Modeling Performance and Degradation of Covers and Liners

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CRESP

2009 Performance Assessment Community of Practice
Technical Exchange Meeting

Objective: Protect Surrounding Environment (Health & Human Safety)

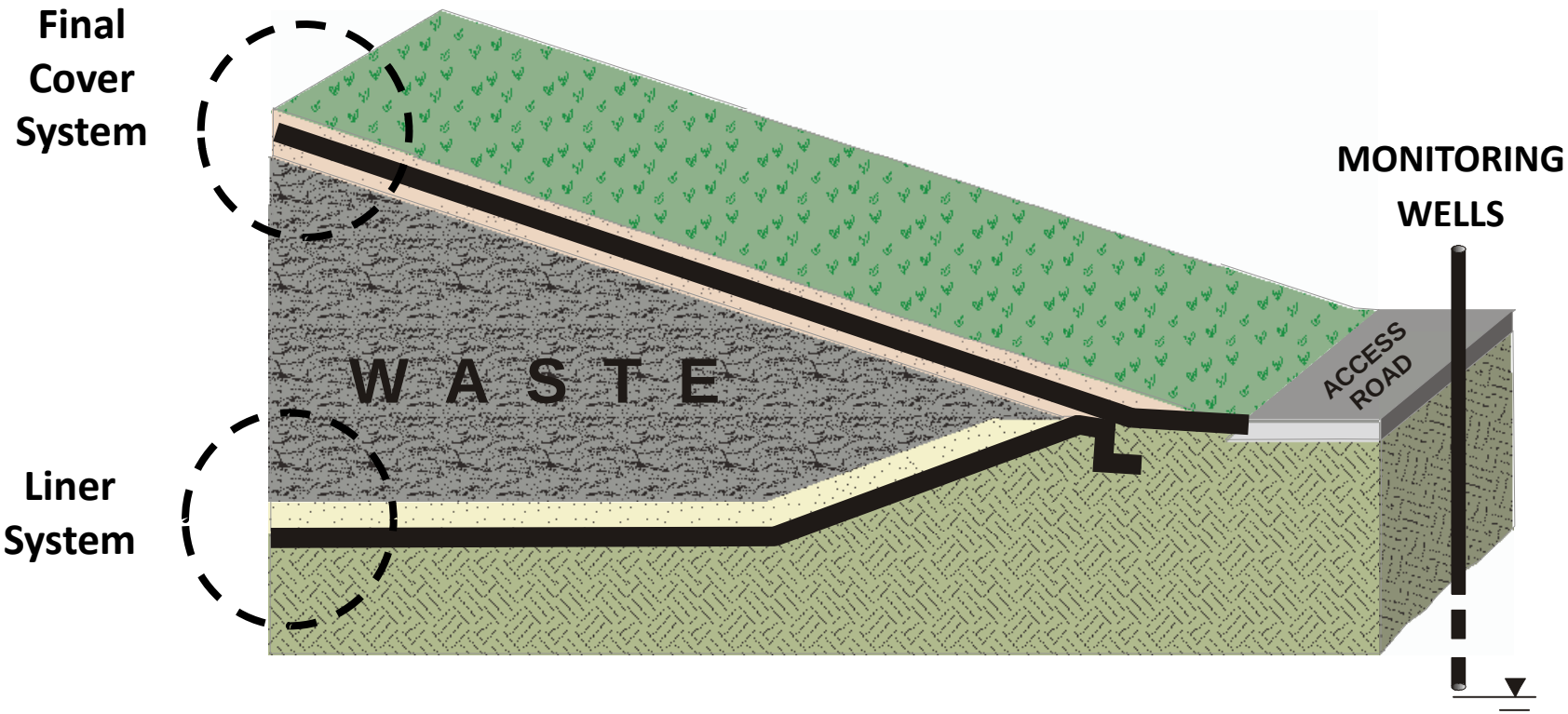
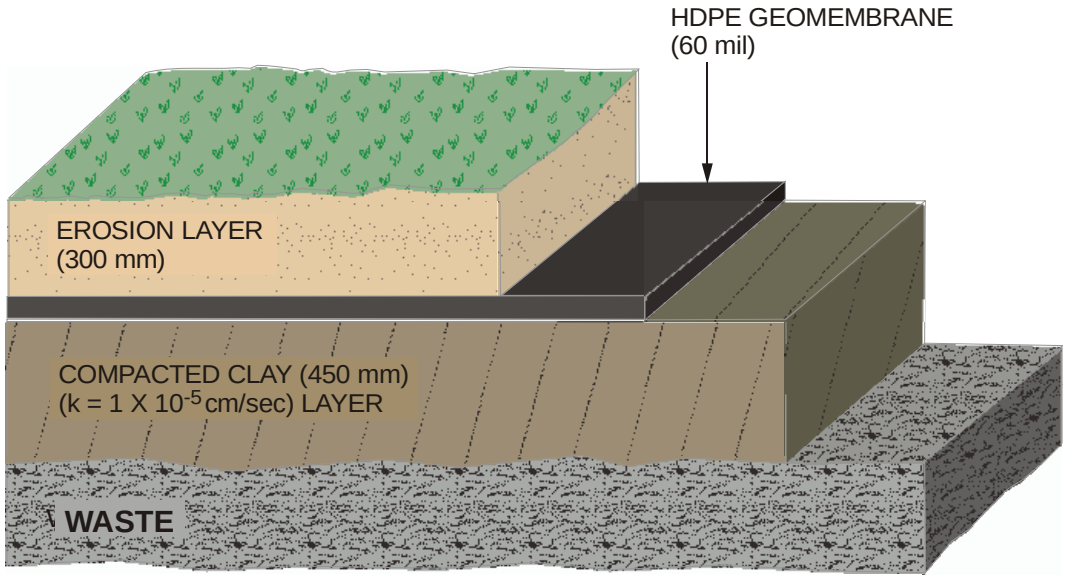
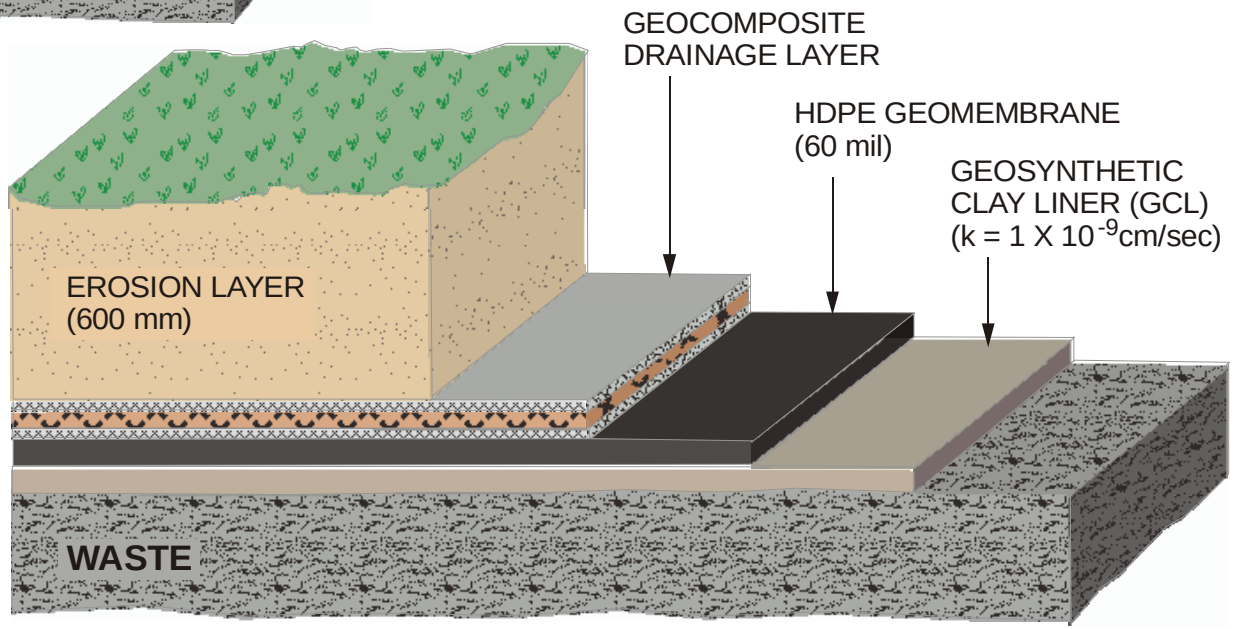


Figure courtesy M. Othman, Geosyntec Consultants

Conventional Final Covers



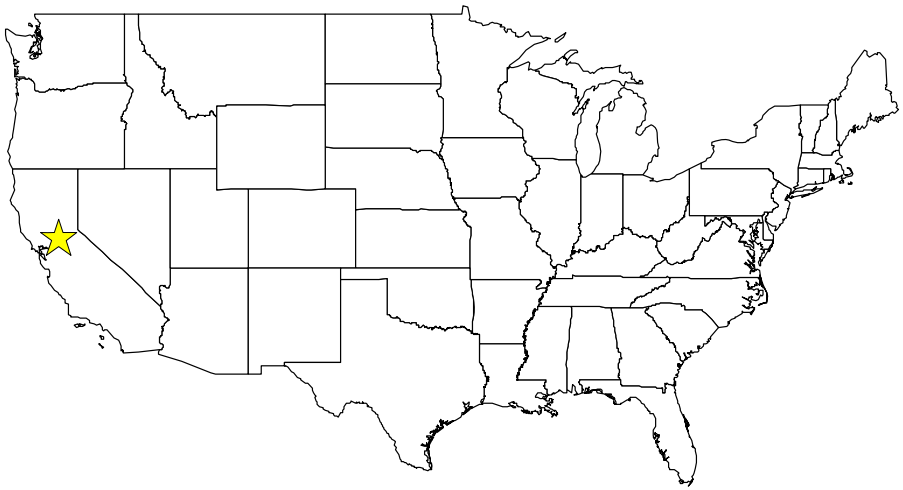
Conventional Cover System



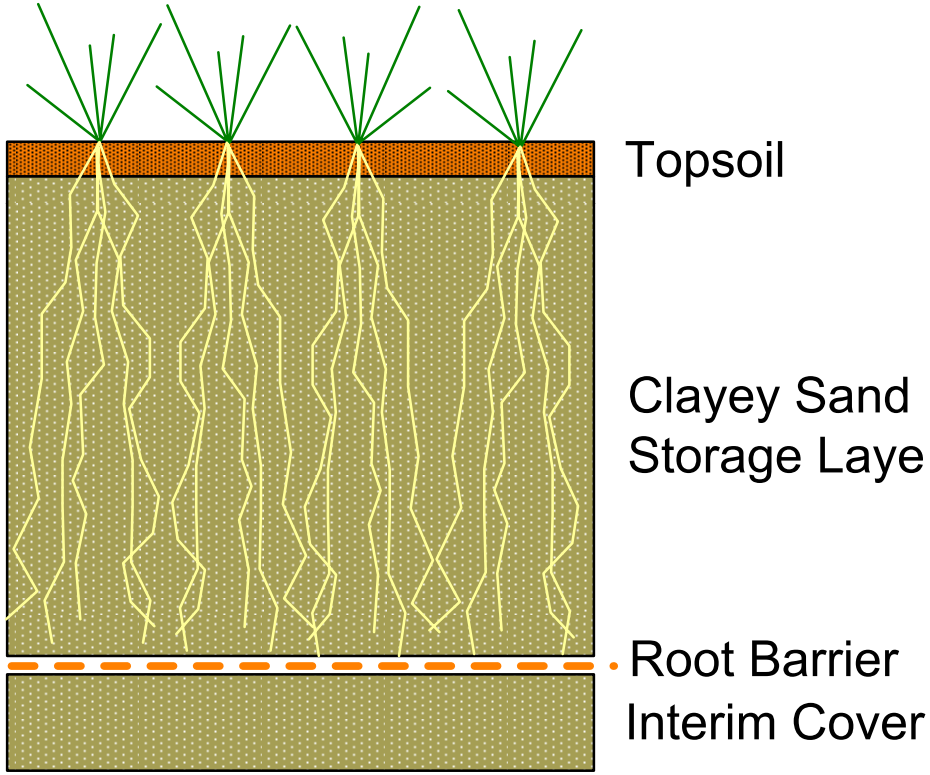
Conventional Cover with Geosynthetics

Figures courtesy M. Othman, Geosyntec Consultants

Water balance cover in Sacramento, CA

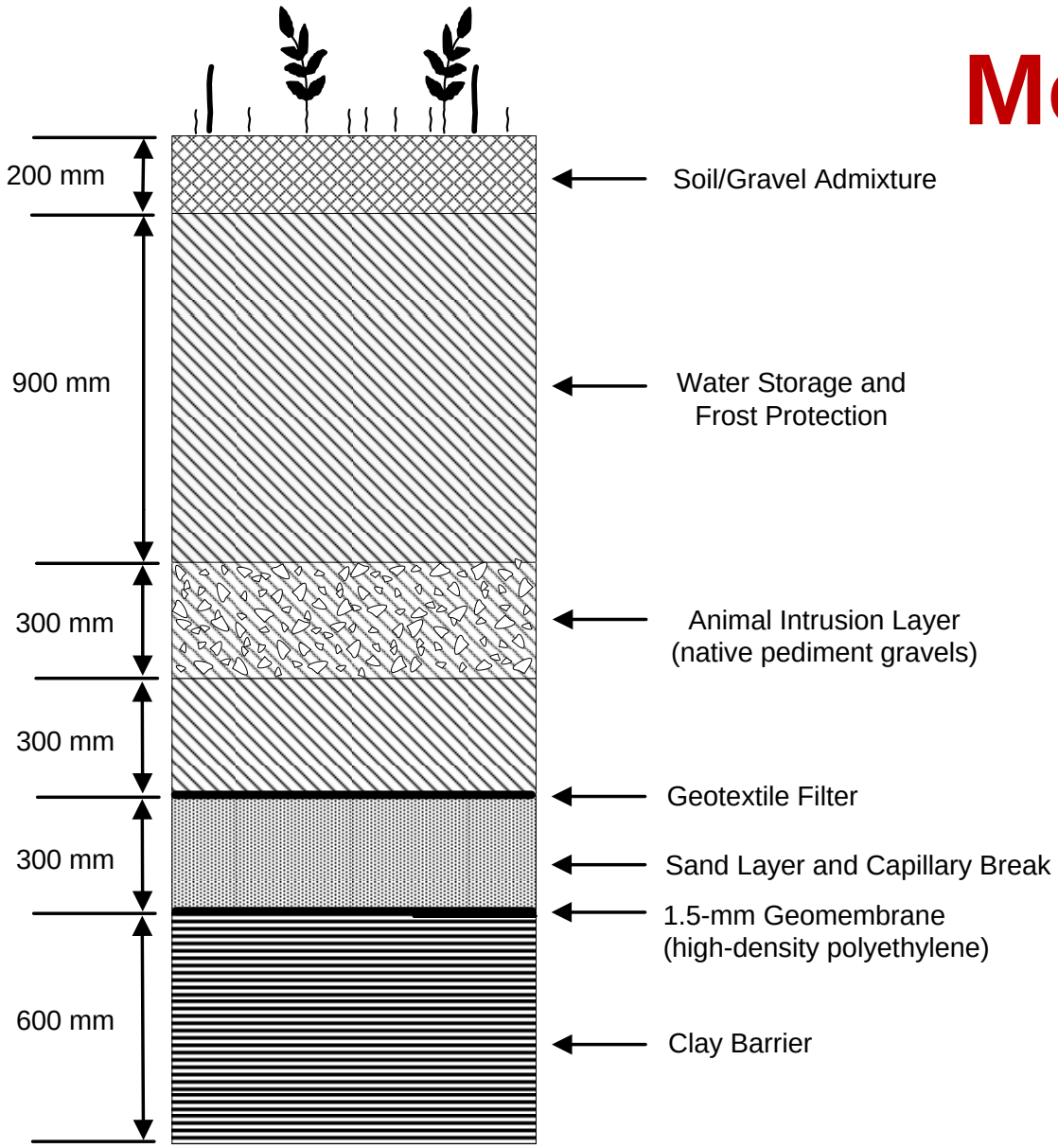


Warm Semi-Arid Climate,
Monolithic Covers
Precipitation = 430 mm/yr
P/PET = 0.33



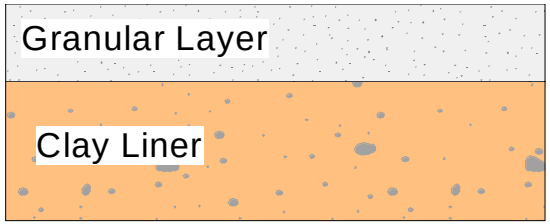
2.5-m-thick Cover

Monticello, UT UMTRA Disposal Cell Cover



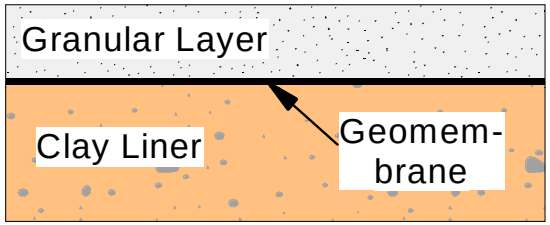
Combination of water balance cover and conventional cover with composite barrier.

Lining Systems



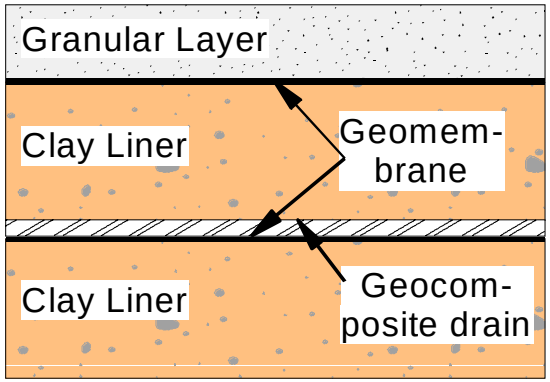
(a) Single Clay Liner

Compacted clay liner ($K < 10^{-7}$ cm/s)
- Effective groundwater protection



(b) Composite Liner

Composite Liner - Very effective groundwater protection due to synergistic combination of clay and geomembrane, Standard for MSW.



(b) Double Composite Liner with Leak Detection

Multiple composite liner – Very effective and redundant system. Standard for HSW and CERCLA remedial actions.

Fundamental Questions

- Do we have models that realistically capture the key physical, chemical, and biological processes controlling the performance of liners and covers?

- Can we adequately parameterize these models to properly represent behavior in the field?

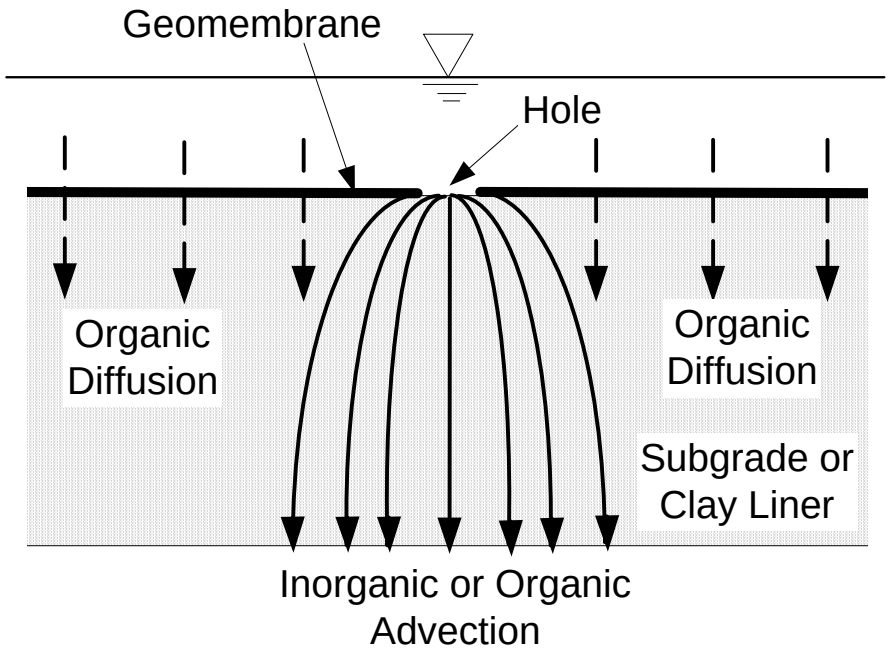
- Do we know how the properties and processes may change over the lifetime of a disposal facility?

Modeling Issues for Liners and Covers

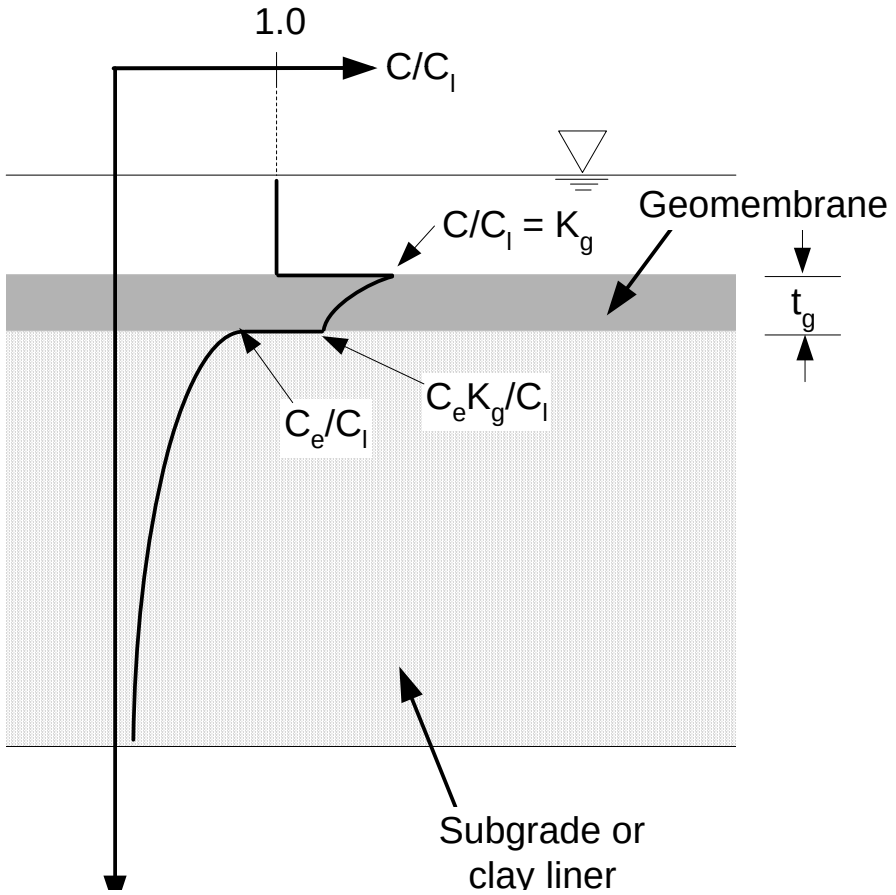
Barrier System	Processes	State of Knowledge
Conventional cover	▪ Unsaturated flow and root water uptake above the geomembrane	▪ High level of capability ▪ Vegetation weak link ▪ Parameterization key
	▪ Unsaturated flow through defects in geomembrane and underlying barrier materials and waste	▪ Low to modest capability ▪ Ad hoc methods currently ▪ Needs R&D
Water balance cover	▪ Unsaturated flow, root water uptake ▪ Soil-plant-atmosphere linkage	▪ High level of capability ▪ Vegetation weak link ▪ Parameterization key
Leachate collection system	▪ Transient variably saturated flow ▪ Geochemical processes	▪ High level of capability ▪ Long-term geochemical impacts unknown
Composite Liners	▪ Saturated flow and transport ▪ Adsorption and attenuation	▪ High sophistication for contaminants in MSW and HSW Landfills ▪ Need to extend to LLW landfills ▪ Parameterization is key

Modeling Liner Systems

Inorganics: Advective-Diffusive Transport through Holes



Organics: Diffusive Transport through Intact Geomembrane



Modeling Liner Systems

- Recent comparisons with data from prototype-scale laboratory experiments and from large lysimeters beneath MSW landfills indicate that liner models (POLUTE and Foose et al. models) predict remarkably well, particularly for volatile organic compounds.

- Comparisons indicate that predictions can be made reliably using conventional laboratory-measured parameters (D, K_d) – VOCs, metals

- All models employ simple partitioning using linear or non-linear isotherms. None of the models accounts for reactive transport based on fundamental geochemical principles.

Modeling Liner Systems

- None of the models has been validated for radionuclides.
- None of the models accounts for reactive transport based on fundamental geochemical principles.
- No data on long-term transport properties of liners, but believe that high level of stress and covered condition will maintain integrity for very long time.
- Analogs of Cl^- transport in aquitards suggest that integrity will be maintained over 1000 yr or more. Geosynthetic elements?

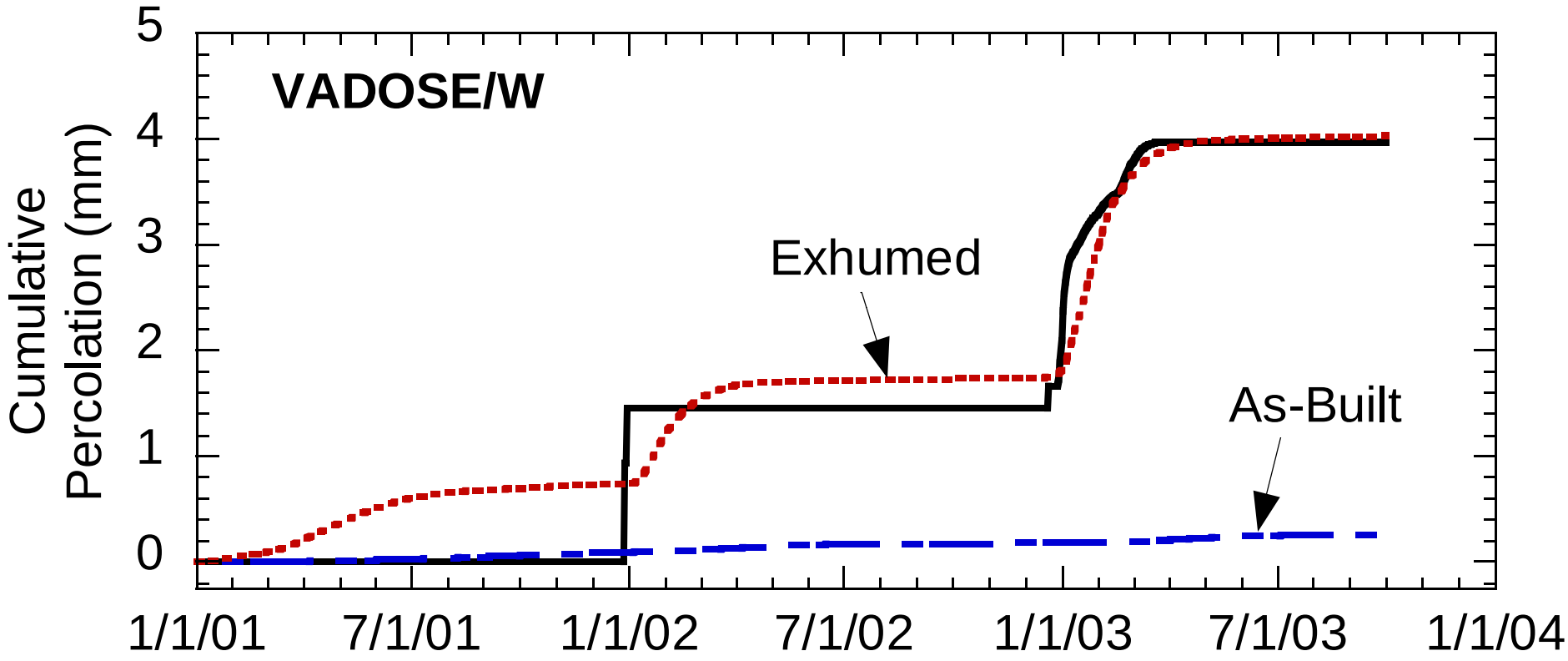
Modeling Cover Systems

- Processes in **earthen** covers are governed by Richards' equation:

$$\frac{\partial\theta}{\partial\psi}\frac{\partial\psi}{\partial t} = -\frac{\partial}{\partial z}\left[K_T\frac{\partial\psi}{\partial z} + K_\psi + q_{vT}\right] - S(z,t)$$

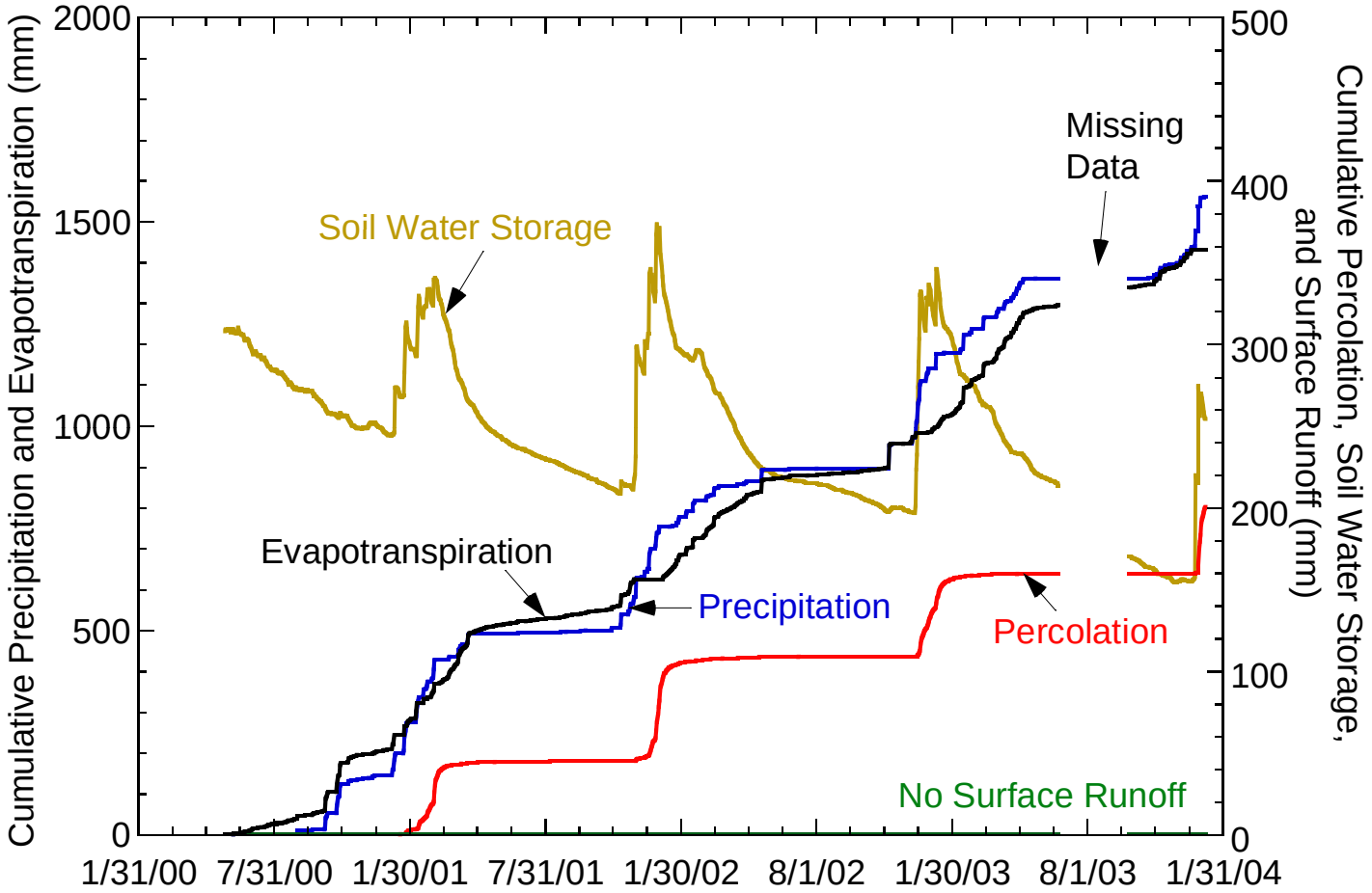
- Atmospheric flux boundary at surface simulating meteorological conditions.
- Several codes available that represent most processes realistically: e.g., UNSAT-H, VADOSE/W, HYDRUS.
- All of the models treat plants simplistically.
- None of the models simulates temporal changes in soils or plants.

Modeling Cover Systems



Data from earthen cover in N. California show that these models can be relatively accurate when properly parameterized.

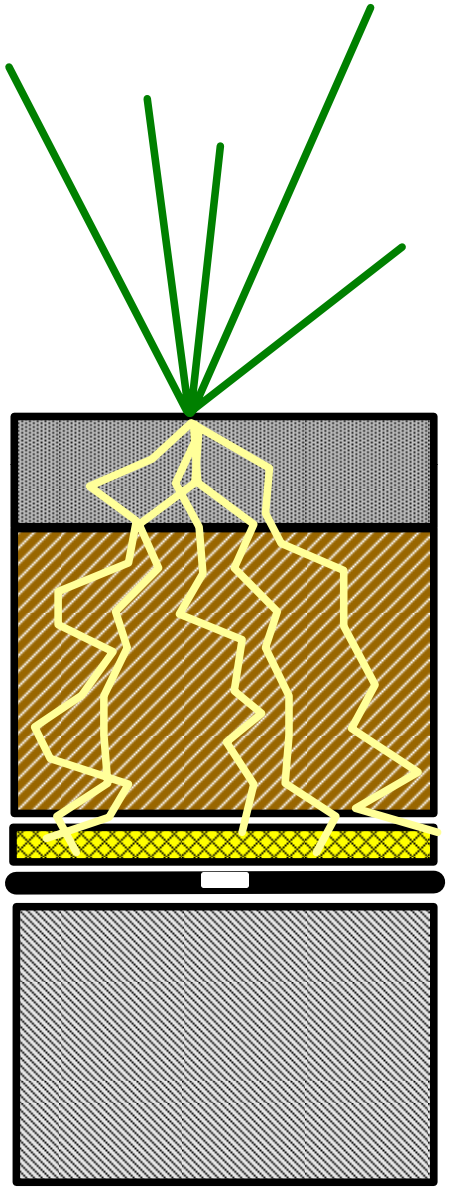
Monolithic Earthen Cover Near Monterey, CA



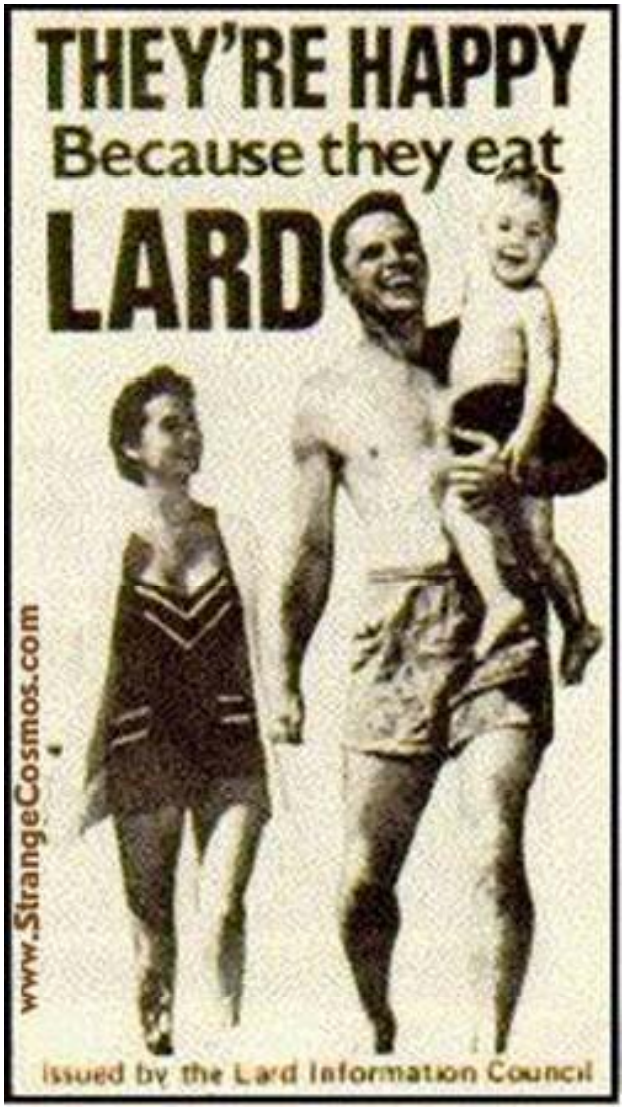
Modeling with soil properties for design indicated that percolation would be < 3 mm/yr. As-built properties did not reflect in-service conditions.

Modeling Cover Systems

- Things get complicated when simulating conventional covers with composite barriers.
- Most rigorous approach in practice is to simulate upper portion of cover with Richards' equation. Output from Richard's equation used as input to analytical solutions for flow through geomembrane defects.
- Anecdotal comparisons with field data suggest that methodology is not conservative.



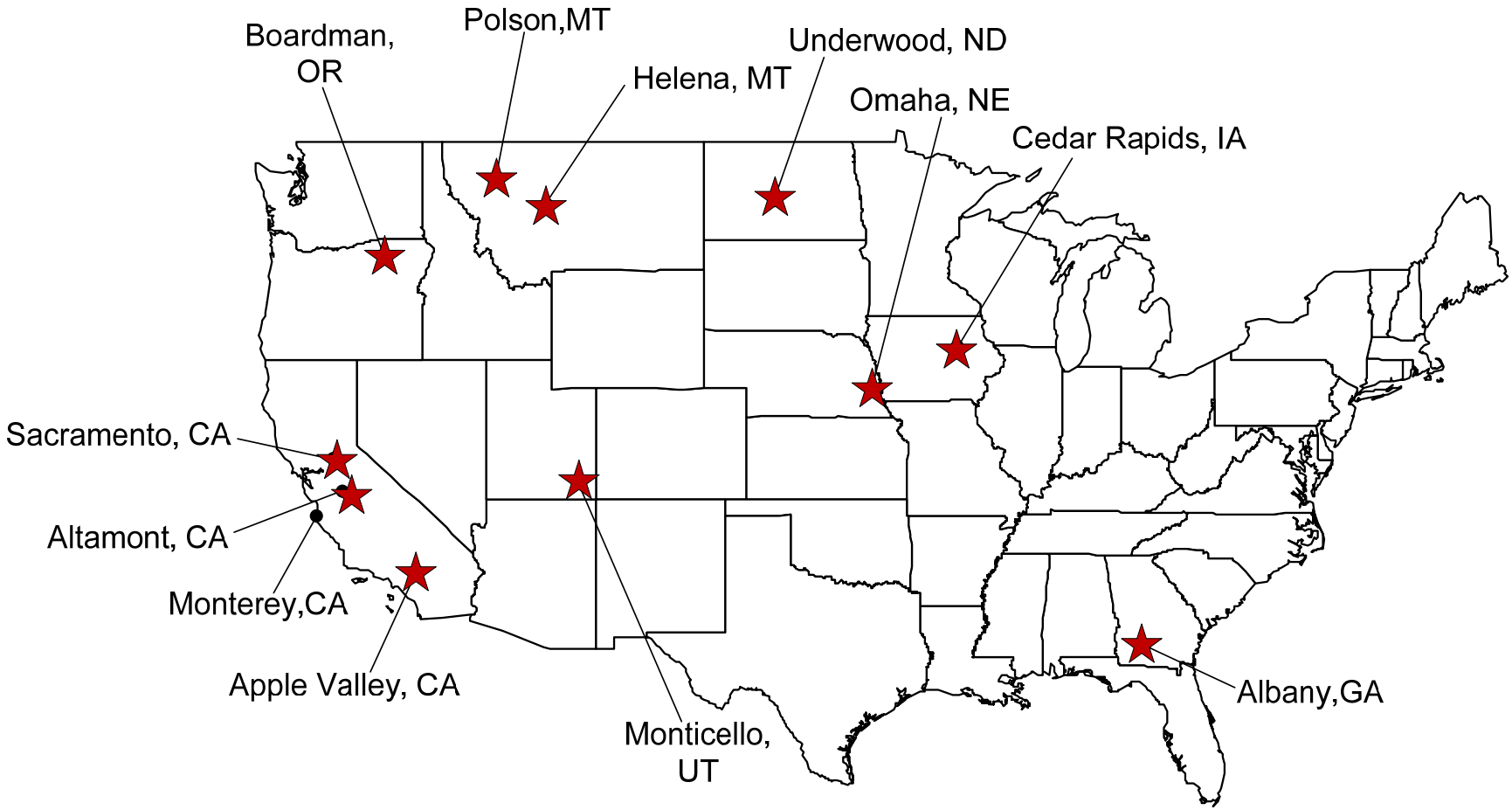
Perspectives Change Based on Data



ACAP Exhumation Study

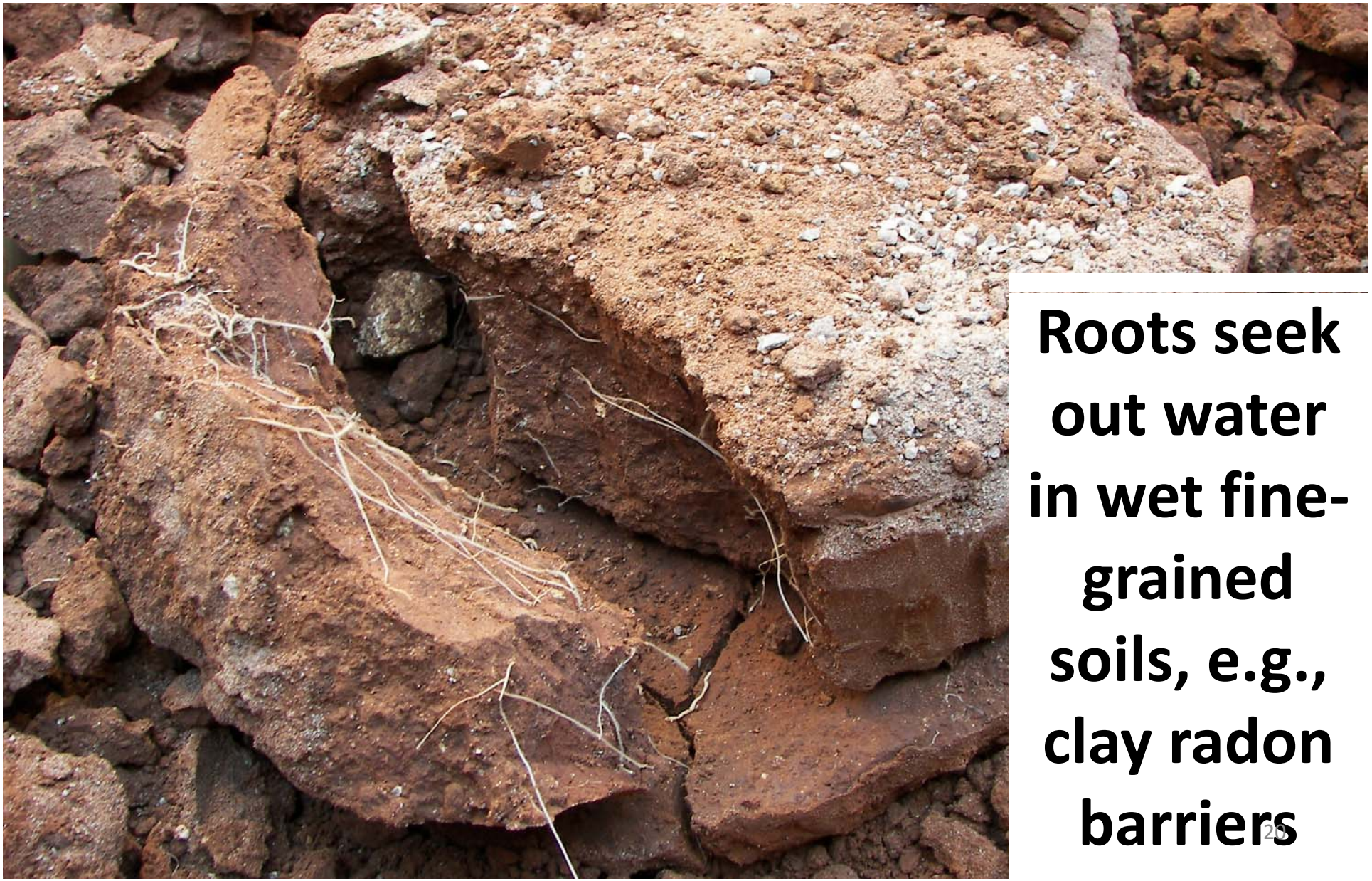
Exhume cover test sections to study how properties of soil and geosynthetics changed since construction.

ACAP Exhumation Study



Geomorphological Survey – Utah Site

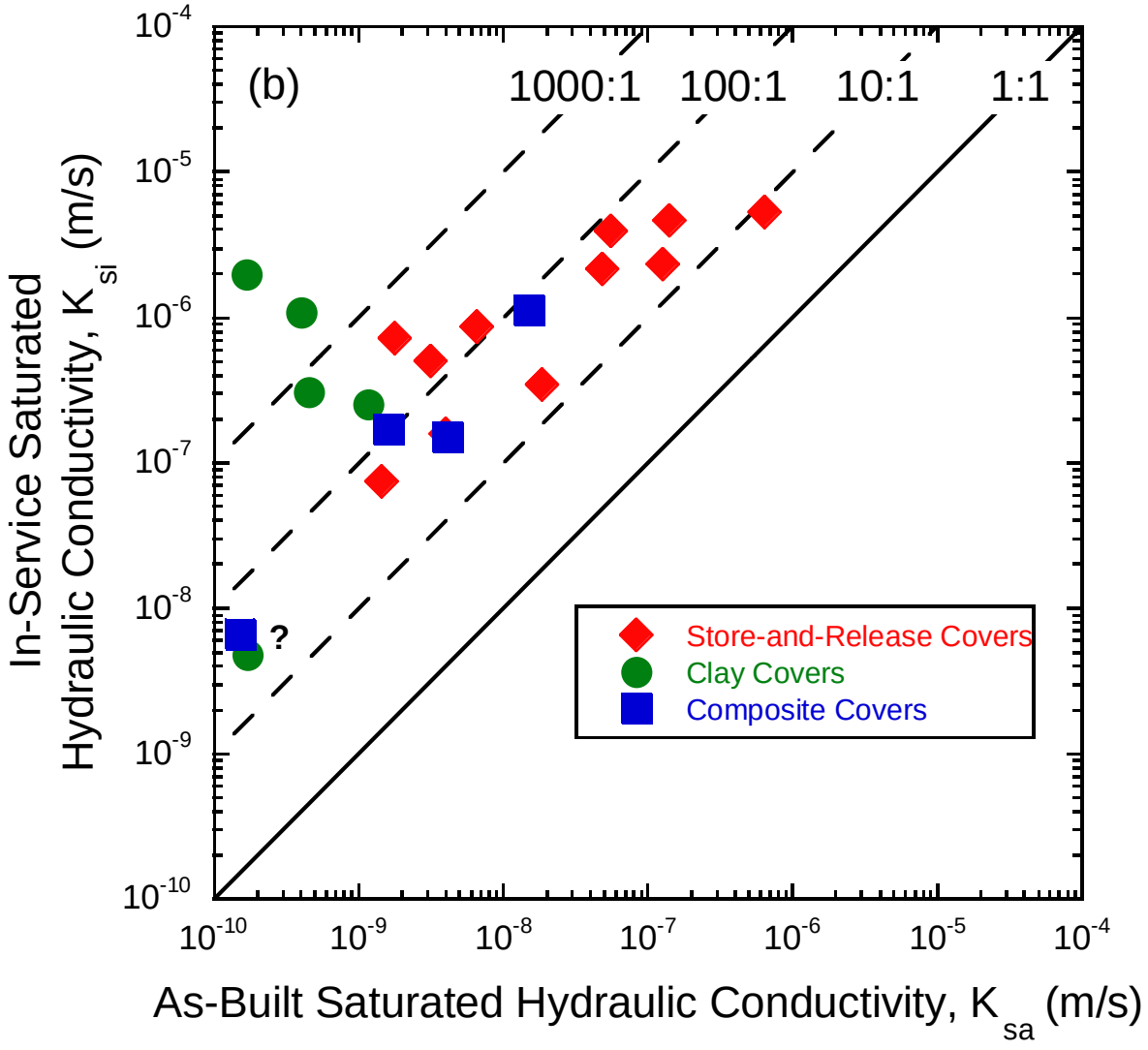
Radon Barrier – Monticello, UT



Roots seek out water in wet fine-grained soils, e.g., clay radon barriers

Drainage Layer Sampling – Wisconsin Site

Earthen Barriers - Saturated Hydraulic Conductivity

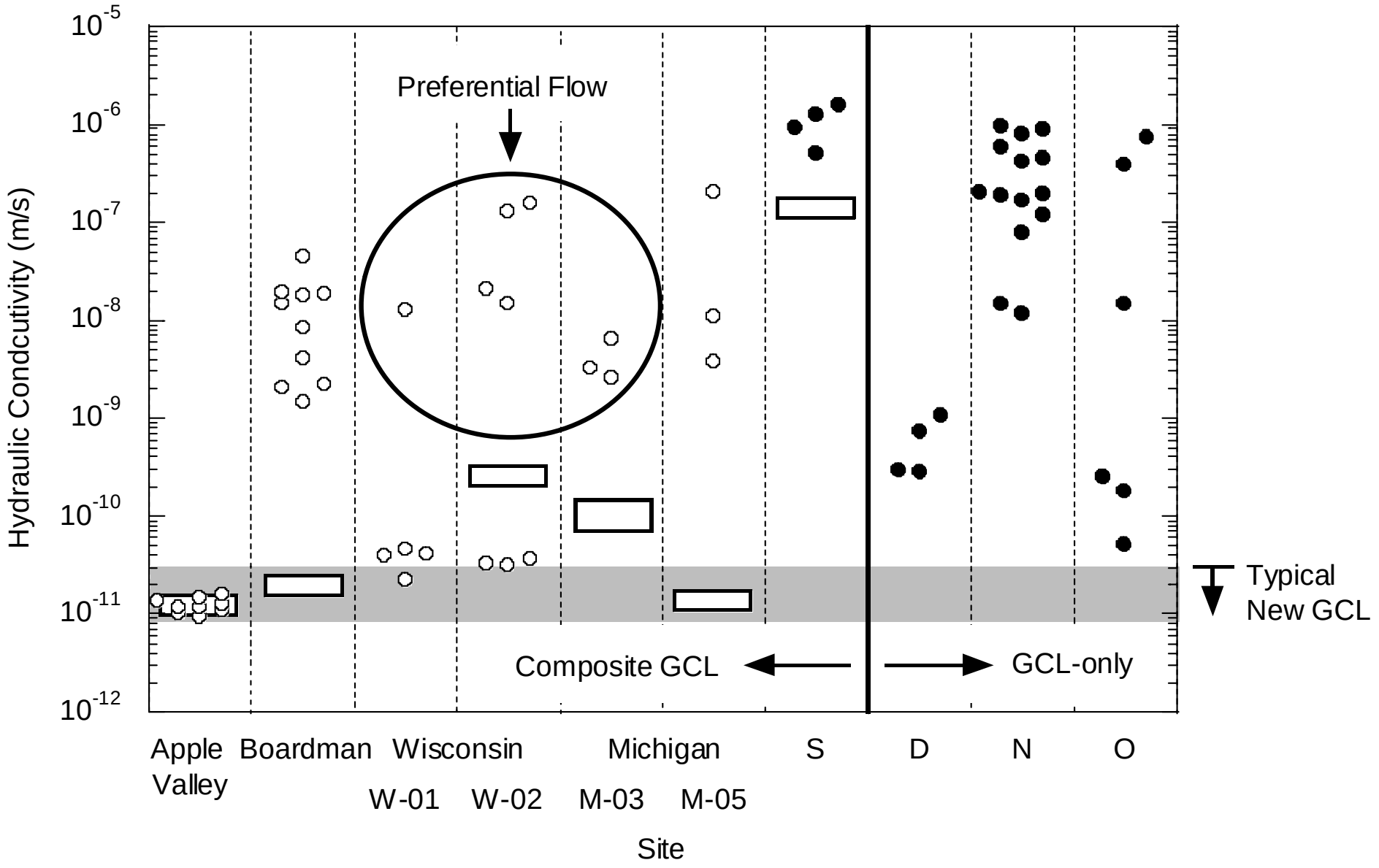


Saturated hydraulic conductivity of ALL barriers increased at least 10x.

None of the conventional covers had hydraulic conductivity < 10^{-9} m/s, common regulatory standard.

No relationship with as-built hydraulic conductivity.

Geosynthetic Clay Liners- Saturated Hydraulic Conductivity

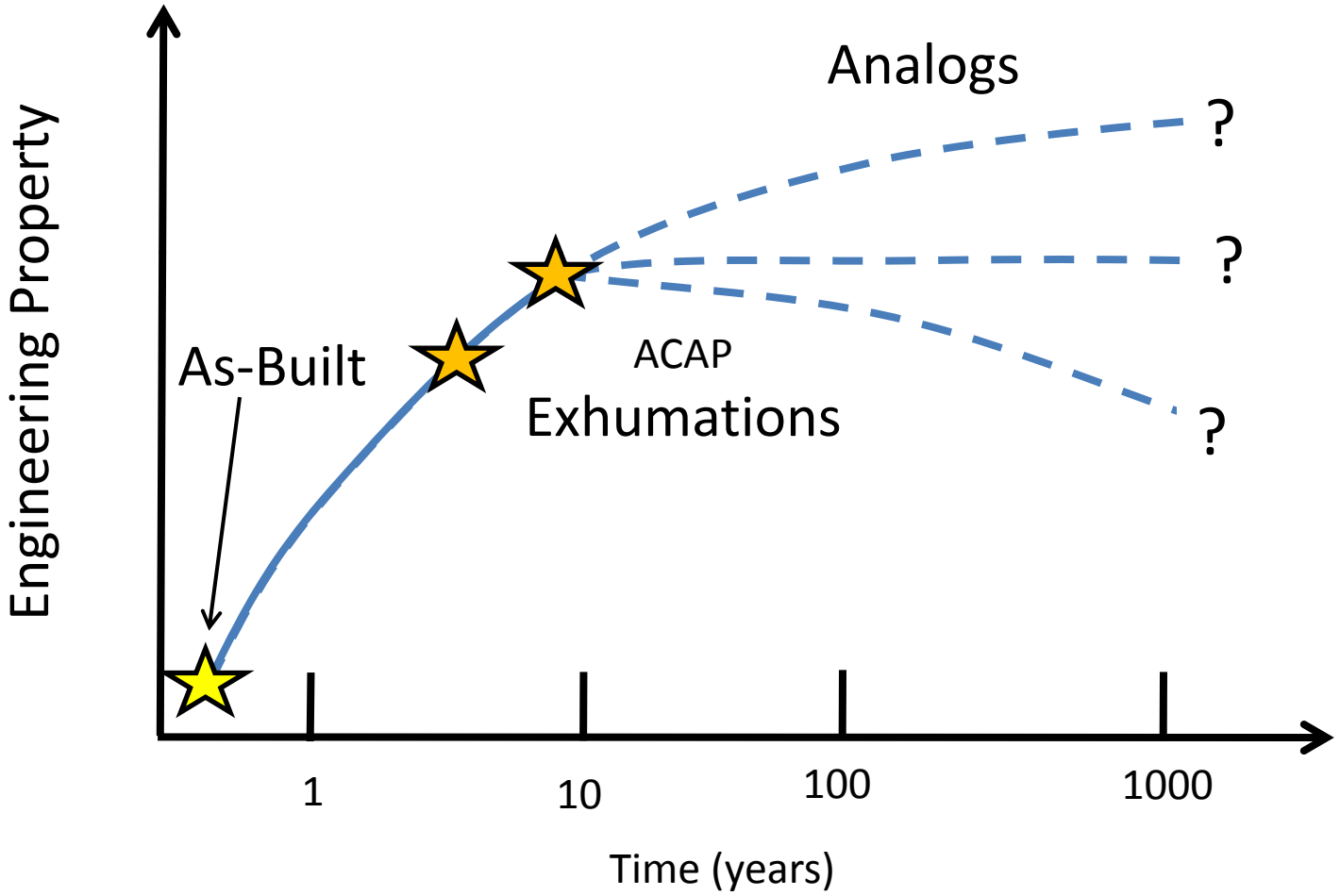


Summary of Exhumation Study

- Saturated & unsaturated hydraulic properties of cover soils changed, increasingly similar.
- Geosynthetic clay liners underwent cation exchange and became much more permeable in some cases, depending on placement condition.
- Geomembranes showed no degradation in properties, and antioxidant depletion followed theory. Lifespan in **covers** 50-150 yr.
- Drainage layers showed modest reduction in transmissivity, about 6-fold every decade.


MONTICELLO, UTAH
URANIUM MILL TAILINGS REPOSITORY
DATE OF CLOSURE: OCTOBER 6, 1999
DRY TONS OF TAILINGS: 3,666,000
RADIOACTIVITY : 2,780 CURIES, RA-226
CAUTION
N
REPOSITORY
0 2,000 FEET
UNDERGROUND
RADIOACTIVE MATERIAL
CONTACT THE U. S. DEPARTMENT
OF ENERGY PRIOR TO ANY
INTRUSIVE ACTIVITY ON THIS SITE

Model Parameterization – Engineering Properties for the Future?



Concluding Remarks

- Model predictions for some liner and cover systems are reliable, provided properly parameterized. Others need more development (e.g., conventional covers with composite barriers) or validation (radionuclide transport in liners).

- Properties of liners are likely to be more stable over time due to higher stress and confinement. Aquitard analogs provided evidence for longevity. Geosynthetic materials need more study.

- None of existing models explicitly accounts for changes in hydraulic properties or vegetation over time, but user can adjust properties over time to simulate longer-term behavior.

Concluding Remarks

- Field data from exhumation efforts show that cover soils become increasingly similar over time. Longer-term properties can be estimated from existing field data for variety of cover types.
- Properties of geosynthetic materials change over time. Some are more predictable (geomembranes and drainage layers) and others less predictable (geosynthetic clay liners).
- Learn from monitoring and reconnaissance data (build better models, create better materials, develop more efficient and effective designs).
- Monitor elements of containment systems to ensure that they are functioning as intended. Monitor to confirm function rather than (or in addition to) for compliance.