



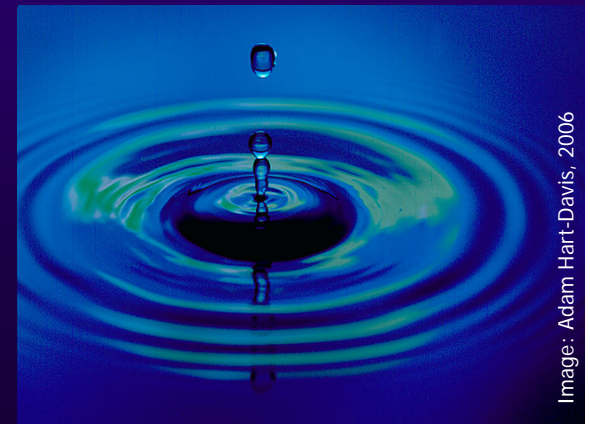


Groundwater Aquifer Testing and Modeling: *Tools to Help Understand How to Manage Water Resources*

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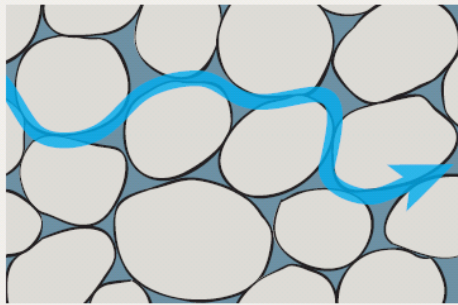
<http://groundwater.ucdavis.edu>



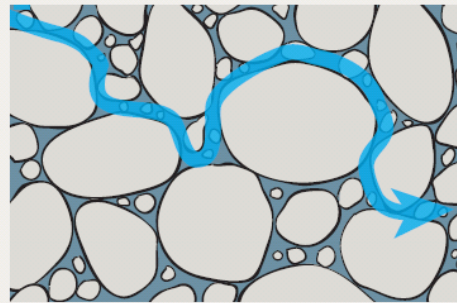
Outline

- Groundwater: how does it work
- Wells: the magic tap
- Aquifer Testing (as opposed to well testing)
- Groundwater Modeling

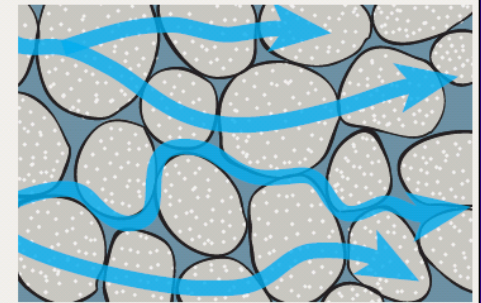
What is Groundwater?



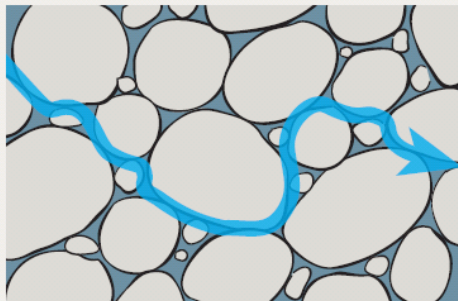
Well-sorted sediment



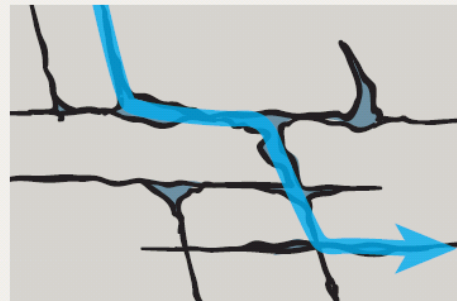
Poorly sorted sediment



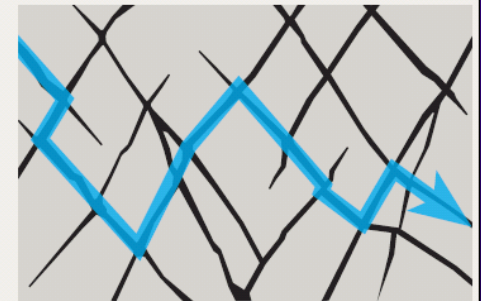
Porous sediment



Consolidated sediment

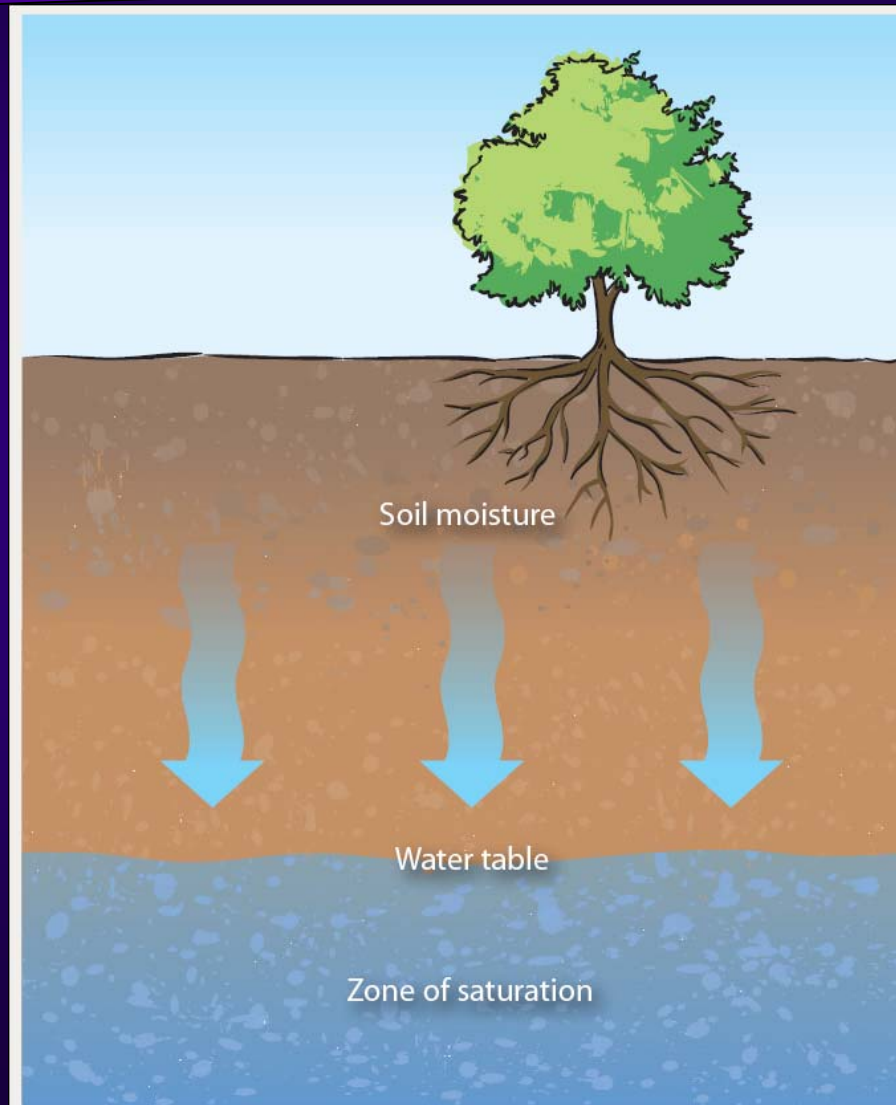


Dissolution of rock




Rock fractures

What is Groundwater?

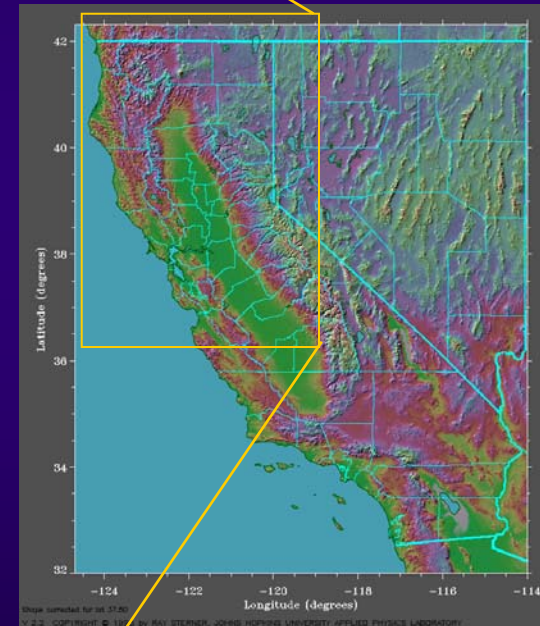
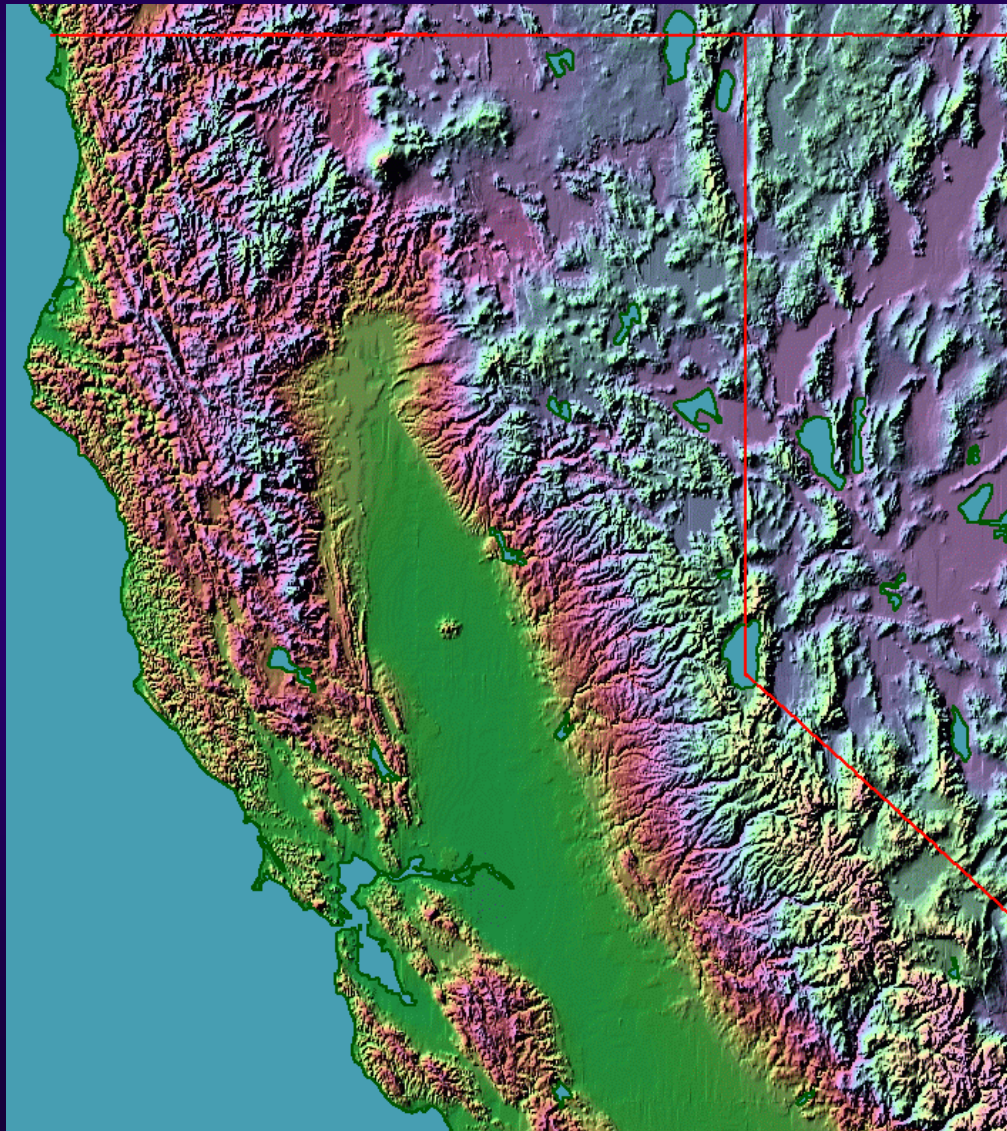


What is Groundwater?

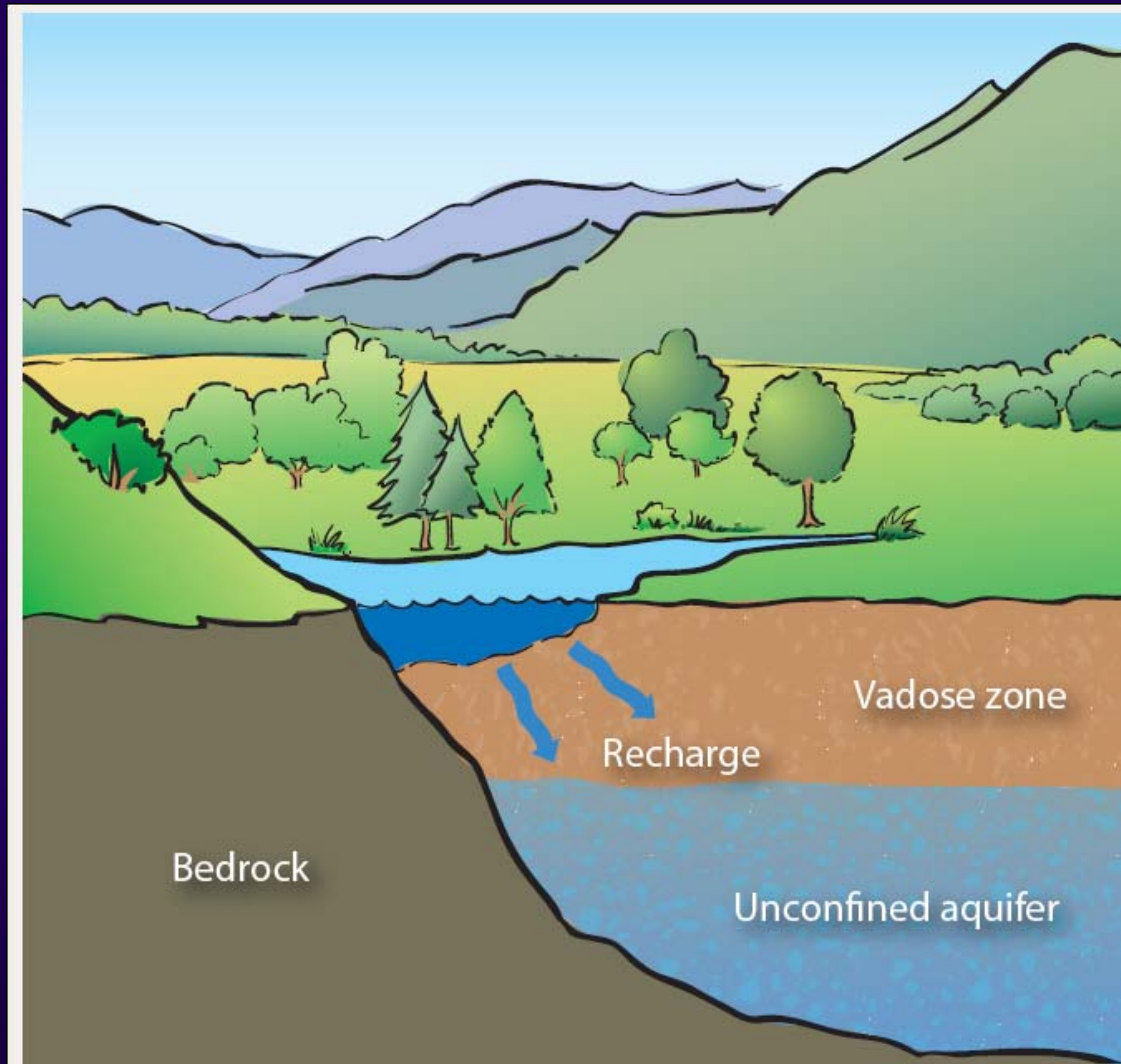


Classification	Particle size (inch)
medium gravel	0.5
coarse sand	0.05
very fine sand	0.005
silt	0.001
clay	0.0001

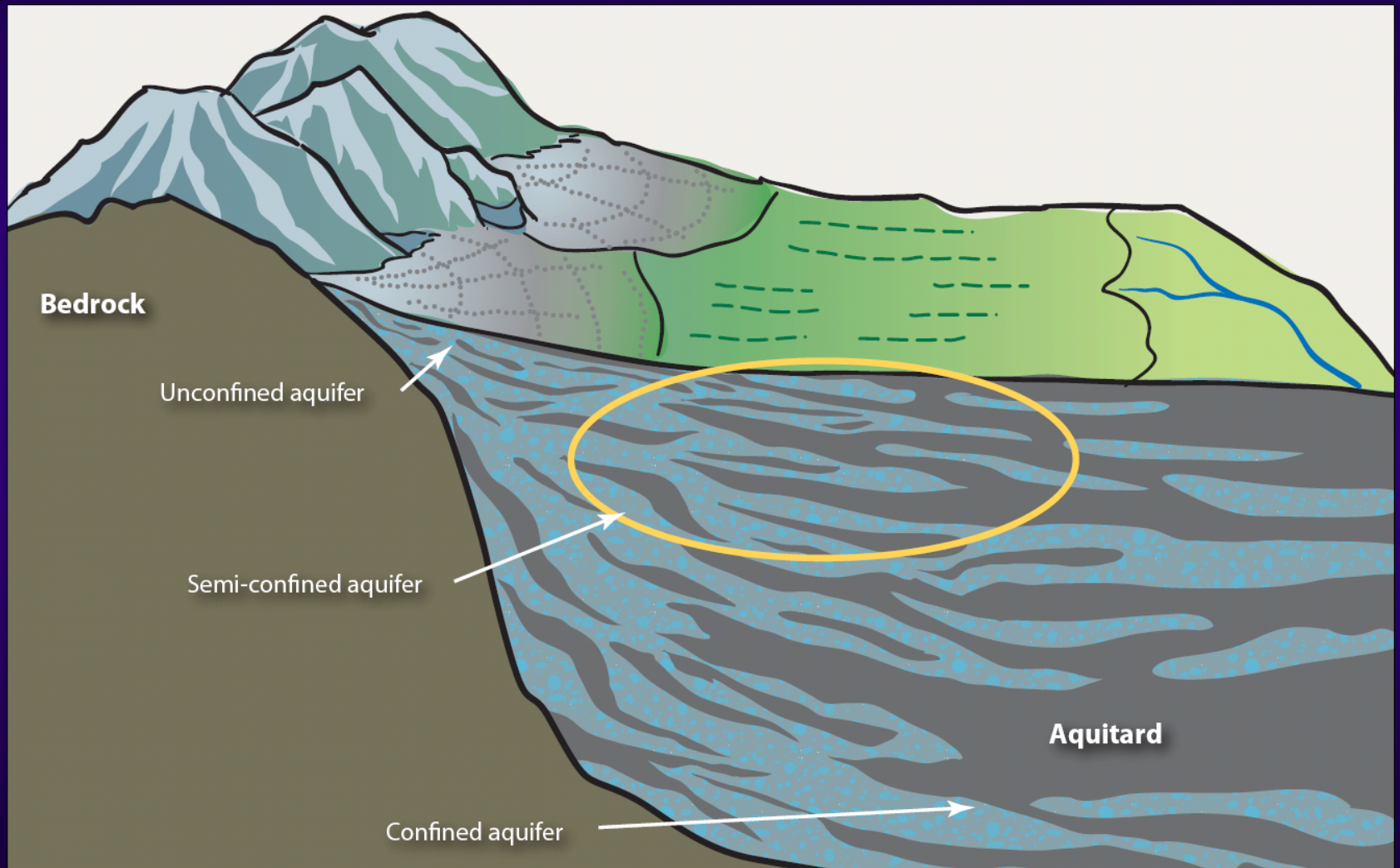
California Groundwater



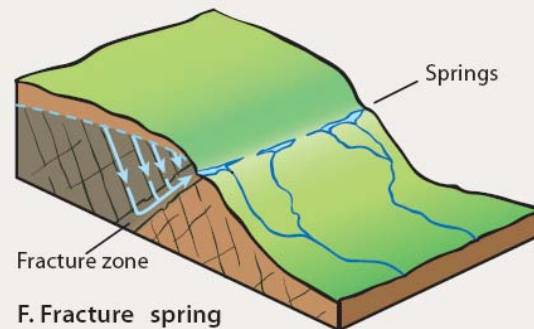
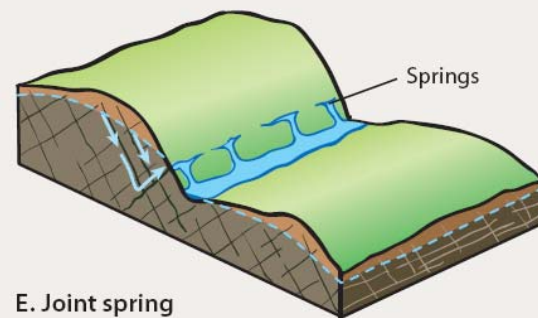
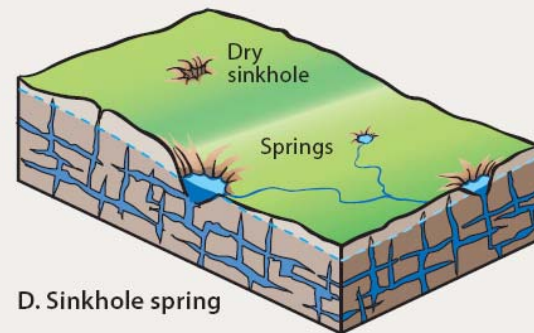
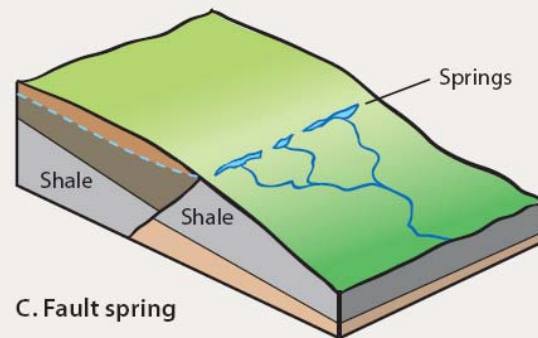
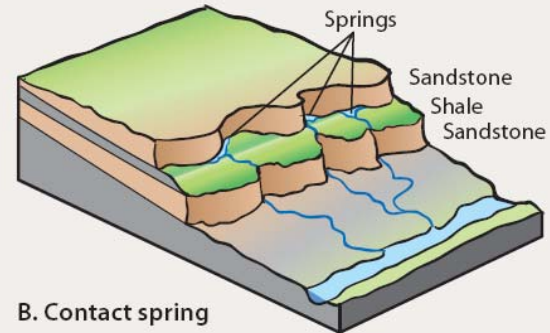
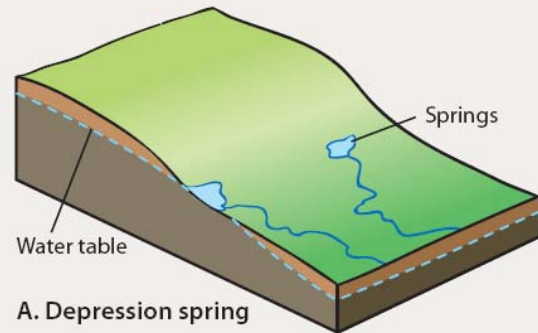
Unconfined Aquifer



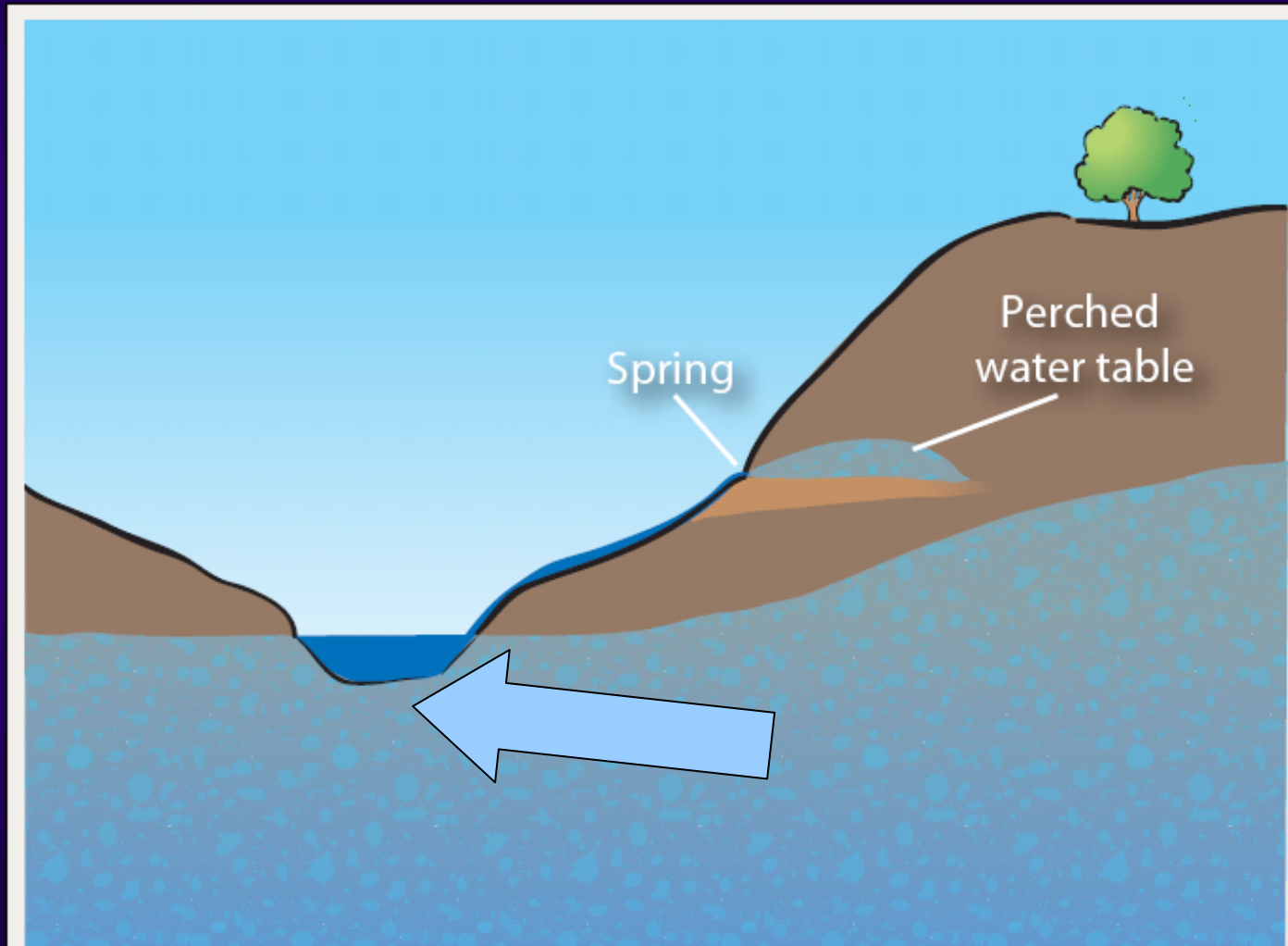
Confined Aquifer



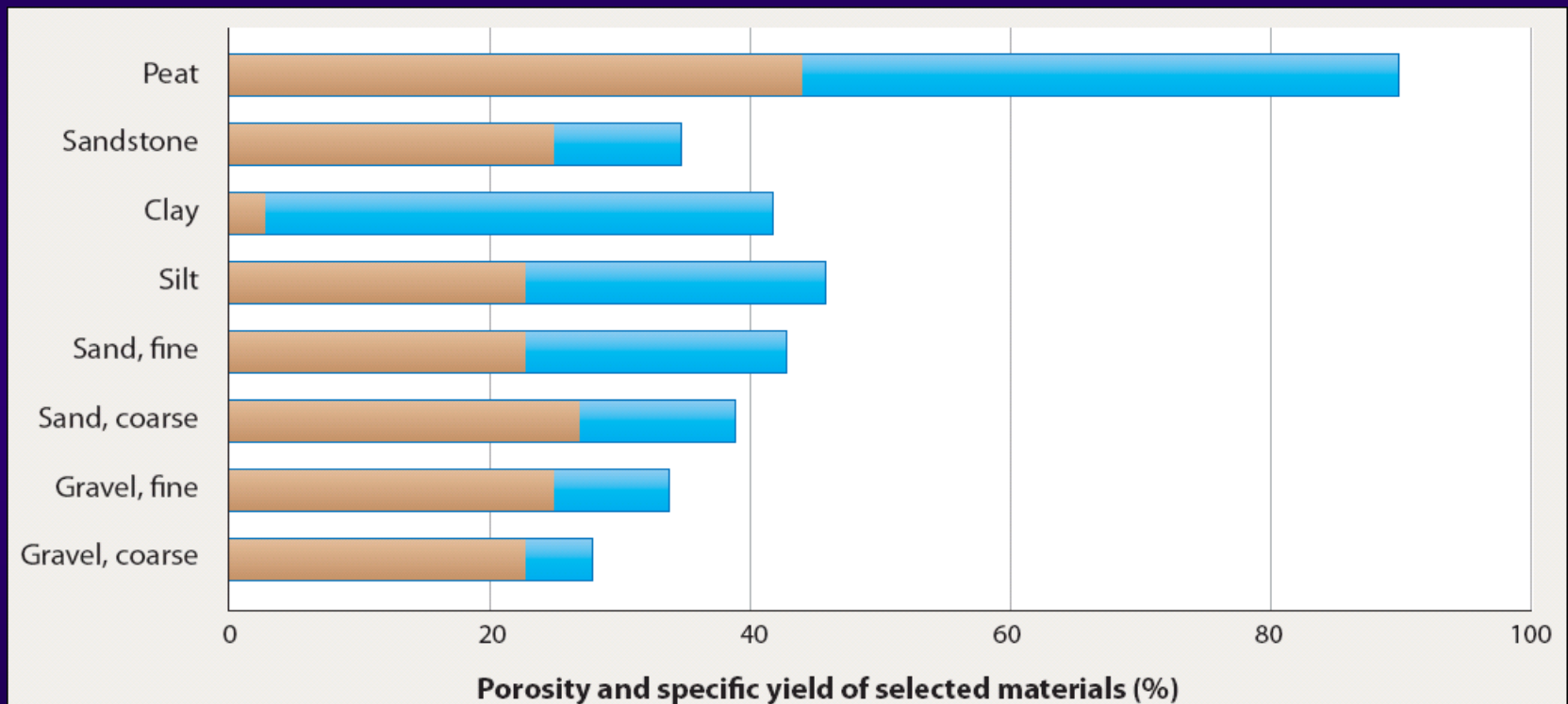
Springs



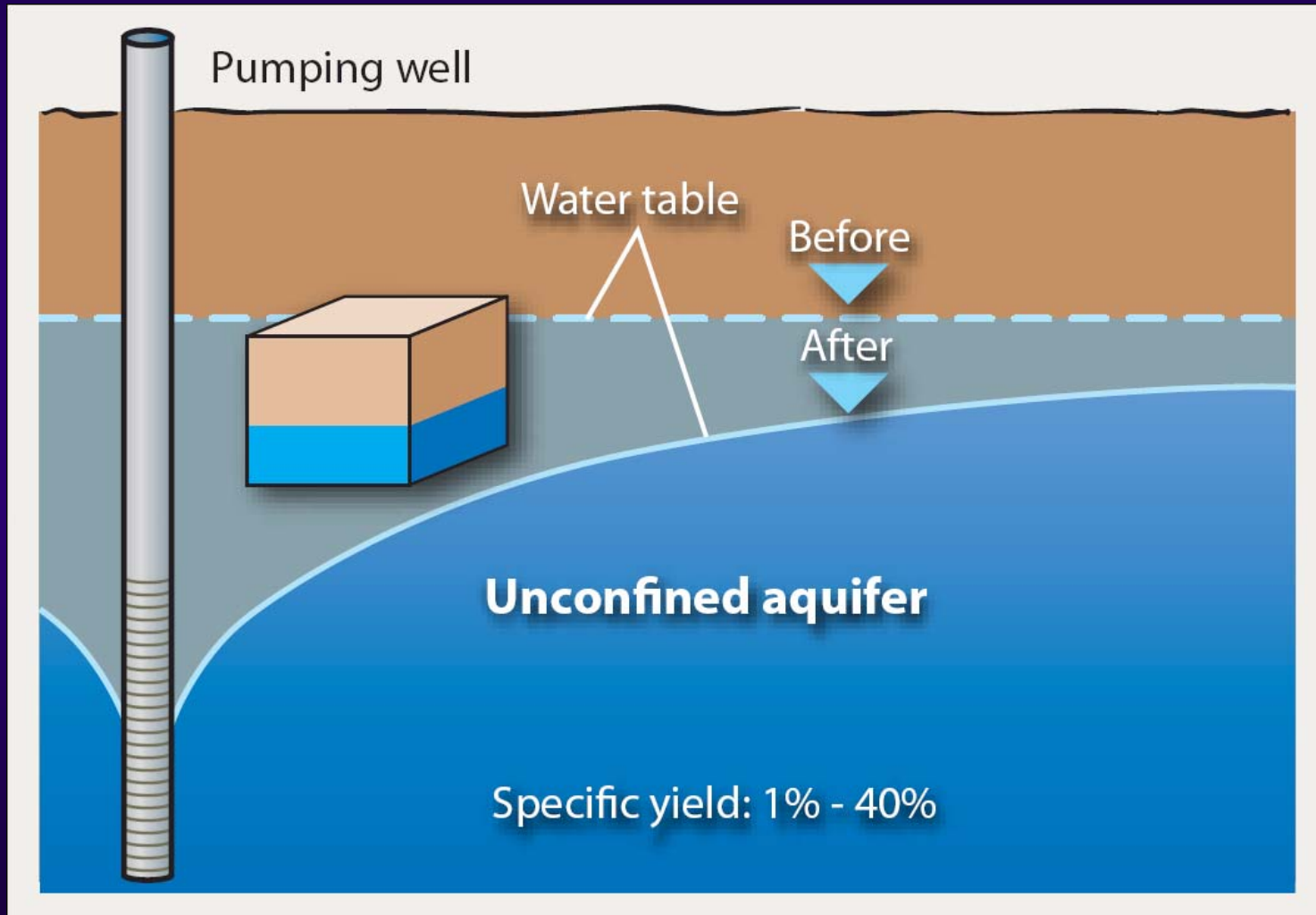
Gaining Stream



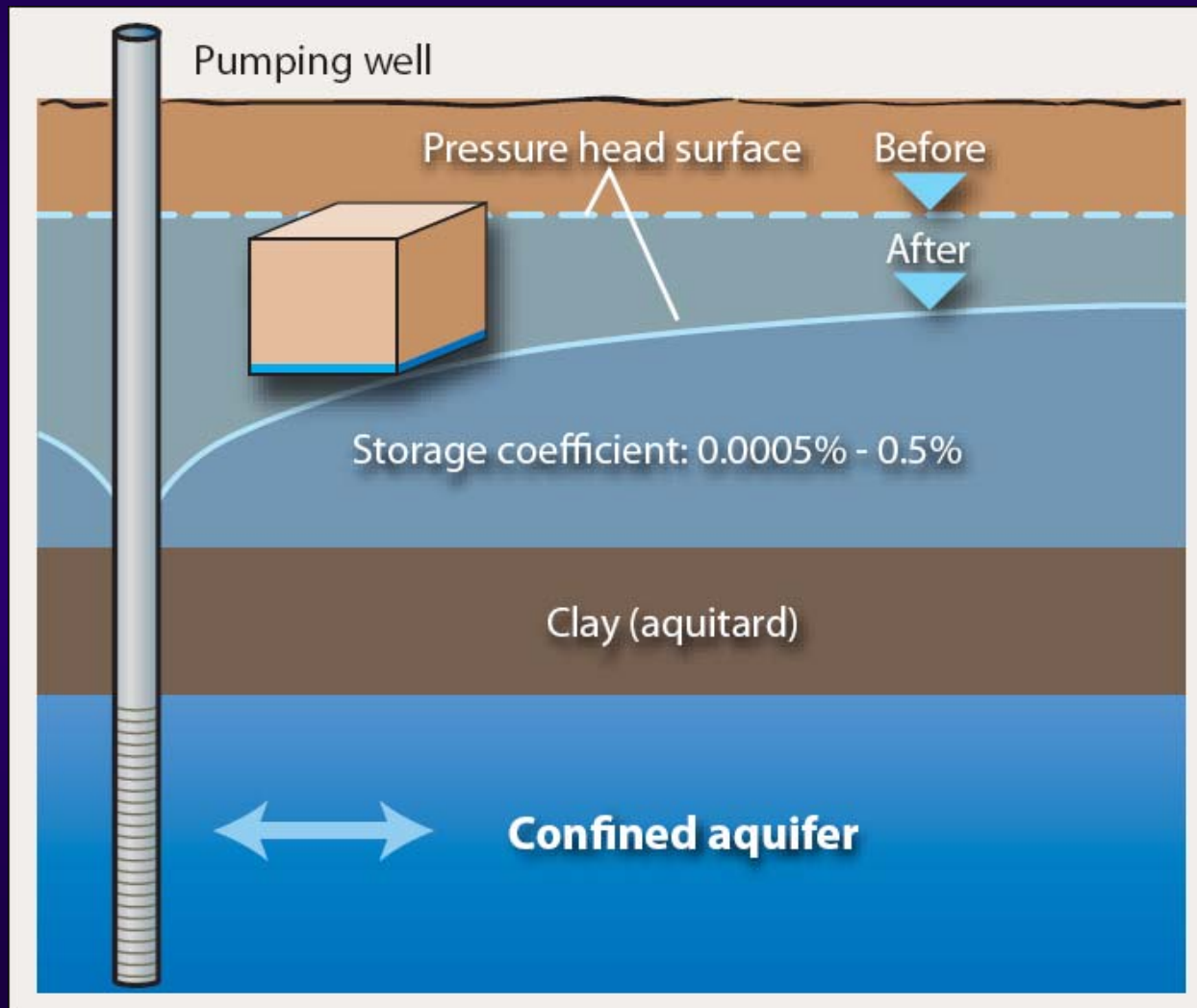
How Much Water is in the Ground?



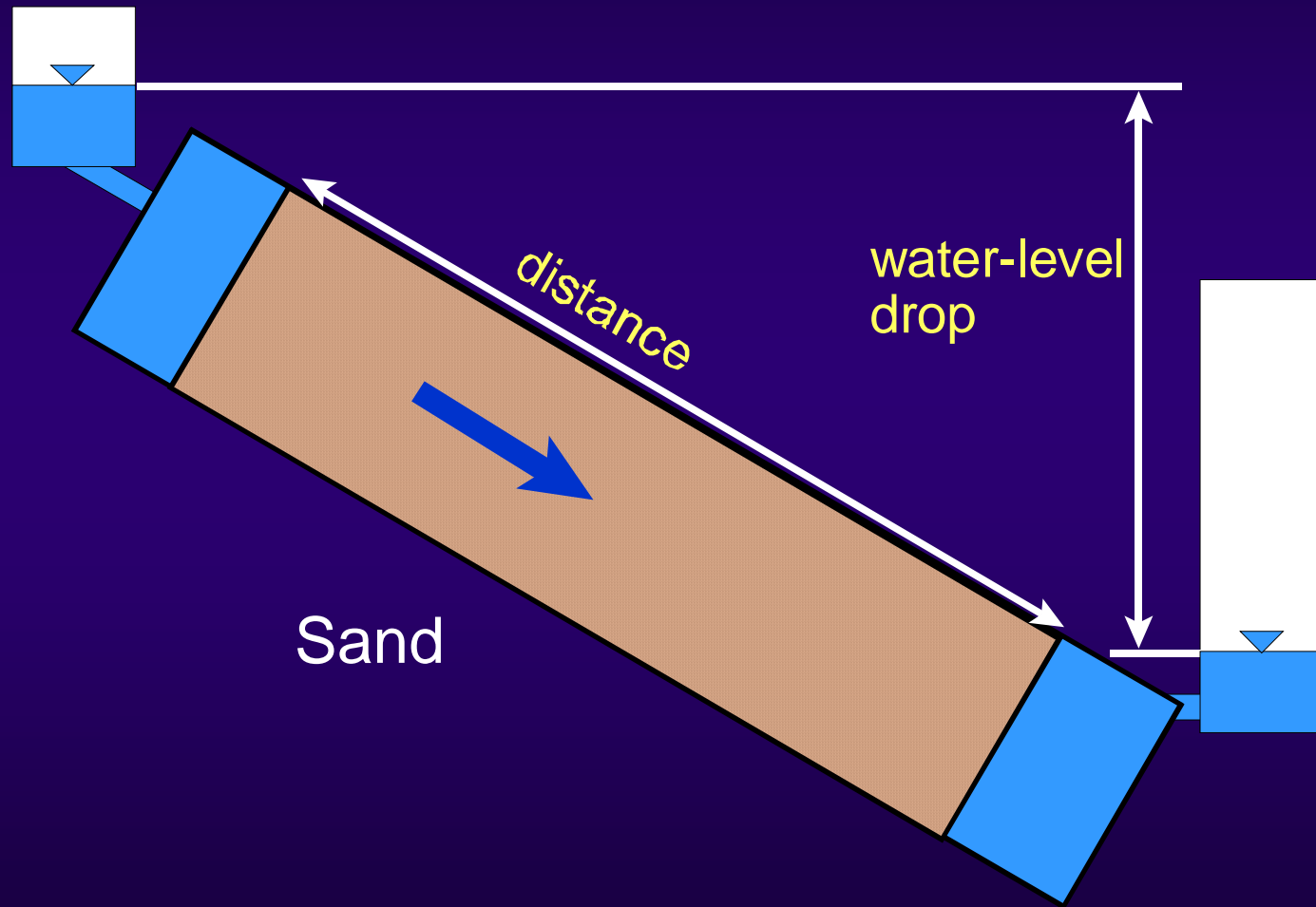
Specific Yield - Unconfined Aquifer



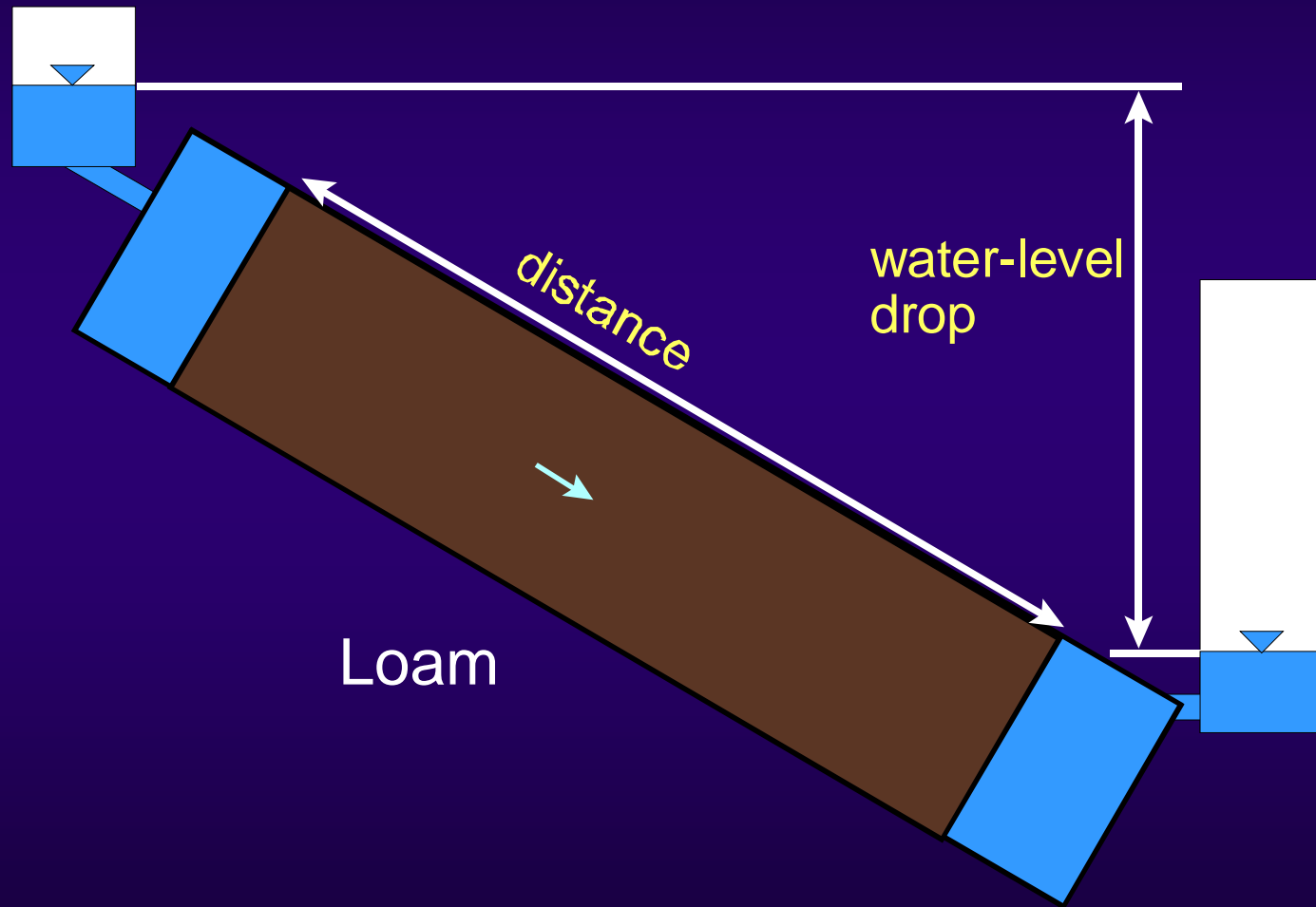
Storage Coefficient - confined aquifer



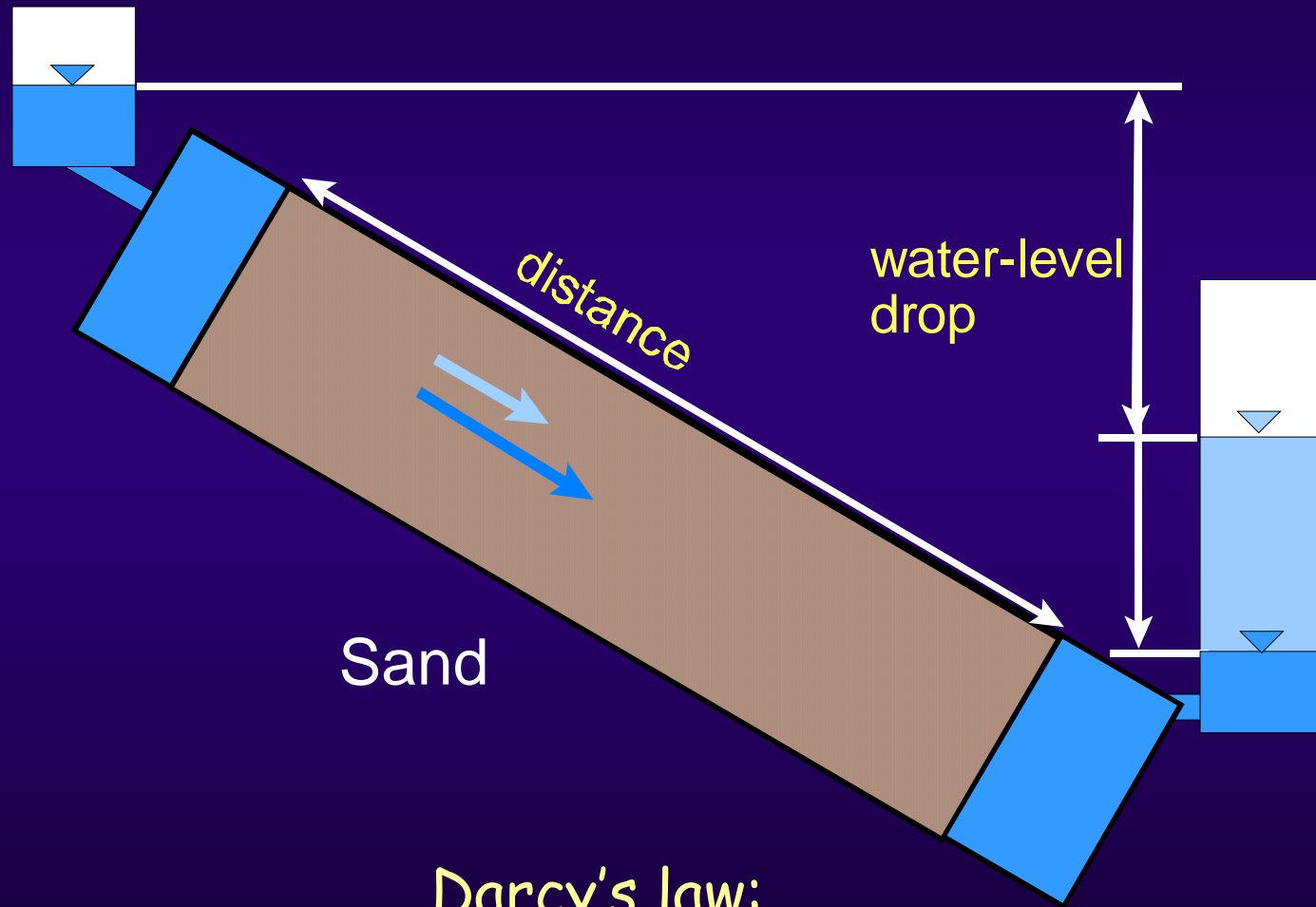
How fast does water flow?



How fast does water flow?

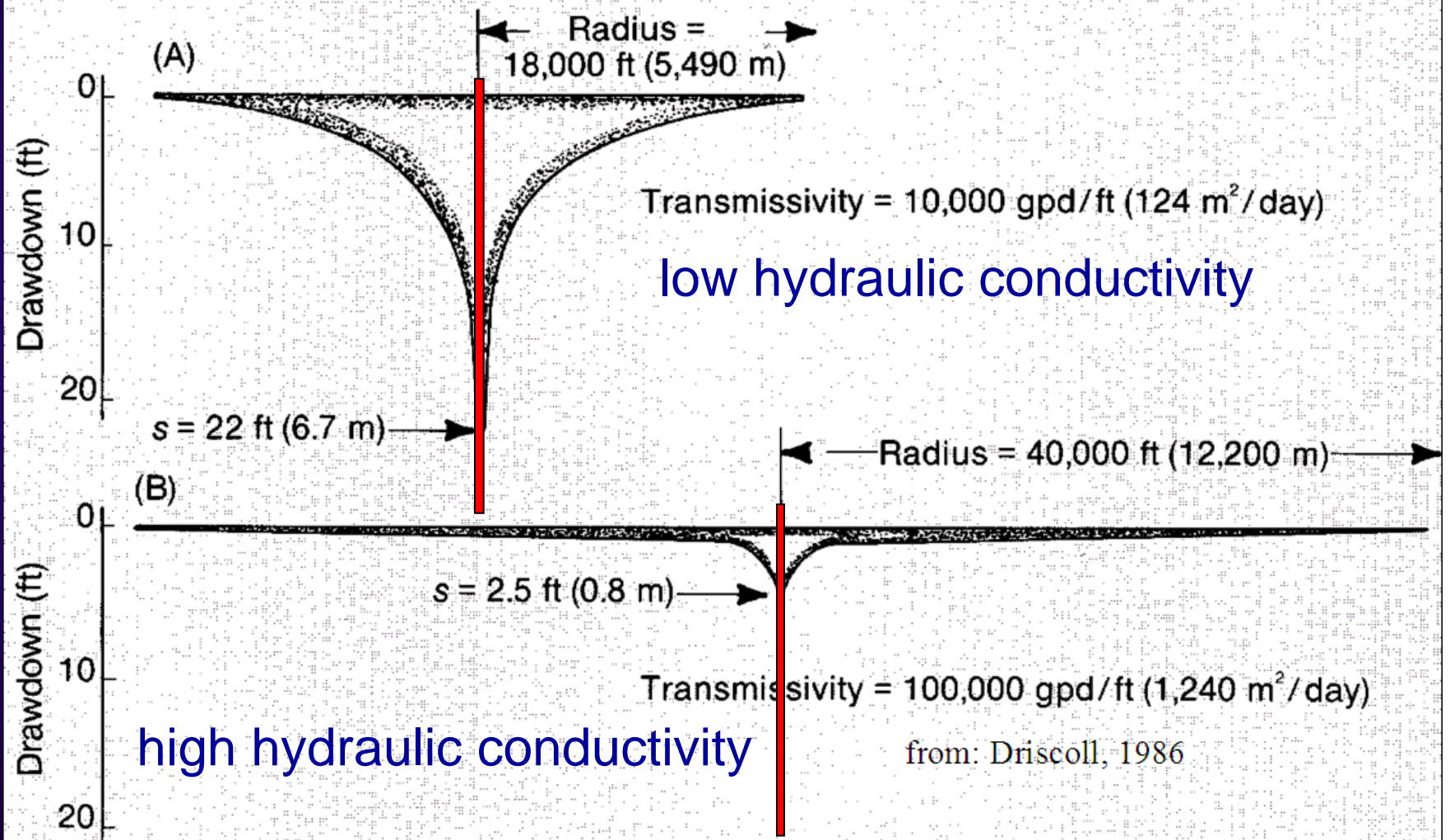


How fast does water flow?

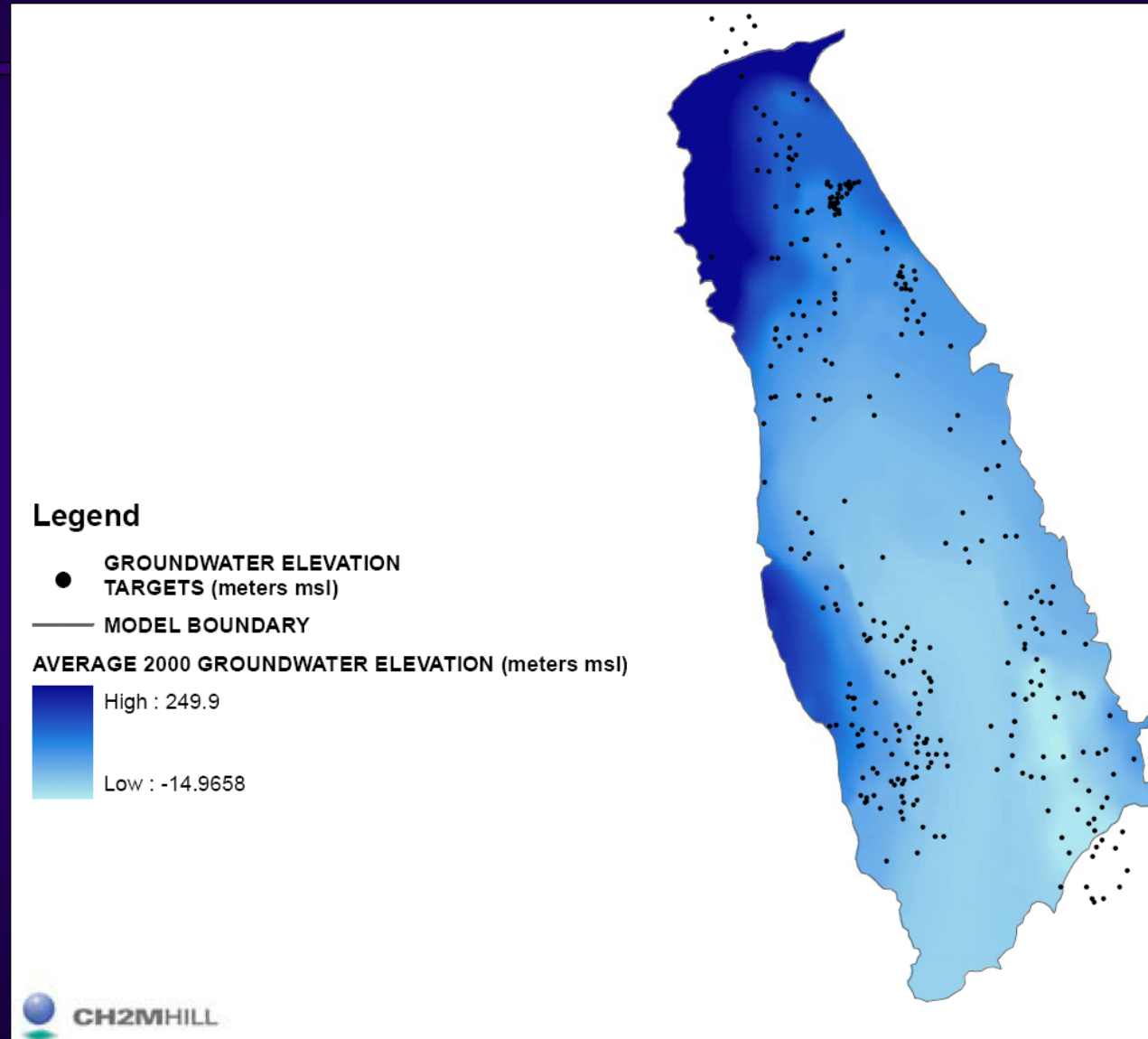


Darcy's law:
groundwater flow = hydraulic conductivity \times pressure gradient

Hydraulic Conductivity and Well Drawdown



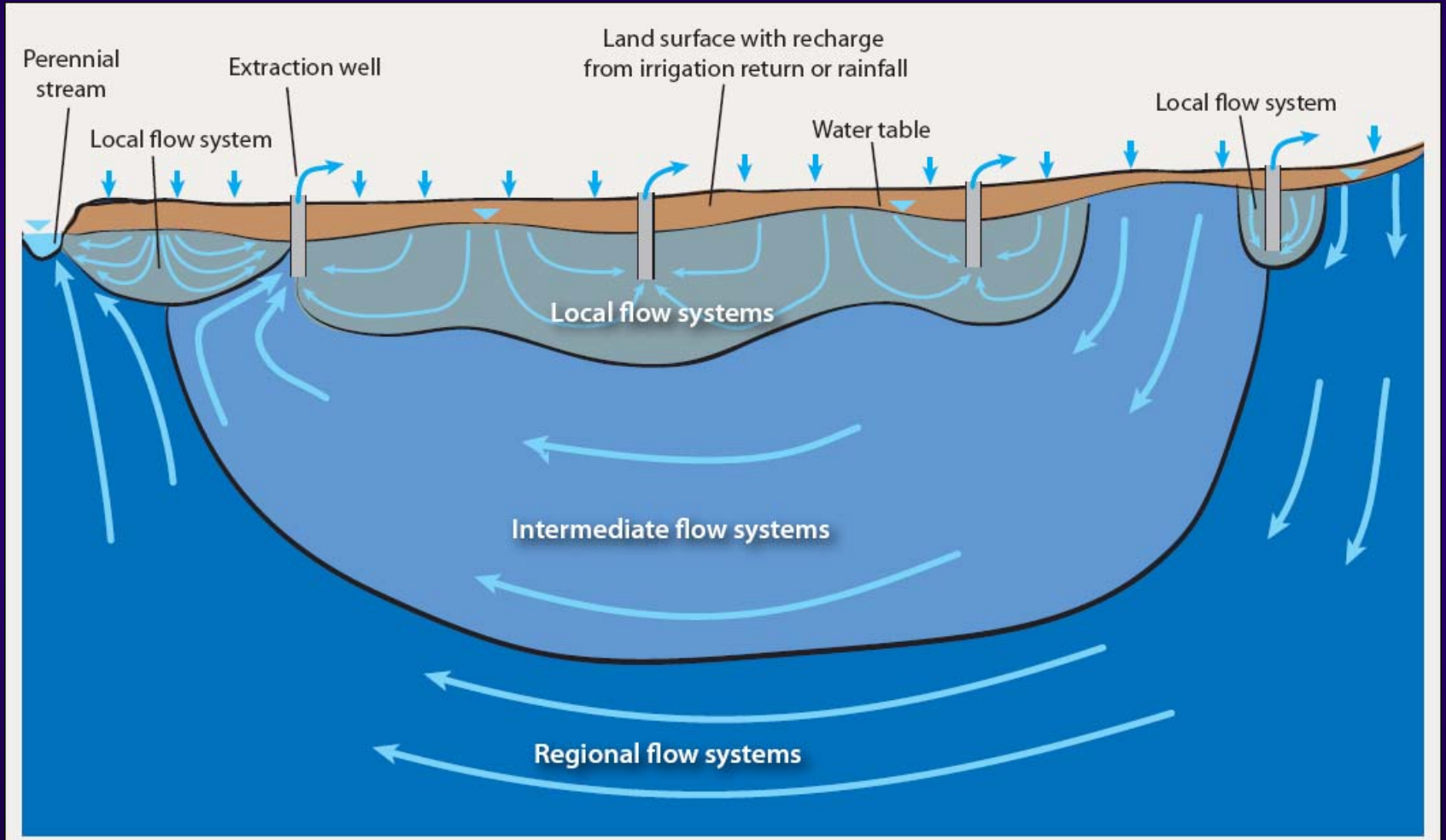
Direction of Groundwater Flow



Courtesy, Peter Lawson, CH2M-Hill, 2008

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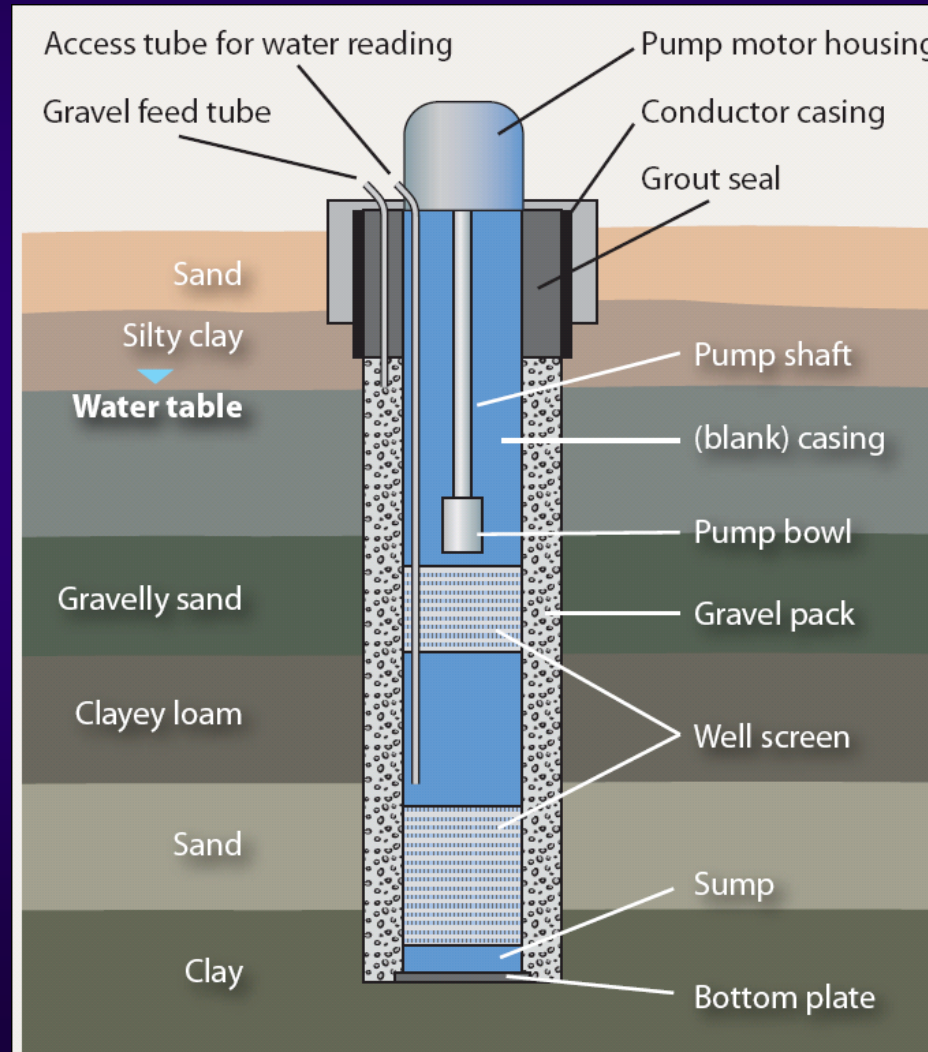
Local & Regional Groundwater Flow



How do we measure hydraulic conductivity?

- Estimate based on sediment type (gravel, sand, silt, clay, fractured rock)
- Measure on sediment/rock cores in laboratory
- Estimate from specific capacity of wells
- Measure using an aquifer test
- Estimate from groundwater models

A Groundwater Well



Well Screen (stainless steel wire-wrap)



Well Testing: Specific Capacity of a Well

Specific capacity of a well =

Rate of pumping per foot of drawdown.
(measured as gpm/ft)

well test usually done by pumping
for 1 hr - 24 hrs

Well Testing for Specific Capacity

- very low: 1 gpm/ft; very high: 100 gpm/ft
- decreases with time during pumping test
- decreases with increased pumping rate
- decreases with lower water level in a well
- larger in a properly designed and developed well
- affected by land subsidence
- approximately proportional to hydraulic conductivity

Hydraulic Conductivity in Sac Valley

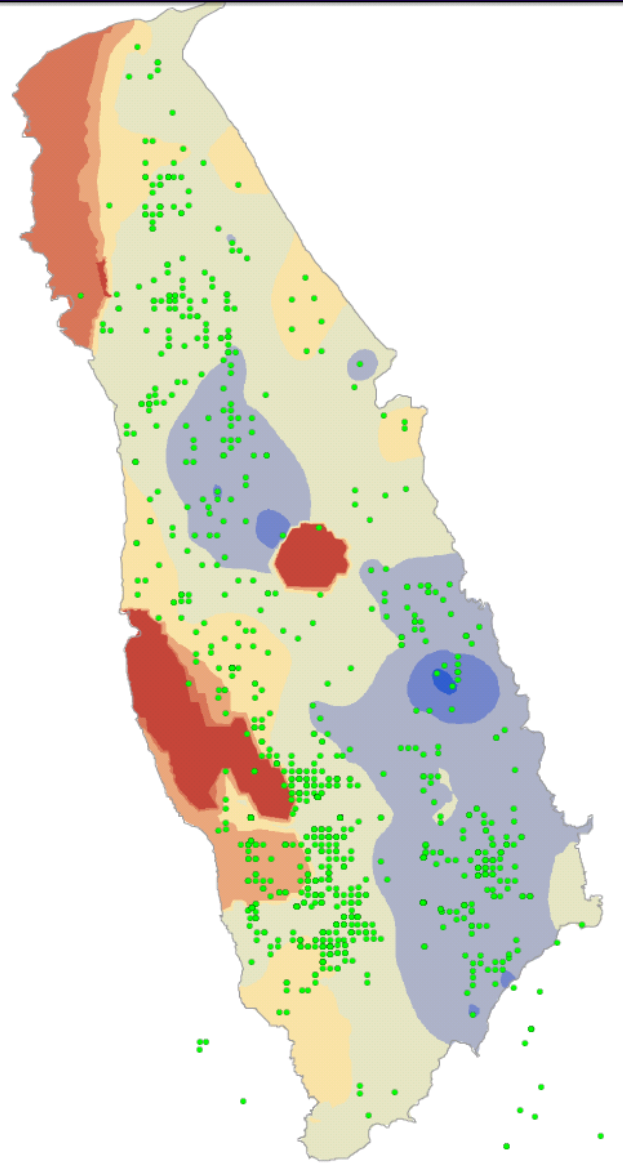
estimated from specific capacity of wells indicated

LEGEND

- HYDRAULIC CONDUCTIVITY DATA POINT
- MODEL BOUNDARY

HYDRAULIC CONDUCTIVITY (feet/day)

- < 0.1
- 0.1 TO 10
- 10 TO 50
- 50 TO 100
- 100 TO 200
- 200 TO 300
- 300 TO 400
- 400 TO 450



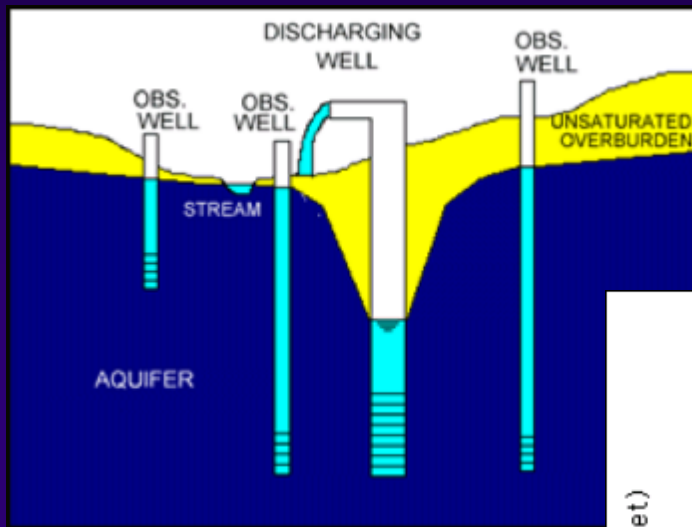
Courtesy, Peter Lawson, CH2M Hill, 2008

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Aquifer Test

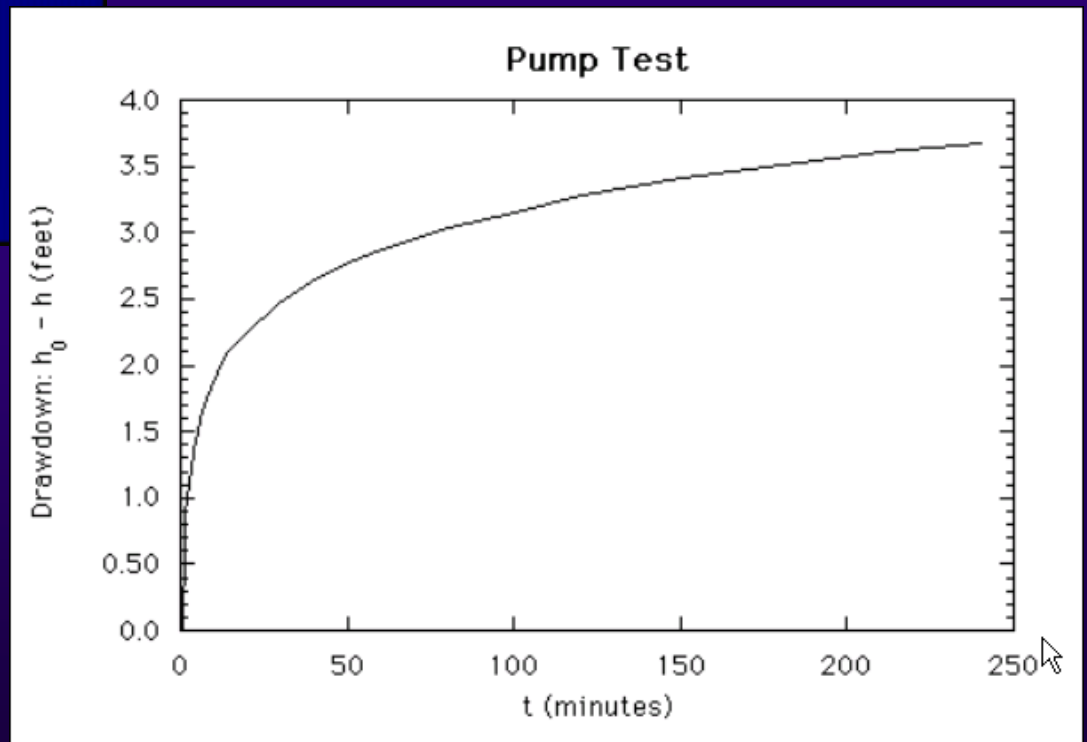
- Determine aquifer hydraulic properties
 - hydraulic conductivity, K , or transmissivity, T
 - specific yield, S_y , or storage coefficient, S
 - leakage through confining units
- Based on matching real world data to the solution of the groundwater flow equation
- The groundwater flow equation is based on two physical principles:
 - mass balance: change in volume = inflow - outflow
 - Darcy's law: $q = K i$

Aquifer Test: How it is done

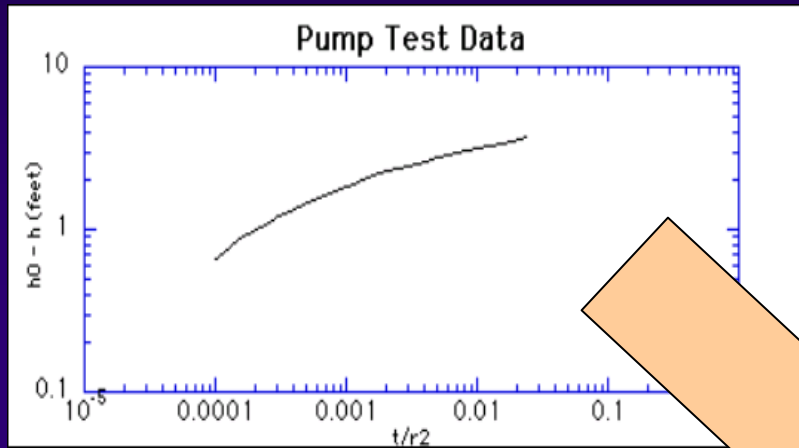


Aquifer test usually by pumping a well 72 hrs - 7 days;

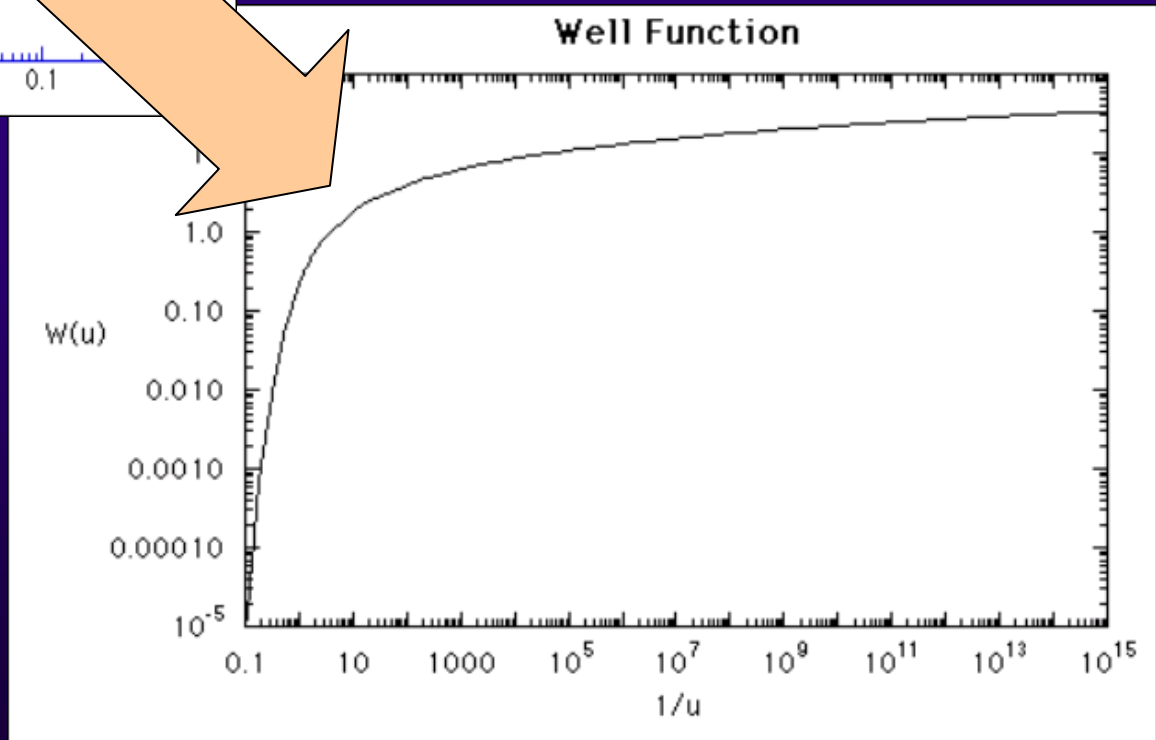
Observe nearby wells also.



Aquifer Test: Getting Results



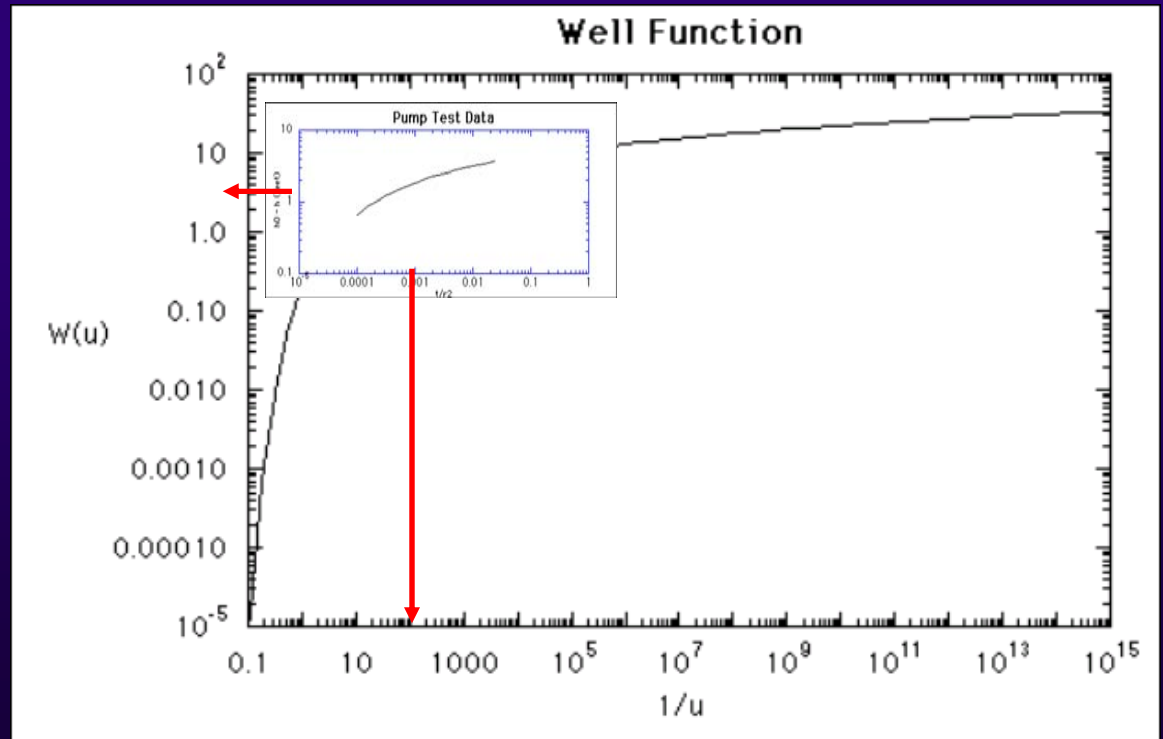
MATCH



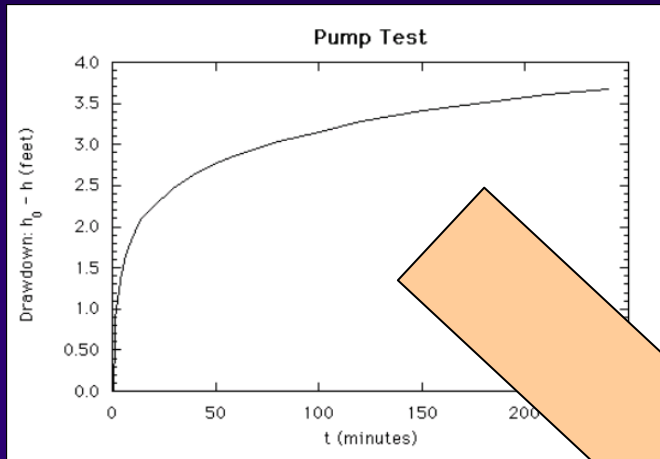
Aquifer Test: Getting Results

$$s = \frac{Q}{4\pi T} W(u)$$

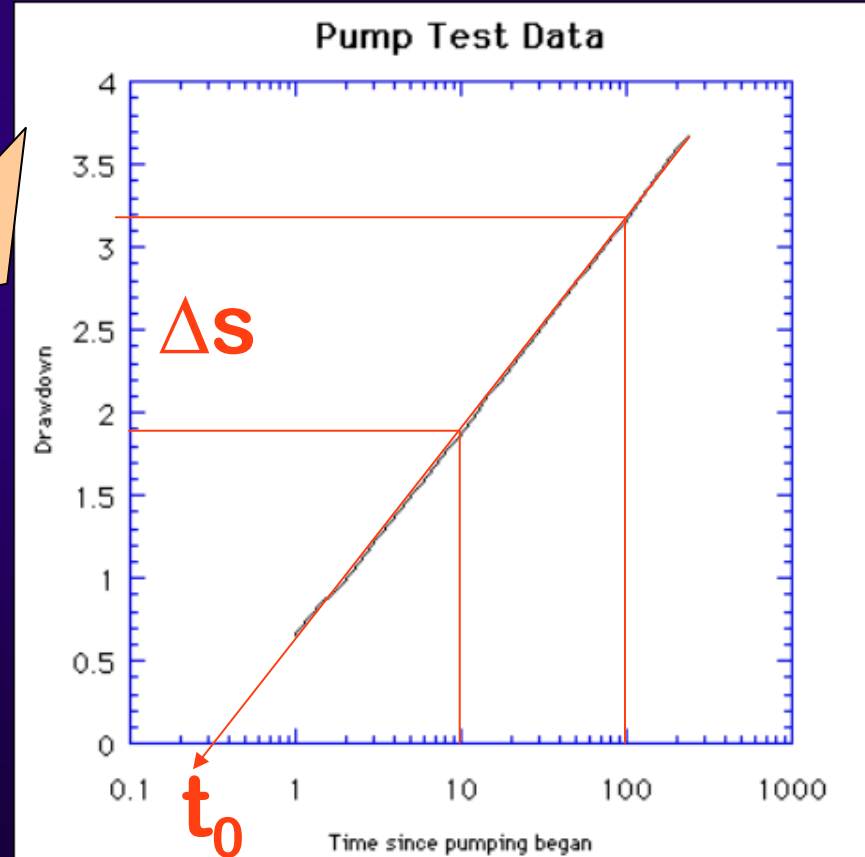
$$u = \frac{r^2 S}{4Tt}$$



Aquifer Test: A simple procedure



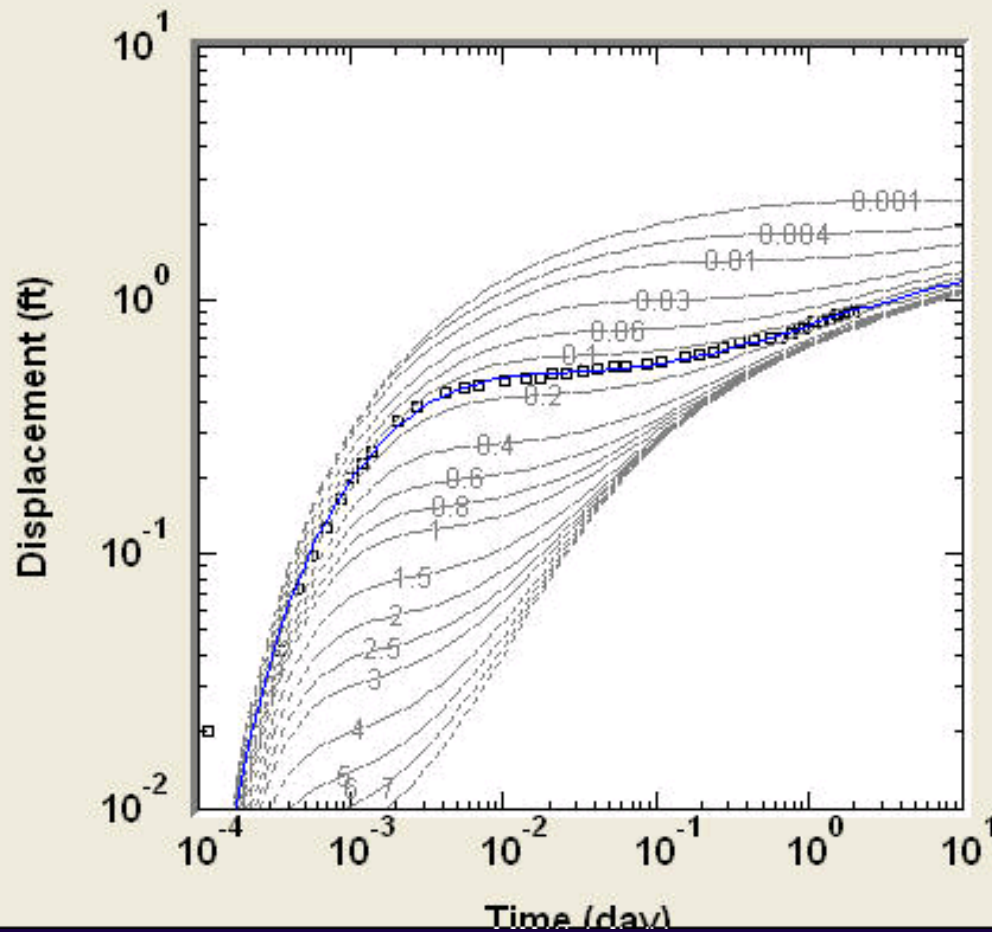
PLOT ON SEMI-LOG PAPER



$$T = \frac{2.3Q}{4\pi\Delta s_{\text{per log cycle}}}$$

$$S = \frac{2.25Tt_0}{r^2}$$

Aquifer Tests: many "Type Curves" to choose from



Obs. Wells

□ SA 1072

Aquifer Model

Unconfined

Solution

Neuman

Parameters

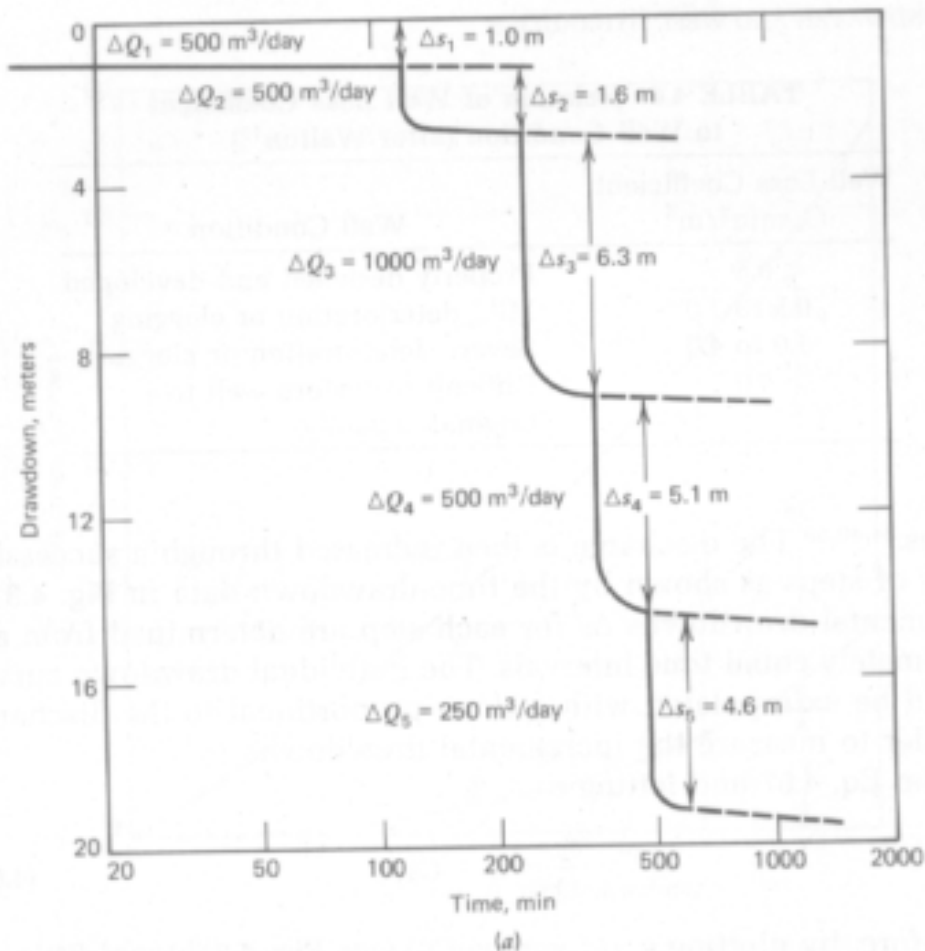
$T = 1.112E+4$ gal/day/ft

$S = 0.01126$

$S_y = 0.3668$

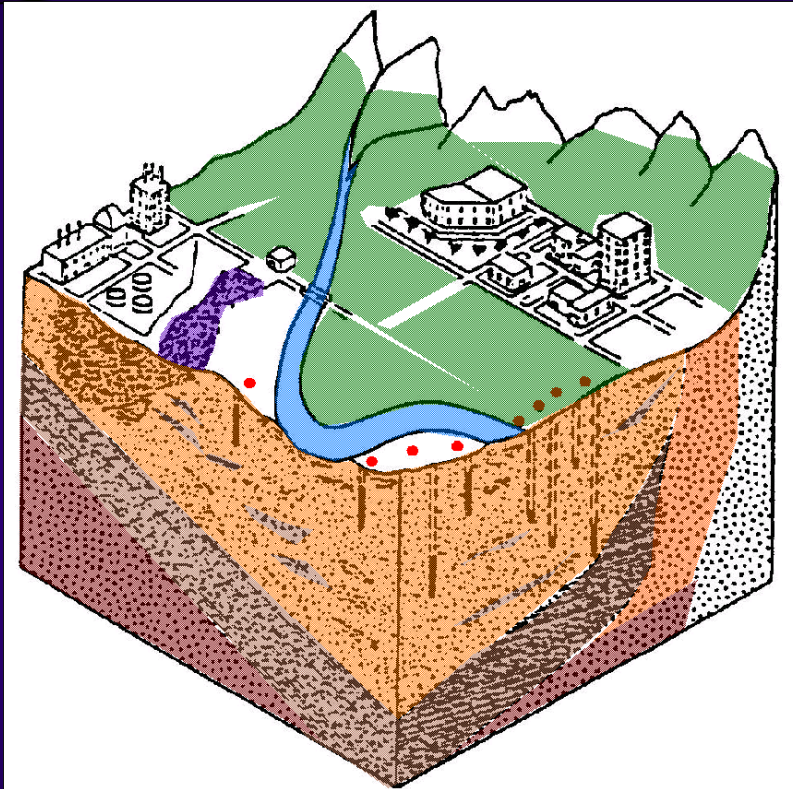
$\beta = 0.1371$

Multistep Test



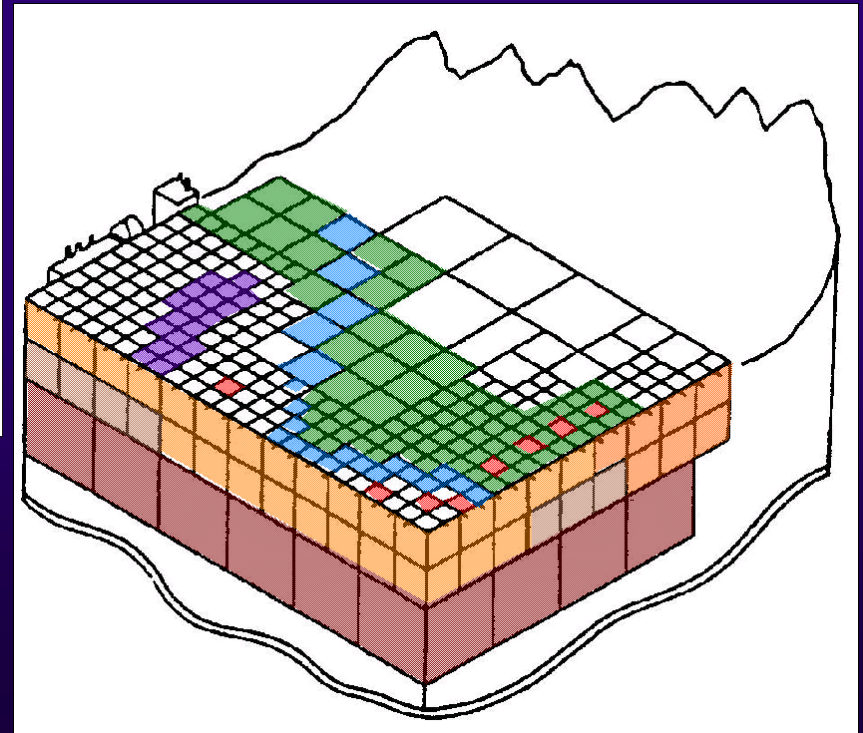
- multistep pump test w/ continuous water level monitoring
- comparison to drawdown in nearby wells (of limited value)
- pump for 1 hour: if water level recovers by 90% within 5 minutes => worst case, unacceptable well losses

Computer Groundwater Model

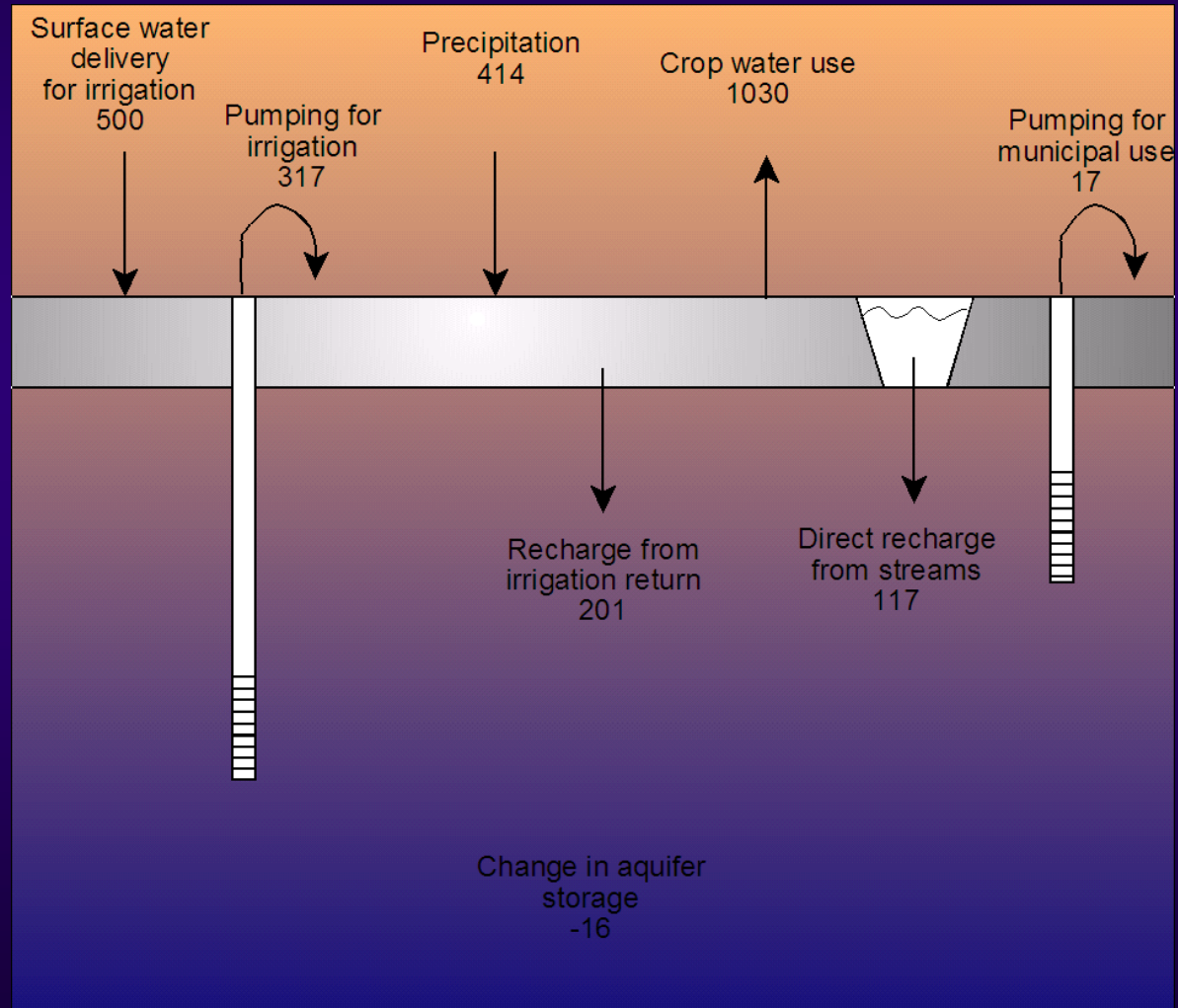


Conceptual model (expert opinion)

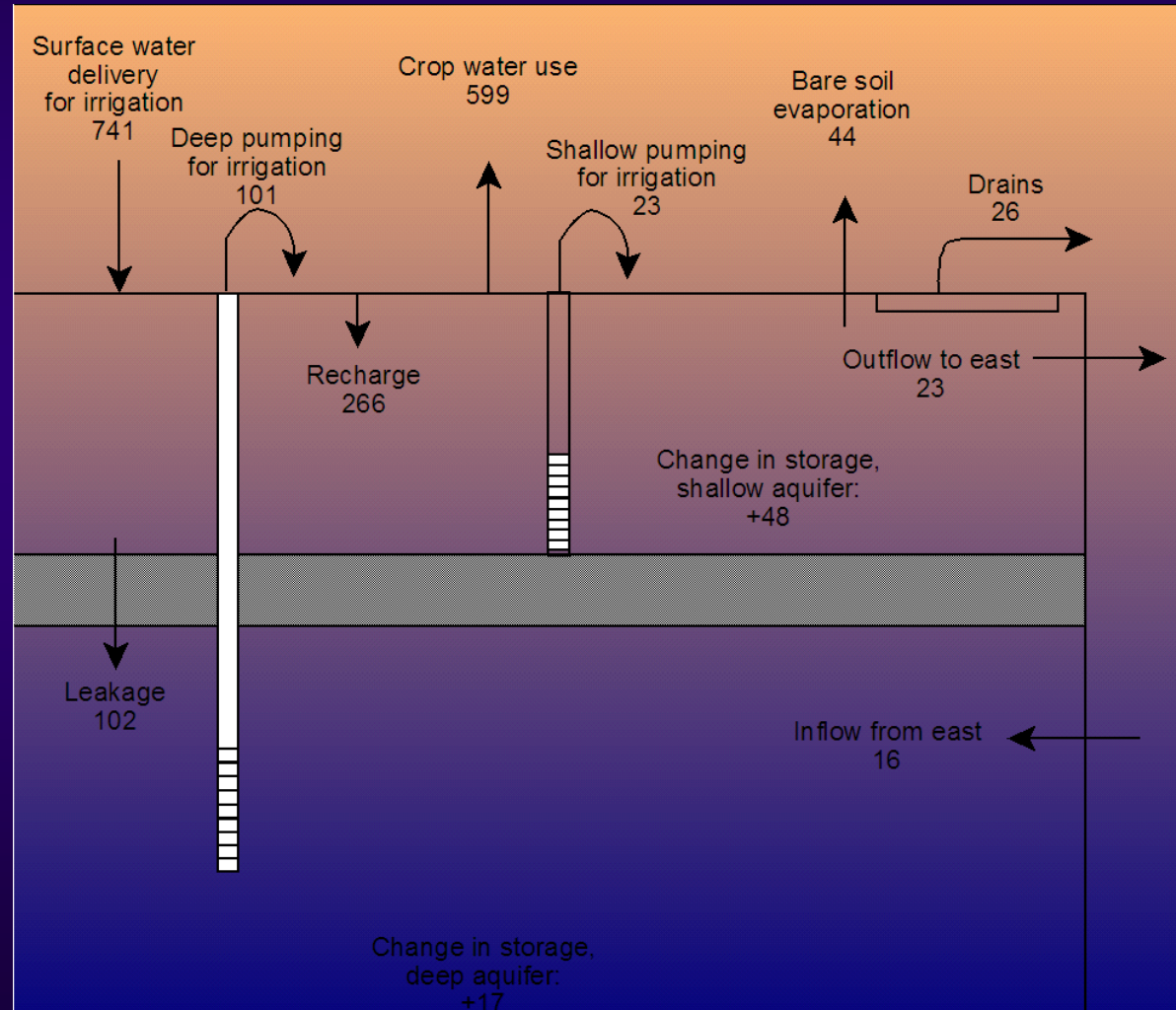
Computer model (physics)



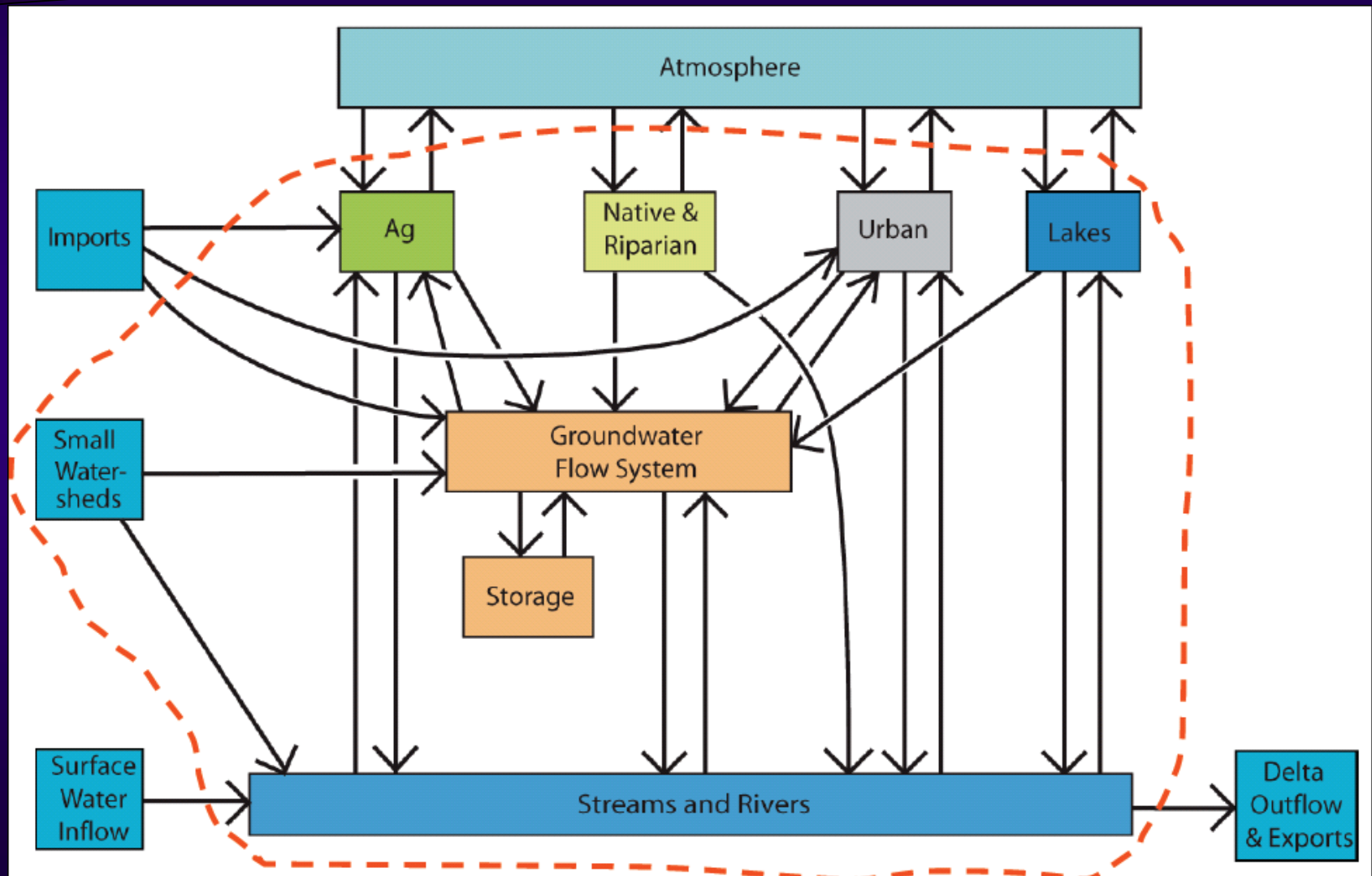
Water Budget (Tulare County)



Water Budget (Westside SJV)



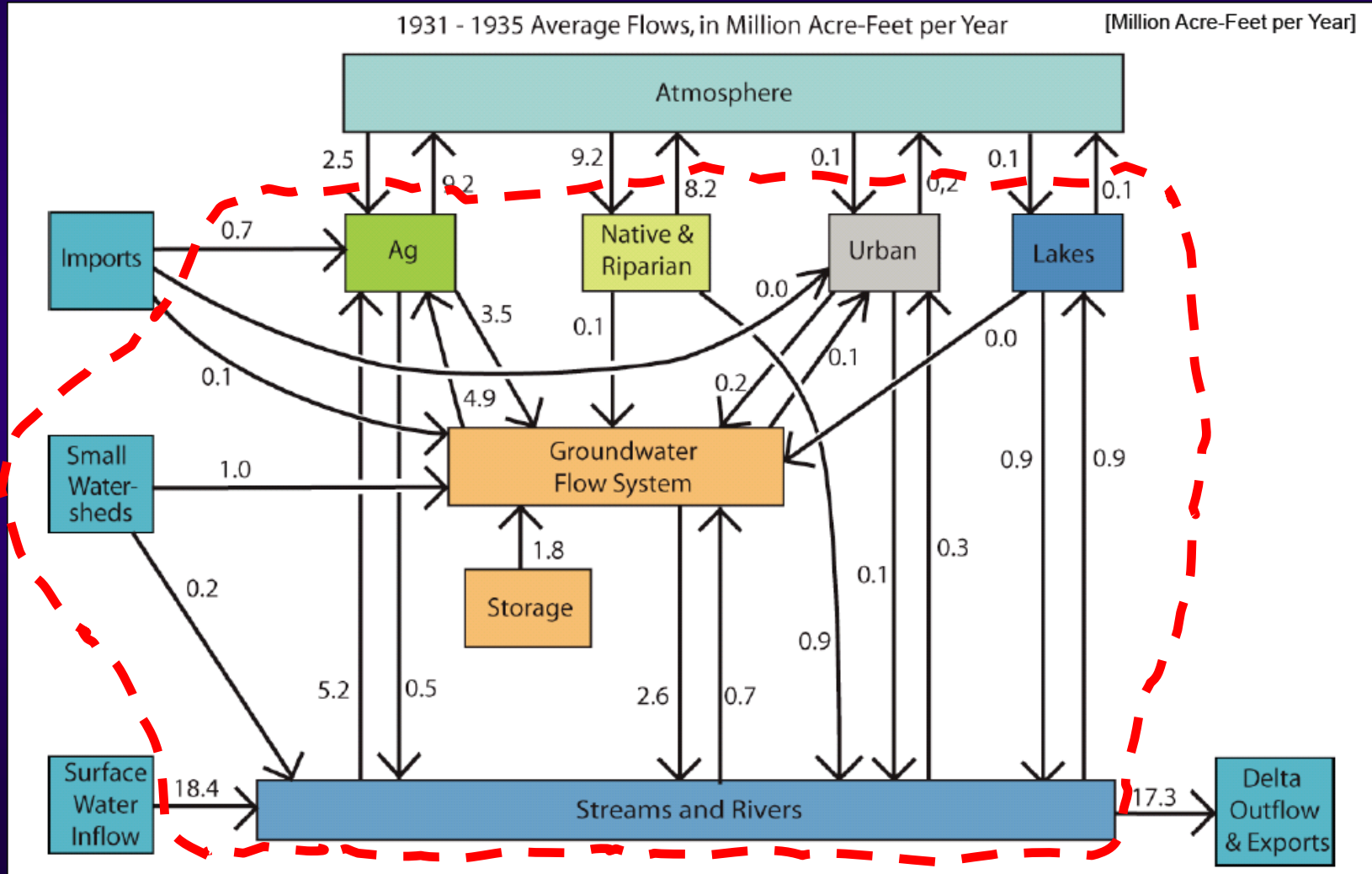
Elements of an Integrated Water Model



Courtesy, Charlie Brush, Ca. DWR, 2008

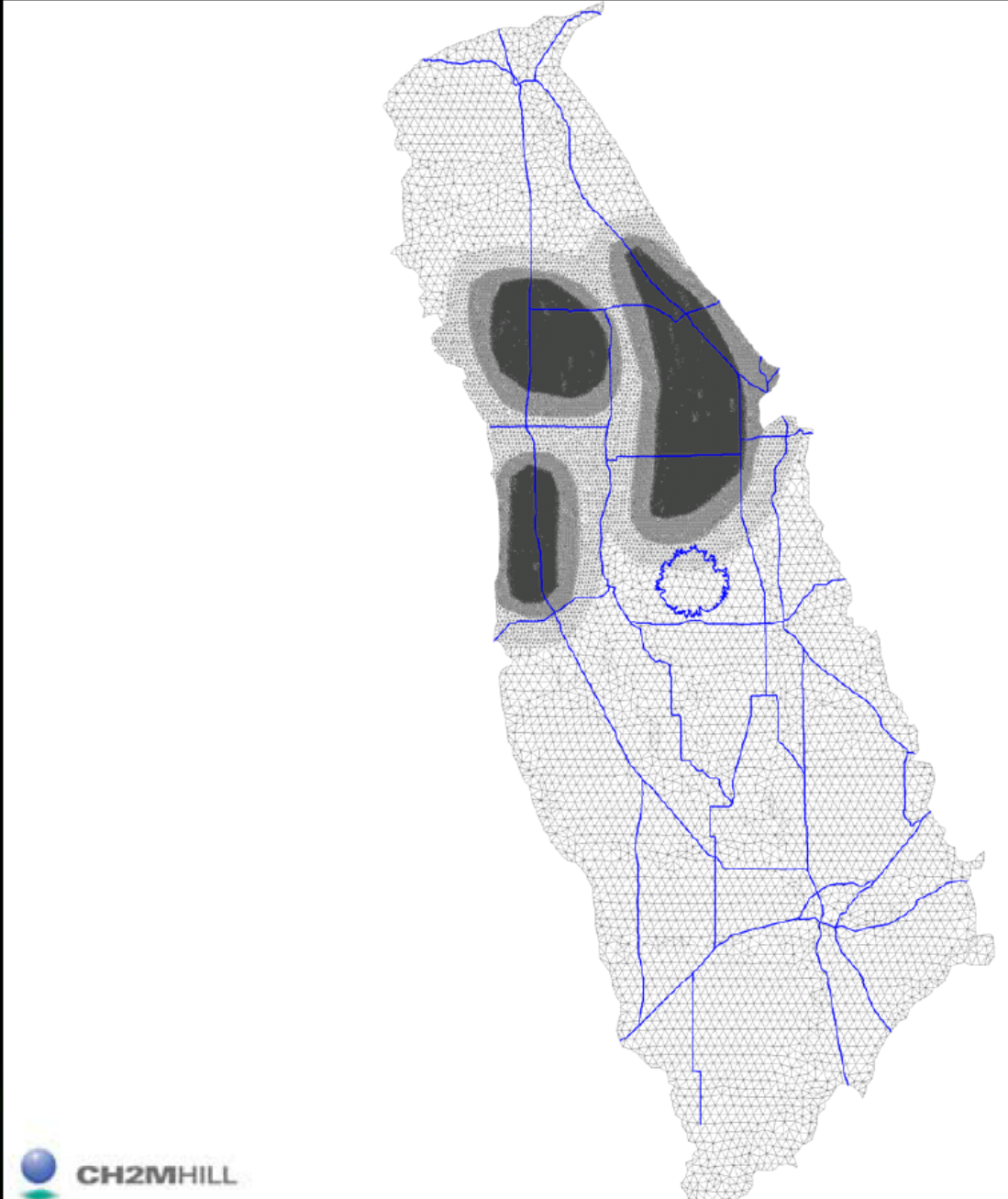
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Water Budget, Central Valley



Courtesy, Charlie Brush, Ca. DWR, 2008

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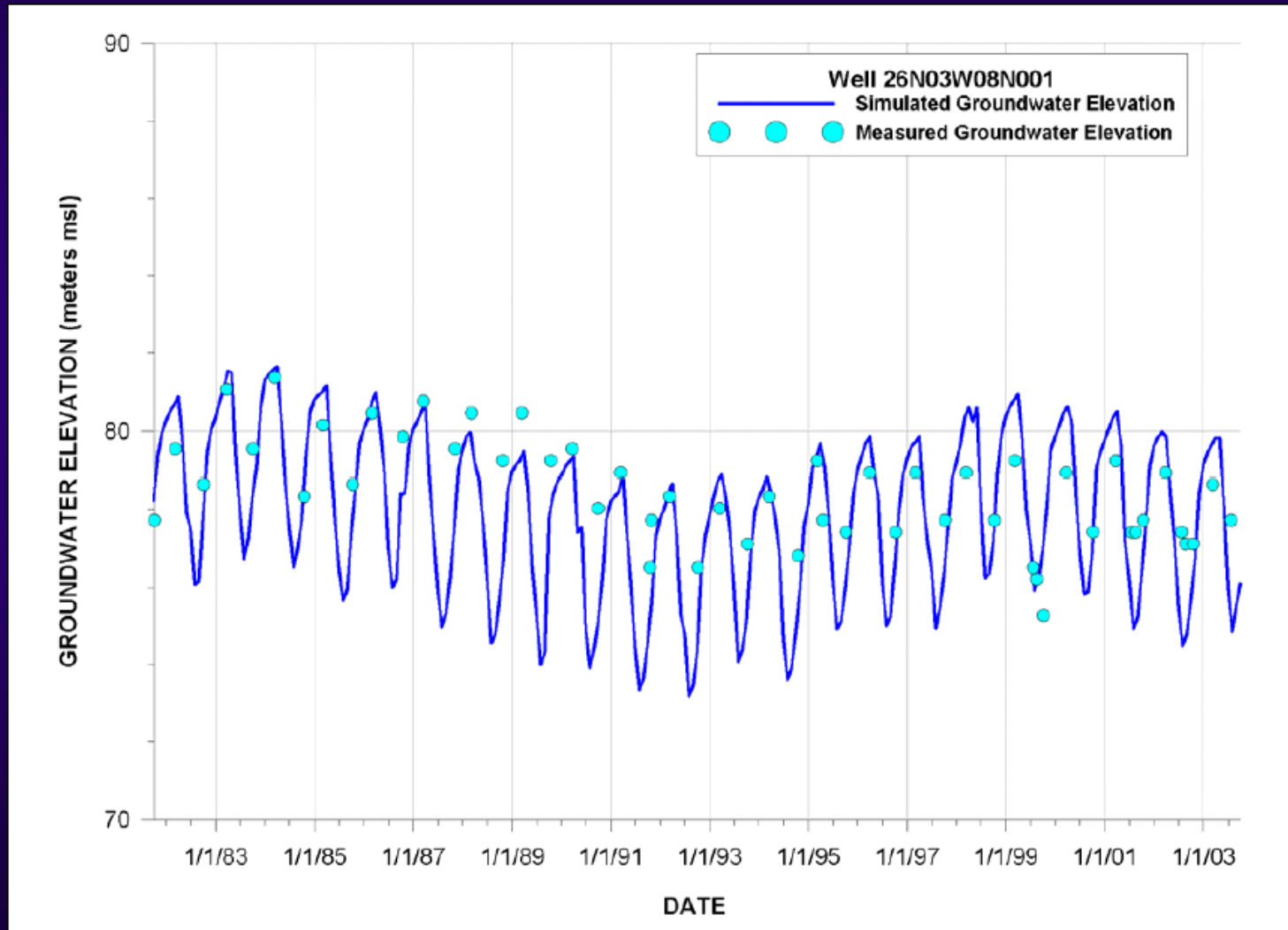
 CH2MHILL

Example of a Sac Valley Model

Courtesy, Peter Lawson, CH2M Hill, 2008

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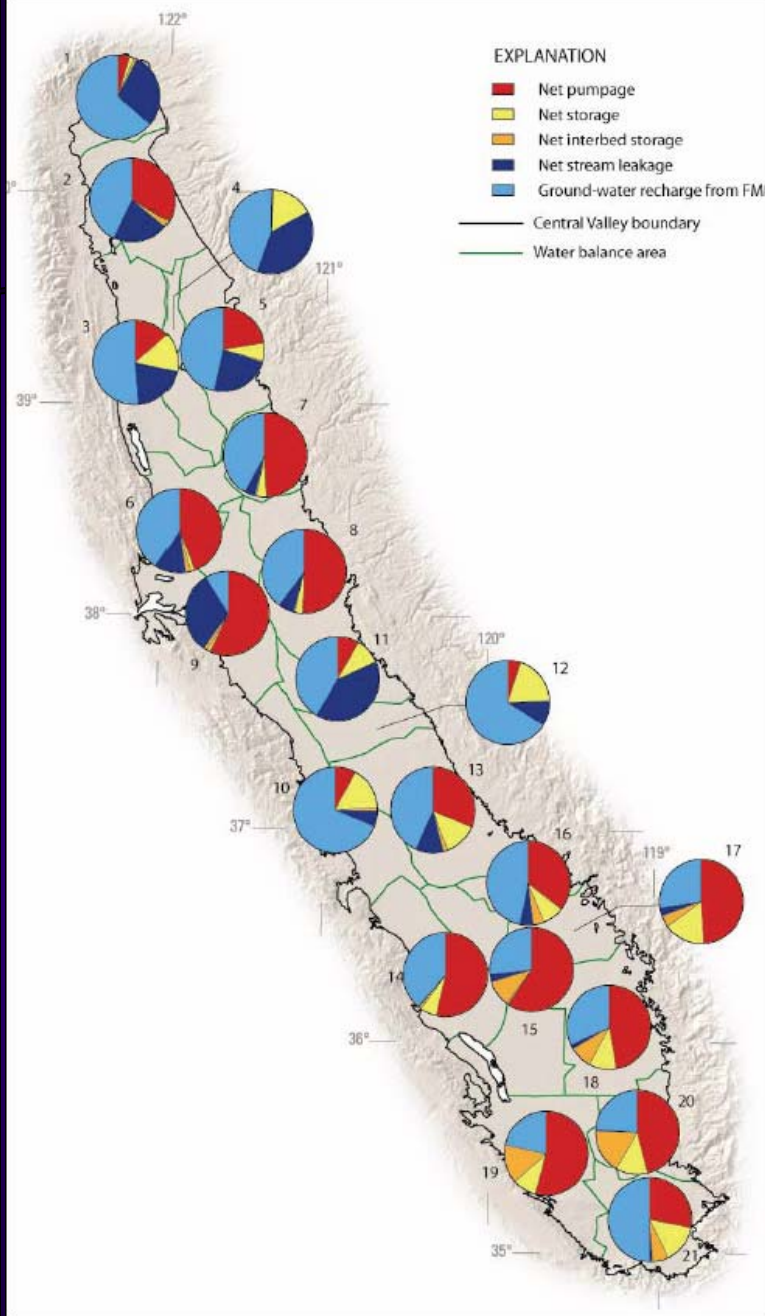
Making sure the model works



Courtesy, Peter Lawson, CH2M Hill, 2008

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Some Useful Model Results



Courtesy, Claudia Fawn, USGS, 2008

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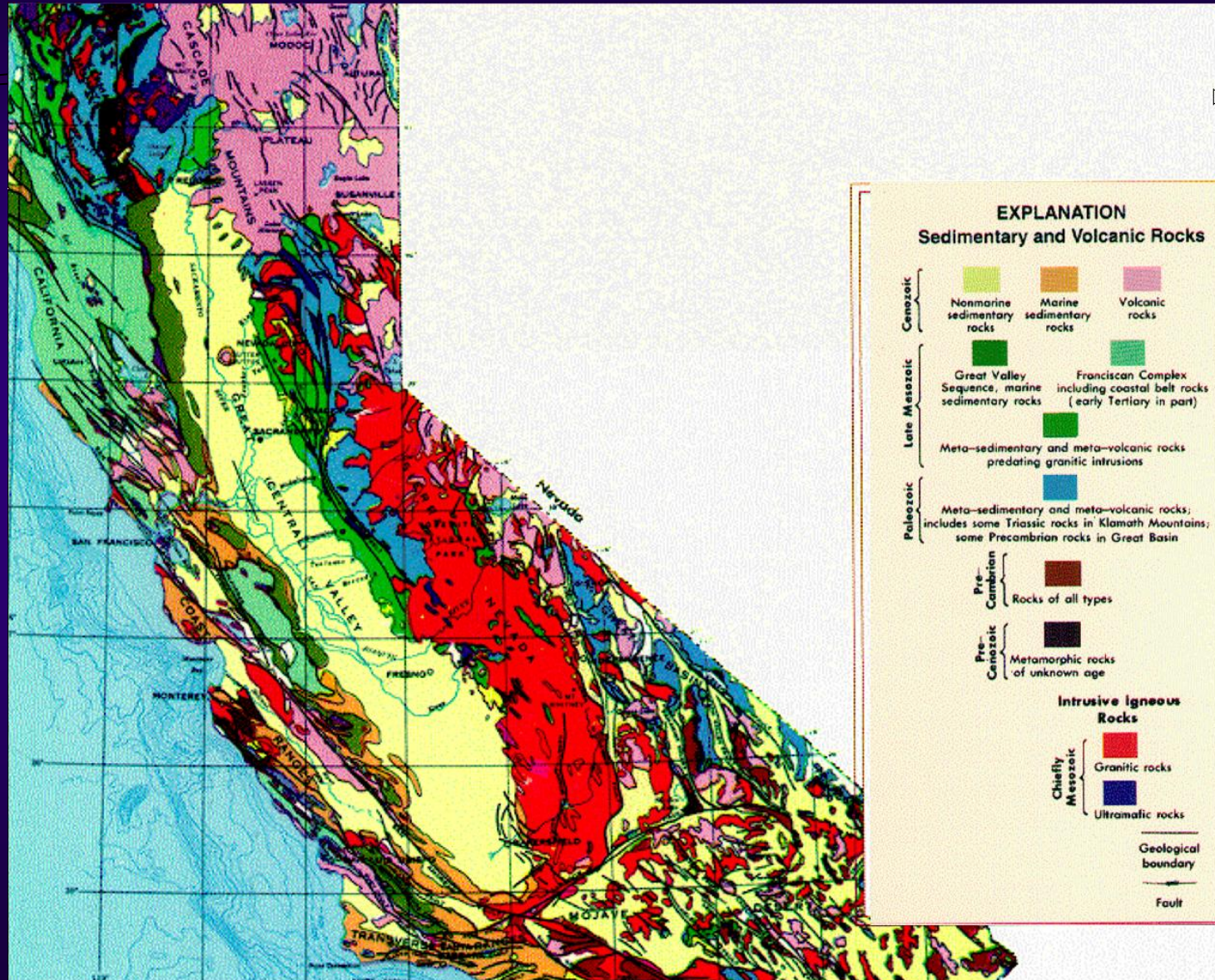
Conclusion

- Groundwater flow = hydraulic conductivity \times pressure gradient
- Aquifer tests: measure hydraulic conductivity
- Water level data: measure pressure gradients across region
- Groundwater models: put everything together we know about the groundwater system (including aquifer test data)
- Compare groundwater models to measured water levels => if ok, use for:
 - Prediction
 - Scenario analysis
 - Identifying additional data needs

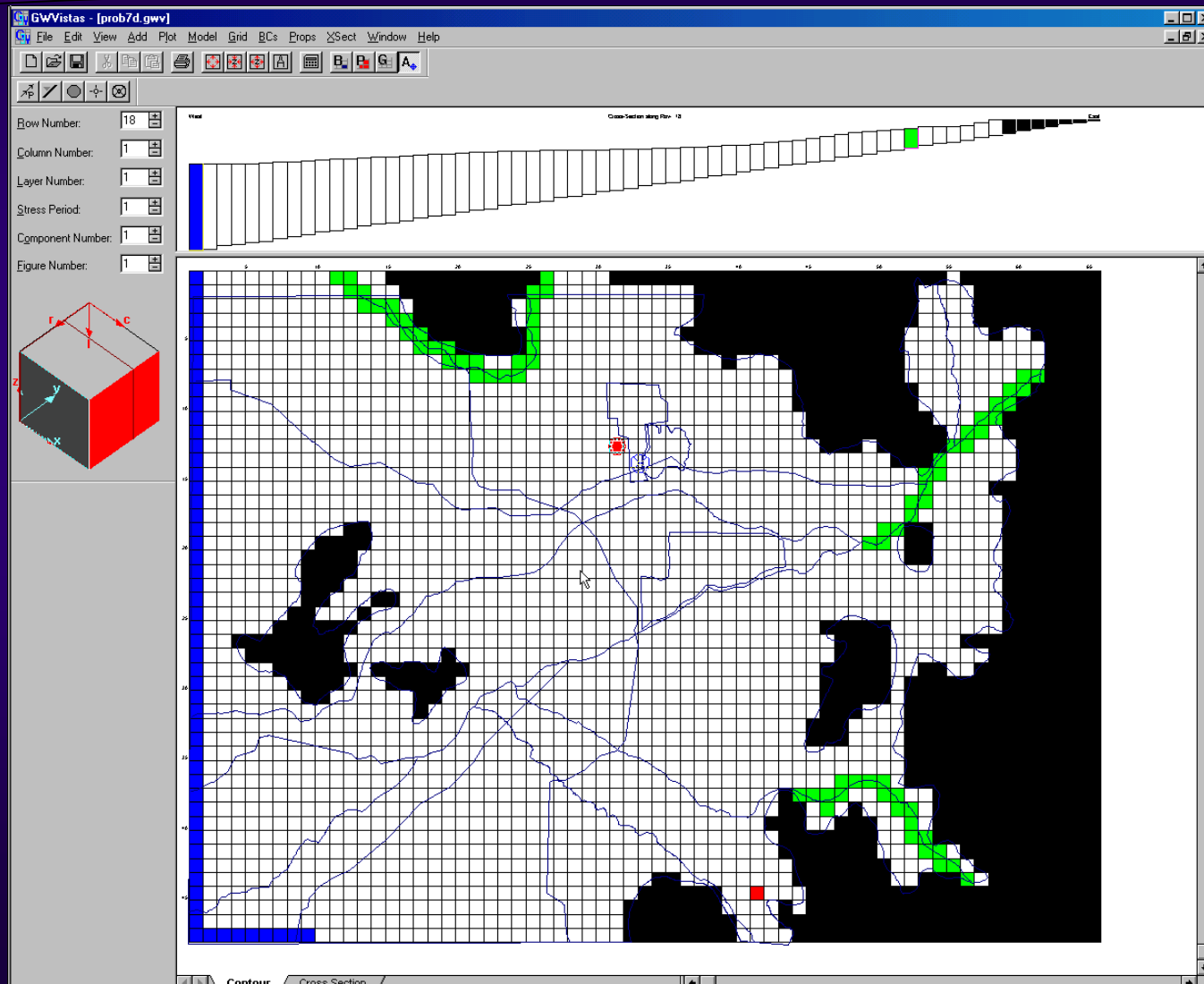
Additional Slides



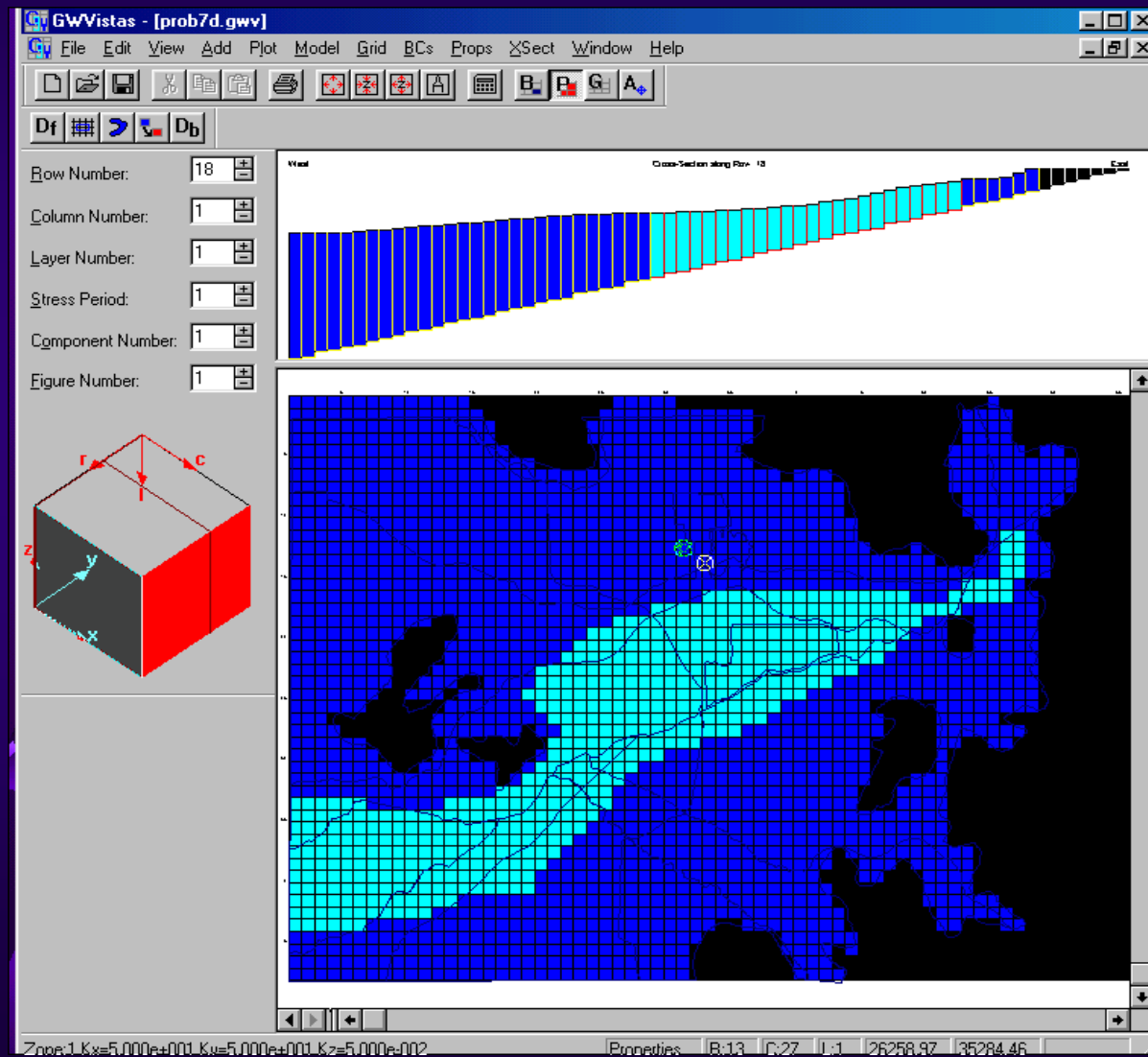
California Groundwater



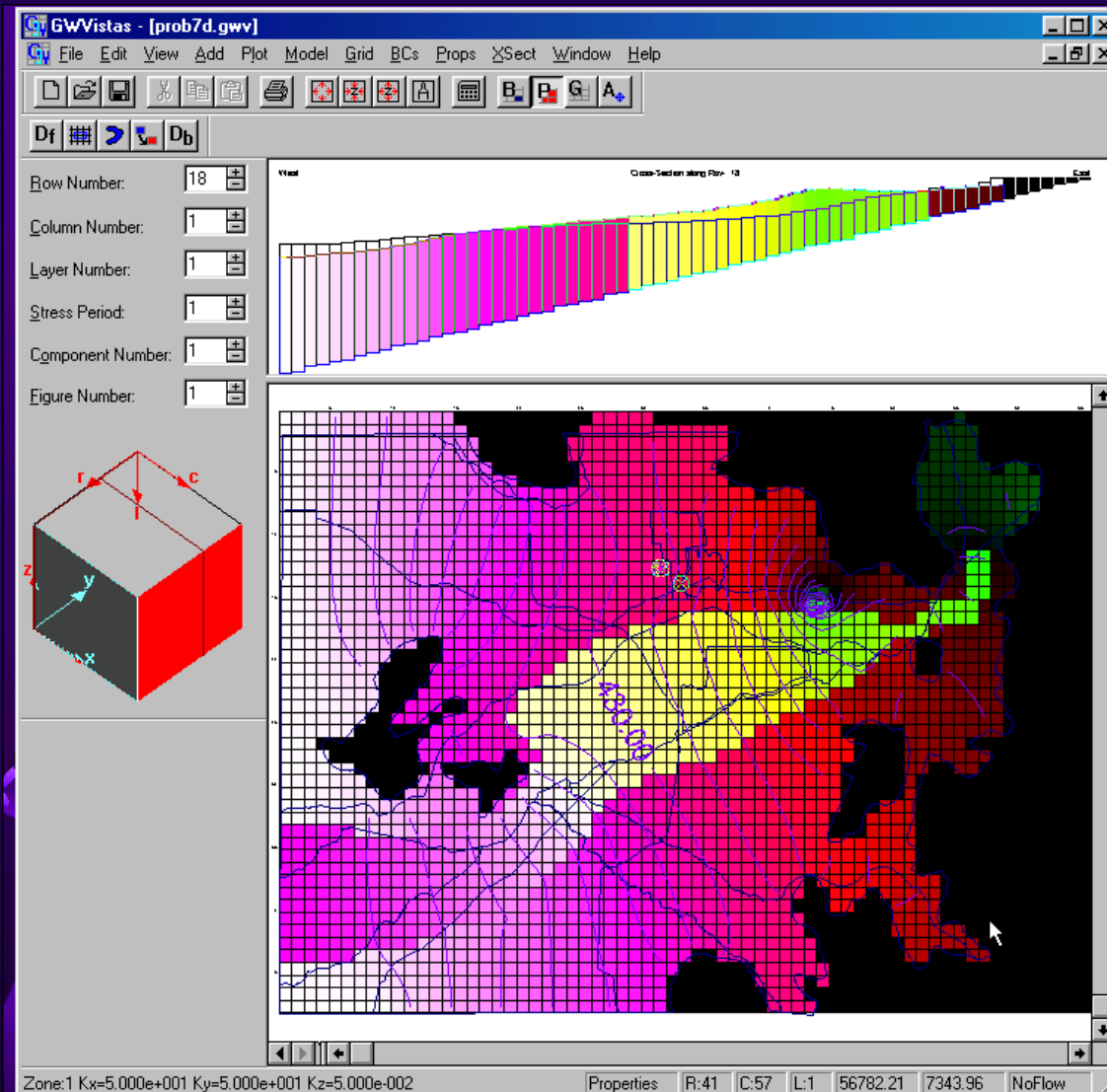
Computer Groundwater Model



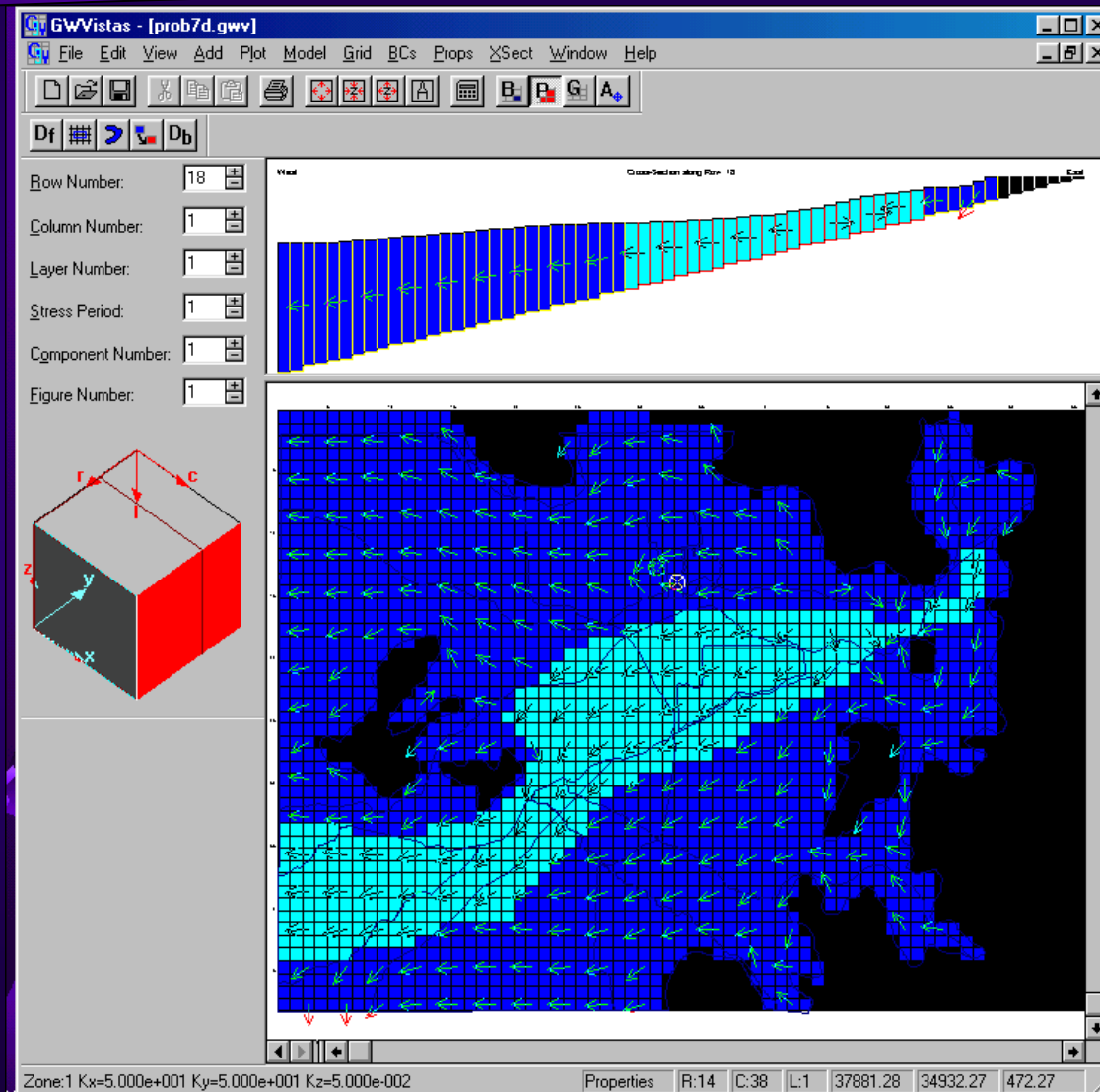
Computer Groundwater Model



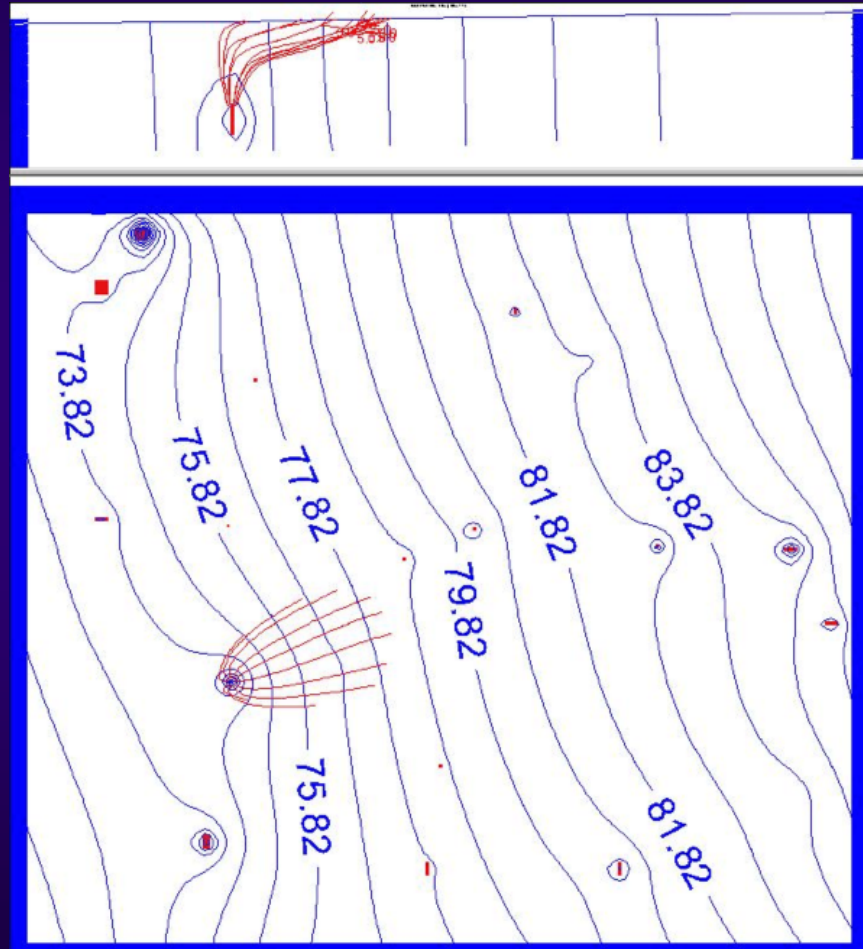
Computer Groundwater Model



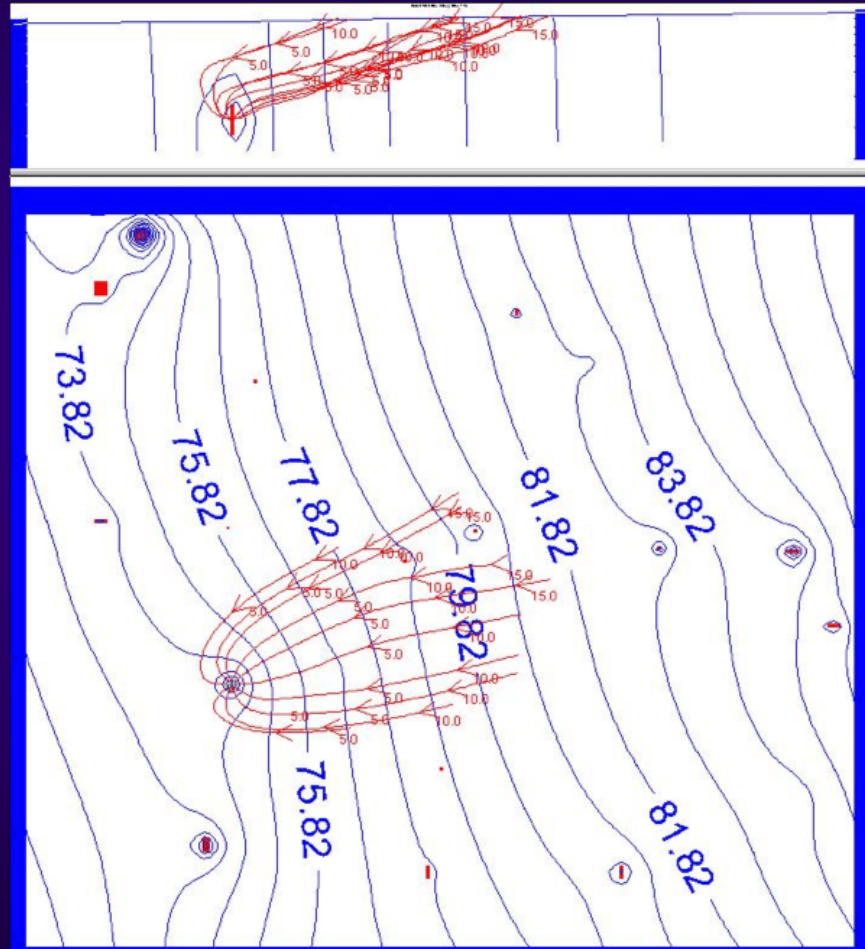
Computer Groundwater Model



Computer Groundwater Model



Computer Groundwater Model



Computer Groundwater Model

