Cementitious Barriers Partnership

Project Number 08.1.3.1.7

D. Kosson (Presenter), CRESP, Vanderbilt U.

D. Esh, M. Furman, J. Phillip, US NRC

S. Mahadevan, A. Garrabrants, K. Brown, CRESP, Vanderbilt U.

H. Van der Sloot, R. Comans, J.C.L. Meeussen, ECN (NL)

E. Garboczi, K. Snyder, NIST

E. Samson, J. Marchand, SIMCO, Inc.

C. Langton, R. Dimenna, G. Taylor, SRNL

Partnership Members

- **Department of Energy – Office of Environmental Management**
  - Principal supporting agency
  - Primary end-user
- **Nuclear Regulatory Commission**
  - Oversight & Research Divisions
  - Primary end-user
- **National Institute of Standards and Technology**
- **Savannah River National Laboratory**
- **Consortium for Risk Evaluation with Stakeholder Participation (CRESP)**
- **Energy Research Centre of the Netherlands**
- **SIMCO**

Expert Advisory Panel organized through CRESP Independent Peer Review Board

Project Description

- **Technology Needs / Requirements**
  - Develop a reasonable and credible set of tools to predict the structural, hydraulic and chemical performance of cement barriers used in nuclear applications over extended time frames (e.g., >100 years for operating facilities and > 1000 years for waste management).
    - Mechanistic / Phenomenological Basis
    - Parameter Estimation and Measurement
    - Boundary Conditions (physical, chemical interfaces)
    - Uncertainty Characterization

Project Description

- **Risk / Cost Issues**
  - Current PA approach may not adequately represent risk and uncertainty of disposal and containment systems and practices
    - Waste form selection, contaminant loading, optimization
    - Disposal decisions
    - Remediation and D&D options evaluations
  - Design improvements of future facilities may not be realized due to lack of mechanistic understanding of cementitious barrier performance
  - Lack of transparency, consistency, and peer review for evaluation of long-term performance may give rise to increased:
    - Cost
    - Schedules
    - Stakeholder concerns

Project Description – Technical Strategy / Approach

- **Technology Description**
  - A set of computational and tools, including evaluation of uncertainties, and suite of parameter test methods will be developed for predicting long-term performance of cementitious barriers used for radionuclide containment.

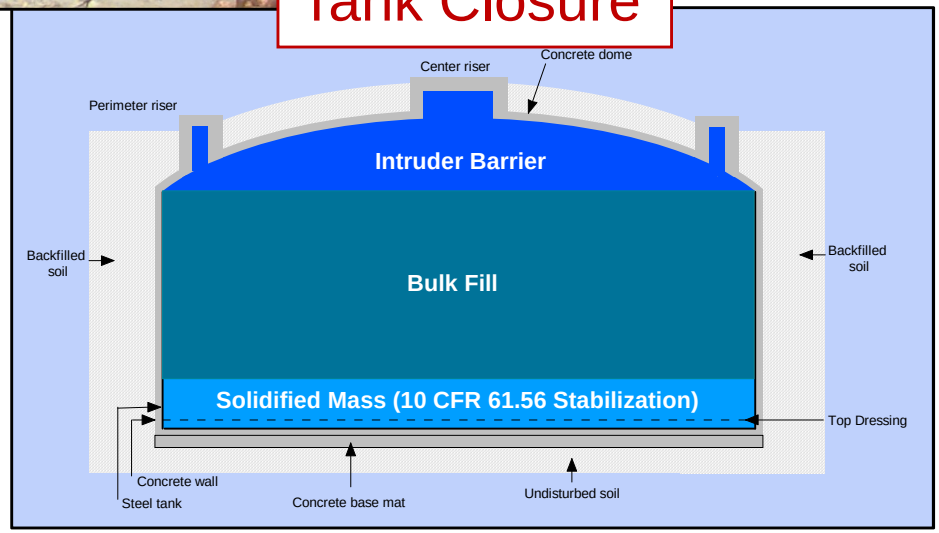
DOE Applications

LAW Disposal

Components in Grout

Saltstone Vaults

Tank Closure



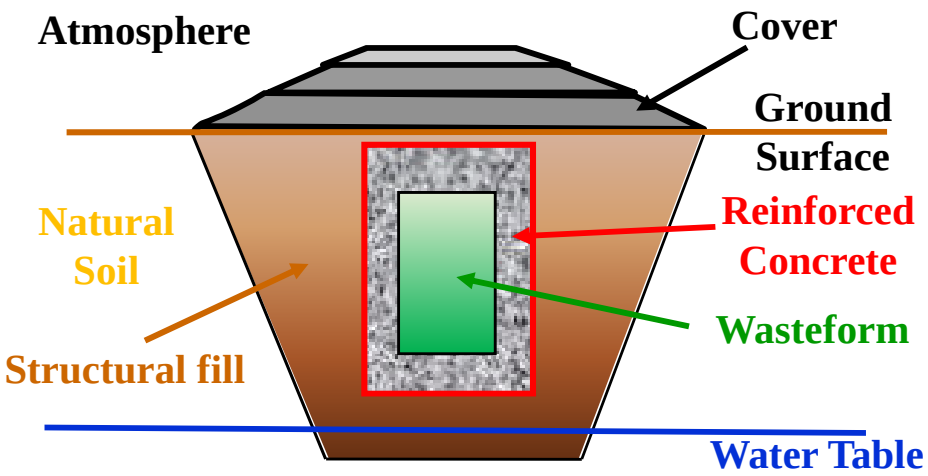
D & D Entombment

Environmental Management

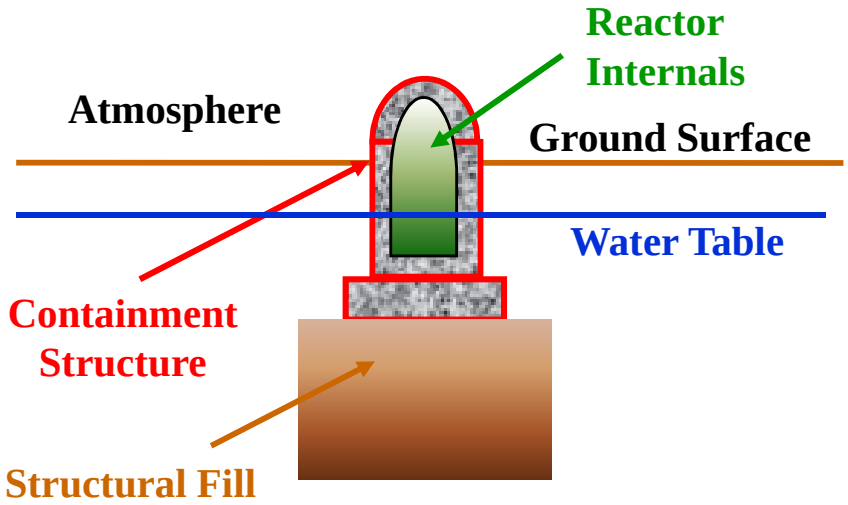
safety ❖ performance ❖ cleanup ❖ closure

www.em.doe.gov

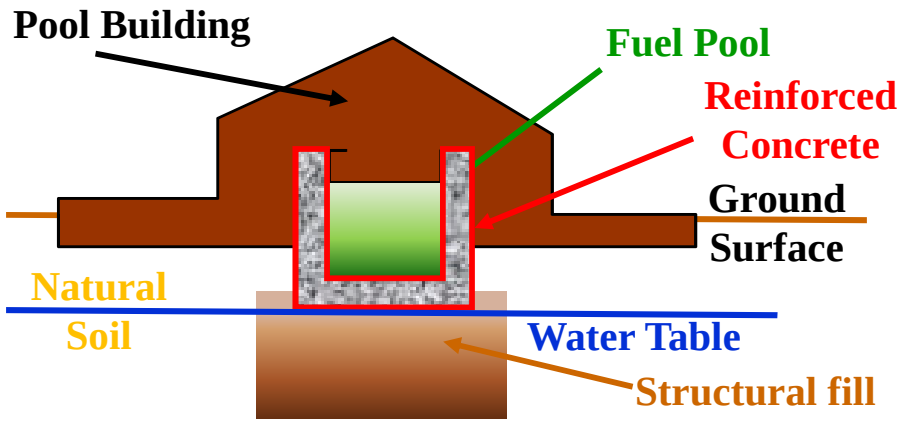
Nuclear Facility Applications



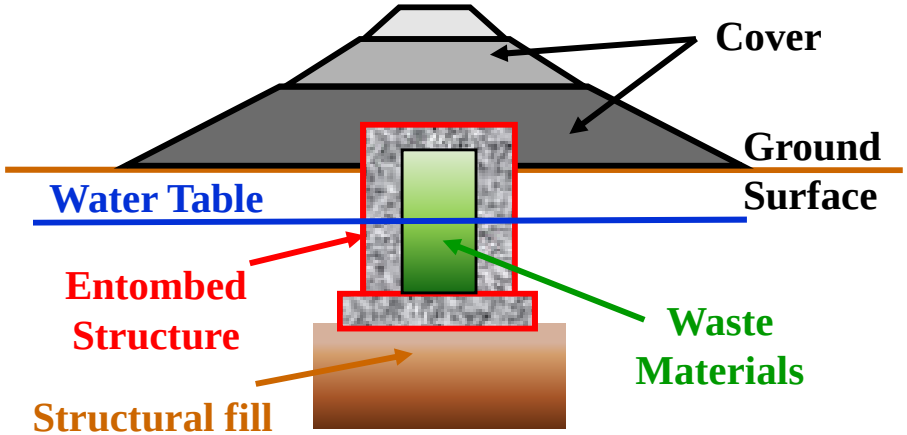
LLW Disposal



Nuclear Power Plant



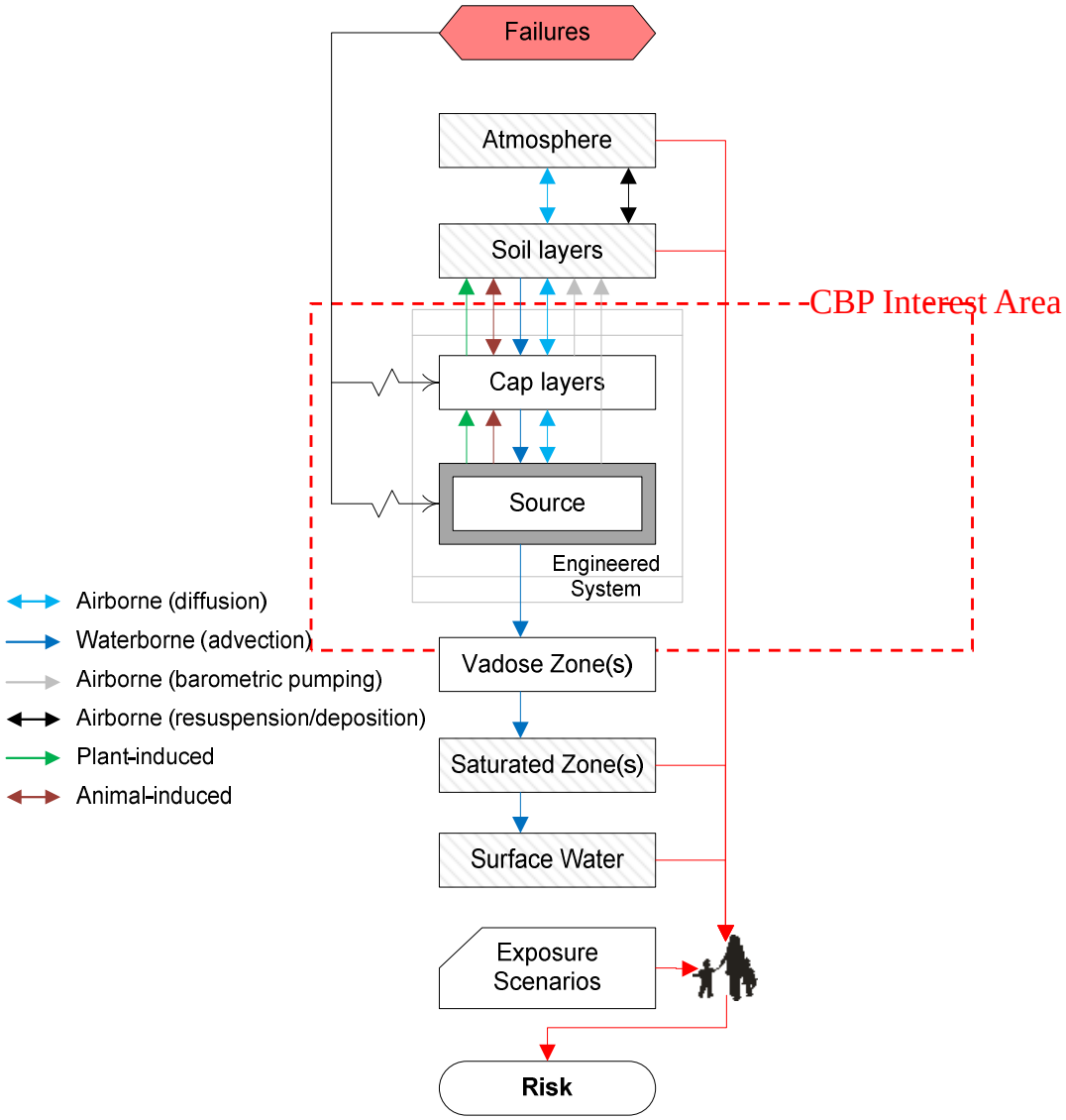
Spent Fuel Pool



Entombment

7

Integration of CBP Tools with PAs



CBP focus:

- Cementitious materials performance as part of engineered system and their interfaces with natural system
- To provide near field source term
- Uncertainty approach being developed to be broadly applicable to PA process.

Technical Strategy/Approach — Integrated Long-Term Degradation

Chemical degradation and physical structure evolution are coupled.

Physical stress

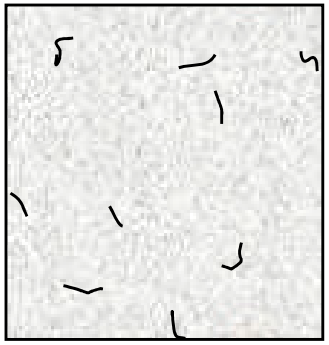
- External loading
- Drying shrinkage
- Seismic events
- Settlement

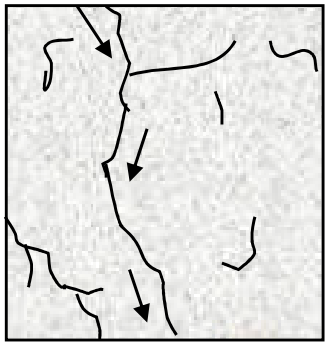
Chemical Alteration

- Oxidation
- Leaching
- Pore & crack evolution
  - Dissolution and cracking
  - Precipitation & sealing
- Expansive reactions & corrosion
  - Carbonation
  - Sulfate attack
  - Rebar corrosion

Microcracks

- Increase porosity
- Increase interaction pore water/surface



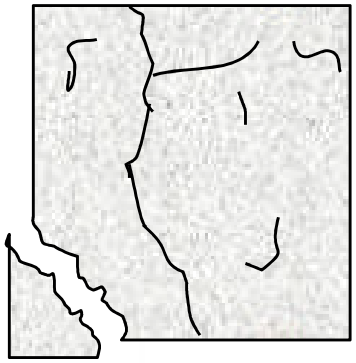


Through-cracks

- Preferential flow path
- Diffusive and convective release
- Loss of strength

Spalling

- Loss of cohesiveness
- Two body problem
- Eventual release from "granular" material



Project Description – Technical Strategy / Approach

- **Reference Cases – provide basis for comparison and demonstration of tools under development**
  - Cementitious waste form in concrete disposal vault with cap
  - Grouted high level waste tank
  - Spent fuel pool
  - Materials – surrogate LAW cementitious waste form, reducing grout, reinforced concrete (historical), reinforced concrete (future)
- **Integration with GoldSim PA framework**
- **Coordinated experimental and computational program**
  - Conceptual model improvement
  - Define test methods and Parameter measurements
  - Model validation

Technical Status and Results

- **Form CBP (Phase 1, Task 5)**
  - MOU complete (DOE, NRC, NIST, Simco, SRNL, VU, ECN)
  - CRADA complete July 1 Start for SRNL, VU and ECN
  - IAA in progress
    - July 31 expected start for NIST and Simco
  - Advisory Committee (being set up by CRESP)
- **State of Art Documentation (Phase 1)**
  - Initiated Task 1, 2, and 3 (Task 4 on hold)
- **Model Development (Phase 2a)**
  - Initiated Task 6 and 7

Expected Project Impact

- Reduced uncertainty and improved consistency for PAs
- Improved system designs (waste management and new facilities)
- Monitoring and maintenance approaches for extended (100s, 1000s yr) service life
- Updated guidance documents (assessment tools, test methods, data)
- Industry-wide technical basis for evaluation amongst stakeholders (DOE, NRC, state regulators, others)
- Assessment transparency
- Improved technology foundation and integration of existing / new science
- Template for assessment of complex systems

Supporting Overheads

Project Management Summary

- Work ongoing for less than one month
- Budget summaries are unavailable
- WBS is being developed for project management tracking
- Project management meeting scheduled for 5-8 August 2008
- FY'09 scope will be developed in PTS-03

Important Parameters

Hydraulic Properties

- Hydraulic Conductivity
- Permeability
- Water Movement (e.g., Richard's Eqn)

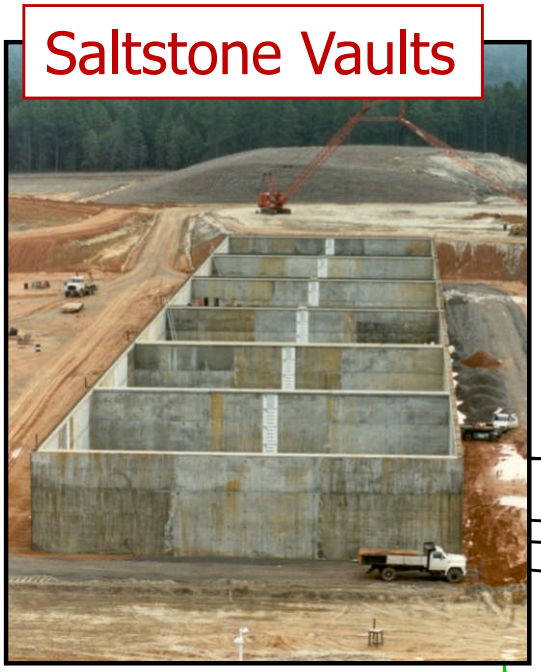
Chemical Properties

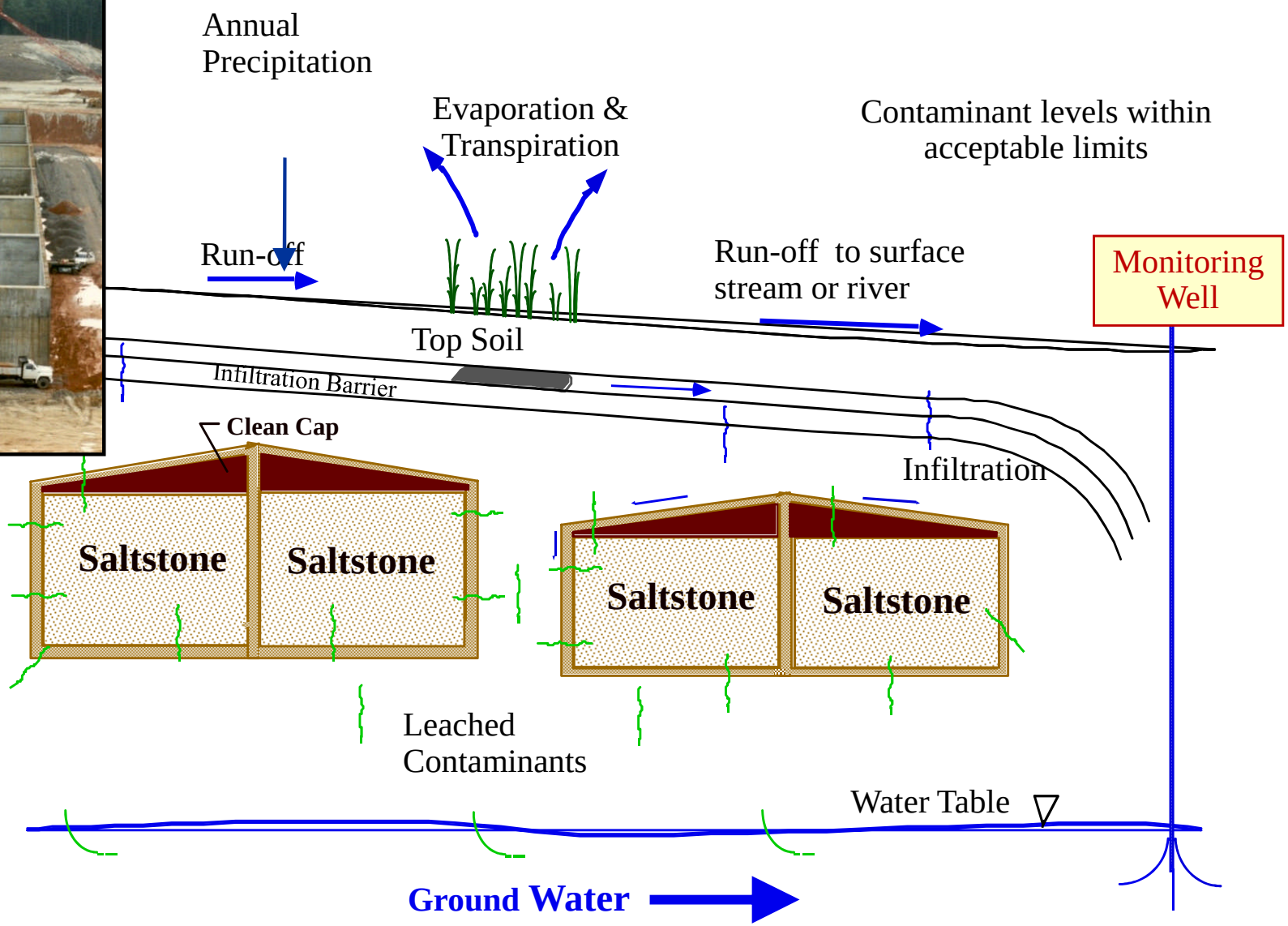
- Mineralogical Evolution
- Constituent Speciation
- Chemical Degradation (e.g., carbonation, oxidation)

Structural Properties

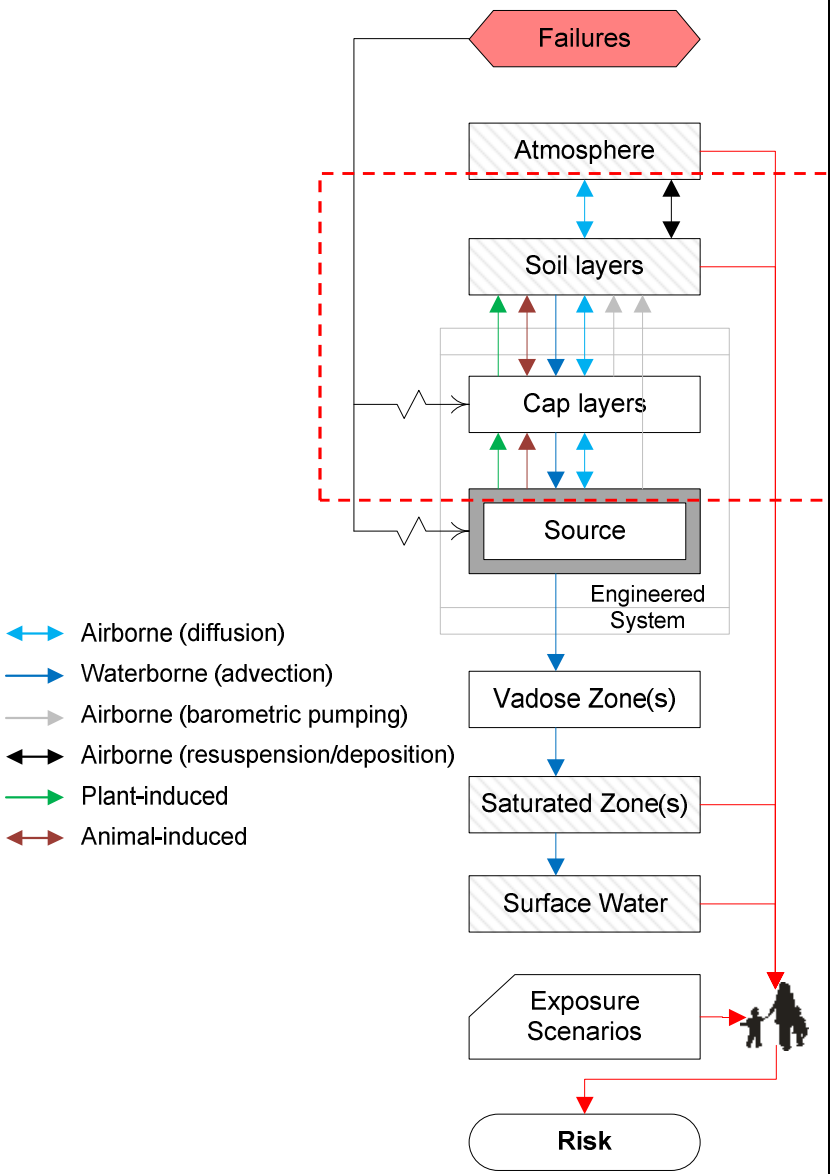
- Crack Development from physical loads or seismic events

DOE Applications





Technical Strategy/Approach—Integration of CBP Tools with PAs



Screening Risk Evaluation	Possible Detailed Risk Evaluation
Cap: *Poisson*(Cap Type) **Drum**: *Weibull*(Stacking, Liner, etc.)	**Cap**: *Poisson*(Cap Type) **Drum**: *Weibull*(Stacking, Liner, etc.) Other types/distributions possible
Near-field: GS *Cell Pathway* Element **Far-field**: *Gaussian Plume Model*	**Near/Far**: *AERMOD* plume model (EPA) Various o
All layers: GS *Cell Pathway* Elements	**Cap/soil**: *HELP* landfill model (EPA) Other landfill/engineered barrier models available
All layers: GS *Cell Pathway* Elements	
Loose: GoldSim (GS) *Source* Element **Boxes**: GoldSim (GS) *Source* Element **Drums**: GoldSim (GS) *Source* Element	**All**: *DUST-MS* release model (INL) Other source release models available
All layers: *Network Pathway* Elements	**All layers**: *TETRAD* transport model (INL) Various other transport models available
All layers: GS *Pipe Pathway* Elements	**All layers**: *TETRAD* transport model (INL) Various other transport models available
All layers: N *Cell Pathway* Elements	**All layers**: *GSFLOW* coupled model (EPA) Other surface water models available
Public: GS *Receptor* Elements **Worker**: GS *Receptor* Elements	**Public**: GS *Receptor* Elements **Worker**: GS *Receptor* Elements
Exposure: Morbidity, mortality, cancer, HQ **Accident**: Injuries, fatalities, probabilities	**Exposure**: Same + cumulative, YPLL **Accident**: Injuries, fatalities, probabilities

CBP Interest Area

Technical Status and Results

- **Task 1**
  - **Review of DOE and NRC PA Approaches**
  - **PA R&D needs**
- **Task 2 (a to f)**
  - **State of art for modeling, chemical degradation, uncertainty**
- **Task 3**
  - **Review of candidate software**
- **Advisory Committee**
- **Task 6**
  - **Reference cases and Model abstractions**
- **Task 7**
  - **Computational tool design**