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TPA 3.2 OVERVIEW

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DOE/NRC Technical Exchange on
Total System Performance Assessment for Yucca Mountain

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TPA 3.2 APPROACH

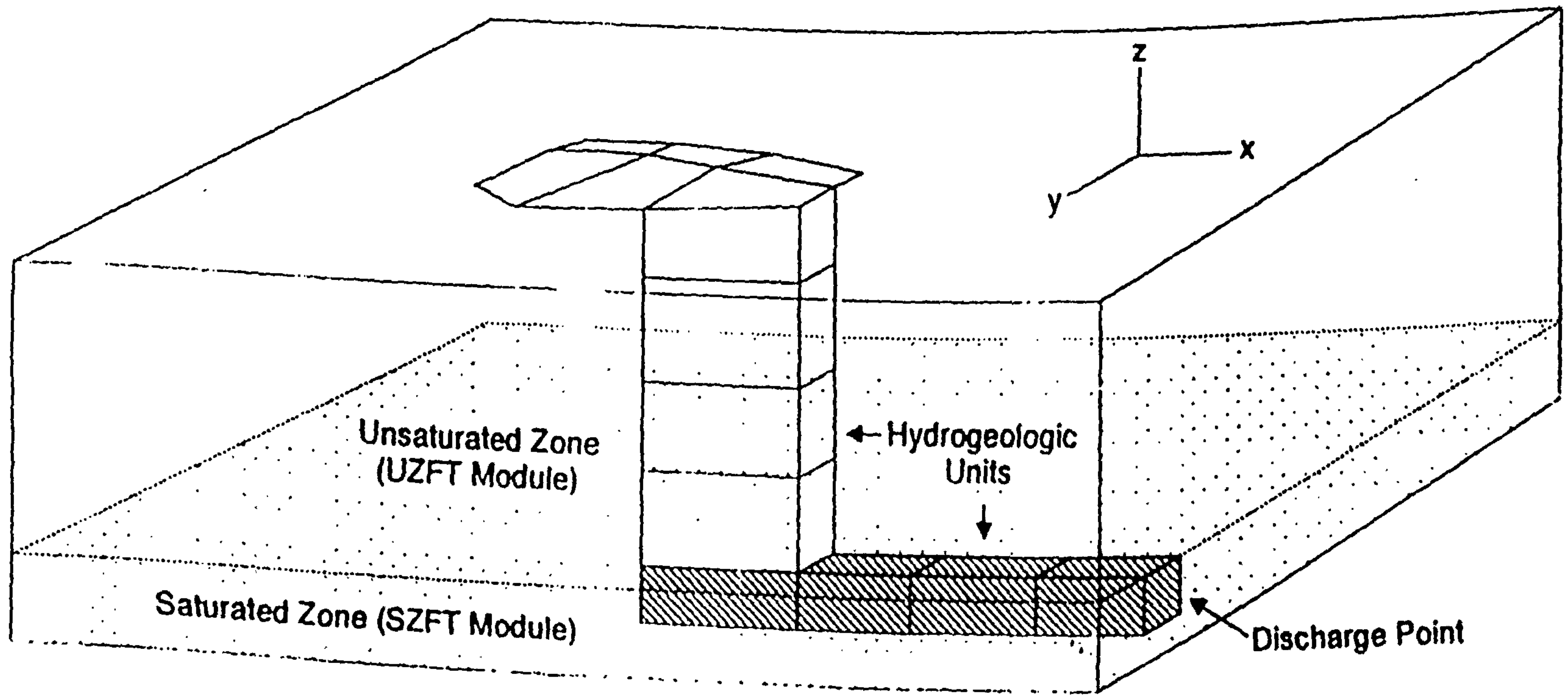
- **TPA 3.2, as part of NRC's Iterative Performance Assessment Program, was developed to provide insights on overall performance and assist reviews of DOE's TSPA**
  - provides a capability/tool with flexibility to consider a variety of concepts and models
  - use of conservative model or data range may be used, as appropriate, to limit the need for further development

- **Site information (including laboratory experiments and information from analogous environments) and results from detailed process models support PA abstractions**

NOTE: Use of a particular approach, model, or parameter in TPA 3.2 should NOT be construed as regulatory acceptance

CAUTION: INSIGHTS AND ASSERTIONS ARE PRELIMINARY
- PARAMETER AND MODEL REFINEMENT IS CONTINUING
- PRELIMINARY OUTPUTS BASED ON LIMITED ANALYSIS

Depiction of One-Dimensional Transport Paths
(Unsaturated and Saturated Zones)



PHYSICAL DESCRIPTION

- **Repository divided into 7 subareas (not limited to seven)**
  - variation in unsaturated zone stratigraphy
  - variation in deep percolation (assumes vertical flow)
  - variation in temperature and humidity

- **Representative waste packages evaluated for each subarea**
  - degradation of waste package
  - distinct failure (i.e., bathtub height) for the various failure modes (e.g., corrosion, rockfall, etc.) - TPA 3.2 improvement
  - release of radionuclides
  - inclusion of invert - TPA 3.2 improvement

- **Four saturated zone stream tubes**
  - two properties considered (fractured tuff, and alluvium)
  - correlation of Kd for chemically similar radionuclides - TPA 3.2 improvement

TPA 3.2 Code Description

1) **Amount and Distribution of Deep Percolation**
   (How much water enters repository drifts?)

2) **Waste Package Degradation**
   (When and what type)

3) **Radionuclide Release**
   (At what rate do radionuclides leave the EBS?)

4) **Unsaturated Zone Transport**
   (At what rate do radionuclides enter the saturated zone?)

5) **Saturated Zone Transport**
   (At what rate do radionuclides arrive at the receptor location?)

6) **Direct Release (volcanic event)**
   (What amount of radionuclides are released by extrusive component to the receptor location)

7) **Dose Calculation**
   (What is the dose at the receptor location?)

AMOUNT AND DISTRIBUTION OF DEEP PERCOLATION

- **Initial Infiltration Varies Between 1 and 10 mm/yr**

- **Temperature and Precipitation Affect Future Infiltration Estimates**
  - Precipitation Increase varies between 1.5 and 2.5 times present value (at glacial maximum, ~45,000 years)
  - Temperature decrease varies between 10 and 5 °C cooler than present (at glacial maximum, ~45,000 years)
  - no consideration of run-off and transpiration

- **Reflux of Water**
  - refluxing water can be sufficient to penetrate the boiling isotherm (lifetime of container minimizes effect on performance when drips do not affect corrosion rate)

- **Distribution of Deep Percolation**
  - affects number of waste packages that get wet (on average 50% of WPs are dripped on)

Waste Package Degradation

- **Waste package corrosion**
  (temperature, humidity and water chemistry at surface of waste package)
  - representative container in a subarea used in determining corrosion of container
  - average failure time of 20,000 years (range of 10,000 - 50,000 yrs)

- **Mechanical disruption of waste package**
  - fracture of the outer overpack due to thermal embrittlement
  - direct disruption due to faulting and igneous activity
  - rupture due to rock falls induced by seismicity

- **Initially Failed Packages**
  - average of 32 waste packages assumed defective

WP Failure due to Faulting and Seismicity (rockfall)

- **Fault occurs once over 10,000 years**
  - 30 WPs fail (average over 1,000 vectors)
  - annual probability 5×10^{-6}

- **Seismically induced Rockfall**
  - four distinct time periods (0 - 2000; 2000 - 5000; 5000 - 10,000; >10,000)
  - fractional area affected varies with magnitude of acceleration
  - WP failures in four time periods are: 0.2; 0.3; 0.7; and 1.2 (average over 1,000 vectors)

Radionuclide Release

- **Amount of Water Contacting Waste**
  - convergence/divergence of deep percolation (0.01 - 3.0)
  - diversion of water in and around drifts and into WP pits

- **Radionuclide release rates**
  - congruent dissolution of spent fuel with surface area calculation
  - user supplied release rate
  - release rate that considers formation of secondary minerals

- **Surface area of waste form contacted by water**
  - Bath tub conceptual model
  - options for cladding credit and flow-through model

UNSATURATED ZONE TRANSPORT

- **Transport will be vertical from the repository to the water table**

- **Unit hydrologic properties and deep percolation used to determine fracture versus matrix flow**
  - Topopah Springs (welded) primarily fracture flow
  - Calico Hills (non-welded, zeolitic) primarily fracture flow
  - Calico Hills (non-welded, vitric) primarily matrix flow (Only present in 2 of 7 subareas)

- **Retardation in fractures**
  - matrix diffusion and sorption on fracture surfaces not considered significant

UNSATURATED ZONE

STRATIGRAPHIC LAYERS AND THICKNESS (m)

Subarea	TSw	CHv	CHz	PP	UCFz	BF	Distance to WT
SA #1	33	---	163	34	67	---	297
SA #2	116	---	154	39	20	---	329
SA # 3	20	---	122	40	158	---	340
SA #4	110	---	132	34	57	---	333
SA #5	20	113	---	38	158	32	361
SA #6	53	125	---	26	136	---	340
SA #7	121	---	114	43	63	---	341

SATURATED ZONE TRANSPORT

- **Four flow paths (repository footprint to receptor location)**
  - initially in fractured tuff (~13 km)
  - alluvium at receptor location (~8 km)

- Fractured Tuff
  - transport only in fractures
  - fracture velocities vary between 50 and 500 m/yr

- **Alluvium**
  - porous flow with retardation
  - alluvium velocities vary between 3 and 5 m/yr
  - Retardation Factors

    Np-237, Loguniform Distribution: [1.0, 3900.]

    Tc-99, Loguniform Distribution: [1.0, 30.]

    I-129, Loguniform Distribution: [1.0., 4.0]

DIRECT RELEASE
Volcanic Event (extrusive component)

- **Entrainment of spent fuel in ash**
  - number of containers intercepted by volcanic conduit (1 to 10 waste packages)
  - incorporation ratio of spent fuel into volcanic ash
- **Air transport of ash**
  - deposition and particle size at receptor location based on wind speed and direction, and eruption energetics
- **Time of event and time of dose**
  - dose decreases significantly with time of event (decay of relatively short-lived radionuclides; e.g., Am-241)
  - dose decreases with length of time between occurrence of event and exposure (decay of radionuclides and erosion of ash blanket)

DOSE CALCULATION

- **Dilution of radionuclides in groundwater**
  - pumping well characteristics and water use
  - pumping rate, Uniform Dist.: [4.5e6,1.3e7] gal/day

- **Dilution of radionuclides in soil**
  (direct release to surface from volcanism)
  - erosion of ash blanket (blanket remains for ~1000 years)

- **Dose conversion factors**
  - lifestyle (time spent outdoors for direct and inhalation doses)
  - diet of locally grown food
  - representative person (mean values) used in dose estimates

EXPECTED ANNUAL DOSE

- **Consequence calculation includes parameter uncertainty in dose estimate**
  - Monte Carlo sampling

- **Consequence is time dependent**
  - early disruptive events have greater impact
    (Shorter lived radionuclides have potential to cause exposure)
  - dose from direct release varies with the length between the release and the exposure

- **Expected dose combines the variation in consequence and probability**

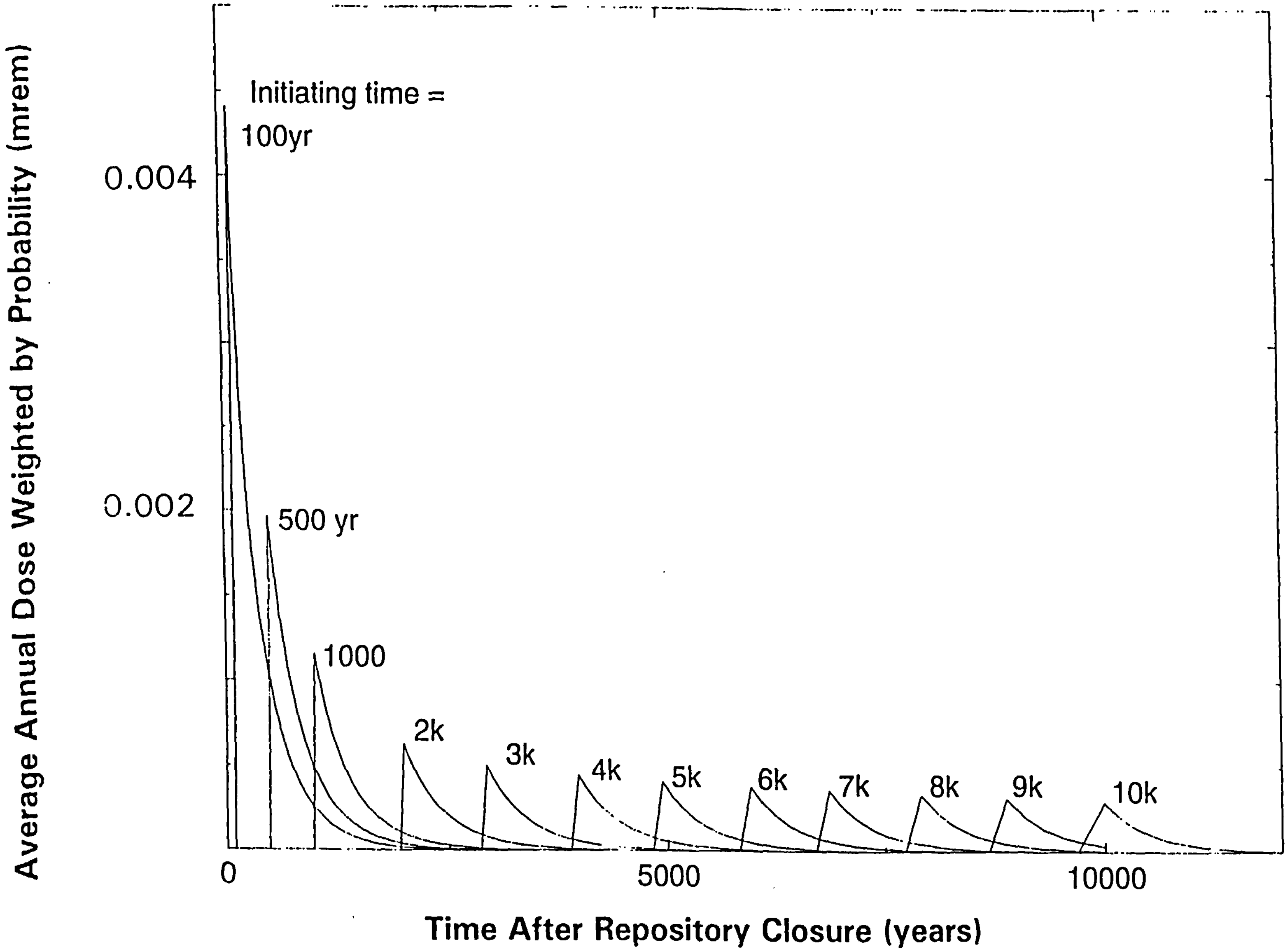
$$R(t) = \sum_{n=1}^{E} \Delta T \cdot p \cdot D_n(t)$$

where:

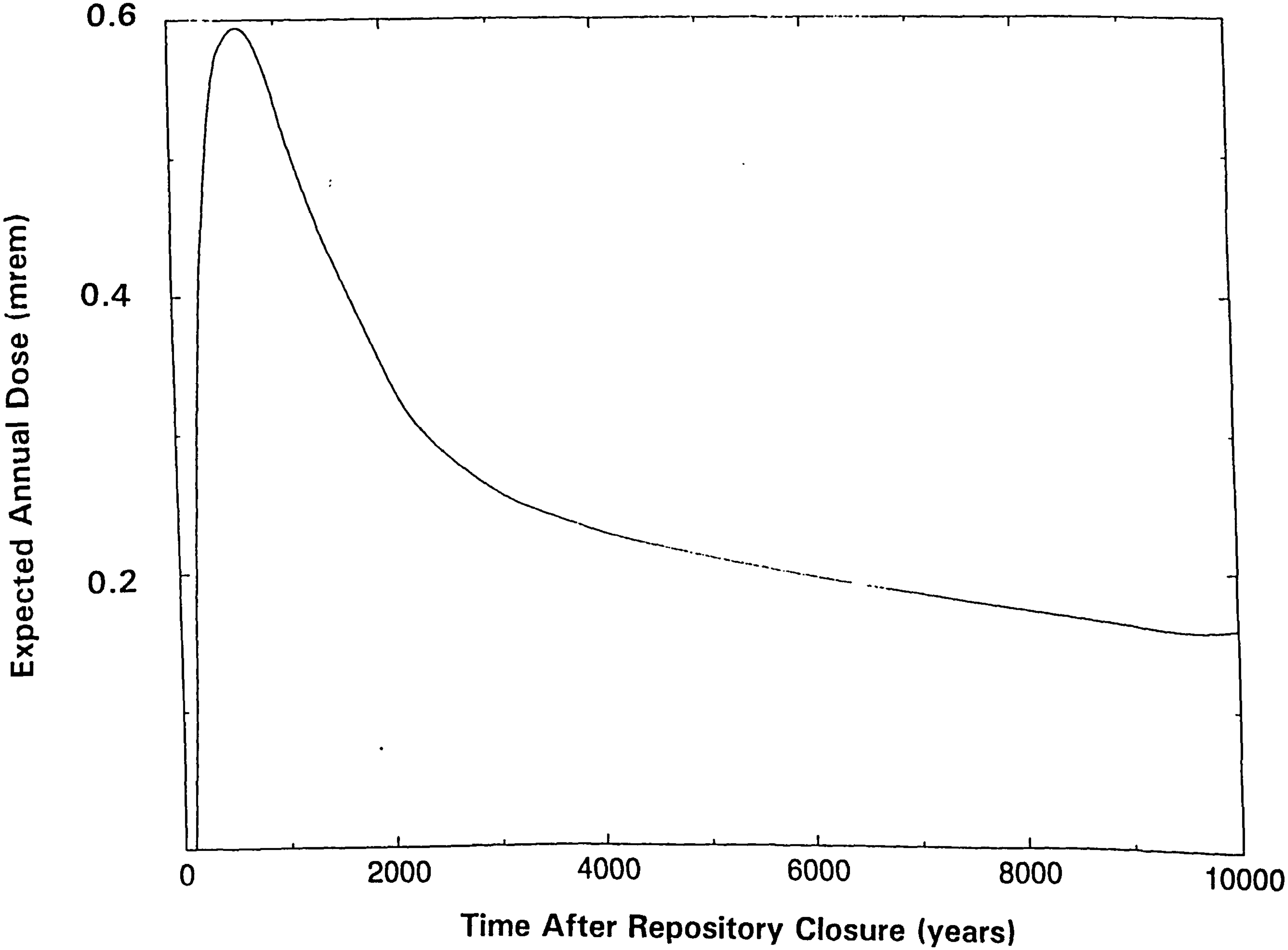
R(t)	=	**expected annual dose at time t**
ΔT	=	**increment of time associated with event n**
p	=	**annual probability for event n**
D_n	=	**average annual dose for event n at time t**
E	=	**number of events**

Average Annual Dose Weighted by Annual Probability for extrusive volcanic events at specific years

(annual event probability is 10^{-7} per year)



Expected Annual Dose for extrusive volcanic events



COMPONENTS OF TOTAL SYSTEM ANALYSIS

SCENARIO CLASSES

- Base Case
  - Undisturbed (present day conditions) + Climate Change (precipitation history) + Seismicity (effects of rockfall on WP failure)

- Base Case + Volcanism

- Base Case + Faulting

SYSTEM LEVEL SENSITIVITY ANALYSES

- Base Case
  - Alternative Conceptual Models
  - VA Comparisons
  - parameter sensitivity

- Disruptive Scenarios
  - parameter sensitivity

Scope of Sensitivity Analyses

TPA 3.2 Provides Flexibility for UNDERSTANDING Performance in the context of different modeling approaches for representing YM

- Variety of statistical methods for examining parameter sensitivity
  - assist understanding of non-linear aspect of sensitivity
- Variety of alternative models
  - assist the understanding of conservatism in modeling approaches
- Long simulation periods (i.e., 50,000 and 100,000 years)
  - assist understanding of the sensitivity of engineered components with very slow degradation rates
  - assist understanding of the sensitivity of retardation factors that may delay doses for very long time periods
  - assist understanding of sensitivity of climatic variations
  - TSPA-VA uses long simulation periods
- All of the above used to evaluate TSPA-VA
  - assist understanding of the adequacy of TPA 3.2 for review of LA

Total System Results

- Total System Calculations in S. Mohanty Presentation
  - mean value simulation and sensitivities
  - total system results

- Sensitivity Analysis in R. Codell Presentation
  - parameter sensitivity
  - alternative models