Linking Stormwater Collection to Managed Aquifer Recharge: Mapping, Modeling, Measurement and Monetization

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City of Santa Cruz

Meeting of the Water Commission

4 April 2016

This is a once-in-a-lifetime opportunity

- Sustainable Groundwater Management Act (SGMA) of 2014
  - California's first statewide groundwater management

March 2016

Designing Effective Groundwater Sustainability Agencies:
CRITERIA FOR EVALUATION OF LOCAL GOVERNANCE OPTIONS

Michael Kiparsky, Dave Owen, Nell Green Nylen, Juliet Christian-Smith, Barbara Cosens, Holly Doremus, Andrew Fisher, and Anita Milman

Groundwater Provides and Receives Hydrologic System Services

Groundwater

Guest Editorial/ by A.T. Fisher
Sept/Oct, 2015

- ***SGMA recognizes SW-GW interactions!***
- ***GSAs need to maintain revenue sources***

Sustainable Groundwater Governance

What GSAs will require

Presentation Overview

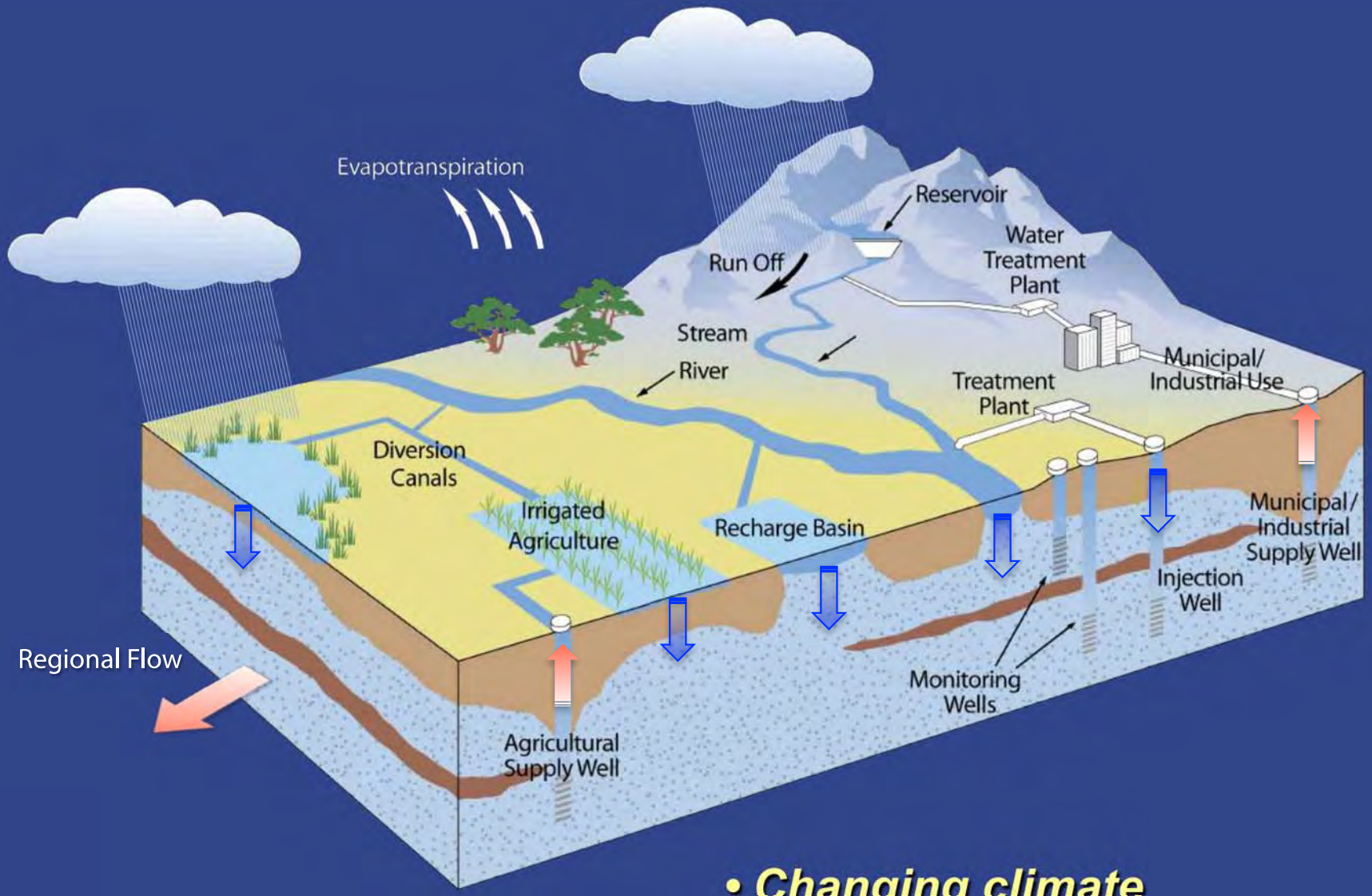
Key question: How can MAR help to secure and sustain freshwater resources?

Presentation:

- Challenges to groundwater management
- One option to increase supply:
  Distributed stormwater collection – managed aquifer recharge
- Analysis of spatial data to assess surface/subsurface conditions
- Analysis of stormwater runoff to assess supply options
- Field assessment of potential project sites
- Monetizing recharge as an incentive: *Recharge Net Metering*

Questions, discussion

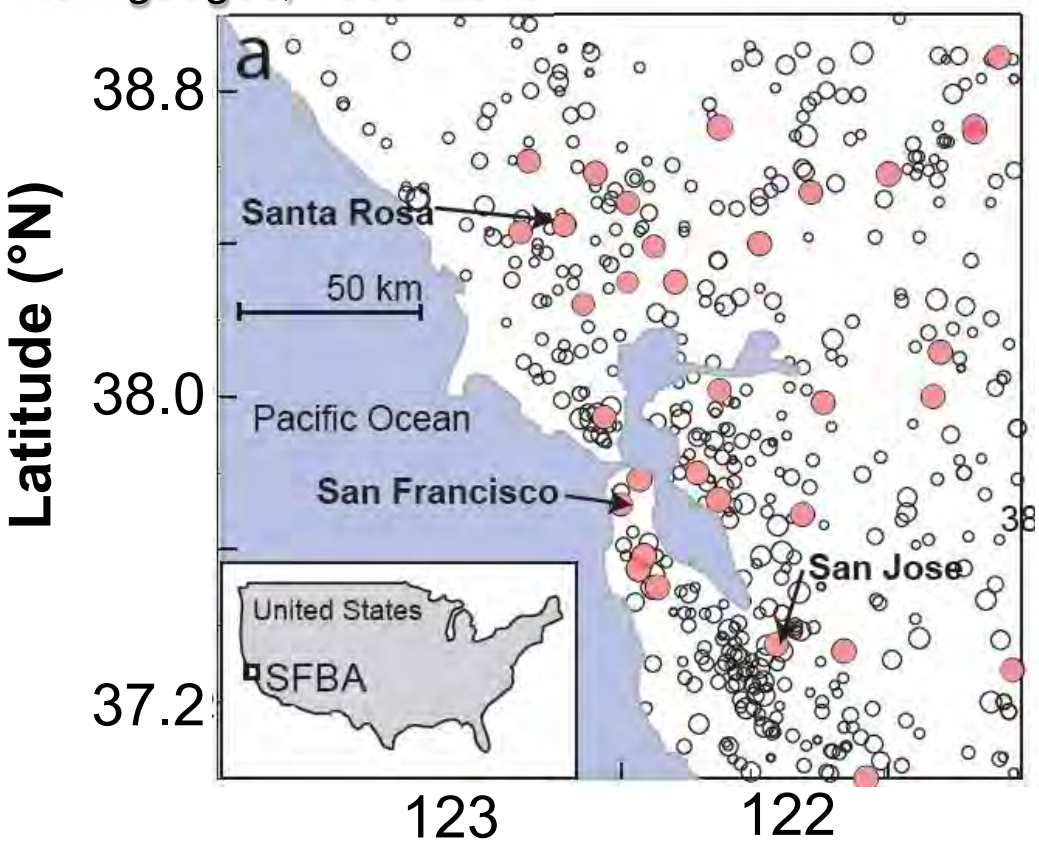
Groundwater Supplies in California Face Multiple Challenges

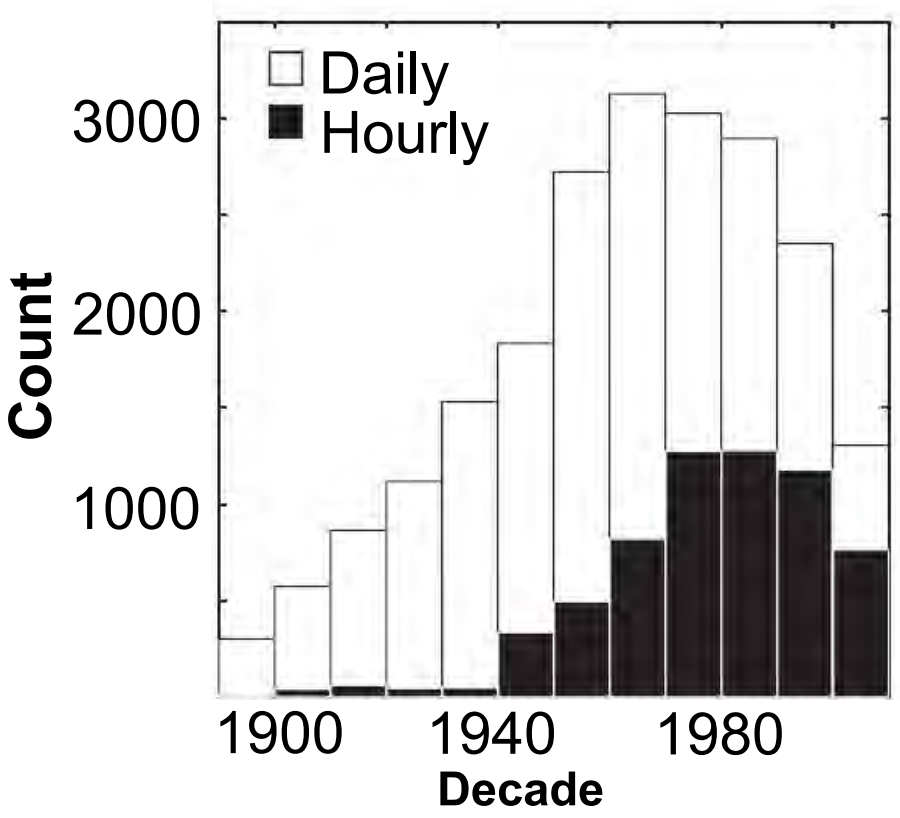


- ***Changing climate***
- ***Shifting land use***
- ***Increasing demand***

Precipitation Records from the San Francisco Bay area (SFBA)

Rain gauges, 1890–2010



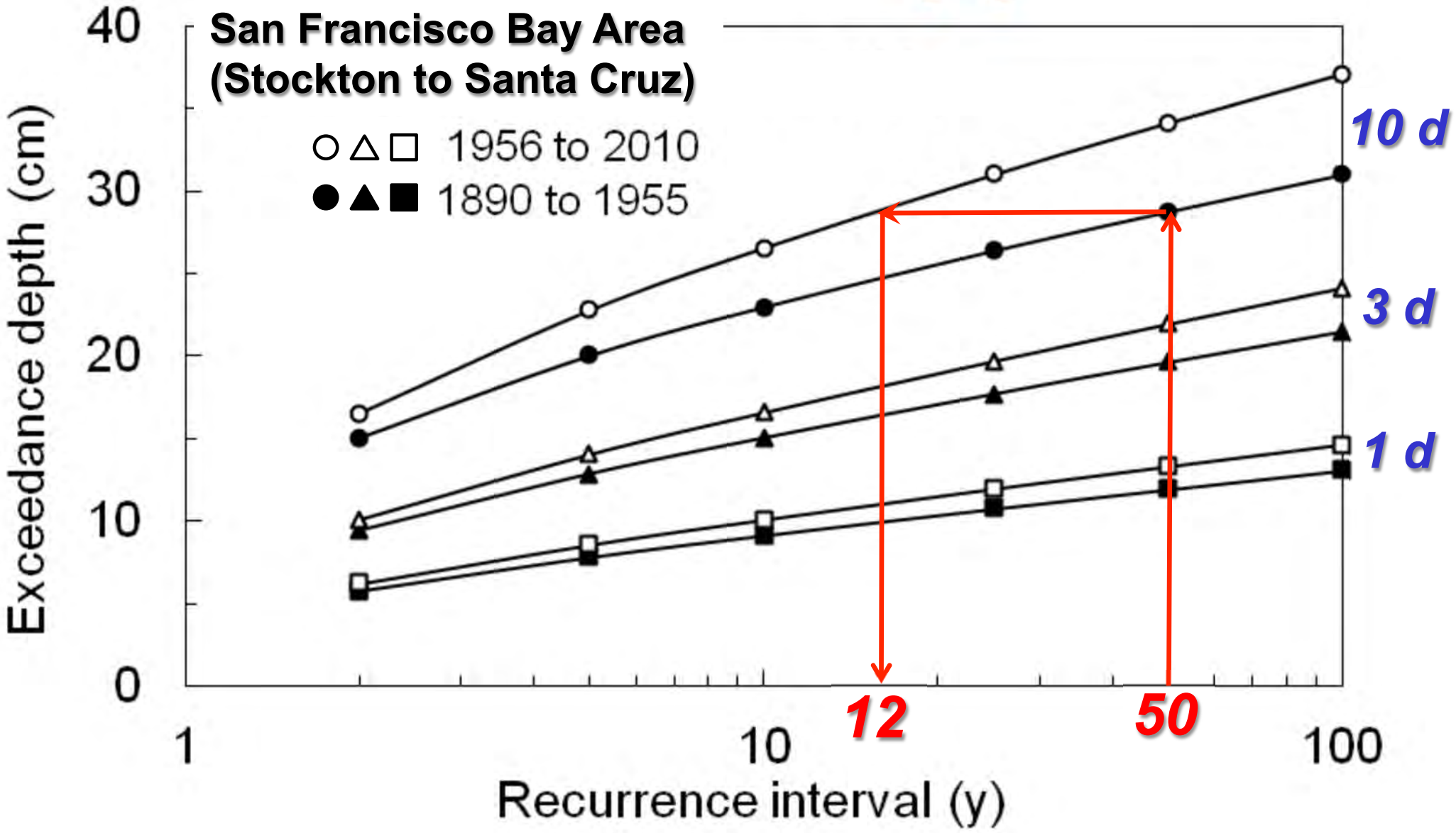


>600 daily stations
>400 hourly stations
31 stations with >100 yr records

- Examined *72 depth-duration pairs* for the largest events of each water year

Russo et al. (2013 – *JGR Atm.*)

Storm intensity has increased in last 120 years, with largest storms changing most



Changes in storm intensity are greater than changes in annual precipitation

Russo et al. (2013 – JGR Atm.)

Implications for Resource Management

Increasing storm intensity tends to mean:

- *a large fraction of runoff (versus infiltration)*

→ ***less groundwater recharge***

Other impacts of more intense precipitation:

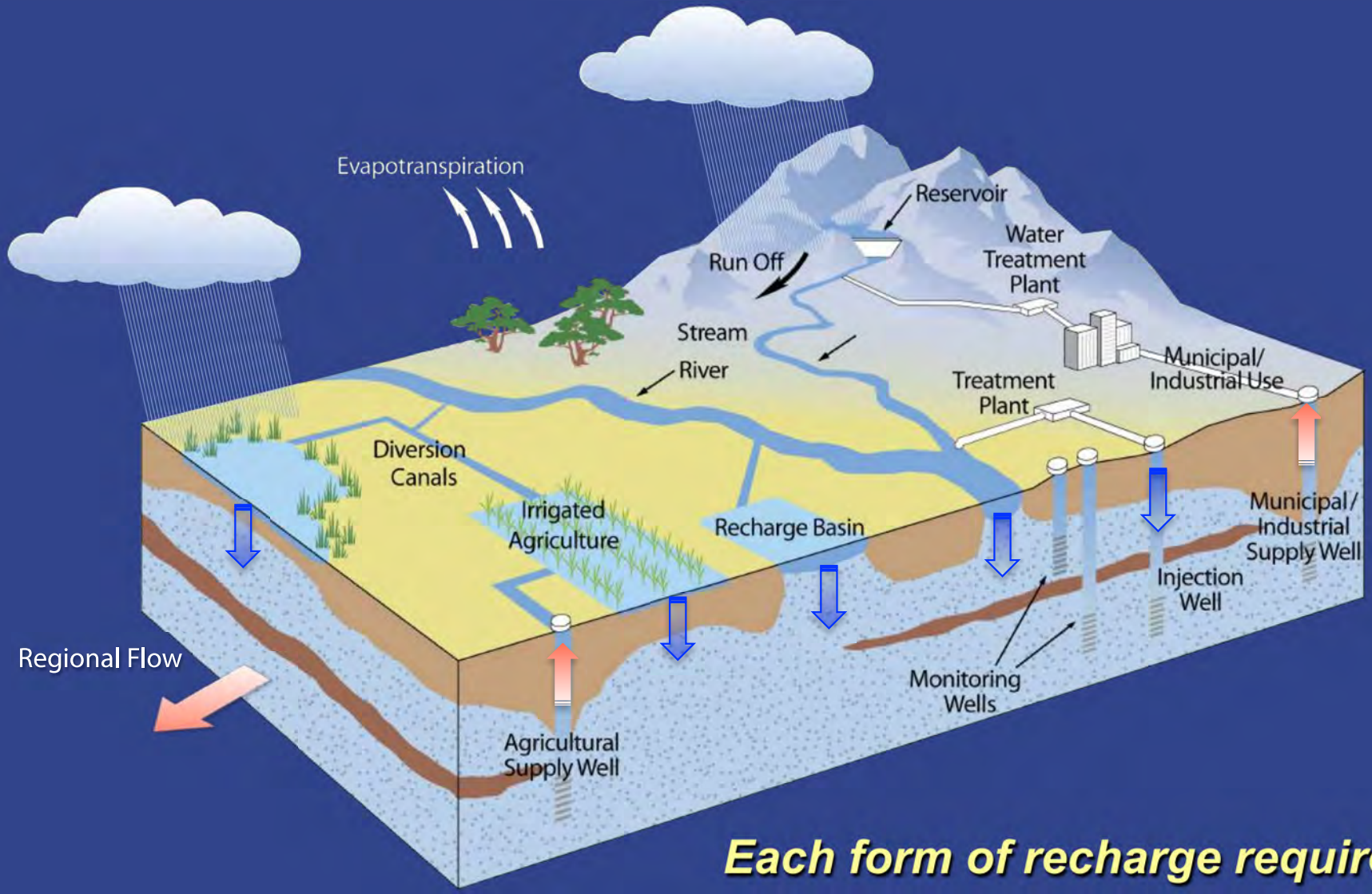
- *more rapid peak discharge (more frequent flooding)*
- *more erosion and export of sediment*
- *infrastructure not designed for current and future conditions*

Not a model prediction: part of the historical record!

Other factors that reduce groundwater supplies:

- *Changes in land use (less input)*
- *Increased demand (more output)*

Many forms of groundwater recharge (natural, managed)



Each form of recharge requires specific conditions, properties, design, operations

Different Scales of Managed Recharge

Low-impact development (LID)

Regional spreading grounds

Different Scales of Managed Recharge

Low-impact development (LID)	Regional spreading grounds
1-10 af/yr per site	10^4-10^5 af/yr per site

Stormwater as a Source for MAR

Low-impact development (LID)

1-10 af/yr per site

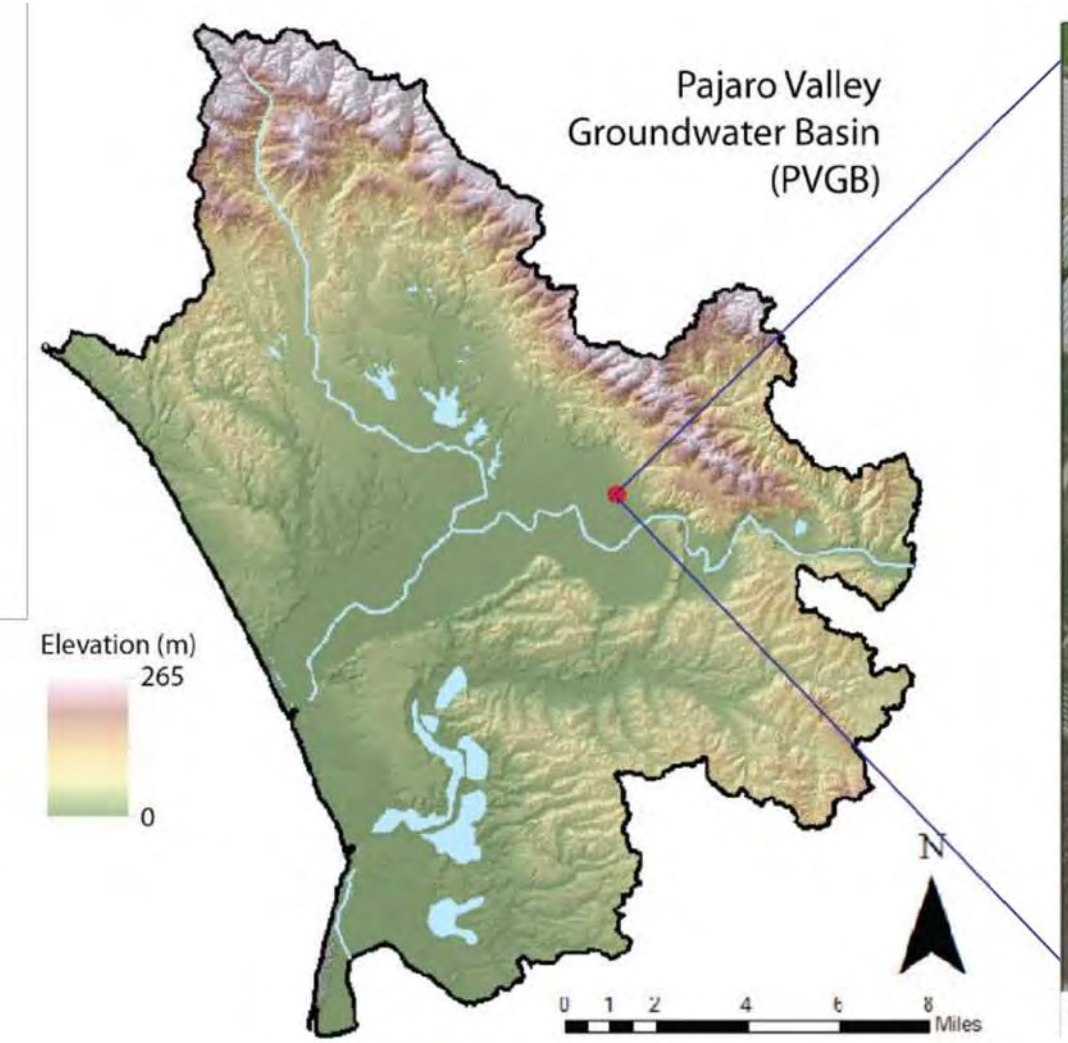
Distributed Stormwater Collection → MAR (DSC-MAR)

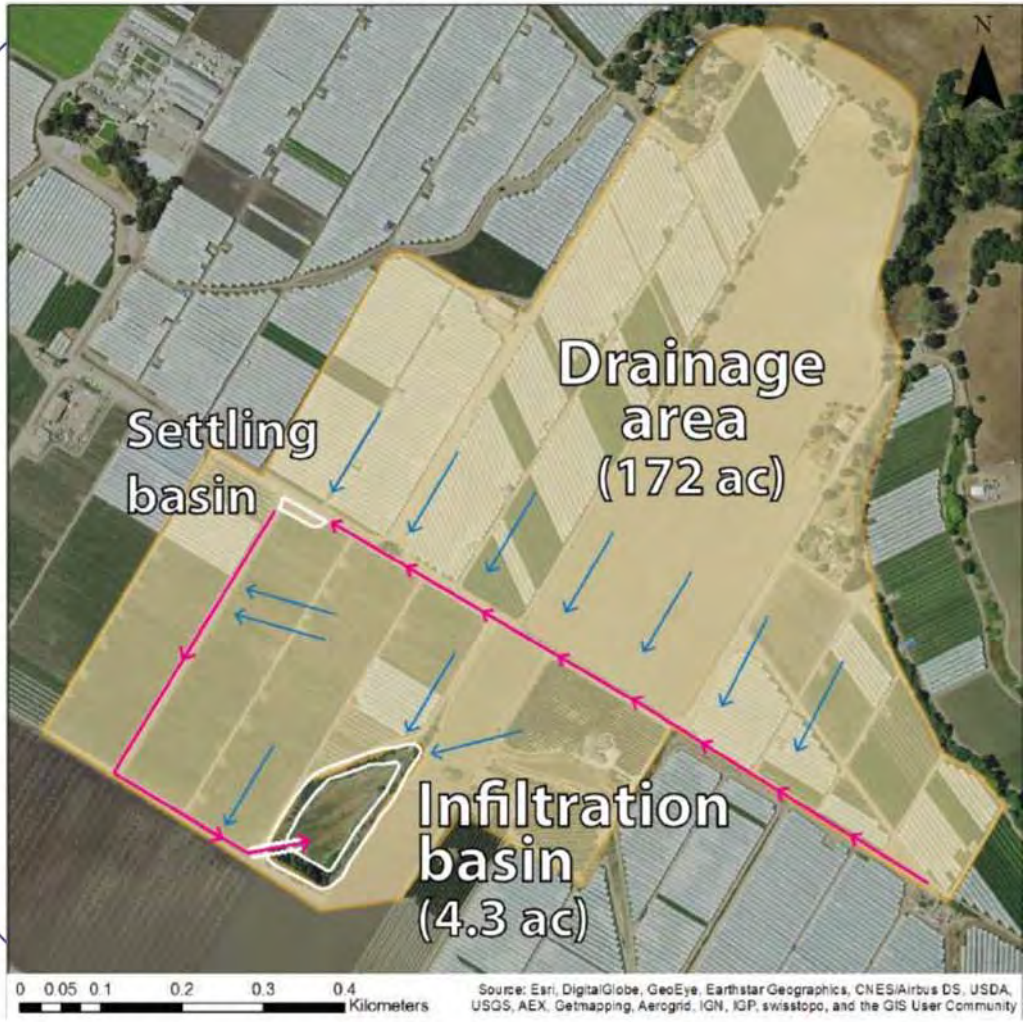
10^2-10^3 af/yr per site

Regional spreading grounds

10^4-10^5 af/yr per site

Stormwater as a Source for MAR: Field Example





Bokariza Ranch

Project goal: ~100 ac-ft/yr

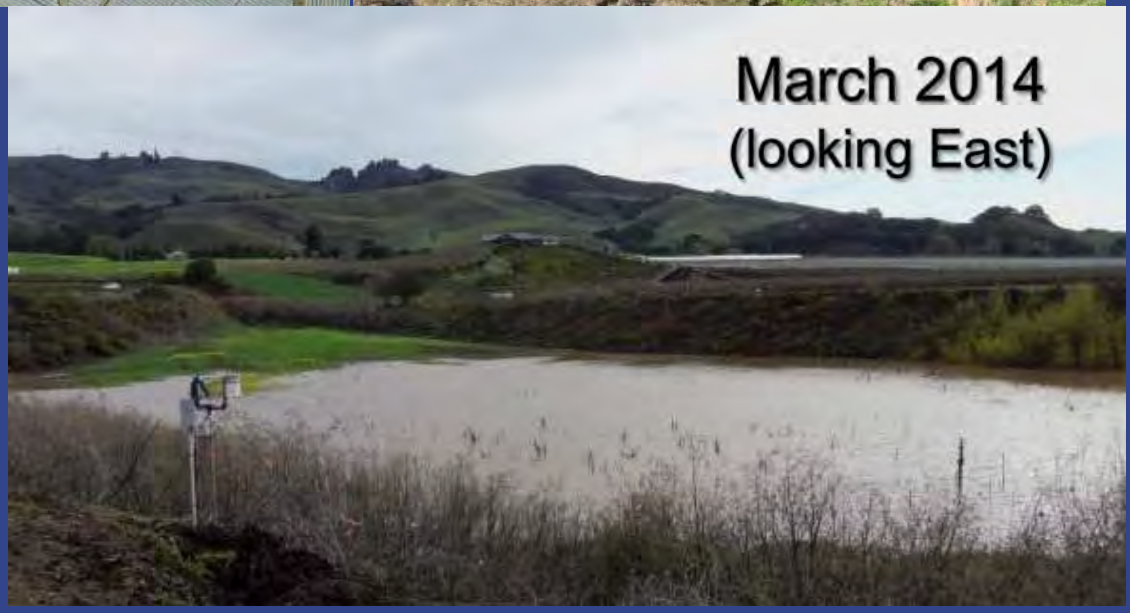
S. Beganskas

Stormwater as a Source for MAR: Field Example

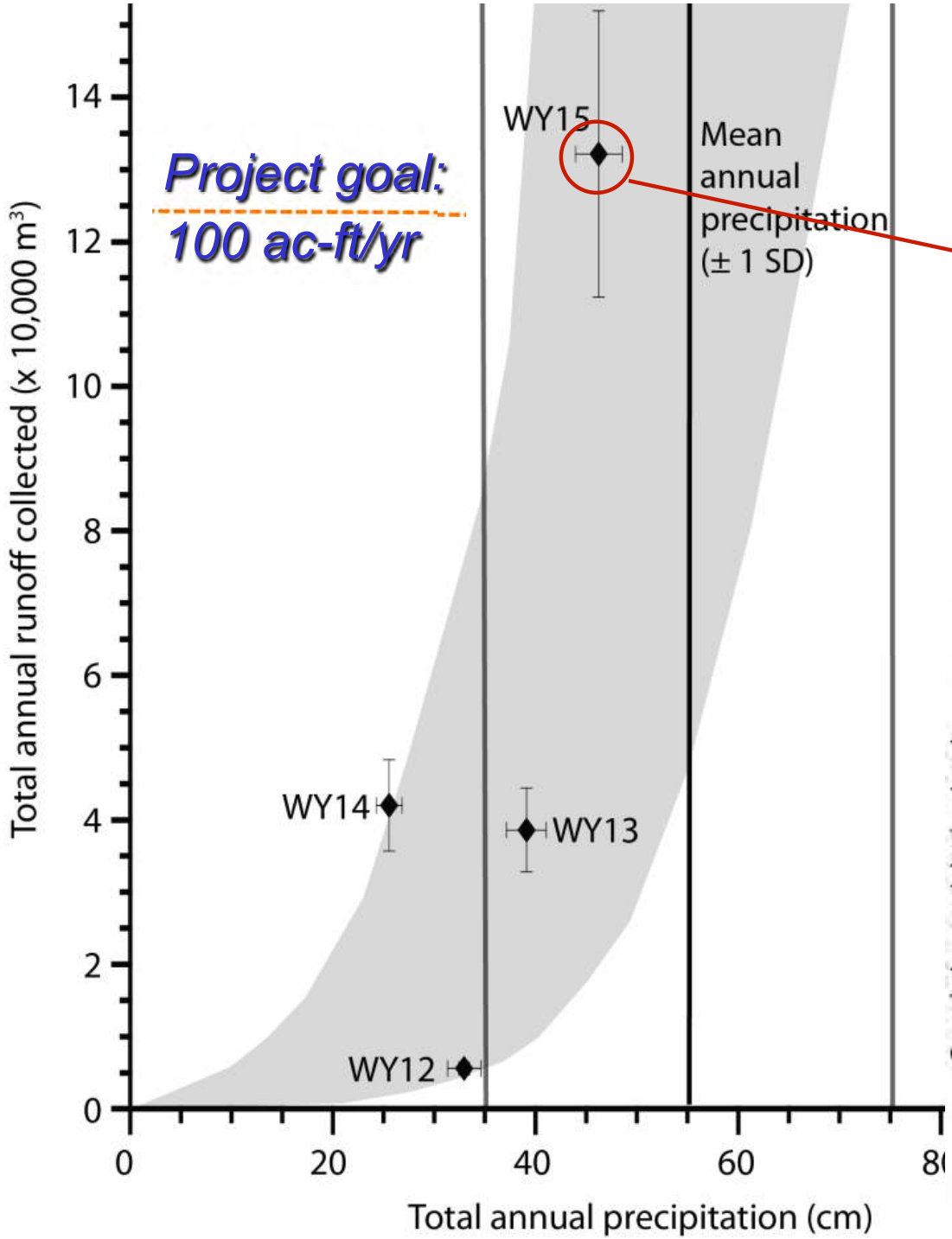
Verified:
2011-present

- Precipitation
- Water level (culvert, basin)
- Infiltration rate
- Sediment accumulation

Real-time sensor network

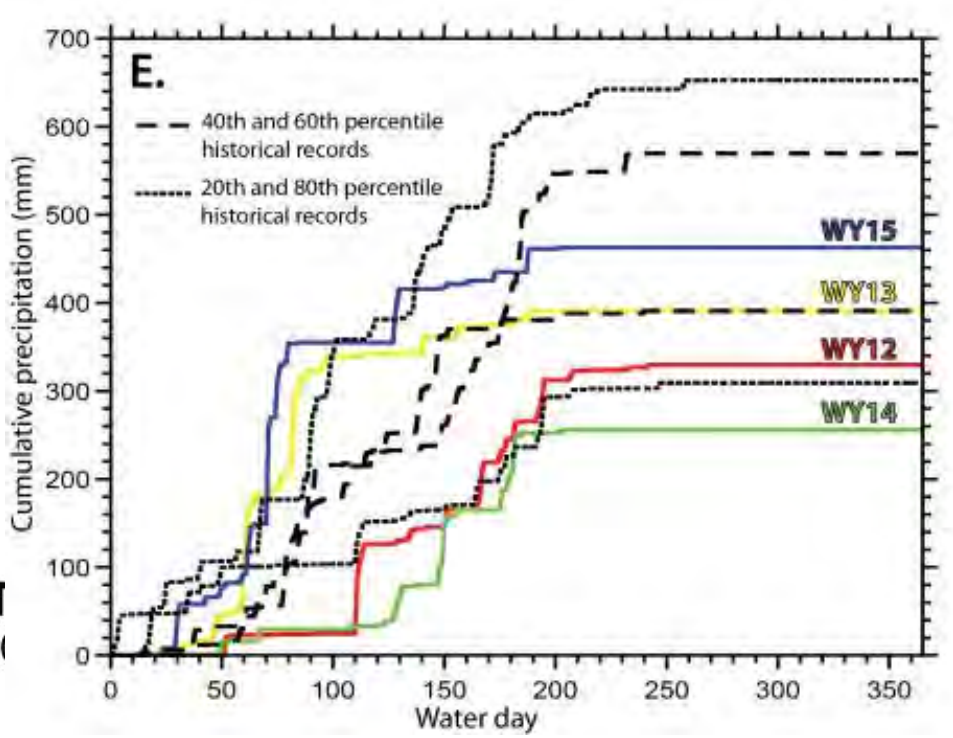


Stormwater as a Source for MAR: Field Example

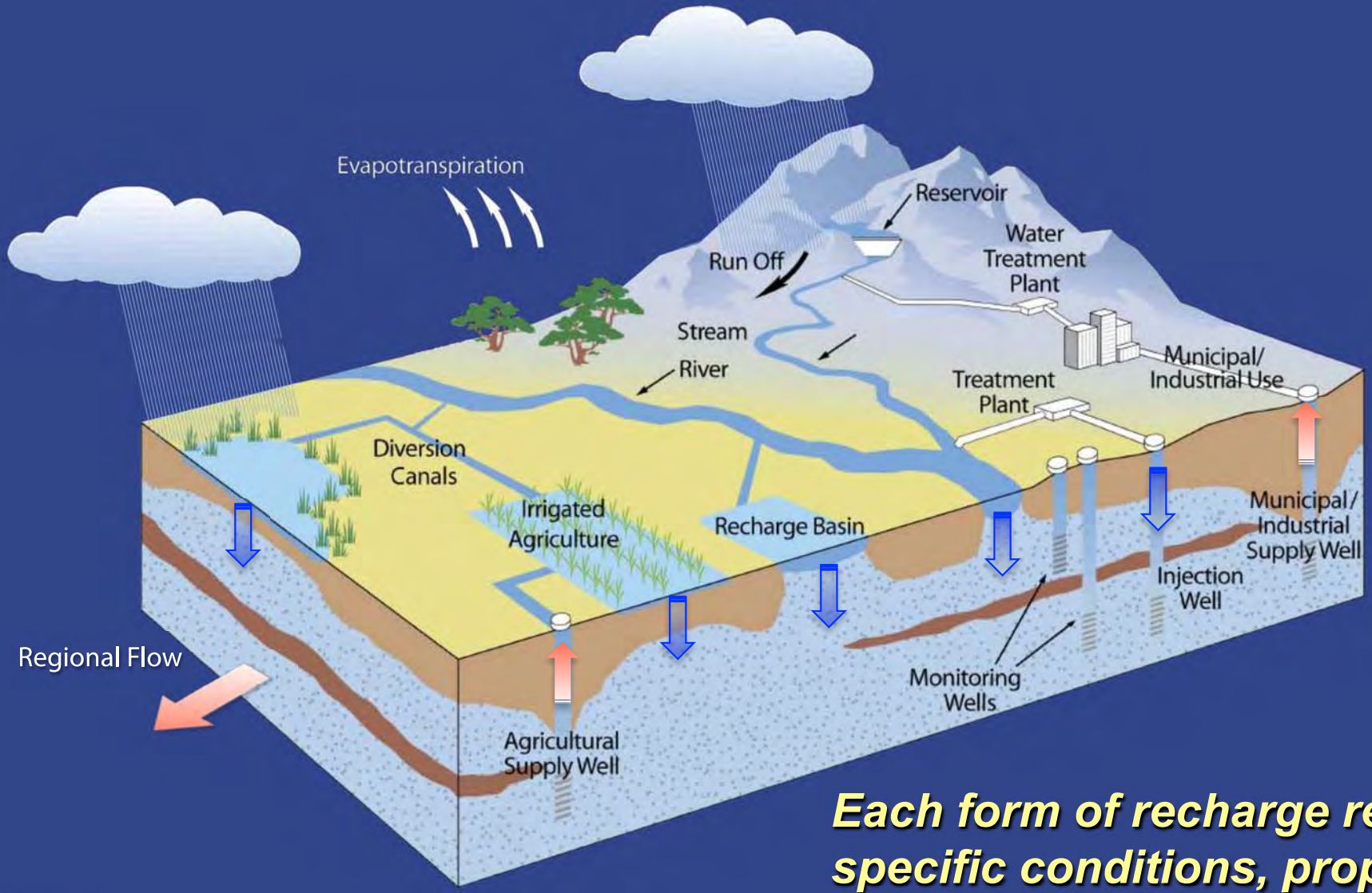


All four years are during ongoing drought

In WY15, most rain fell in a single long storm, > 100 af of runoff/infiltration!



Where to place and how to manage recharge projects…

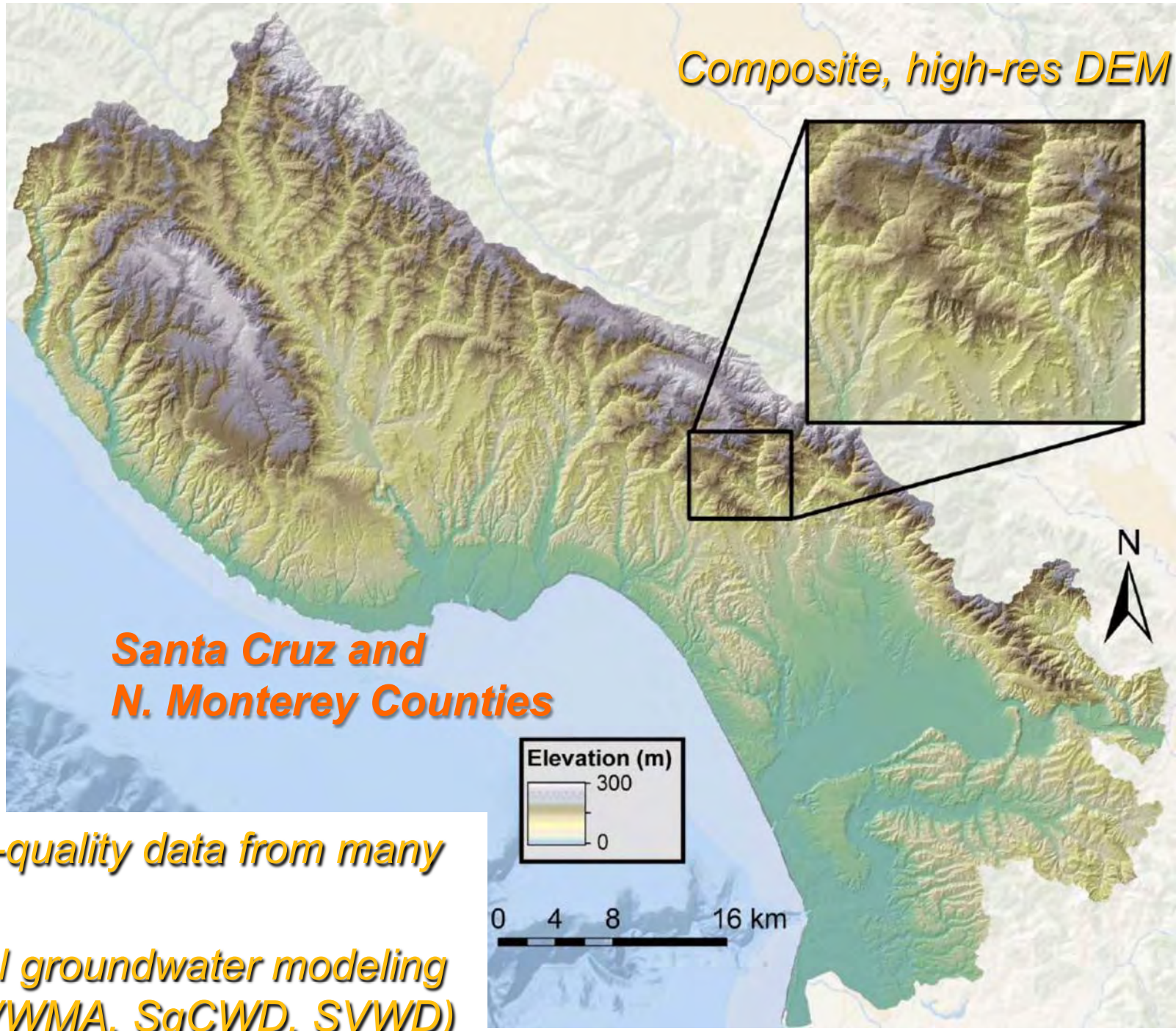


Each form of recharge requires specific conditions, properties, design, operations

Funding:

- *CS-CC Project #13-118 (lead: RCD-SCC)*
- *UC Water Security and Sustainability*

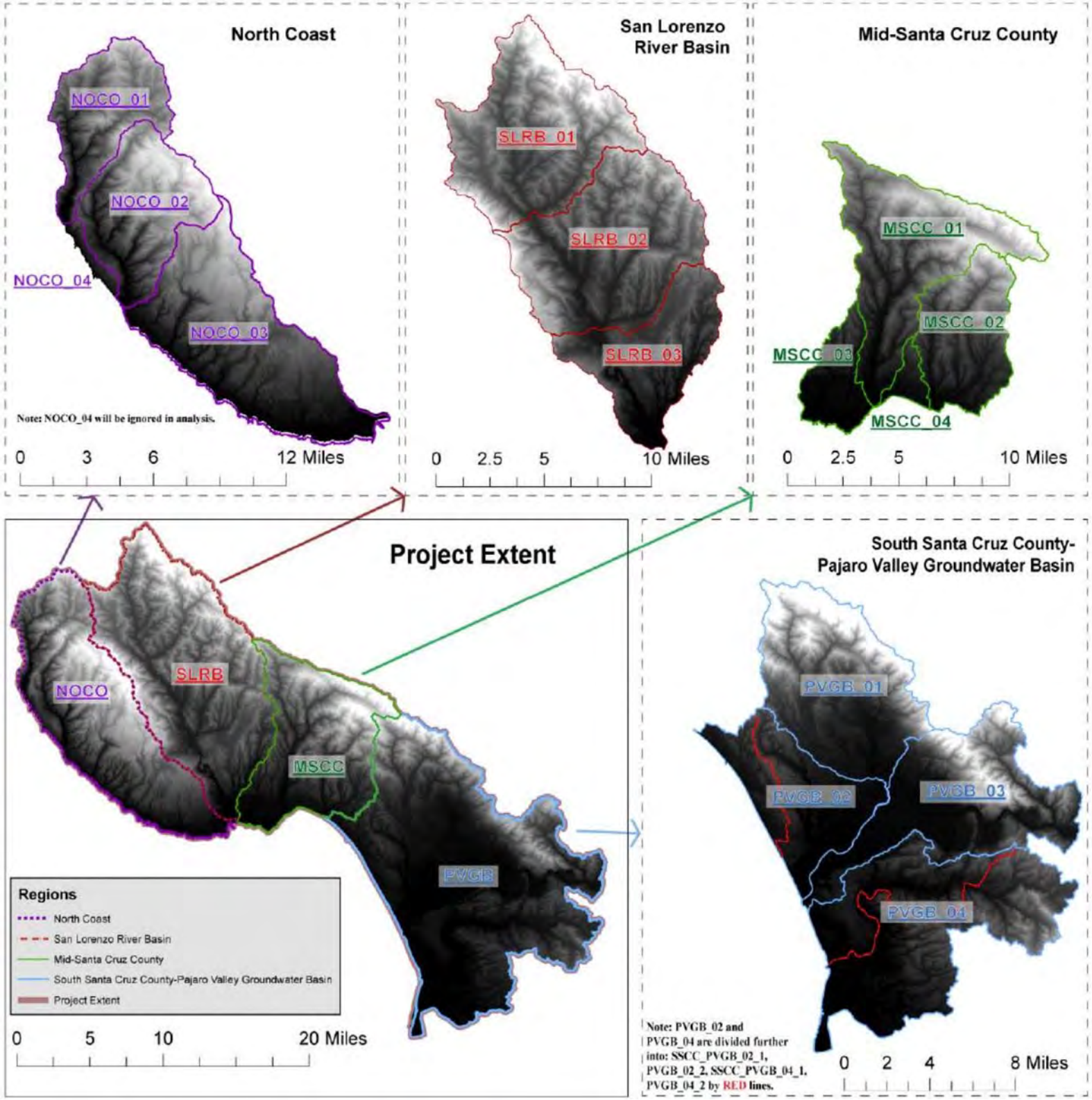
Where to Place Recharge Projects?



- *Combining high-quality data from many sources…*
- *Linked with local groundwater modeling efforts (e.g., PVWMA, SqCWD, SVWD)*

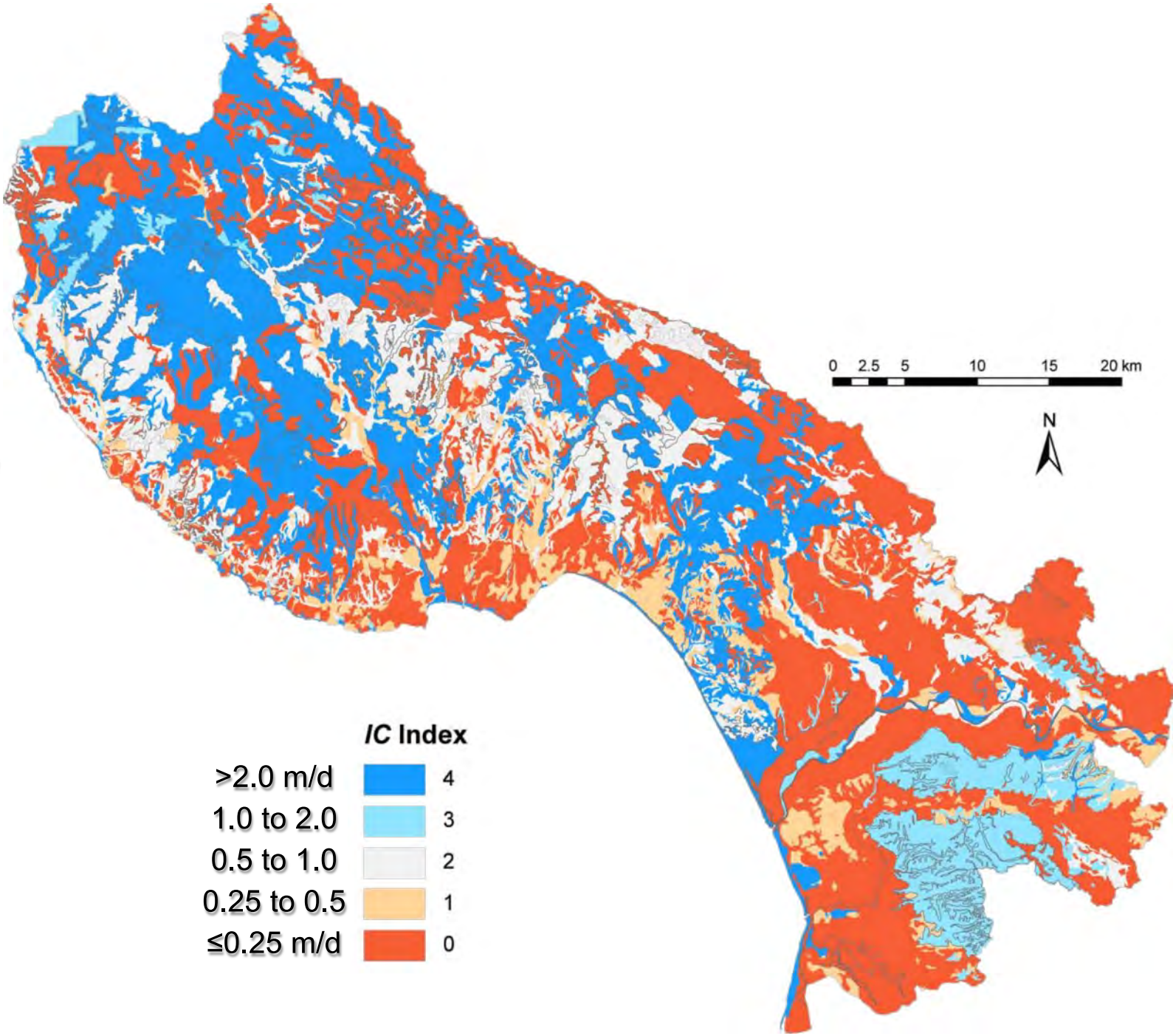
Project Extent and Basin Subareas

- Santa Cruz and northern Monterey Counties
- Four topographic basins
- One GIS project (with groundwater subareas)
- Three RO projects



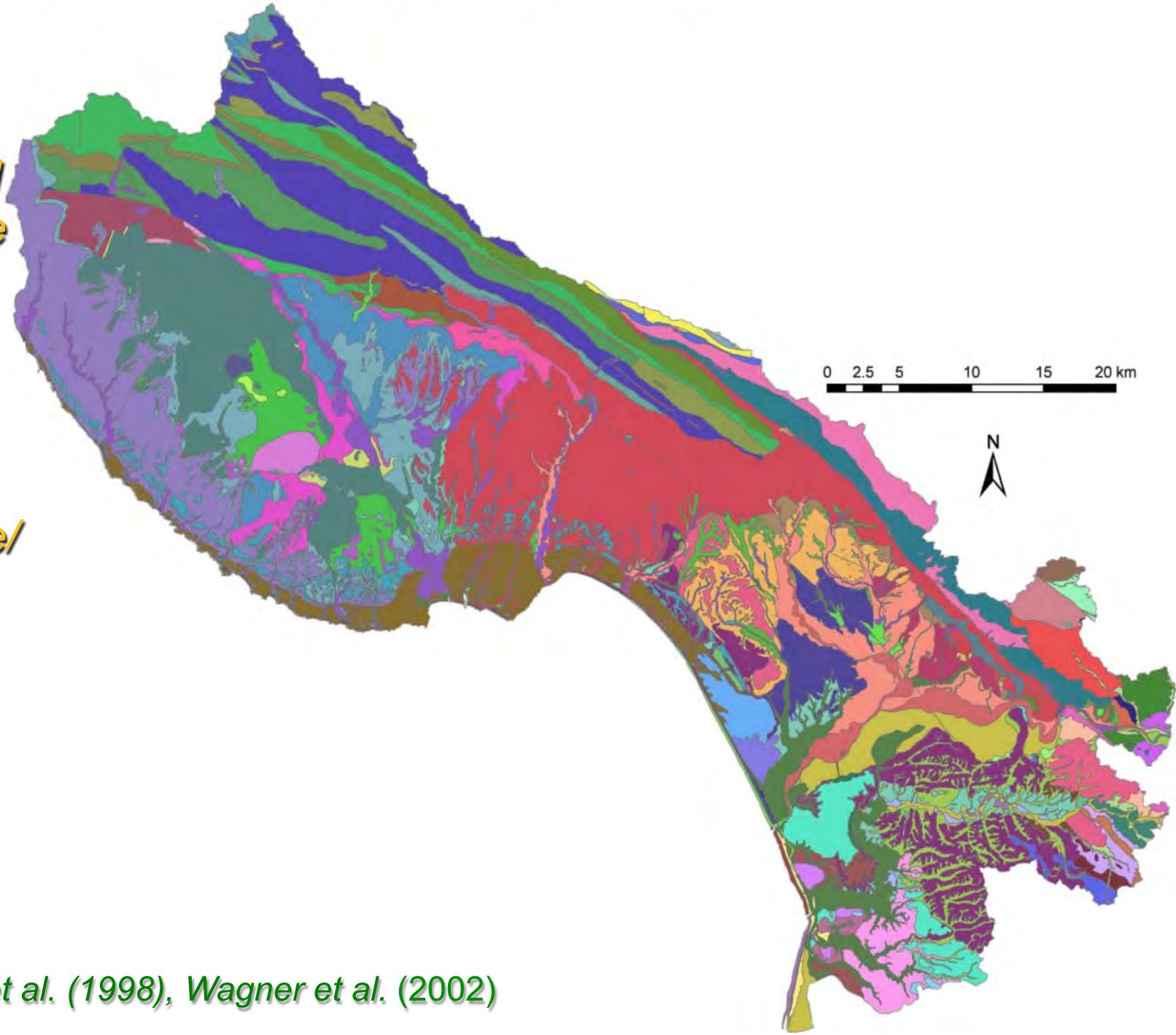
Regional Soils: calculated Infiltration Capacity (IC)

- Assess multiple soil layers, using geometric mean of IC range for each layer
- Combine layers to derive harmonic mean of IC
- Assign IC index on log_2 scale (selected to distribute values across full range)



Regional Bedrock: Unit Classification

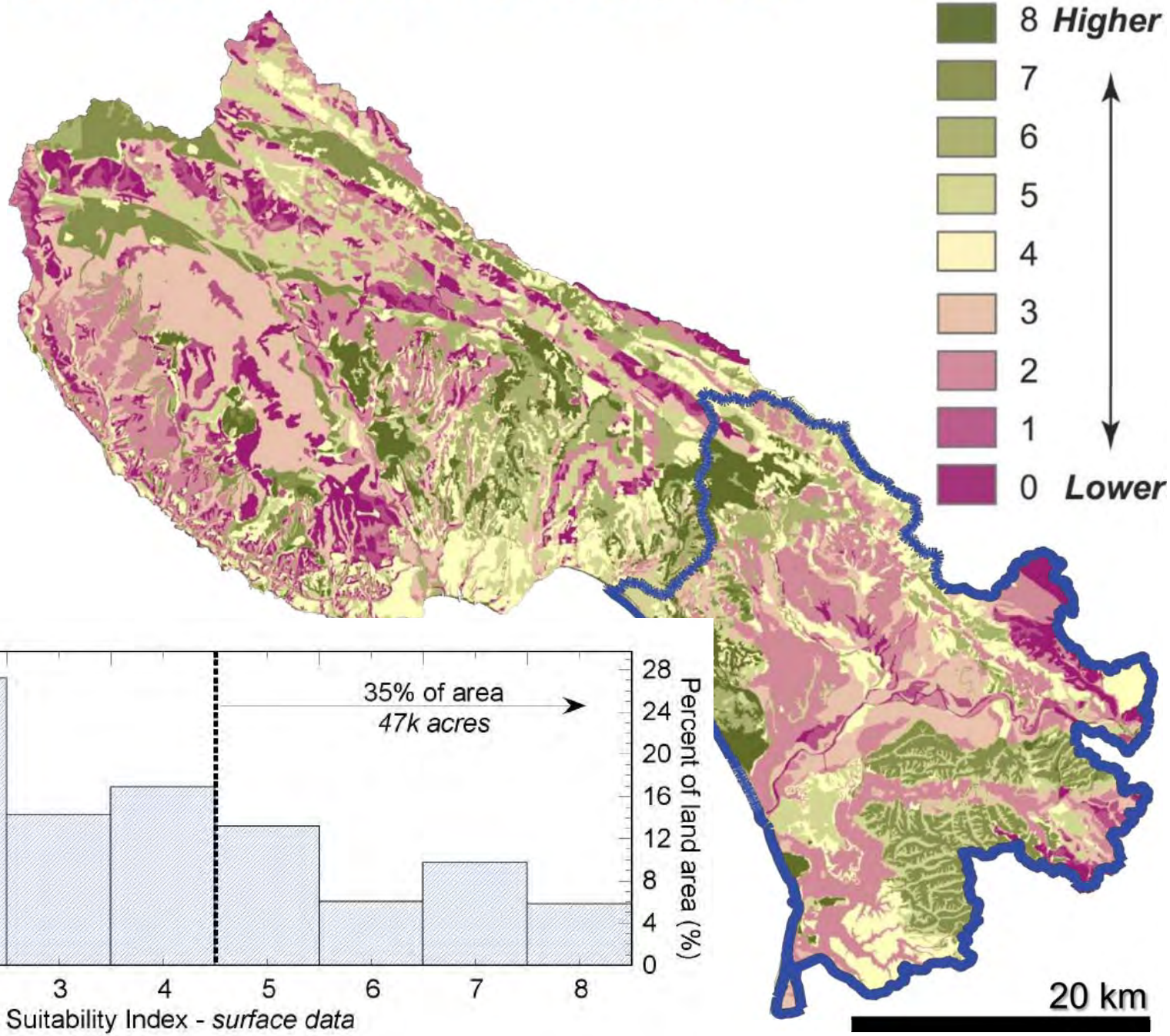
- Combine regional data from multiple reports/maps
- Evaluate unit by unit to determine which bedrock units are/might be/ are not aquifers
- Assign classification as an index



Brabb (1989), Brabb et al. (1998), Wagner et al. (2002)

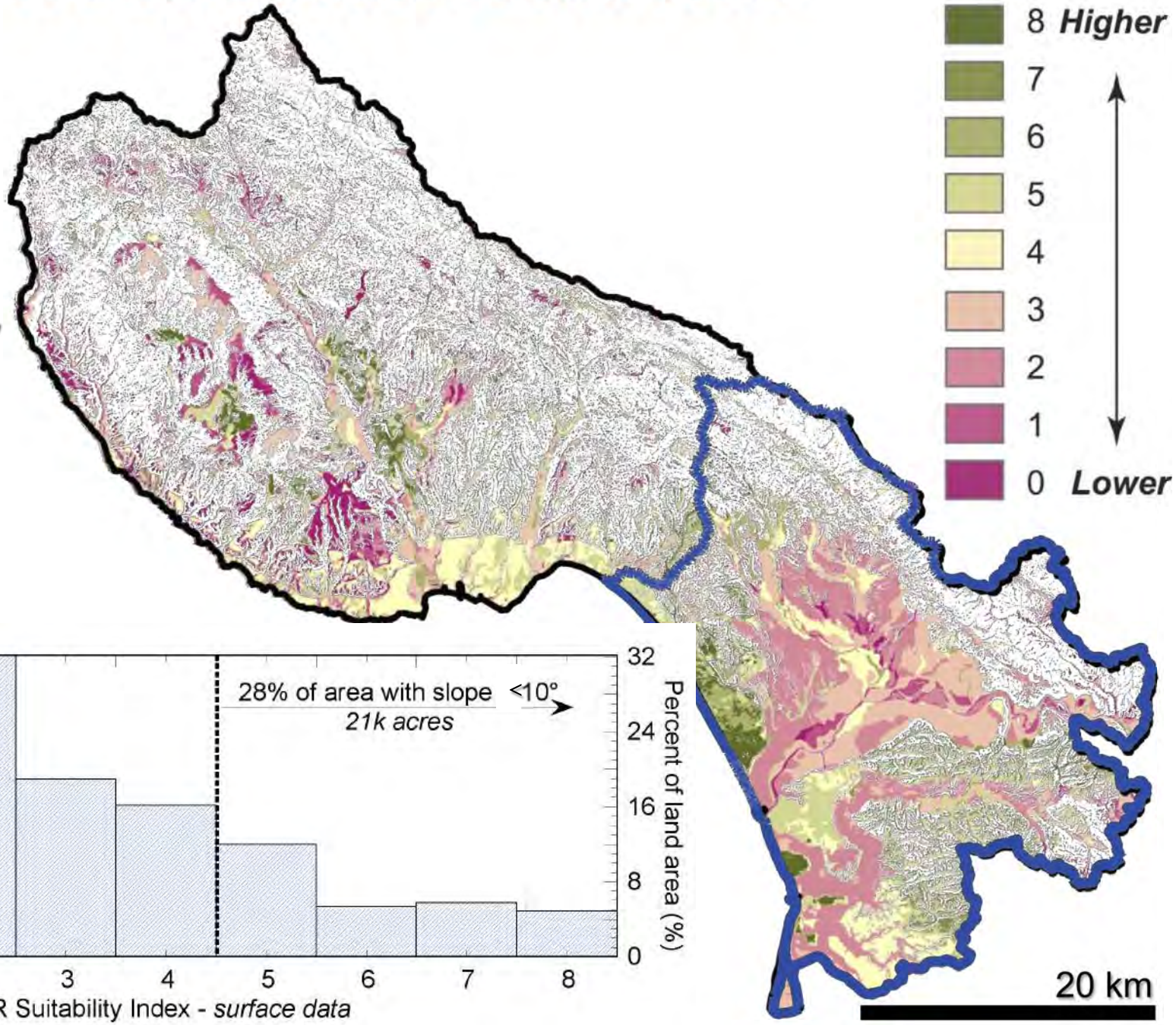
Suitability for Managed Aquifer Recharge based on Surface Conditions

- *Add indices for IC, bedrock geology*
- *Additional considerations include: slope, land use, veg*
- *Varies considerably by basin within full project region*
- *For PVGB…*

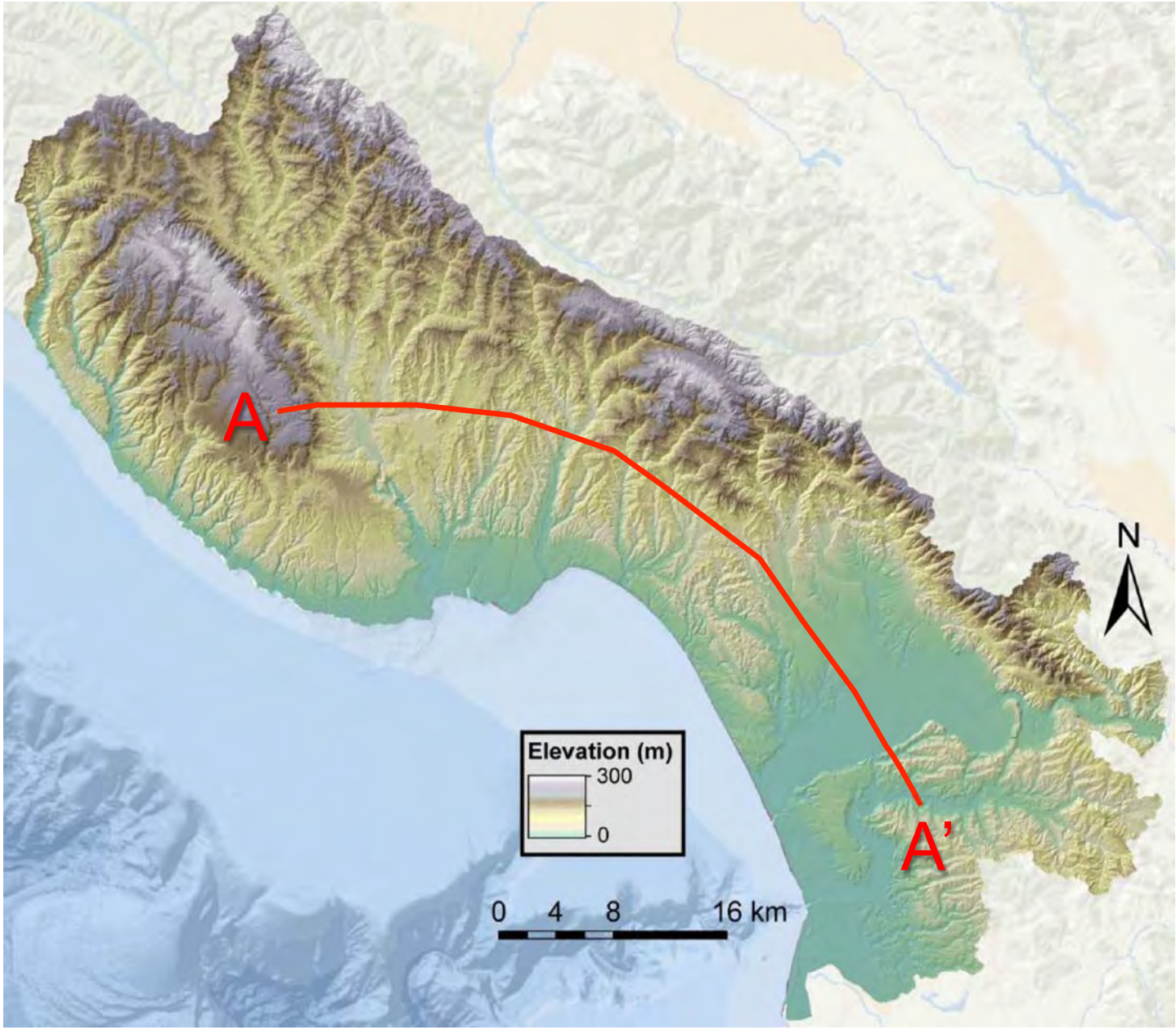


Suitability for Managed Aquifer Recharge based on Surface Conditions

- *Slopes <10°*
- *Much smaller area, but sites distributed through the region*

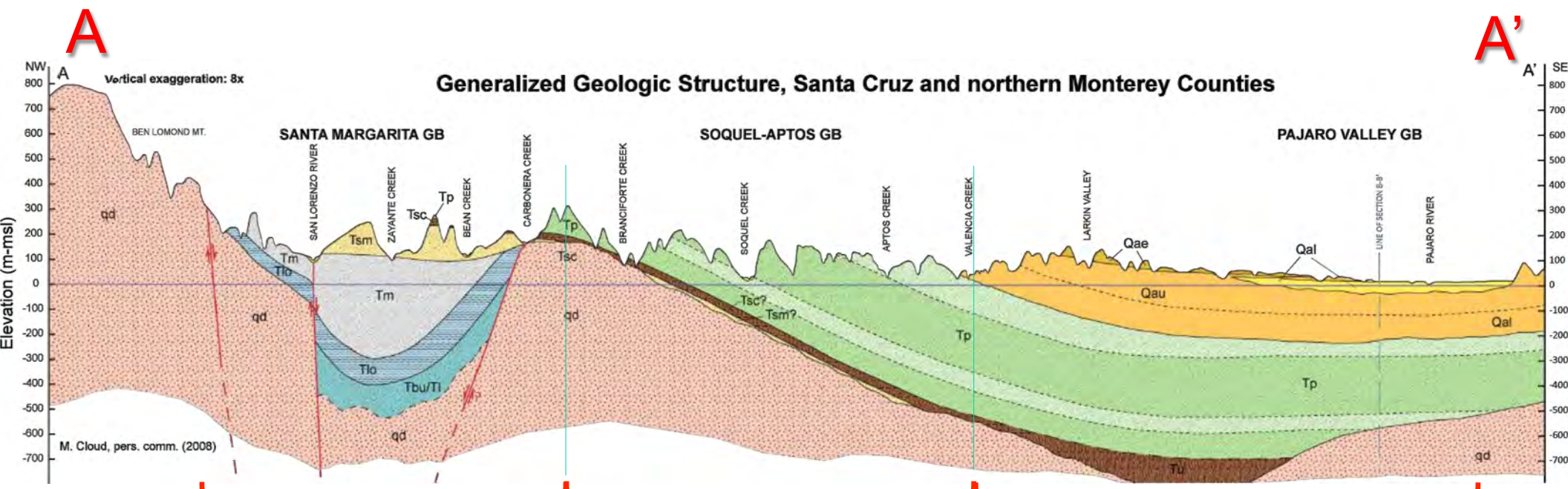


Subsurface conditions also matter…



Underway for SLRB, PVGB, MidSCC coming next…

One county, three (+?) groundwater basins, many jurisdictions



San Lorenzo River Basin

- *Mountainous, rural/urban*
- *GW levels down by 100 m*
- *Inland, no SW intrusion*

Pajaro Valley GW Basin

- *Agricultural, urban, rural*
- *Considerable SW intrusion*
- *Special Act District*

Soquel/Aptos GW Basin

- *Mountainous, rural/urban*
- *First hints of SW intrusion*
- *Models say: critical overdraft (so does DWR!)*

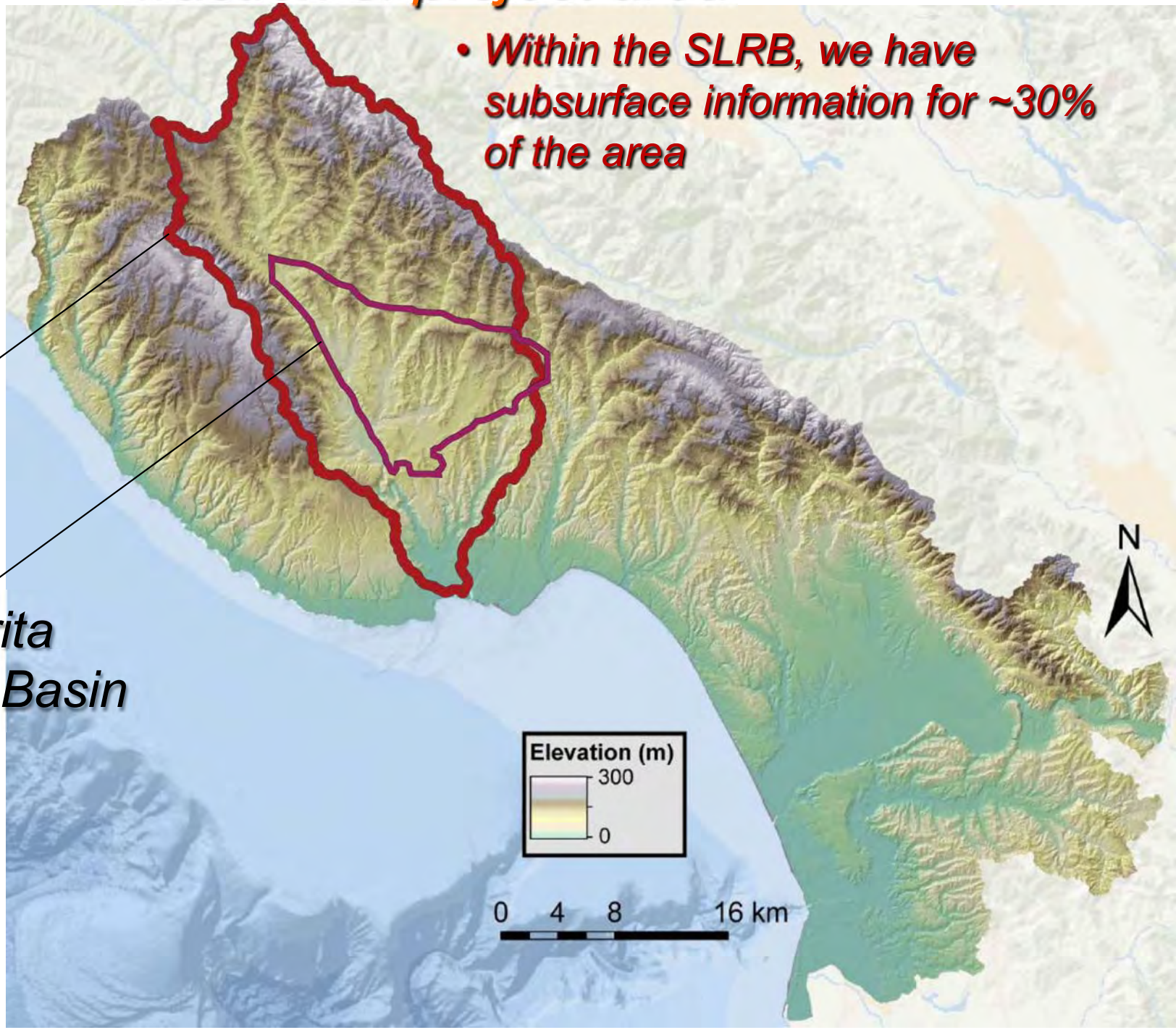
M. Cloud, pers. comm.

Mapped subsurface data exists for a fraction of project area

- Within the SLRB, we have subsurface information for ~30% of the area

Example: SLRB

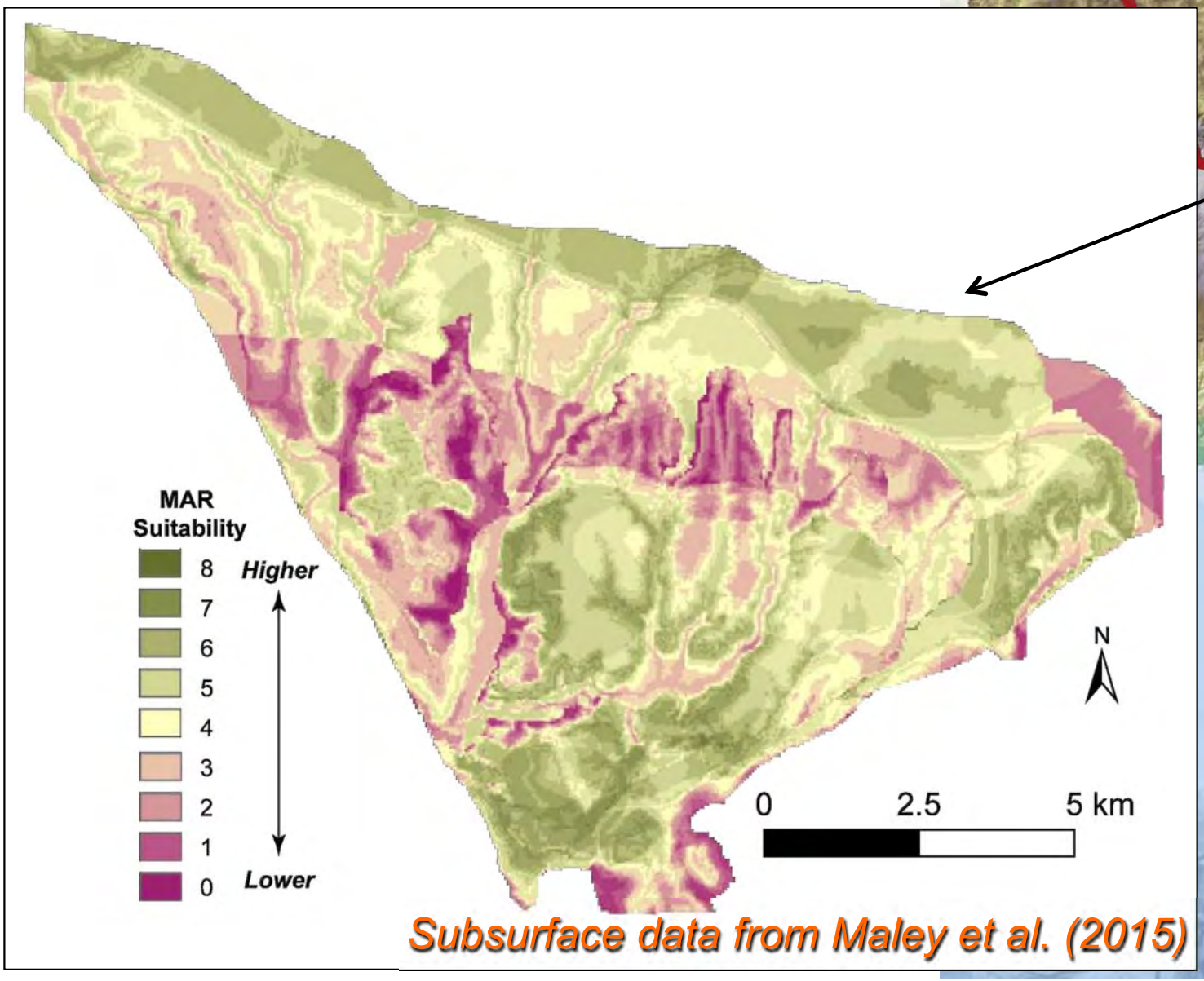
Santa Margarita Groundwater Basin

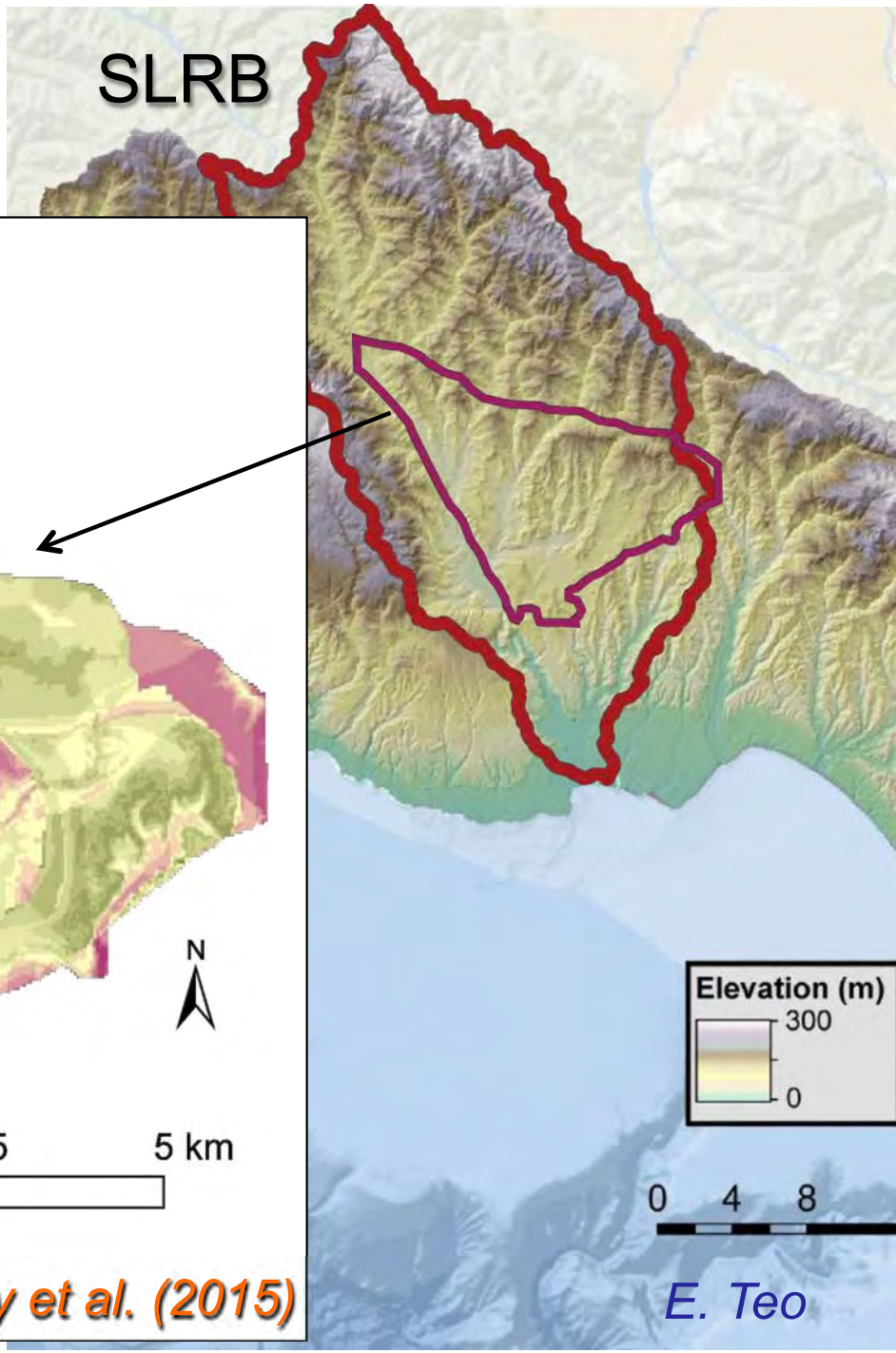


E. Teo

MAR Suitability: Subsurface Data

- *Transmissivity, vadose zone thickness, depth to water, available storage, change in storage*



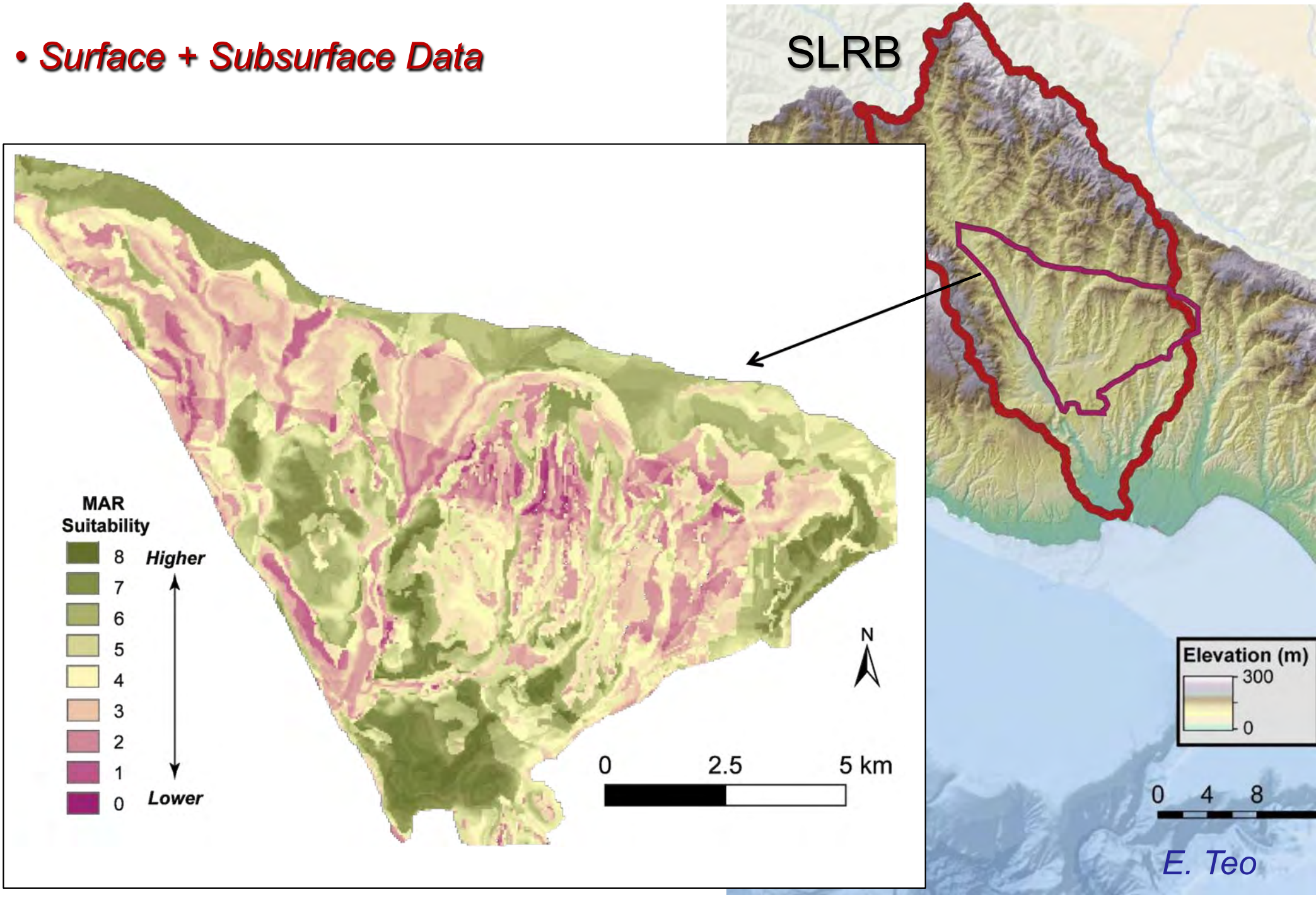


Subsurface data from Maley et al. (2015)

E. Teo

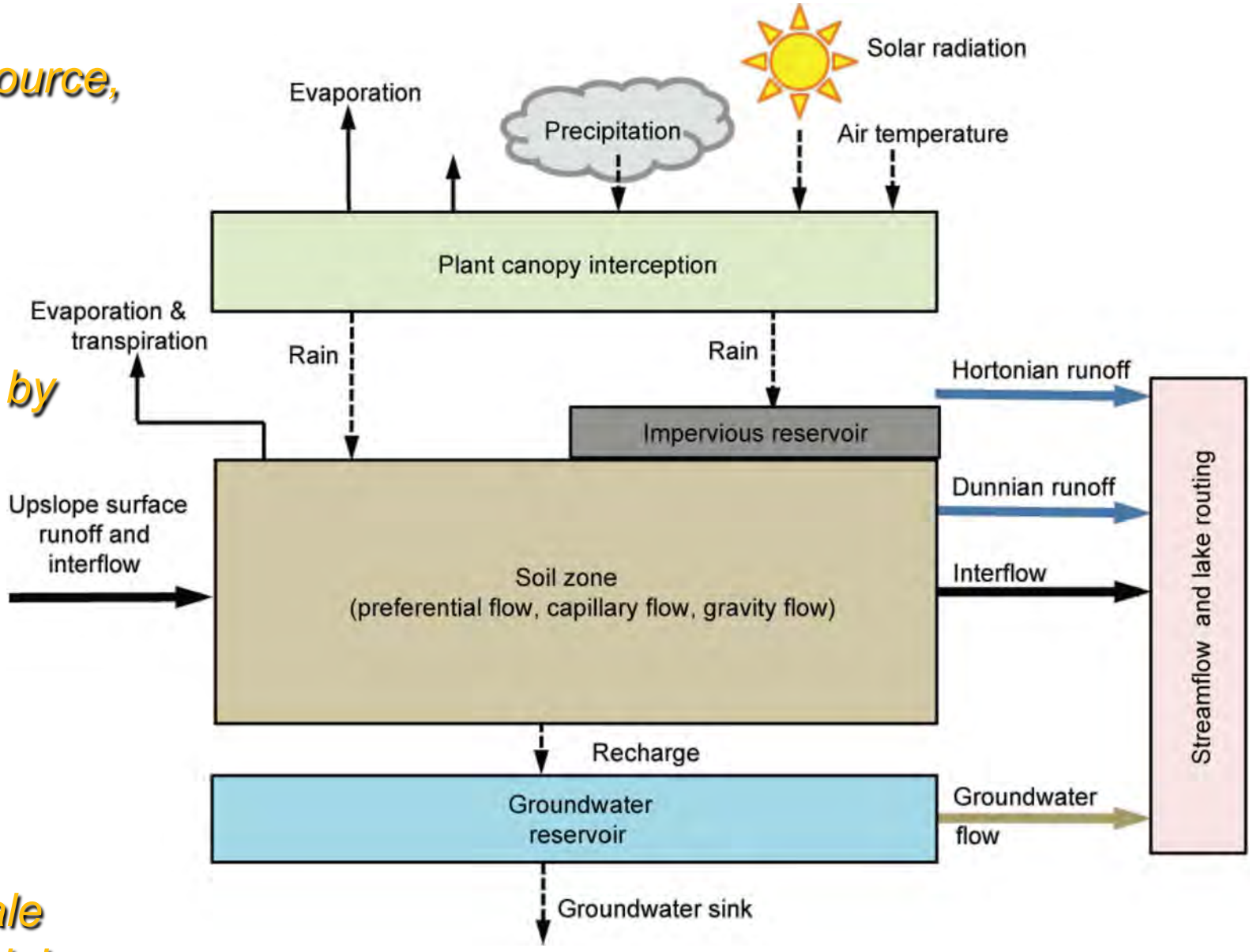
MAR Suitability: Composite

- *Surface + Subsurface Data*



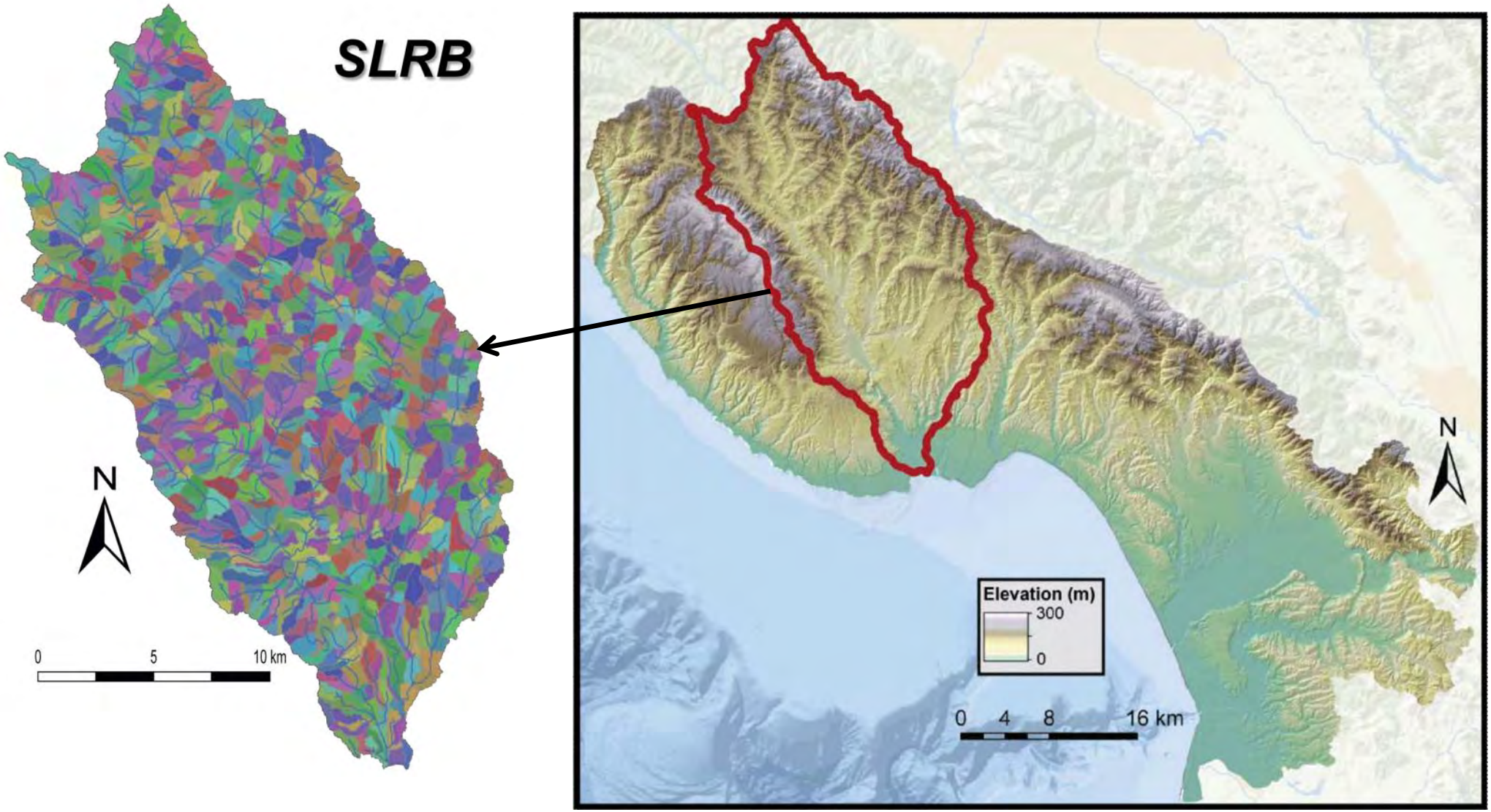
Precipitation Runoff Modeling System (PRMS)

- *USGS, open source, widely used*
- *Water is added by precipitation, routed through four main reservoirs (no snow for us!)*
- *Watershed-scale hydrologic model*



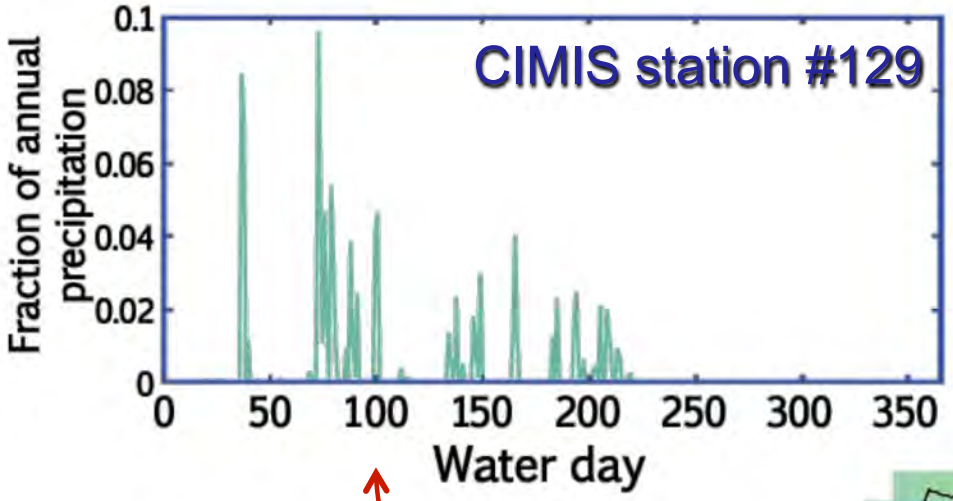
modified from Markstrom et al. (2015)

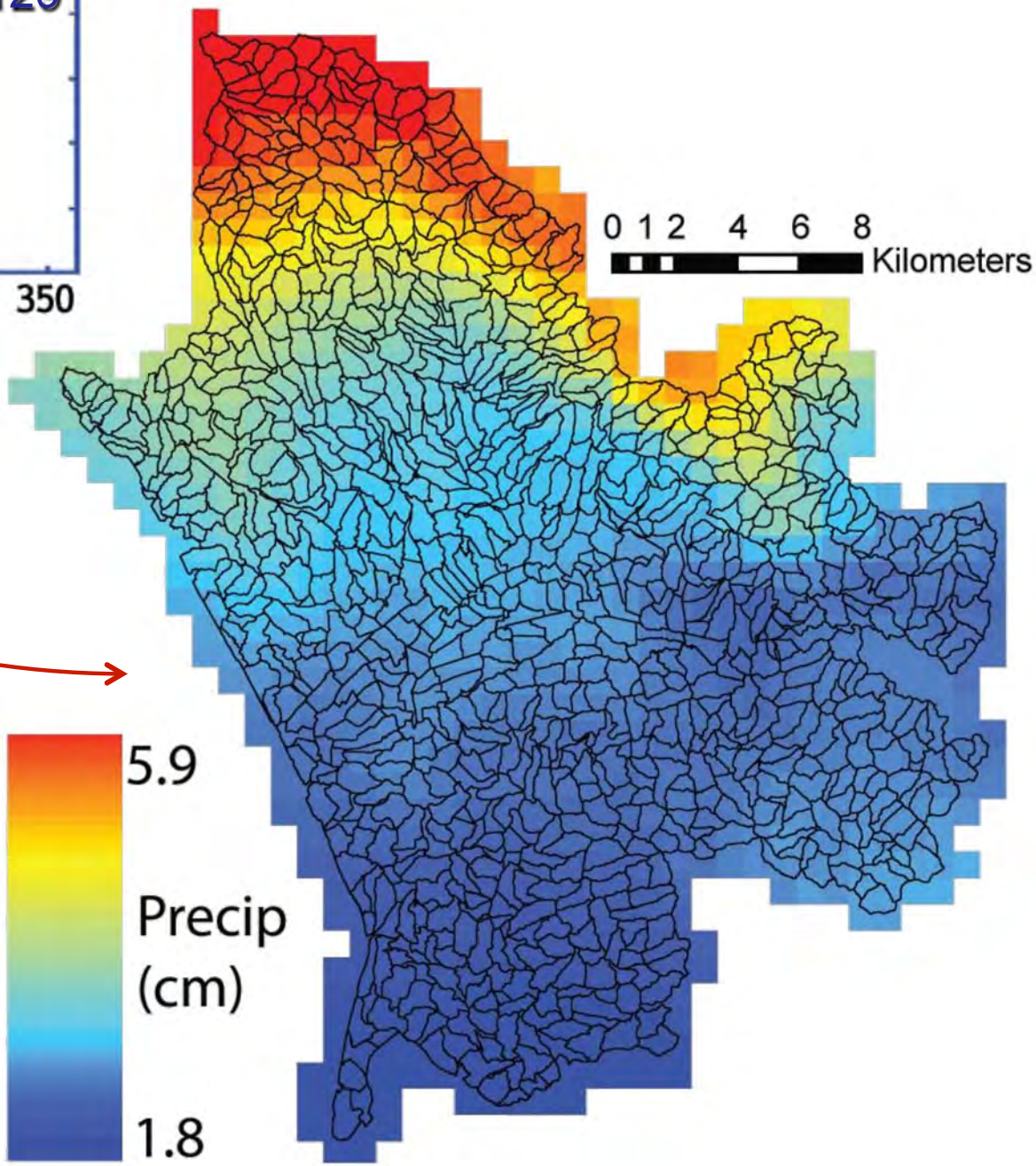
Where to Collect Stormwater Runoff?



- *HRUs defined by topoography, land use, properties*
- *HRUs = 0.1 to 1.0 km^2 (25 – 250 acres)*

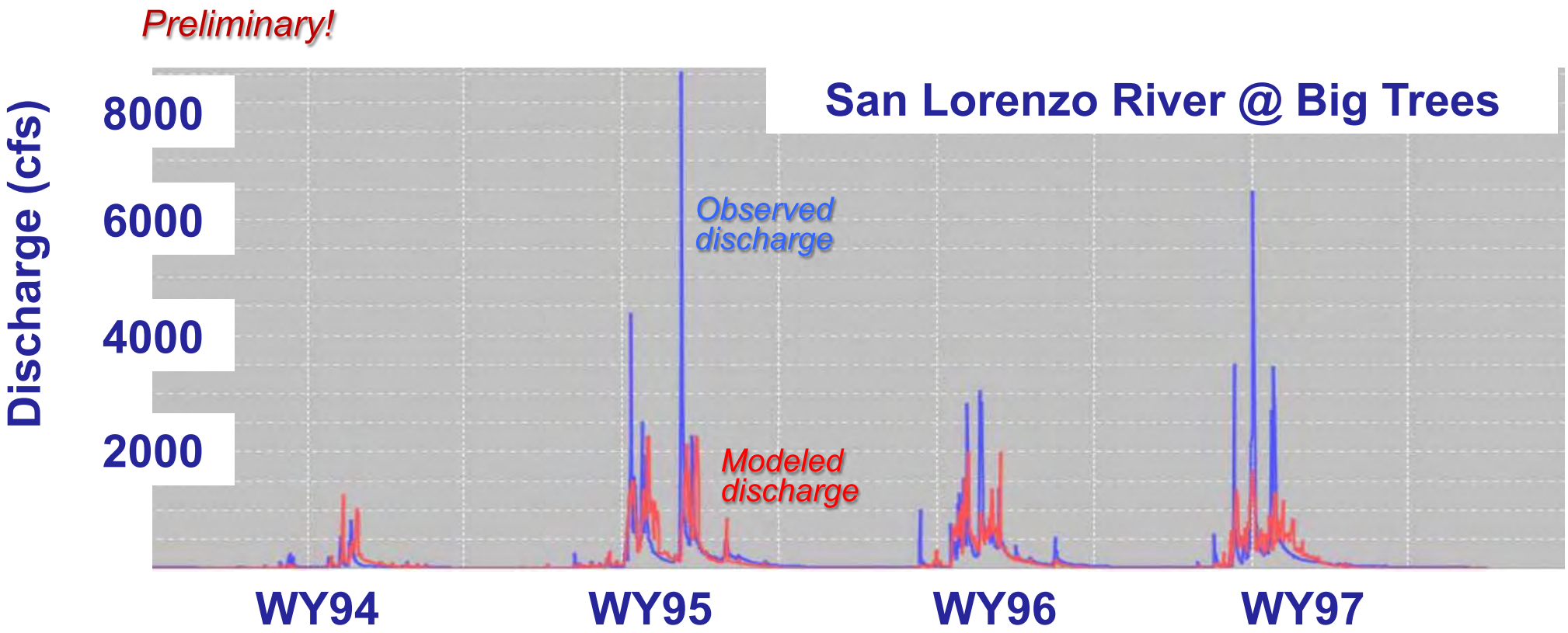
Incorporating high-resolution (800-m) PRISM met





- Example: Day 101 (Jan 10, 2003)
- Daily PRISM data generated for 34-year period of record

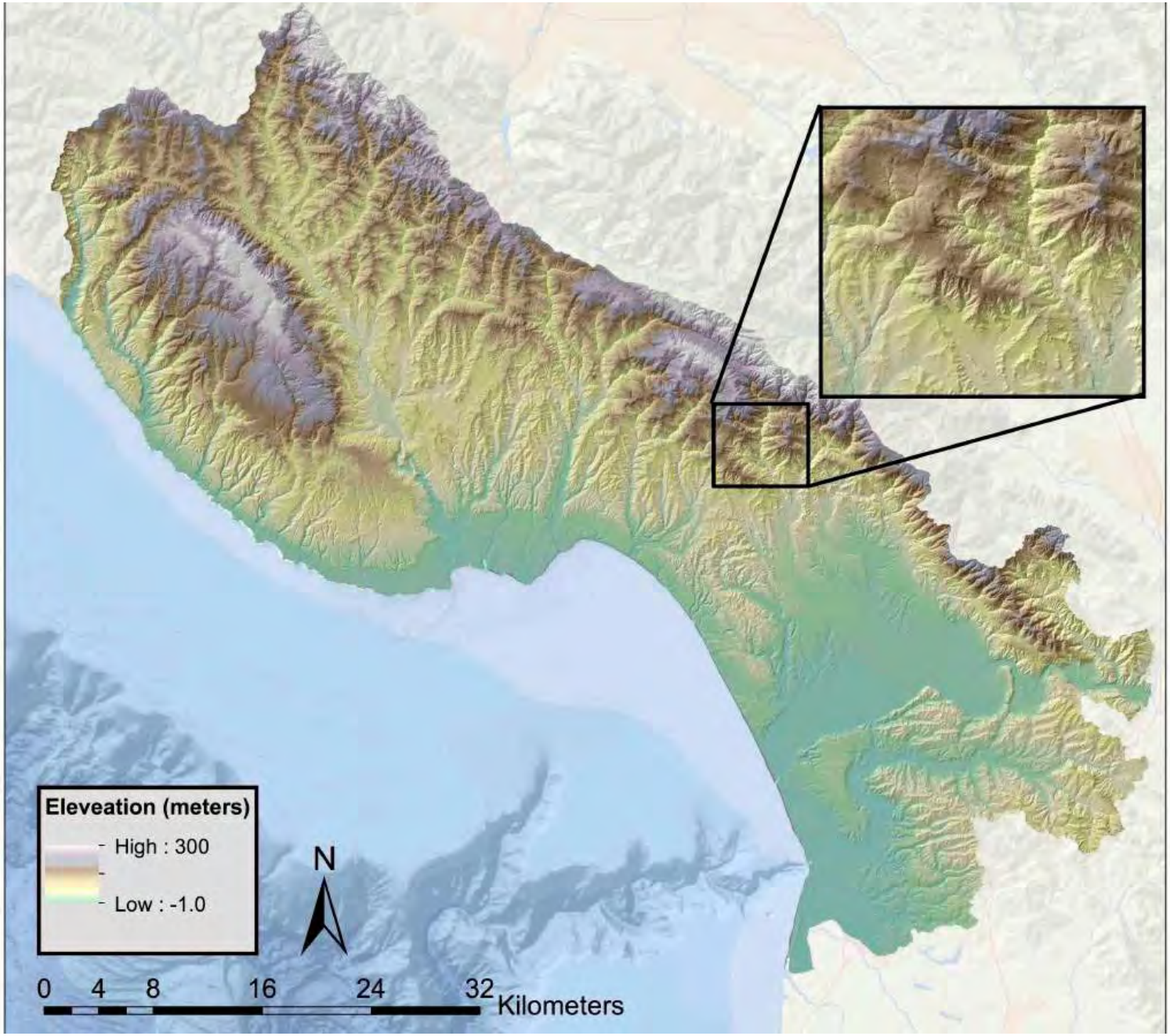
Initial PRMS model output – calibration in progress…



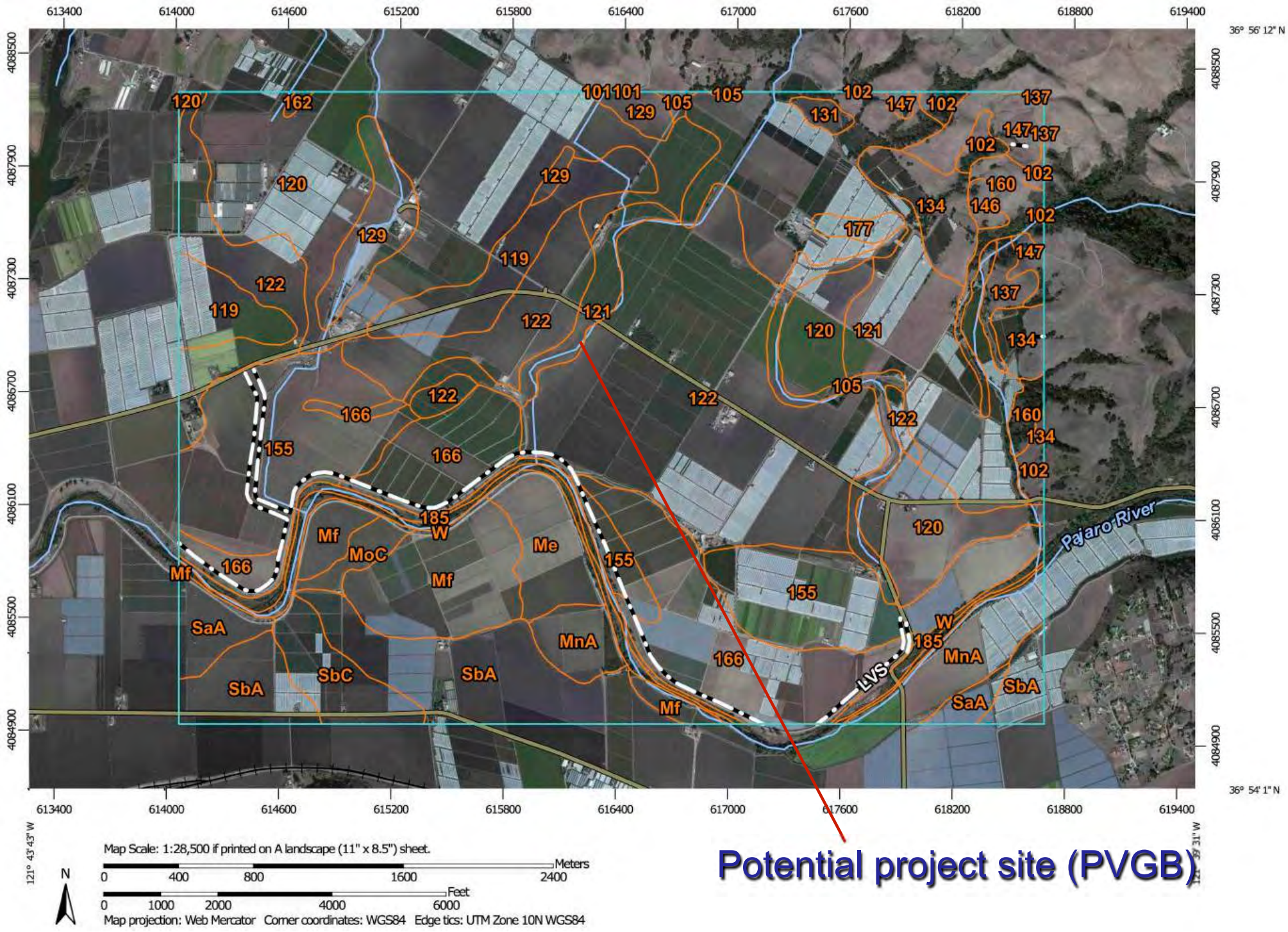
- *Calibration: tuning of soil, hydrologic, vegetation, channel, routing, and other parameters to achieve consistent precipitation/runoff relations*
- *Assess amounts and fractions of event precipitation that becomes runoff*
- *Quantify where runoff flows over/near "highly suitable" MAR sites*

K. Young, S. Beganskas

What are field conditions at project location?

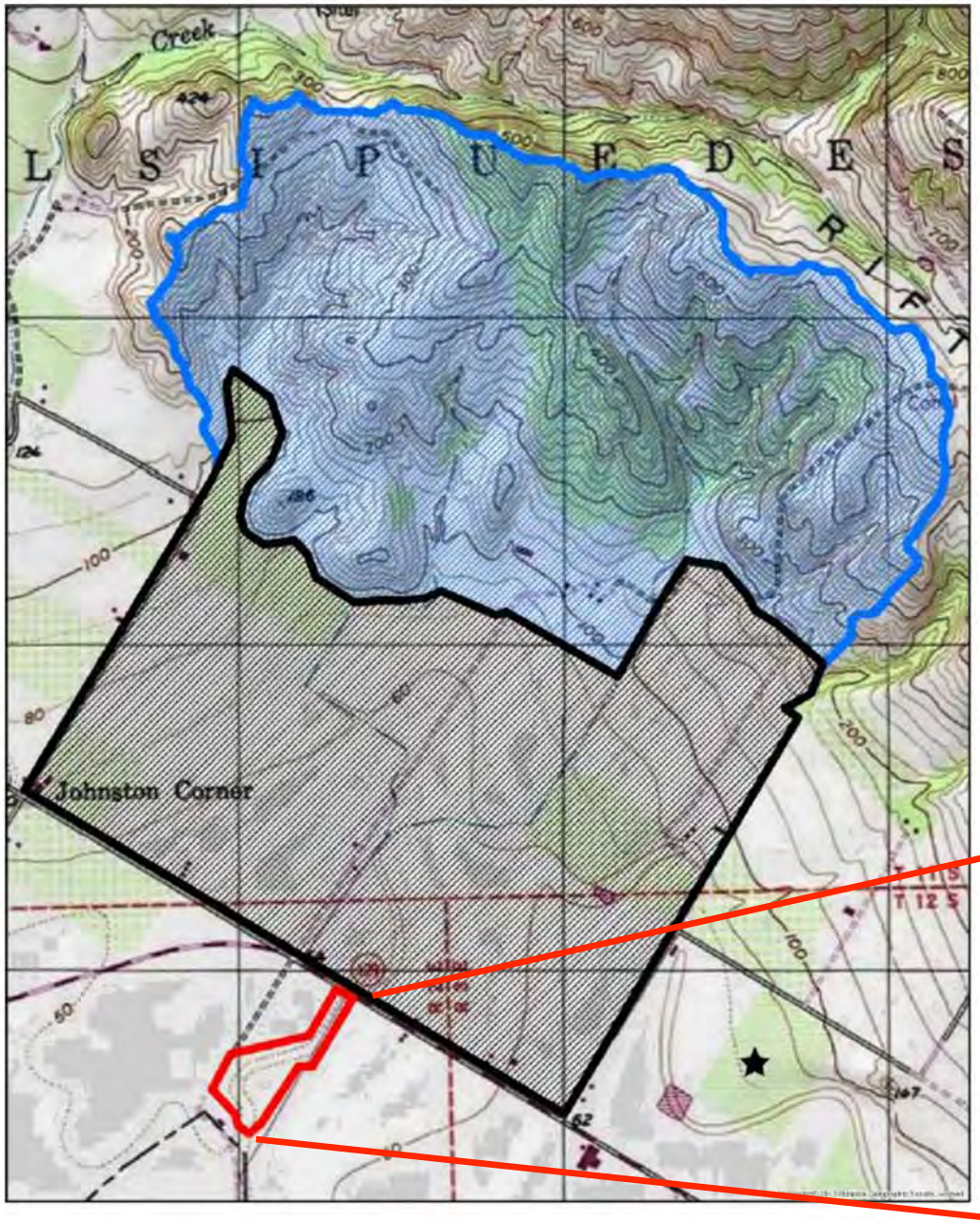


Extreme variability at parcel scale…



Potential Project Site

- *Working ranch and rangeland*
- *>1300 acres draining into 15 acres*
- *interest in improvement to water supply and water quality*



Locations and areas (approximate)

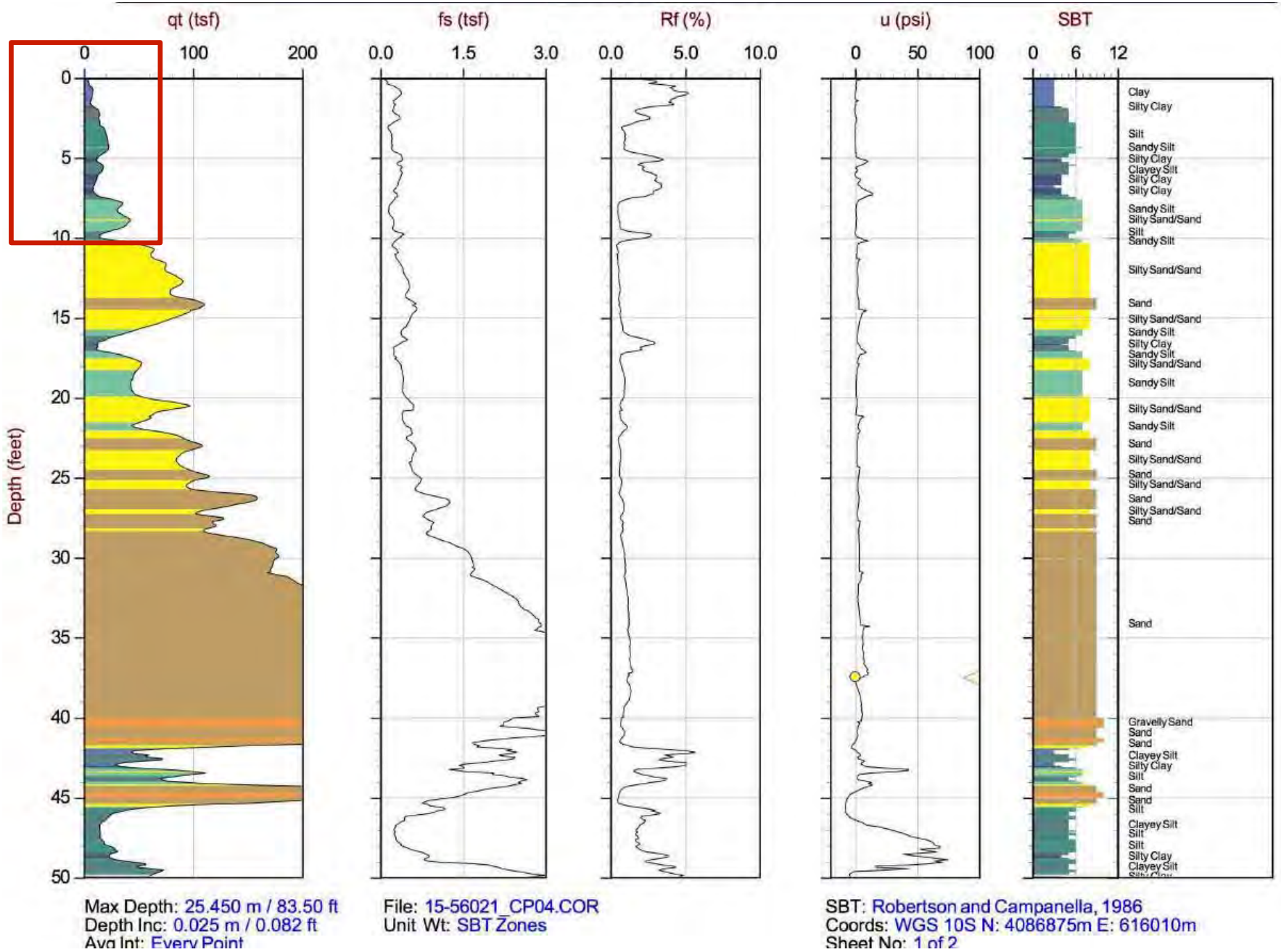
- Developed (620 acres)
- Undeveloped/less developed (700 acres)
- Potential infiltration area
- ★ Nearby infiltration project

Soil survey (drilling)

Field conditions at potential project locations?

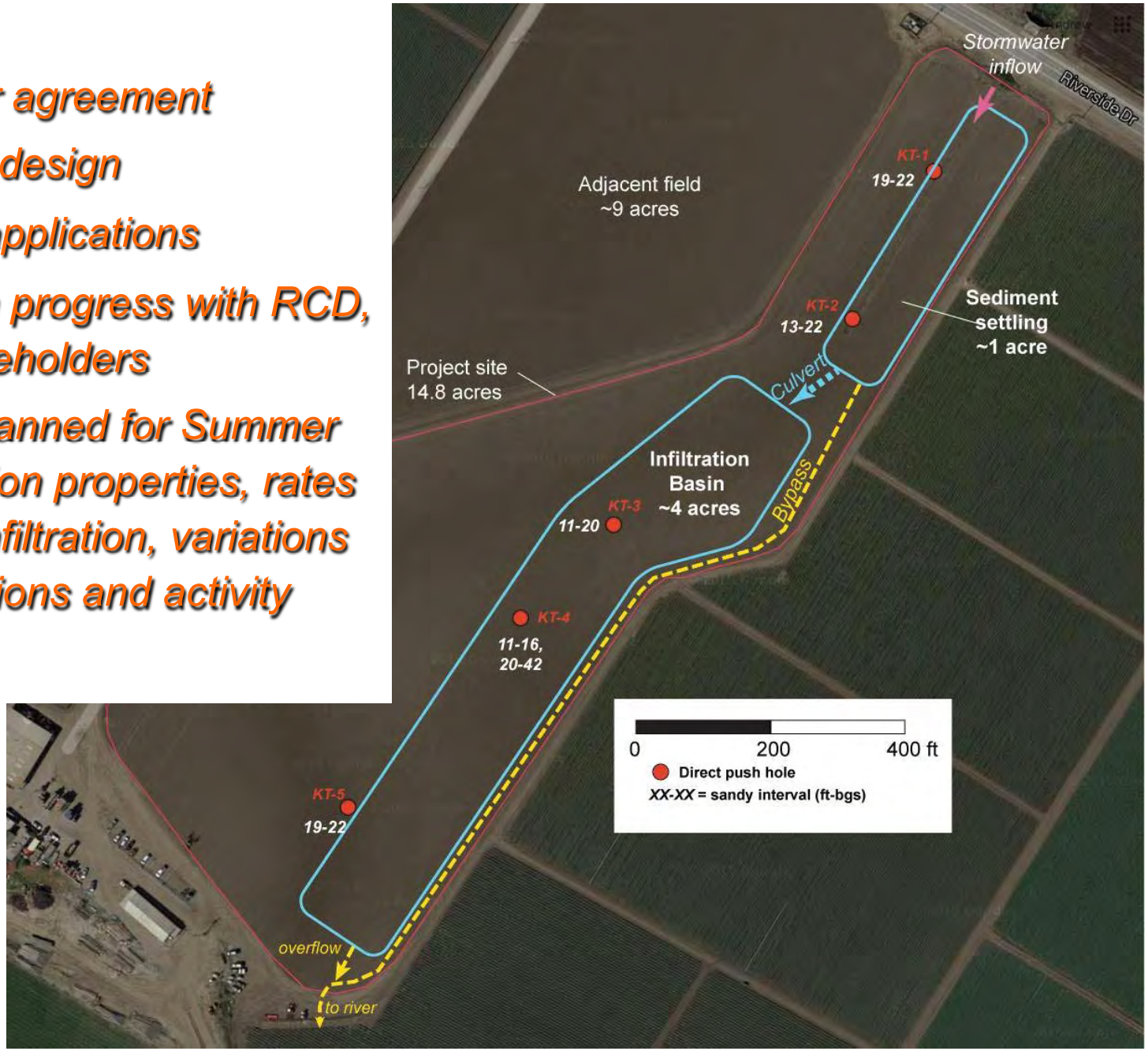
Direct push to assess soils (to 80+ ft)

Field conditions at potential project locations?



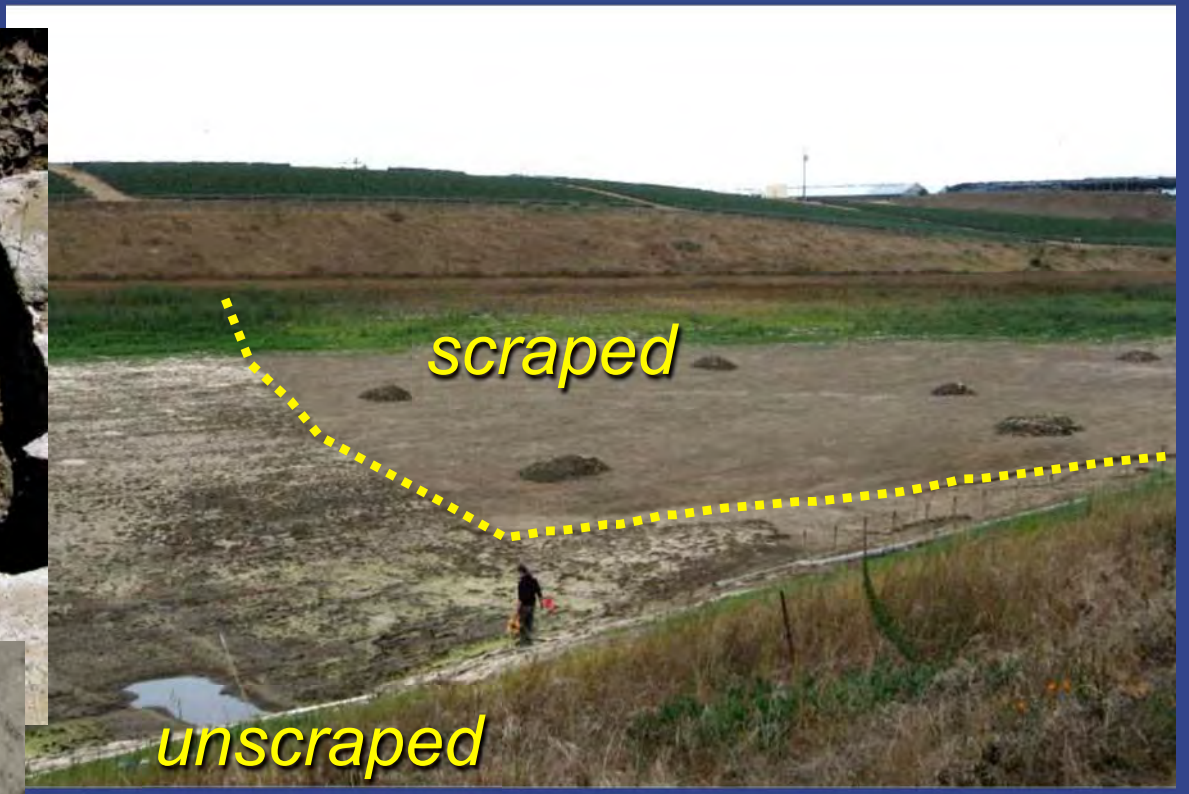
Conceptual project design

- √ Secured land-owner agreement
- √ Prelim. engineering design
  - needed for grant applications
- Grant applications in progress with RCD, PVWMA, local stakeholders
- Field experiments planned for Summer 2016 to test infiltration properties, rates of reaction during infiltration, variations in microbial populations and activity



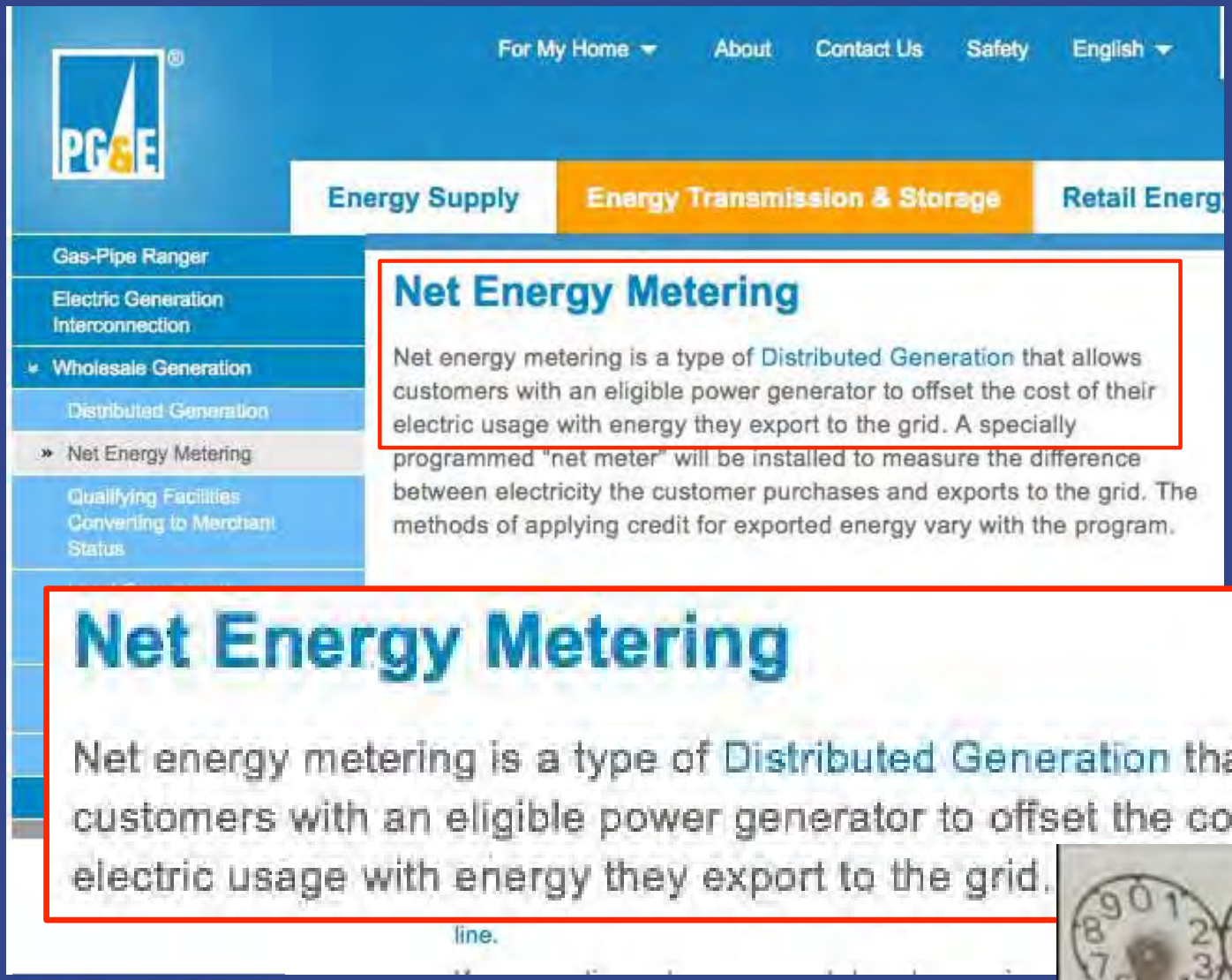
Costs to Growers/Landowners for DSC-MAR

- *Land taken from production*
- *Maintenance of infiltration structures (basins, drywells)*



How can participation be incentivized?

There is a Workable Example: Net Energy Metering



- *generate energy locally*
- *account for net usage*
- *excess power goes on the grid for sale (and eventual use)*

- *Requires*
  - *– reliable measurement and accounting*
  - *– formula to calculate benefit/rebate*
  - *– stakeholder and Agency trust*

UCSC Hydrogeology

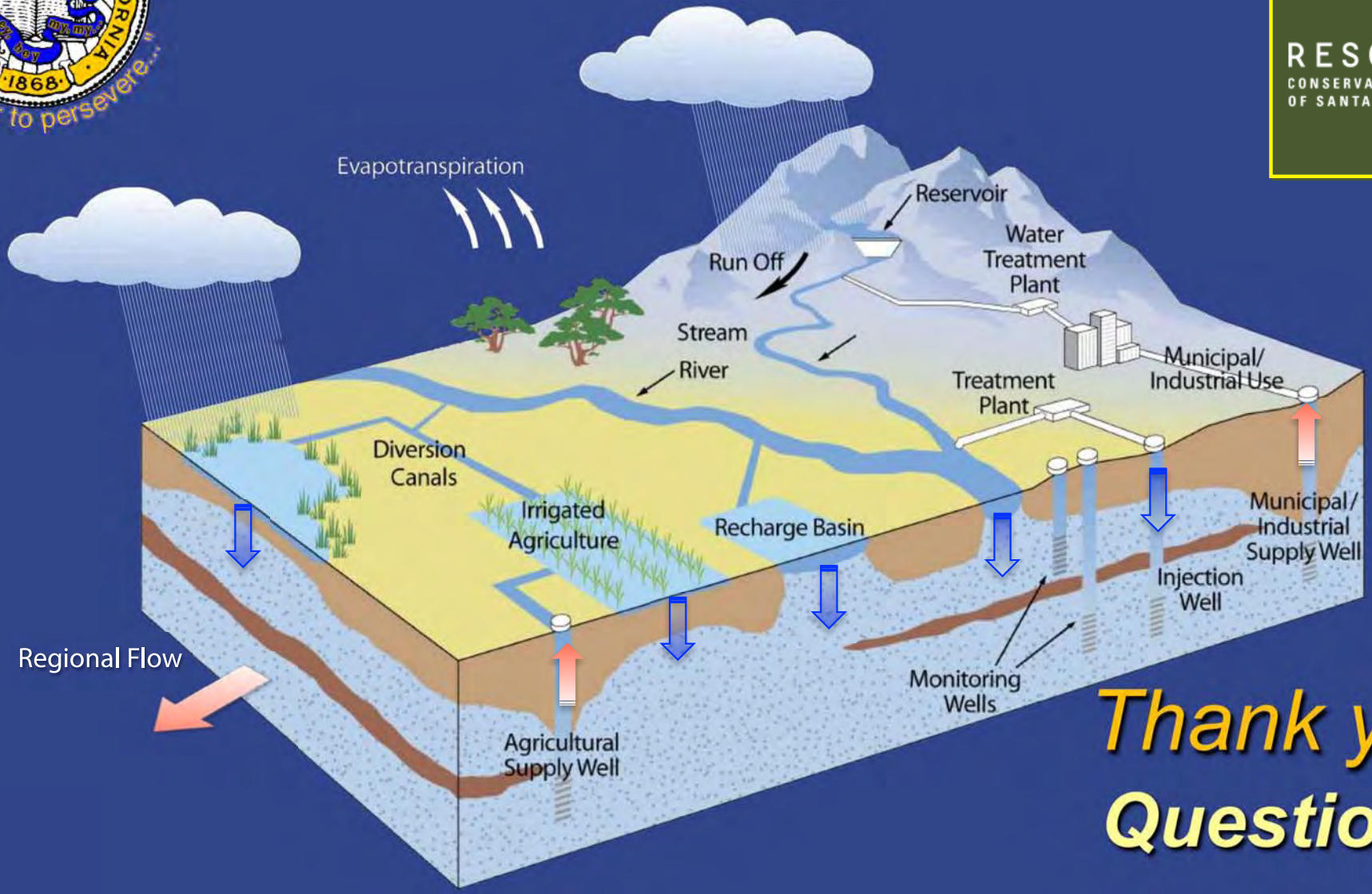
"Endeavor to persevere..."

The Recharge Initiative

Replenish • Recover • Restore

www.rechargeinitiative.org

RESOURCE CONSERVATION DISTRICT OF SANTA CRUZ COUNTY



Thank you!

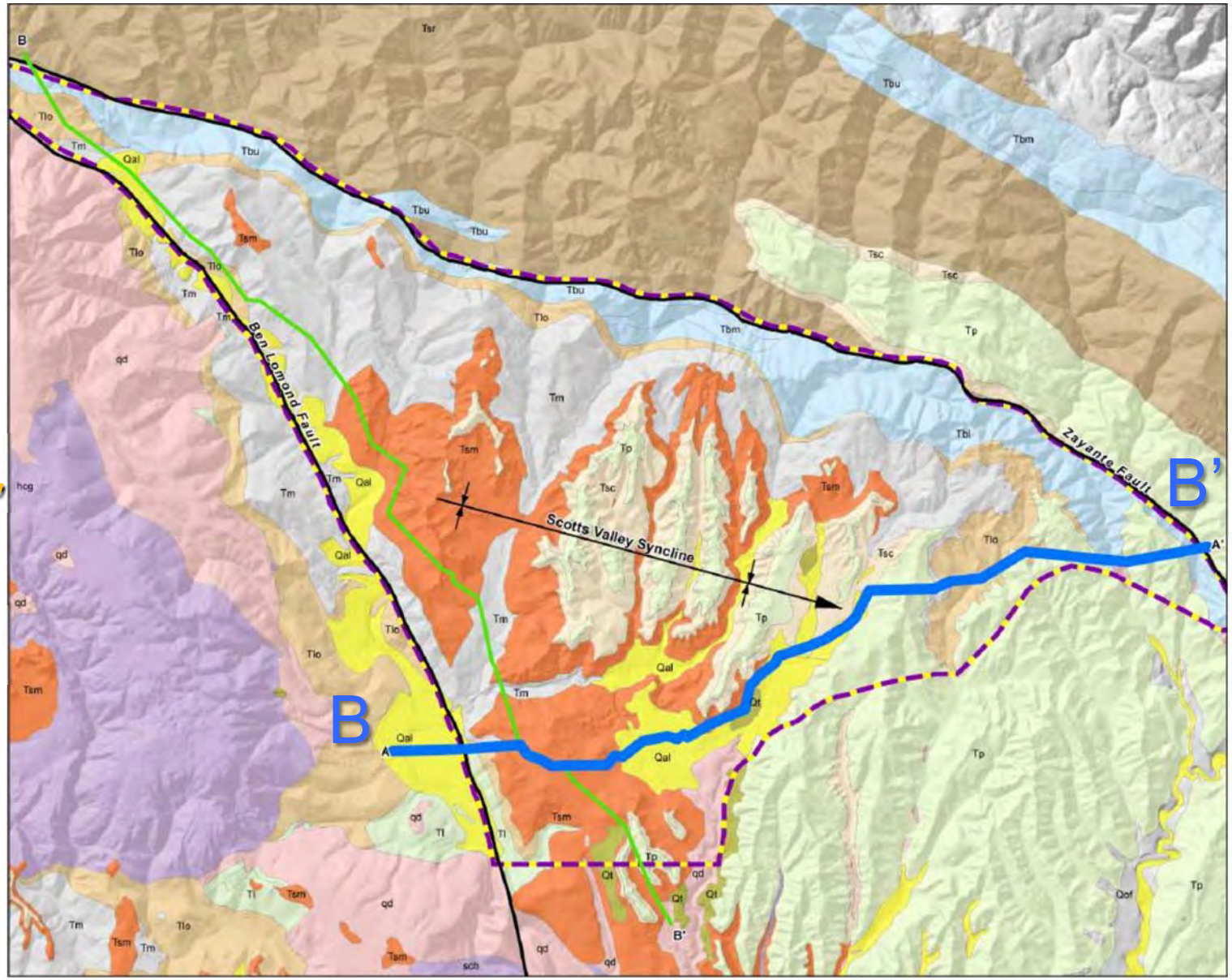
Questions?

State of California Coastal Conservancy

UC WATER Security and Sustainability Research Initiative

Santa Margarita Groundwater Basin Model

- *Multi-year project*
- *Update of earlier generation of groundwater flow models*
- *~33.5 m resolution, based on hundreds of well logs, mapped data*



Maley et al. (2015)

Hypothetical Example for Ranch in Pajaro Valley

Area in production:
50 ac

Depth of applied water:
2.5 ft/yr (berries, mixed)

Pumpage:
125 ac-ft/yr

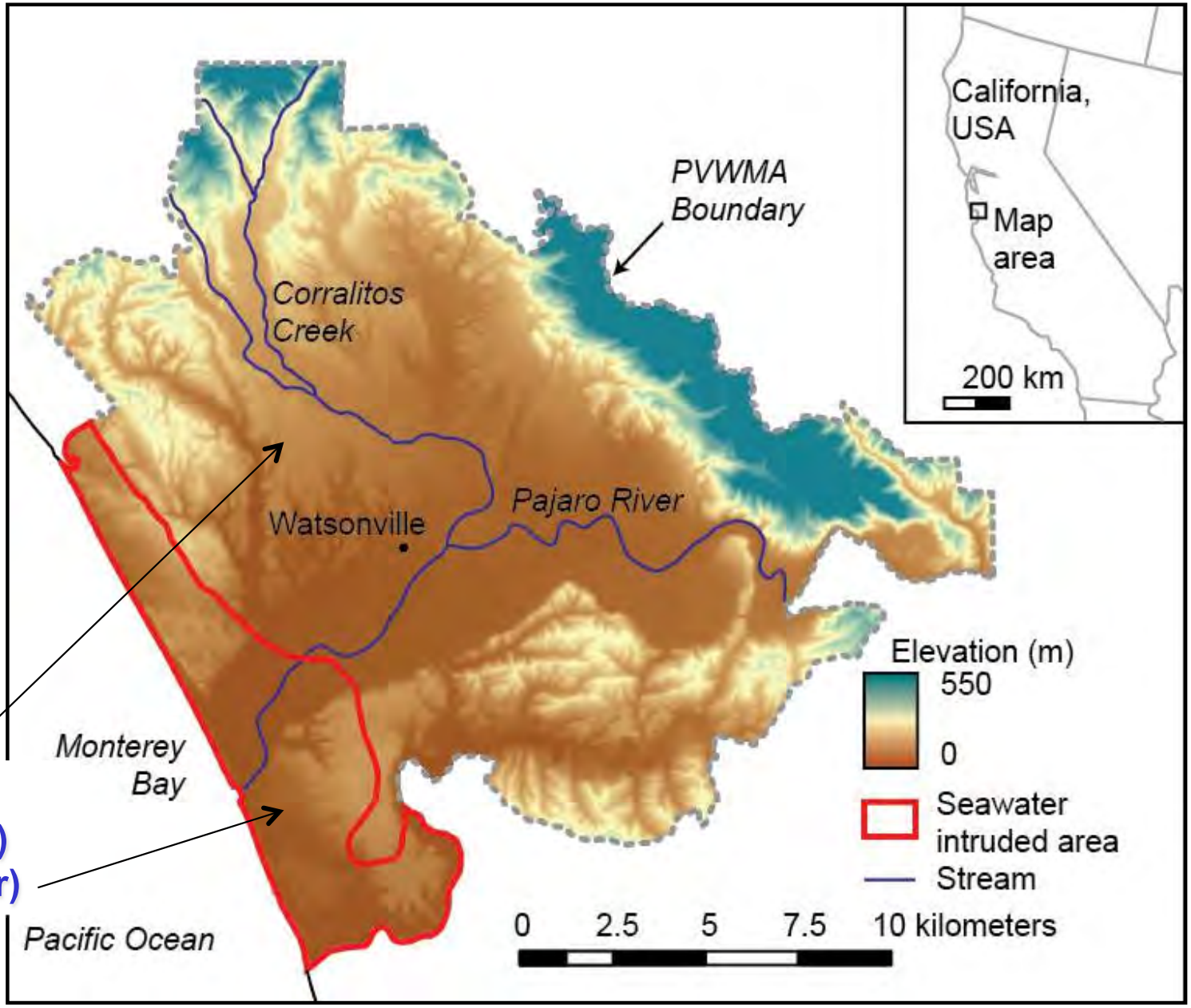
Precipitation:
1.5 ft/yr

Drainage area:
100 – 300 ac

Infiltration area:
1.5 – 2.5 ac
(3-5% of production)

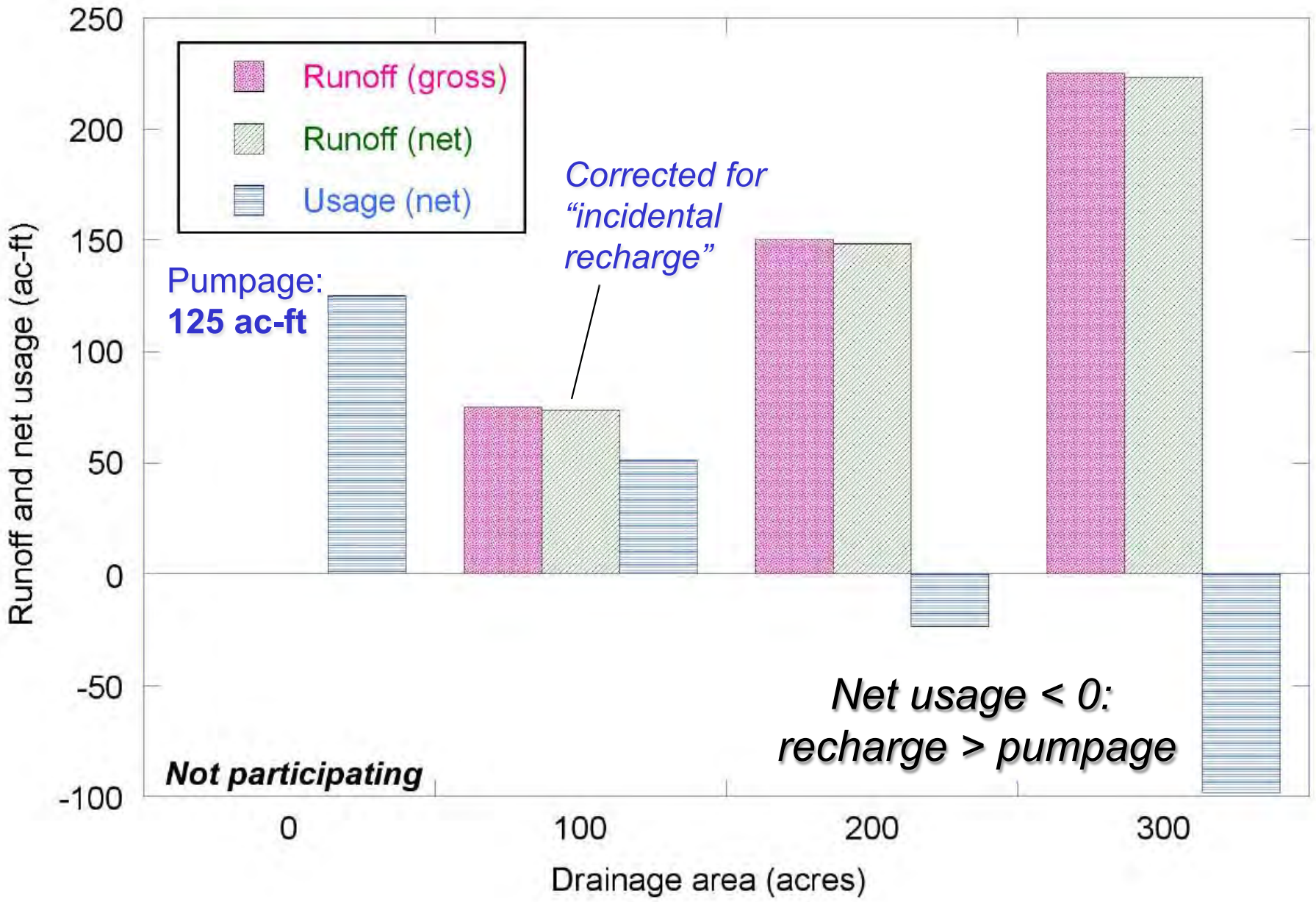
Water rates:
$179/ac-ft (metered GW)
$338/ac-ft (project water)

Assumed fee reduction:
50% of metered/delivered water rate

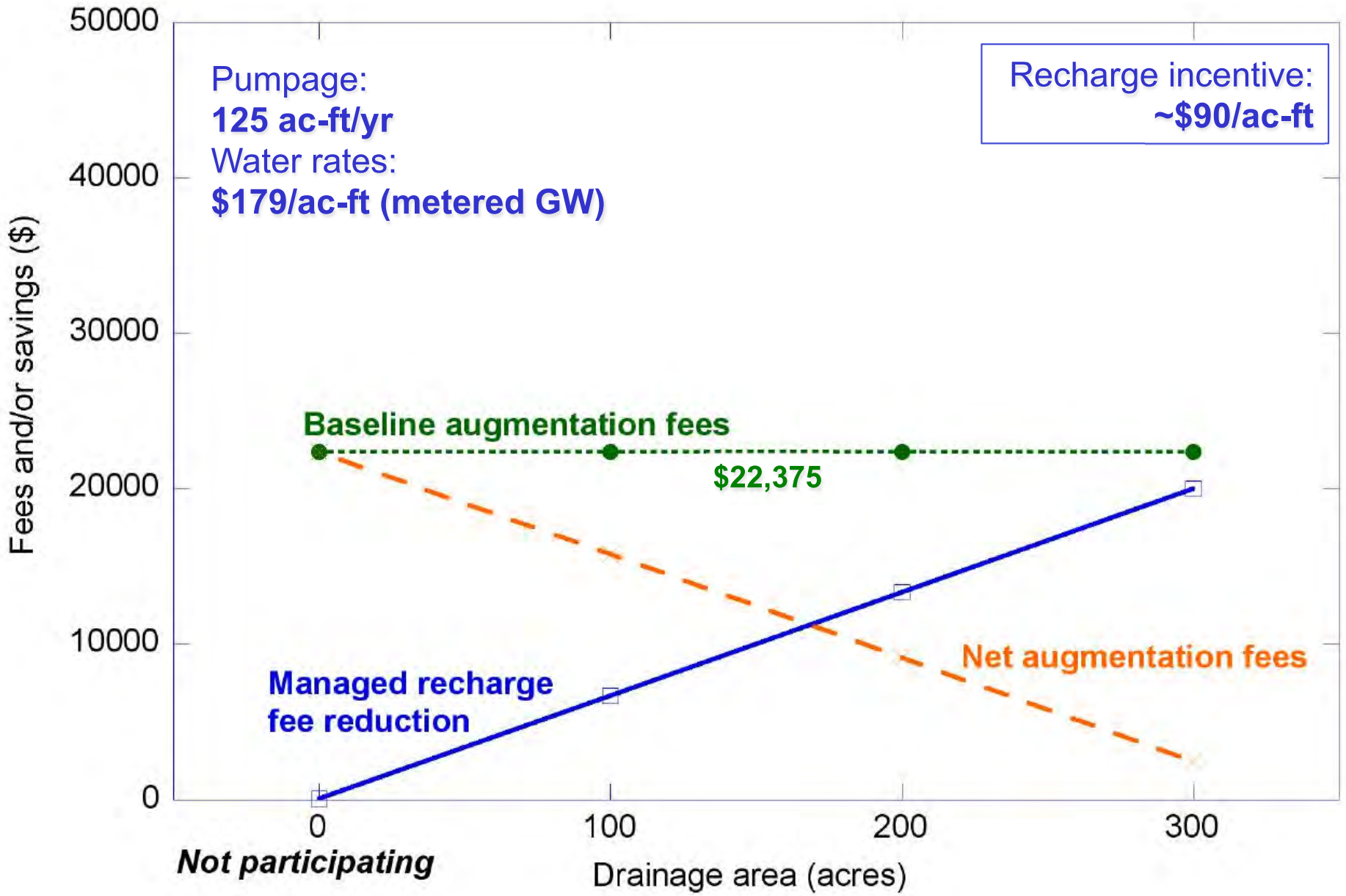


Assumed runoff coefficient: **0.5**

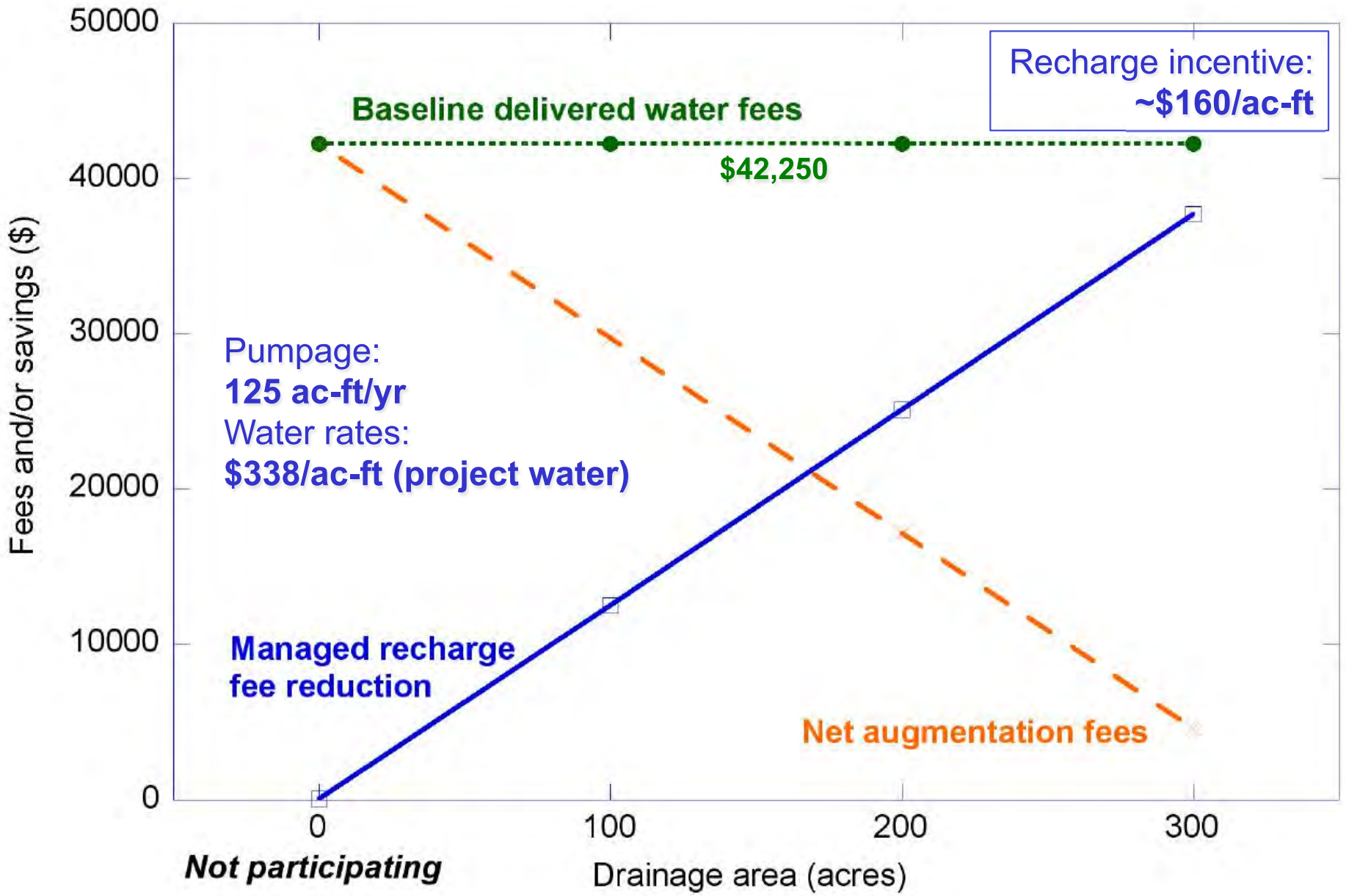
Hypothetical Example: Net Recharge



Hypothetical Example: Metered groundwater



Hypothetical Example: Delivered project water



Recharge Net Metering (ReNeM): FAQ-1

- *Who will be the TPC?*

One option: UCSC (The Recharge Initiative) and RCD personnel.

- *Wont this be a lot of work for the Agency?*

Not if planned and run carefully. TPC will consult with Agency on technical and financial issues, but will run the program independent of the agency. TPC will report on the program each year, including benefits achieved.

- *Wont this program be expensive?*

ReNeM is cost effective in comparison to alternative water supplies. The rebate reduces revenue from pumped/delivered water on participating farms, but can serve additional customers.

- *Will there be dozens of tiny projects?*

Only a projects big enough to meet design criteria will be added. A window of application will open each year, with the goal of identifying the best project options. Only 1-2 projects will be added each year.

Recharge Net Metering (ReNeM): FAQ-2

- *What if a site does not perform as expected?*

It will be improved or retired.

- *What about water quality?*

Work at Harkins Slough suggests water quality improvement during MAR. Some sites will be assessed to verify, will depend on funding source.

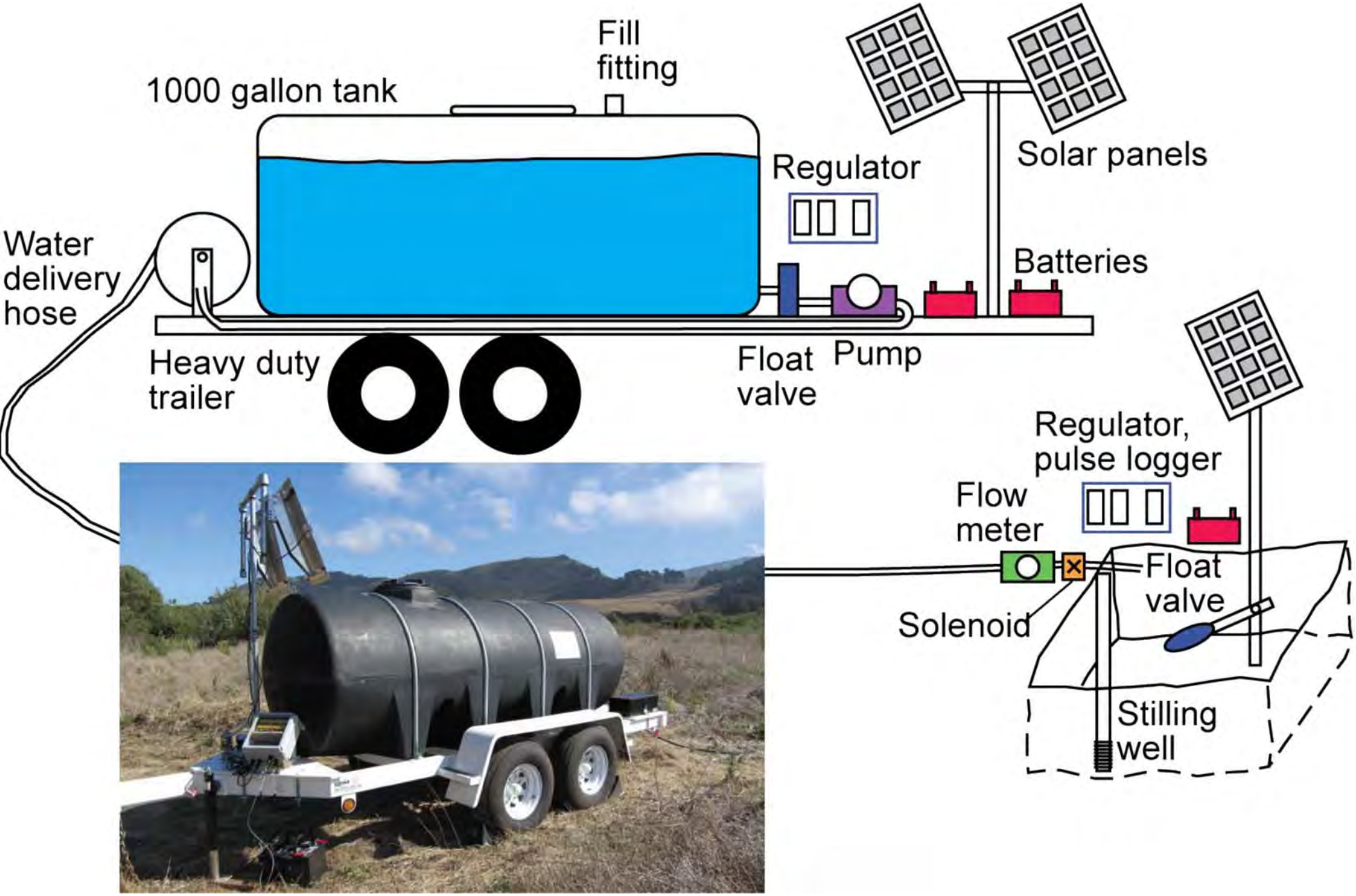
- *Who pays the TPC?*

For initial five-year period, TPC to be supported by external funds. One goal of the pilot program is to develop realistic time, personnel, and funding requirements for sustainability, determine how to establish a funding stream to support a continuous program.

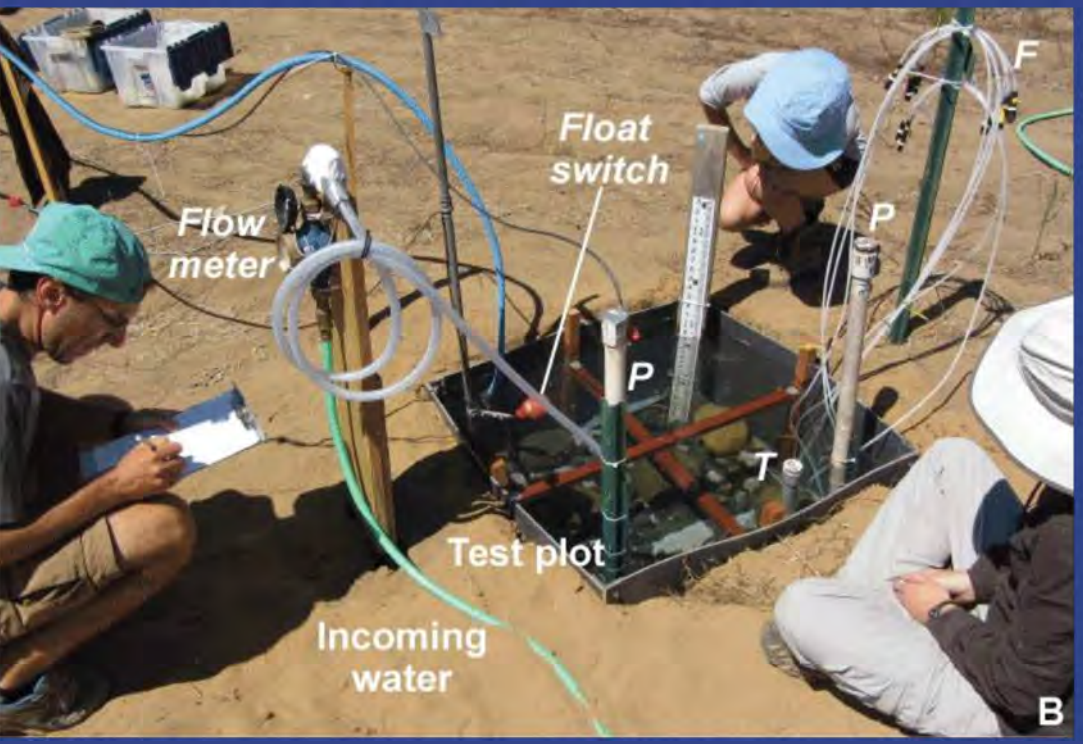
- *Why should the Agency run a ReNeM program?*

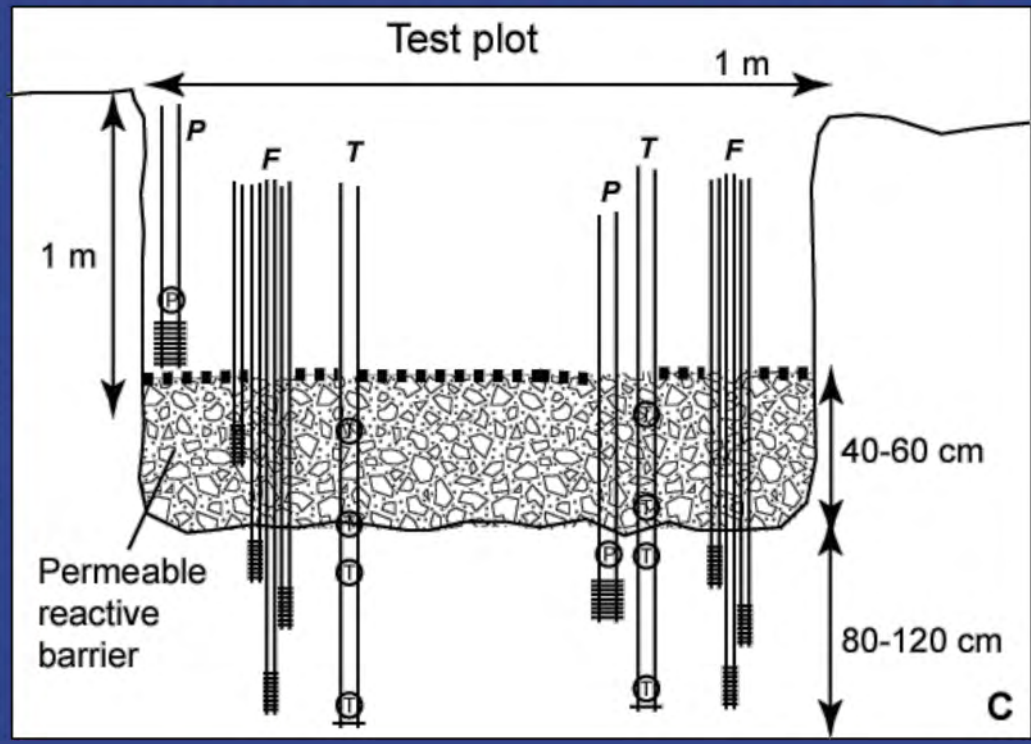
Get a jump on the BMP; some years will be dry; rain is getting more intense (more runoff/less infiltration); more water = more resilience; need to increase inflow to help make up for historical overdraft.

Infiltration test system to evaluate MAR potential



Infiltration/Denitrification Testing System





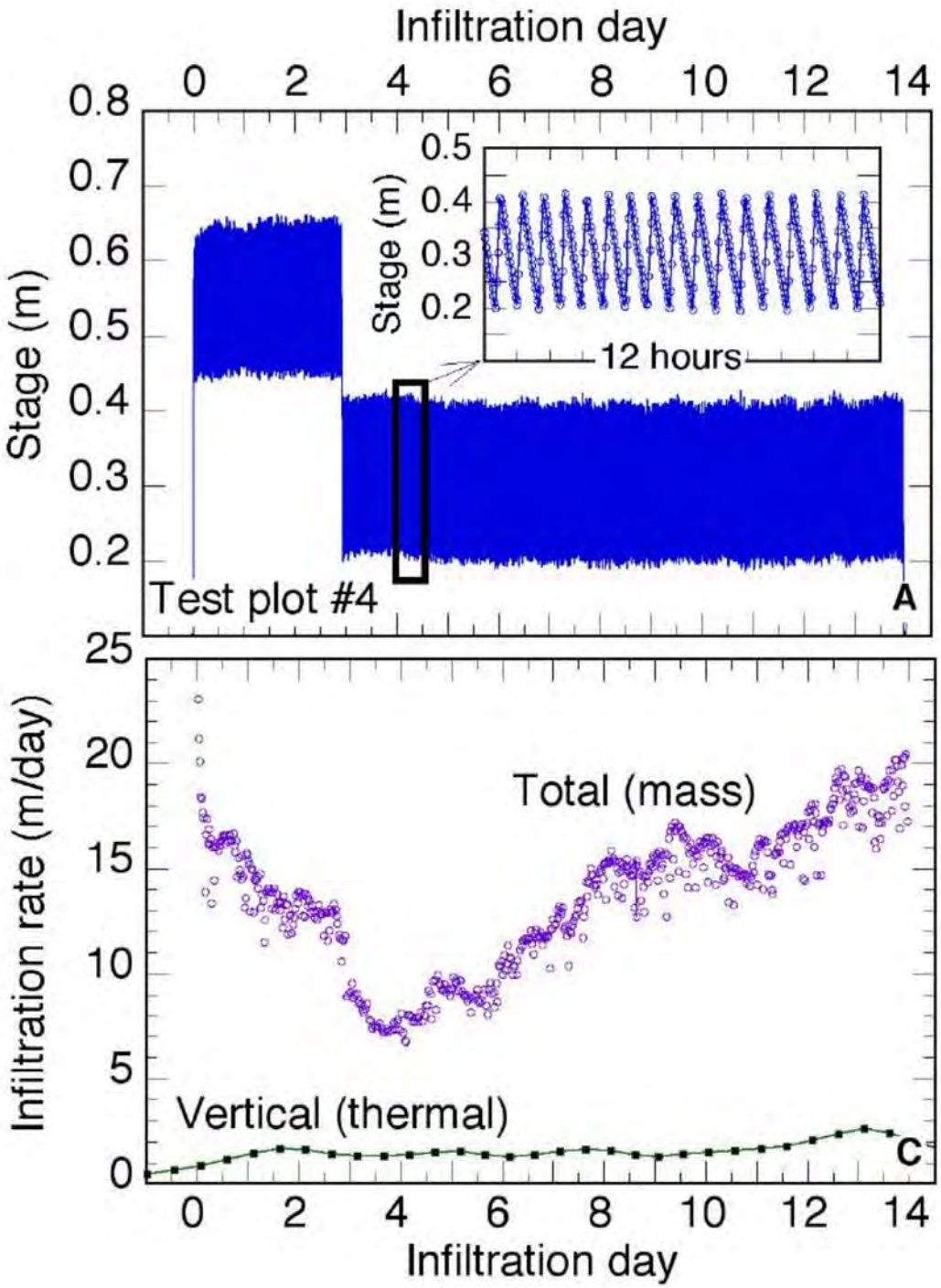
Infiltration/Denitrification Testing System

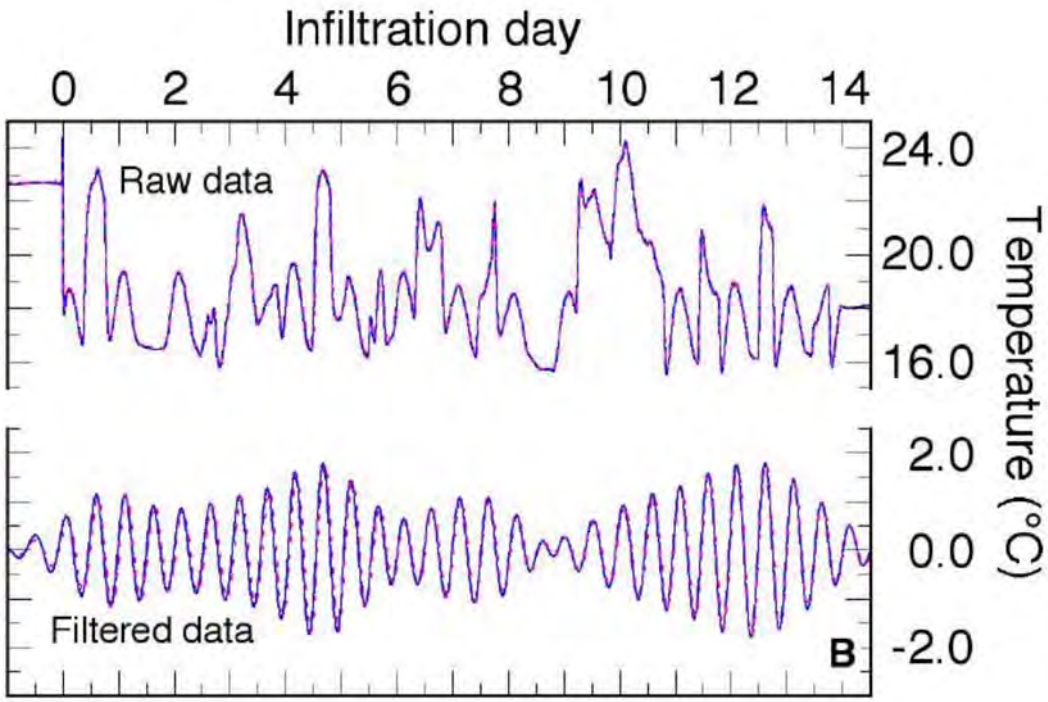
Ready to run!

Multiple fill/empty cycles

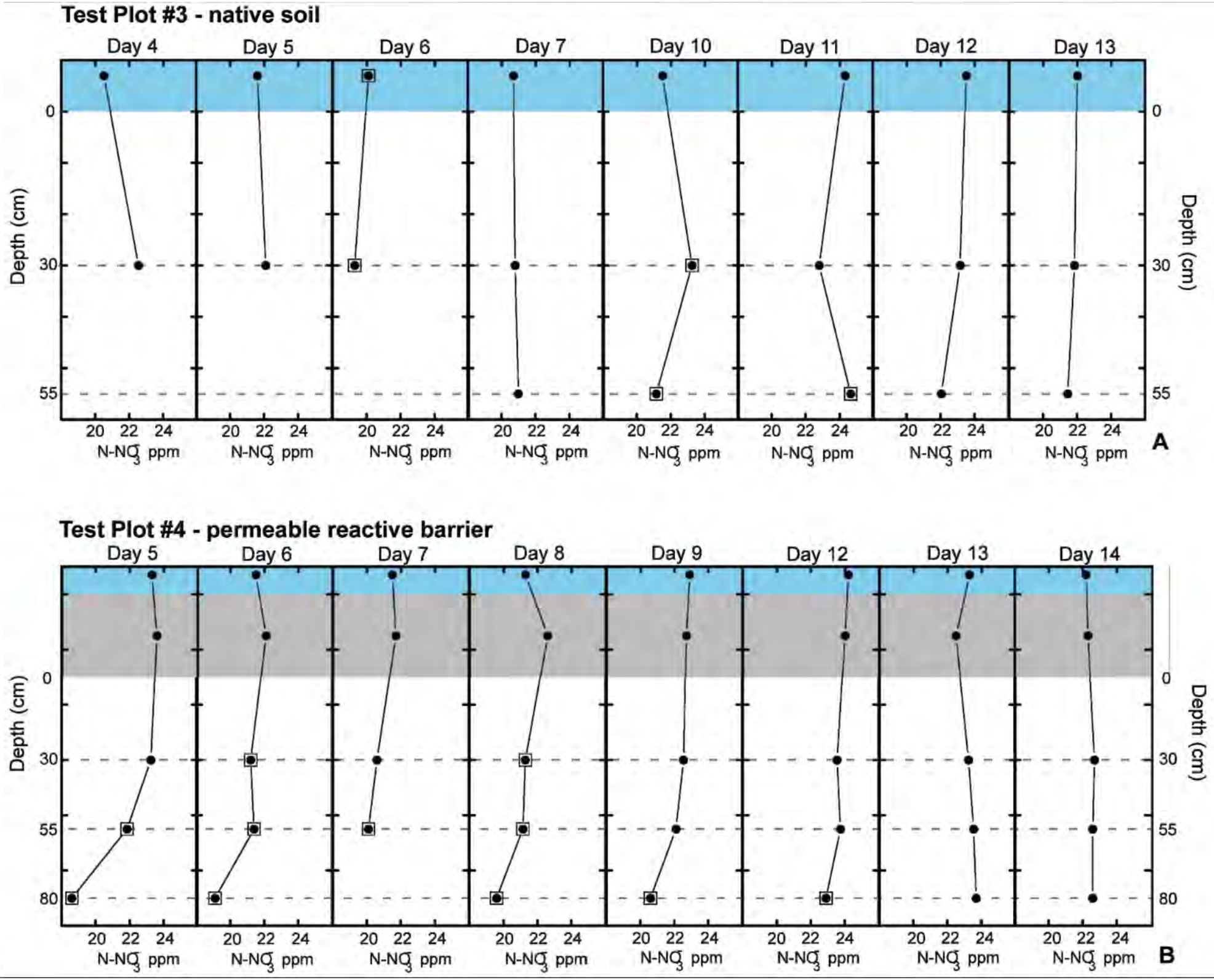
Infiltration/Denitrification Testing System

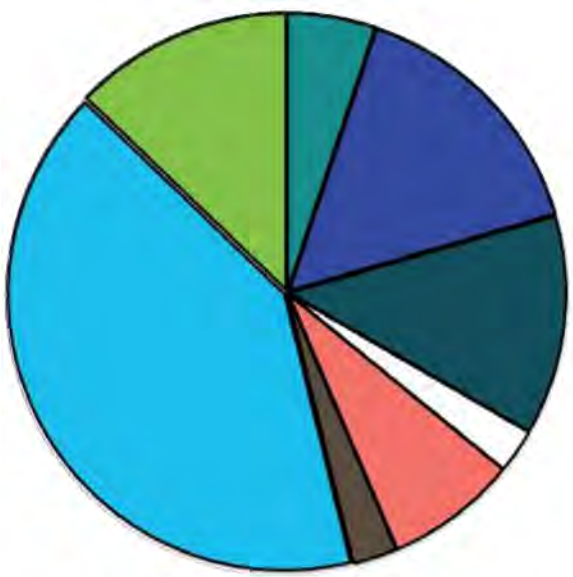
Daily fluid sampling (multiple depths)

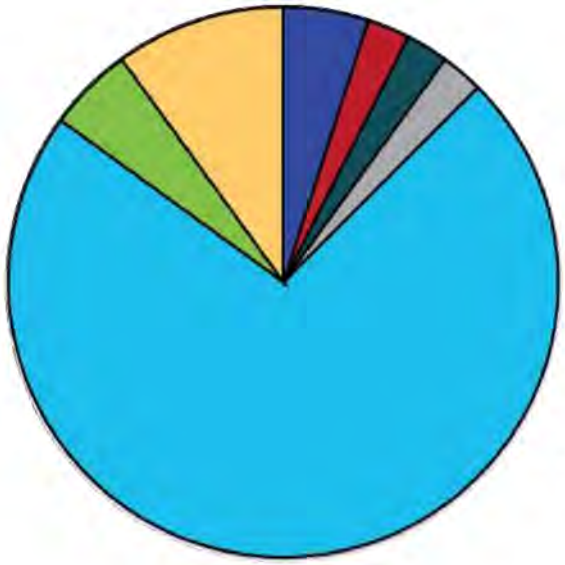




- *Very rapid infiltration (dune sand)*
- *Much higher total infiltration than vertical infiltration*

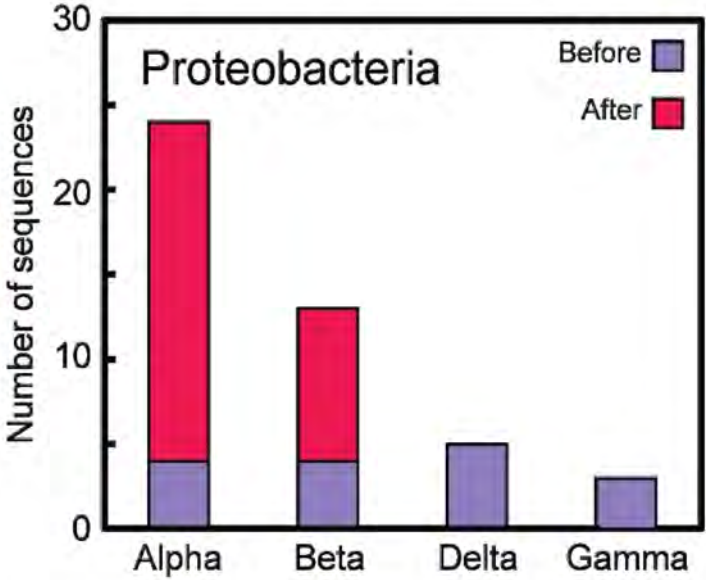

Test Plot #3 - native soil
Day 4
Day 5
Day 6
Day 7
Day 10
Day 11
Day 12
Day 13
Depth (cm)
0
30
55
20 22 24
N-NO3 ppm
A
Test Plot #4 - permeable reactive barrier
Day 5
Day 6
Day 7
Day 8
Day 9
Day 12
Day 13
Day 14
Depth (cm)
0
30
55
80
20 22 24
N-NO3 ppm
B





Before infiltration

After infiltration



Proteobacteria
Actinobacteria
Armatimonadetes
Unclassified bacteria
Verrucomicrobia
Gemmatimonadetes
Chloroflexi
Nitrospirae
Acidobacteria
Plantomycetes
Latescibacteria

Test plot #4 with PRB

Comparing conditions before/after infiltration:
Change in microbial ecology