Liners and Covers: Field Performance & Life Expectancy

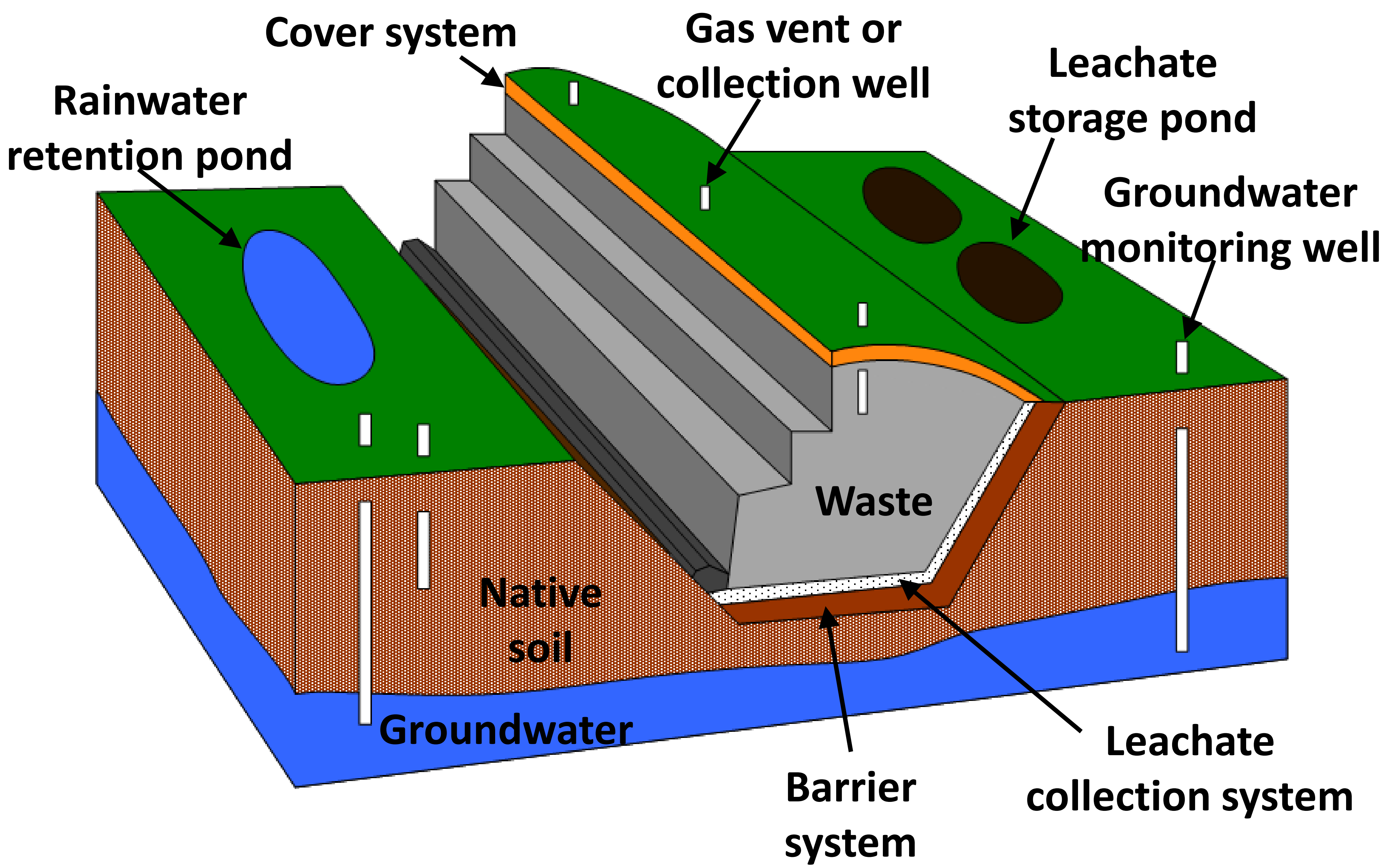
Craig H. Benson, PhD, PE, NAE
Wisconsin Distinguished Professor
University of Wisconsin-Madison

CRESP

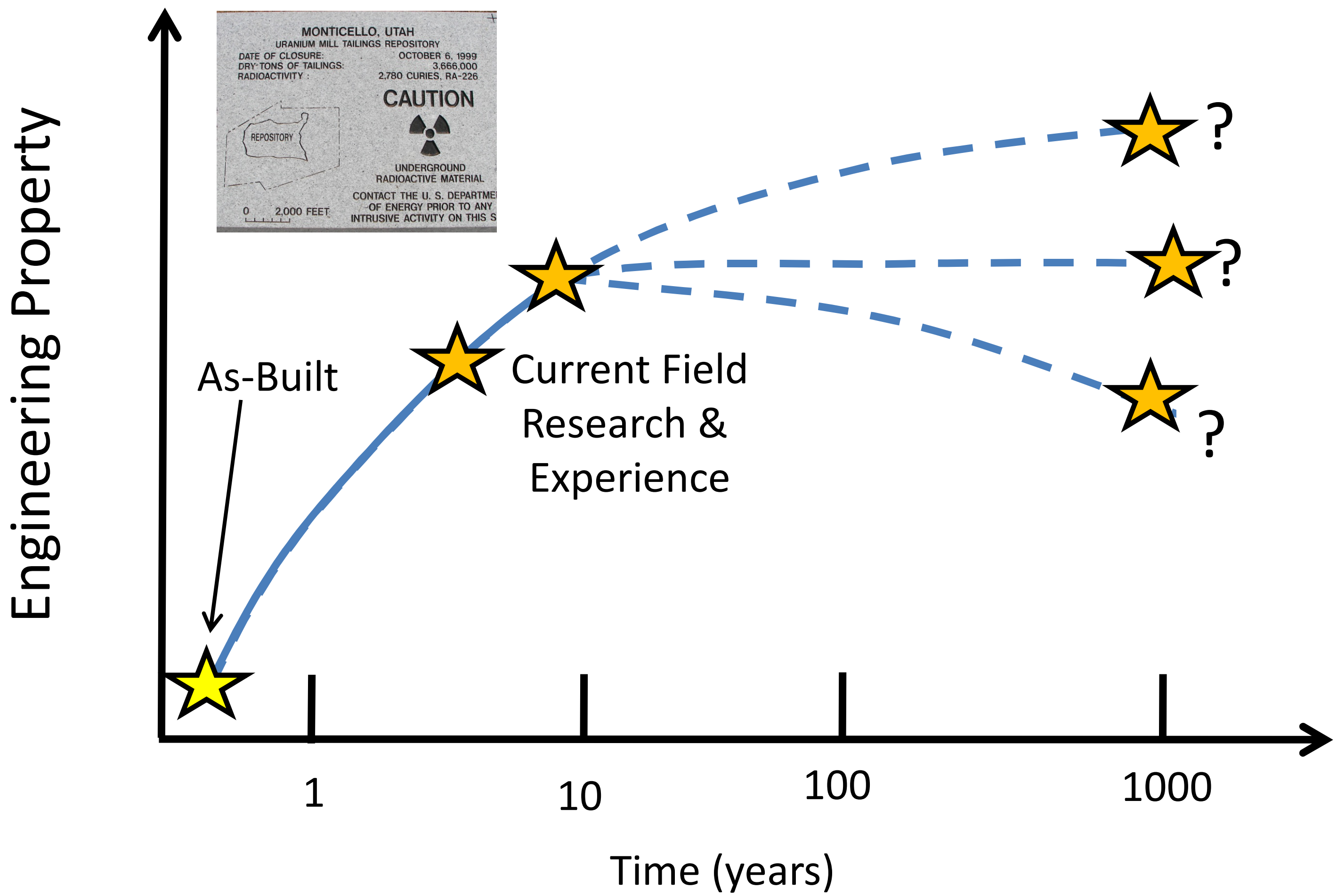
Interagency Steering Committee on Performance and Risk Assessment
Community of Practice Annual Technical Exchange Meeting
11-12 December 2014
Las Vegas, Nevada, USA

Geological Engineering
UNIVERSITY OF WISCONSIN–MADISON

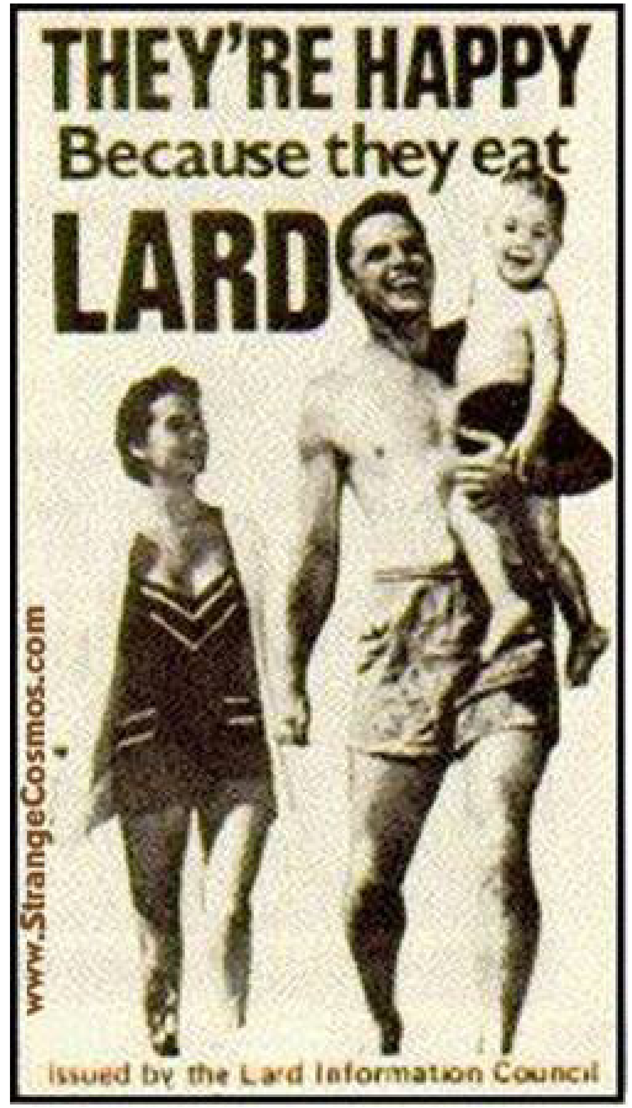
Covers & Waste Containment



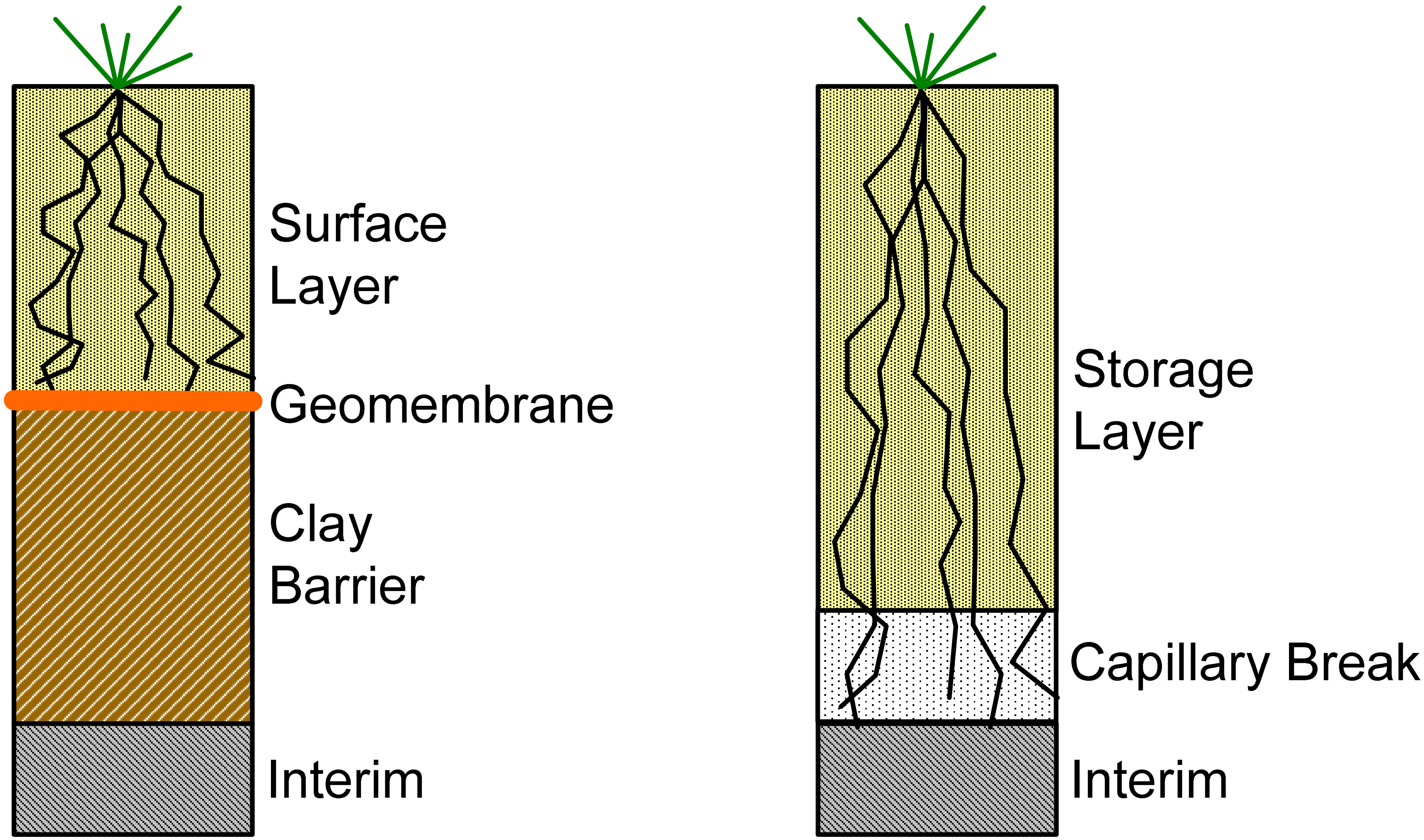
Predicting with Confidence for a Millennium or More



Perspectives Change Based on Data



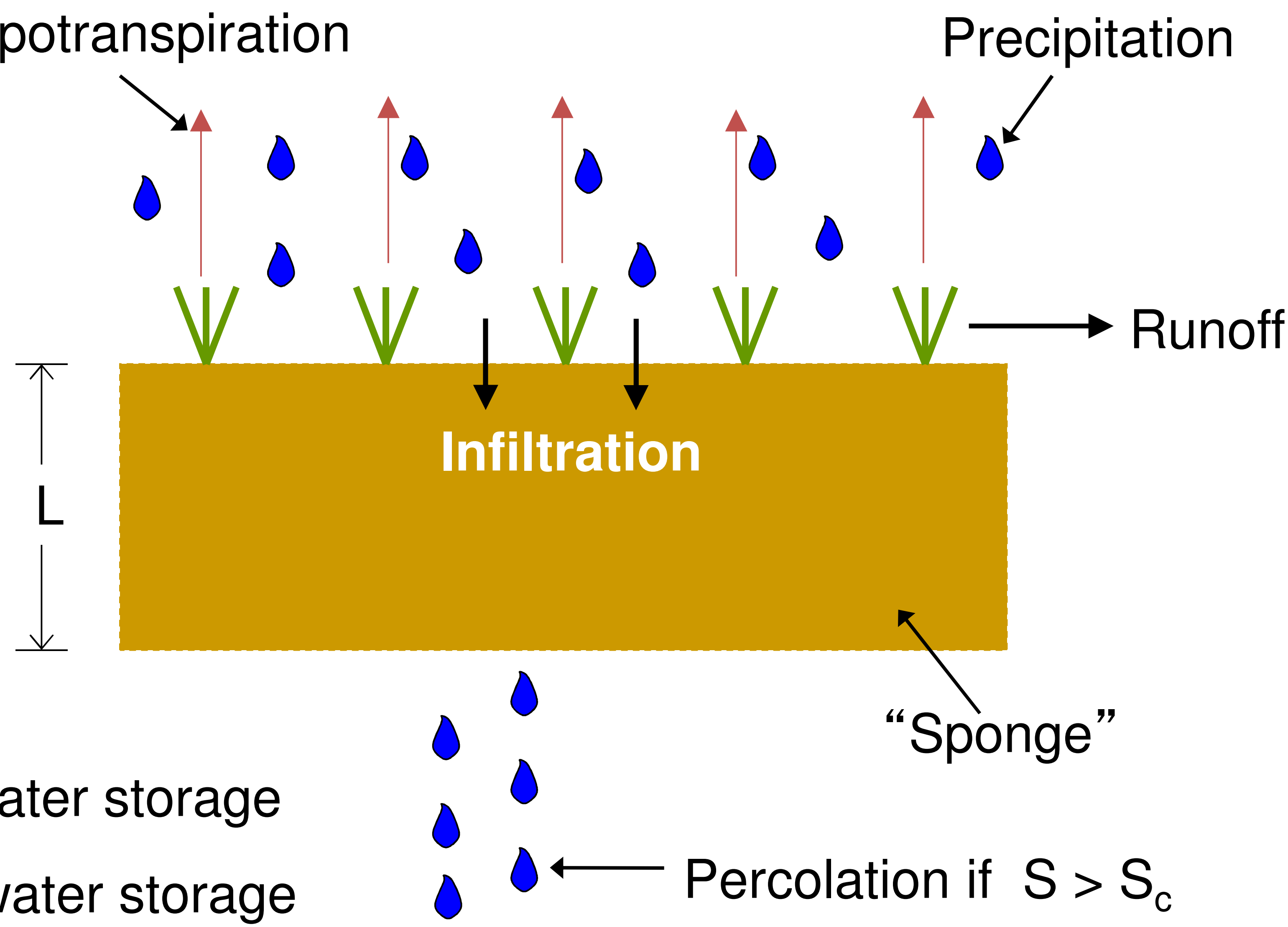
Conventional vs. “Alternative Covers”



Conventional Cover

Water Balance Cover

Balancing Storage and Evapotranspiration



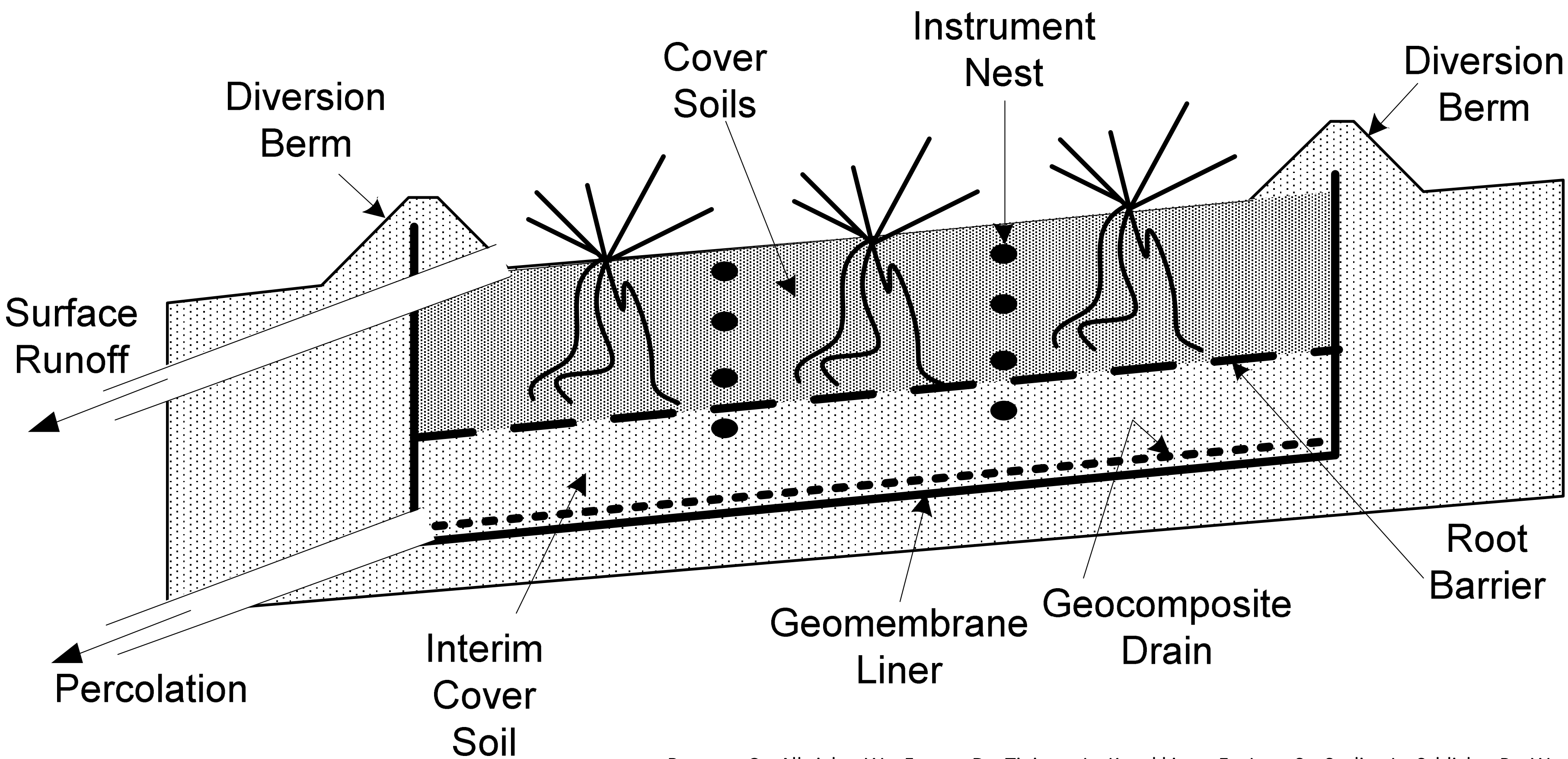
S = soil water storage

S_c = soil water storage capacity

Monitoring Hydrology Using Lysimeters

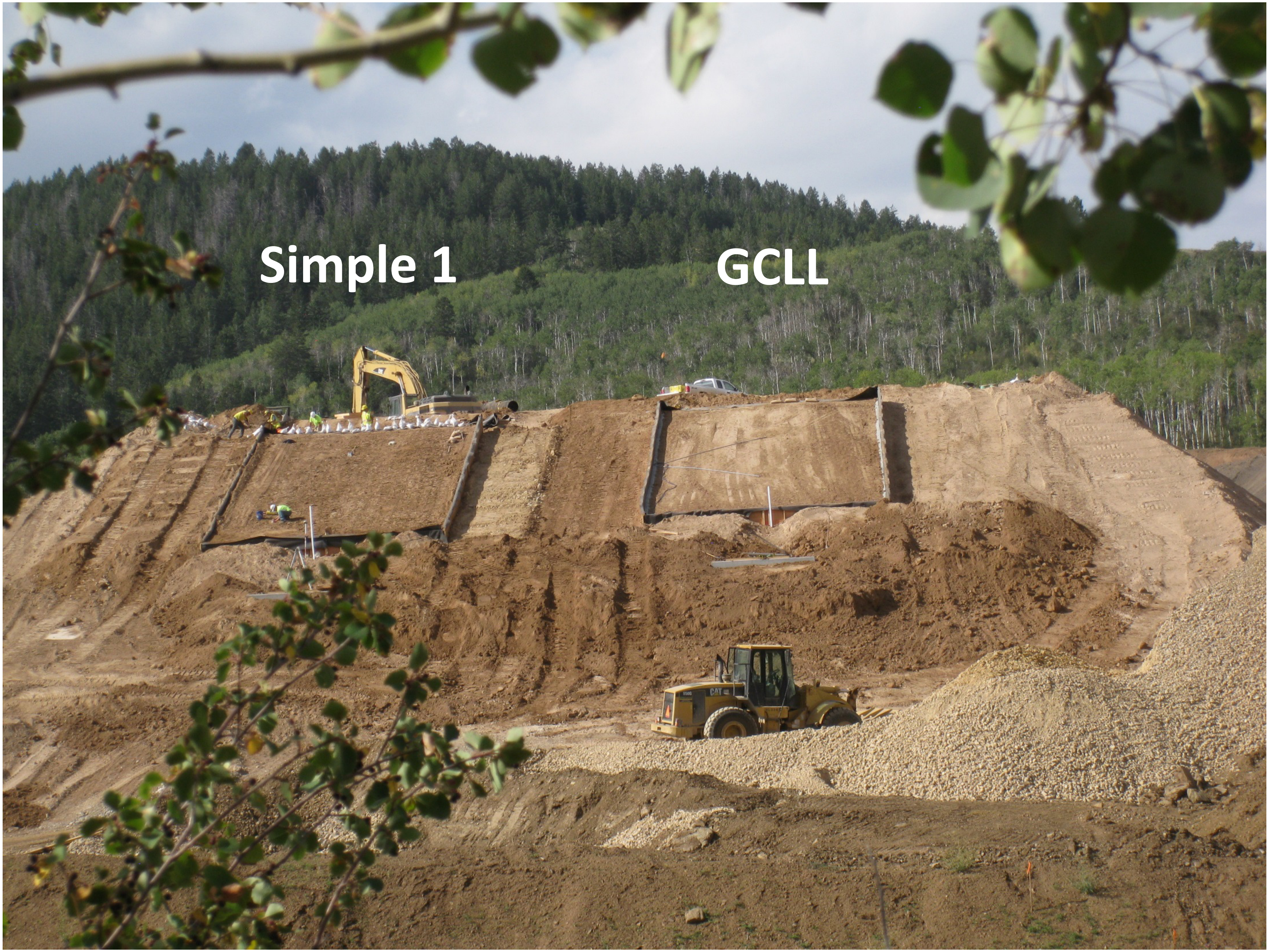
Confirm design meets performance goal by directly monitoring percolation. Monitor by function rather than by compliance criteria.

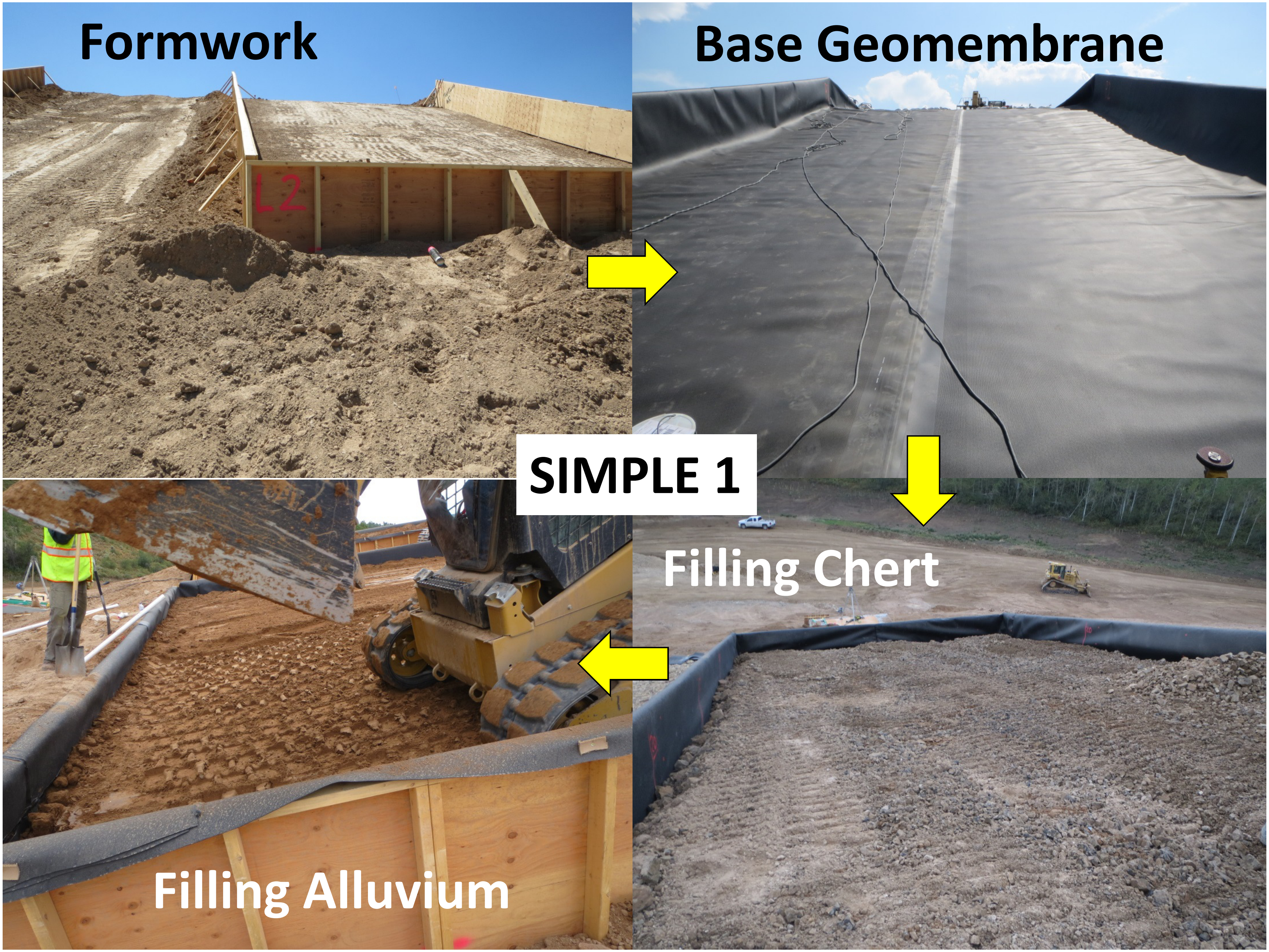
Recommended in NUREG CR-7028



Benson, C., Albright, W., Fratta, D., Tinjum, J., Kucukkirca, E., Lee, S., Scalia, J., Schlicht, P., Wang, X. (2011), Engineered Covers for Waste Containment: Changes in Engineering Properties & Implications for Long-Term Performance Assessment, NUREG/CR-7028, Office of Research, U.S. Nuclear Regulatory Commission, Washington.

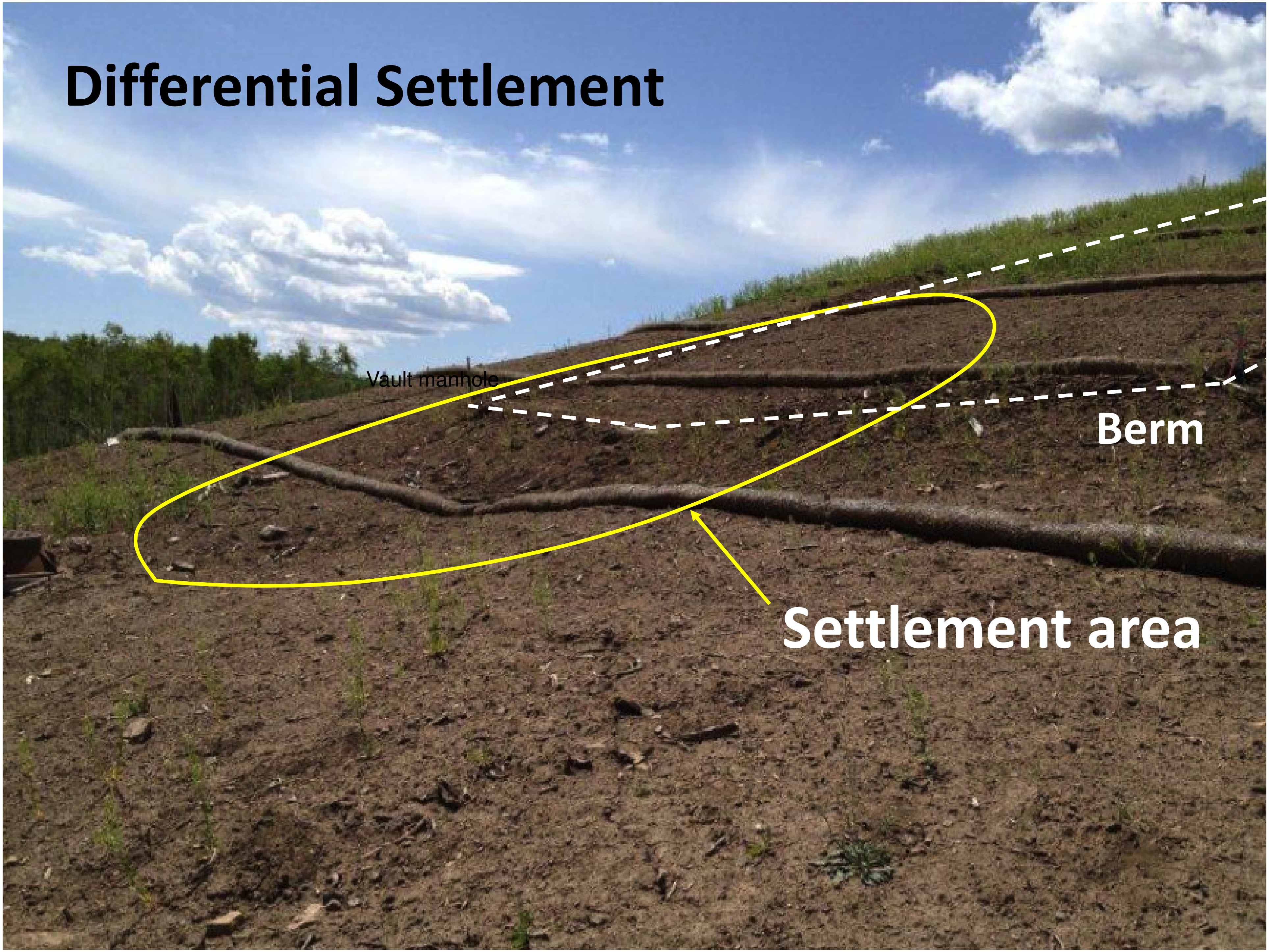

CAT 299D

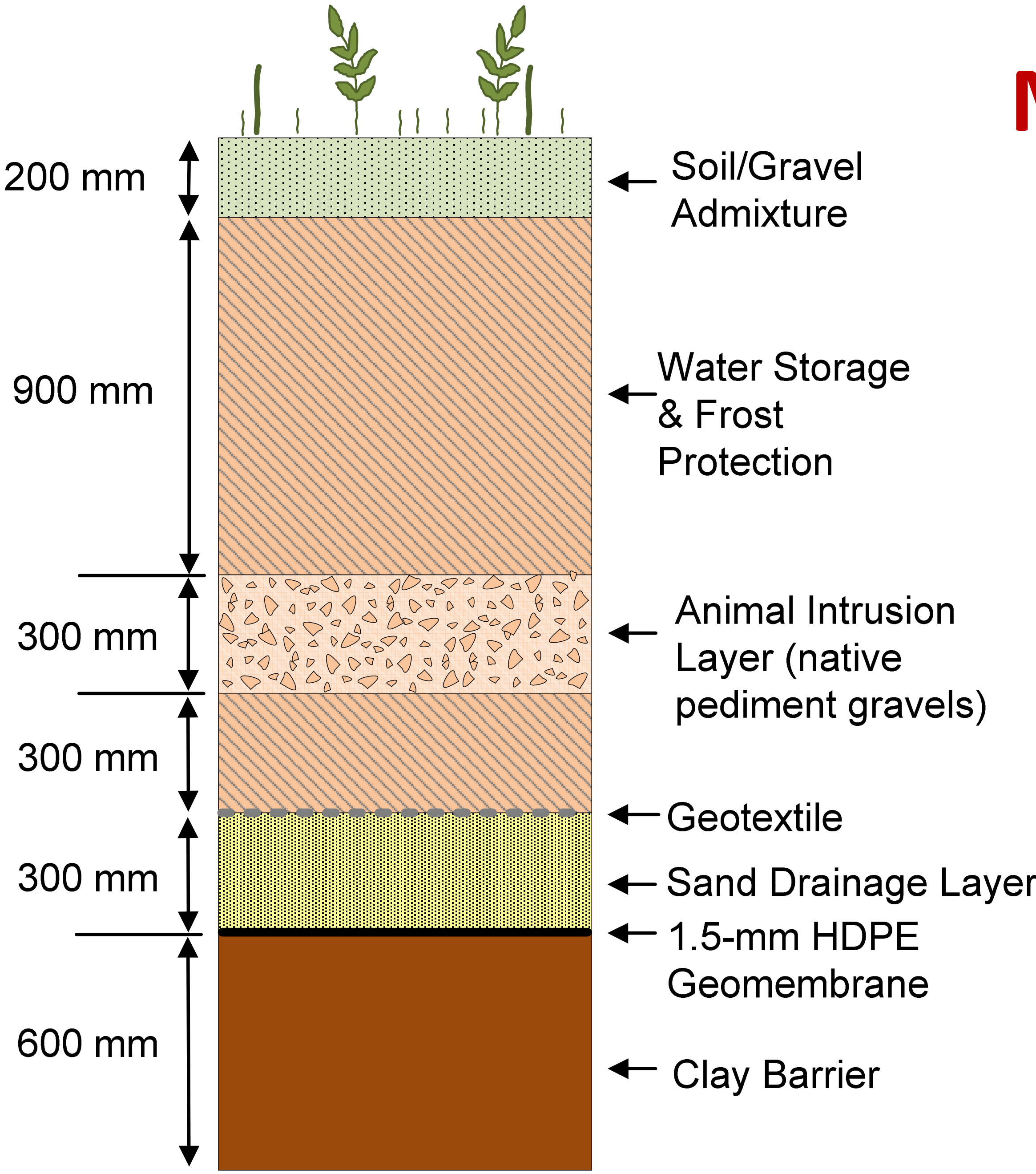

Simple 1
GCLL


Formwork
Base Geomembrane
SIMPLE 1
Filling Chert
Filling Alluvium

Freezing Conditions & Snow Accumulation

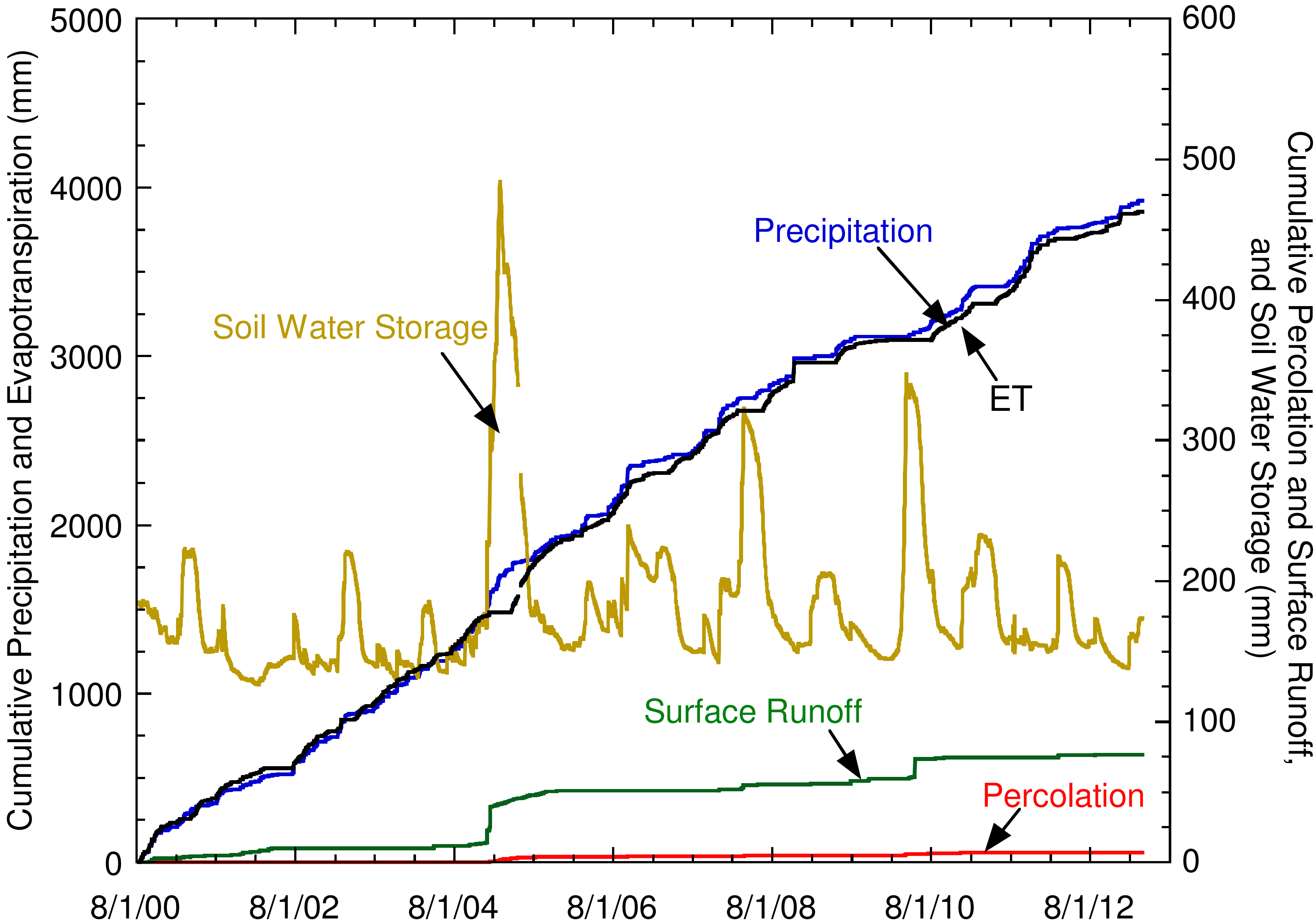
Differential Settlement





Monticello Cover

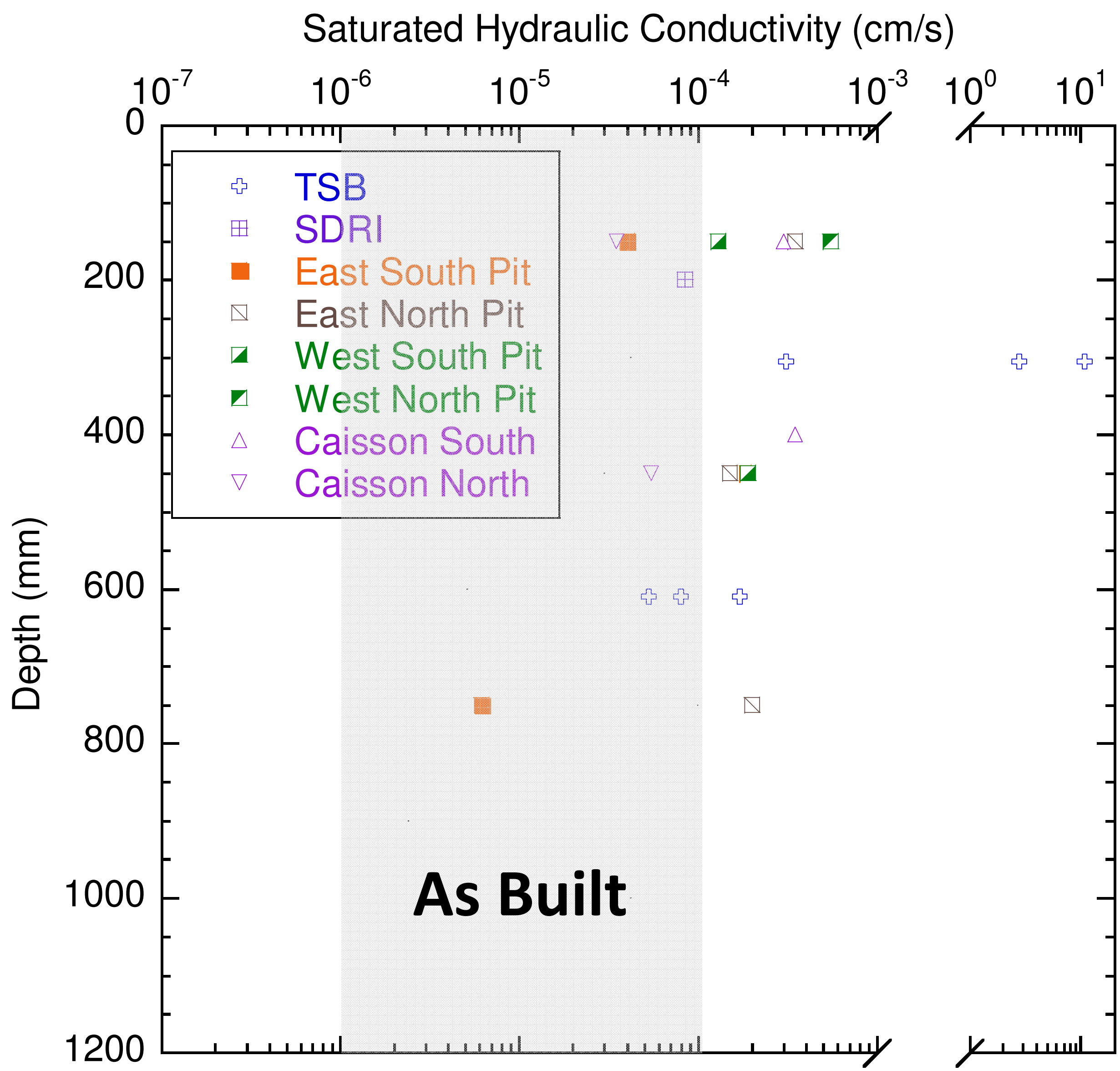
- Dual cover system- water balance cover over drainage layer and composite barrier
- Sand intended to function as capillary break & lateral drain
- Biota barrier is cobble in fine-textured matrix
- ACAP test section monitored since August 2000



Cumulative Precipitation and Evapotranspiration (mm)
Cumulative Percolation and Surface Runoff, and Soil Water Storage (mm)
5000
4000
3000
2000
1000
0
600
500
400
300
200
100
0
8/1/00
8/1/02
8/1/04
8/1/06
8/1/08
8/1/10
8/1/12
Precipitation
ET
Soil Water Storage
Surface Runoff
Percolation

Year	Precip (mm)	Runoff (mm)	ET (mm)	Perc (mm)
00	202	2.8	235	0.0
01	259	4.2	400	0.0
02	273	3.3	221	0.0
03	345	0.0	360	0.0
04	**436**	**12.3**	**352**	**0.2**
05	**420**	**28.1**	**516**	**3.8**
06	**439**	**0.0**	**389**	**0.2**
07	318	1.2	318	0.0
08	**297**	**3.6**	**329**	**0.7**
09	128	4.0	247	0.0
10	**217**	**15.0**	**446**	**1.9**
11	375	0.1	395	0.1
12	172	2.3	287	0.0
13	274	1.4	269	0.0

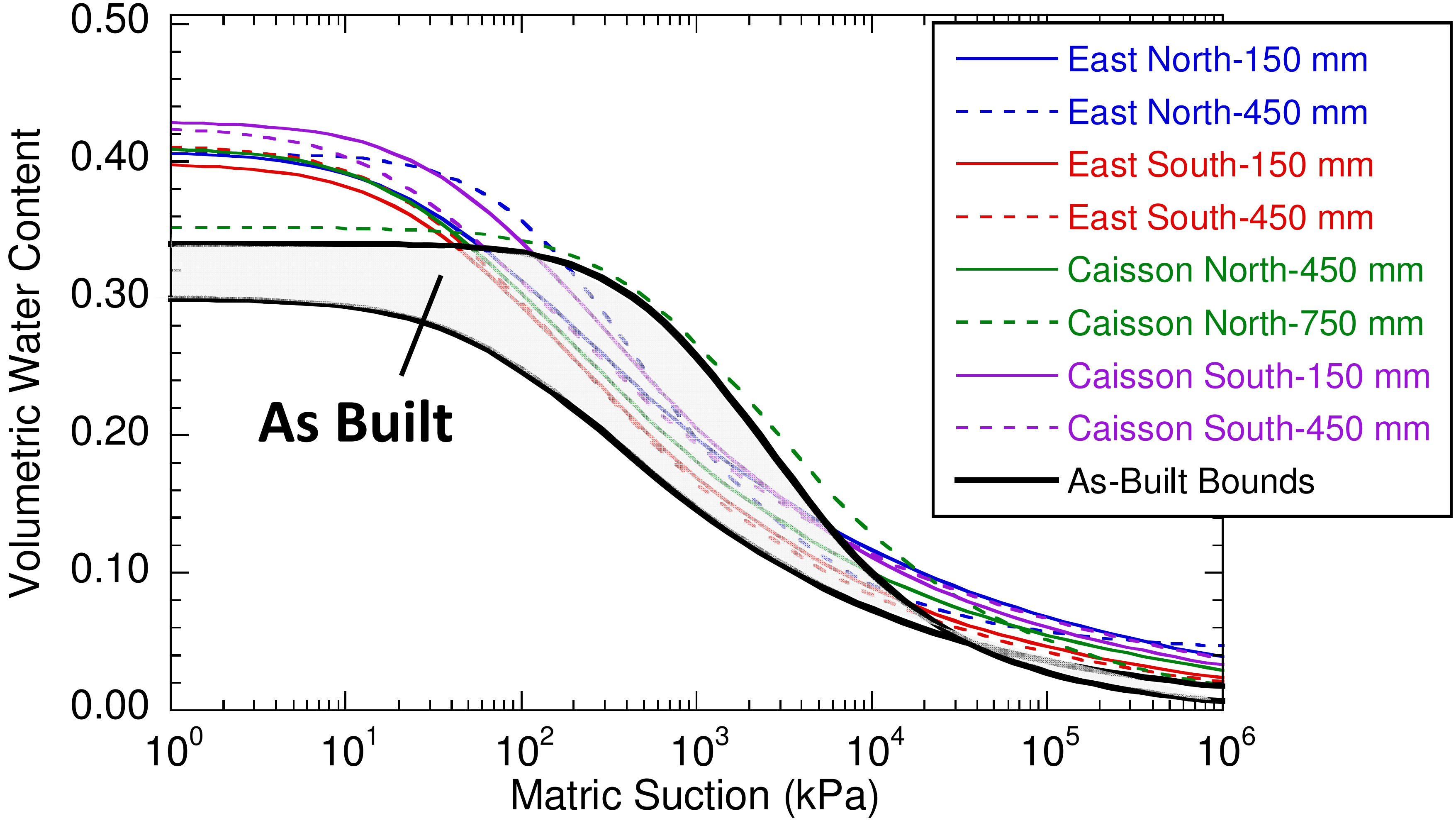
Changes in Water Transmission



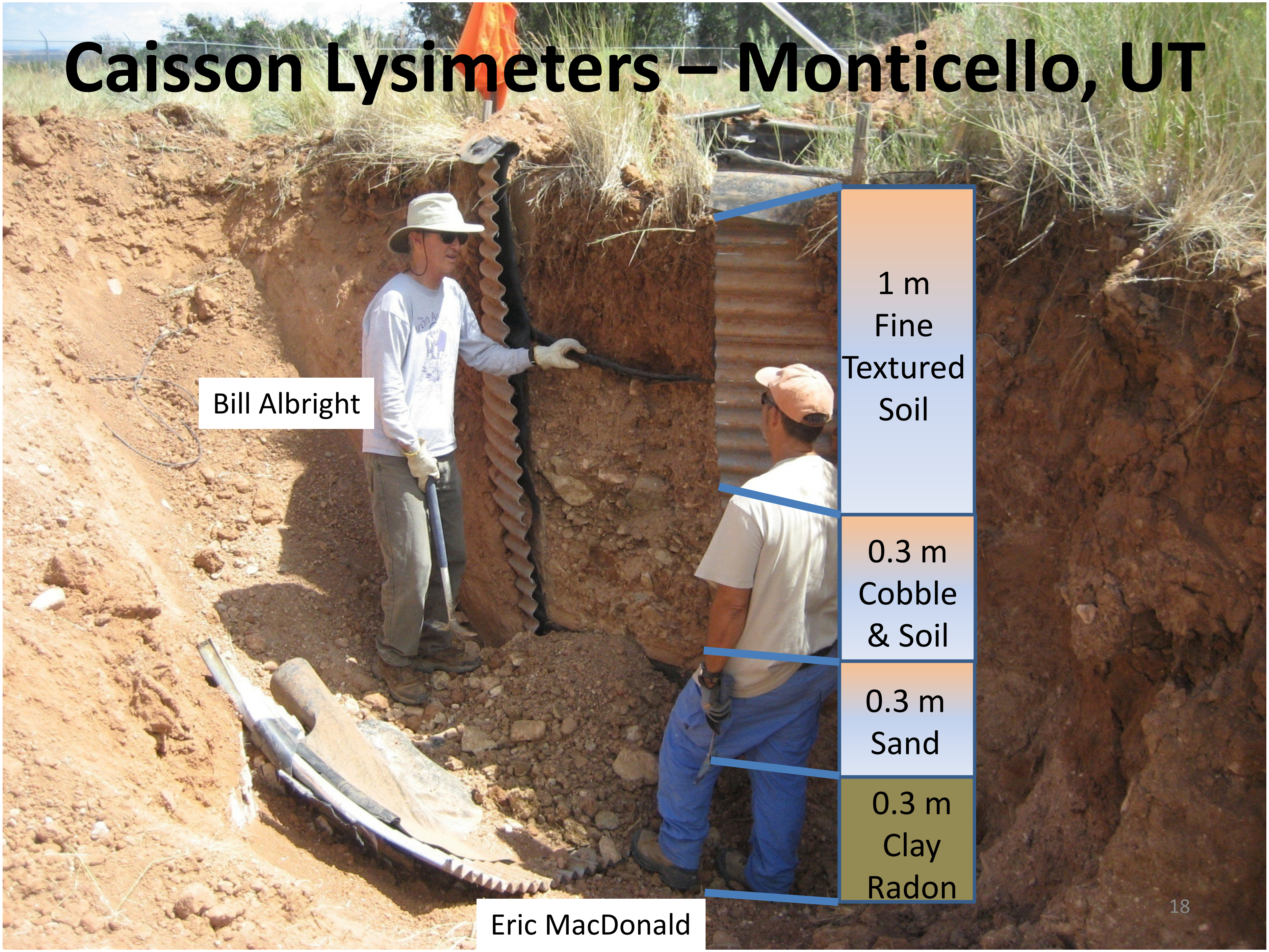
Properties measured in field or in lab using large-scale block samples.

Monticello in-service K_s about 10x higher than as-built K_s

Changes in Water Retention



Caisson Lysimeters – Monticello, UT



Radon Barrier – Monticello, UT

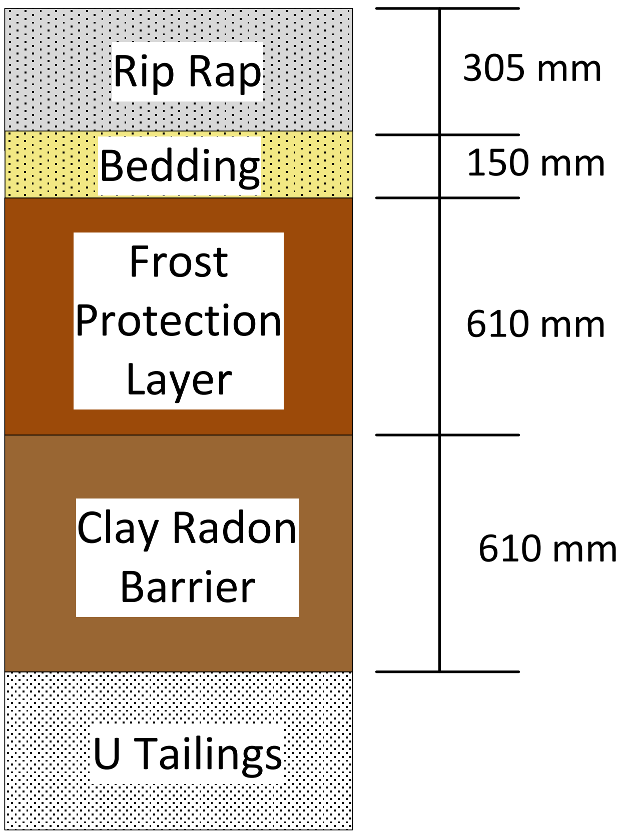
Roots seek out water in wet fine-grained soils, e.g., clay radon barriers, even at 1.6-1.9 m depth

Lessons Learned from Monticello

- Monticello functioned as a **very effective** monolithic water balance cover despite a deep sand layer that could create a capillary break.
- Percolation at Monticello occurs in response to spring infiltration due to melt of snow stored on surface during winter.
- Soils at Monticello experienced pedogenesis, increase in K_s, θ_s, and α, slight decrease in n. Plan for pedogenesis during design.

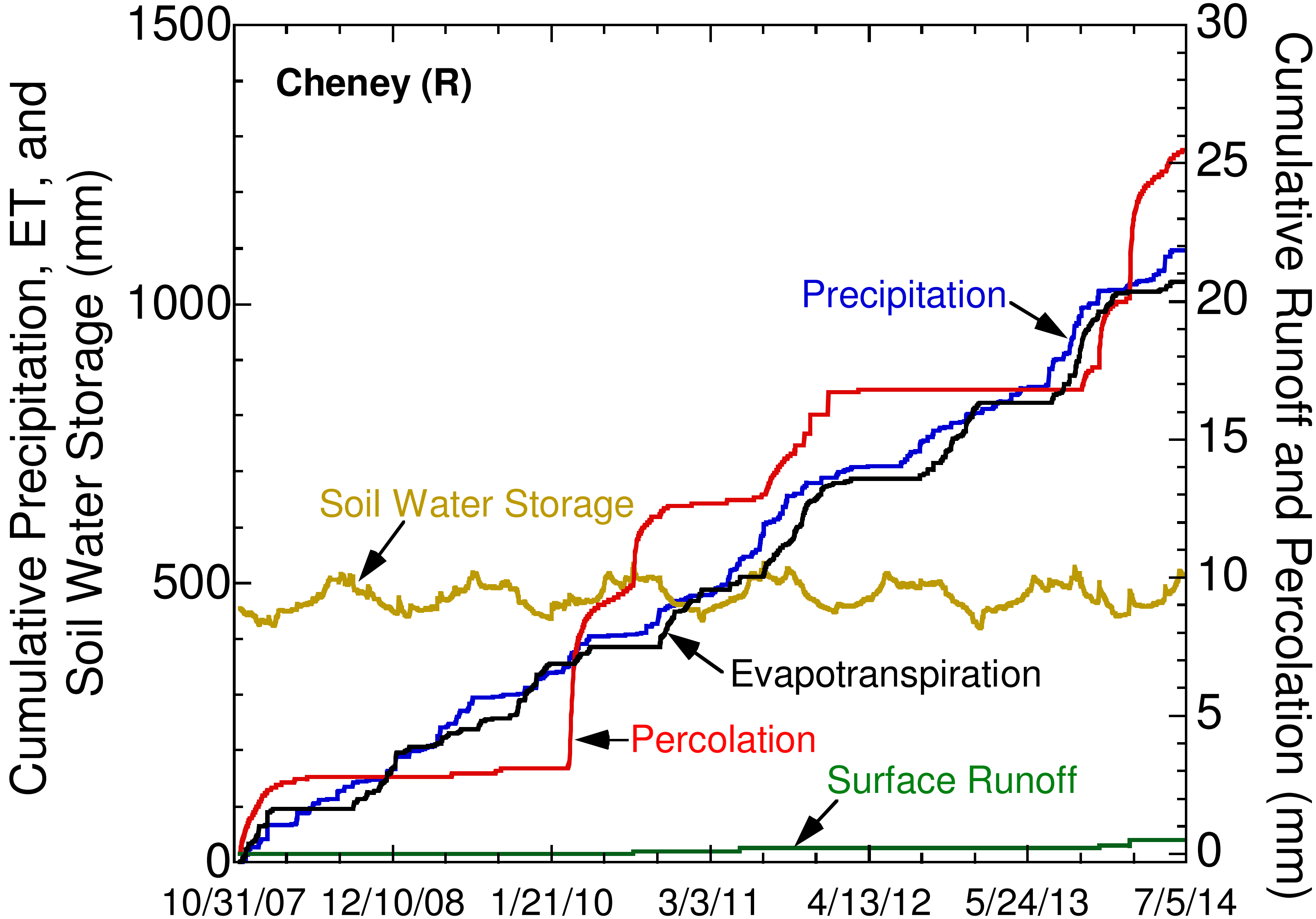
Cheney UMTRCA-Style Disposal Facility

Armored Cover with Clay Rn Barrier



Vegetation on the surface is controlled with herbicide – no vegetation on cover

Cheney Water Balance

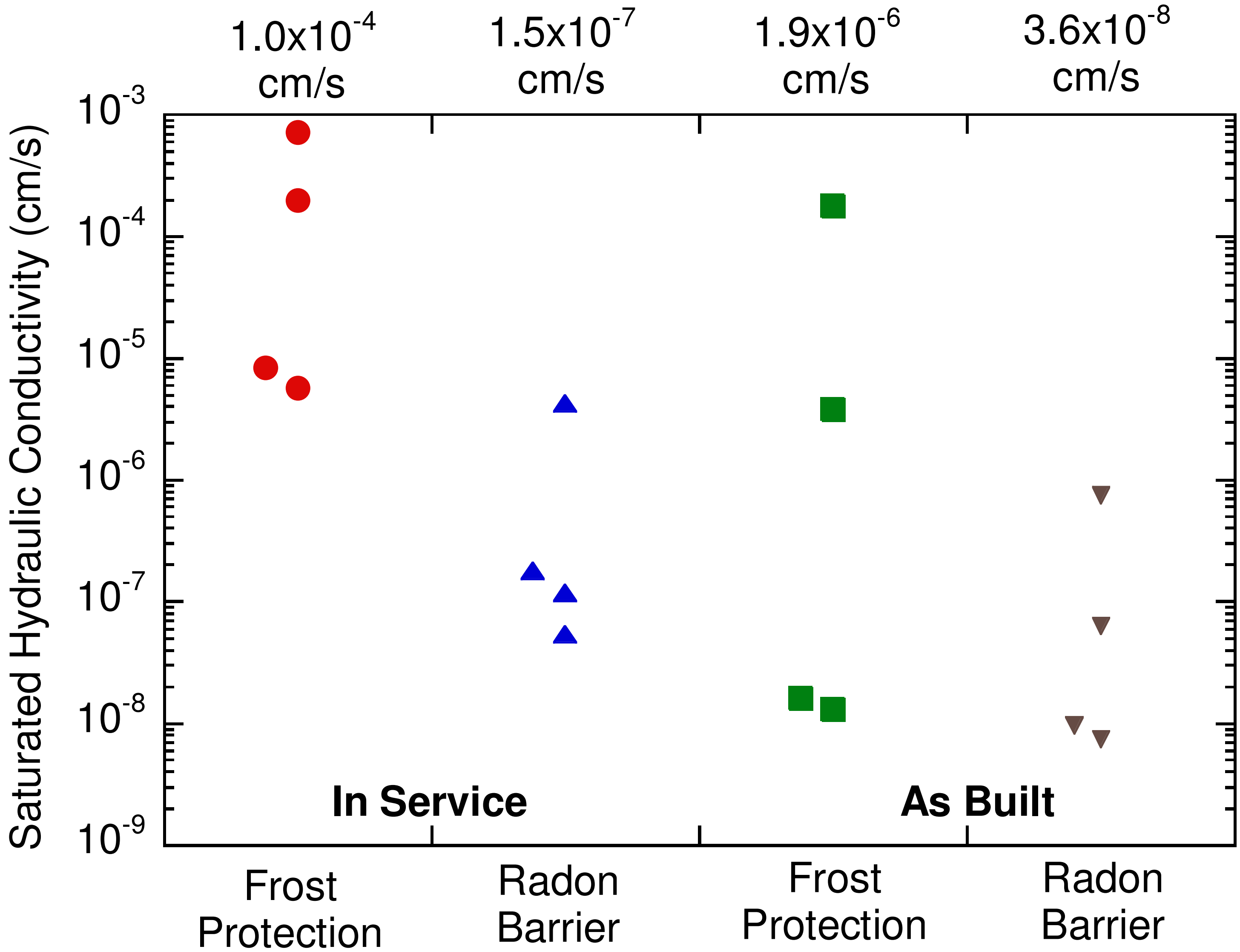


Cheney Water Balance

Water Year	Water Balance Quantities (mm)					
	Precip.	Runoff	ET	D Storage	R Perc.	C Perc.
07-08	**113**	0.0	100.3	49.7	**2.77**	**1.40**
08-09	**170**	0.0	163	4.3	**0.08**	**0.45**
09-10	**123**	0.0	224	-5.9	**6.40**	**0.56**
10-11	**154**	0.1	233	-7.0	**3.62**	**1.26**
11-12	**150**	0.0	188	-15.8	**3.93**	**0.62**
12-13	**140**	0.0	108	0.6	**0.01**	**0.97**
13-14	**246**	0.3	346	18.4	**8.67 (2.2%)**	**8.91 (2.3%)**

Even in resistive barrier system without vegetation, nearly all water lost via evaporation

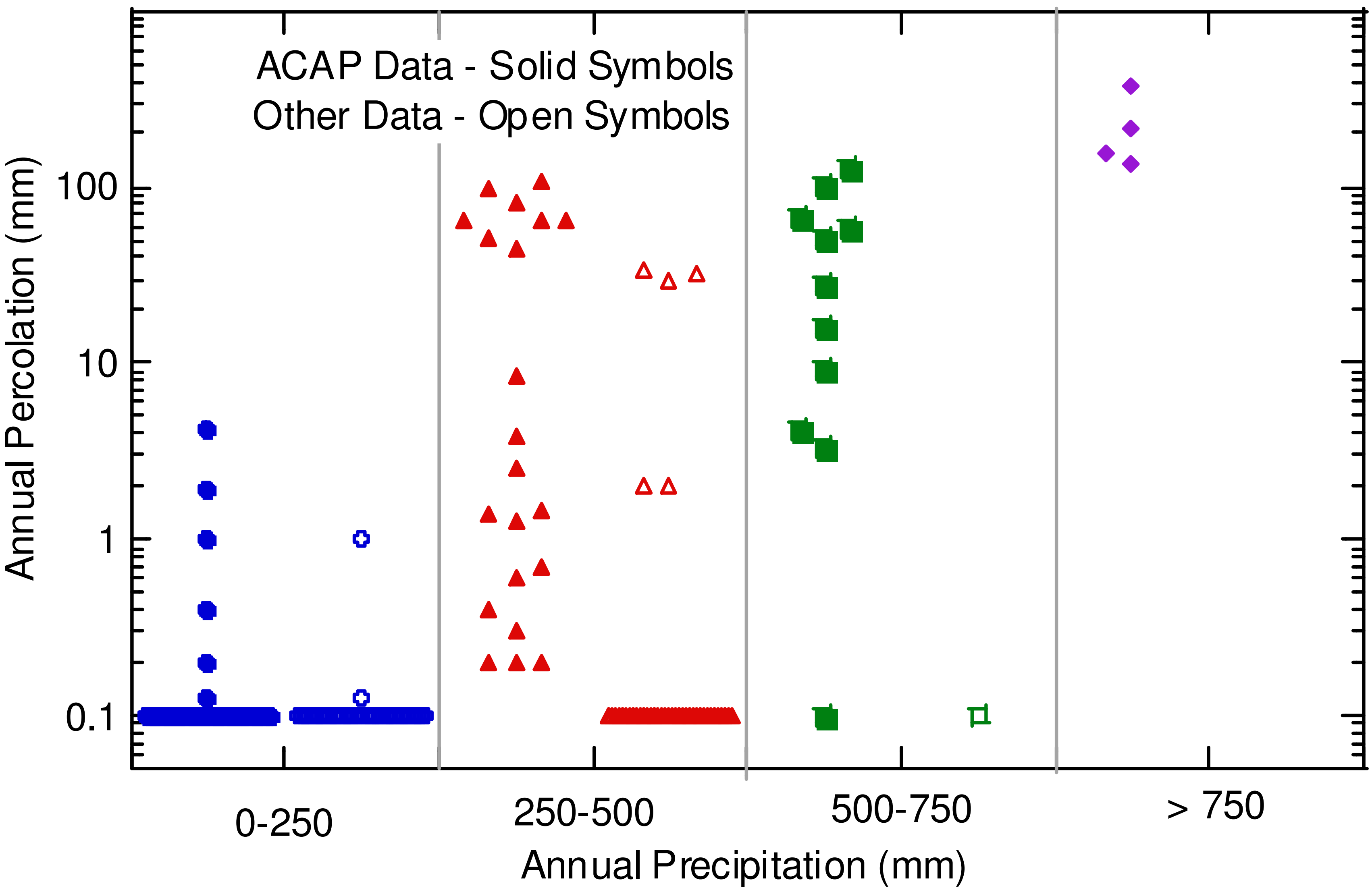
Cheney Saturated Hydraulic Conductivity



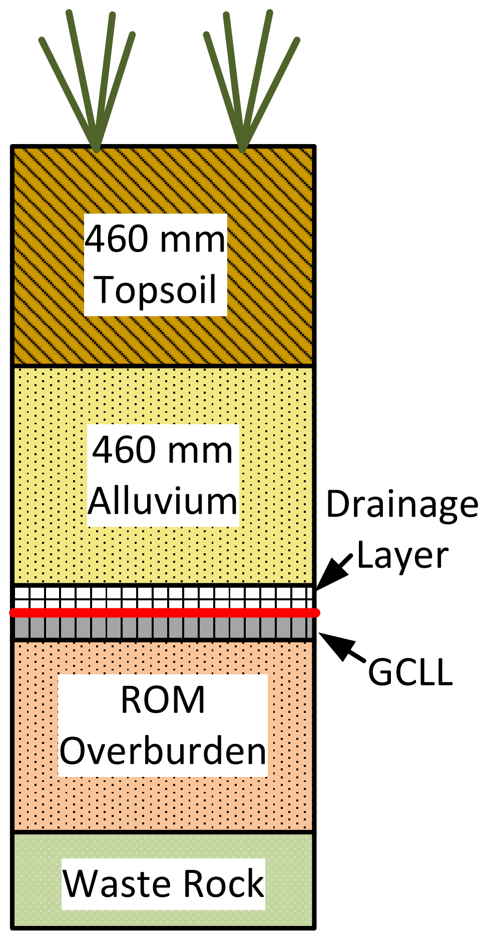
Lessons Learned from Cheney

- Conventional UMTRCA armored earthen cover very effective at controlling percolation.
- Frost protection layer & “reverse capillary barrier” protecting radon barrier from desiccation – slight water content cycling.
- Hydraulic properties of frost protection and radon barriers are evolving due to weathering.
- Contingent on preventing vegetation (herbicide).

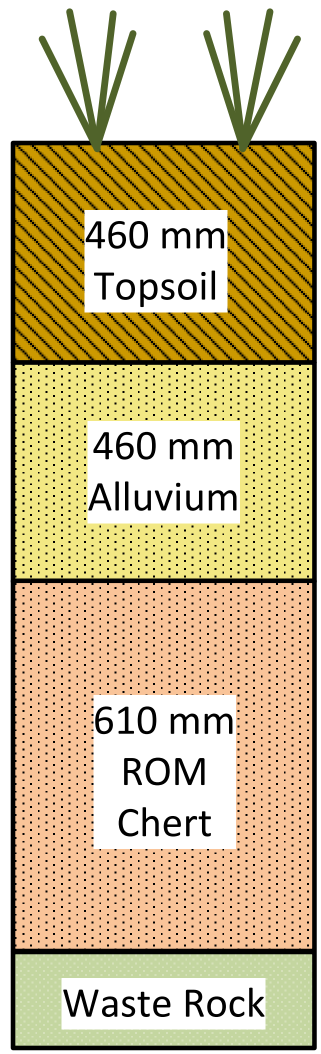
Earthen Covers - Generalizing to Broader Climates



Blackfoot Bridge Covers



GCLL Cover

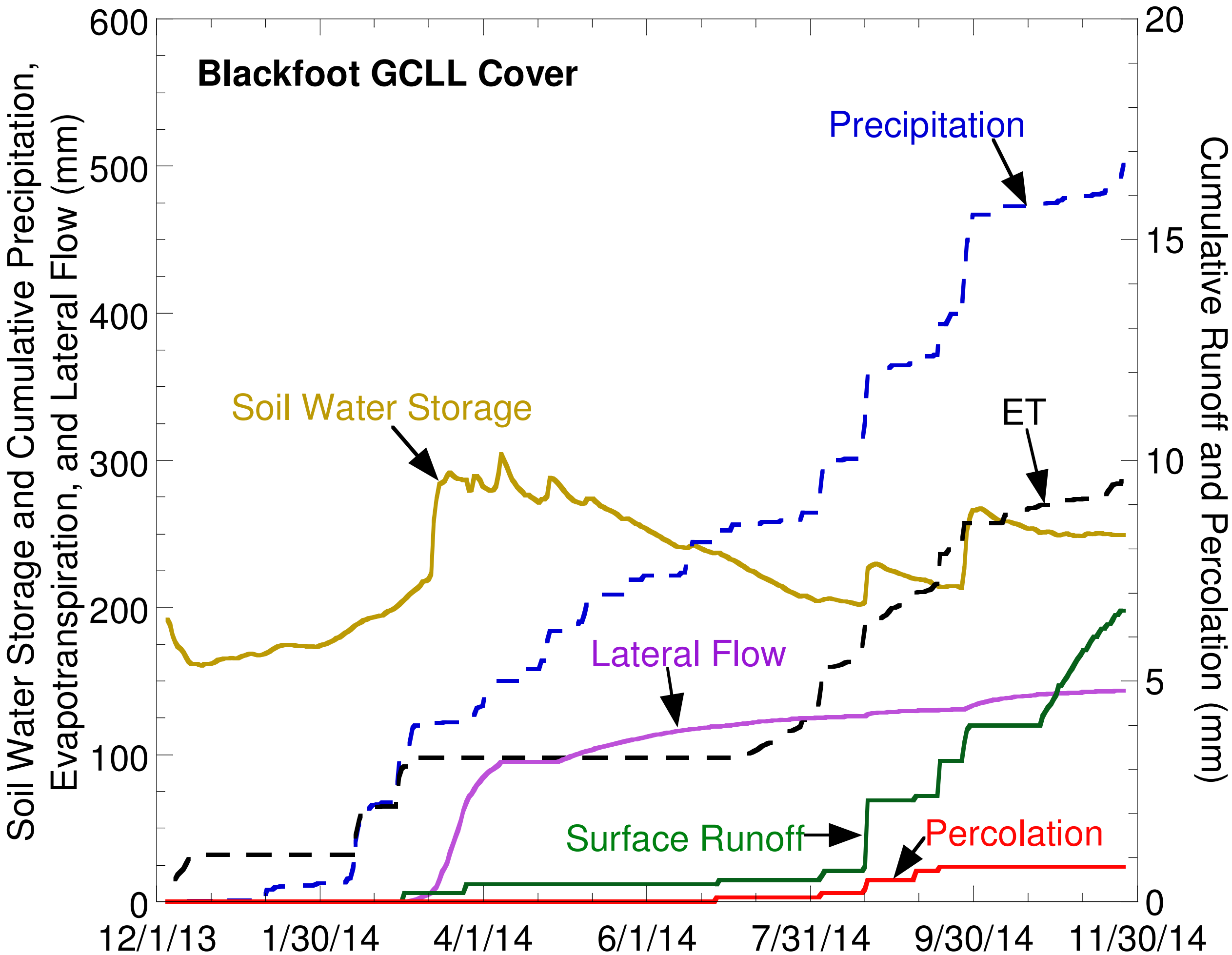


Simple 1 Cover

GCLL used for tight percolation control over more seleniferous waste rock.

Simple 1 used over less seleniferous rock.

Blackfoot Bridge GCLL Water Balance



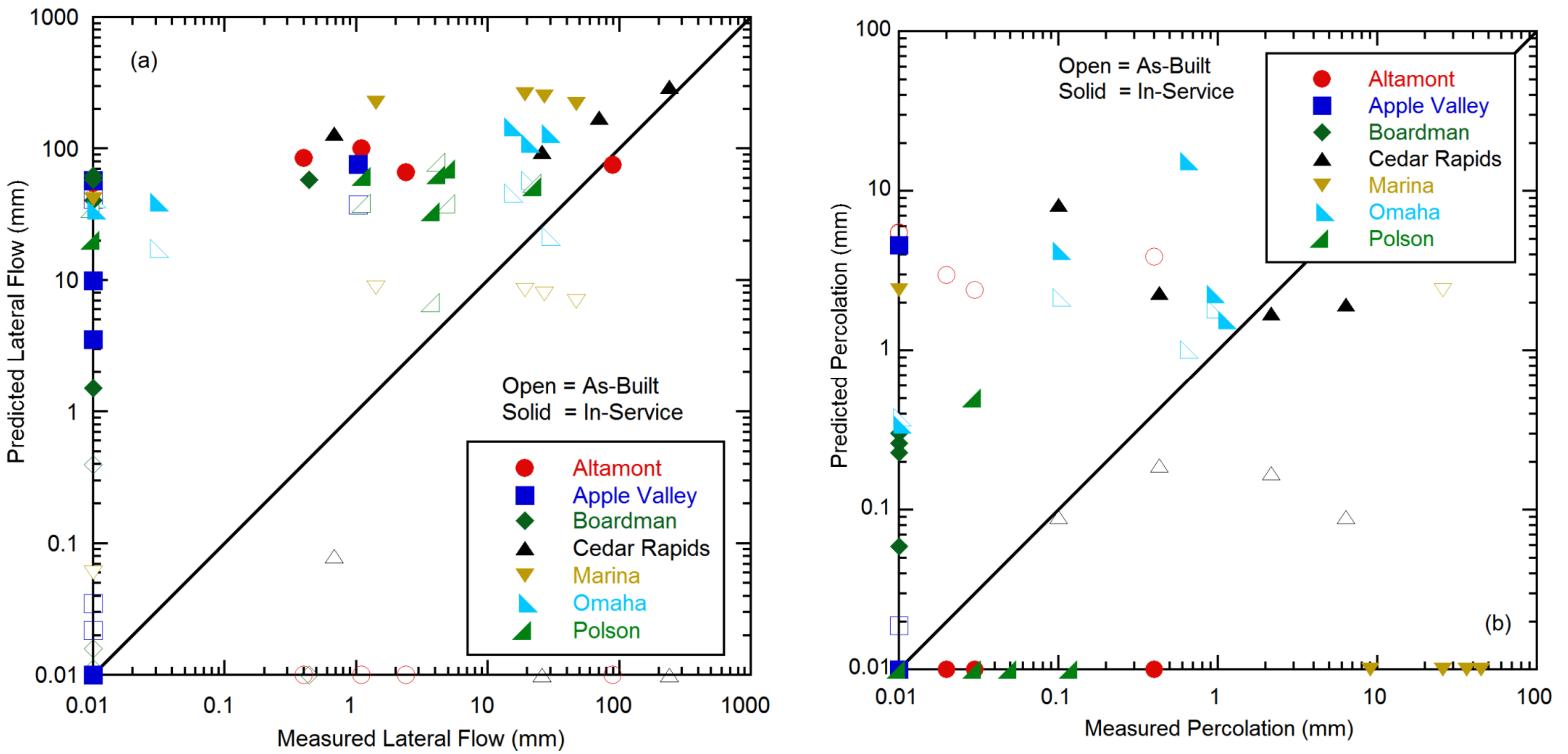
Summary 13-14

- Precip = 476 mm
- Runoff = 7.0 mm
- Interflow = 144 mm
- ET = 268 mm
- Perc = 0.8 mm

Lessons Learned from Blackfoot

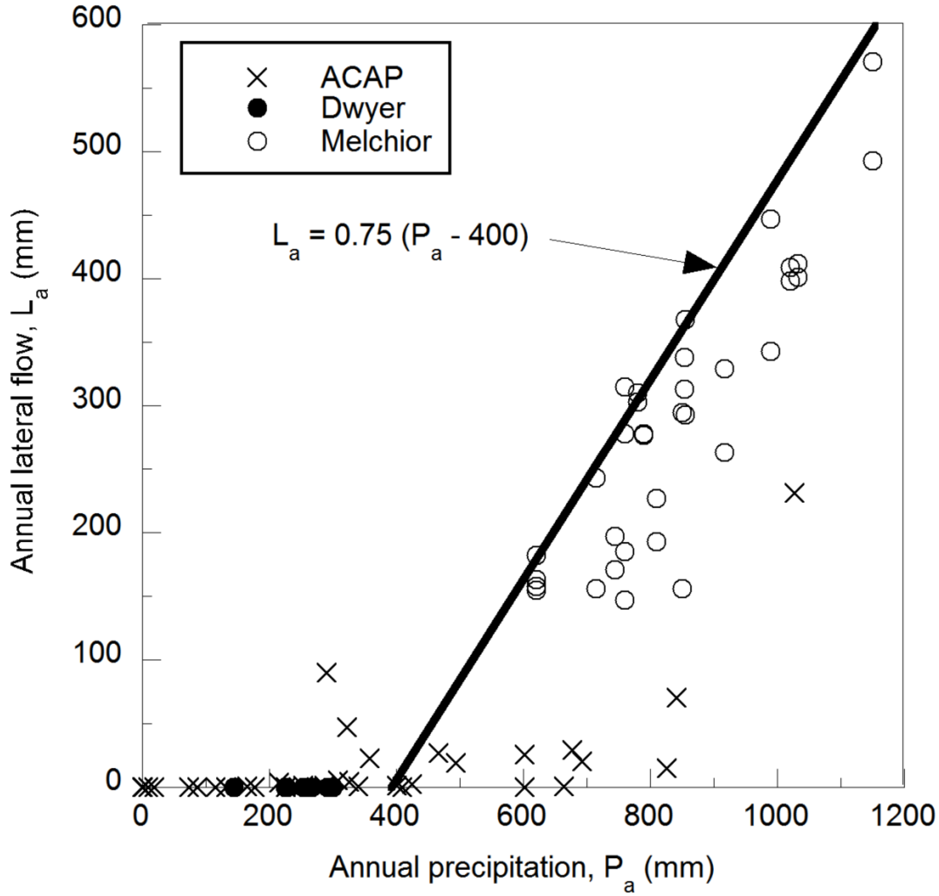
- GCLL composite cover very effective in controlling percolation to low levels (< 1 mm) as predicted.
- Interflow is large component of water balance.
- Runoff modest, but limited snowpack.
- **Only** one year of data – 50 year monitoring requirement in ROD.

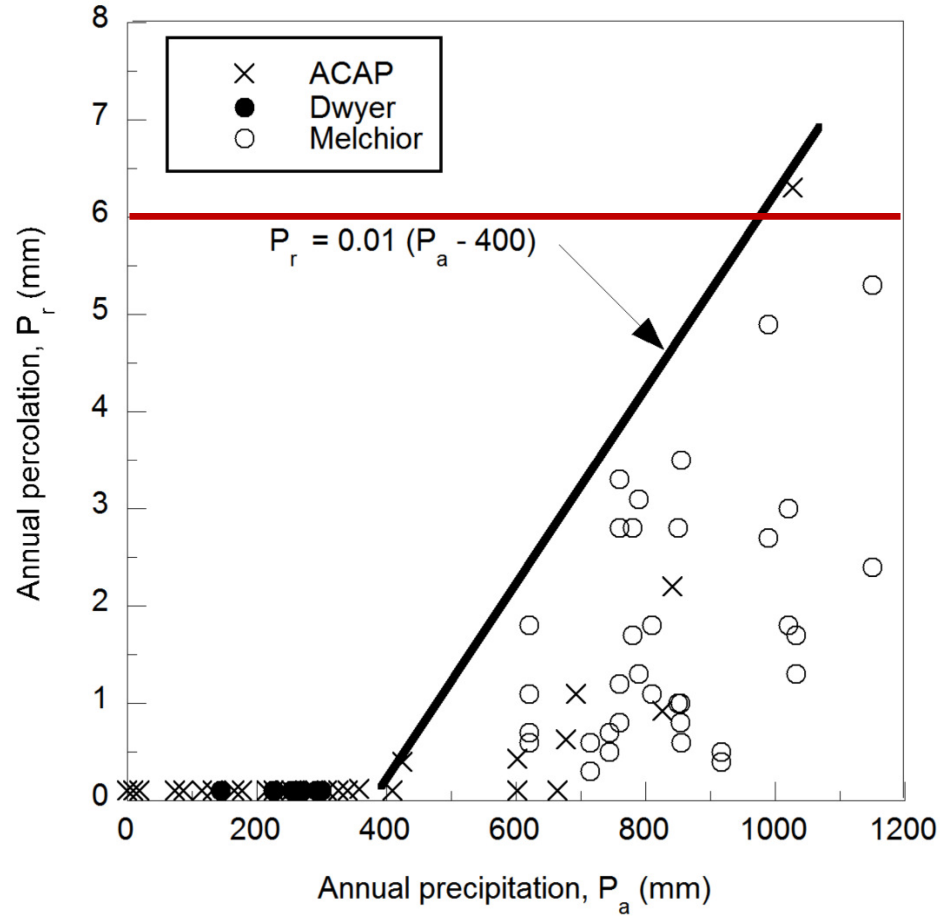
Predictions with HELP Model



Predictions with the HELP model are "estimates."
Lateral flow over-predicted; prediction of percolation not reliable.

Lateral Flow & Percolation vs. Precipitation

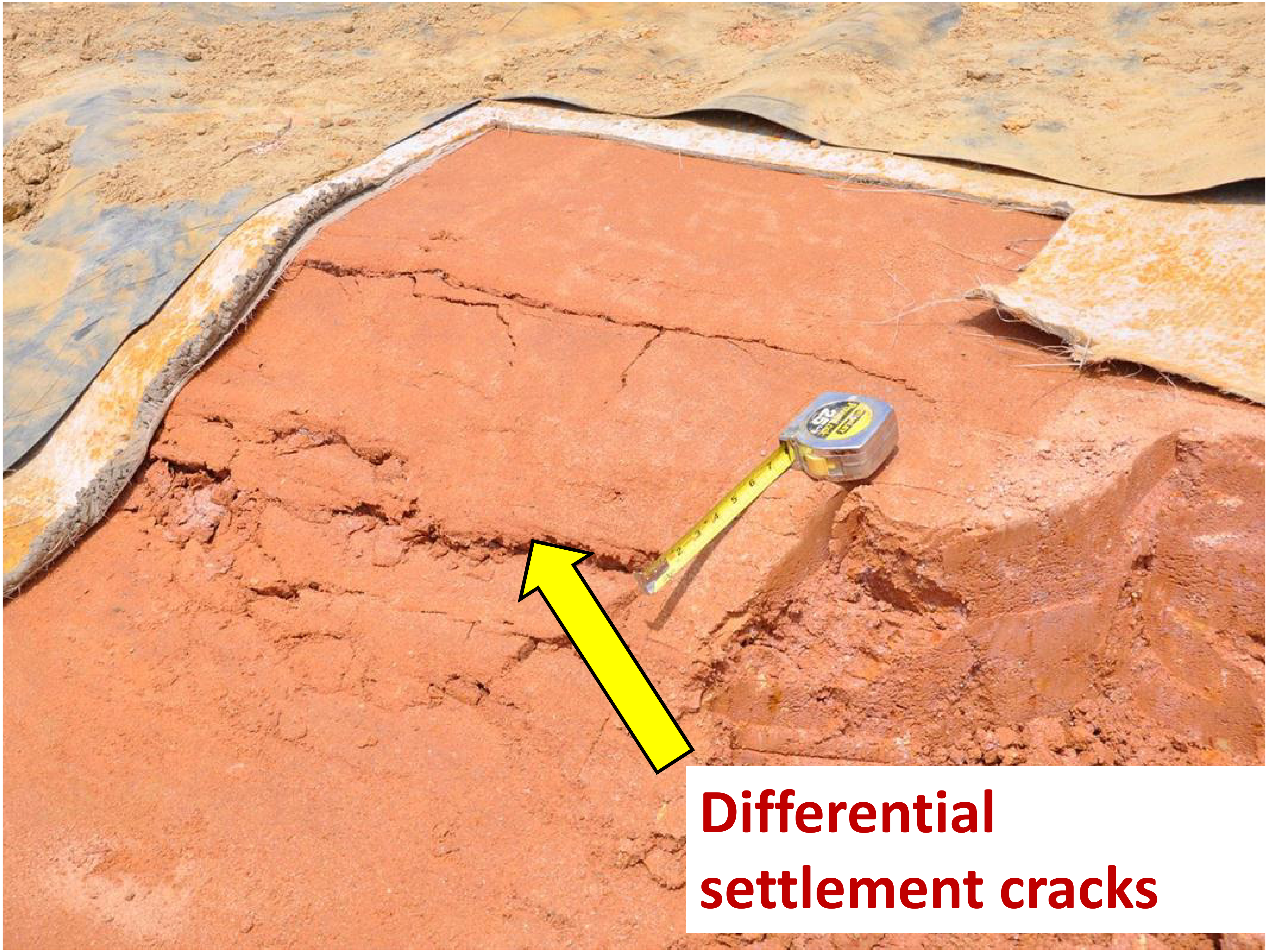


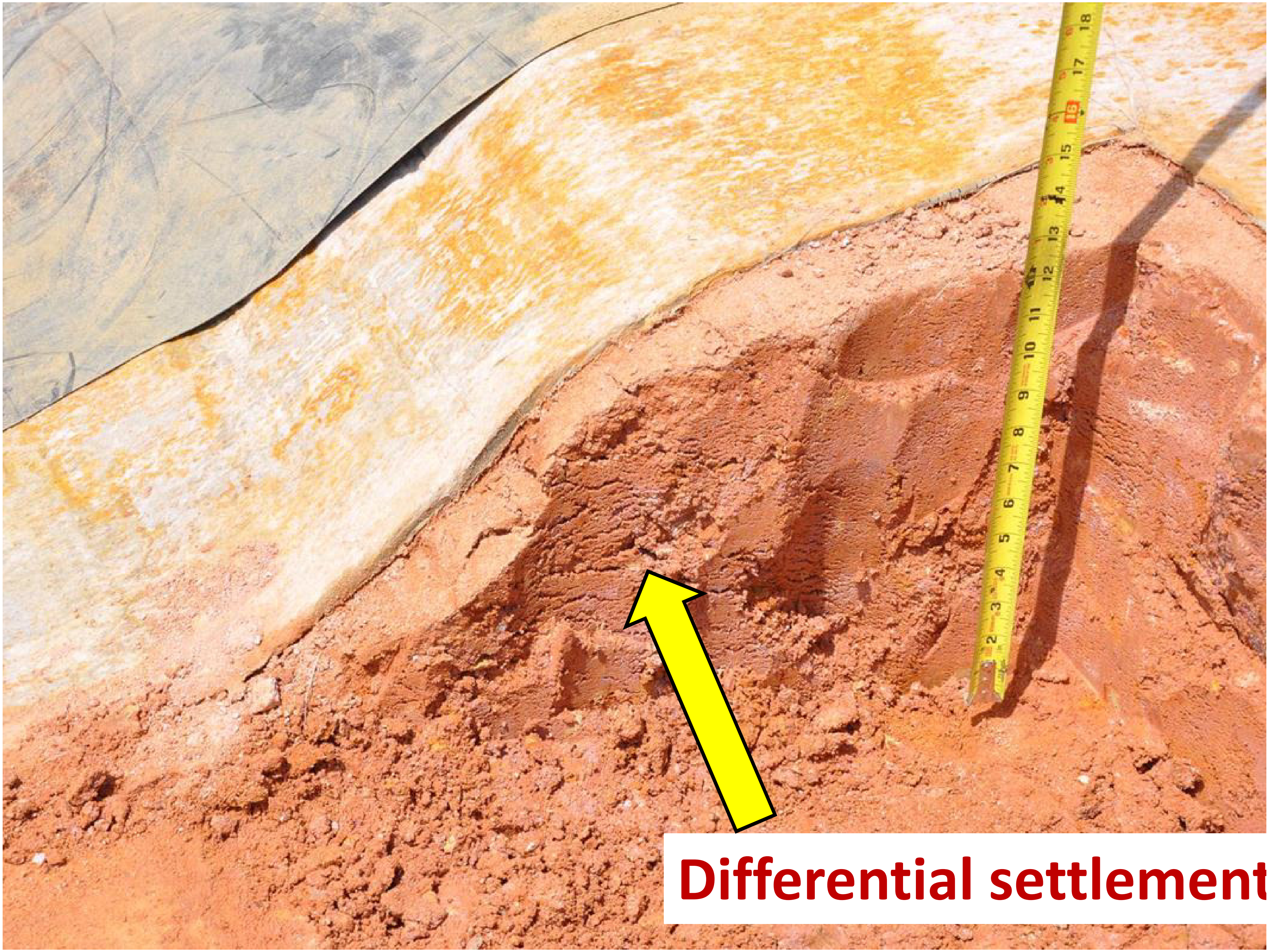


Although percolation increases with annual precipitation, percolation rate <u>low</u>.

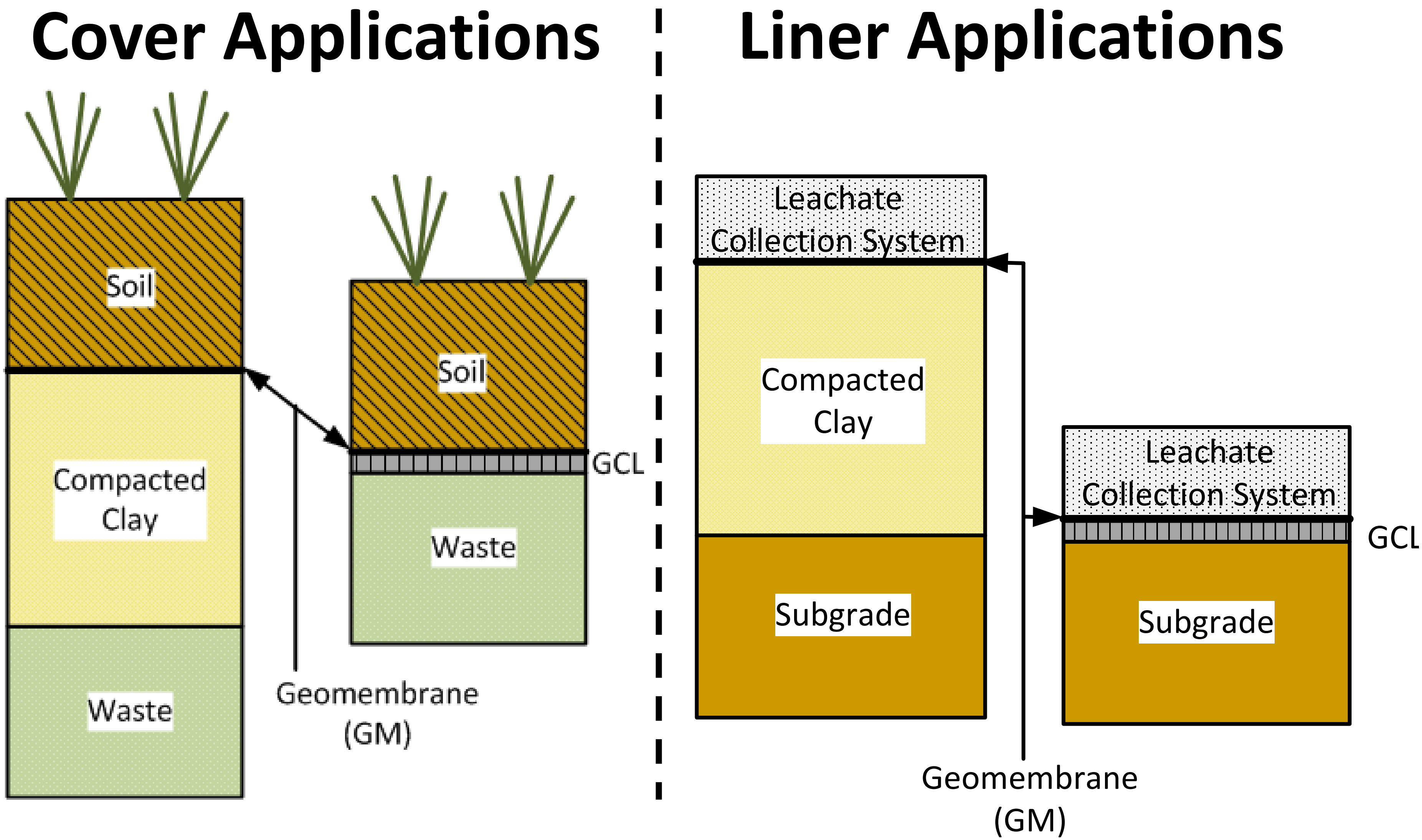
Hole frequency in test sections is 10x higher than in practice. Actual percolation rates 10x lower than shown.


Differential settlement
BENTOFIX


Differential
settlement cracks

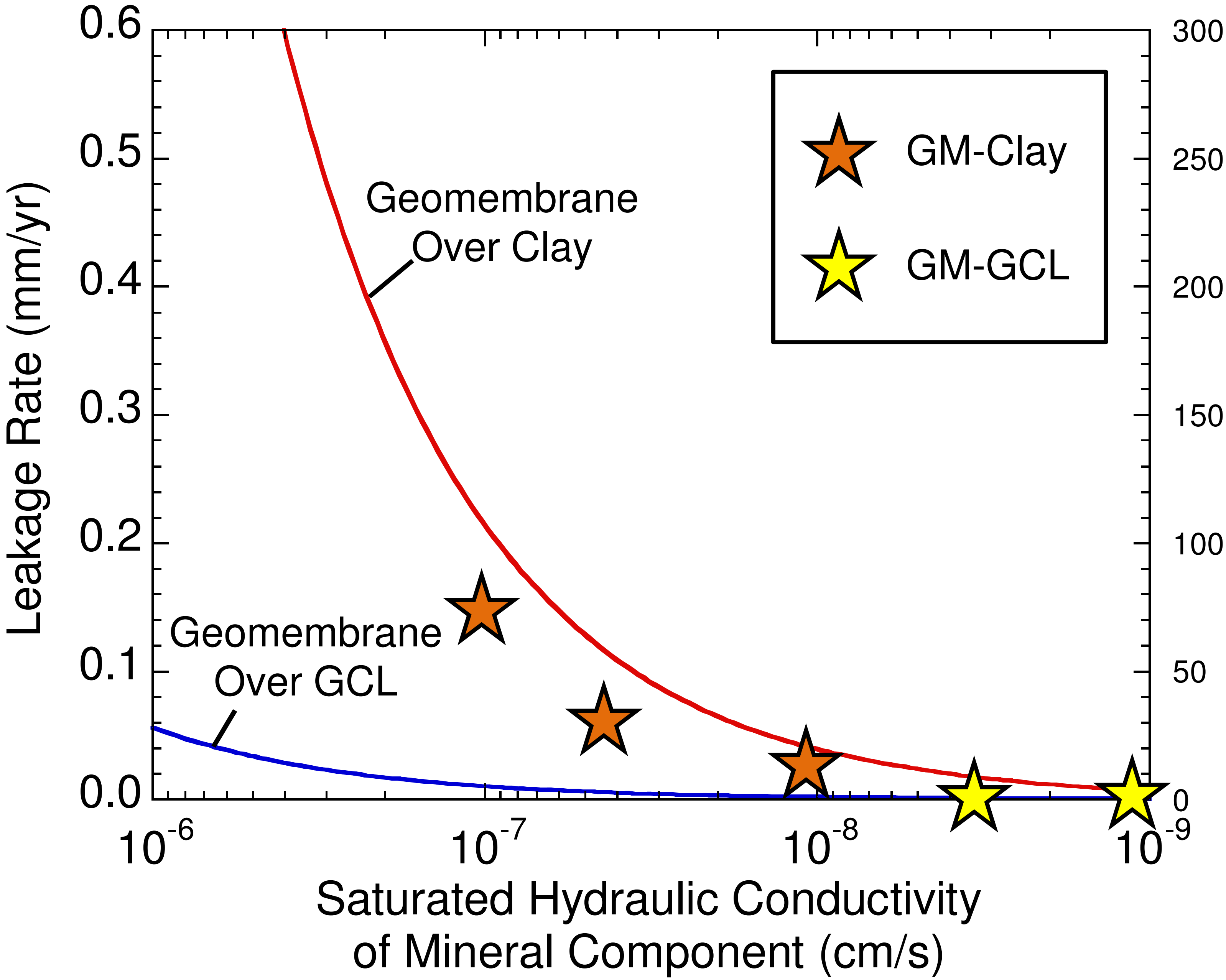

Differential settlement

Covers with Composite Barriers

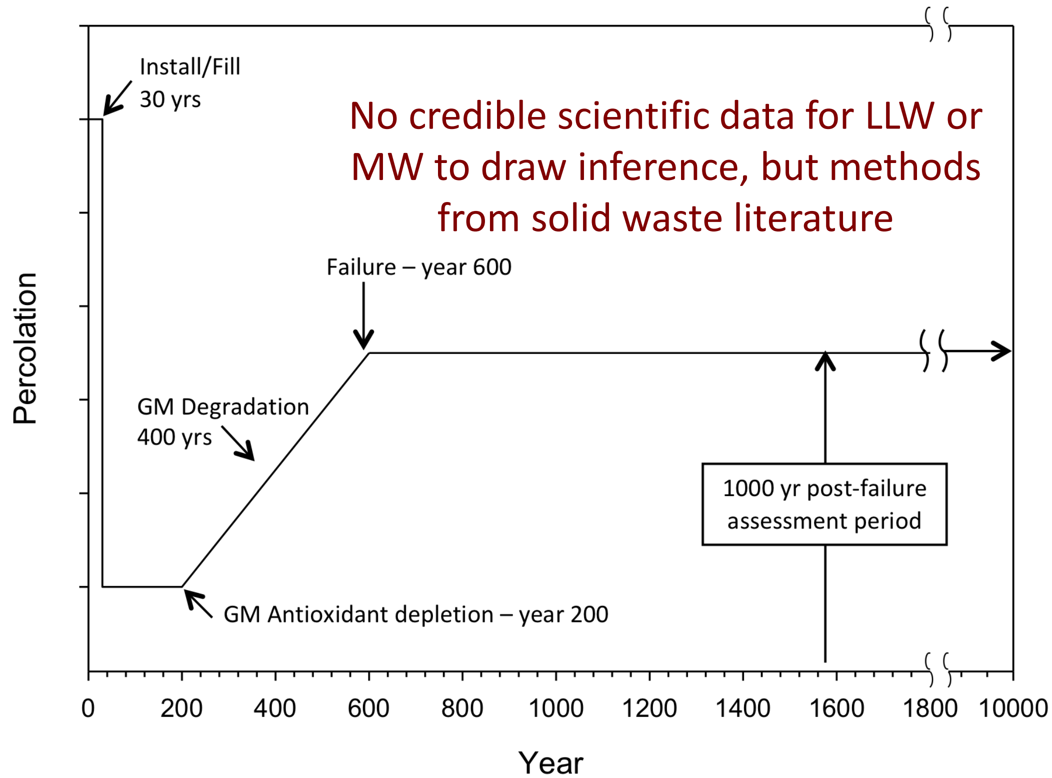


Note: drainage layer normally placed over geomembrane in cover, but not shown for simplicity.

Leakage Rates for Composite Liners



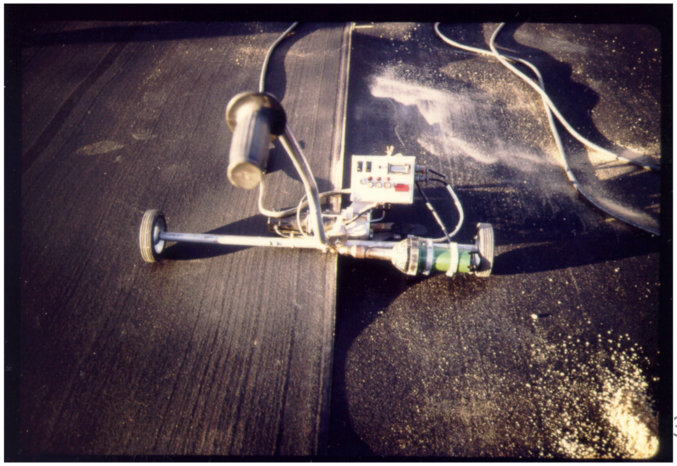
Geomembrane Service Life for LLW?



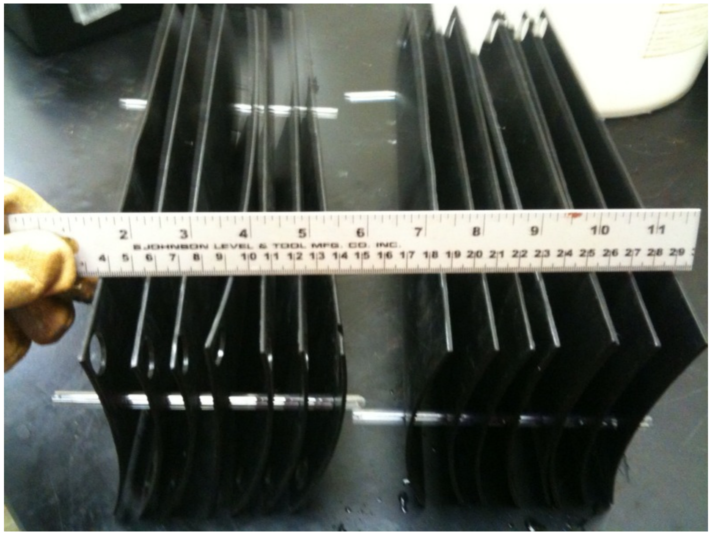
Speculative discussion at Paducah in March '11.

Literature suggests lifespan may be more than 1000 yr.

No data for conditions in LLW or MW facilities.

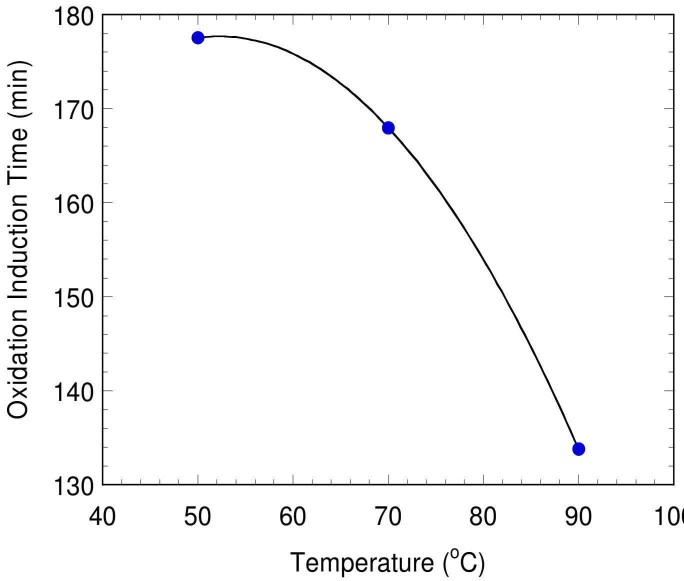


Geomembrane Lifetime Evaluation

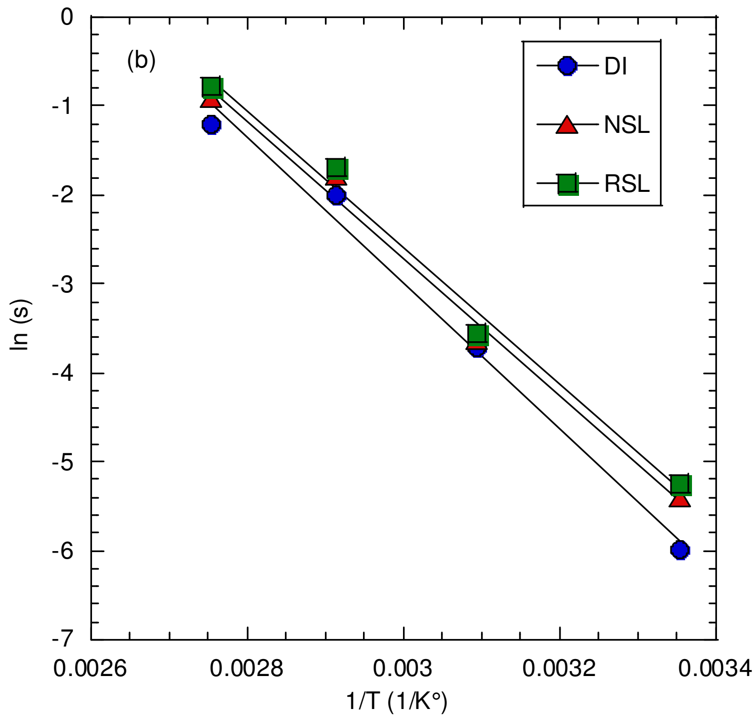


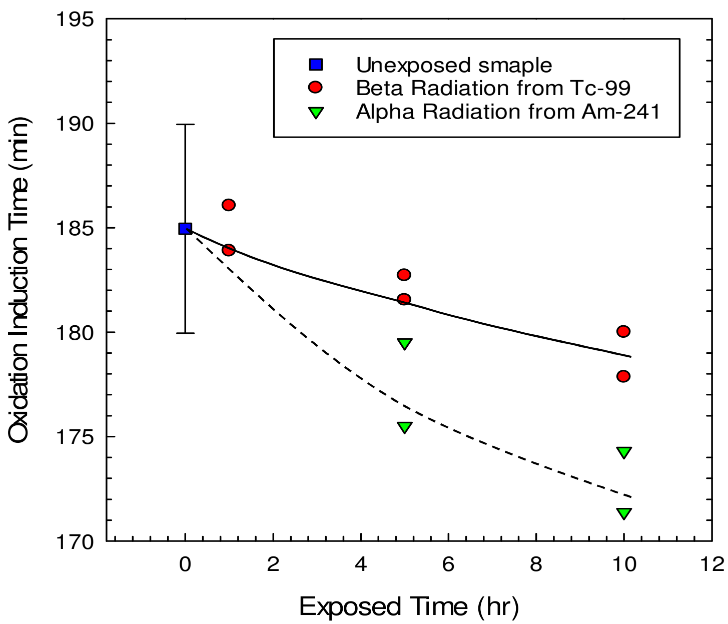
Accelerated Service Life Experiments

- Three temps (50, 70, 90 C)
- Three solutions (DI, RSL, and NSL) – two simulating DOE LLW
- 2 mm HDPE (ERDF, OSDF, OSDC).



Radiation & Service Life of Geomembranes





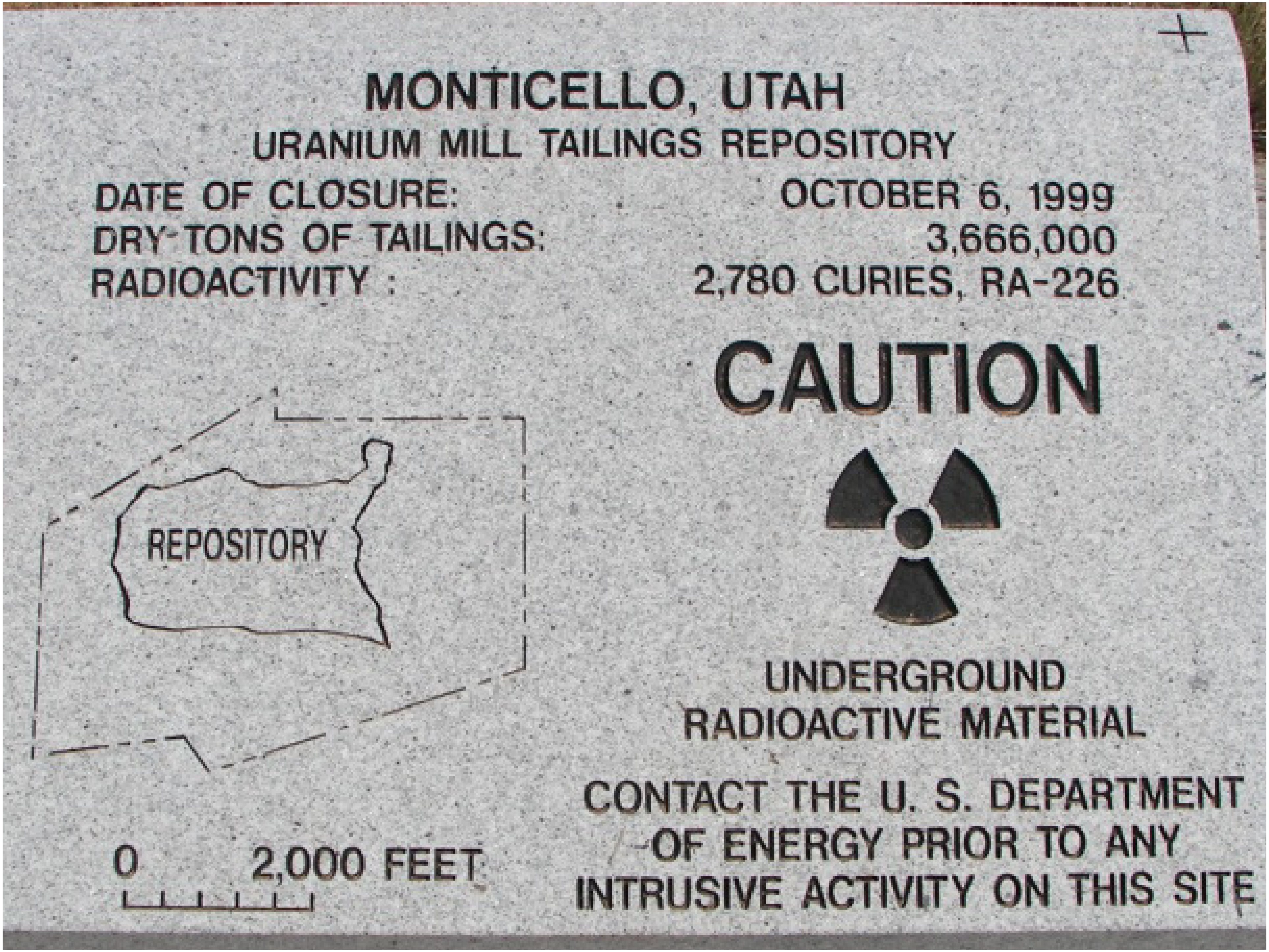
- Accelerated testing experiments on RSL and NSL show that radionuclides have no impact on antioxidant depletion and service life.
- LLW leachate less severe than municipal solid waste leachate (minimal surfactants).
- Antioxidant depletion increases as radiation dose increases.
- Service life ~ 800-1400 yr.

Take Away Messages

- Hydrologic effectiveness of earthen covers consistent with expectations when predictions are based on realistic properties that account for pedogenesis.

- Geosynthetic covers with composite barriers limit percolation to very small amounts in nearly all climates. Durable and resilient to distress – but predicting performance is challenging.

- Liners with composite barriers function very well, with leakage rates < 1 mm/yr. Understanding service life in LLW environment is current challenge. Estimates suggest 800-1400 yr life span.


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
REPOSITORY
UNDERGROUND
RADIOACTIVE MATERIAL
0 2,000 FEET
CONTACT THE U. S. DEPARTMENT
OF ENERGY PRIOR TO ANY
INTRUSIVE ACTIVITY ON THIS SITE