Field–Scale Hydrology of Dry Covers: US EPA's Alternative Cover Assessment Program (ACAP)

Craig H. Benson
Geo Engineering Program
University of Wisconsin-Madison
Madison, WI 53706 USA
benson@engr.wisc.edu

and

William H. Albright
Water Resources Center
Desert Research Institute
Reno, NV 89512
bill@dri.edu

ACAP Objectives:

- Collect field scale data characterizing field hydrology of alternative (i.e., store and release) and conventional covers (clay barriers, geomembranes). *Percolation is today's focus*.

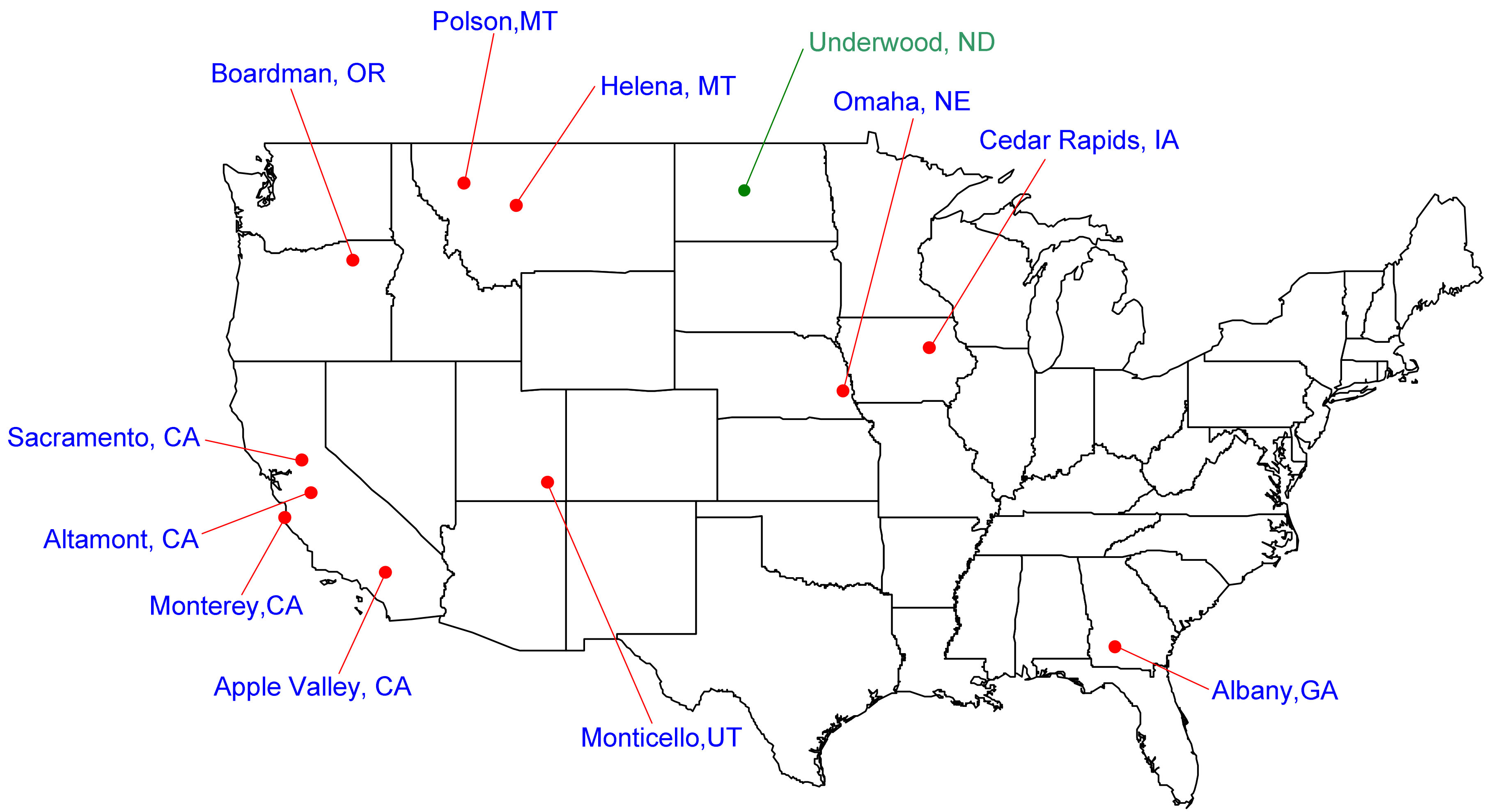
- Evaluate accuracy of hydrologic models used for final cover design

- Develop guidance for alternative cover designers

ACAP Test Sites:

- 27 test covers at 12 sites in 8 states.
- 12 conventional covers (7 composite and 5 clay)
- 15 *alternative covers* (9 monolithic barriers and 6 capillary barriers); also known as *store-&-release covers*. ***Today's focus.***
- 9 sites with side-by-side comparison of conventional and alternative covers

ACAP Field Sites



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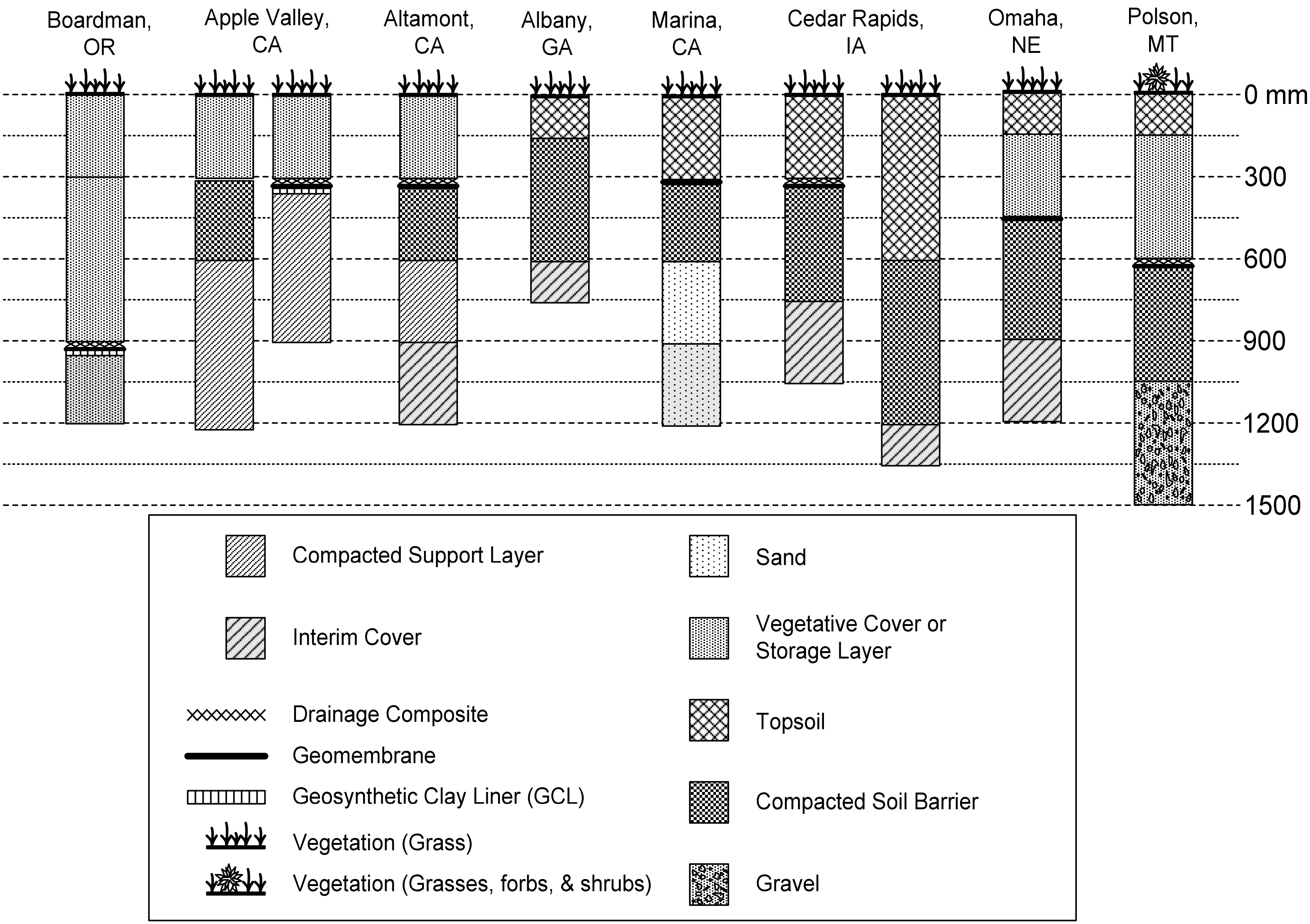
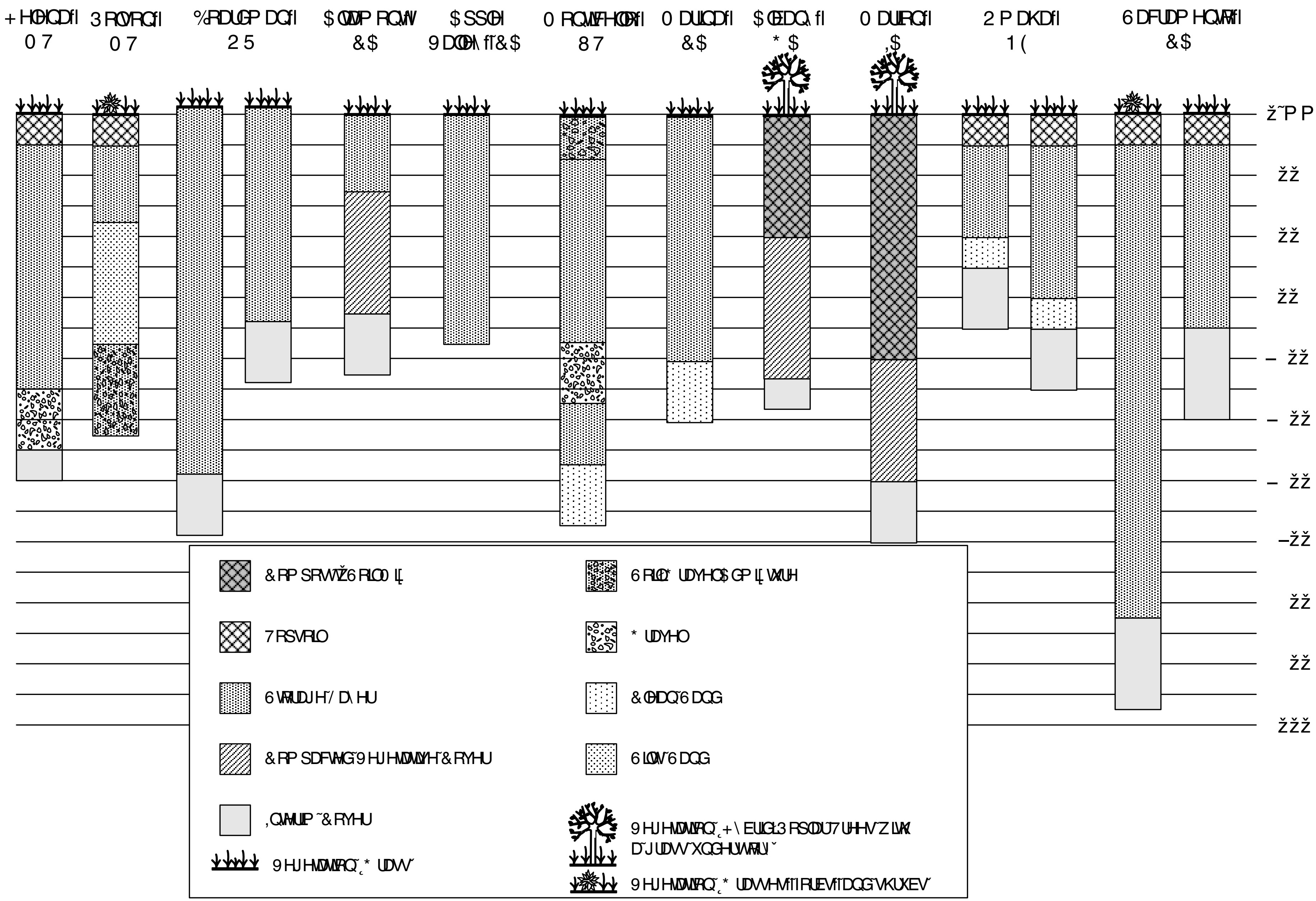
Conventional Covers Evaluated by ACAP

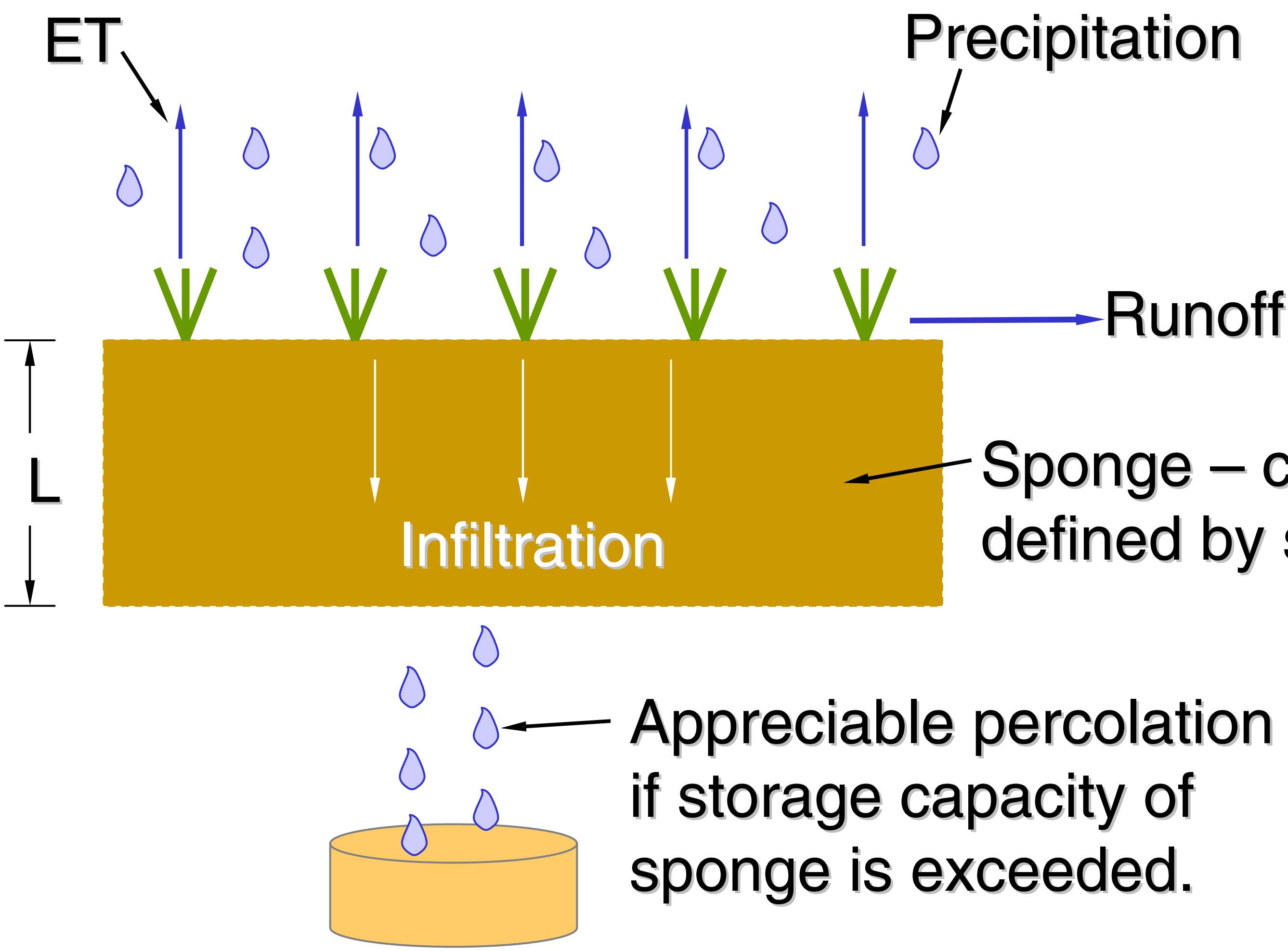


Alternative Final Covers Evaluated by ACAP

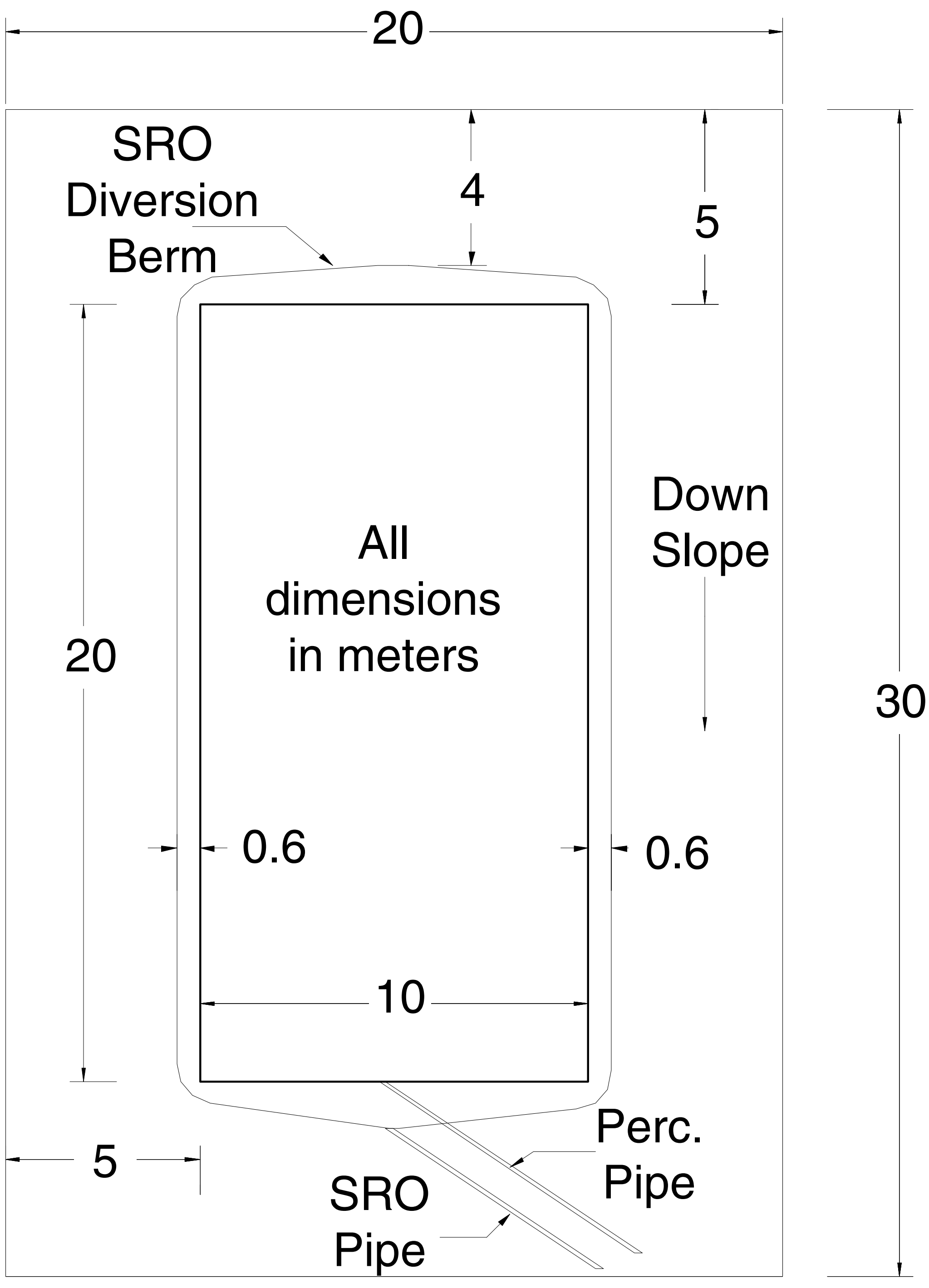


Store-&-Release Water Balance Principle

Balance the storage capacity of finer textured soil with the water removal capabilities of evaporation & transpiration.



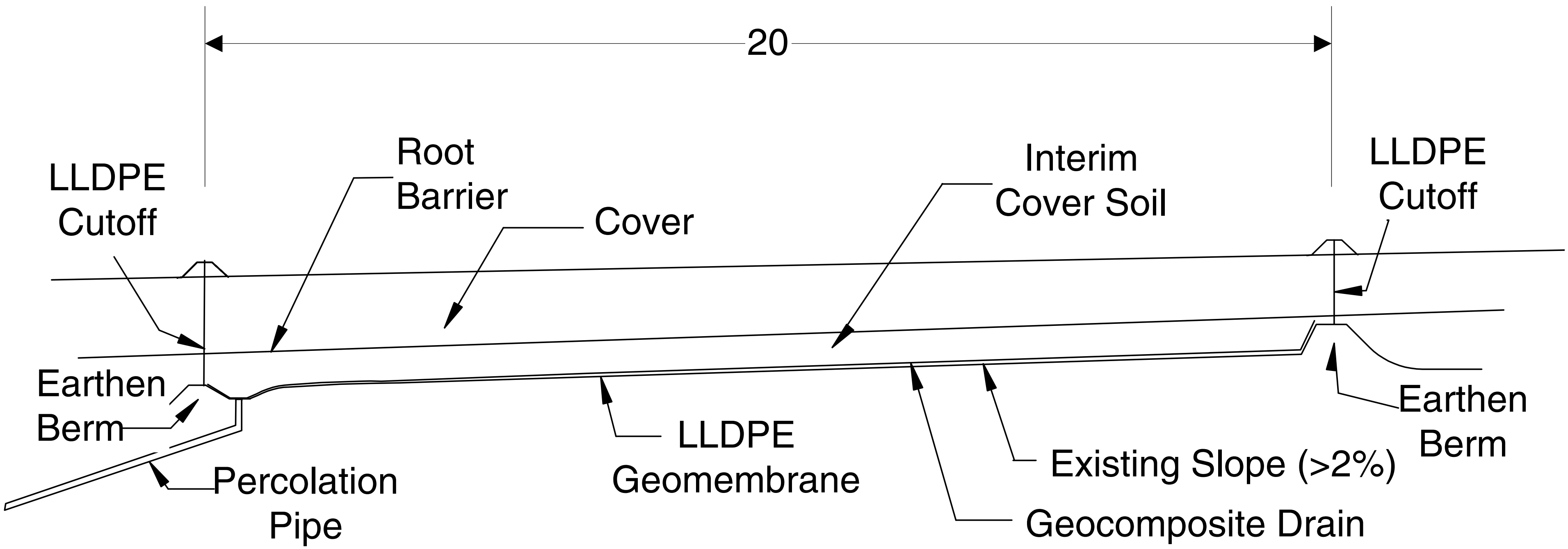
Target percolation rates ~ 1 mm/yr or less.



ACAP Test Section Plan View

Large bathtub filled with cover soil and instruments.

Typical Lysimeter Cross-Section




Test section with geomembrane walls held up with formwork. Interim cover placed and ready for placement of cover profile.
Altamont, CA


Filling and grading. Full-scale equipment used to greatest extent practical.
Altamont, CA

Aerial view of completed test sections at Kiefer Landfill, Sacramento County, California.

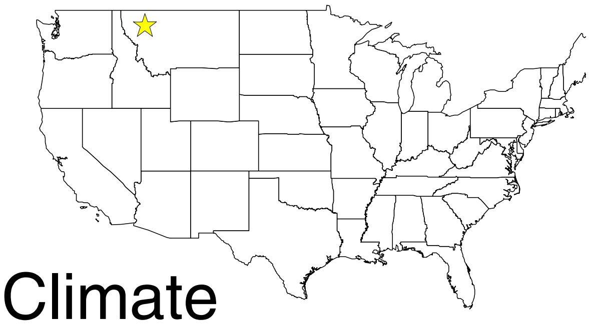
Kiefer Site:
Eight months after construction

Installed weather station & datalogger with cellular telecommuni-cations.

Continuous record of all components of water balance, except ET.

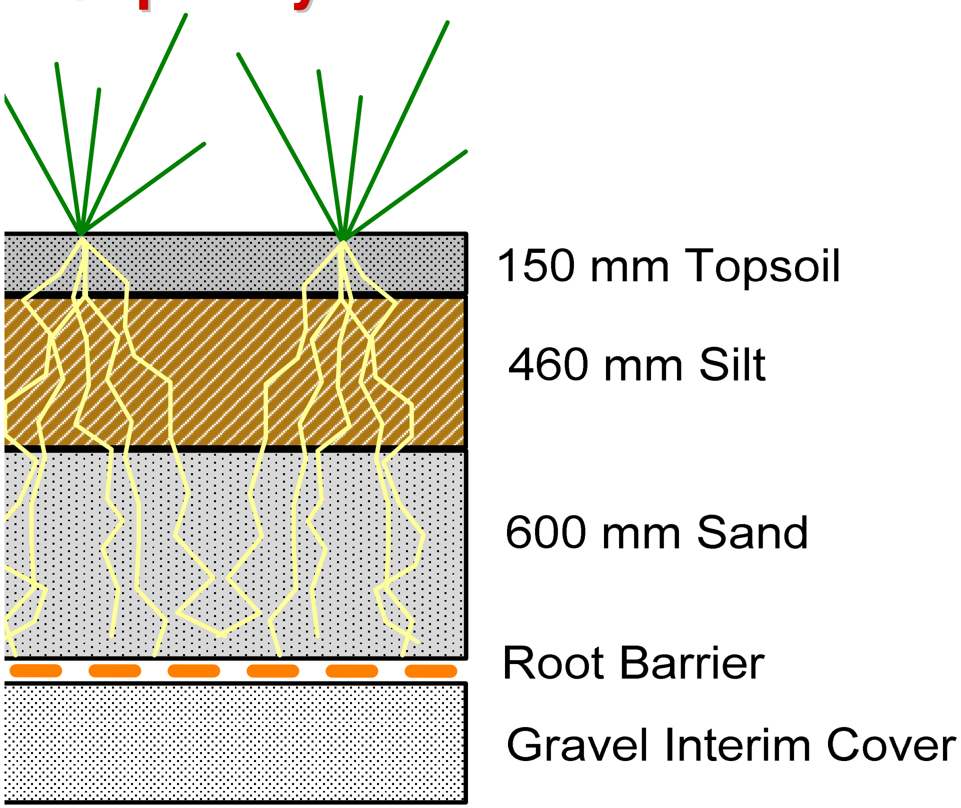
Trimming block sample from cover soil.

Polson, MT

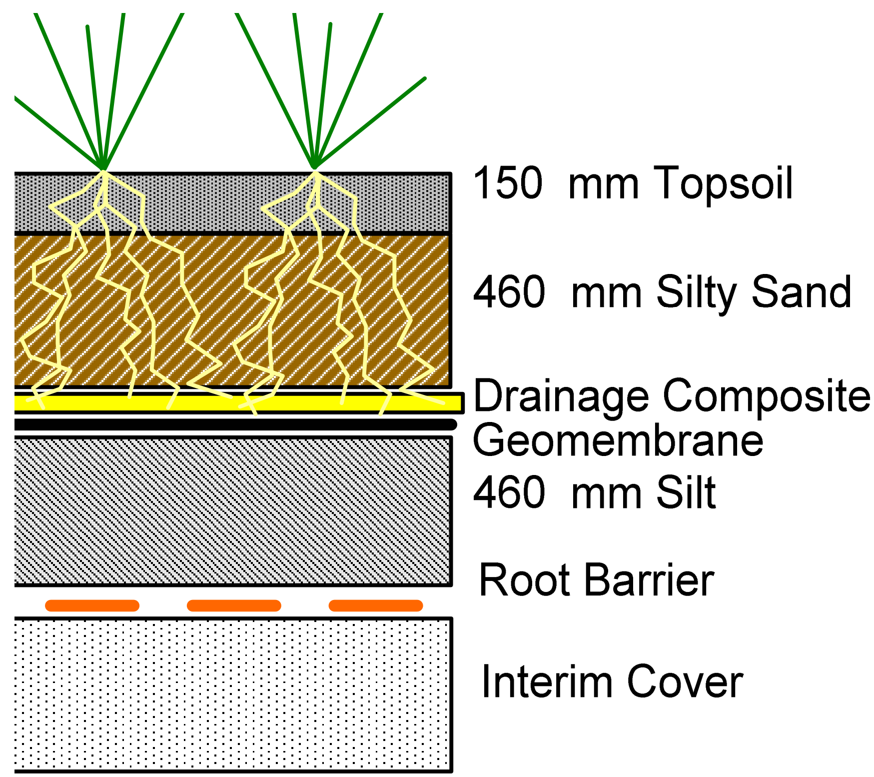


Cool and Seasonal Semi-Humid Climate
Capillary Barrier and Conventional Composite Covers
(precipitation ~ 380 mm/yr)

Capillary Barrier

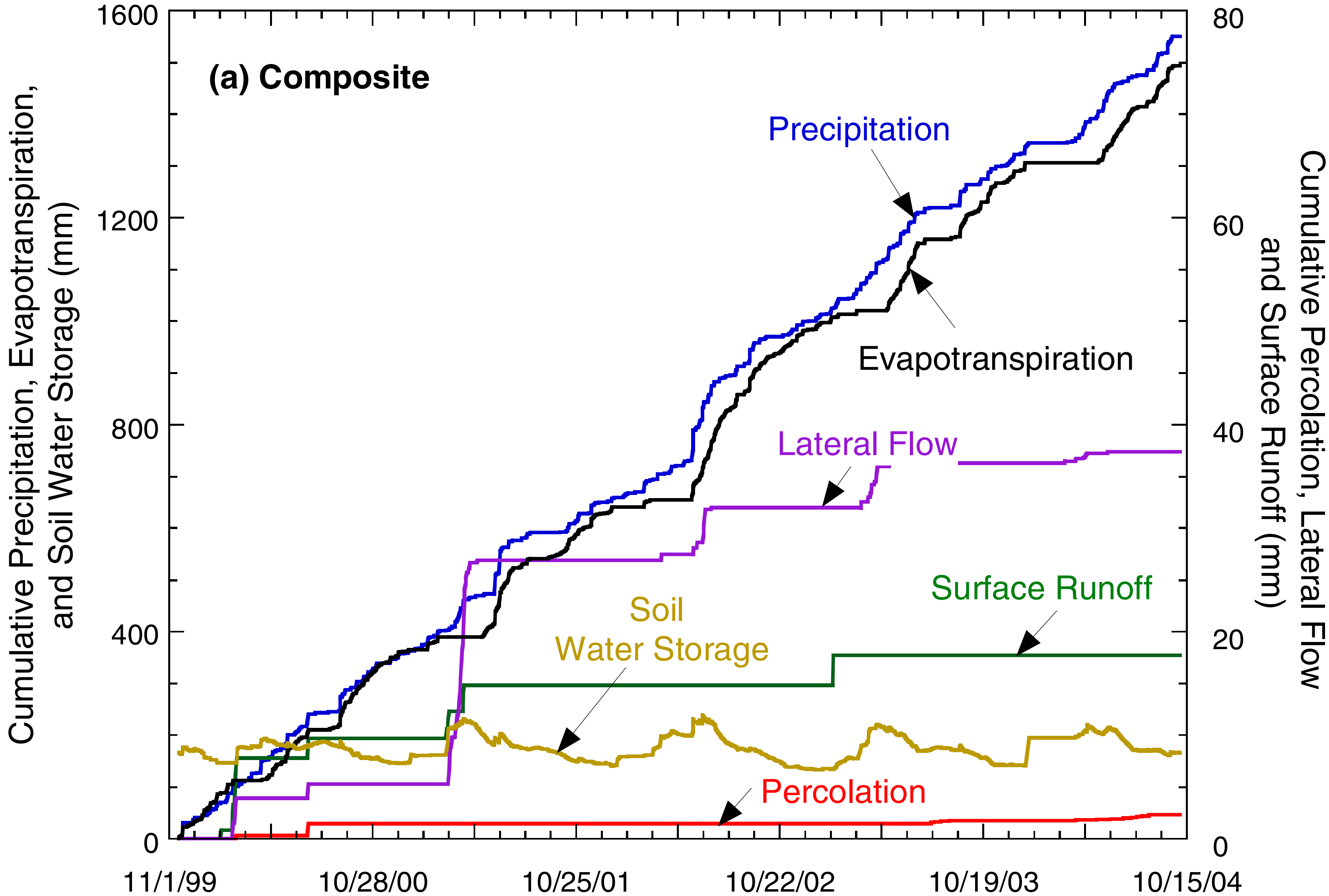


Conventional Composite



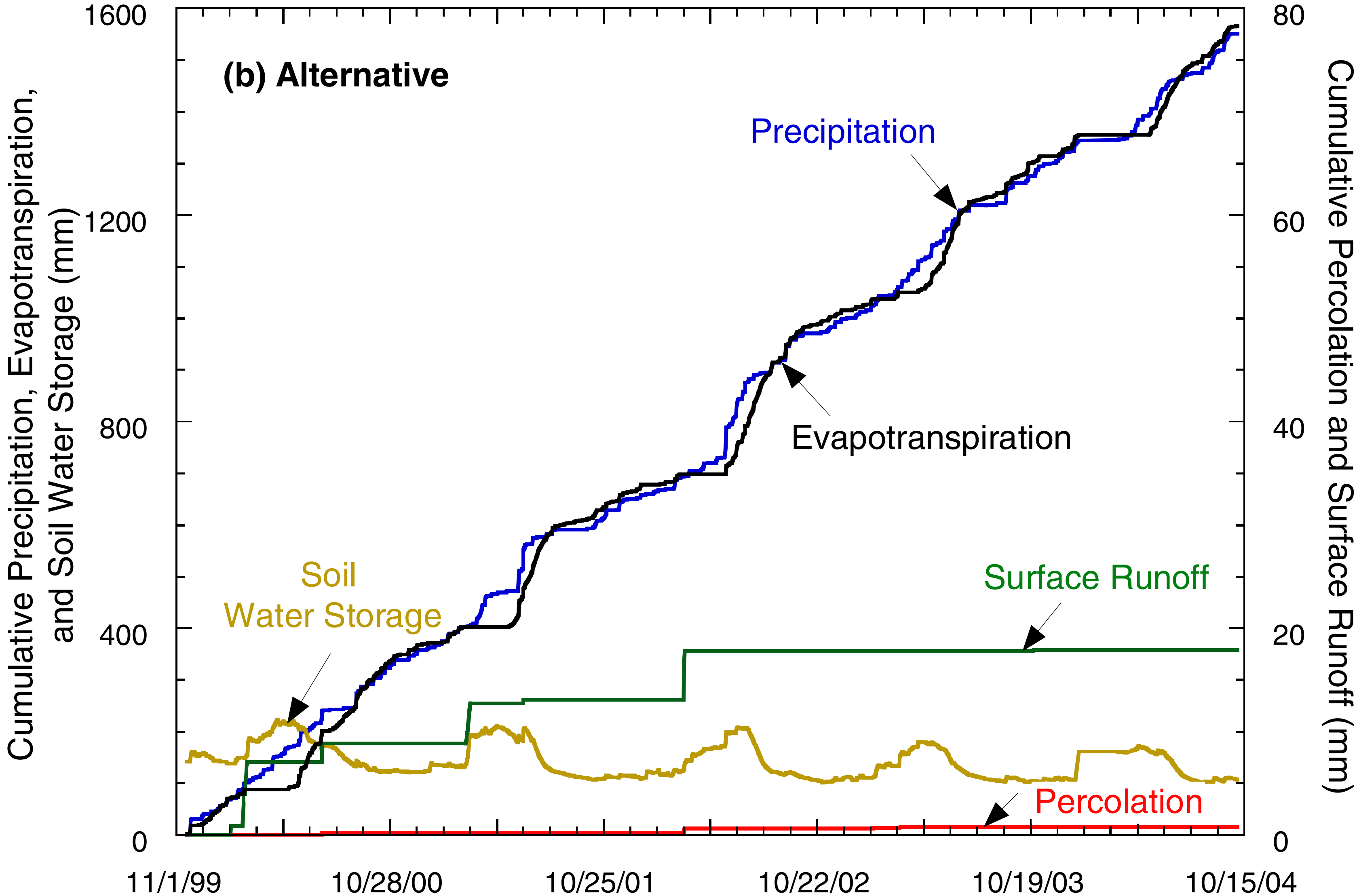
Staking root barrier.

Composite Barrier: Polson, MT

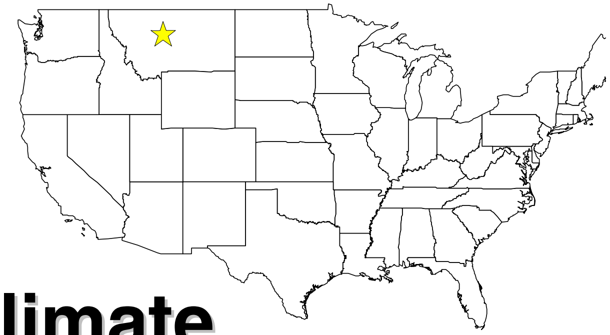


2.3 mm percolation over 5 yr

Capillary Barrier: Polson, MT



0.8 mm percolation over 5 yr! *Less than* composite.

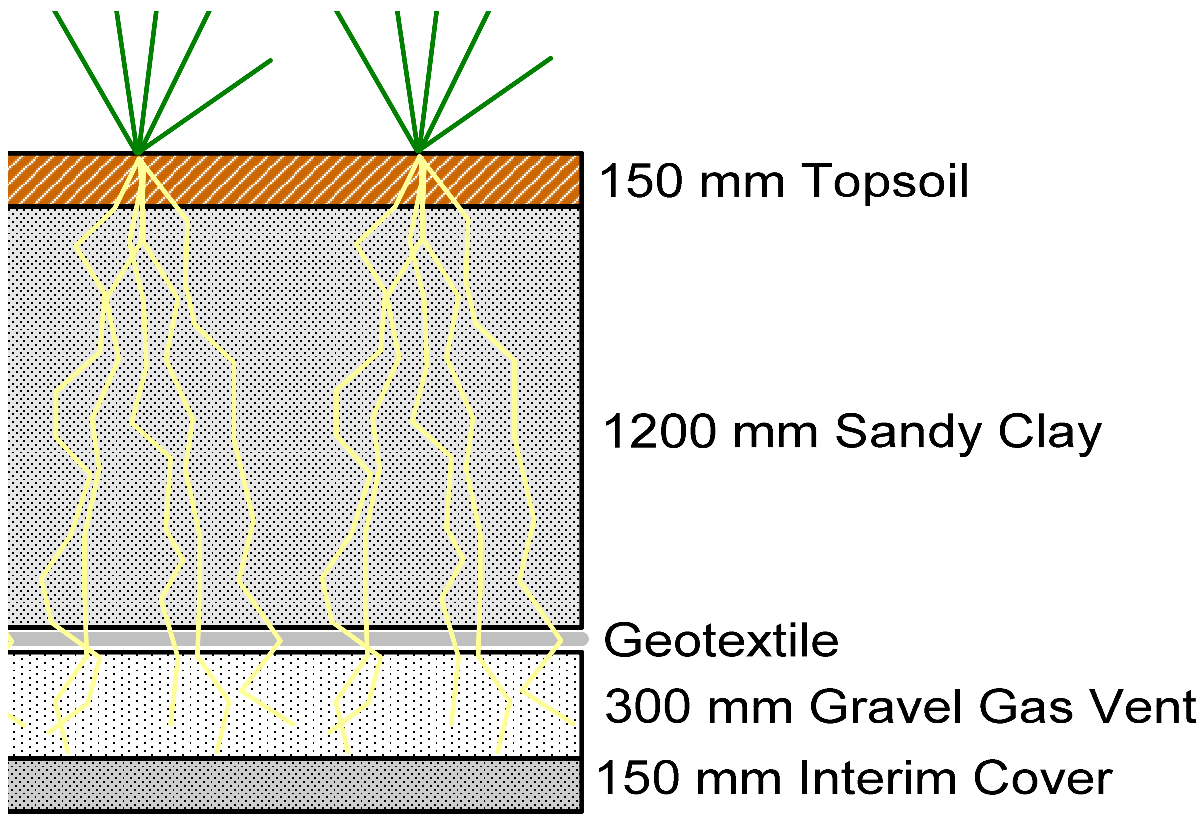


Helena, MT

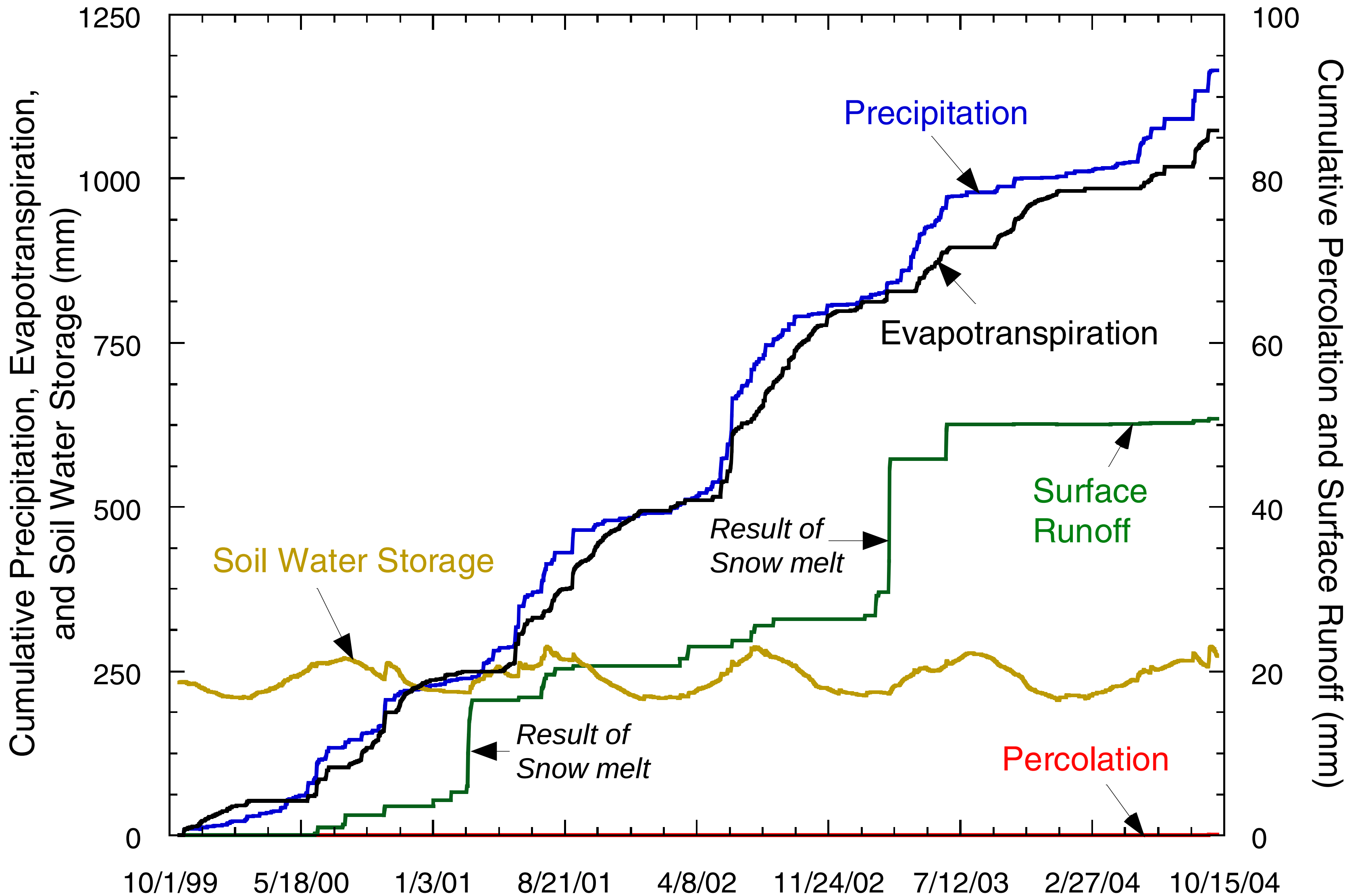
Cool and Seasonal Semi-Arid Climate

Monolithic Cover

(precipitation ~ 290 mm/yr, most in summer)



Capillary Barrier: Helena, MT

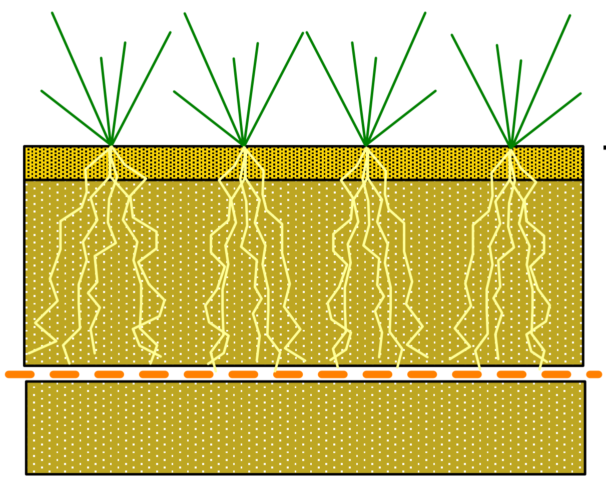


0.1 mm percolation over 5 yr!

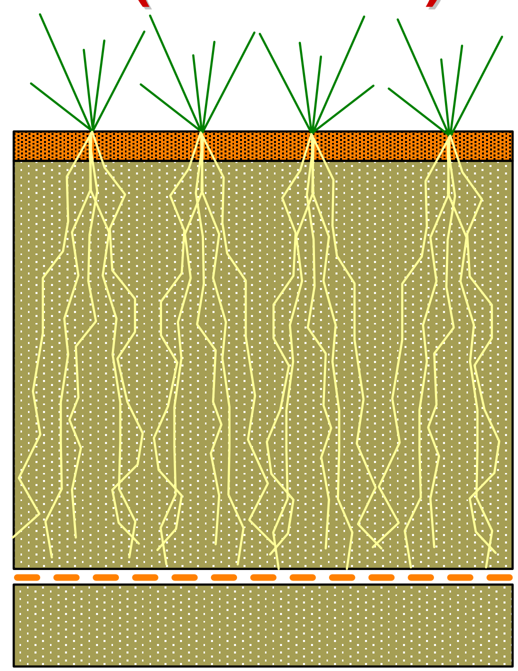
Sacramento, CA

Warm Semi-Arid Climate, Monolithic Covers (precipitation ~ 430 mm/yr)

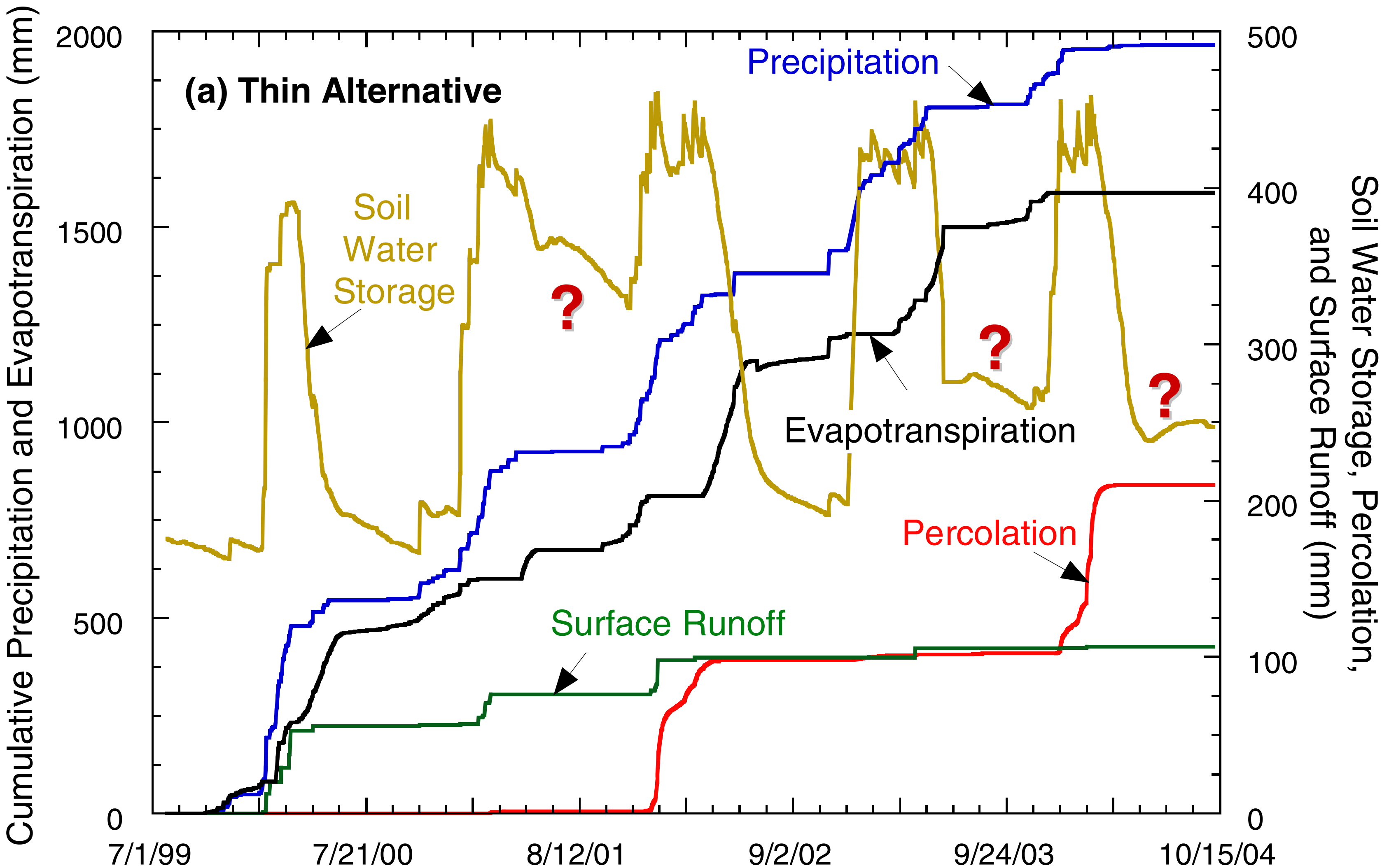
Thin (1080 mm) Cover



Thick (2450 mm) Cover

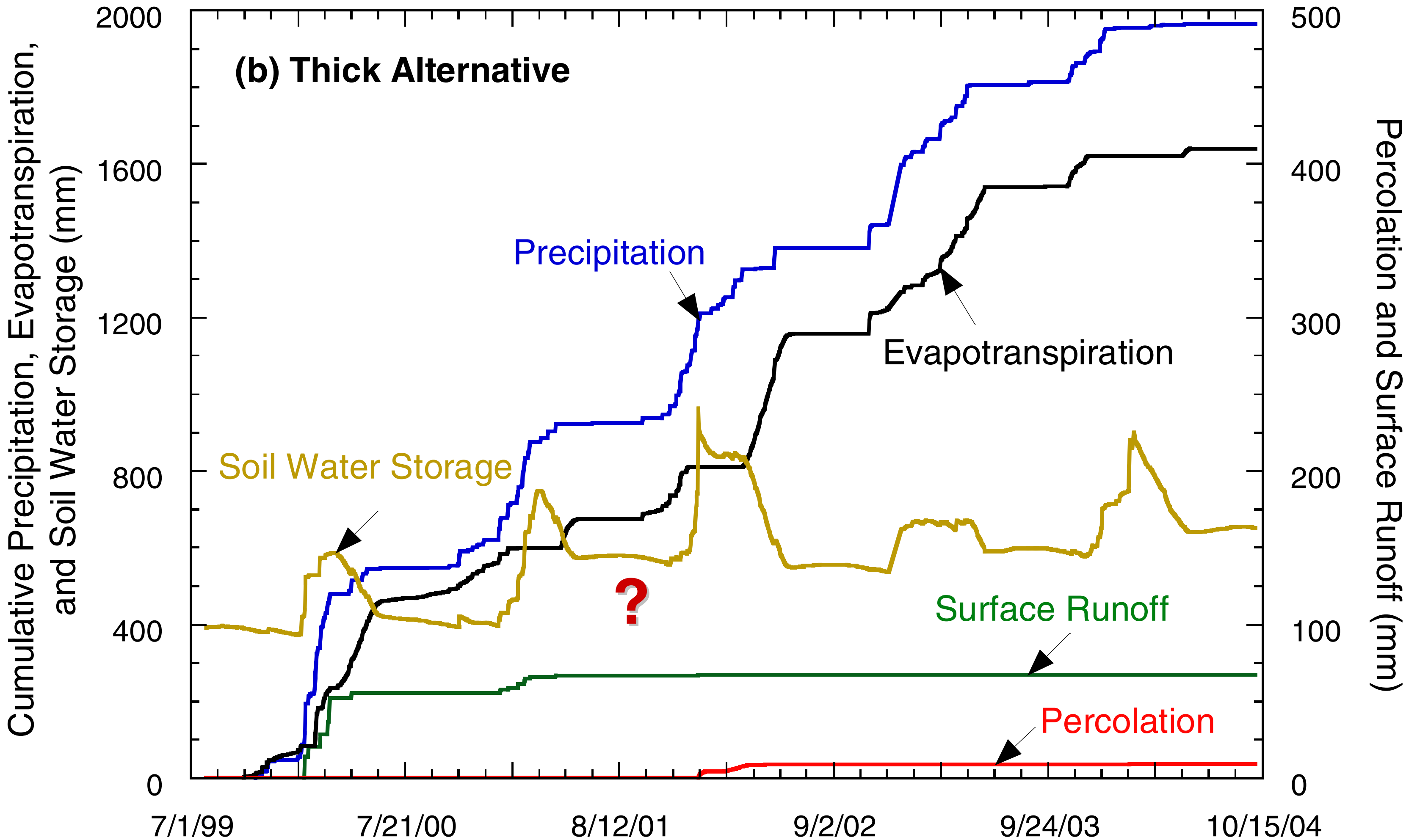


Thin Monolithic Cover: Sacramento



Vegetation does not always empty the reservoir!
~ 100 mm percolation in subsequent years

Thick Monolithic Cover: Sacramento



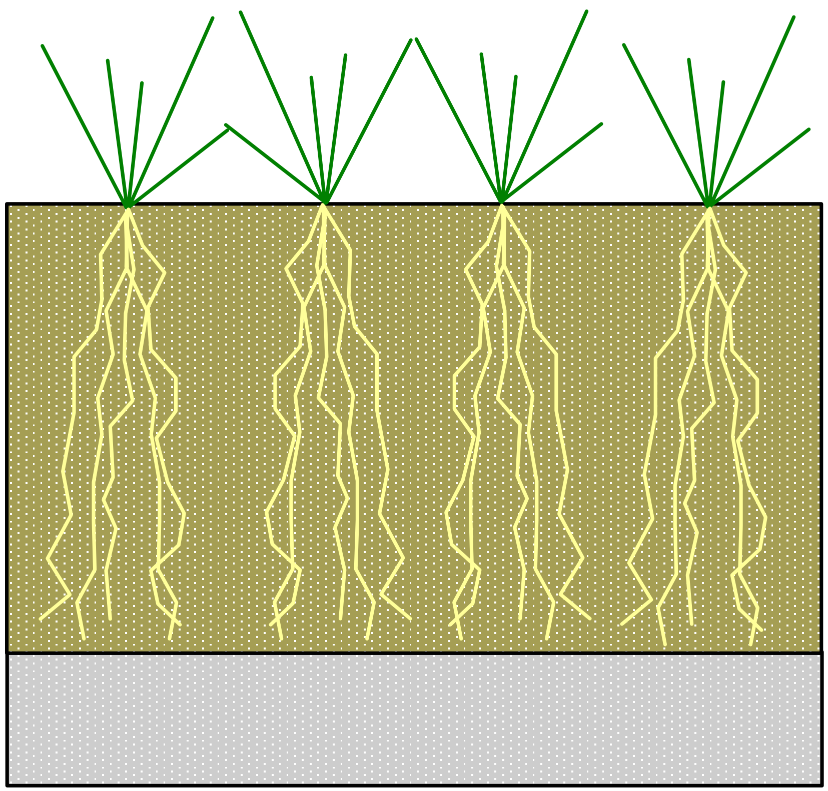
9 mm percolation in 5 yr, all in 2001.

Thicker cover compensates for vegetation problem

Need to store ≈ *400 mm* infiltration!

Altamont, CA

Hot Semi-Arid Climate, Monolithic Cover
(precipitation ~ 358 mm/yr)



* UDVVHV

–ž ž˜P P
&UXVKHG˜&OD\˜6WRQH
6WRUDJH˜/D\HU

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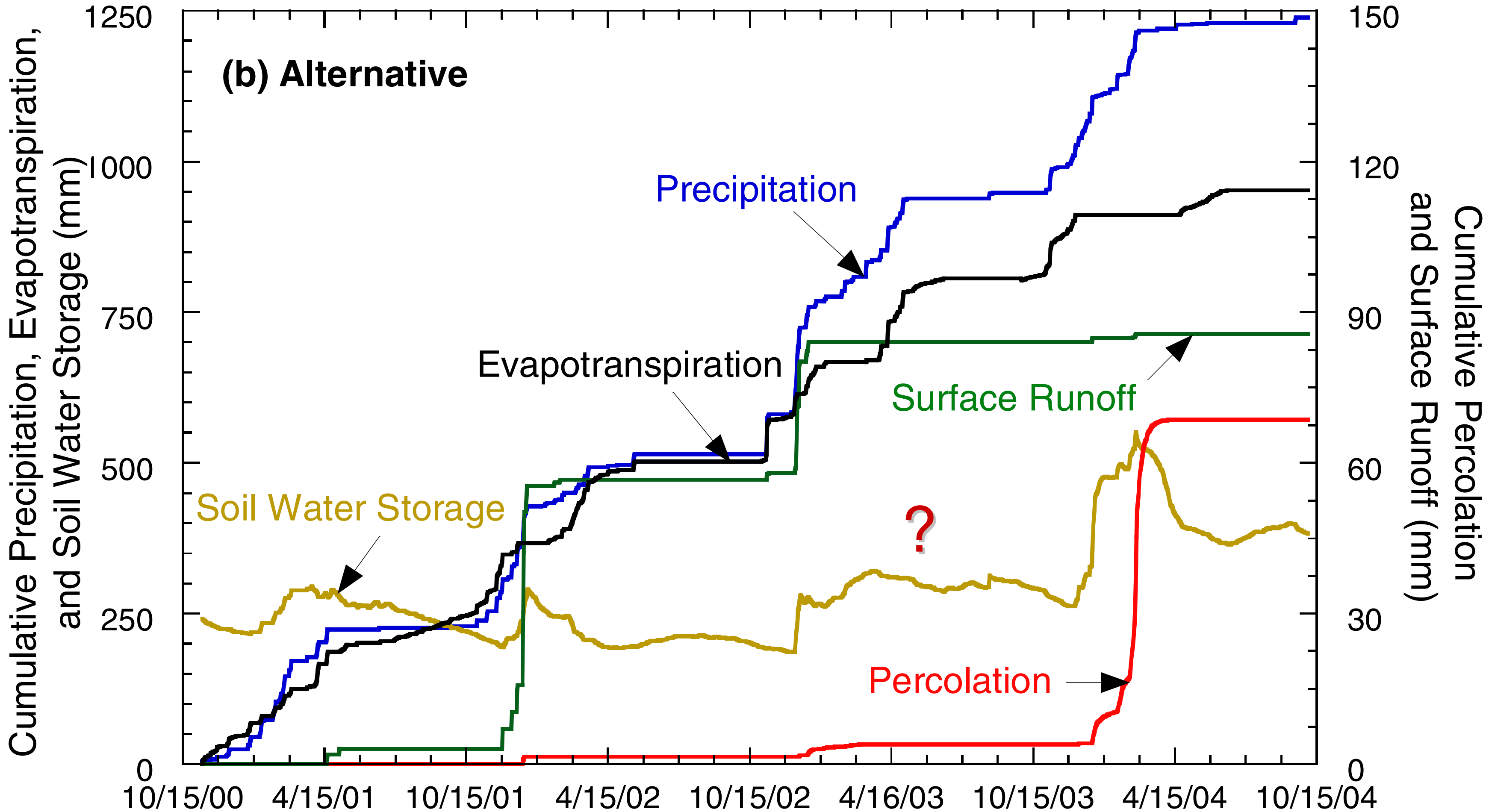
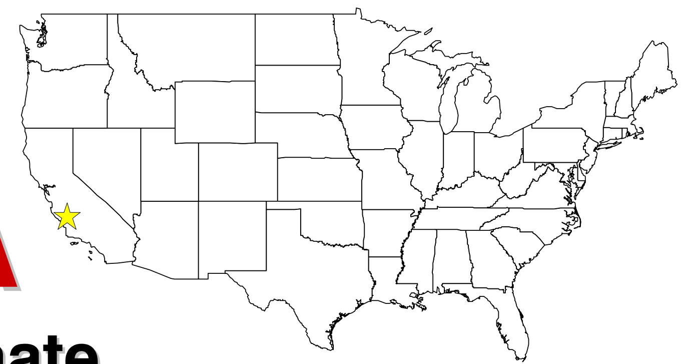
,QWHULP˜&RYHU

Monolithic Cover: Altamont, CA

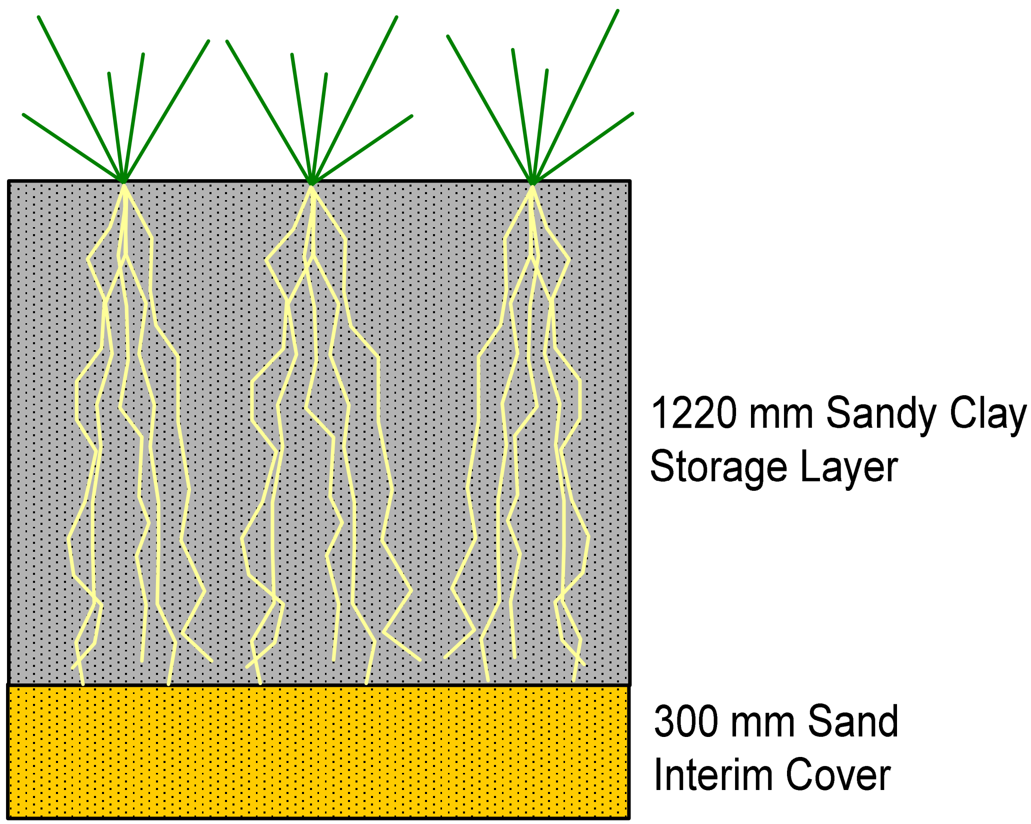


Vegetation does not empty the reservoir!
Followed by wet winter results in 65 mm percolation

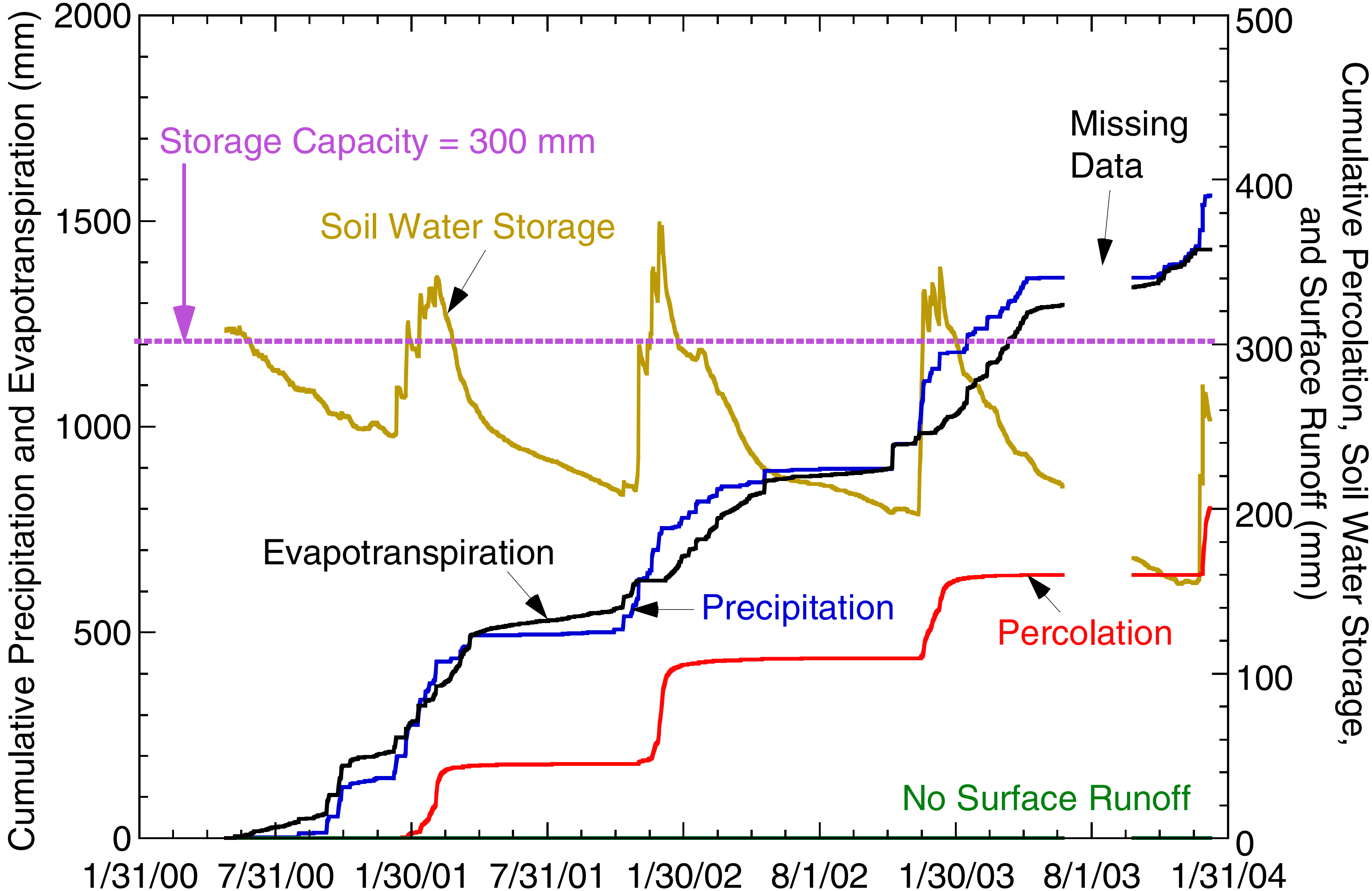


Marina, CA

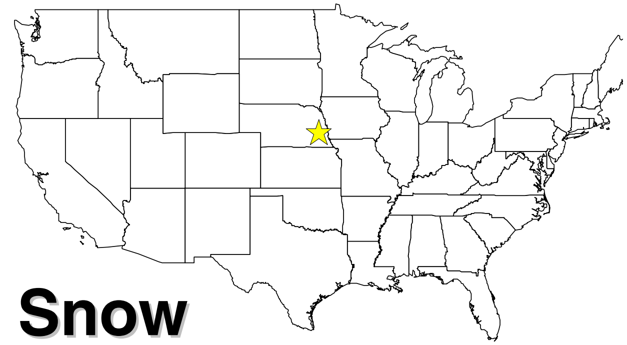
Costal Semi-Arid Climate
Conventional Composite Cover
(precipitation ~ 466 mm/yr)



Water Balance of Capillary Barrier: Marina, CA



Percolation occurs every year when storage capacity is exceeded.

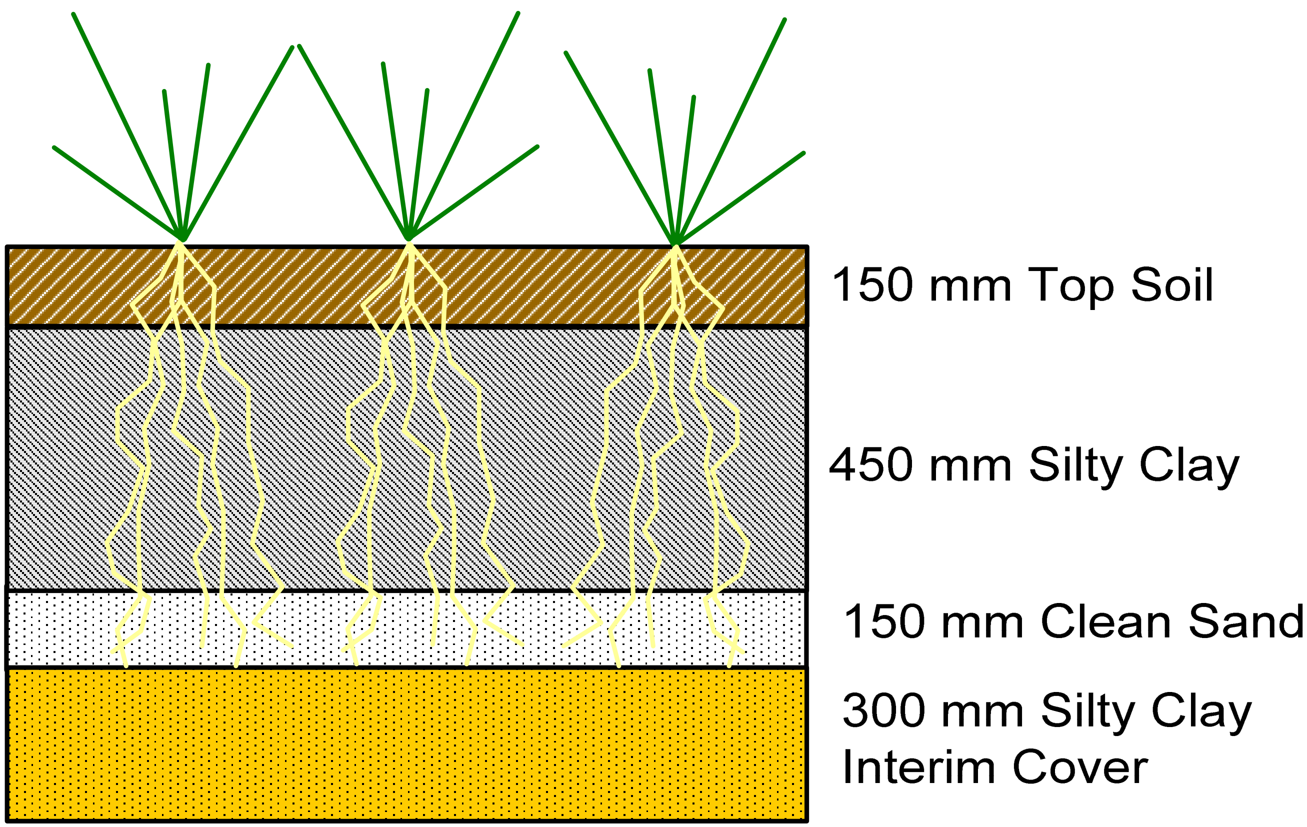


Omaha, NE

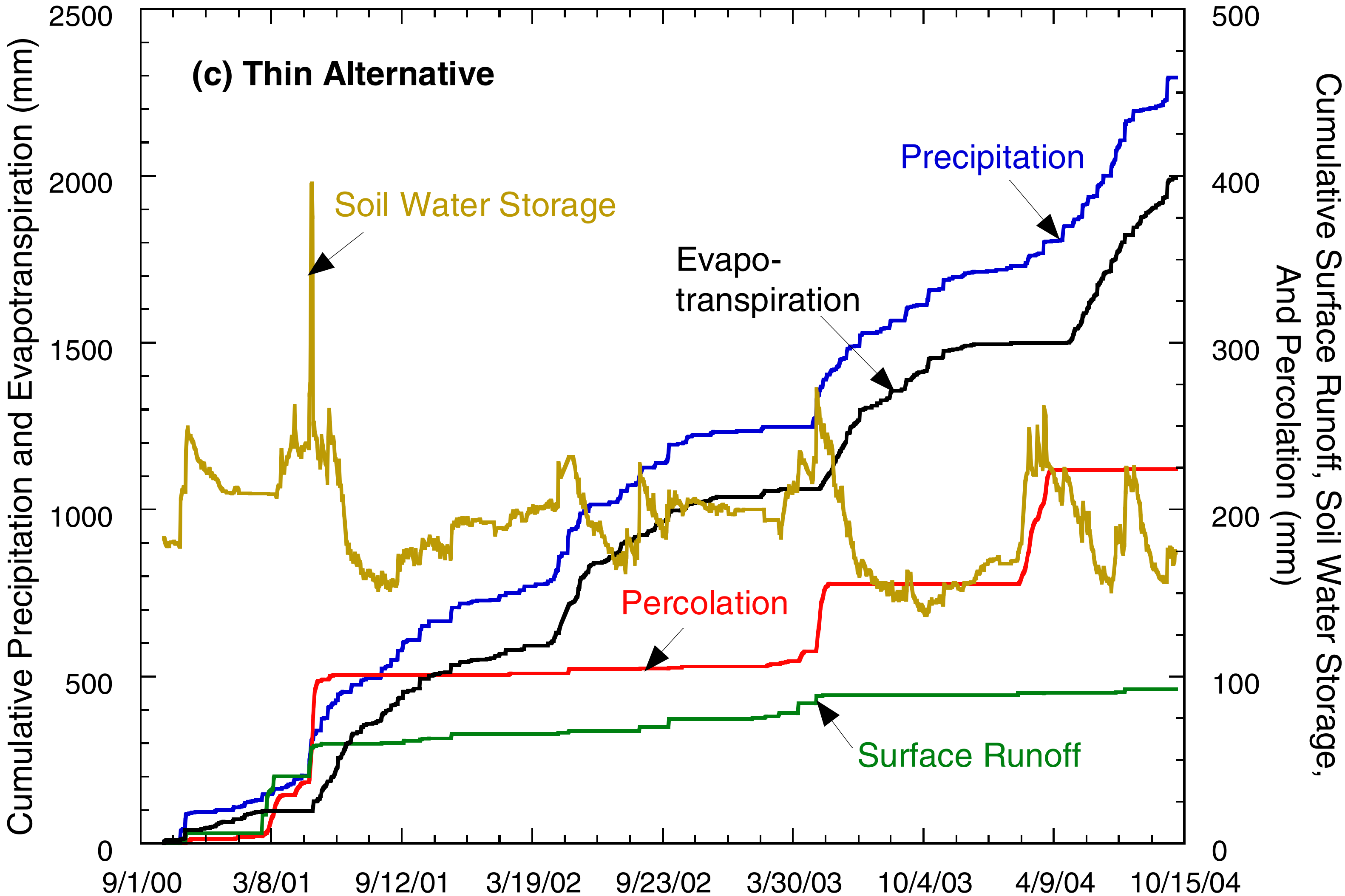
Seasonal Humid Climate with Snow

Capillary Barrier

(precipitation ~ 760 mm/yr)

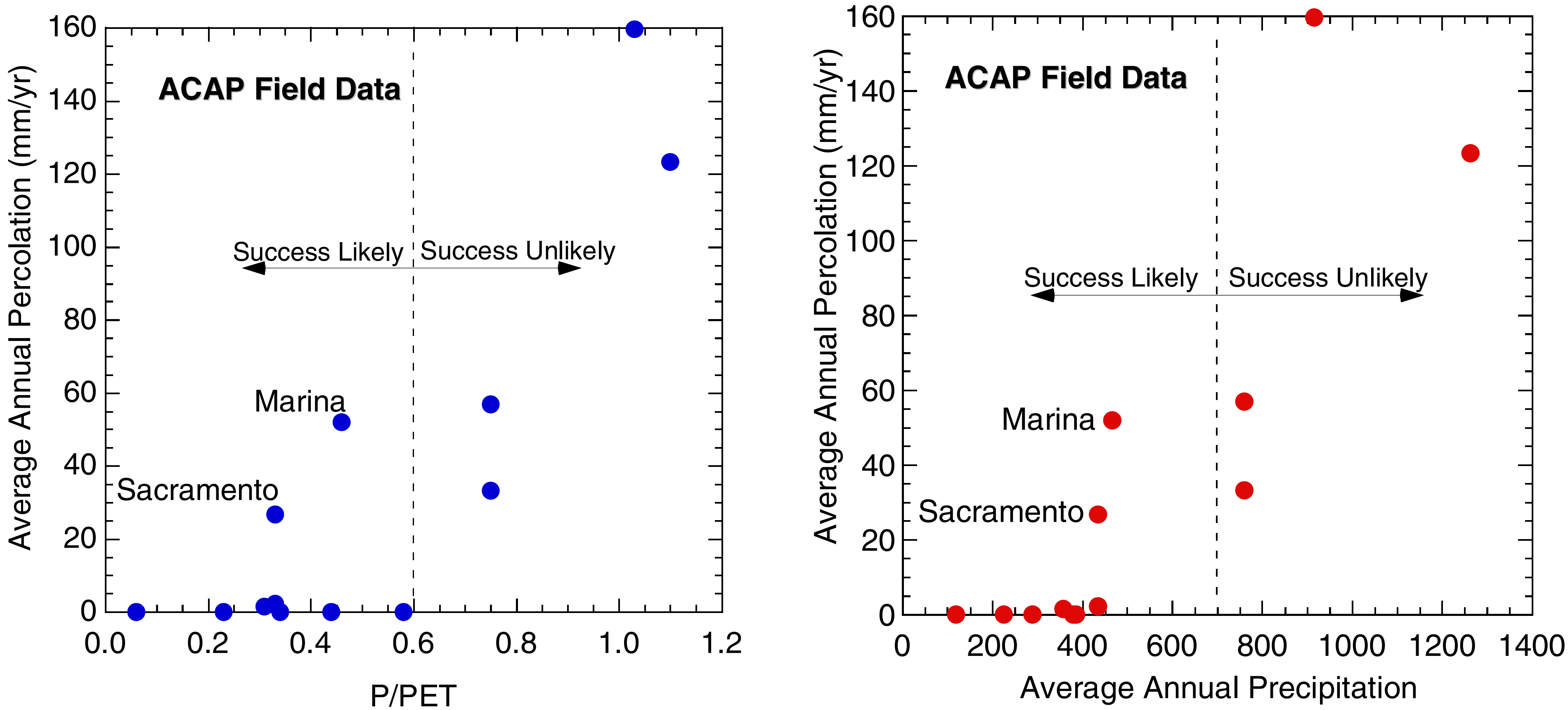


Capillary Barrier: Omaha, Nebraska



Too much water to manage!
50-100 mm/yr percolation

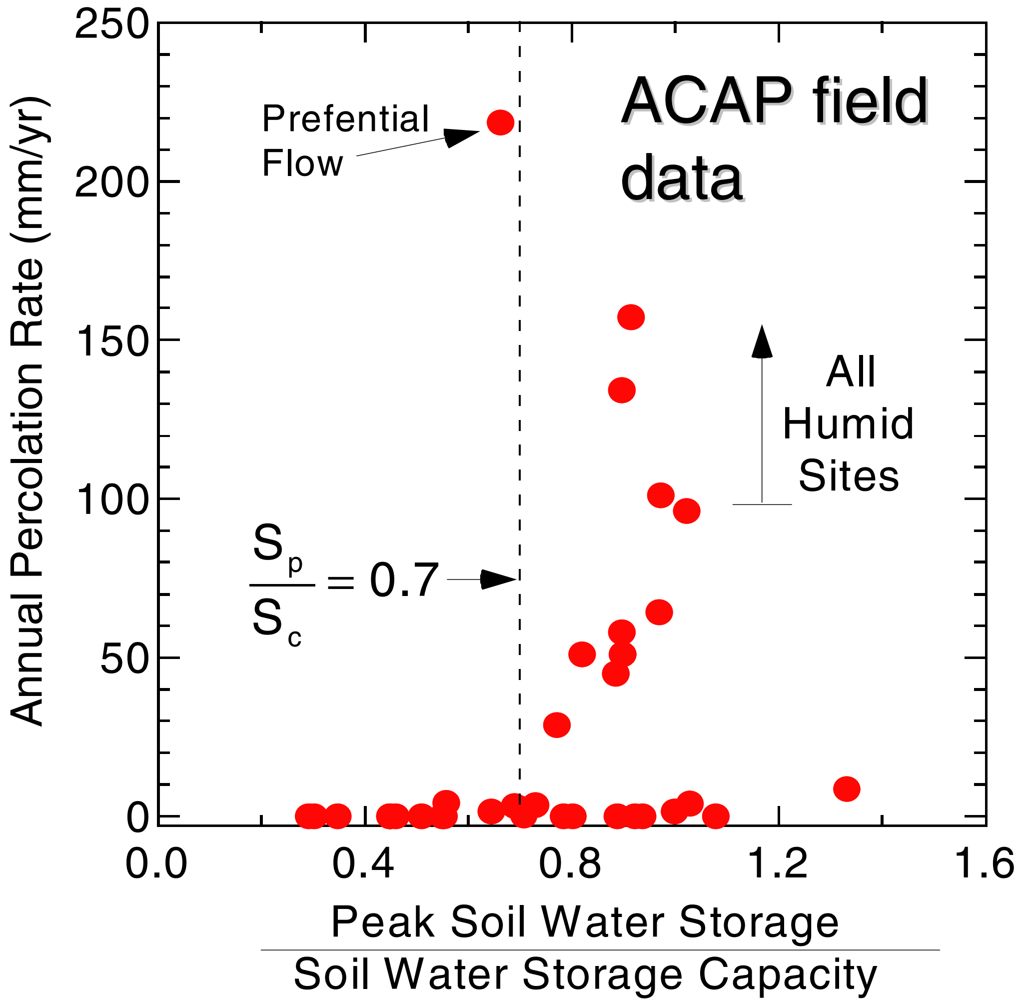
Summary of Percolation Data



Most Suitable Sites: P/PET < 0.6, P < 600 mm/yr

Contingent on adequate storage capacity, vegetation effective annually

Lab-to-Field Scaling



Storage capacity (S_c) of ACAP covers computed assuming $S_c = L\theta_{fc}$, where L = cover thickness.

Conceptually, percolation should be negligible if peak soil water storage < storage capacity.

Data suggests that percolation can be appreciable at 70% of storage capacity based on laboratory-measured water retention properties.

Practical Lessons Leaned

- Percolation rates for alternative covers in semi-arid and sub-humid climates can be very low (< 1 mm/yr), provided:
  - adequate storage capacity
  - vegetation effectively removes stored water each year

- Unpredictable response of vegetation/transpiration confounds predictions. Need to understand how phenology of plants responds to meteorological conditions and geotechnical conditions. More research needed to be reliable long-term conditions.

- Low percolation rates (1 mm/yr or less) cannot be achieved with alternative covers at all sites. Suitable conditions:
  - Precipitation < 600 m/yr
  - P/PET < 0.6

Data Summary

Field Water Balance of Landfill Final Covers

William H. Albright,* Craig H. Benson, Glendon W. Gee, Arthur C. Roesler, Tarek Abichou, Preecha Apiwantragoon, Bradley F. Lyles, and Steven A. Rock

ABSTRACT

Landfill covers are critical to waste containment, yet field performance of specific cover designs has not been well documented and seldom been compared in side-by-side testing. A study was conducted to assess the ability of landfill final covers to control percolation into underlying waste. Conventional covers employing resistive barriers as well as alternative covers relying on water-storage principles were monitored in large (10 × 20 m), instrumented drainage lysimeters over a range of climates at 11 field sites in the United States. Surface runoff was a small fraction of the water balance (0–10%, 4% on average) and was nearly insensitive to the cover slope, cover design, or climate. Lateral drainage from internal drainage layers was also a small fraction of the water balance (0–5.0%, 2.0% on average). Average percolation rates for the conventional covers with composite barriers (geomembrane over fine soil) typically were less than 12 mm/yr (1.4% of precipitation) at humid locations and 1.5 mm/yr (0.4% of precipitation) at arid, semiarid, and subhumid locations. Average percolation rates for conventional covers with soil barriers in humid climates were between 52 and 195 mm/yr (6–17% of precipitation), probably due to preferential flow through defects in the soil barrier. Average percolation rates for alternative covers ranged between 33 and 160 mm/yr (6 and 18% of precipitation) in humid climates and generally less than 2.2 mm/yr (0.4% of precipitation) in arid, semiarid, and subhumid climates. One-half (five) of the alternative covers in arid, semiarid, and subhumid climates transmitted less than 0.1 mm of percolation, but two transmitted much more percolation (26.8 and

of a fine-grained soil having low saturated hydraulic conductivity or a "composite barrier" consisting of a geomembrane (plastic sheet, 1–2 mm thick) underlain by fine-grained soil (USEPA, 1992). The layer of fine-grained soil (typically 450 mm thick) is compacted to achieve sufficiently low saturated hydraulic conductivity ($<10^{-5}$ or $<10^{-7}$ cm/s, depending on the properties of the base liner in the landfill). Alternatively, a geosynthetic clay liner (thin, factory-manufactured material consisting of 3.5 to 6.0 kg/m^2 of bentonite clay sandwiched between two geotextiles) may be substituted for the compacted fine-grained soil. In most cases, conventional covers are required to meet material specifications (e.g., a maximum saturated hydraulic conductivity for the barrier layer), but are not subjected to a performance criterion such as a maximum percolation rate.

The RCRA also includes a provision that permits alternative final covers that are "equivalent" to the recommended conventional cover in terms of percolation rate (i.e., the percolation rate from the alternative cover must be less than or equal to that from the conventional cover) [U.S. Code of Federal Regulations, Section 258.60(b)(1); United States Government, 2002]. Because of the relatively high cost of conventional covers and questions

Albright, W., Benson, C., Gee, G., Roesler, A., Abichou, T., Apiwantragoon, P., Lyles, B., and Rock, S. (2004), Field Water Balance of Landfill Final Covers. *J. of Environmental Quality*, 33(6), 2317-2332.

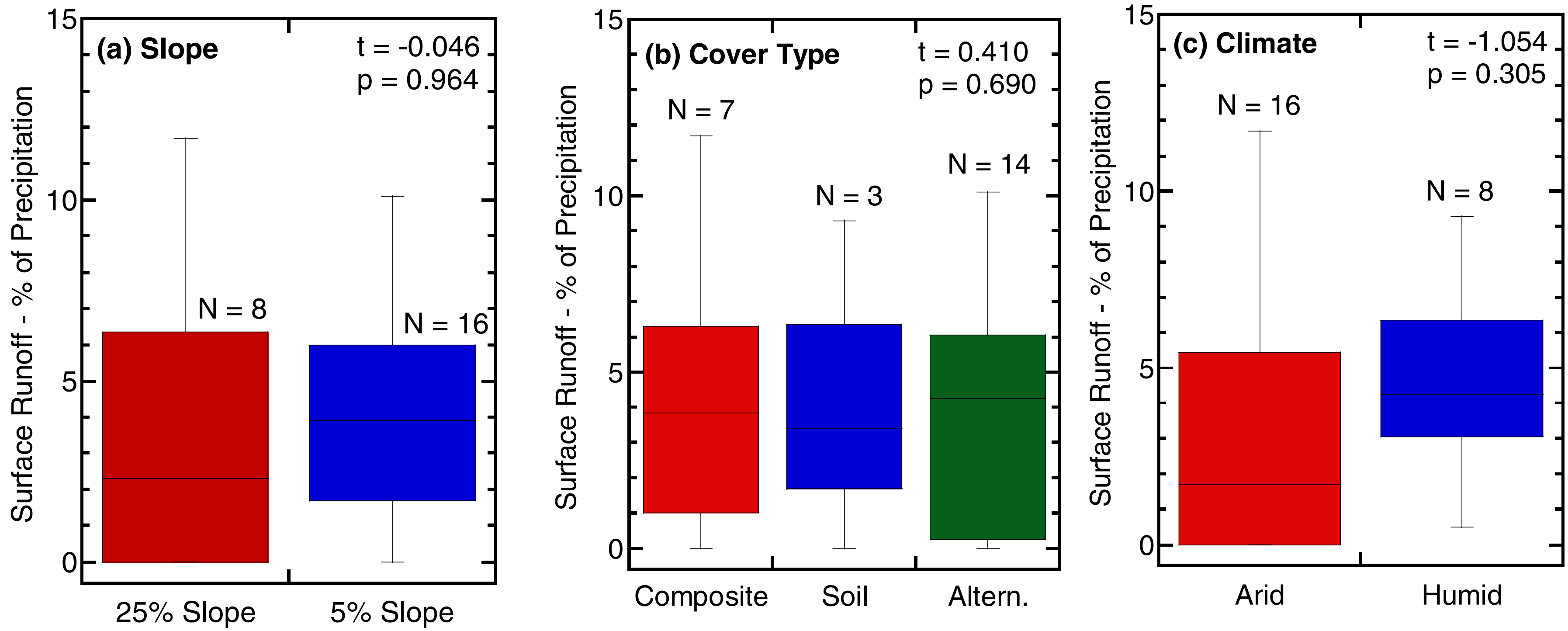
Sponsors

- US EPA, US DOE, USMC
- Waste Management, Inc., Waste Connections Inc.
- Monterey Solid Waste Management District, Bluestem Solid Waste Agency
- Lake County, MT, Lewis and Clark County, MT

More Information

- www.acap.dri.edu
- www.uwgeotech.org

Surface Runoff



Surface runoff is a small component of the annual water balance, 5-10%.

Slope, cover type, and climate have *no statistically significant effect* on runoff as a fraction of water balance.