Understanding Groundwater

December 9, 2015

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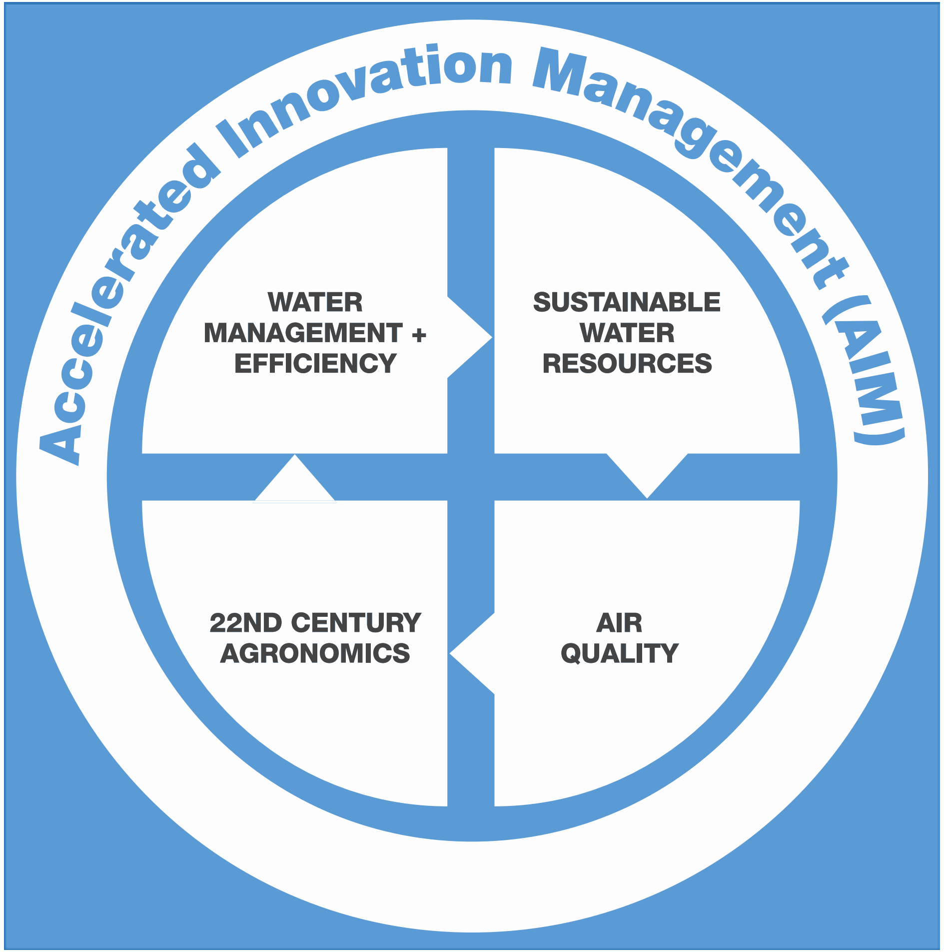
Accelerated Innovation Management (AIM)
WATER MANAGEMENT + EFFICIENCY
SUSTAINABLE WATER RESOURCES
22ND CENTURY AGRONOMICS
AIR QUALITY


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Speakers

Gabriele Ludwig, Almond Board (Moderator)

Graham Fogg, University of California, Davis

Gabriele Ludwig,
Almond Board

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Graham Fogg,
University of California, Davis

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Understanding Groundwater: The Hidden Resource

Graham E. Fogg

The Almond Conference

Sacramento, California

December 9, 2015

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Outline

- Groundwater fundamentals
  - California groundwater occurrence & general background
  - Climate change and a new epoch of scarcity
  - Overdraft & negative consequences
    - Non-sustainable storage depletion
    - Subsidence
    - Surface water & ecosystem effects
    - Increased energy costs
    - Bad water intrusion from aquitards and from depth
    - Basin salt imbalance
    - Seawater intrusion
  - Sustainable yield
- Groundwater myths
  - Pumping of “fossil water” is non-sustainable
  - Groundwater storage depletion always takes a long time to recover
  - Groundwater levels tell us how much groundwater storage is changing
  - Quality of most groundwater is degraded
  - Good quality groundwater today is likely to stay that way
  - Potential myth: climate change will decrease groundwater recharge

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California

Water System

http://www.water.ca.gov/maps/allprojects.html

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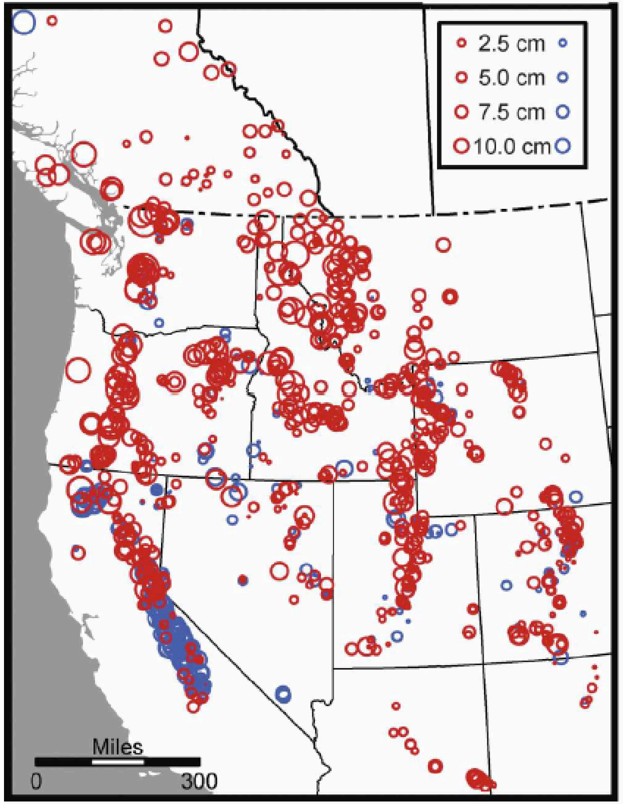
Snow Water Storage

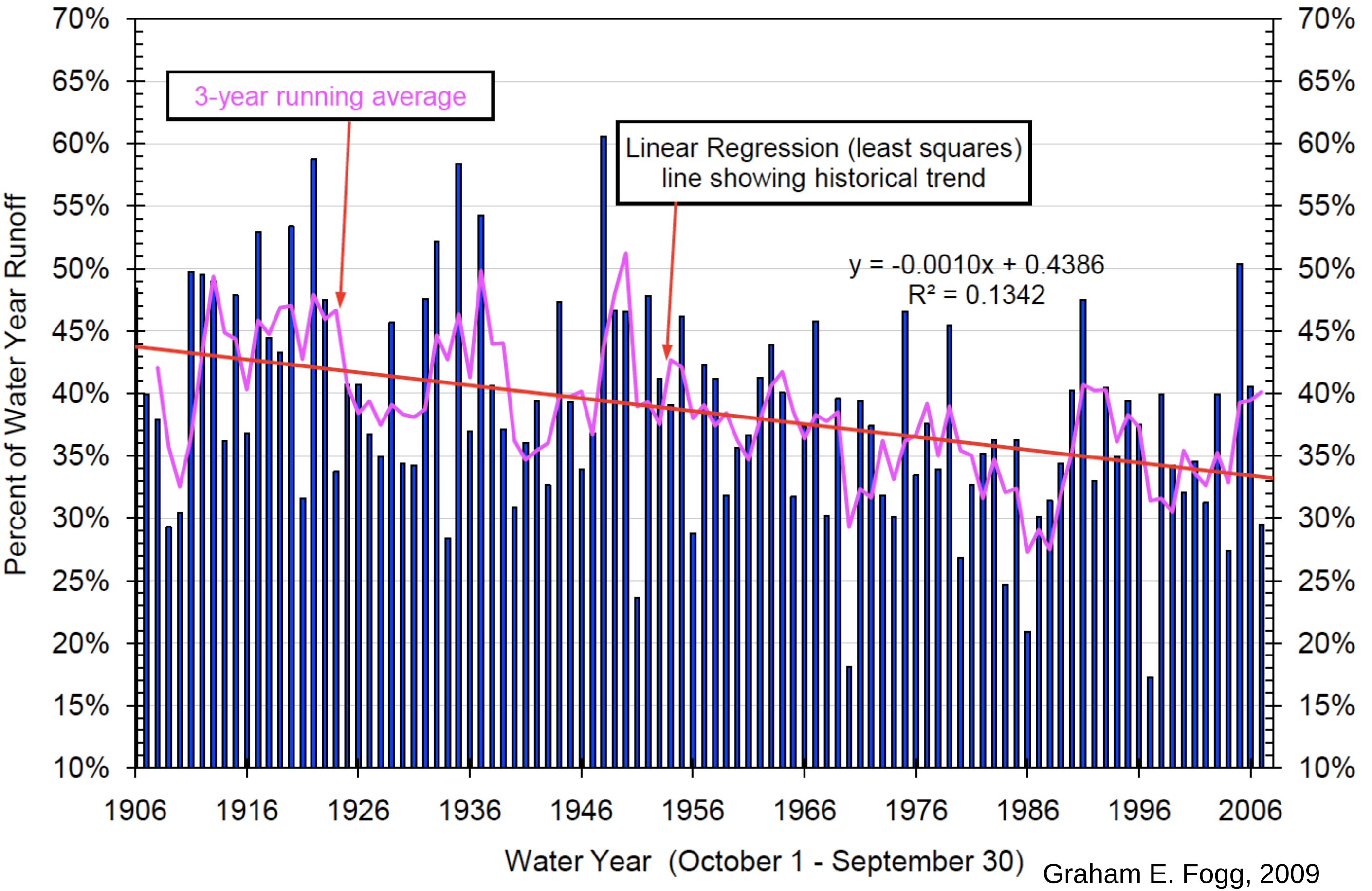
Slides: Bryan Weare, 2012.

Definition: Snow-Water Equivalent (SWE) is a common snowpack measurement. It measure the volume of water contained within the snowpack (as a measure of depth).

Figure: Mote (2006) Fig 5a: Observed changes in 1 April Snow-Water Equivalent over the 1960 to 2002 period of record from snow course observations.



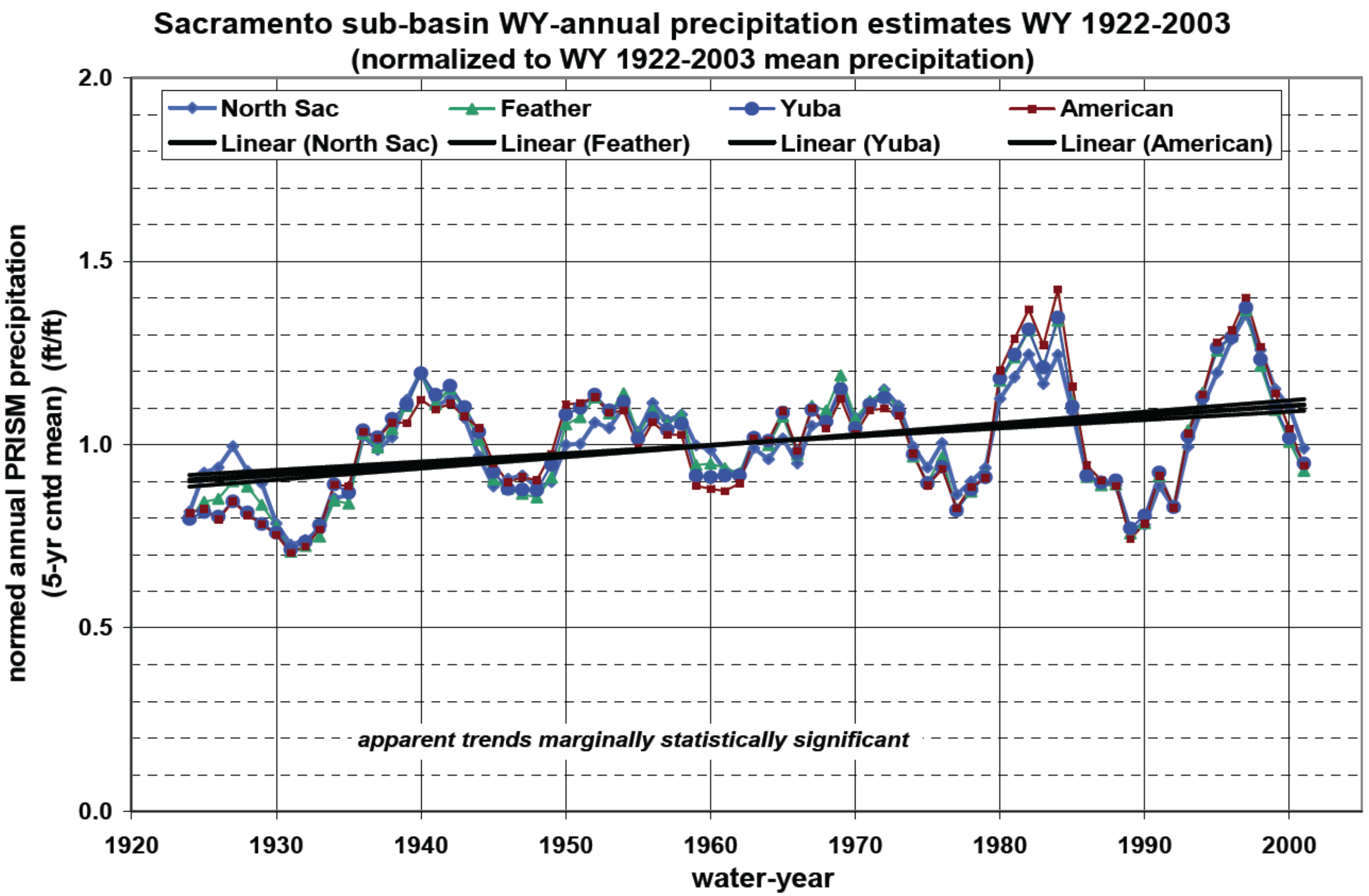
Sacramento River Runoff
April - July Runoff as Percent of Water Year Runoff



Graham E. Fogg, 2009

http://www.oehha.ca.gov/multimedia/epic/pdf/ClimateChangeIndicatorsApril2009.pd
f

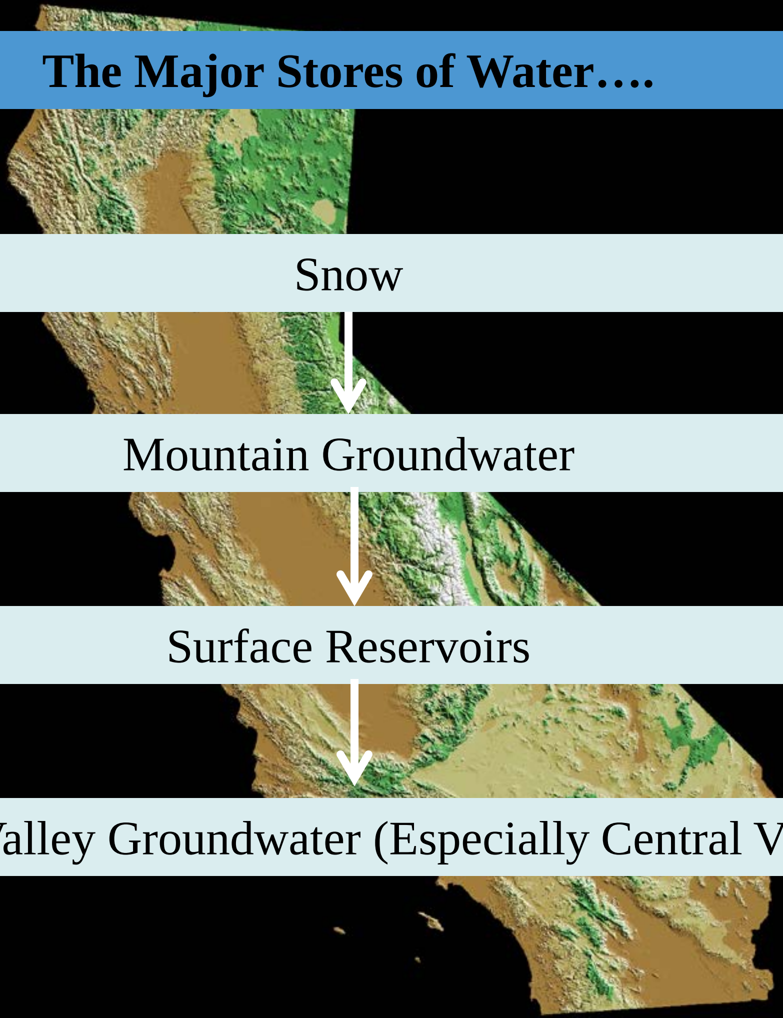
Source: DWR, 2008


Sacramento sub-basin WY-annual precipitation estimates WY 1922-2003
(normalized to WY 1922-2003 mean precipitation)
North Sac
Feather
Yuba
American
Linear (North Sac)
Linear (Feather)
Linear (Yuba)
Linear (American)
normed annual PRISM precipitation
(5-yr cntd mean) (ft/ft)
2.0
1.5
1.0
0.5
0.0
1920
1930
1940
1950
1960
1970
1980
1990
2000
water-year
apparent trends marginally statistically significant

The CA Water Quantity Problem

- 8^{th} largest economy in the world.
- Produces 50% of nation's fruits & vegetables w/ irrigation.
- Depends on snow-storage and historically well-timed snow-melt to satisfy demand.
- This system cannot function properly as the snow pack diminishes due to warming.

The Major Stores of Water….



Snow

↓

Mountain Groundwater

↓

Surface Reservoirs

↓

Alluvial Valley Groundwater (Especially Central Valley)

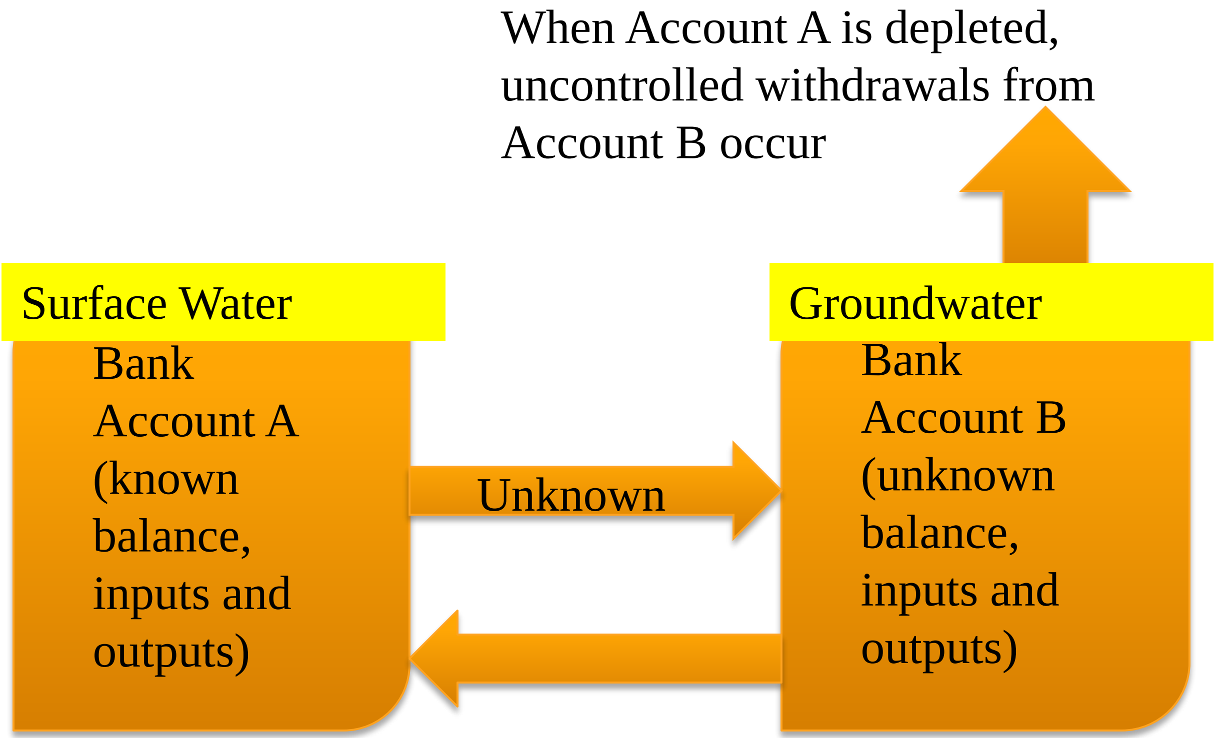
Available Central Valley Groundwater Storage Volume

- 10 to 50×10^6 ac-ft

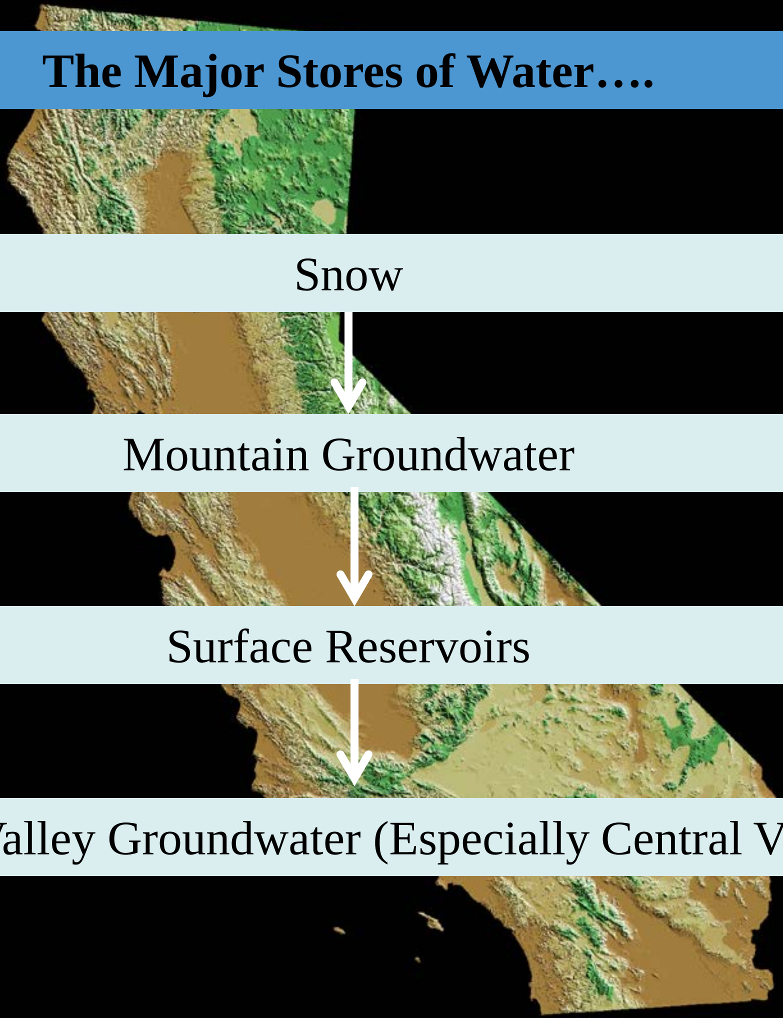
- CA's 4 largest reservoirs = 13×10^6 ac-ft

(Shasta, Oroville, Trinity, New Melones)

Two Bank Accounts



The Major Stores of Water….



Snow

↓

Mountain Groundwater

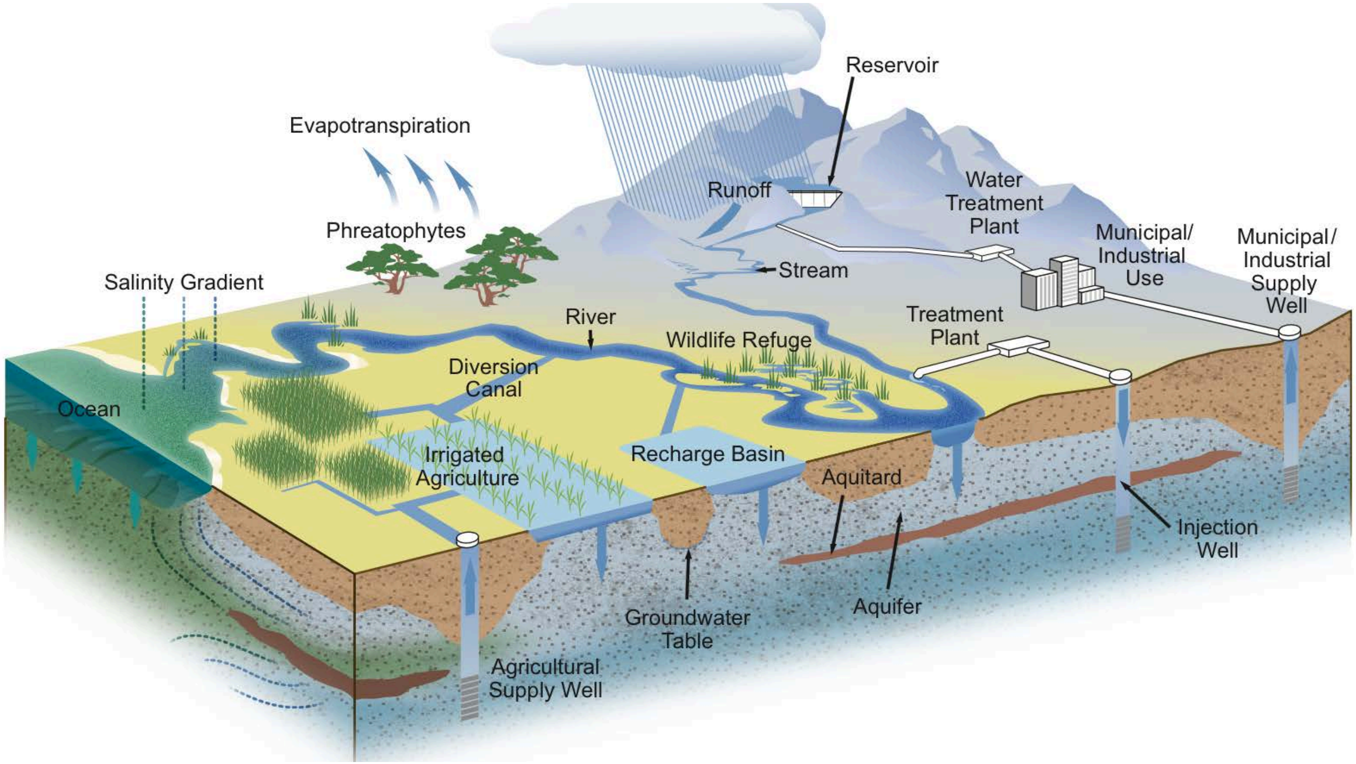
↓

Surface Reservoirs

↓

Alluvial Valley Groundwater (Especially Central Valley)

Groundwater and Surface Water



From CA Water Plan 2014

UNIVERSITY OF CALIFORNIA

UC Water
Security and Sustainability Research Initiative

http://ucwater.org info@ucwater.org twitter: @ucwater

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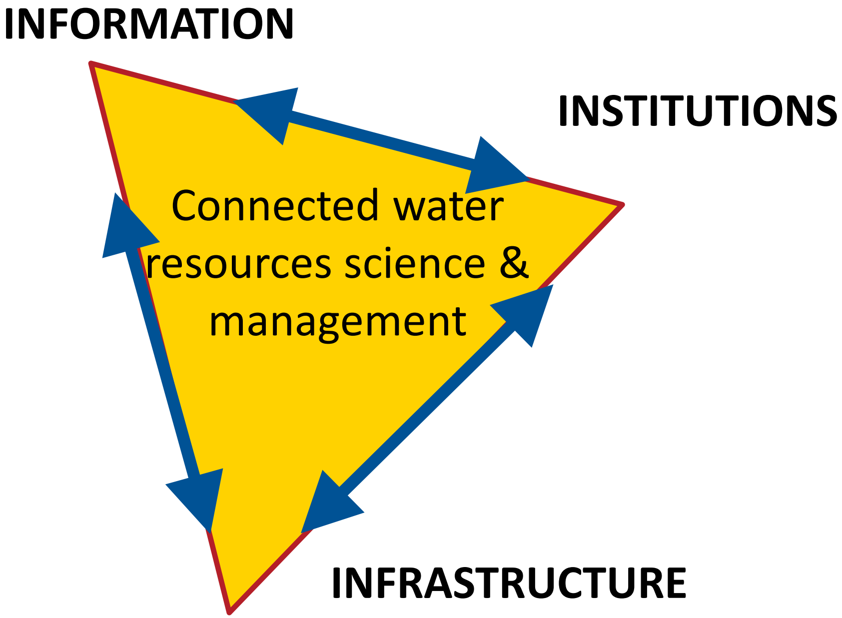
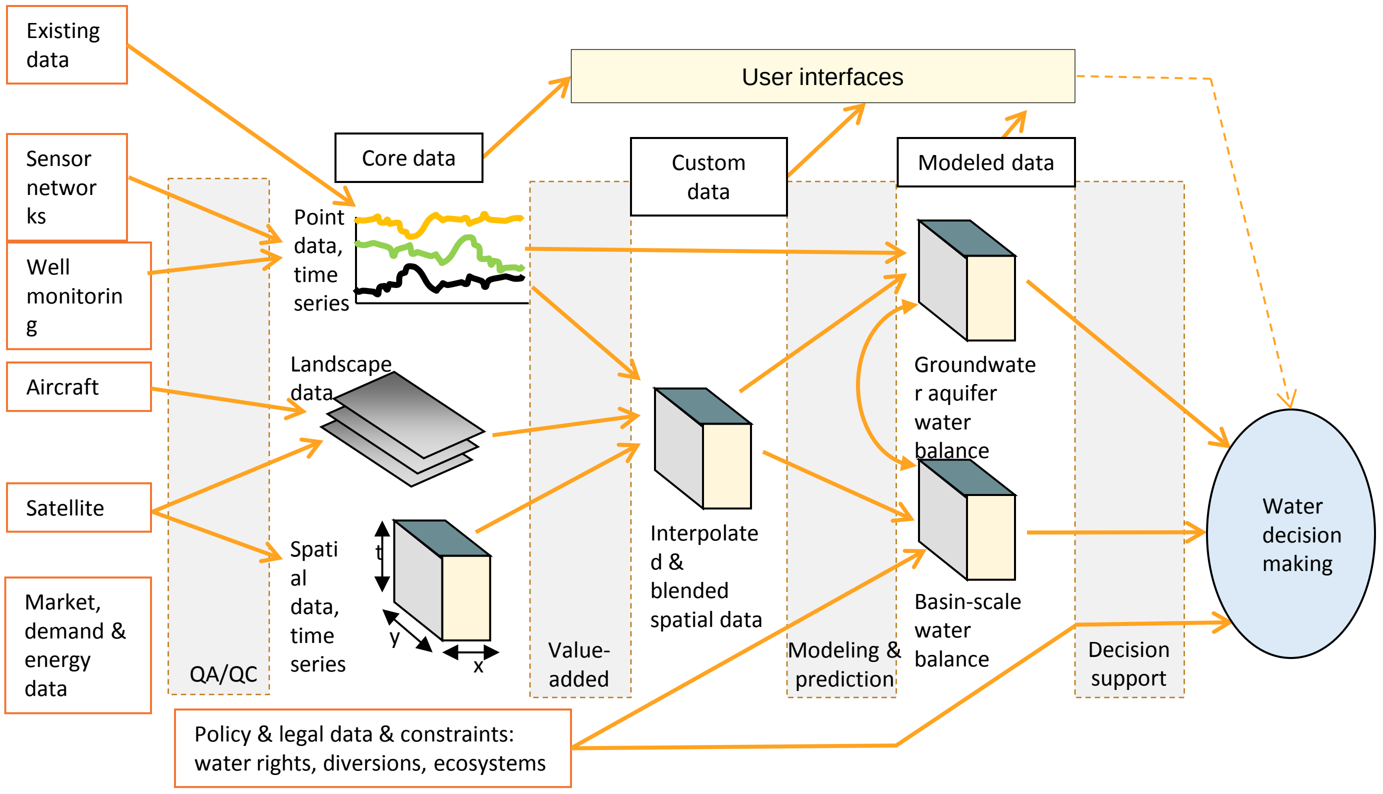
We apply three perspectives to every project.



Current program foci:
- Headwater Management
- Groundwater Management
- Water-Energy Nexus
- Intelligent Water System

Integrating water-resources data & information systems



UC Water Security and Sustainability Research Initiative
http://ucwater.org/ Aug 31, 2015

Winter Fallow Irrigation
(Dr. Helen Dahlke, UCD)

Sutter Bypass, Sutter Co., 1997 flood

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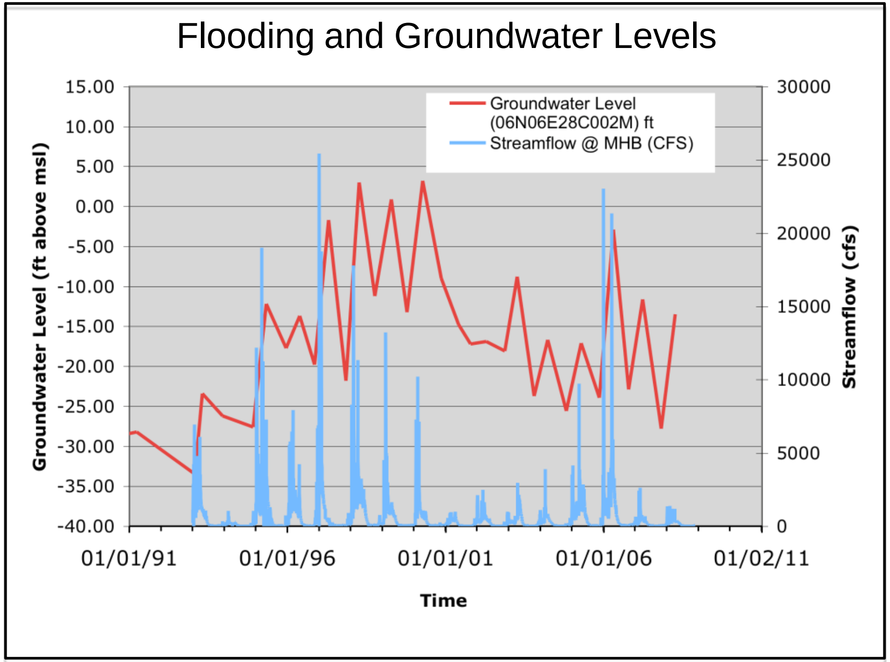
Climate Change and Groundwater: Higher Flooding Risks BUT Greater Recharge??

1997, 1995 Flood Events
Sacramento County, CA



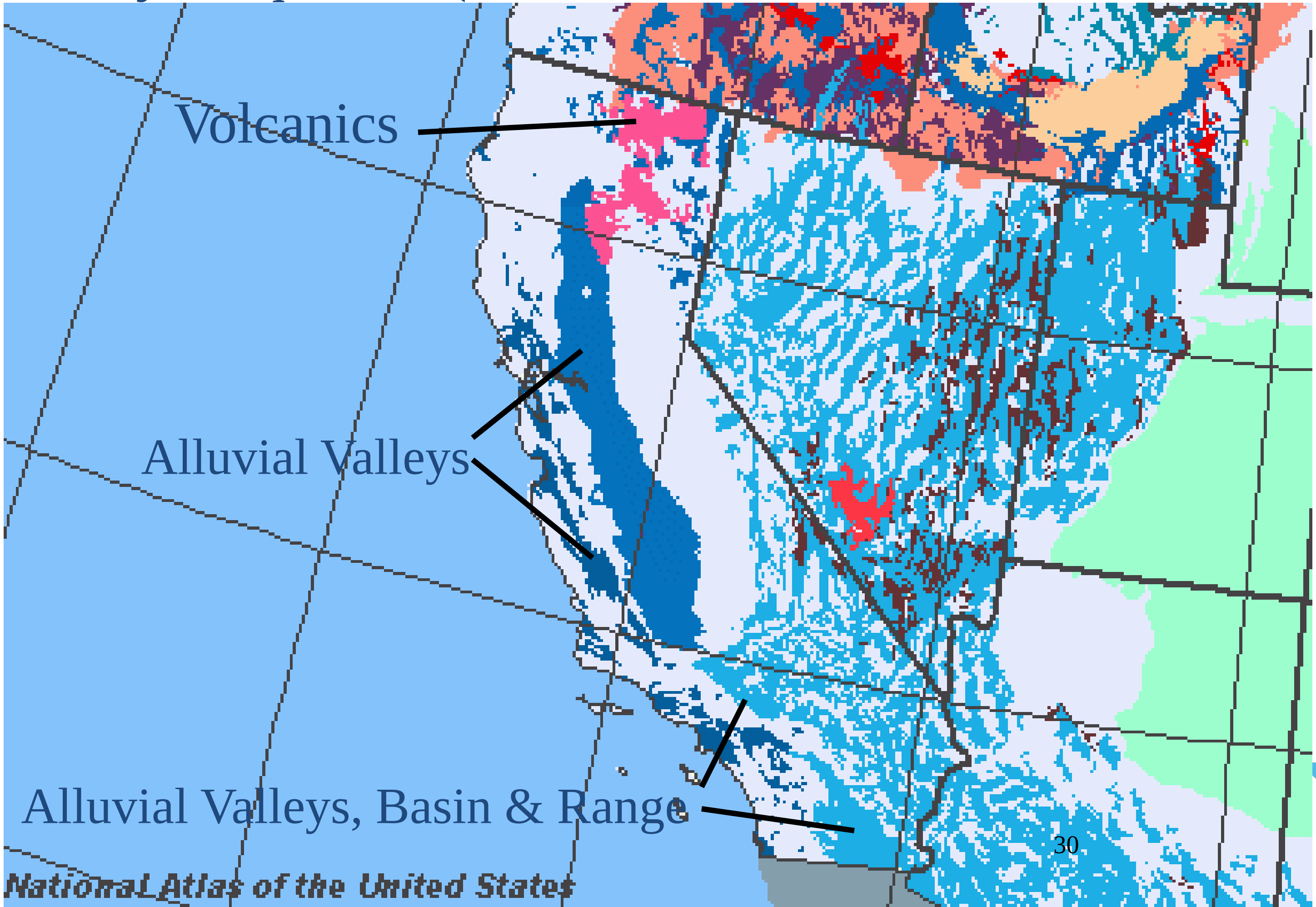
No Floodplain:

-----------------------------VERSUS:-----------------------------------

Floodplain w/ set-back levees:

Groundwater Occurrence

Major Aquifers (http://nationalatlas.gov/natlas/natlasstart.asp)



San Joaquin Valley Groundwater (from Faunt, 2009)

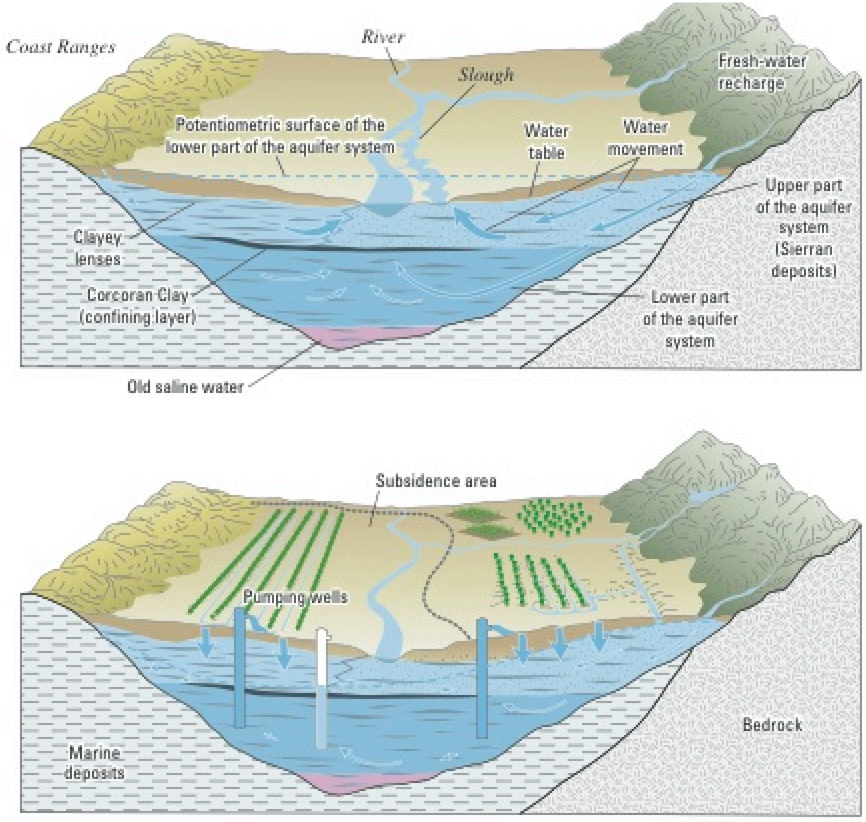


Figure A9. Continued.

Pre-Development

Post-Development

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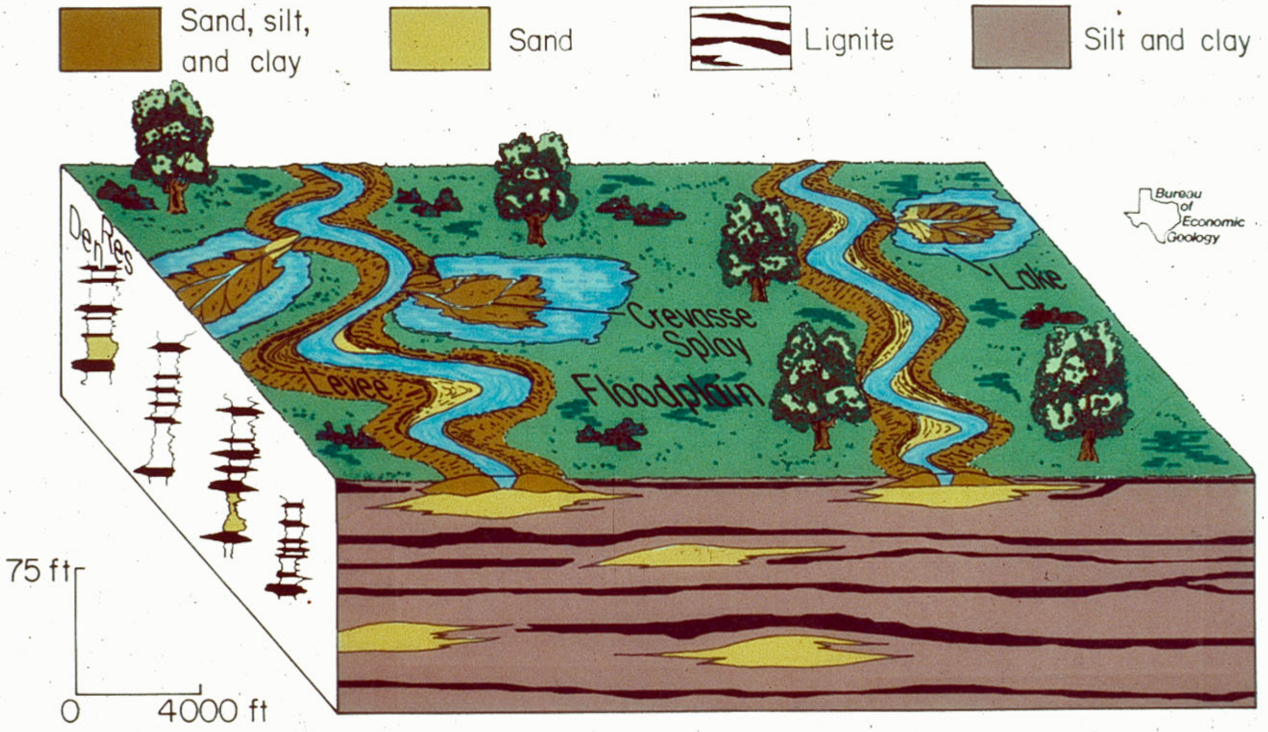
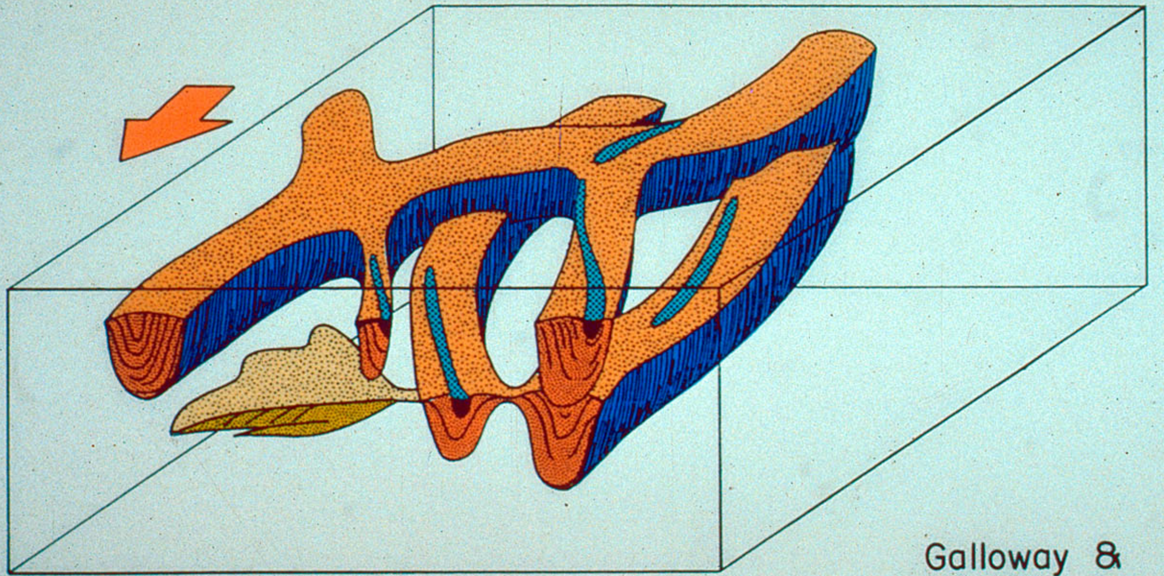


MIXED- AND SUSPENDED-LOAD CHANNEL SYSTEM
CALVERT BLUFF FORMATION

FACIES ARCHITECTURE



Suspended-load channel

Galloway &
Hobday 1983

Bureau of Economic Geology QA-2480

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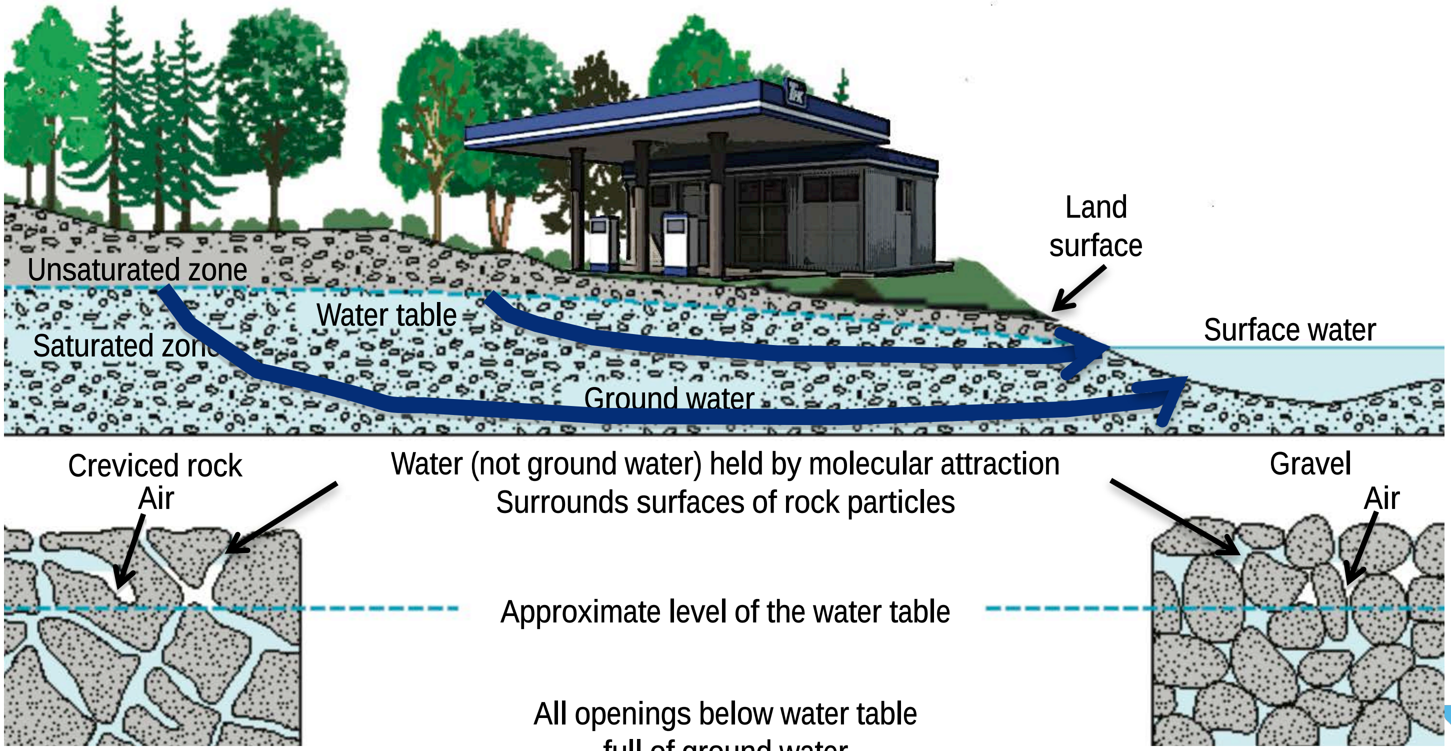
Groundwater



Confined Aquifer Schematic (from Driscoll, 1986)

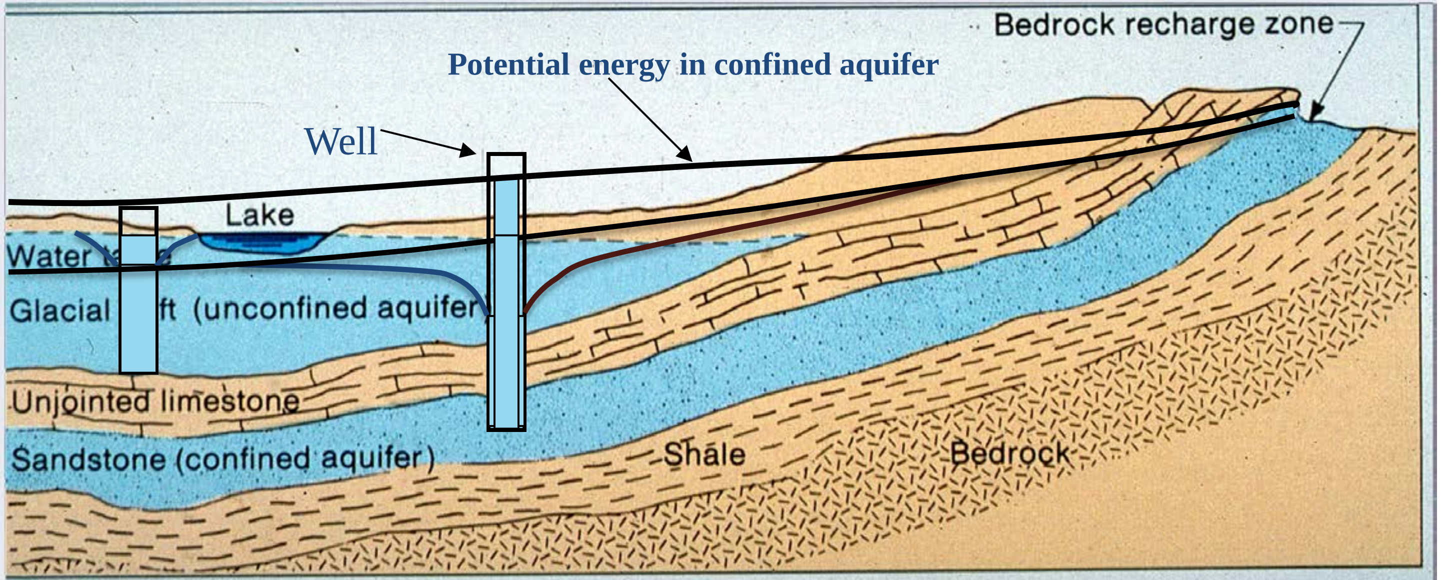


Figure 5.2. Groundwater exists in the underground in two major environments: unconfined and confined.

Myth: Old (1,000's of yrs) groundwater is fossil water that is not replenished enough to support pumping.

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Groundwater Overdraft: Pumping more groundwater than the system can sustain

Potential consequences:

- Non-sustainable storage depletion
- Subsidence
- Surface water & ecosystem effects
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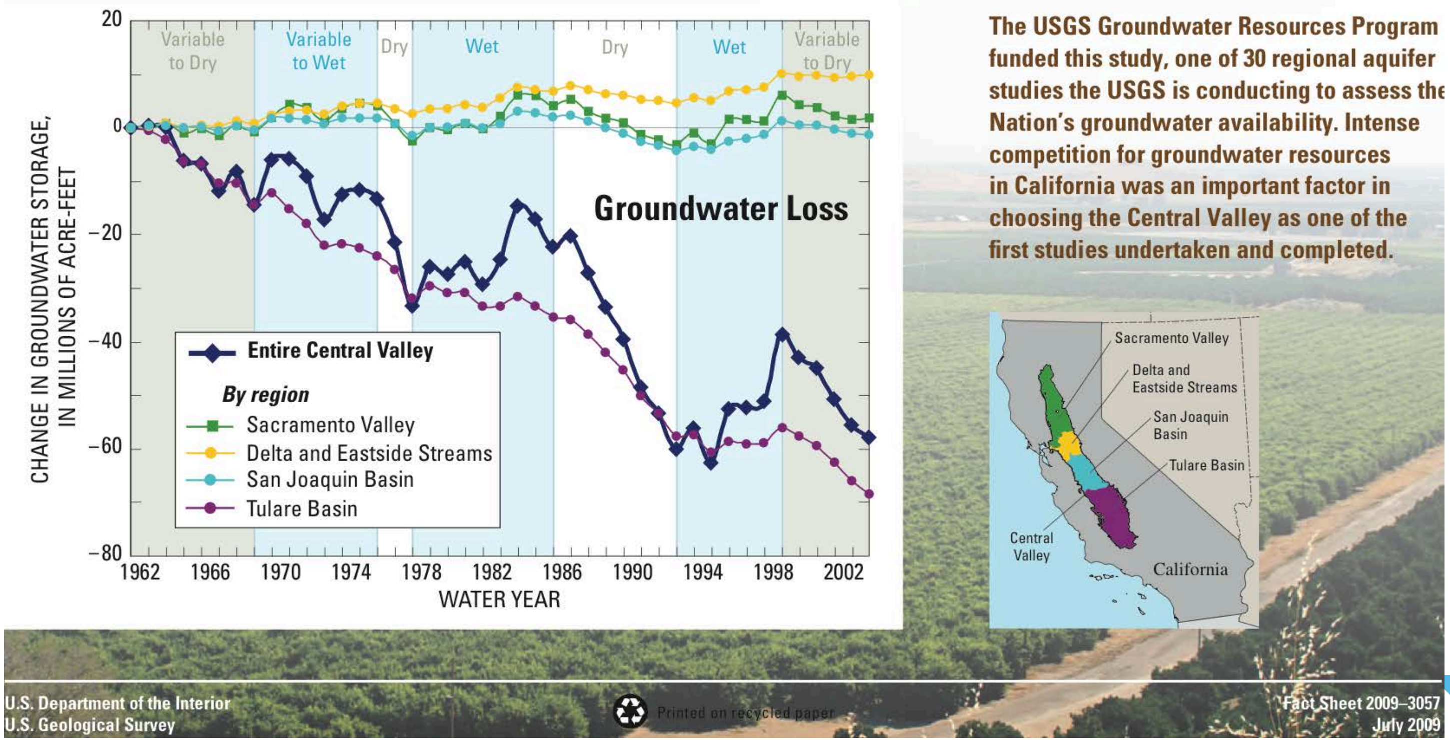
- Basin salt imbalance
- Seawater intrusion

Groundwater Overdraft Trends, Central Valley



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Mining Ground Water

San Joaquin Valley, California

Approximate location of maximum subsidence in the United States identified by Joe Poland (pictured)

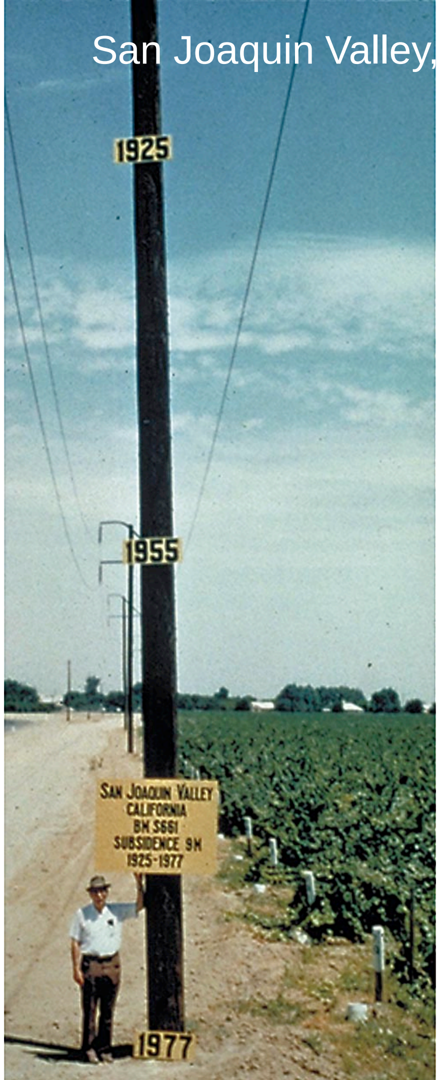
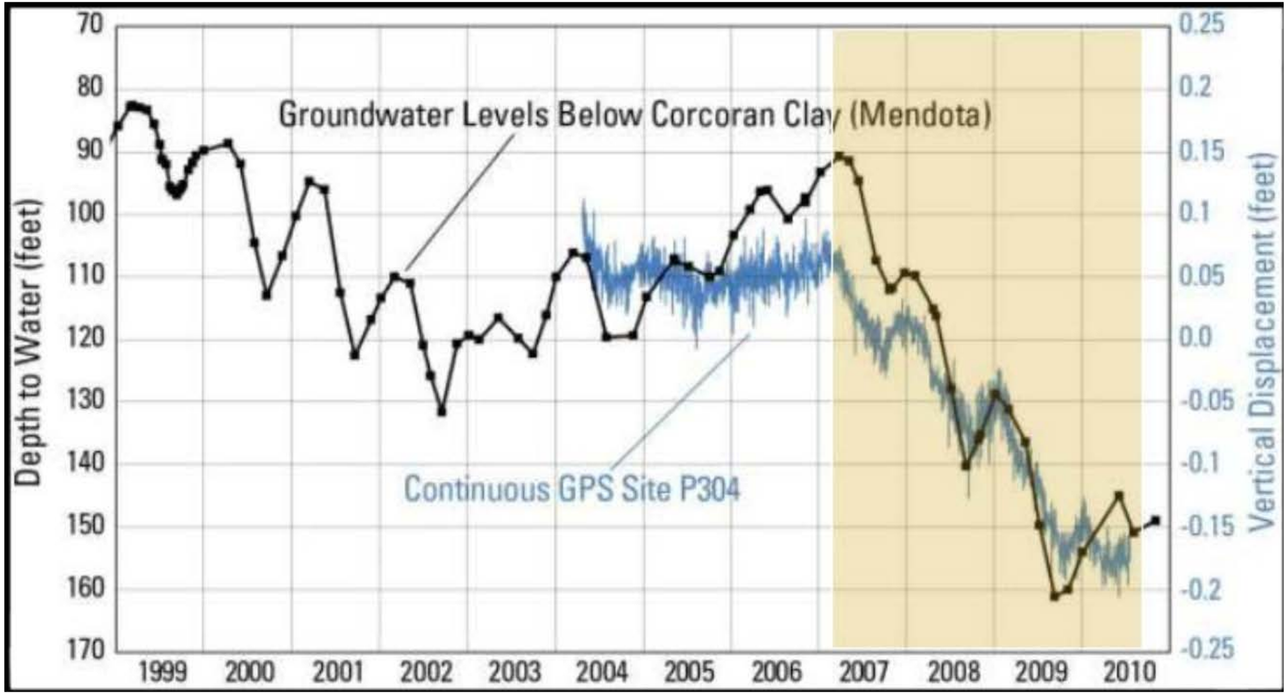


Figure TL-23 **Depth to Groundwater Hydrograph and Vertical Land Surface Displacement at UNAVCO GPS Site 304, near the City of Madera**



Source: USGS 2011 presentation on Central Valley subsidence. Land surface elevation data from UNAVCO Station 304; depth to water data provided by Luhdorff and Scalmanini Consulting Engineers

Subsidence Induced Canal Damage

From http://www.rcac.org/pages/714?i=1002

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From Alley et al. (1999)

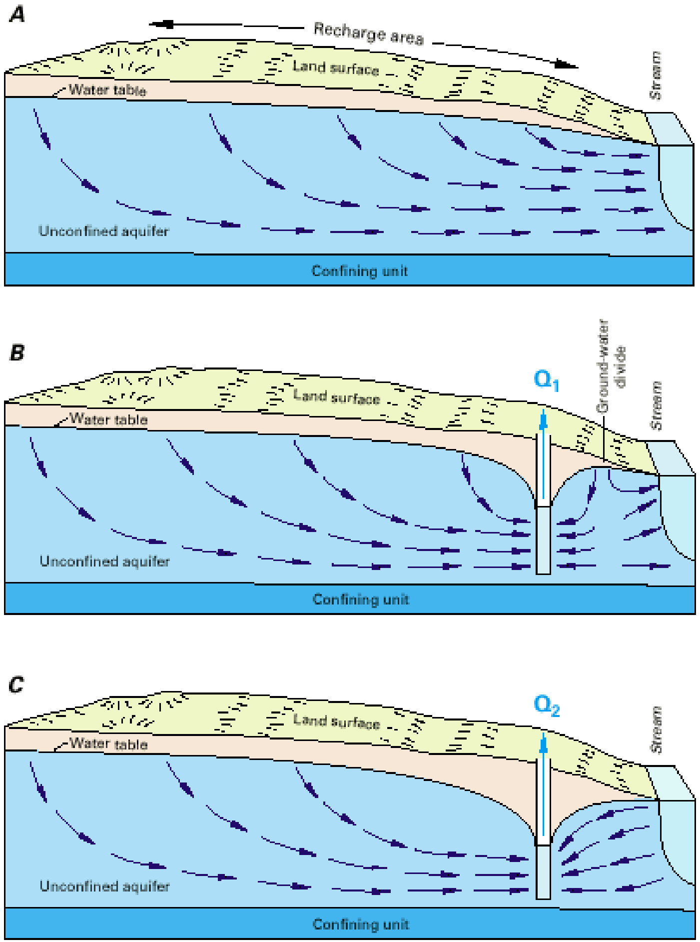

Figure 13. Effects of pumping from a hypothetical ground-water system that discharges to a stream. (Modified from Heath, 1983.)

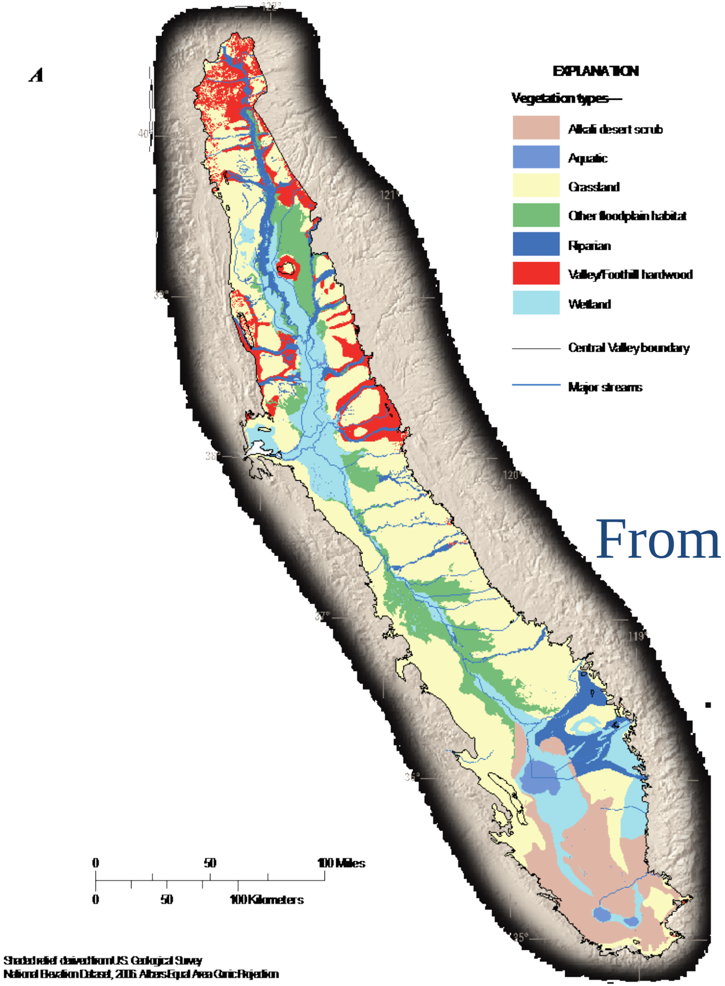

Figure A21. Distribution of *A*, Pre-1900 land-use patterns (modified from California State University, Chico, 2003), *B*, land-use patterns in 2000 (California Department of Water Resources, 2000) for the Central Valley, California.

From Faunt (2009)

Groundwater Overdraft: Pumping more groundwater than the system can sustain

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Potential for Water Quality Degradation from Below is Clear and Present, but Unaddressed

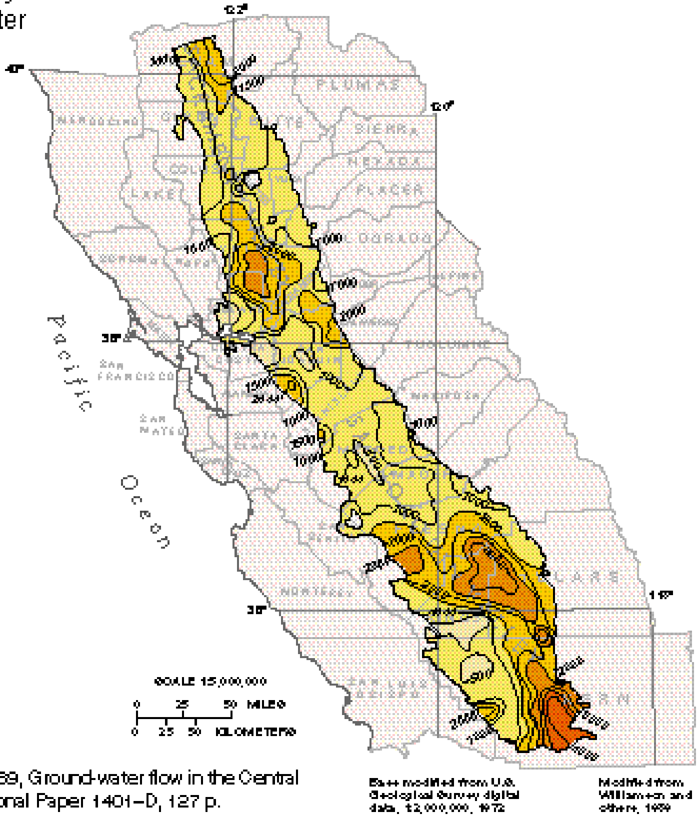
Figure 98. The thickness of the Central Valley aquifer system that is saturated with freshwater is greatest in the San Joaquin Valley, where freshwater extends to a depth of more than 4,000 feet below land surface.

EXPLANATION

Thickness of aquifer saturated with fresh ground water, in feet

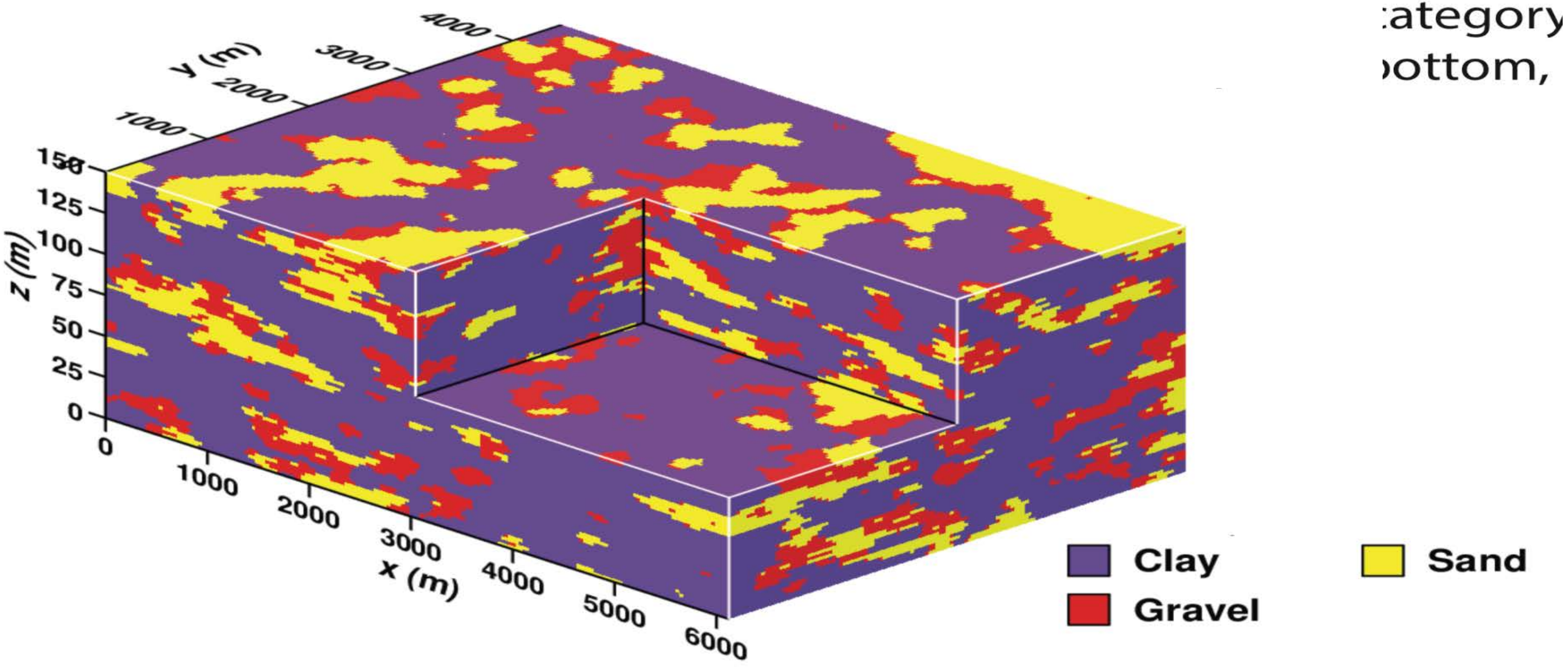
500
1,500
2,500
3,500

—1000— **Line of equal thickness of aquifer saturated with fresh ground water—**
Interval 500 feet



Williamson, A.K., Prudic, D.E., and Swain, L.A., 1989, Ground-water flow in the Central Valley, California: U.S. Geological Survey Professional Paper 1401–D, 127 p.

Woodland Area Aquifer System Network (Stephen Maples, HYD 273)



Groundwater Overdraft: Pumping more groundwater than the system can sustain

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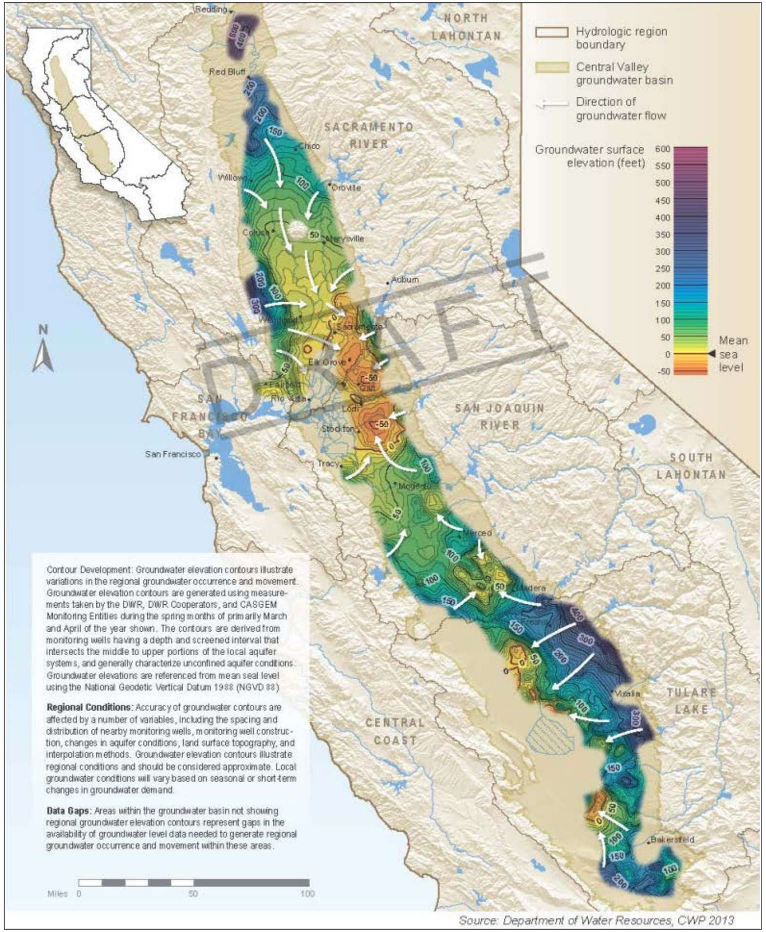
Figure TL-26 Spring 2010 Groundwater Elevation Contours for the Tulare Lake Hydrologic Region

[This figure is for the Central Valley; it will be updated with figure for the Tulare Lake Hydrologic Region]



Source: Department of Water Resources, CWP 2013

The danger of a hydrologic basin losing its outlet….

San Joaquin Valley Groundwater (from Faunt, 2009)

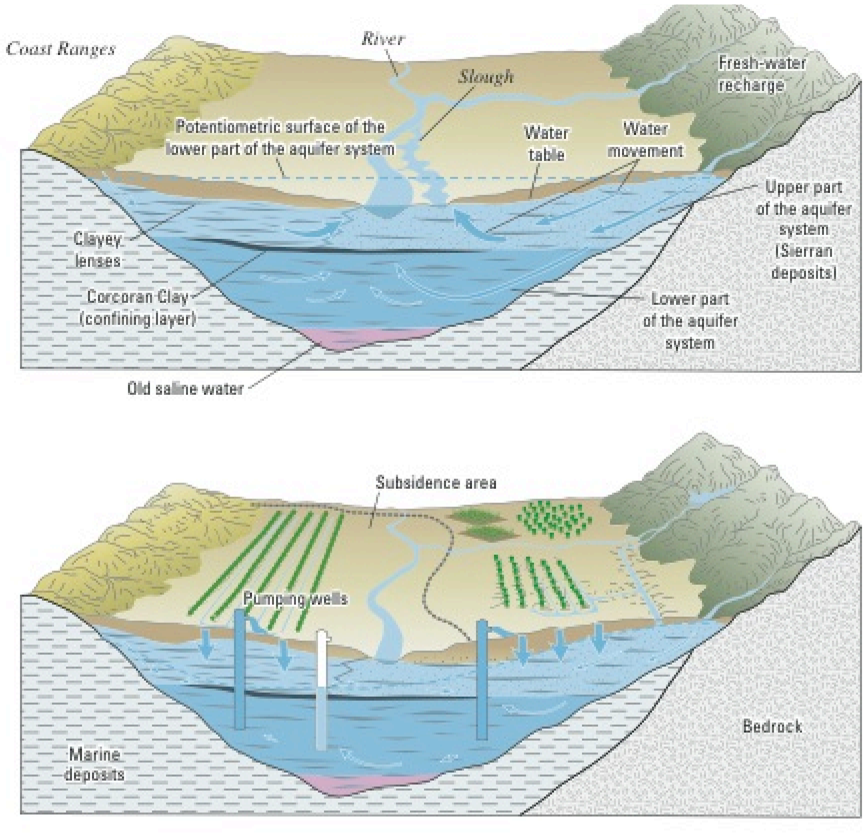


Figure A9. Continued.

Pre-Development

Post-Development

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Mono Lake: Closed Basin

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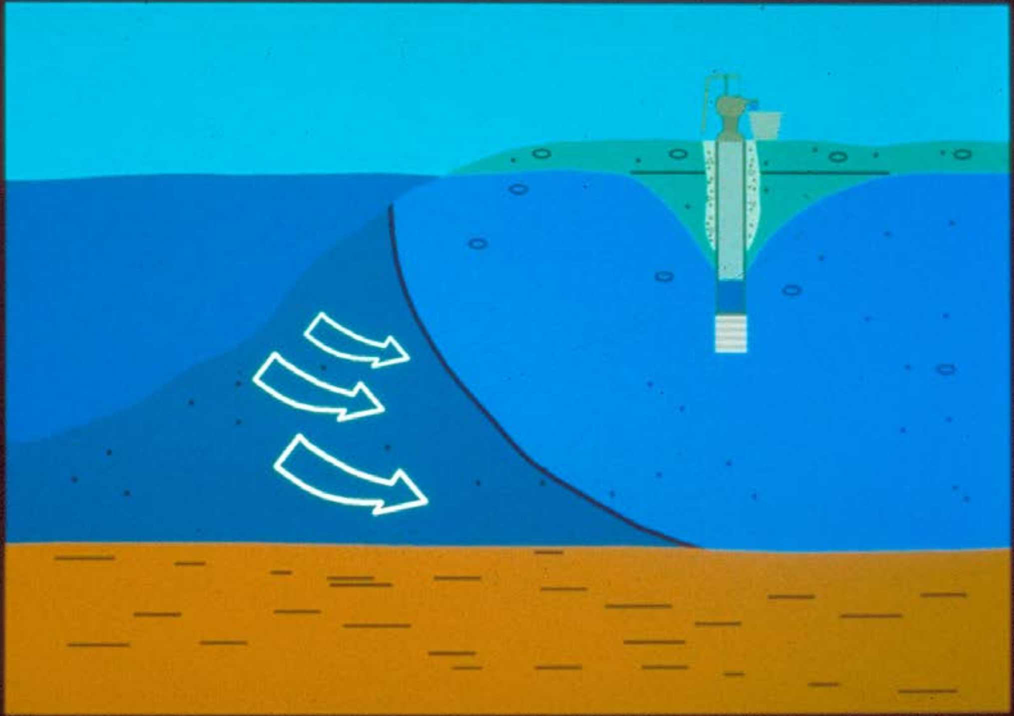
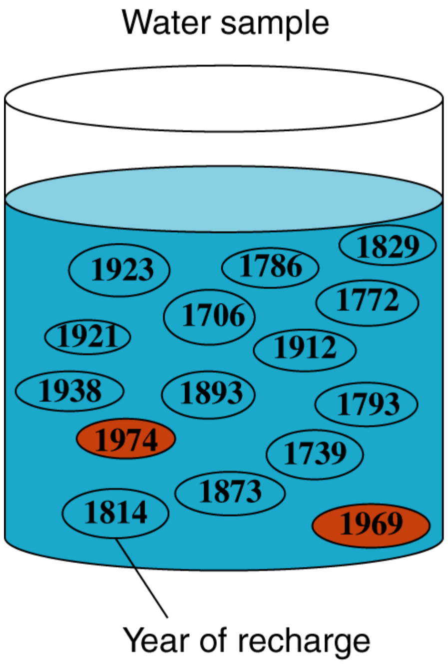
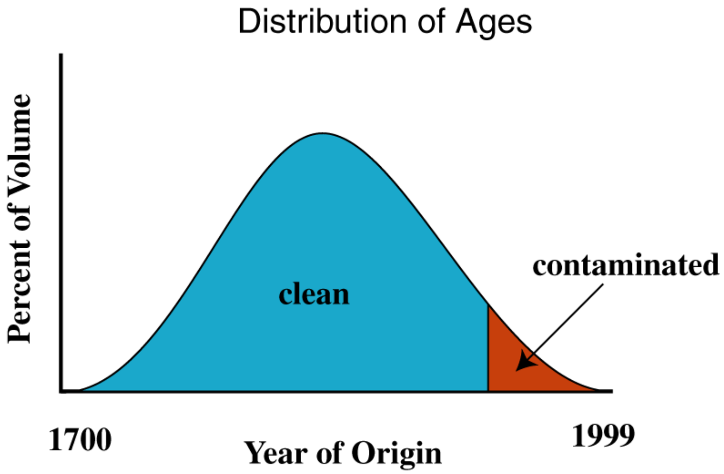
Salt Water Intrusion



Groundwater Quality is Degrading in Many Systems, But Most of the Groundwater Quality is Still Good

Age Distribution & Sustainability: Groundwater Ages are Highly Mixed!





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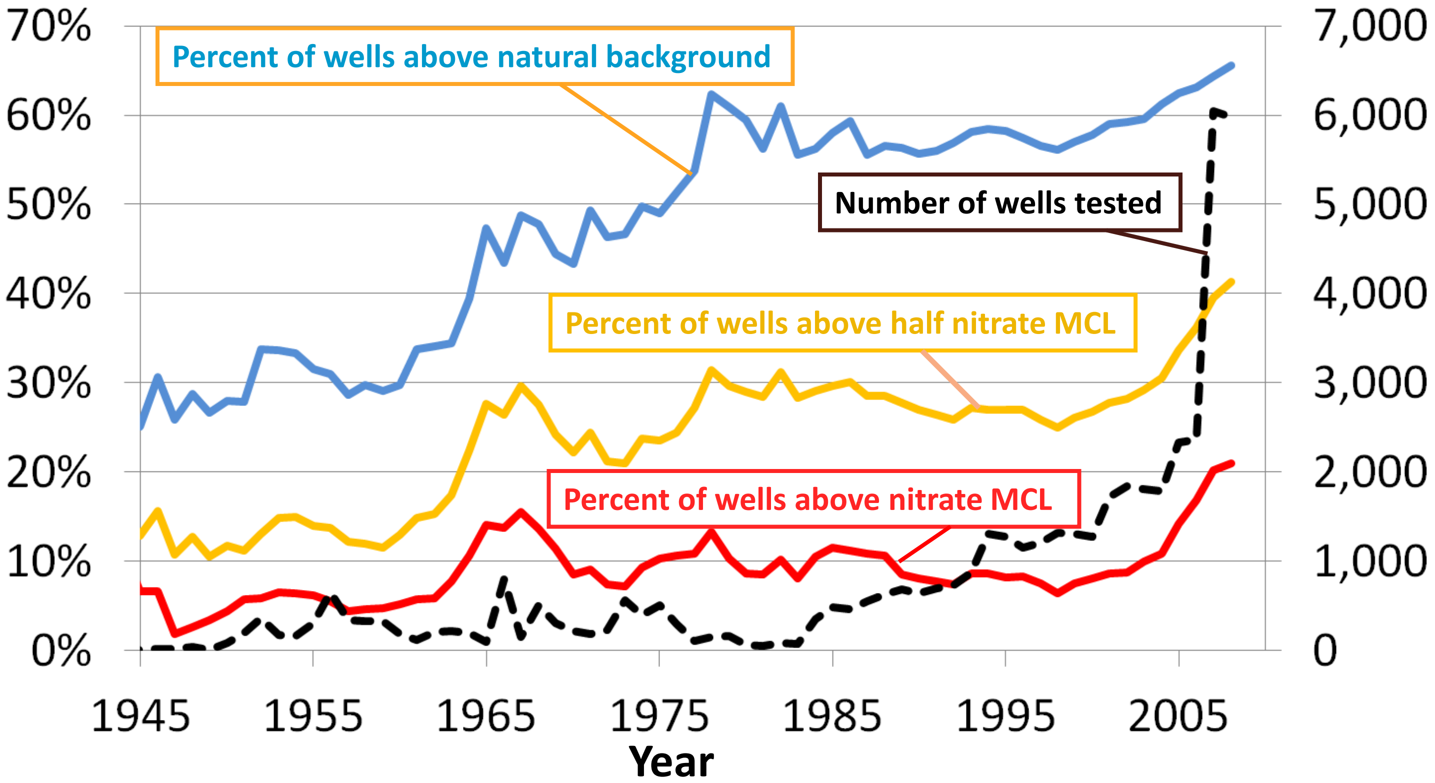
Historic Nitrate Trends, TLB: Exceedance Rate



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