

# Conjunctive Use and Managed Recharge: Technical and Scientific Research Frontiers

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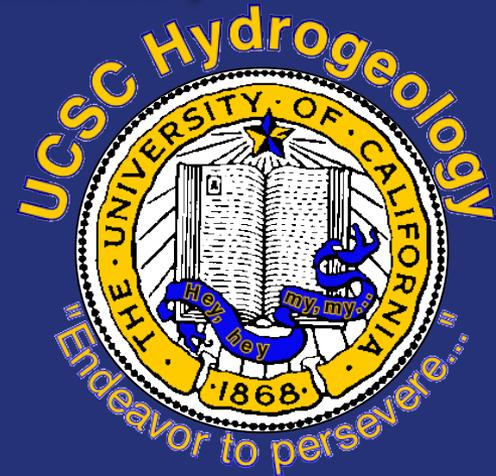
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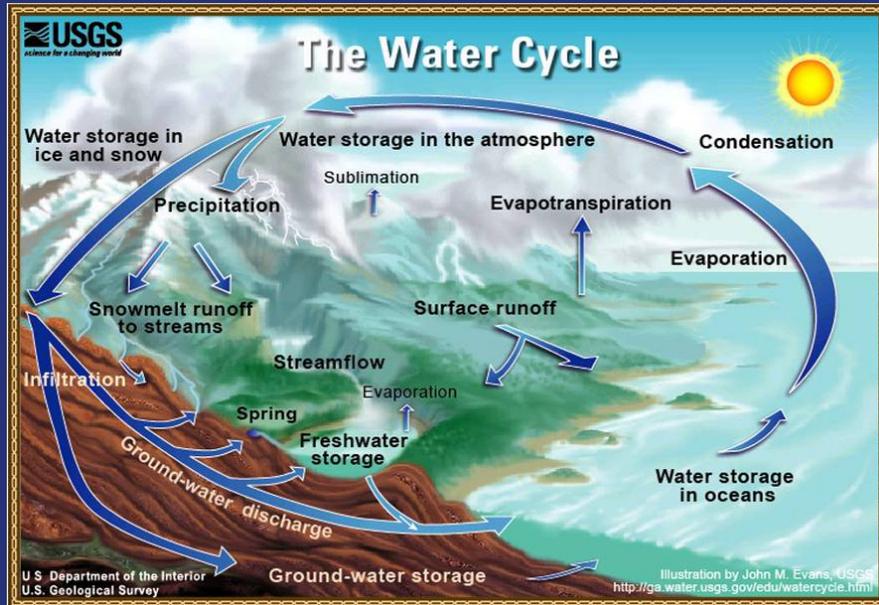
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Climate Change and the  
Future of Groundwater in California  
CCWAS-IGERT  
UC Davis  
16 April 2014



# Groundwater recharge: essential for sustaining water resources, a hydrologic research frontier



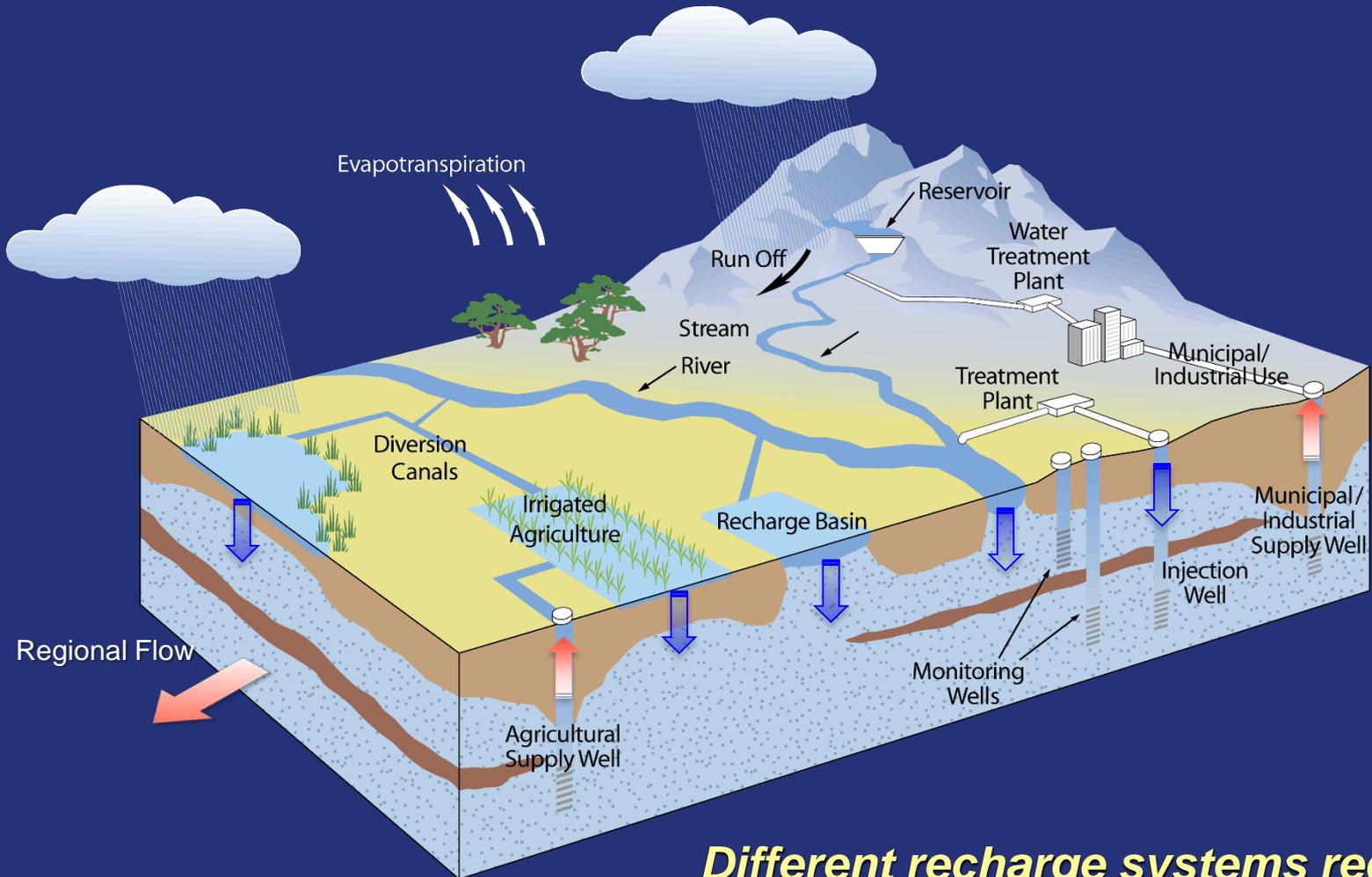
## Groundwater recharge is:

- Naturally occurring process
- Primary input to most aquifers
- Most difficult component of hydrologic cycle to measure

## Managed Aquifer Recharge (MAR) is:

- Increasingly important for groundwater management in CA
- Feasible in many groundwater basins
- Dependent on availability of appropriate supplies
- Method to improve both water *supply* and water *quality*
- A window into cryptic, subsurface processes (*natural laboratory*)

# Many forms of groundwater recharge (natural, managed)



***Different recharge systems require specific conditions, design, operations – "all recharge is local"***

# *Some Questions in Planning and Operating Managed Recharge Projects*

- *Where are the best locations to enhance recharge?*
- *What will be the source of the water?*
- *What operational plan will provide the greatest benefit?*
- *How does recharge vary in space and time?*
- *What controls variability in recharge rates?*
- *What maintenance will be required for operating systems?*
- *What will be the impacts on water quality?*
- *What is the fate of recharged groundwater?*
- *What is the value of recharged water?*
- *Can recharge be monetized/incentivized?*
- *Who receives the benefits?*

# Pajaro River and Pajaro Valley basins

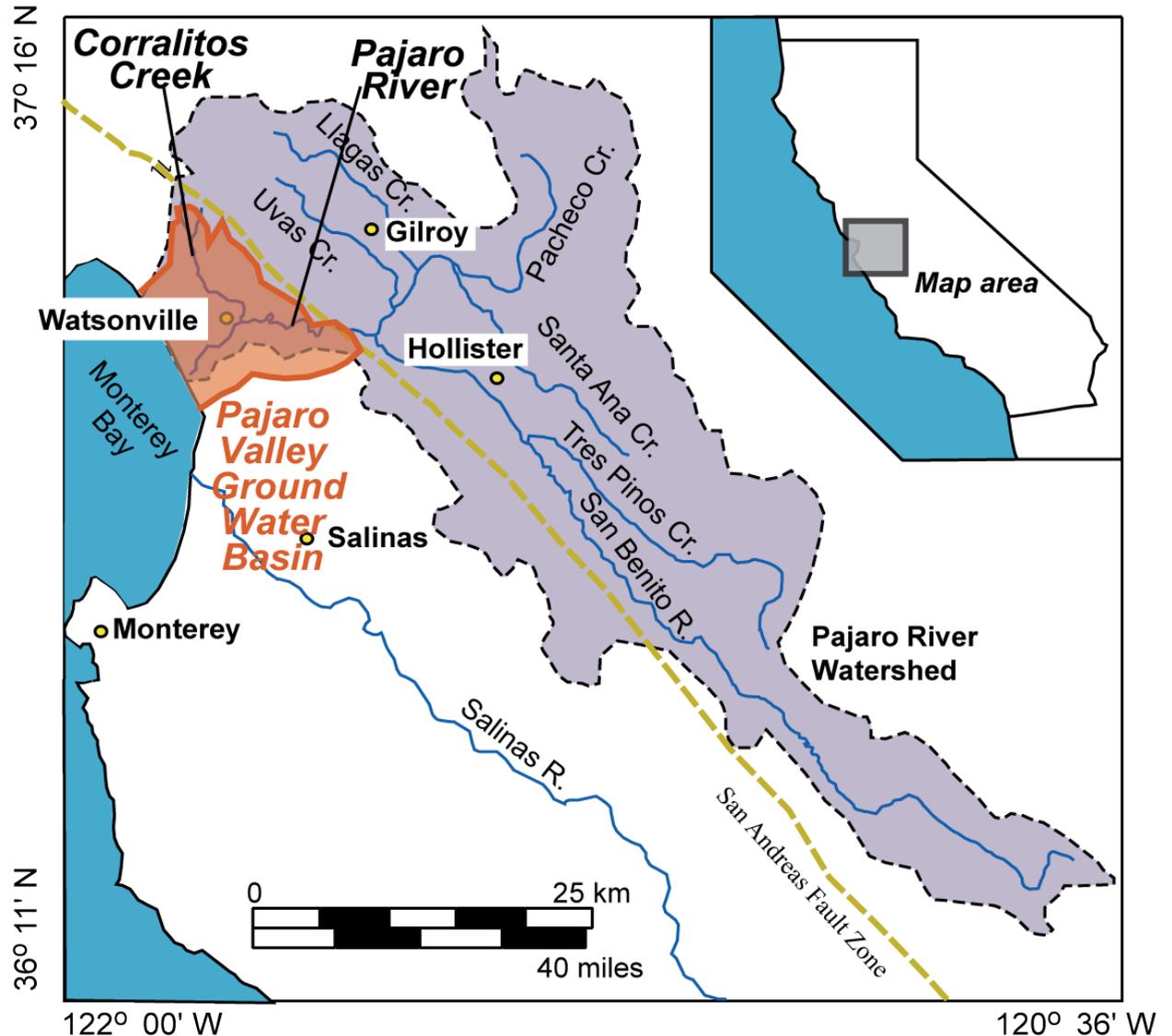
PR basin: 3400 km<sup>2</sup>,  
multiple counties,  
tributaries, creeks

PV land use: urban,  
agricultural, rural

Surface water  
systems impaired  
by elevated  
nutrients and  
sediment (EPA)

Primary fresh water  
resource is  
groundwater

PV GW extraction  
*exceeds the  
sustainable yield  
of the basin*



# Overdraft is a regional challenge

## Pumping:

~55k ac-ft/yr

## City of Watsonville:

~7k ac-ft/yr

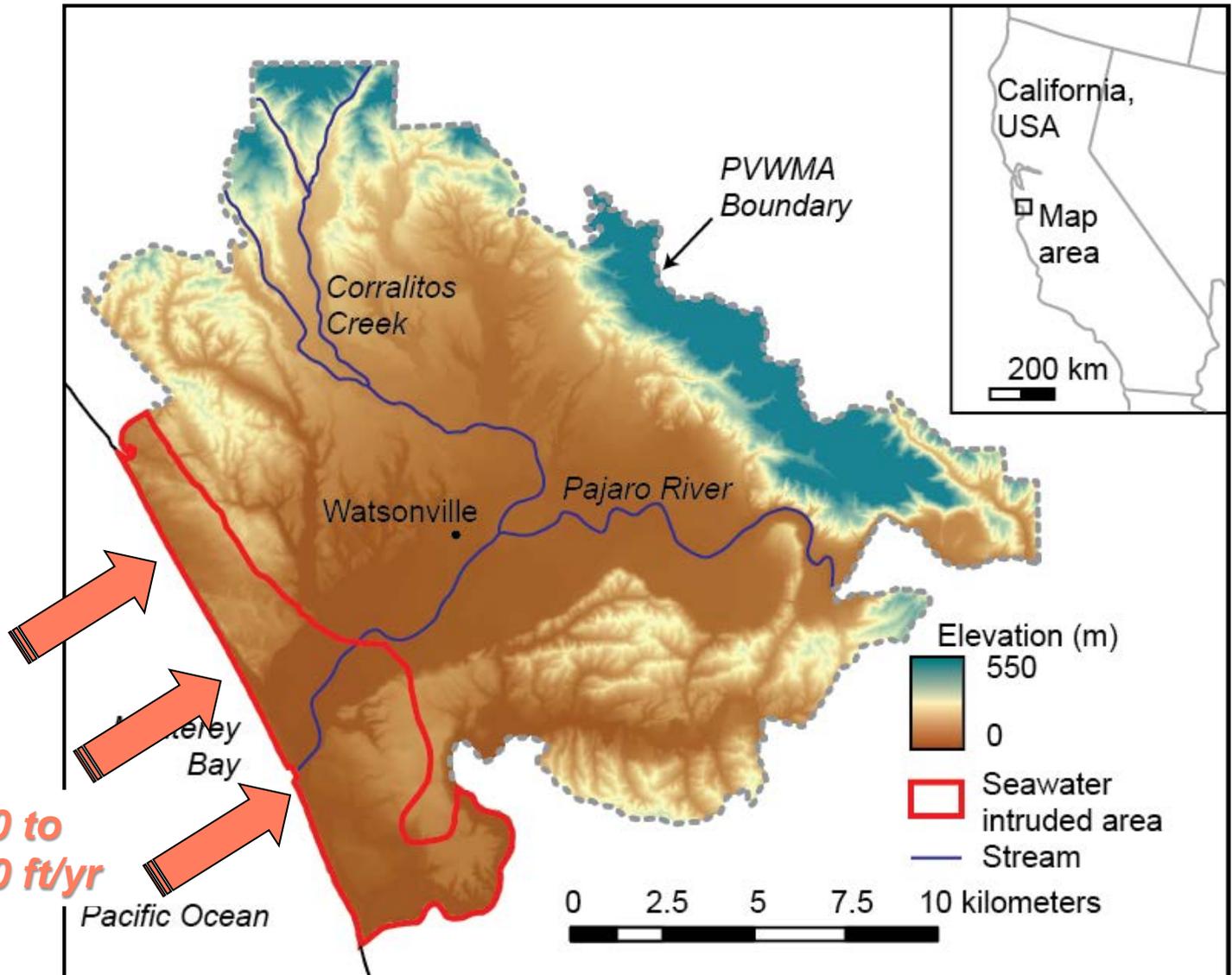
## Sustainable yield:

40k–45k (?) ac-ft/yr  
(depends on pumping distribution, time horizon, natural variability)

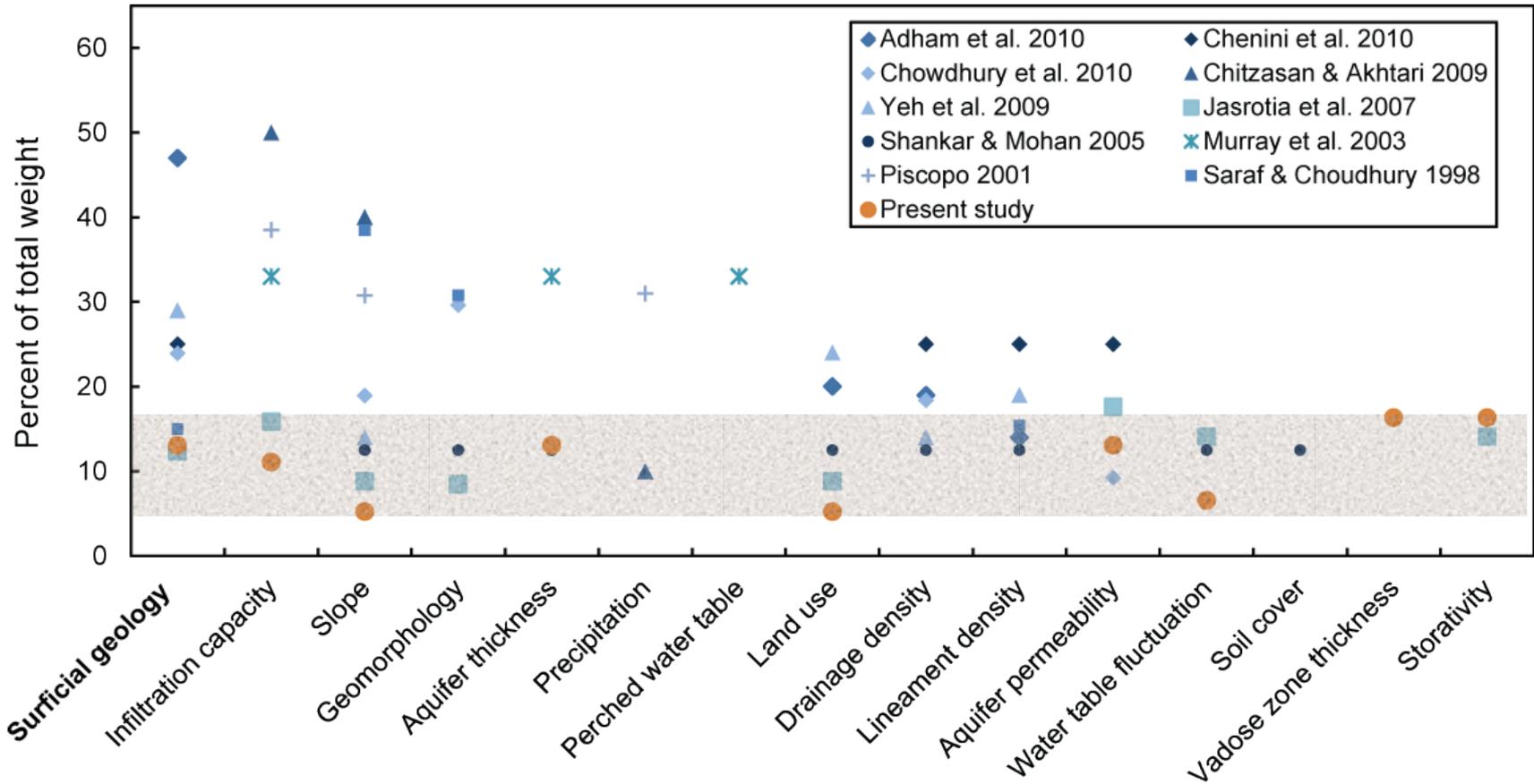
## Overdraft:

10k–15k (?) ac-ft/yr  
(depends on definition, annual conditions,  
**definitely large,**

**200 to  
350 ft/yr**

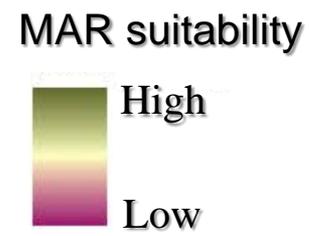
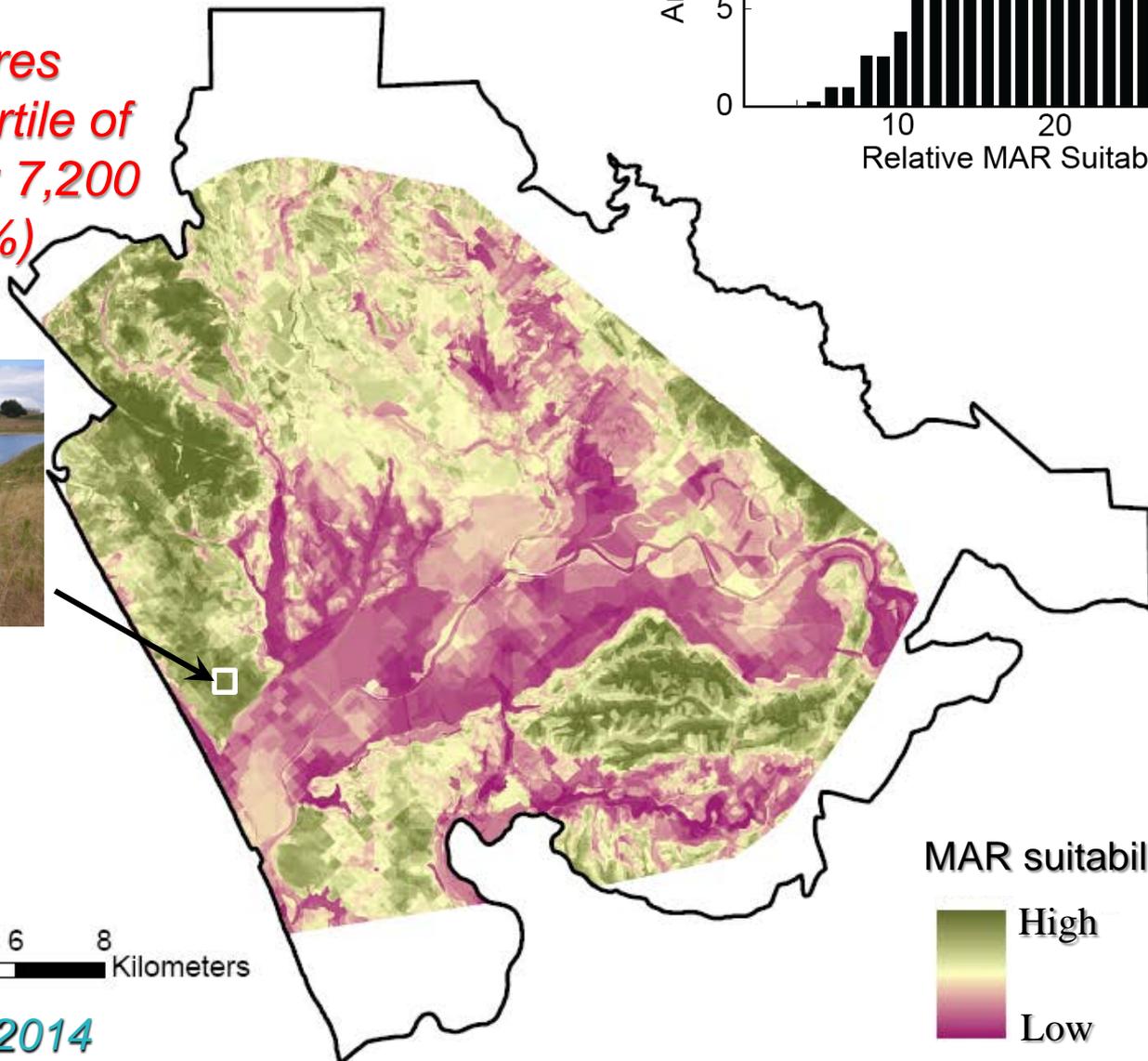
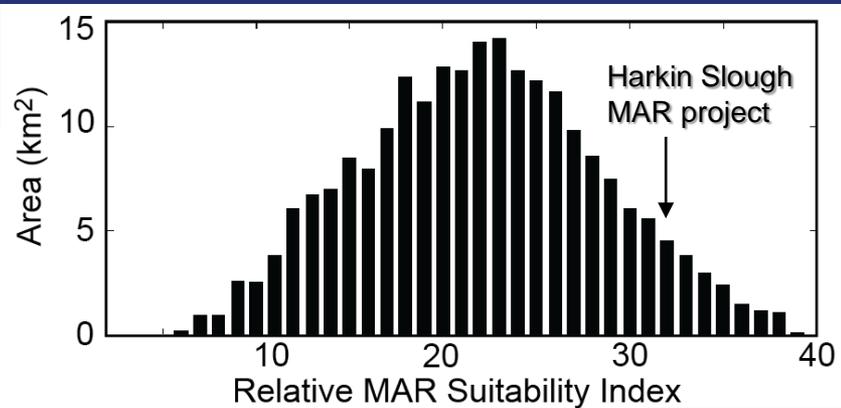


# Weighting Surface and Subsurface Data

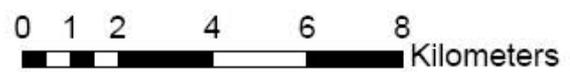


# MAP of MAR Suitability

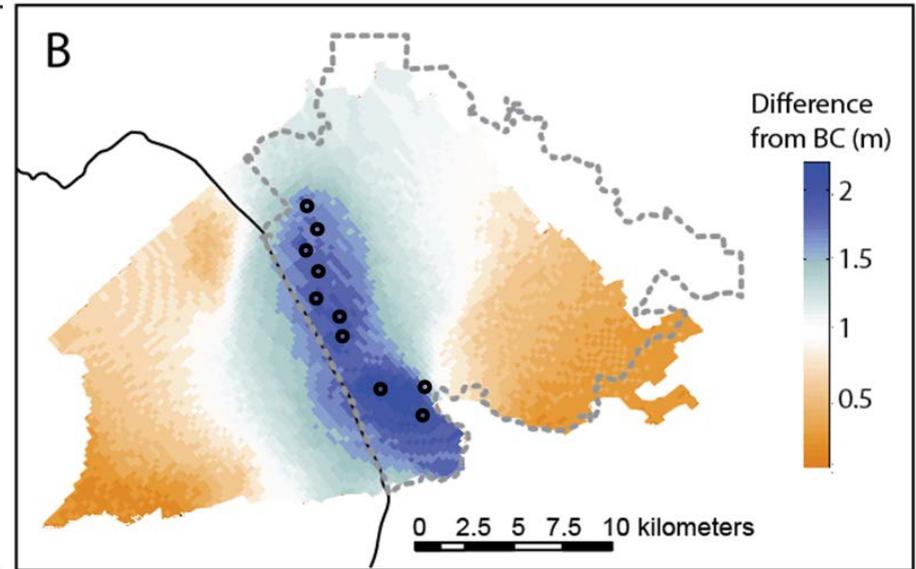
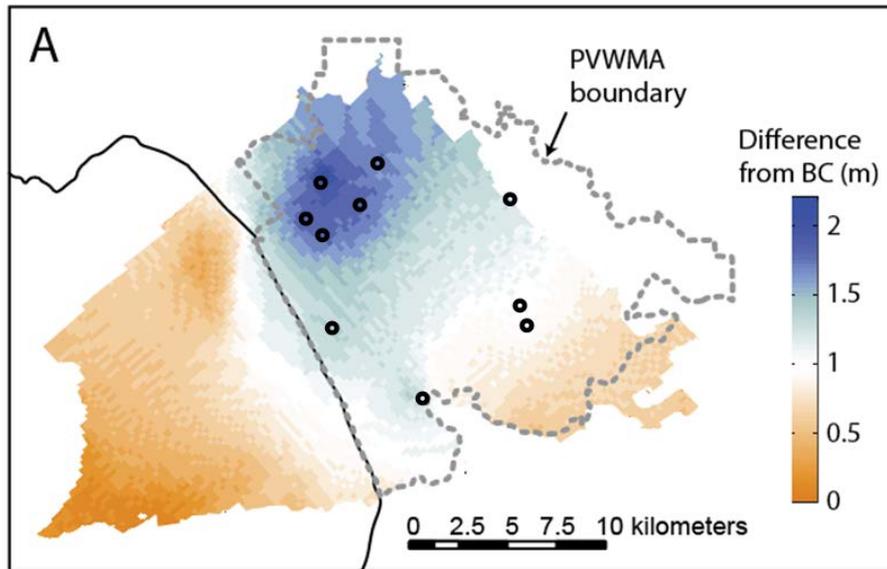
- Total area: 56,000 acres
- Upper quartile of SI (30-40): 7,200 acres (13%)



Harkins Slough  
MAR project  
(SI = 32)



# Modeling MAR Influence



*High MAR suitability*

*Coastal MAR*

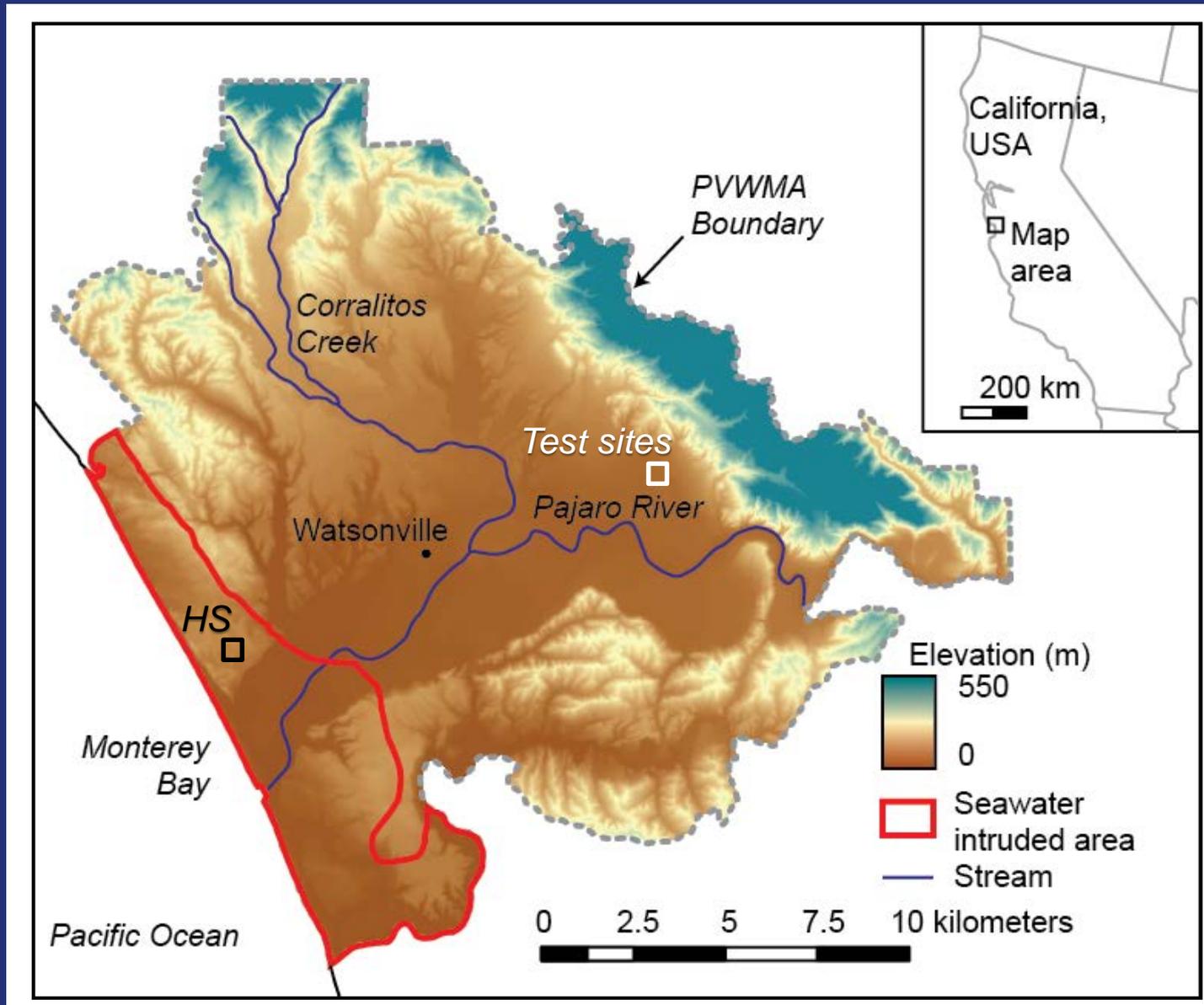
*Russo et al., 2014*

*Variations in groundwater levels resulting from:*

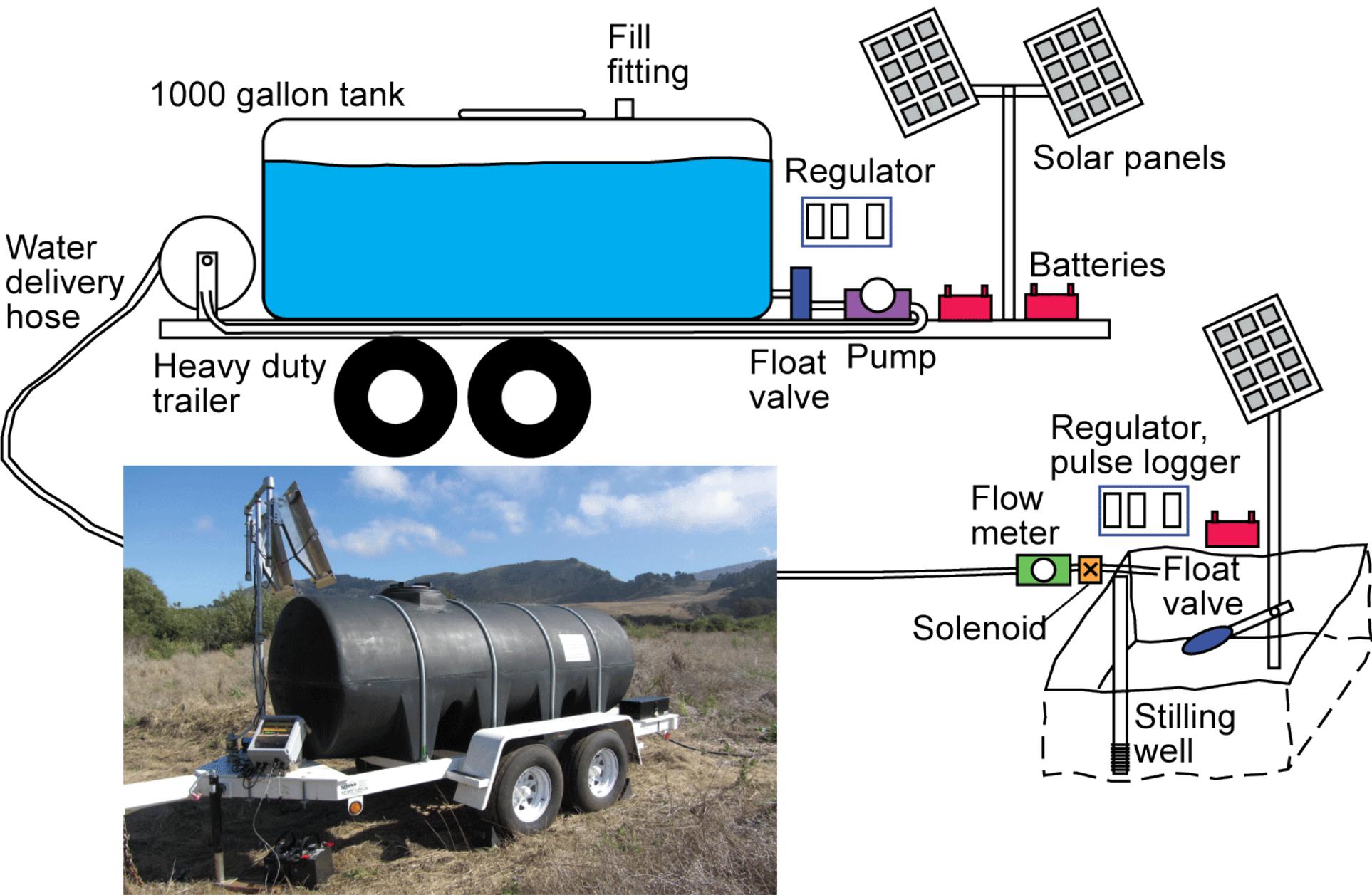
- *Ten MAR projects, distributed randomly*
- *4,000 ac-ft/yr additional MAR throughout basin*
- *34 years of model operation (compare to basecase)*

*Coastal MAR gives faster benefit, at cost of "recovery efficiency"*

# Testing Field Conditions for MAR Suitability



# Infiltration test system to evaluate MAR potential



# Installing Infiltration Testing System

**1. Dig pit**



**2. Build liner**



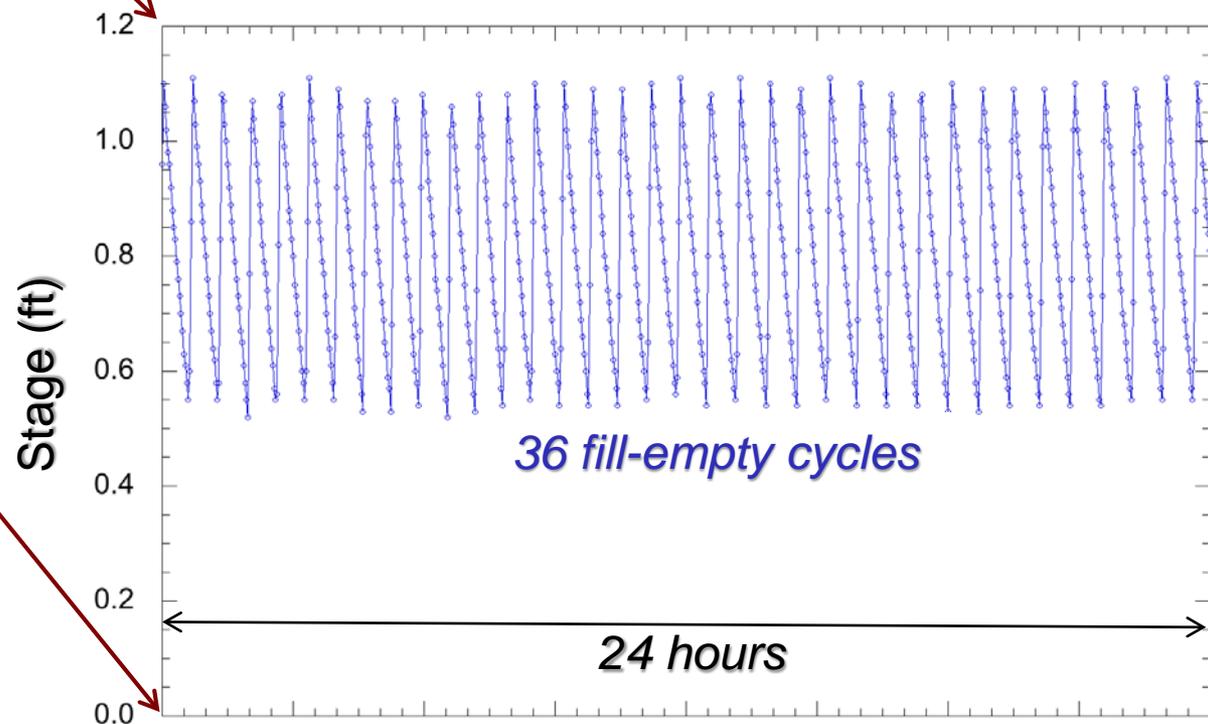
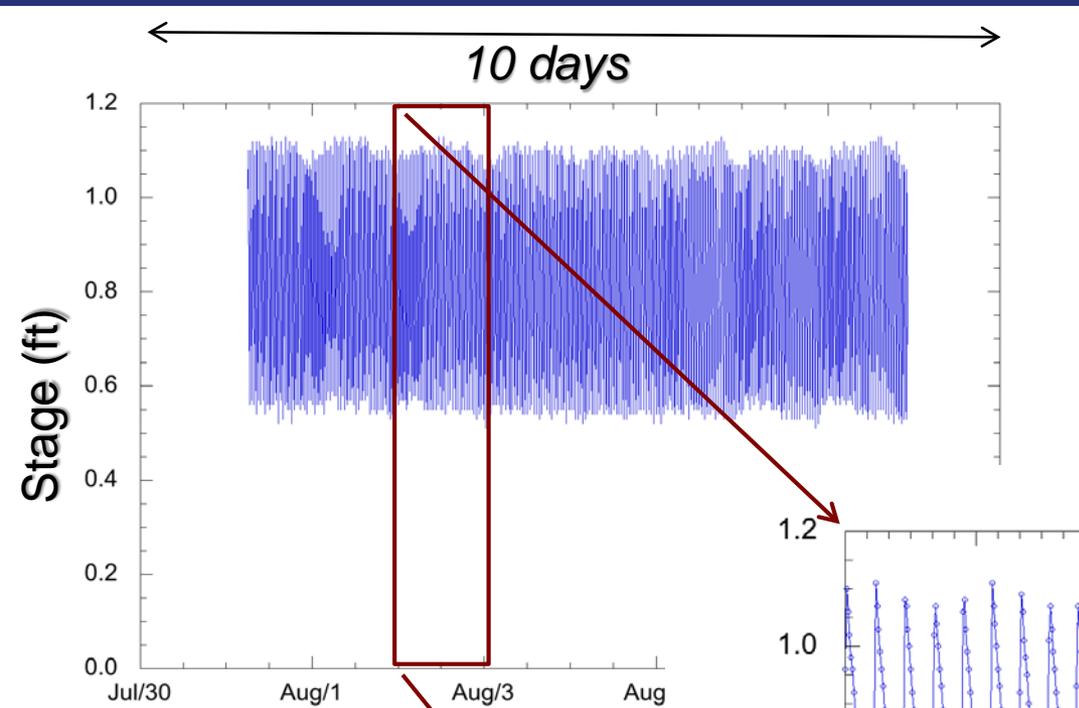
**3. Install thermal probes**



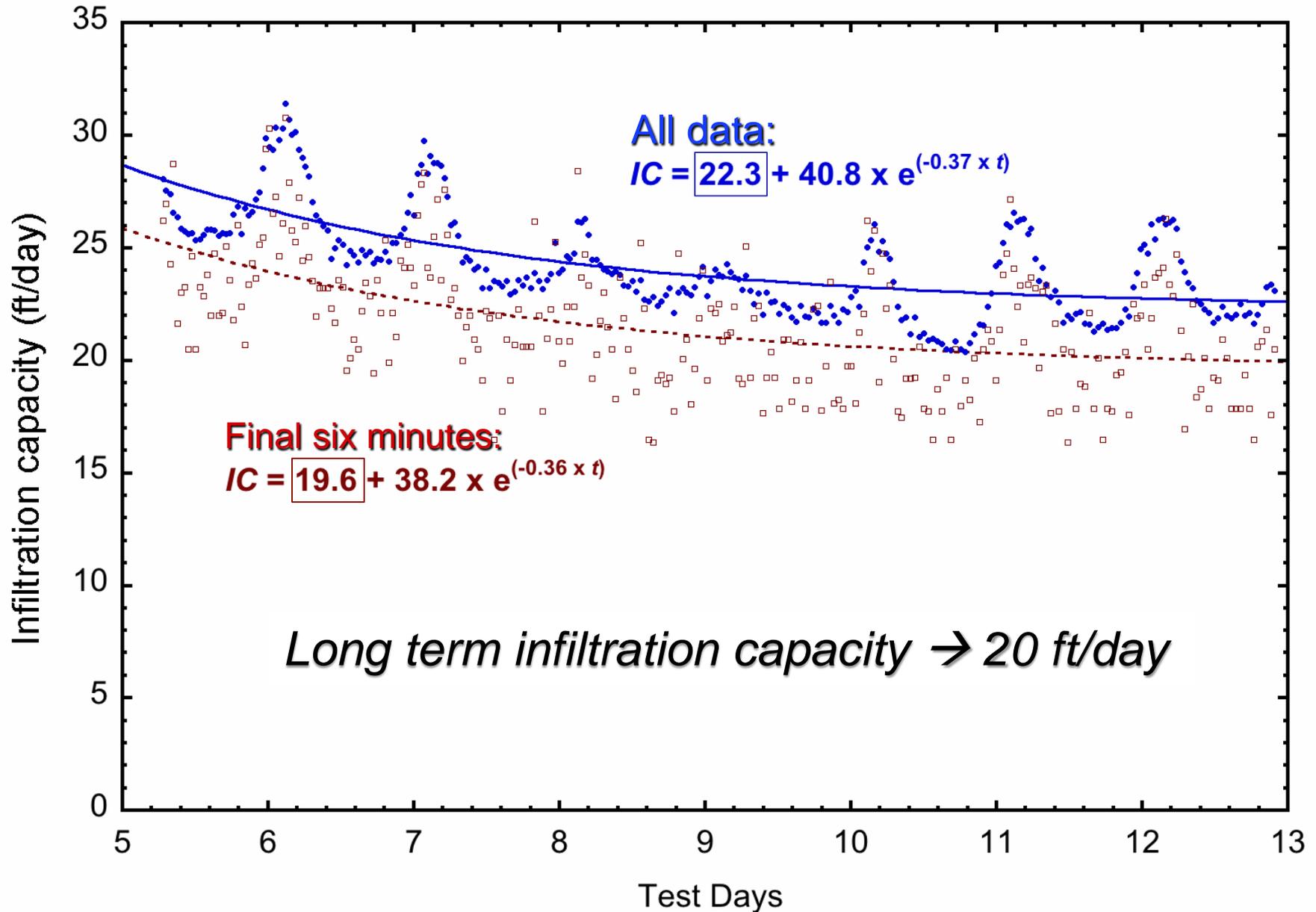
**4. Fully instrumented**



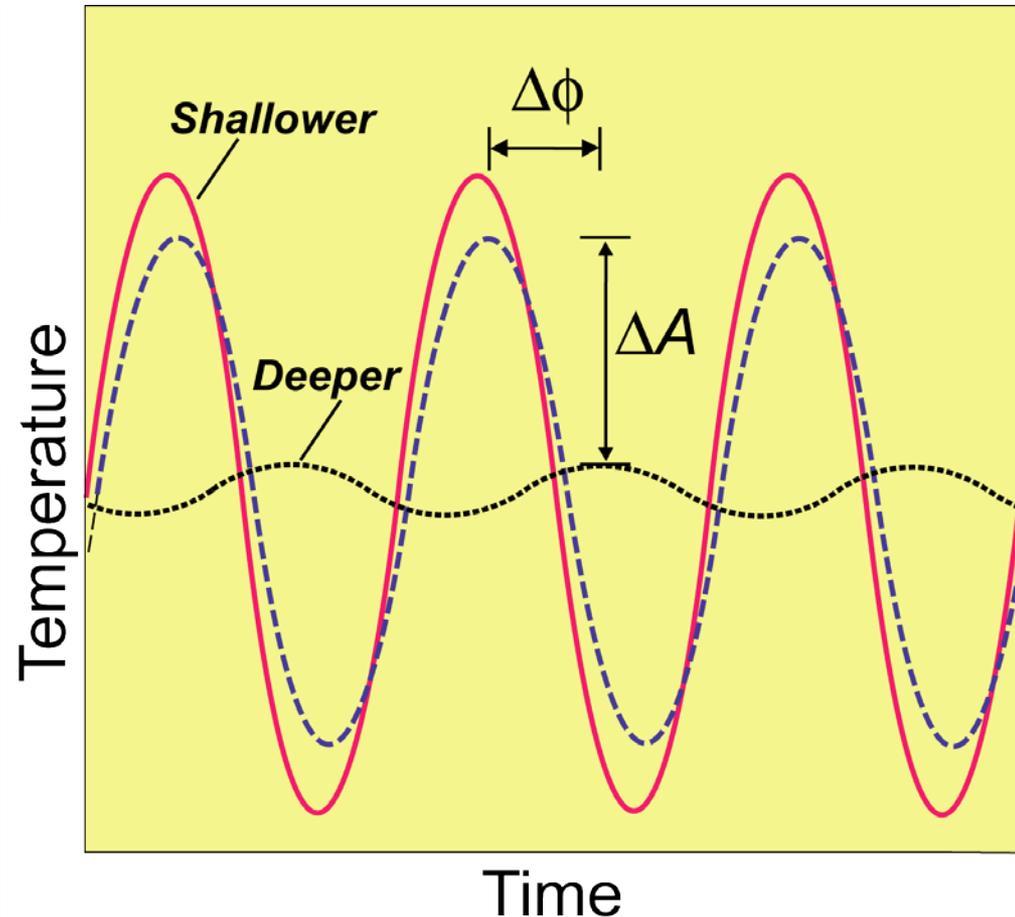
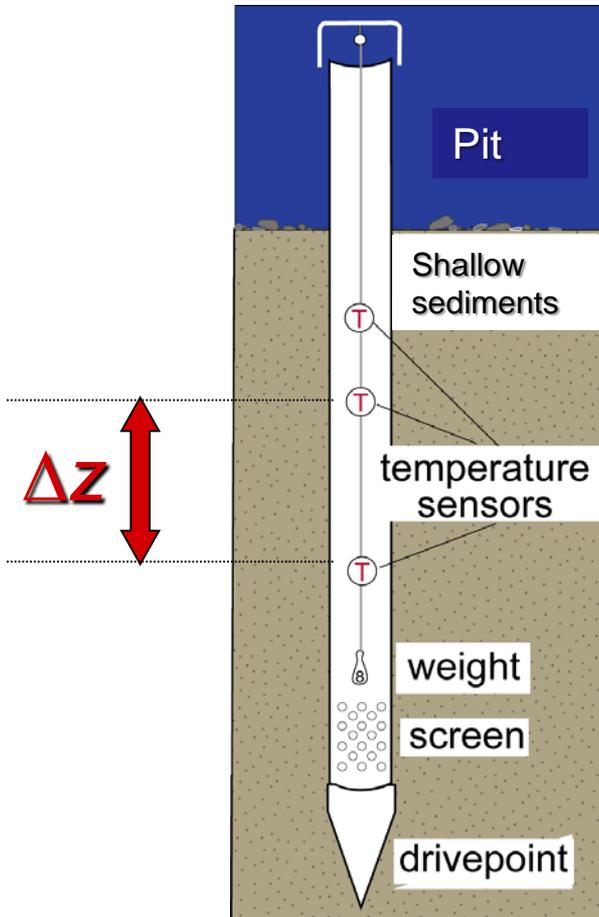
# *Infiltration Test Data: Stage versus time*



# Infiltration Test Data: Stage versus time



# Thermal Probes Used to Determine Vertical Infiltration Rate

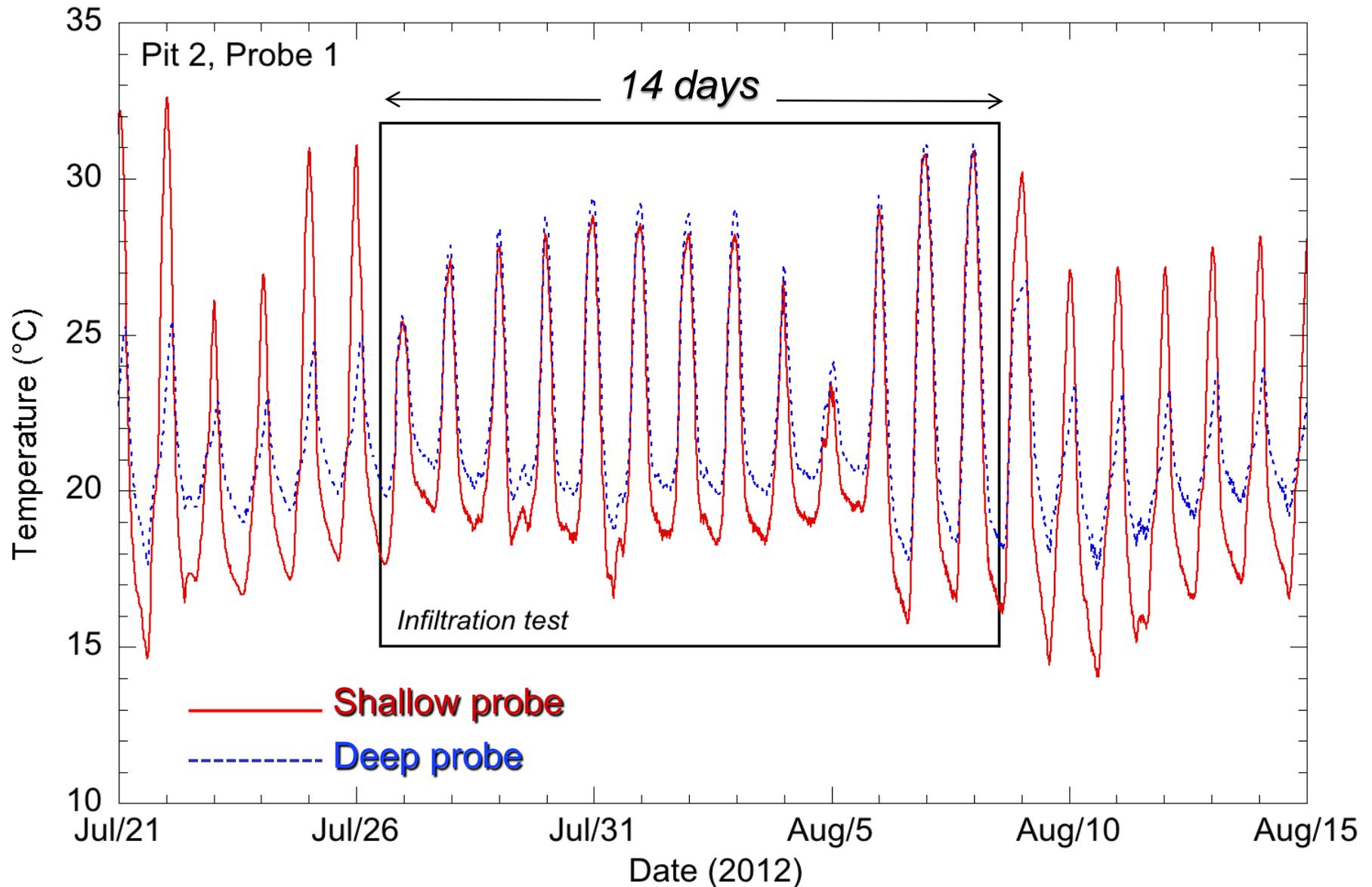


- Autonomous thermal probes in tubes at base of pit
- Diel temperature changes carried downward by infiltrating water

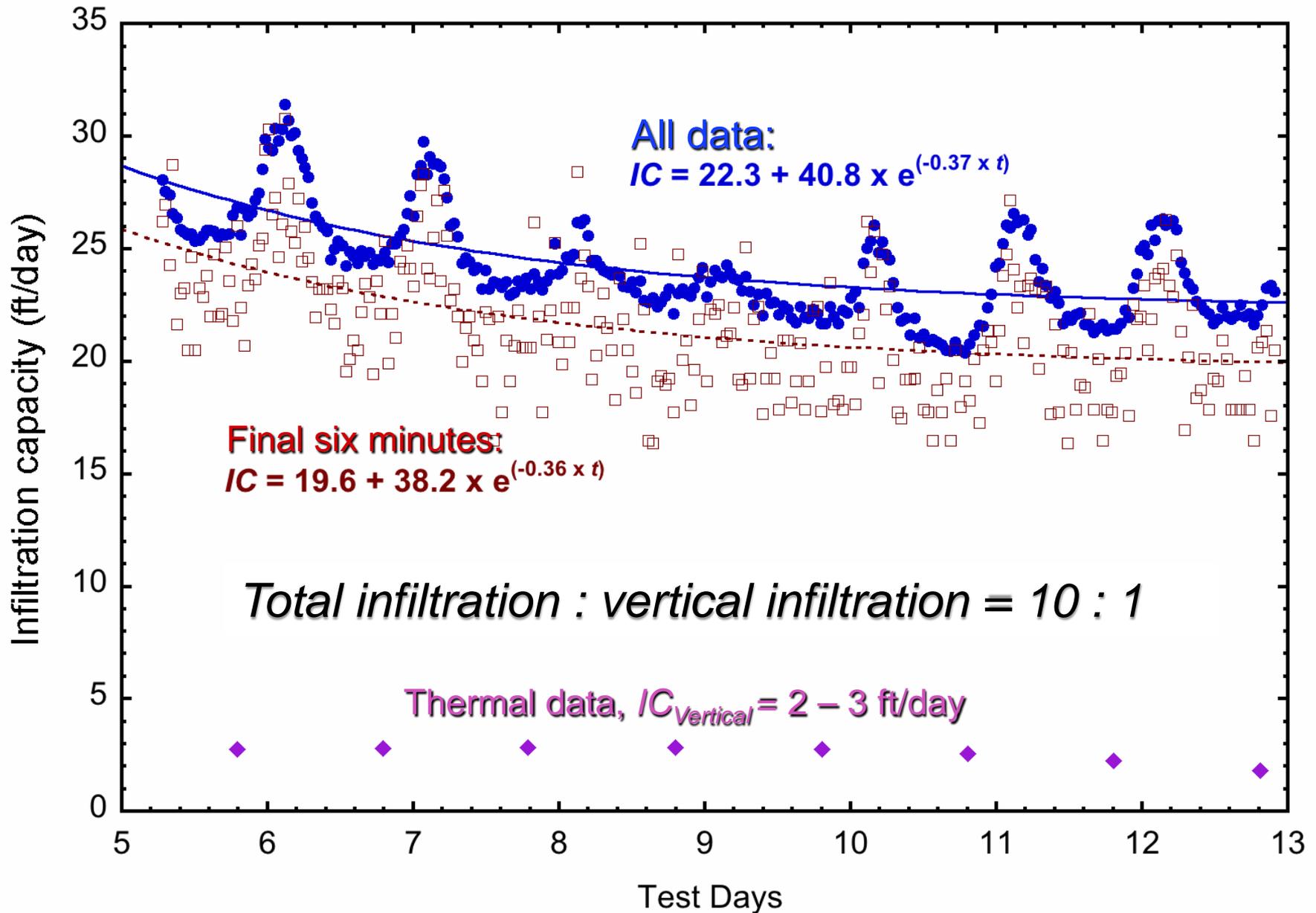
$\Delta\phi$  = Phase shift

$A_r = A_d/A_s$  = Amplitude ratio

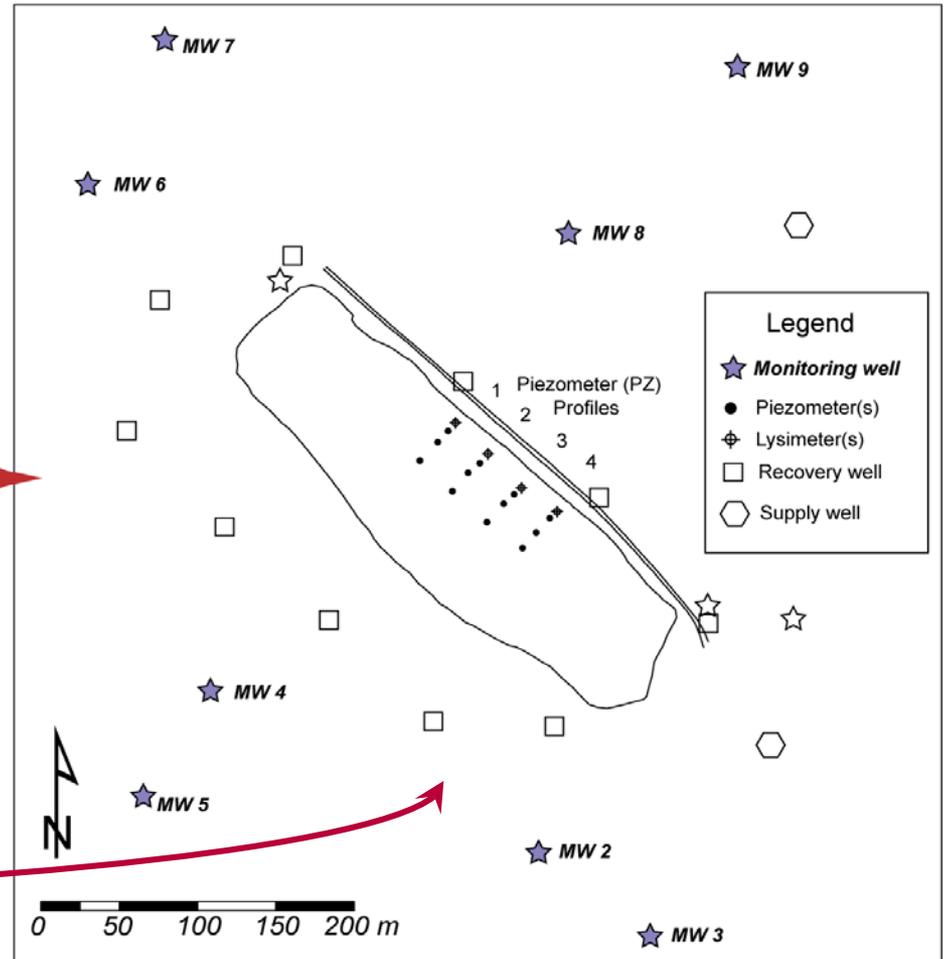
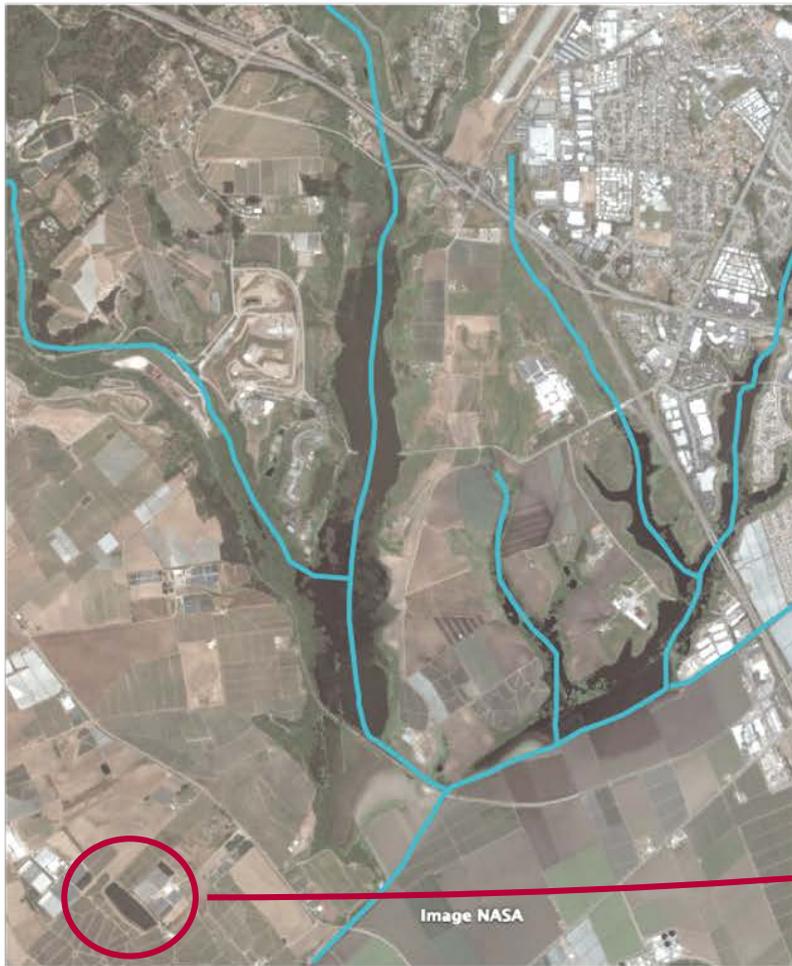
# *Infiltration Test Data: Temperature versus time*



# Infiltration Test Data: Total and vertical infiltration



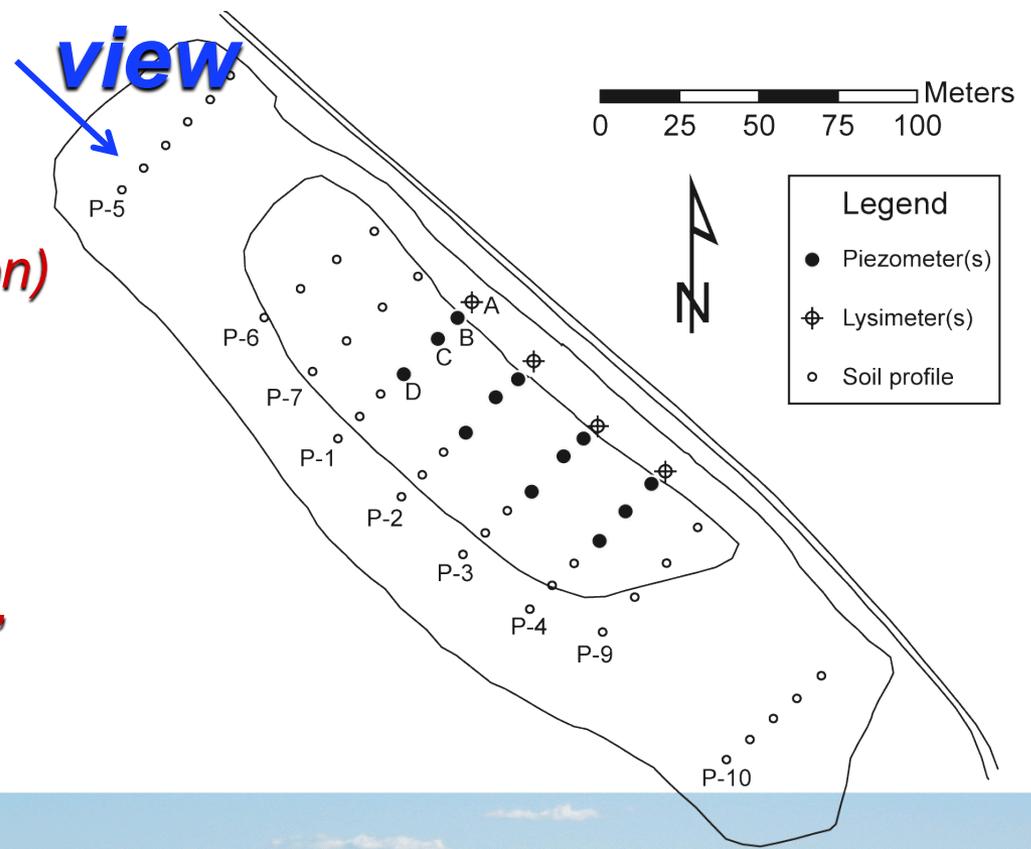
# Harkins Slough MAR project



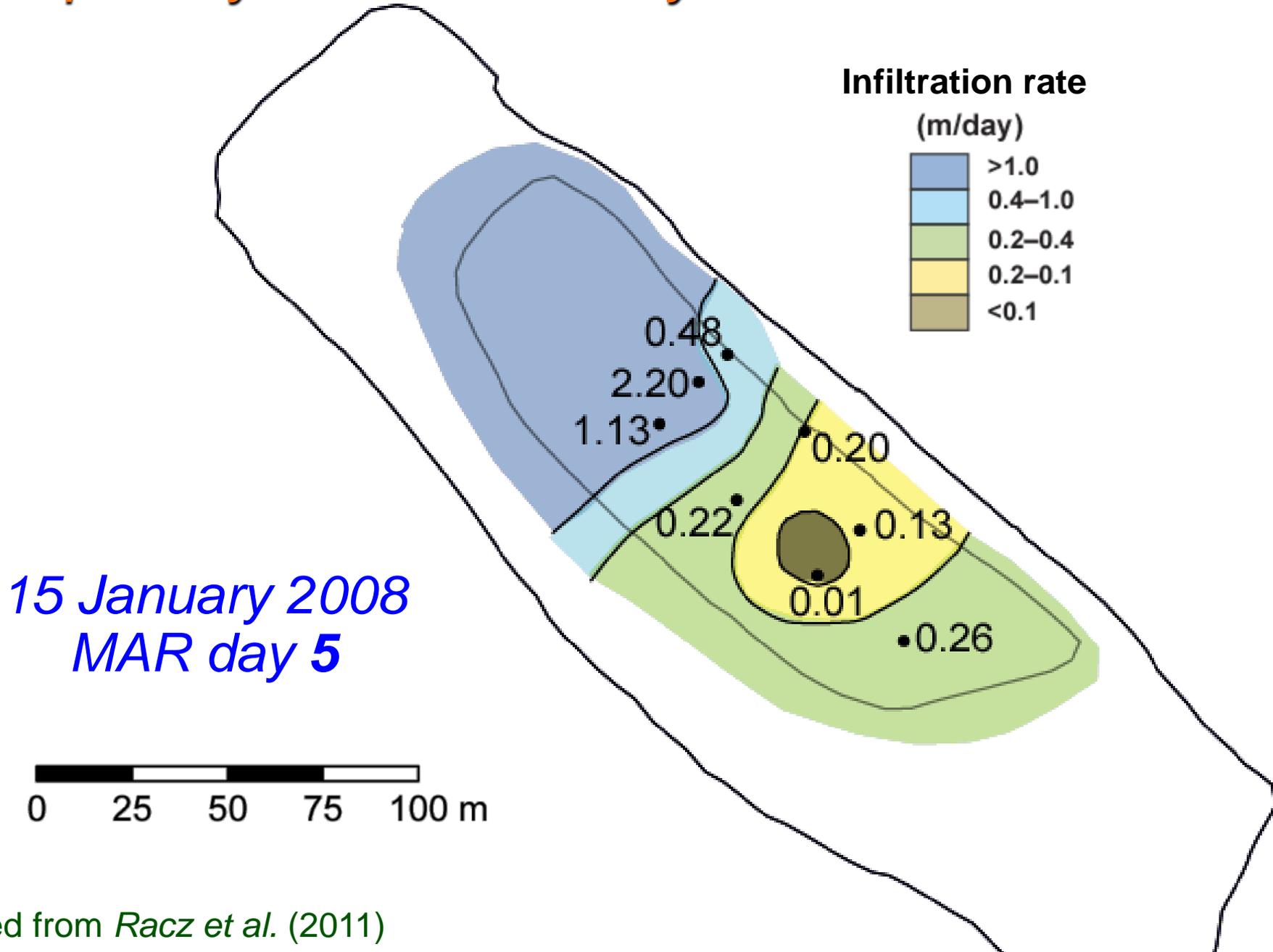
- **Up to 2000 ac-ft of water may be diverted from Harkins Slough to 7-acre recharge pond, infiltrated into shallow aquifer**
- **Water later recovered, blended with recycled water and other groundwater, distributed using coastal pipeline**

# Sampling and instrumentation

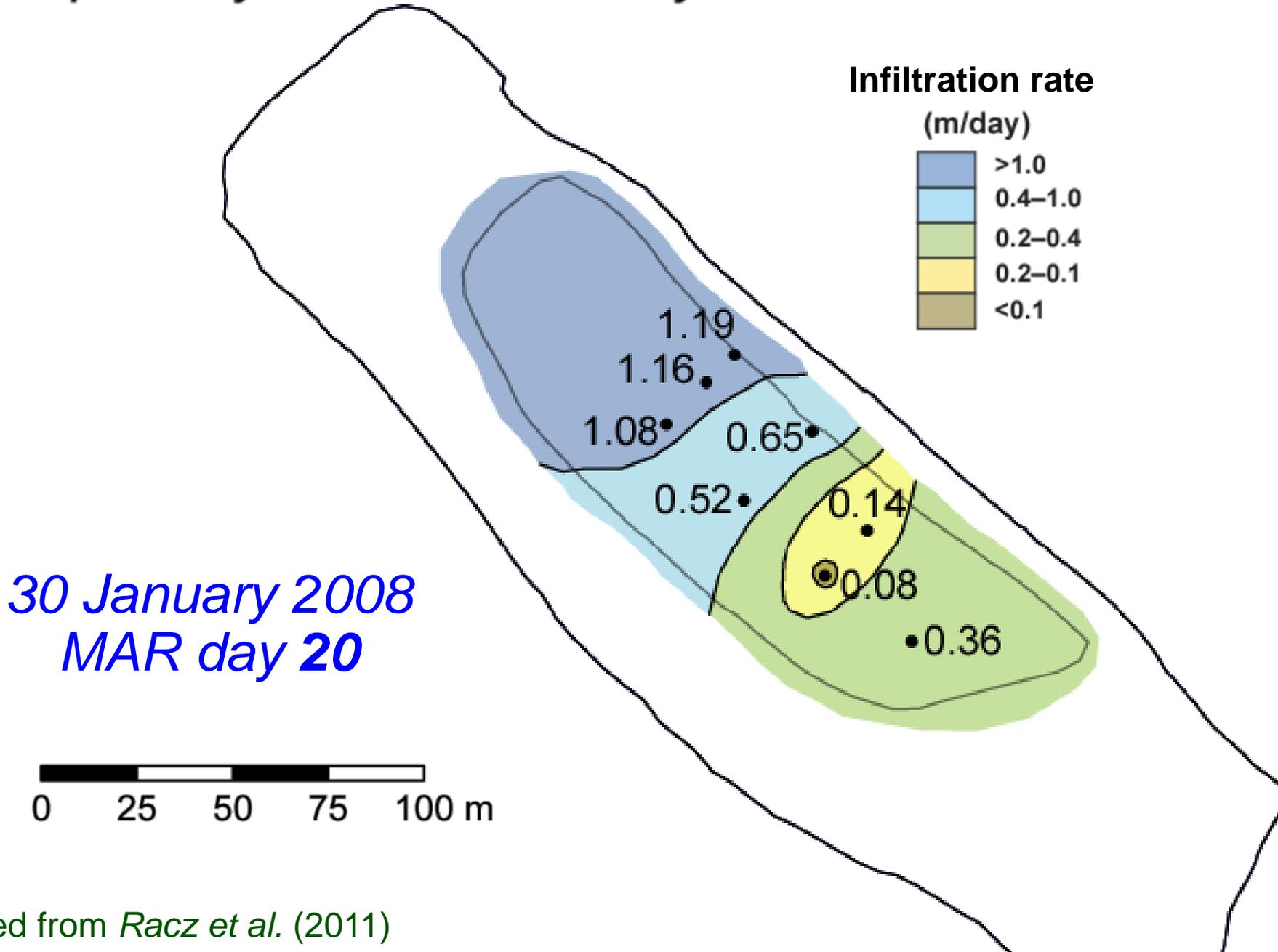
- Soil borings (grain size, carbon)
- Thermal and pressure probes (flow rates, soil properties)
- Piezometers and lysimeters (infiltration-fluid sampling)
- Monitoring wells (water levels, aquifer water sampling)



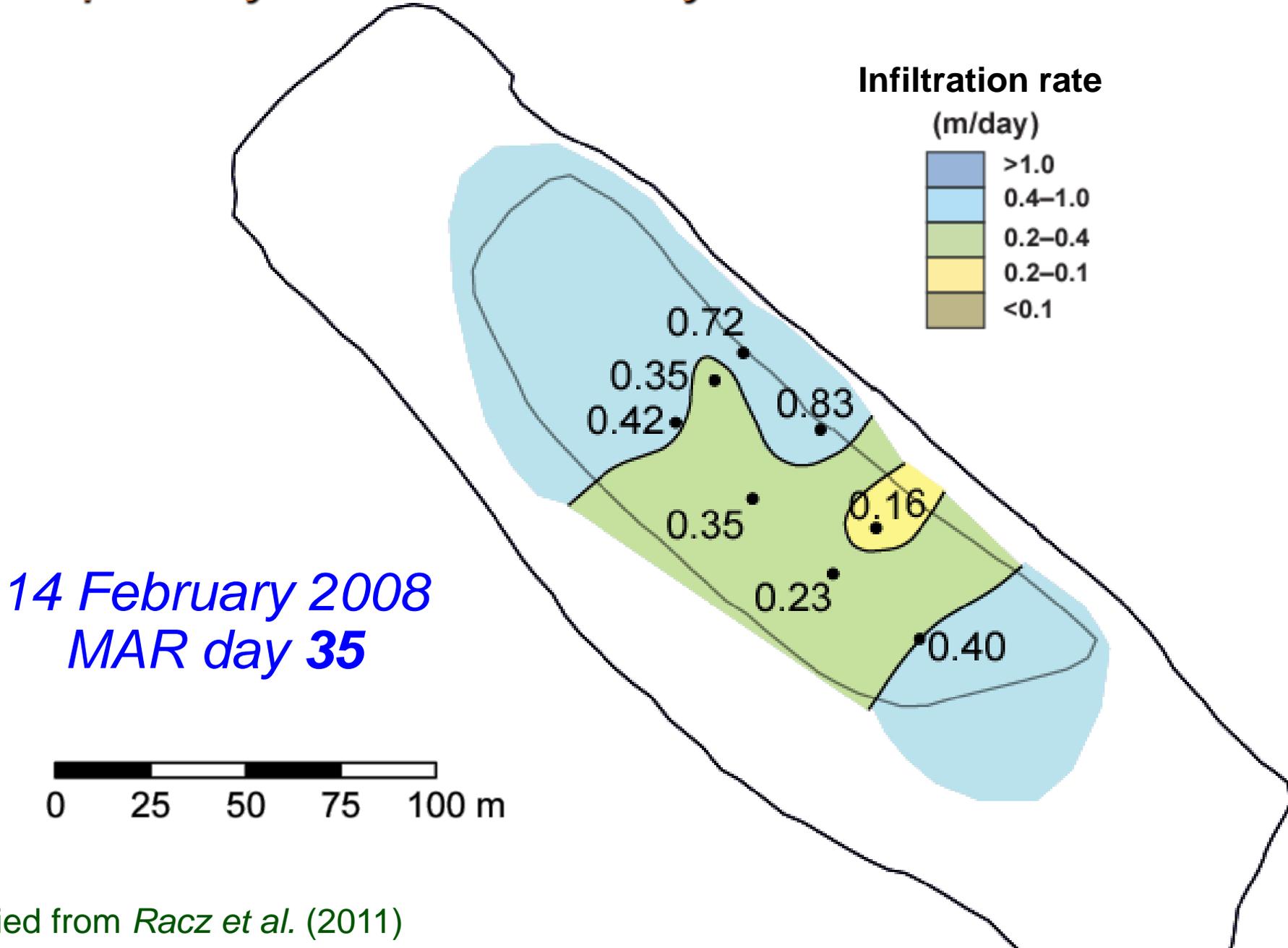
# Spatially variable and dynamic infiltration



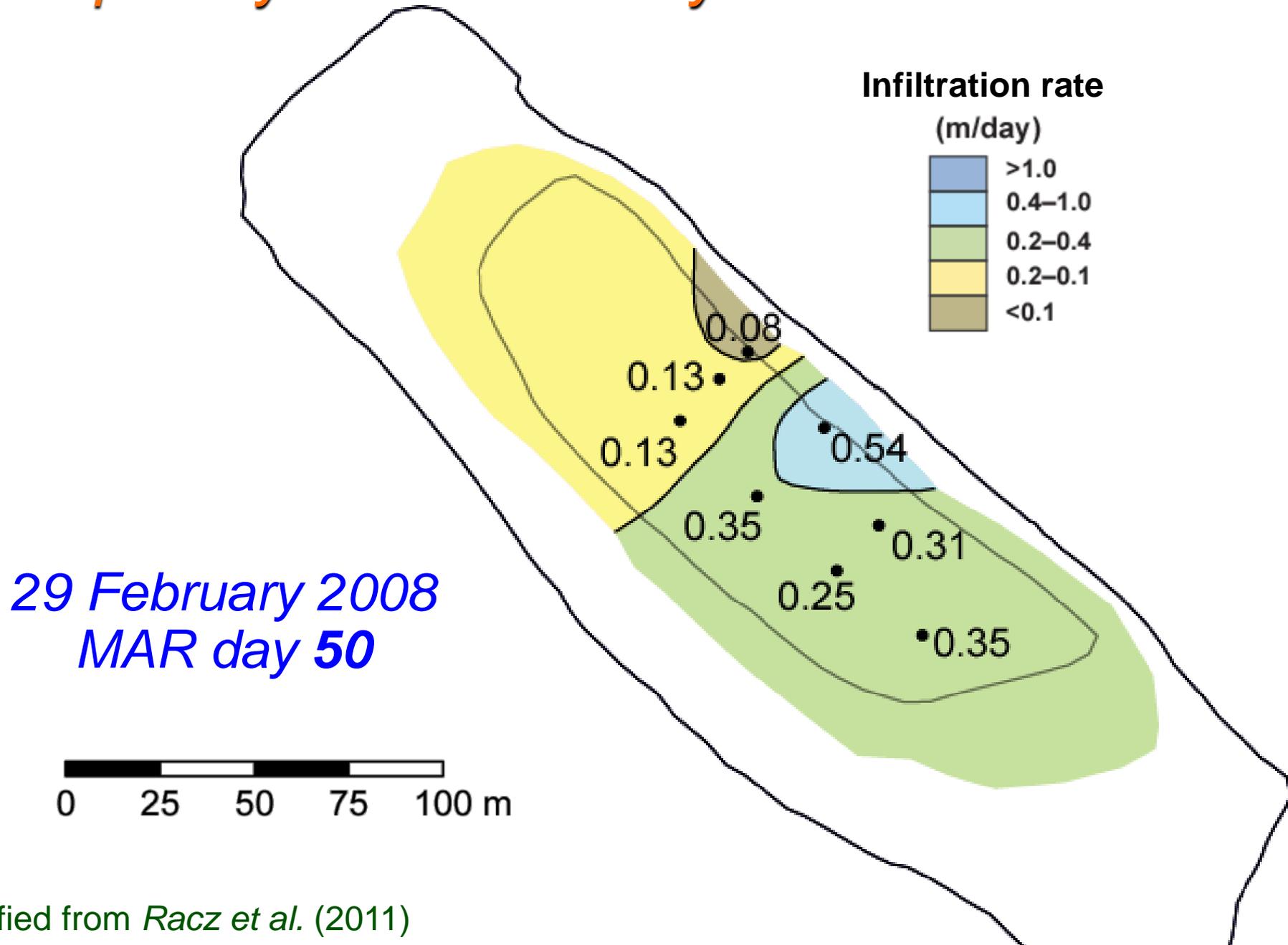
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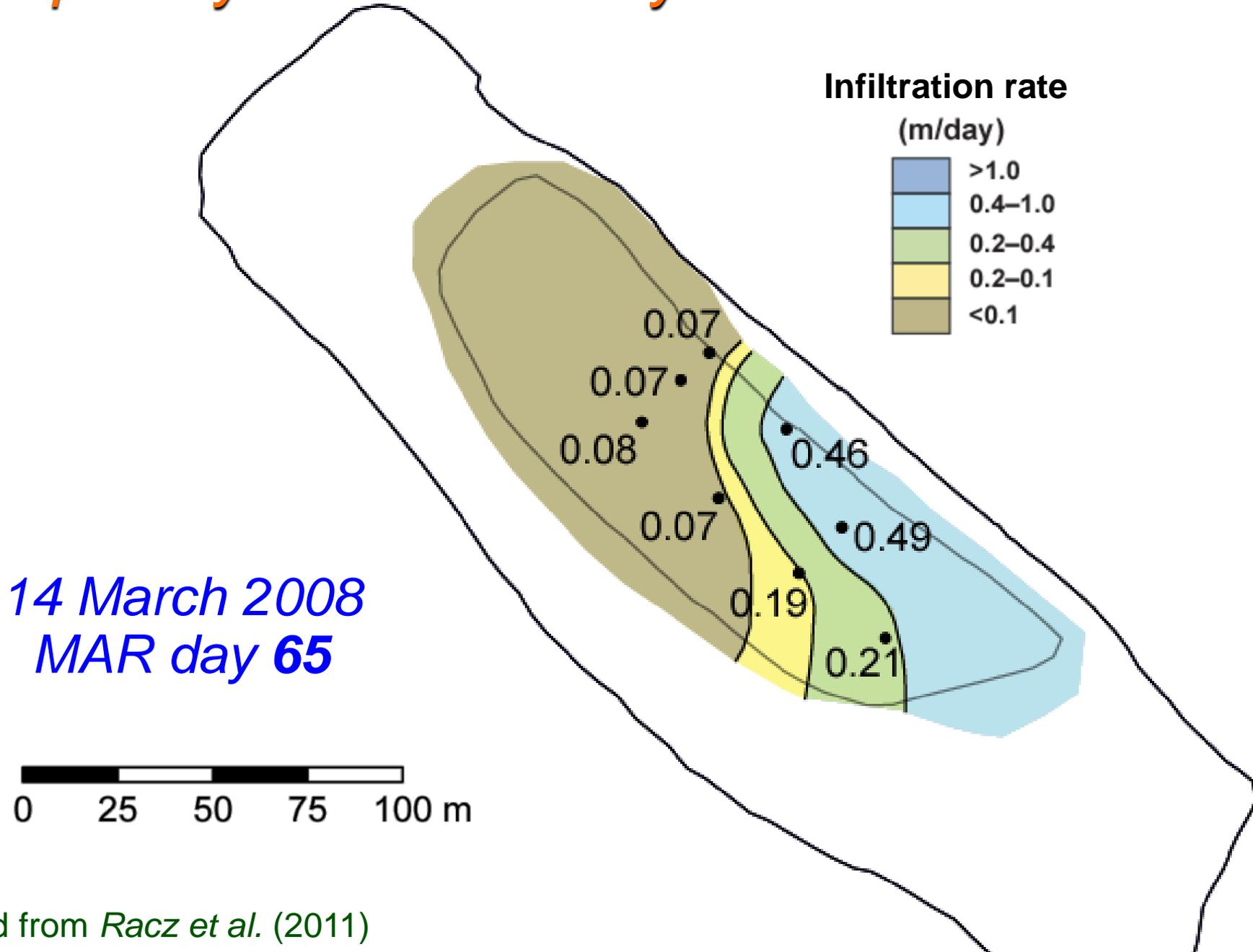
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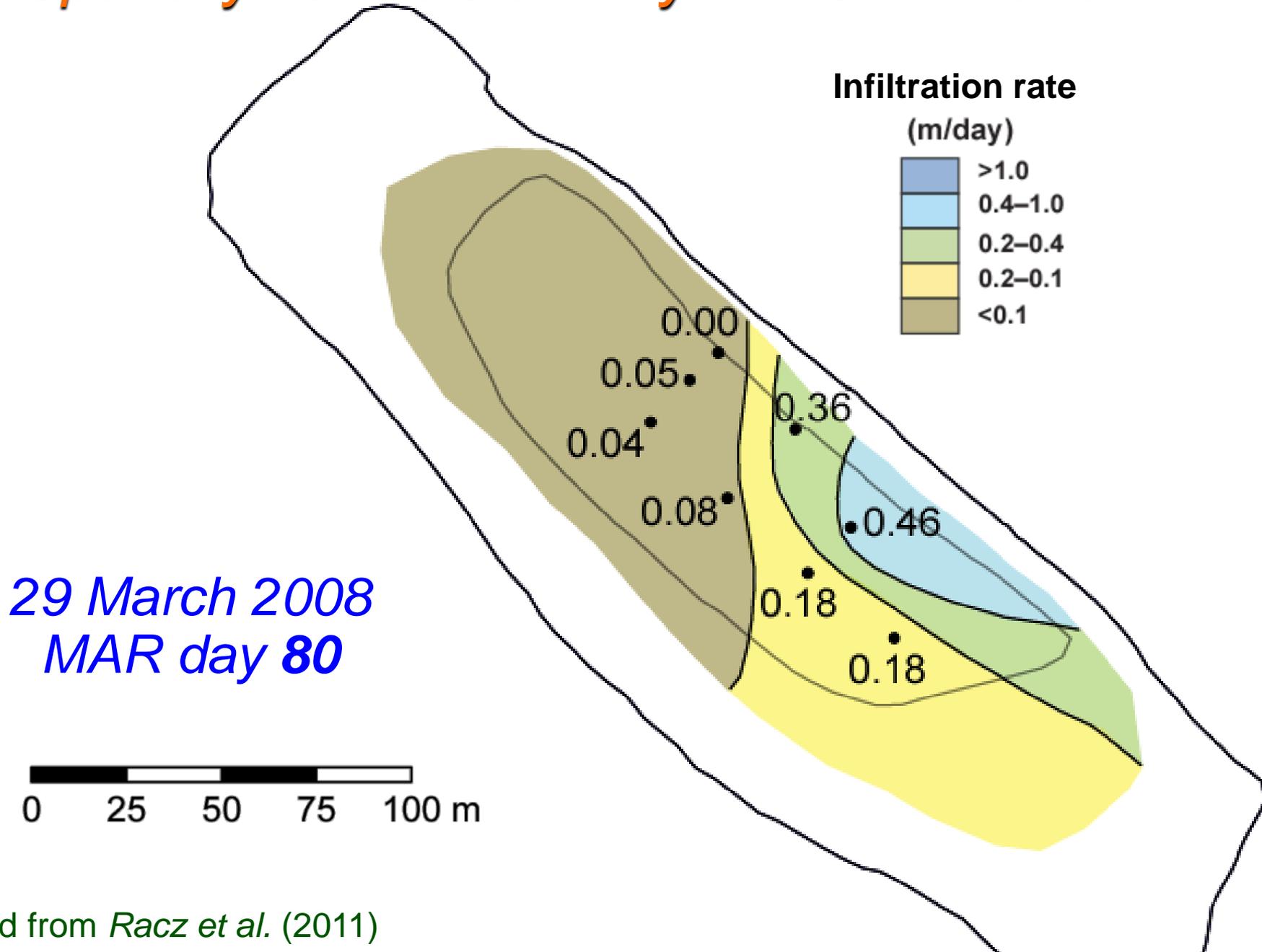
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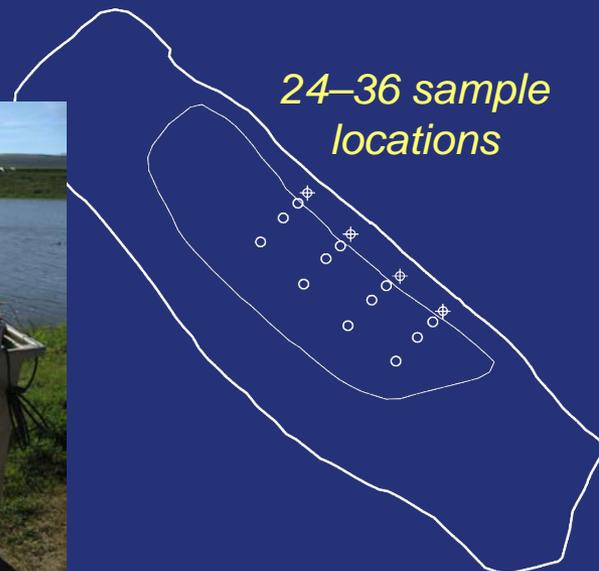
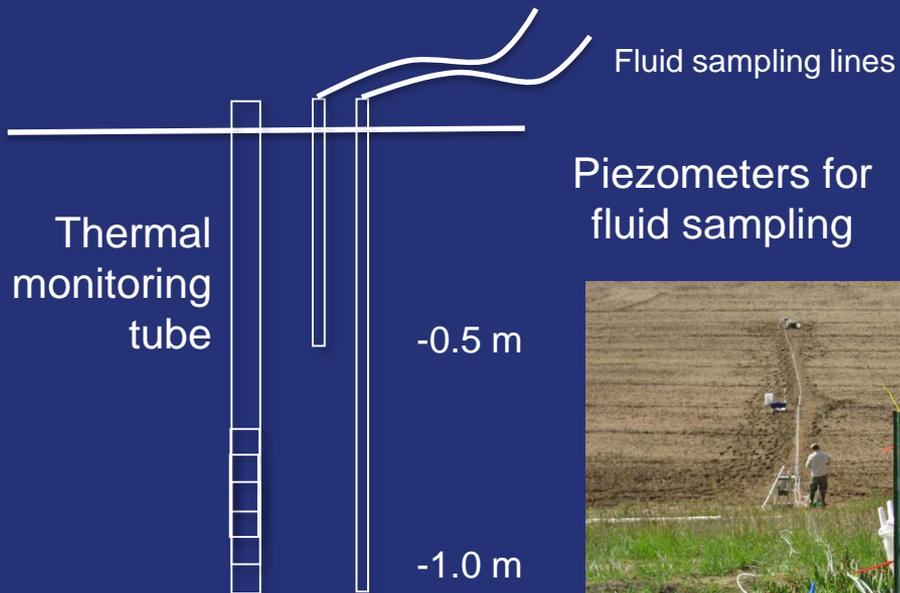
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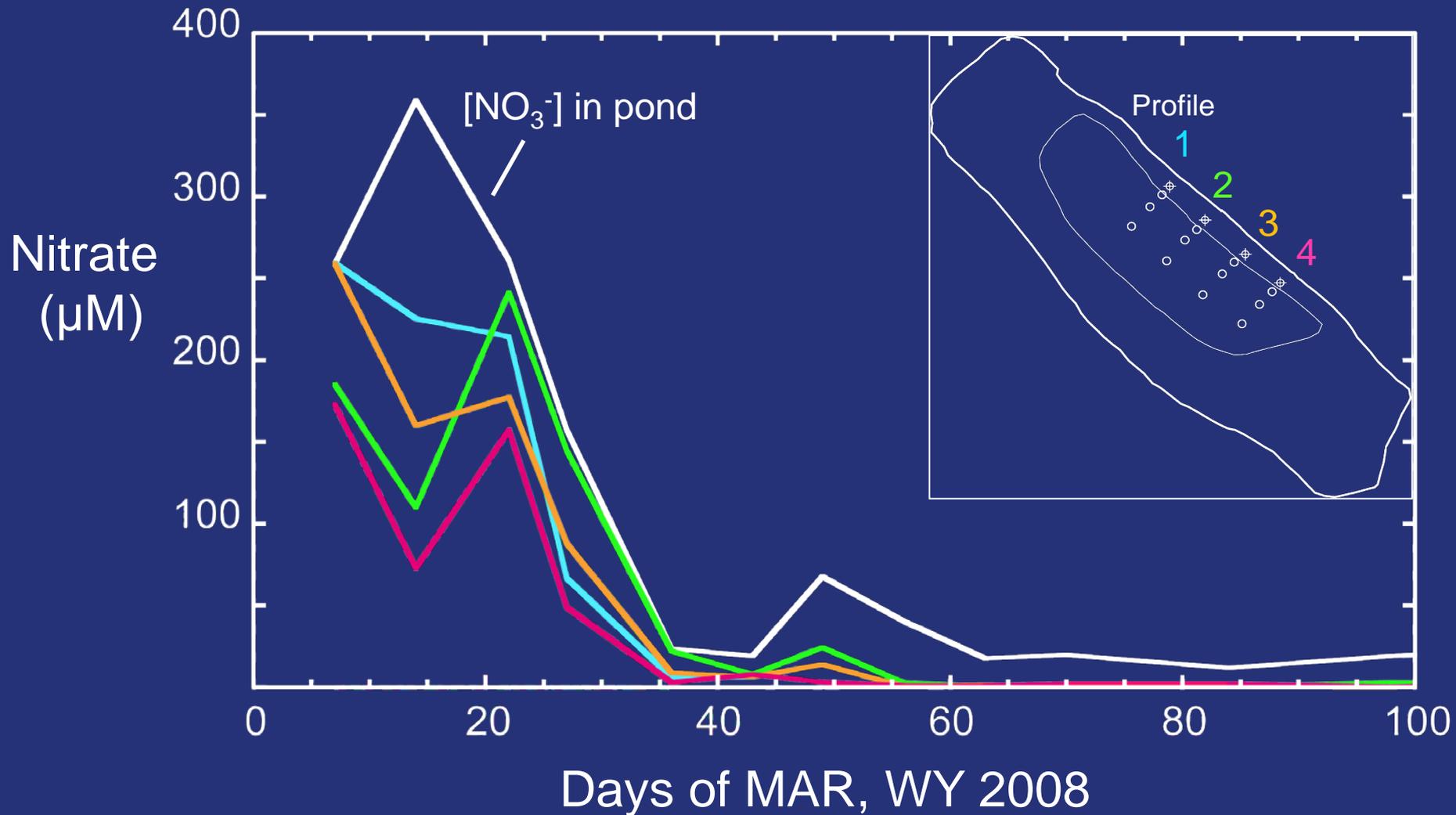


# Fluid sampling to assess changes in water quality as a function of infiltration rate, other parameters

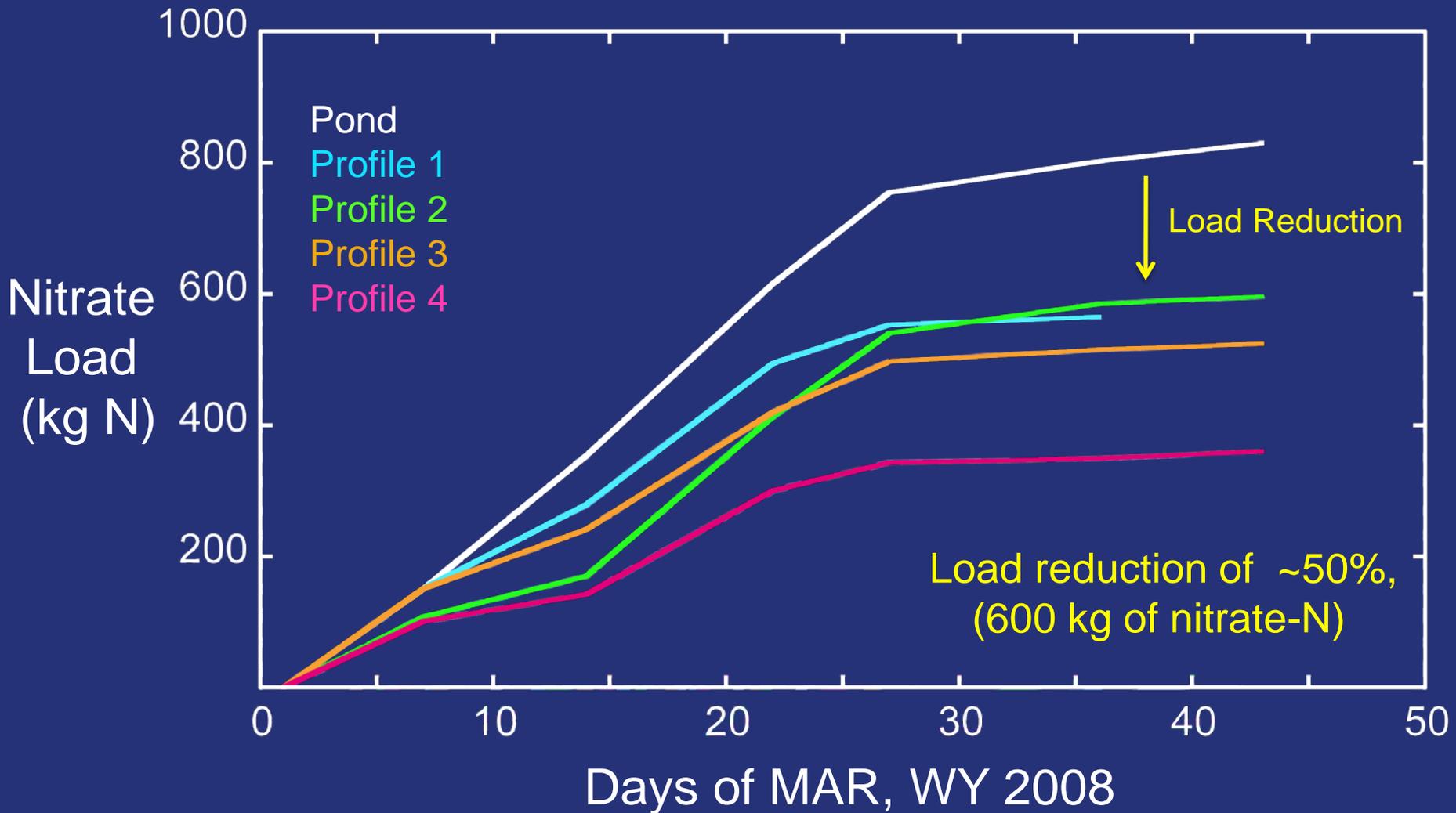


C. Schmidt, USF

# Nitrate concentration is reduced during infiltration



## Nitrate load is reduced as well...



...as a function of infiltration rate

Schmidt et al. (2011a)



# The Recharge Initiative

Replenish • Recover • Restore

[www.rechargeinitiative.org](http://www.rechargeinitiative.org)

*Thank you!*

*Questions?*

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