Congress 2015

Managing Groundwater for Drought, Clean Water, Food Security, and Ecosystems

Thomas Harter
University of California Davis
ThHarter@ucdavis.edu

http://groundwater.ucdavis.edu

UC DAVIS
UNIVERSITY OF CALIFORNIA


Photo: Justin Sullivan / Getty Images


Veronica Rocha / Los Angeles Times


Brad Zweerink for Earth Justice

Jim Wilson/ The New York Times

Jim Wilson/ The New York Times

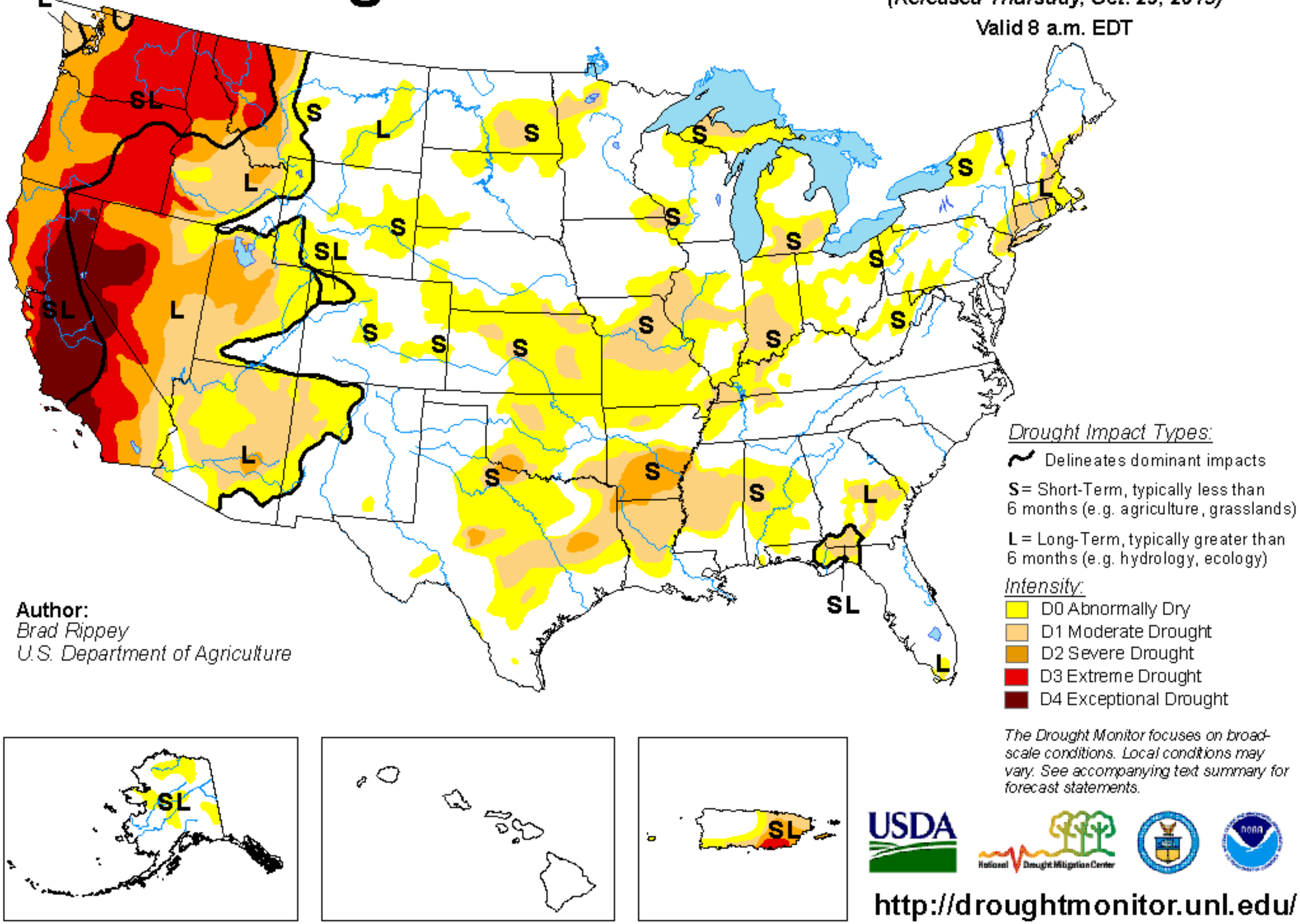
Jim Wilson/ The New York Times

U.S. Drought Monitor

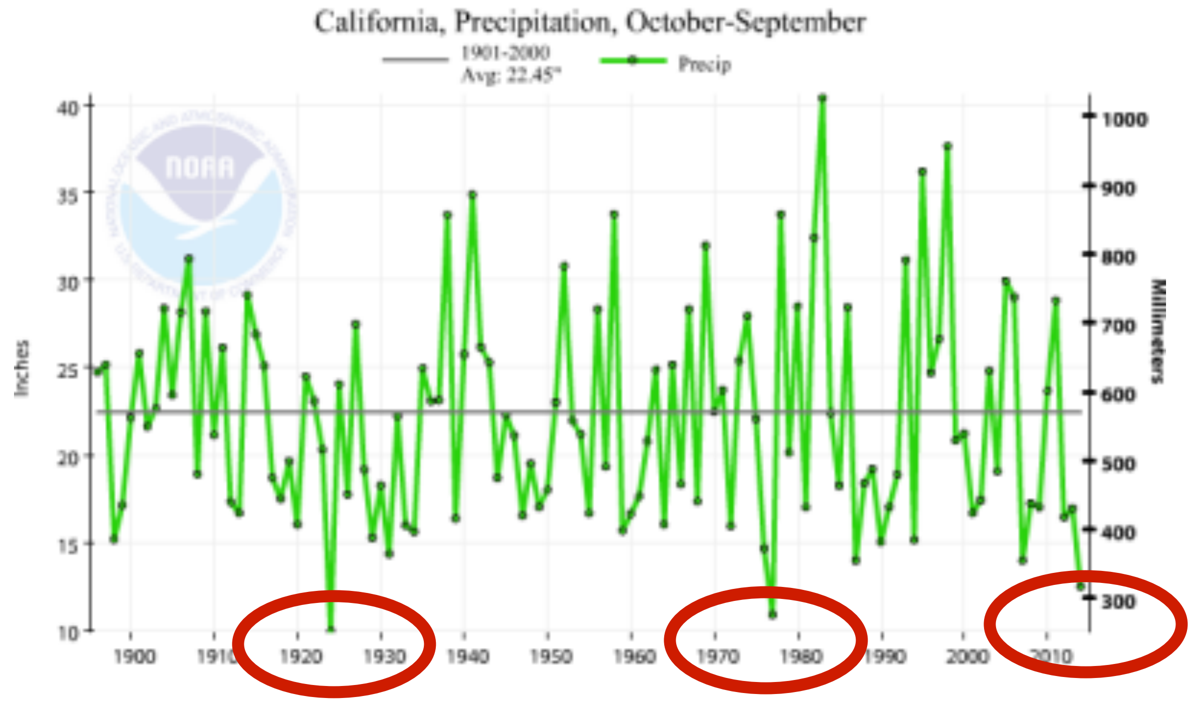
October 27, 2015

(Released Thursday, Oct. 29, 2015)

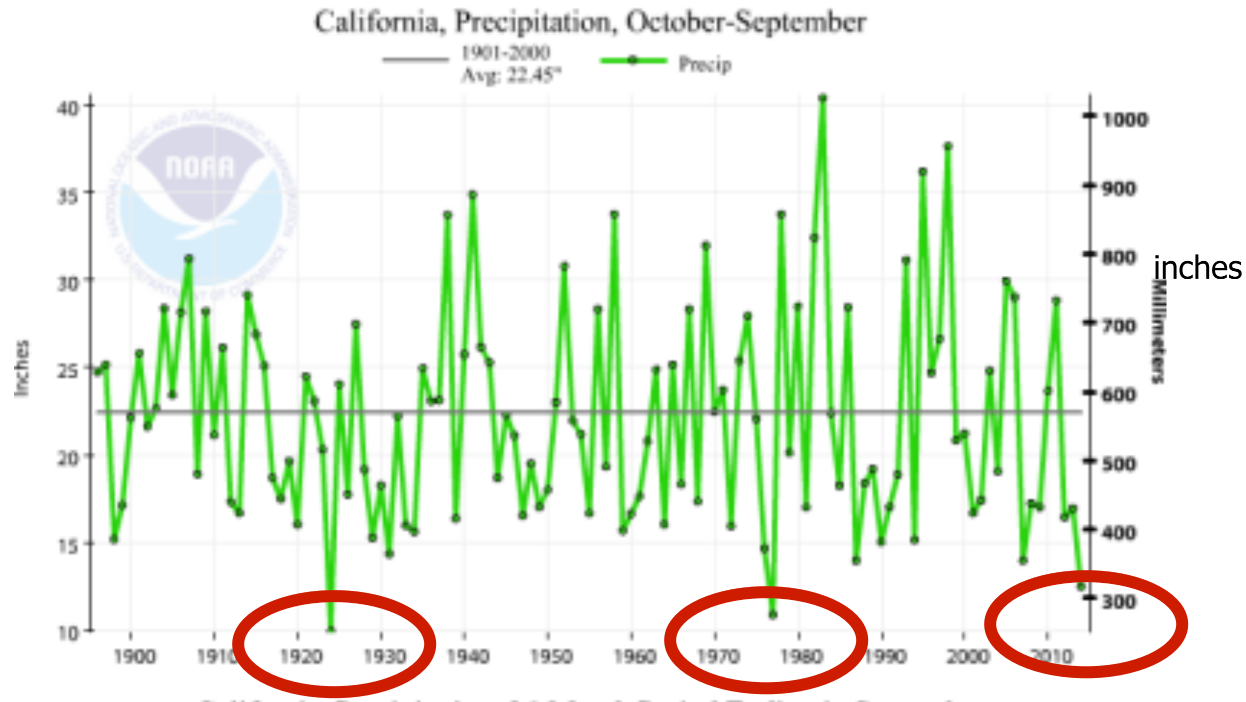
Valid 8 a.m. EDT



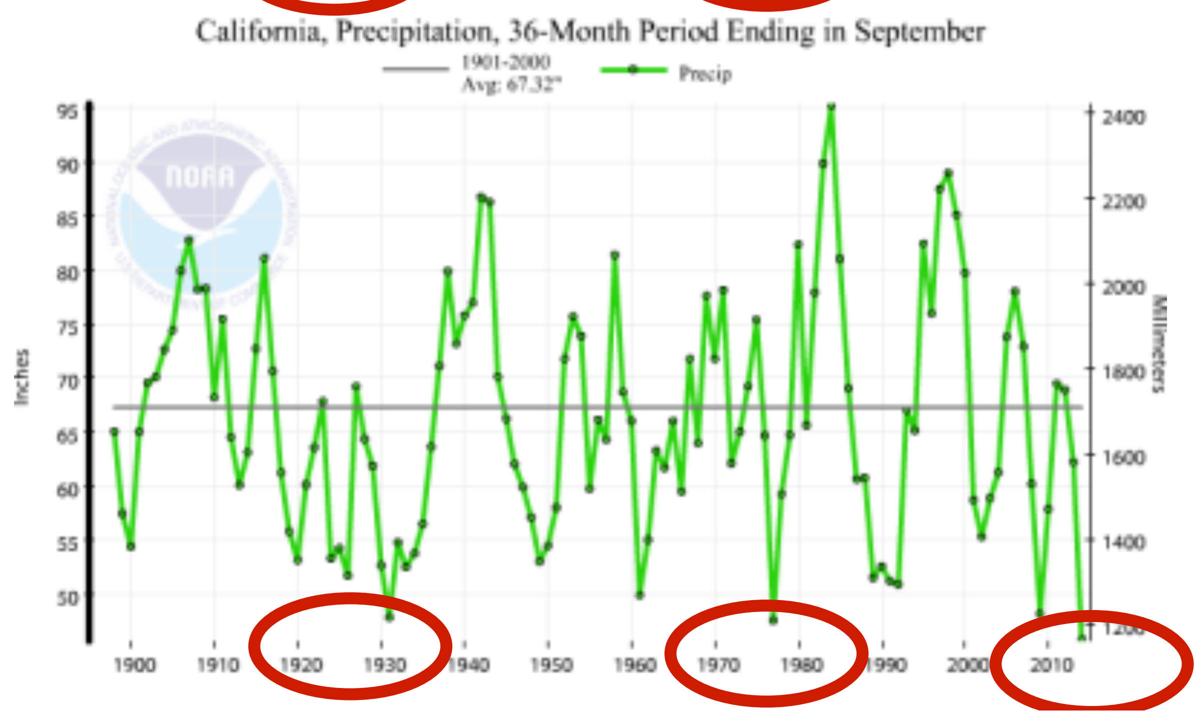
Annual P
[inches]



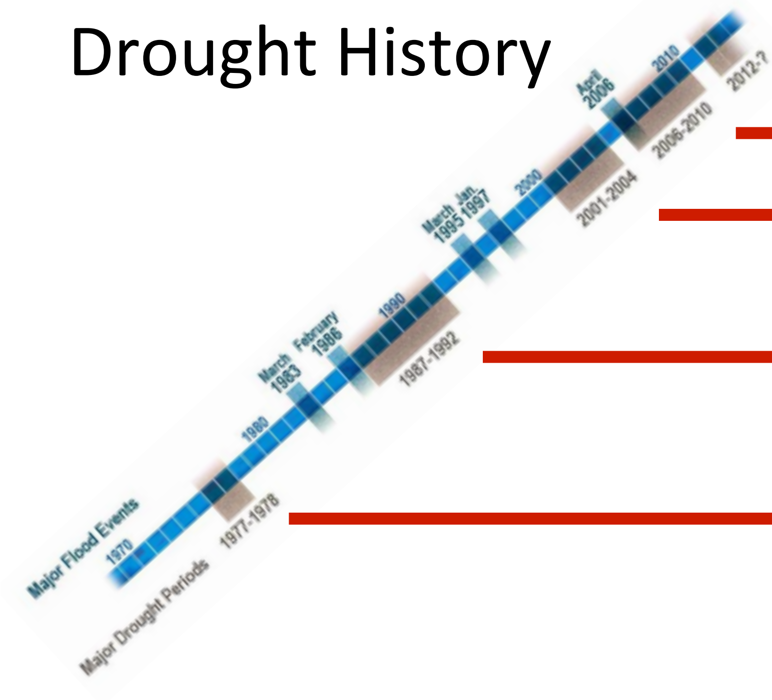
Annual P [inches]



Tri-annual P [inches]



Drought History



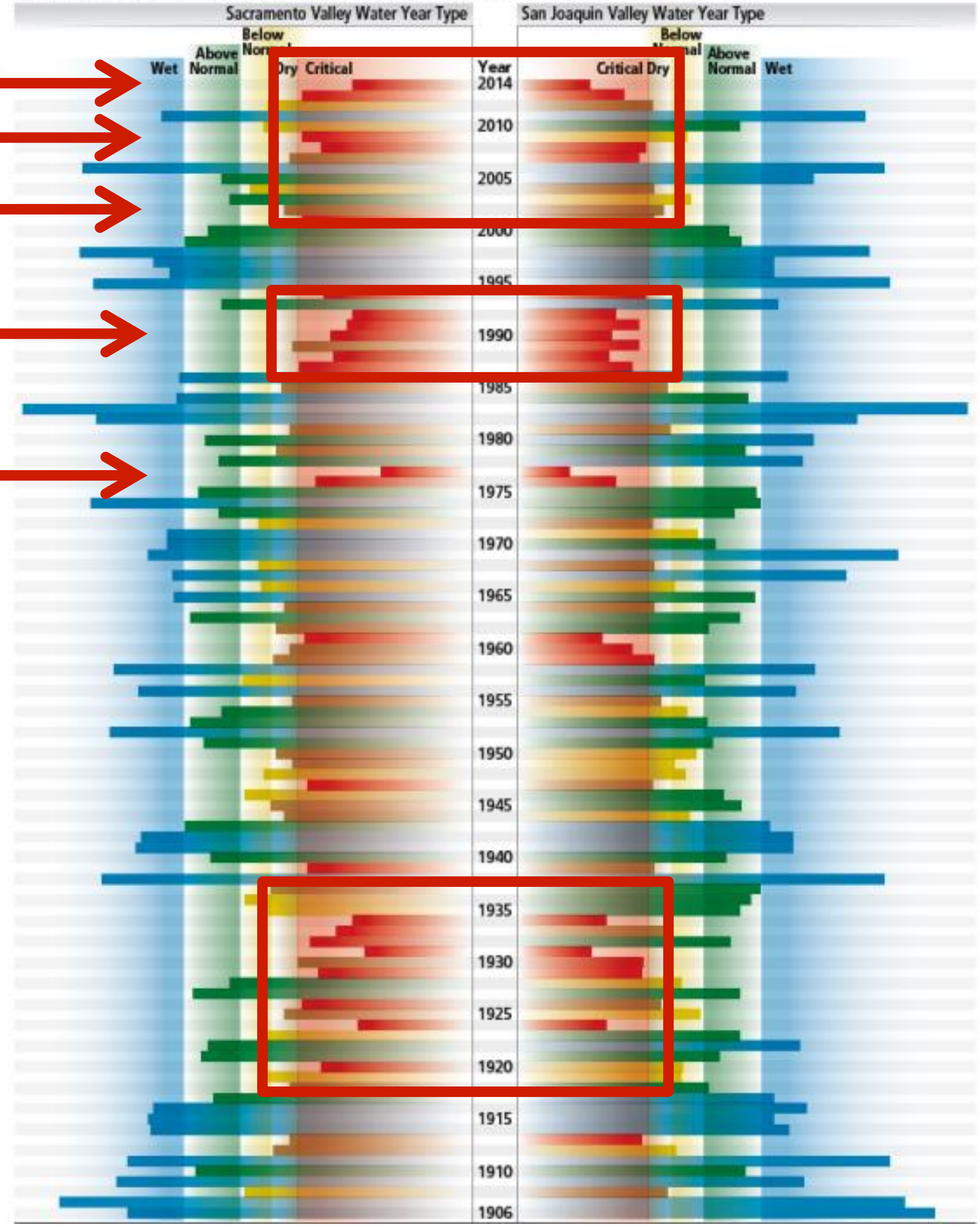
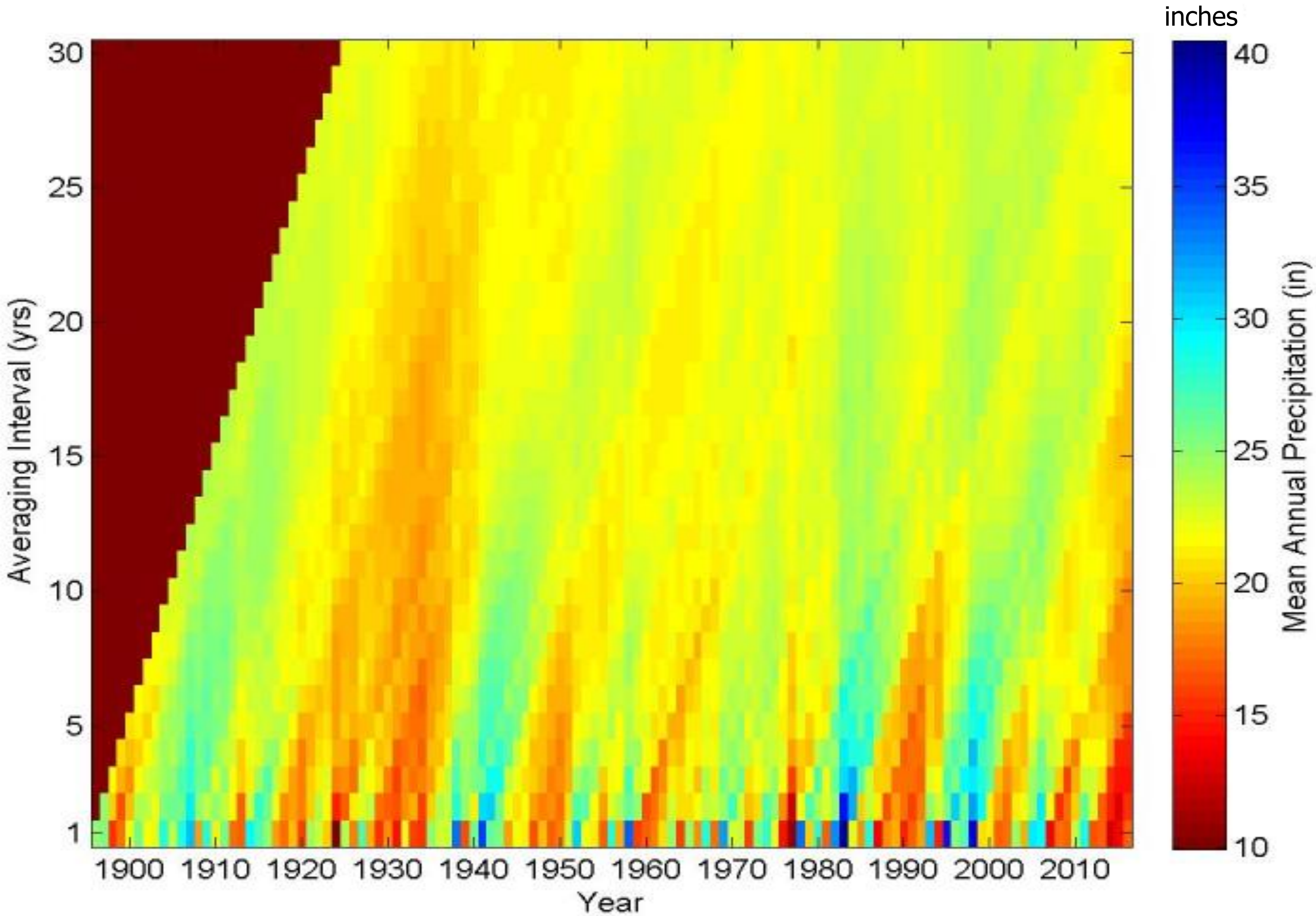


Figure 1: Sacramento Valley and San Joaquin Valley Water Year Types – 1906 to 2014

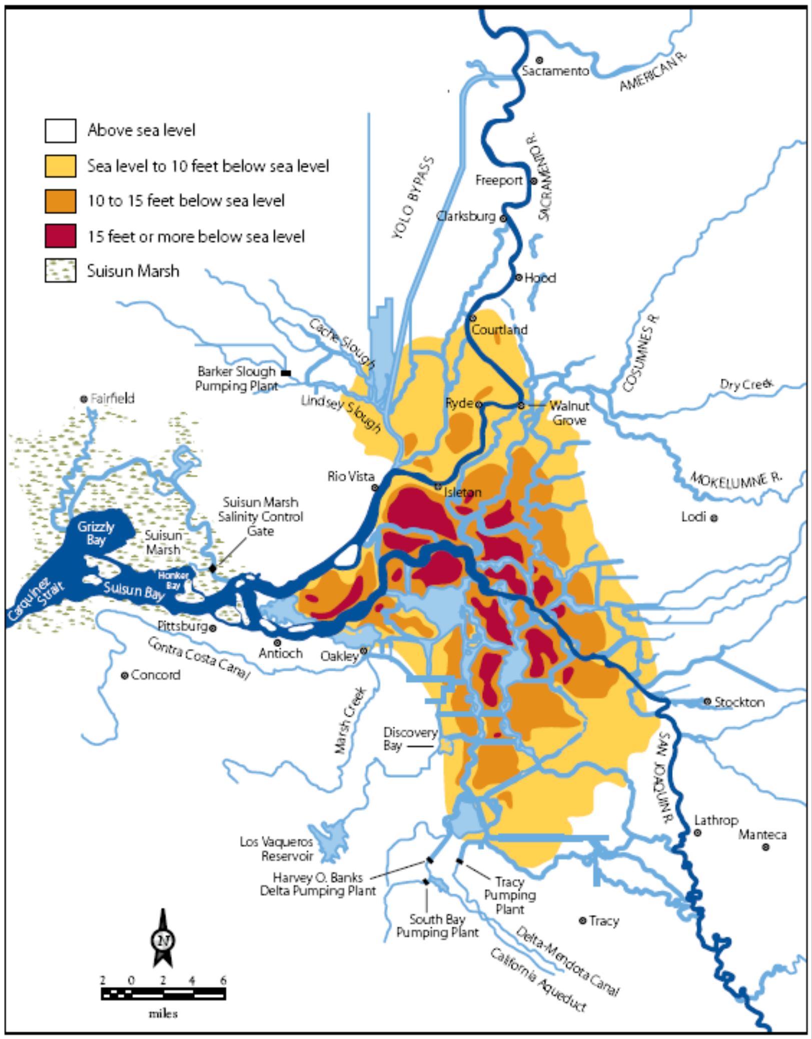
California Department of Water Resources;
Drought Response Update Fall 2014

California Precipitation 1896 – **2016**: Preceding Multiyear Average [inches]



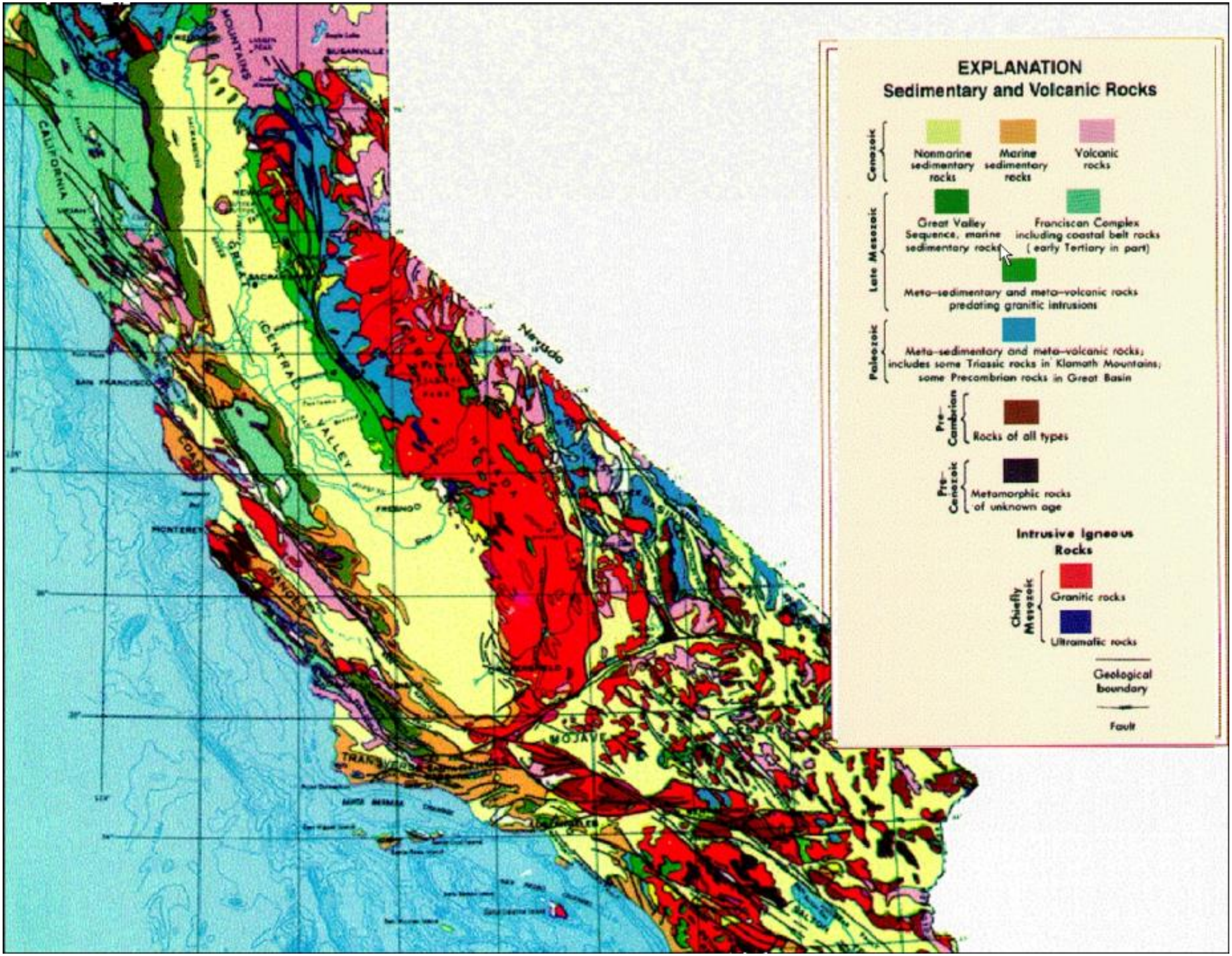
Harter and Tolley, UC Davis (annual precipitation data courtesy of Tim Ross, DWR; http://www.wrcc.dri.edu/cgi-bin/divplot2_form.pl?0405

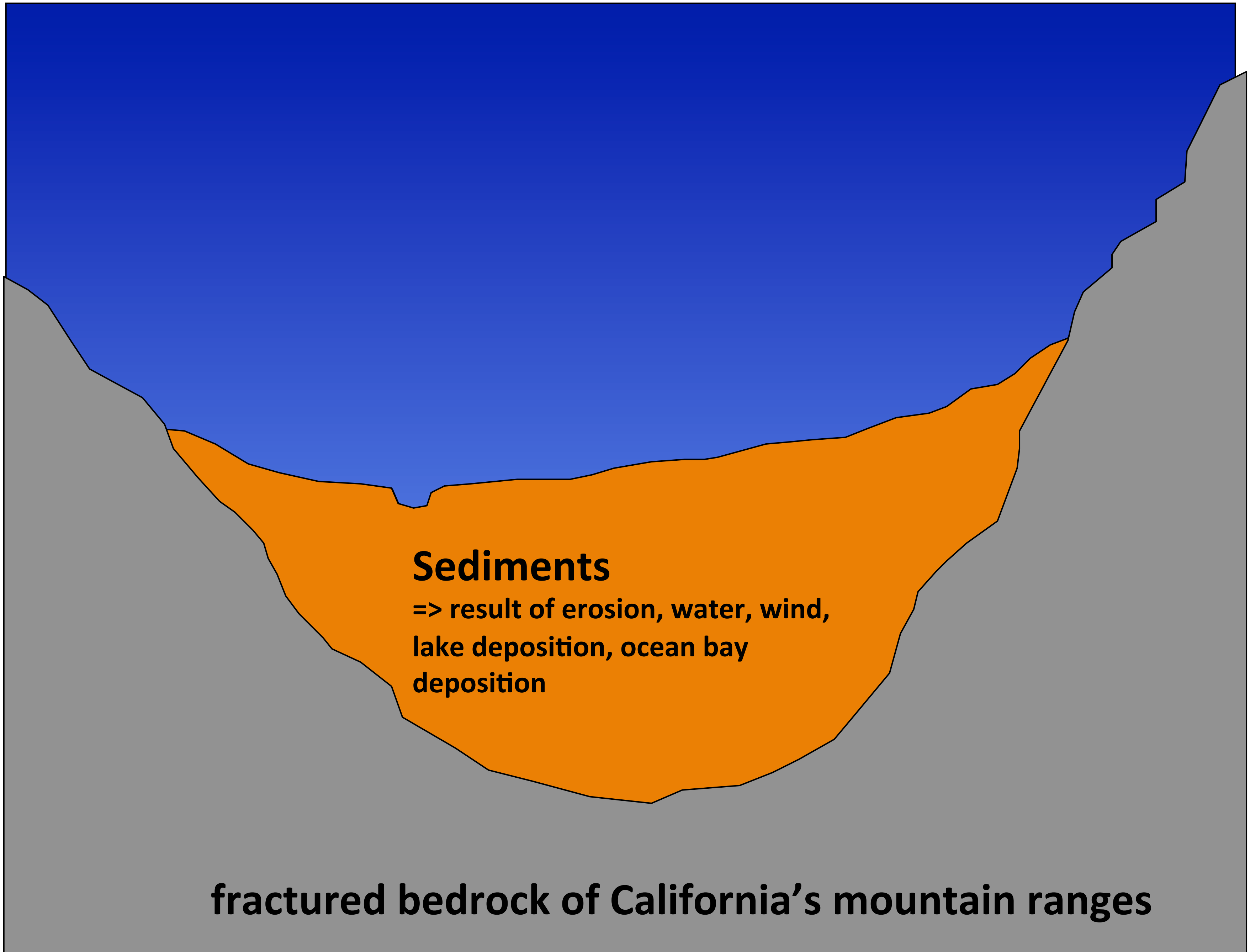
Central Water Hub: Sacramento – San Joaquin Delta



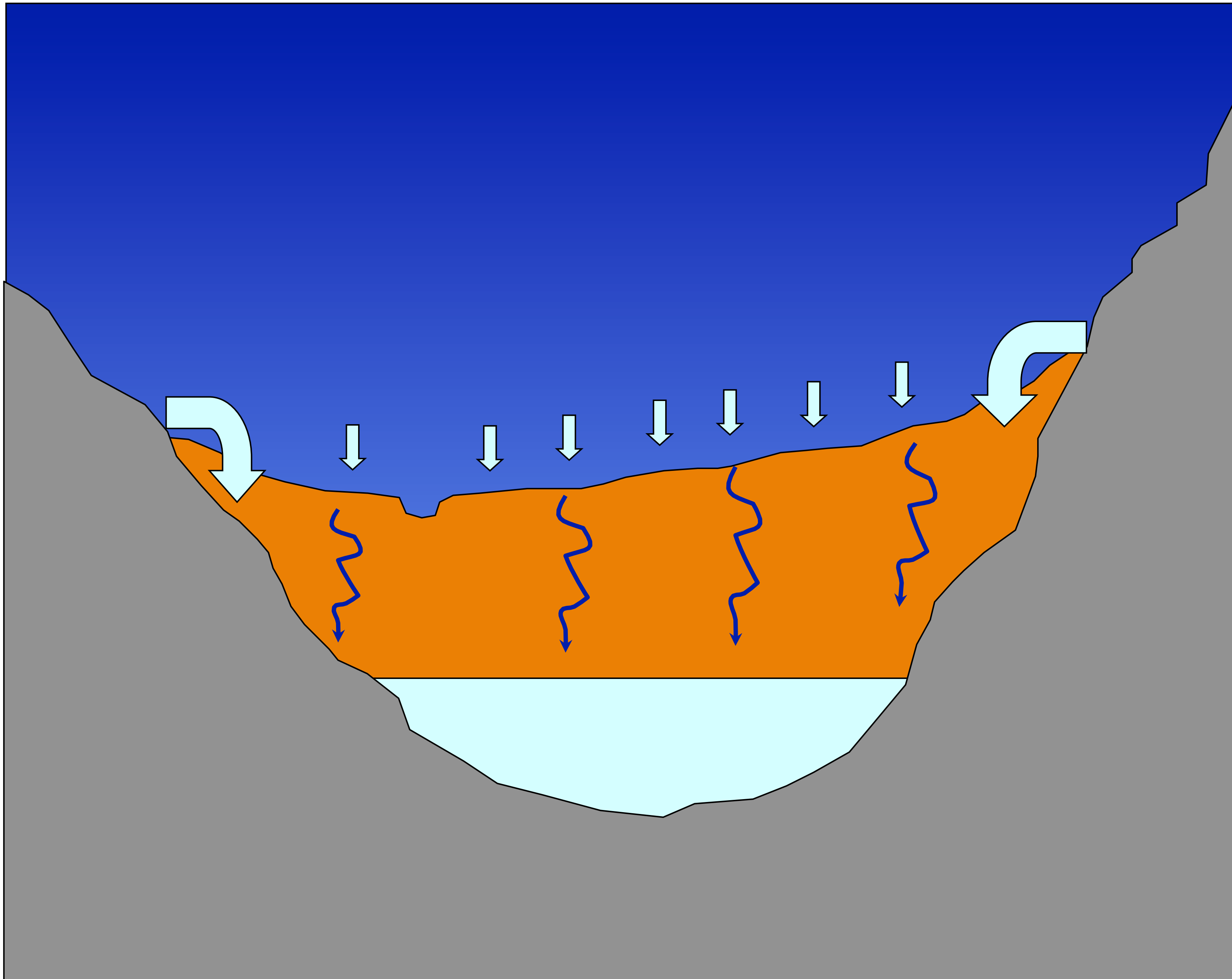
SOURCE: Department of Water Resources, Sacramento–San Joaquin Delta Atlas (1995).

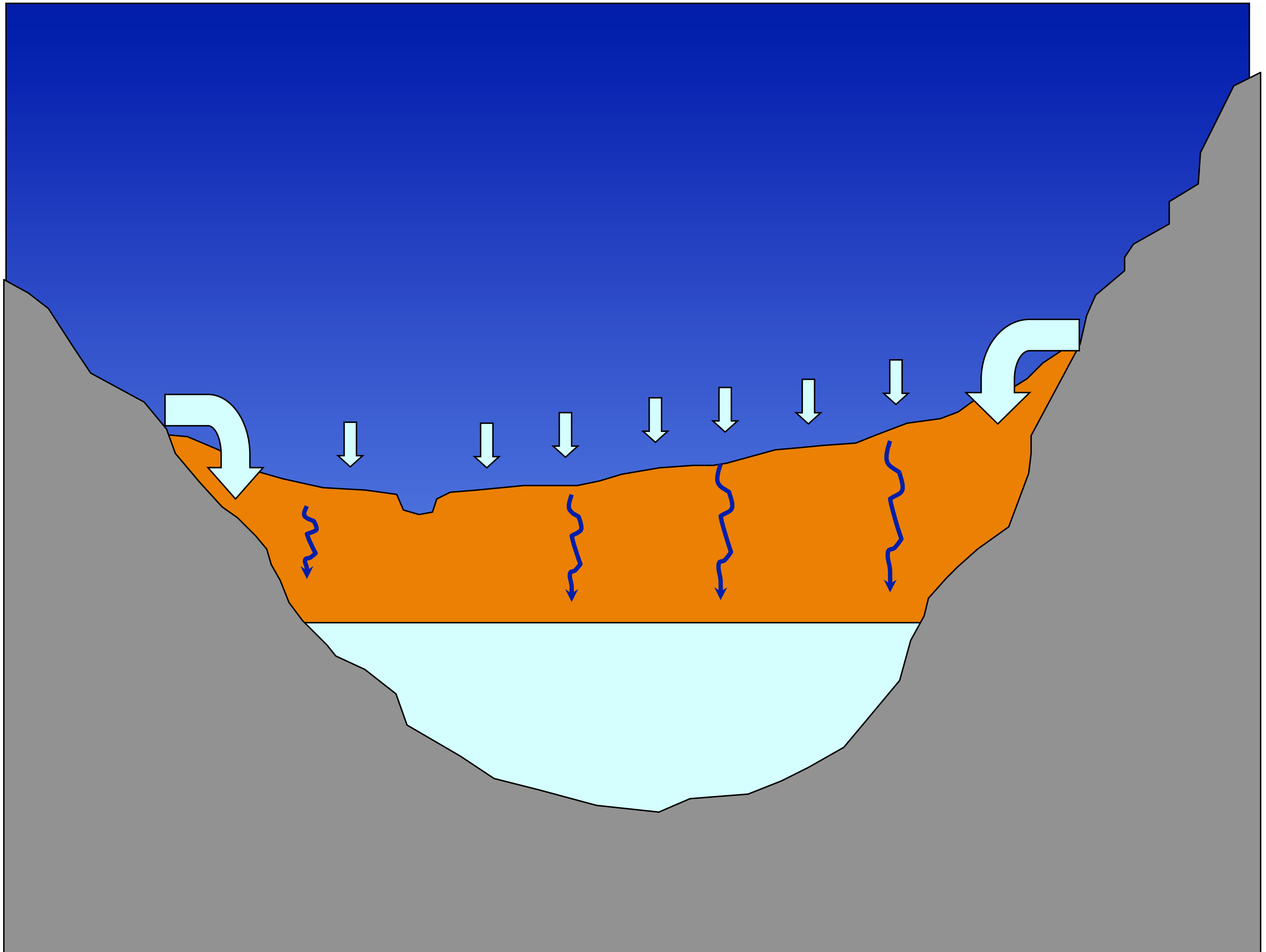
California Water Plan, Bulletin 160-2005

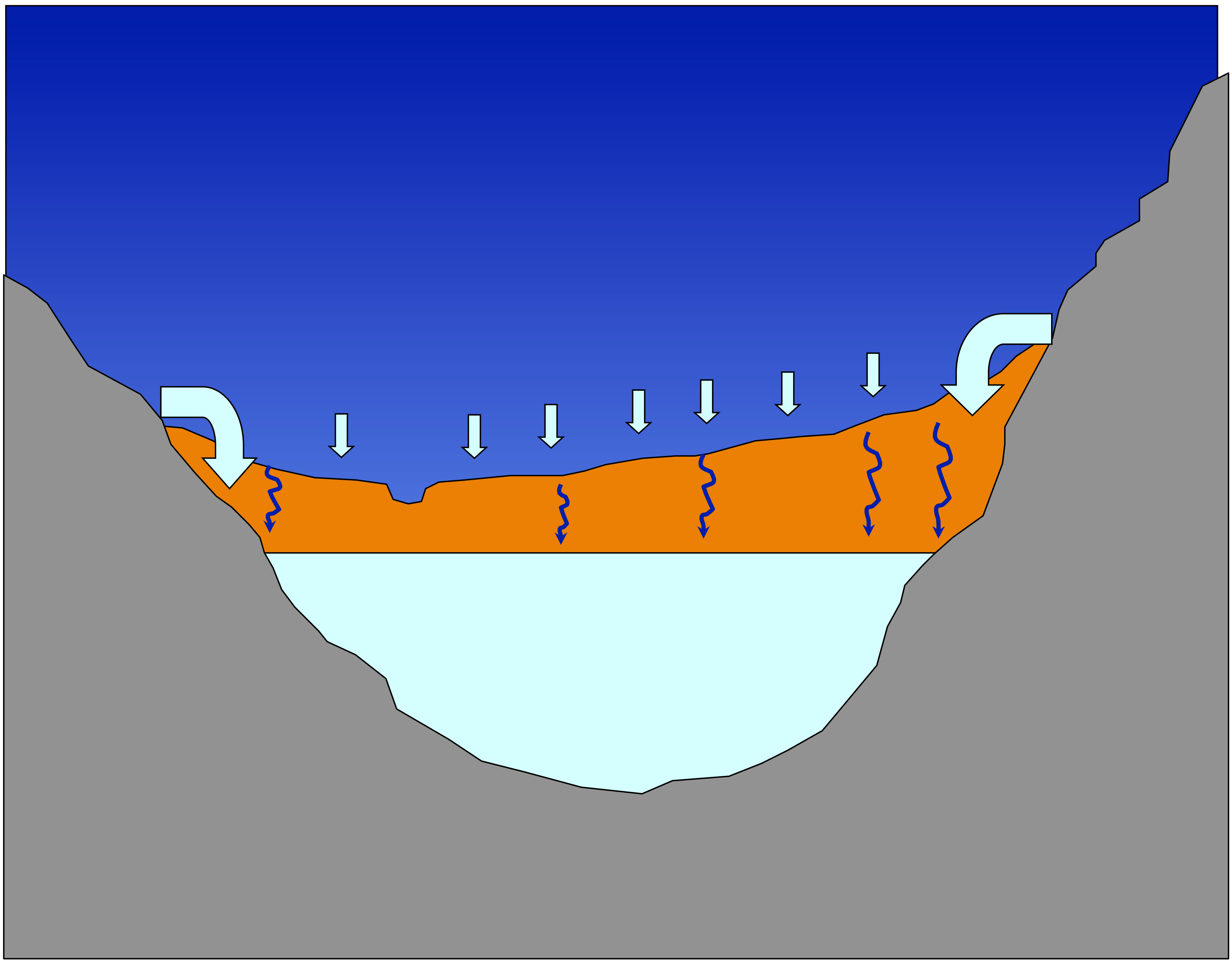

EXPLANATION
Sedimentary and Volcanic Rocks
Cenozoic
Nonmarine sedimentary rocks
Marine sedimentary rocks
Volcanic rocks
Late Mesozoic
Great Valley Sequence, marine sedimentary rocks
Franciscan Complex including coastal belt rocks (early Tertiary in part)
Meta-sedimentary and meta-volcanic rocks predating granitic intrusions
Paleozoic
Meta-sedimentary and meta-volcanic rocks; includes some Triassic rocks in Klamath Mountains; some Precambrian rocks in Great Basin
Pre-Cambrian
Rocks of all types
Pre-Cenozoic
Metamorphic rocks of unknown age
Intrusive Igneous Rocks
Chiefly Mesozoic
Granitic rocks
Ultramafic rocks
Geological boundary
Fault
CALIFORNIA
SAN FRANCISCO
MONTEREY
FRESNO
Nevada
MOJAVE
SUSANVILLE
CENTRAL
VALLEY

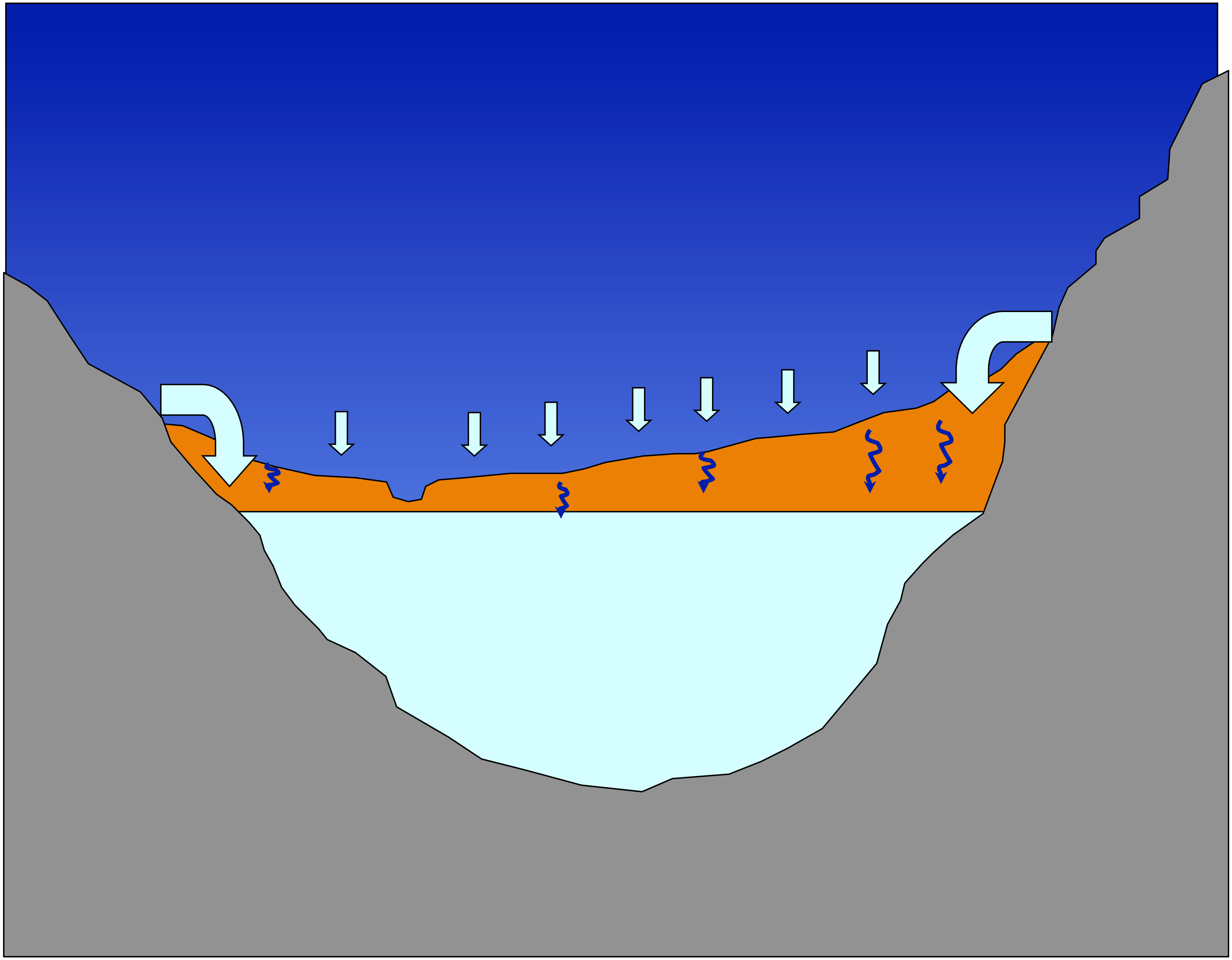


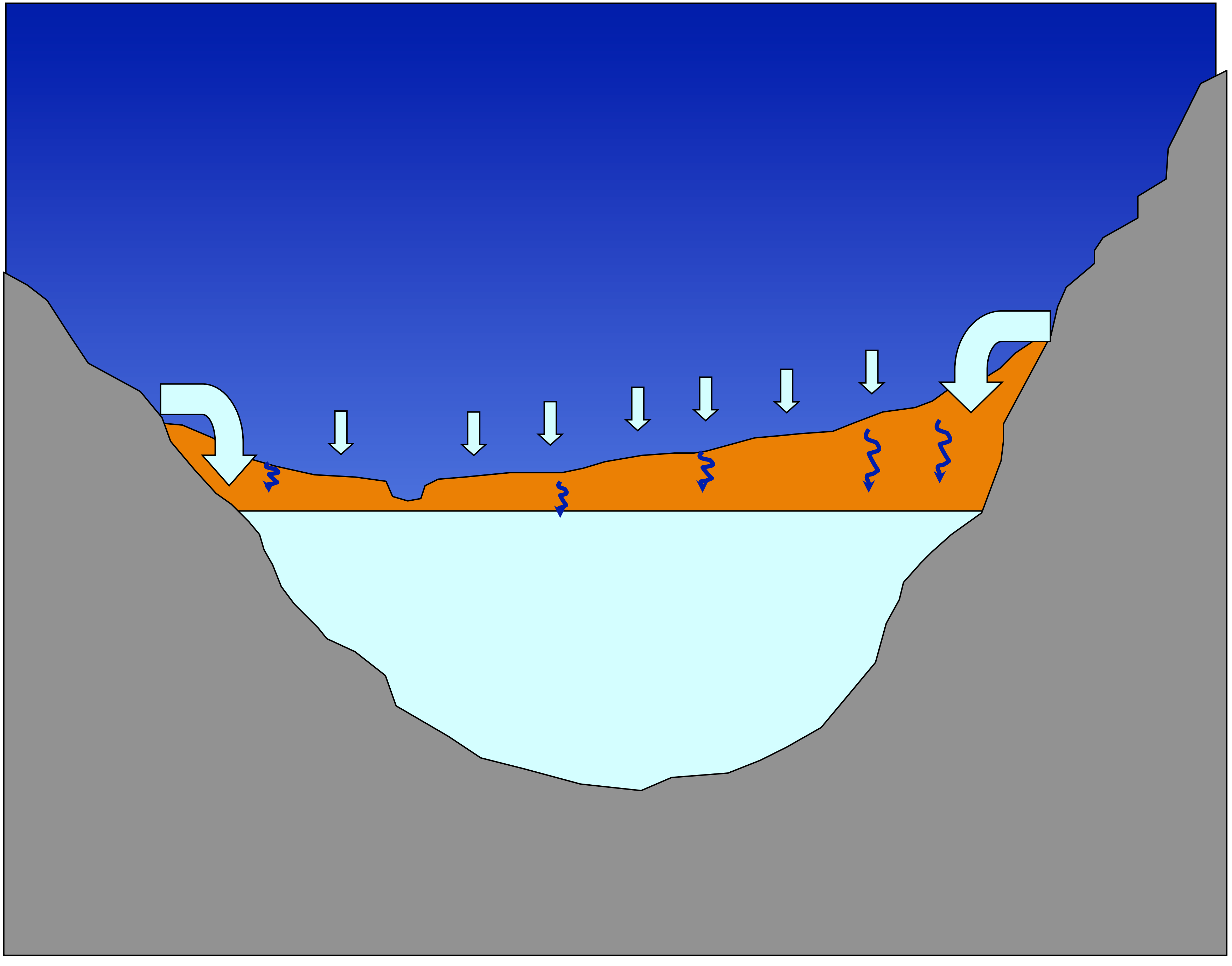
Sediments
=> result of erosion, water, wind, lake deposition, ocean bay deposition
fractured bedrock of California’s mountain ranges

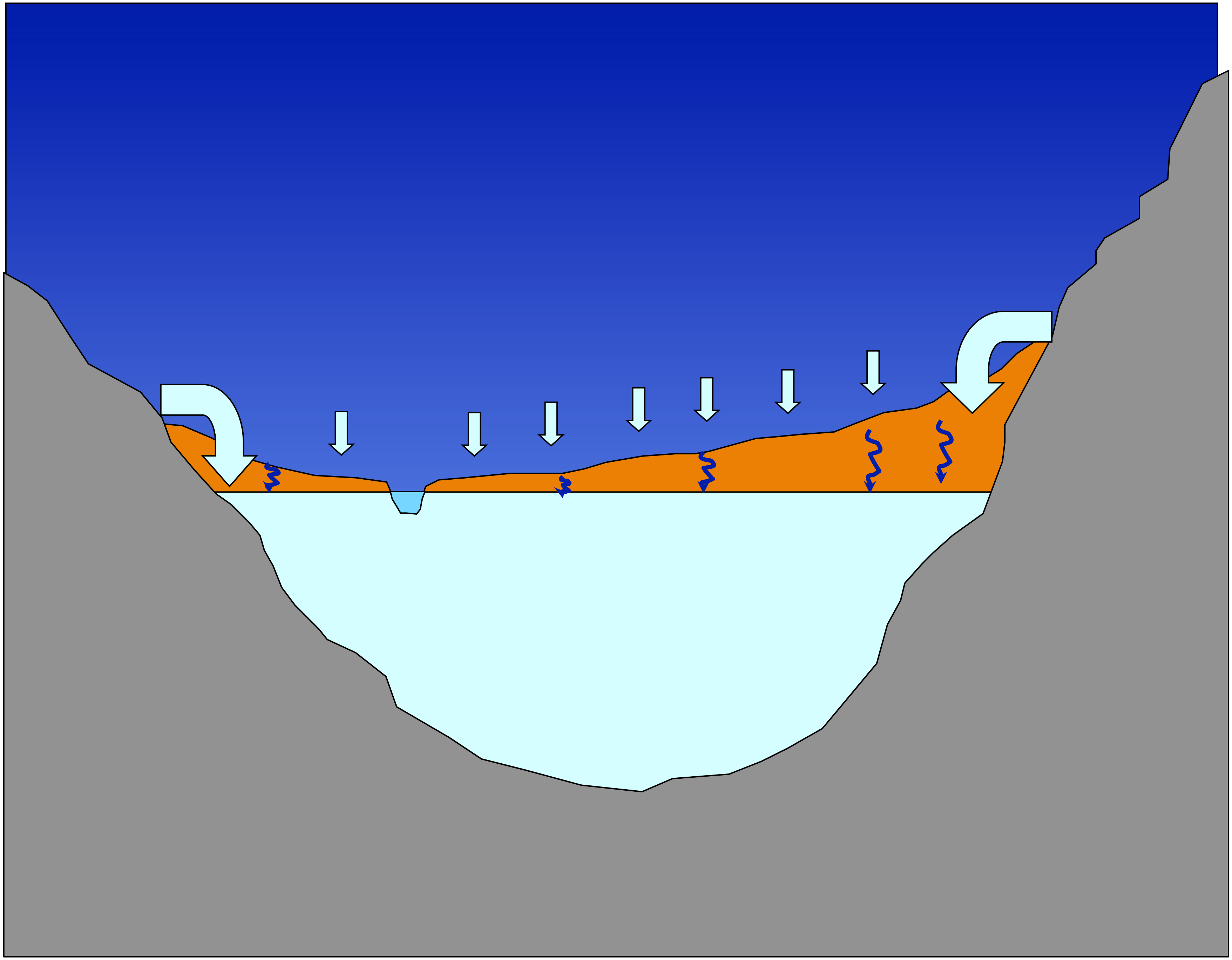


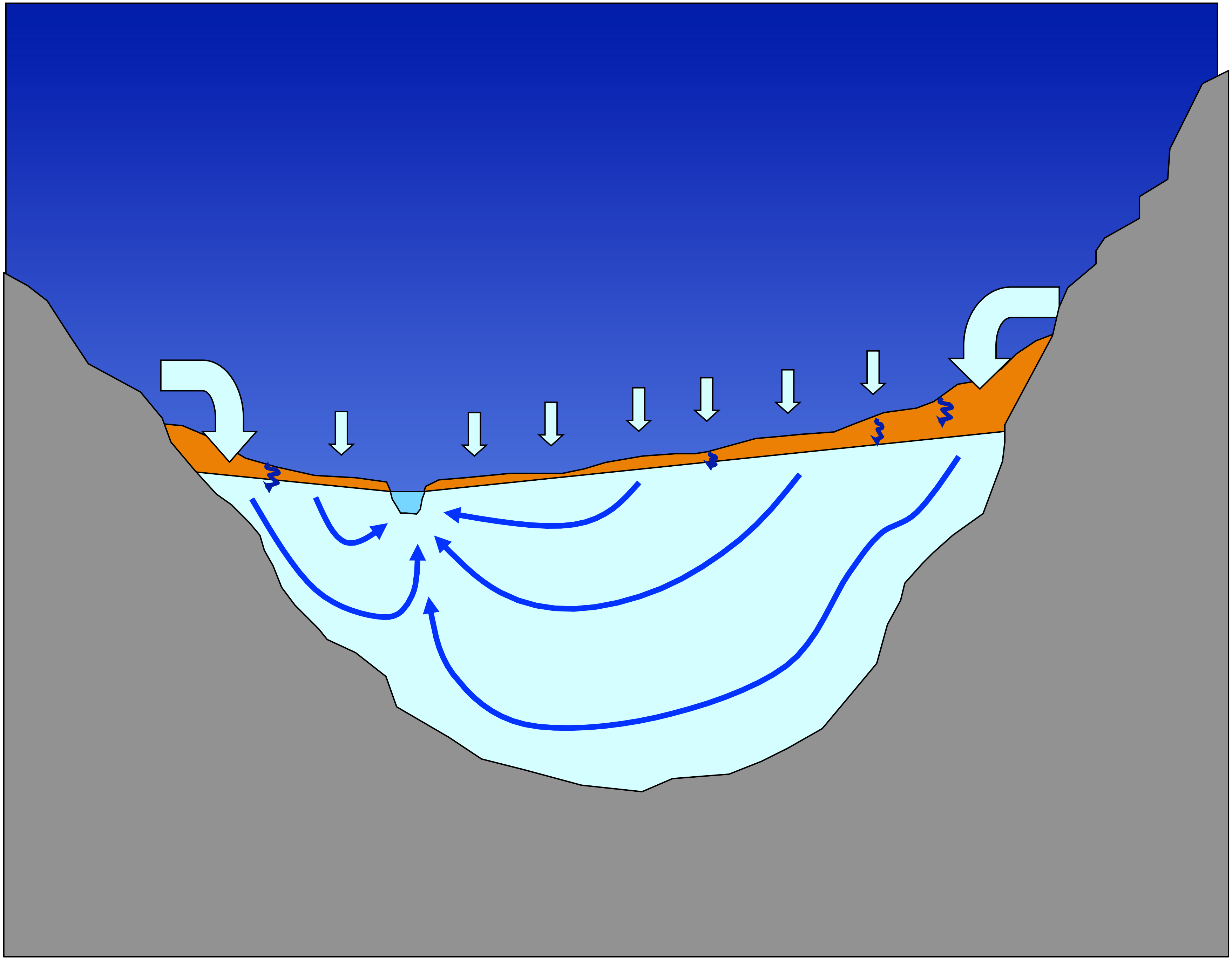


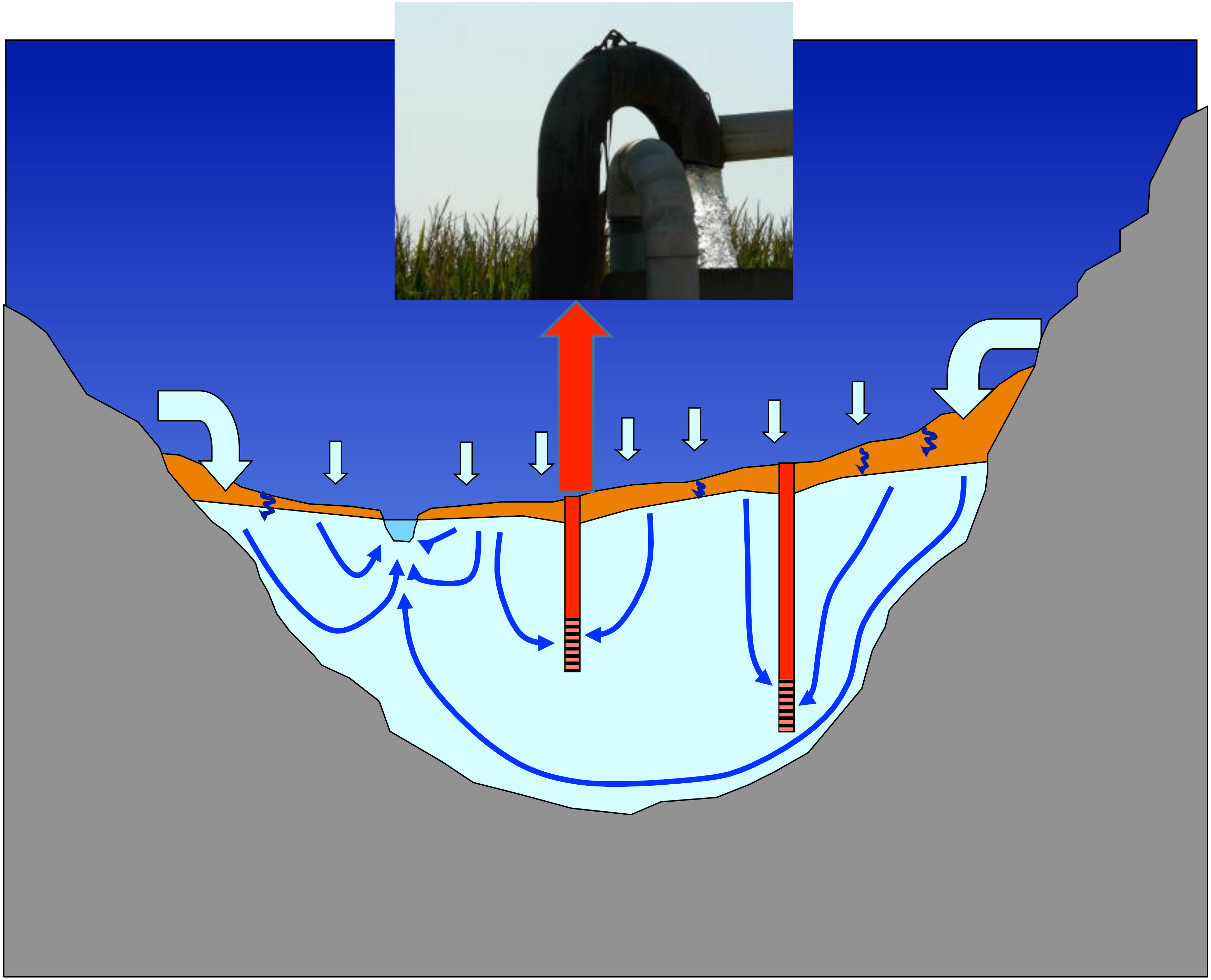


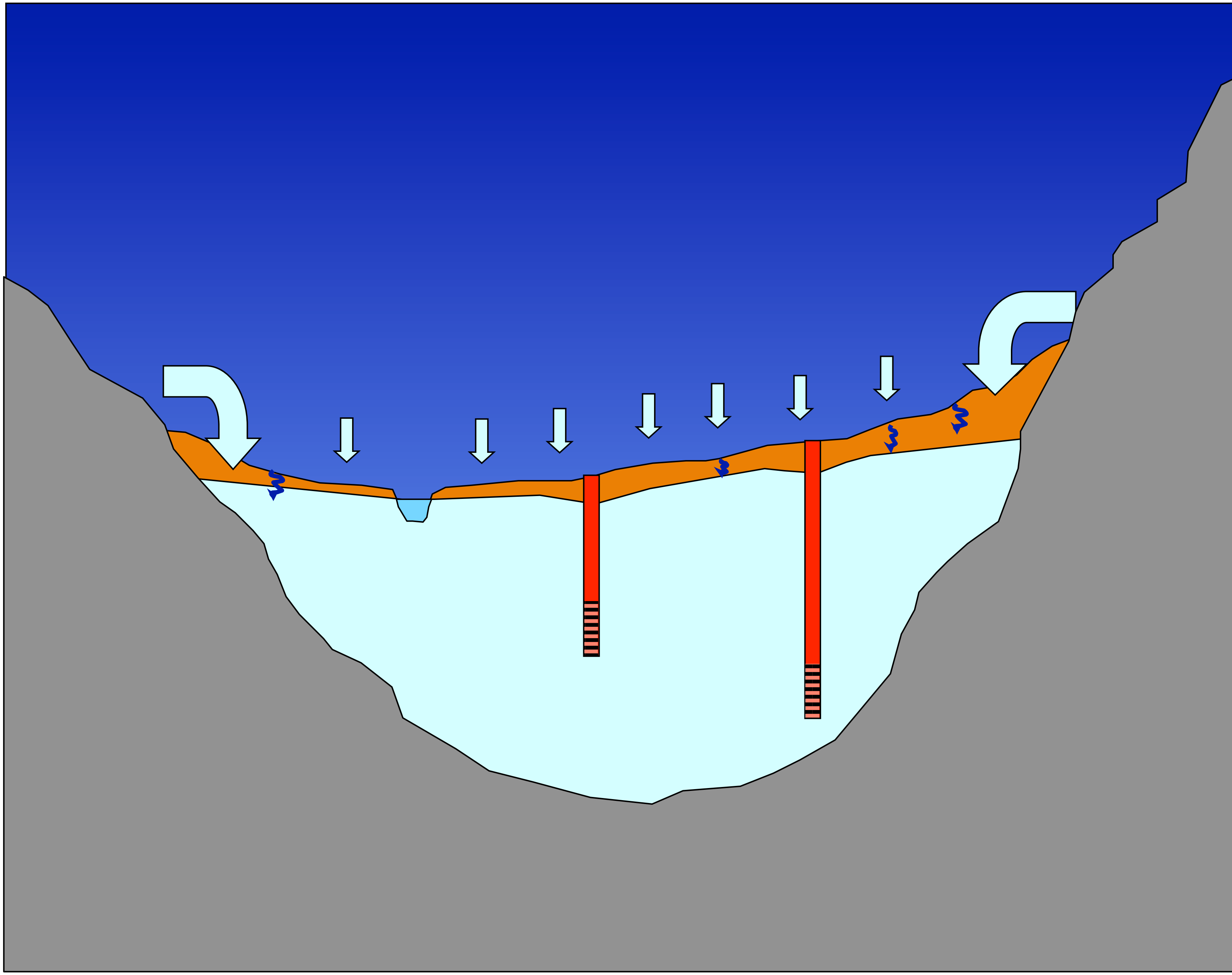


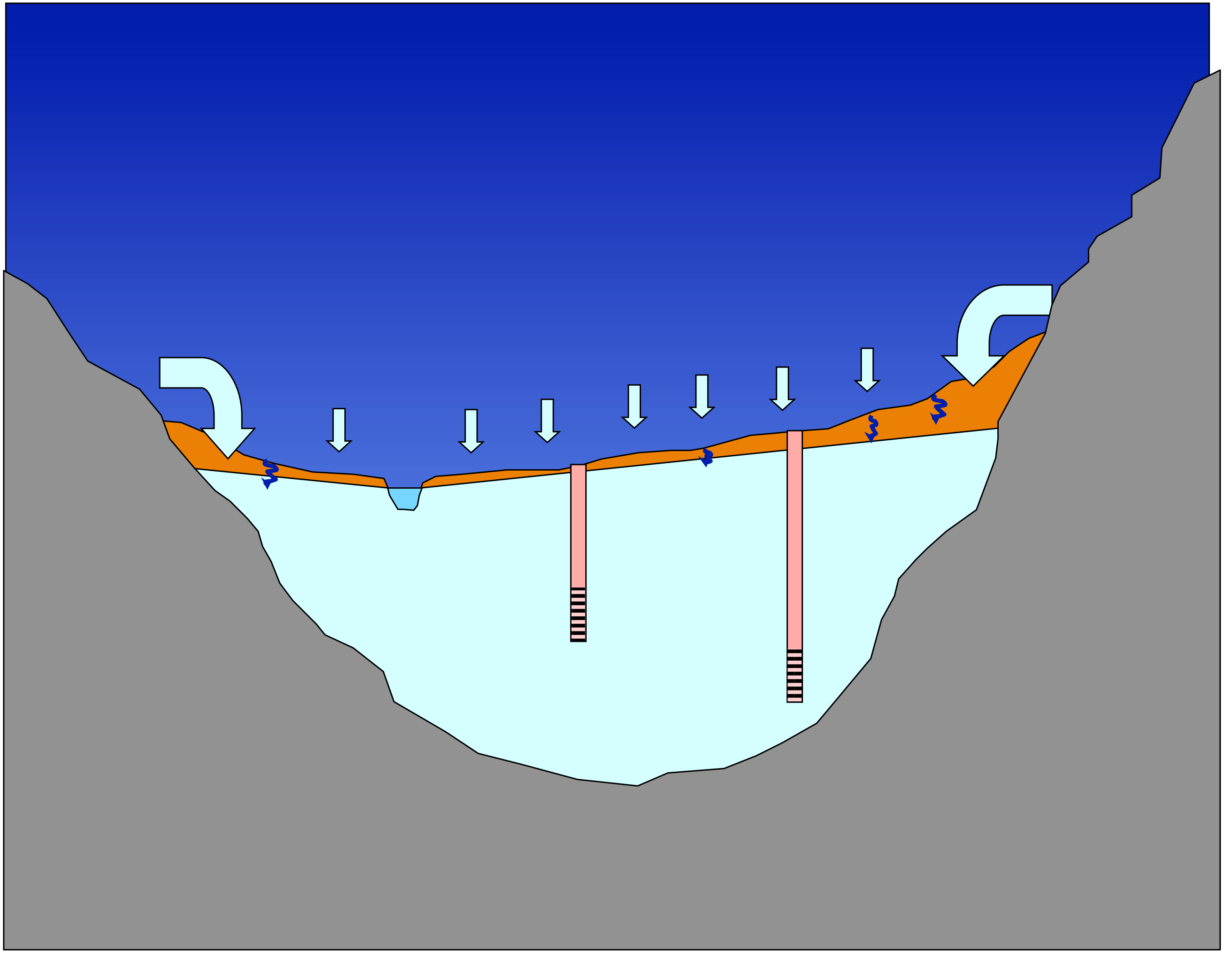


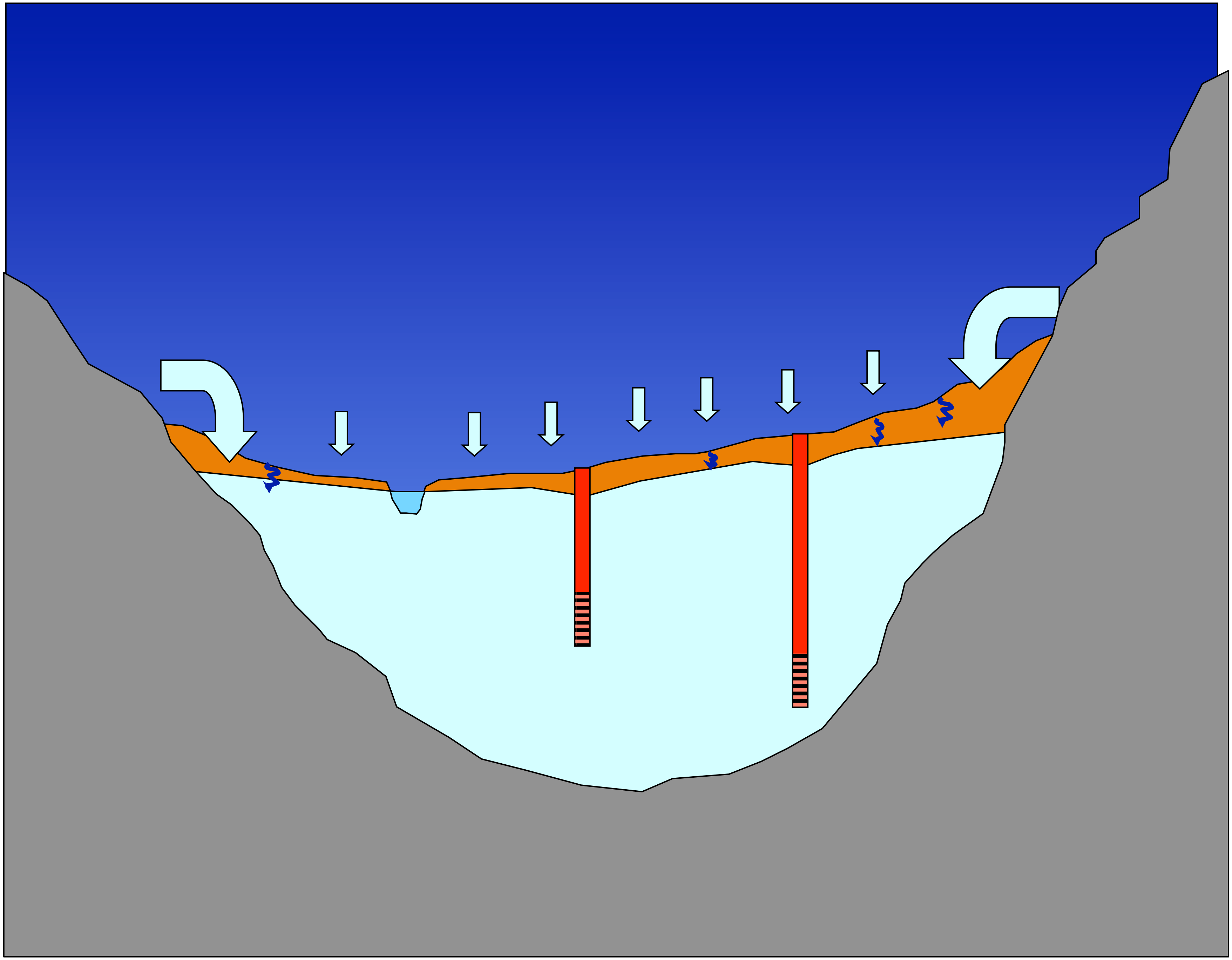


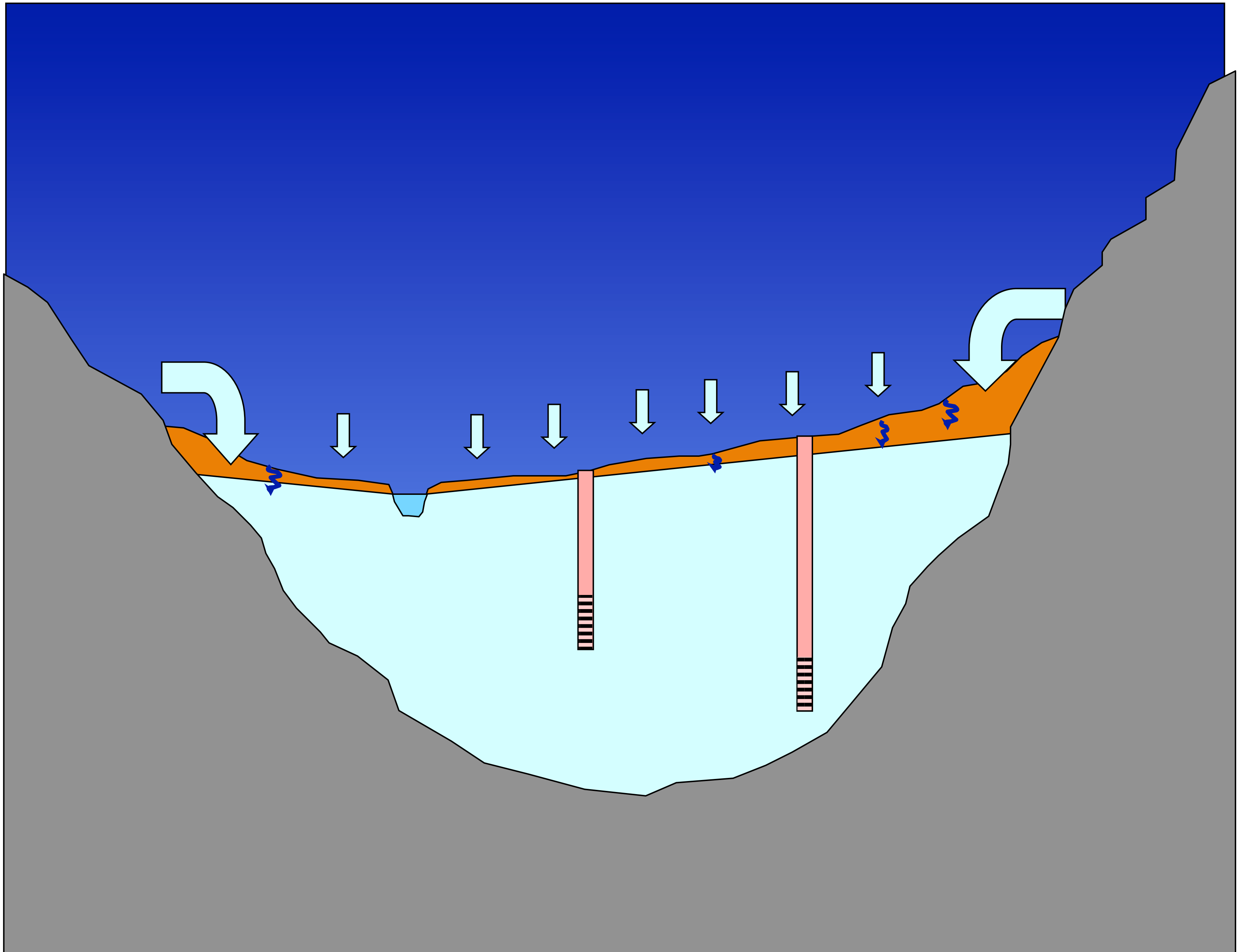


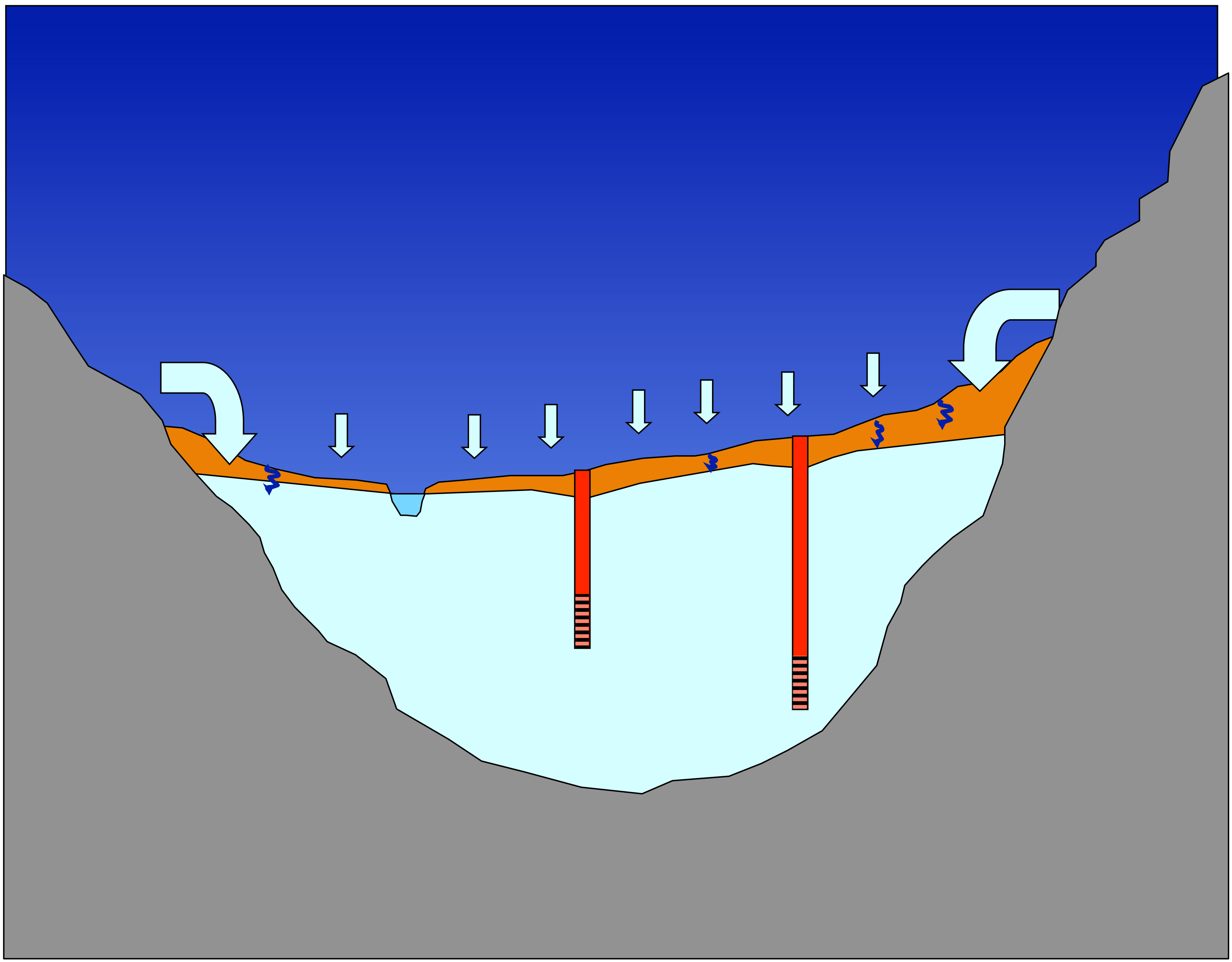






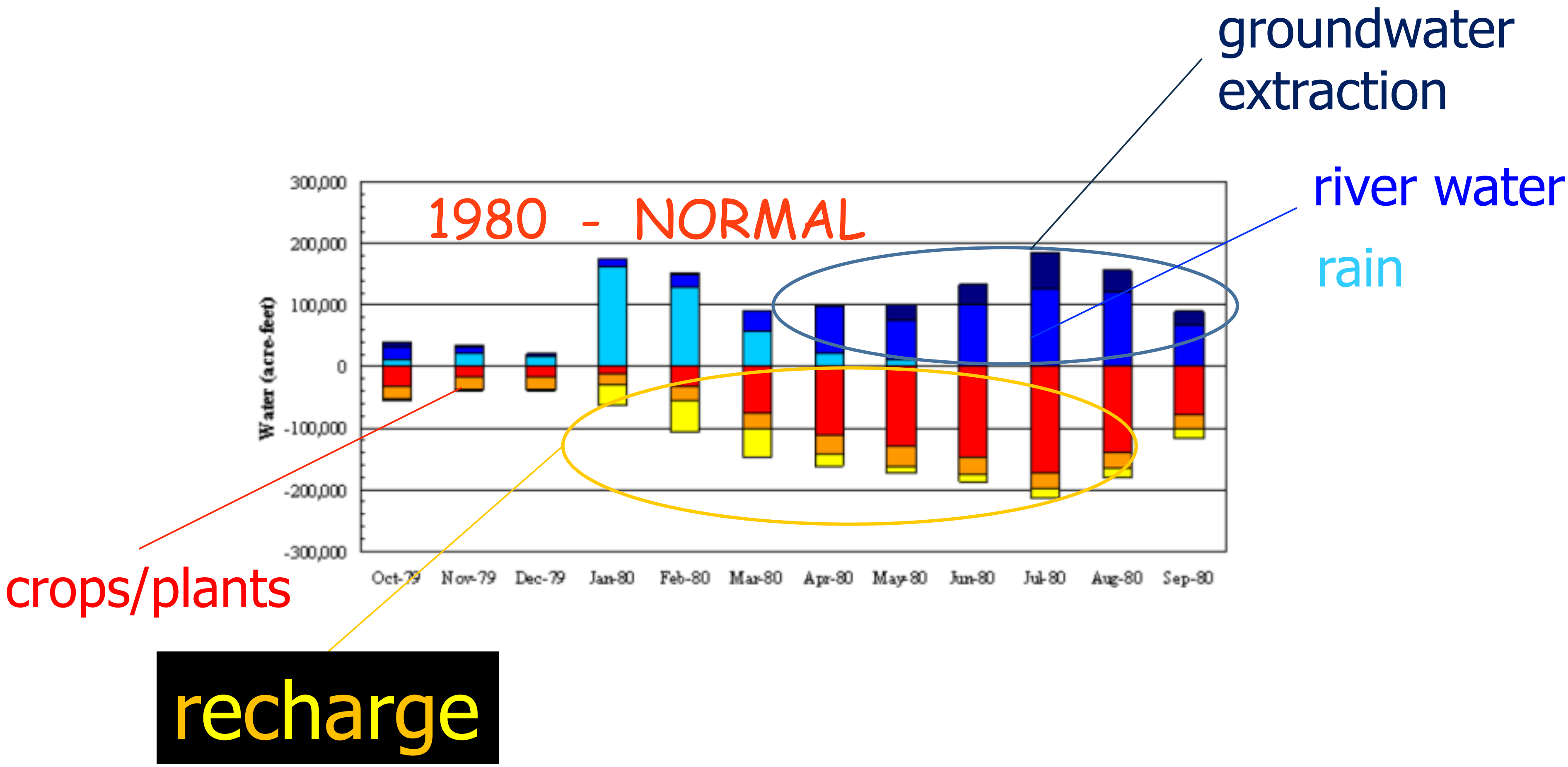






Monthly Landscape Water Budget
October – September

Tule River Basin, Tulare County



Ruud, Harter et al., 2003, 2004

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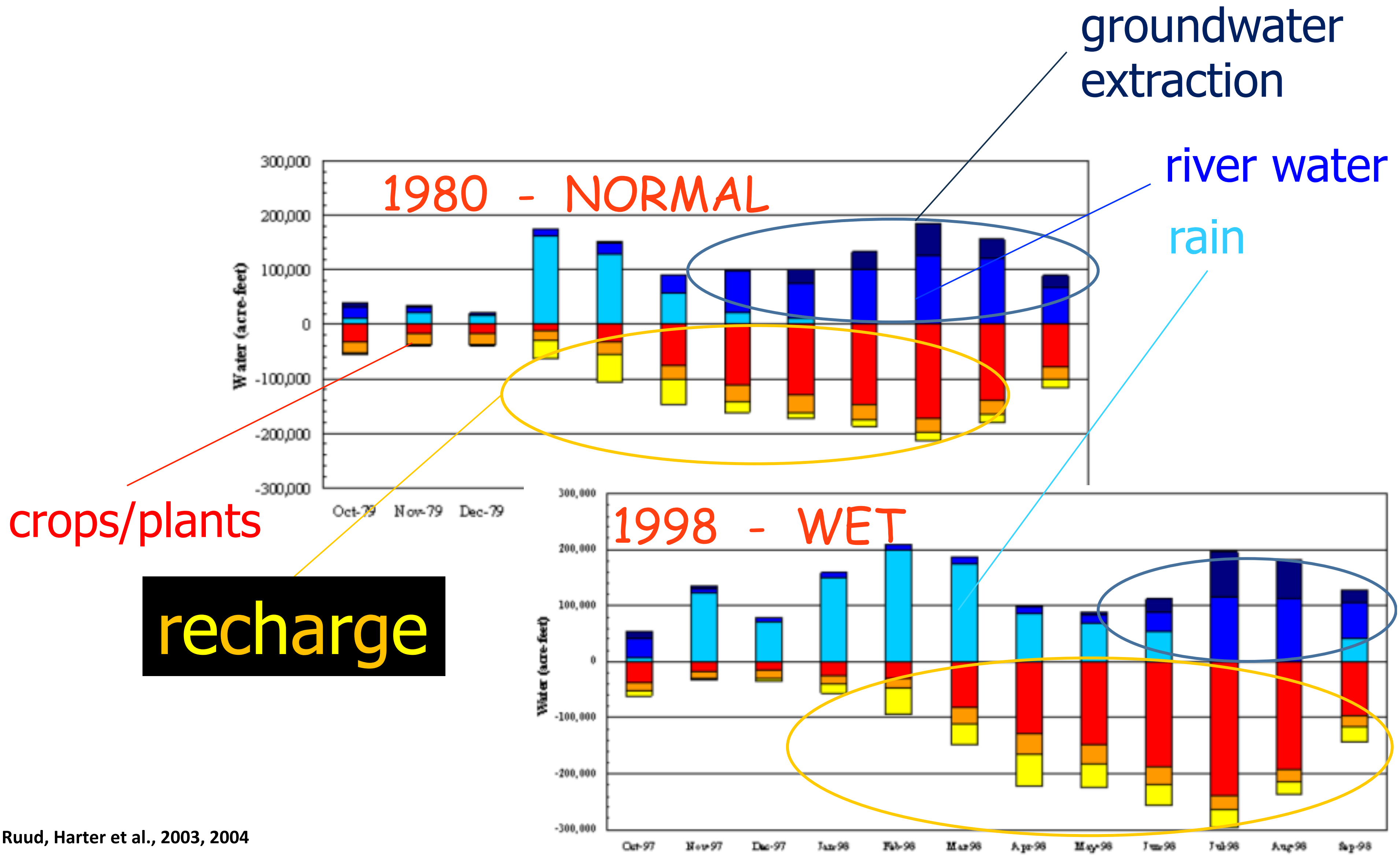

Ruud, Harter et al., 2003, 2004

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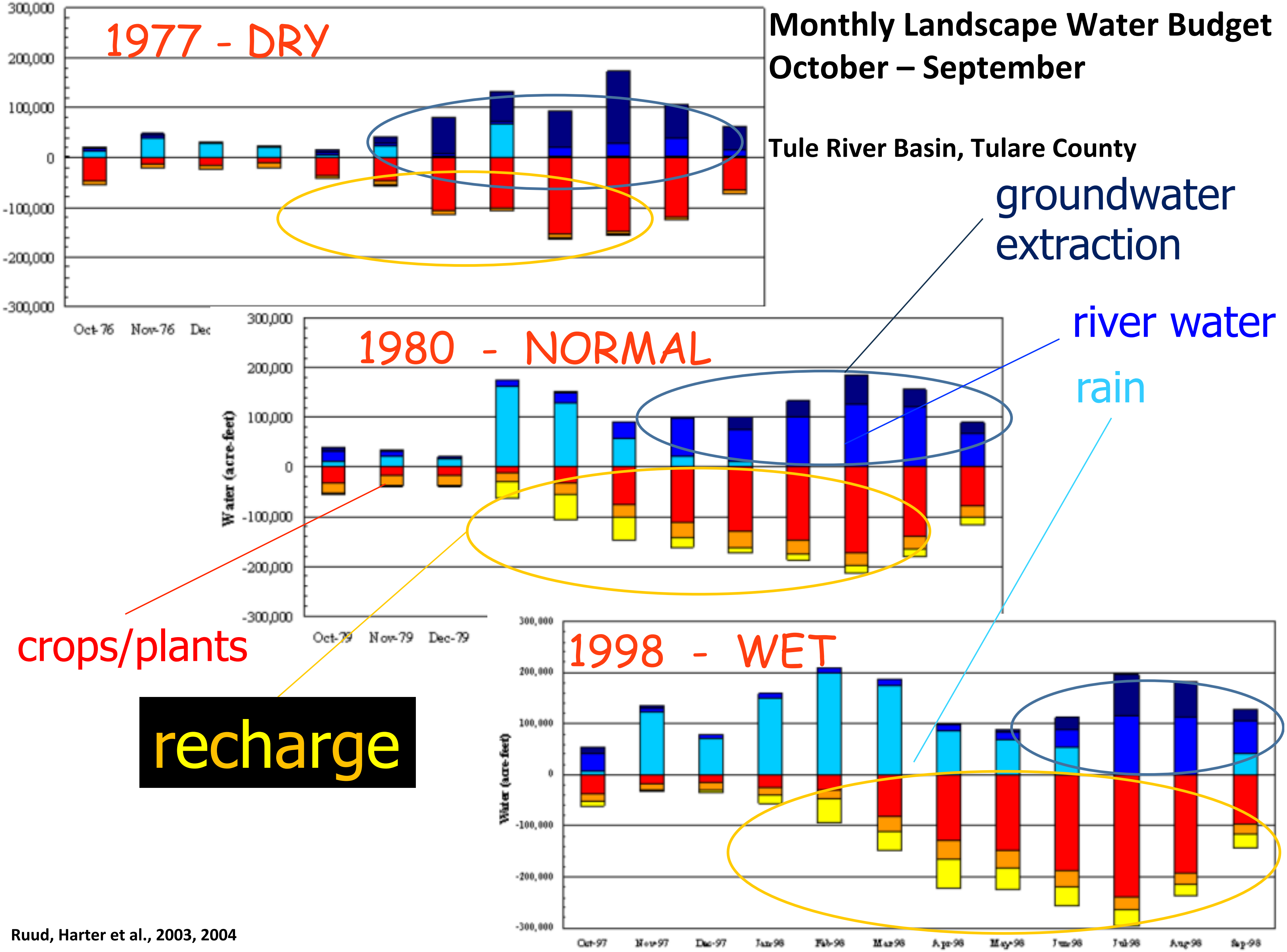
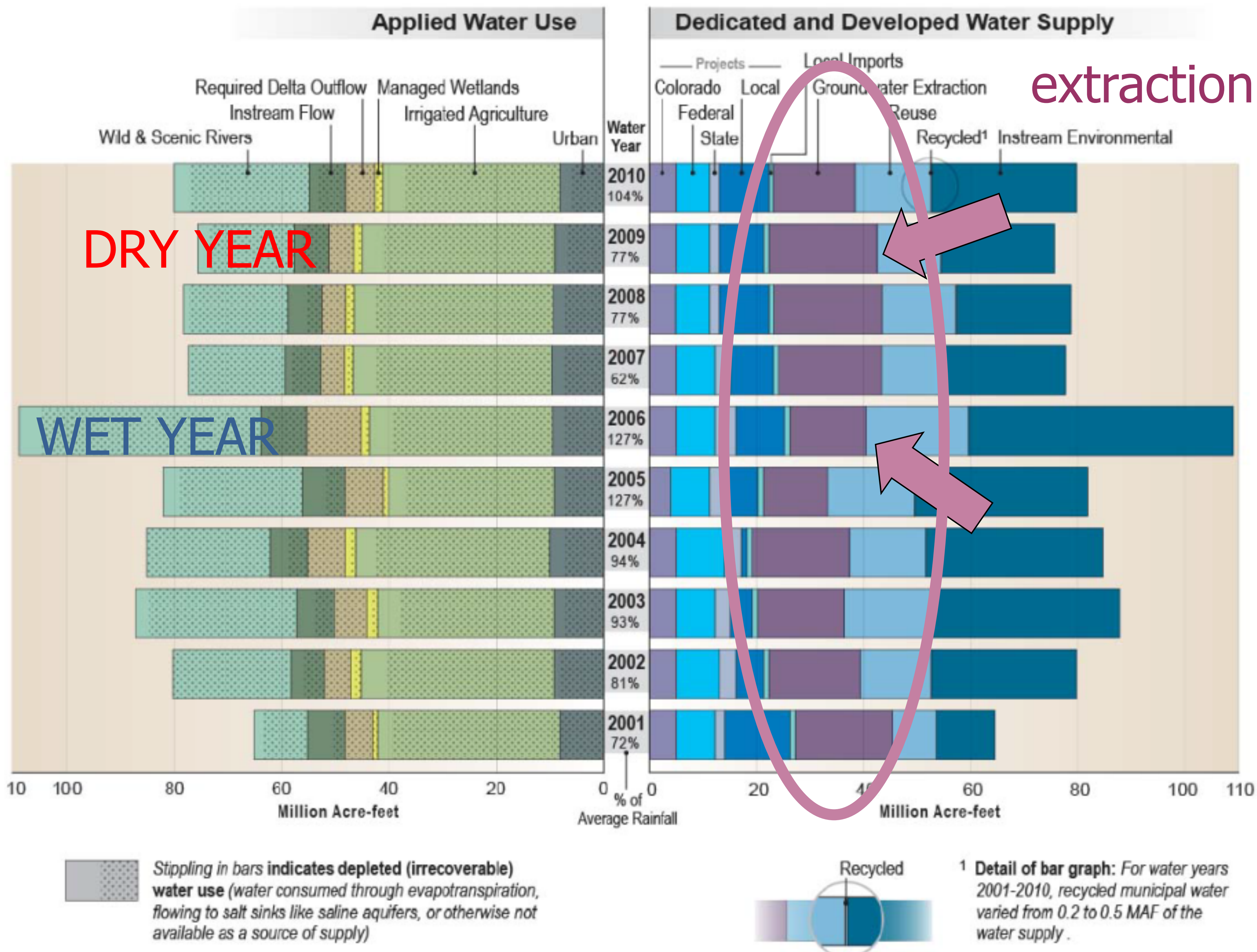
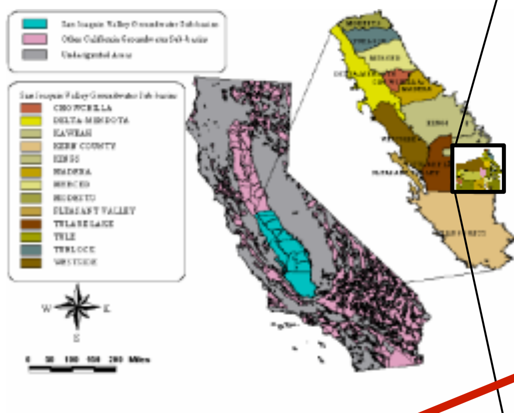


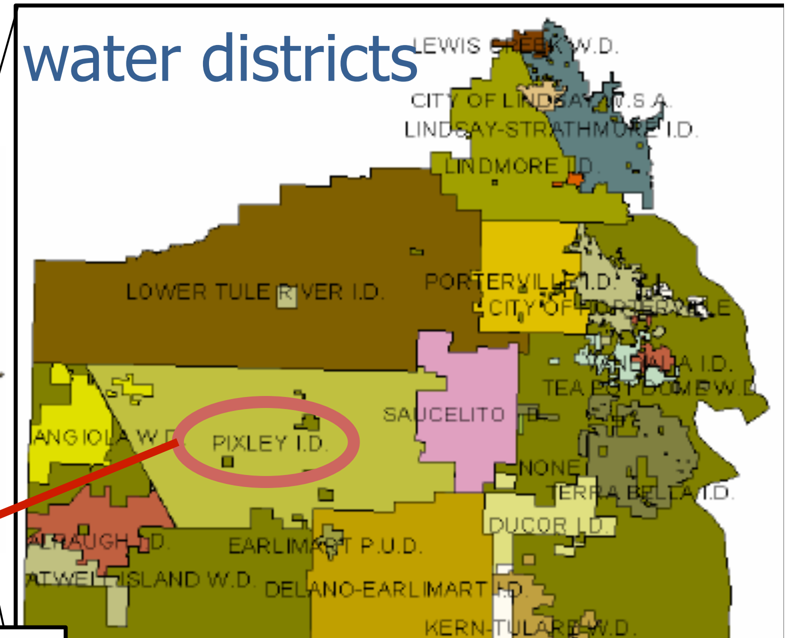
Ruud, Harter et al., 2003, 2004

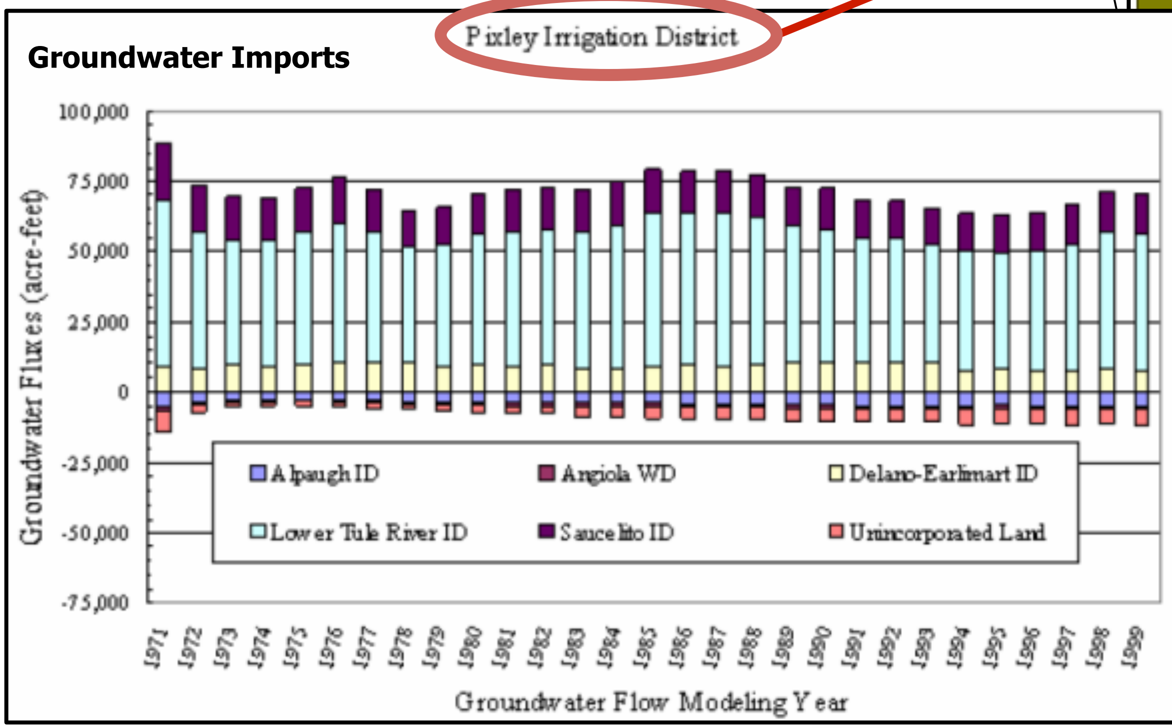


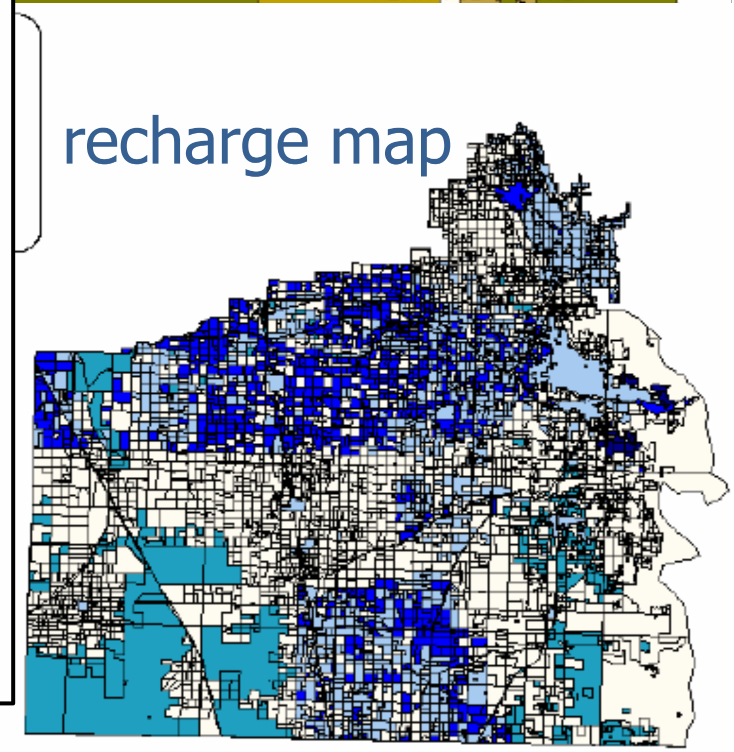
From: DWR California Water Plan 2013 - Draft (Bulletin 160-2013)

Estimating Groundwater Flows Across Subbasin / Political Boundaries



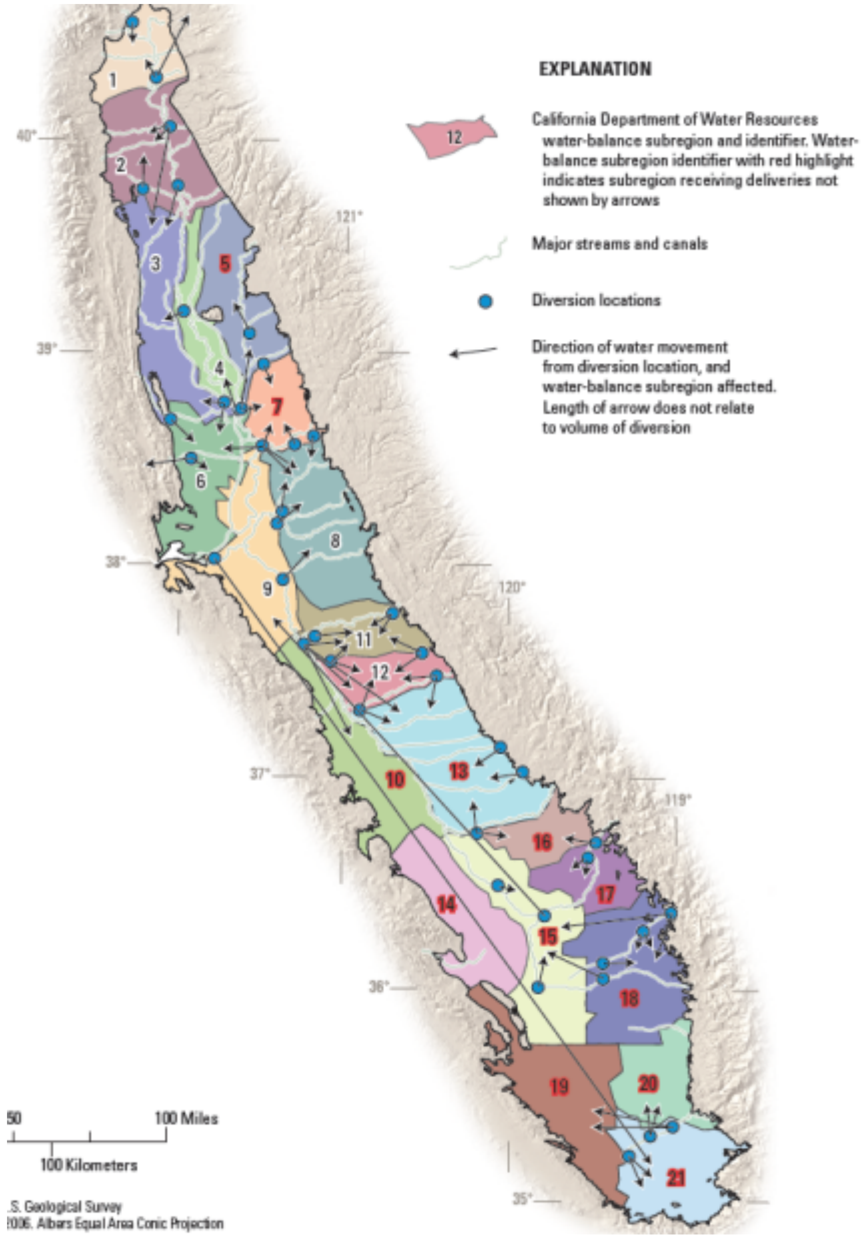






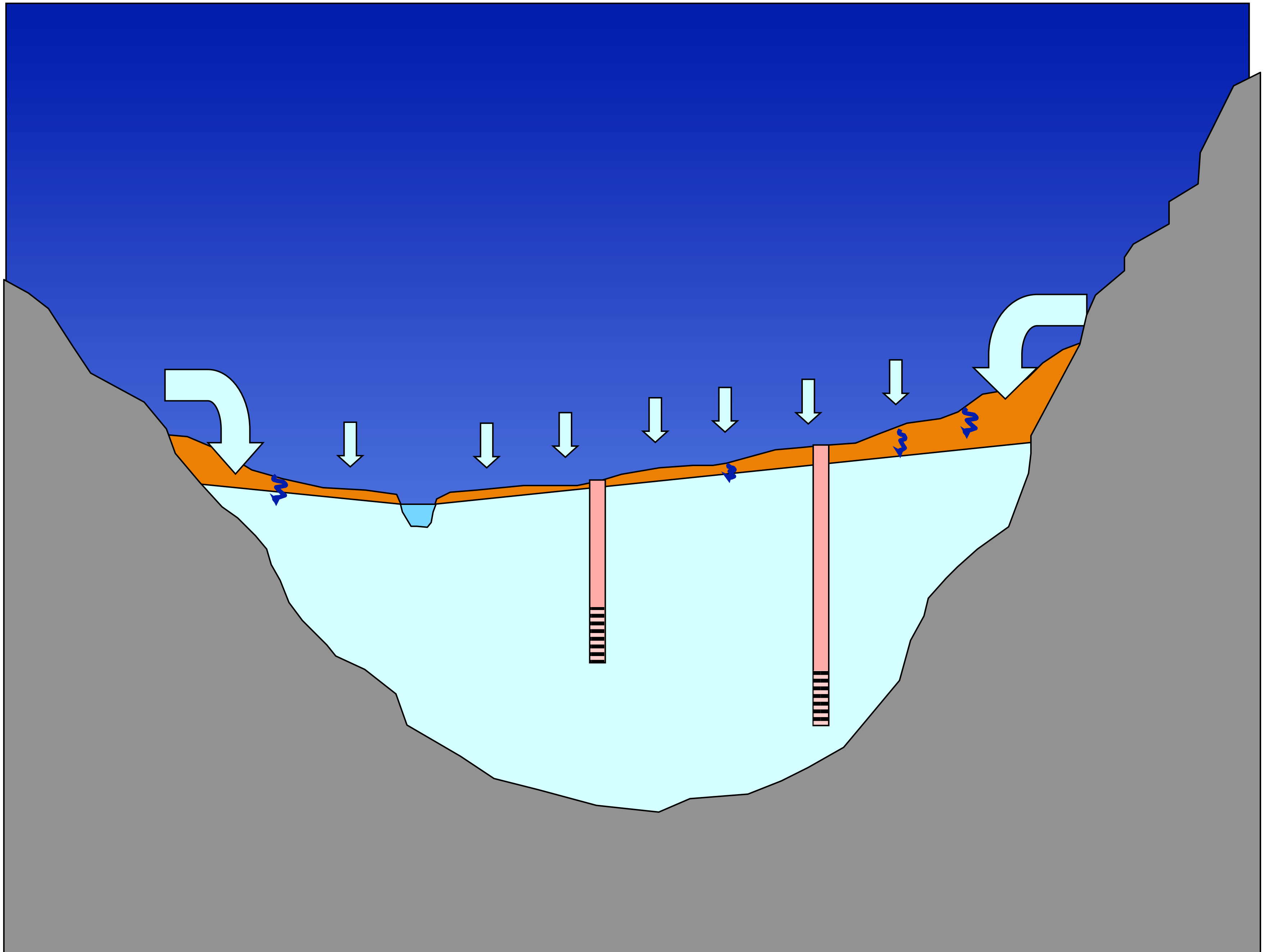
Ruud et al,. 2003; http://groundwater.ucdavis.edu/files/136420.pdf

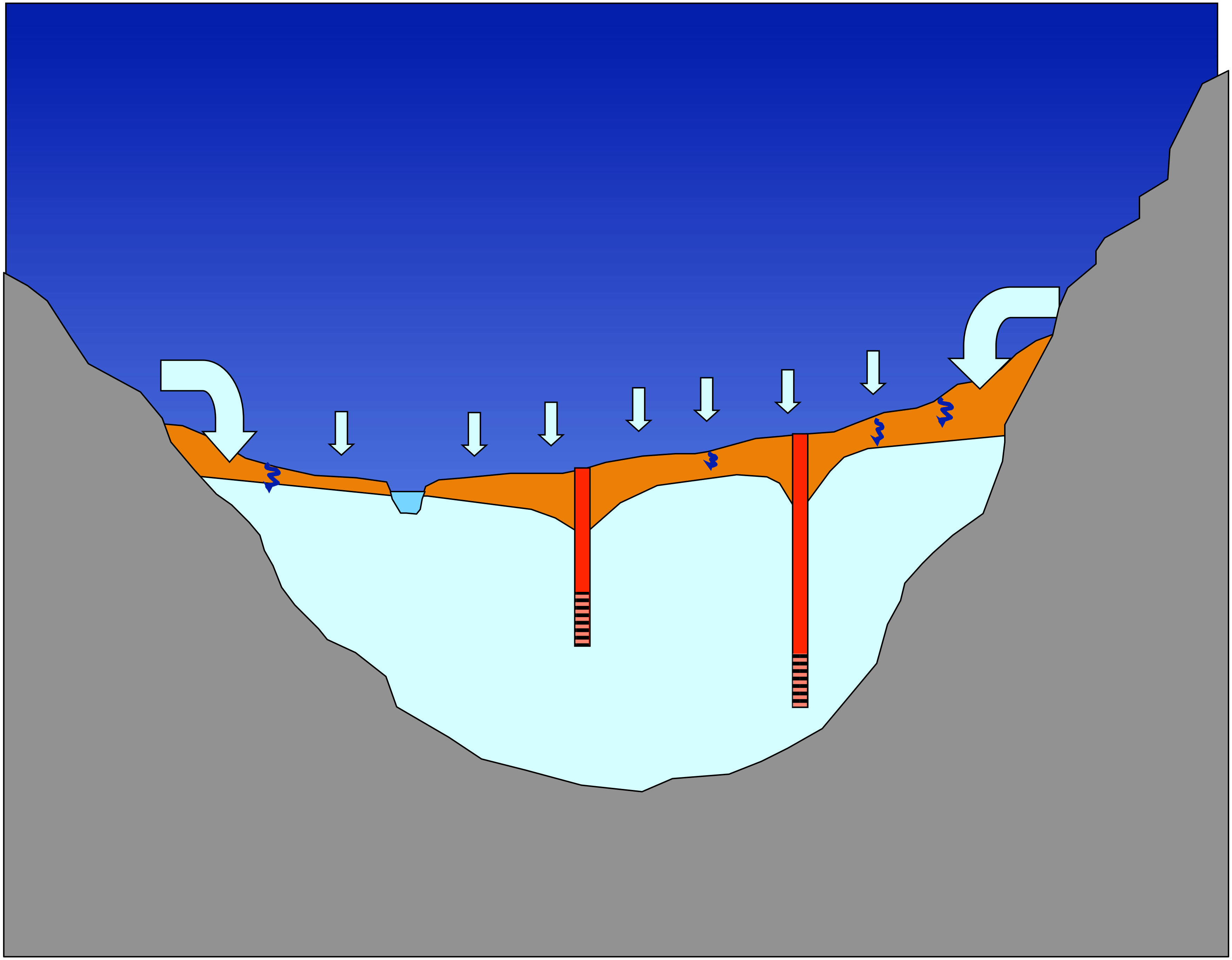
Interbasin Flows in the Central Valley

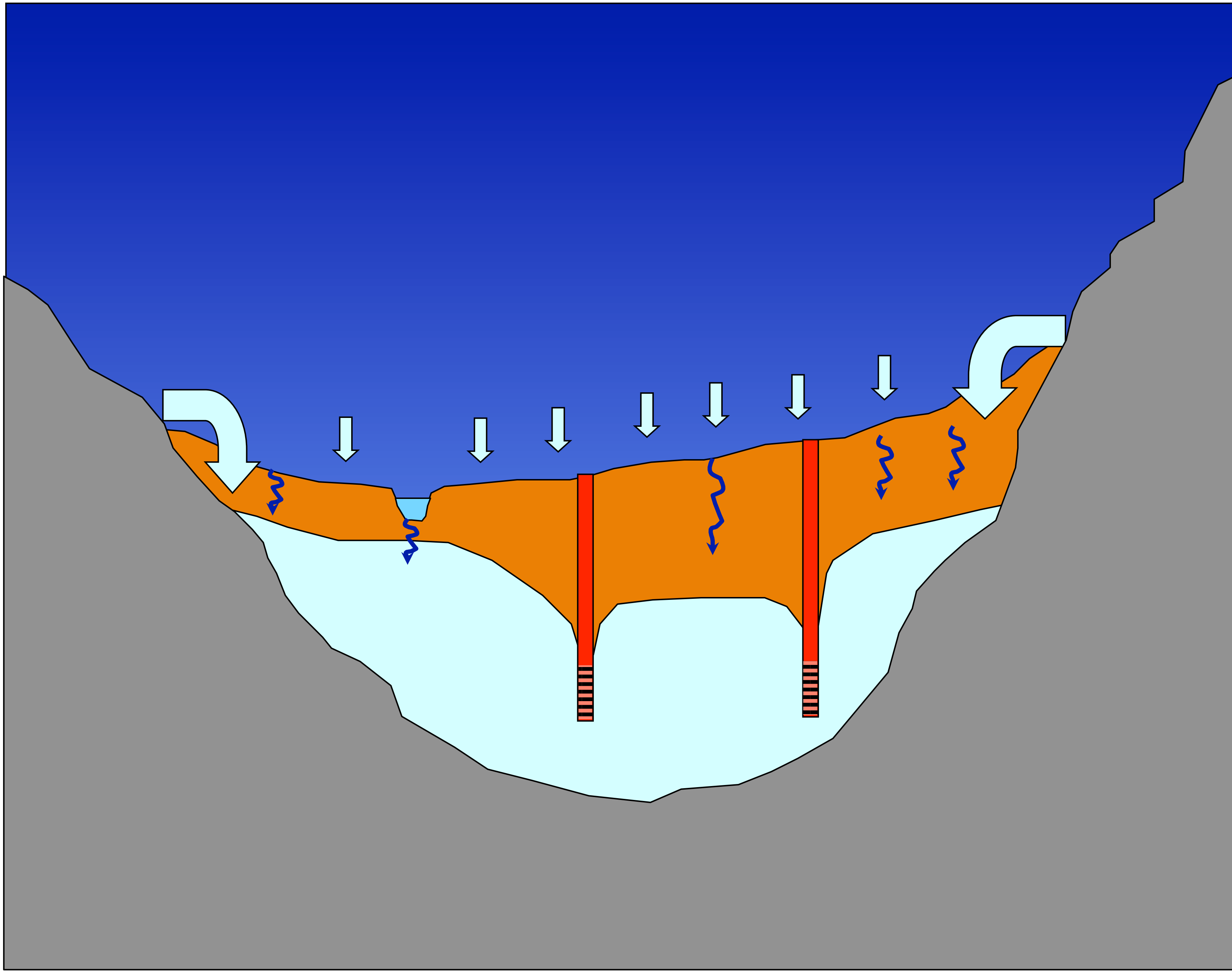


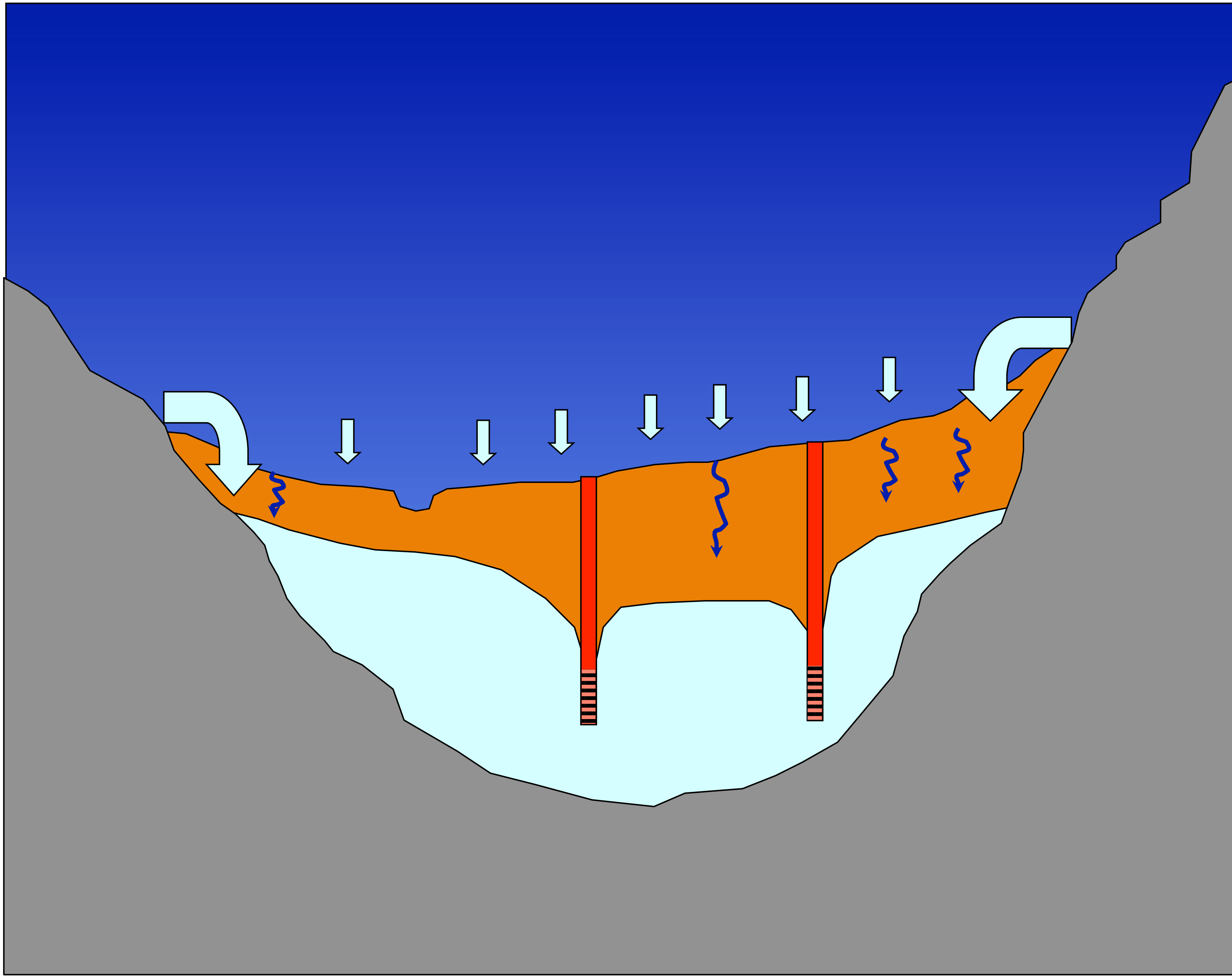
Subregion	Average Annual Interbasin Flow 1980-1993 (TAF/yr)	
		CVHM
1		-312.1
2		44.2
3		-225.8
4		558.6
5		-184.9
6		-47.2
7		19.4
8		50.3
9		237.7
10		-79.9
11		-54.9
12		-73.4
13		-0.8
14		85.2
15		621.8
16		-196.1
17		-176.8
18		-20.1
19		212.2
20		-164.4
21		-292.9
SAC TOTAL		140.2
SJ TOTAL		-209
Tulare TOTAL		68.9
CV TOTAL		0

Zikalala & Lund, UC Davis M.S. Thesis, 2012

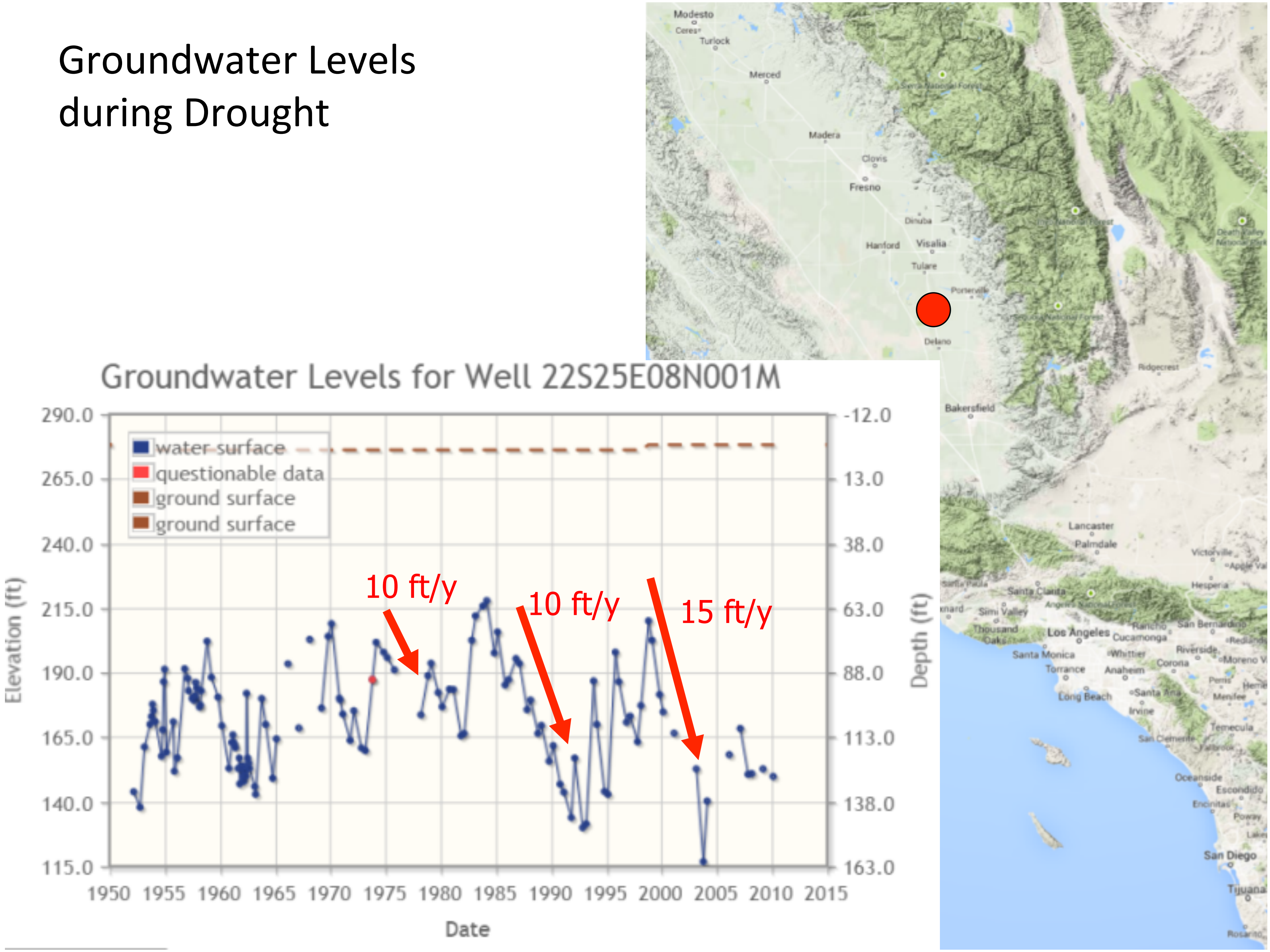








Groundwater Levels during Drought



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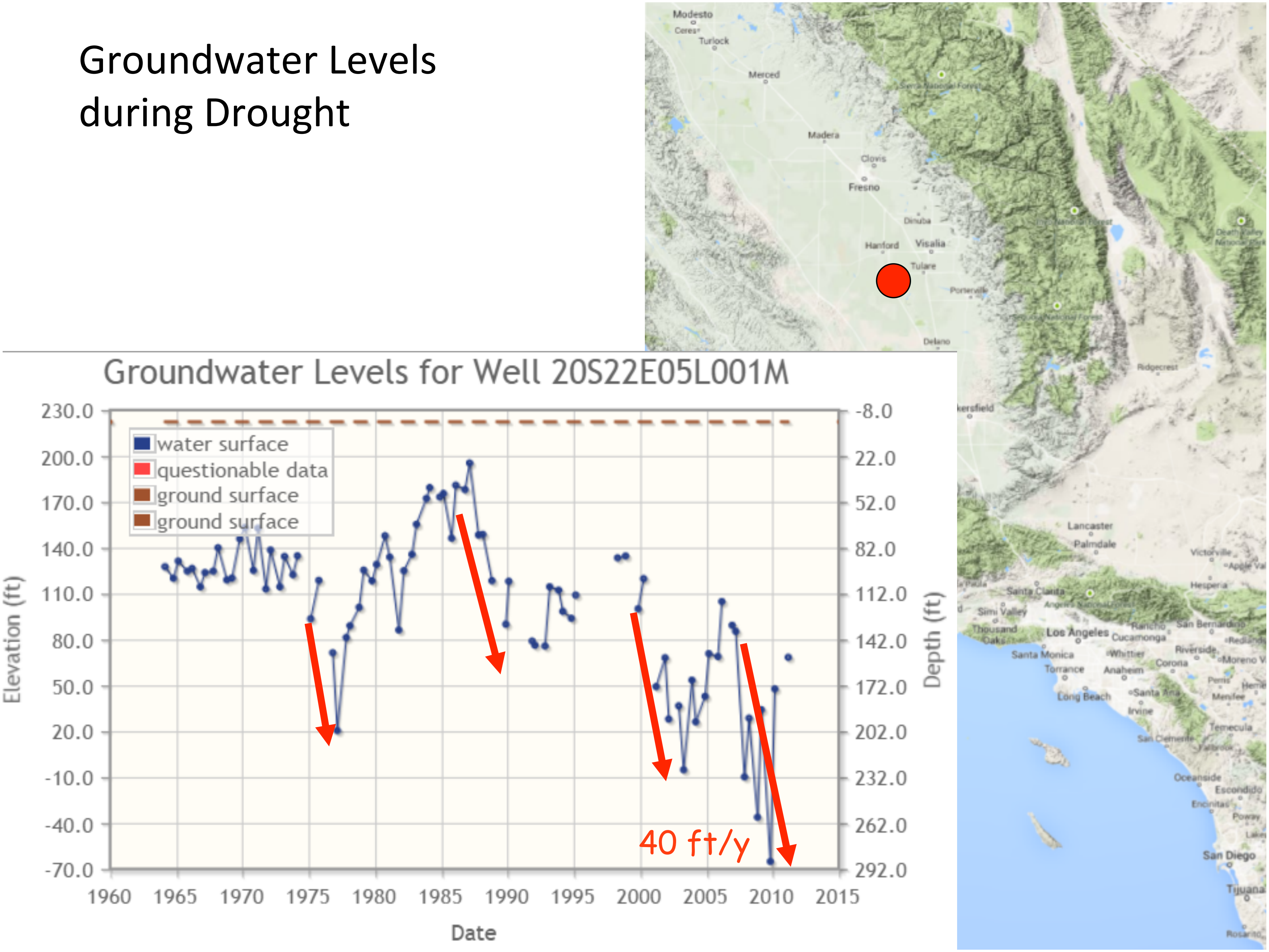
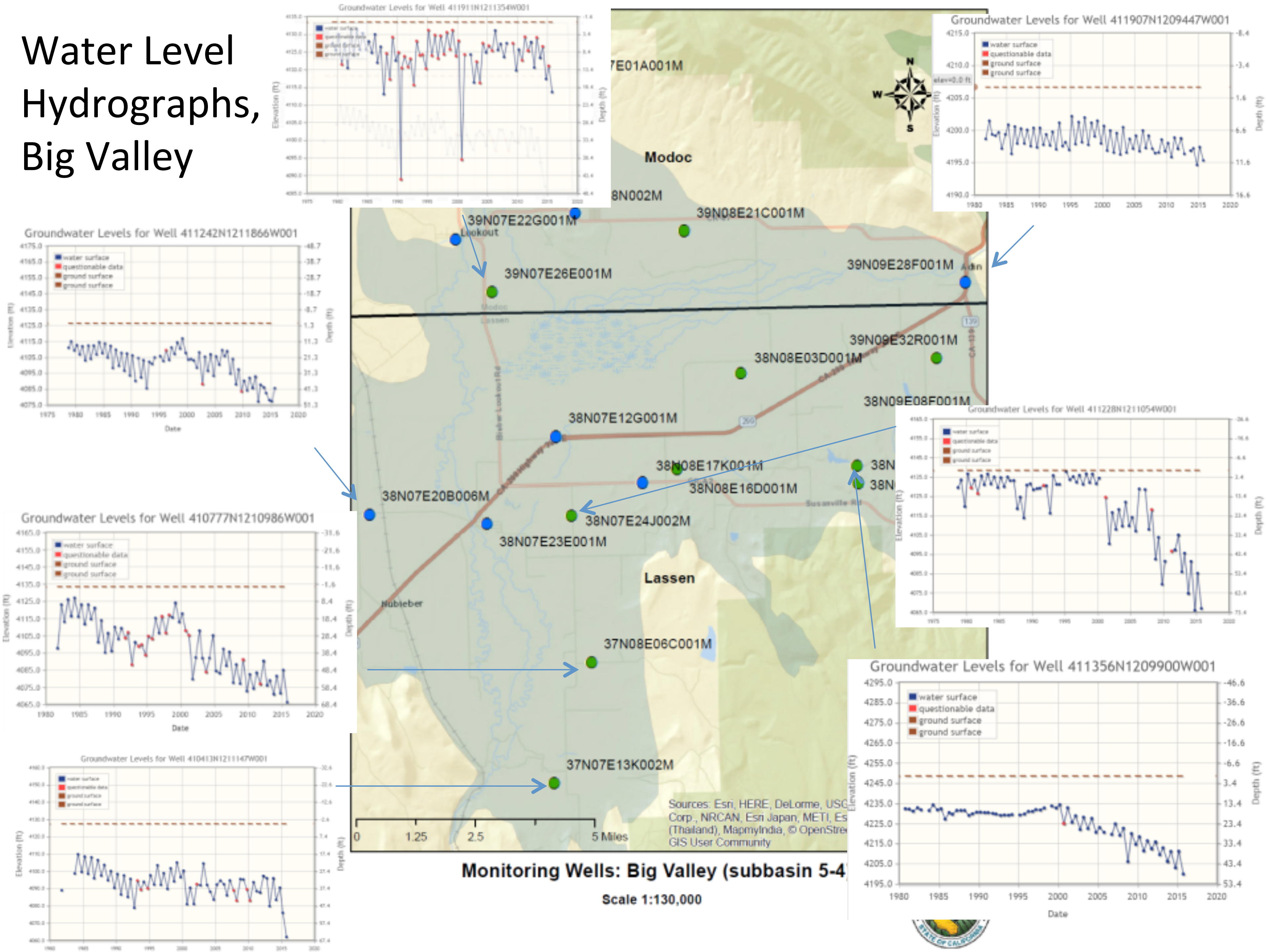
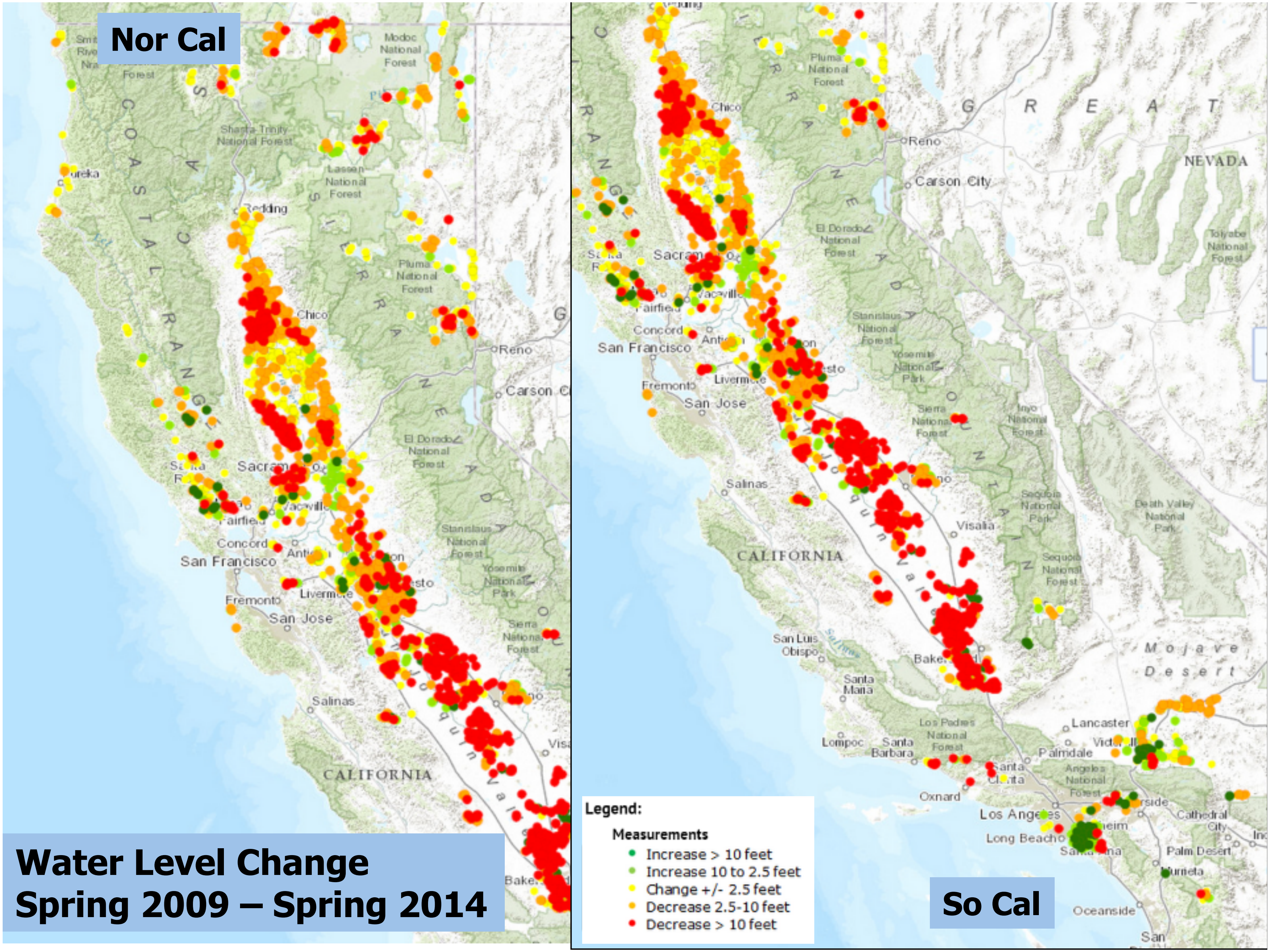


Water Level Hydrographs, Big Valley

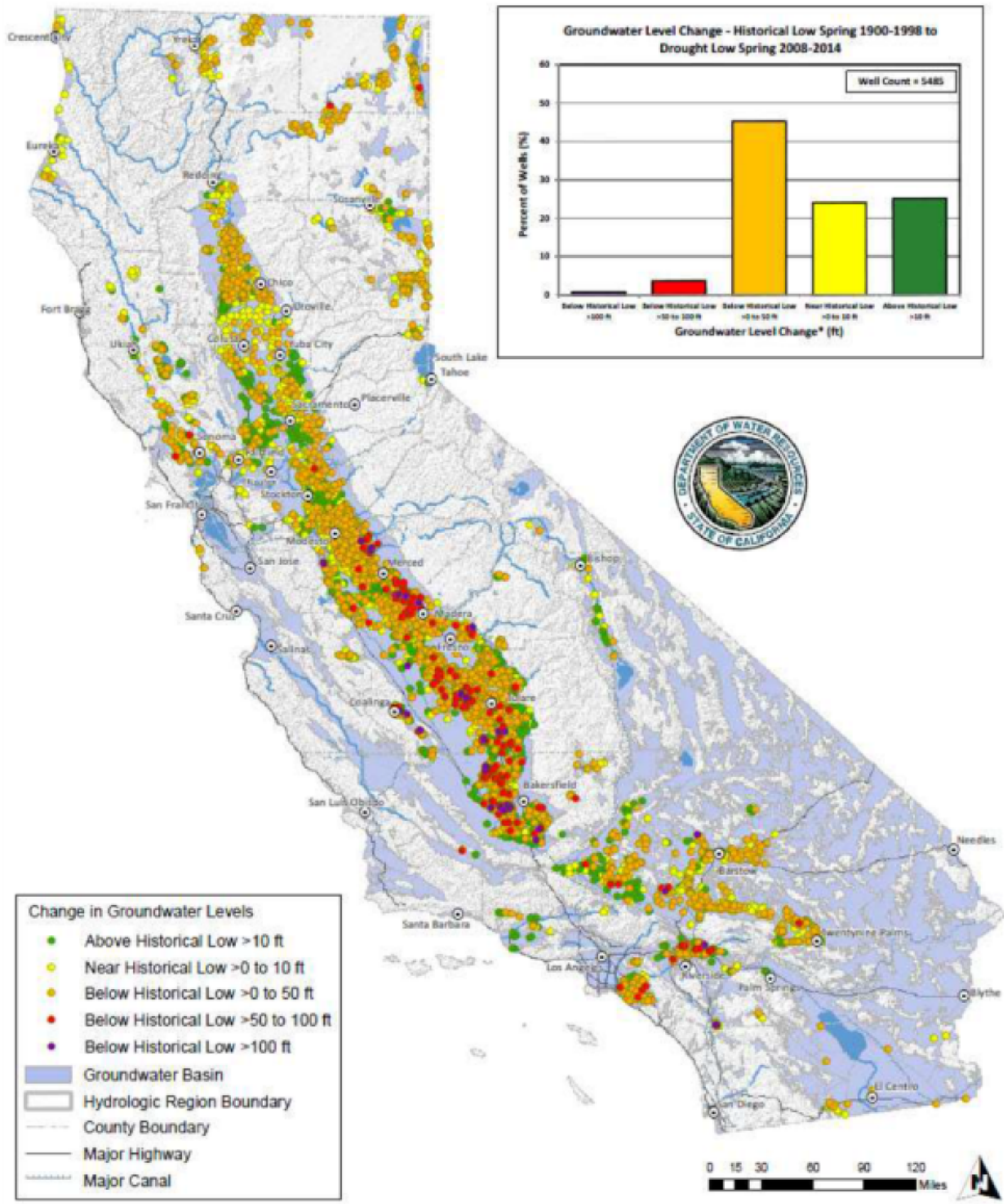



Nor Cal
So Cal
Water Level Change
Spring 2009 – Spring 2014
Legend:
Measurements
Increase > 10 feet
Increase 10 to 2.5 feet
Change +/- 2.5 feet
Decrease 2.5-10 feet
Decrease > 10 feet

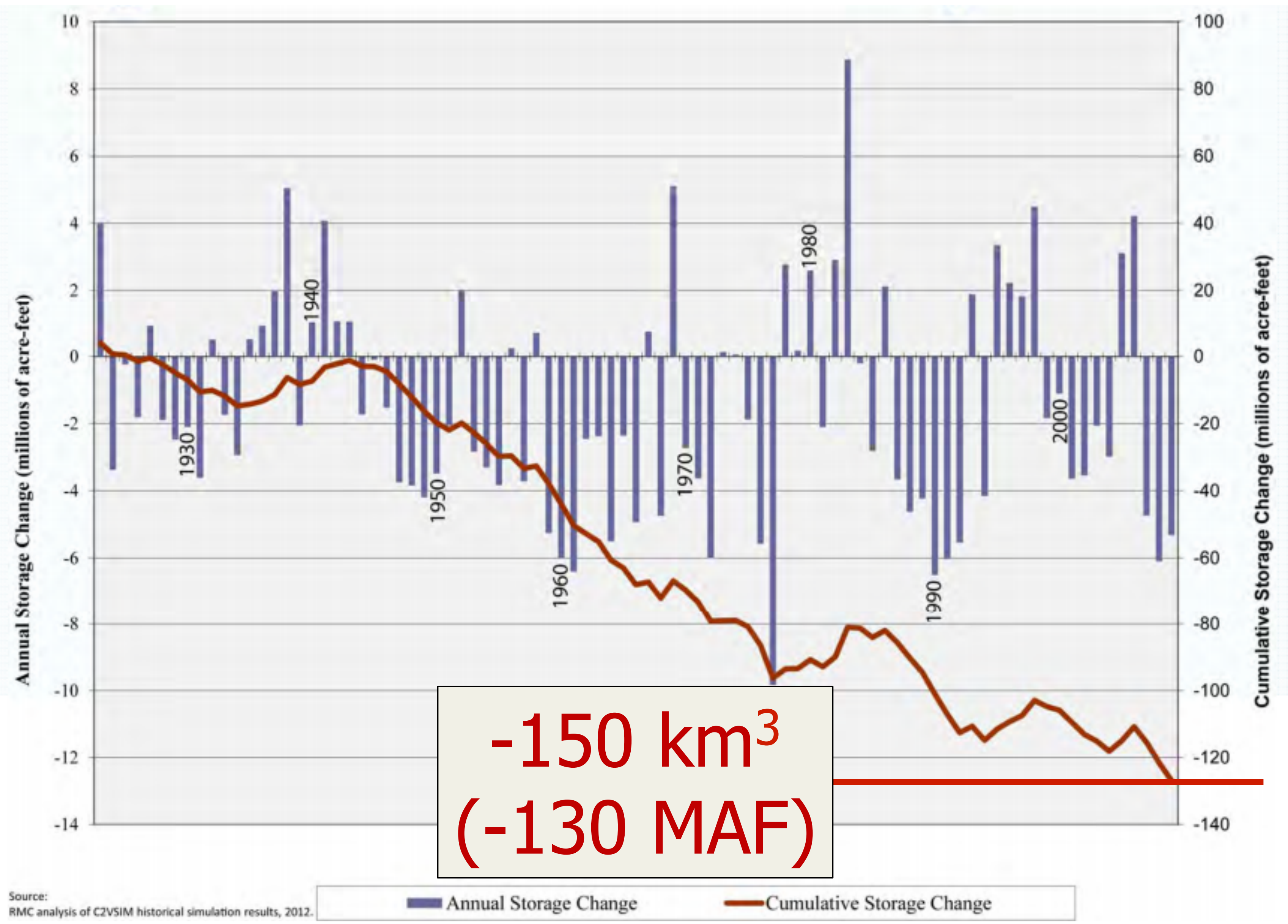
Change in Groundwater Level

Record Low 20th Century to Drought 2008-2014

http://www.water.ca.gov/waterconditions/docs/Drought_Response-Groundwater_Basins_April30_Final_BC.pdf



Change in Groundwater Storage in the Central Valley, 1920 - 2010



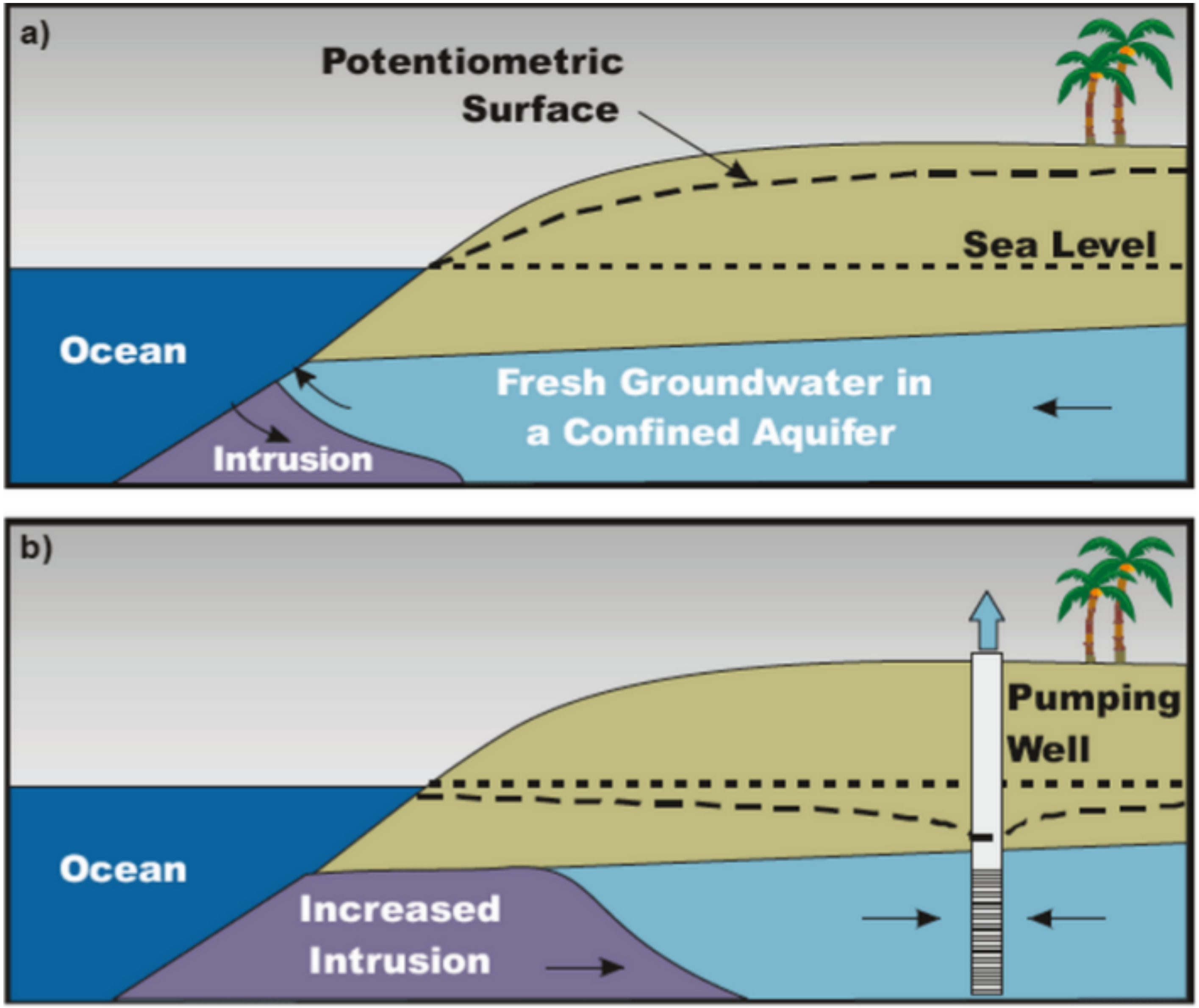
from: Lester Snow, CA Water Foundation

Consequences of Groundwater Overdraft…

- Seawater intrusion
- Increased pumping cost & cost of drilling new wells
- Land subsidence
- Water quality degradation
- Surface water depletion
- Impact to groundwater dependent ecosystems

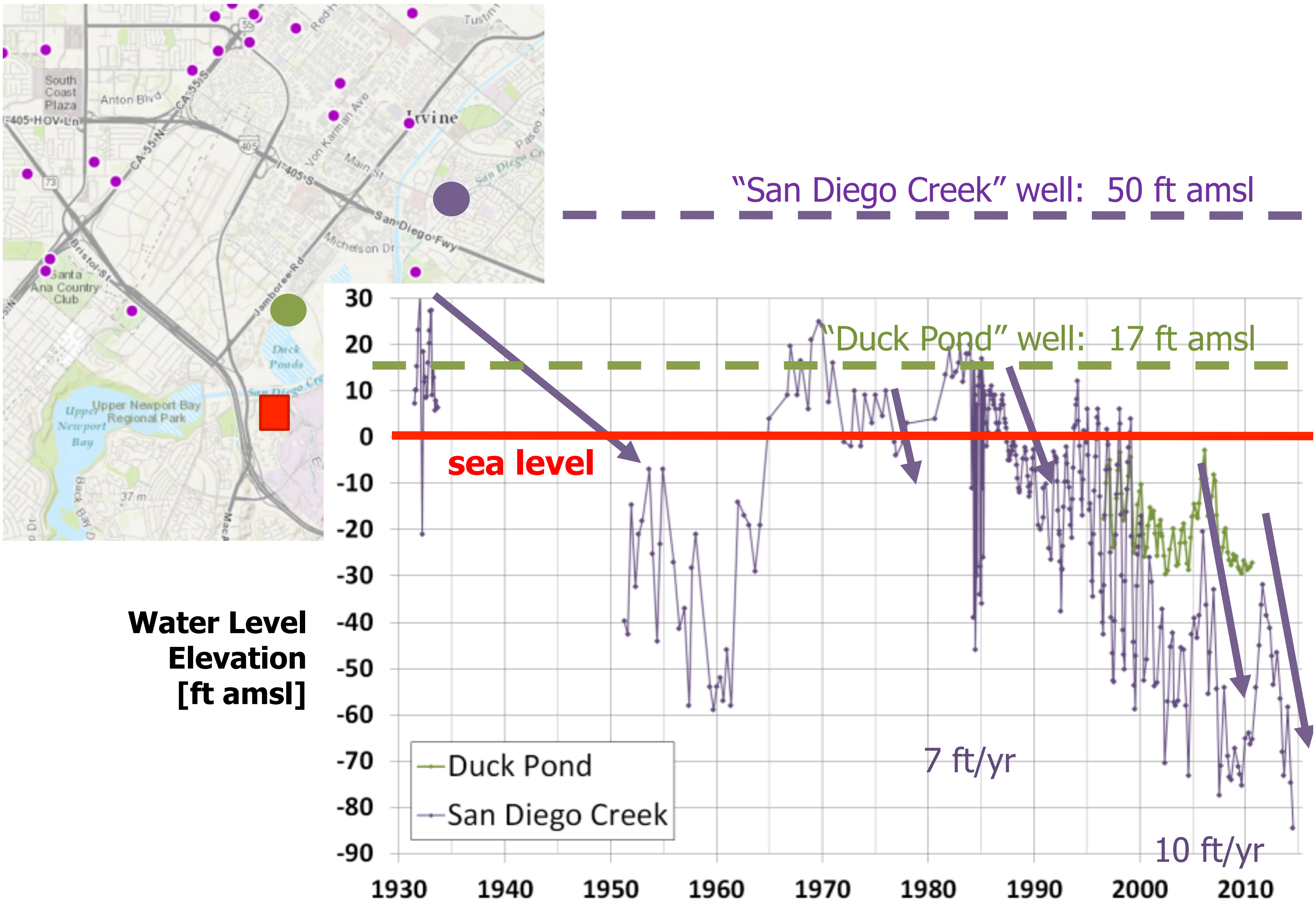
…Long Before Running Out of Groundwater!

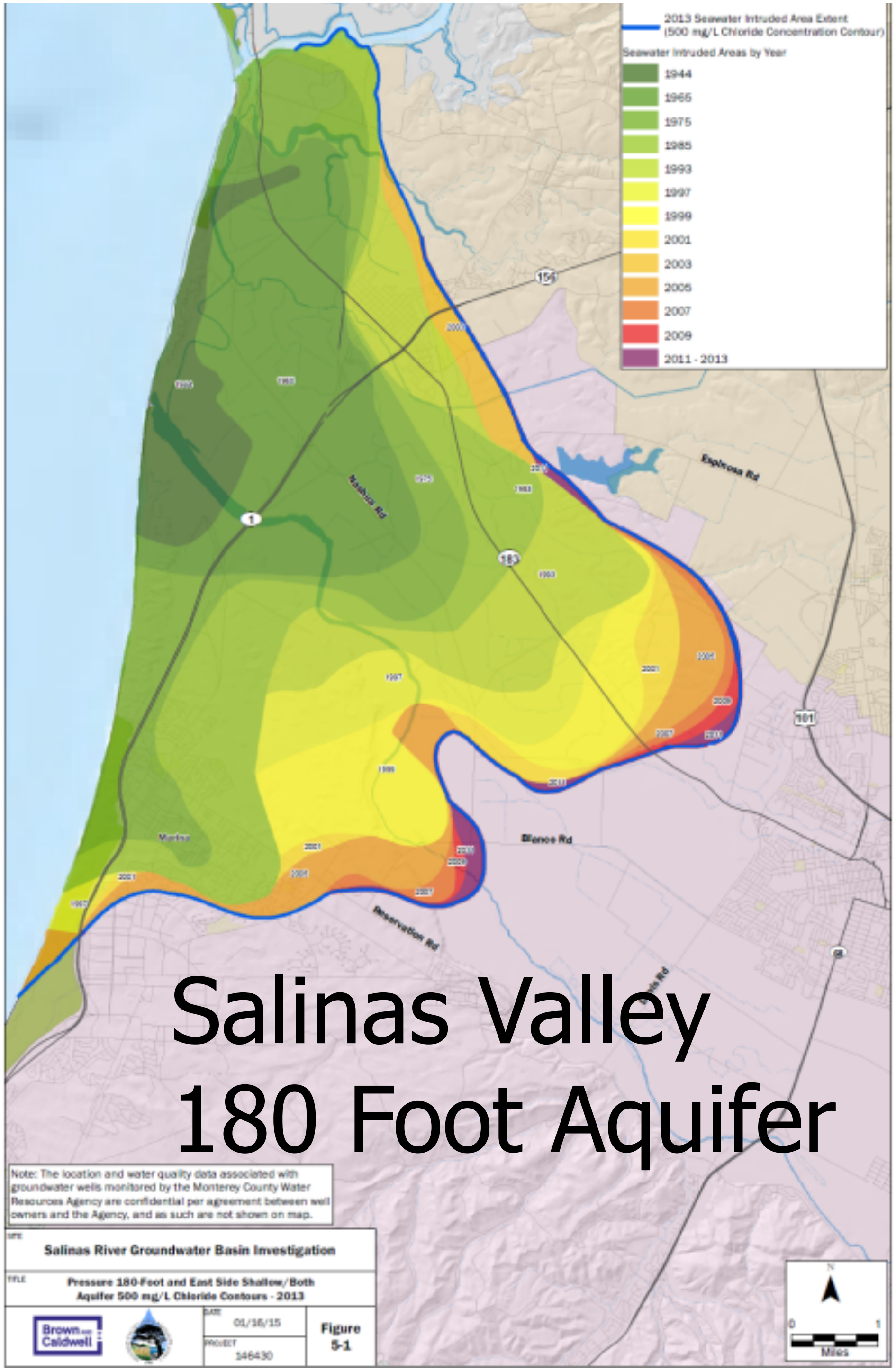
Seawater Intrusion

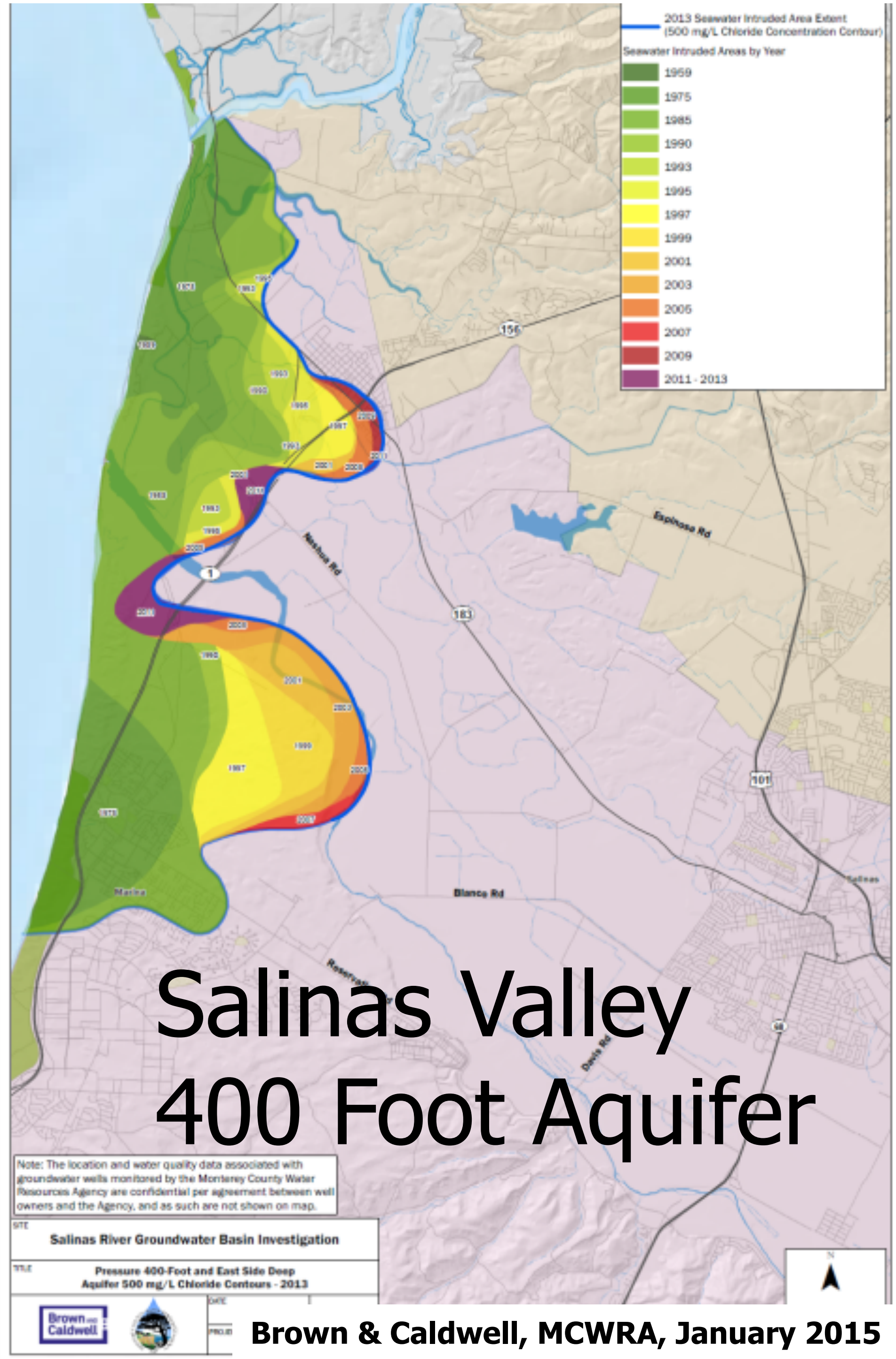


Ted Johnson, Water Replenishment District, 2007

Groundwater Levels during Drought: Irvine

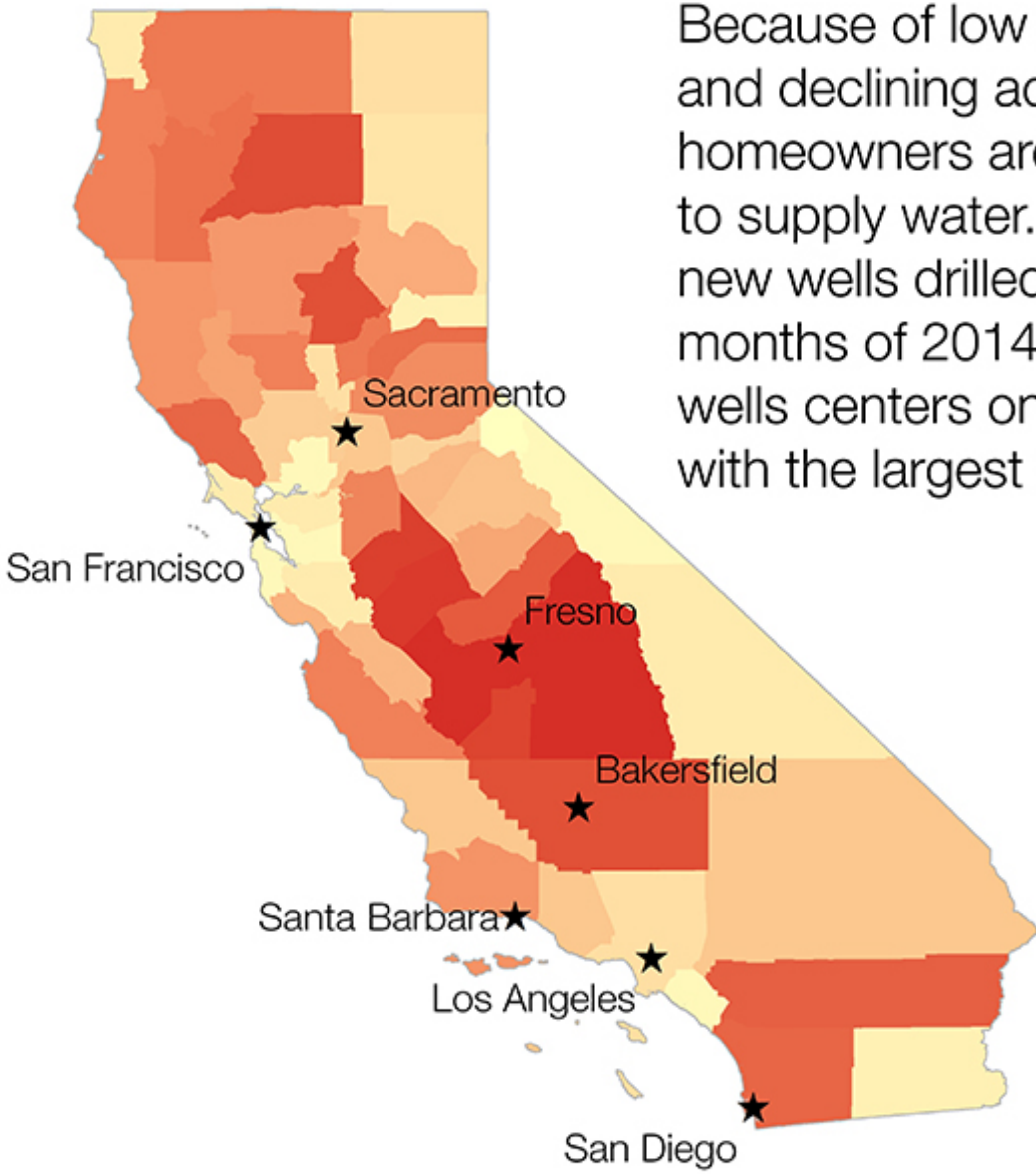


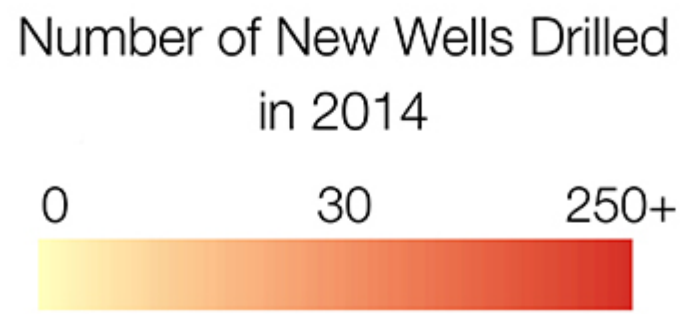




Brown & Caldwell, MCWRA, January 2015

Because of low river flows, depleted reservoirs, and declining aquifers, farmers and homeowners are drilling more and deeper wells to supply water. This map shows the number of new wells drilled by county during the first nine months of 2014. The largest increase in new wells centers on the Central Valley, coinciding with the largest declines in the water table.



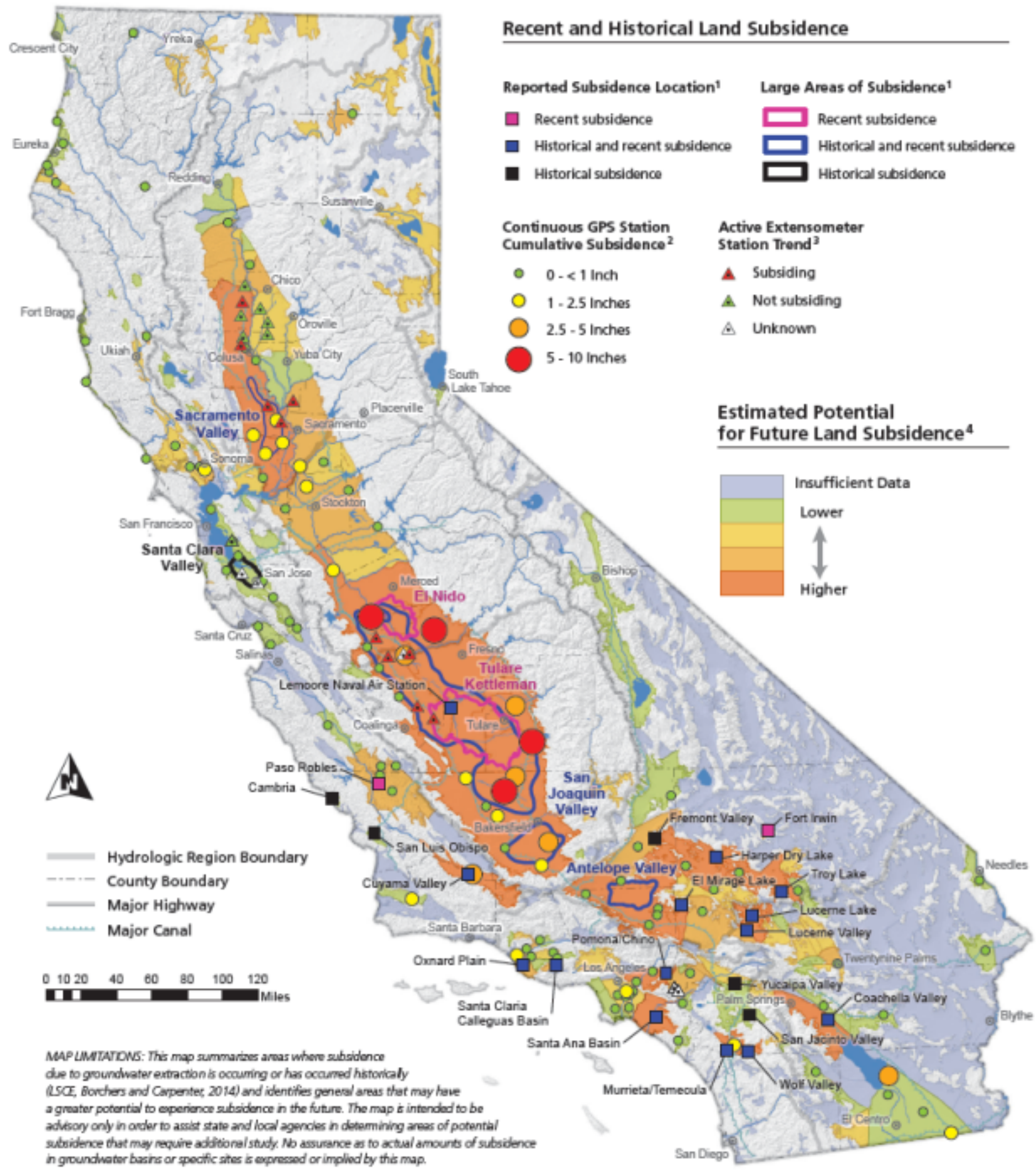


urces: California Department of Water Resources,
lifornia Statewide Groundwater Elevation Monitoring Program

circle of blue


Randi Lynn Beach / Huffington Post

Land Subsidence



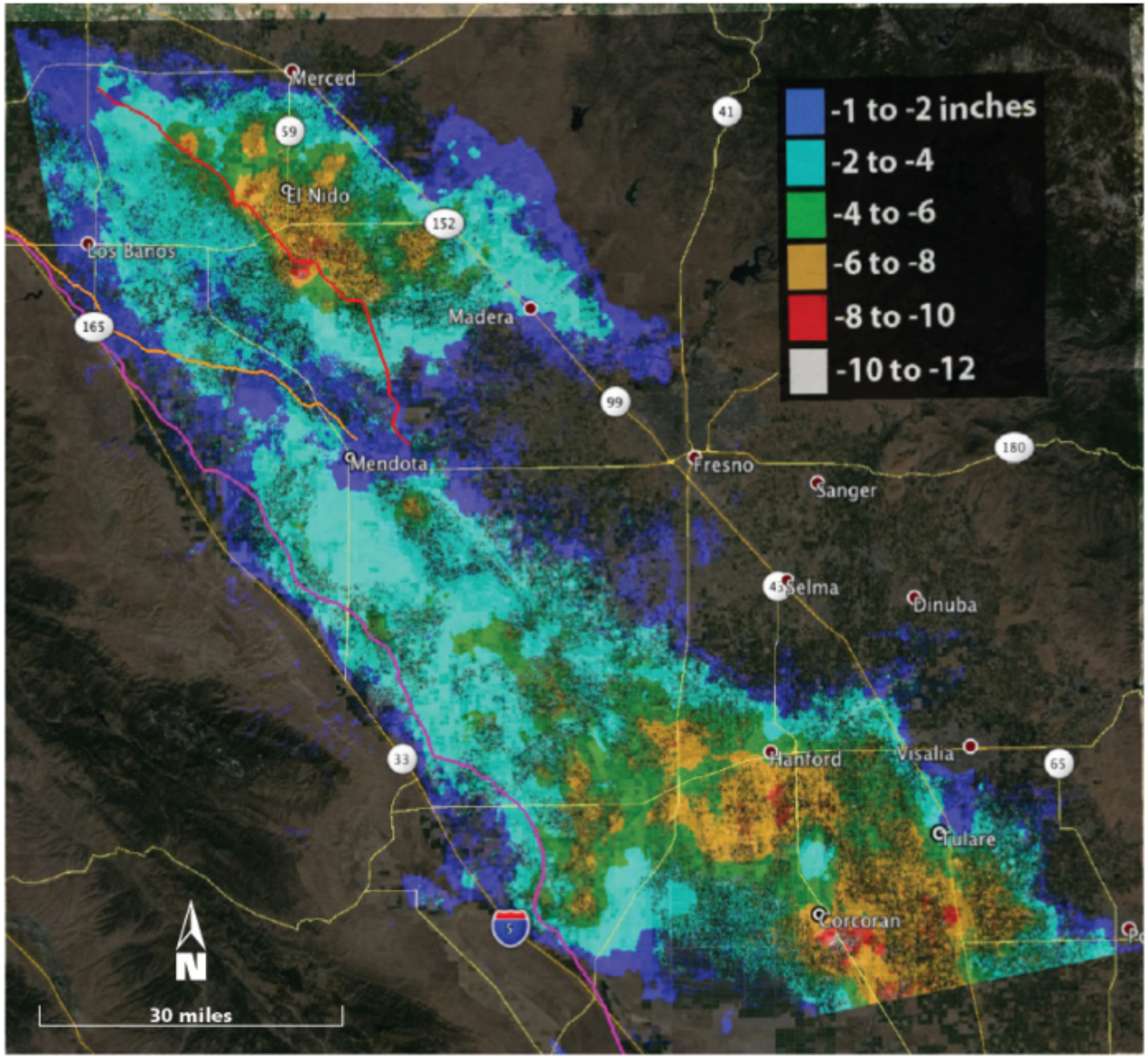
California Department of Water Resources;
Drought Response Update Fall 2014

Land Subsidence: San Joaquin Valley

Subsidence, May 3 - October 18, 2014
Measured by Radarsat-2, processed by
Jet Propulsion Laboratory

Legend
California Aqueduct
Delta-Mendota Canal
Eastside Bypass

California Department of Water Resources;
Drought Response Update Fall 2014




M.C. Rains et al., 2006 and 2008


M.C. Rains et al., 2006 and 2008

California Groundwater Rights: Background

- Correlative Rights Doctrine – safe yield of groundwater basin shared by overlying users
  - Katz v. Wilkinshaw, 1908
- California constitutional mandate for beneficial use (1928)
- Special districts (20 different types, about 2,300 districts)
  - Water districts, irrigation districts, private water companies, reclamation districts, water conservation districts, water replenishment districts, water storage districts, etc.
- County police power – controls groundwater exports
  - Baldwin vs. Tehama County, 1994
- The Courts: basin adjudication / "physical solution" – controls extraction
  - Many Southern California (sub)basins, mid 20th century
  - City of Barstow vs. Mojave Water Agency, 2000:
    - Right of water users to negotiate physical "equitable, practical" solution, regardless of water rights
    - Individual water rights holders cannot be forced into a voluntary agreement

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    - Right of water users to negotiate physical "equitable, practical" solution, regardless of water rights
    - Individual water rights holders cannot be forced into a voluntary agreement
- State groundwater management:
  - Voluntary local groundwater management plans: AB 3030 (1992)
  - Financial incentives for local groundwater management: SB 1938 (2002)
  - **Sustainable Groundwater Management Act of 2014: mandatory & expanded local control**

Sustainable Groundwater Management Act of 2014

SEC. 2.

Section 113 is added to the Water Code, to read:

113.

It is the policy of the state that **groundwater resources be managed sustainably for long-term reliability and multiple economic, social, and environmental benefits** for current and future beneficial uses.

Sustainable groundwater **management is best achieved locally** through the development, implementation, and updating of plans and programs based on the best available science.

[emphasis added]

Sustainability = No "Undesirable Results"

10721. Unless the context otherwise requires, the following definitions govern the construction of this part:

(u) "Sustainable groundwater management" means the management and use of groundwater in a manner that can be maintained during the planning and implementation horizon without causing undesirable results.

(w) **"Undesirable result" means one or more of the following** effects caused by groundwater conditions occurring throughout the basin (Section 10721 (w)):

(1) **Chronic lowering of groundwater levels** indicating a significant and unreasonable depletion of supply if continued over the planning and implementation horizon. Overdraft during a period of drought is not sufficient to establish a chronic lowering of groundwater levels if extractions and recharge are managed as necessary to ensure that reductions in groundwater levels or storage during a period of drought are offset by increases in groundwater levels or storage during other periods.

(2) Significant and unreasonable **reduction of groundwater storage**.

(3) Significant and unreasonable **seawater intrusion**.

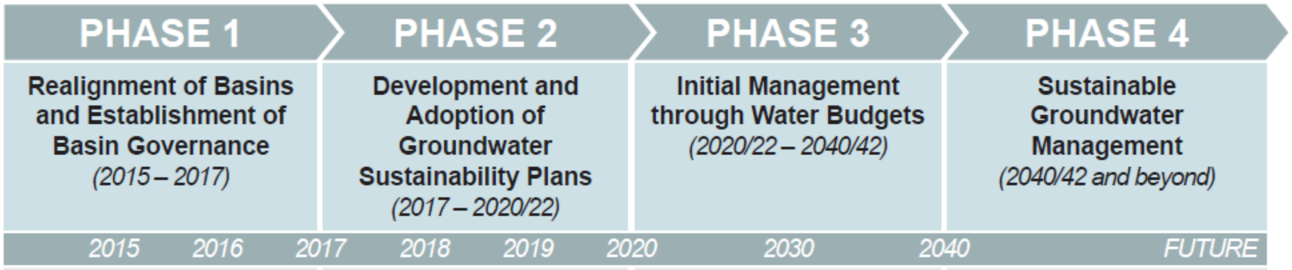
(4) Significant and unreasonable **degraded water quality**, including the migration of contaminant plumes that impair water supplies.

(5) Significant and unreasonable **land subsidence** that substantially interferes with surface land uses.

(6) **Surface water depletions** that have significant and unreasonable adverse impacts on beneficial uses of the surface water.

[emphasis added]

So What Exactly Will Happen?



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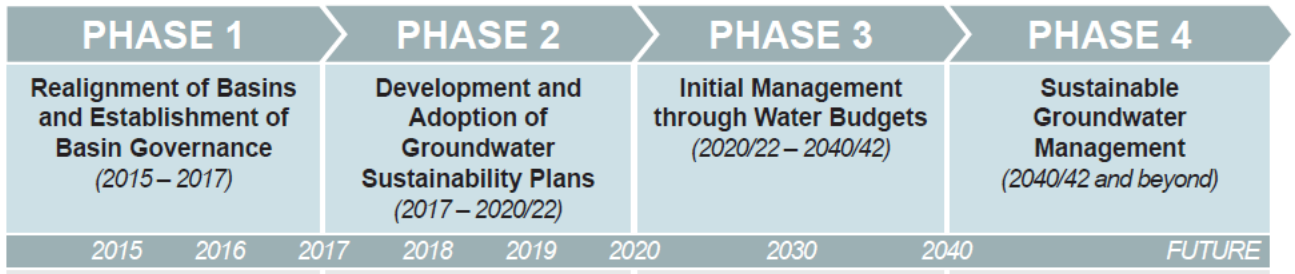
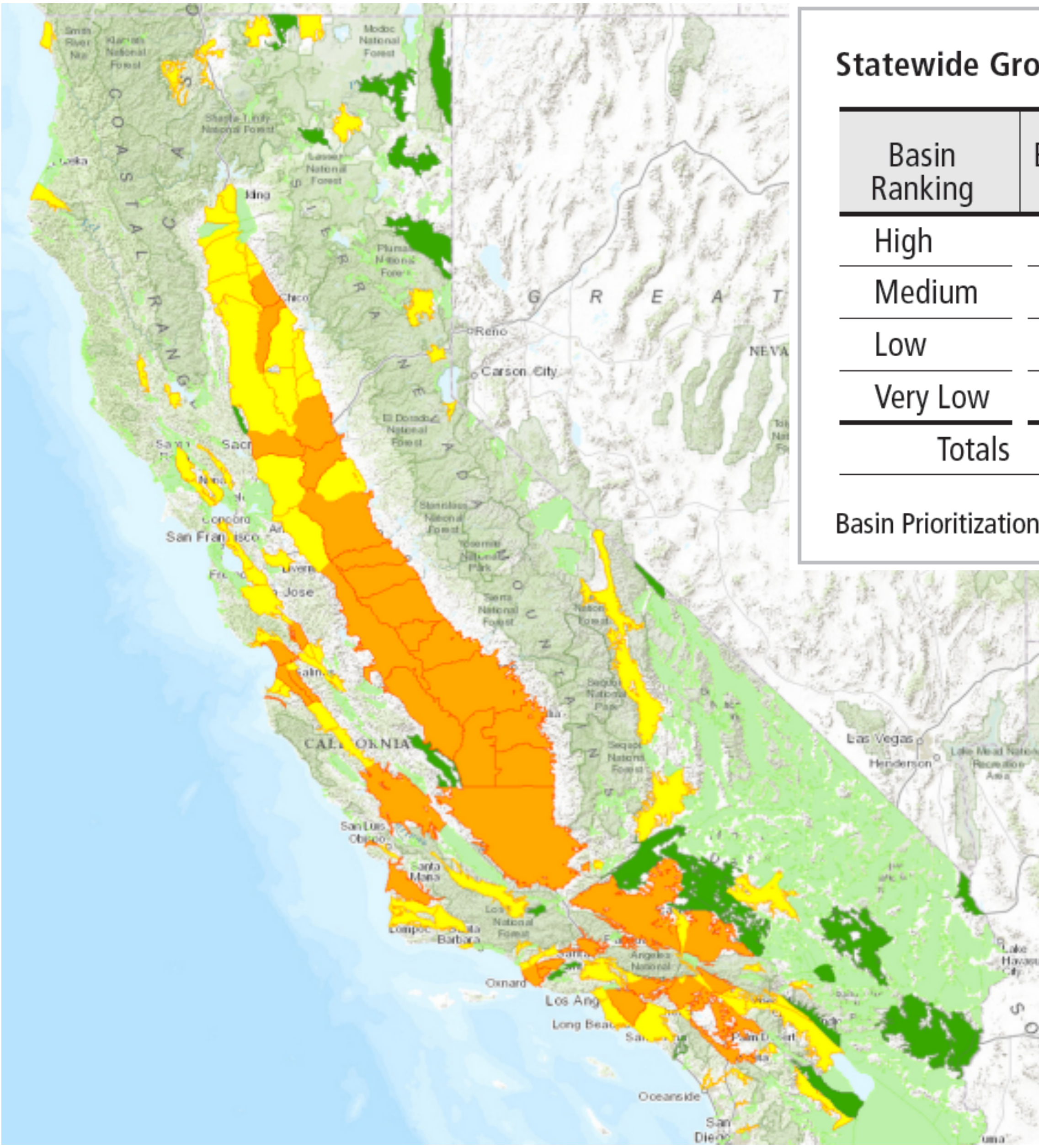


- **First Step: forming a Groundwater Sustainability Agency (GSA)**
  - By June 2017

Medium and High Priority Groundwater Basins



Statewide Groundwater Basin Prioritization Summary

Basin Ranking	Basin Count per Rank	Percent of Total for State	
		GW Use	Overlying Population
High	43	69%	47%
Medium	84	27%	41%
Low	27	3%	1%
Very Low	361	1%	11%
Totals	515	100%	100%

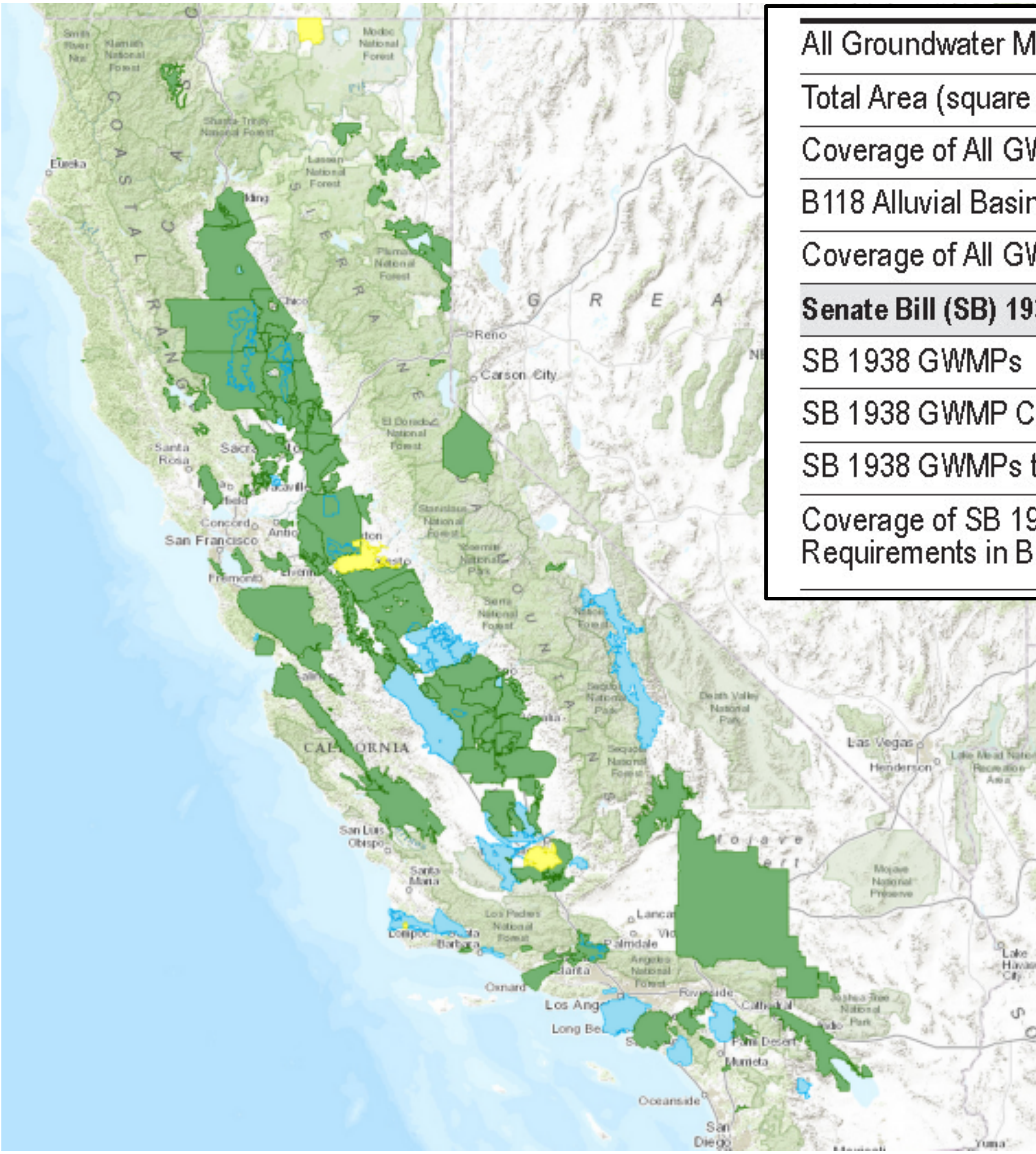
Basin Prioritization results – June 2, 2014

CASGEM Groundwater Basin Prioritization

- High
- Medium
- Low
- Very Low

California Department of Water Resources, 2015

Existing Groundwater Management Plans: Inventory and Assessment (No or Limited Implementation)



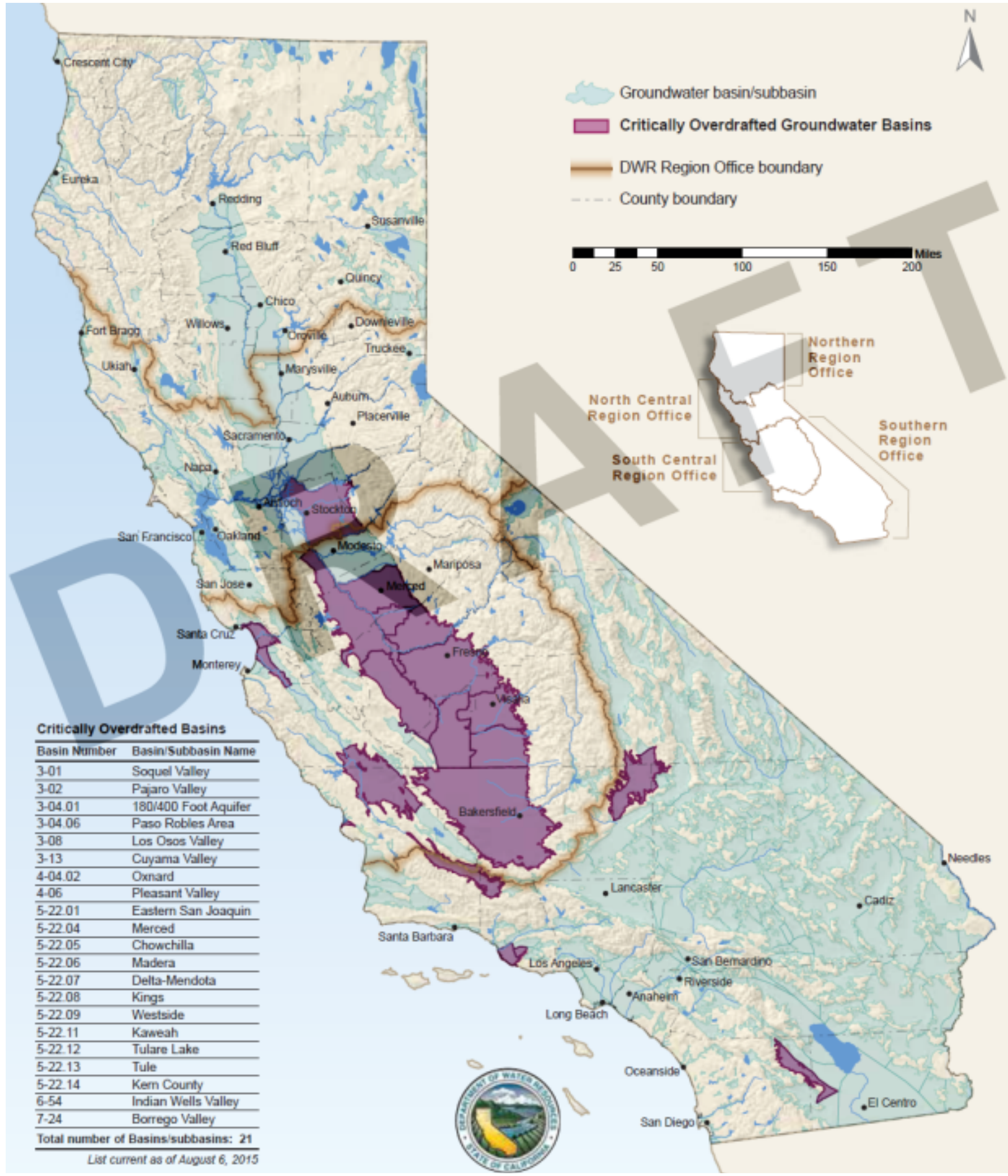
All Groundwater Management Plans (GWMP)	119
Total Area (square miles)	158,600
Coverage of All GWMPs (%)	20%
B118 Alluvial Basin Area (square miles)	61,900
Coverage of All GWMPs in B118 Basins Area (%)	42%
Senate Bill (SB) 1938 GWMPs Overlying B118 Alluvial Basins	
SB 1938 GWMPs	83
SB 1938 GWMP Coverage in B118 Basin Area (%)	32%
SB 1938 GWMPs that include all CA Water Code Requirements	35
Coverage of SB 1938 GWMPs that include all CA Water Code Requirements in B118 Basin Area (%)	17%

Groundwater Management Plans

- AB 359
- SB 1938
- AB 3030

California Department of Water Resources, 2015

Critically Overdrafted Basins – Plans Due in 2020



Critically Overdrafted Basins

Basin Number	Basin/Subbasin Name
3-01	Soquel Valley
3-02	Pajaro Valley
3-04.01	180/400 Foot Aquifer
3-04.06	Paso Robles Area
3-08	Los Osos Valley
3-13	Cuyama Valley
4-04.02	Oxnard
4-06	Pleasant Valley
5-22.01	Eastern San Joaquin
5-22.04	Merced
5-22.05	Chowchilla
5-22.06	Madera
5-22.07	Delta-Mendota
5-22.08	Kings
5-22.09	Westside
5-22.11	Kaweah
5-22.12	Tulare Lake
5-22.13	Tule
5-22.14	Kern County
6-54	Indian Wells Valley
7-24	Borrego Valley

Total number of Basins/subbasins: 21

List current as of August 6, 2015

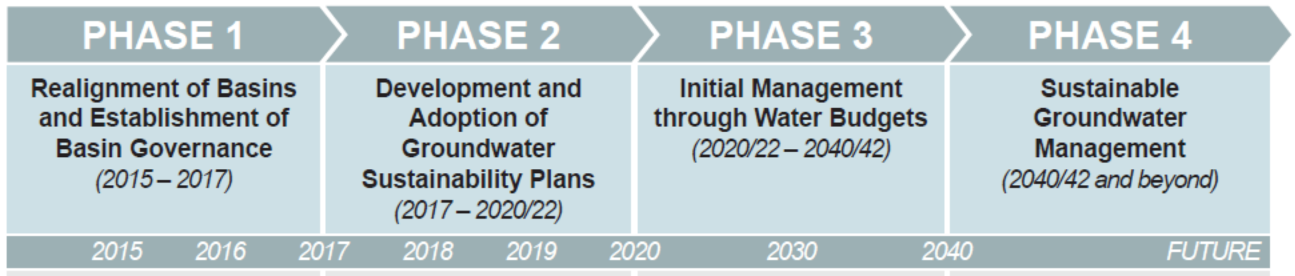
Who can be a GSA?

- Exempt:
  - Adjudicated basins (mostly in southern CA)
  - Functional equivalent of a GSA, adjudicated basin
- Any local public agency
  - Cities
  - Counties
  - Water / irrigation districts
  - Other public agencies with responsibility for:
    - water supply,
    - water management, or
    - land use
  - NEW special acts districts (created by legislature, then CEQA, LAFCO, public vote) => Paso Robles

GSA Formation: Next Steps

- County: Groundwater Advisory Committee
- Stimulate dialogue / communication among local agencies, key stakeholders (e.g., Farm Bureau)
- Engage broad range of interested parties
- Gather information about the basin / find out where the information is / what is available
- Understand what Groundwater Sustainability Planning entails
- Look over the fence and see what's happening elsewhere
- Transparency, transparency, transparency
- DEADLINE: June 30, 2017

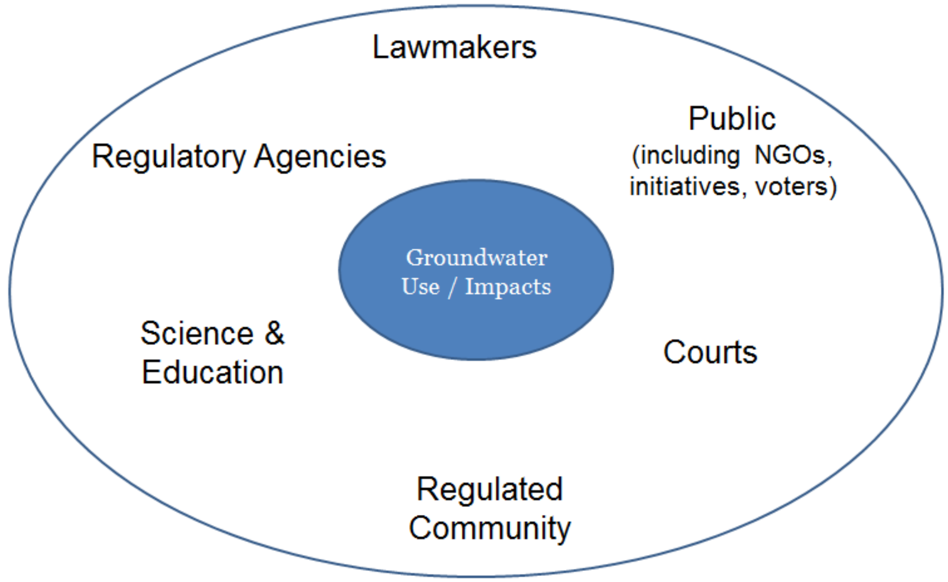
So What Exactly Will Happen?



- First Step: forming a Groundwater Sustainability Agency (GSA)
    - By June 2017
- **Second Step: developing a Groundwater Sustainability Plan (GSP)**
    - Within 5 years of GSA formation

Key Elements of (Local/regional) California Groundwater Management Plans

Key Actors in Environmental Resource Management
- connected via **communication** / information flow -



- Context / Basin Description
- Public and agency involvement
- Basin management objectives
- Monitoring
- Accountability and review

Sustainable Groundwater Mgmt Act:

- Enforcement mandate
- Empowerment for demand management (in addition to supply management)
- Integration with surface water management
- Integration with water quality management (source control, remediation, containment)
- Integration with landuse planning
- Local control / enforcement, with state oversight / enforcement

Groundwater Management Portfolio: Overview

- Data collection, monitoring, modeling, assessment
- Supply management
- Demand management
- Stakeholder engagement and management

Monitoring and Assessment

Groundwater Sustainability Agencies have *discretionary* authority to:

- Conduct studies
- Register & monitor wells
- Set well spacing requirements
- Require extraction reporting
- Regulate extractions
- Implement capital projects
- Assess fees to cover costs

Some exemptions for smaller private well owners

COURTESY - Marcus Trotta, Sonoma County Water Agency, 2015

METRIC

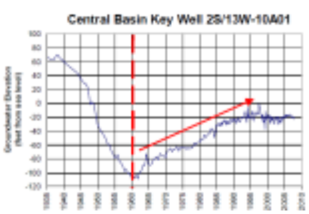
• **Healthy**	• **Sustainable Groundwater**
Health Maintenance • Nutrition • Exercise • Relationships/social engagement • Monitoring & Assessment	**Groundwater Management** • Adaptive supply management • Adaptive demand management • Stakeholder engagement • Monitoring & Assessment
TRIGGER(s)	
• **Ill**	• **Reversible undesirable impacts**
Treatment Mode • Medication / therapy • Additional monitoring & Doctor's assessment	**Extraordinary Measures** • Supply enhancement / demand reduction • Additional monitoring & assessment
THRESHOLD(s)	
• **Critically ill**	• **Major undesirable impacts**
Emergency Mode • Emergency Room • Surgery	**Emergency Mode** • SGMA Chapter 11 • Probationary Status
• **Death**	• **Groundwater unusable/ unavailable**

Thomas Harter, Univ. of California, 2015

Undesirable Result & Measurable Objective	Metric	Possible Threshold
Chronic lowering of groundwater levels: maintain desired range	Water level at key locations	• No less than at any time AFTER earlier mitigation of undesirable results and PRIOR to 2015, OR • No less than at any time prior to 2015, OR • No less than at any time prior to 2042, OR • Any fixed level arrived at through local/state political consensus about "significant and unreasonable", driven by economic cost: • Significant and unreasonable increase in pumping cost • Significant and unreasonable cost of new well installation / well deepening
Reduction in groundwater storage: maintain desired range	Water level at key locations	
Seawater intrusion: Stop or reverse water quality degradation	Water level at key locations or GW Salinity	Identify seawater intrusion threat via geologic and geochemical characterization & modeling => define safe water level thresholds for land subsidence. Threshold: • Higher than land subsidence-driven threshold or any of the above, whichever is higher
Degraded water quality: no harm to SWRCB regs	Porter-Cologne/ anti-degradation	• set by current and future RWB regulations • Use modeling and assessment to link groundwater management actions to RWB objectives
Land subsidence: stop or minimize subsidence	Water level at key locations	Identify subsidence threat via geologic characterization & modeling => define safe water level thresholds for land subsidence. Threshold: • Higher than land subsidence-driven threshold or any of the above, whichever is higher
Depletion of interconnected surface water & adverse impacts on SW beneficial uses: minimum required streamflow	Water level at key locations (within 1 mile of stream?), surface critical low flows at key locations & times	Use modeling and assessment to link impact of groundwater management/use to beneficial uses of surface water => set thresholds • No less than at any time AFTER earlier mitigation of undesirable results and PRIOR to 2015 => no further assessment needed • Higher than surface water beneficial use-driven thresholds or any of the above, whichever is higher

Thomas Harter, Univ. of California, 2015

Relationship between **Measurable Objectives (MO) and Management Practices**



M E T R I C

THRESHOLD(s)

Measurement / Monitoring

Certainty

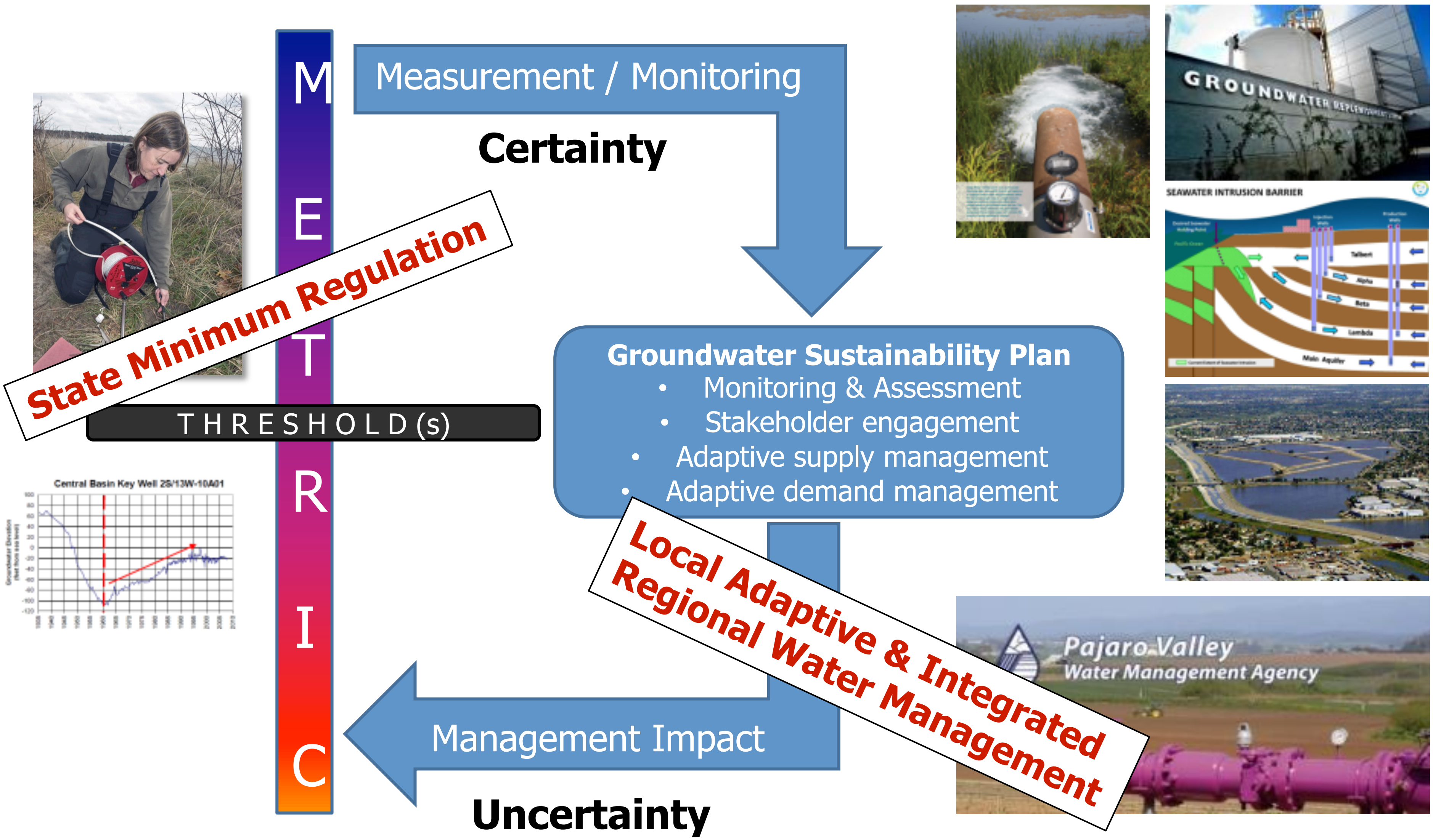
Groundwater Sustainability Plan
- Monitoring & Assessment
- Stakeholder engagement
- Adaptive supply management
- Adaptive demand management

Management Impact

Uncertainty

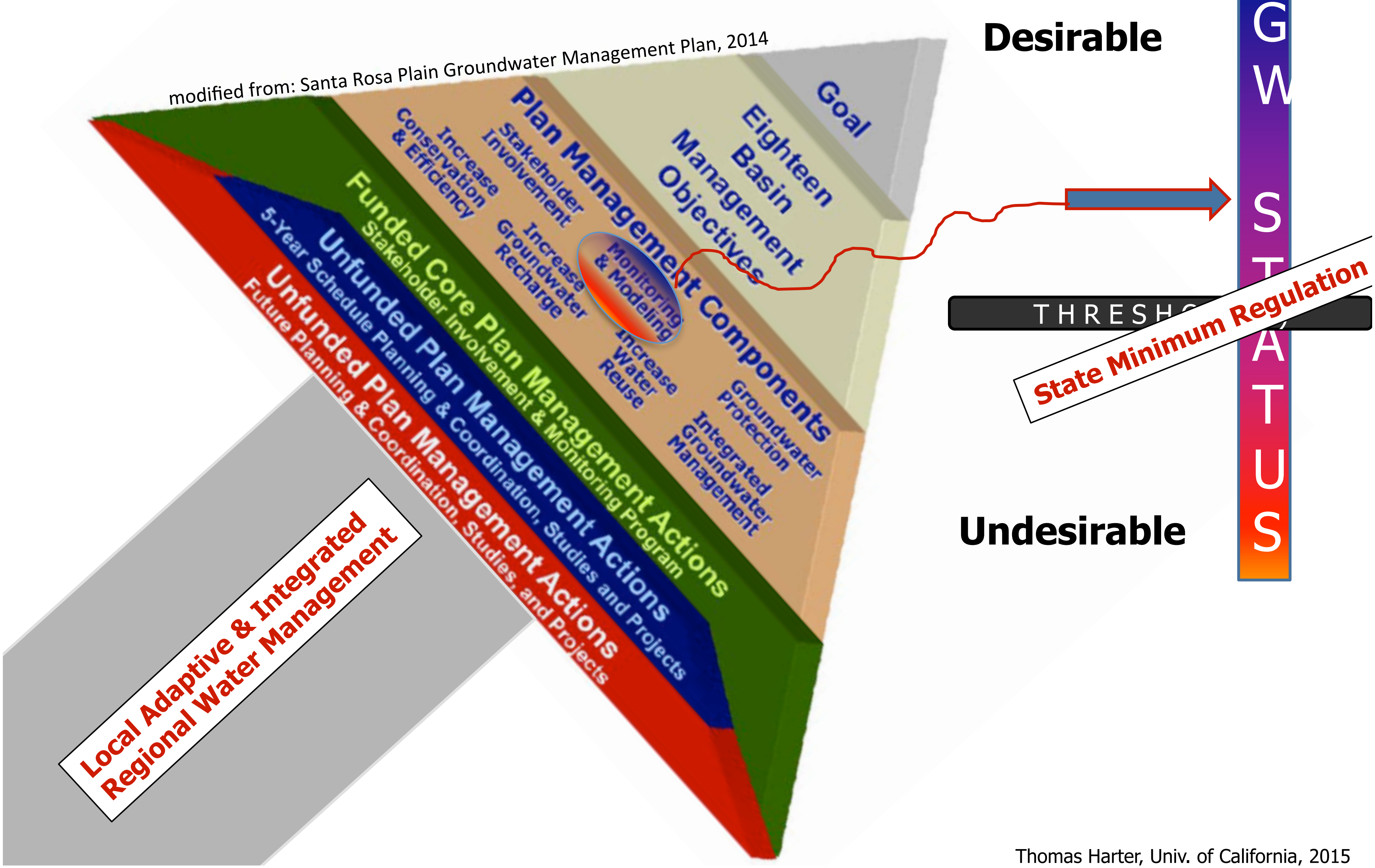
Thomas Harter, Univ. of California, 2015

Relationship between **Measurable Objectives (MO)** and **Management Practices**



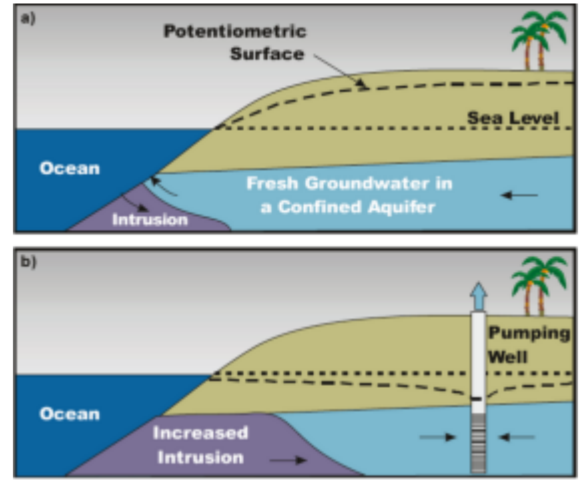
Thomas Harter, Univ. of California, 2015

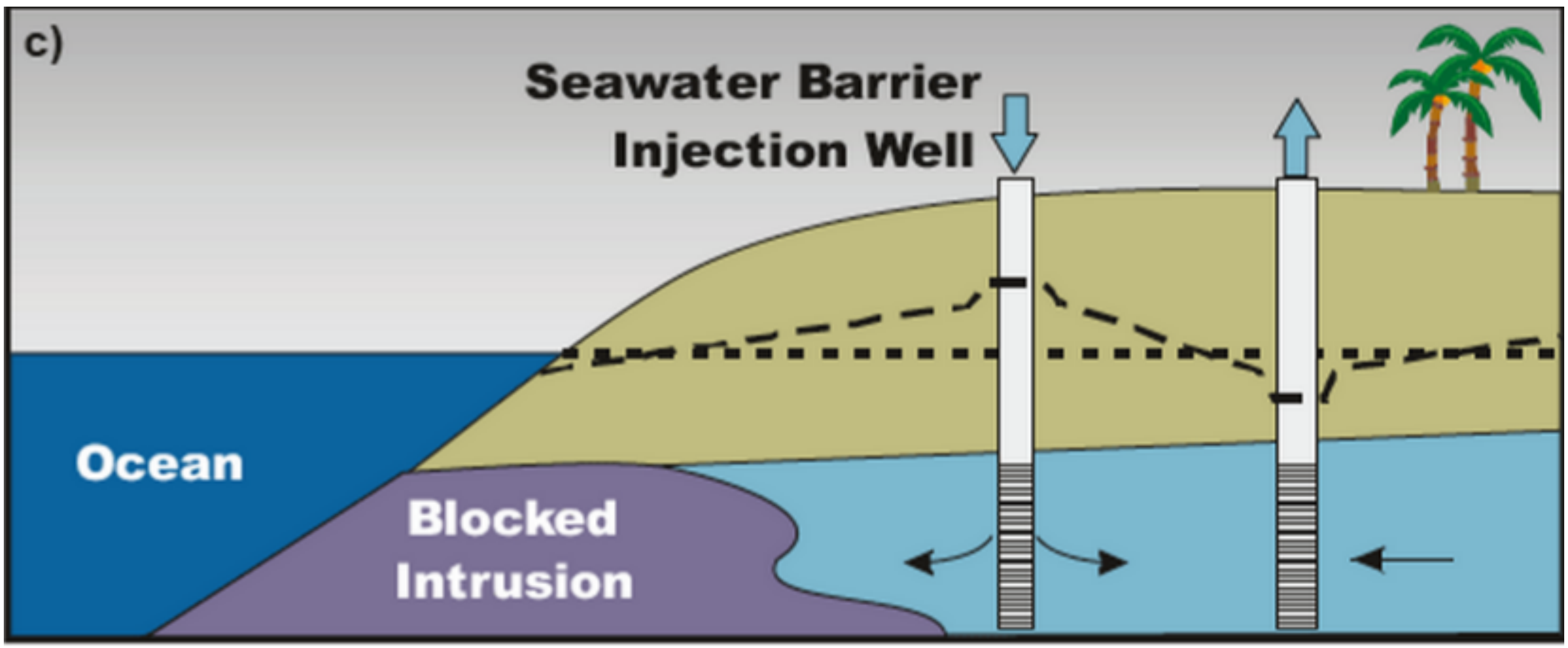
Core Link between Local Planning Effort and State Oversight: Monitoring & Modeling/Assessment



Thomas Harter, Univ. of California, 2015

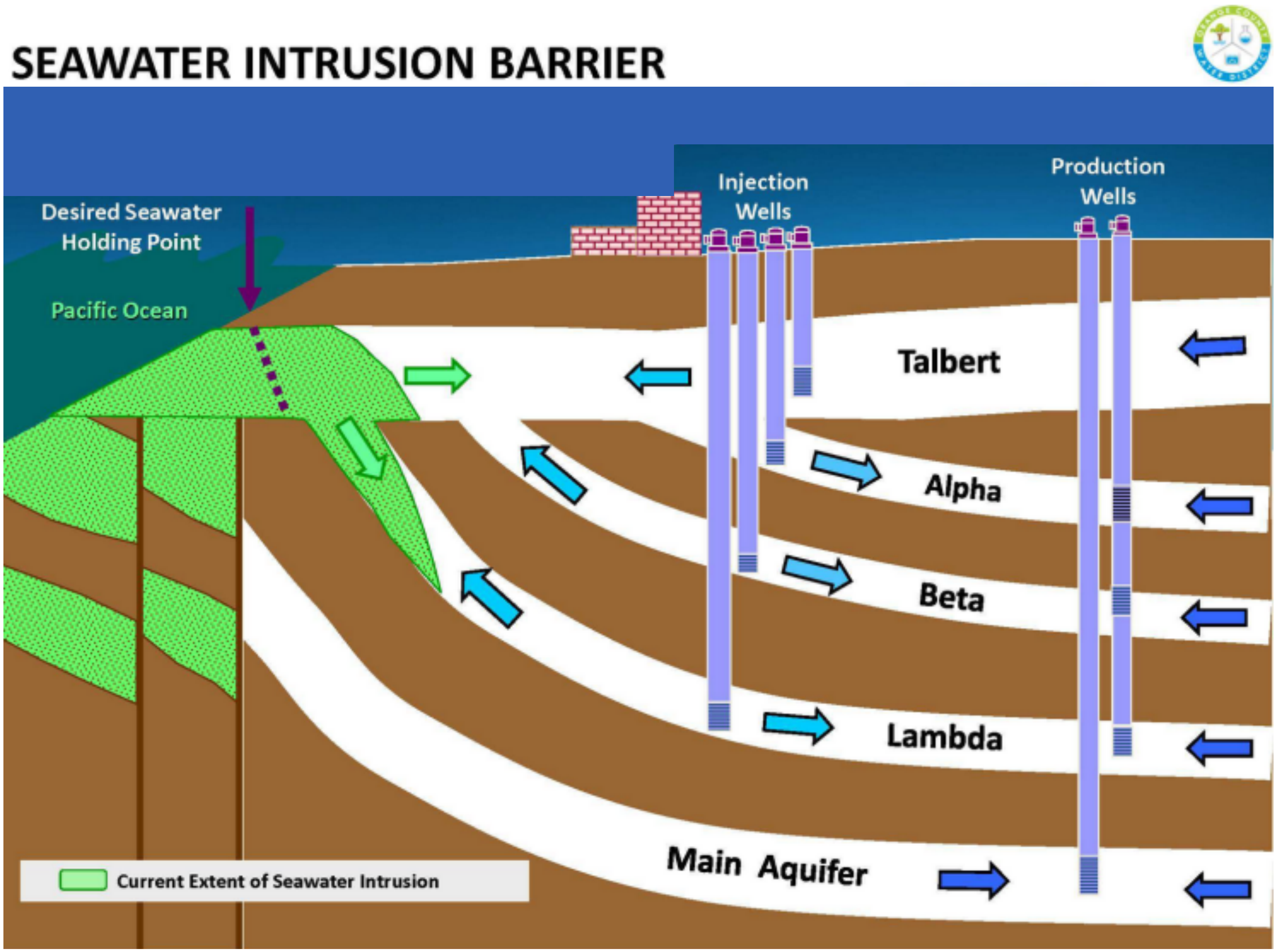
Seawater Intrusion





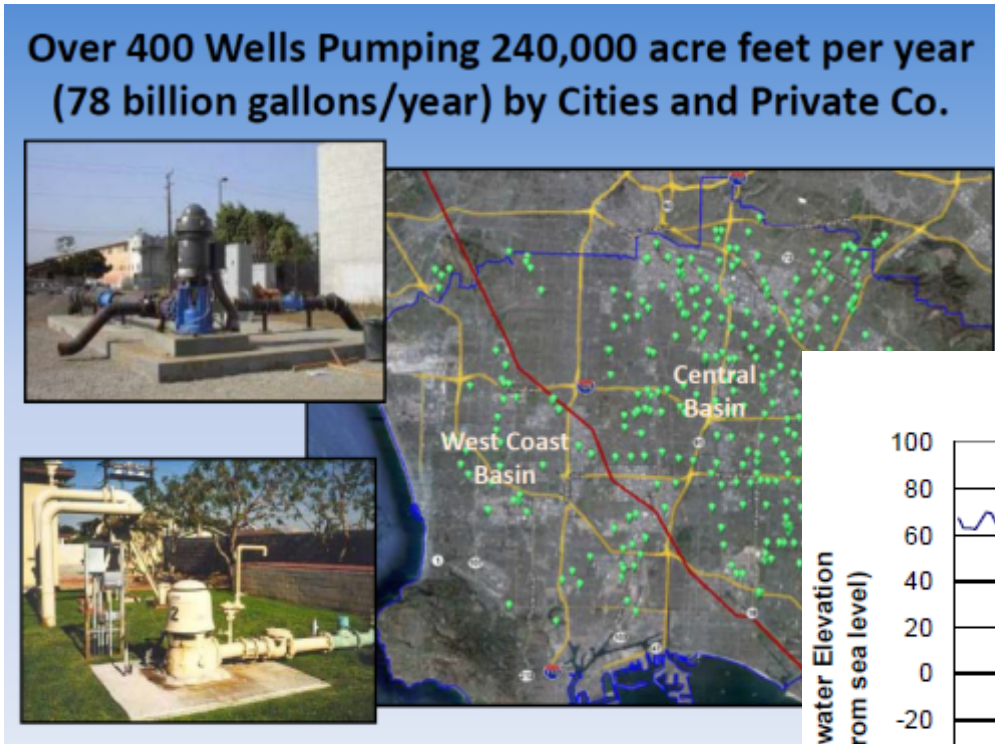
Ted Johnson, Water Replenishment District, 2007

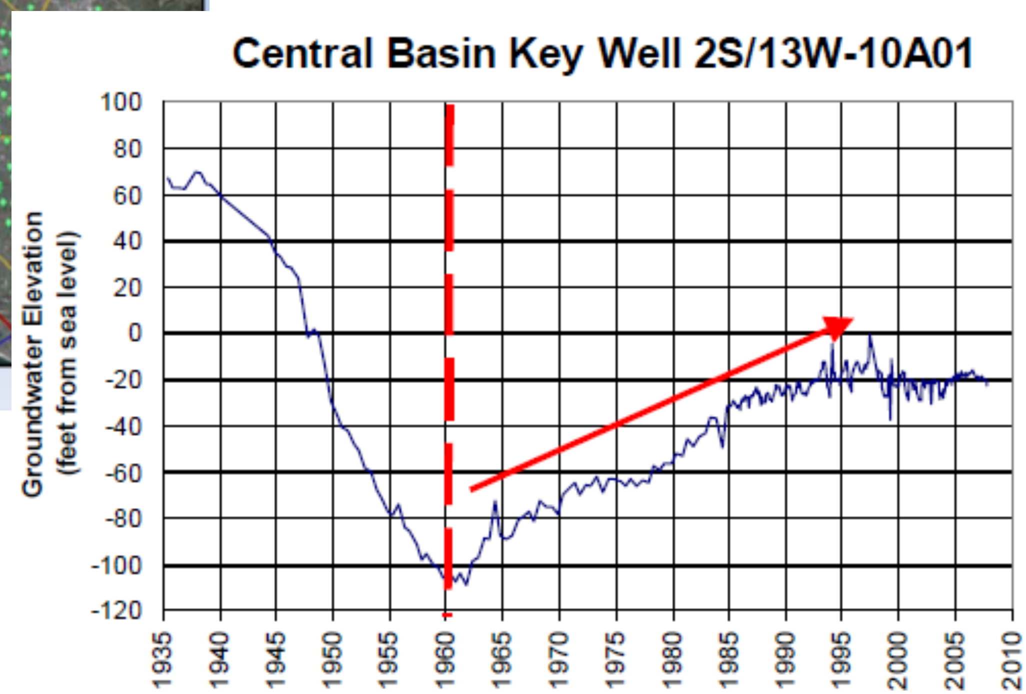
Seawater Intrusion



Orange County Water District, 2014

Storage for Local Use:
Water Replenishment District of So. Cal. (founded in 1959)

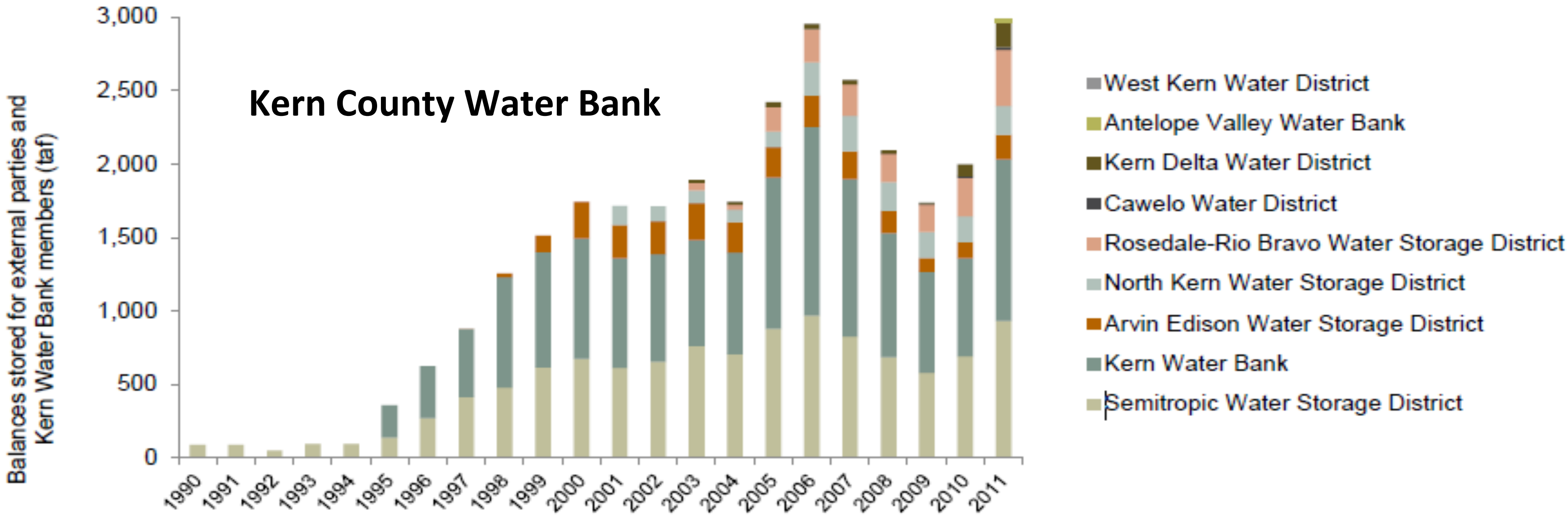


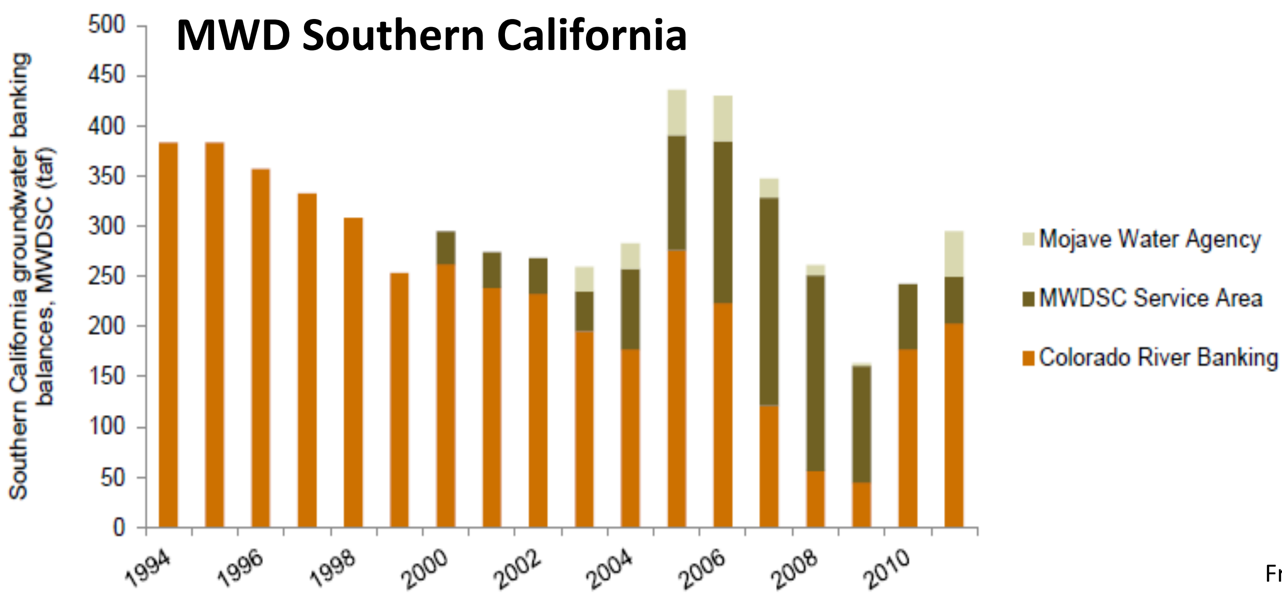


=> also to prevent seawater intrusion!

WRD and Maven's Notebook, 2013

Long-Term Storage via Import/Export: Groundwater Bank



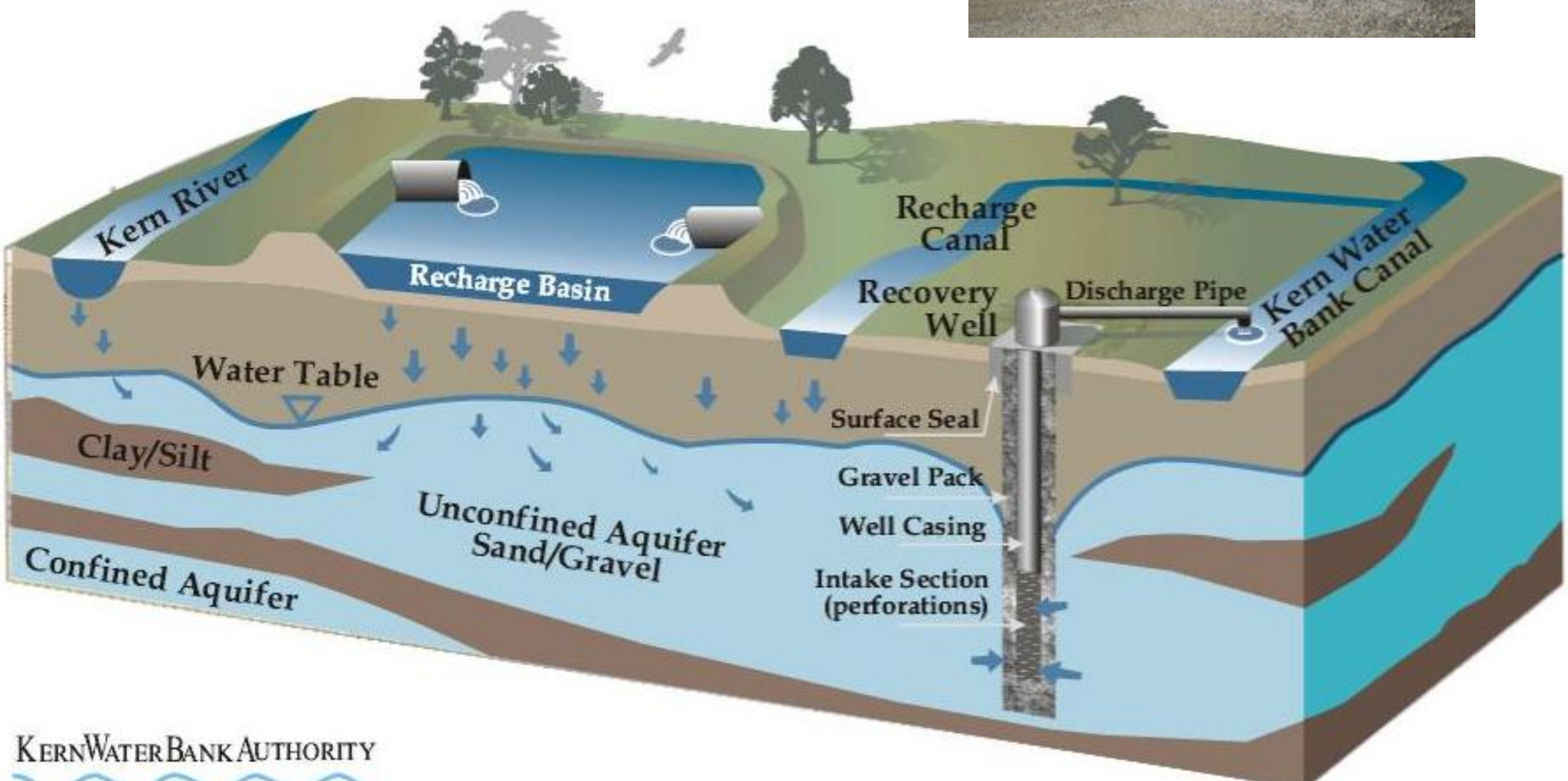


From: Hanak et al., PPIC 2012

Yuba River: Infrastructure, such as this water discharge pipe, allow water districts and agencies to manage surface water and groundwater within the same hydrologic area as a single resource, using one source to balance the other when surface water or groundwater levels are low. This can reduce water diversions and groundwater pumping, enhance local supply, and increase the amount of water available for transfer.

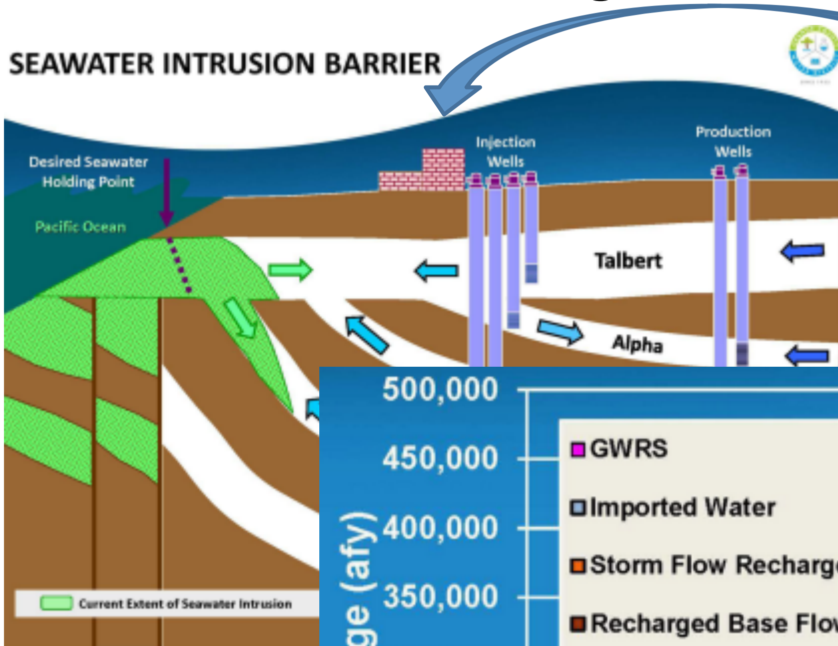
From: Ted Johnson, WRD 2013

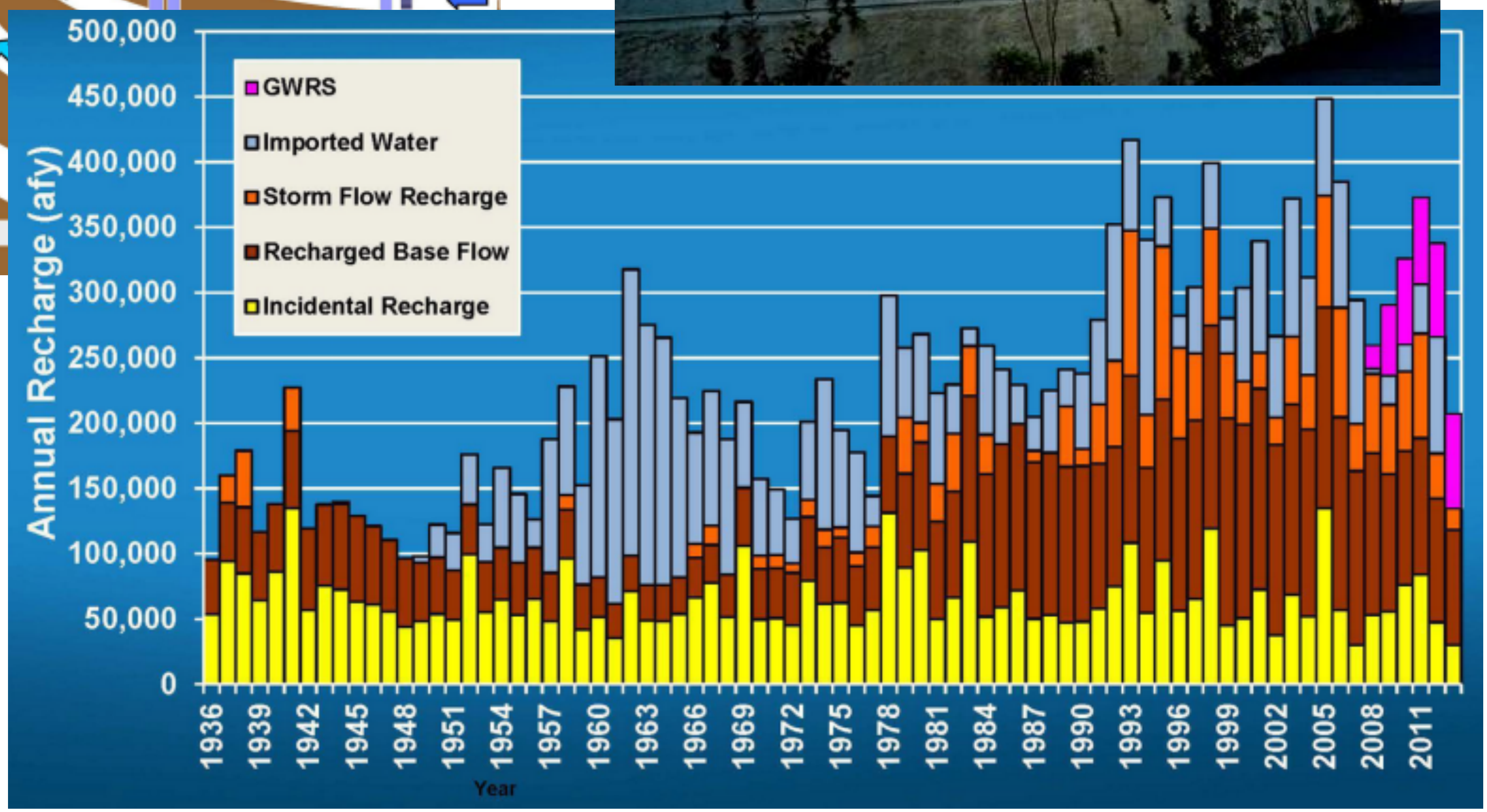
DWR, California Water Plan Update 2013



KERN WATER BANK AUTHORITY

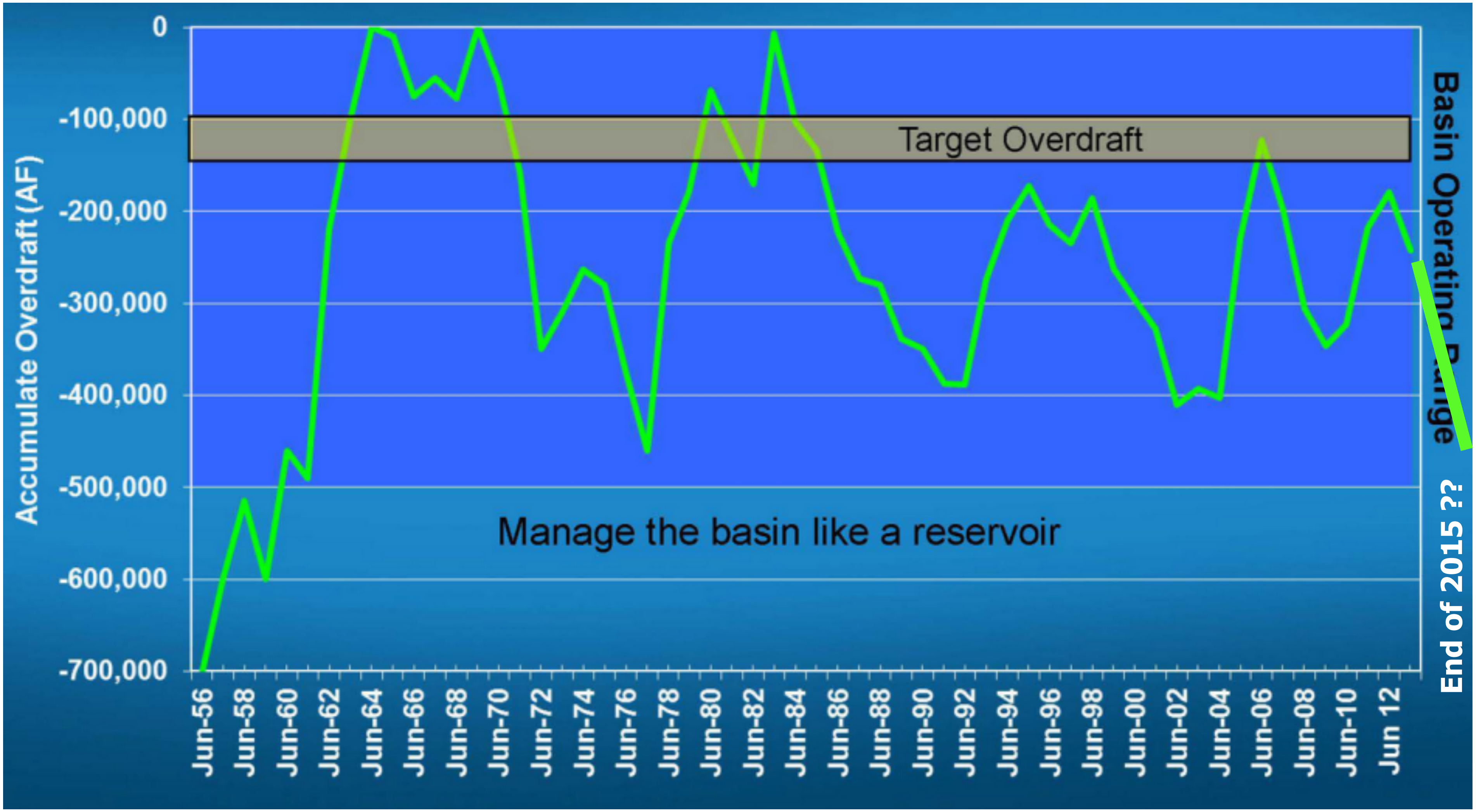
Orange County: Groundwater Recharge Portfolio





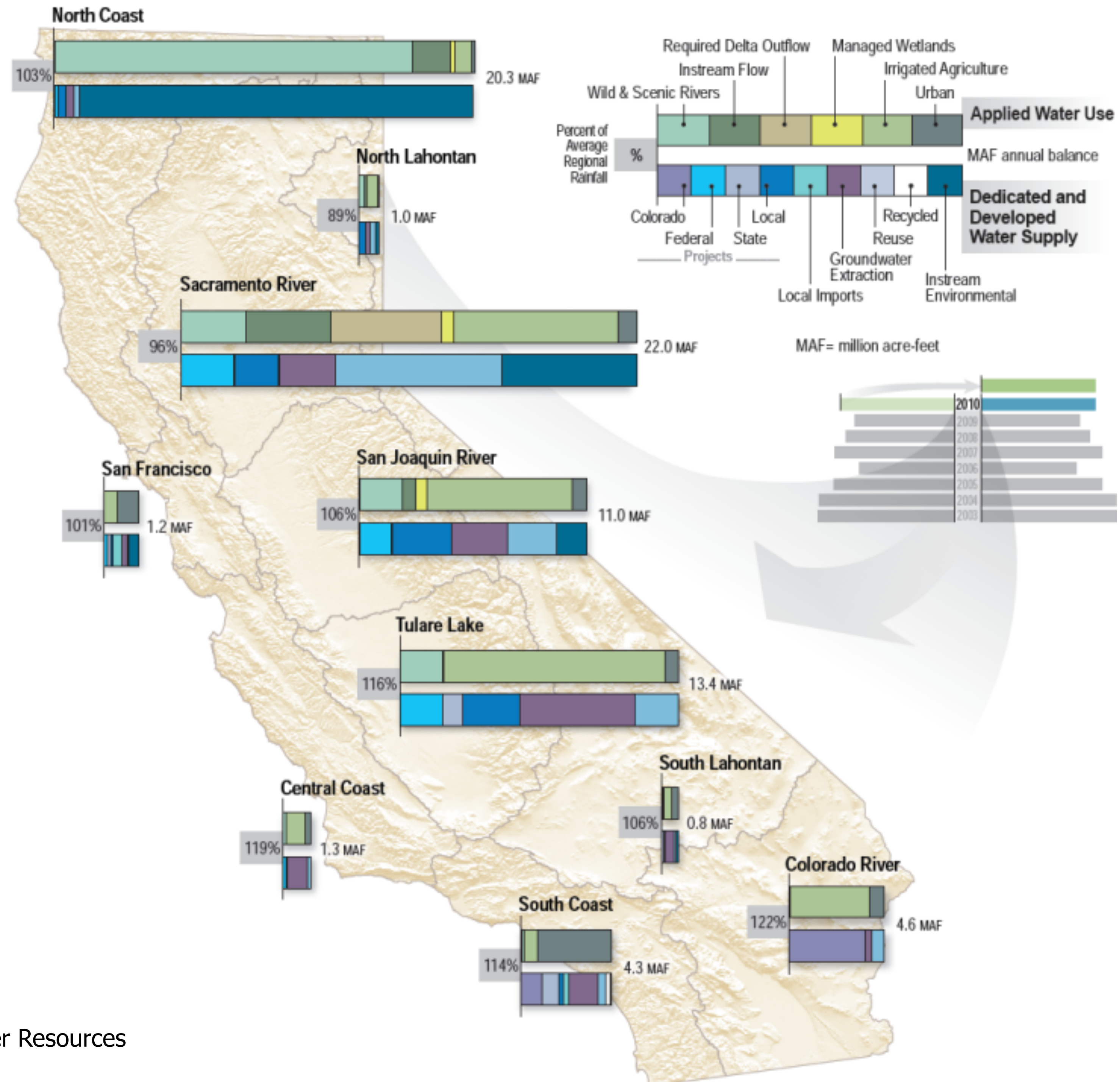
Orange County Water District, 2014

Managing GW Storage to Prevent Seawater Intrusion: Orange County Water District



Orange County Water District, 2014

Water Balance by California Region (2010)



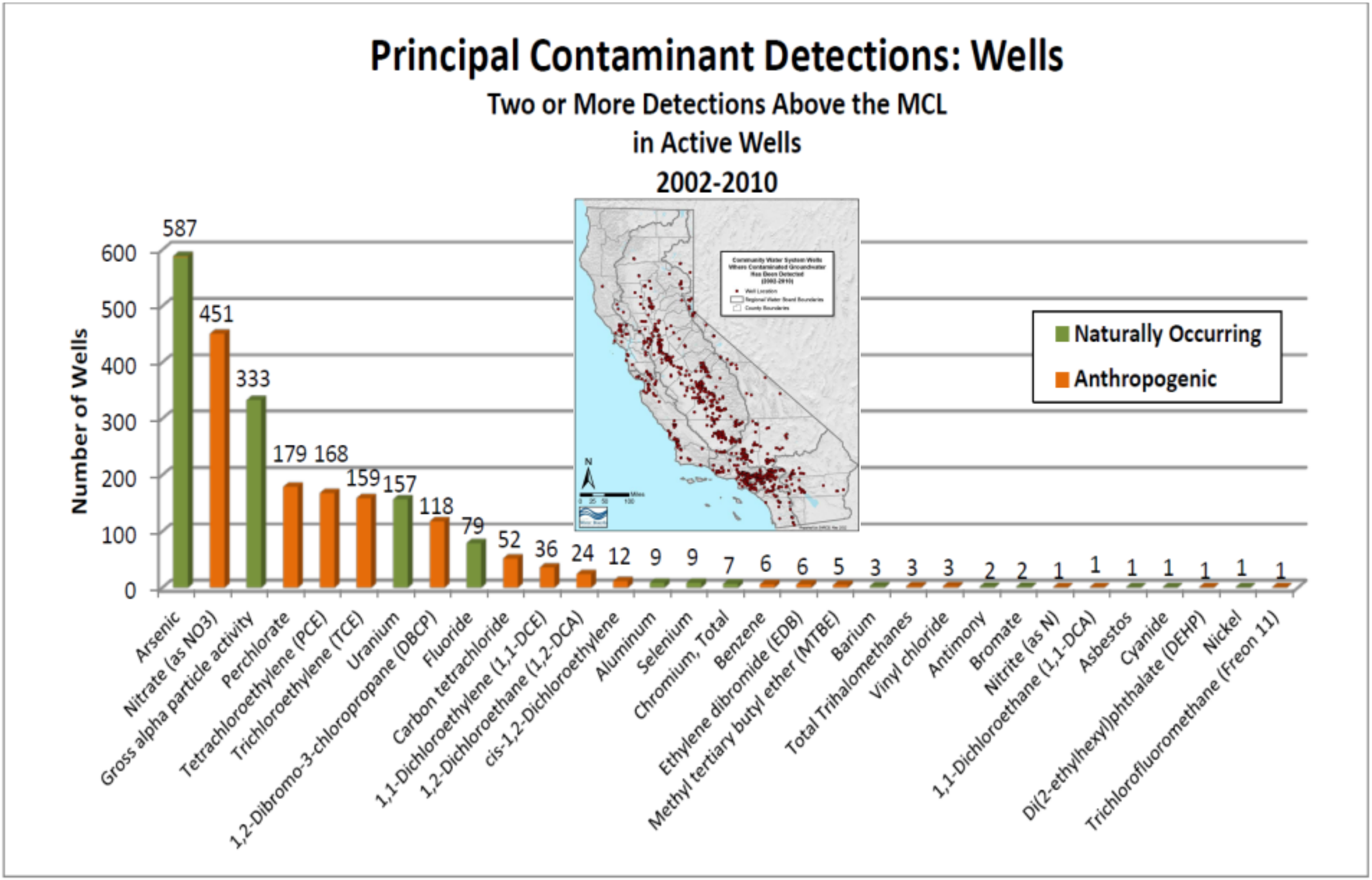
California Department of Water Resources
Water Plan Update 2013

Groundwater Banking for Environmental Flows: Scott Valley, Siskiyou County

So What Exactly Will Happen?

- First Step: forming a Groundwater Sustainability Agency (GSA)
  - By June 2017
- Second Step: developing a Groundwater Sustainability Plan (GSP)
  - Within 5 years of GSA formation
- **Third Step: implementing Groundwater Sustainability Plan**
  - **achieve sustainable management no later than 2040**

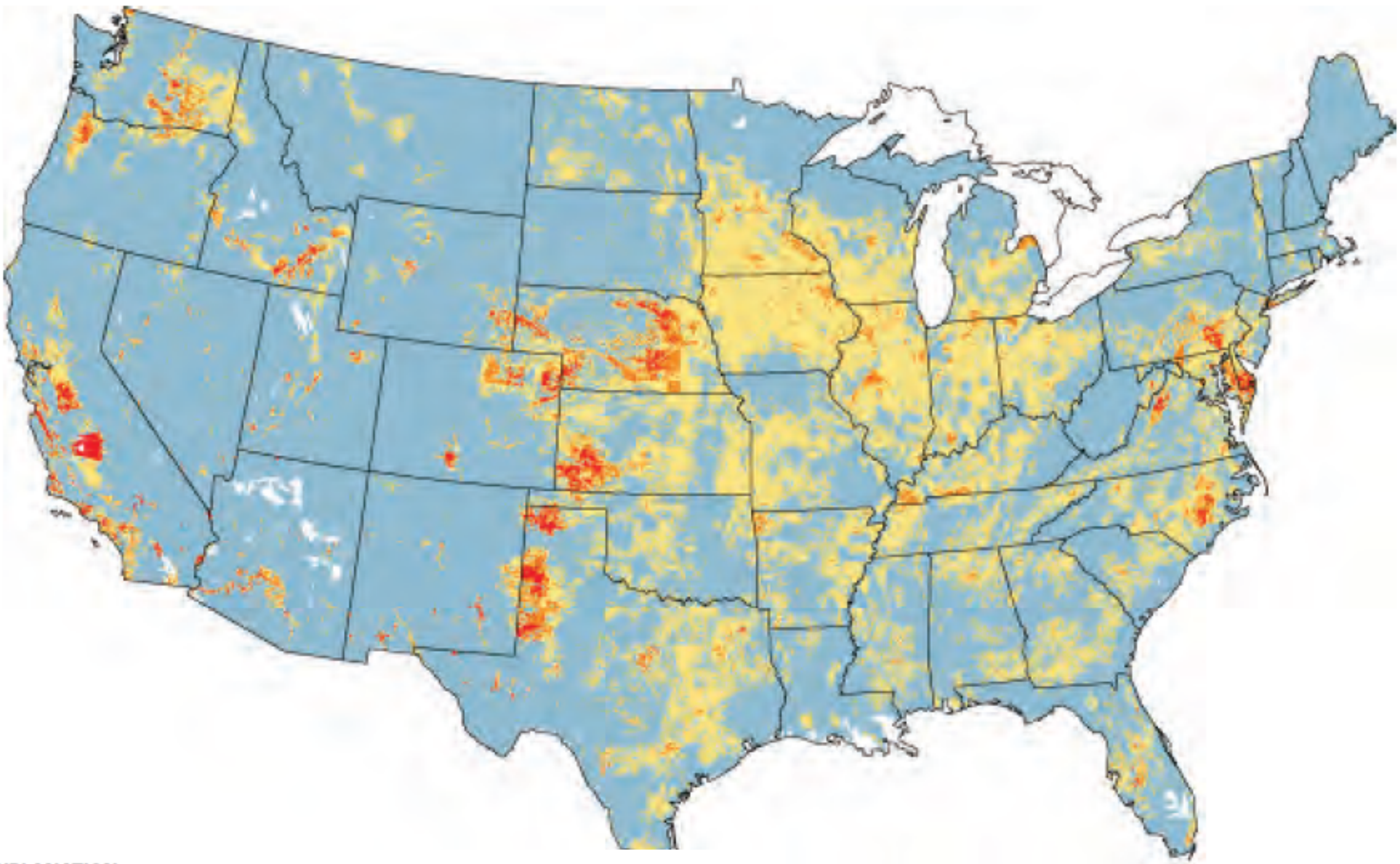
Laura Bliss / Atlantic City Lab



total active public supply wells in California: 8,396
with contaminated groundwater (before treatment): 1,659

State Water Resources Control Board, AB2222 Report to Legislature, January 2013

Model for deep groundwater used as drinking water (50-m simulation depth)



EXPLANATION

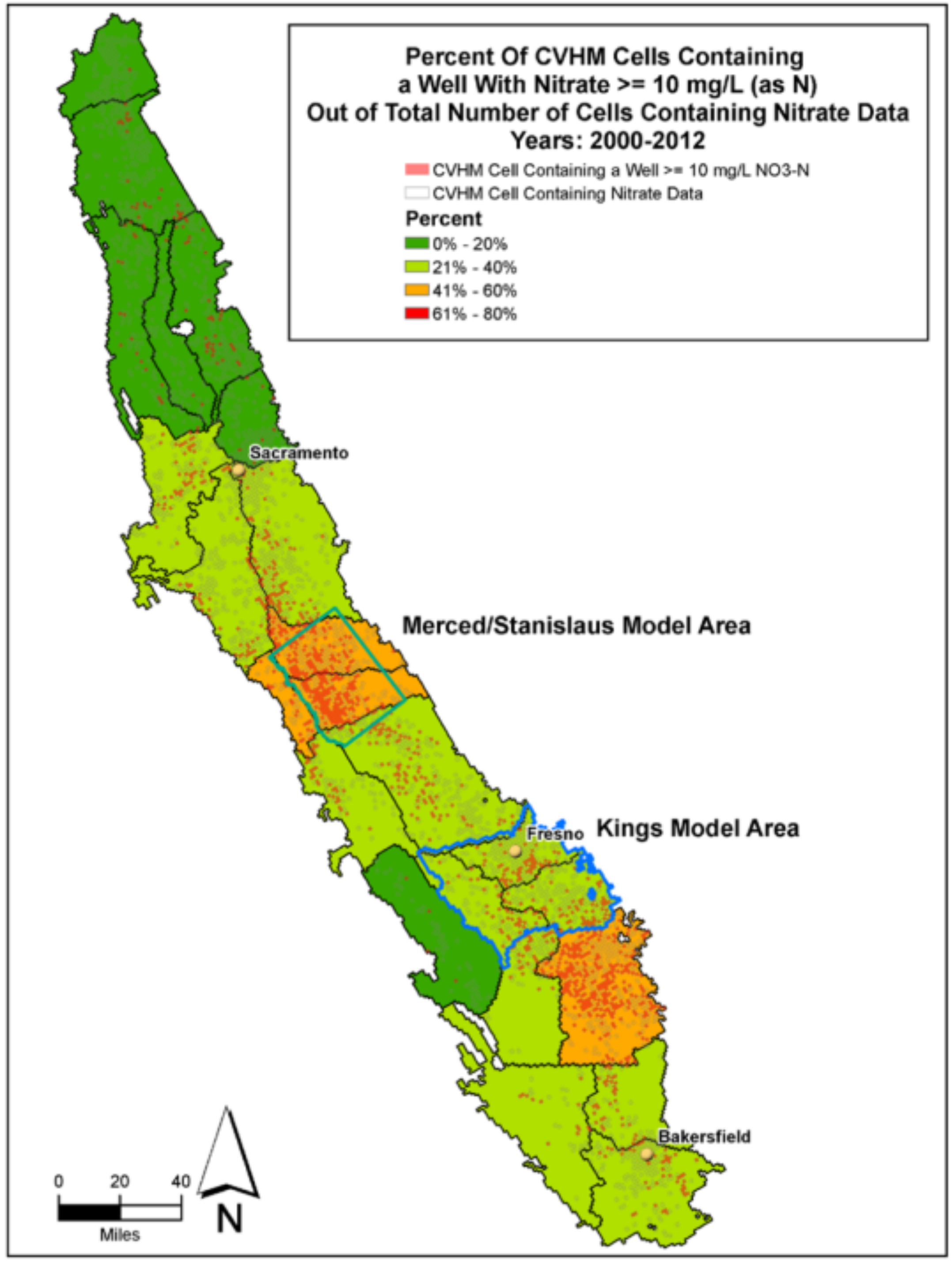
Predicted nitrate concentration, in milligrams per liter as N

≤1 | >1–5 | >5–10 | >10 | Missing data

Dubrovsky et al., USGS, 2010

Nitrate: Impacted regions within the Central Valley

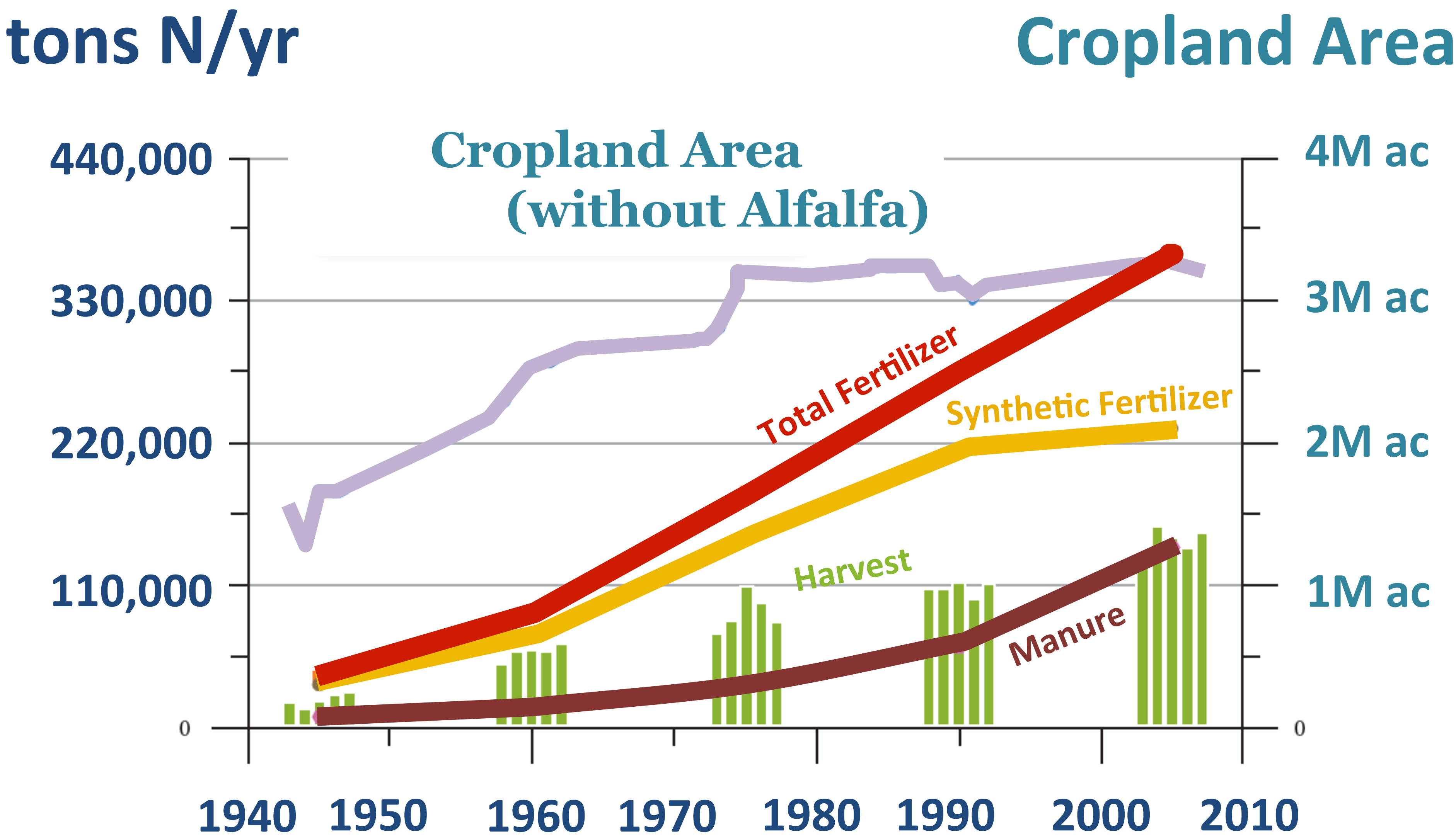
red dots: wells above MCL for nitrate

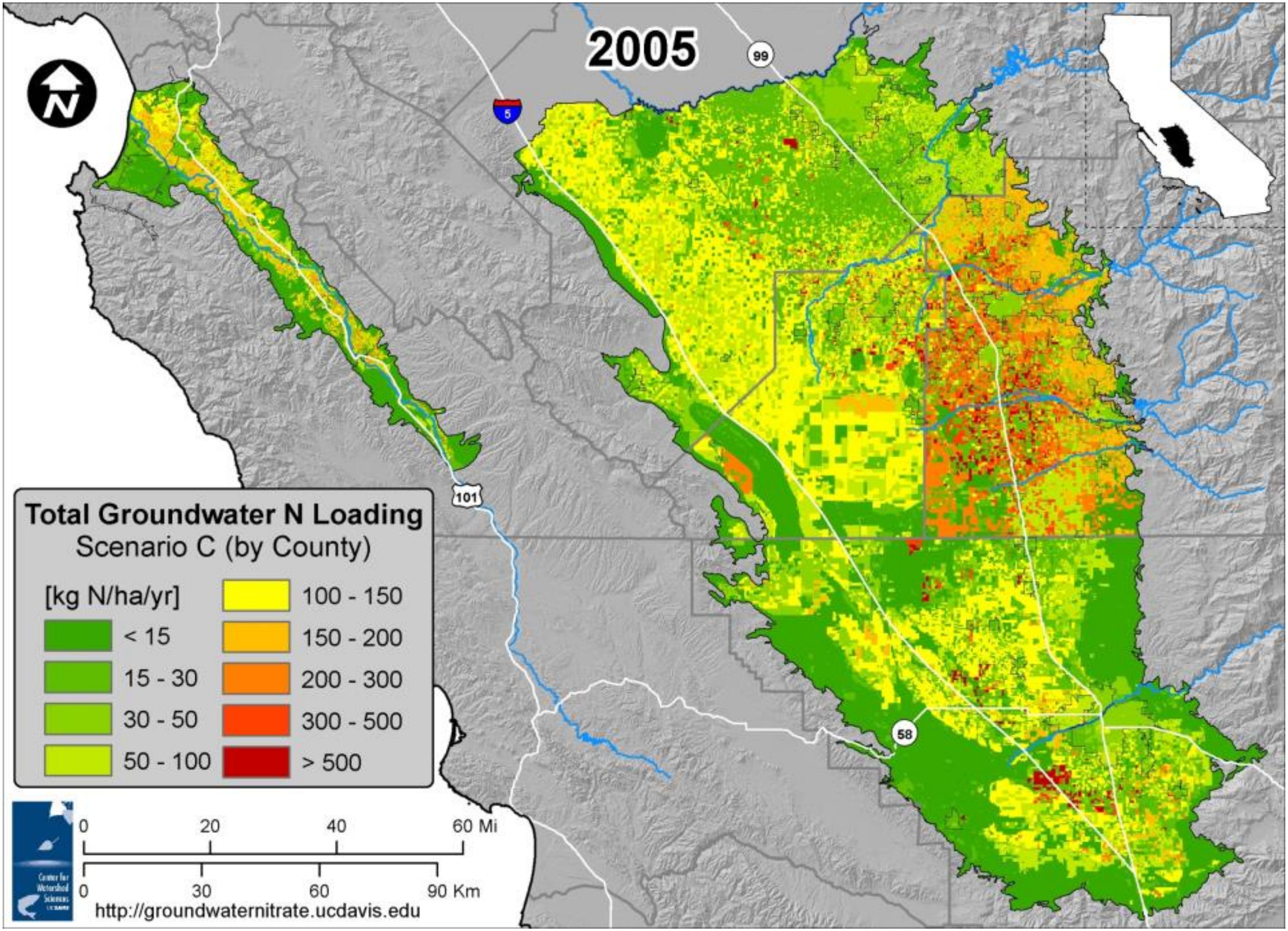


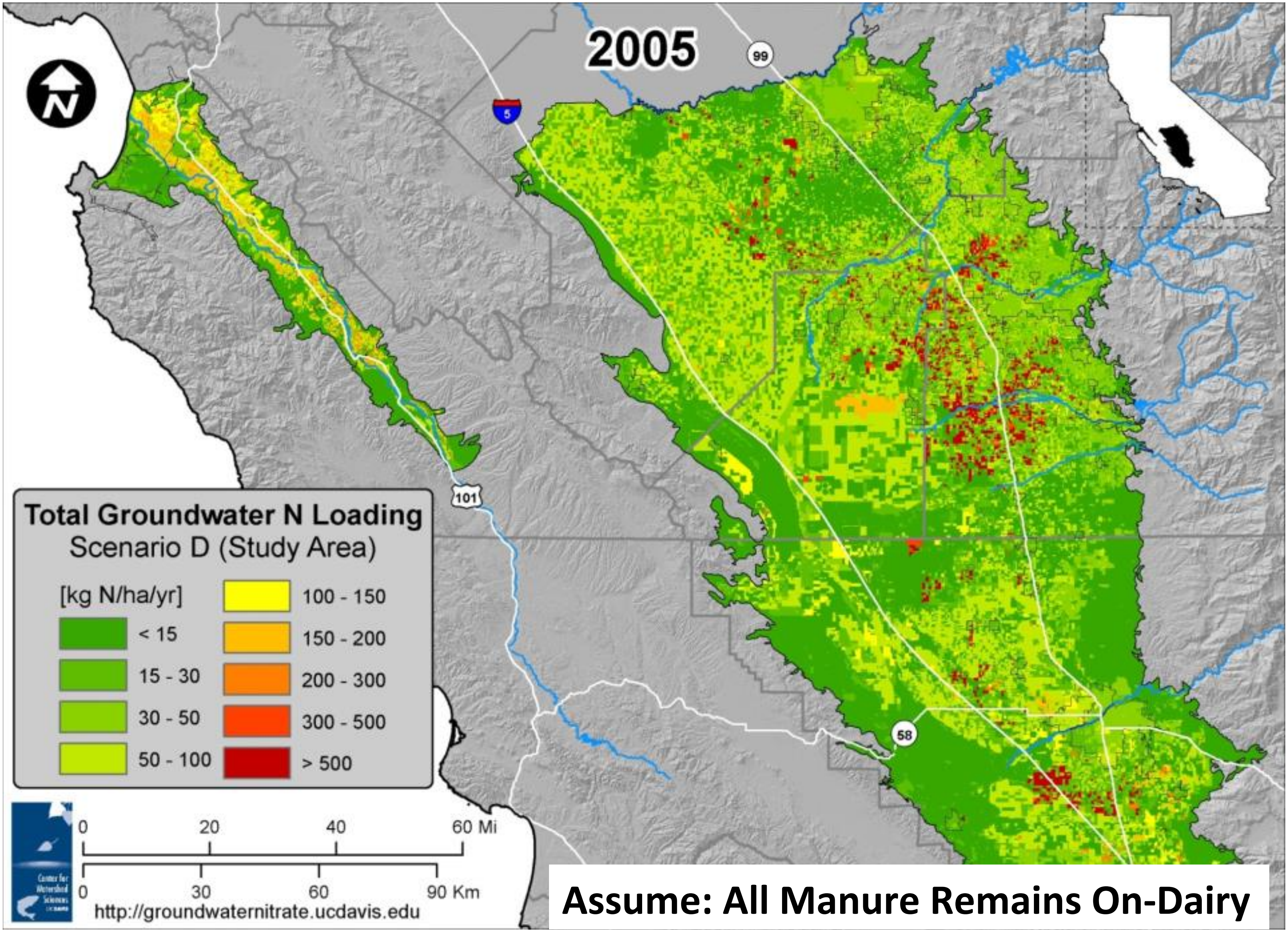
CVSALTS, Tasks 7 and 8 – Salt and Nitrate Analysis for the Central Valley Floor
Final Report, December 2013

Figure 7-14

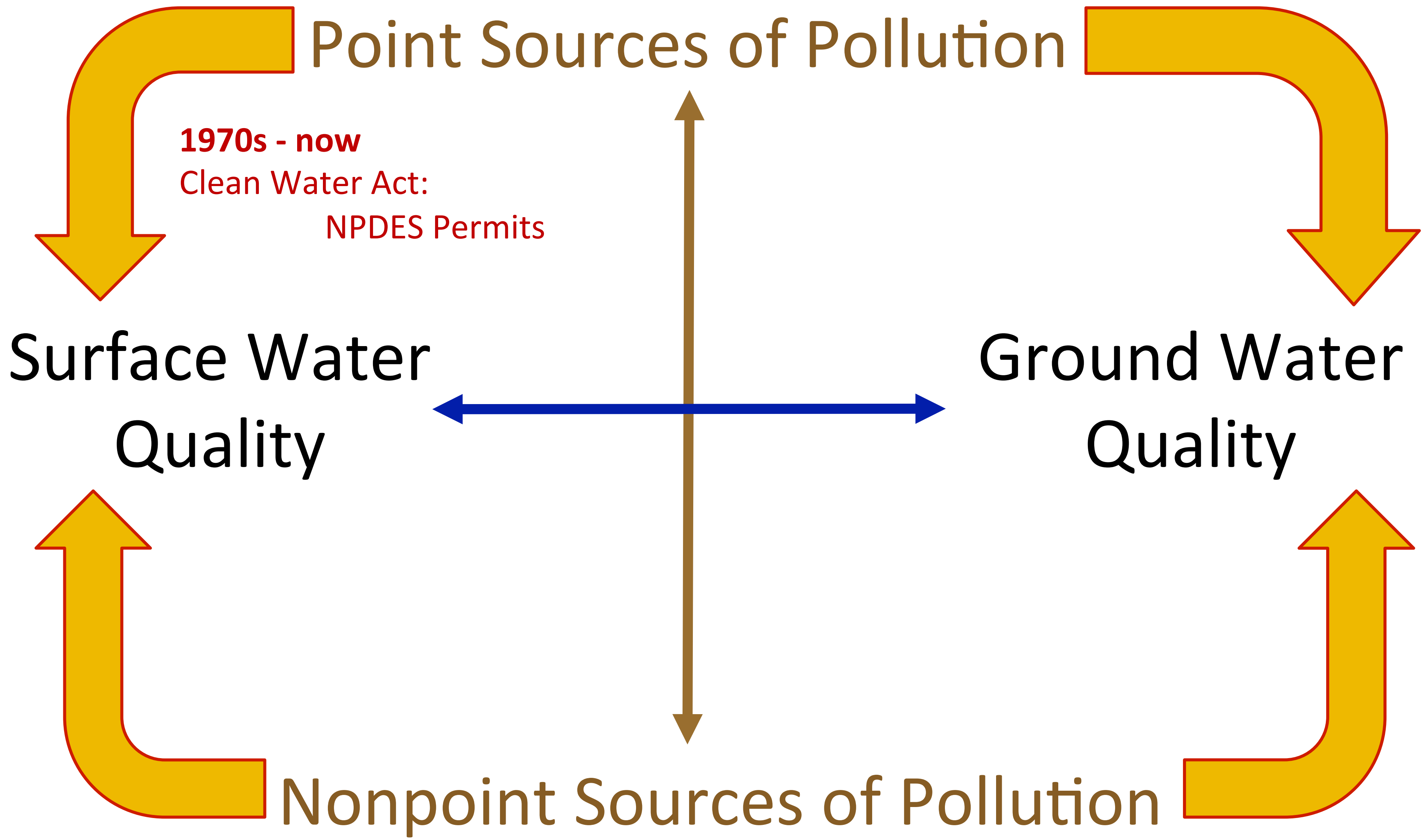
Historic Nitrogen Fluxes



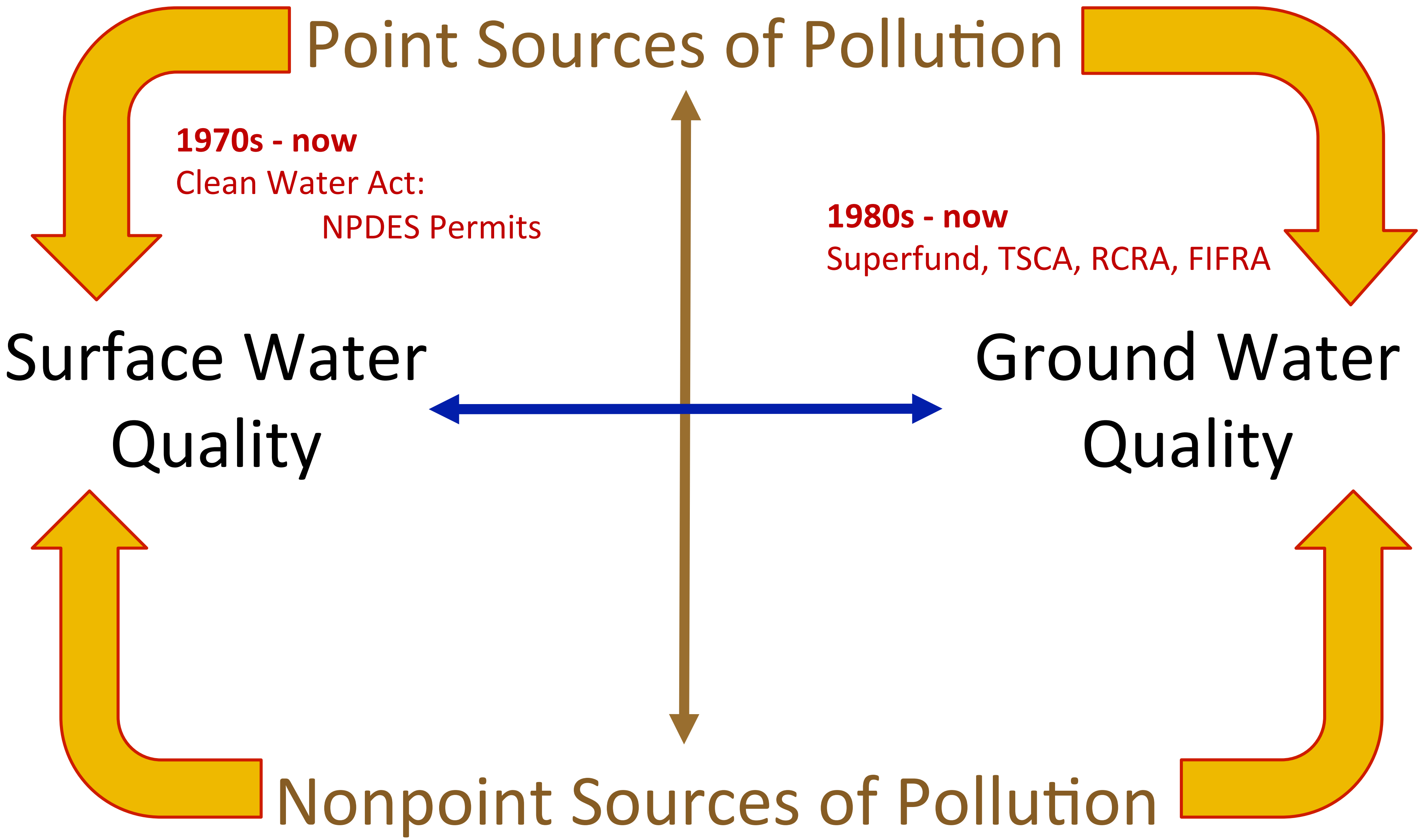

2005
99
5
101
58
Total Groundwater N Loading
Scenario C (by County)
[kg N/ha/yr]
< 15
15 - 30
30 - 50
50 - 100
100 - 150
150 - 200
200 - 300
300 - 500
> 500
0
20
40
60 Mi
0
30
60
90 Km
http://groundwaternitrate.ucdavis.edu


2005
Total Groundwater N Loading
Scenario D (Study Area)
[kg N/ha/yr]
< 15
15 - 30
30 - 50
50 - 100
100 - 150
150 - 200
200 - 300
300 - 500
> 500
0 20 40 60 Mi
0 30 60 90 Km
http://groundwaternitrate.ucdavis.edu
Assume: All Manure Remains On-Dairy

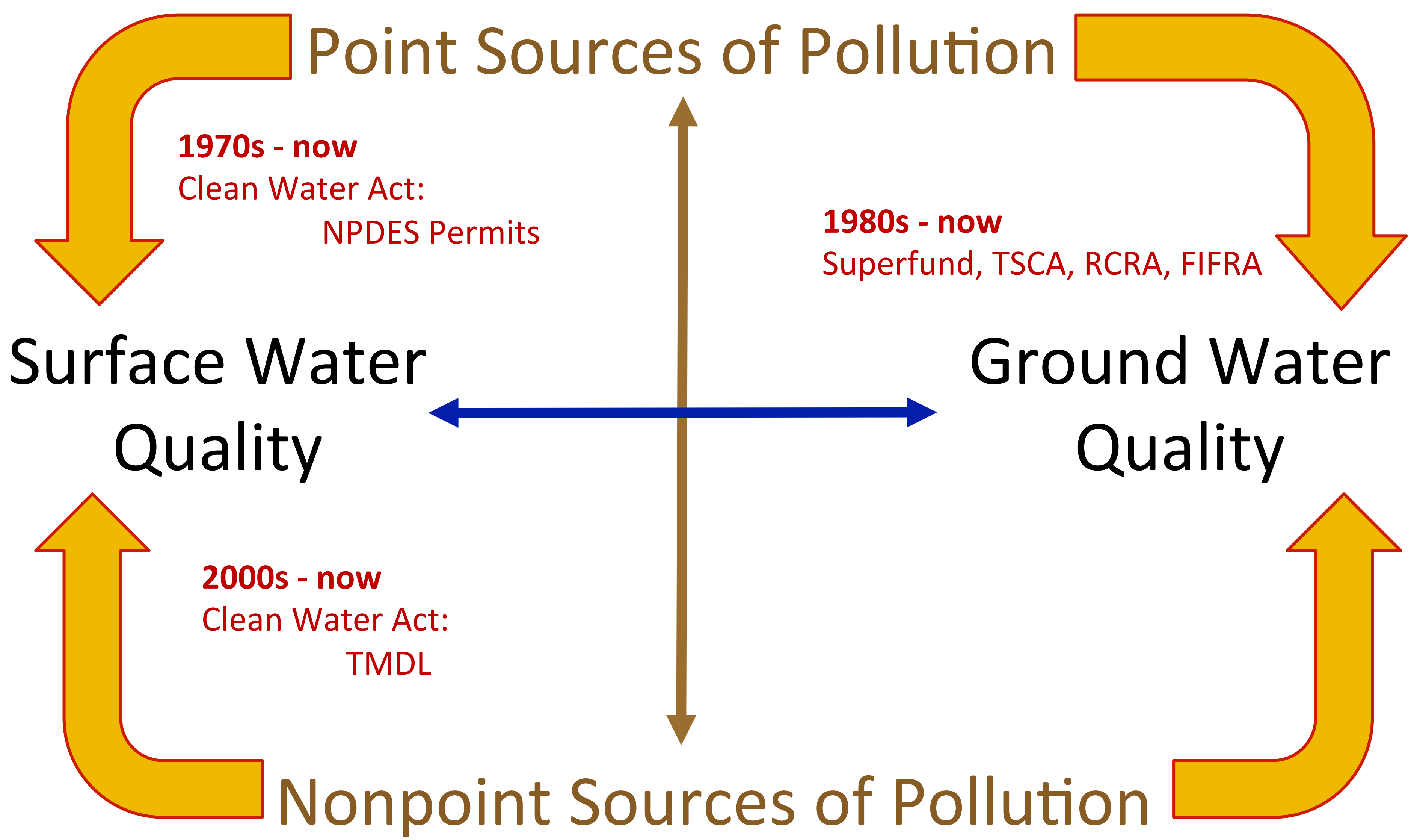
Regulating Water Pollution Sources



Regulating Water Pollution Sources



Regulating Water Pollution Sources



Focus: Enforcement Monitoring

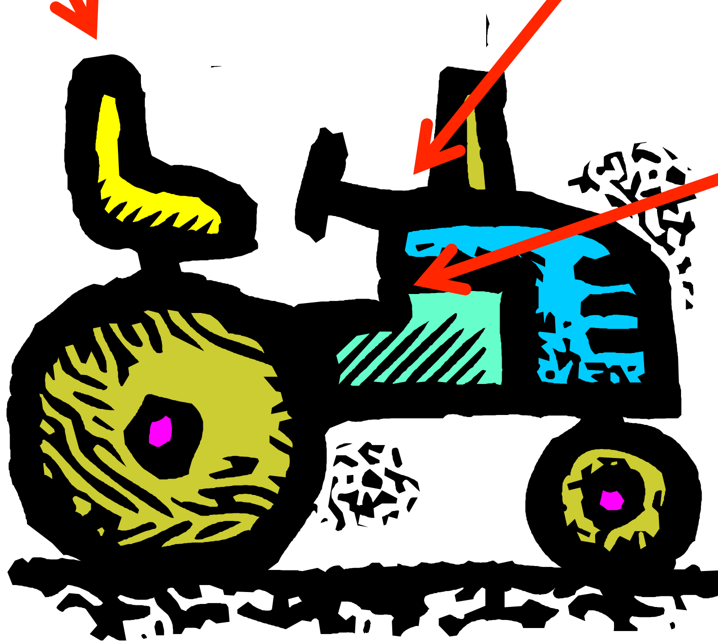
Example of Working with a Regulation: Speed Limit

Responsible Party:
Driver

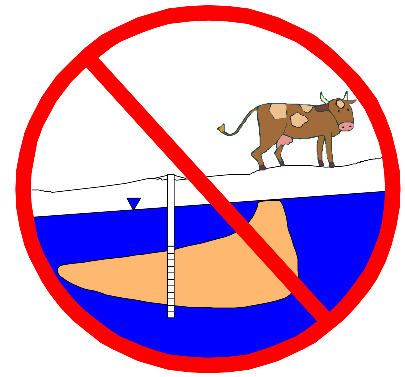
Feedback:
Speedometer

Management Tool:
Brakes

Enforcement:
Radar Controls



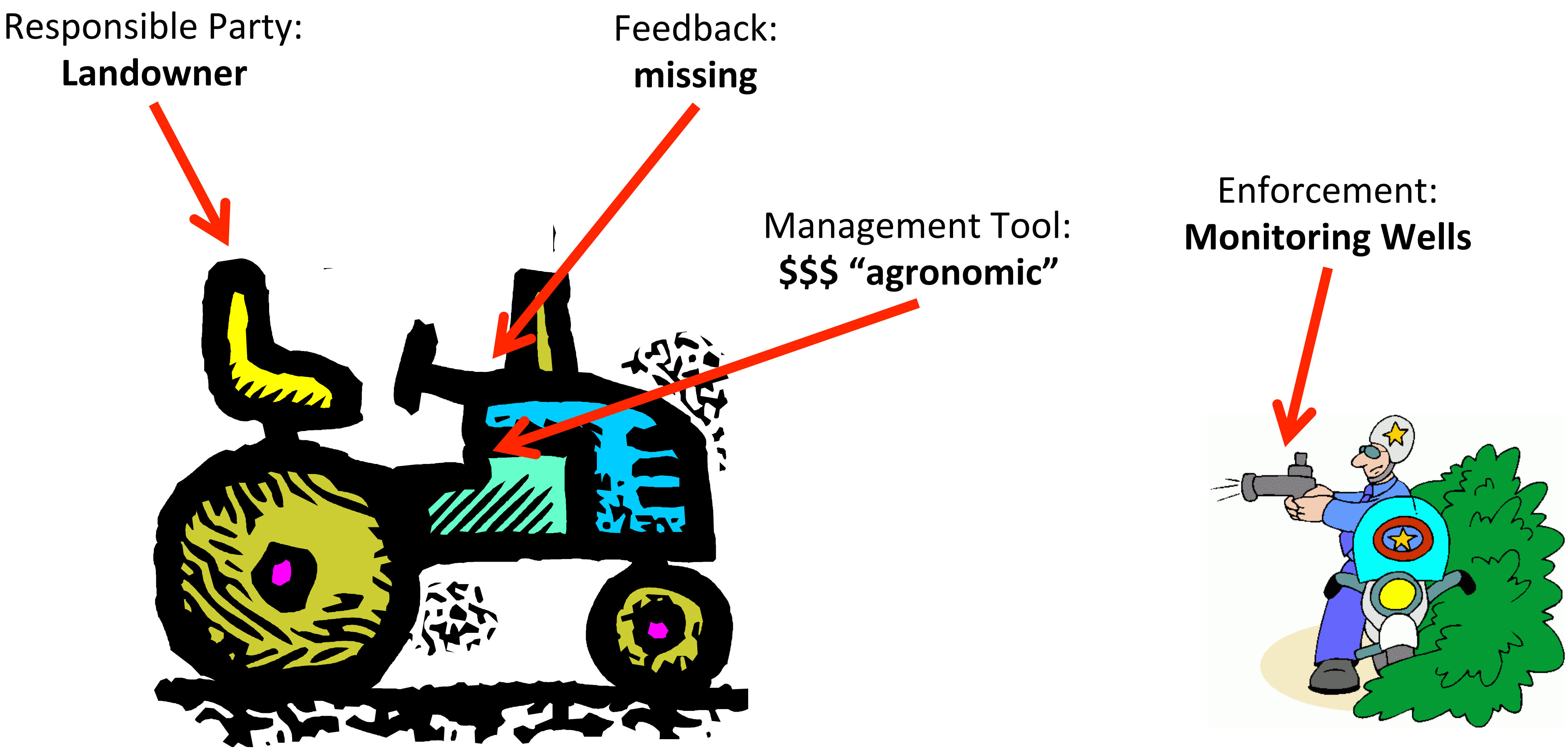
Why is Nonpoint Source Pollution Different from Point Source Pollution of Groundwater?



- Scale
  - Millions of acres vs. 1-10 acres
- Intensity
  - Within ~1 order magnitude above MCL vs. many orders of magnitude above MCL
- Hydrologic Function
  - Recharge vs. non-leaky
- Frequency
  - Ongoing/seasonally repeated vs. incidental
- Heterogeneity & Adjacency

Focus: Enforcement Monitoring

Applying Point Source Approach to Nonpoint Source:



Focus: Enforcement Monitoring

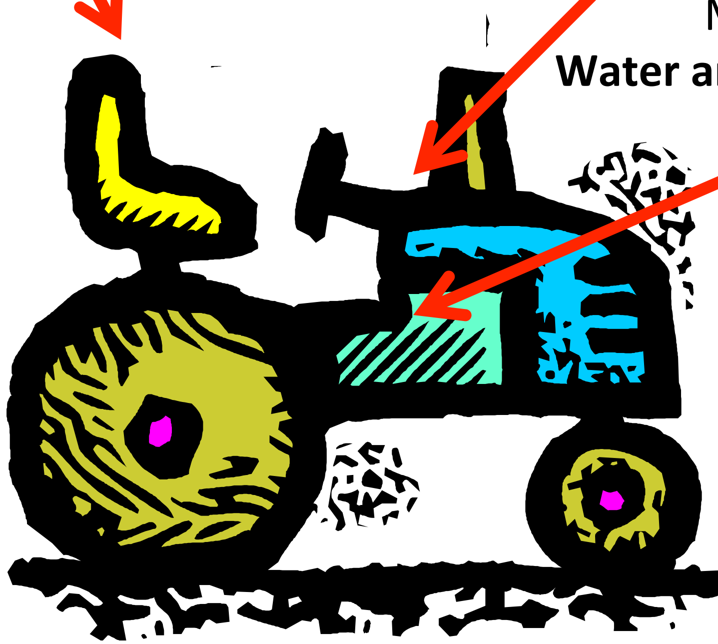
Alternative Monitoring Approach to Nonpoint Source:

Responsible Party:
Landowner

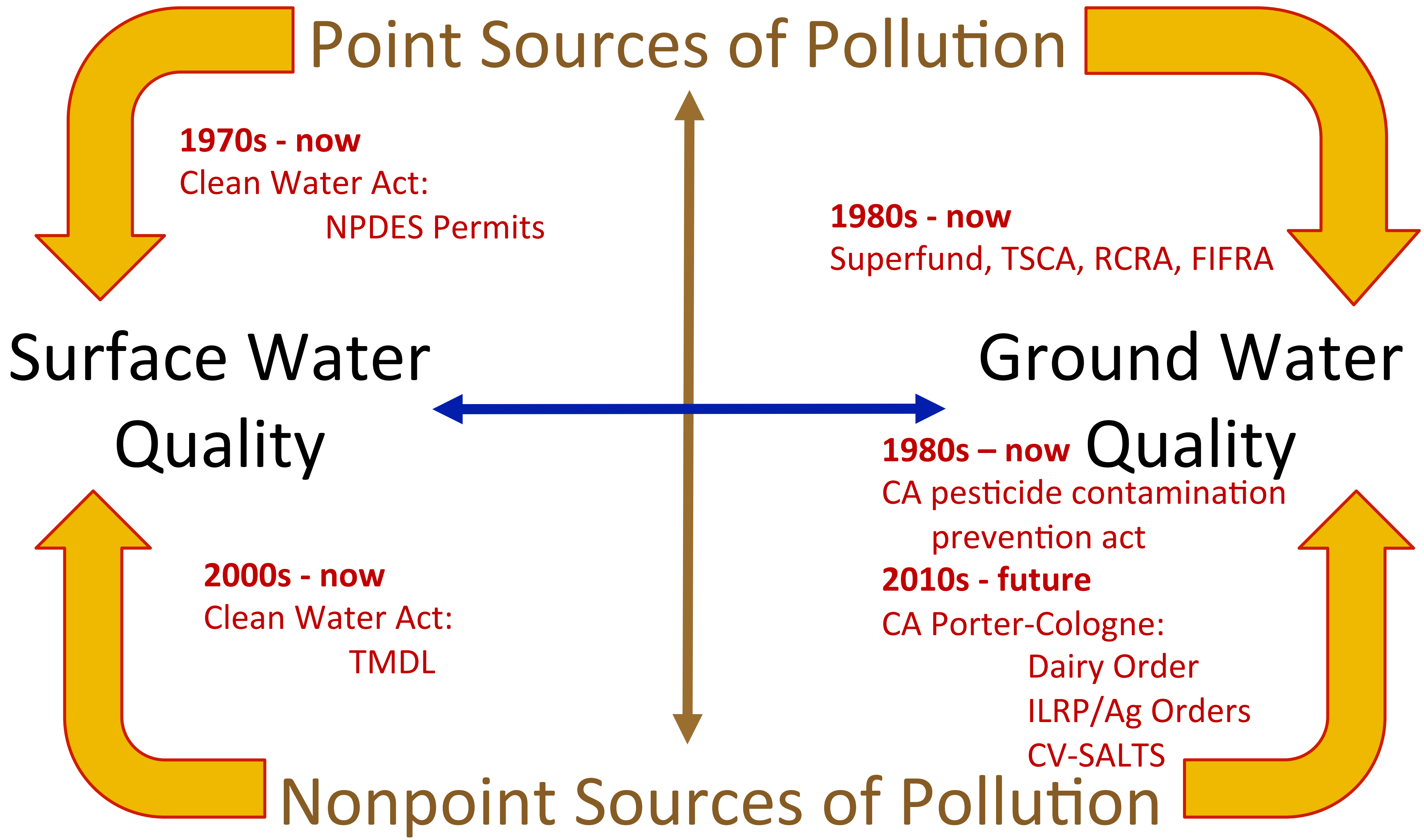
Feedback:
Nutrient/Water Monitoring & Assessment

Management Tool:
Water and Nutrient Management

Enforcement:
Annual Nitrogen Budget
+
Management Practice Assessment
+
Regional Trend Monitoring



Regulating Water Pollution Sources



Future of Groundwater Management in Agricultural Regions:

Opportunity for creative solutions to **simultaneously** address

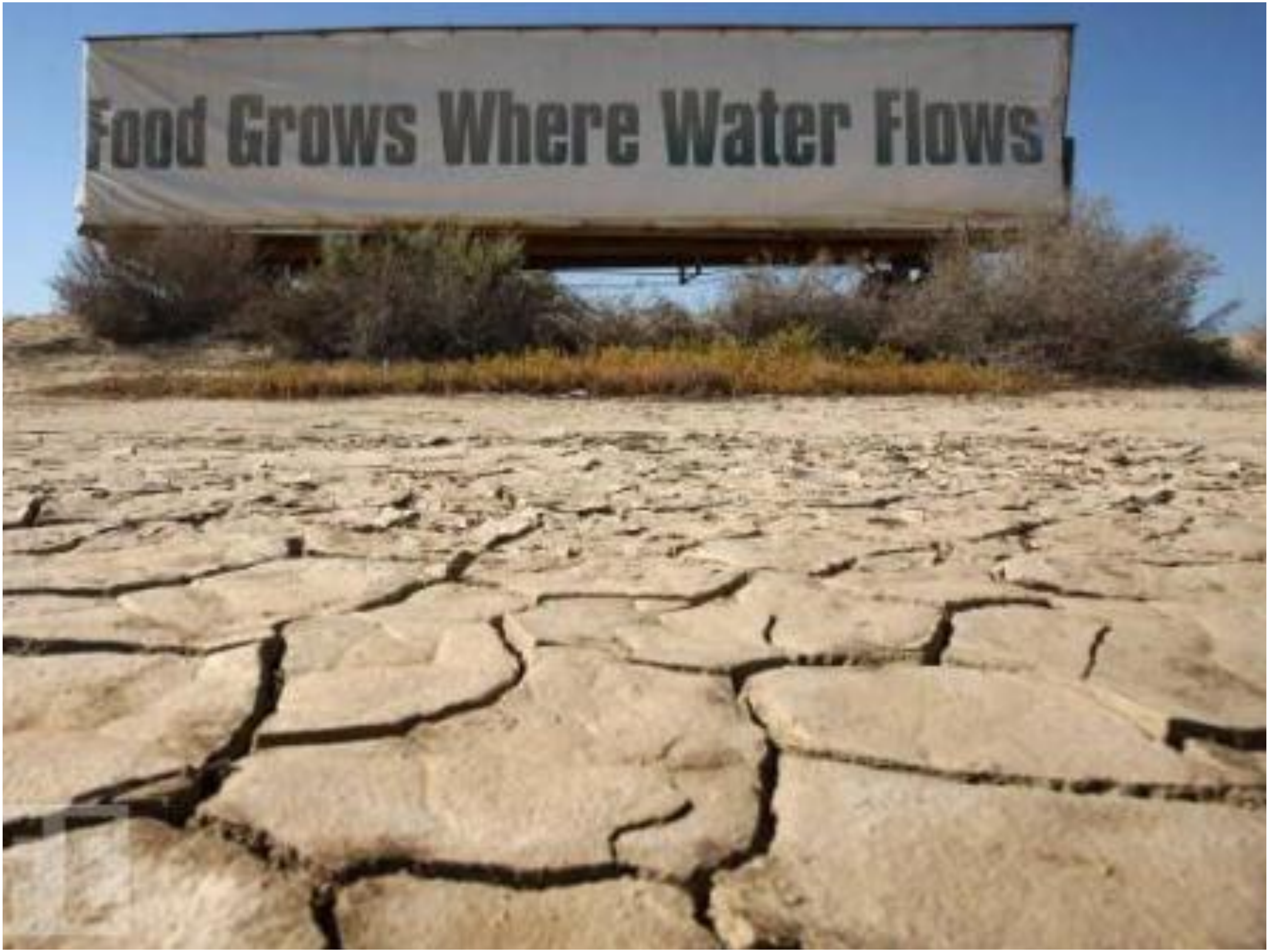
- groundwater supply enhancement
- groundwater quality improvement
- drinking water protection
- economic viability of agriculture

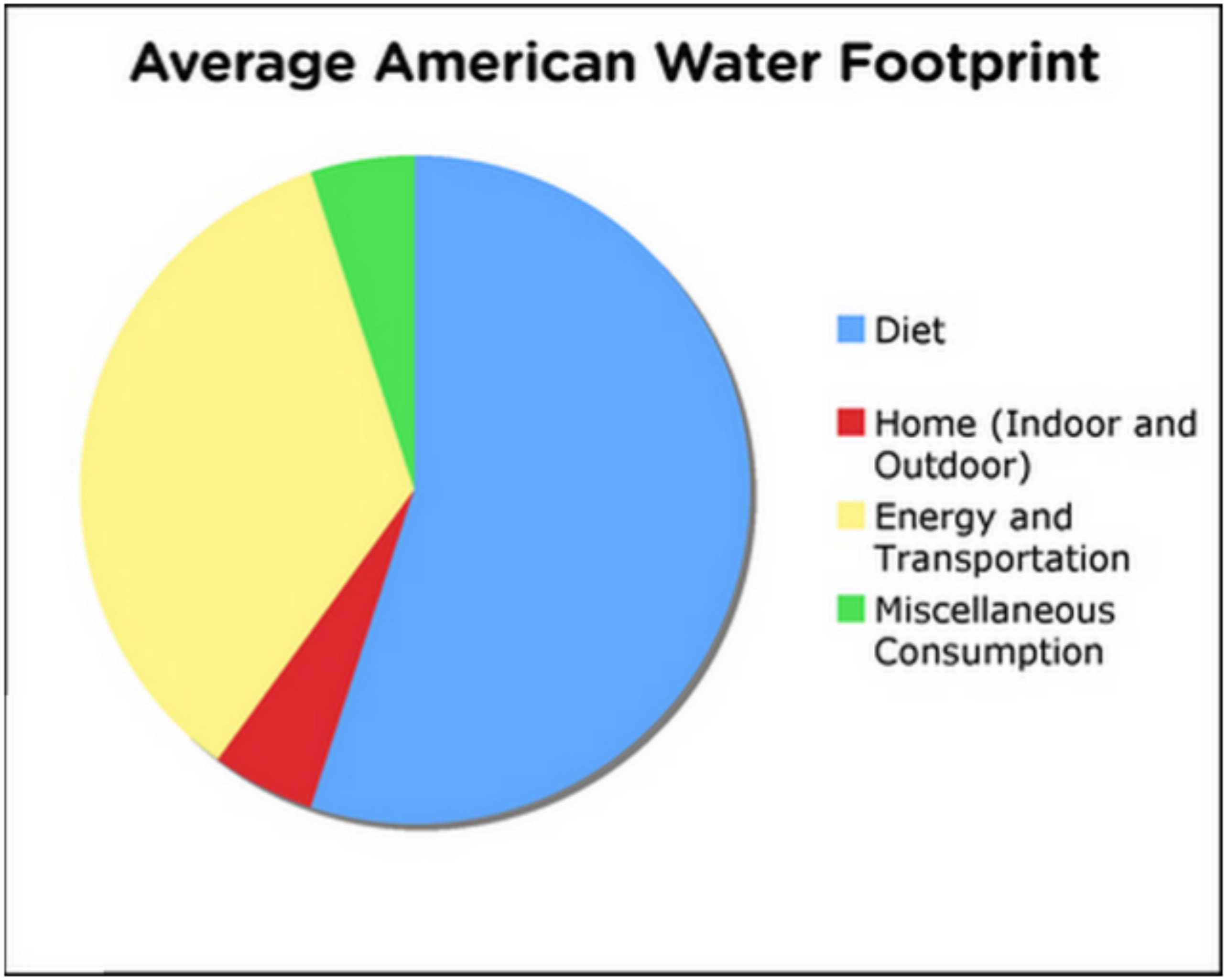
High irrigation efficiency + High nutrient use efficiency + CLEAN groundwater recharge

Online Resources

- http://groundwater.ucdavis.edu/sgma
- http://groundwater.ucdavis.edu/calendar
- http://www.water.ca.gov/groundwater/casgem/ (California DWR groundwater level monitoring program
- http://www.water.ca.gov/waterconditions/drought/# (California DWR drought information)
- http://www.waterboards.ca.gov/gama/geotracker_gama.shtml (California groundwater quality information)
- http://groundwater.ucdavis.edu/links_California/ (miscellaneous groundwater information sources)
- Contact Dr. Thomas Harter at ThHarter@ucdavis.edu

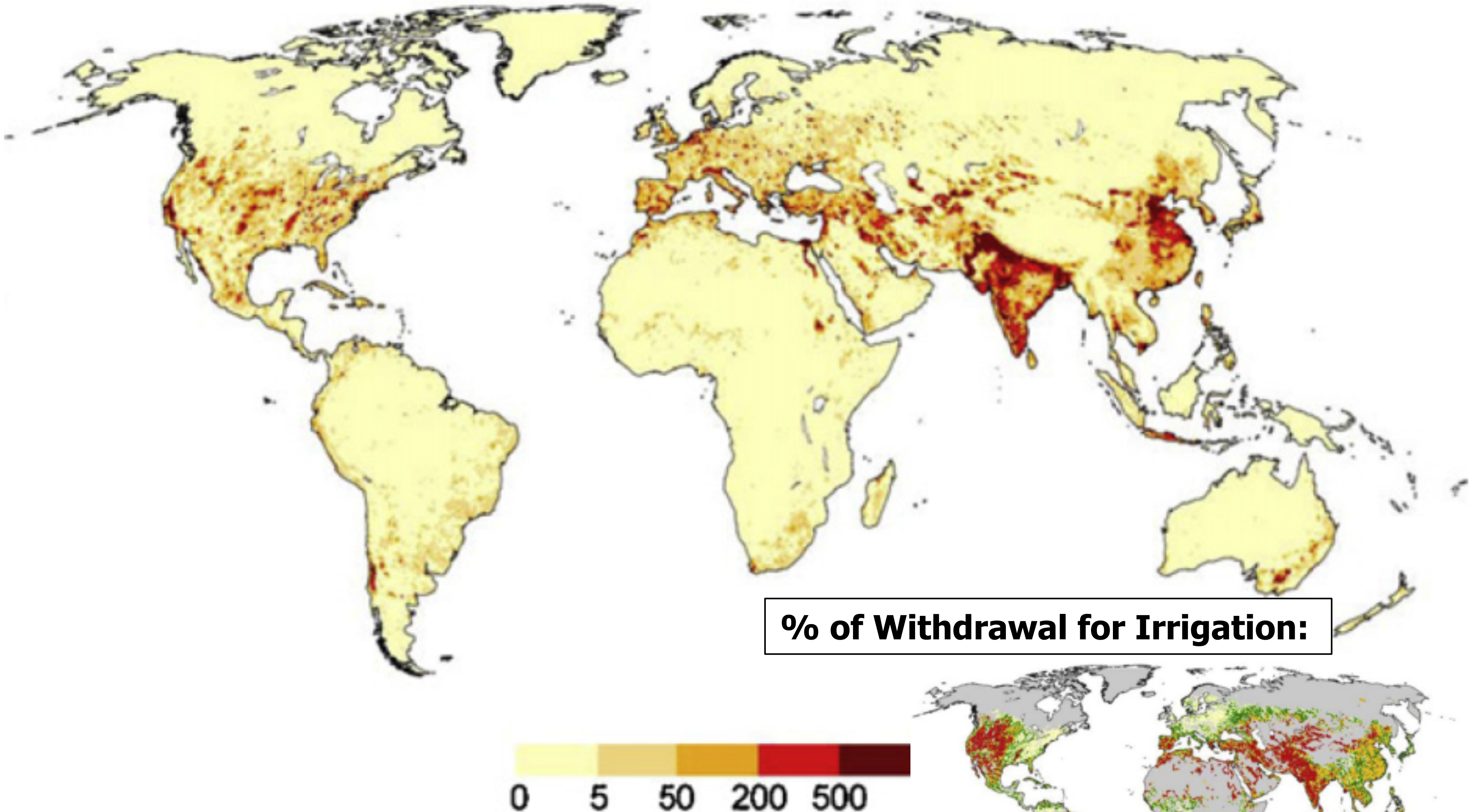

THE
END


Food Grows Where Water Flows

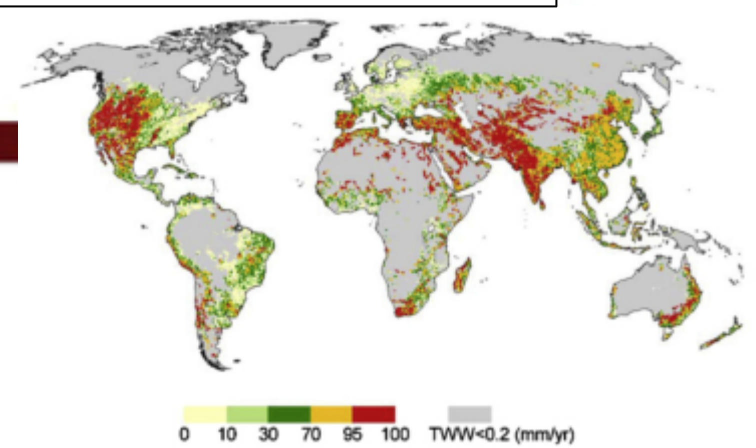


National Geographic, 2010

Total Groundwater Withdrawals [mm/yr]

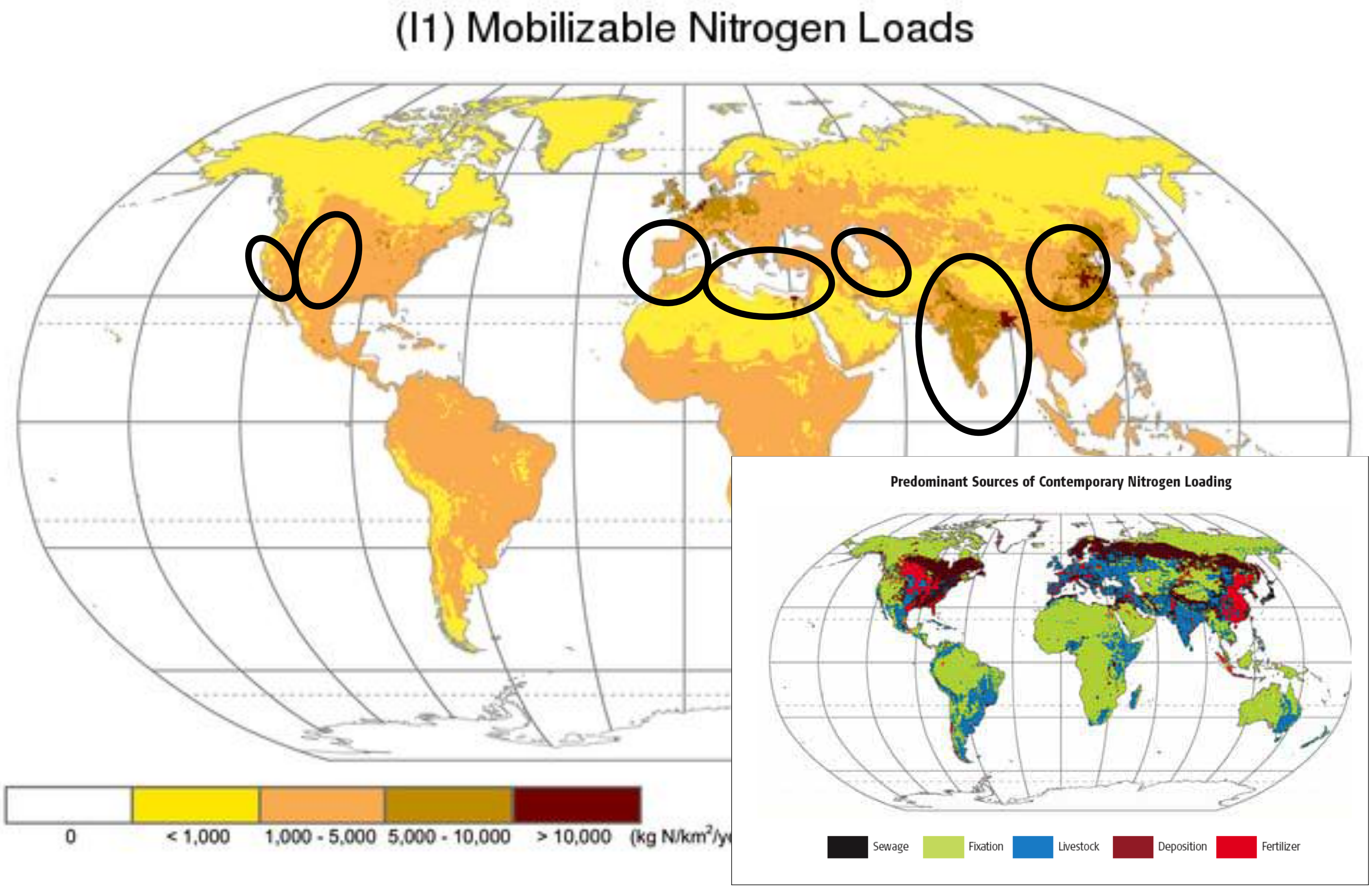


% of Withdrawal for Irrigation:



Doell et al., J Geodynam. 2012

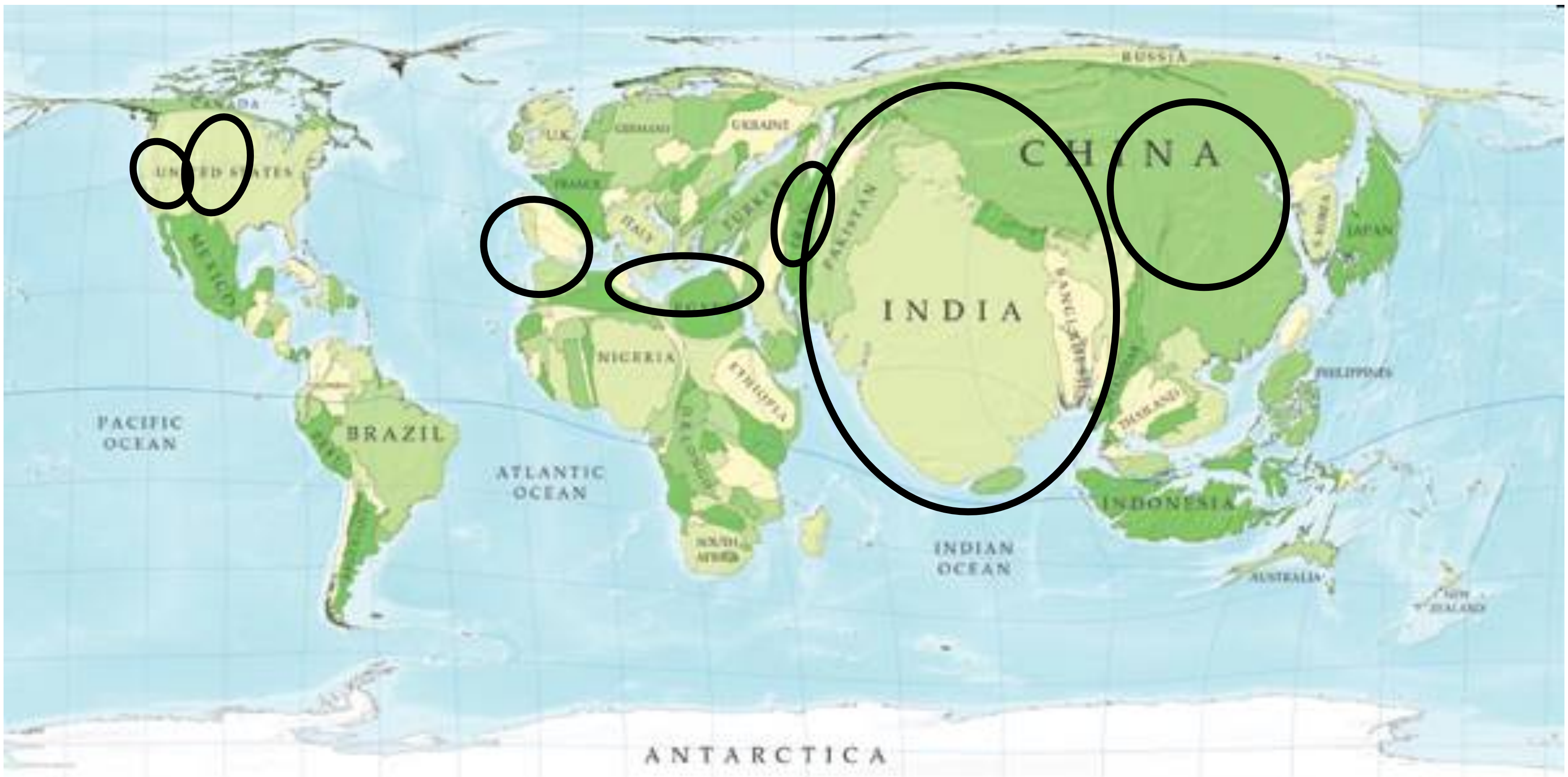
Global Risk of GW Nitrate



Note: 10 mg N/l = 10 kg N/km^2/yr for each 1 mm/yr recharge

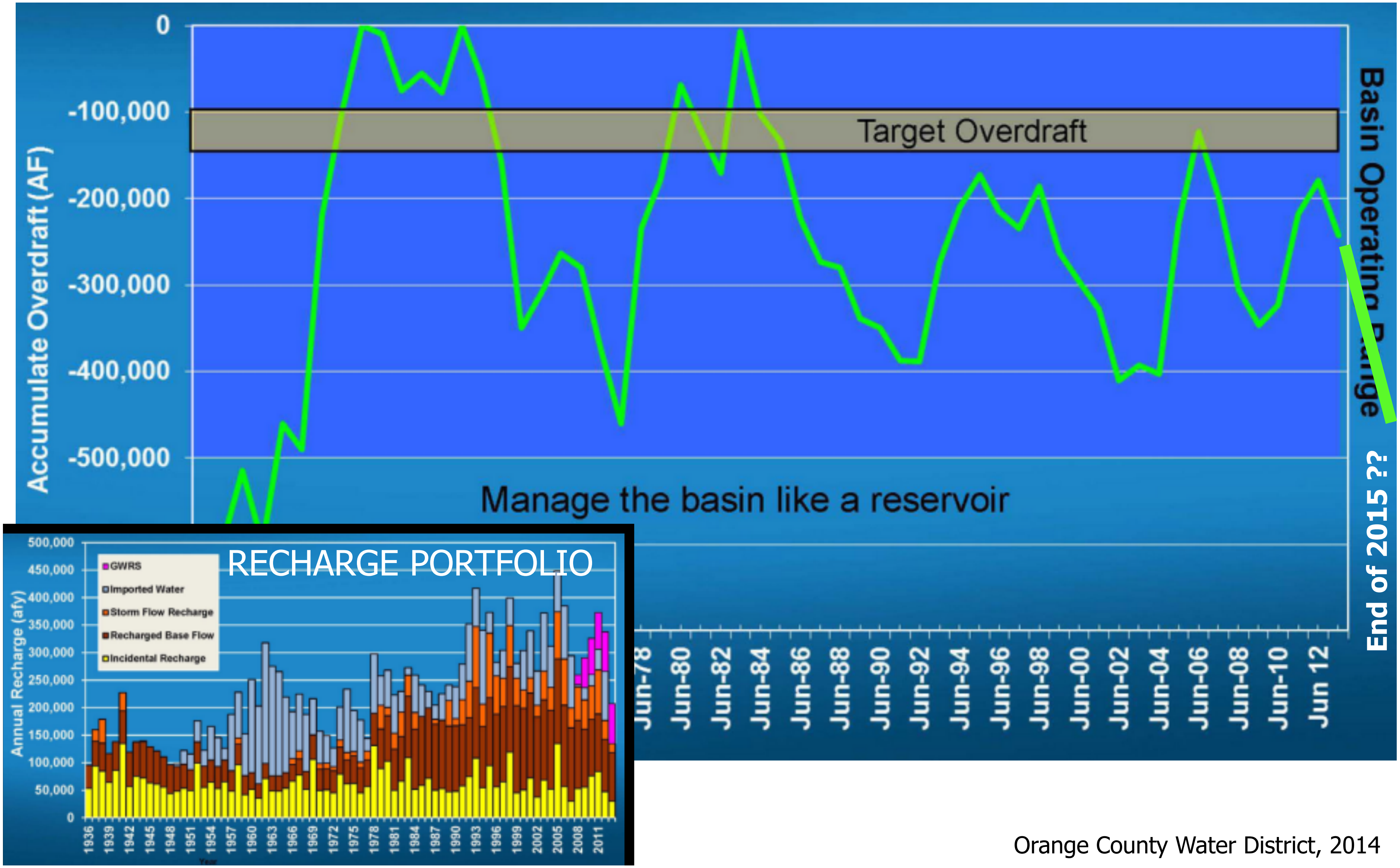
UN World Water Development Report II, 2006

Population Map of the World
& Major GW Withdrawal Centers



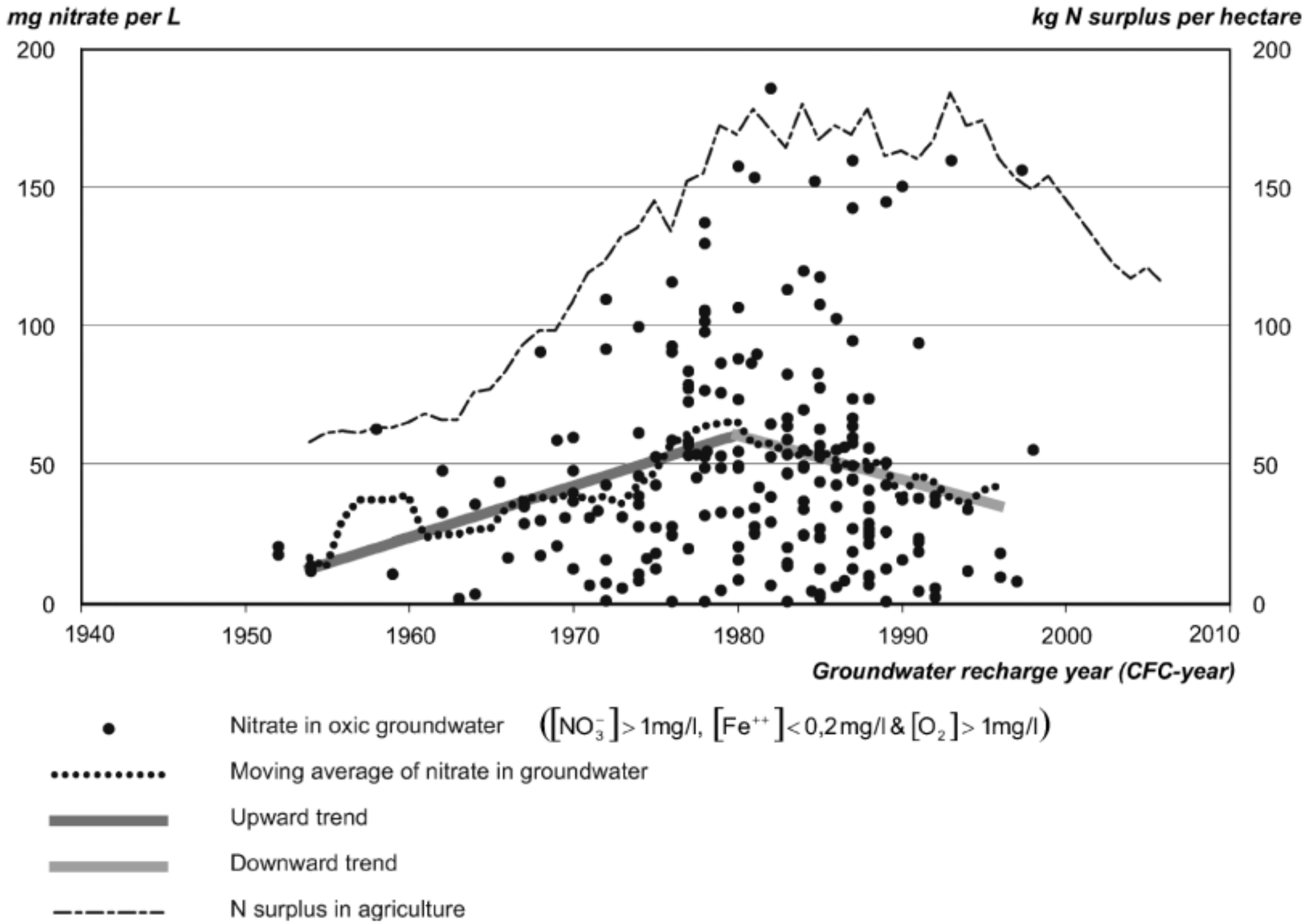
Modified with world population map from: Nature **439**, 800 (16 February 2006) | doi:10.1038/439800a

CA Ag Future: Demonstrated Groundwater Sustainability

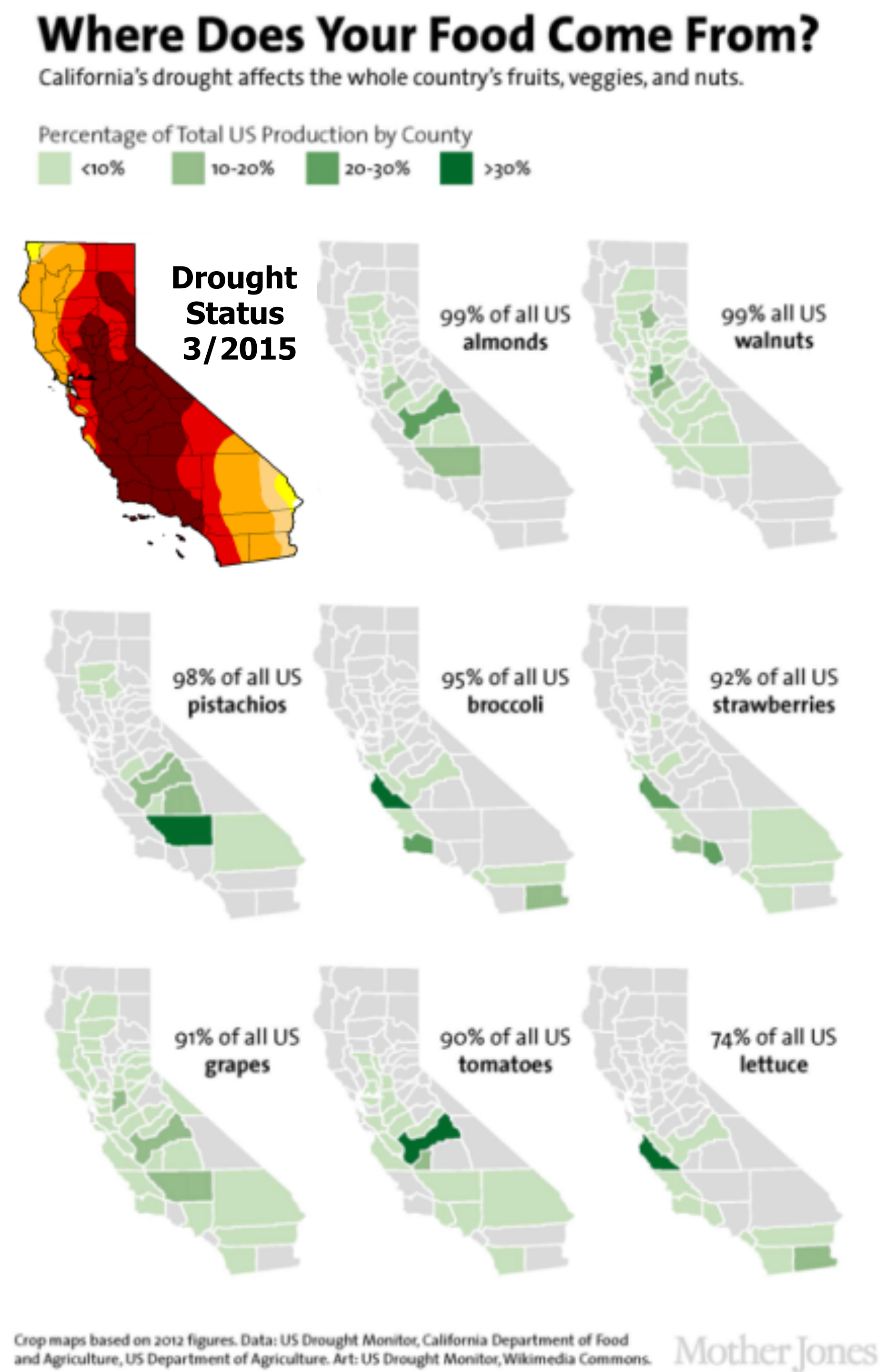


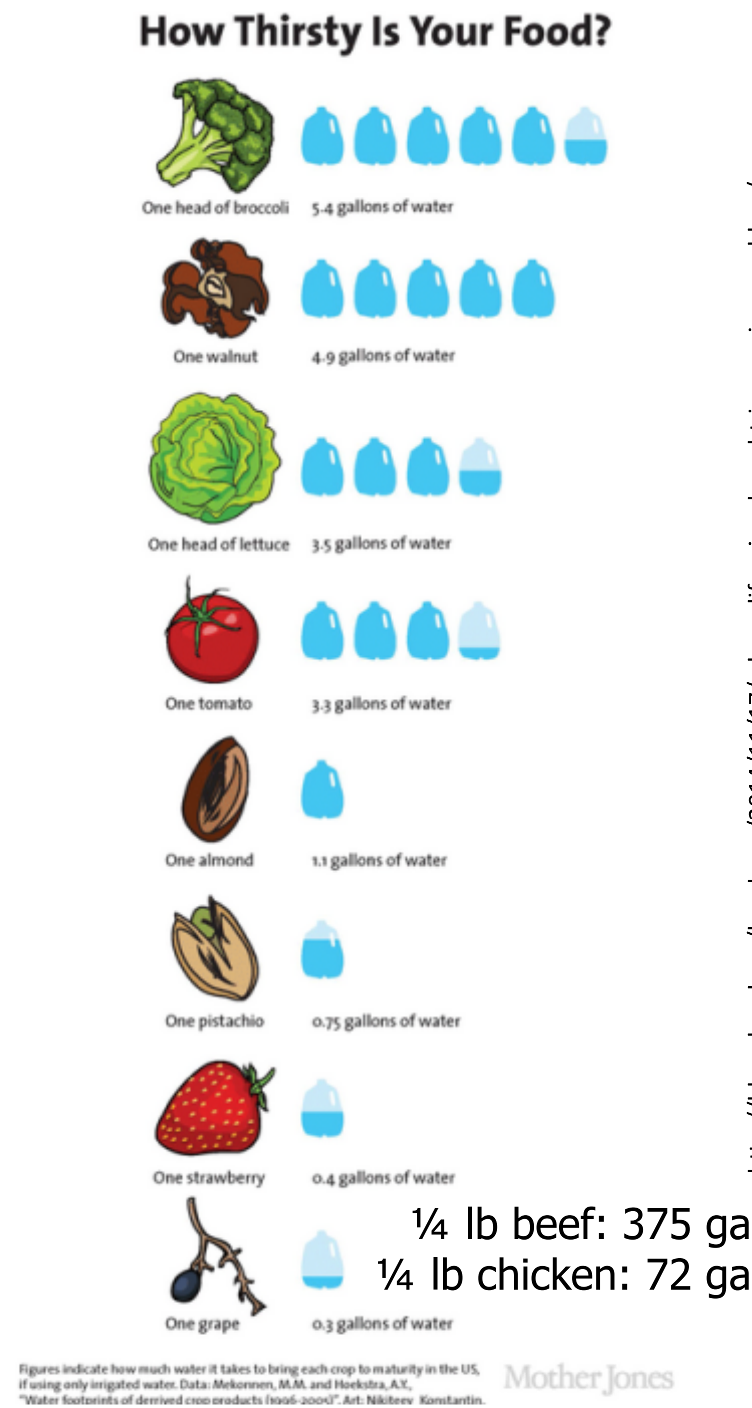
Orange County Water District, 2014

CA Ag Future: Demonstrated Improvements in GW Quality



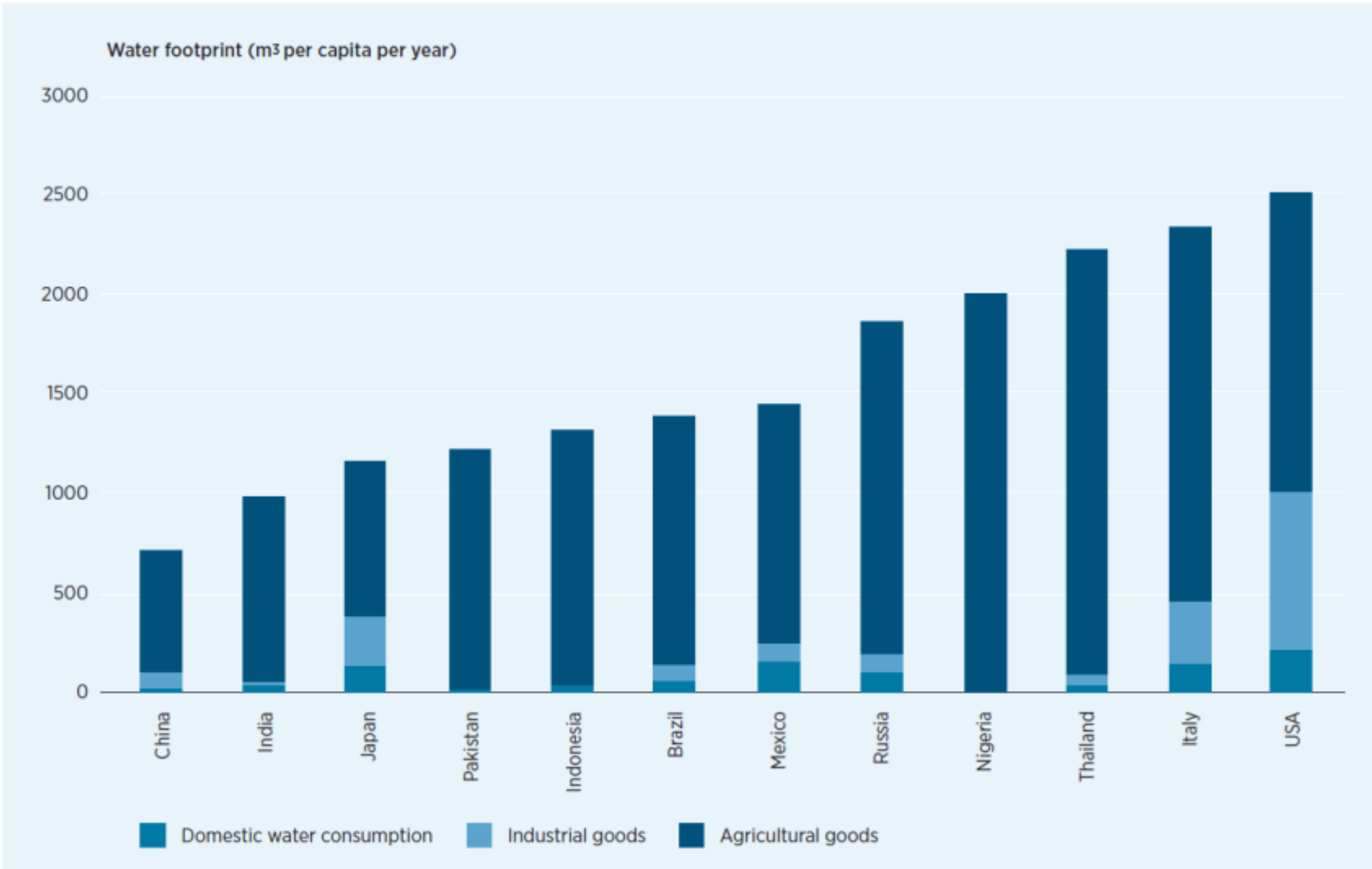
Hanson et al., ES&T 2011: Trend reversal in Danish groundwater





http://blogs.kqed.org/lowdown/2014/11/17/why-californias-drought-is-americas-problem/

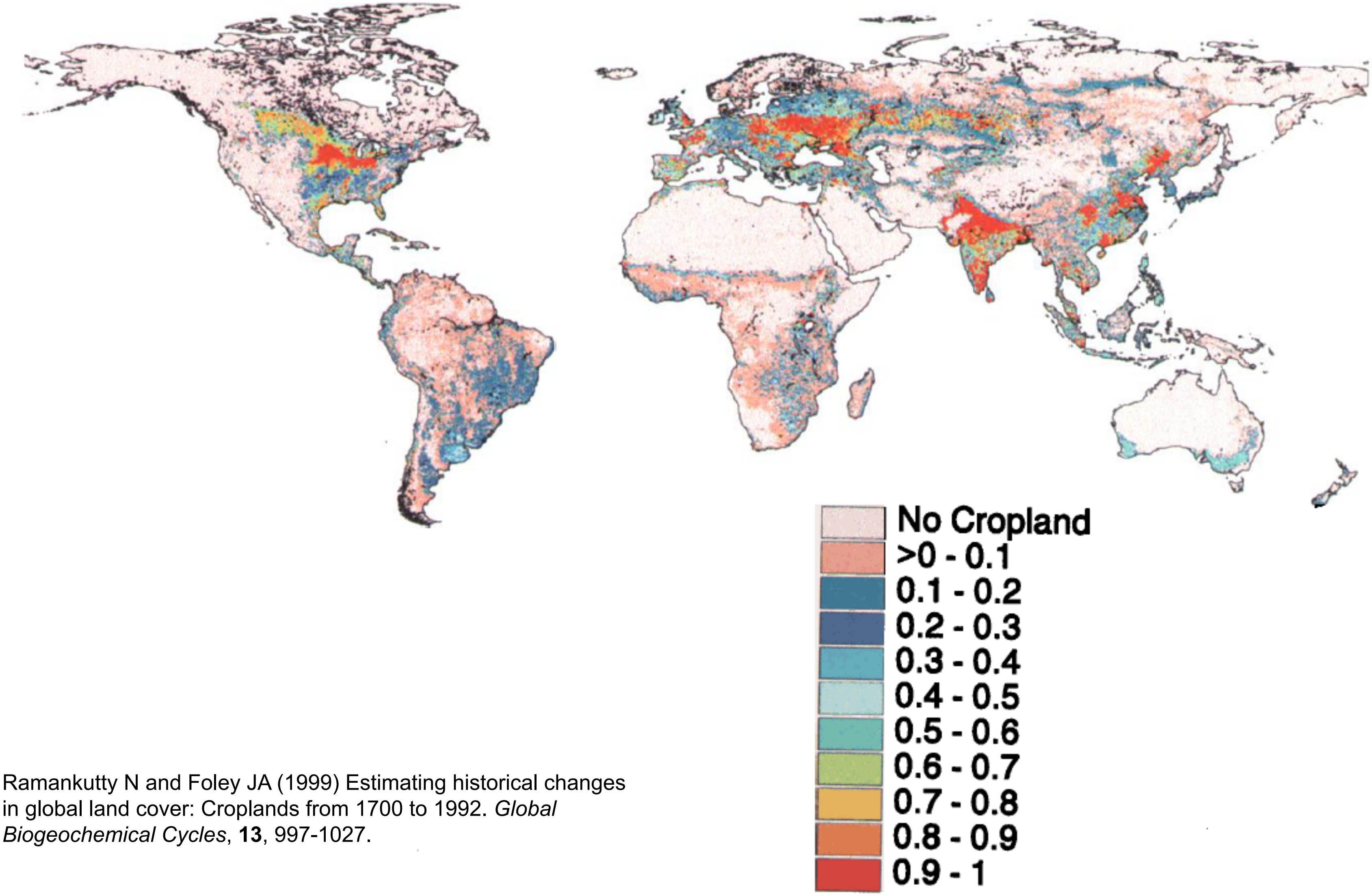
National water footprint, by sector [cu. m/capita/year]



Source: Hoekstra and Chapagain (2007, fig. 5). Reproduced by permission from Springer Science+Business Media B.V.

World Water Development Report 4, 2012 (Chapter 15)

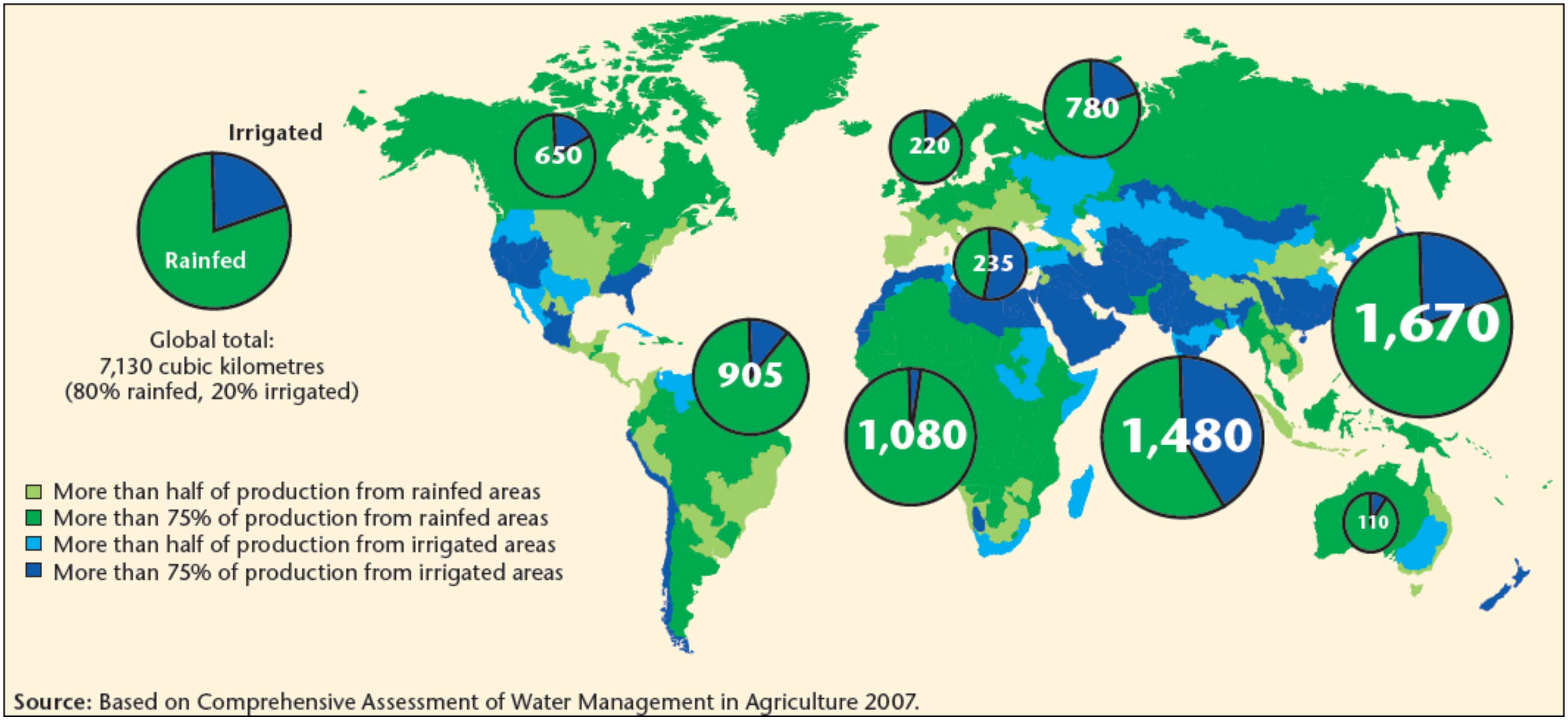
Global Fraction of Cropland, 1992



Ramankutty N and Foley JA (1999) Estimating historical changes in global land cover: Croplands from 1700 to 1992. *Global Biogeochemical Cycles*, **13**, 997-1027.

Plate 1. Global fractional cropland area at 5 min resolution. This is an updated version of the data set presented by *Ramankutty and Foley* [1998].

"Green" vs. "Blue" Water Use in Agriculture



Rainfed agriculture = 80% of cultivated land, 60% of crop production
Irrigated agriculture = 70% of applied water use, 90% of consumptive use
20% of cultivated land, 40% of crop production

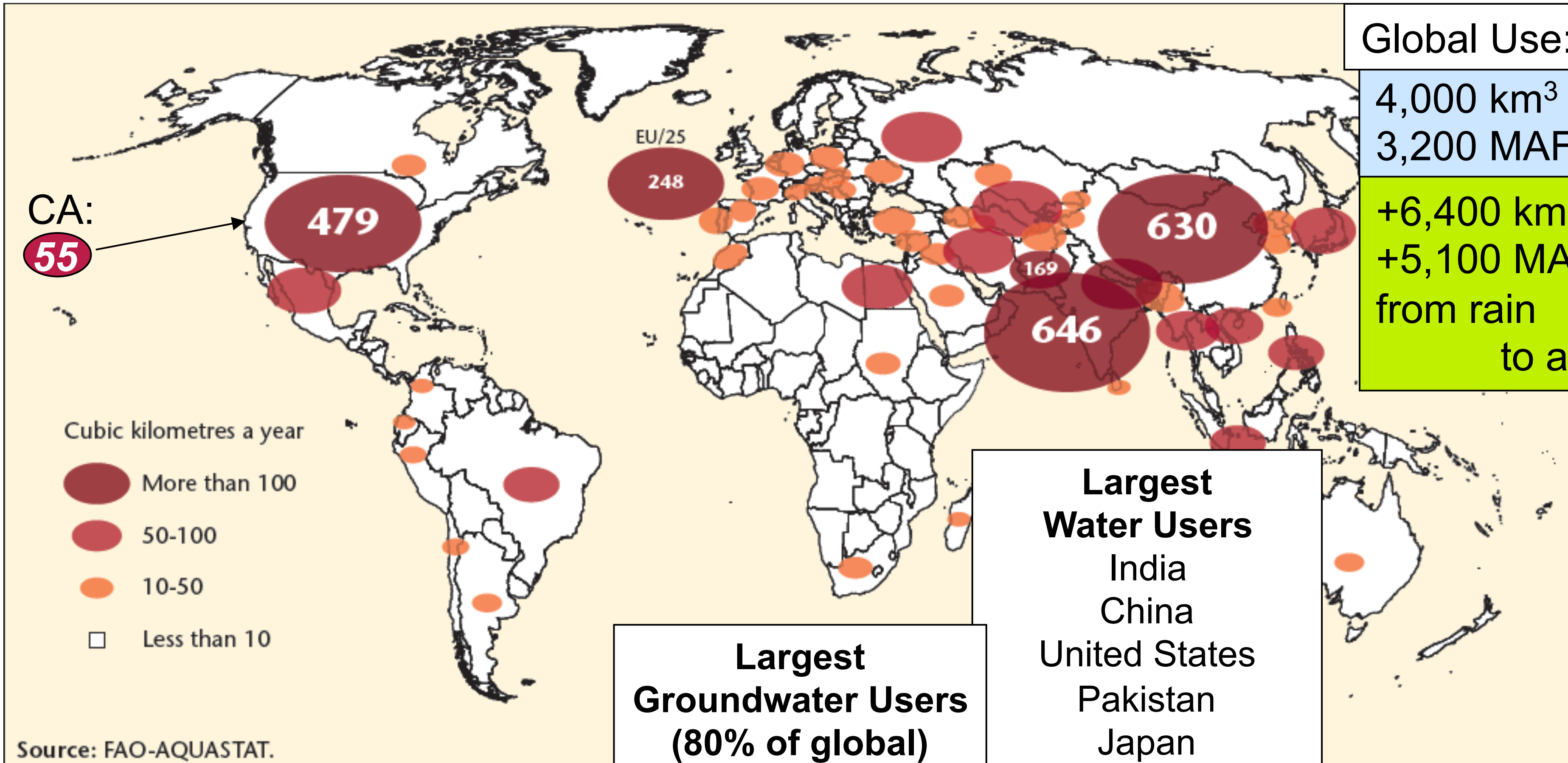
from: United Nations World Water Development Report, 2009

Why use groundwater in agriculture?

- Ubiquity
- Upfront capital costs lower than surface water irrigation systems
- Affordable / no large organization needed
- Gov'mt subsidies (rural energy, pumps)
- Irrigation on demand
- Much higher value crops
- Drought resilience
- Water scarcity meets increasing food & feed demand (more [concentrated] animal ag)

Shah, Villholth, Burke, "Groundwater: a global assessment of scale and significance", IWMI, 2007

Total Water Use Map



Global Use:

4,000 km^3
3,200 MAF

+6,400 km^3
+5,100 MAF
from rain
to ag

Largest Groundwater Users (80% of global)

India
China
United States
Iran
Bangladesh
Pakistan

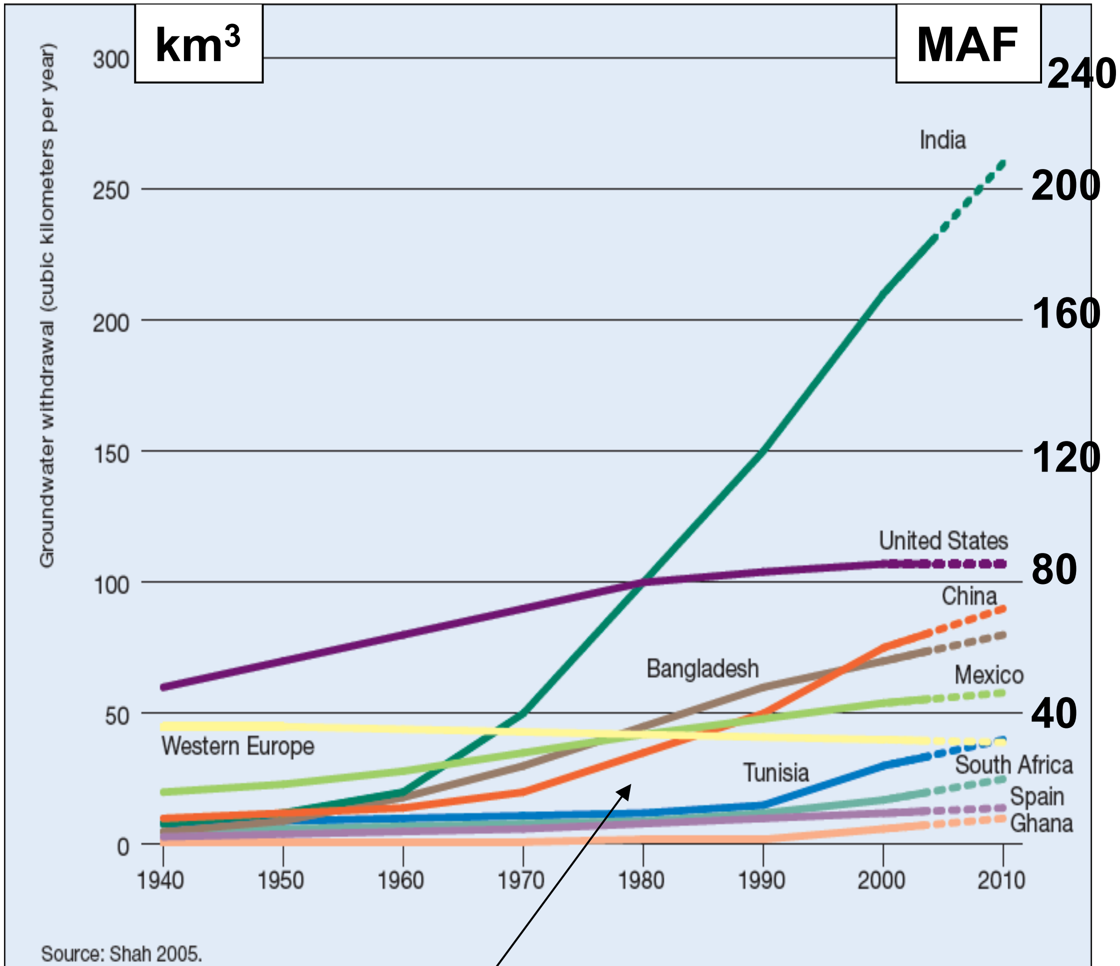
Largest Water Users

India
China
United States
Pakistan
Japan
Thailand
Indonesia
Bangladesh
Mexico
Russian Federation

modified from:
United Nations World Water Development Report, 2009

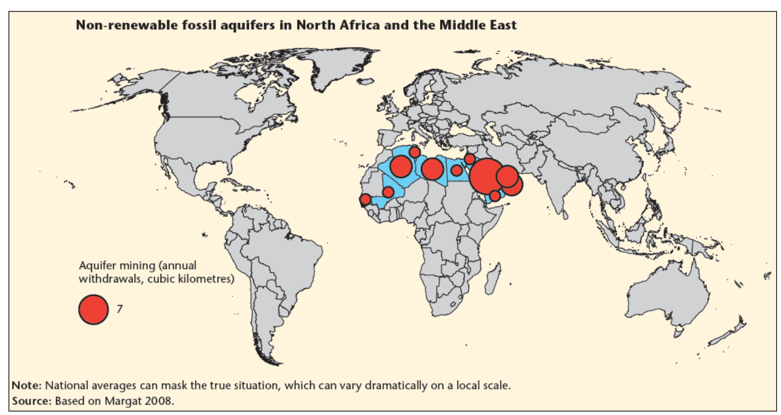
100 km^3 = 80 MAF

Trends in Groundwater Use

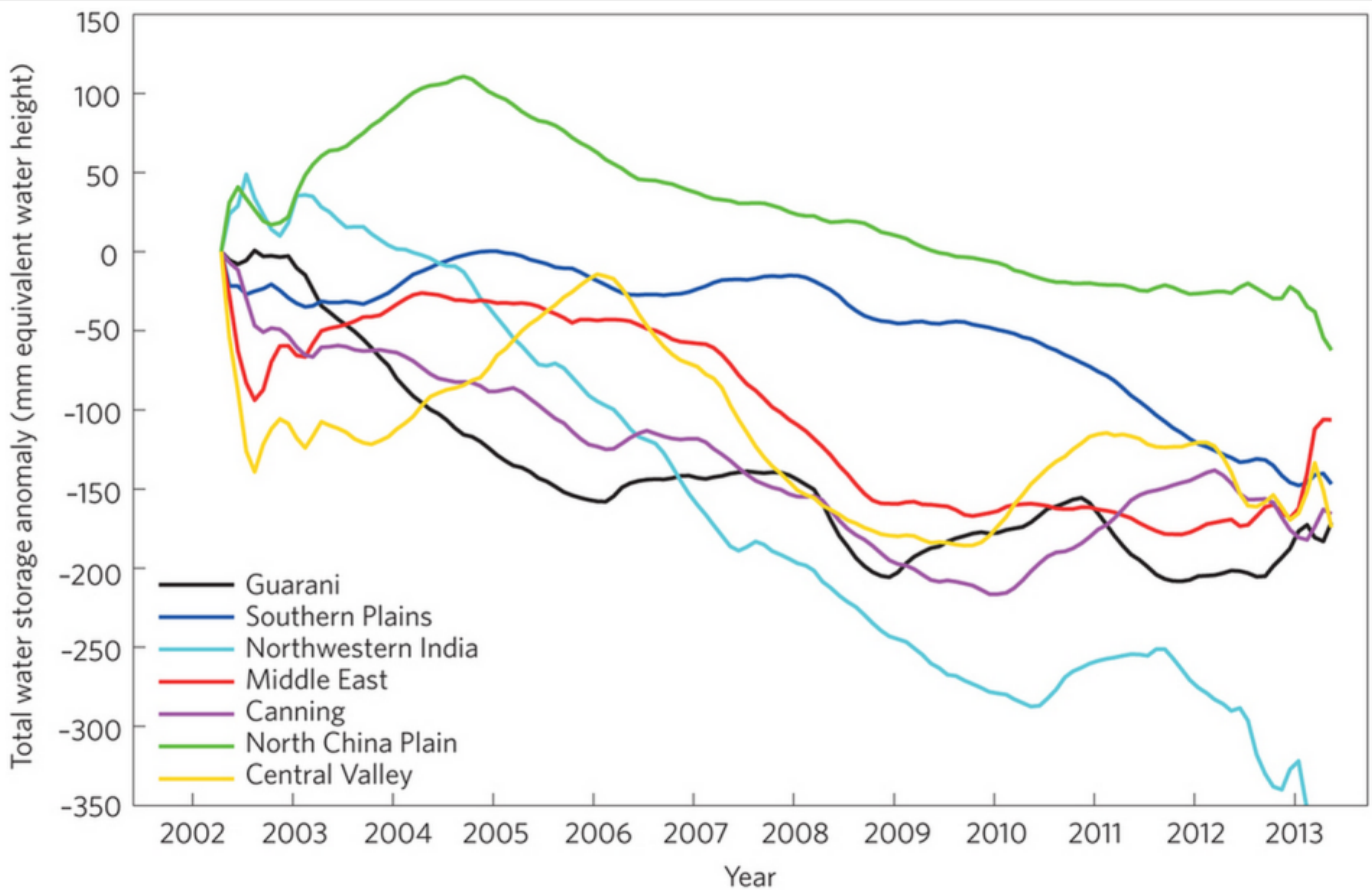


from: Shah et al, 2007

CA: 13-25 km^3/ 10-20 MAF

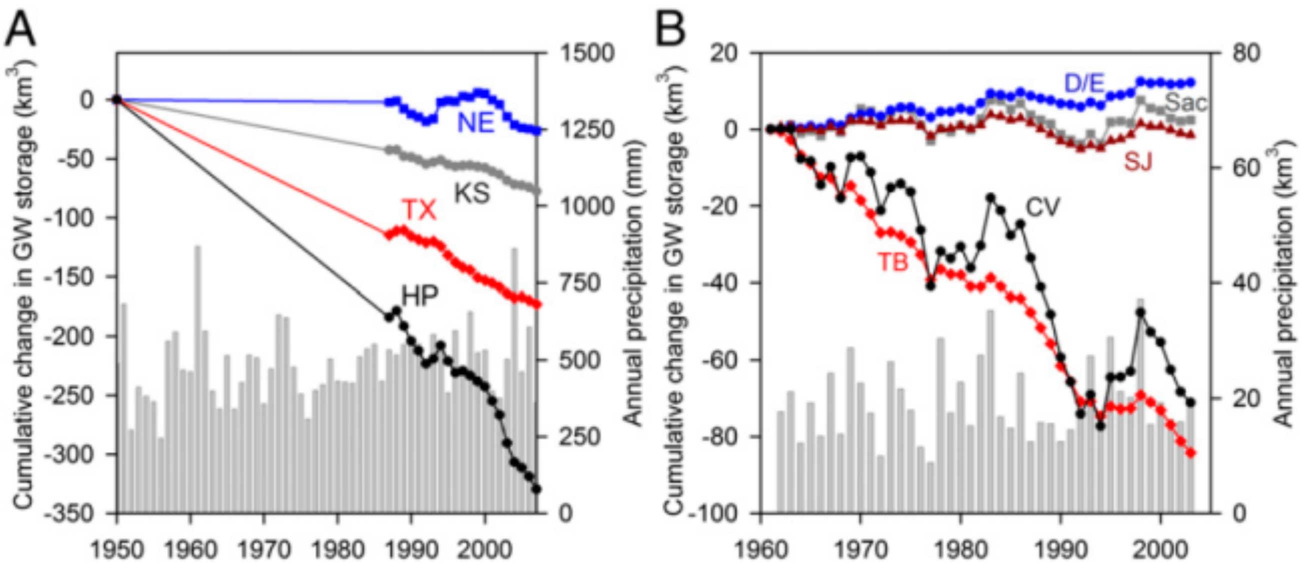


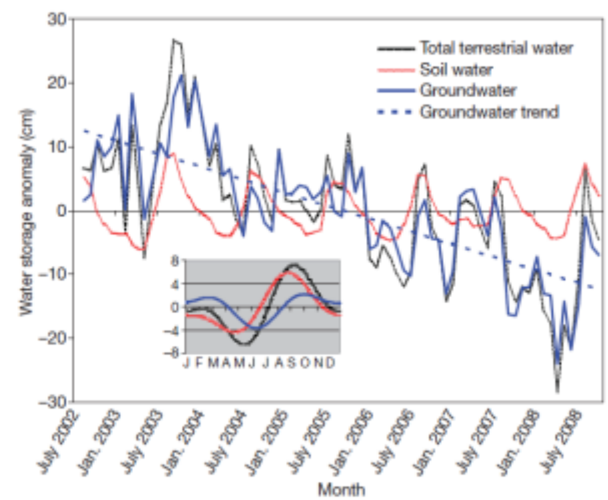
from: United Nations World Water Development Report, 2009

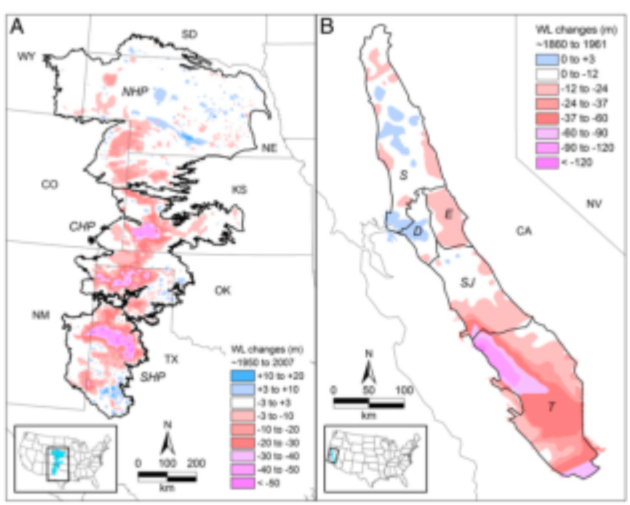


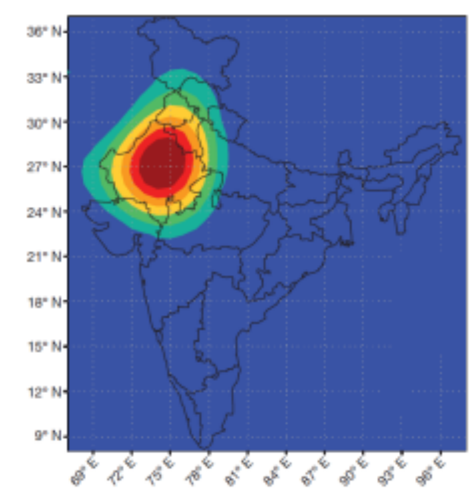
The monthly storage changes are shown as anomalies for the period April 2002–May 2013, with 24-month smoothing. Image: J. T. Reager, NASA Jet Propulsion Laboratory, California Institute of Technology, USA.

Groundwater Overdraft







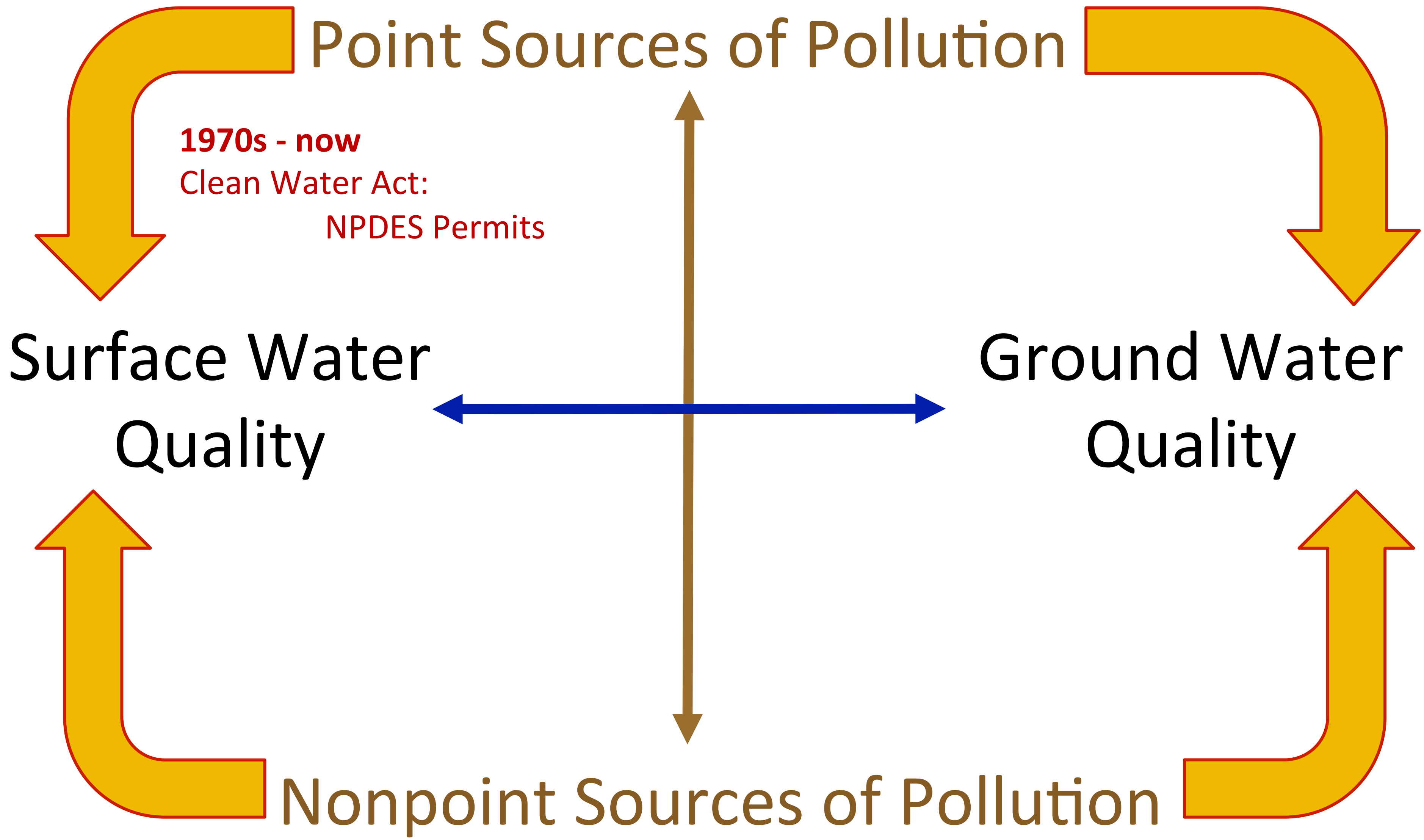


Scanlon et al., PNAS 2012

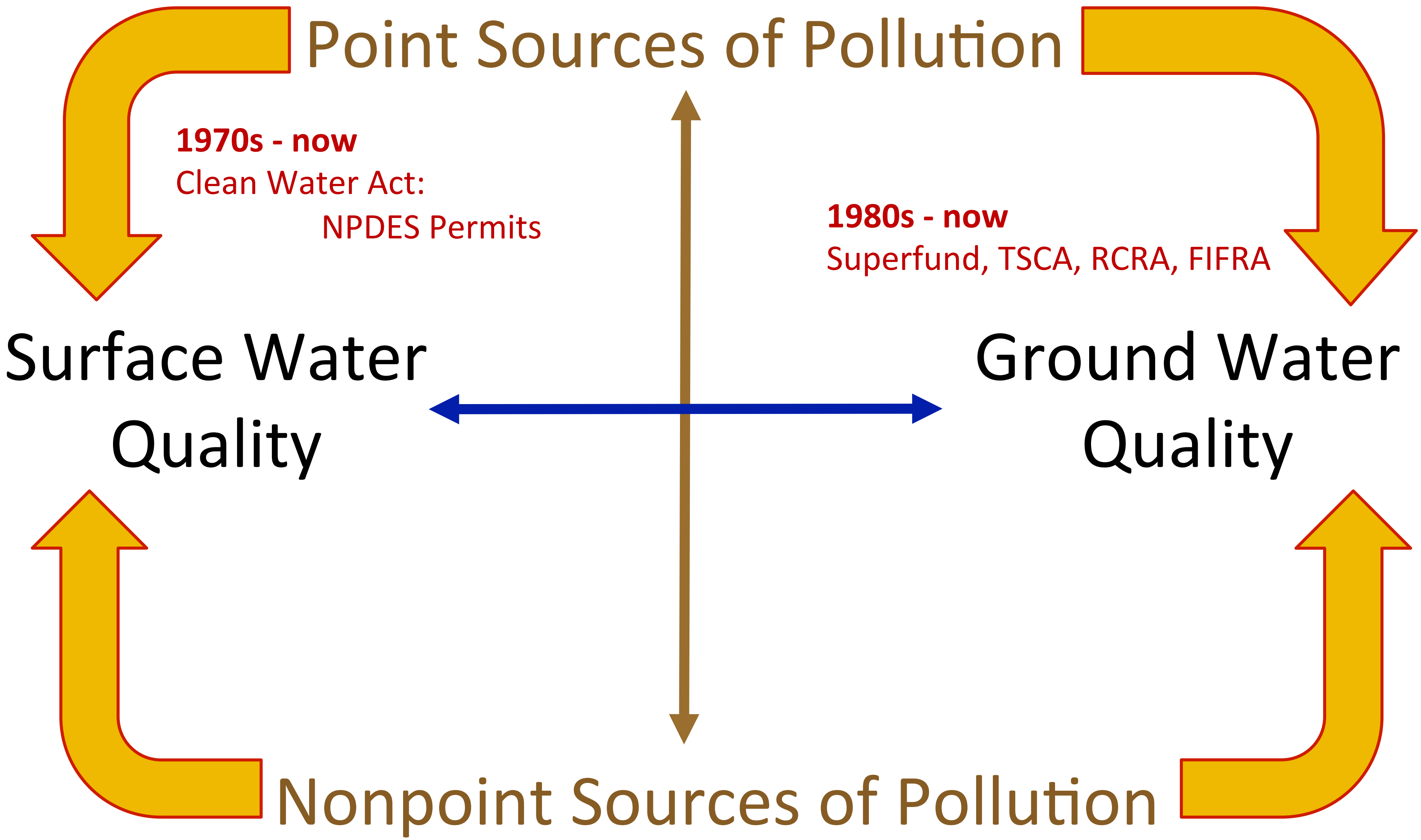
Rodell et al., Nature 2009


13
15
20
18
18

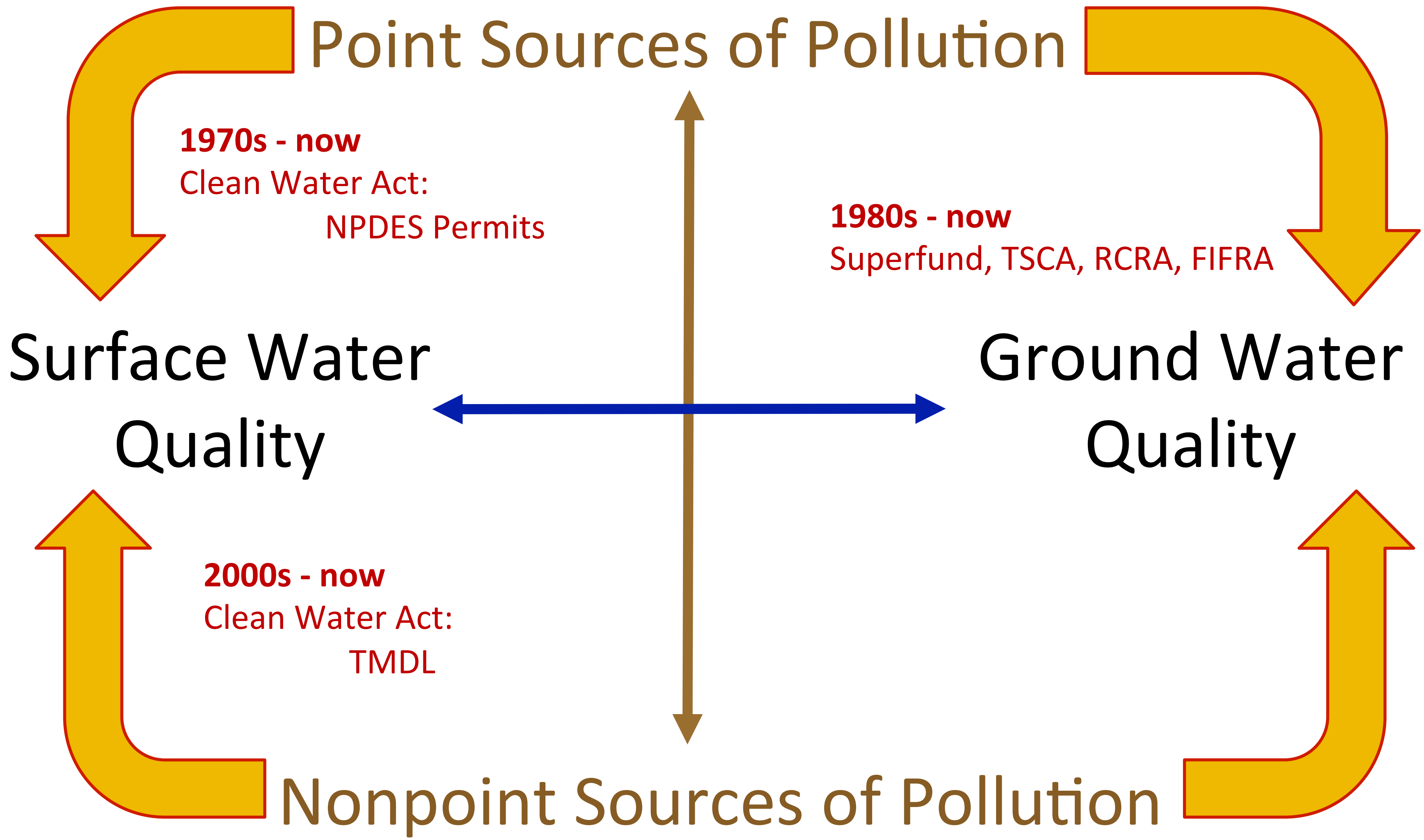
Regulating Water Pollution Sources



Regulating Water Pollution Sources



Regulating Water Pollution Sources



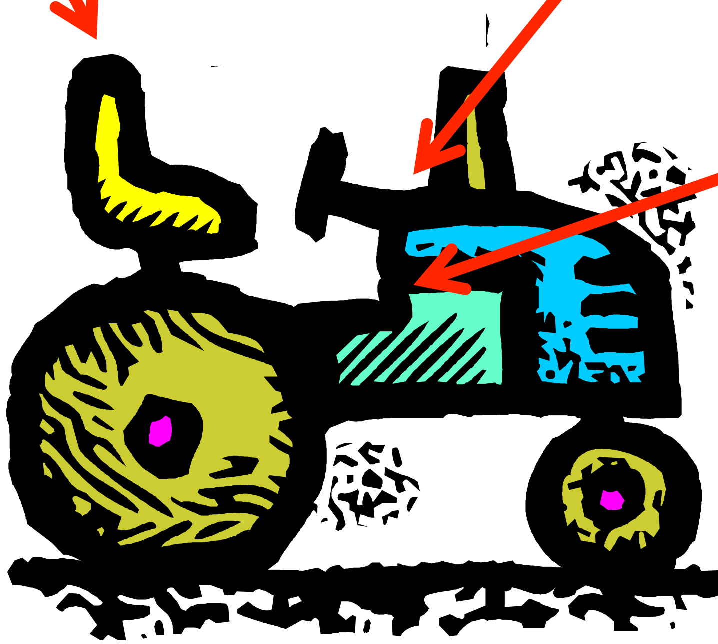
Focus: Enforcement Monitoring

Example of Working with a Regulation: Speed Limit

Responsible Party:
Driver

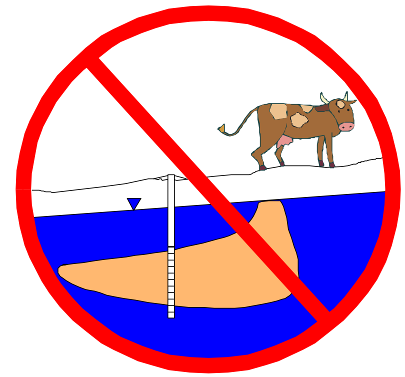
Feedback:
Speedometer

Management Tool:
Brakes



Enforcement:
Radar Controls

Why is Nonpoint Source Pollution Different from Point Source Pollution of Groundwater?



- Scale
  - Millions of acres vs. 1-10 acres
- Intensity
  - Within ~1 order magnitude above MCL vs. many orders of magnitude above MCL
- Hydrologic Function
  - Recharge vs. non-leaky
- Frequency
  - Ongoing/seasonally repeated vs. incidental
- Heterogeneity & Adjacency

Focus: Enforcement Monitoring

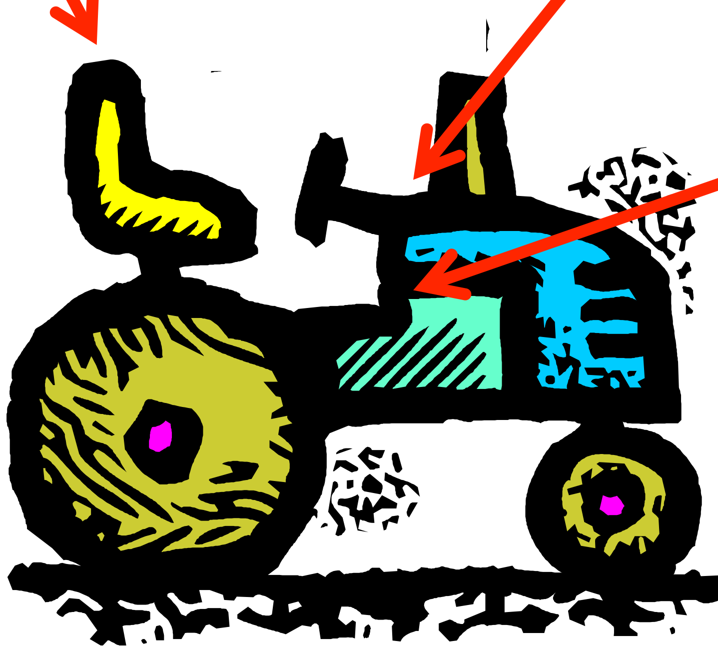
Applying Point Source Approach to Nonpoint Source:

Responsible Party:
Landowner

Feedback:
missing

Management Tool:
$$$ “agronomic”

Enforcement:
Monitoring Wells



Key Elements to Future "Groundwater" Monitoring of NPS

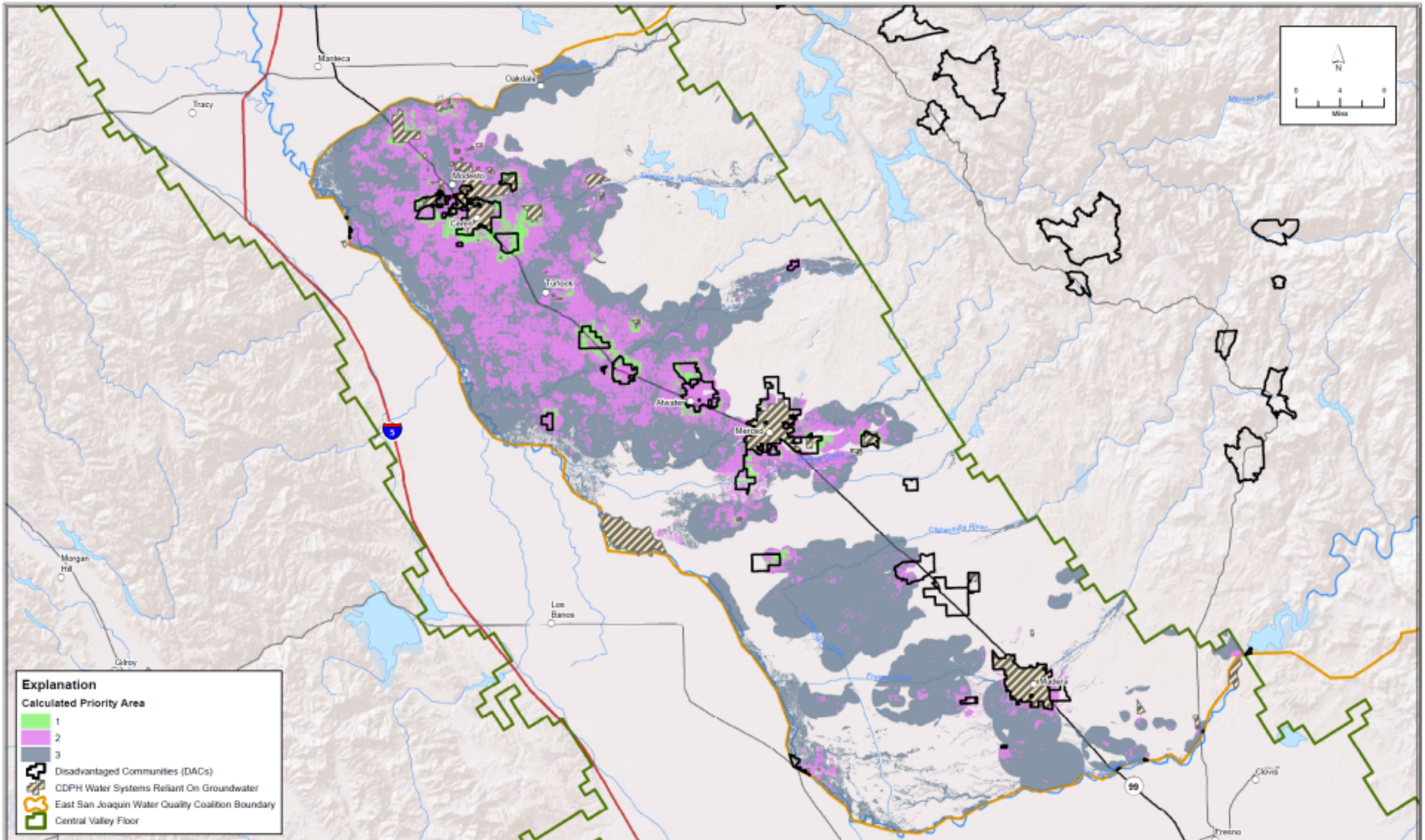
- Three-track monitoring:
  - **Enforcement**: Monitor/report key outcomes of farm management practices, e.g., **annual nitrogen budgets** – "proxy" for measuring "groundwater discharge"
  - **Research**: link "proxy monitoring" to actual groundwater discharge at intensely monitored sites & using models (**mgmt practice evaluation**)
  - **Assurance**: **Regional trend monitoring** network (e.g., GAMA)

STEP 1: GROUNDWATER ASSESSMENT

High Vulnerability Areas: Key Criteria (ESJV Coalition)

- Hydrogeologically high vulnerability
  - statistical analysis of groundwater nitrate occurrence based on hydrogeology, soils, depth to groundwater, landscape slope, recharge
- Further prioritization (high – 1, medium – 2, low – 3):
  - Exceedances of water quality objectives,
  - Proximity to areas contributing recharge to urban and rural communities that rely on groundwater as a source of supply,
  - Existing field and operational practices that are possibly the cause or source of groundwater quality degradation,
  - The largest acreage commodity types comprising up to at least 80 percent of irrigated agriculture in the high vulnerability areas,
  - Legacy or ambient groundwater conditions,

Eastern San Joaquin Valley Coalition: High Vulnerability Area



LUHDORFF & SCALMANINI CONSULTING ENGINEERS

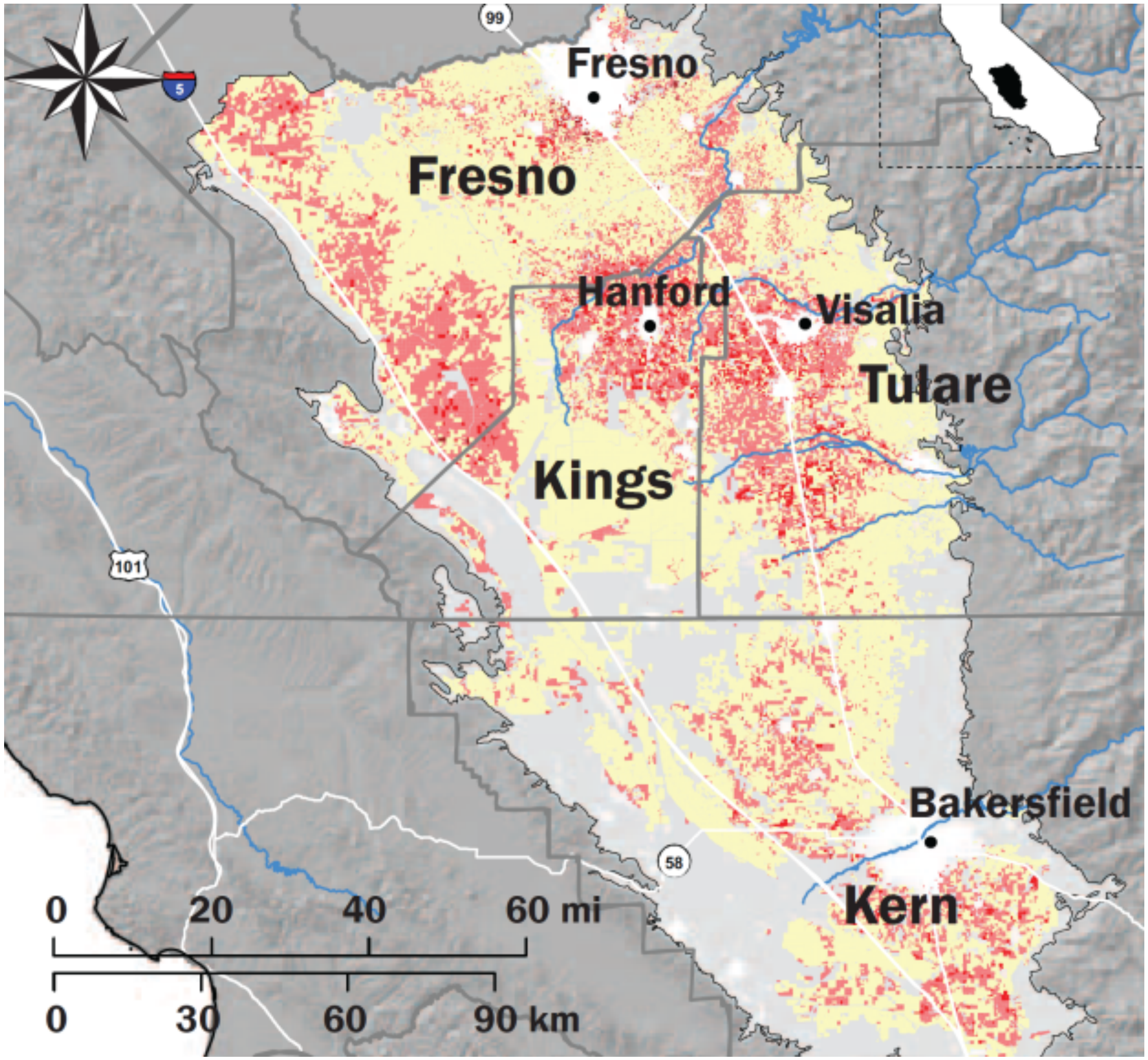
Figure 2

Calculated High Vulnerability Priority Areas in Relationship to DACs and Public Water Systems Reliant on Groundwater

Another Vulnerability Scheme: Nitrate Hazard Index

Based on:

Soil
Crop
Irrigation

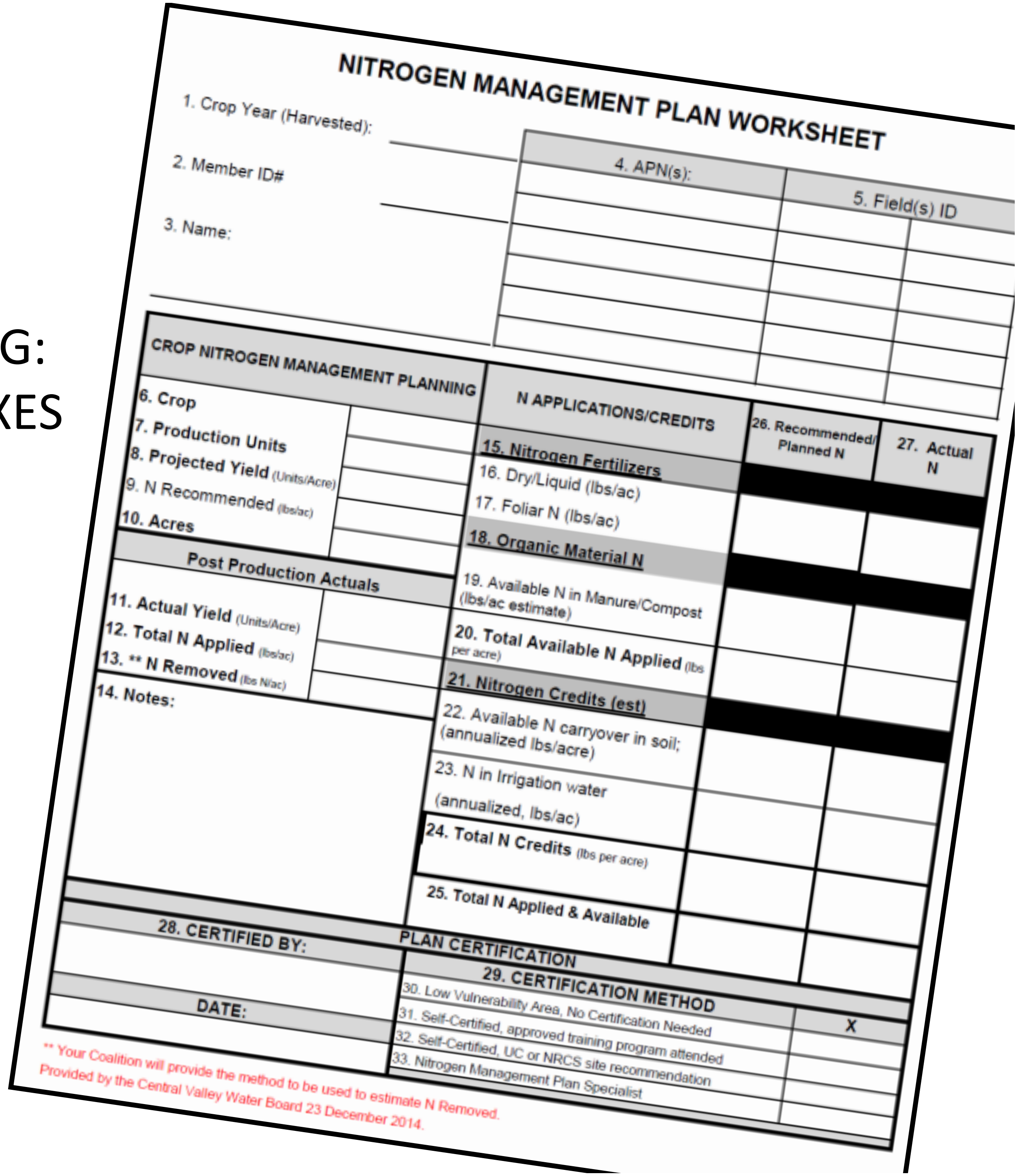


Dzurella, Pettygrove et al.,
Journal Soil Water Conservvation, 2015

STEP 2: MONITORING (three-pronged)

A: PROXY MONITORING: FARM NITROGEN FLUXES

Eastern San Joaquin Valley



NITROGEN MANAGEMENT PLAN WORKSHEET

1. Crop Year (Harvested):
2. Member ID#
3. Name:

4. APN(s):	5. Field(s) ID	

CROP NITROGEN MANAGEMENT PLANNING	
6. Crop	
7. Production Units	
8. Projected Yield (Units/Acre)	
9. N Recommended (lbs/ac)	
10. Acres	
Post Production Actuals	
11. Actual Yield (Units/Acre)	
12. Total N Applied (lbs/ac)	
13. ** N Removed (lbs N/ac)	
14. Notes:	

N APPLICATIONS/CREDITS	26. Recommended/ Planned N	27. Actual N
15. Nitrogen Fertilizers		
16. Dry/Liquid (lbs/ac)		
17. Foliar N (lbs/ac)		
18. Organic Material N		
19. Available N in Manure/Compost (lbs/ac estimate)		
20. Total Available N Applied (lbs per acre)		
21. Nitrogen Credits (est)		
22. Available N carryover in soil; (annualized lbs/acre)		
23. N in Irrigation water (annualized, lbs/ac)		
24. Total N Credits (lbs per acre)		
25. Total N Applied & Available		

PLAN CERTIFICATION

28. CERTIFIED BY:	29. CERTIFICATION METHOD	X
	30. Low Vulnerability Area, No Certification Needed	
DATE:	31. Self-Certified, approved training program attended	
	32. Self-Certified, UC or NRCS site recommendation	
	33. Nitrogen Management Plan Specialist	

** Your Coalition will provide the method to be used to estimate N Removed.
Provided by the Central Valley Water Board 23 December 2014.

Focus: Enforcement Monitoring

Alternative Monitoring Approach to Nonpoint Source:

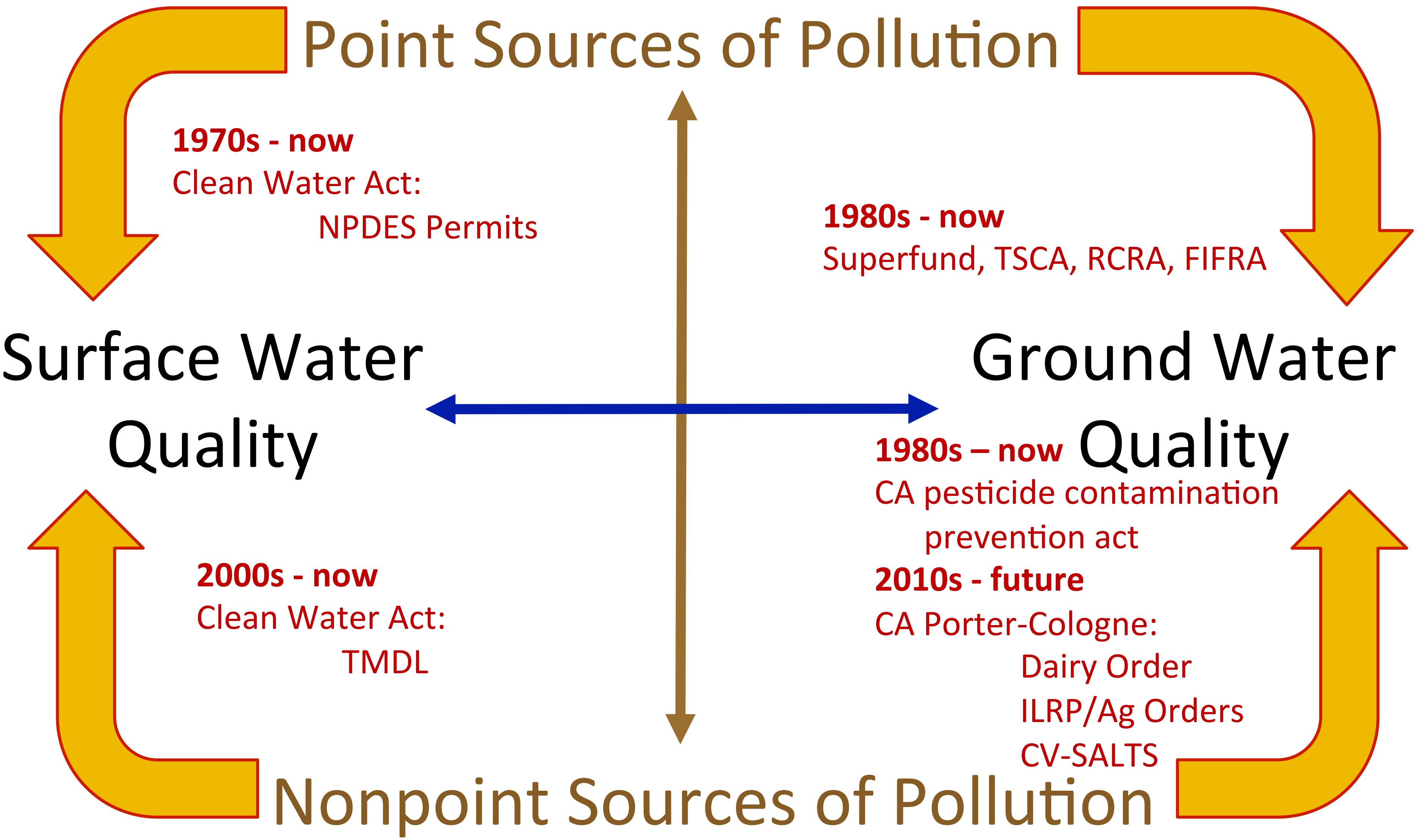
Responsible Party:
Landowner

Feedback:
Nutrient/Water Monitoring & Assessment

Management Tool:
Water and Nutrient Management

Enforcement:
Annual Nitrogen Budget
+
Management Practice Assessment
+
Regional Trend Monitoring

Regulating Water Pollution Sources



Governance Models: Form follows Function

- The entire groundwater basin must be covered by one or multiple GSAs
- Likely governance:
  - Single water district, county, city
  - MOU or other contractual agreement between public agencies
  - JPA among public agencies
  - Special acts district
- Centralized GSA
- Distributed GSA
- Hybrid GSA
  - Central authority on some mandates, distributed authority on other mandates
  - One GSA, many GSPs
  - Many GSAs, one GSP

GSA Formation: What's Next

- Stimulate dialogue / communication among local agencies, key stakeholders (e.g., Farm Bureau)
- Engage broad range of interested parties
- Gather information about the basin / find out where the information is / what is available
- Understand what Groundwater Sustainability Planning entails
- Consider facilitation services
- Look over the fence and see what's happening elsewhere
- Transparency, transparency, transparency
- DEADLINE: June 30, 2017

Groundwater Management Organizations: Key Action Areas for Innovative Thinking

- Planning process
  - Governance structures
  - Finding agreement on goals, reporting, enforcement, cooperation with neighboring agencies
- Cooperation and stakeholder involvement
  - Identifying and engaging participants / stakeholders
  - Structures for involving stakeholders
  - Avoiding / resolving disputes, dispute facilitation
- Collecting information about groundwater context
  - Improving groundwater information collection, analysis, presentation
  - Metering of extraction at the discretion of GSA
- Groundwater management portfolio

From: Nelson, Innovative GW Management, Stanford 2011

Groundwater Management Tools for Regional Organization

- Limiting Groundwater Use / Mandates:
  - Limit extraction
  - Mandate reductions in current pumping
  - Limit construction of new wells
  - Requiring water conservation measures
  - Fees to support management/infrastructure/communication efforts
- Infrastructure measures:
  - Water efficiency projects
  - Wastewater treatment and recycling
  - Importing water
  - Conjunctive use of surface water and groundwater
  - Groundwater banking
  - Monitoring networks, data collection, and data analysis/modeling
- Communication and networking measures
  - Facilitate stakeholder participation
  - Education
  - Data analysis and reporting
  - Secure funding (grants, project applications,….)

Role of the State: **Carrot**

- Department of Water Resources has a key role:
  - Technical assistance and funding (Prop 1: $100 million for SGMA)
  - Regulation
    - Groundwater basin boundary adjustments
    - Minimum guidelines for appropriate GSP
  - Control
    - Review and approve GSPs
    - Review implementation

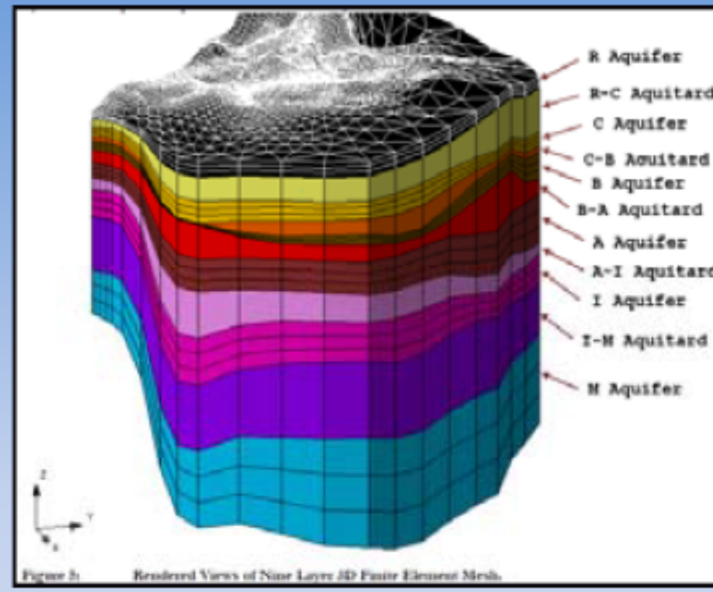
Role of the State: Carrot **& Stick**

- Department of Water Resources has a key role:
  - Technical assistance and funding (Prop 1: $100 million for SGMA)
  - Regulation
    - Groundwater basin boundary adjustments
    - Minimum guidelines for appropriate GSP
  - Control
    - Review and approve GSPs
    - Review implementation
- State Water Resources Control Board:
  - Enforcement where local control fails (after 2017)
    - "pobabationary status"
    - Public hearing and 180 days to fix the problem
  - After 180 days: SWRCB poses as interim GSA
    - Groundwater extraction reporting mandatory
    - Possibly temporary control of groundwater extraction
    - Development and implementation of interim GSP
  - When locals are ready: get authority back from state

California Groundwater Rights: Background

- Correlative Rights Doctrine – safe yield of groundwater basin shared by overlying users
  - Katz v. Wilkinshaw, 1908
- California constitutional mandate for beneficial use (1928)
- Special districts (20 different types, about 2,300 districts)
  - Water districts, irrigation districts, private water companies, reclamation districts, water conservation districts, water replenishment districts, water storage districts, etc.
- County police power – controls groundwater exports
  - Baldwin vs. Tehama County, 1994
- The Courts: basin adjudication / "physical solution" – controls extraction
  - Many Southern California (sub)basins, mid 20^{th} century
  - City of Barstow vs. Mojave Water Agency, 2000:
    - Right of water users to negotiate physical "equitable, practical" solution, regardless of water rights
    - Individual water rights holders cannot be forced into a voluntary agreement
- State groundwater management:
  - Voluntary local groundwater management plans: AB 3030 (1992)
  - Financial incentives for local groundwater management: SB 1938 (2002)
  - Sustainable Groundwater Management Act of 2014: mandatory & expanded local control
- => if local/regional control fails: State Water Resources Control Board
- **The Courts**
  - **Streamlined adjudication (legislation in 2015?)**

WRD Monitoring and Modeling Programs

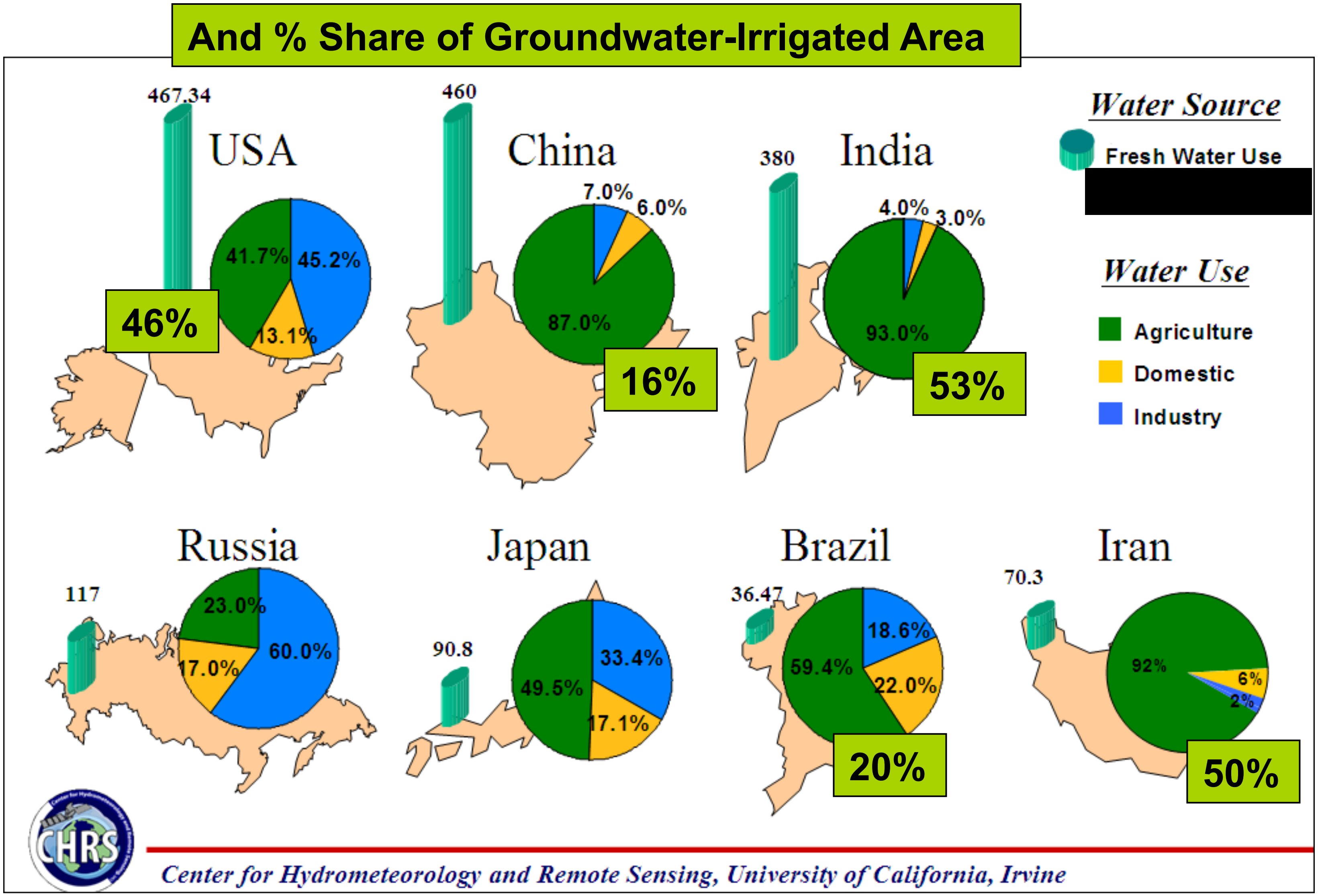


WRD and Maven's Notebook, 2013

Groundwater Modeling: Central to Planning Effort

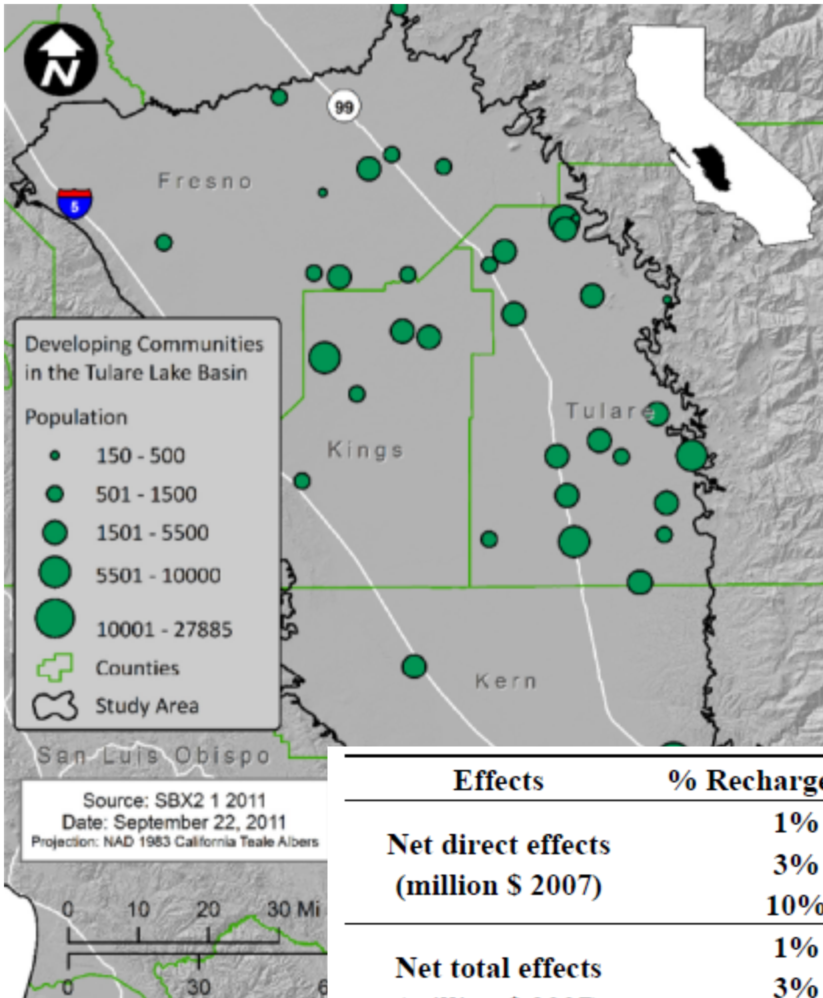
modified from: Santa Rosa Plain Groundwater Management Plan, SRP Basin Advisory Panel, Sept 2014

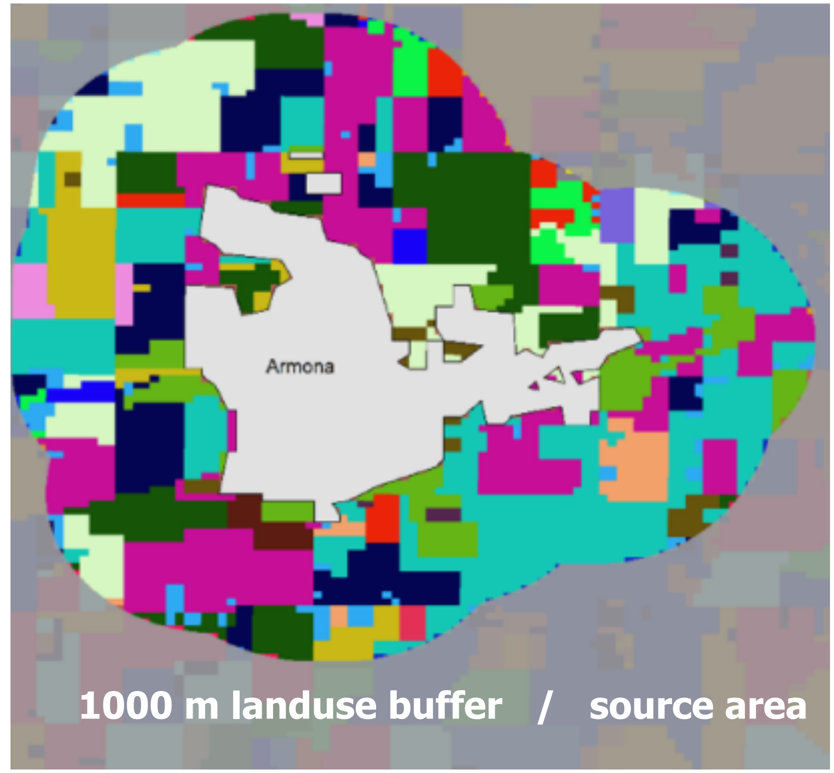
Water Use



Groundwater Irrigated Area Data are from: Shah, Villholth, Burke, "Groundwater: a global assessment of scale and significance", IWMI, 2007

Example: Agricultural Landuse Buffers





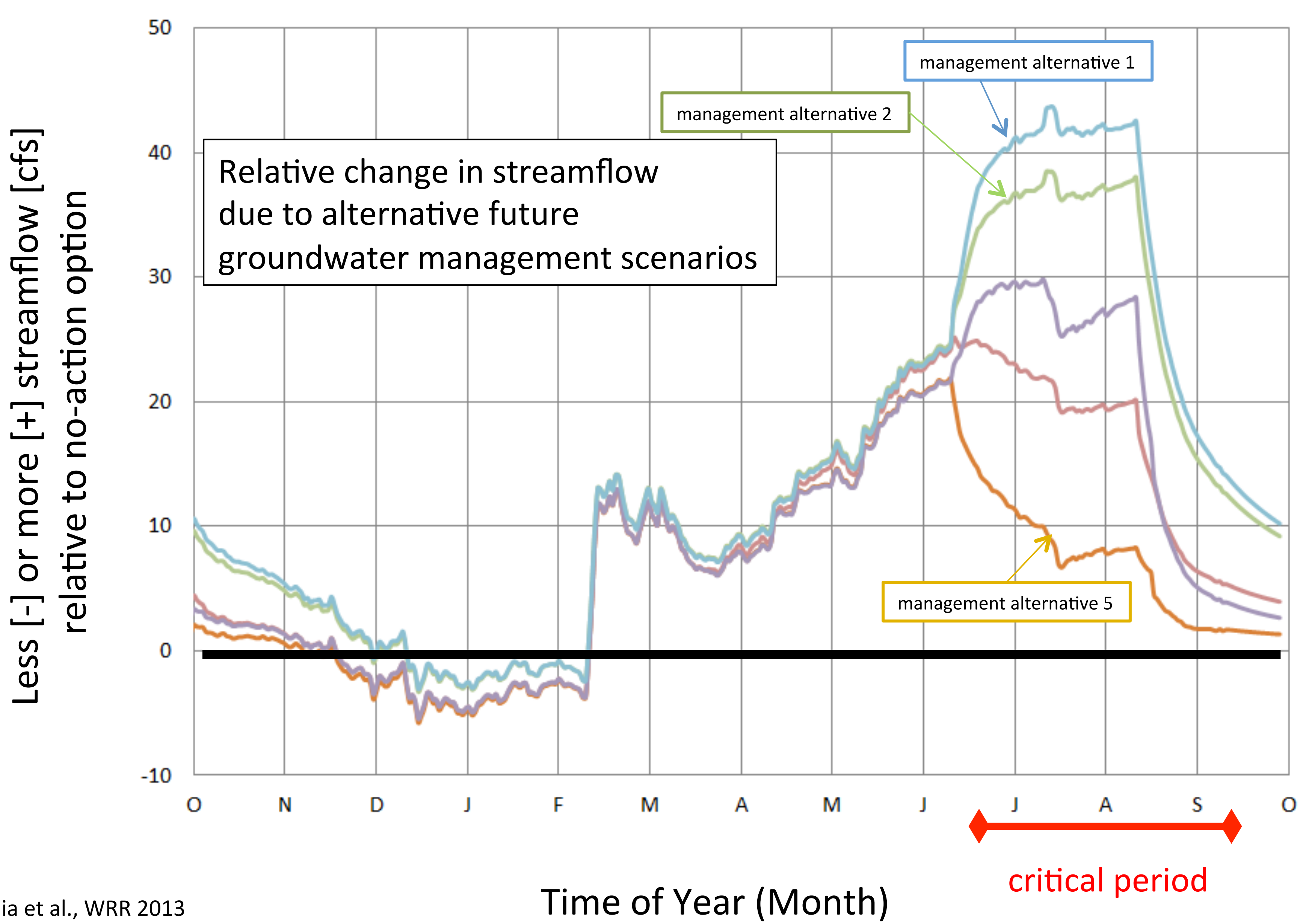
Effects	% Recharge Basins	0/100	10/90	33.3/66.7	50/50	66.7/33.3	90/10	100/0
Net direct effects (million $ 2007)	1%	16.0	11.8	1.9	−5.2	−12.3	−22.1	−26.4
	3%	14.8	10.6	0.9	−6.0	−12.9	−22.6	−26.8
	10%	10.4	6.6	−2.4	−8.8	−15.3	−24.2	−28.1
Net total effects (million $ 2007)	1%	33.6	24.7	3.9	−10.9	−25.7	−46.5	−55.4
	3%	31.0	22.3	1.9	−12.6	−27.1	−47.5	−56.2
	10%	21.9	13.8	−5.1	−18.5	−32.0	−50.9	−59.0

Mayzelle et al. J. of Water, 2015

Moving Towards Better Control of Nonpoint Sources (NPS) of Groundwater: Needs

- **SCIENCE NEEDS**
  - NPS source control methods
  - NPS pollution soil/groundwater fate, transport
  - NPS pollution assessment, monitoring tools
- **REGULATORY FRAMEWORK**
  - Enforcement: Paradigm shift in monitoring approaches
- **AGRICULTURE (largest NPS)**
  - Socio-cultural change needed to work within new regulatory frameworks

Investigate Impact of Alternative Management Practices

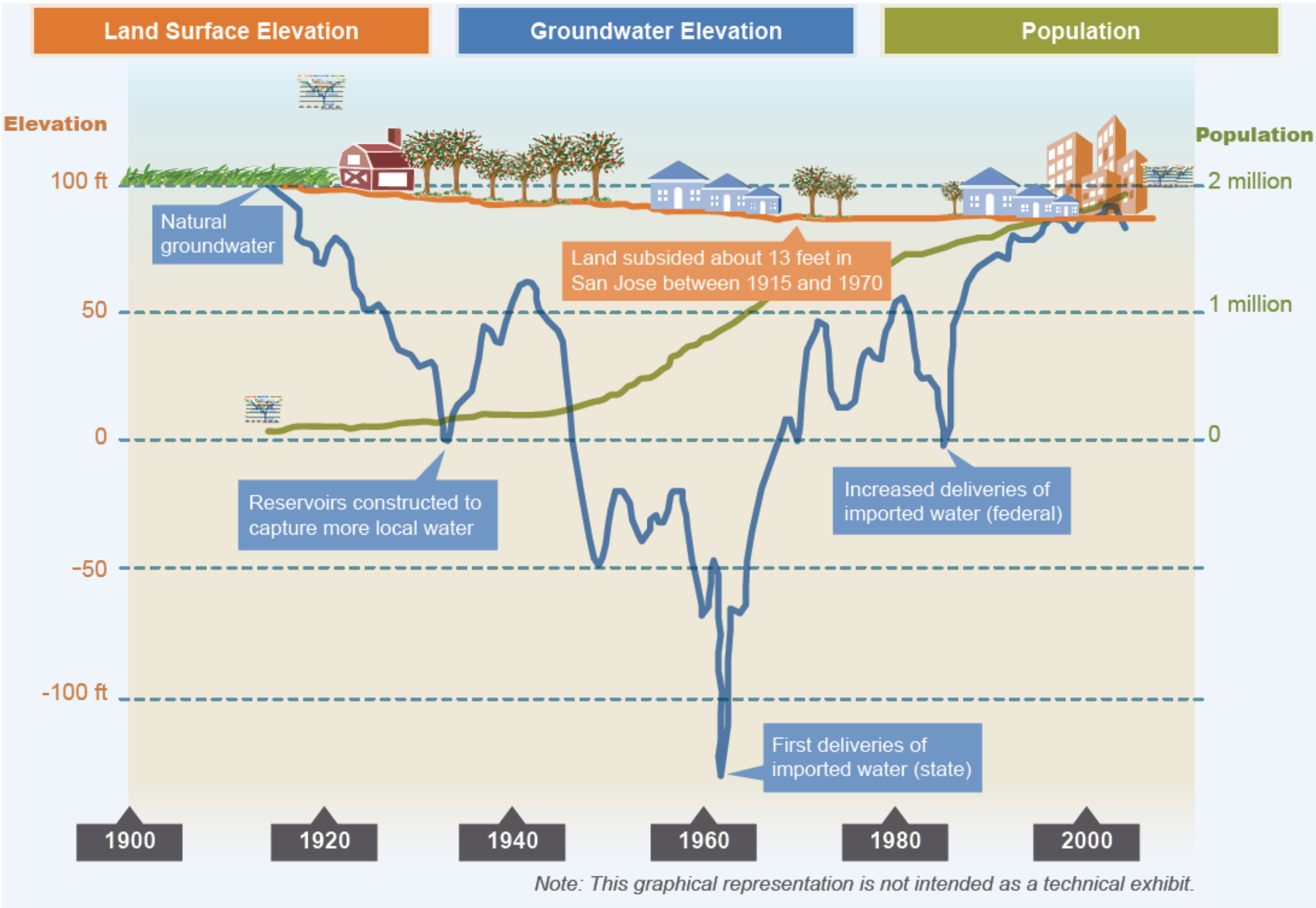


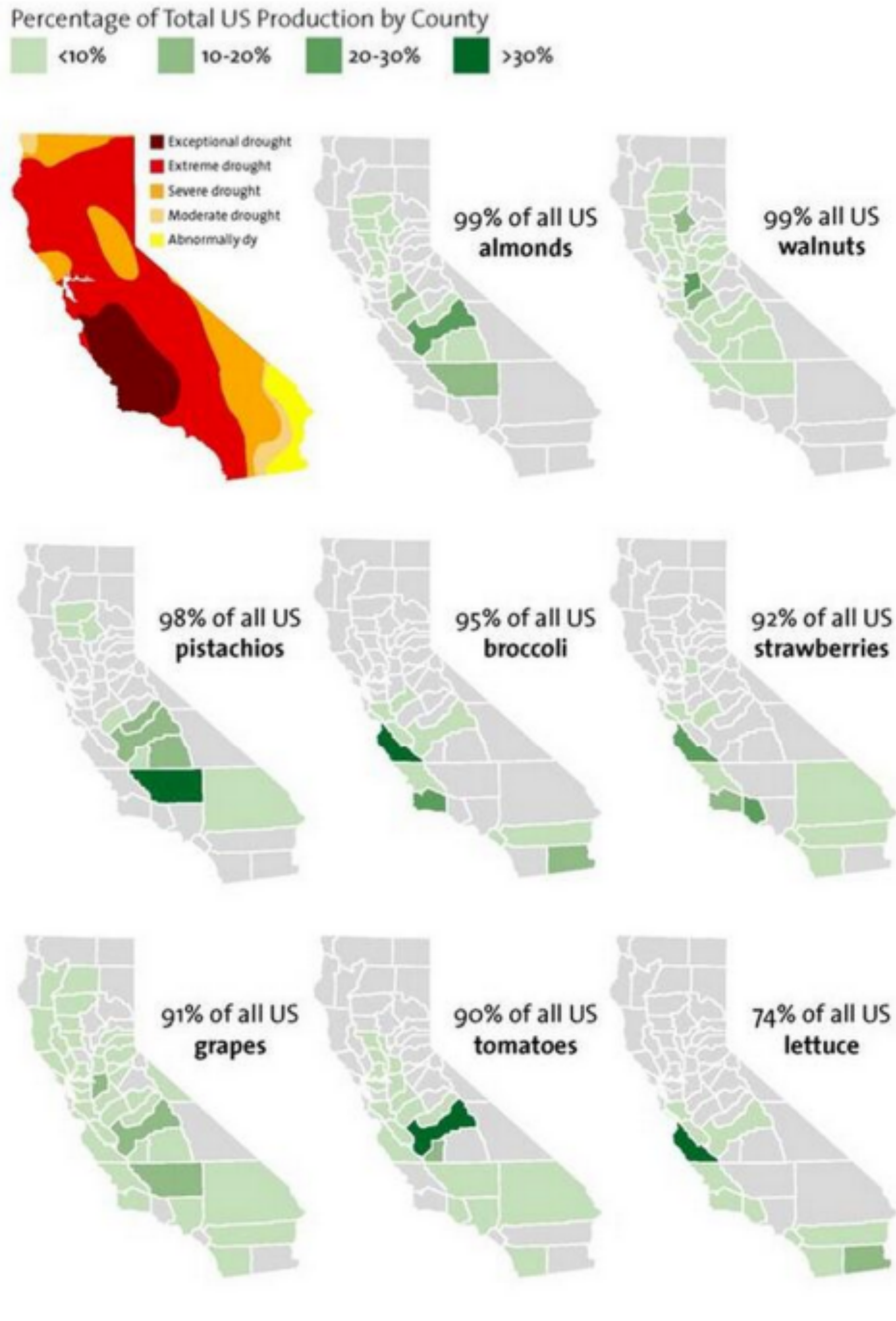
Foglia et al., WRR 2013

Summary of Key Challenges to Viticulture

- Participate and facilitate local GSA forming by engaging, informing stakeholders
- Increasing recharge in agriculture: Develop management practices to replace “poor irrigaton efficiency” with “high irrigation efficiency AND clean groundwater recharge”
- Identify public well source areas and focus N management on those areas => great place to have vineyards with low N input
- Participate in ILRP coalitions: management practice evaluations that INCLUDE deep soil and/or groundwater N flux measurements
- Participate in ILRP coalitions: regional trend monitoring networks

Storage for Local Use: Santa Clara Valley Water District

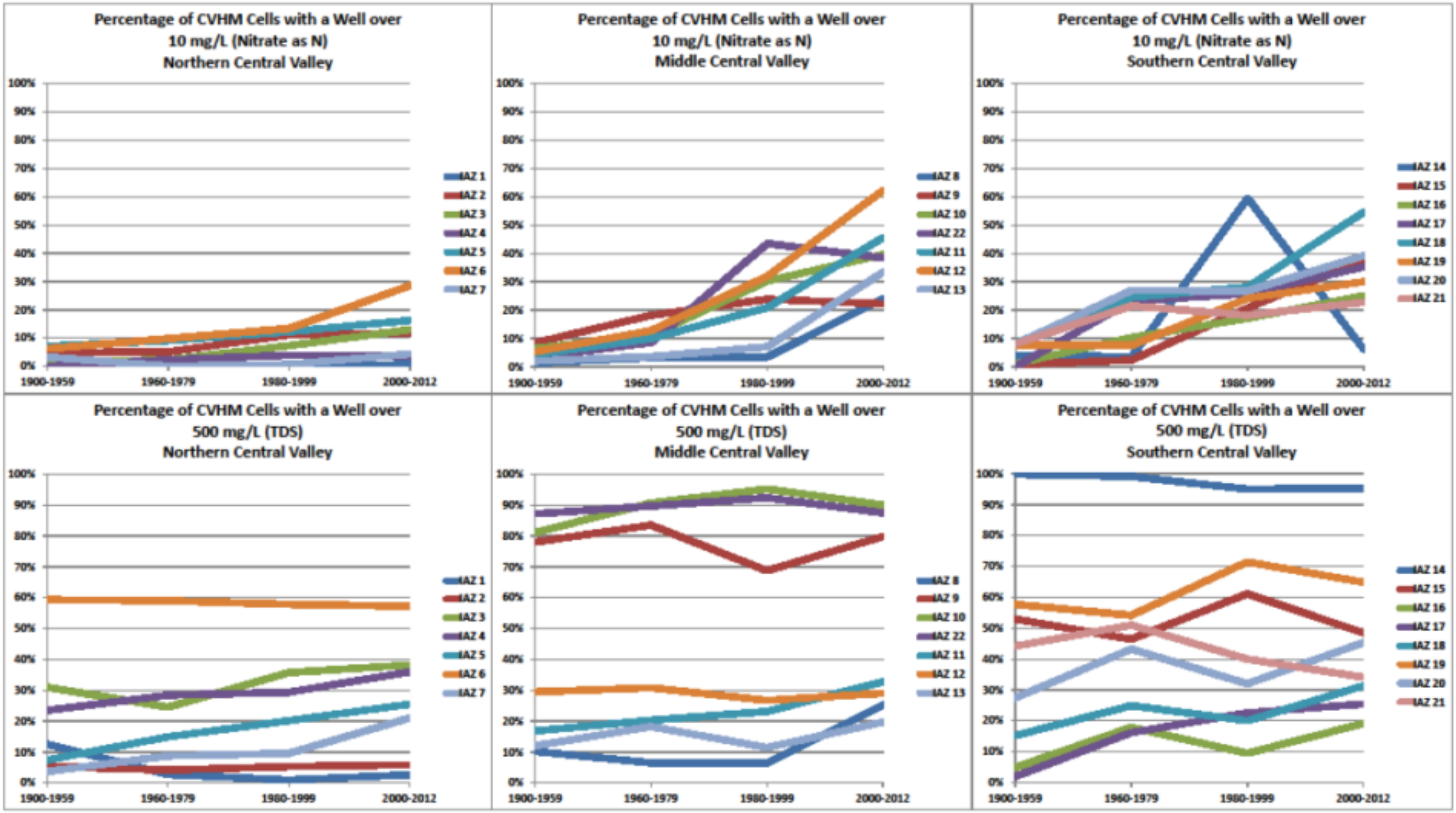




Crop maps based on 2012 figures. Data: US Drought Monitor, California Department of Food and Agriculture, US Department of Agriculture. Art: US Drought Monitor, Wikimedia Commons.

Mother Jones

Nitrate and salinity dynamics in the Central Valley



CVSALTS, Tasks 7 and 8 – Salt and Nitrate Analysis for the Central Valley Floor
Final Report, December 2013

Figure 7-13

http://www.cvsalinity.org/index.php/docs/committee-document/technical-advisory-docs/conceptual-model-development/initial-conceptual-model-icm/2630-icm-final-report-december-2013/file.html


Randi Lynn Beach / Huffington Post


M.C. Rains et al., 2006 and 2008