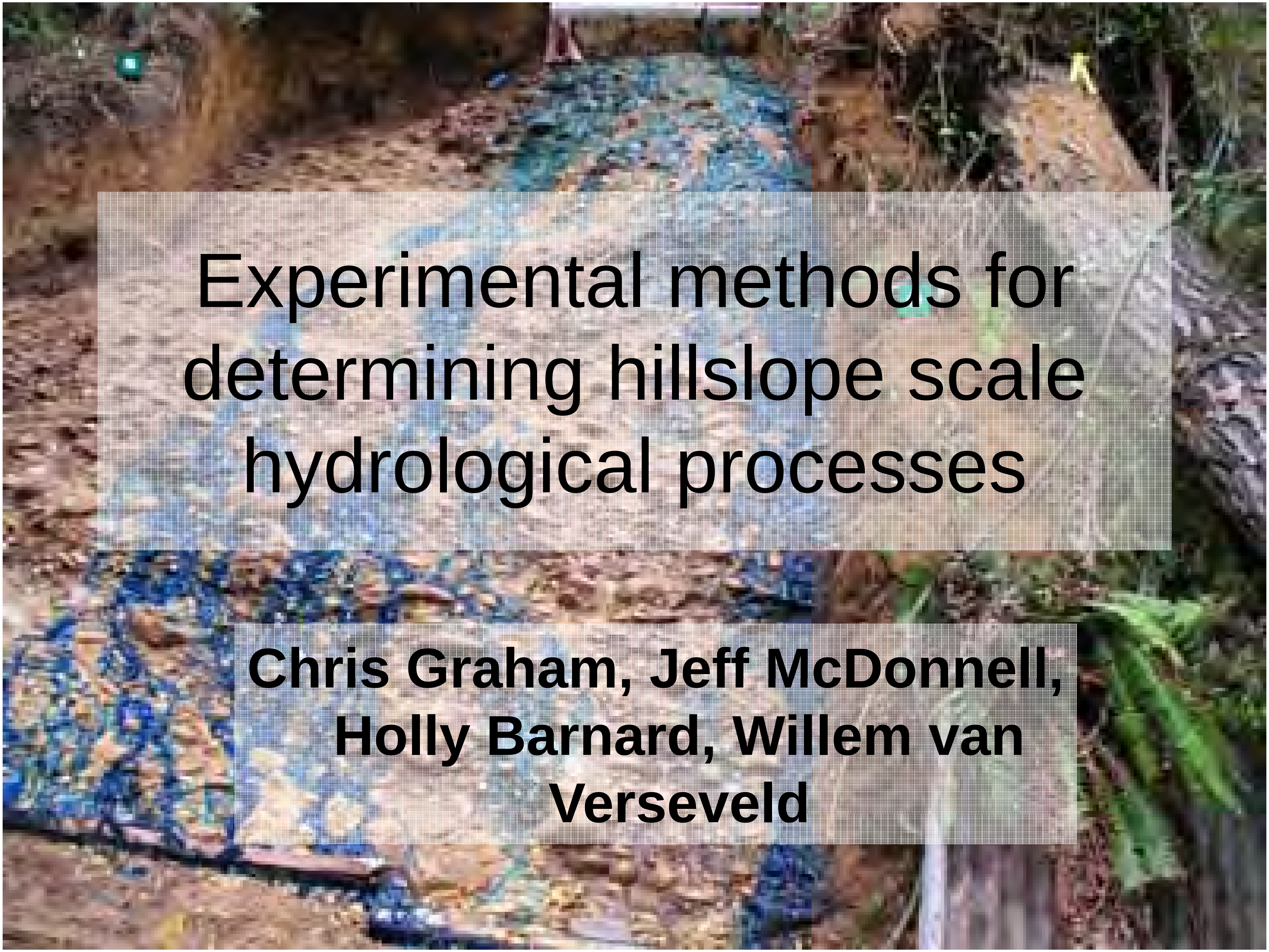


Experimental methods for determining hillslope scale hydrological processes

Chris Graham, Jeff McDonnell, Holly Barnard, Willem van Verseveld

Hillslopes – the fundamental landscape unit

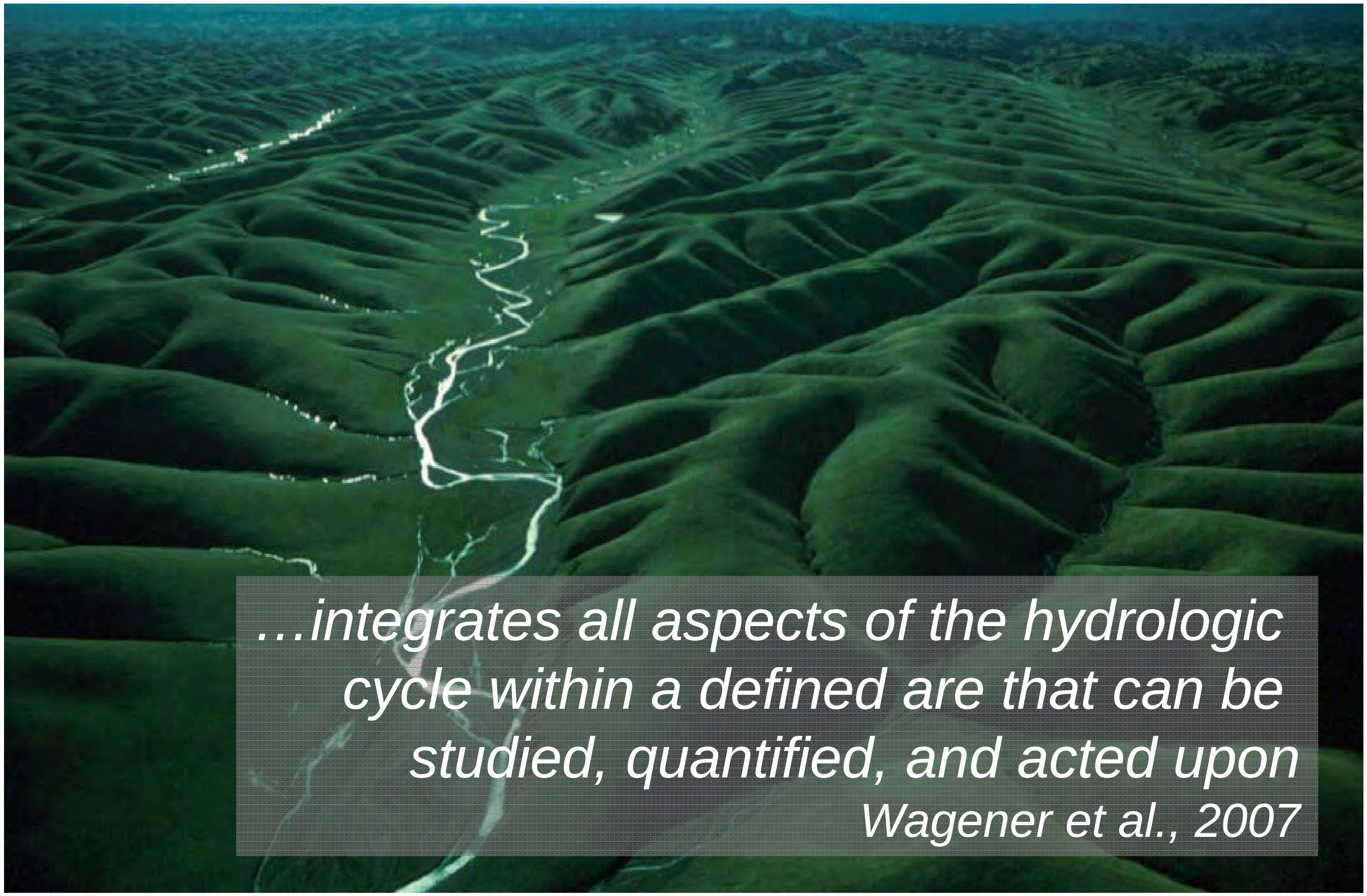


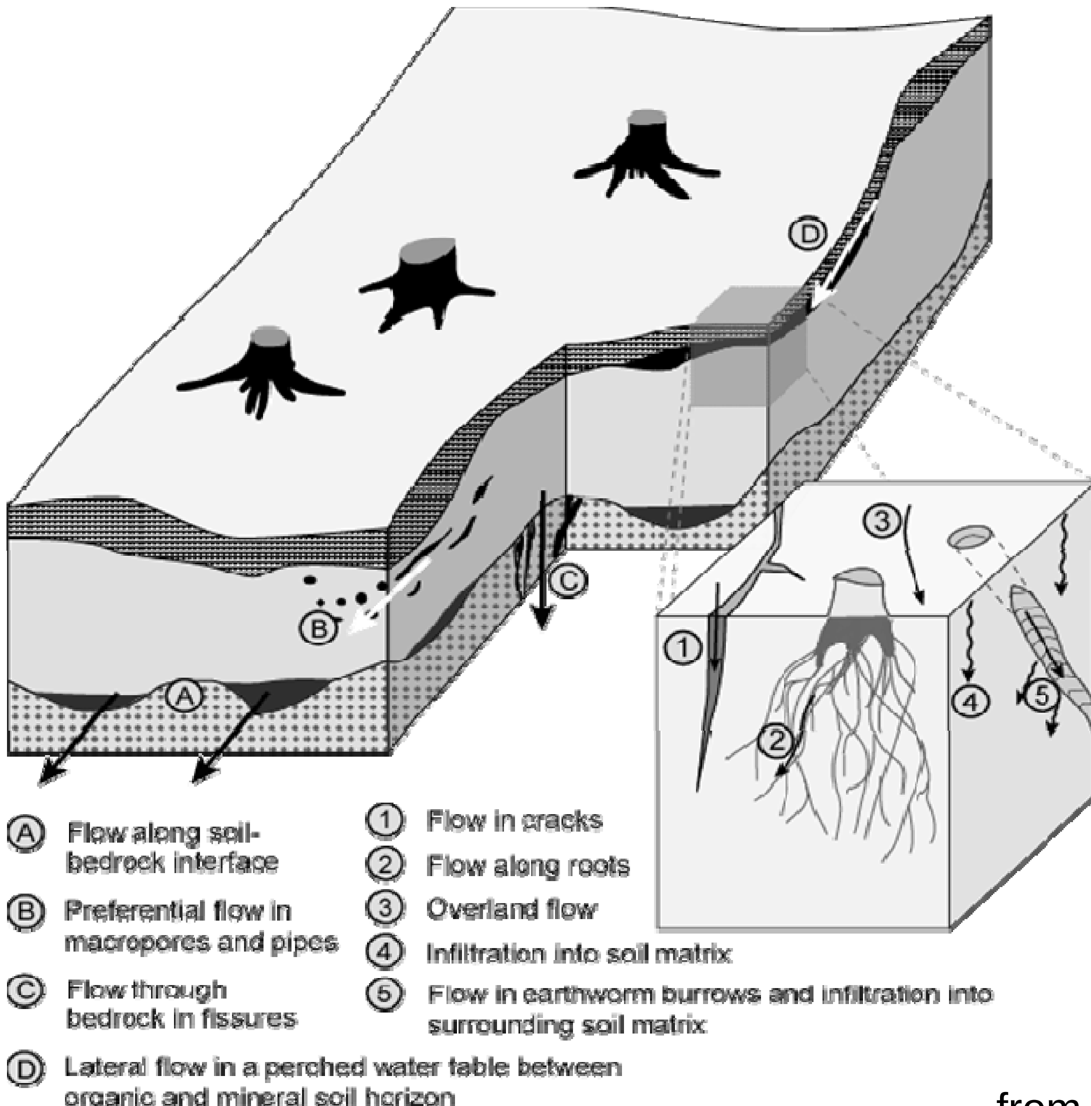
photo from Jim Kirchner

Hillslope hydrological processes are poorly understood

- How is the water balance partitioned?
- What determines the dominant subsurface flow processes?
- How do soil and rock modulate the key states, stocks and flows of water in the subsurface?
- How do these systems hold water for weeks to months, then rapidly release the water during events?

photo from Markus Weiler

Complexity hidden in the soil



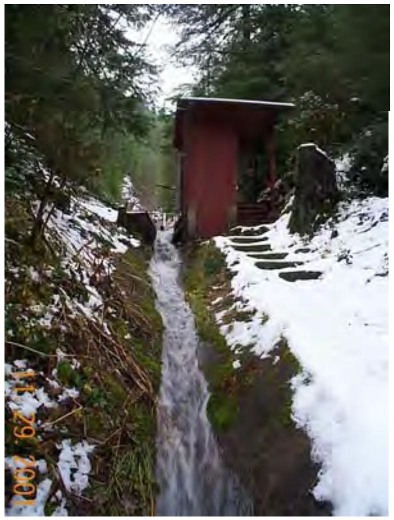
from Roy Sidle, 2006

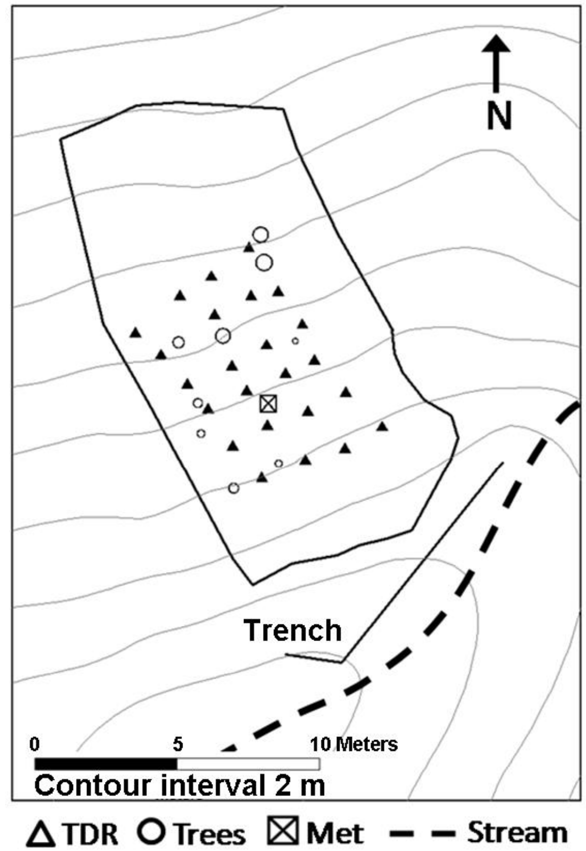
Hillslope scale experiments

- Control of initial and boundary conditions
- System manipulations
- Focused field work

photo from Jeff McDonnell

Watershed 10, HJ Andrews LTER





photos by Kevin McGuire

WS10 - perceptual model of storm response

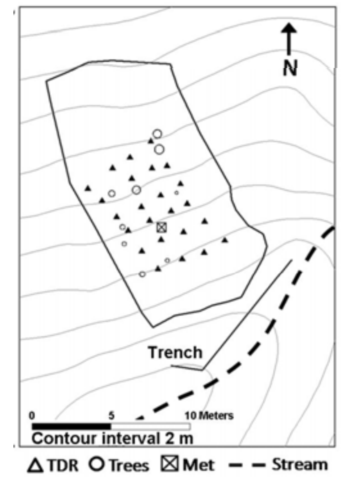
- Rapid response

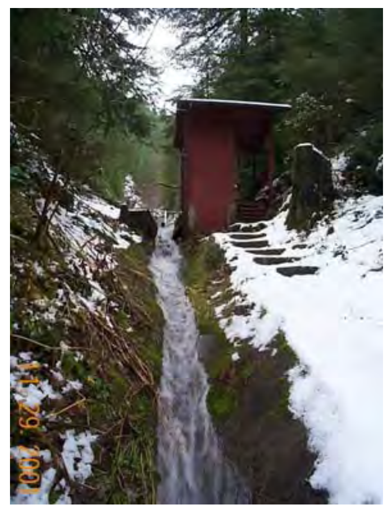
Unknowns:
Partitioning of water balance
Subsurface flow velocities
Storage discharge relationship

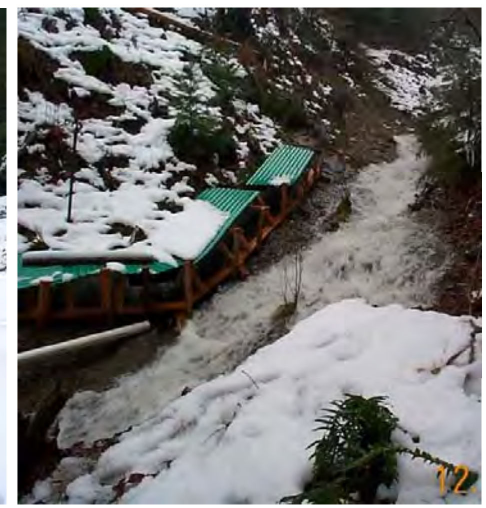
lateral during events

from McGuire 2004

24 day steady state irrigation







Water balance

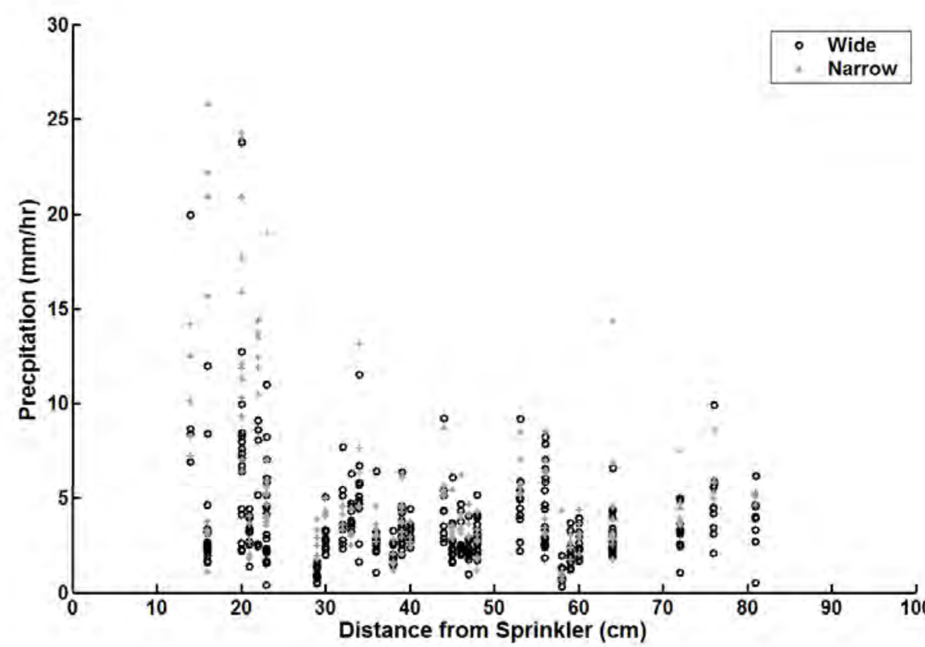
$$P = Q + L + ET + \Delta S$$

- P = precipitation
- Q = runoff
- L = leakage into bedrock
- ET = evapotranspiration
- ΔS = change in soil moisture storage

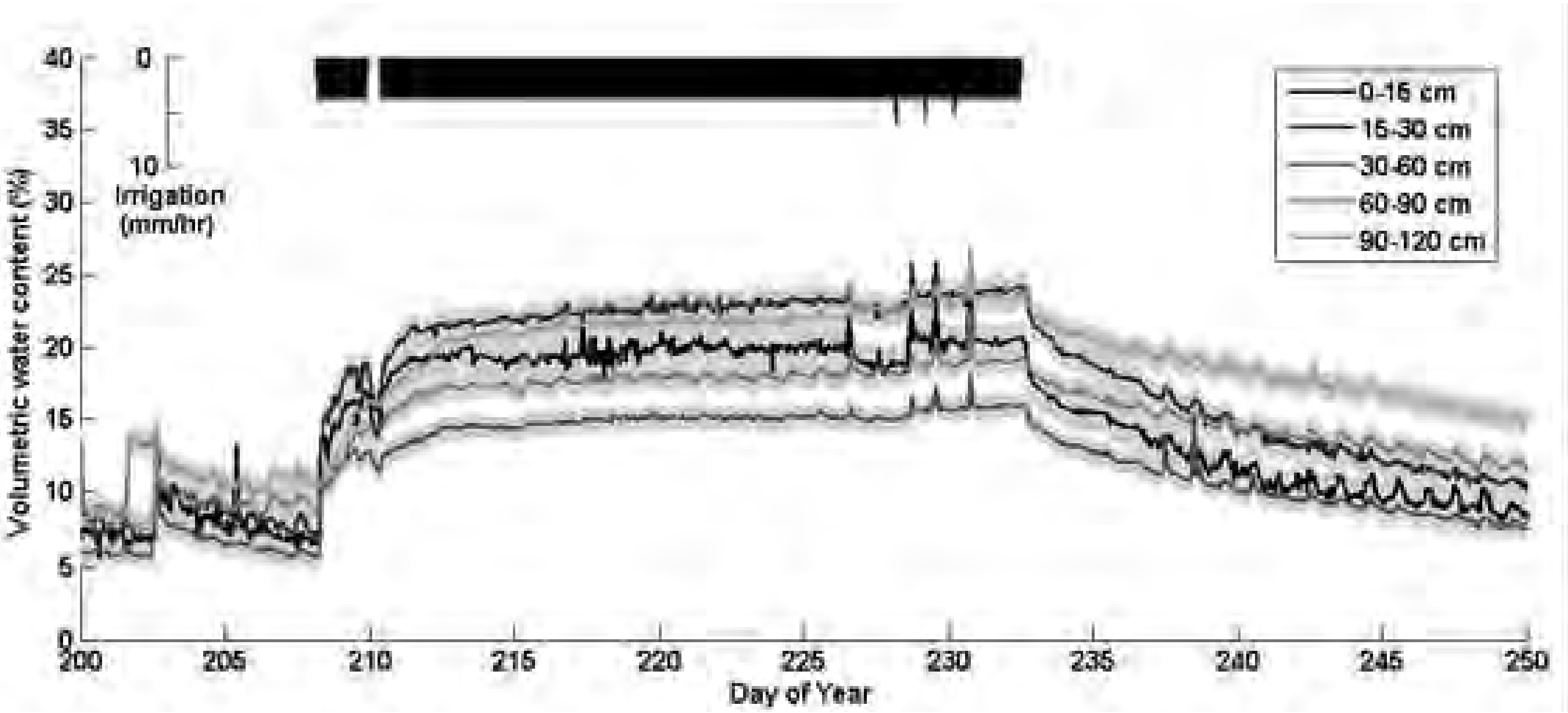
Precipitation (P)

- Irrigation on from day of year 208 through 232
- 4 sprinkler malfunctions
  - •Off for 9 hours on day 210
  - •High pulse on days 227, 229 and 231

At steady state
P = 659 ± 33 L/hr



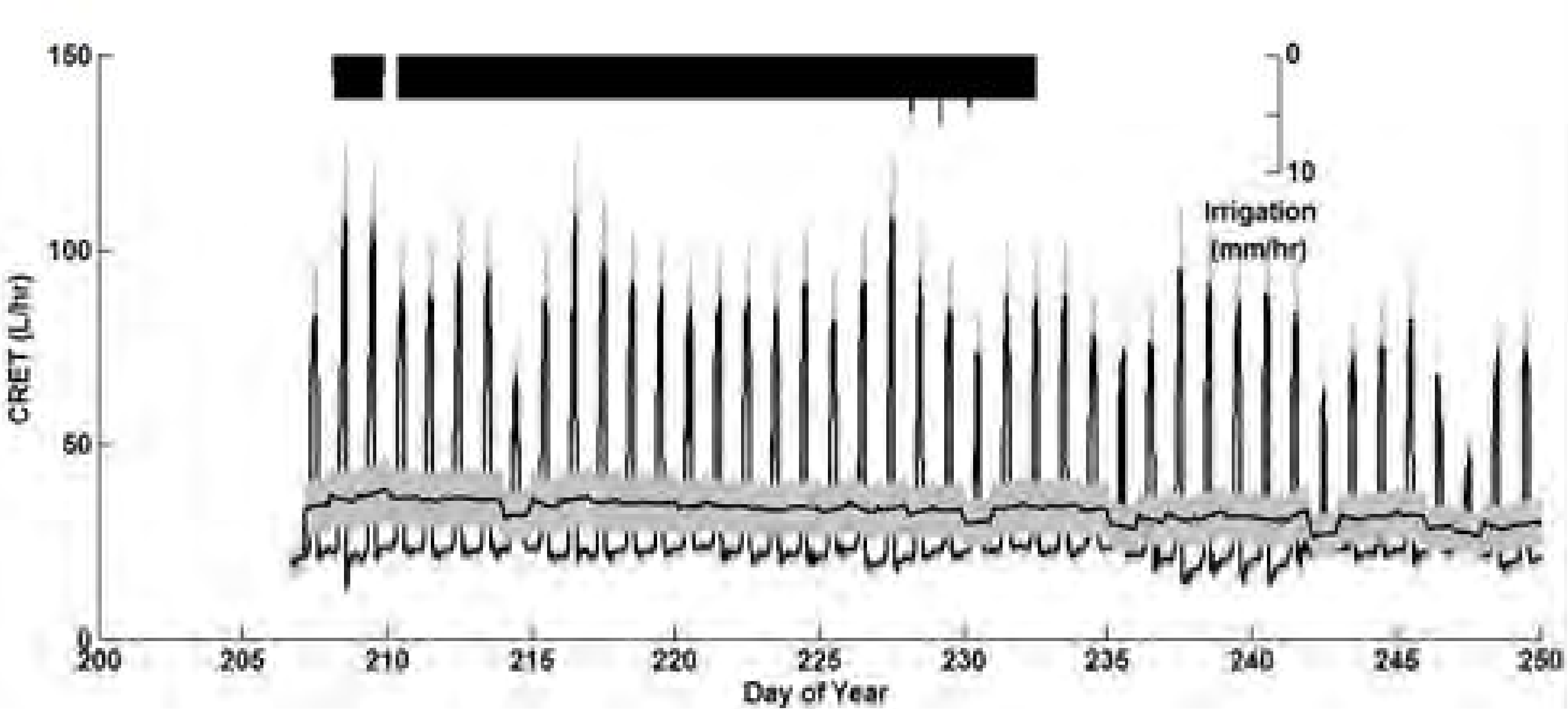
Soil storage (ΔS)



At steady state

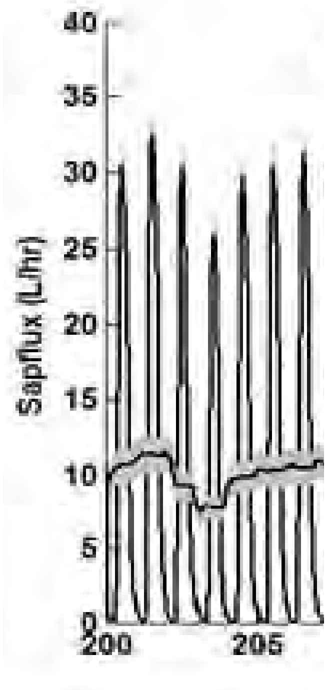
ΔS = 4 ± 1 L/hr < 1%

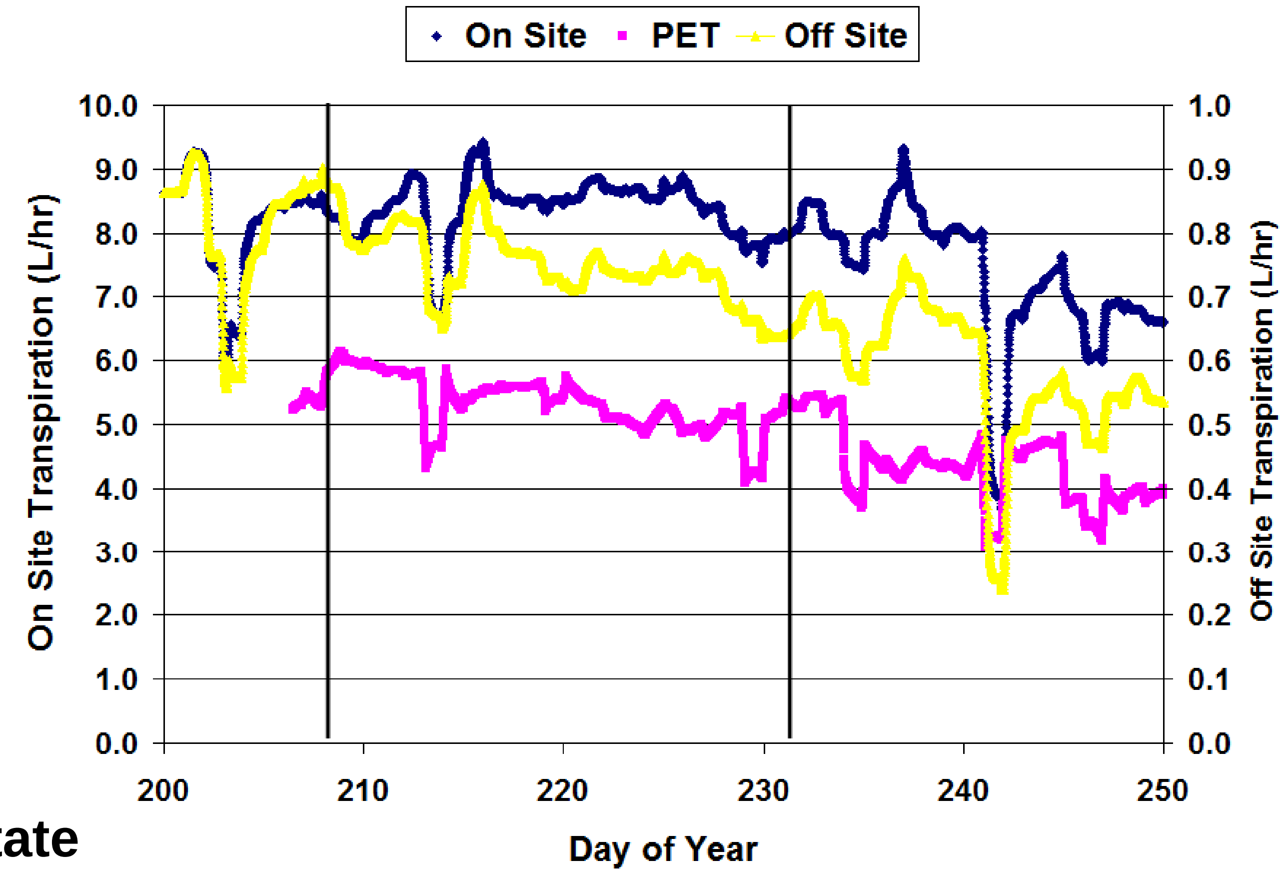
Evapotranspiration (ET)



At steady state
ET = 50 ± 21 L/hr ~ 9%

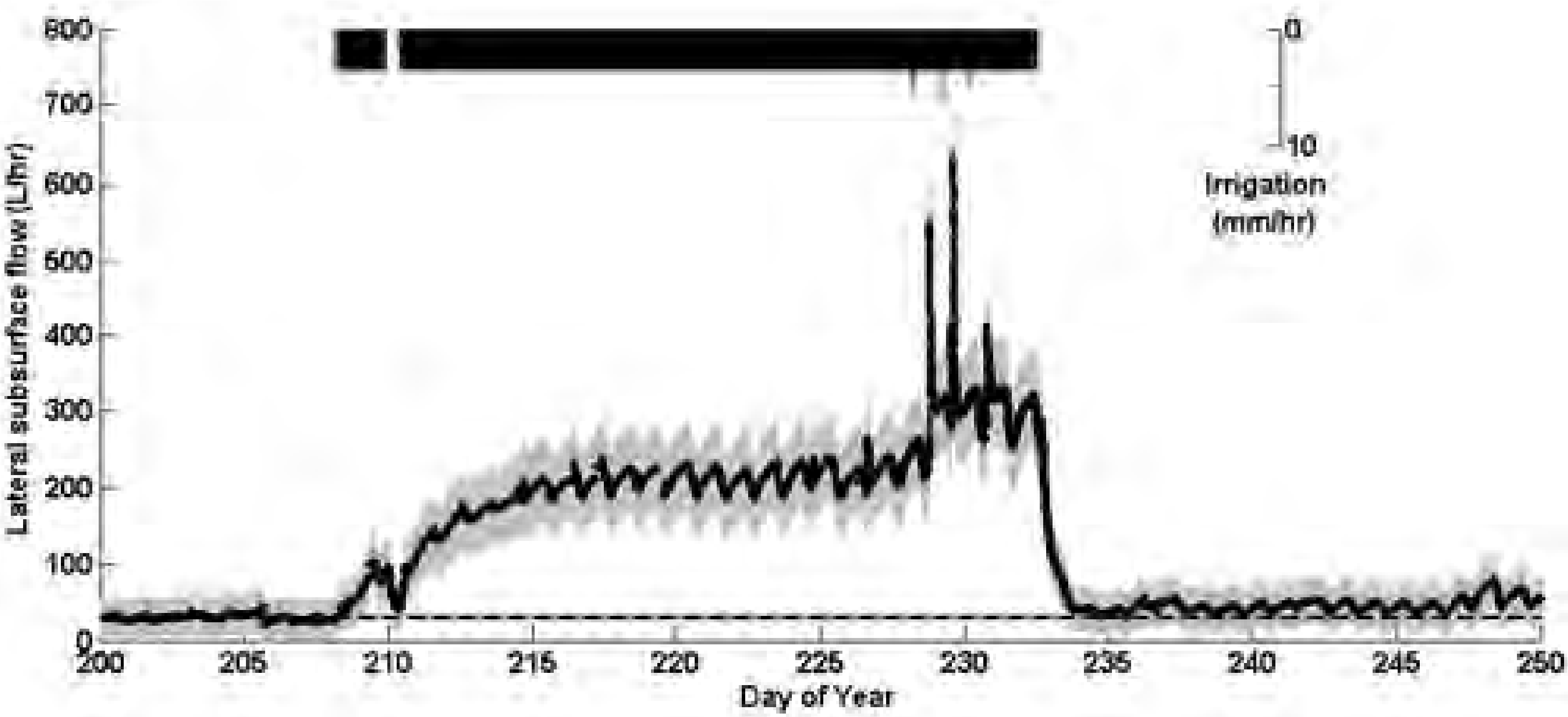
Transpiration (T)





At steady state
T = 9 ± 1 L/hr ~ 1%

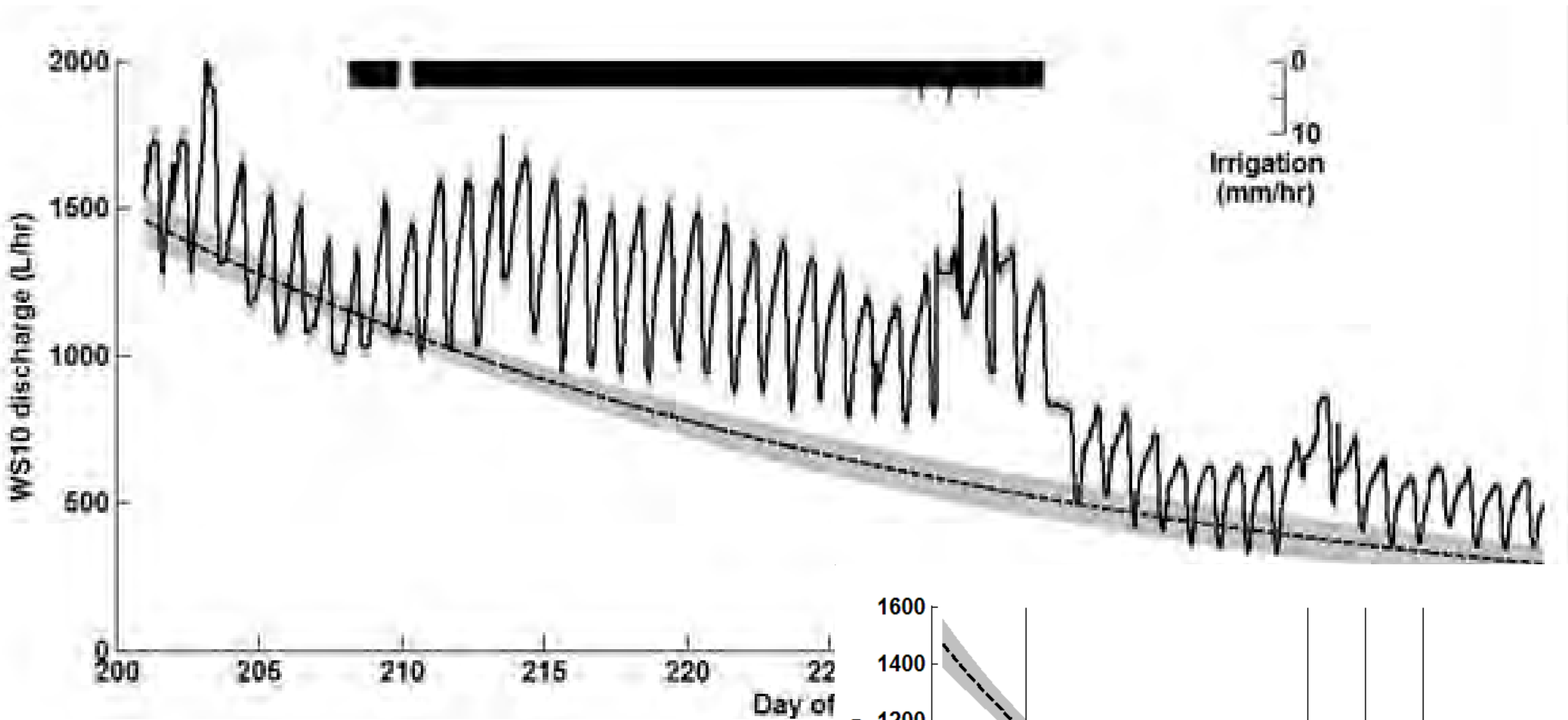
Hillslope discharge (Q_{hill})



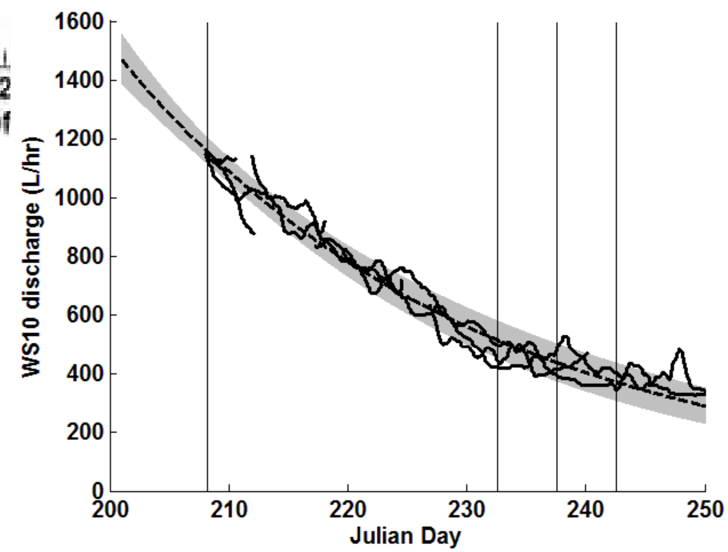
At steady state

Q_{hill} = 284 ± 20 L/hr ~ 44%

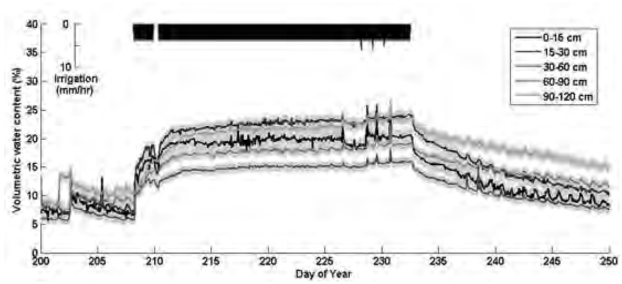
Watershed discharge (Q)

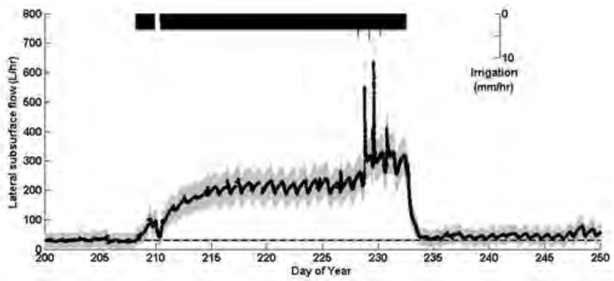


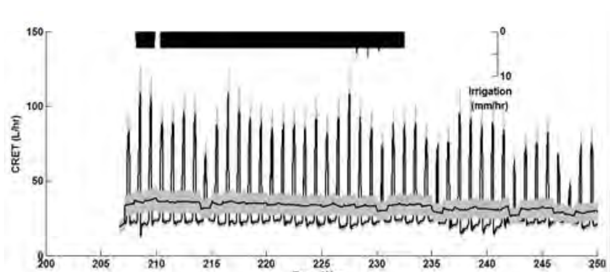
At steady state
Q = 461 ± 115 L/hr ~ 70%



Estimating Hillslope Scale Leakage







$$L = P - (Q + ET + \Delta S)$$

P = 659 ± 33 L/hr

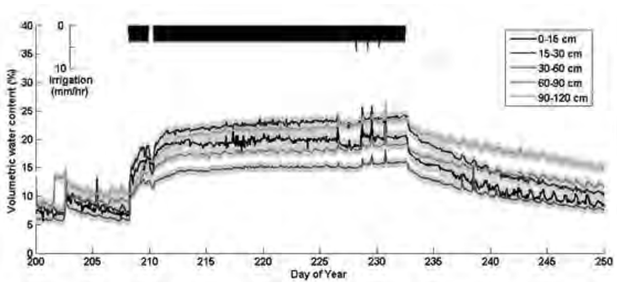
ΔS = 4 ± 33 L/hr

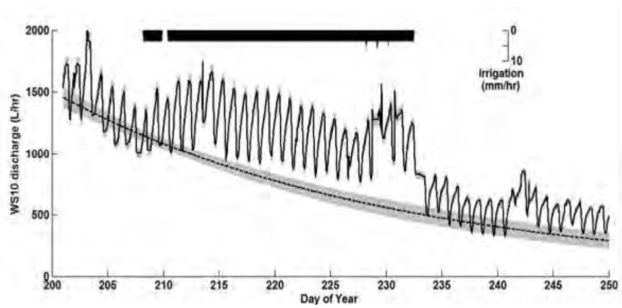
ET = 50 ± 21 L/hr

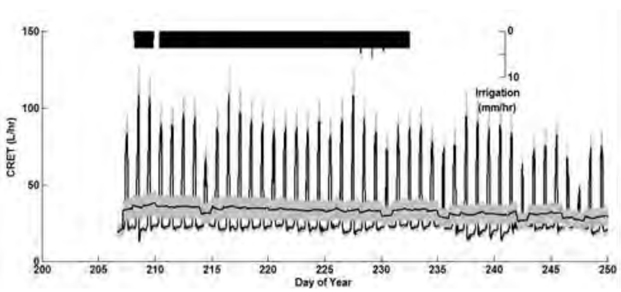
Q_{hill} = 284 ± 20 L/hr

L = 207 ± 55 L/hr

Estimating Catchment Scale Leakage







$$L = P - (Q + ET + \Delta S)$$

P = 659 ± 33 L/hr

ΔS = 4 ± 33 L/hr

ET = 50 ± 21 L/hr

Q = 461 ± 115 L/hr

L = 148 ± 121 L/hr

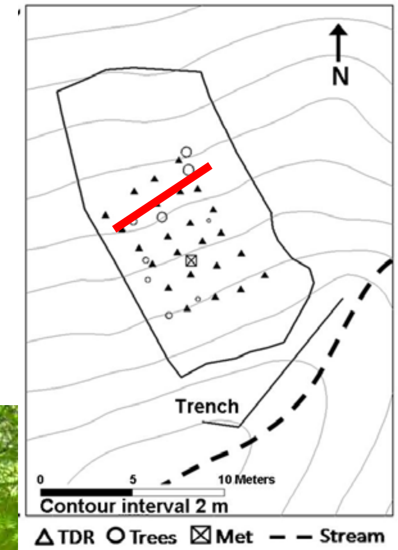
Water balance summary

Water balance component	… + 10 (l)
Irrigation	19 700
Hill	10 507
WS10	65 578
Transpiration	470
CRET	17 721
ΔS	1559
Hillslope deep seepage	66 423
Catchment deep seepage	70 746

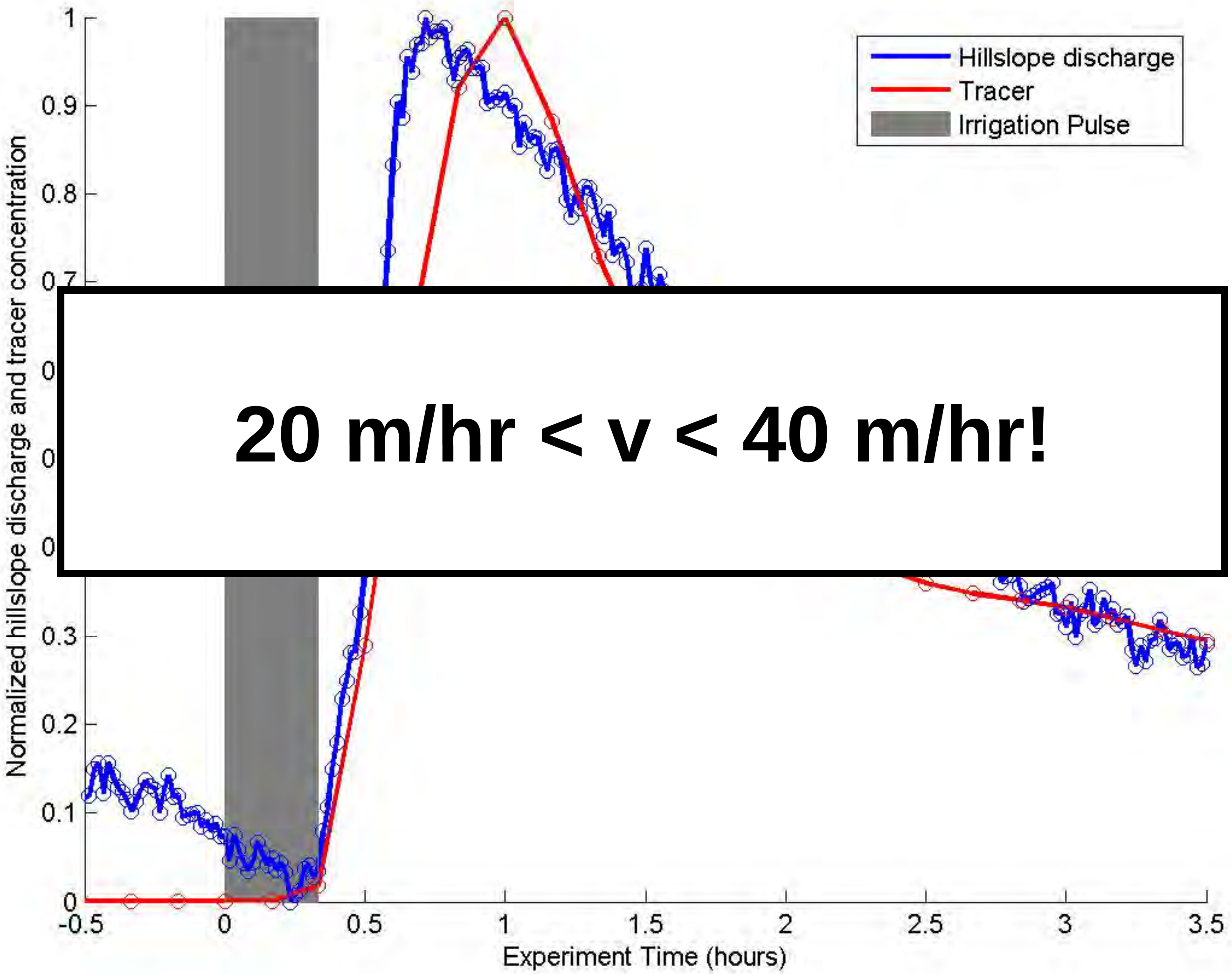
Leakage into bedrock is a significant component of the water balance at the hillslope, but not at the catchment scale

Subsurface flow velocity

- Coincident tracer and irrigation pulse 13 m upslope during steady state conditions
  - (experiment day 16)

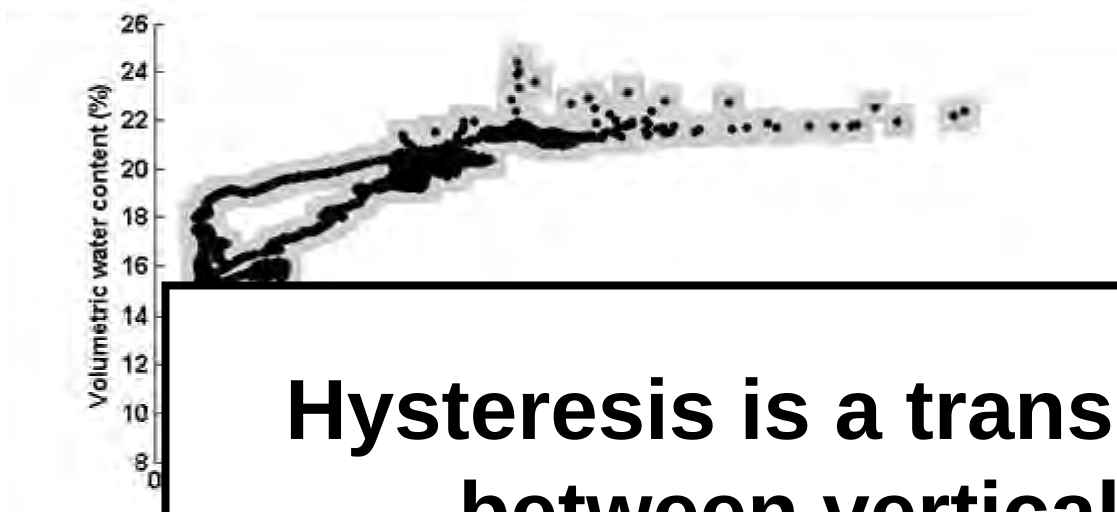


Subsurface flow velocity

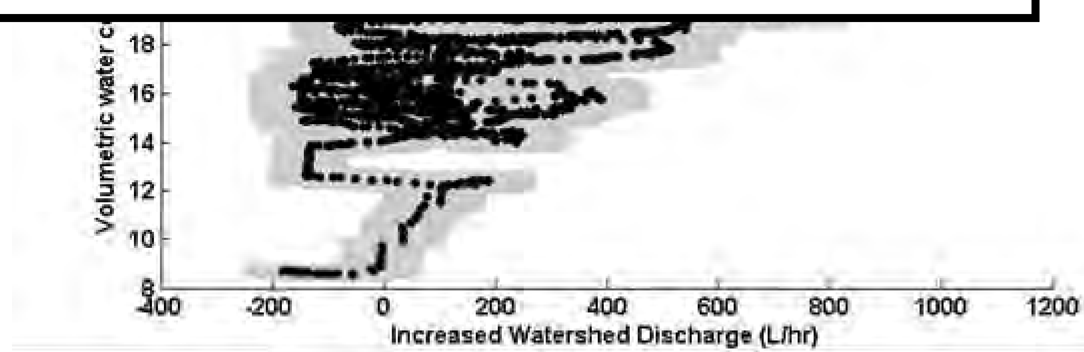


20 m/hr < v < 40 m/hr!

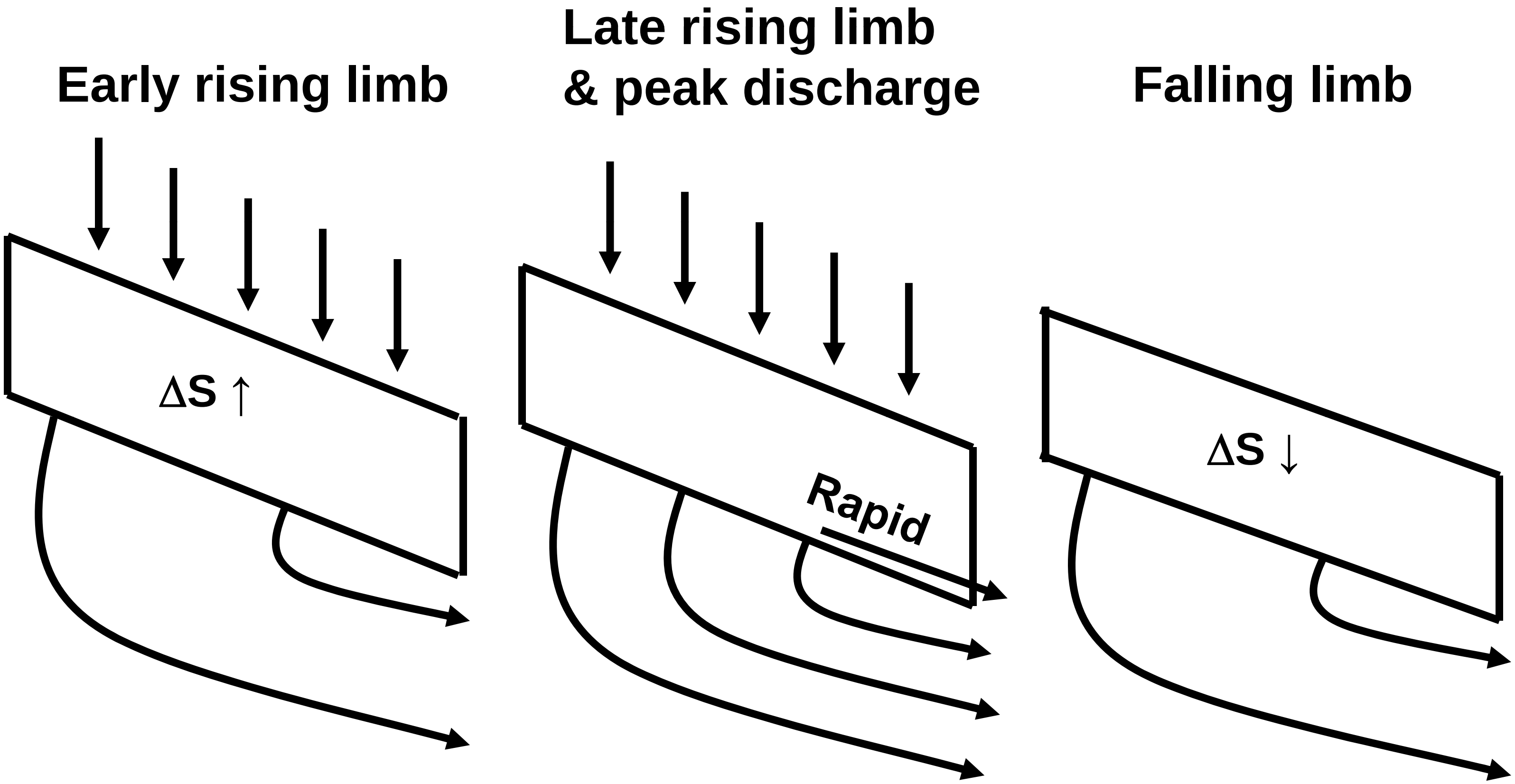
Storage vs. discharge



Hysteresis is a transition between vertical and lateral flow



WS10 – new perceptual model of storm response



Conclusions etc…

- Leakage to bedrock significant at hillslope scale, not at catchment scale
- Measurement uncertainty is important!
- Field scale experiment!!