No Surface Water = No Groundwater

Sustainable Water Resources Roundtable

NASA Ames Research Center at Moffett Field

A State of Drought: California Surface and Groundwater Sustainability Assessments

Carl Hauge

20 November 2014

Yogi Bera, New York Yankees Catcher

* In theory there is no difference between theory and practice. In practice there is.

Topics

* Groundwater realities relating to sustainability
* The groundwater commons
* External help—legislation
* Missing data
* Water budget

The realities

* Permitting jurisdiction over groundwater
* Groundwater management in other states
* What rivers used to look like
* Stream flow depletion
* The hyporheic zone
* Groundwater substitution in Sacramento Valley
* Subsidence

Permitting jurisdiction over groundwater

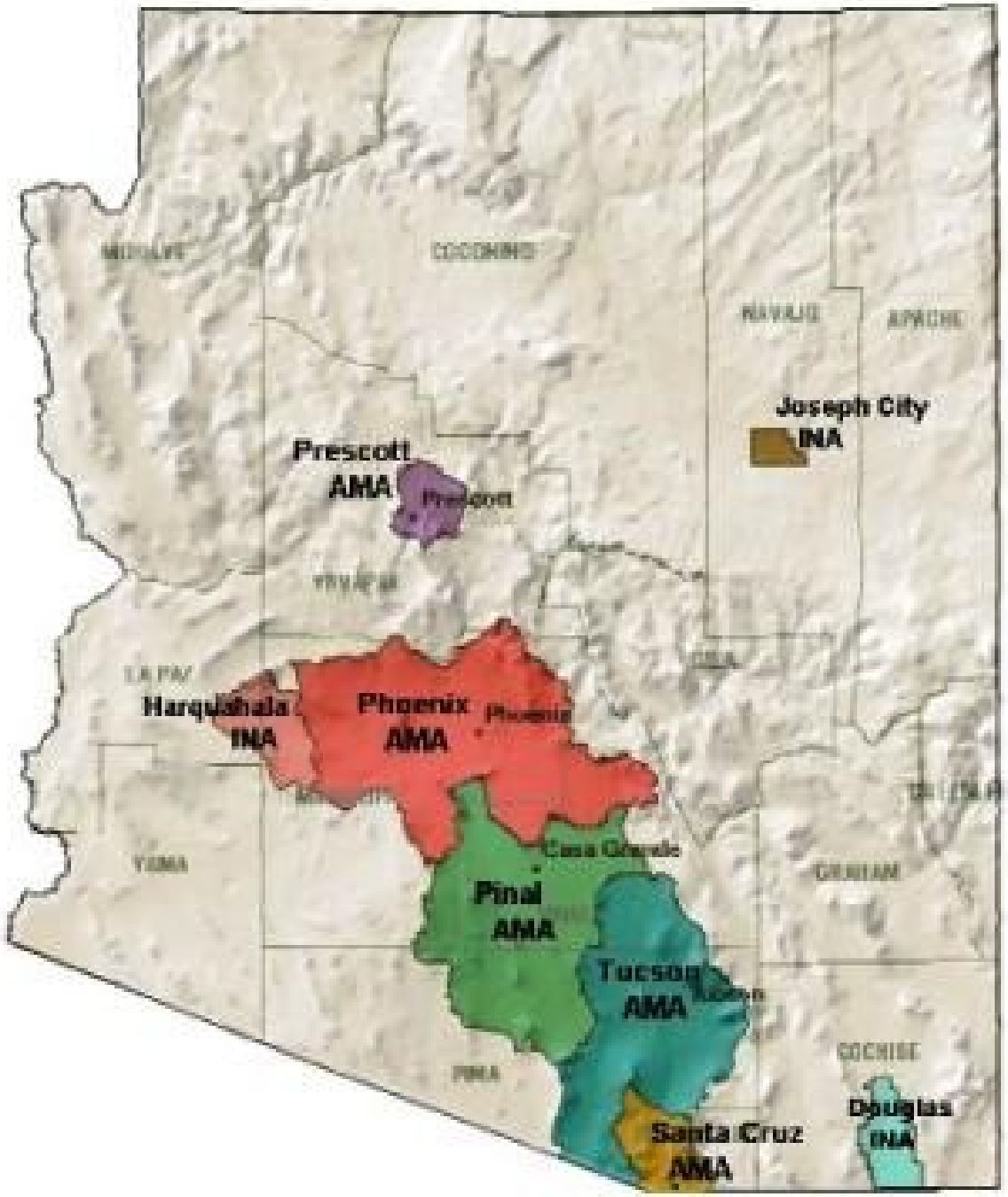
* Water Commission Act introduced into the Legislature in 1913 included jurisdiction over groundwater
* A lobbyist argued that because the courts had ruled on groundwater the courts had primacy
* The legislature could not interfere
* The legislature amended the bill to exclude groundwater

Groundwater management in other states

* Arizona
* Nevada
* Oregon
* Washington
* Other states

Arizona

* 5 Active Management Areas were supposed to reach their safe yield by 1995
* They did not
* The new goal is by 2025


COCONINO
NAVAJO
APACHE
Joseph City
INA
Prescott
AMA
Prescott
LA PAZ
Harquahala
INA
Phoenix
AMA
Phoenix
YUMA
Casa Grande
Pinal
AMA
GRAHAM
Tucson
AMA
COCHISE
PIMA
Santa Cruz
AMA
Douglas
INA

Nevada

* Southern Nevada Water Authority laid claim to groundwater in central & eastern Nevada
* Carbonate aquifer, complex geology, thrust faults, springs that support pupfish and arthropods
* State engineer has permitting authority
* Studies said pumping would not endanger the aquifer for 500 years
* State engineer said that is beyond the planning horizon
* The permits were approved

Oregon

* 2 separate codes for surface water & groundwater
* Exempt wells for domestic use up to 15,000 gpd

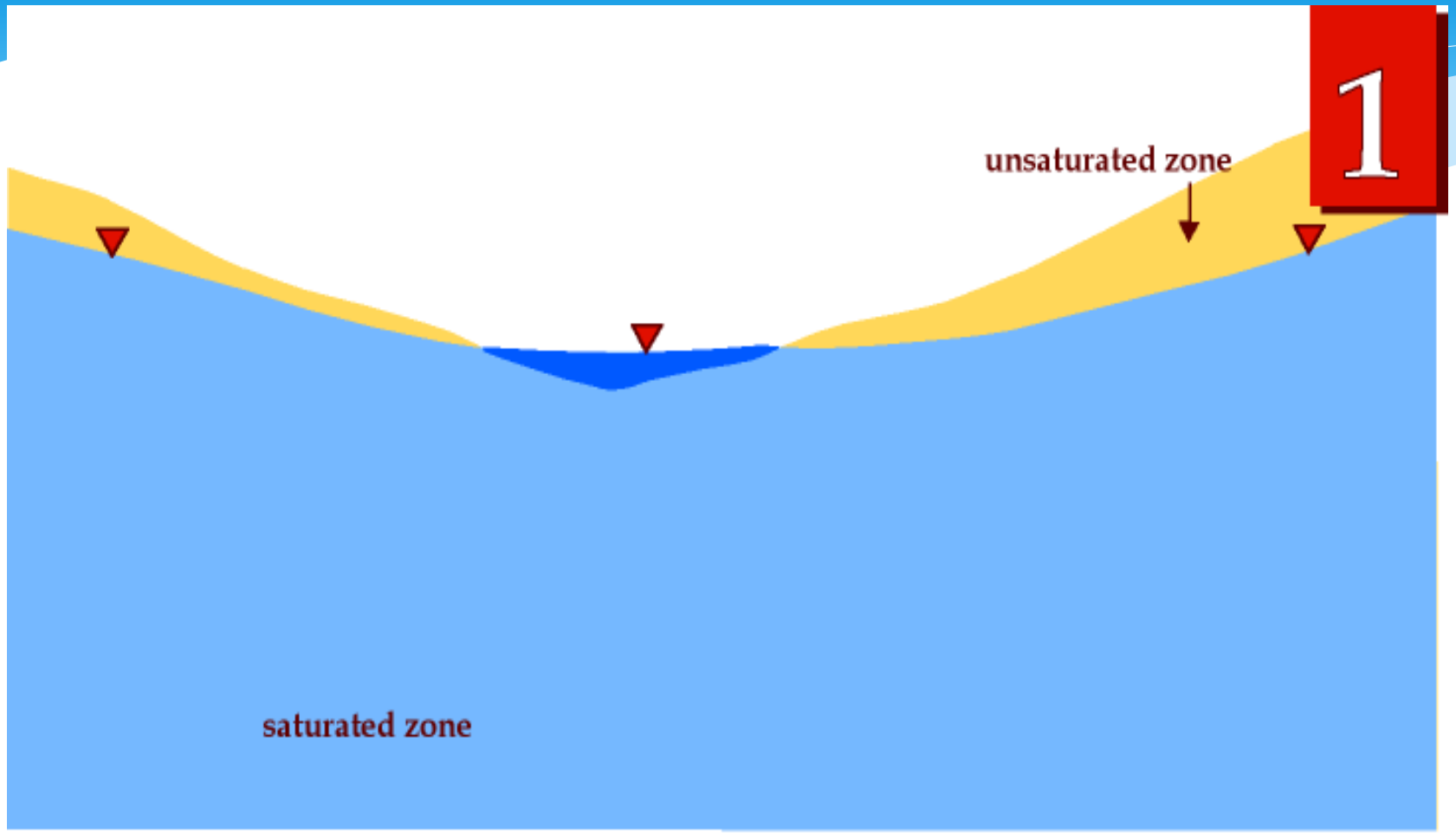
Washington

* 2 separate codes for groundwater & surface water
* Domestic wells are exempt <5000 gpd
* Recent court decision struck down agency permission for 400 exempt wells in Skagit River watershed
* East of Cascades groundwater levels in basalt aquifers are declining

Conclusions about other states

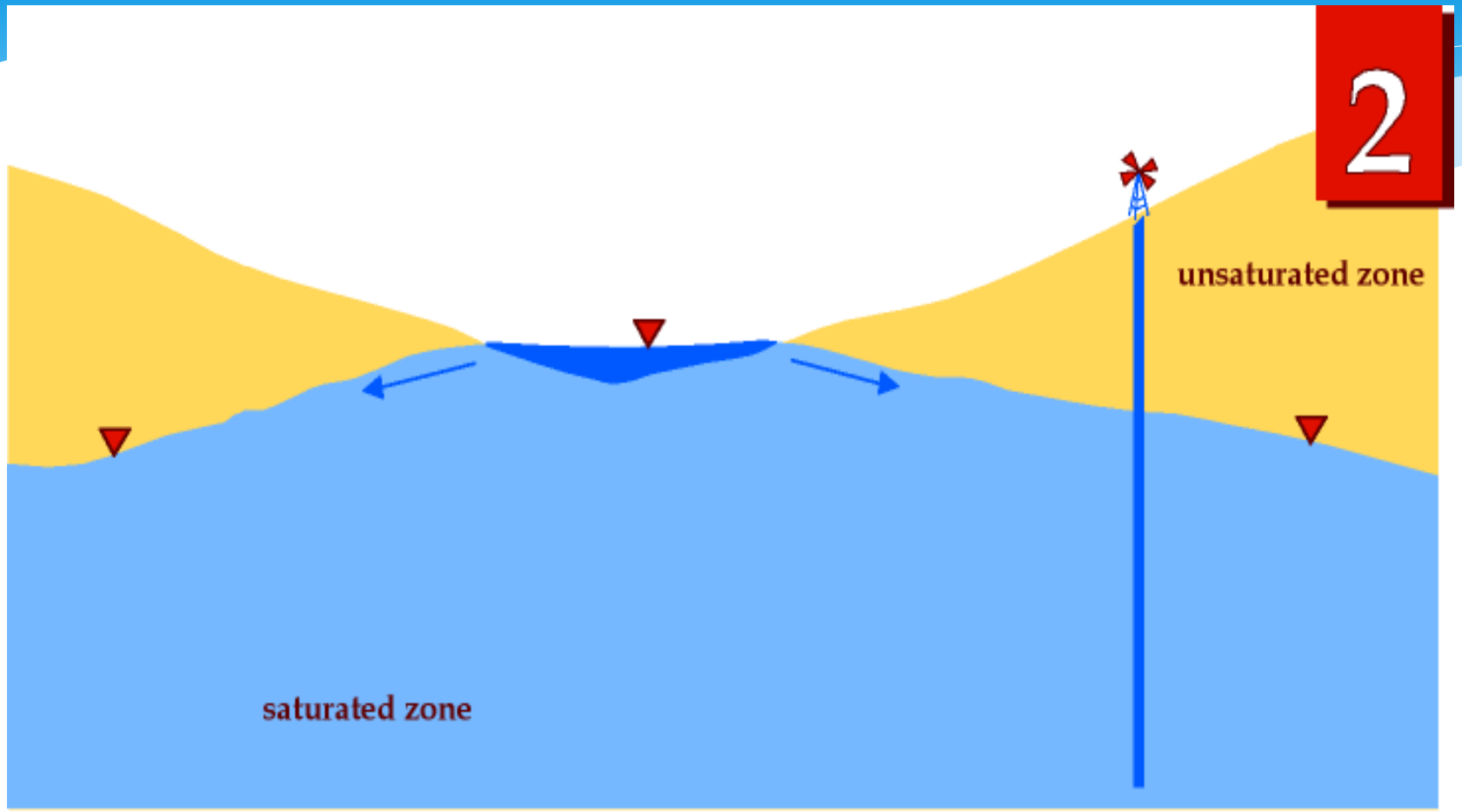
* Each has different statutes
* Their codes address groundwater but they still have problems
* SW & GS are treated as 2 separate sources of water
* “Subterranean streams” are still a problem

What did rivers look like when Europeans arrived in the west?



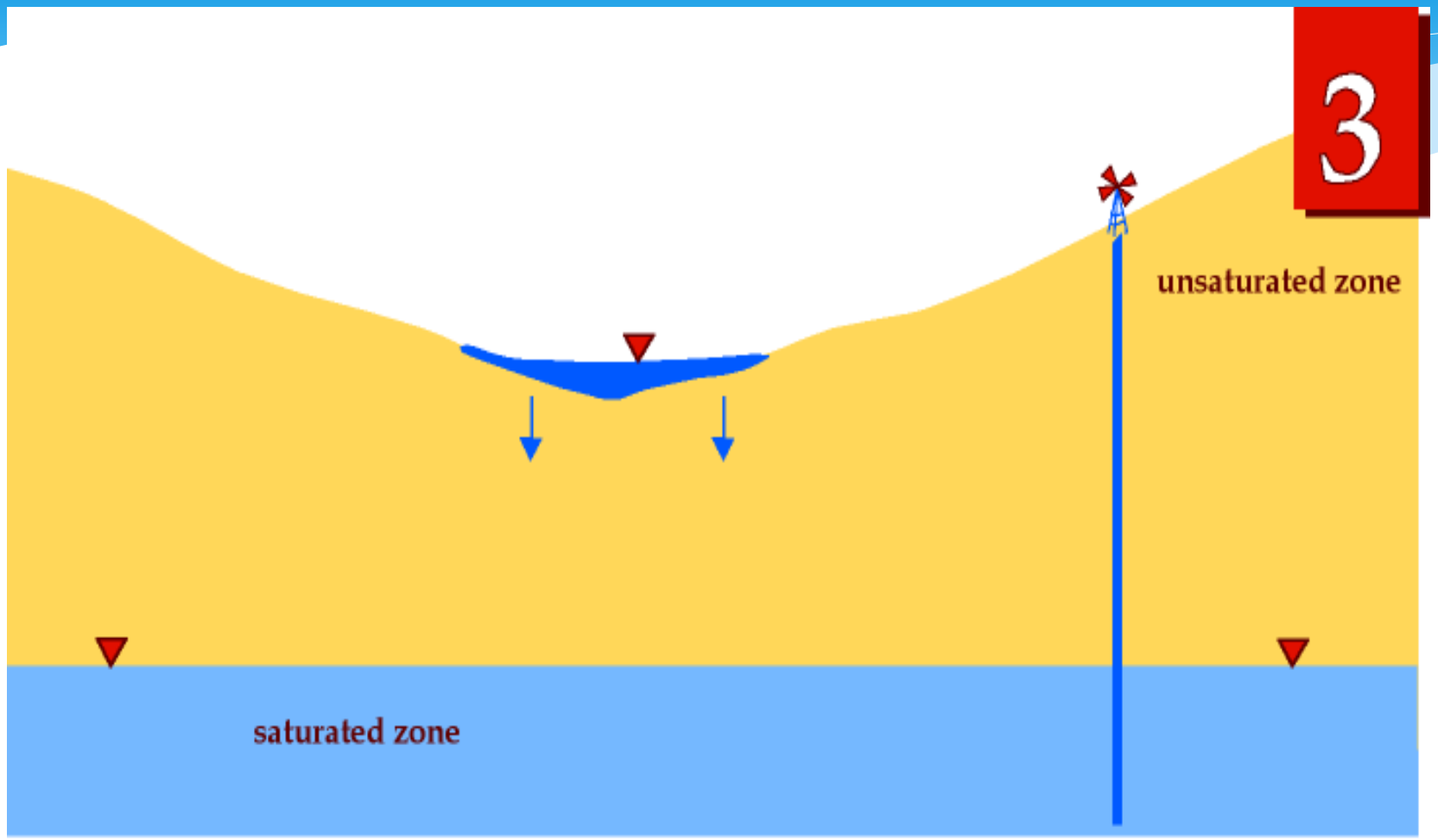
Full basin

Streams are drains for the overflowing ground water reservoir

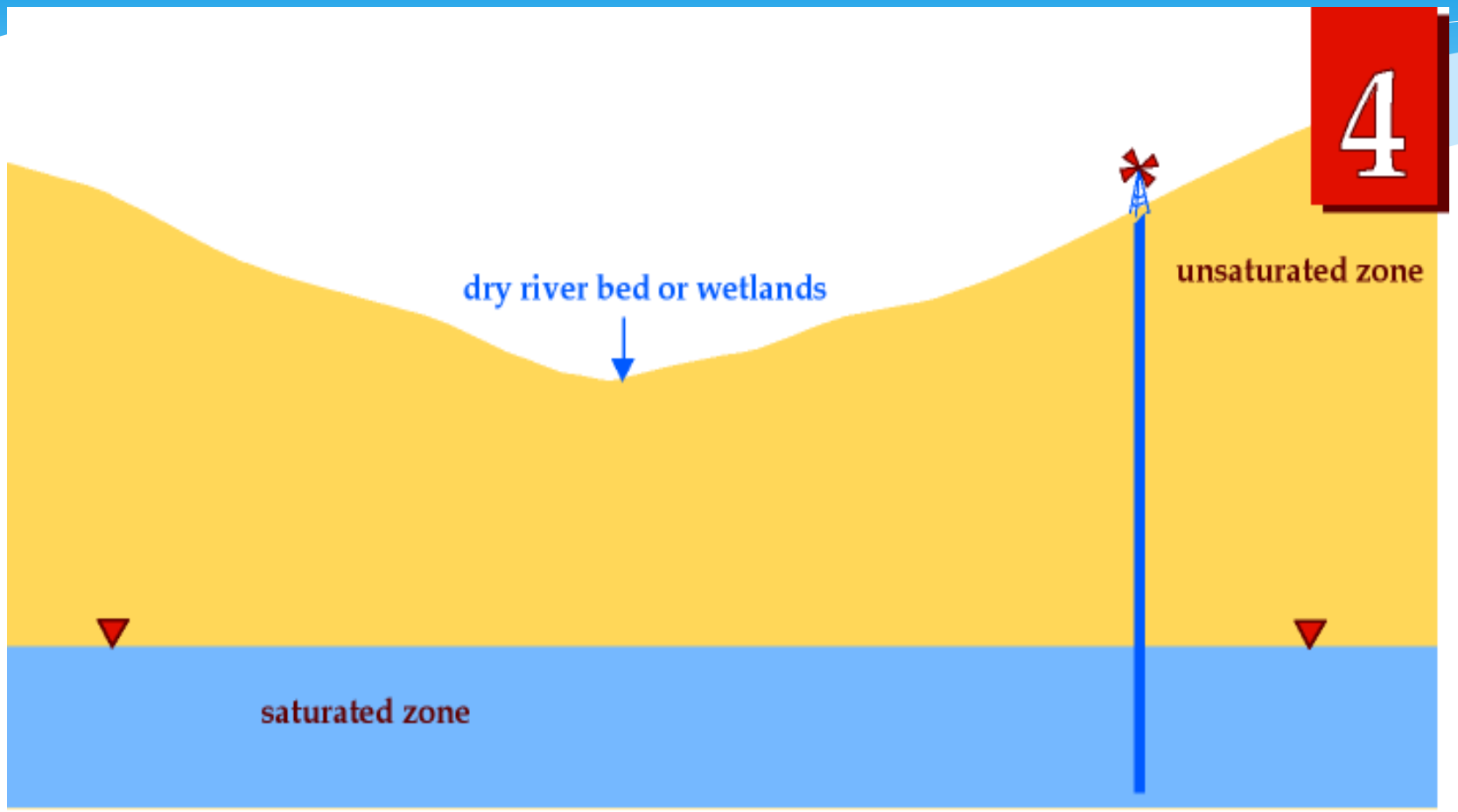


Some extraction of ground water

Storage capacity is made available for additional water and a gradient is created that induces recharge from streams



Rate of extraction exceeds rate of recharge



No surface water available

All surface water percolates through the channel bottom up river.

Desiccated riparian habitat

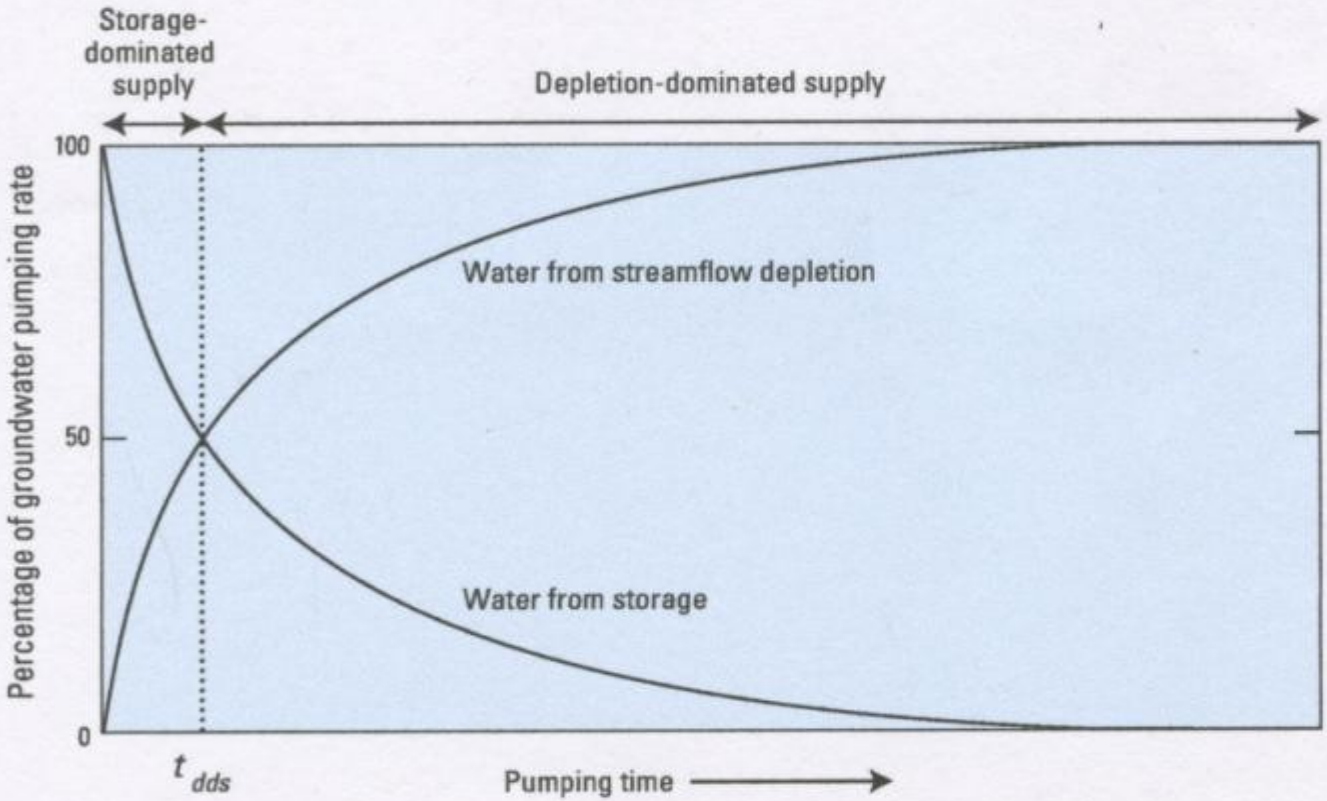


Figure 9. Relation of storage change and streamflow depletion as sources of pumped groundwater through time for a hypothetical well. Initially, the source of water (or supply) to the well is dominated by reductions in aquifer storage. At later times, streamflow depletion is the dominant source of supply. The condition of more than half of the pumping rate coming from streamflow depletion is designated as depletion-dominated supply, and variable t_{dds} is the time to reach the condition of depletion-dominated supply for a particular pumping location.

When the pump is turned on the source of water is from reductions in aquifer storage. Later, stream flow depletions is the source. If there are no streams the source is only from reductions in aquifer storage.

Reality

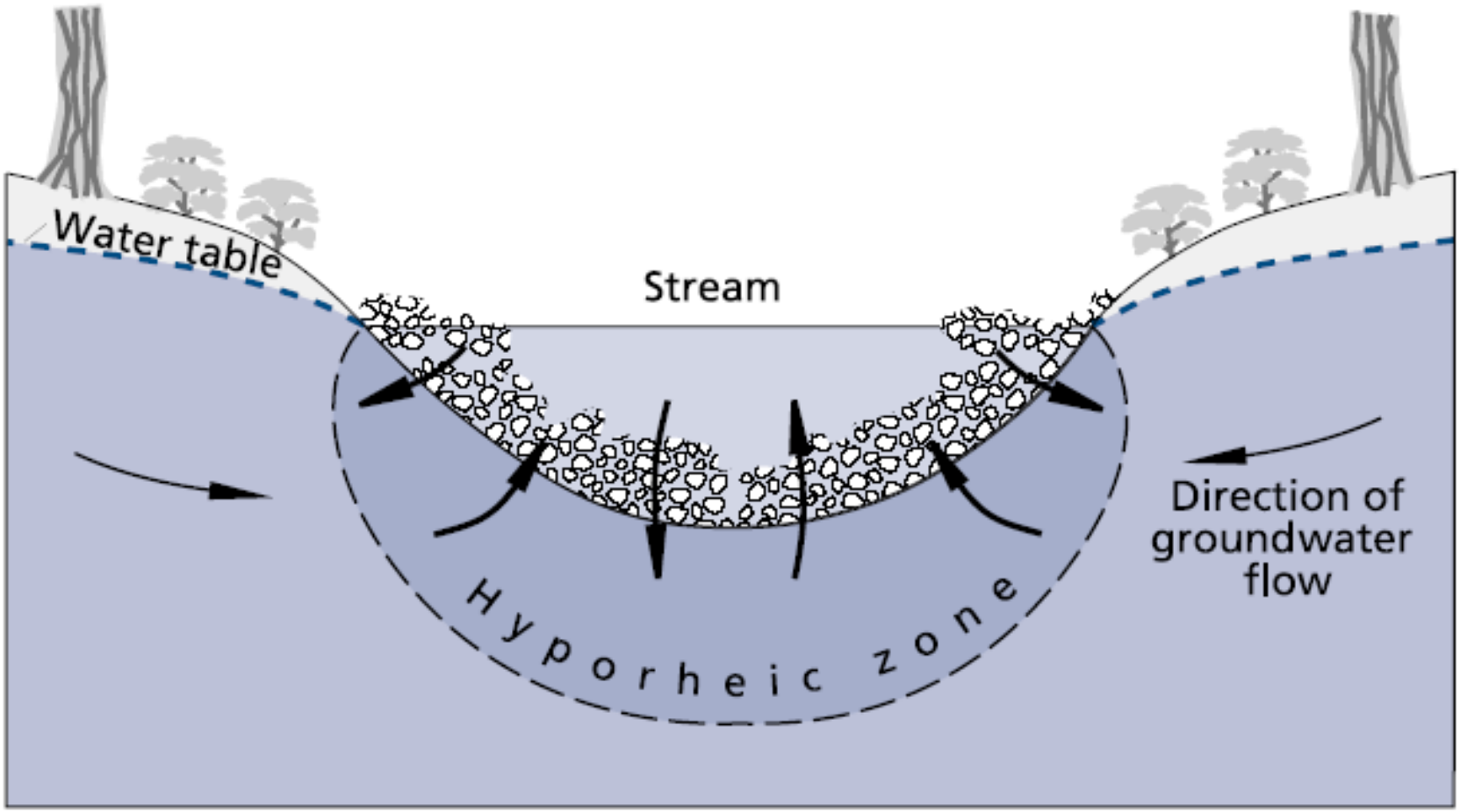
* When groundwater is pumped out of an aquifer, stream flow is diminished
* The size of the stream system and the amount of groundwater pumped determines when that decrease will show up
  * Small systems—fairly quickly
  * Large systems—after a longer period of time, up to decades

Groundwater pumping and decreased flow in rivers

* Occurs over many years, decades, several generations
* Changes in the river take place over years & therefore are not noticed by the persons who live there at the time
* Eventually the river is dry because the groundwater pumping has taken all the water

Cosumnes River

* No dams
* Low elevation watershed
* Front edge of the live stream has retreated in recent years
* Why? Because more wells have been built that extract water that is contiguous with stream flow, i.e., a losing stream
* A good example of what has happened to other rivers in California


Water table
Stream
Direction of groundwater flow
Hyporheic zone

GW & SW nexus

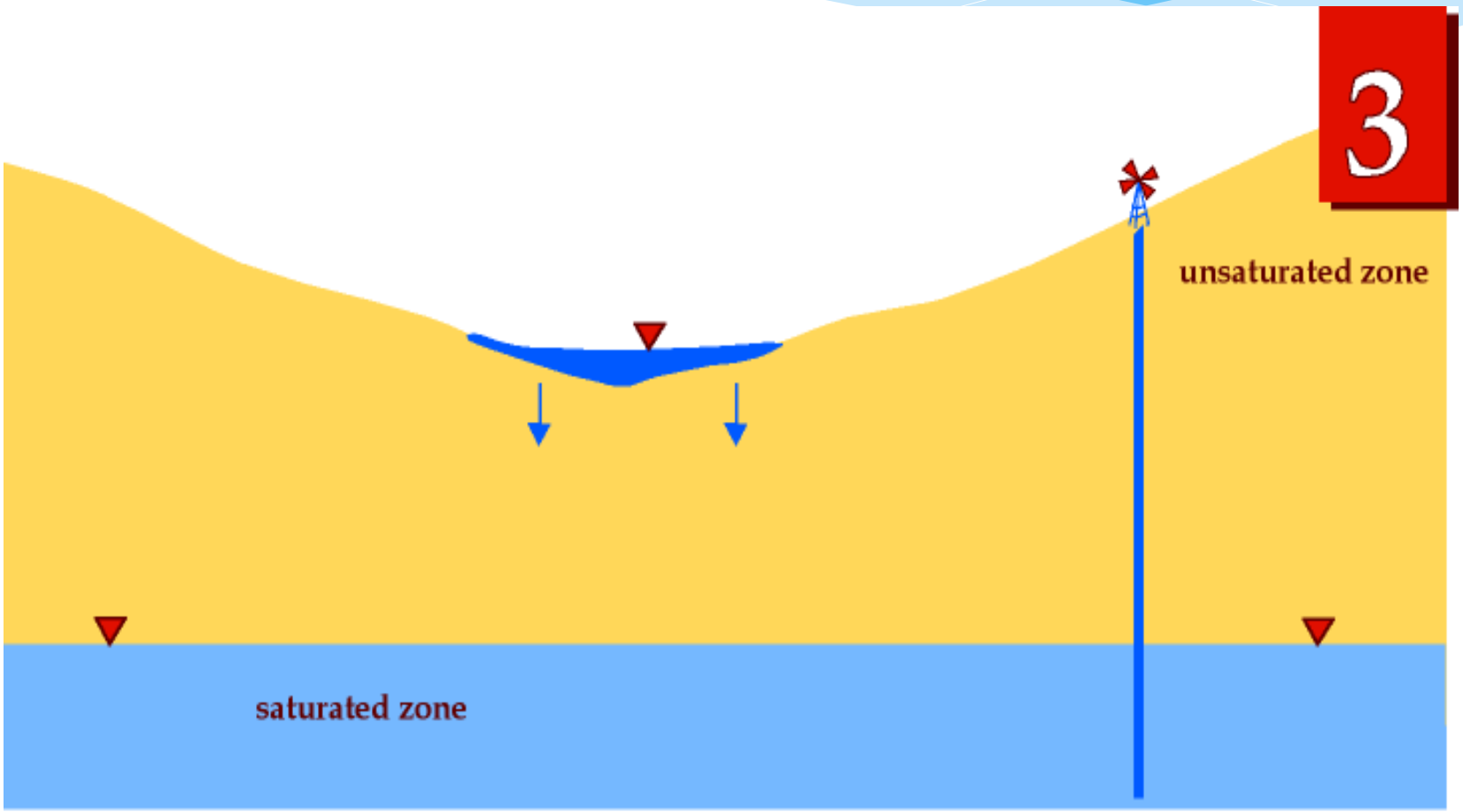
* Water flows in and out depending on head
* Nutrients are added
* Nutrients remain longer in a large zone
* Meiofauna—0.5 to 0.045 mm
  * Arthropods, worms, 80 species at one site
* Found in groundwater 1 km from the stream
* Food source for fish

High productivity

* Bacteria, fungi, protozoa live on sediments
* Convert nutrients into food
* Nutrients delivered to the stream system
* Marine nutrients via dead salmon
* Redds receive oxygenated water
* Moderates winter & summer stream temp

Channelized rivers

* Hyporheic zone is eliminated or greatly reduced
* A decrease in
  * Interchange of sw & gw
  * Water quality benefits
  * Temperature buffering
  * Nutrients
  * Food sources

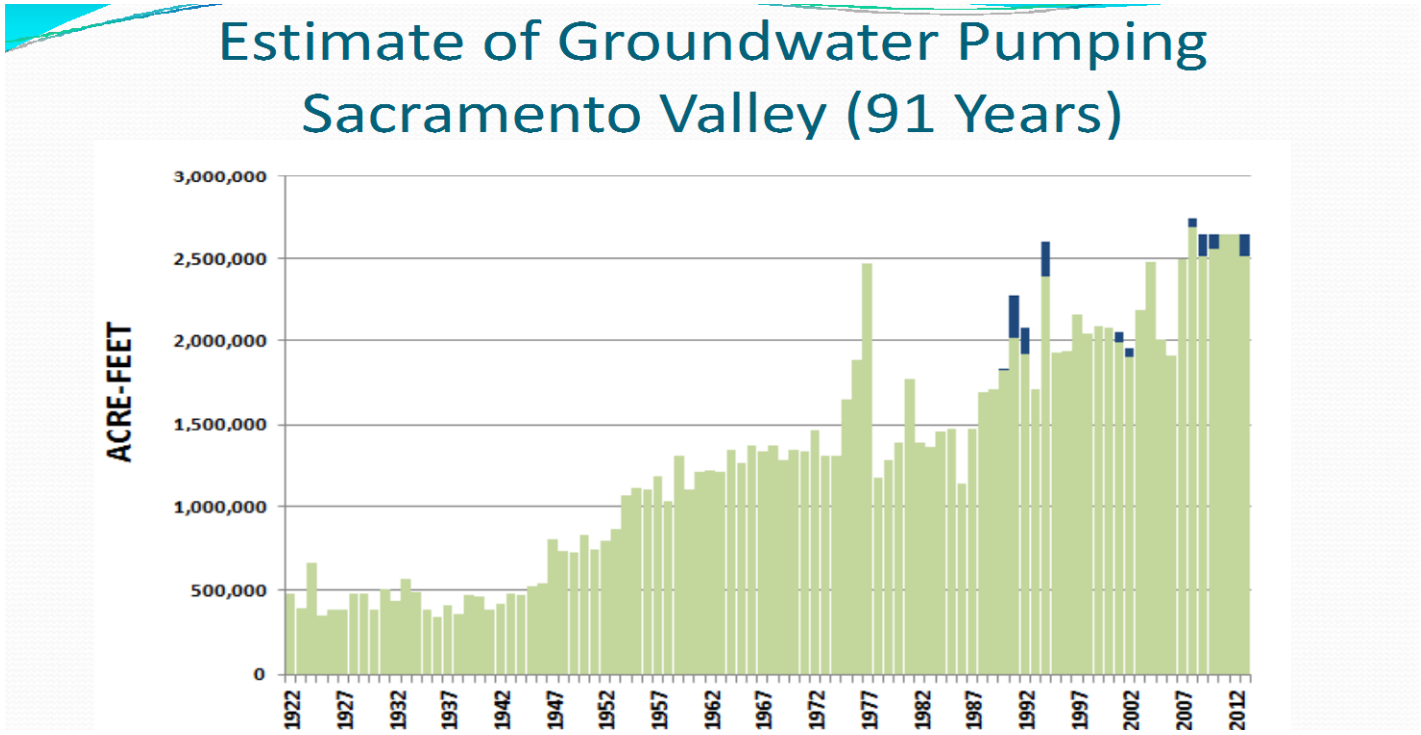


Rate of extraction exceeds rate of recharge

Next Slide

* Shows increase in groundwater pumping in Sacramento Valley from 1922 to 2012
* About 500,000 acre-feet per year until after World War 2
* Increasing steadily to over 2,500,000 af/y in 2012

Groundwater substitution in Sacramento Valley



Where did that groundwater come from?

* It's not magic
* That groundwater came from the streams and rivers in Sacramento valley
* The amount of stream flow depletion that occurred during that period was not monitored
* But an estimate would be that the amount of stream flow depletion was equal to the total amount of groundwater that was extracted

Next Slide

* Joe Poland USGS, beside a utility pole with signs showing where the land surface was in 1925 and how much it has subsided thru 1977
* Map of San Joaquin Valley showing areas of subsidence
  * Los Baños-Kettleman City area
  * Tulare-Wasco area
  * Wheeler Ridge-Maricopa area

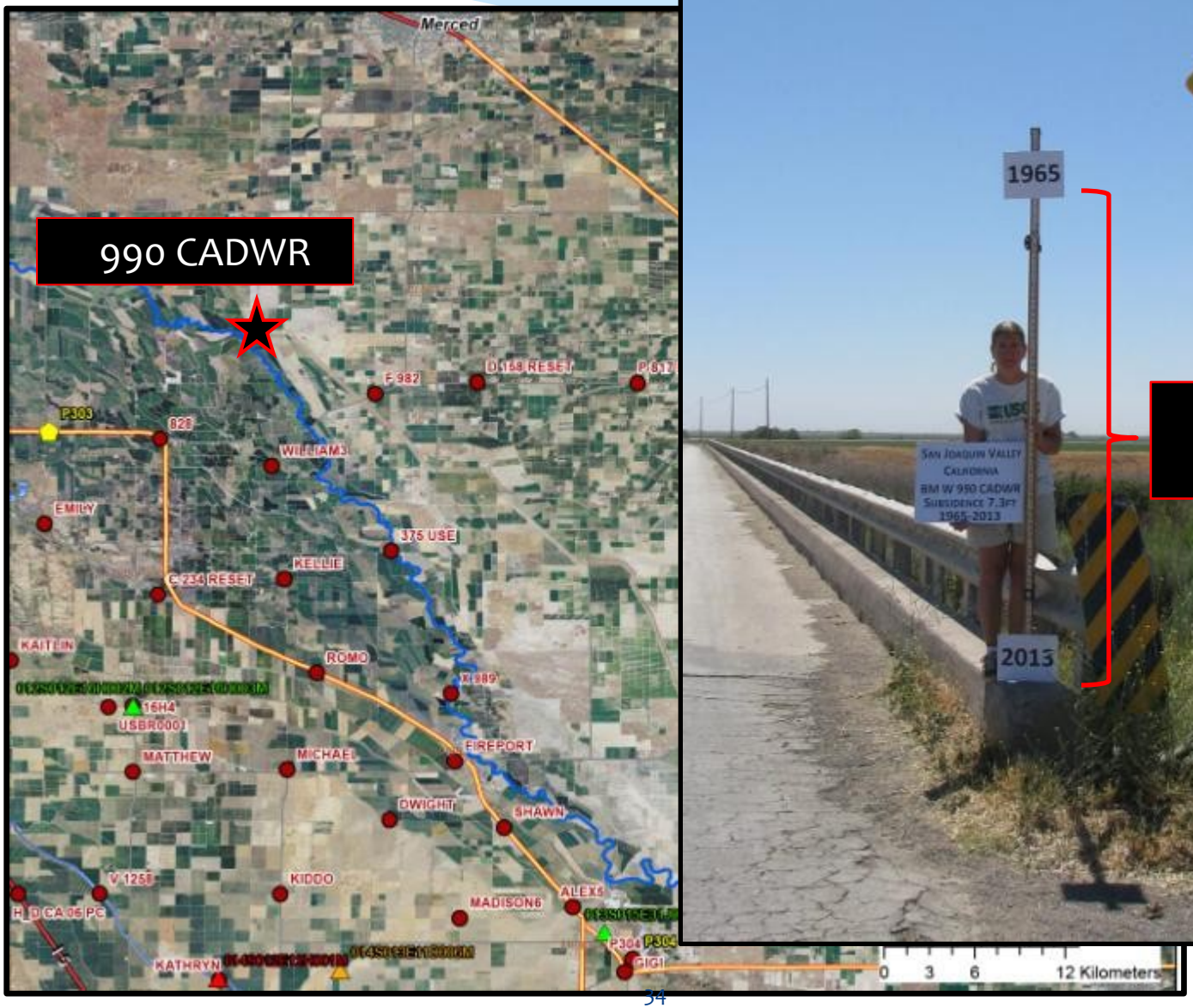
Land subsidence from 1926 to 1970

(Modified from Poland and others, 1975)

Next 2 Slides

* Michelle Sneed, USGS, with pole on a bridge near San Joaquin River showing subsidence from 1965 to 2013
* Map of southwest showing areas where subsidence caused has occurred

Elevation Comparisons



[redacted]

Data from National Geodetic Survey and Bureau of Reclamation

RAFT RIVER
SACRAMENTO
SANTA CLARA
SAN JOAQUIN
LANCASTER
LAS VEGAS
SAN JACINTO
LUKE
QUEEN CREEK
ELOY
STANFIELD
HOUSTON-GALVESTON
BATON ROUGE
NEW ORL
MEXICO
0 500 1000
KILOMETRES

Causes of subsidence

* Geologic processes
  * Lithification
  * Tectonic deformation
  * Hydrocompaction
* Caused by *Homo sapiens*
  * Oxidation of peat
  * Withdrawal of fluids
    * water
    * petroleum products

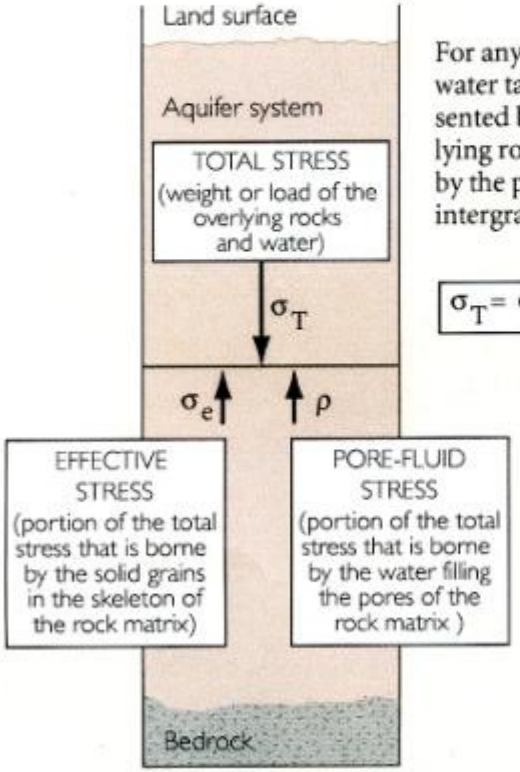
Next Slide

* The diagram on the left shows the forces in the aquifer in equilibrium: the overlying sediments and water, or total stress, $\sigma\tau$ are supported by the effective stress of the grain to grain contact, σe, plus the pore-fluid stress, ρ
* When extraction of groundwater lowers the pore pressure more of the overlying mass is transferred to the clay grains, which, in their present configuration, can not support the stress of the overlying mass
* Thus, they are compacted, causing subsidence

Aquitard Drainage and Aquifer-System Compaction

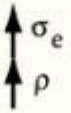
The Principle of Effective Stress

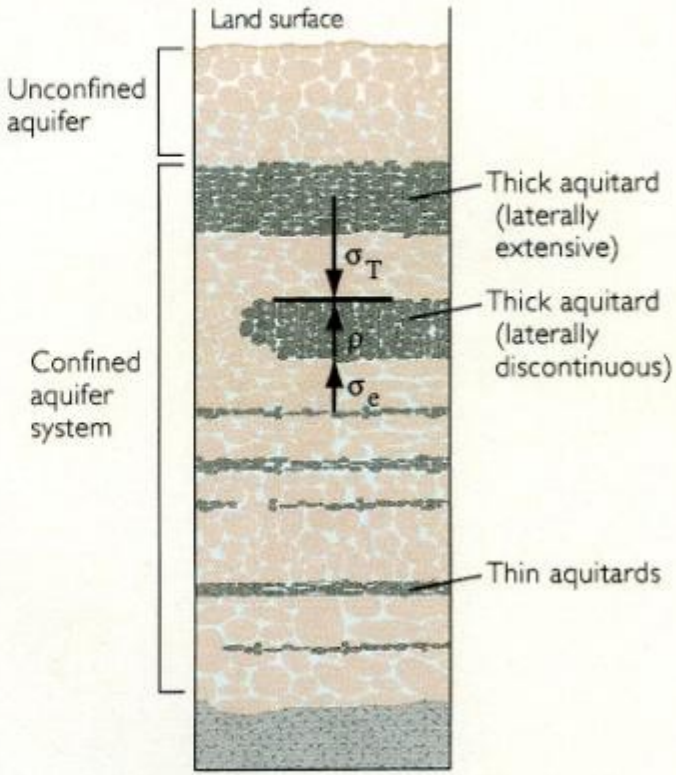
This principle describes the relation between changes in water levels and deformation of the aquifer system.



For any arbitrary plane below the water table, the total stress represented by the weight of the overlying rock and water is balanced by the pore-fluid pressure and the intergranular or effective stress.

$$\sigma_T = \sigma_e + \rho$$





Next Slide

* The y-axis on the left shows the volume of subsidence
* The y-axis on the right shows the amount of cumulative groundwater pumpage
* Both are in acre feet from 1926 to 1969
  * Subsidence volume = 10,000,000 acre feet
  * Pumpage = 30,000,000 acre feet
* Thus, the water from the compacted clays equals 10,000,000 af or 1/3 of the total amount pumped
* This 'subsidence water' will never again be available

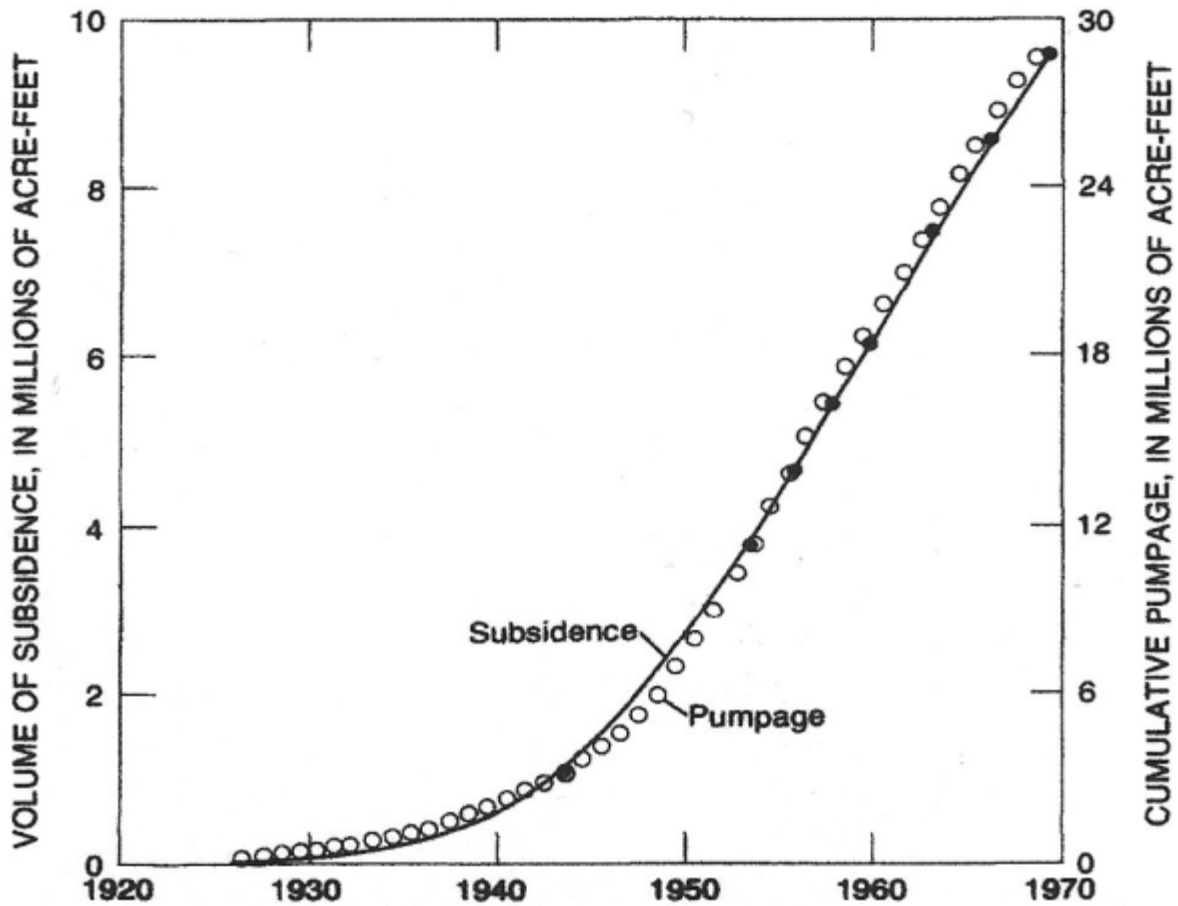


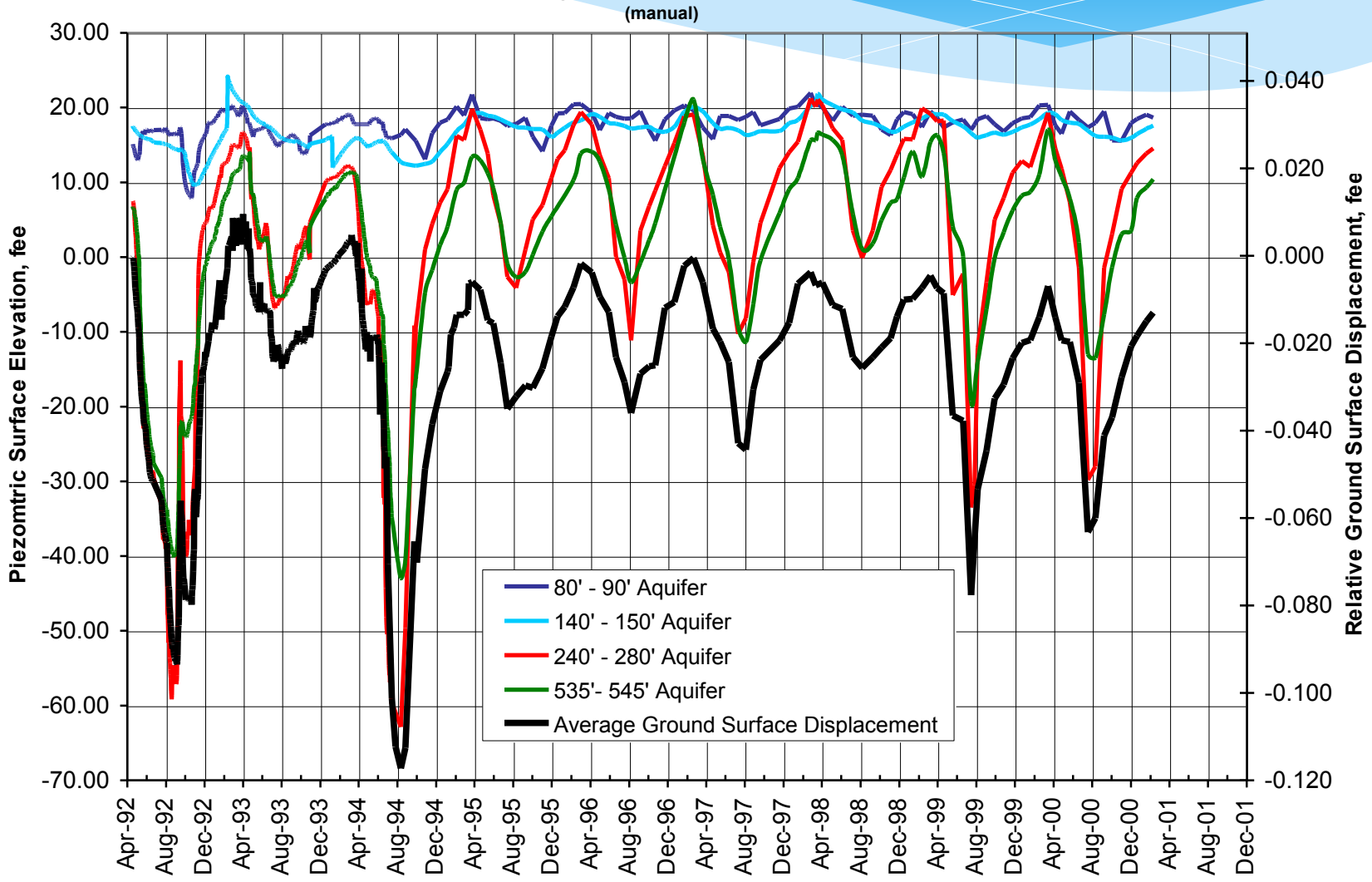
FIGURE 19.—Cumulative volumes of subsidence and pumpage, 1926–69, Los Banos—Kettleman City area. Points on subsidence curve indicate times of leveling control.

What about the loss of storage?

* Water that was stored in the clays that was pumped out will never be replaced
* The coarser-grained part of the aquifer system will continue to store water and release it to wells
* The aquifer will be recharged faster & pumping will lower groundwater levels faster but the aquifer will still be a useful reservoir
* Bottom line: the aquifer part of the system is not destroyed

Next Slide

* The blue lines show water levels in wells in the unconfined aquifer
* The red & green lines show water levels in wells in the confined aquifer
* The black line shows elevation of the land surface in hundredths of a foot
* The land surface subsides slightly when the 2 confined wells are pumped but recovers when groundwater levels recover; that is elastic subsidence
* But the slight negative slope of a line thru the peaks of the black line indicate that some inelastic subsidence is occurring; that is not recoverable


Piezometric Head Changes and Relative Ground Surface Displacement
Conaway Ranch Extensometer
(manual)
Piezomtric Surface Elevation, fee
Relative Ground Surface Displacement, fee
30.00
20.00
10.00
0.00
-10.00
-20.00
-30.00
-40.00
-50.00
-60.00
-70.00
0.040
0.020
0.000
-0.020
-0.040
-0.060
-0.080
-0.100
-0.120
Apr-92
Aug-92
Dec-92
Apr-93
Aug-93
Dec-93
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Apr-01
Aug-01
Dec-01
80' - 90' Aquifer
140' - 150' Aquifer
240' - 280' Aquifer
535'- 545' Aquifer
Average Ground Surface Displacement

History of groundwater use in California—a commons

* Everyone uses it
* No one manages it
* Behavior in one's self-interest is contrary to the group's long-term interests
* Resulting in depletion of the common resource

Difficulty in managing the commons

* Factors internal to a given group
  * No capacity or willingness to communicate with one another
  * No way to develop trust
  * No sense that they must share a common future

In addition:

* Powerful individuals may stand to gain from the current situation while others lose
* The powerful may block efforts by the less powerful to change the rules of the game
* **External assistance** is needed to break out of the perverse logic of their situation

  * Elinor Ostrom, 1990, Governing the Commons, Nobel Prize Winner, 2009

External assistance

* AB 1739, Assemblyman Roger Dickinson
* SB 1168, Senator Frances Pavley
* SB 1319, Senator Frances Pavley
* All 3 bills signed into law by Governor Jerry Brown
* Go to the Office of Planning & Research site for an integrated document

Sustainable Groundwater Management Act

* Applies to:
  * Groundwater basins defined in DWR Bulletin 118
  * Federal and tribal lands as authorized
* Does not apply to:
  * Adjudicated basins
  * Low and very low priority basins as designated by CASGEM, altho they are encouraged to participate

Action dates

* 1 June 16—DWR develops guidelines to evaluate GSA plans
* 1 Jan 17—DWR publishes BMPs for sustainable management of groundwater
* 30 June 17—Local agencies affirm they will become a Groundwater Sustainability Agency (GSA)
* 31 Jan 20—Critically overdrafted high & medium priority basins adopt a gw sustainability plan (GSP)
* 31 Jan22—All other high & med priority basins adopt a GSP

Some requirements

* Periodic reporting
* Develop a process for public participation
* Planning timeframe is 50 years
* Measure groundwater extraction
* Include specific components
* Multiple plans must use the same data

Functional equivalent

* Local agencies that demonstrate that current management has achieved a sustainable yield for at least 10 years will be in compliance with plan requirements

State will intervene if 1 of 4 conditions prevail--

* Local agencies fail to have subbasin-wide governance within 2 years (by 1 Jan 17)
* Local agencies do not adopt a subbasin-wide plan within 5 years for high & medium priority basins (by 1 Jan 20)
* DWR determines either the plan or
* The implementation of the plan is inadequate & SWB determines the subbasin is in long-term overdraft or is depleting stream flow

A comment: Land use

* As 1 water district manager said the land in Stanislaus County where nut trees have been planted & in San Luis Obispo County where grape vines have been planted is great for grazing cattle but not great for permanent crops because of the limited water supply
* Whether this requirement that requires coordination with land use agencies will be effective is unknown
* But the message is clear, don't mess with local land use authority

Basin boundaries

* Identified in DWR Bulletin 118 unless other boundaries are established pursuant to SGMA
* Local agencies may request revisions
* Requests must be supported by technical data and coordination with other agencies
* DWR will publish regulations for basin boundary revisions 1 January 2016

Adverse impact to habitat & surface water resources

* DWR will consult with Calif Dept of Fish & Wildlife to develop criteria to identify basins affected adversely
* These criteria will be incorporated into prioritization at the next update after 1 Jan 17

Adjudication

* Nothing in the SGMA prevents a legal action to adjudicate water rights

Definitions: Sustainable yield

* The maximum quantity of water, calculated over a base period representative of long-term conditions in the basin and including any temporary surplus, that can be withdrawn annually from a groundwater supply without causing an undesirable result

Undesirable results

* Significant and unreasonable:
  * Depletion of groundwater in storage
  * Seawater intrusion
  * Degraded groundwater quality
  * Land subsidence
  * Surface water depletion causing adverse effects

Historical note: safe yield

* The amount of water that can be withdrawn from a groundwater basin annually without producing an undesirable result.
* David Todd, 1959

A comment: the evolution of terminology

* Safe yield
* Basin yield
* Annual yield
* Perennial yield
* Sustainable yield (now in the Water Code)

De minimis extractor

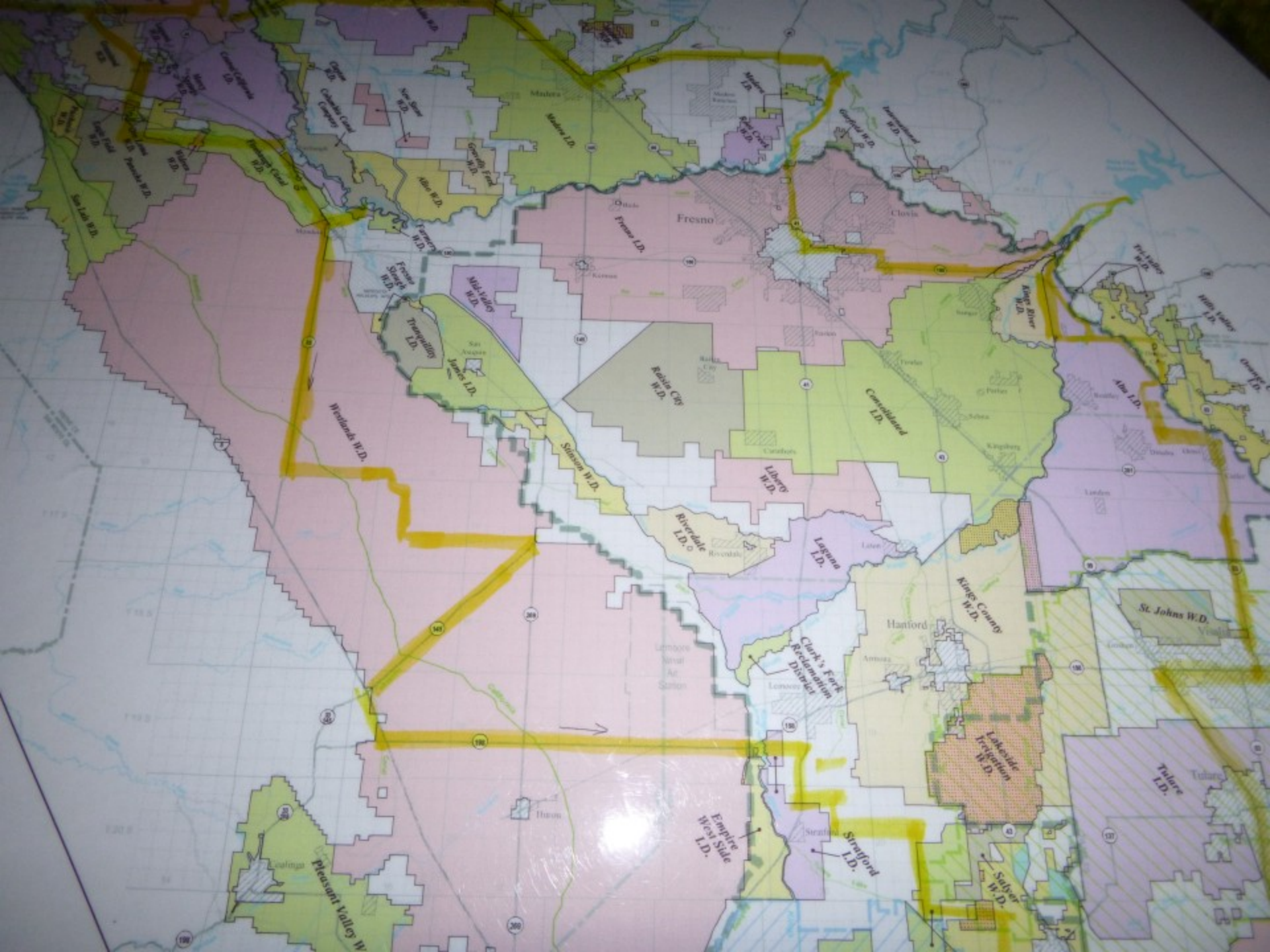
* A person who extracts, for domestic purposes, two acre-feet or less per year [1785 gpd]
* Extraction reporting requirements do not apply to a de minimis extractor
* Other states call these “exempt wells”

Personal information treated like utility information

* Government Code section 6254.16
* "Nothing in this chapter shall be construed to require the disclosure of the name, credit history, utility usage data, home address, or telephone number of utility customers of local agencies…"
* Individual extraction numbers will not be made public
* Agencies will publish 'aggregated' extraction numbers

Impediments to establishing governance

* 22 different types of local agencies
* Different statutory authority
* Each has a board of directors
* Revenue sources may differ
* Some use surface water, some groundwater, some both
* May have different conveyance systems
* The next slide shows a number of agencies within the same basin between San Joaquin River and Kings River


Fresno
Clovis
Madera
Madera I.D.
Madera W.D.
Gravelly Ford W.D.
Alta W.D.
Fresno I.D.
Fresno Slough W.D.
Mid-Valley W.D.
Tranquillity I.D.
San Joaquin
Jamie I.D.
Reclamation Dist. 1606
Reclamation Dist. 1606
Reclamation Dist. 1606

Reasons to form a governance structure

* The Water Code requires it
* Or the state will step in
* Cooperation between agencies in a basin will provide a water supply
* It will be less than before but it will be more dependable
* Success will depend on the attitudes of the people involved

DWR Bulletin 3, 1957, page 219

* Safe yield of a groundwater basin is not a fixed number
* The hydrogeologic characteristics of many basins are unknown
* These data will be necessary for adjudication
* Without these data the basin can not be operated properly.

Missing data

* Surface water
  * Runoff amount
  * Water quality
  * Reservoir boundaries
  * Amount in storage
  * Amount of diversions
  * Place of use
* Groundwater
  * Groundwater levels
  * Groundwater quality
  * ***Aquifer boundaries?***
    * ***x, y, z?***
    * ***Recharge area?***
  * ***Amount recharged?***
  * ***Amount in storage?***
  * ***Amount extracted?***
  * ***Place of use?***

Inflow – Outflow = Change in Storage

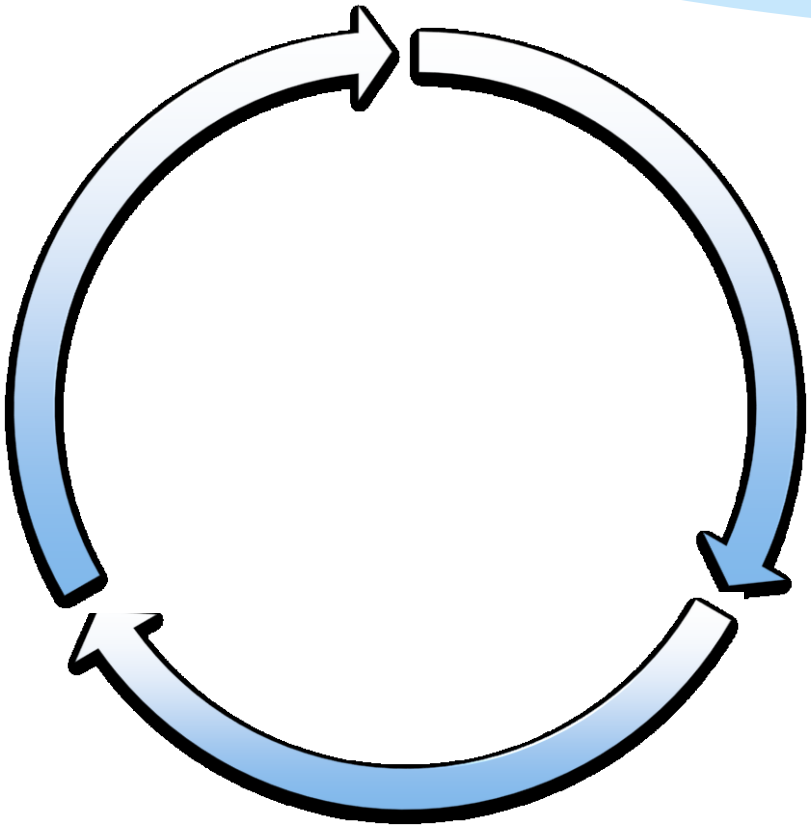
* Inflow
  * Infiltration from precipitation
  * Infiltration from streams and unlined canals
  * Groundwater flow into the aquifer
  * Artificial recharge
  * Deep percolation from irrigation
* Outflow
  * Groundwater entering streams flowing out of the basin
  * Groundwater flow out of the aquifer
  * Pumping
  * Consumptive use
  * evapotranspiration

Other names for a water budget

* Hydrologic equation
* Hydrologic balance
* Basin balance
* Law of mass conservation
* Water balance
* Water equation
* Water budget

DWR Bulletin 3, 1957, page 219

* In some basins, lowered groundwater levels will cause no damage to the aquifer system
* In other basins, damage to the system can be caused by:
  * Compaction of clays and subsidence of the land surface
  * Sea water intrusion
  * Intrusion of lower quality water



Requirements for a sustainable groundwater supply

DWR Bulletin 118-1980 per Water Code Section 12924

* Critical condition of overdraft
  * A basin is subject to critical conditions of overdraft when continuation of present water management practices would probably result in significant adverse overdraft-related environmental, social or economic impacts.

Issues that must be addressed in any water management planning

* Political
* Legal
* Institutional
* Technical
* Economic

Conclusions

* 100 years without effective groundwater management is a blot on California's history
* AB 3030 was not a big enough nudge to get landowners to manage water
* The Sustainable Groundwater Management Act provides a stick that can provide results
* Assemblyman Dickinson, Senator Pavley & Governor Brown deserve a lot of credit

Conclusions 2

* We criticize local agencies for not doing enough
* Employees of the agencies are doing the bidding of their board of directors, composed of landowners
* So it is the landowners who have caused the problem
* They maximized profits while participating in a circular firing squad

Conclusions 3

* The Sustainable Groundwater Management Act is a significant change
* Local agencies have a lot of work to complete
* Success will depend on the attitudes of the people involved
* This last point can not be overemphasized

Conclusions 4

* Climate change may affect results significantly
* Some issues may end up in court
* Persons are working on an accelerated adjudication process
* The same data will be needed whether it is by means of a GSA or an adjudication

Work load

* DWR & SWB also have a lot of work ahead of them
* The SGMA does not include funding
* Both agencies are working on budget augmentations

Reality?

* Sally Jewell visited California to observe the drought and said—"Nobody's going to get the amount of water they are hoping for."
* I think this applies to all water management—we have reached the limit of our water supply and must begin to reduce water use
* It is well past time that we started talking about this reality

References

* *California Groundwater Management by GRA*
* *California's Groundwater* DWR Bulletin 118-2003
* Basin analyses on line at water.ca.gov Bull. 118-2003
* *Basic Ground Water Hydrology* USGS WSP 2220
* *Unquenchable* by Robert Glennon
* *The End of Abundance* by David Zetland
* *Governing the Commons* by Elinor Ostrom
* *Stream Flow Depletion* USGS Circular 1376
* *The West Without Water* by Ingram & Malamud-Roam

And remember,

No surface water =

no groundwater