Deep Percolation and Mountain Front Recharge: San Gabriel Mountains

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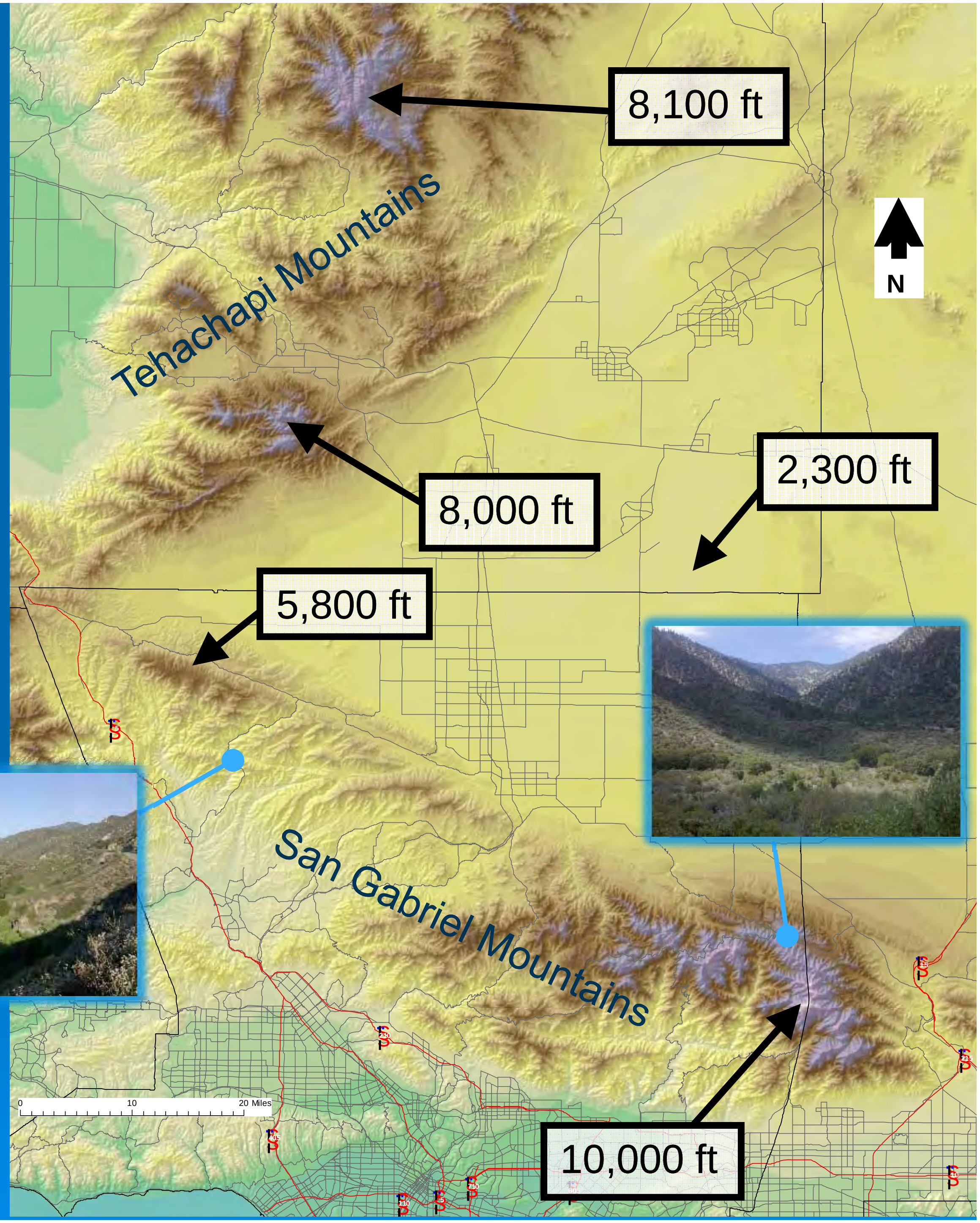
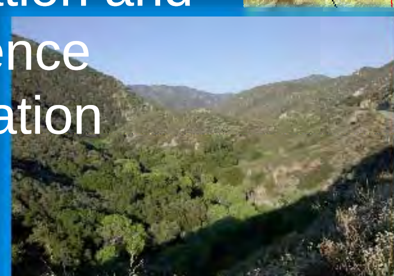
San Gabriel Mountains

(Los Angeles)

Mountain elevations are high with steep slopes

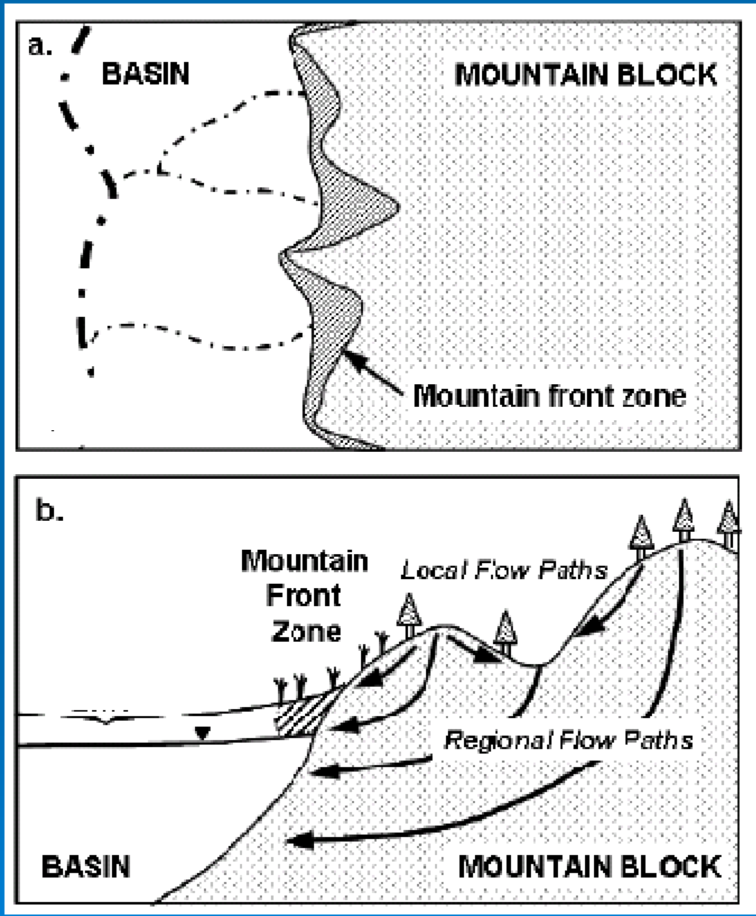
Topo slope and aspect influence precipitation and strongly influence evapotranspiration





Motive: Estimate Mountain Front Recharge

is all water that passes from the mountain to the adjacent basins



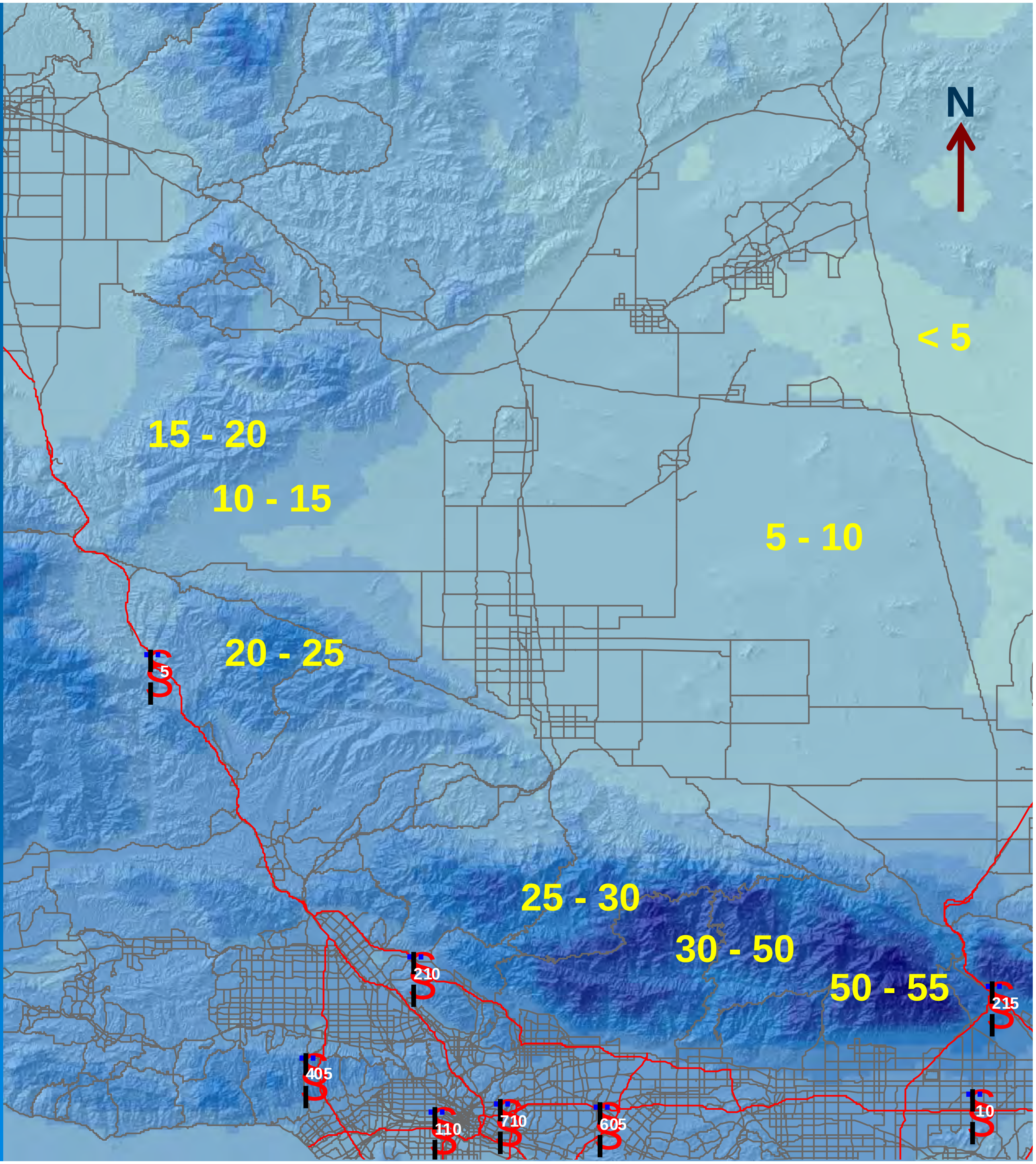
Wilson, J.L. and H. Guan, Mountain-Block Hydrology and Mountain-Front Recharge, in *Groundwater Recharge in a Desert Environment: The Southwestern United States*, edited by F. M. Phillips, J. Hogan, and B. Scanlon, American Geophysical Union, Washington, DC, 2004.

Mean Annual Precipitation from PRISM

(inches)

Data source for spatial pattern of precipitation.

There is significant orographic influence, with highest precipitation at higher elevations

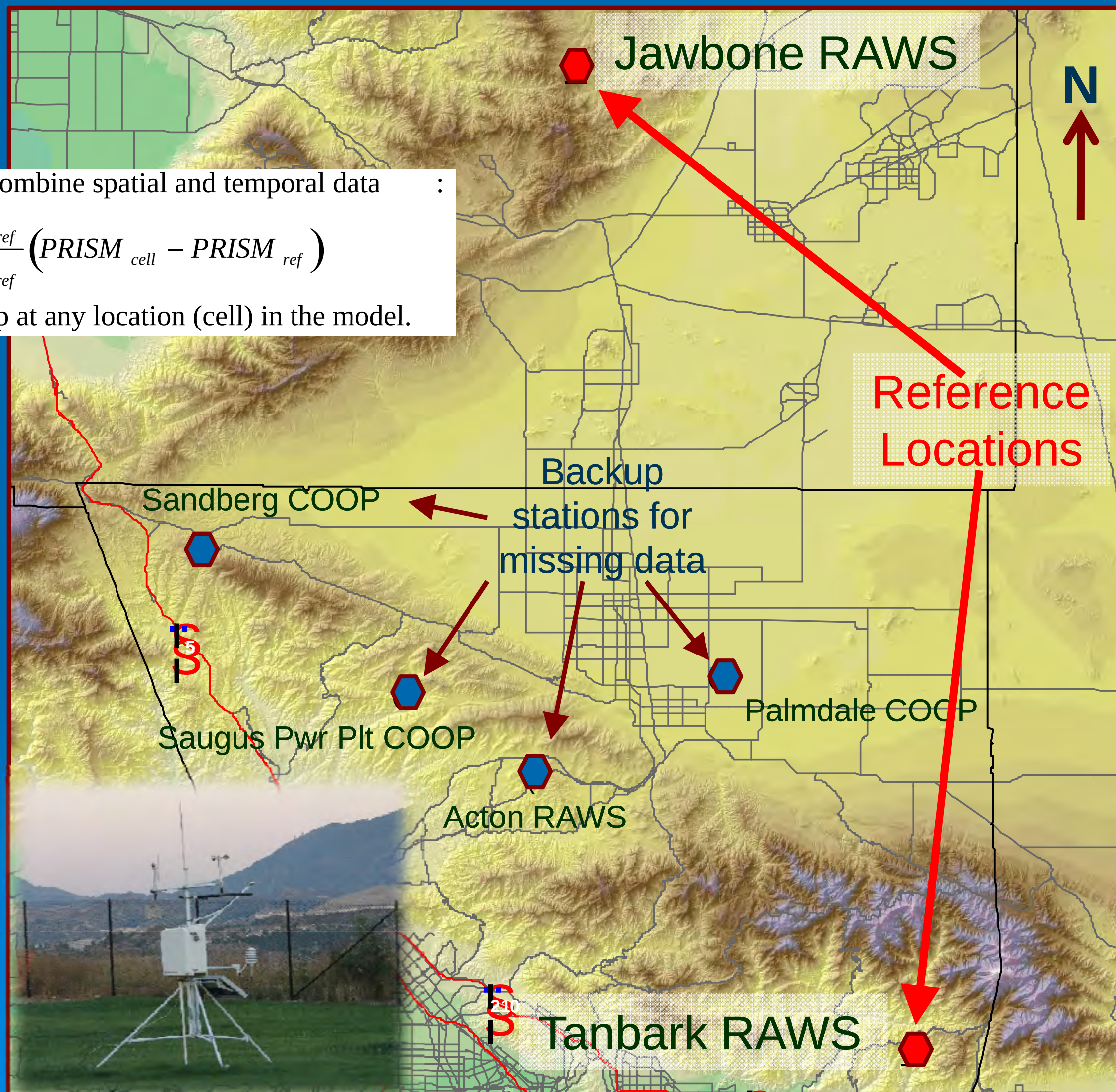


Local Weather Stations Used to Estimate the Temporal Pattern of Daily Precipitation

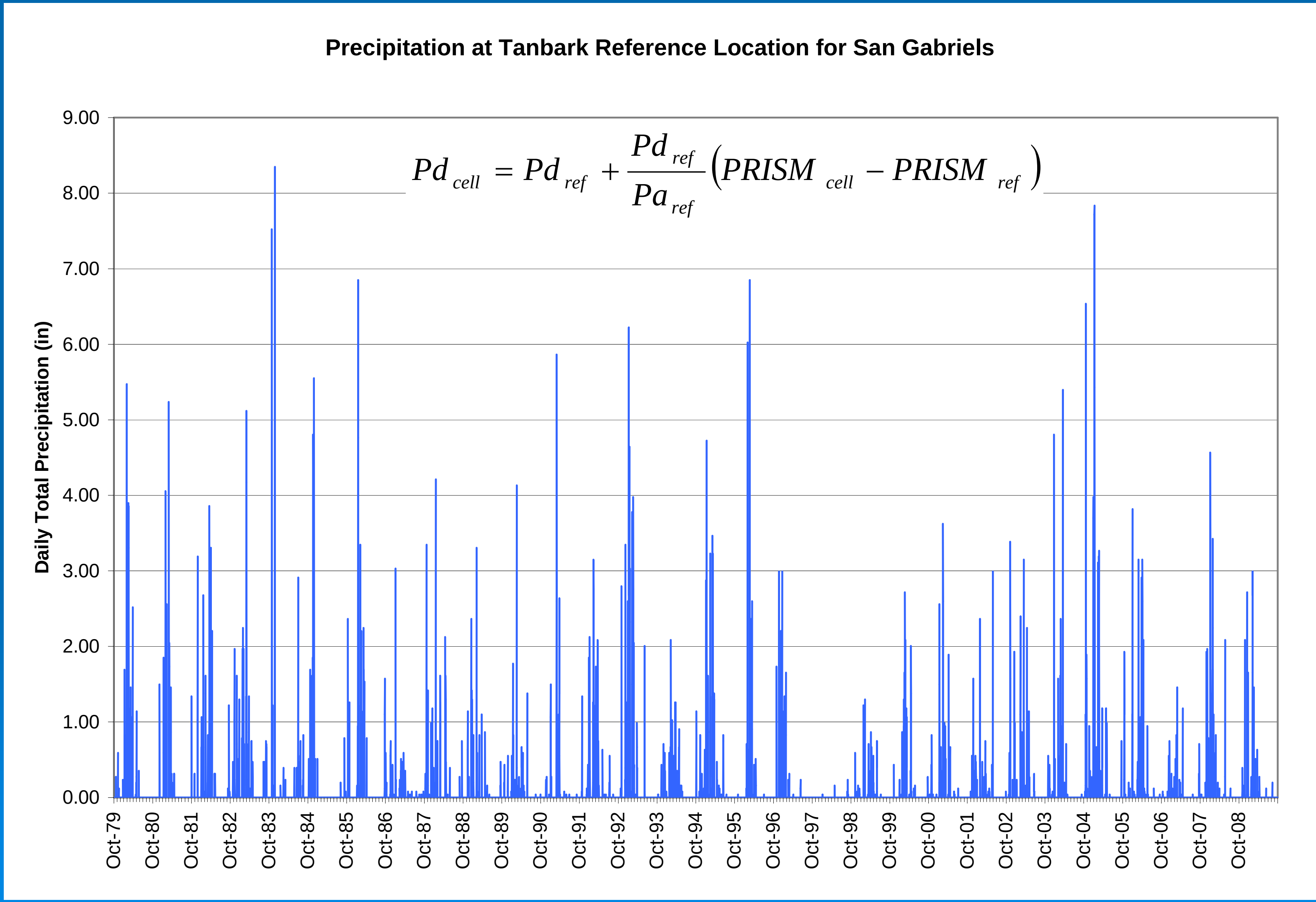
Algorithm used to combine spatial and temporal data :

$$Pd_{cell} = Pd_{ref} + \frac{Pd_{ref}}{Pa_{ref}}\left(PRISM_{cell} - PRISM_{ref}\right)$$

Pd_{cell} = Daily precip at any location (cell) in the model.



Daily Time Series Has Important Event, Seasonal, and Annual Variation of Precipitation (Input to Model)

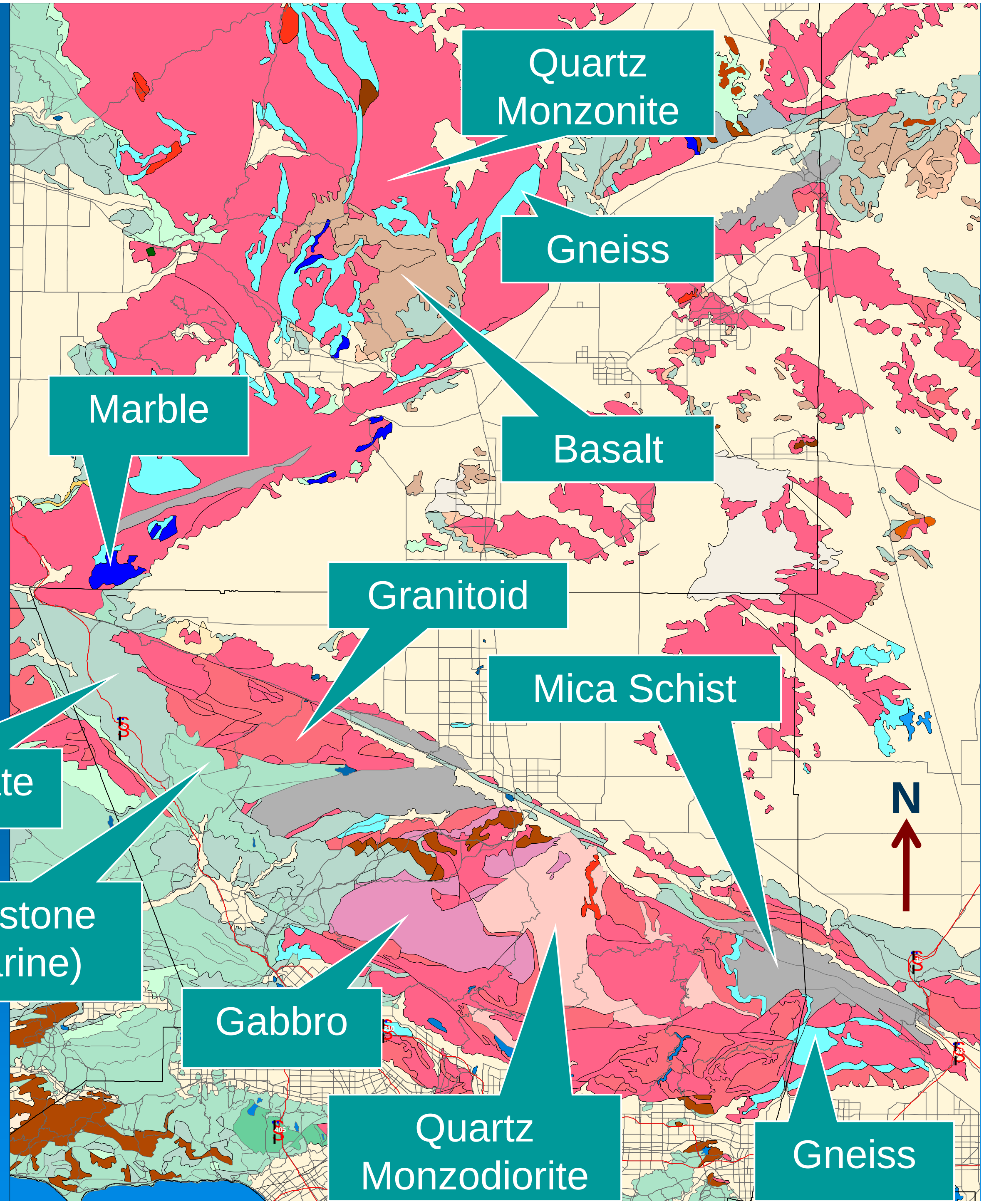


Geology

from USGS

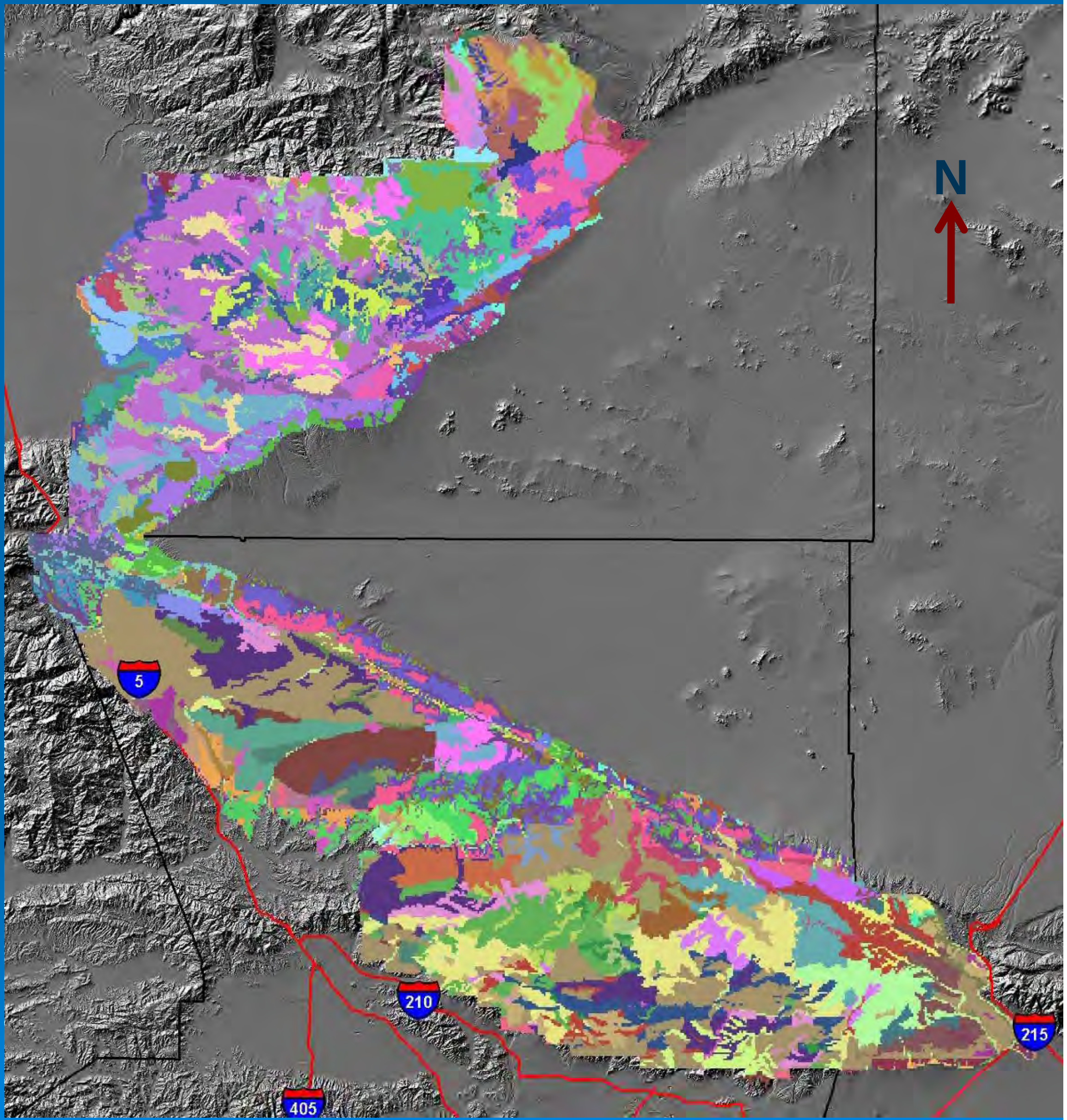
Bedrock in the San Gabriel and Tehachapi Mountains is heavily fractured and faulted.

Geology influences evapotranspiration, runoff, and deep percolation of water into the bedrock



Over 400 soil types
from USDA Data

Soil type influences evapotranspiration, runoff, and deep percolation of water into the bedrock

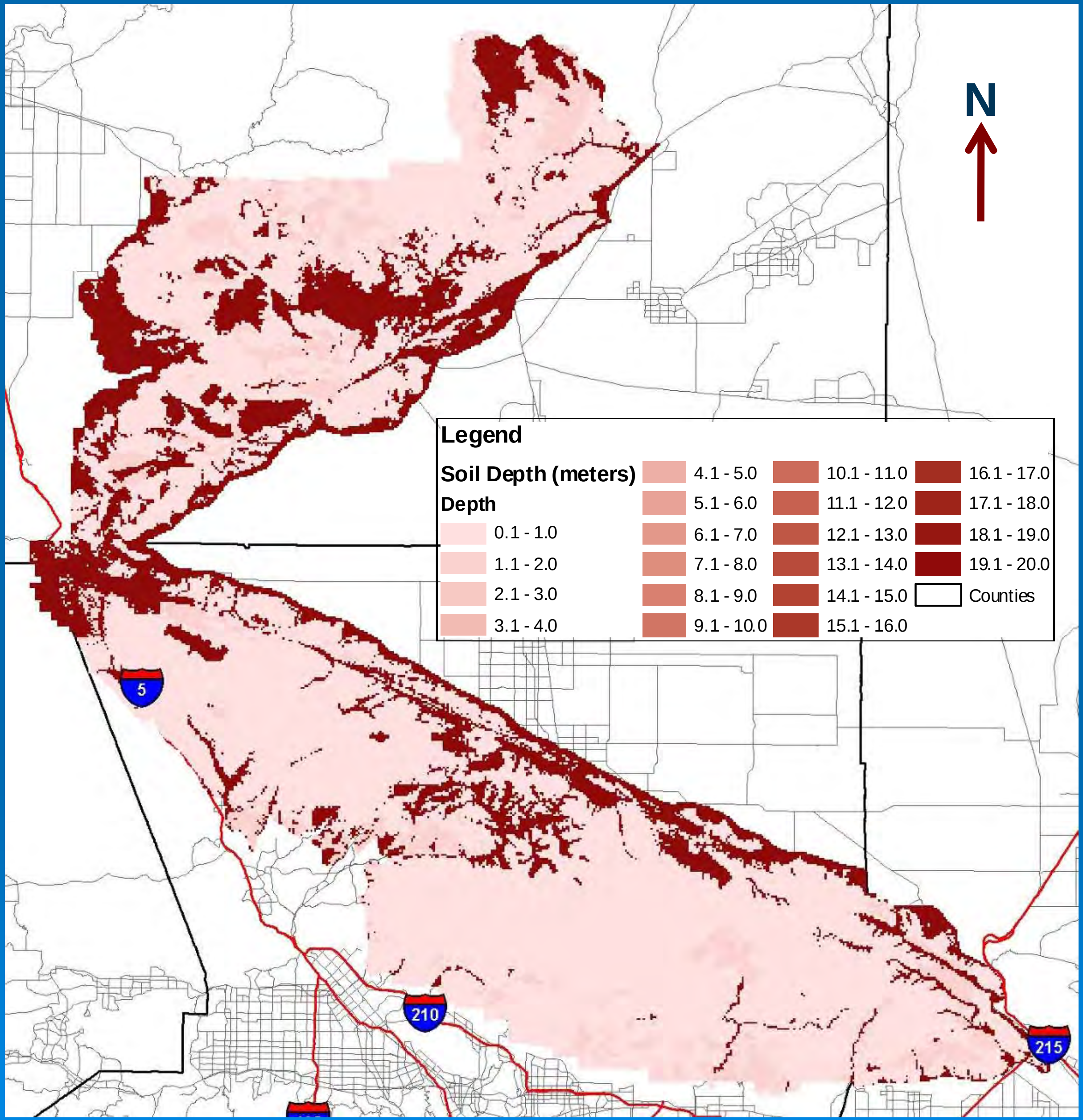


Soil Depth

from USDA Data

Soil depth influences evapotranspiration, runoff, and deep percolation of water into the bedrock

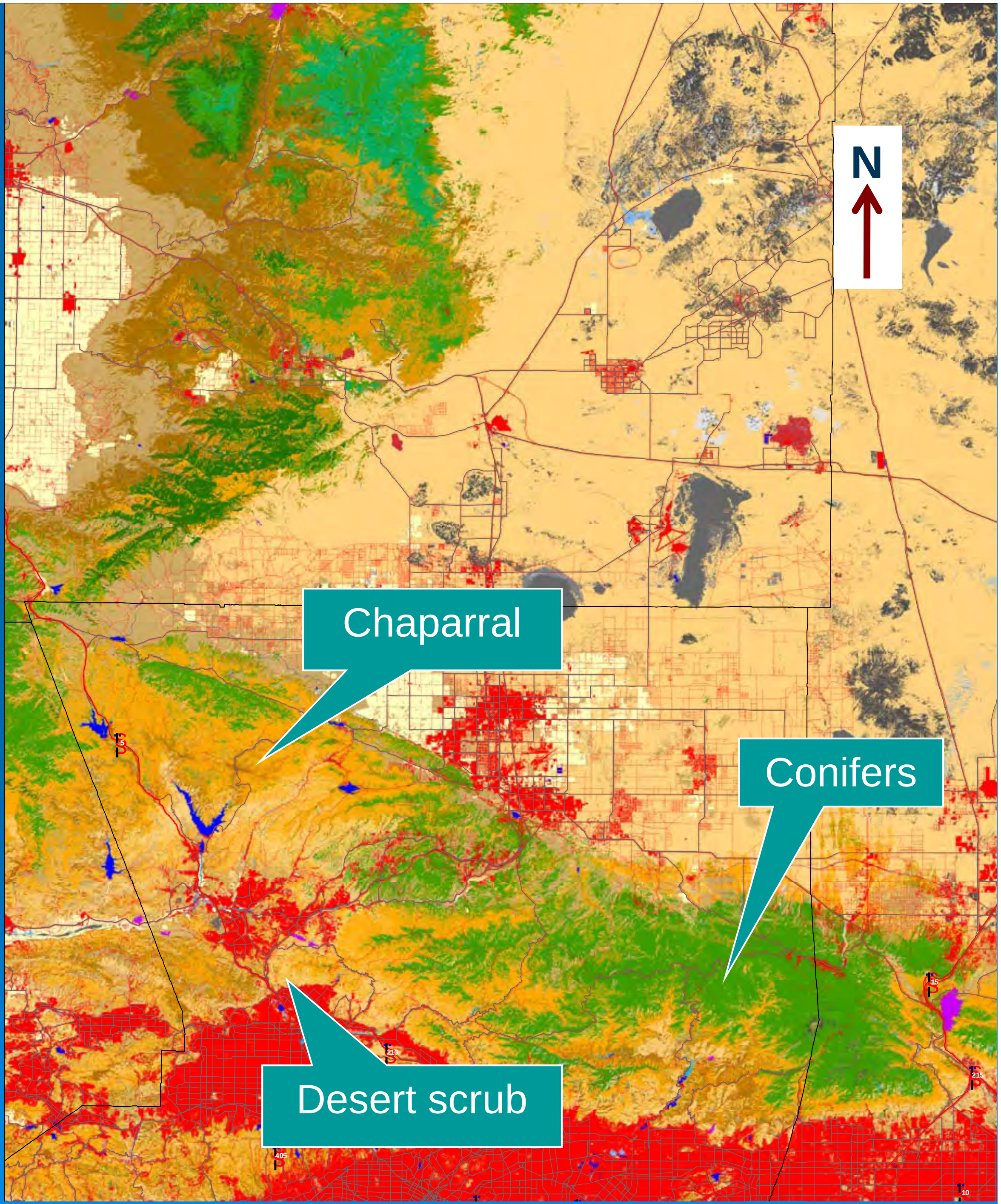
Soils are often less than one meter (~3 ft.) thick; less soil-water storage, less evapotranspiration, more runoff, more deep percolation



Vegetation

Vegetation influences evapotranspiration, runoff, and deep percolation of water into the bedrock

Vegetation changes with elevation, slope, and aspect

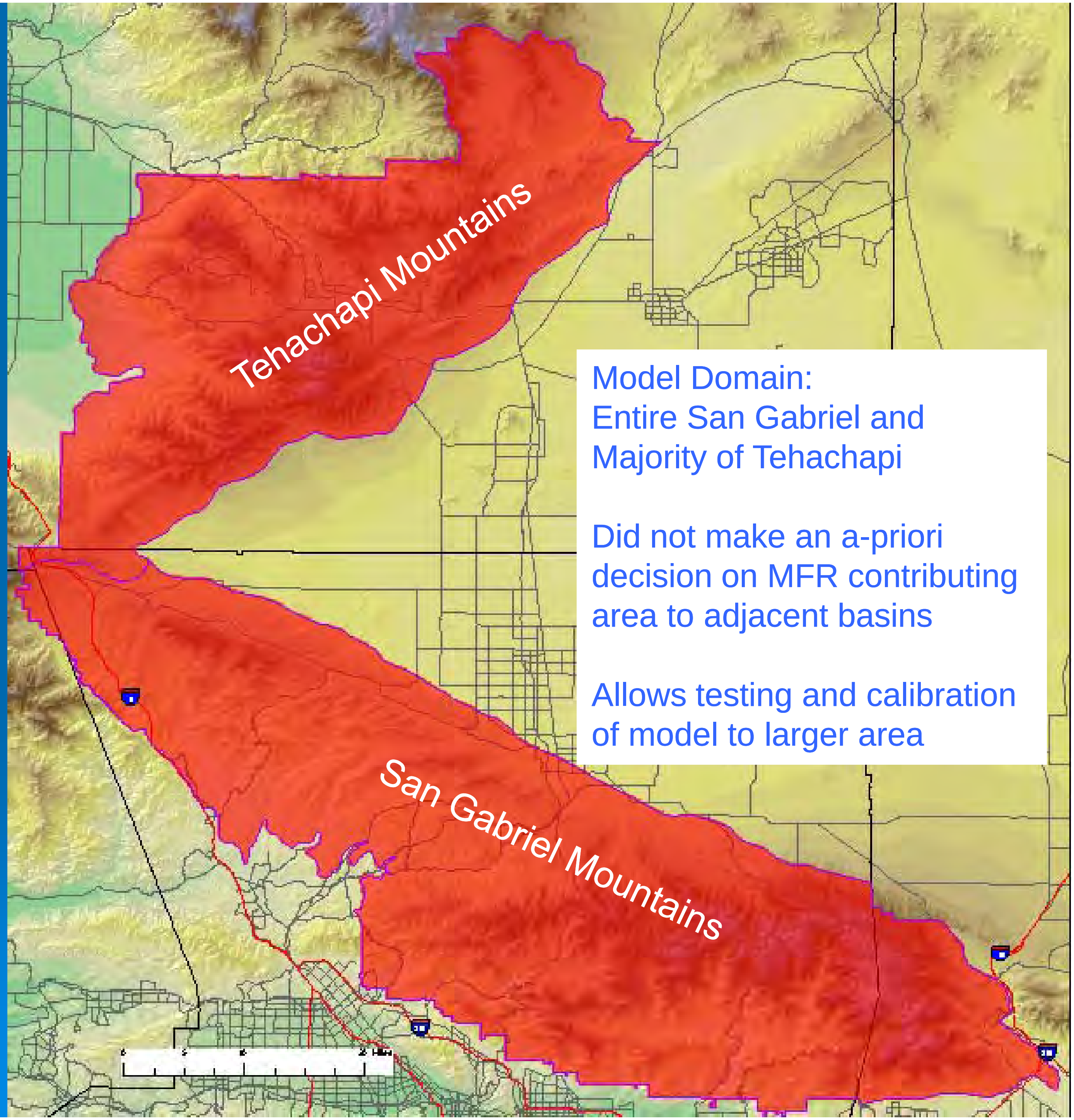


Chaparral near Bouquet Reservoir in the San Gabriel Mountains

Model Area

We modeled the mountains blocks

and not the valley floor and playas, and not the bedrock outcrops in the valley



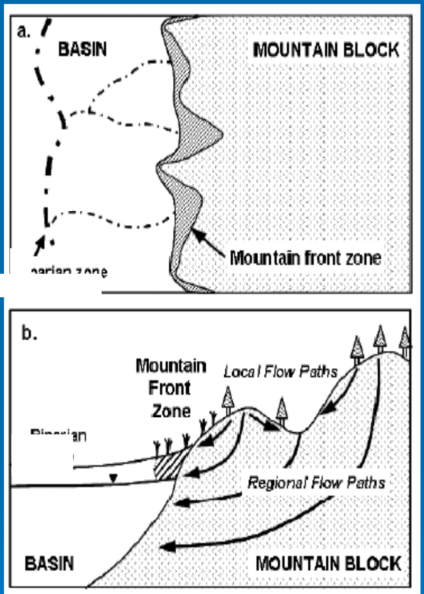
Model Domain:
Entire San Gabriel and Majority of Tehachapi

Did not make an a-priori decision on MFR contributing area to adjacent basins

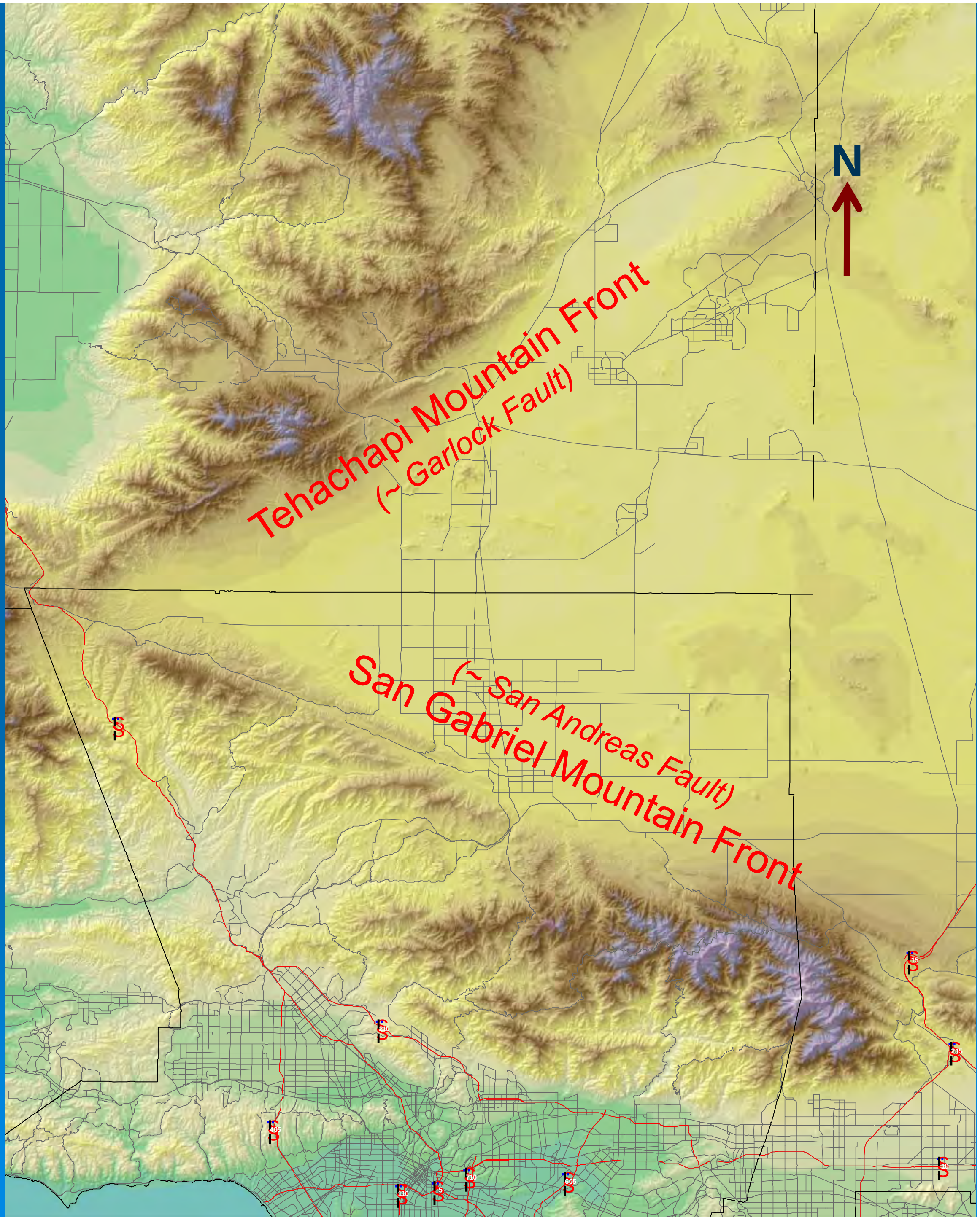
Allows testing and calibration of model to larger area

Mountain Front

(and topography)

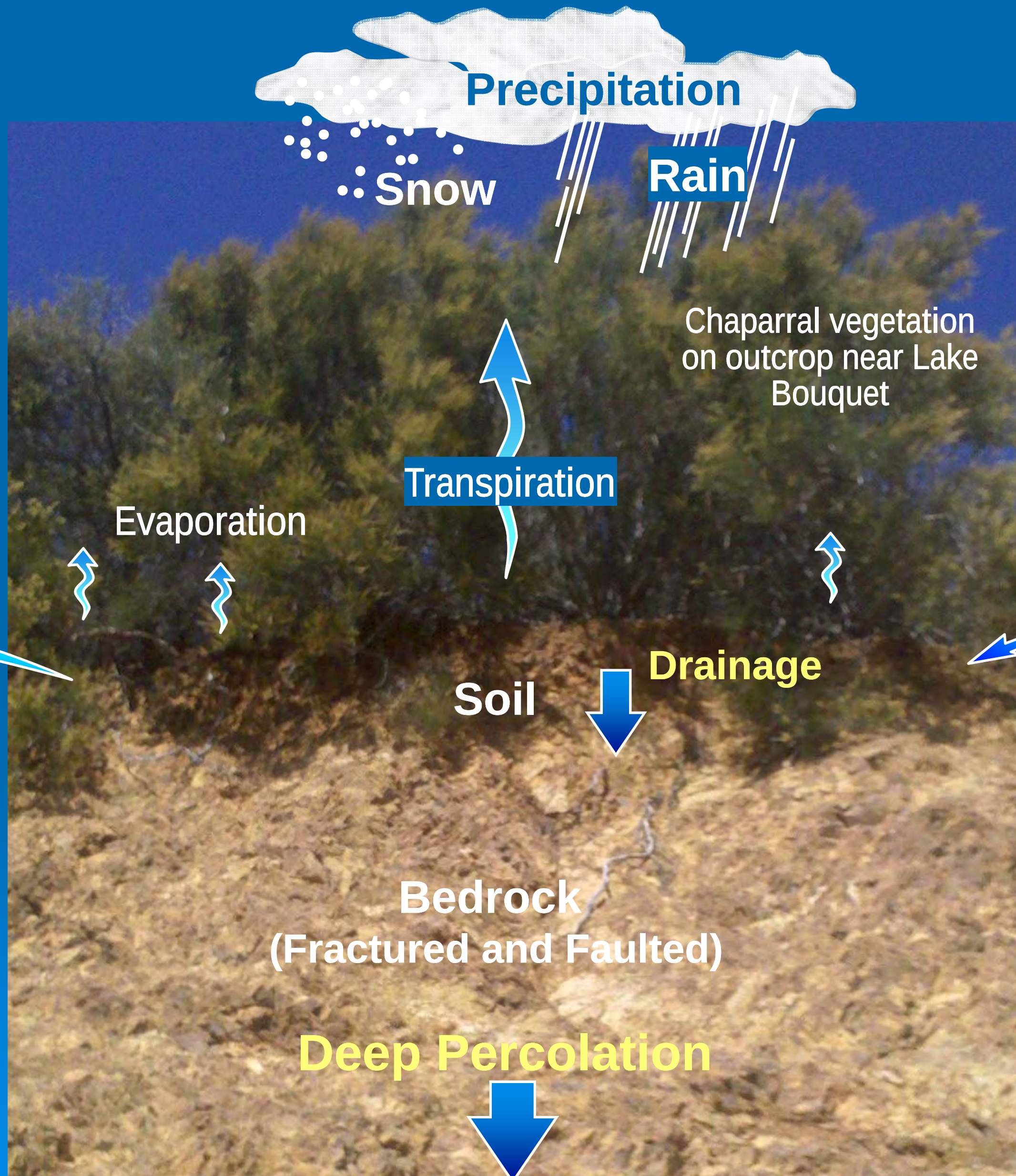


Wilson and Guan (2004)



Distributed Parameter Watershed Model (DPWM)

Schematic of Water Balance Components at the Land Surface



Precipitation is partitioned into soil water storage, evapotranspiration, runoff, and deep percolation into the bedrock.

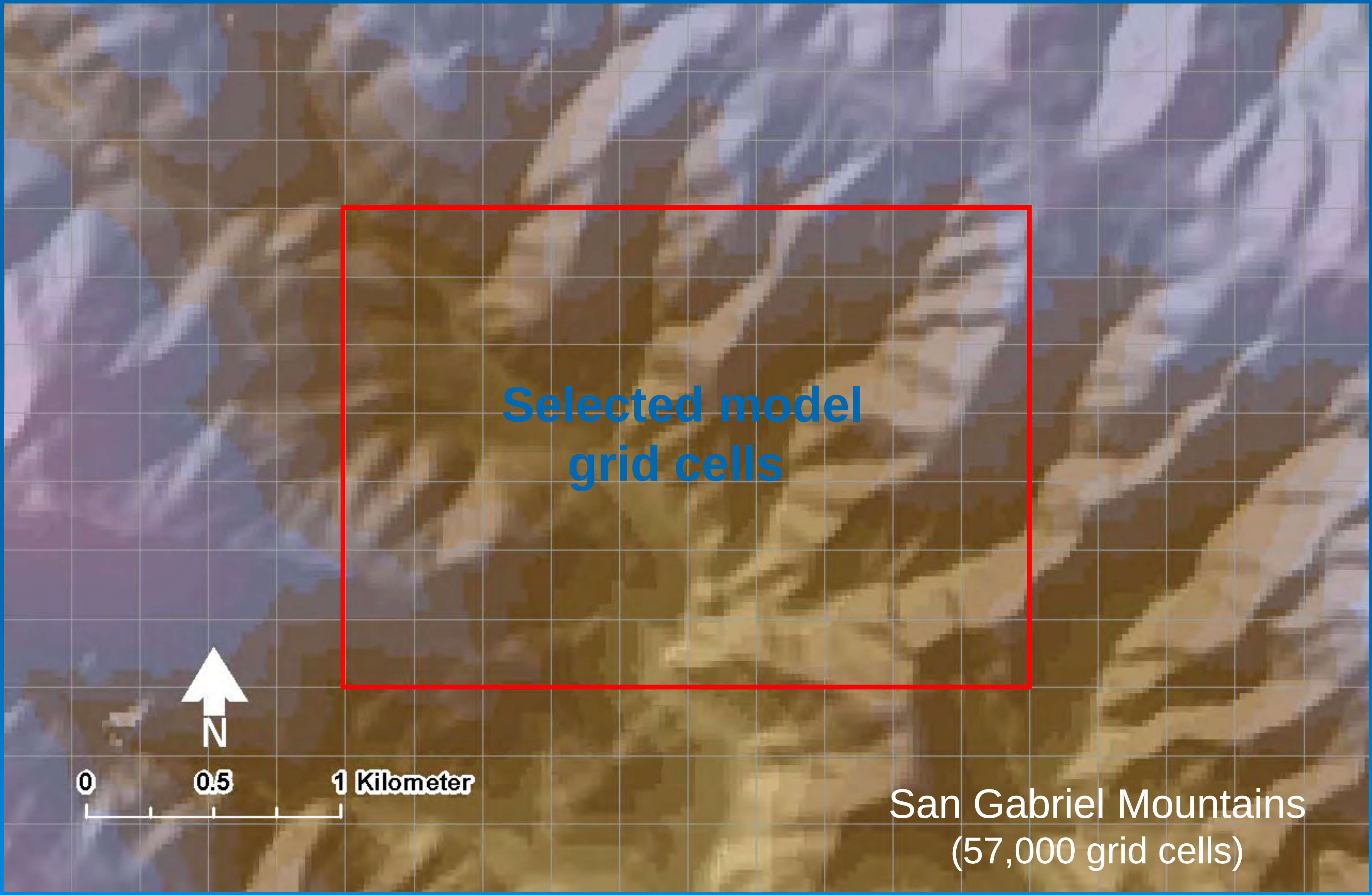
Distributed Parameter Watershed Model

DPWM History of Development

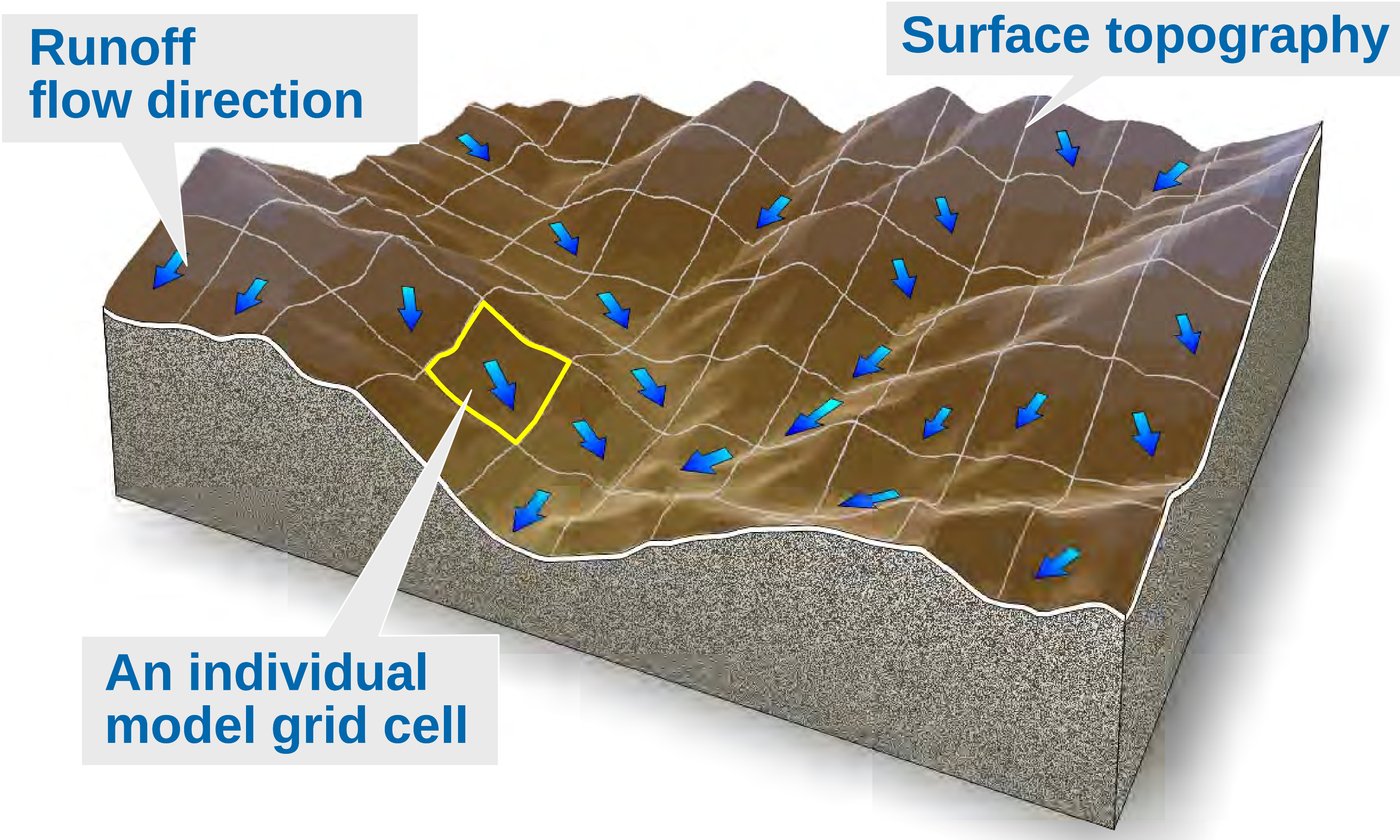
- USGS – PRMS
- USGS – INFIL & BCM (Basin Characterization Model)
- Sandia National Lab – MASSIF
  - Yucca Mountain
- Umstot, Hendrickx, Wilson– DPWM
  - Water rights hearings before the Nevada State Engineer
  - Salt Basin (NM/TX) on behalf of the NM State Engineer
  - Antelope Valley, CA

Portion of DPWM Model Grid

260 grid cells shown, each 270m on a side *(about length of 3 football fields)*

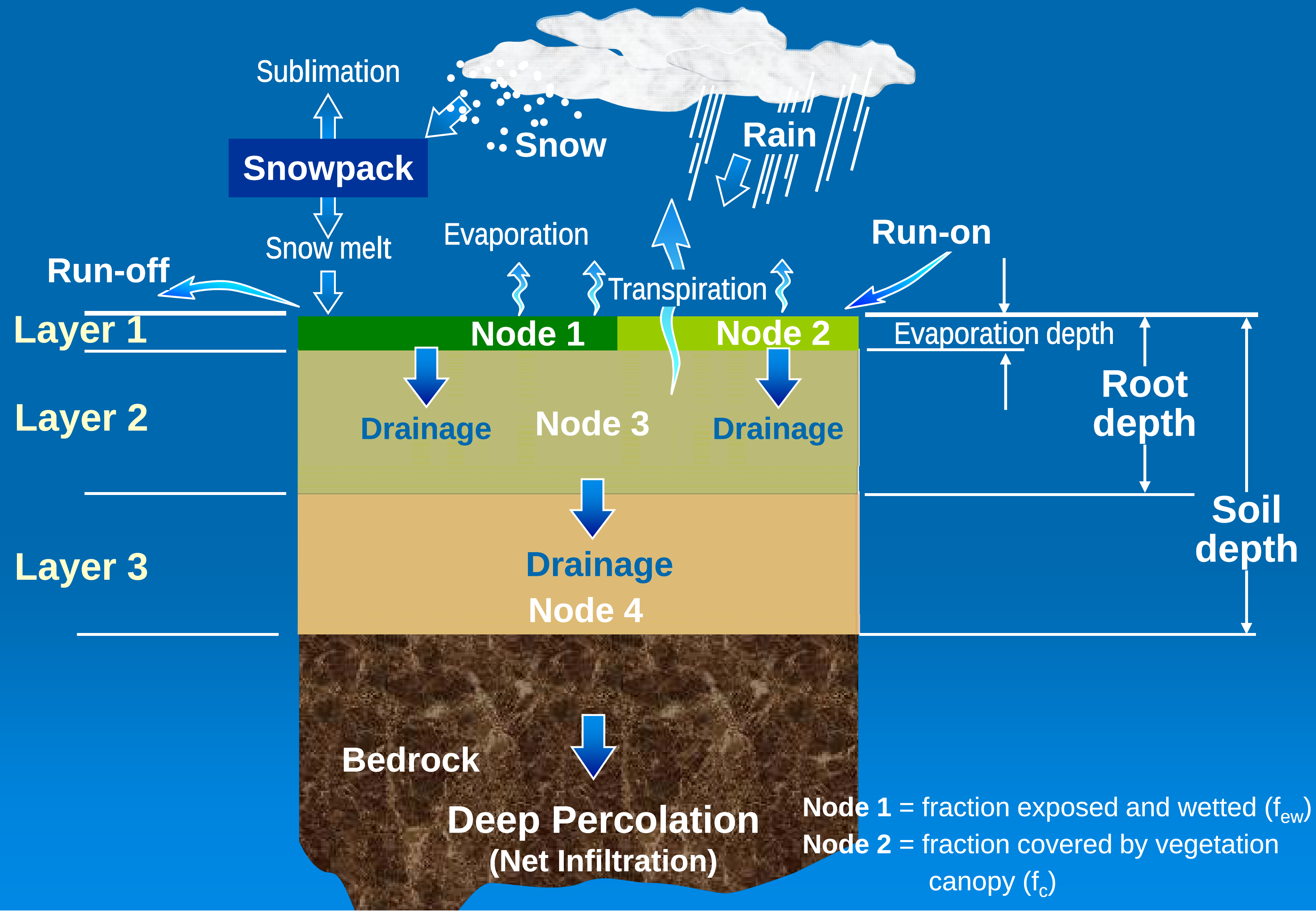


Model Grid (3D view)



Accounts for the variable topographic elevation, slope and aspect

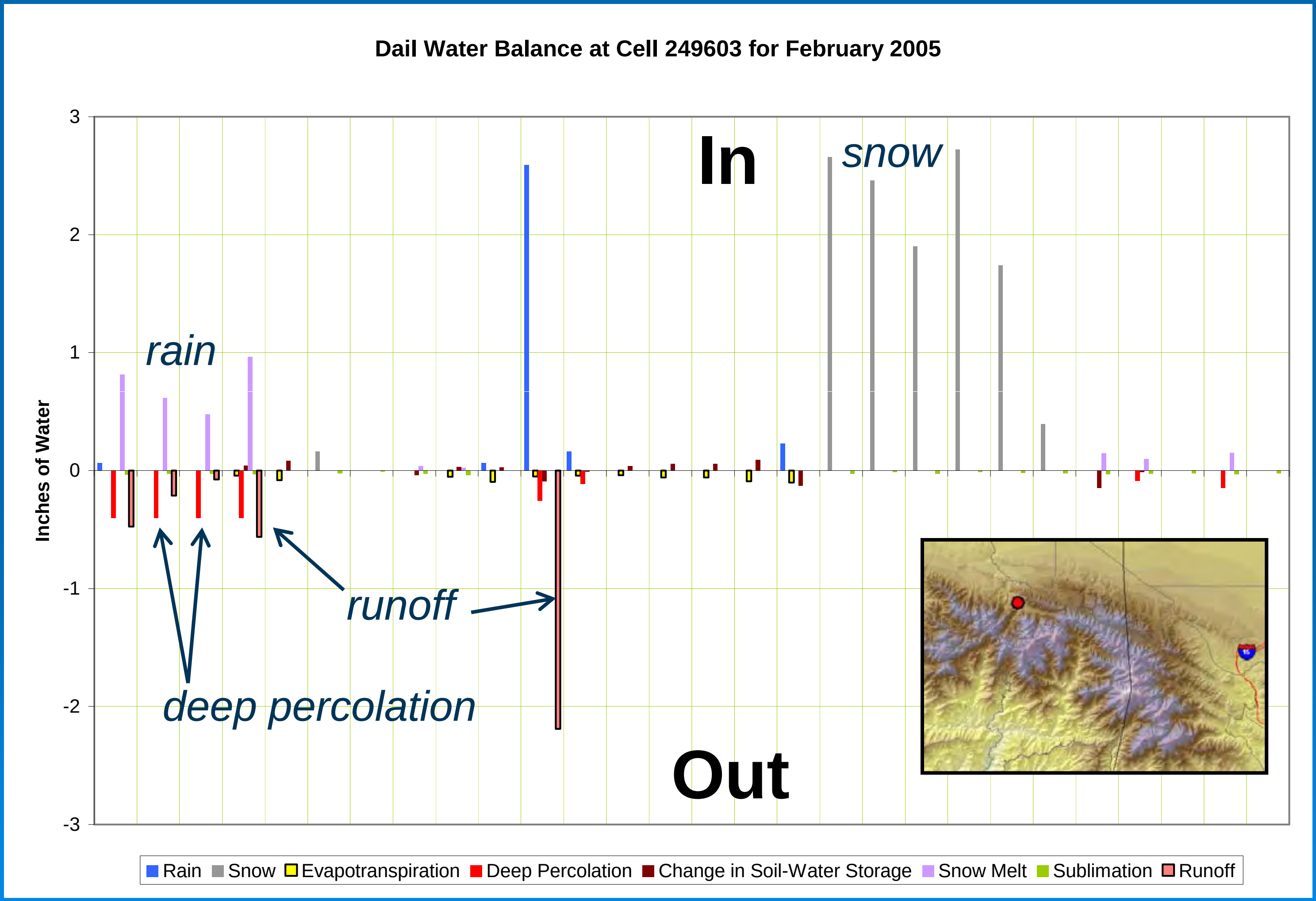
Schematic of Water Balance Components and Computational Nodes Present in a Single Model Cell



Runoff & Deep Percolation Are Episodic

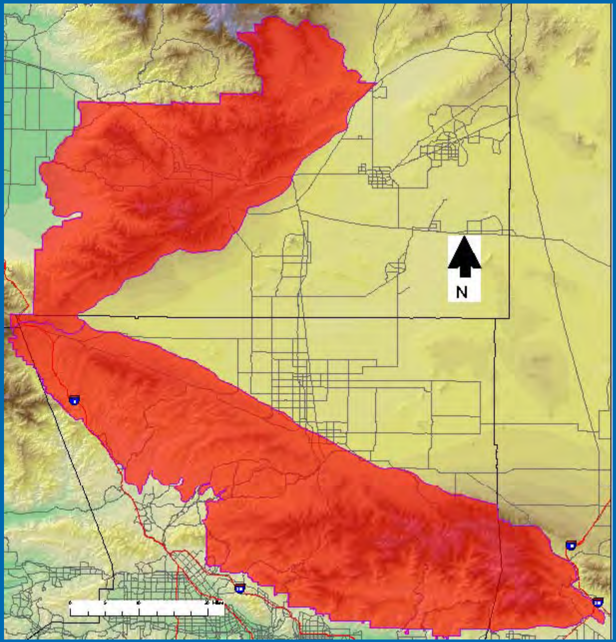
at the daily time scale

Example: Daily Water Balance at One Model Cell for February 2005



DPWM Provides a Long-term Water Balance Over an Entire Mountain Block

- In:
  - Precipitation
- Out:
  - Evapotranspiration +
  - Mountain Front Recharge
    - Runoff – to the surface watershed
    - Deep percolation – to the groundwater catchment



The DPWM allows one to relate mountain front recharge to precipitation in mountainous areas

Model Sensitivity Analysis

- To determine the most-important parameters
  - Perform new computer runs varying one parameter at a time
  - Examine model output (e.g., soil water storage, evapotranspiration, runoff, etc)
  - Initially used only downloaded data
- Topography very important but it is well known
- Most important <u>and</u> uncertain?
  - Soil thickness, texture, vegetation rooting depth
    - These are soil-water storage parameters
  - Soil and bedrock hydraulic conductivity
    - These are water transmission parameters

Model Calibration

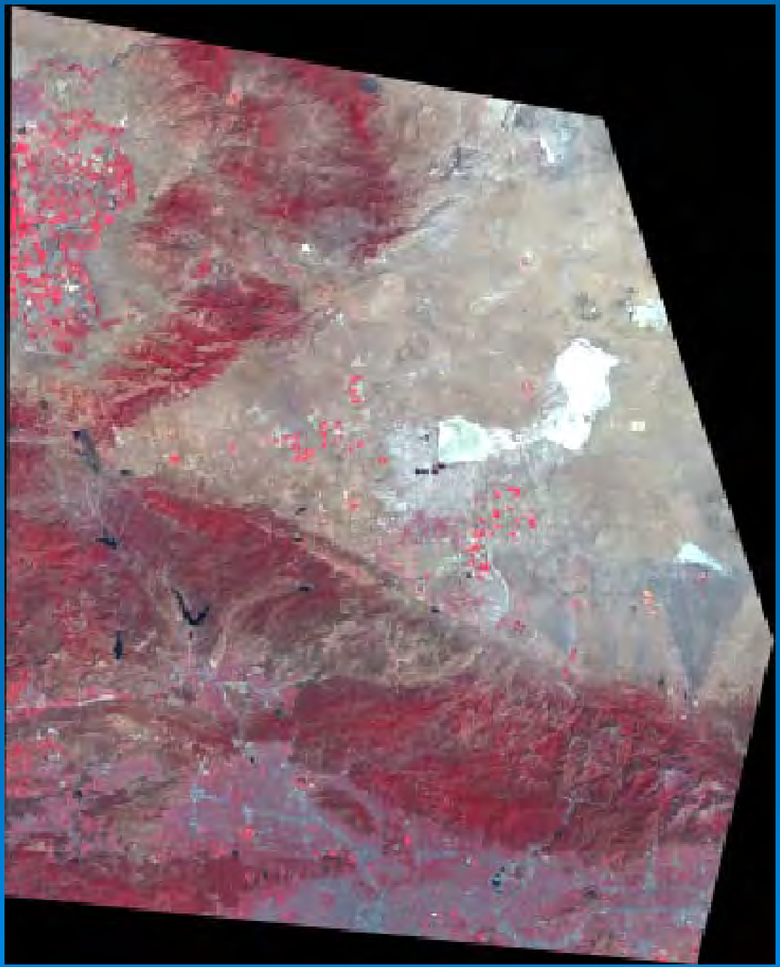
- Calibration focused on important and uncertain parameters …
  - Soil-water storage parameters
  - Soil and bedrock hydraulic conductivities

- Used two kinds of additional data
  - Remote sensing information (landsat imagery) on soil-water storage
    - To estimate net effect of soil-water storage capacity parameters
    - Led by Jan Hendrickx
  - Monthly streamflow (USGS gage data)
    - To estimate hydraulic conductivities

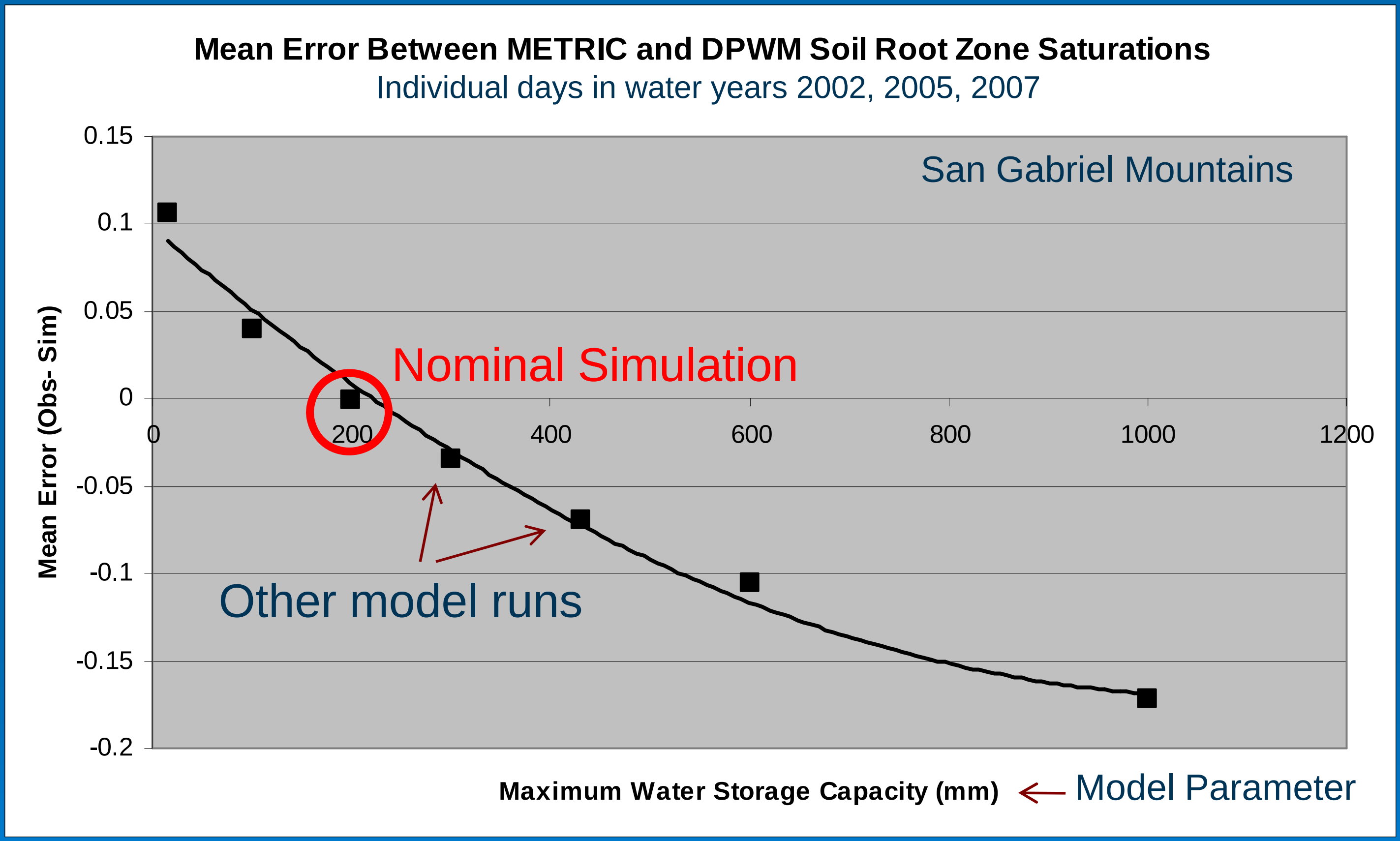
Landsat Image 30 August 2006

Natural Colors: Bands 1, 2, 3

False Colors: Bands 4, 3, 2



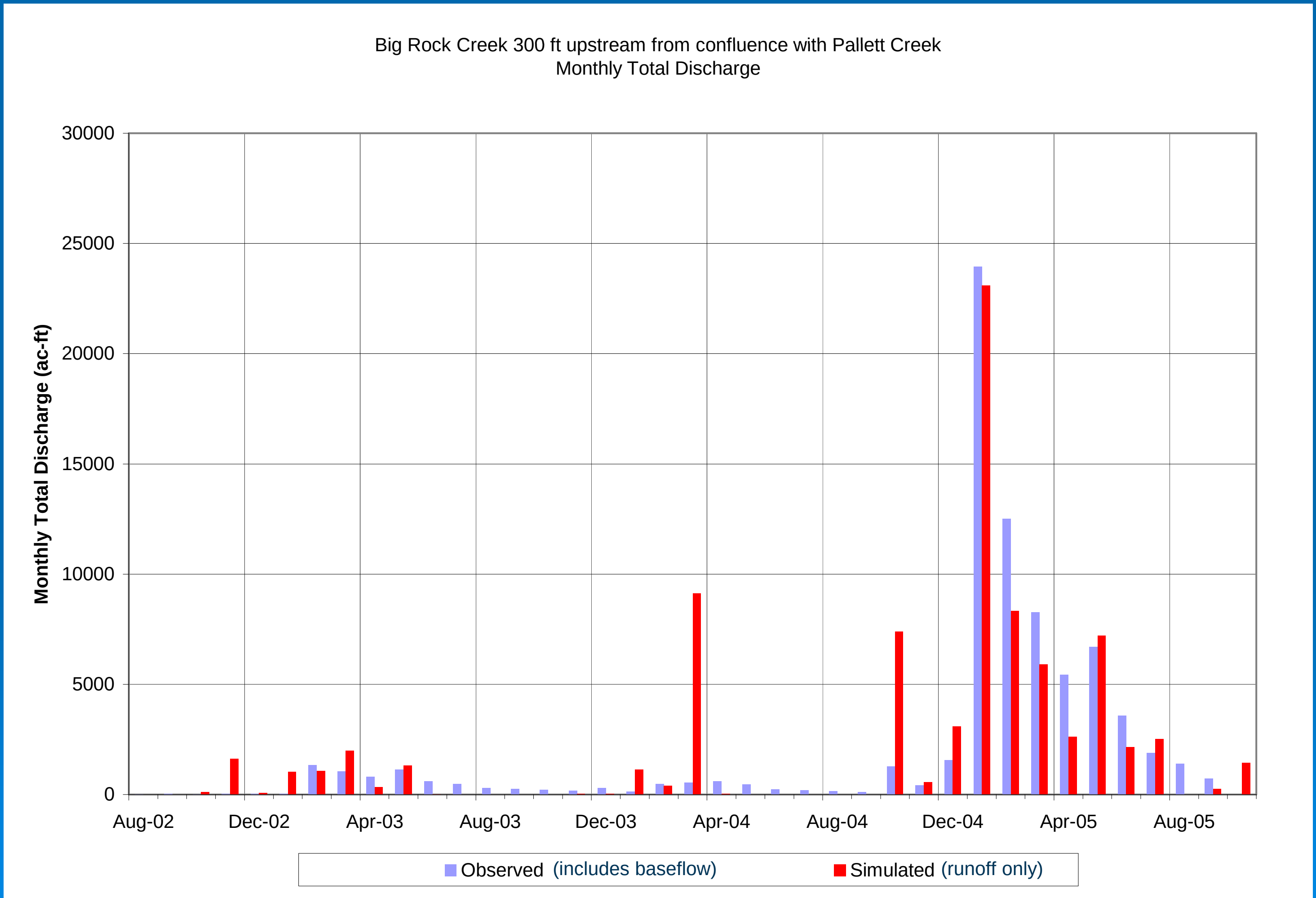
Model Soil Water Storage Best Calibrated with Remote Sensing Data



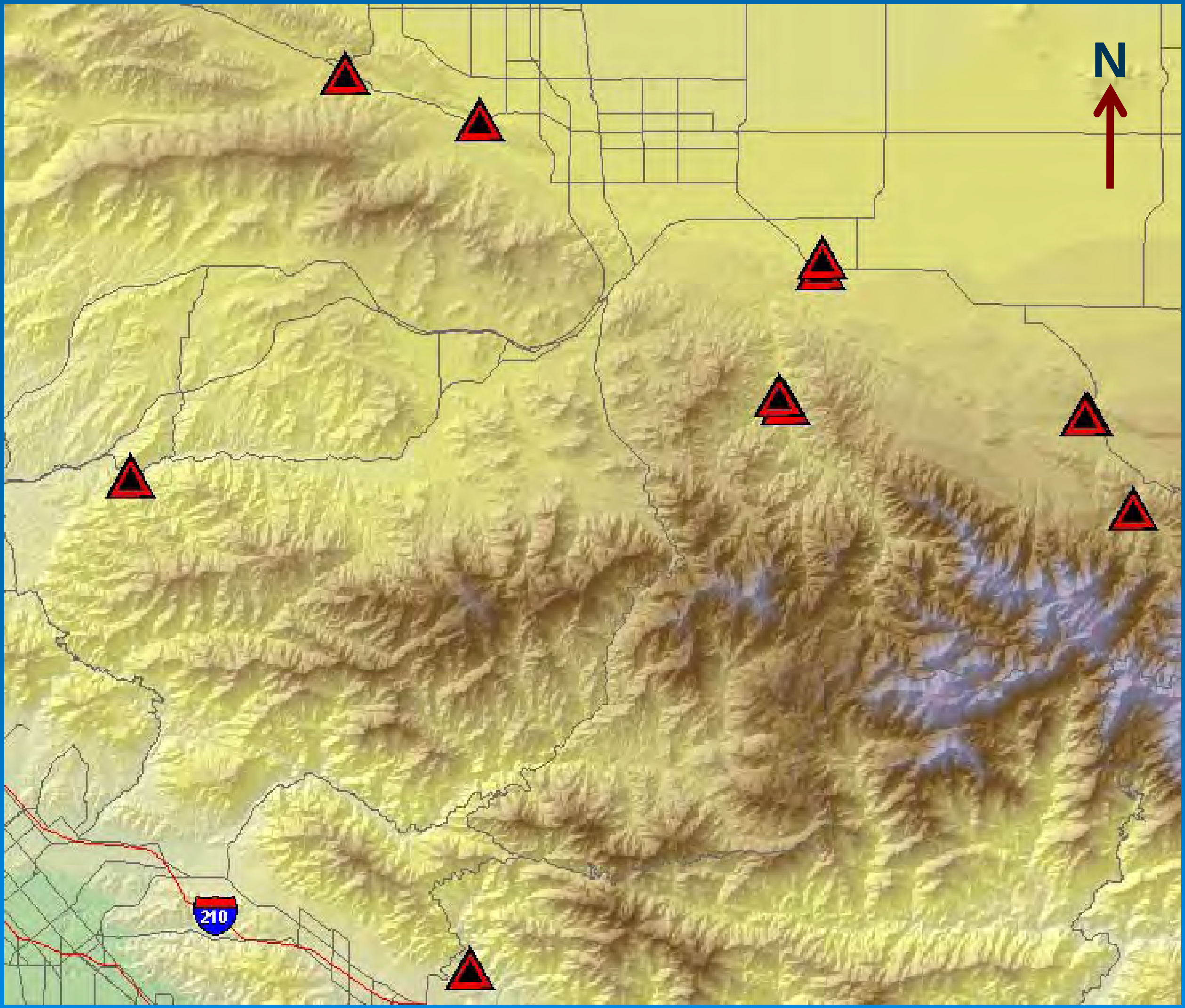
Using remote sensed (Landsat) data on selected days (when image available) to estimate the maximum root-zone water storage capacity for each cell

Model Calibrated to Monthly Stream Flow

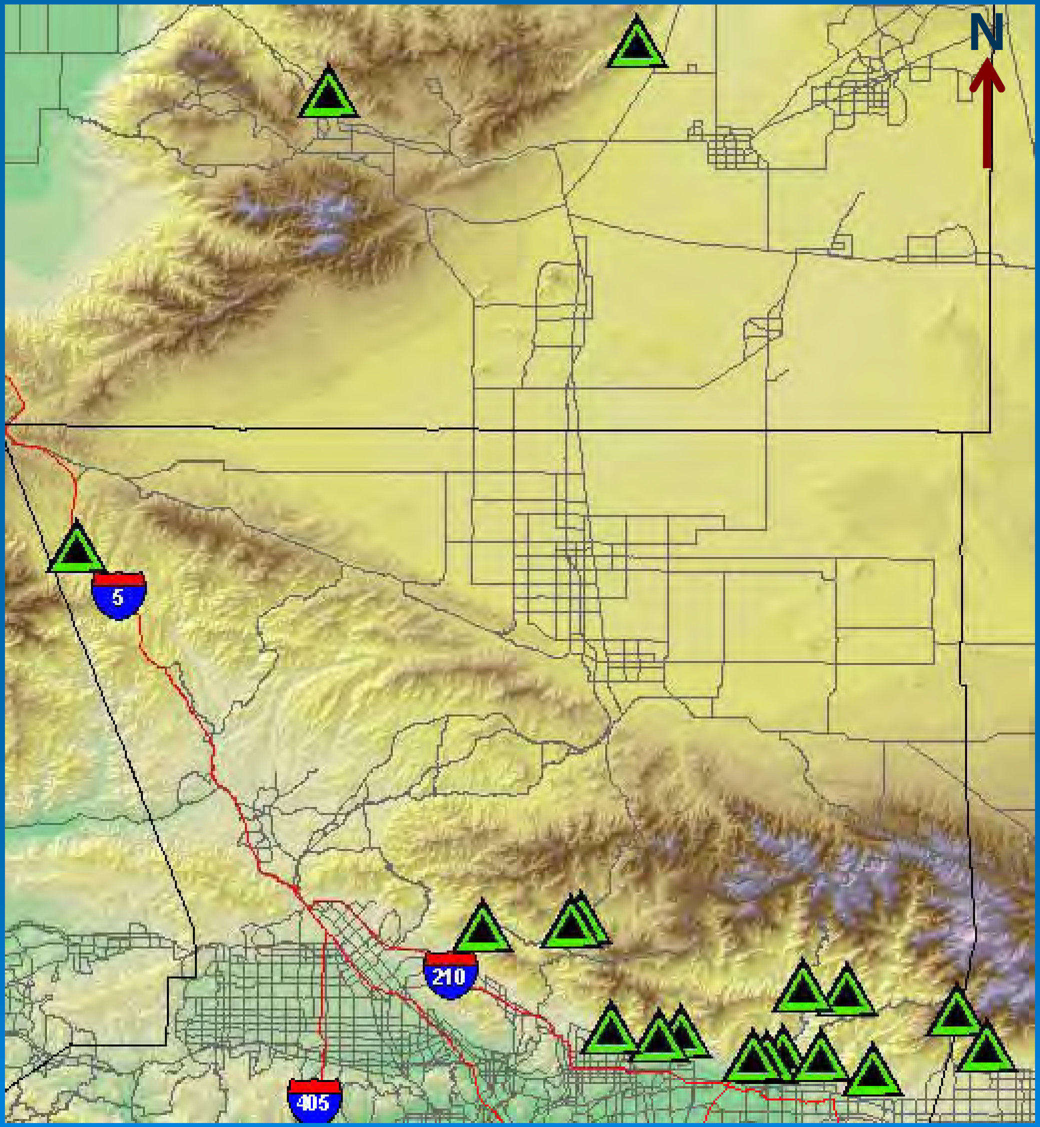
Example: 3 yrs of monthly flow on Big Rock Creek



Stream Flow Gauges Used for Calibration

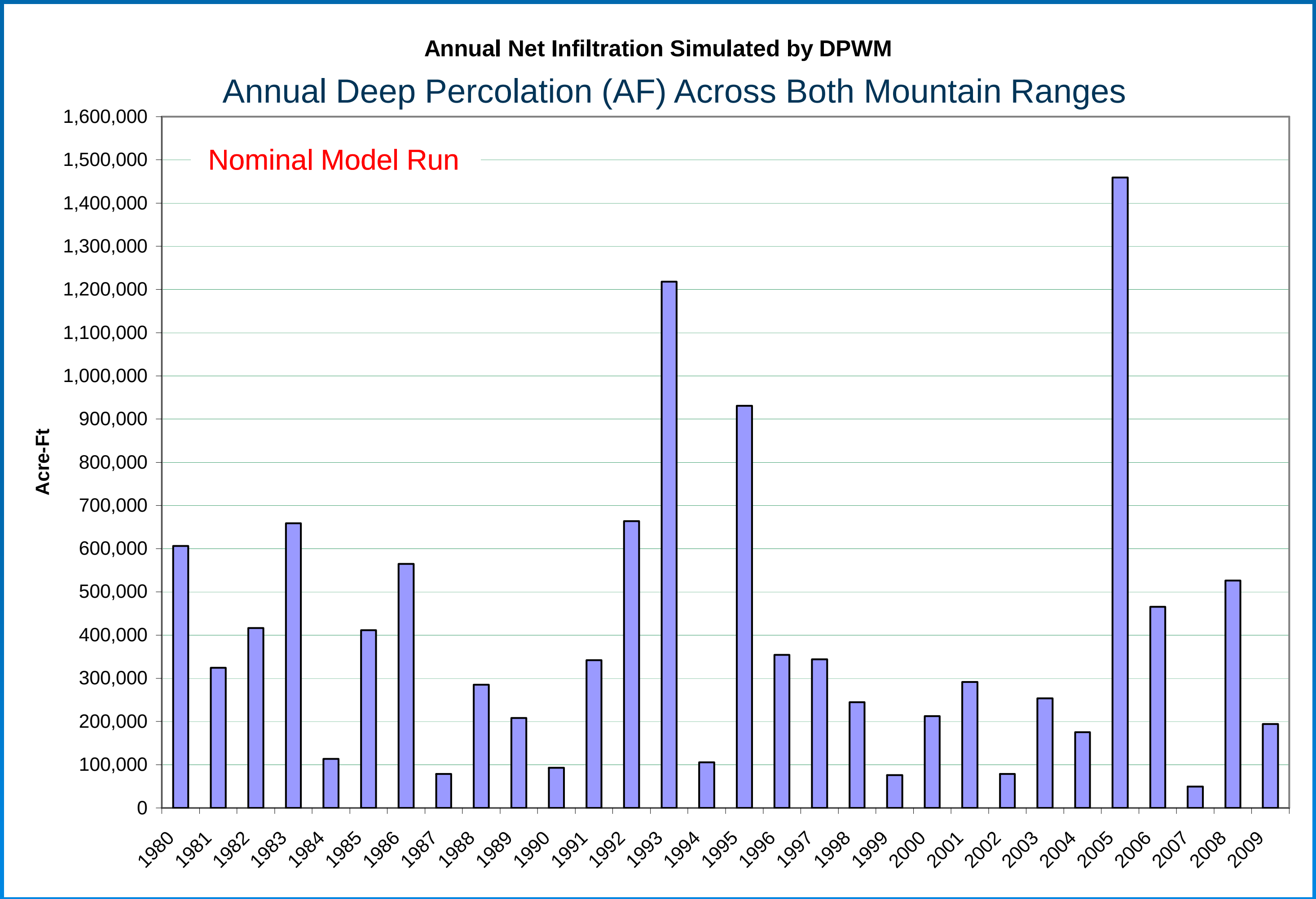


Stream-Flow Gauges Used for Testing



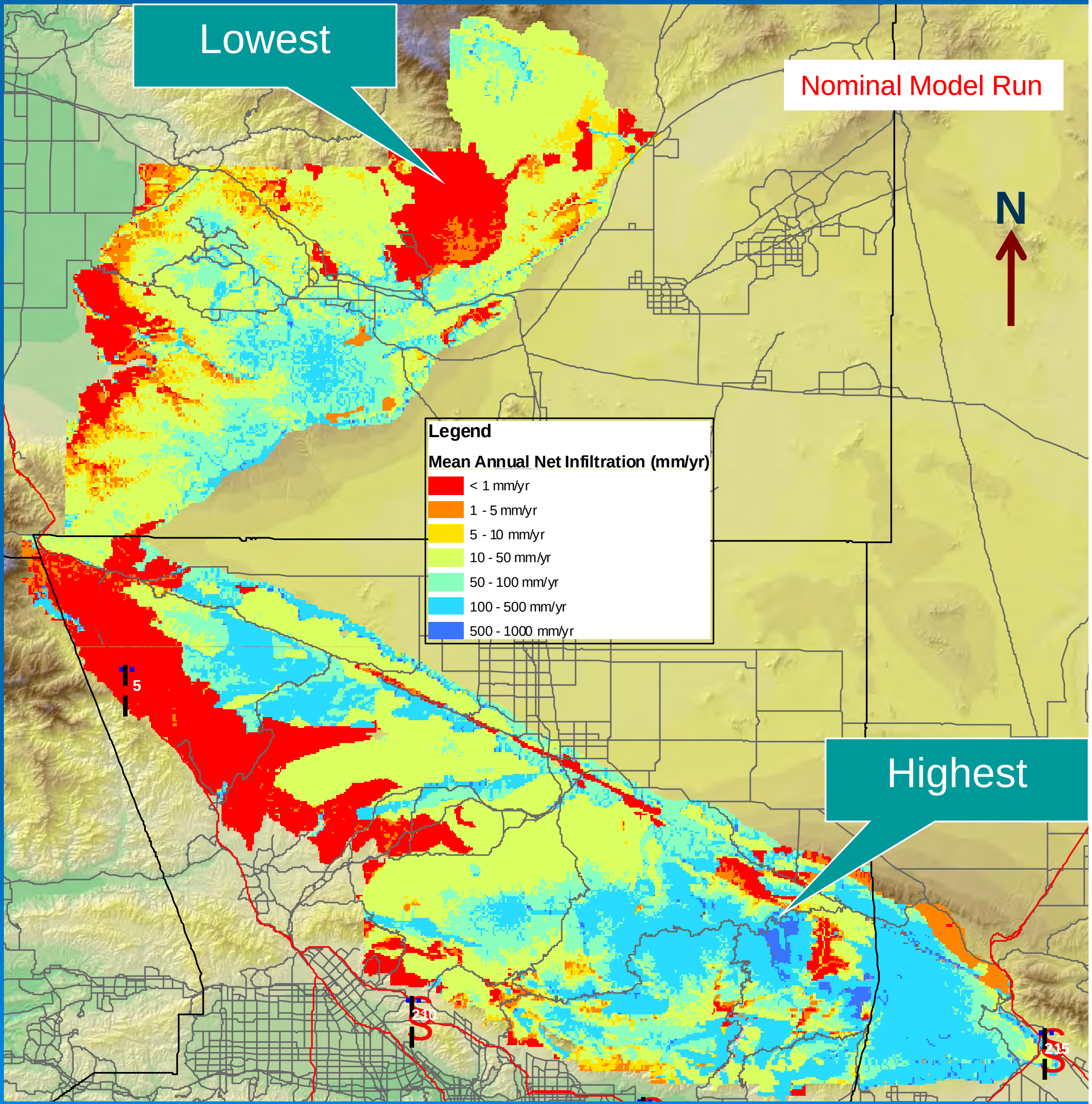
Total Deep Percolation Simulated by DPWM varies from year to year

in the San Gabriels and Tehachapis



Deep Percolation to Mountain Blocks Varies Spatially

30-year annual average (mm)



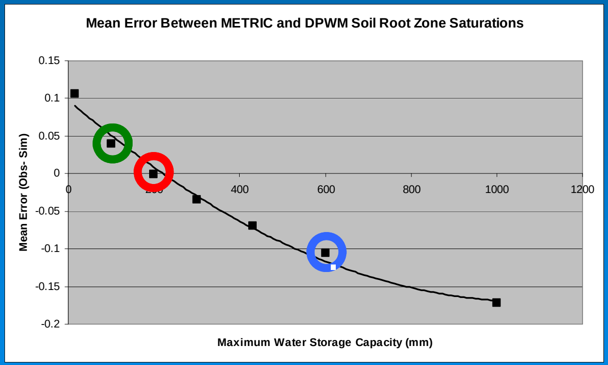
Simulated Water Balances for the San Gabriels

	Annual Mountain Front Recharge for San Gabriel Mountains (AF)					Three simulations
	a	b	c	d	e	
Estimate:	Precipitation	Evapotransp. =a-e	Runoff	Deep Percolation	Mountain Front Recharge = c+d	Maximum Water Storage Capacity
~Nominal	1,868,000	1,015,200	544,900	307,900	852,800	200 mm
~High	1,868,000	893,800	610,200	364,000	974,200	100 mm
80% Range						
~Low	1,868,000	1,287,800	394,500	185,700	580,200	600 mm

Nominal = based on model best fit to remote sensing data that assesses soil water storage capacity

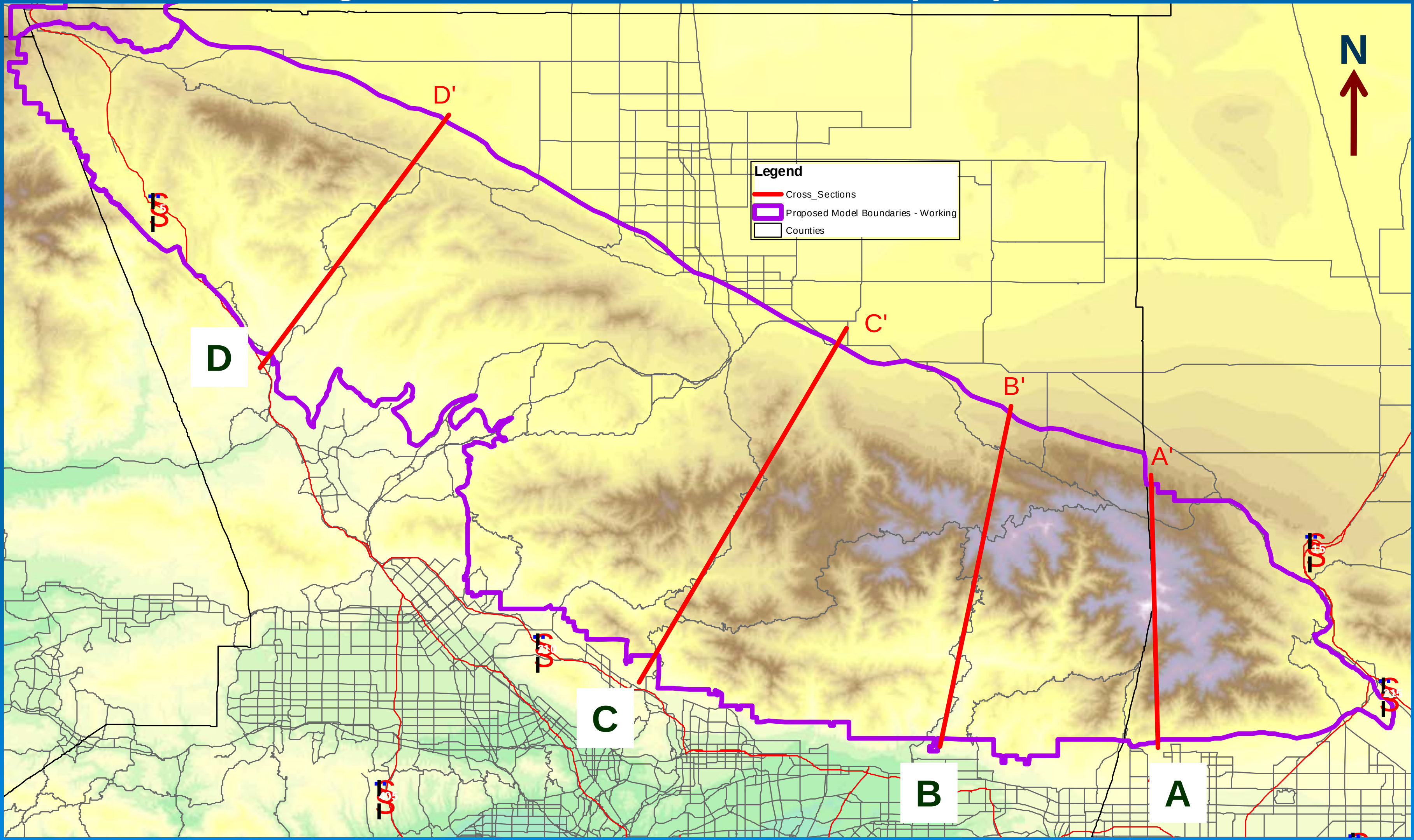
80% Range = probability that actual value lies between the given low and high estimates

Simulated values rounded to the nearest 100 AF



Mountain Groundwater Evaluated

using four cross-secitonal (2D) models

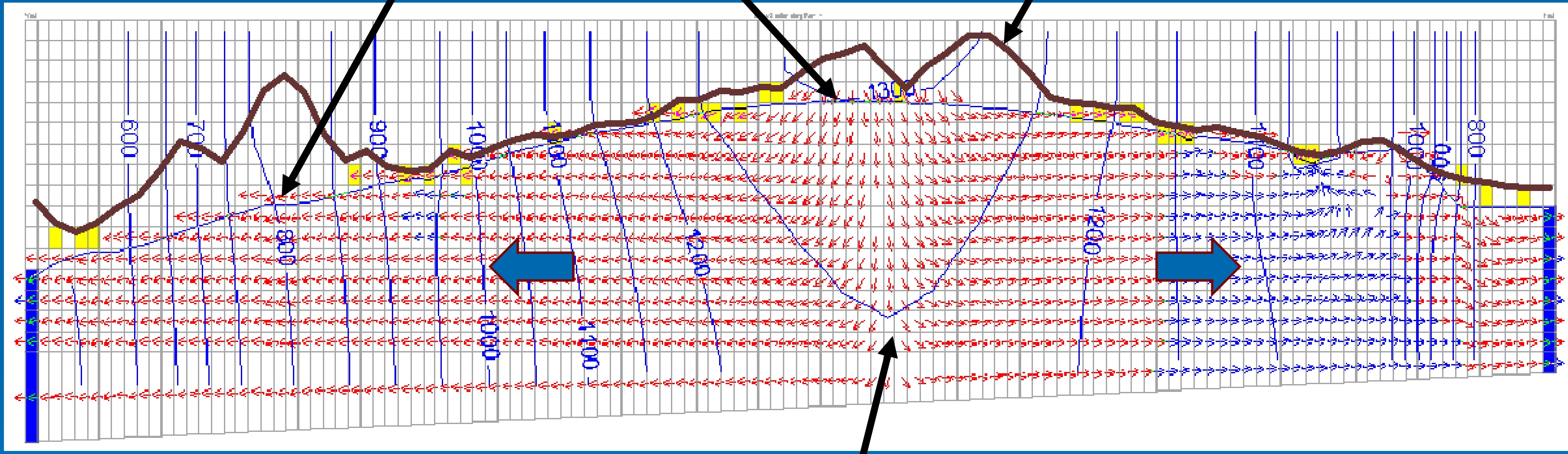


Groundwater Flow Splits at the GW Divide
contributing to different basins

Mountain Cross-Sectional Groundwater Model

La Cresenta ←

Antelope Valley →



Cross-Section C

Groundwater Divide Does Not Lie Under Surface Water Divide