juvenile Failure
- Criticality

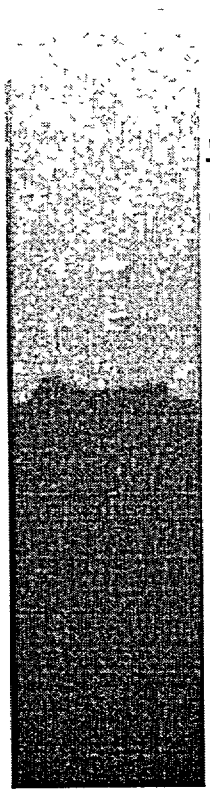
PA Perspective on Key WP Issues



<u>Environmental Conditions, Uniform Corrosion, Passivity, Localized Corrosion, Materials Aging</u>

- Higher risk-significance for mechanisms (or combination of) that could result in numerous reasonably-sized openings.
- Important to understand consequence and identify likelihood of transpassivity/localized corrosion

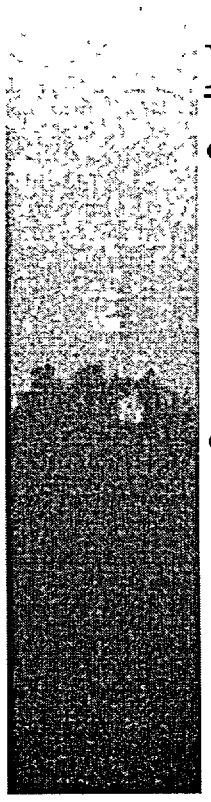
PA Perspective on Key WP Issues



Stress Corrosion Cracking (SCC)

- Frequency and size of openings not likely to create significant "risk" unless combined with conservative release modeling (see slide 11).
- Advective release not expected based on size of SCC failures and capillarity argument.
- Lower risk-significance.

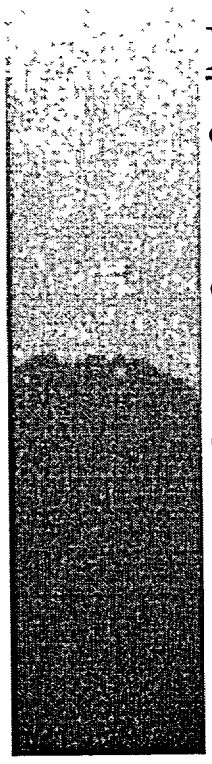
PA Perspective on Key WP Issues



Drip Shield Performance

- If drip shield is preventing numerous rockfall failures or preventing aggressive chemical conditions, would be much more risk-significant than current results indicate (see slide 25)
- Lower risk-significance (quantitative), Moderate risk-significance (thought)?

PA Perspective on Key WP Issues



Mechanical Failure

- Current analyses suggest combination of likelihood of occurrence and consequences are lower risk (rockfall)
- However, extent of drift degradation (likelihood) and resultant consequences need to be further analyzed
- Lower risk-significance (rockfall), drift degradation?

PA Perspective on Key WP Issues

Juvenile Failures

- Current TSPA results suggest frequency not high enough to create significant risk (see slides 4, 8)
- Lower risk-significance

Criticality

- Coupled to other degradation modes
- Current analyses suggest likelihood not large enough to create significant risk
- Lower risk-significance

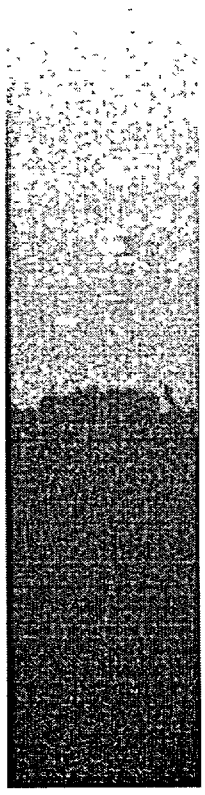
TSPAI Agreements and WP Key Issues

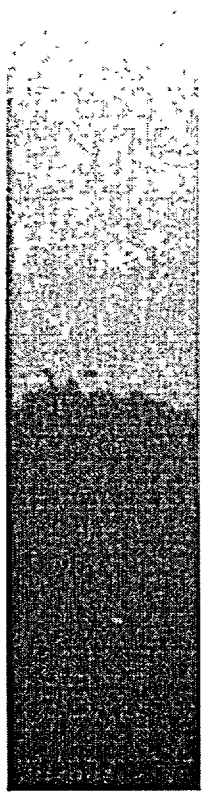
- 42 Agreements for TSPAI subissue 3 (model abstraction)
- Many TSPAI agreements deal with uncertainty
- ~ 30% pertain to uniform corrosion/passivity, localized corrosion, and environmental conditions

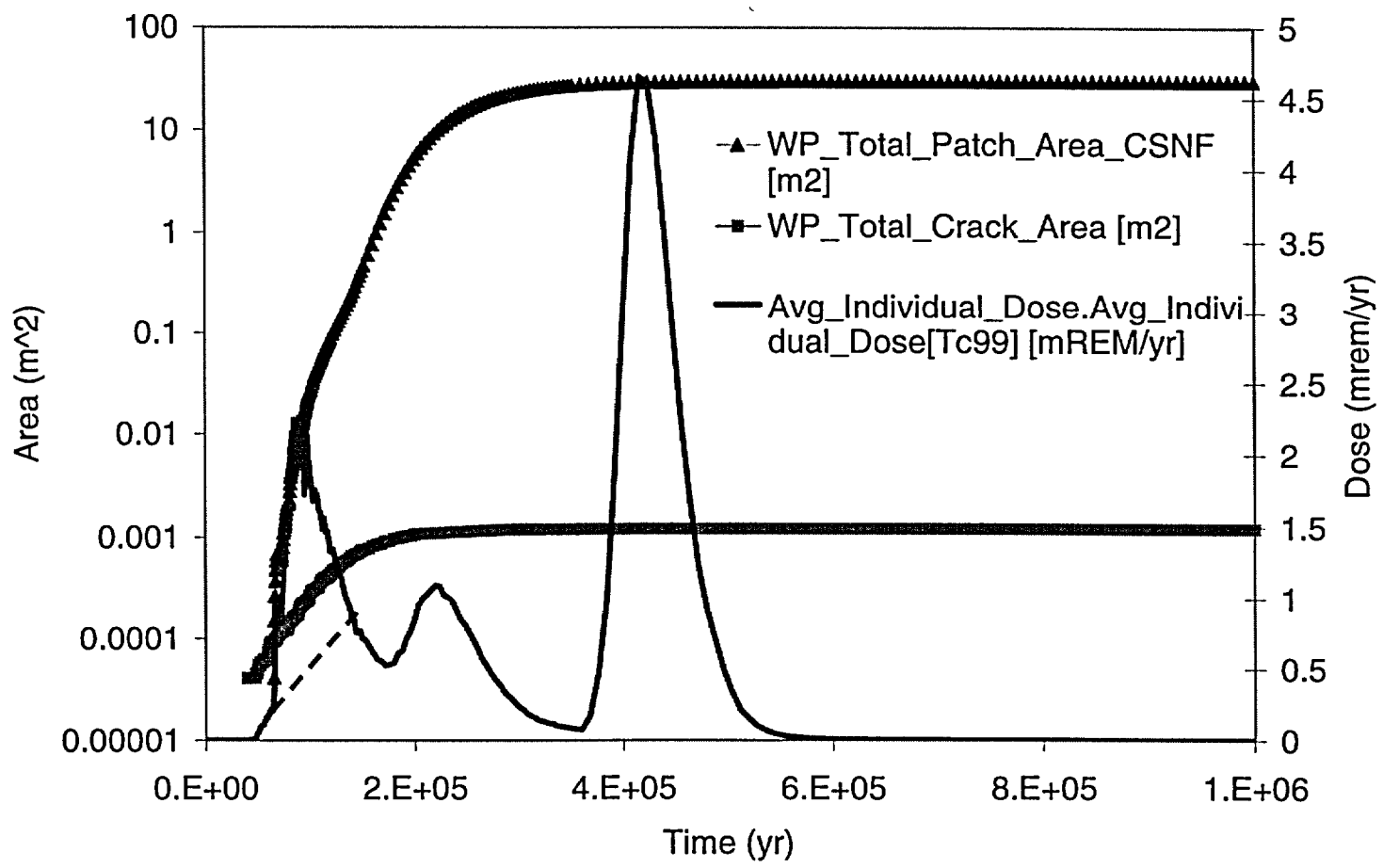
Conclusions

- The waste package is an important barrier, *but* the performance of other system components limit risks
- Caution is needed in utilizing conservatism and in interpreting results (from conservative models)
- PA results and additional analyses are used to condition thinking
- The assigned relative risk importance to CLST issues is based on current understanding

Back-up Slides





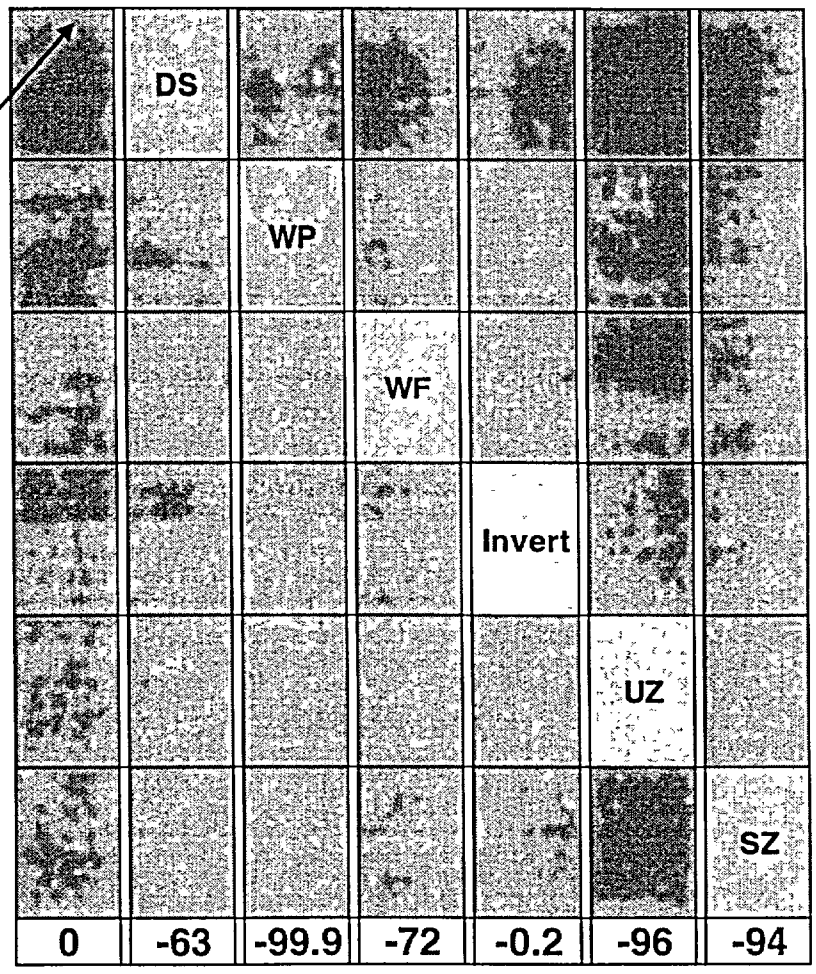

100
10
1
0.1
0.01
0.001
0.0001
0.00001
Area (m^2)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Dose (mrem/yr)
WP_Total_Patch_Area_CSNF [m2]
WP_Total_Crack_Area [m2]
Avg_Individual_Dose.Avg_Individual_Dose[Tc99] [mREM/yr]
0.E+00
2.E+05
4.E+05
6.E+05
8.E+05
1.E+06
Time (yr)

Parametric

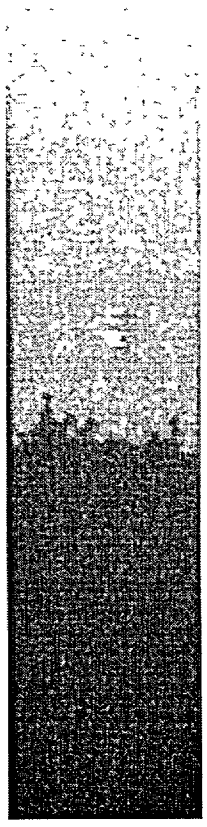
	NOMINAL CASE
1	Mean annual infiltration at start
2	WP flow multiplication factor
3	Spent fuel dissolution model pre-exponent
4	Subarea wet fraction
5	Drip shield failure time
6	Well pumping rate
7	Defective Fraction of WPs
8	Tuff-alluvium interface distance
9	Retardation of Np in SZ alluvium
10	Condensate toward repository

Barrier Component

Suppressed Barrier Component



% change w.r.t dose when all barrier components suppressed



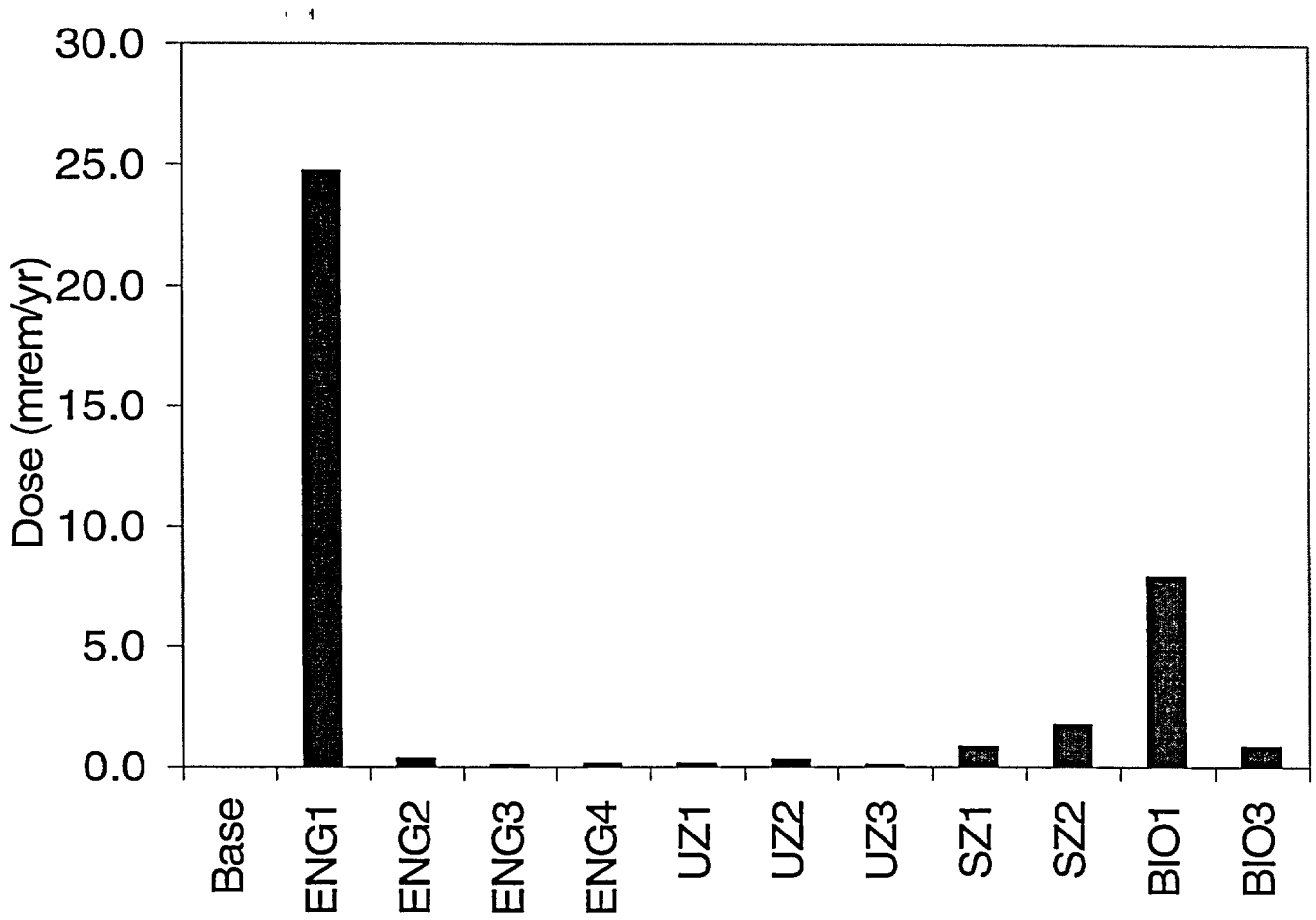


Figure 1 from (Esh, Codell, and McCartin, IHLW 2001)

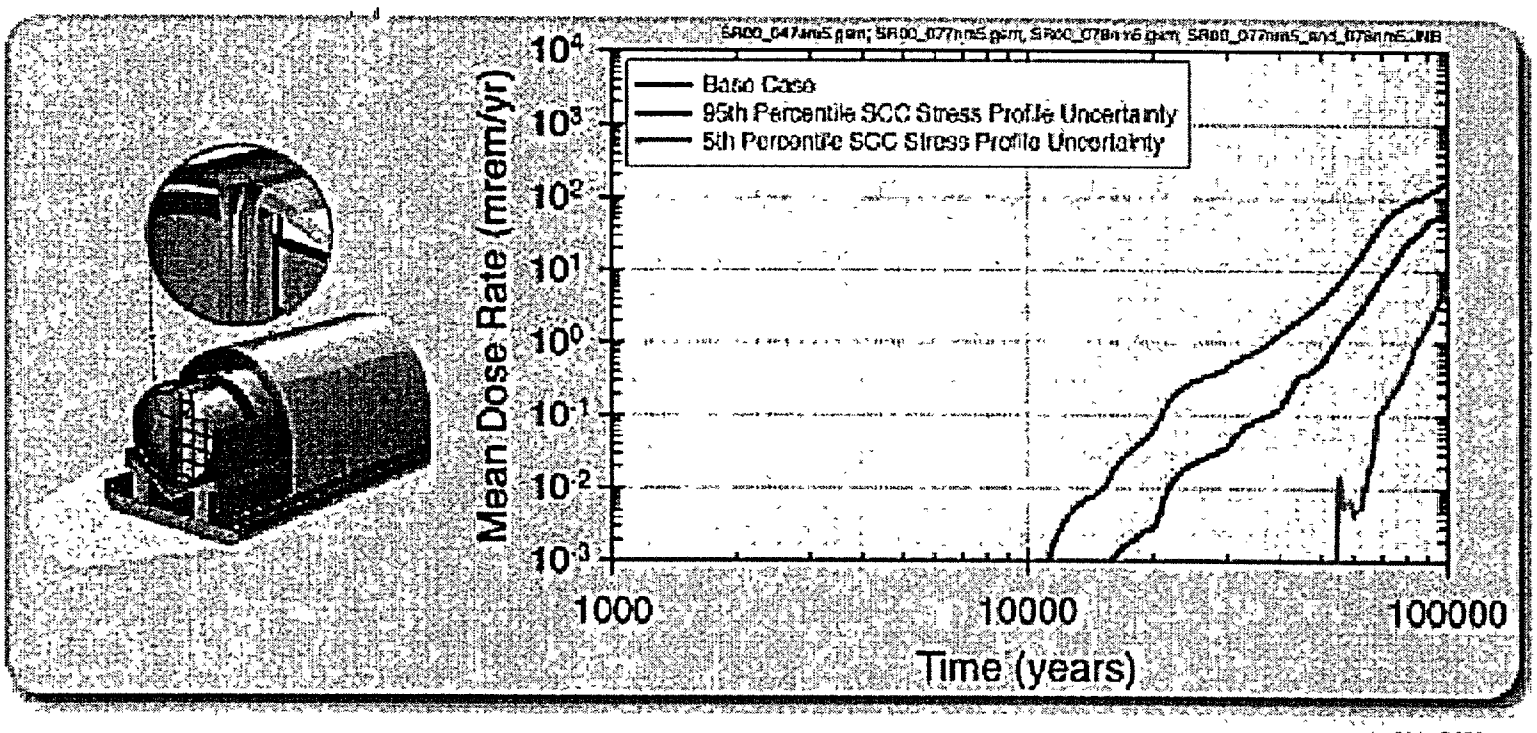


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Figure 5.2-3. Sensitivity of the Mean Dose Rate Profile to the Uncertainty of the Residual Hoop Stress and Stress Intensity Factor in the Outer Lid and Inner Lid Closure Welds

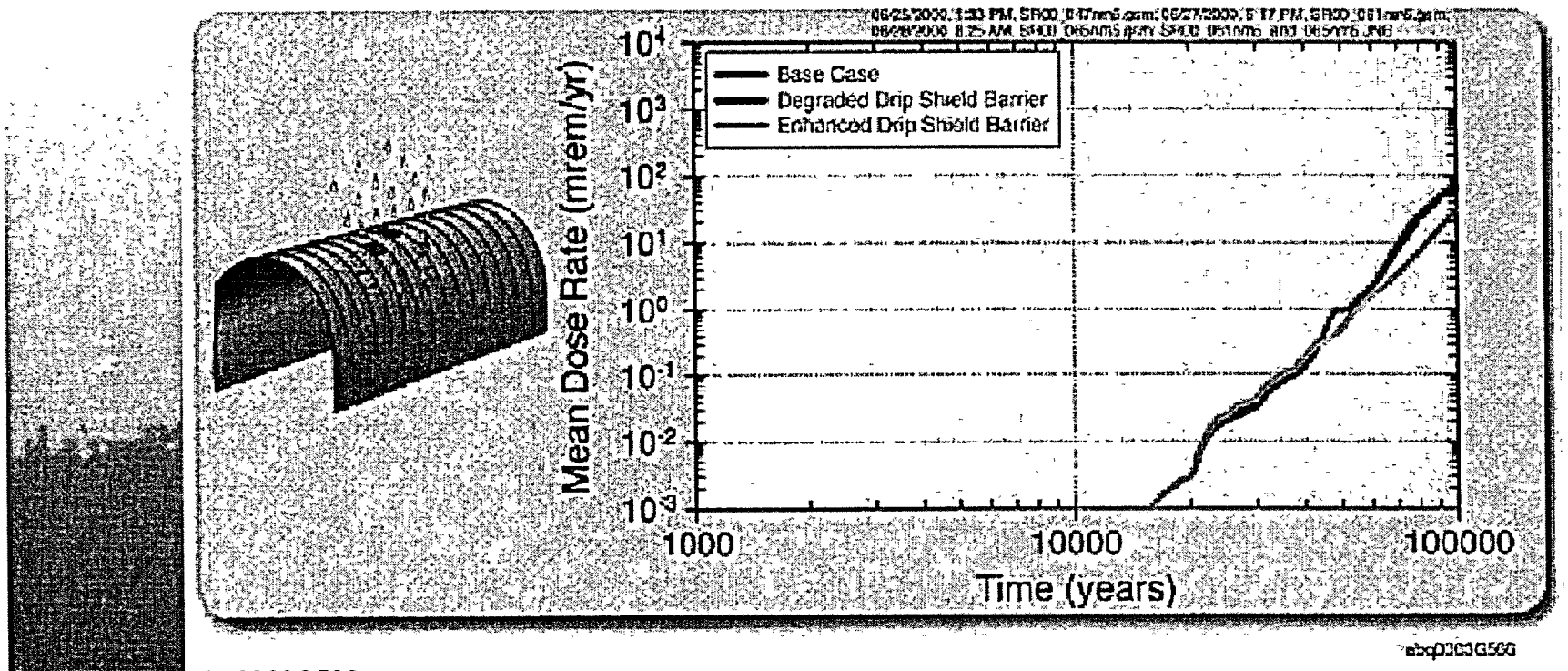

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Figure 5.3-3. Sensitivity of the Predicted Mean Dose Rate Profile to the Degraded and Enhanced Drip Shield Cases

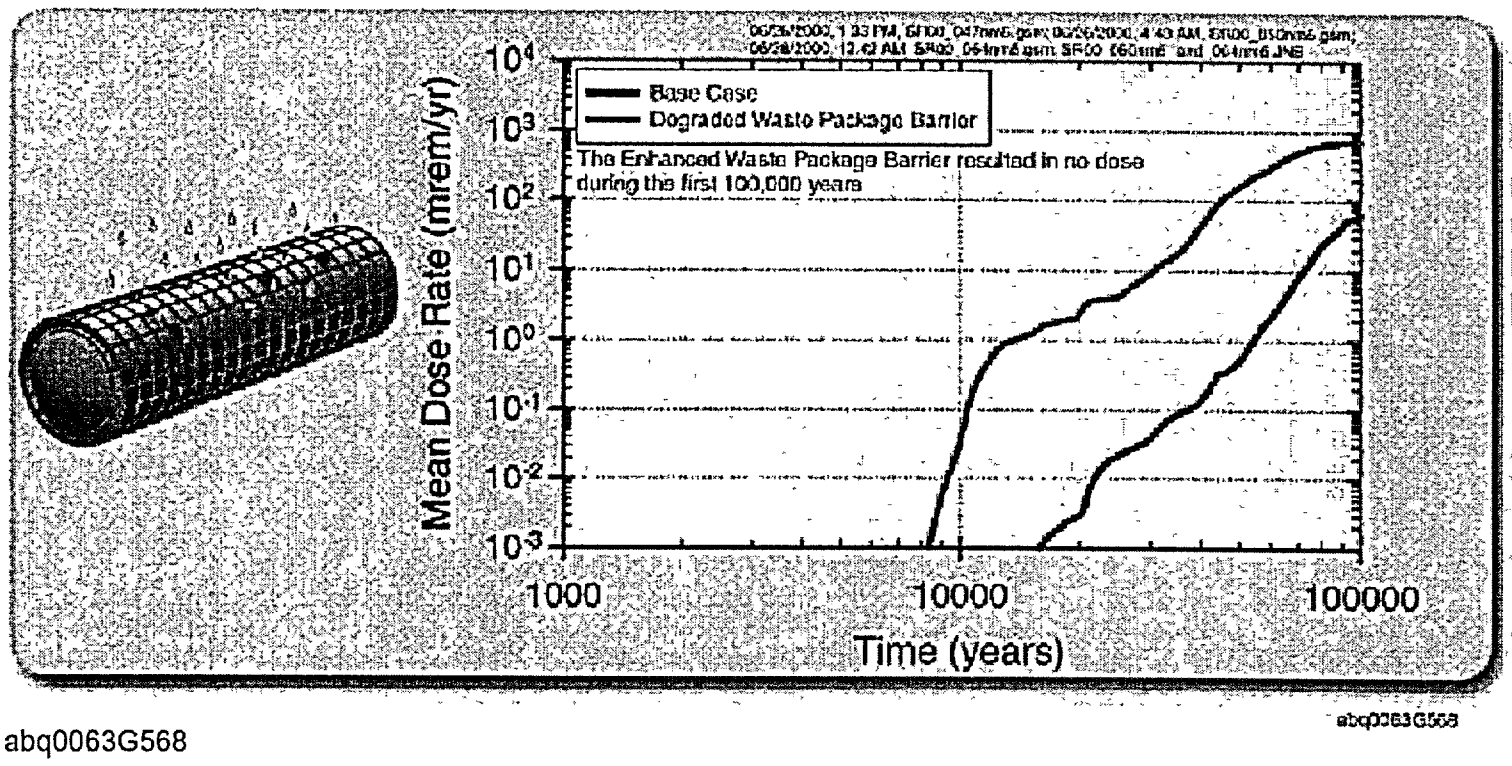

Figure 5.3-5. Sensitivity of the Predicted Mean Dose Rate Profile to the Degraded and Enhanced Waste Package Cases