Drought Effects on Groundwater Management

- 2015 Irrigation and Nutrient Management Meeting -

Thomas Harter

University of California Davis

http://groundwater.ucdavis.edu

Justin Sullivan / Getty Images

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Overview

1. Understanding groundwater in California

3. Consequences of overpumping

4. Sustainable groundwater management

5. Water quality protection

Veronica Rocha / Los Angeles Times


Brad Zweerink for Earth Justice

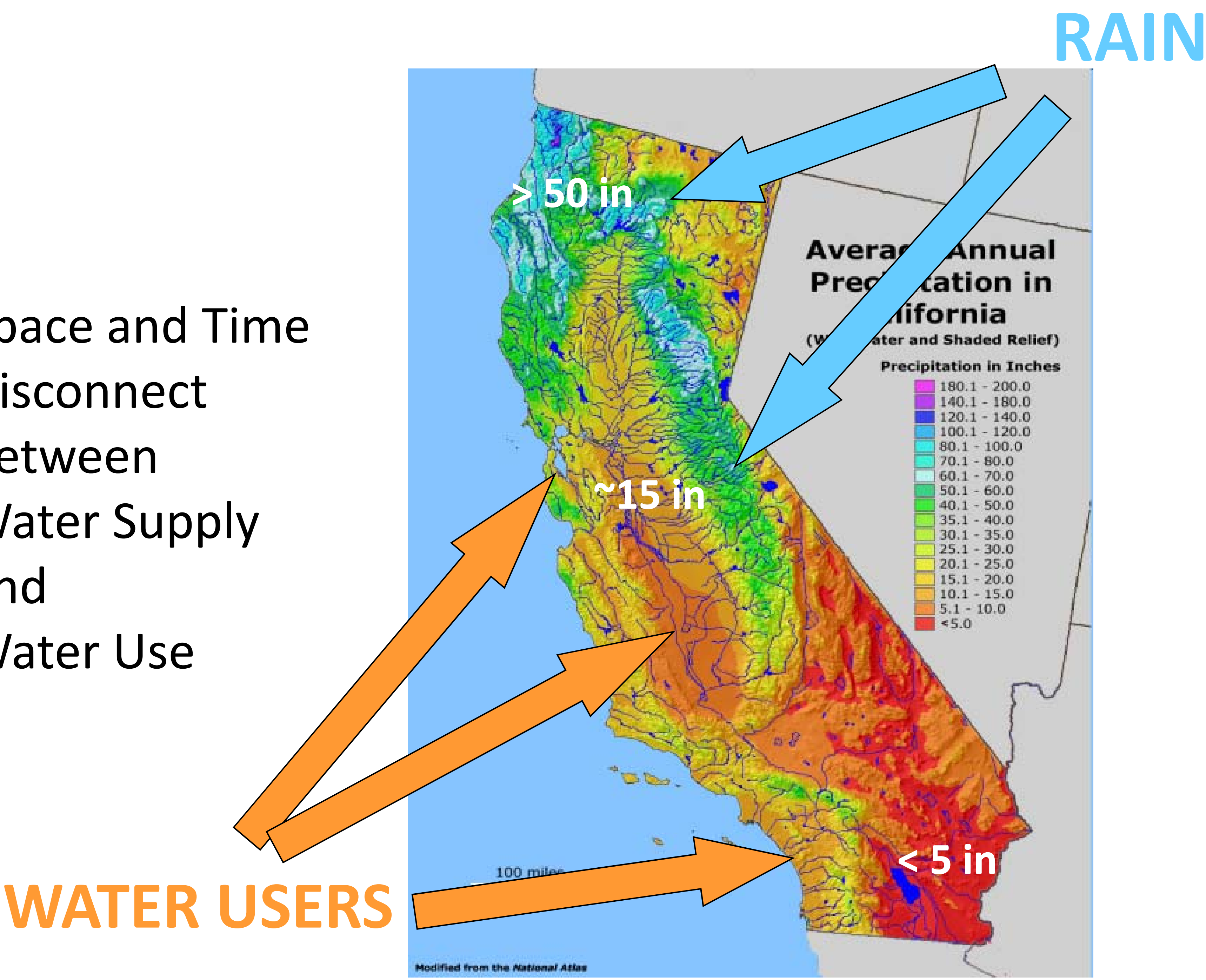

Jim Wilson/ The New York Times

Jim Wilson/ The New York Times

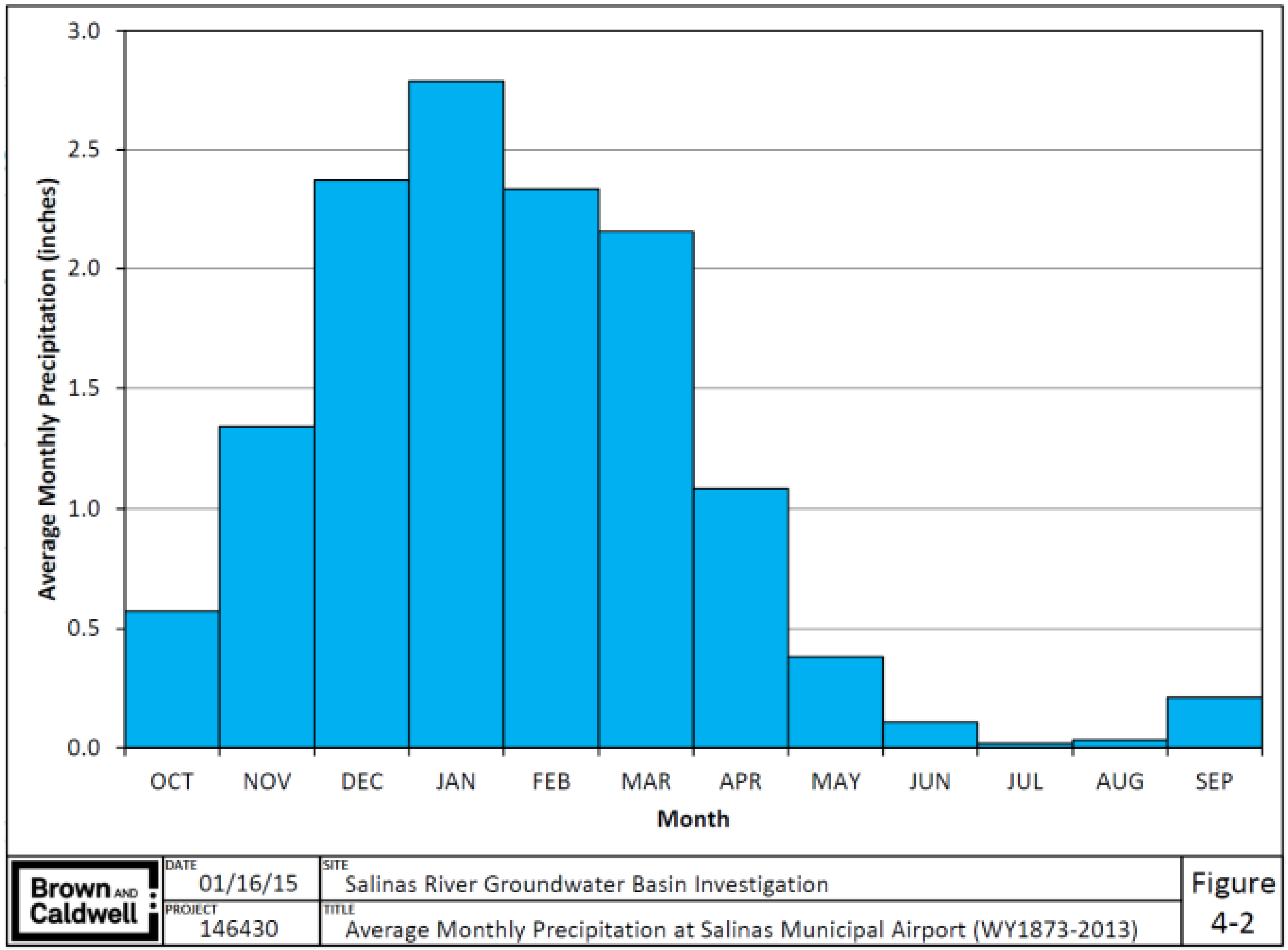
Jim Wilson/ The New York Times


Laura Bliss / Atlantic City Lab

Space and Time Disconnect between Water Supply and Water Use



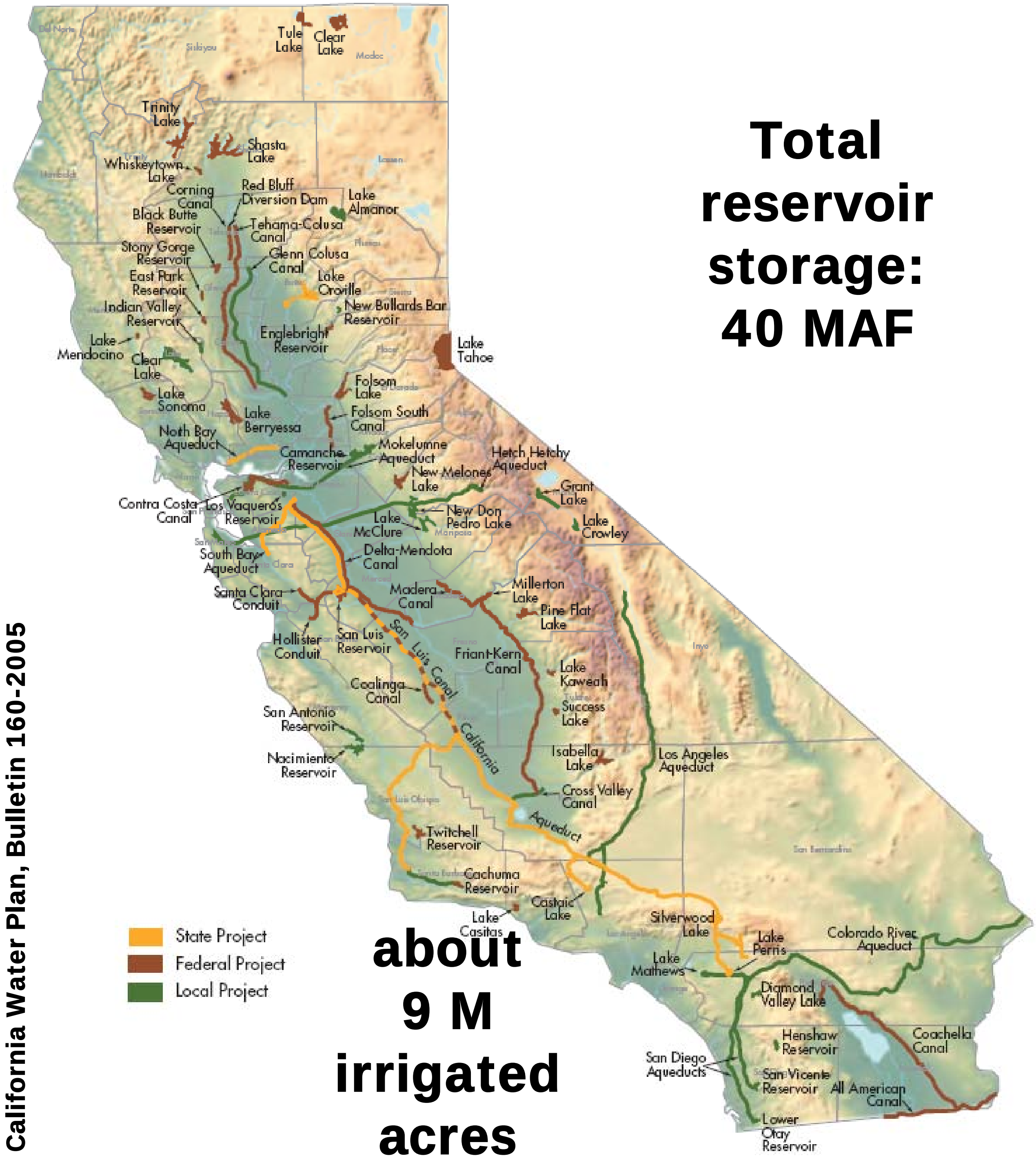
Salinas Valley Average Monthly Precipitation (October – September)



Brown & Caldwell, MCWRA, January 2015

California Water
Infra-structure:

Bridging
the Spatial
and Temporal
Disconnect
between
SUPPLY
and
USE



California Water Plan, Bulletin 160-2005

Total reservoir storage: 40 MAF

about 9 M irrigated acres

Salinas Valley Water Infra-structure:

Bridging
the Spatial
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Disconnect
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USE

Brown & Caldwell, MCWRA, January 2015

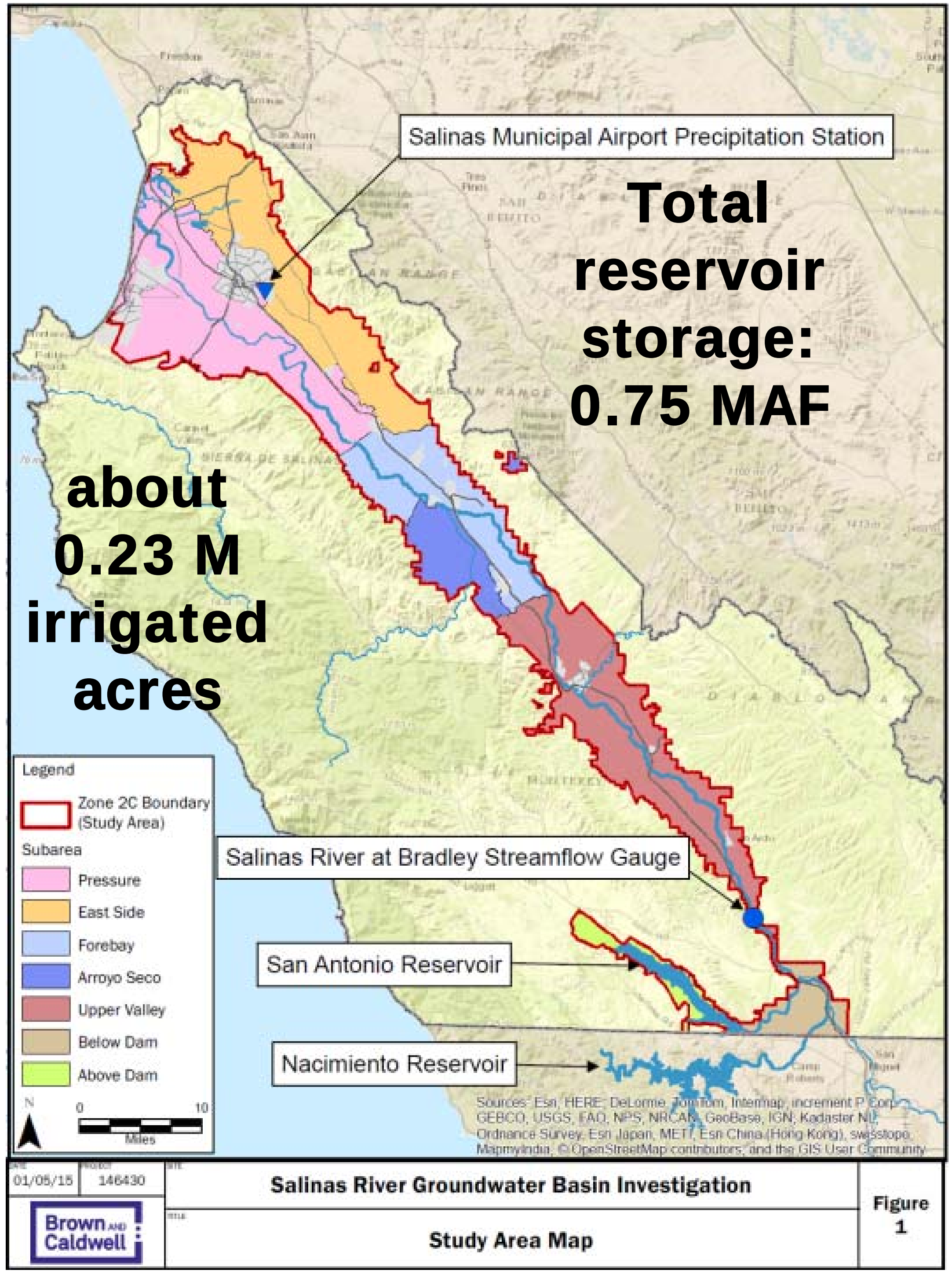


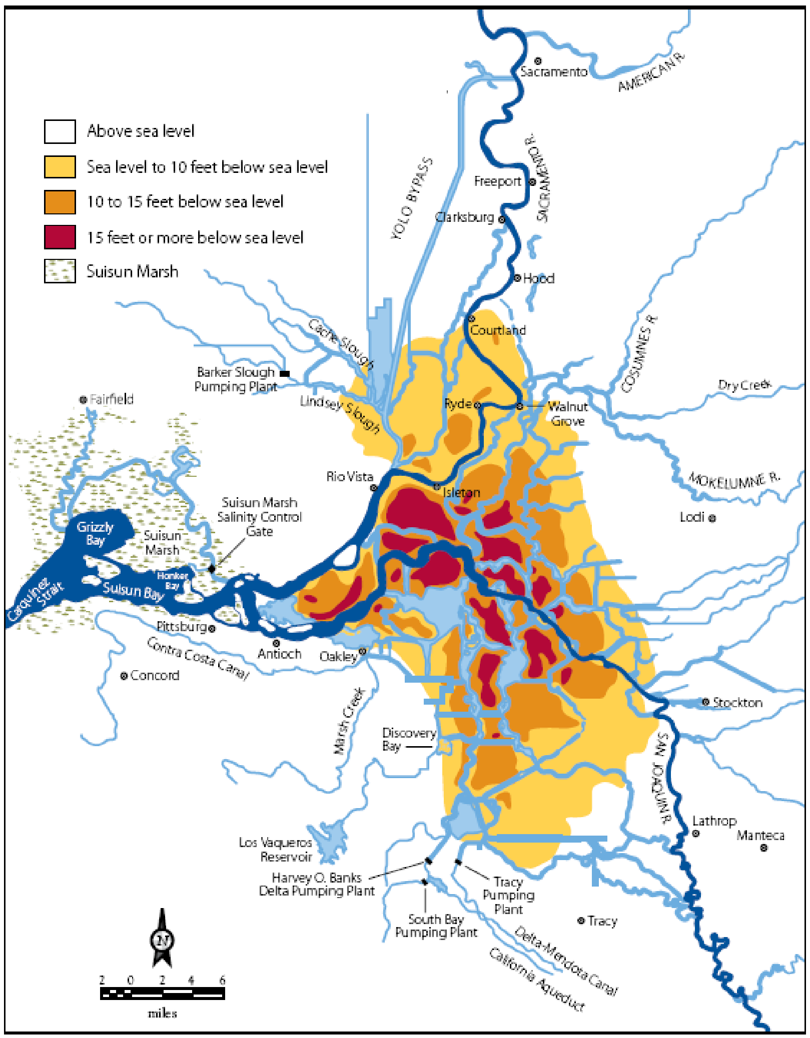
Table ES-2. Groundwater Storage					
Subarea	Storage Coefficient (ft^3/ft^3)[a]	Land Area (acres)[b]	Storage Capacity (acre-feet)[a]	Groundwater in Storage (acre-feet)[a]	Available Storage (acre-feet)
Pressure	0.036	126,000	7,240,000	6,860,000	380,000
East Side	0.08	75,000	3,690,000	2,560,000	1,130,000
Forebay	0.12	87,000	5,720,000	4,530,000	1,190,000
Upper Valley	0.10	92,000	3,100,000	2,460,000	640,000
Total	--	380,000	19,750,000	16,410,000	3,340,000

[a] *From DWR (2003).*

[b] *From the Salinas Valley Integrated Ground and Surface Water Model (SVIGSM).*

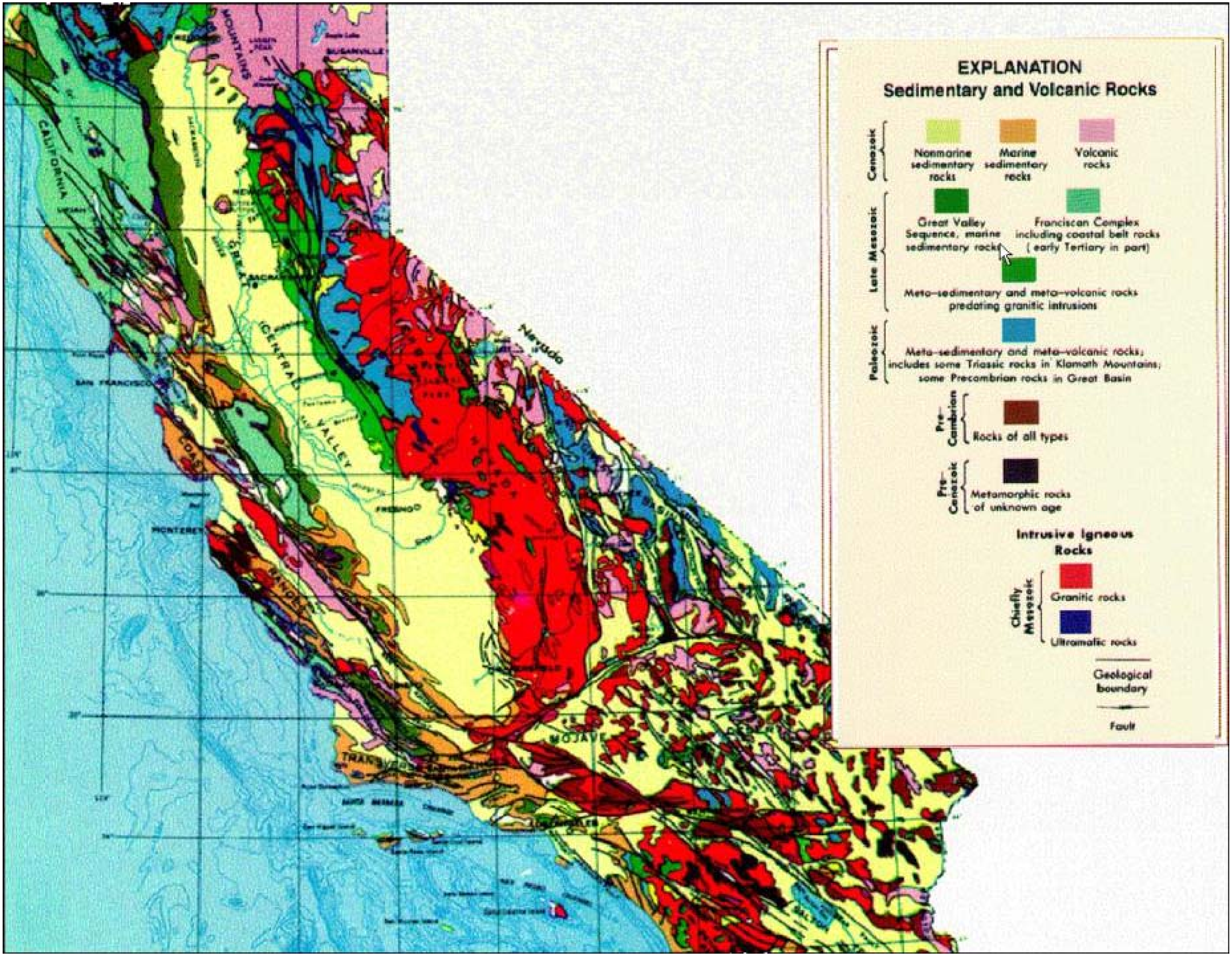
Brown & Caldwell, MCWRA, January 2015

Central Water Hub: Sacramento – San Joaquin Delta



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

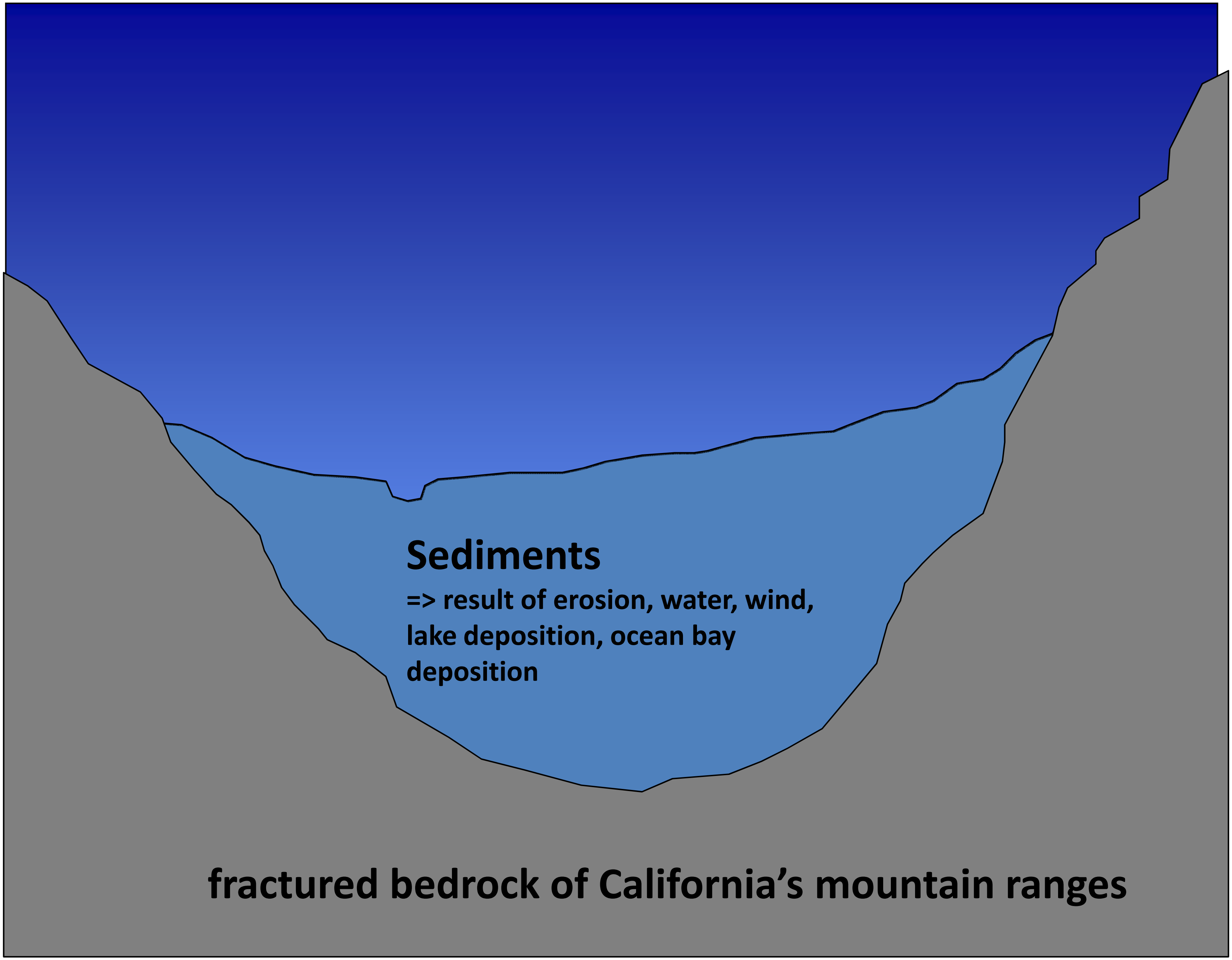
California Water Plan, Bulletin 160-2005

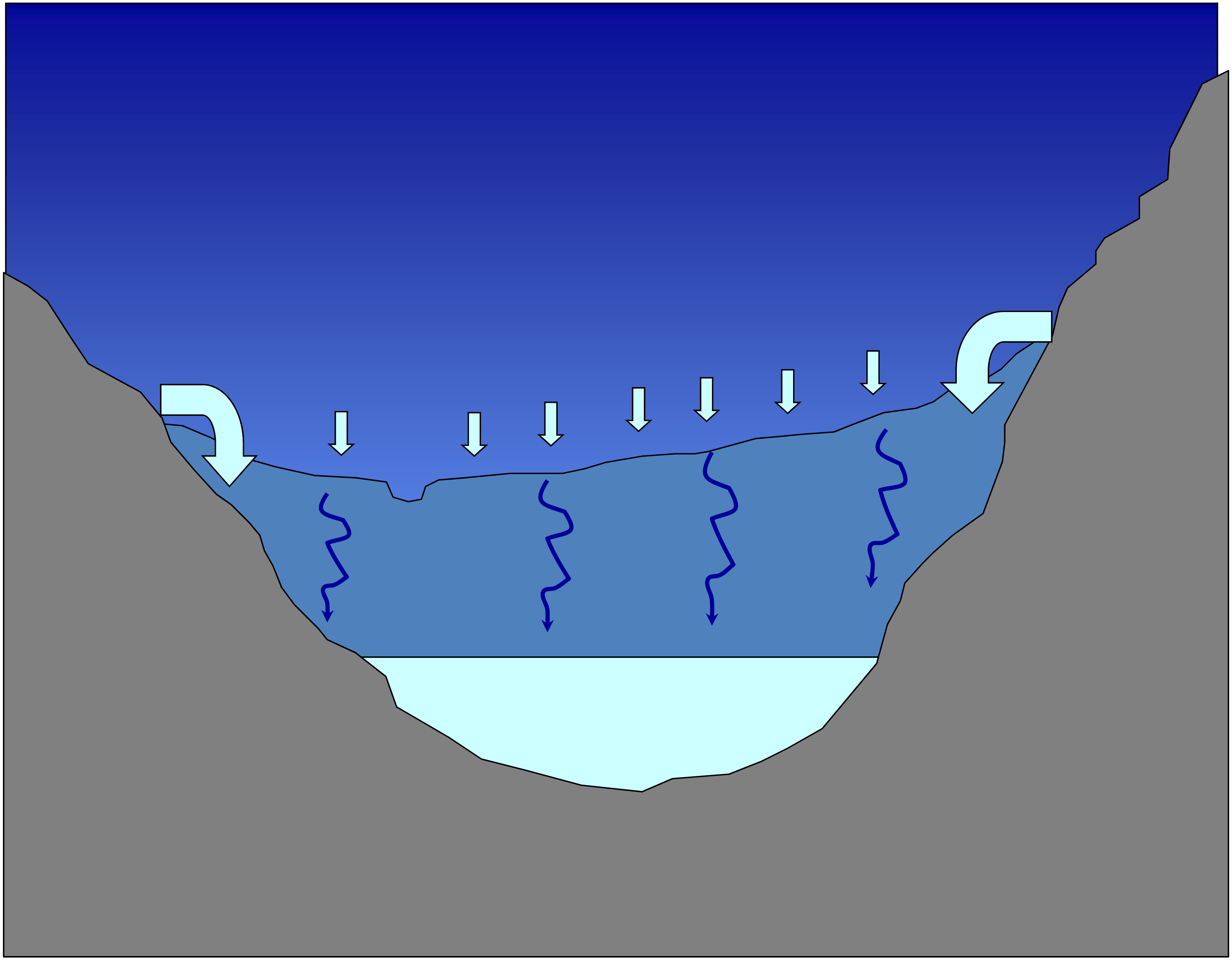

EXPLANATION
Sedimentary and Volcanic Rocks
Cenozoic
Nonmarine sedimentary rocks
Marine sedimentary rocks
Volcanic rocks
Late Mesozoic
Great Valley Sequence, marine sedimentary rocks
Franciscan Complex including coastal belt rocks (early Tertiary in part)
Meta-sedimentary and meta-volcanic rocks predating 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
CENTRAL VALLEY
GREAT
COAST
MOJAVE
Nevada
MOUNTAINS

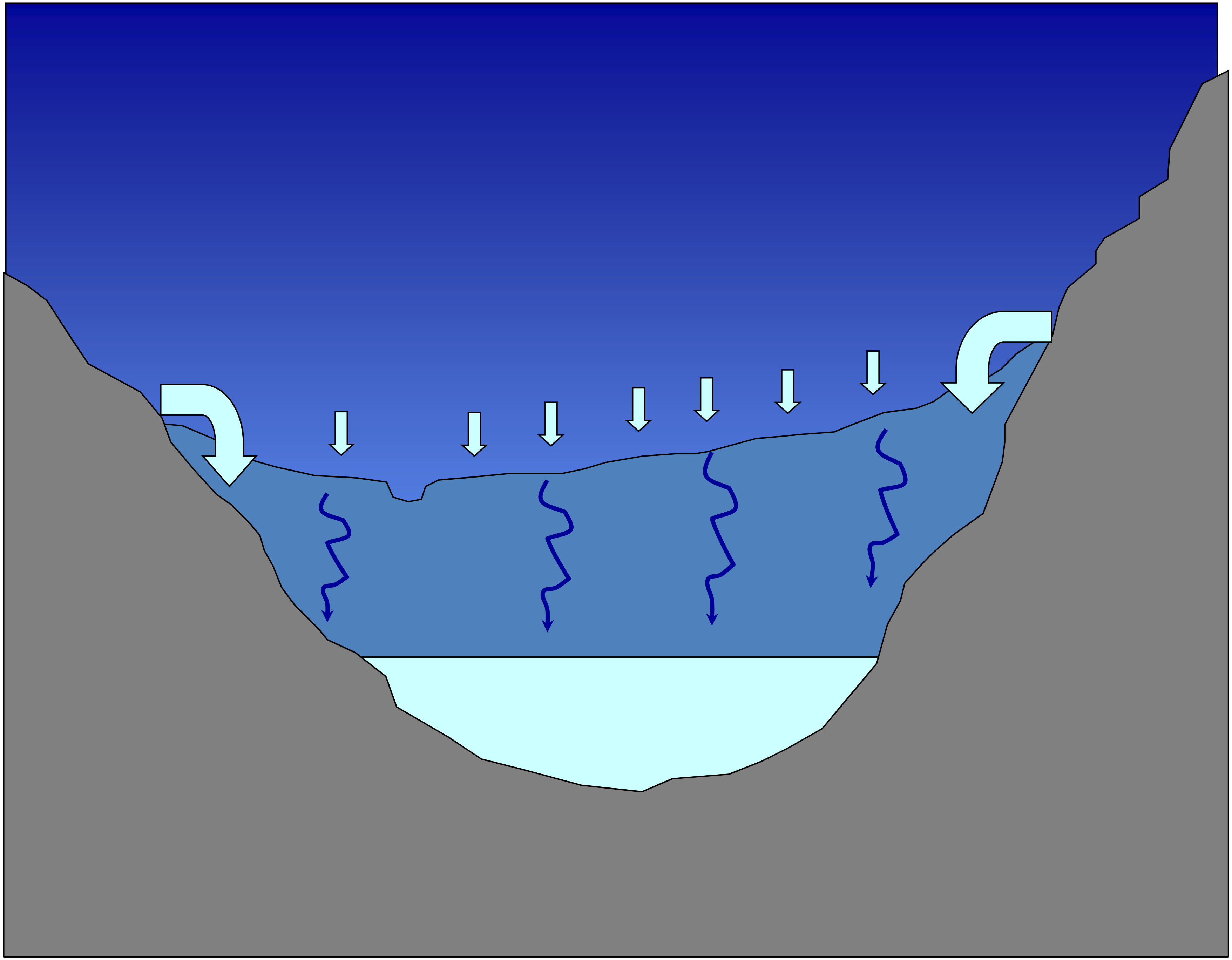
California Groundwater Basins

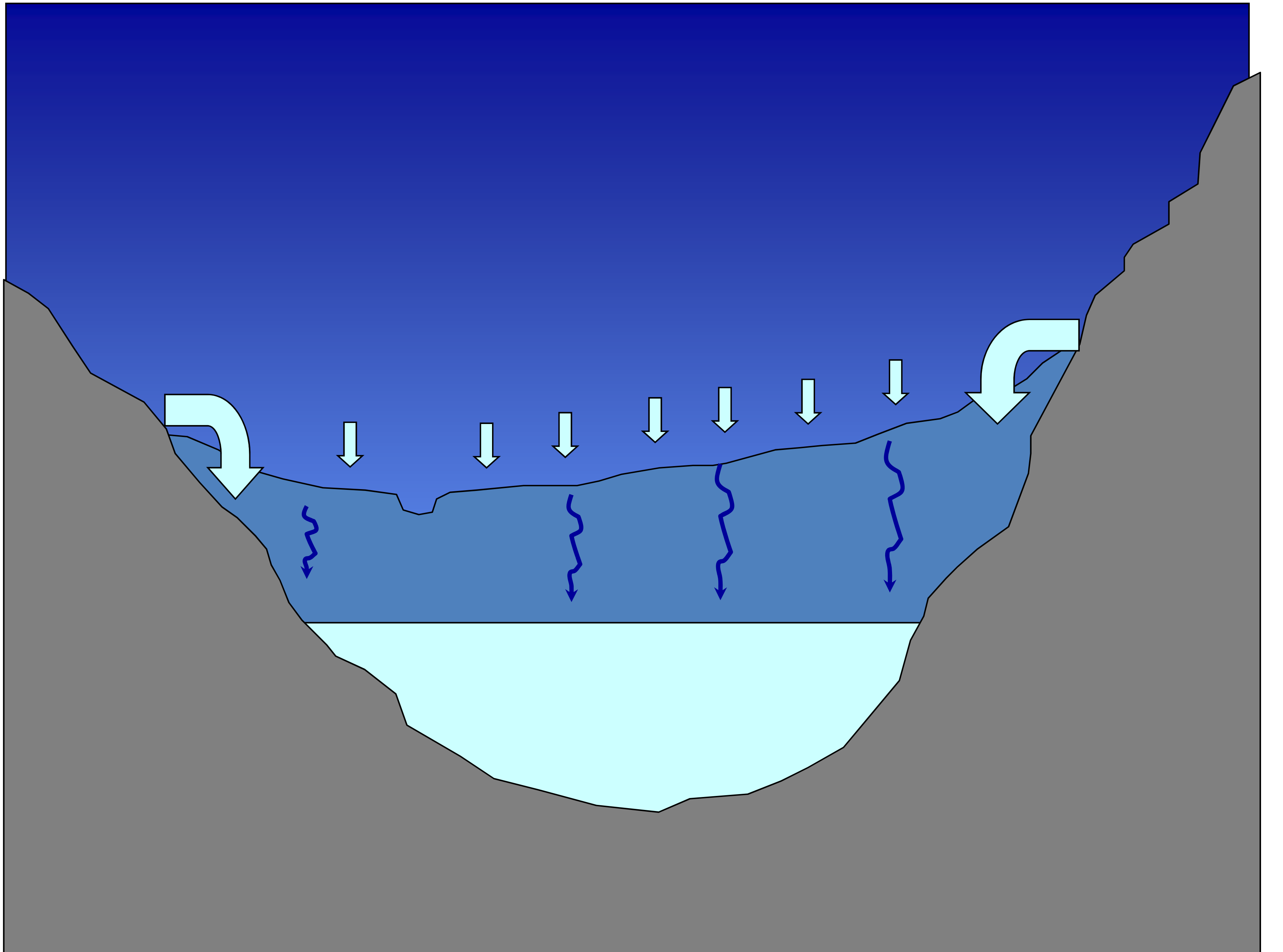
- 515 groundwater basins
- 30% - 40% of urban and agricultural water supplies

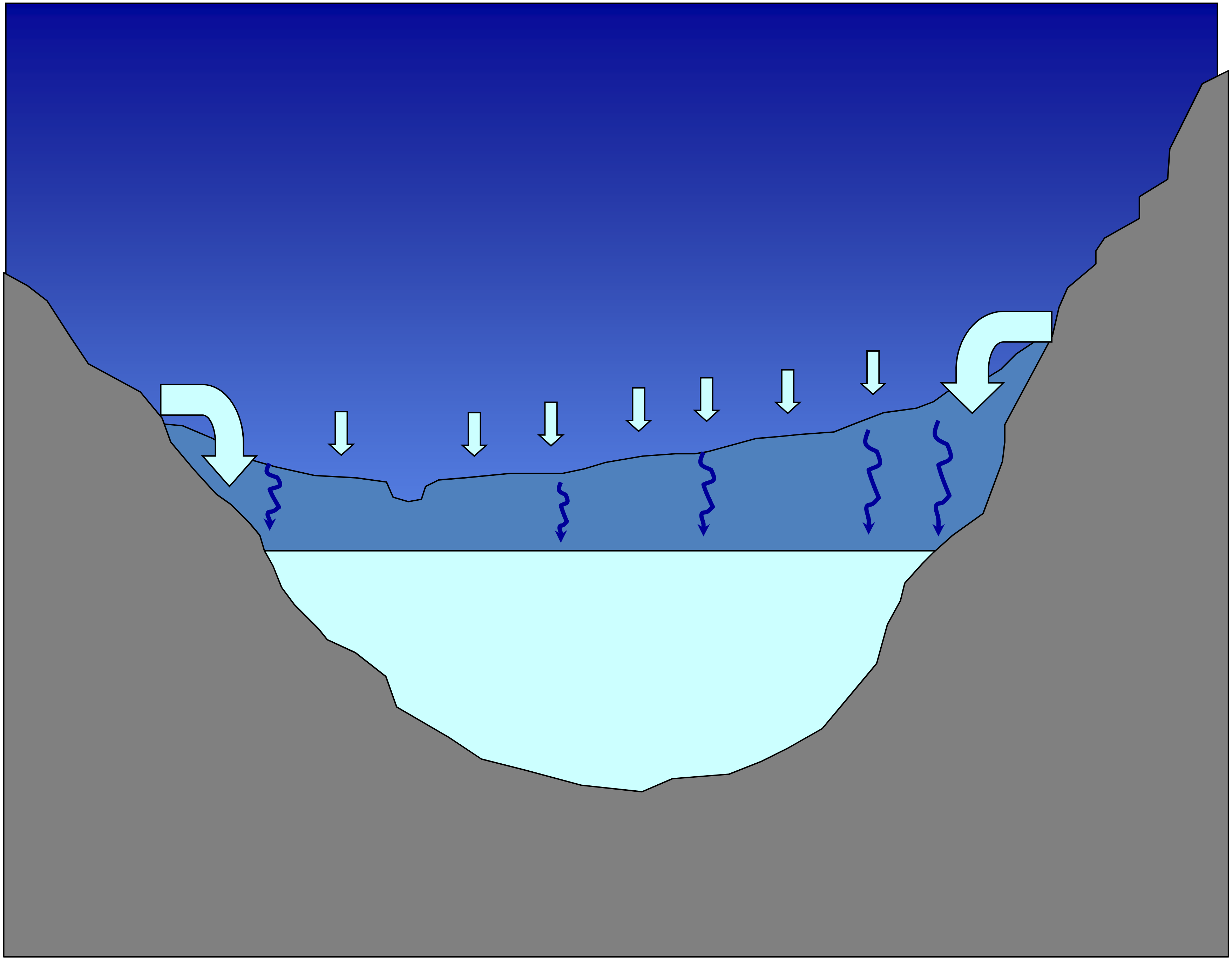
From: California Department of Water Resources

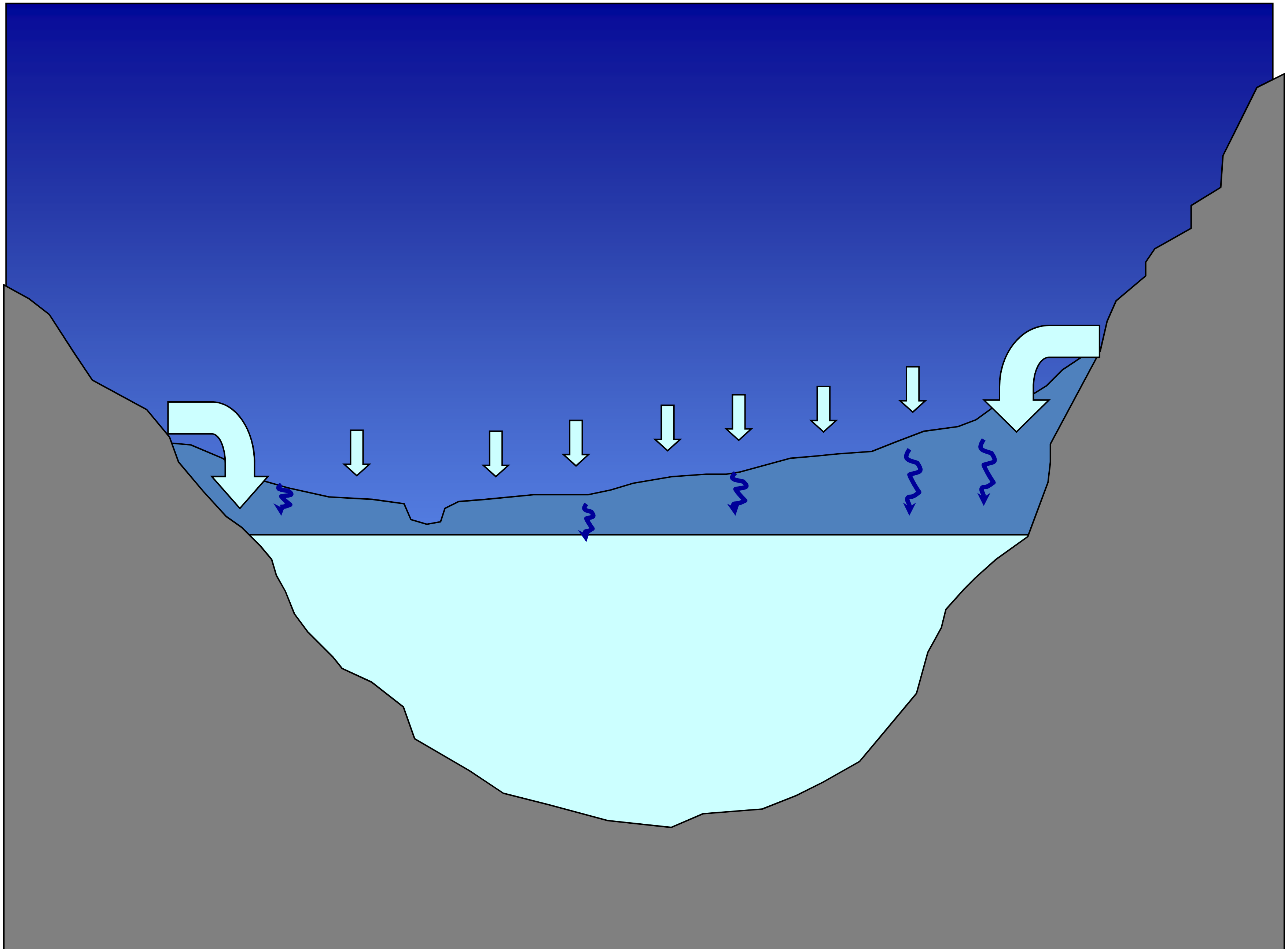

Sediments
=> result of erosion, water, wind, lake deposition, ocean bay deposition
fractured bedrock of California's mountain ranges

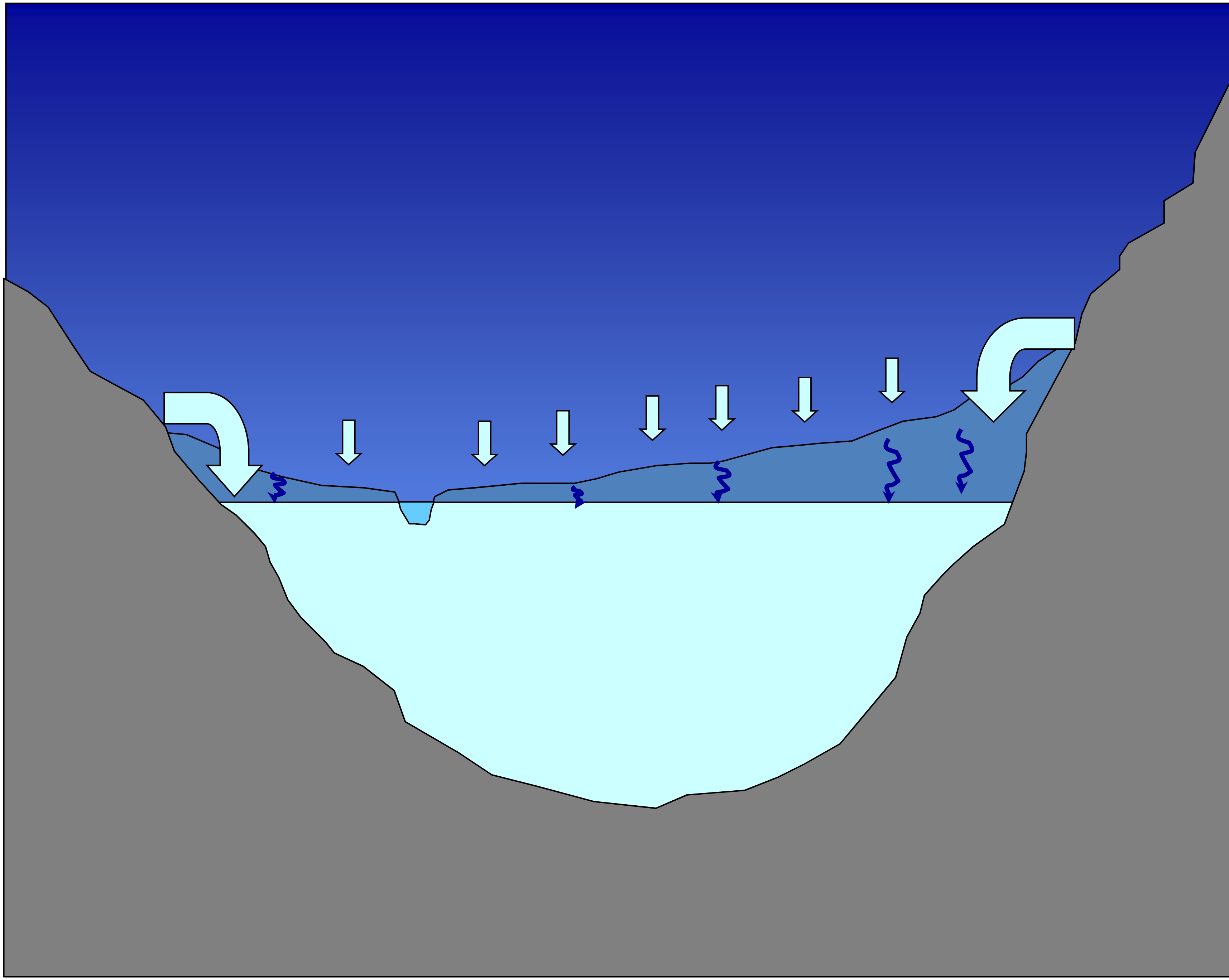


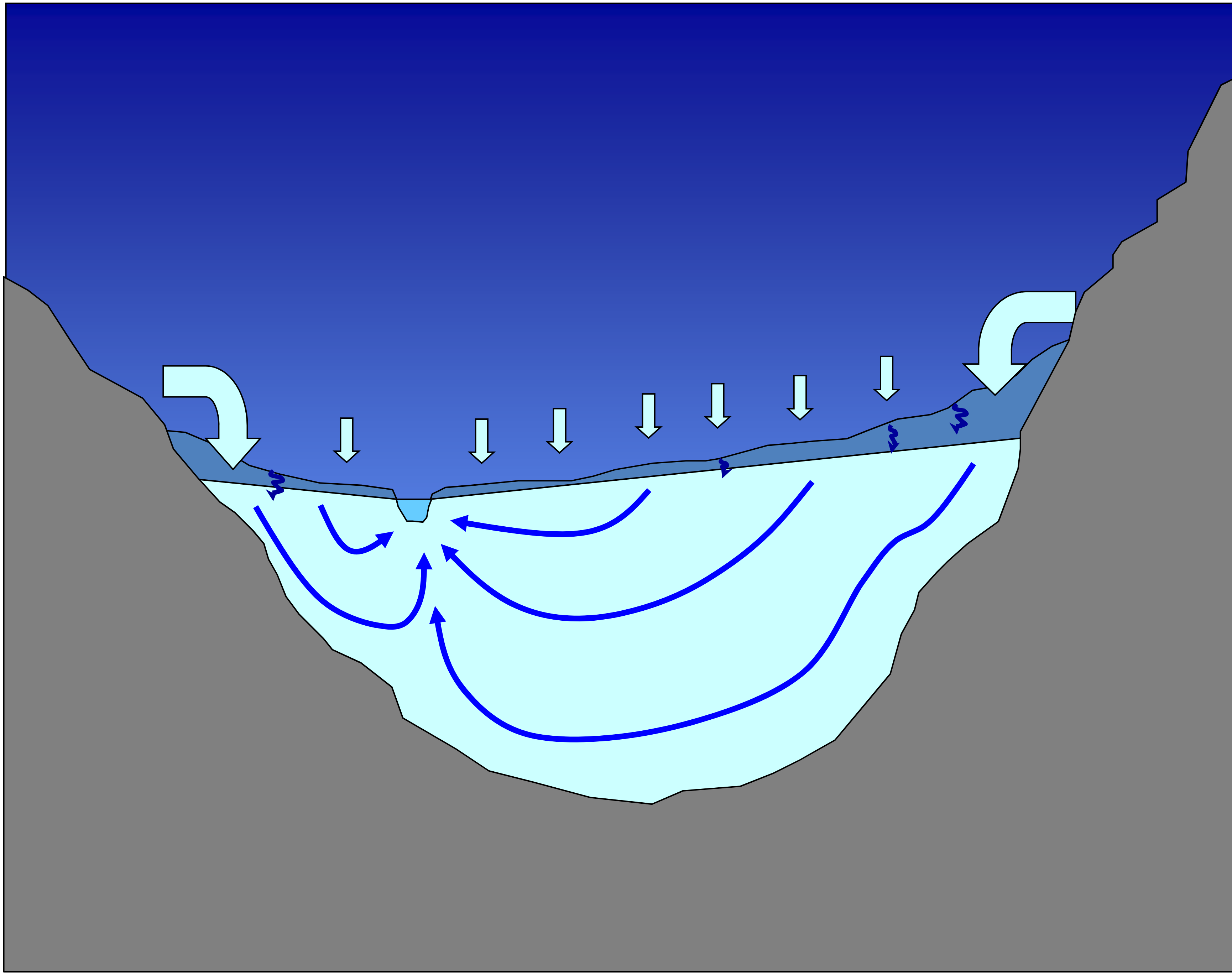


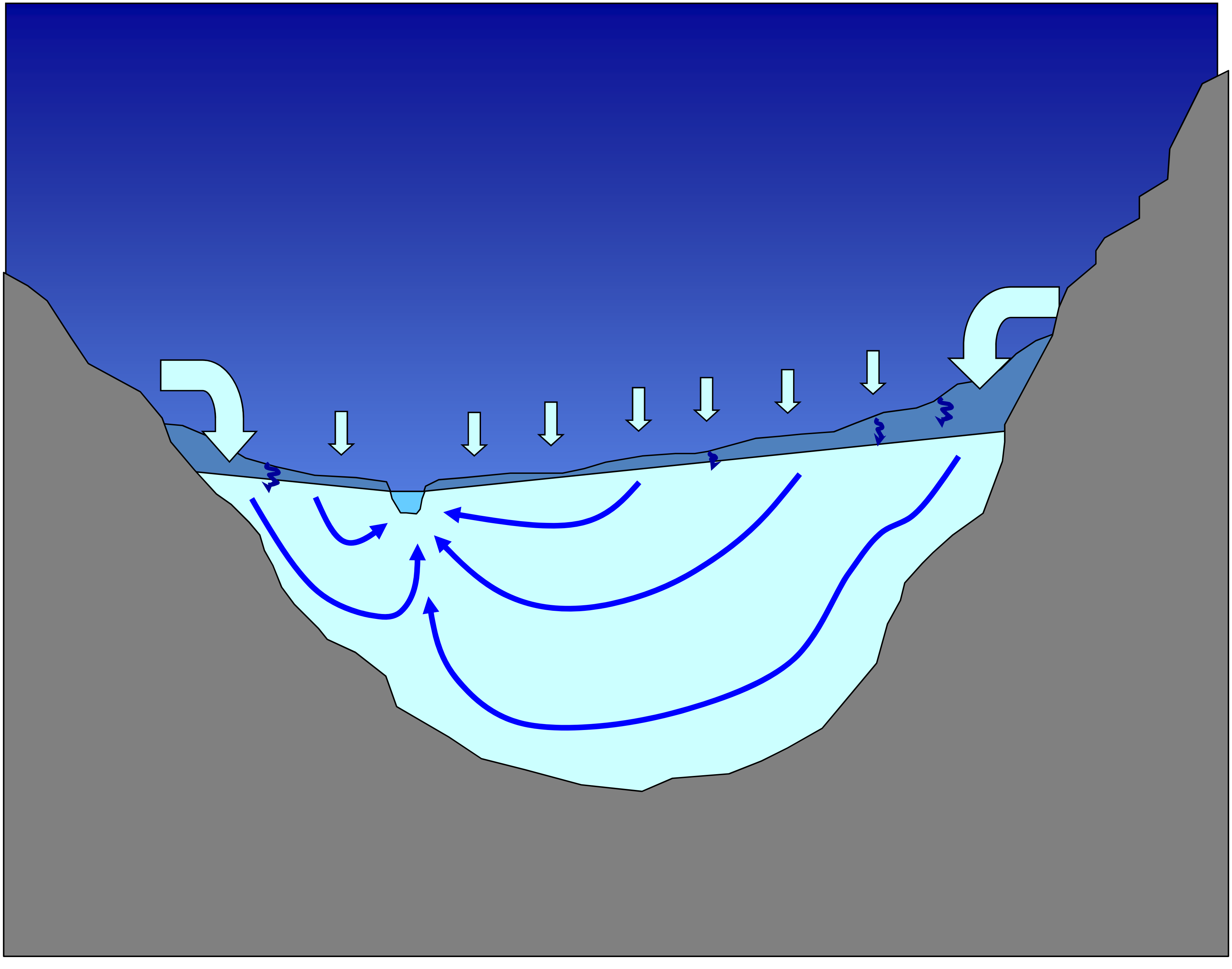


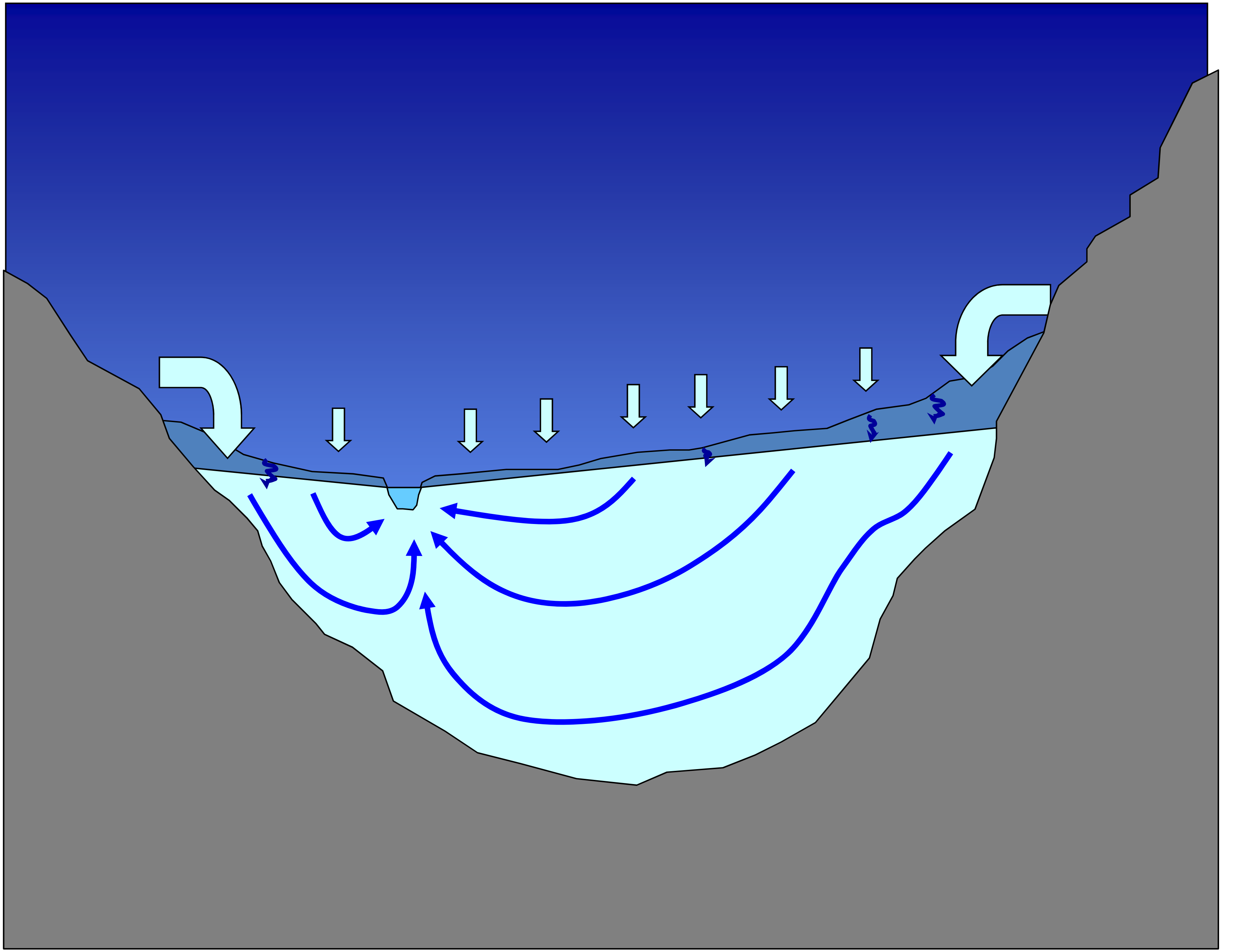


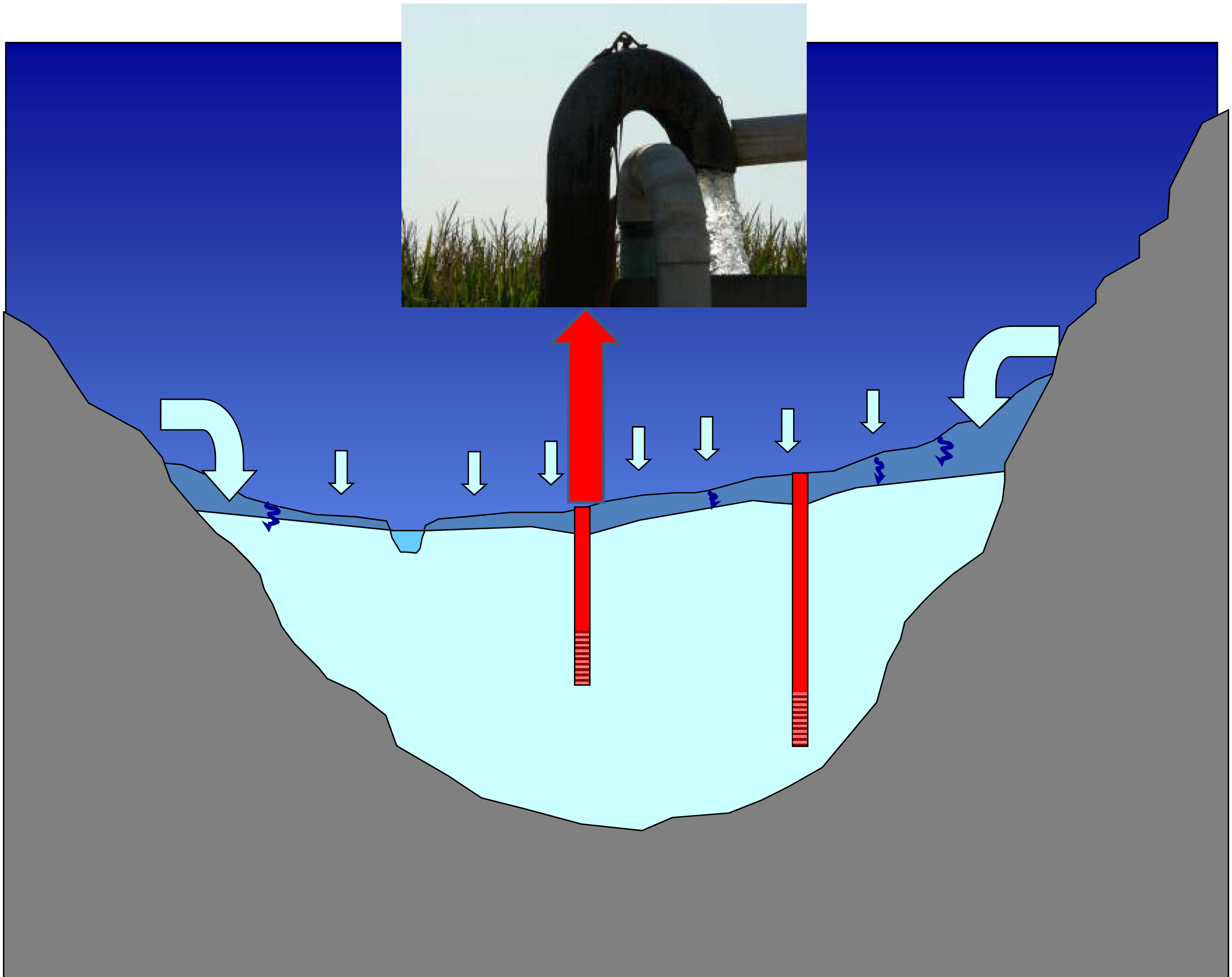


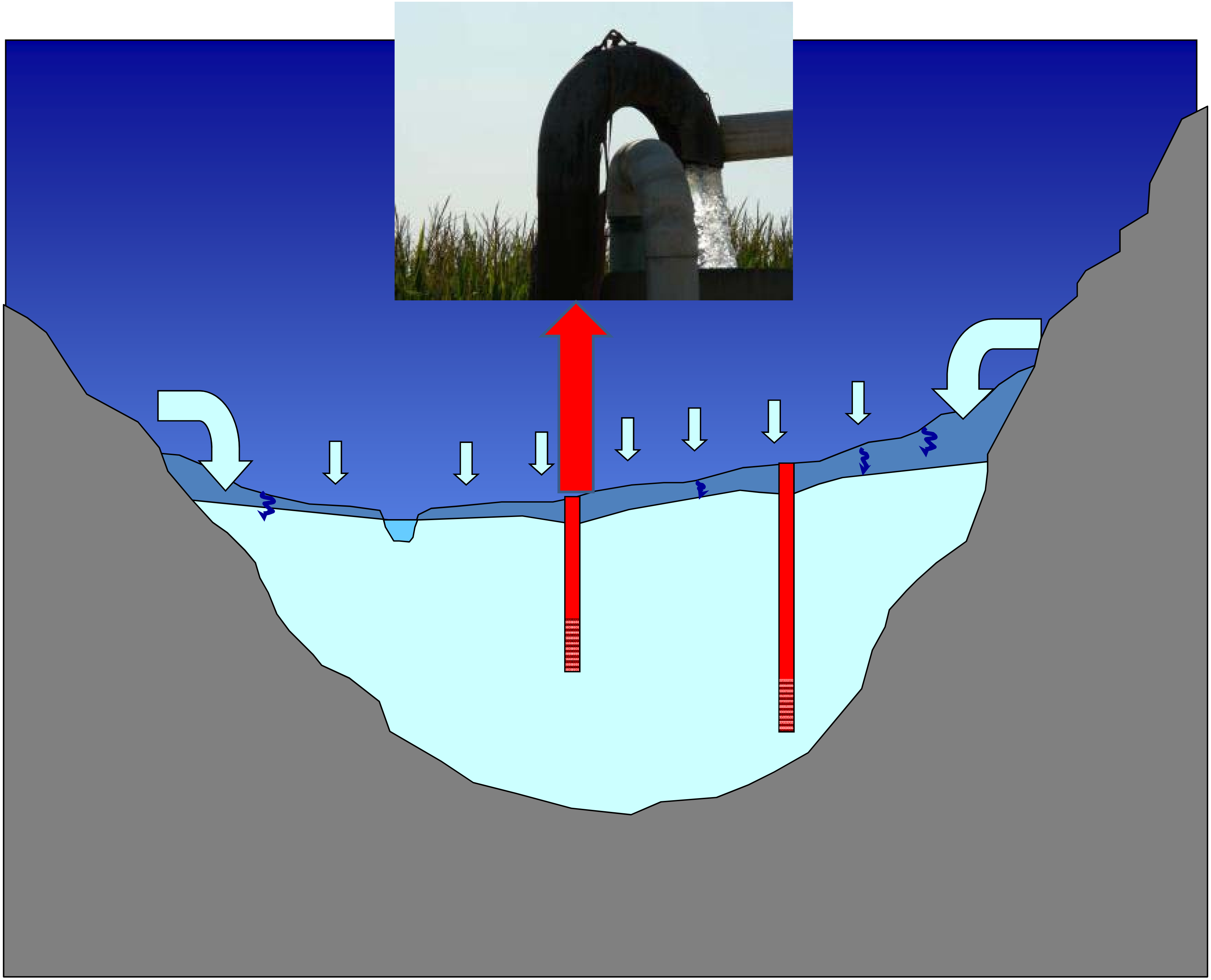


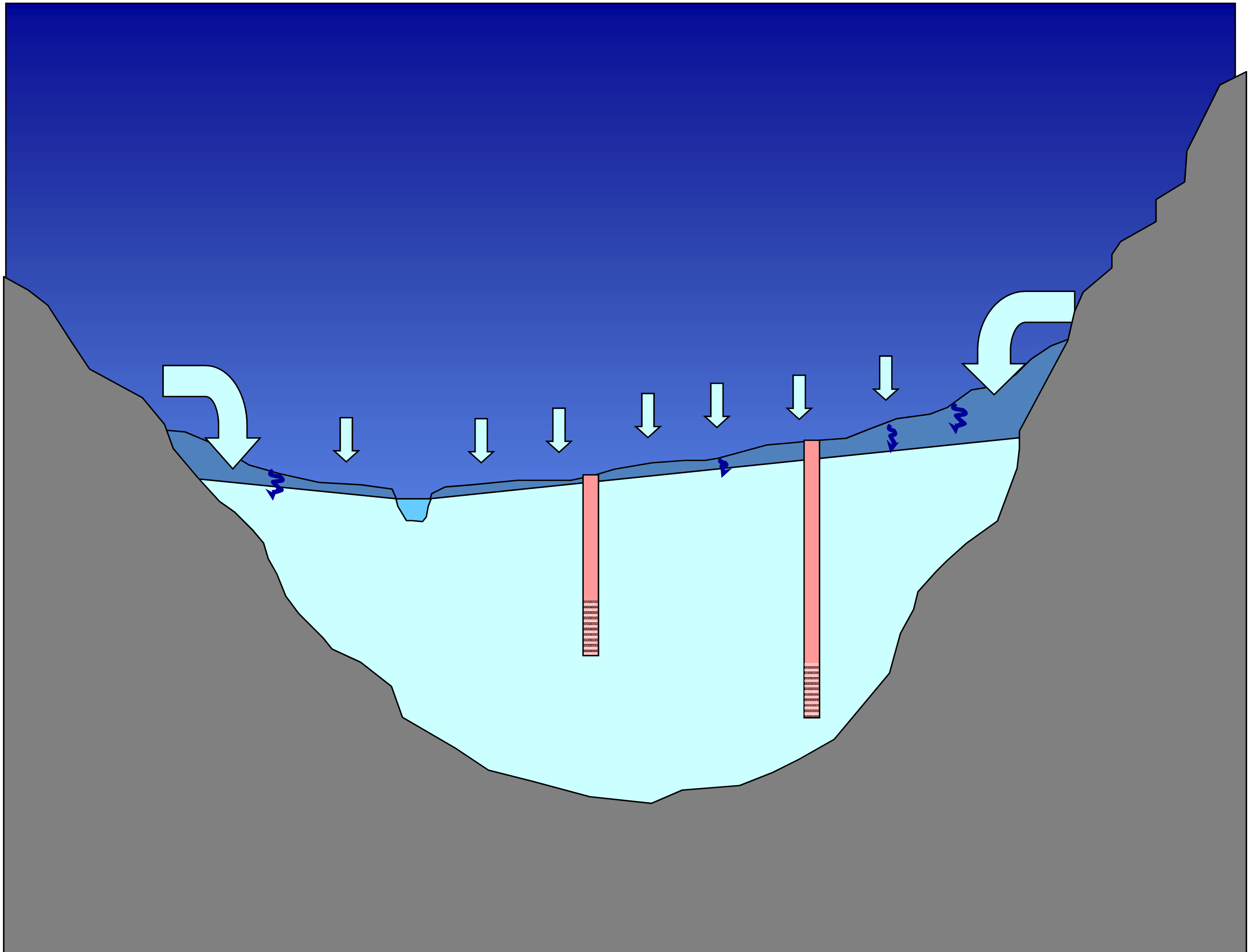


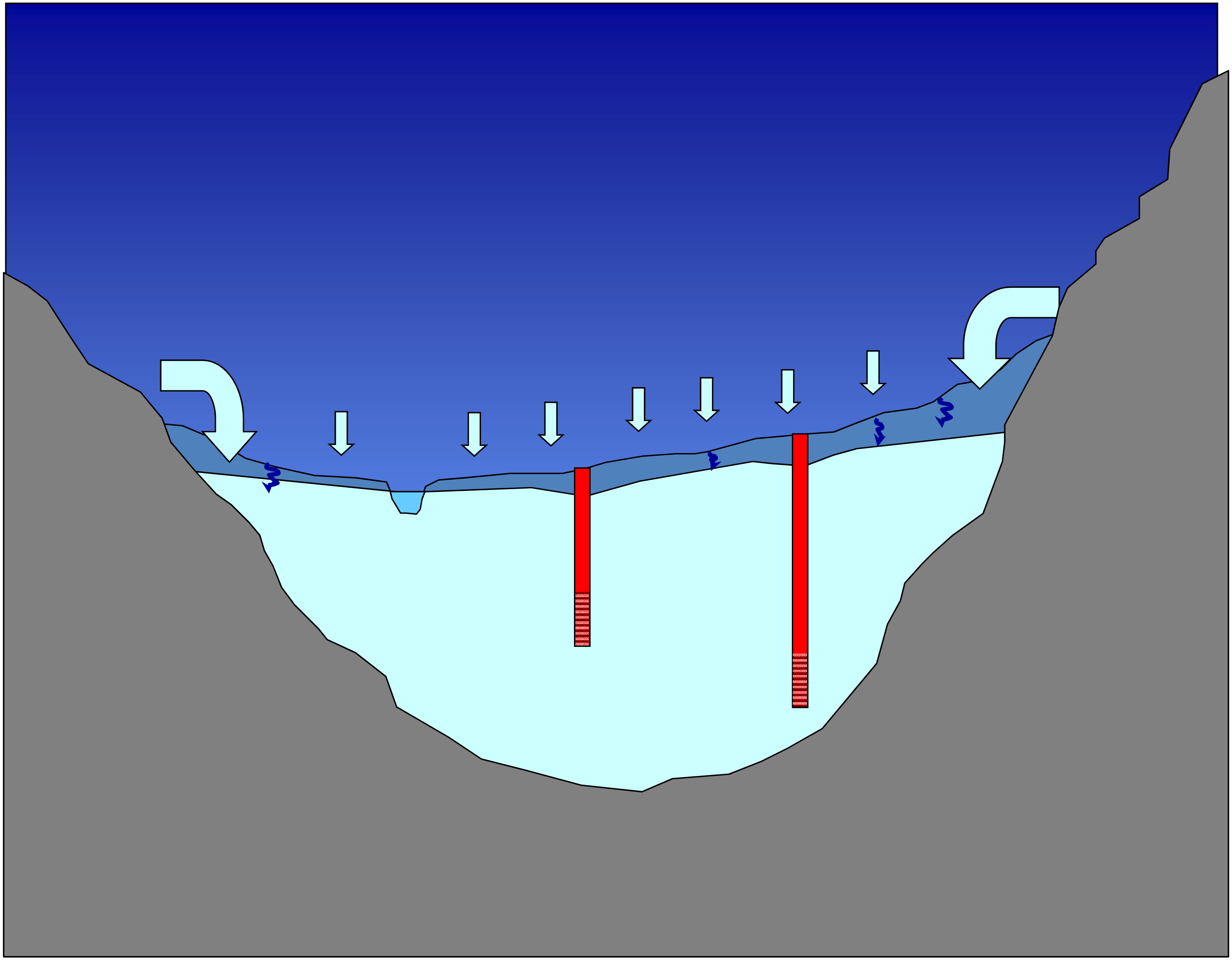


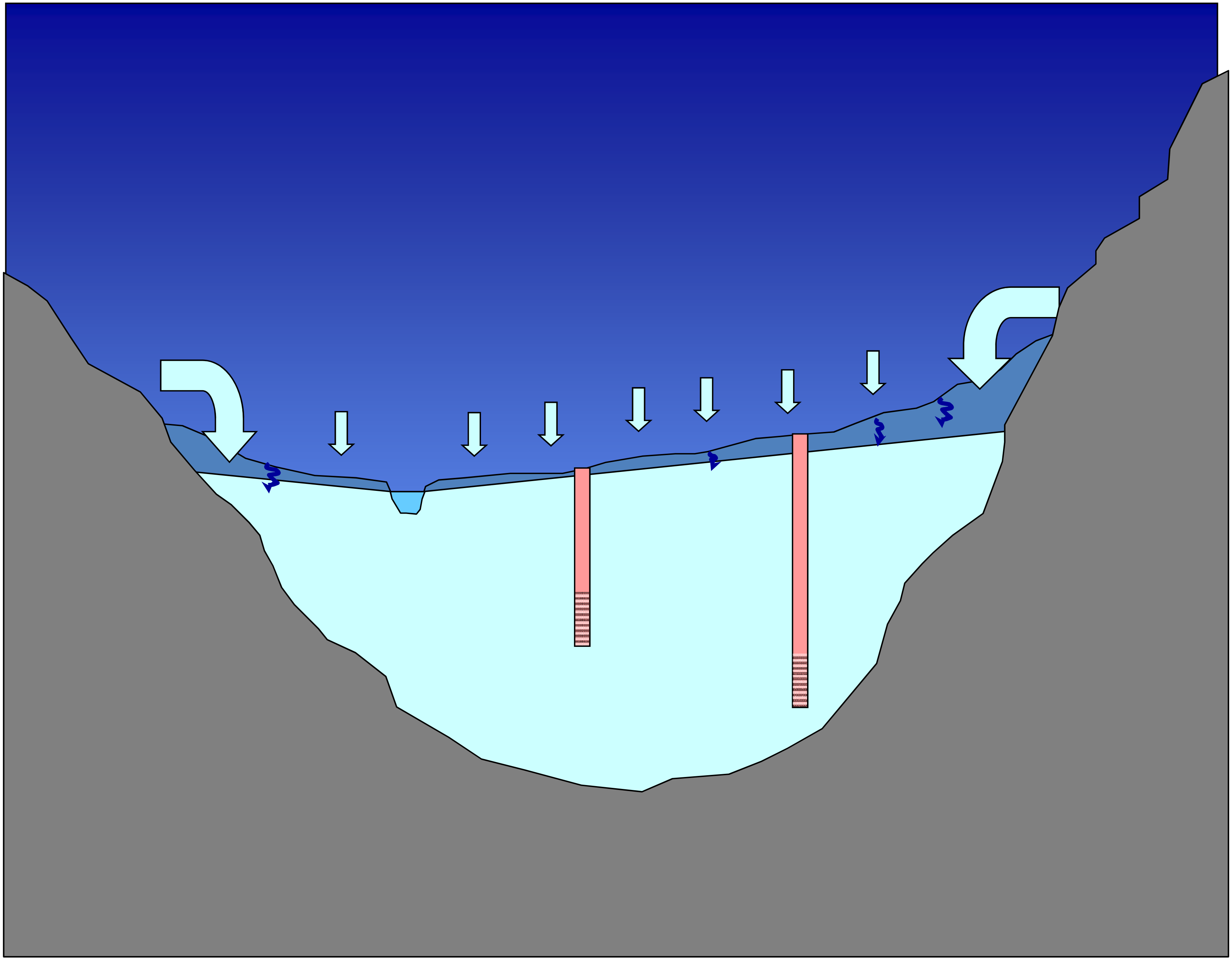


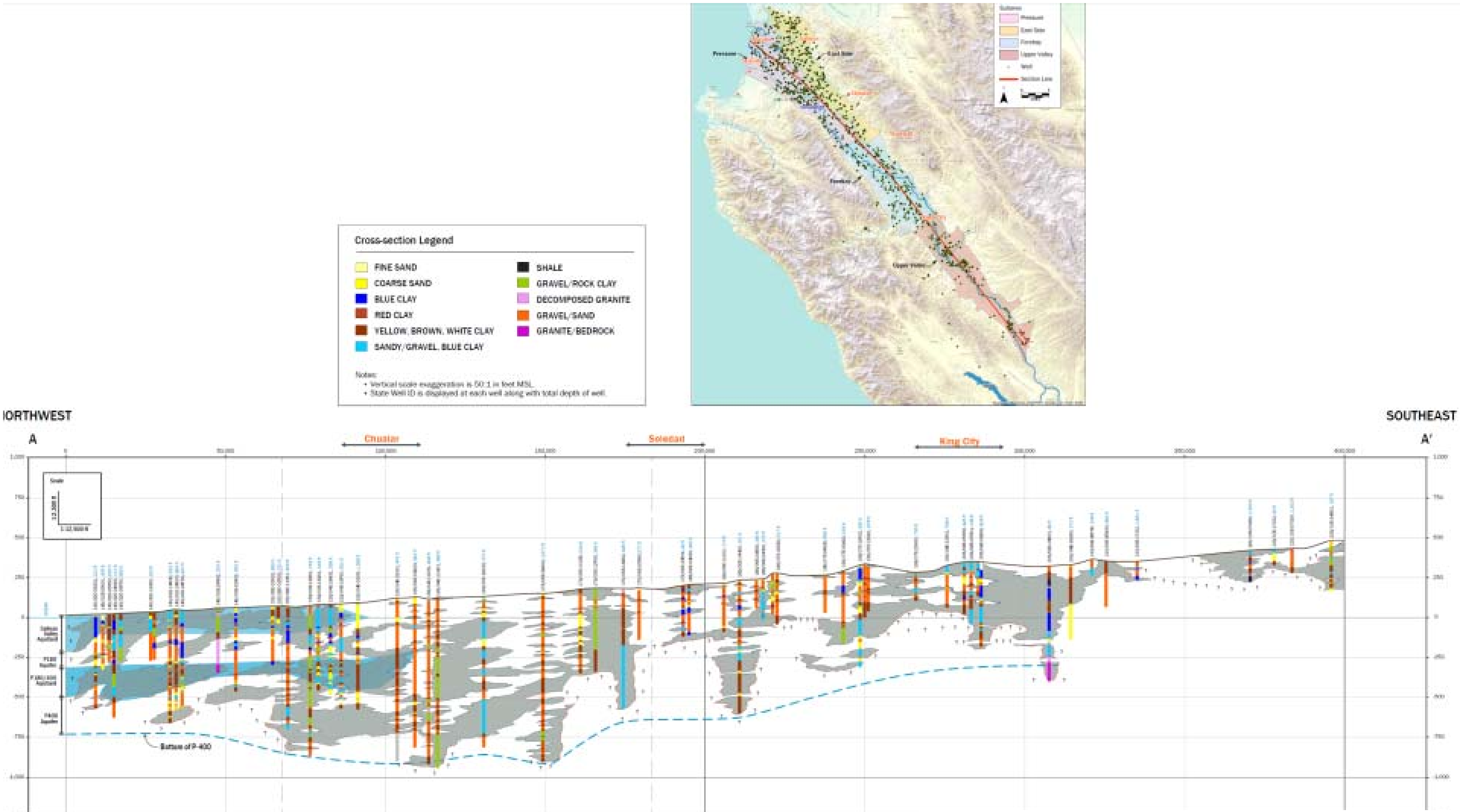






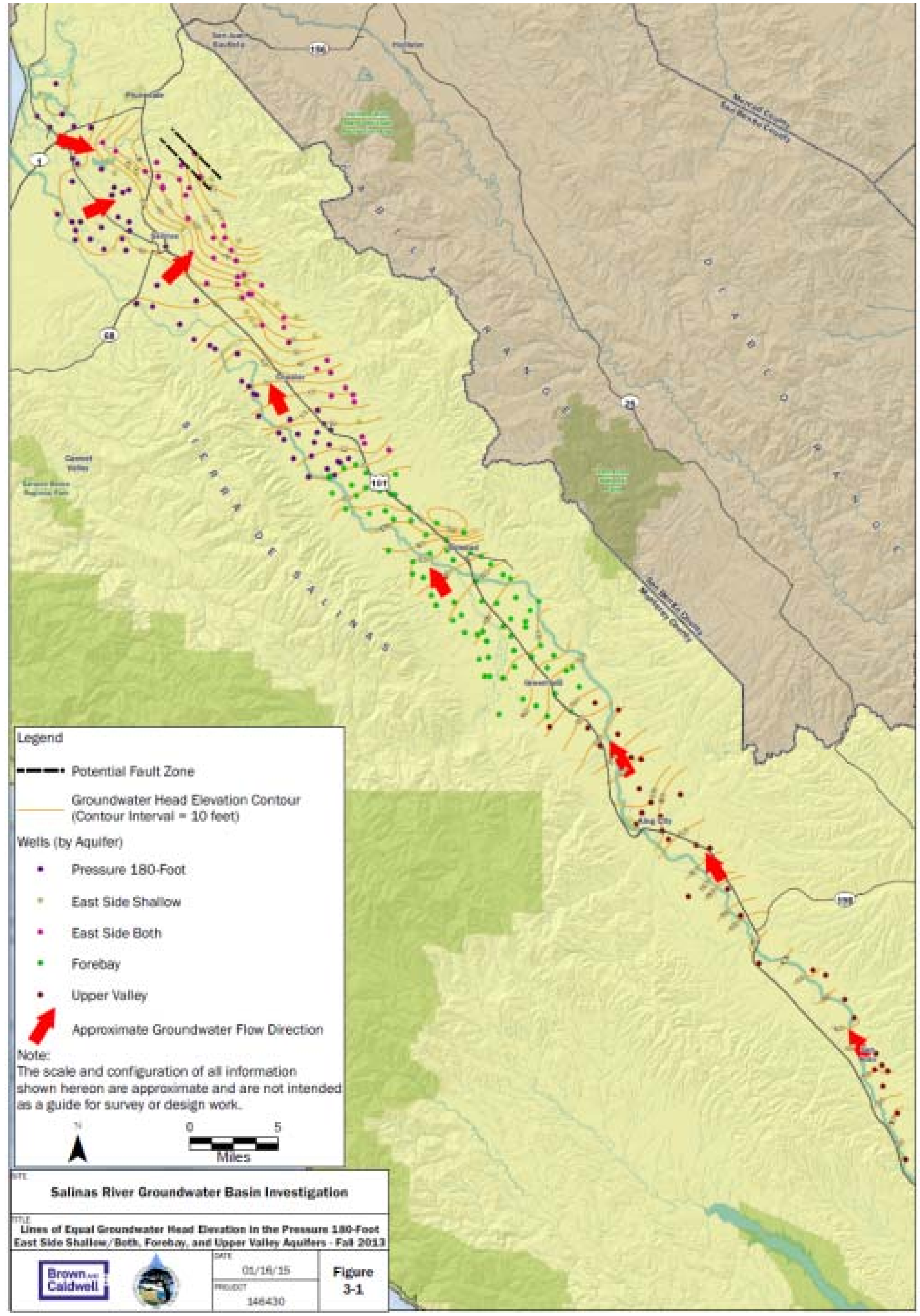






Brown & Caldwell, MCWRA, January 2015

Groundwater Level and Groundwater Flow Fall 2013



Brown & Caldwell, MCWRA, January 2015

Groundwater Budget: Inflows and Outflow

Table ES-1. Water Budget Components by Subarea					
Subarea	Average of WY 1958-1994 (from MW, 1998)				2013 Groundwater Pumping (reported by MCWRA)[c]
	Inflow		Outflow		
	Natural Recharge[a]	Subsurface Inflow	Groundwater Pumping[b]	Subsurface Outflow	
Pressure	117,000	17,000	130,000	8,000	118,000
East Side	41,000	17,000	86,000	0	98,000
Forebay	154,000	31,000	160,000	20,000	148,000
Upper Valley	165,000	7,000	153,000	17,000	145,000
TOTAL:	477,000	72,000 |	529,000	45,000 |	509,000

INFLOW 549,000 OUTFLOW: 574,000

Sources of Groundwater:

50% stream recharge
44% precipitation and irrigation return water
6% subsurface inflow

Brown & Caldwell, MCWRA, January 2015

Using Groundwater Aquifers for Seasonal Storage:

Depth to Water (monthly)
October – September

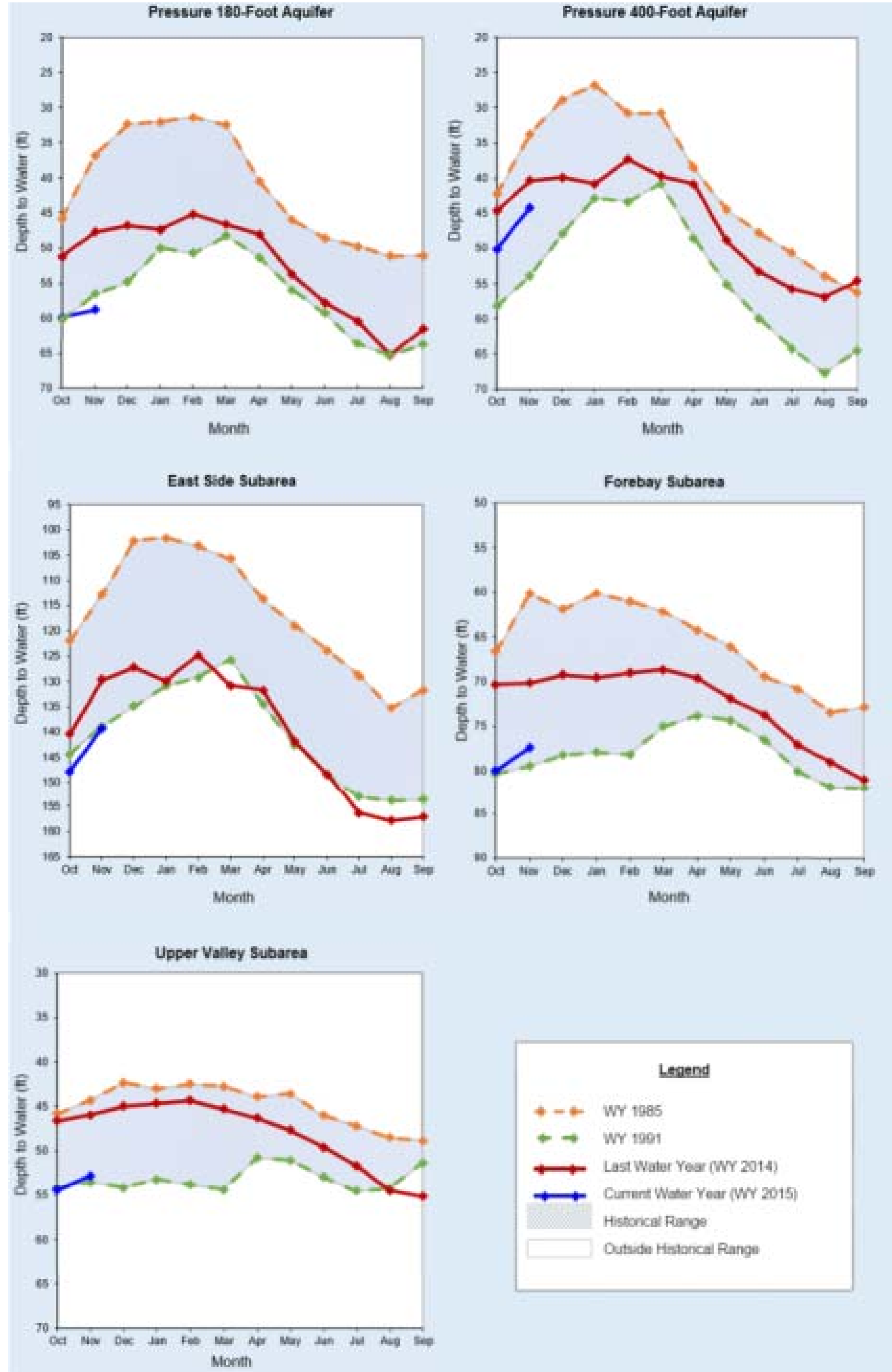
storage equivalent: ~500,000 af

Legend:

Average Year ——

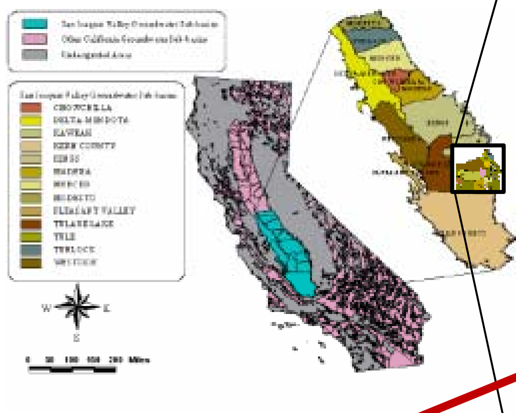
Water Year 2014 ——

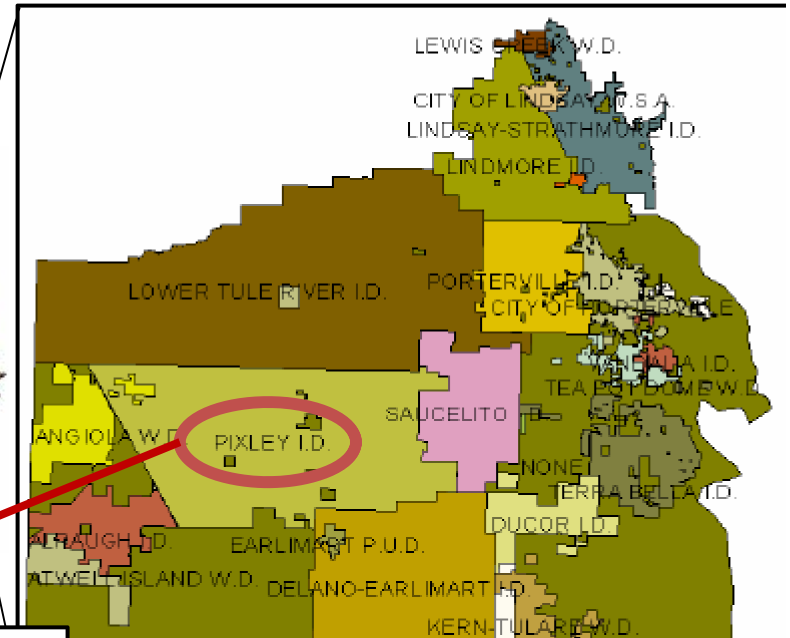
Dry Year ——

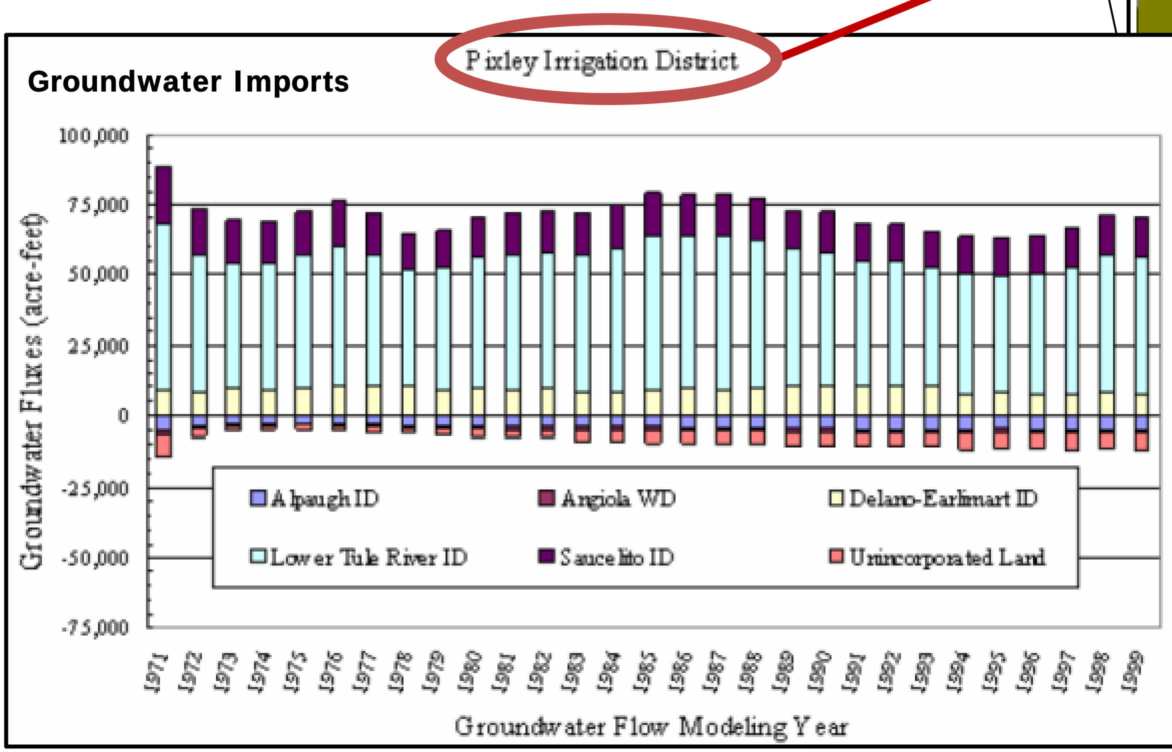


MCWRA, 2015

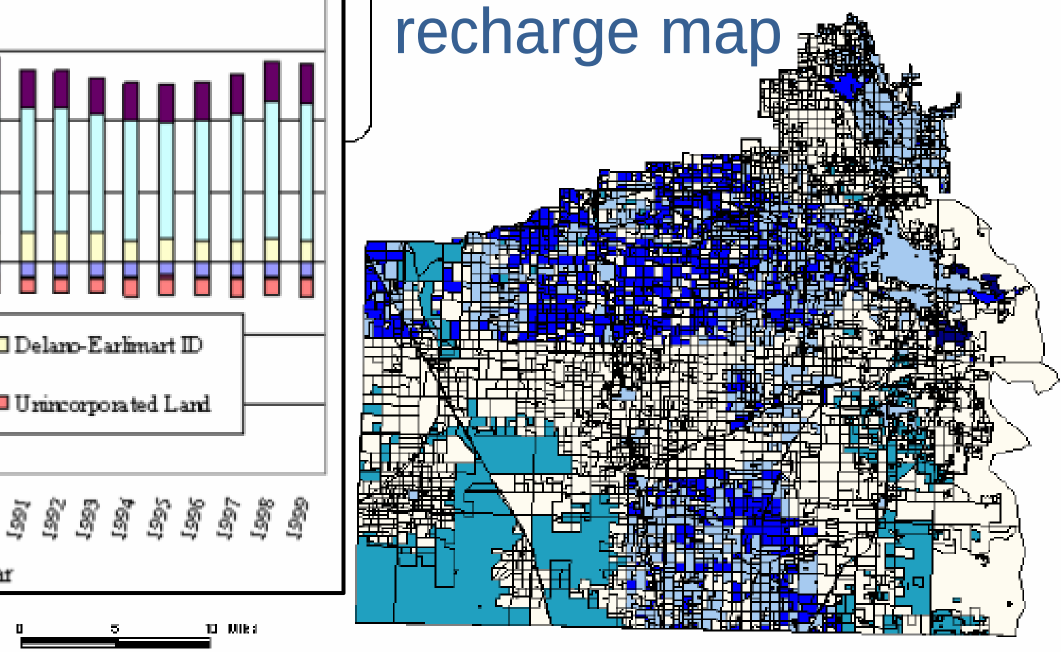
Estimating Groundwater Flows Across Subbasin / Political Boundaries





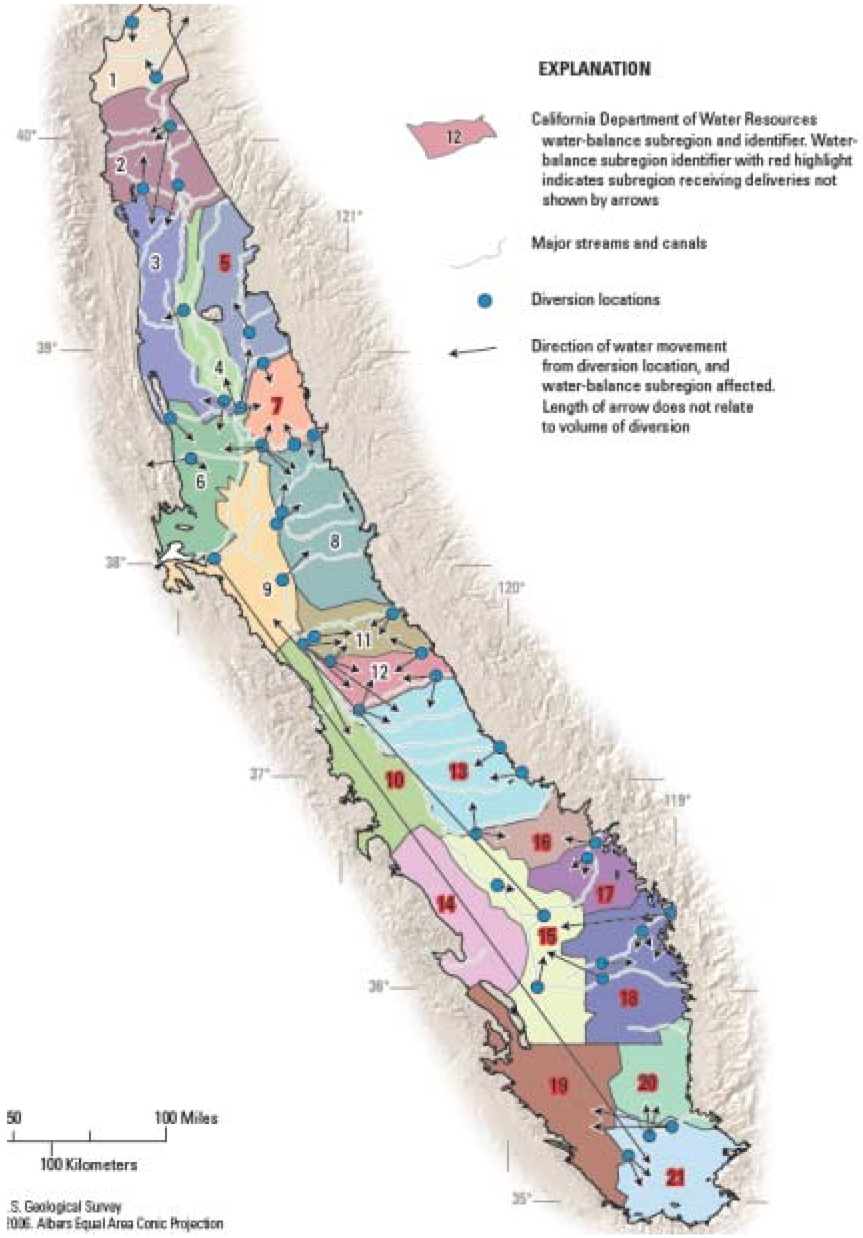


recharge map



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

Interbasin Flows



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 Budget: Inflows and Outflow

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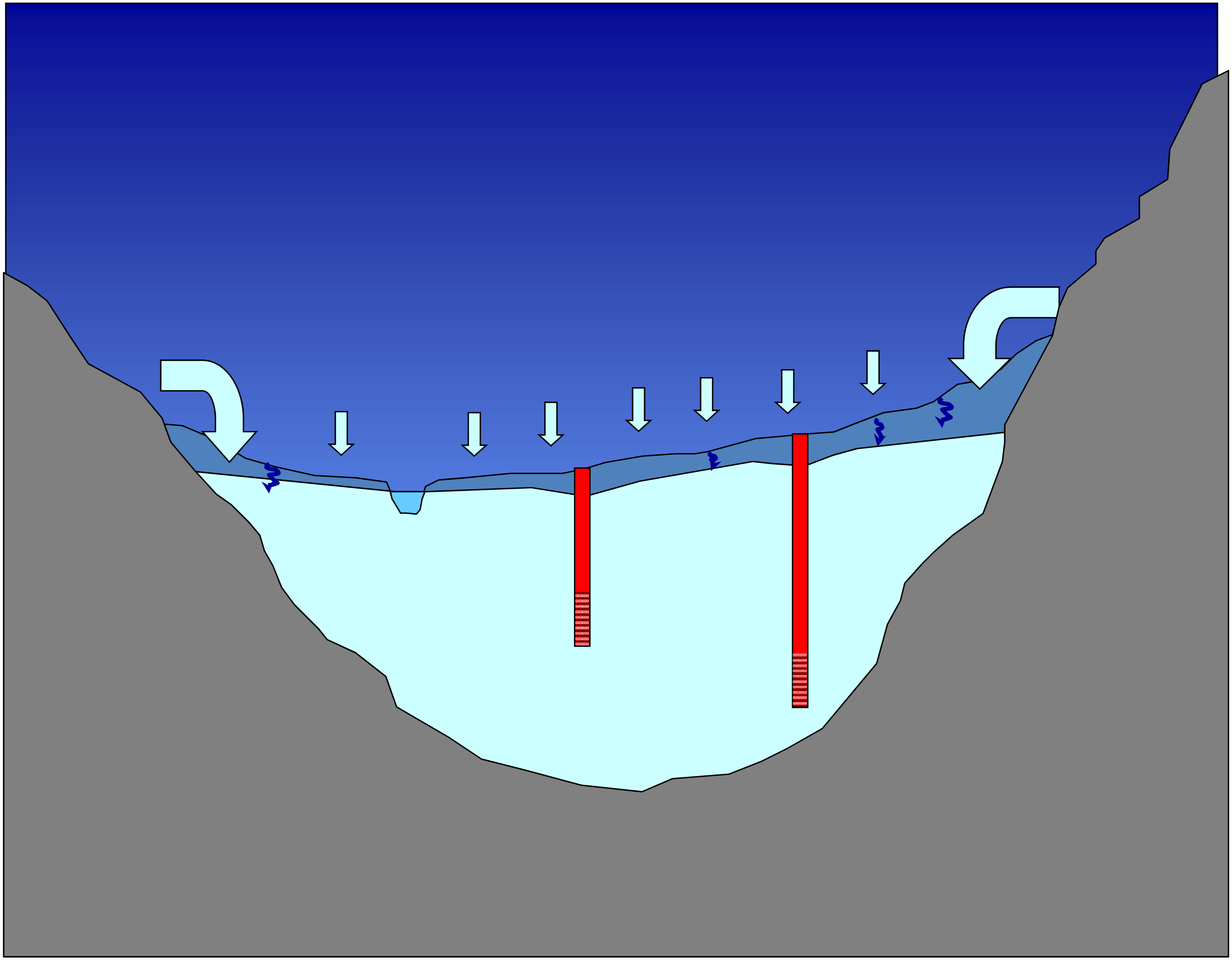
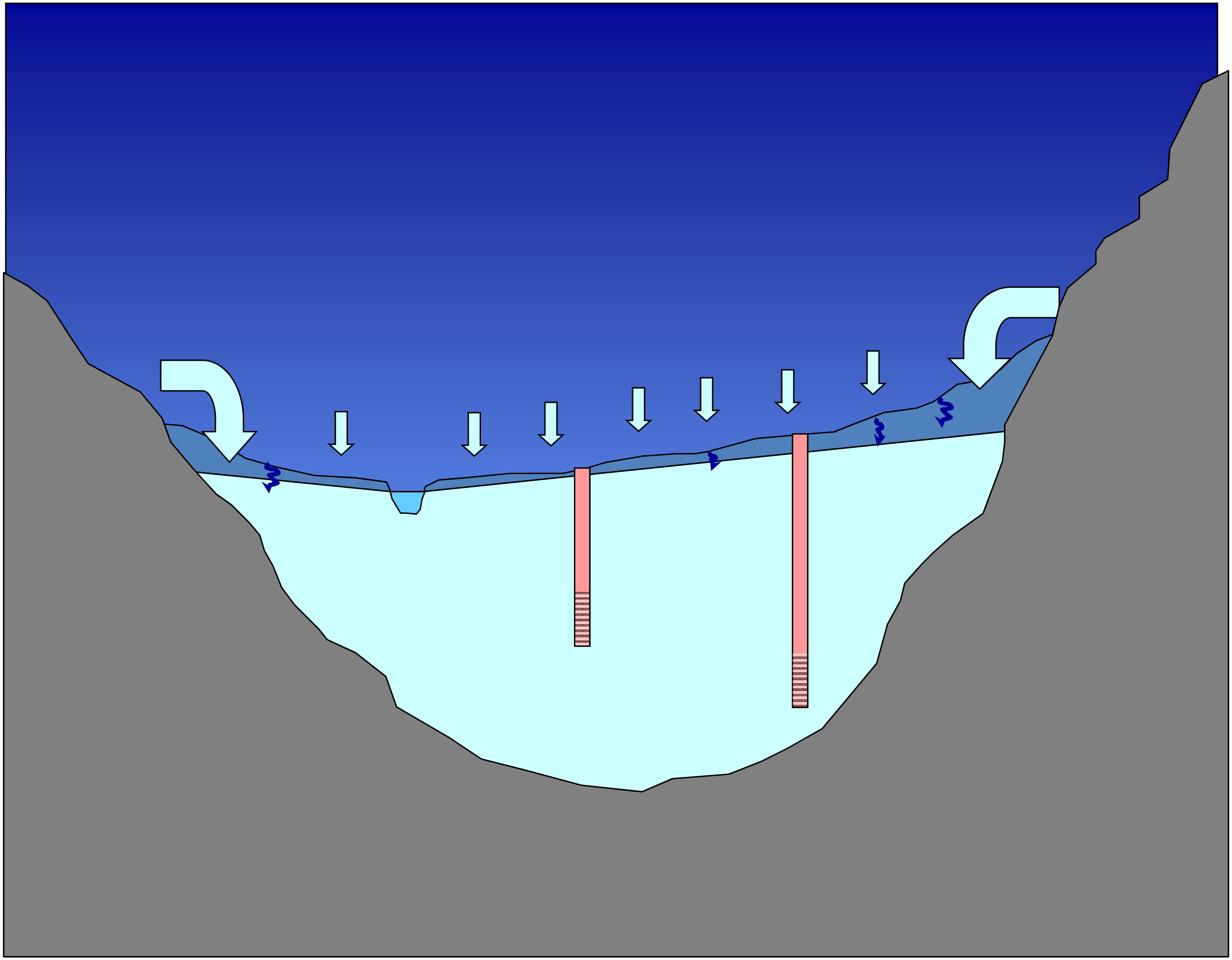
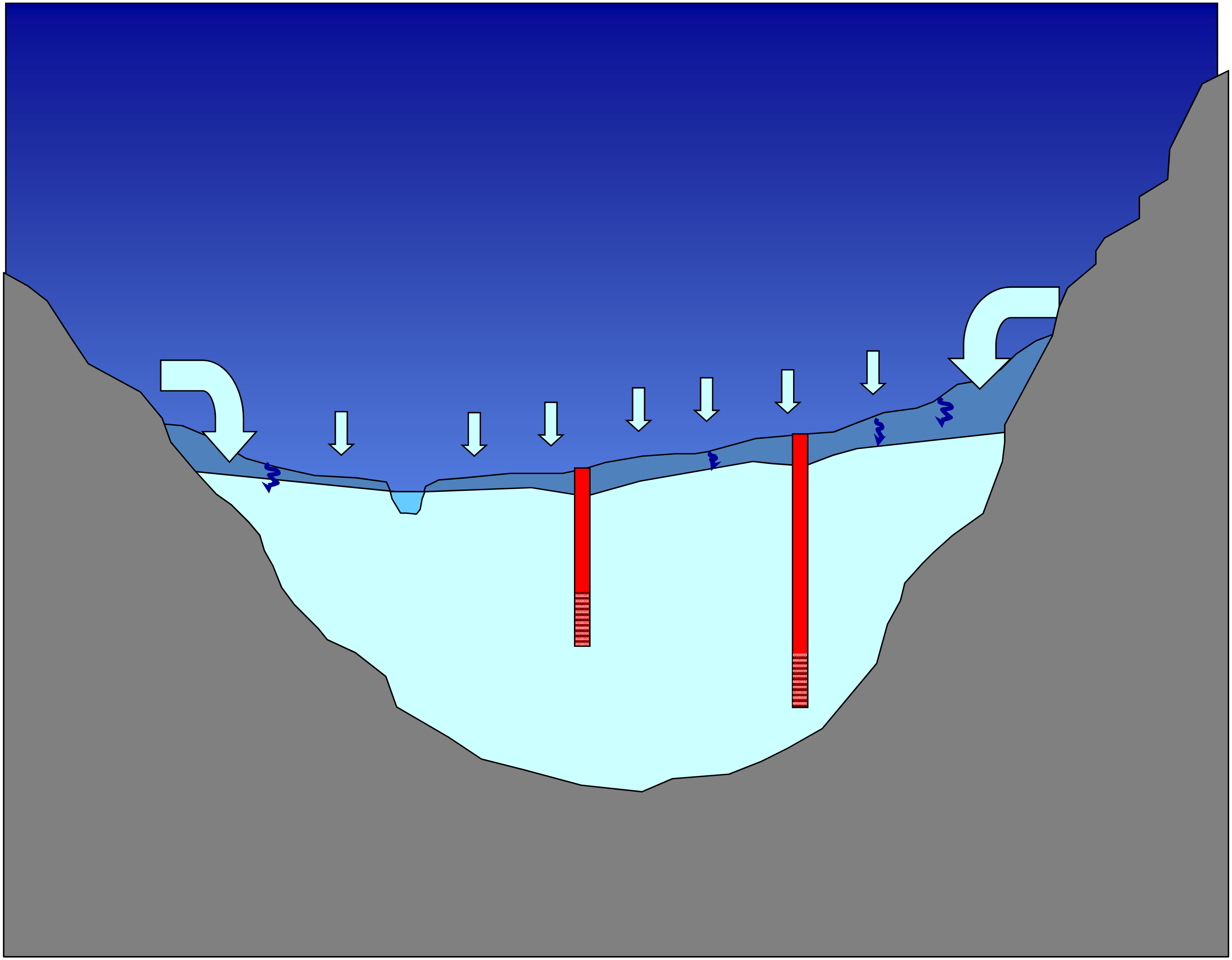
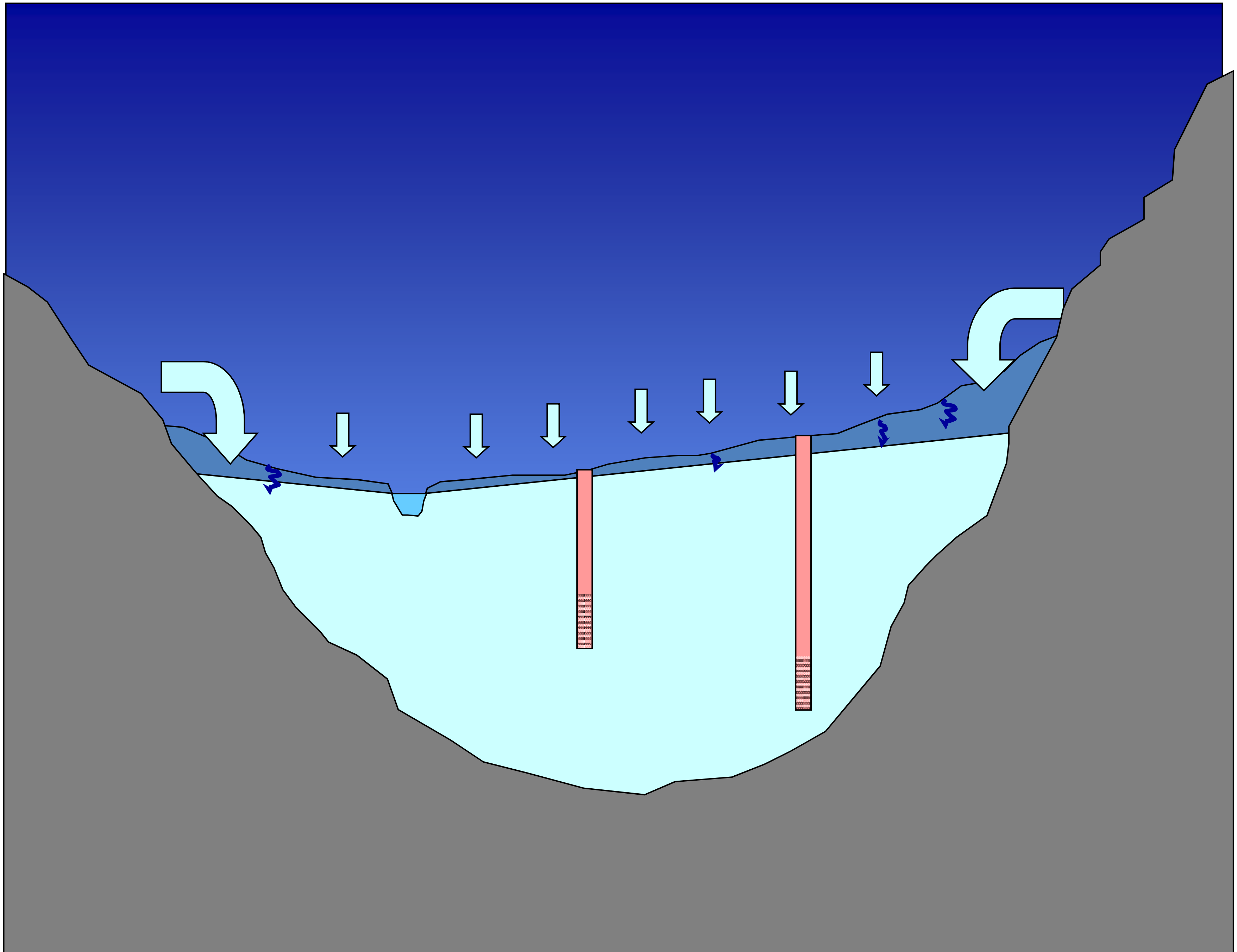
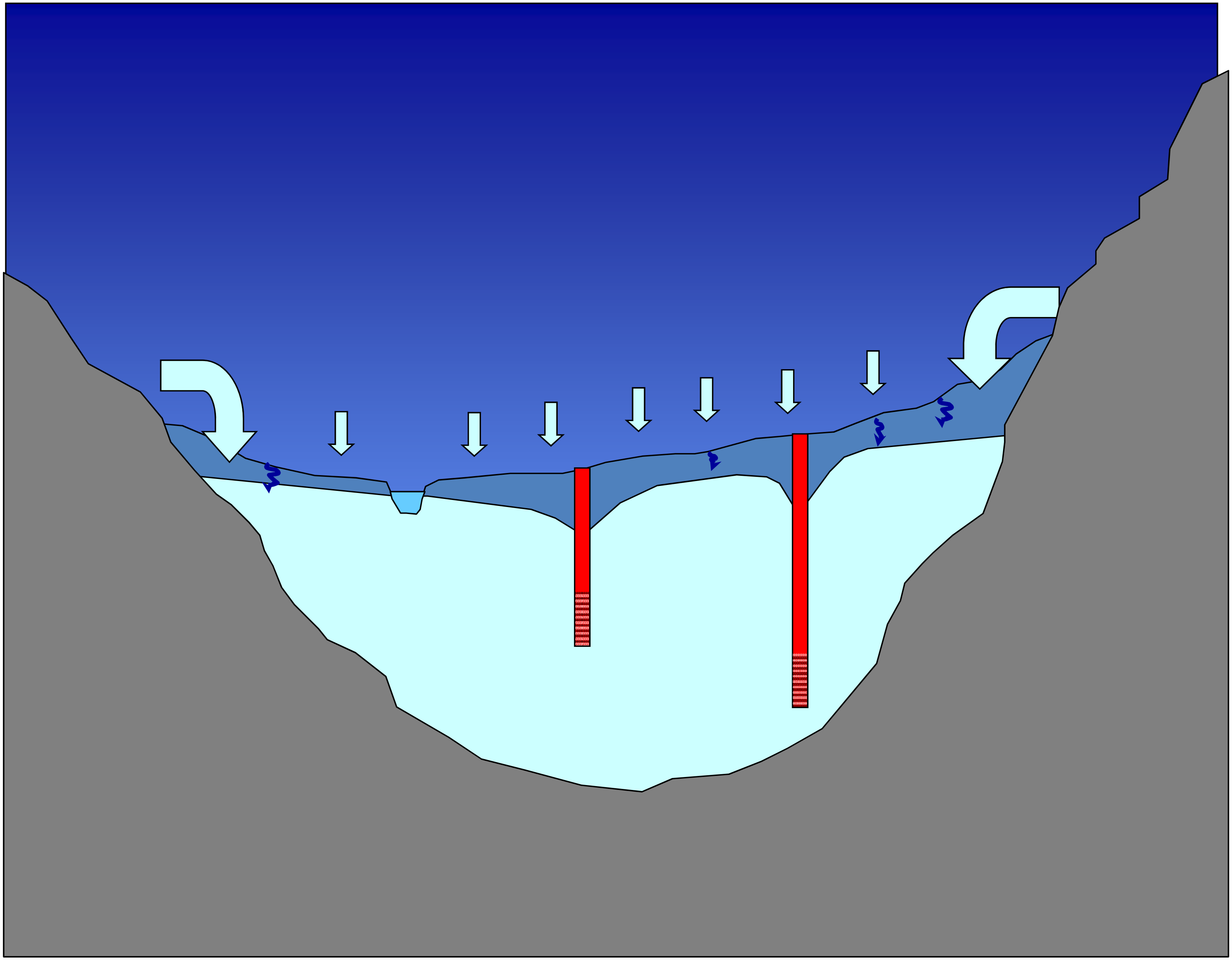
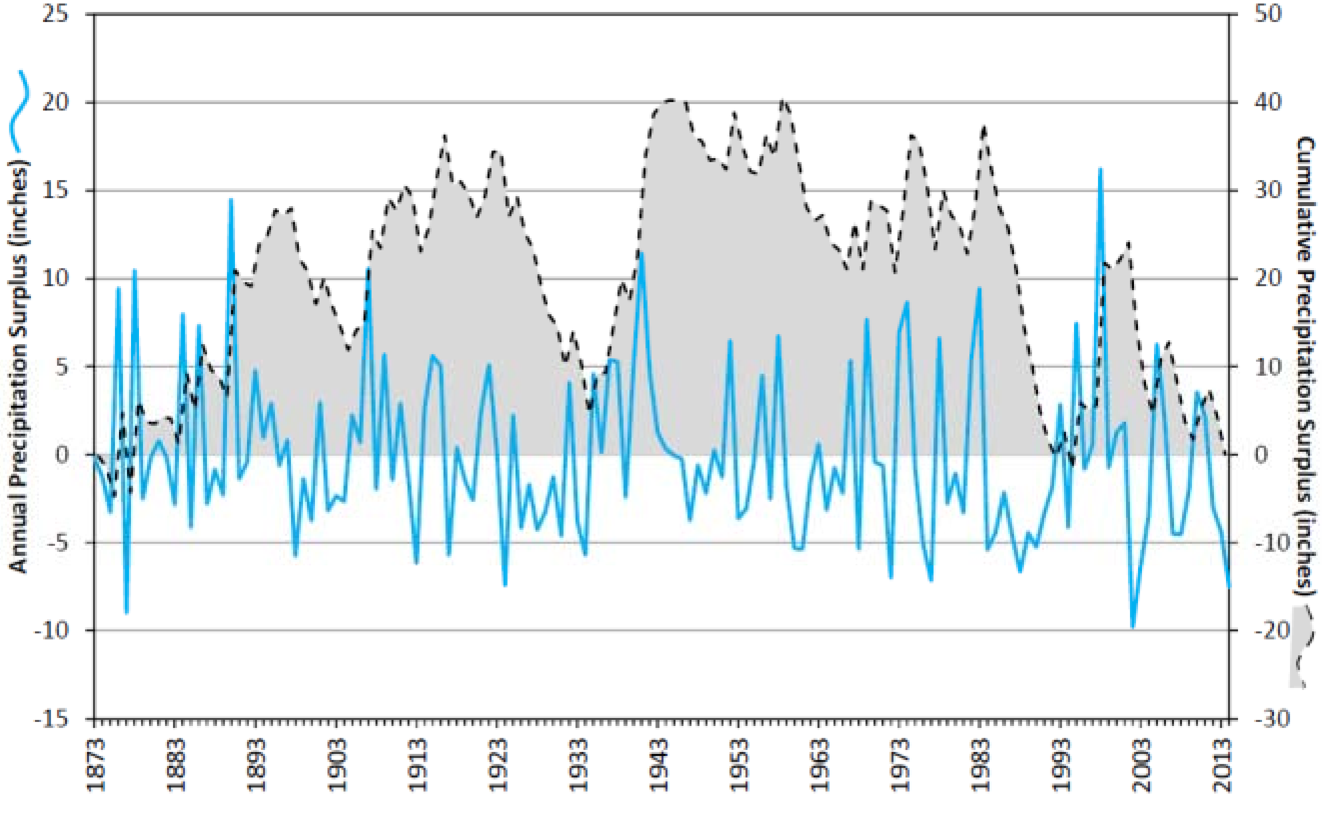








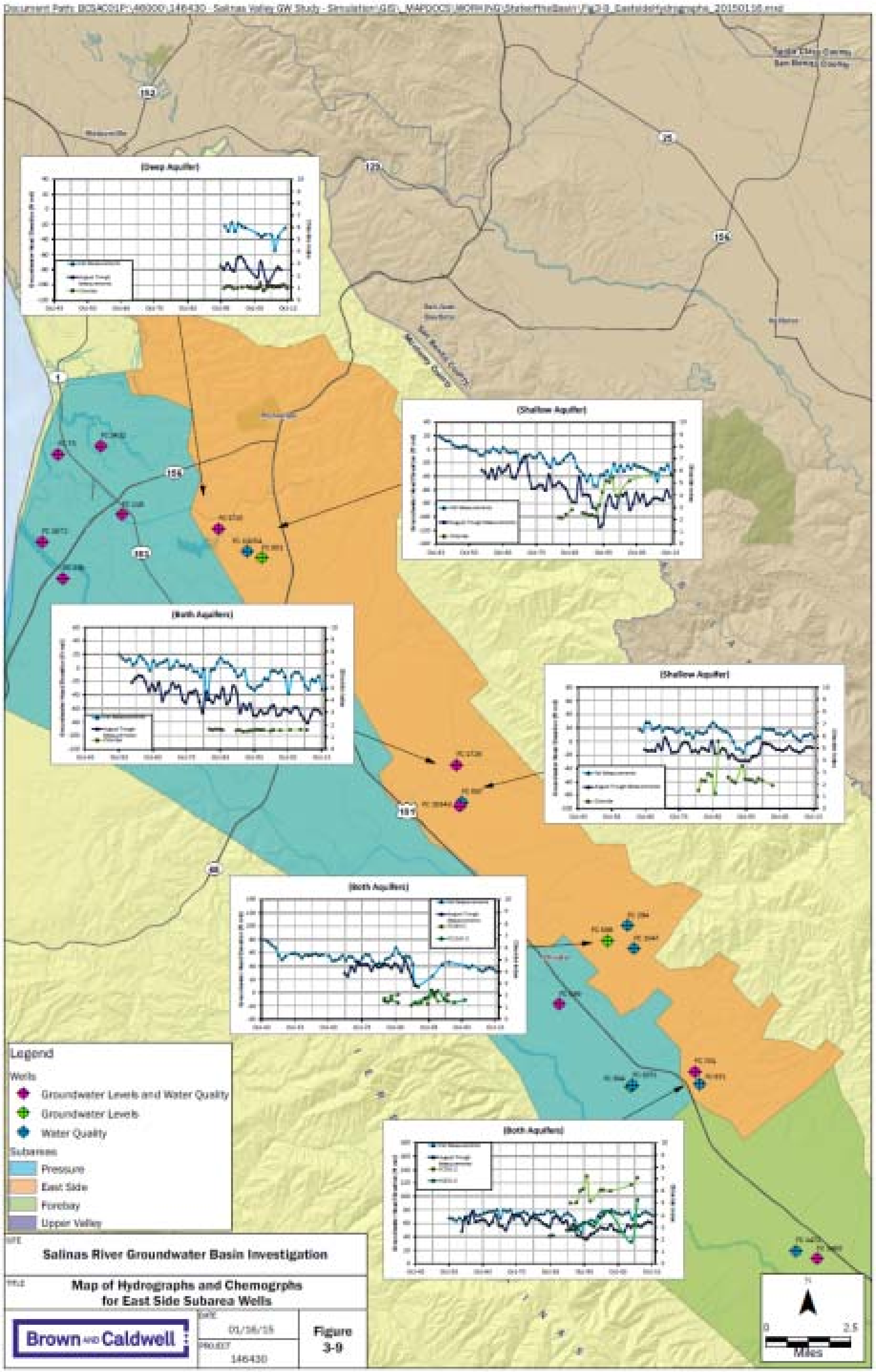


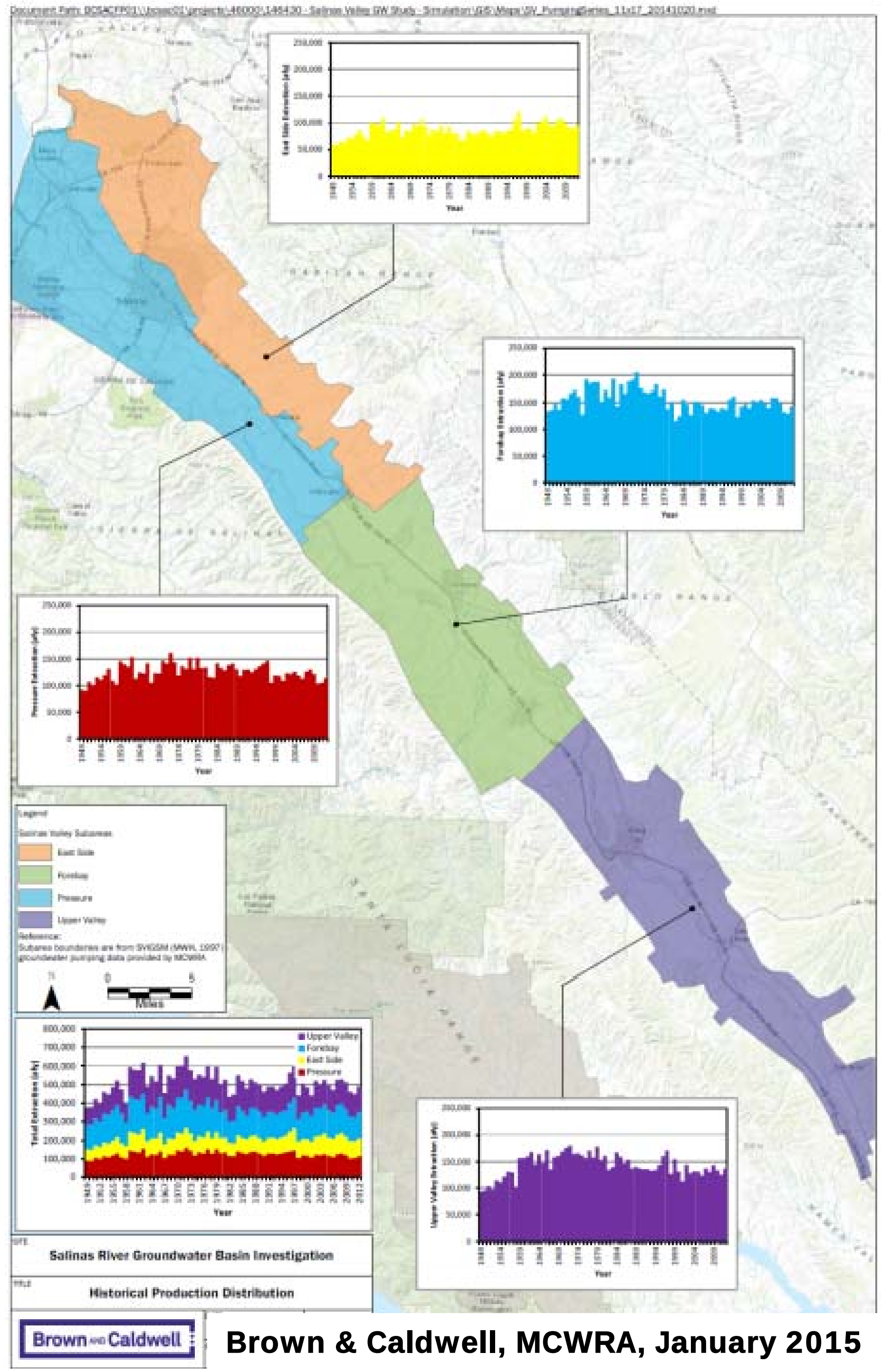


Note: The annual precipitation surplus represents the difference between the annual precipitation and the long-term mean.

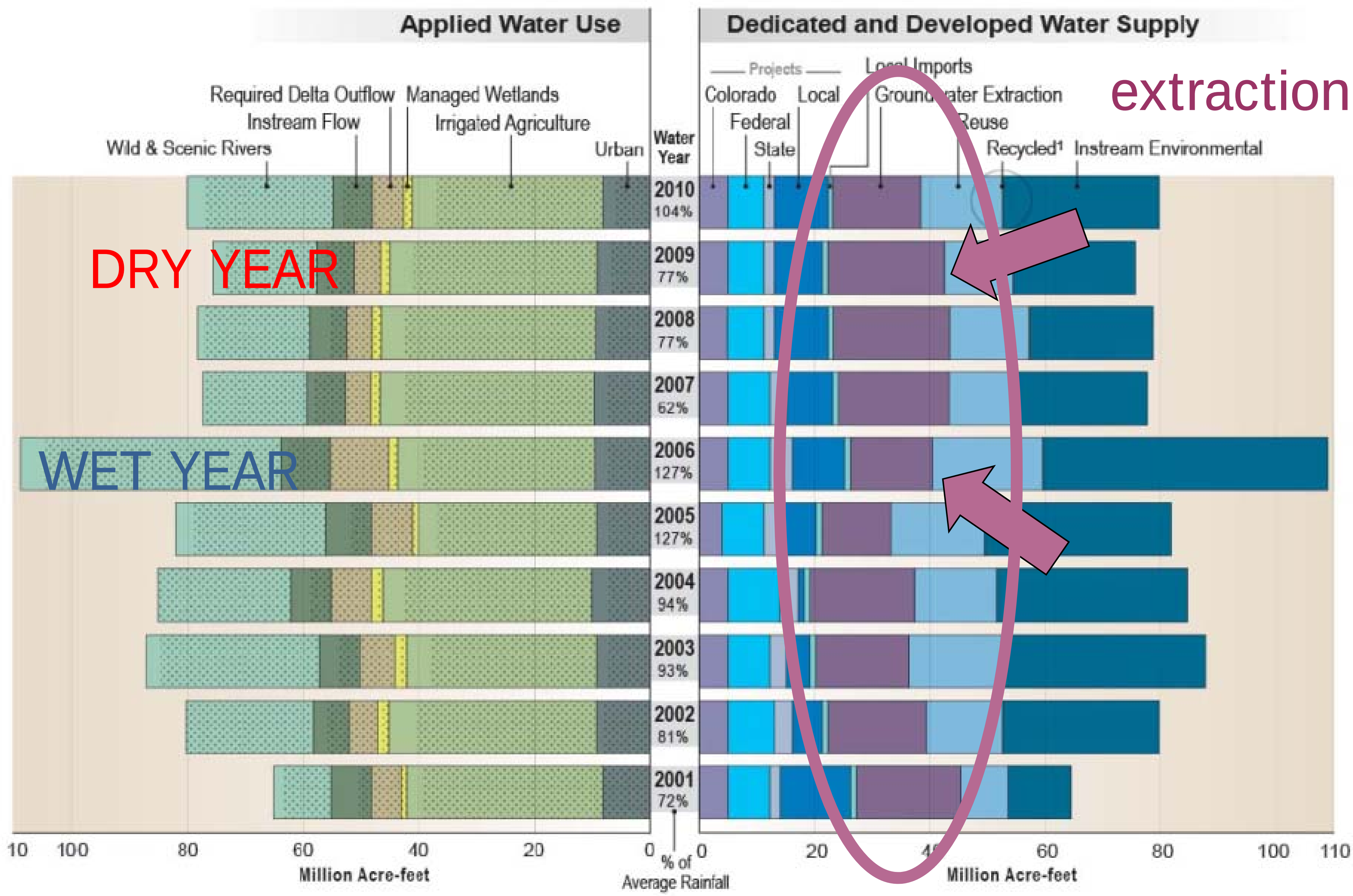
Brown AND Caldwell	DATE 01/16/15	SITE Salinas River Groundwater Basin Investigation	Figure ES-4
	PROJECT 146430	TITLE Annual and Cumulative Precipitation Surplus at Salinas Municipal Airport	

Brown & Caldwell, MCWRA, January 2015





Brown & Caldwell, MCWRA, January 2015

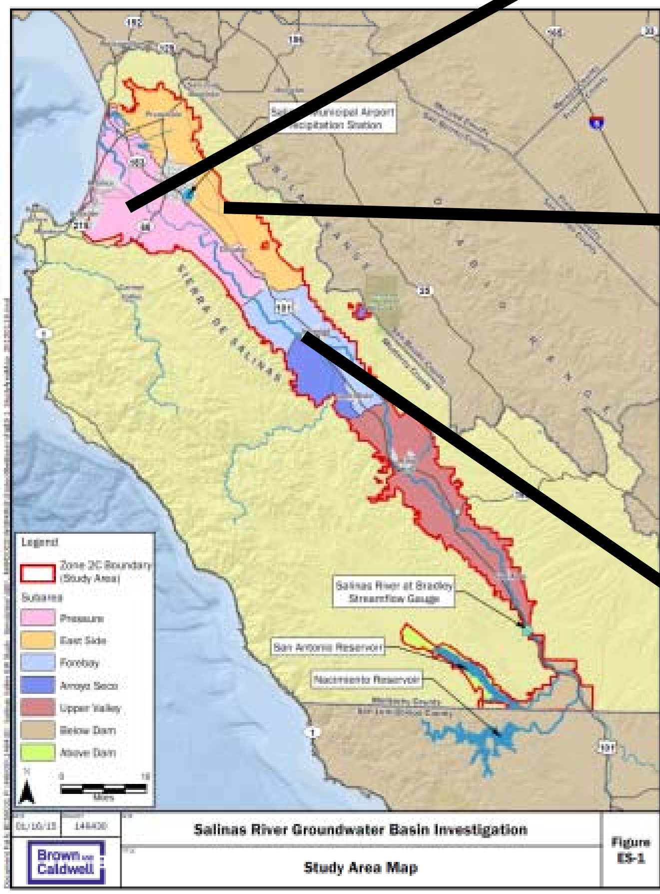


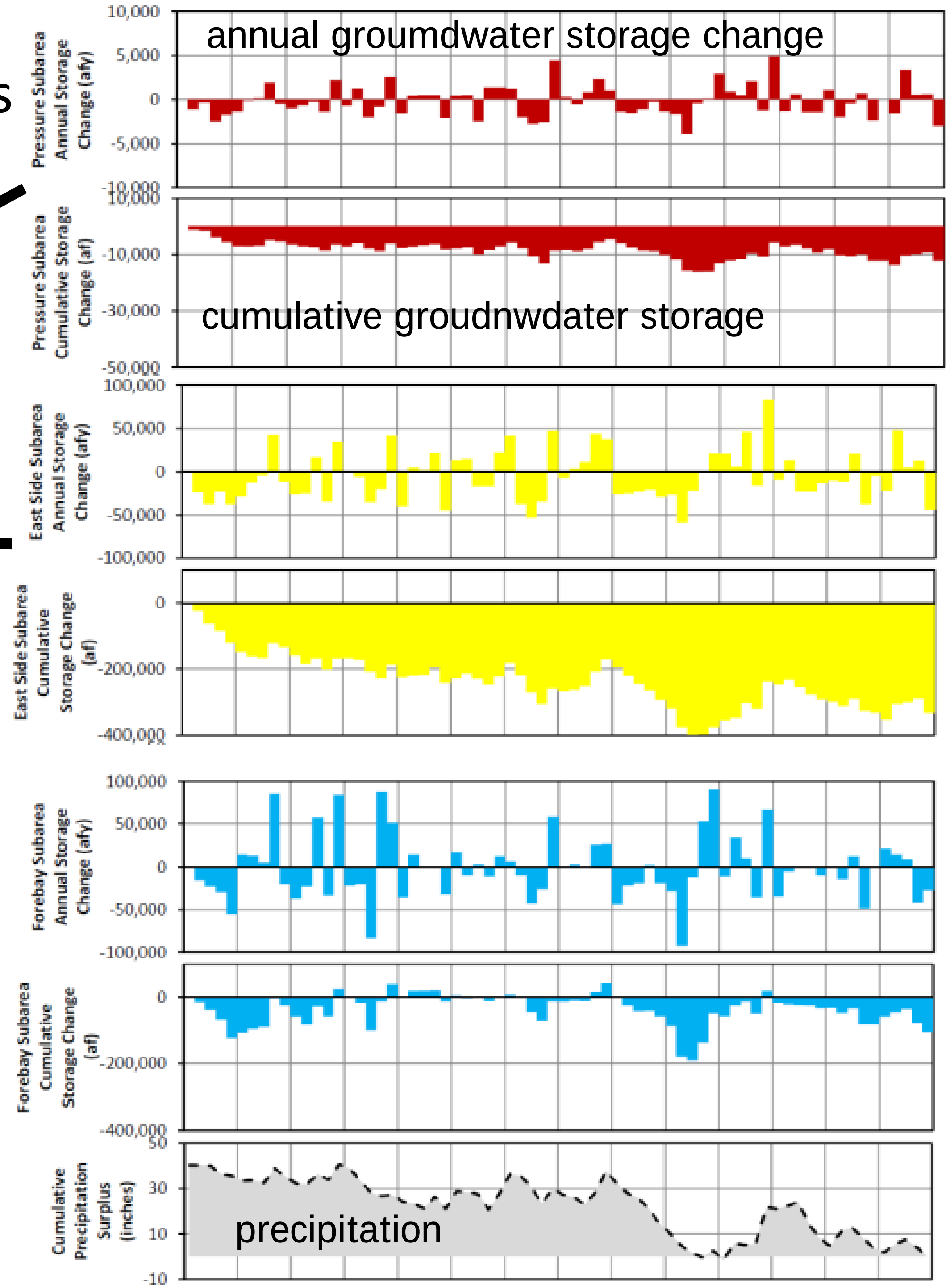
Stippling in bars **indicates depleted (irrecoverable) water use** *(water consumed through evapotranspiration, flowing to salt sinks like saline aquifers, or otherwise not available as a source of supply)*

[1] **Detail of bar graph:** *For water years 2001-2010, recycled municipal water varied from 0.2 to 0.5 MAF of the water supply .*

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

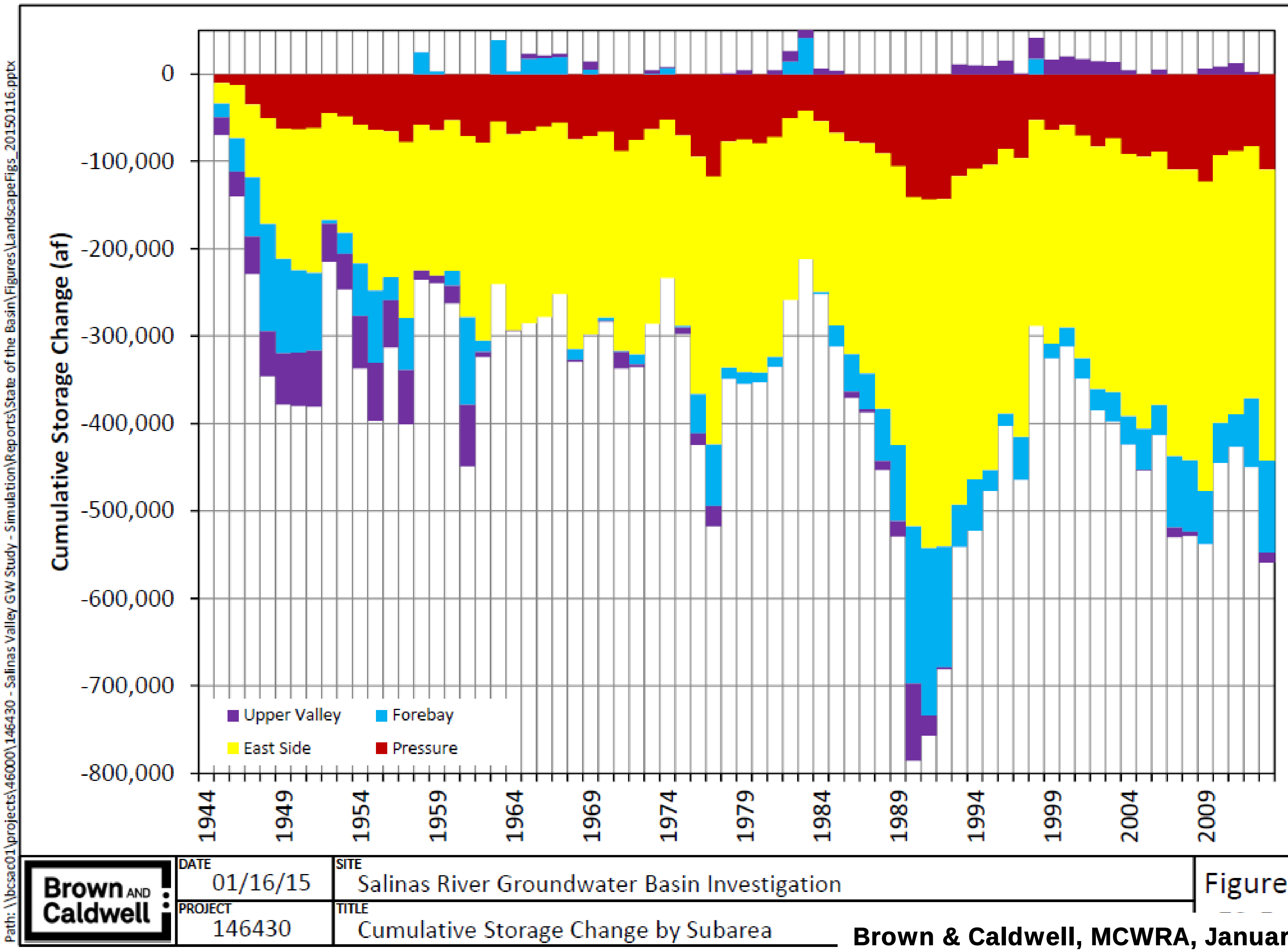
Groundwater Storage Changes





Brown & Caldwell, MCWRA, January 2015

Cumulative Storage Change in the Salinas Valley



Brown & Caldwell, MCWRA, January 2015

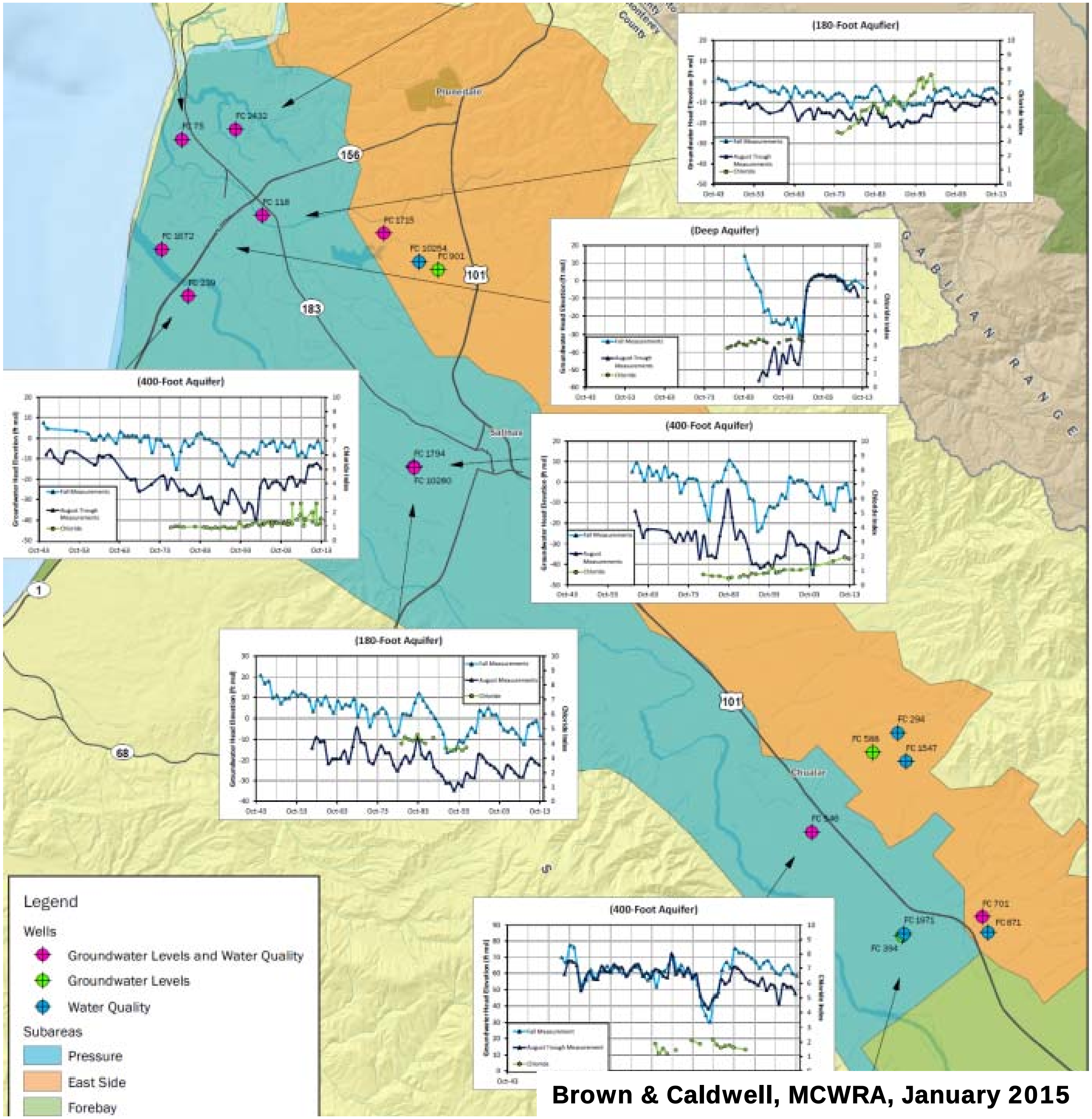
Change in Water Table Elevation [ft], 1943 - 2013

Legend:

Fall Measurement ——

August Measurement ——

Chloride (Salinity) ——



Brown & Caldwell, MCWRA, January 2015

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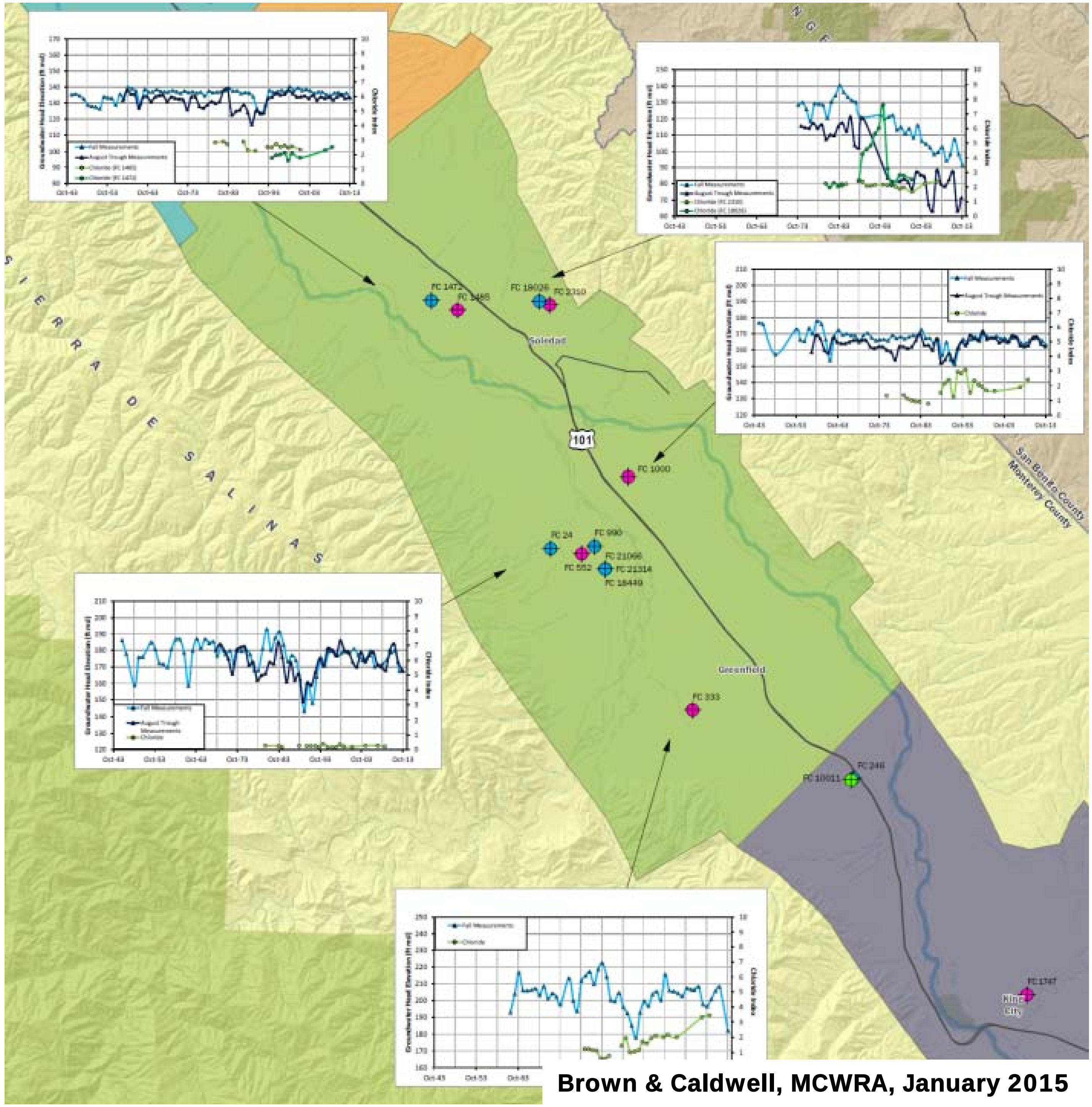


Brown & Caldwell, MCWRA, January 2015

SUMMARY OF ANNUAL FALL WELL MEASUREMENTS
SALINAS VALLEY BASIN

Change in Groundwater Elevation from Fall 2012 to Fall 2013

PRESSURE 180

Area and Quadrant	No of Wells	Average Change (ft.)
13S/02E	7	-2.2
14S/02E	15	-4.7
14S/03E	6	-7.0
15S/03E	8	-5.7
15S/04E	1	-6.7
16S/04E	11	-3.4
16S/05E	7	-1.9
17S/04E	1	-3.5
Total	56	-4.2

PRESSURE 400

Area and Quadrant	No of Wells	Average Change (ft.)
13S/02E	11	-6.2
14S/02E	27	-9.5
14S/03E	3	-9
15S/02E	3	-3.6
15S/03E	16	-6.2
15S/04E	3	-6.7
16S/04E	8	-4.8
16S/05E	1	-1.6
17S/04E	1	-3.3
Total	73	-7.2

PRESSURE DEEP ZONE

Area and Quadrant	No of Wells	Average Change (ft.)
13S/01E	1	0.5
13S/02E	2	-2.7
14S/02E	2	-34.2
Total	5	-14.6

EAST SIDE

Area and Quadrant	No of Wells	Average Change (ft.)
13S/02E	2	-17.1
13S/03E	2	-9.3
14S/02E	3	-13.2
14S/03E	25	-11.2
14S/04E	4	-16.5
15S/03E	4	-6.4
15S/04E	24	-1.4
16S/05E	7	-3.4
Total	71	-7.4

FOREBAY

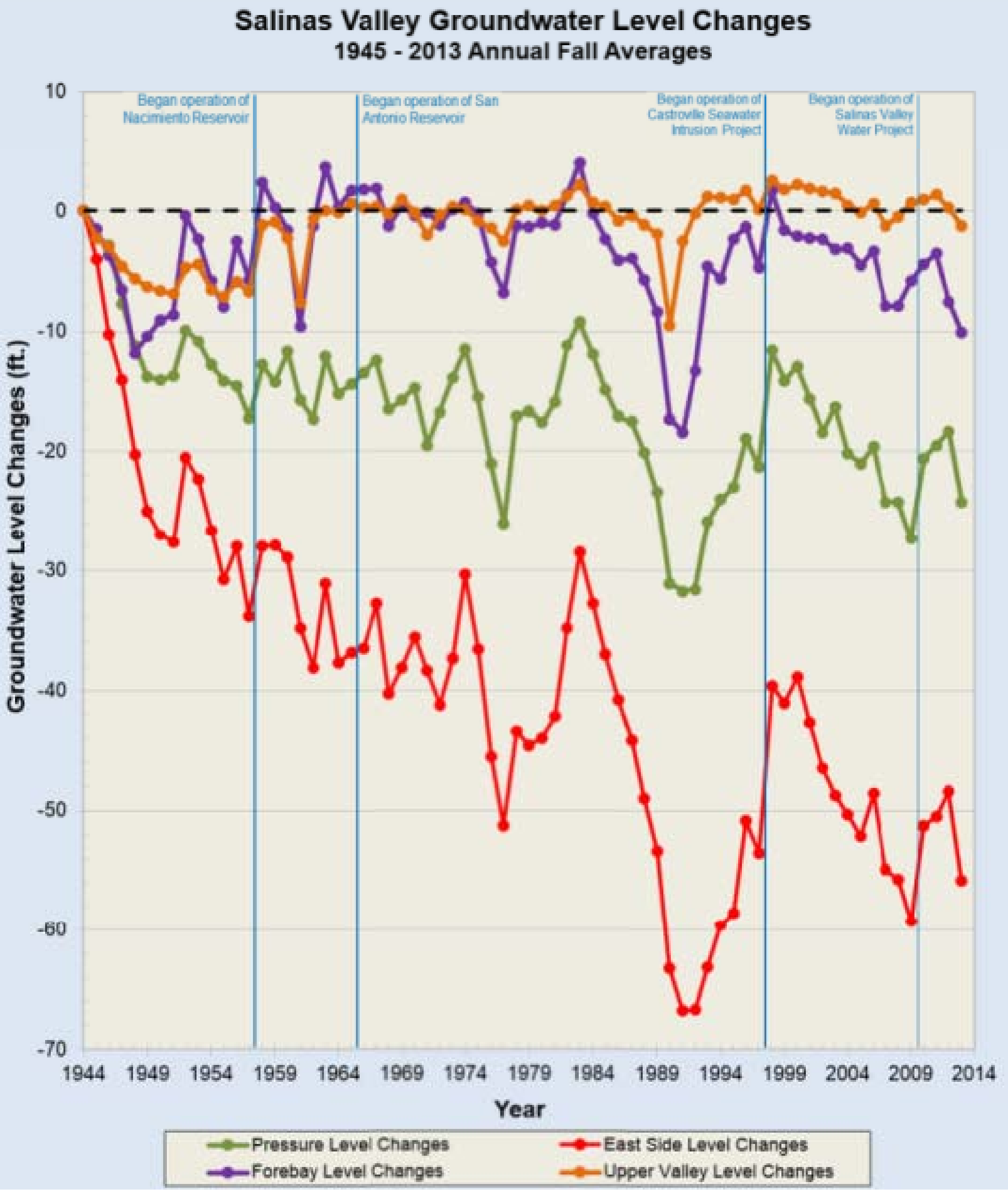
Area and Quadrant	No of Wells	Average Change (ft.)
16S/05E	5	-2.5
17S/05E	18	-1.7
17S/06E	14	-2.7
18S/06E	29	-3.2
18S/07E	8	-0.9
19S/06E	1	-2.2
19S/07E	3	-6.7
Total	78	-2.6

UPPER VALLEY

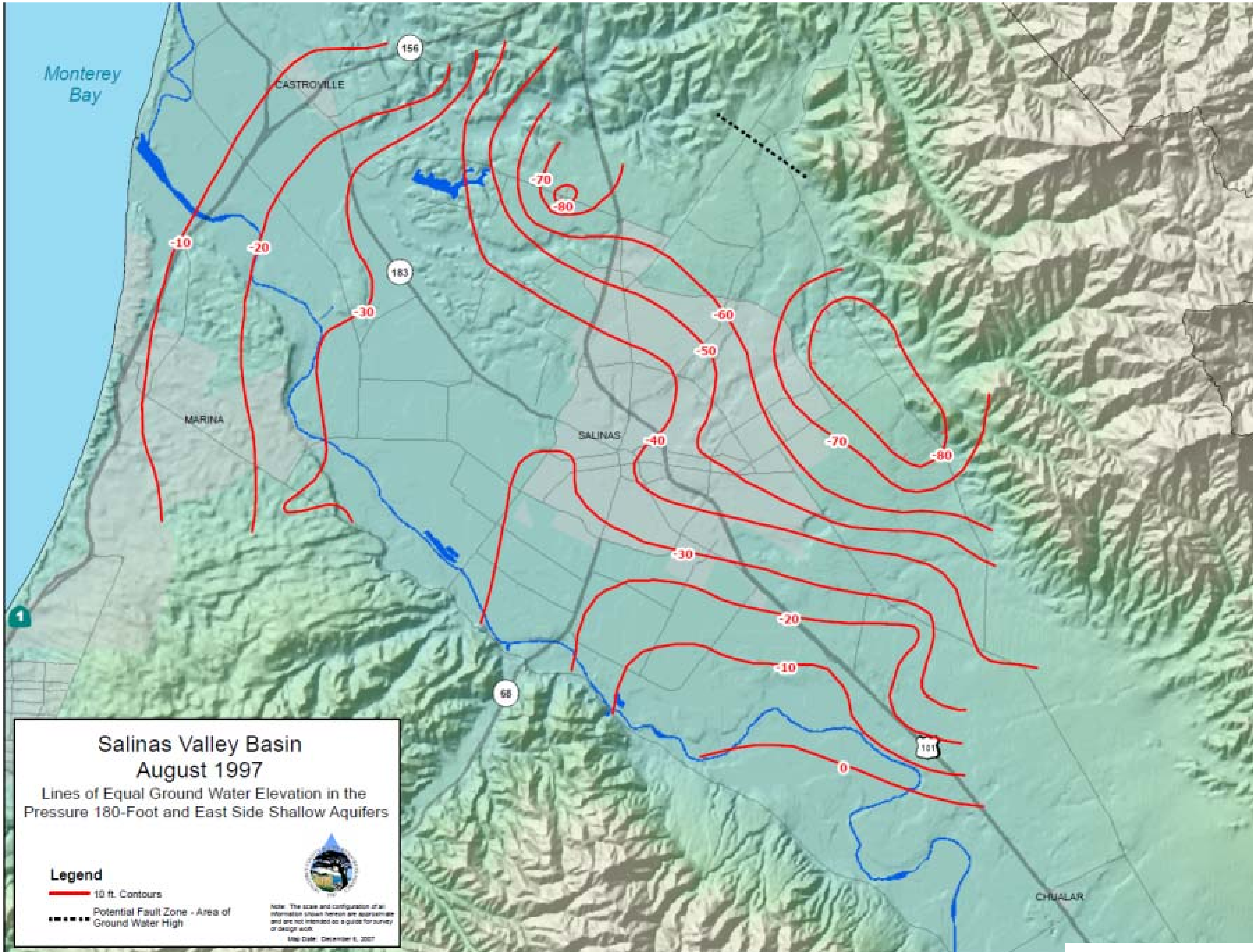
Area and Quadrant	No of Wells	Average Change (ft.)
19S/07E	7	-1.1
19S/08E	3	-1.8
20S/08E	10	-2.3
21S/09E	3	-1.7
21S/10E	2	0.1
22S/10E	4	-0.8
23S/10E	1	-0.9
Total	30	-1.5

Total number of wells compared: 313

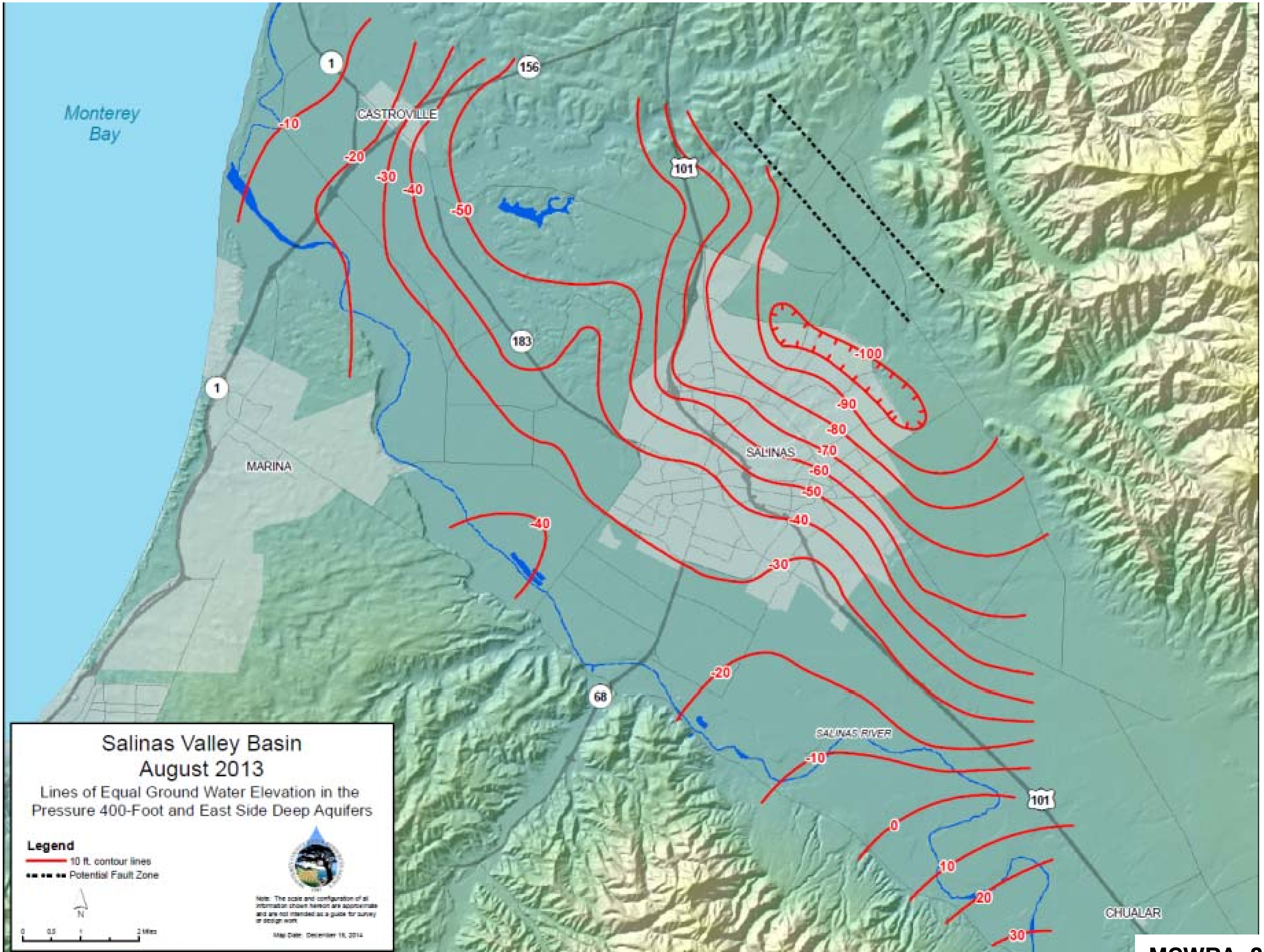
Average change for the Salinas Valley (ft.): -5.1



MCWRA, 2015


Salinas Valley Basin
August 1997
Lines of Equal Ground Water Elevation in the Pressure 180-Foot and East Side Shallow Aquifers
Legend
10 ft. Contours
Potential Fault Zone - Area of Ground Water High
Monterey Bay
CASTROVILLE
MARINA
SALINAS
CHUALAR
156
183
68
1
101
-10
-20
-30
-40
-50
-60
-70
-80
-70
-80
-30
-20
-10
0

MCWRA, 2015

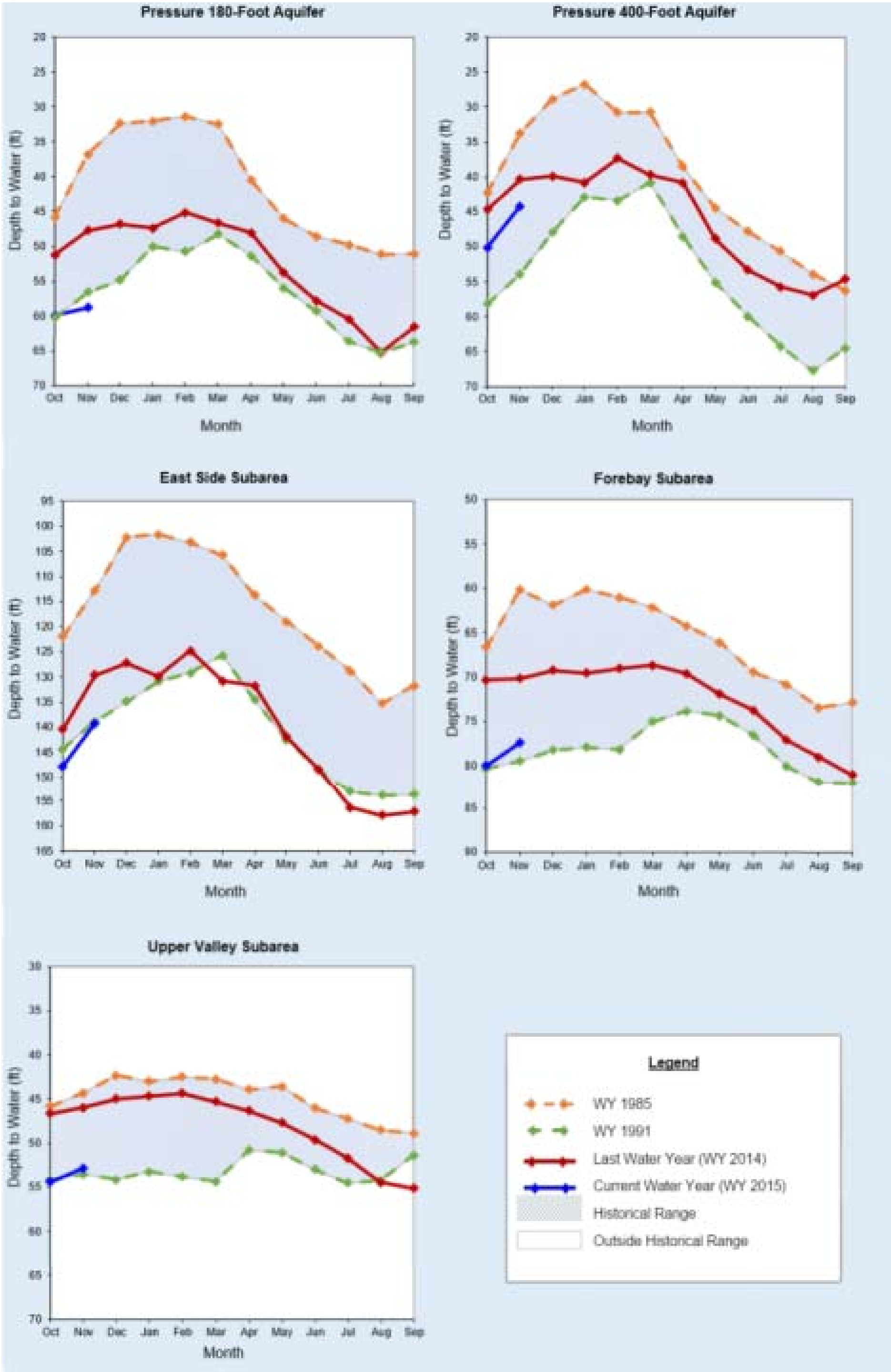


Monterey
Bay
CASTROVILLE
MARINA
SALINAS
CHUALAR
SALINAS RIVER
1
156
101
183
68
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
0
10
20
30
Salinas Valley Basin
August 2013
Lines of Equal Ground Water Elevation in the
Pressure 400-Foot and East Side Deep Aquifers
Legend
10 ft. contour lines
Potential Fault Zone
N
0
0.5
1
2 Miles

MCWRA, 2015

Seasonal Groundwater Storage:

Monthly Changes of Water Table Elevation



Legend:

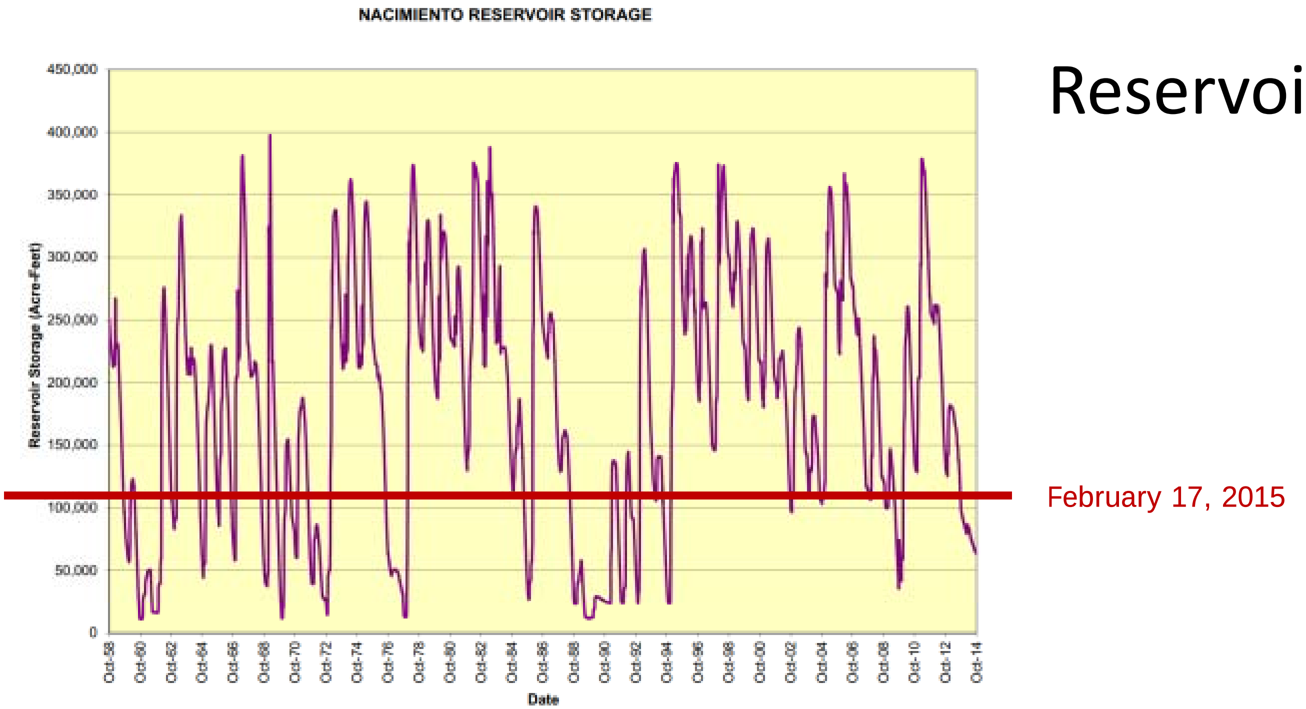
Average Year ——

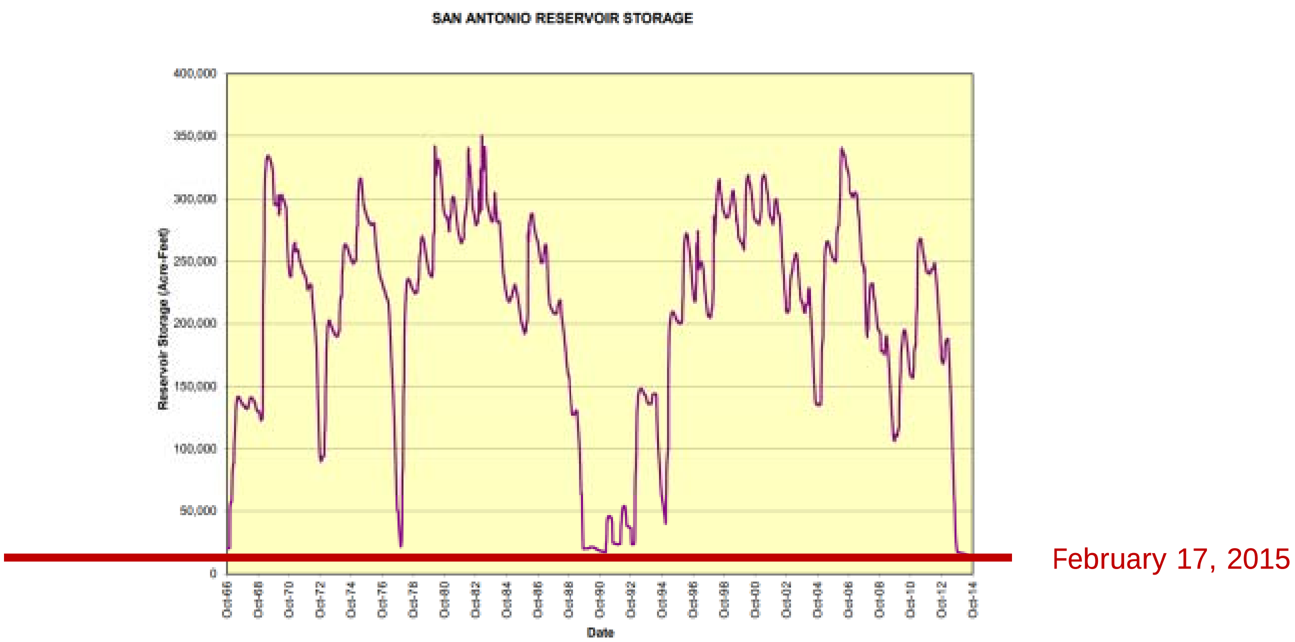
Water Year 2014 ——

Dry Year ——

MCWRA, 2015

Reservoir Levels





MCWRA, 2015

What if the drought continues?

Table ES-3. Calculated Storage1 Change by Subarea, 1944 to 2013						
Subarea	Minimum Annual (af)	Maximum Annual (af)	Annual Average (afy)	Minimum Cumulative (af)	2013 Cumulative (af)	Predicted Change If Drought Continues (afy)
Pressure	-35,000	+44,000	-2,000	-144,000 (1991)	-110,000	-10,000 to -20,000
East Side	-58,000	+83,000	-5,000	-398,000 (1991)	-333,000	-25,000 to -35,000
Forebay[a]	-93,000	+98,000	-2,000	-192,000 (1991)	-105,000	-10,000 to -15,000
Forebay[a]	-93,000	+98,000	-2,000	-192,000 (1991)	-105,000	-80,000 to -90,000
Upper Valley[a]	-70,000	+65,000	-200	-88,000 (1990)	-12,000	-5,000 to -15,000
Upper Valley[b]	-70,000	+65,000	-200	-88,000 (1990)	-12,000	-50,000 to -70,000
Zone 2C[a]	-256,000	+217,000	-8,000	-786,000 (1990)	-559,000	-50,000 to -85,000
Zone 2C[b]	-256,000	+217,000	-8,000	-786,000 (1990)	-559,000	-165,000 to -215,000

Note: af = acre-feet; afy = acre-feet per year

[a] *Based on calculated storage changes over the extended drought of WY 1984 to 1991*

[b] *Based on calculated storage changes for years with very low reservoir release (WYs 1961 and 1990)*

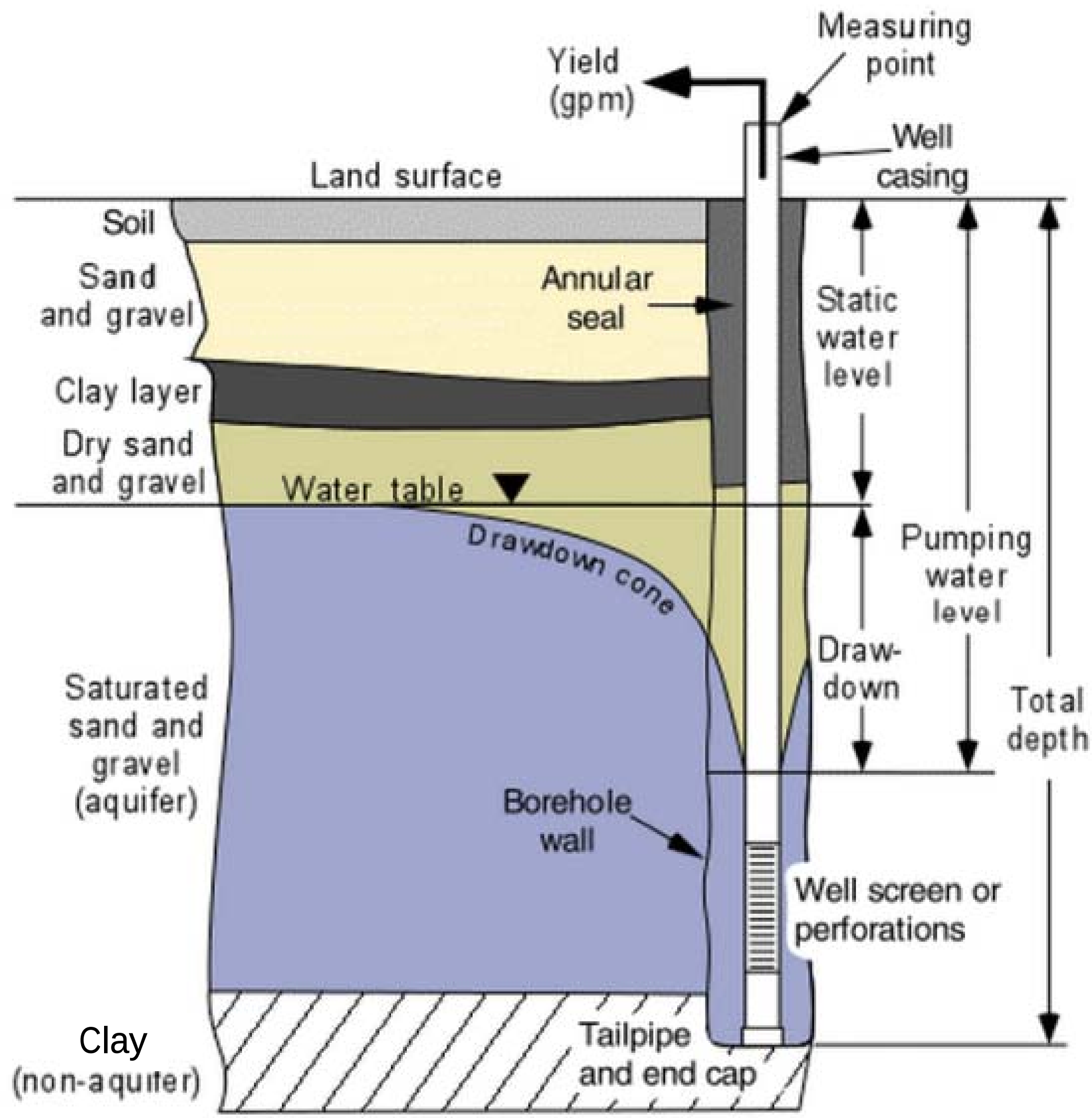
Brown & Caldwell, MCWRA, January 2015

Consequences of Groundwater Overdraft

- Seawater intrusion
- Increased pumping cost
- Land subsidence
- Water quality degradation
- Surface water depletion
- Impact to groundwater dependent ecosystems

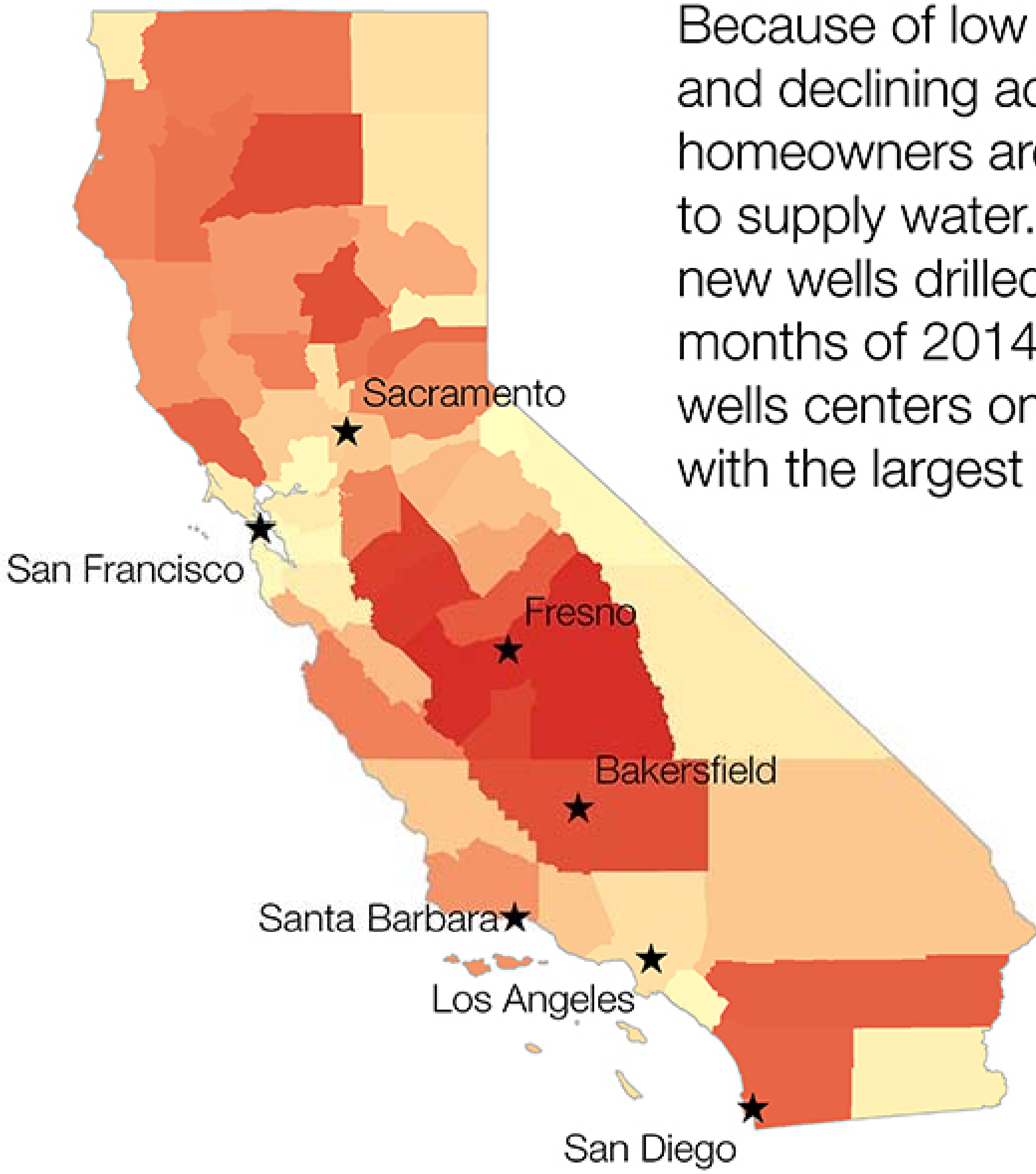
How may this affect my well?

- Lower water table
- Pumping air / spudding
- Increase in turbidity
- Well casing collapse
  - Poor well construction
  - High entry velocity
  - Pressure difference between outside and inside of pipe
  - Turbidity impacting screen
  - Land subsidence



Montana Groundwater Information Center
http://mbmggwic.mtech.edu/sqlserver/v11/help/welldesign.asp

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.



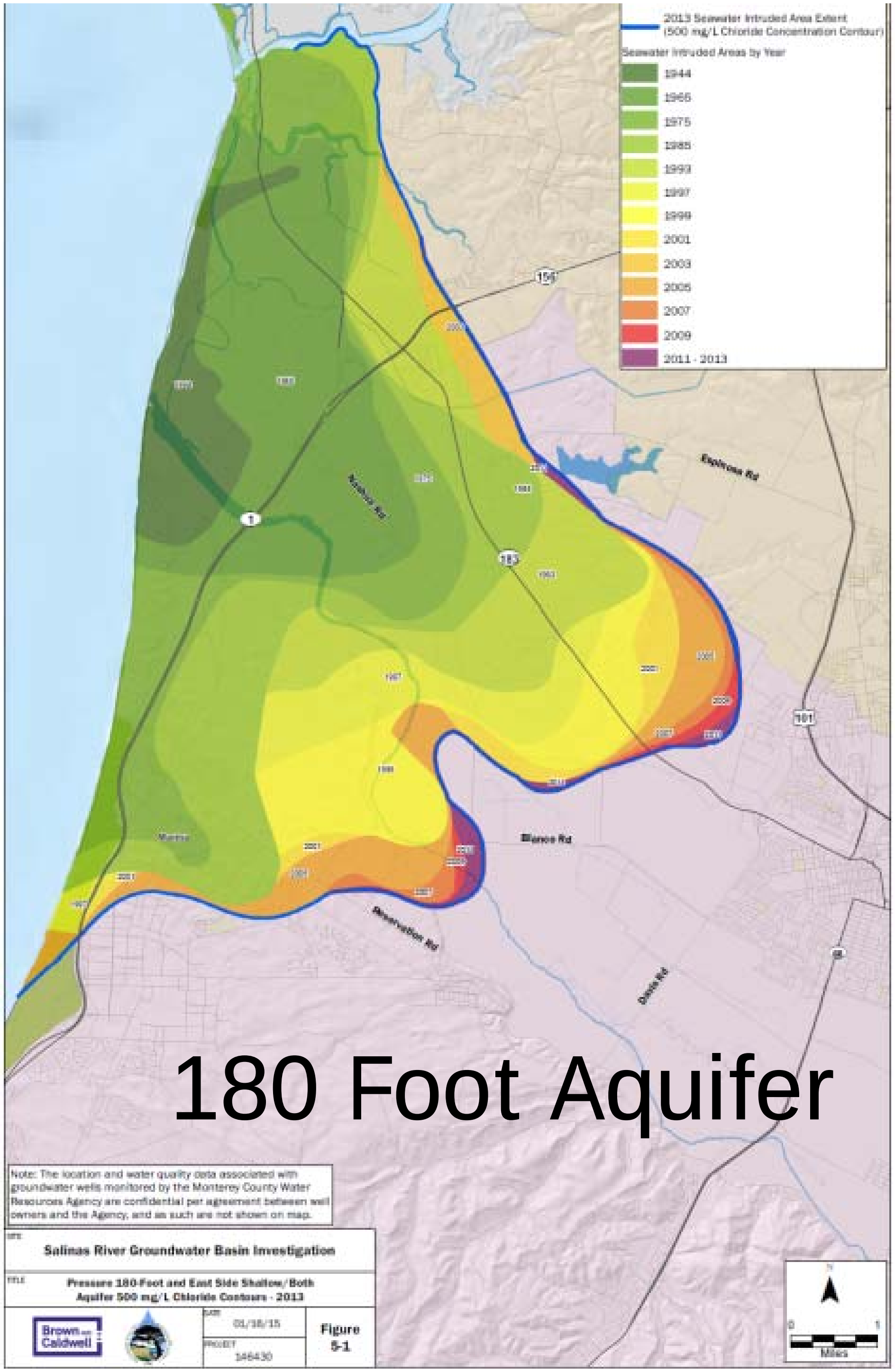
Number of New Wells Drilled in 2014

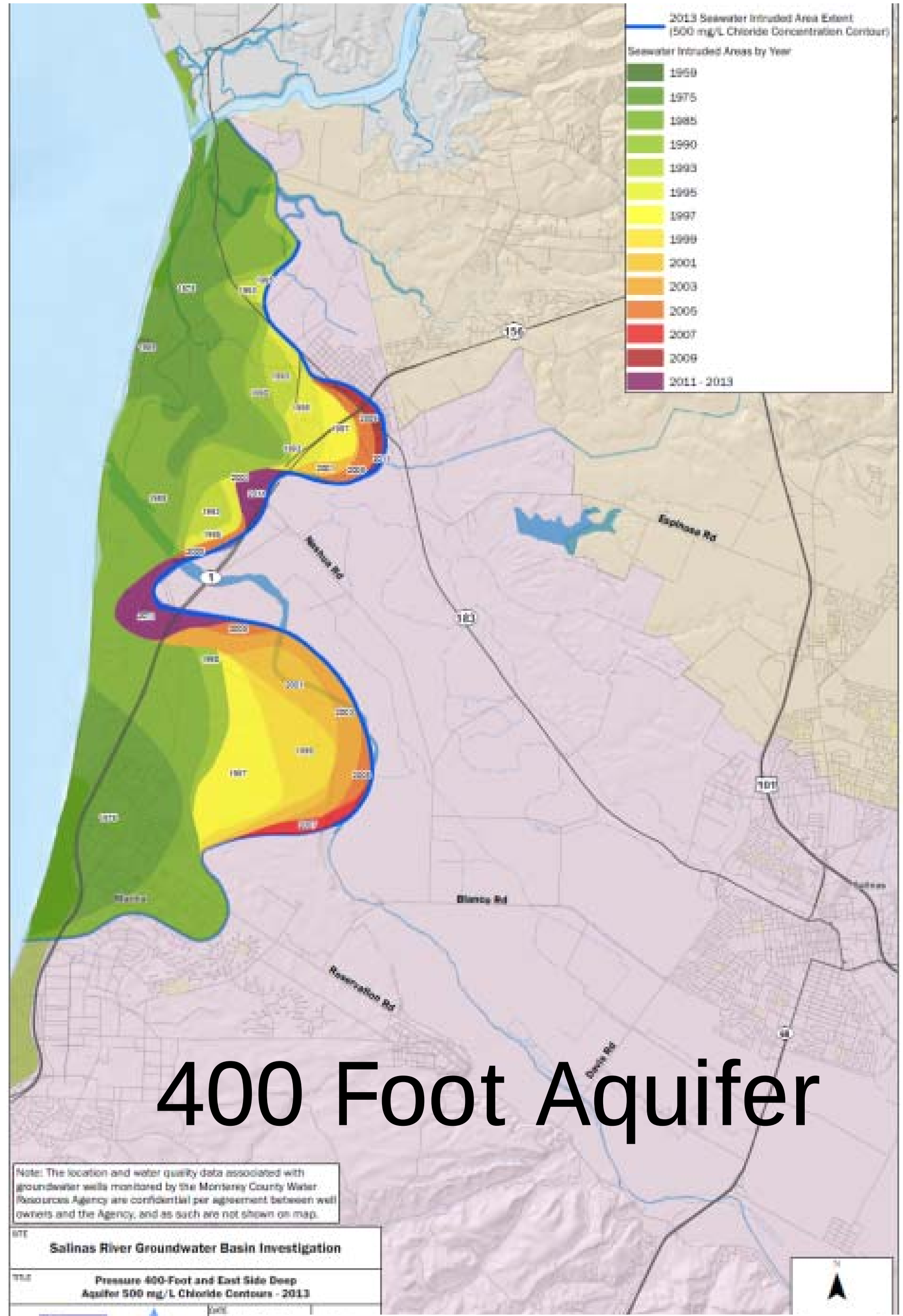
0 30 250+

urces: California Department of Water Resources,

circle of blue

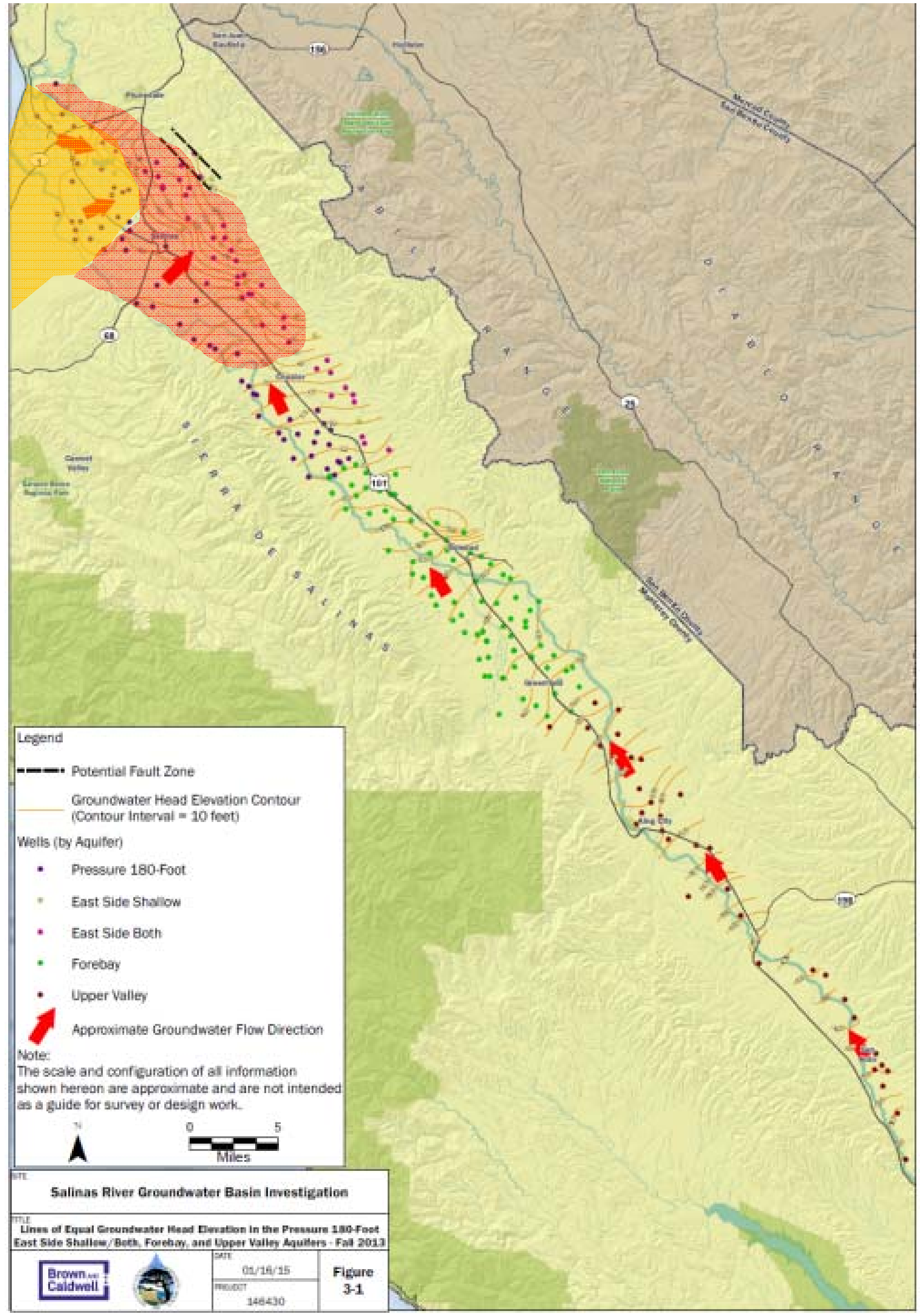
Randi Lynn Beach / Huffington Post





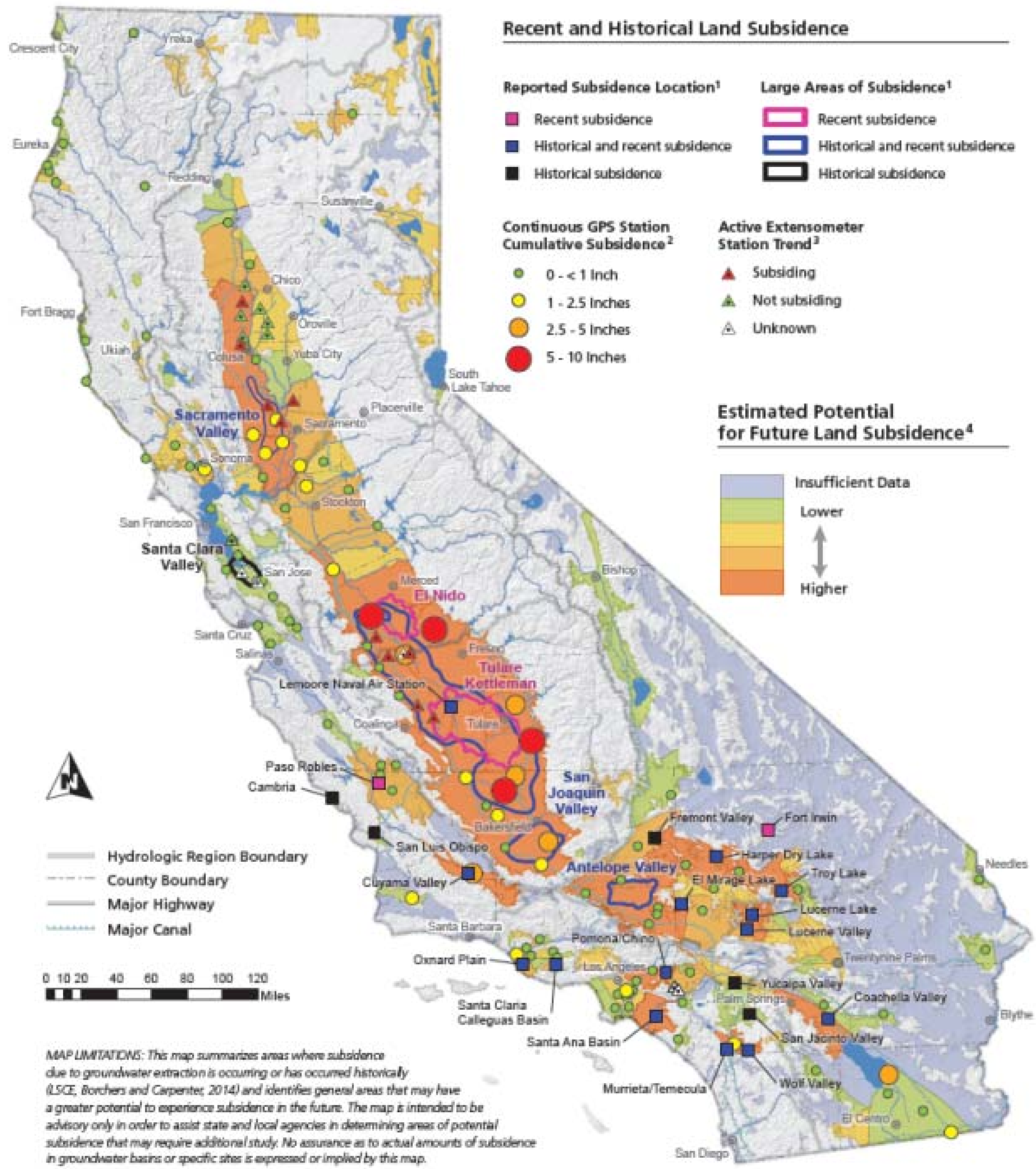
Brown & Caldwell, MCWRA, January 2015

Saline Groundwater Extent Mid to Late 21st Century??



Brown & Caldwell, MCWRA, January 2015

Land Subsidence



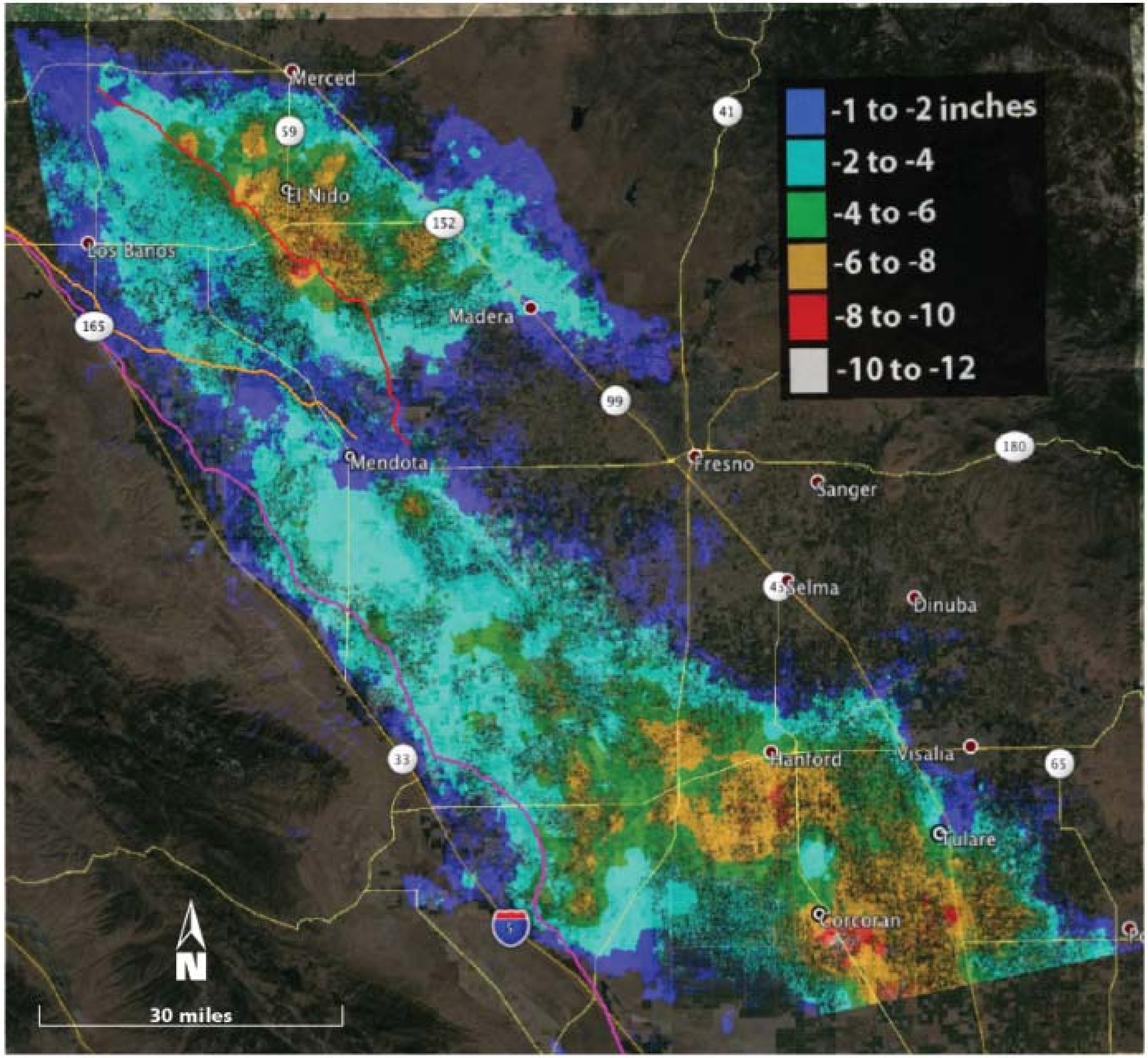
California Department of Water Resources;
Drought Response Update Fall 2014

Land Subsidence: San Joaquin Valley

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

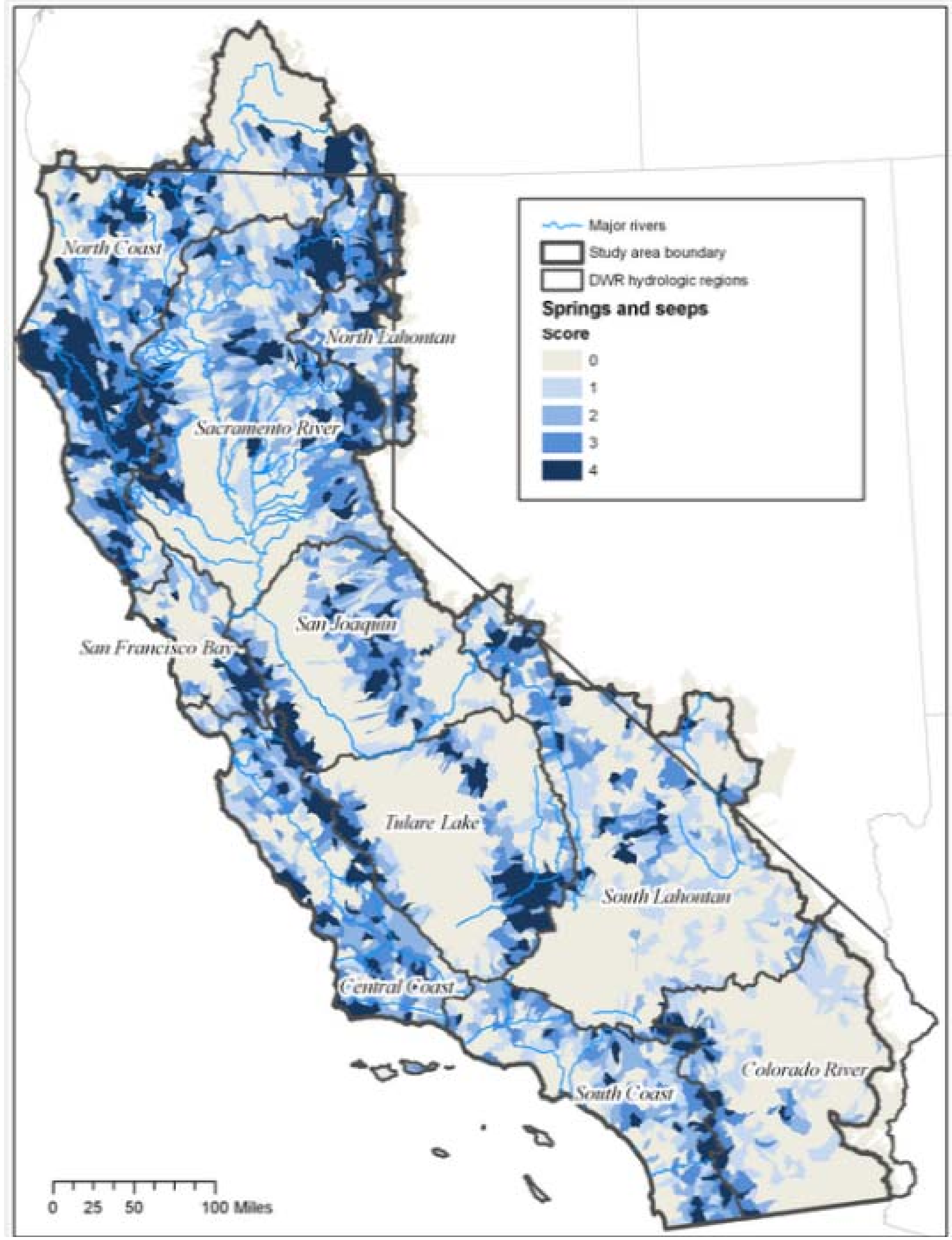
Legend
- California Aqueduct
- Delta-Mendota Canal
- Eastside Bypass

California Department of Water Resources;
Drought Response Update Fall 2014



Groundwater Dependent Ecosystems:

Springs and Seeps



Howard and Merrifield, 2010, PlosONE,
DOI: 10.1371/journal.pone.0011249

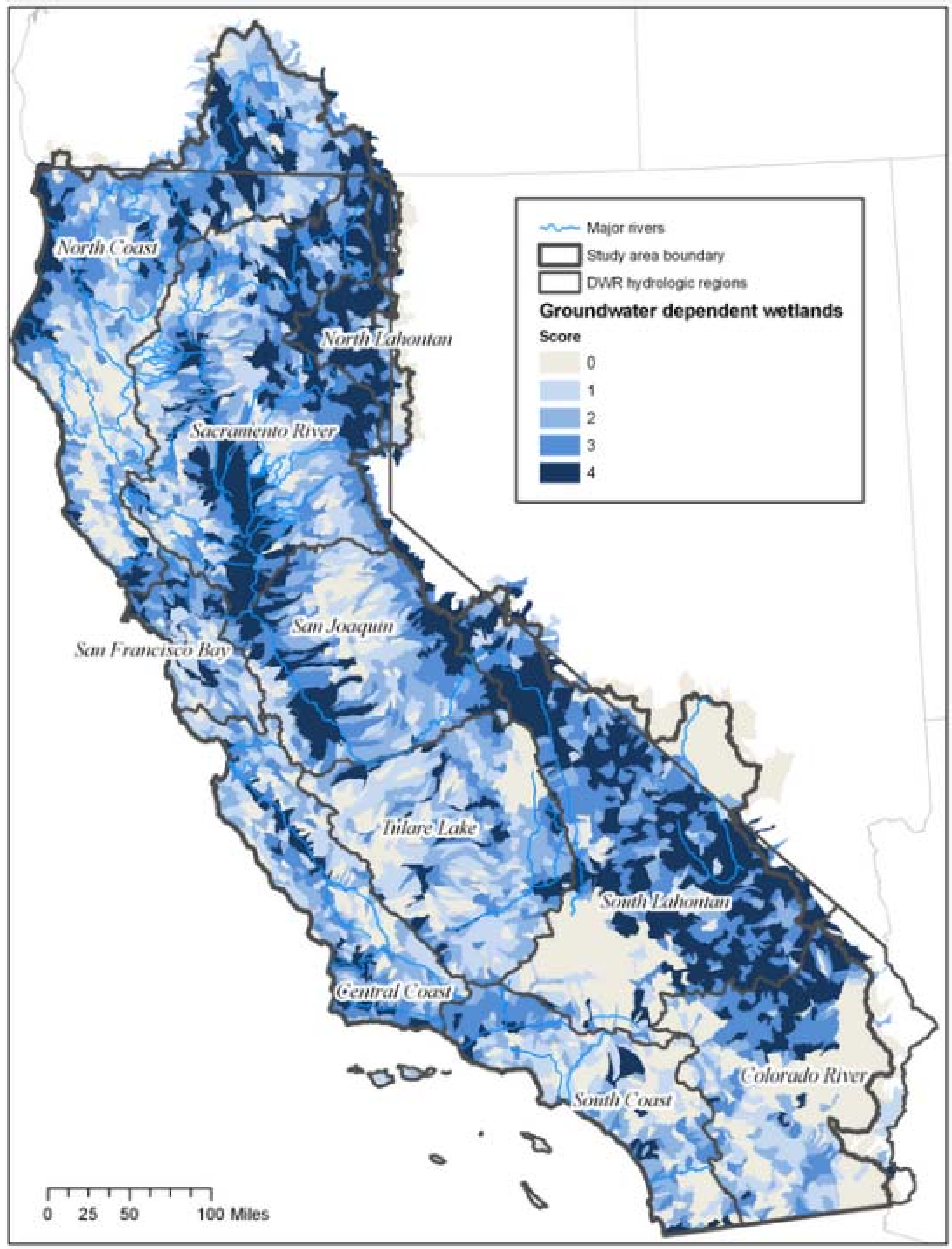

M.C. Rains et al., 2006 and 2008


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

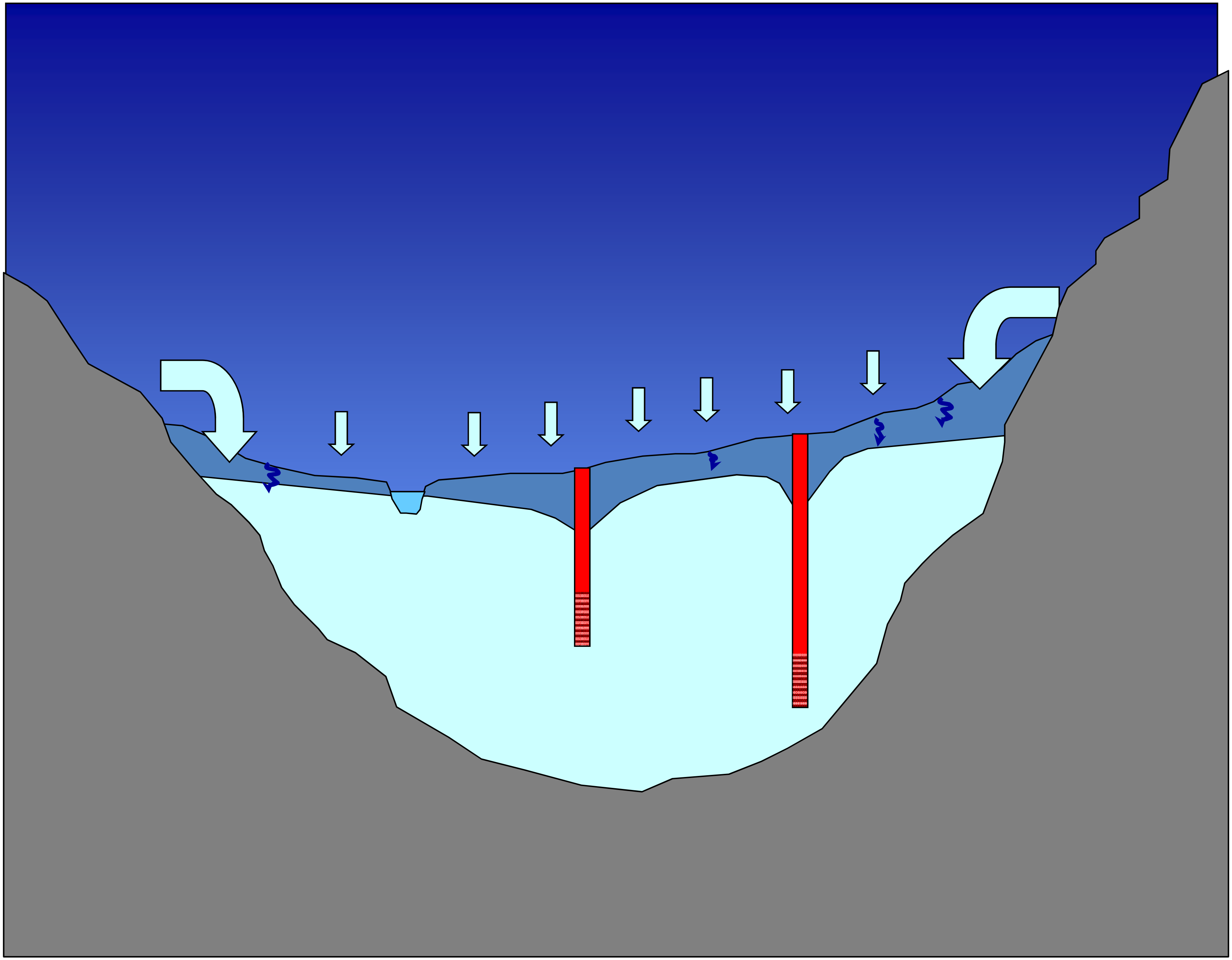

M.C. Rains et al., 2006 and 2008

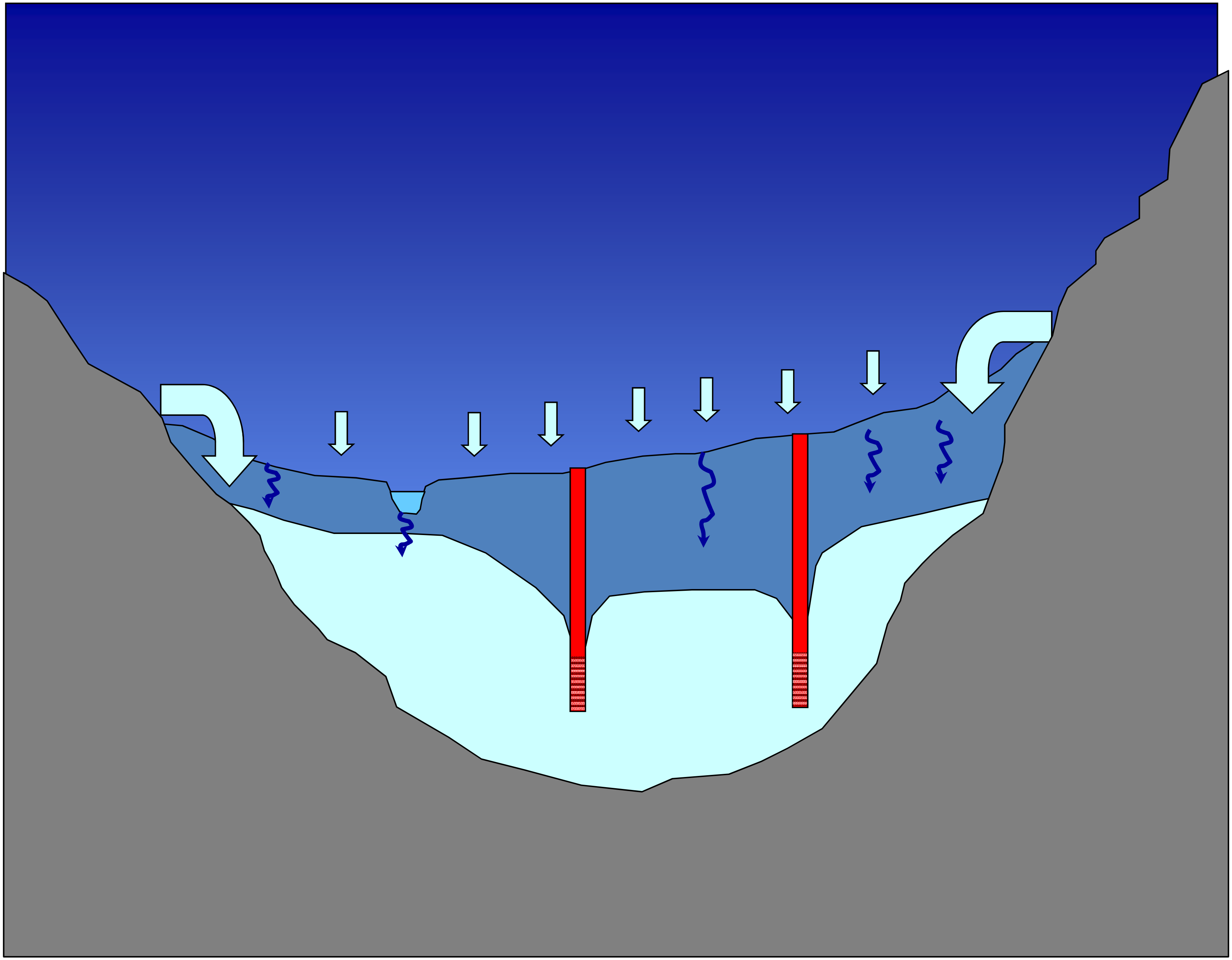
Groundwater Dependent Ecosystems:

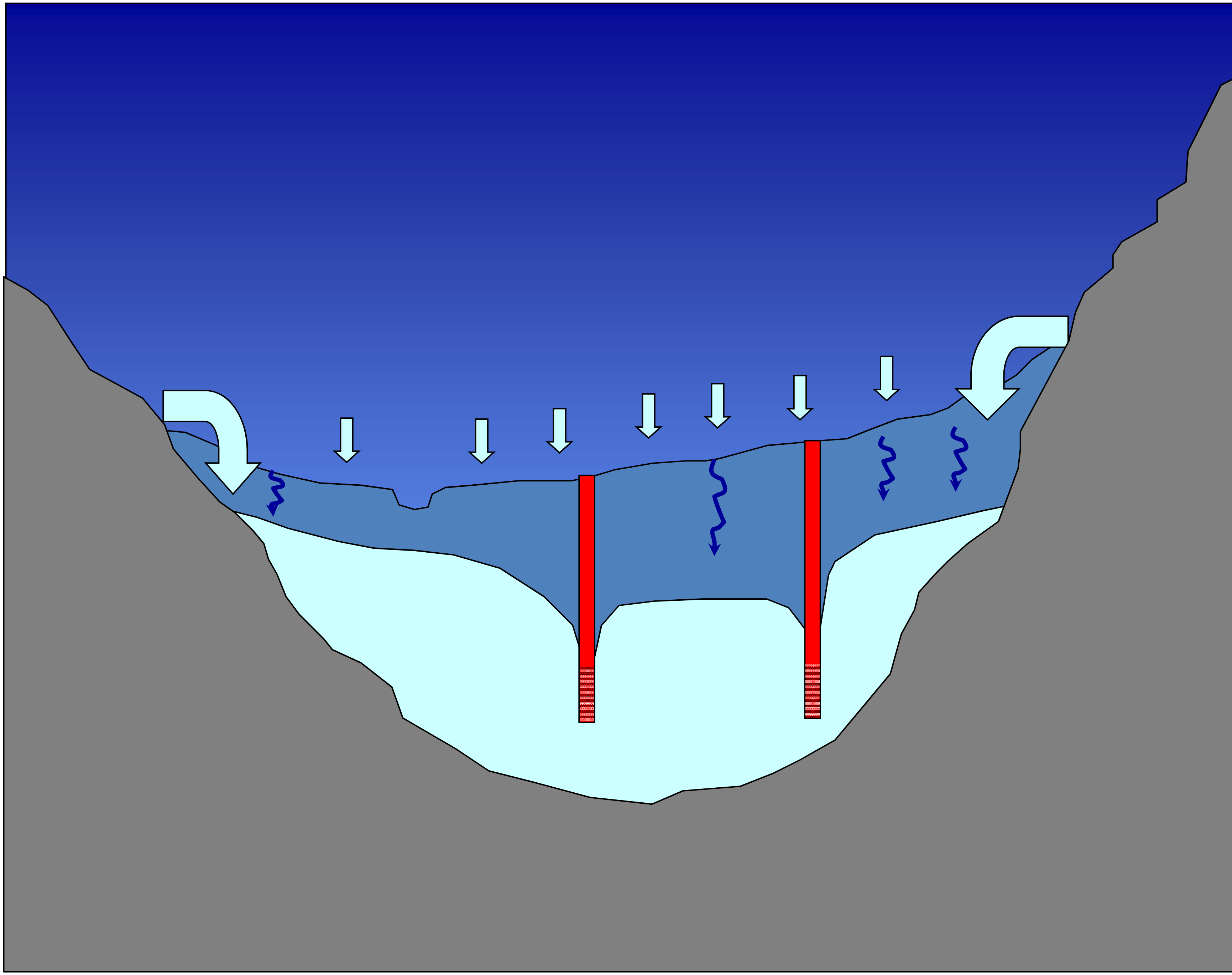
Wetlands



Howard and Merrifield, 2010, PlosONE,
DOI: 10.1371/journal.pone.0011249

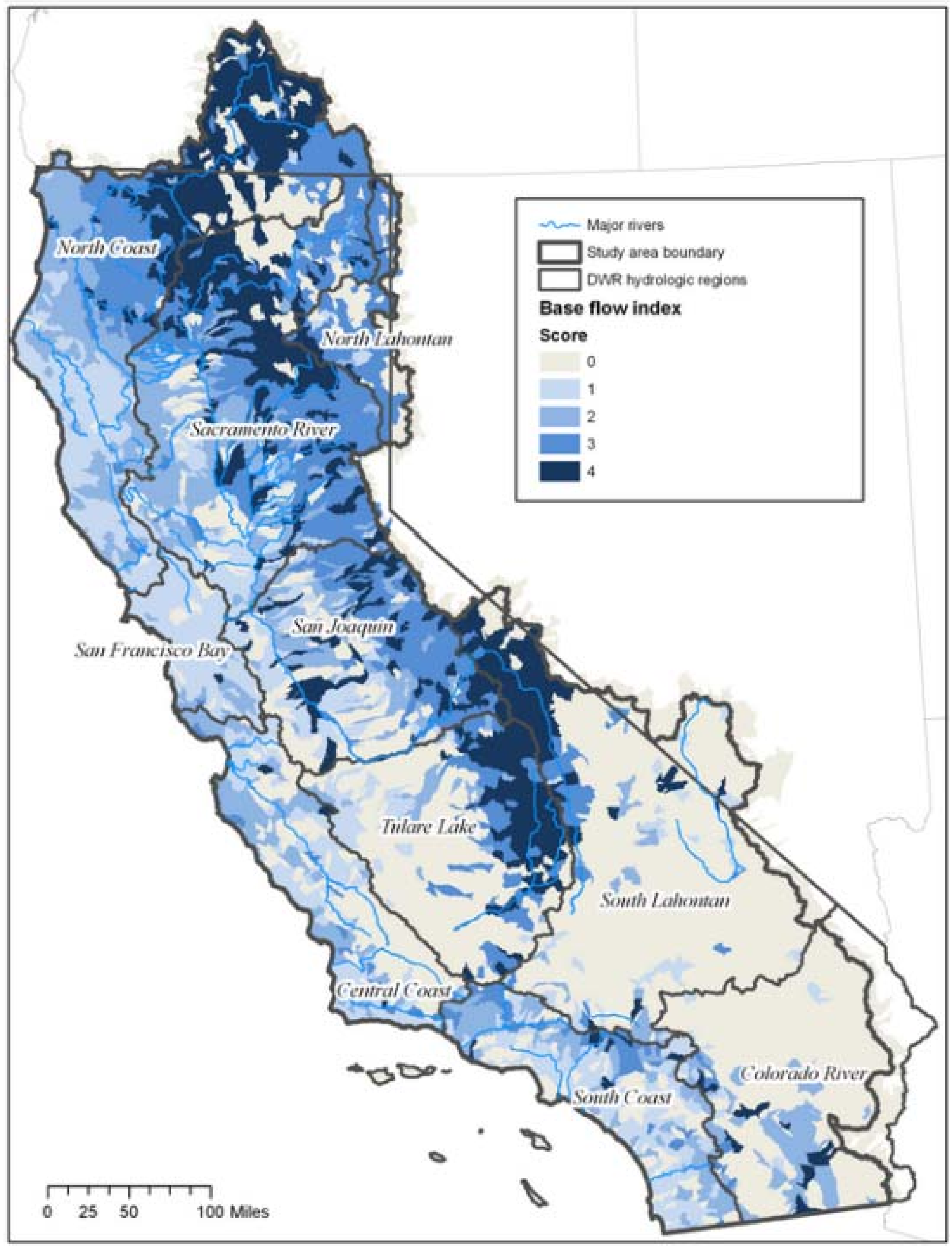






Groundwater Dependent Ecosystems:

Baseflow



Howard and Merrifield, 2010, PlosONE,
DOI: 10.1371/journal.pone.0011249

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
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    - Right of water users to negotiate physical "equitable, practical" solution, regardless of water rights
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    - 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]

Sustainable Groundwater Management Act: Goals

SEC. 3.

Part 2.74 (commencing with Section 10720) is added to Division 6 of the Water Code, to read:

PART 2.74. Sustainable Groundwater Management

CHAPTER 1. General Provisions

10720.

This part shall be known, and may be cited, as the "Sustainable Groundwater Management Act."

10720.1.

In enacting this part, it is the intent of the Legislature to do all of the following:

(a) To provide for the **sustainable management of groundwater basins**.

(b) To **enhance local management** of groundwater consistent with rights to use or store groundwater and Section 2 of Article X of the California Constitution. It is the intent of the Legislature to preserve the security of water rights in the state to the greatest extent possible consistent with the sustainable management of groundwater.

(c) To **establish minimum standards** for sustainable groundwater management.

(d) To **provide local groundwater agencies with the authority and the technical and financial assistance** necessary to sustainably manage groundwater.

(e) To **avoid or minimize subsidence**.

(f) To **improve data collection and understanding** about groundwater.

(g) To **increase groundwater storage** and remove impediments to recharge.

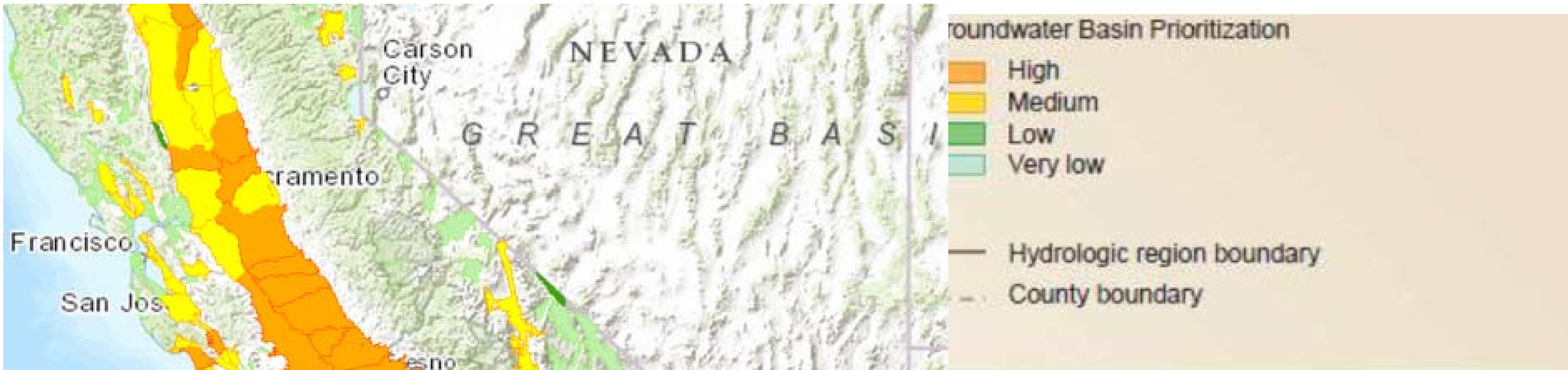
(h) To manage groundwater basins through the actions of local governmental agencies to the greatest extent feasible, while **minimizing state intervention** to only when necessary to ensure that local agencies manage groundwater in a sustainable manner.

[emphasis added]

So What Exactly Will Happen?

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

Medium and High Priority Groundwater Basins (CASGEM)

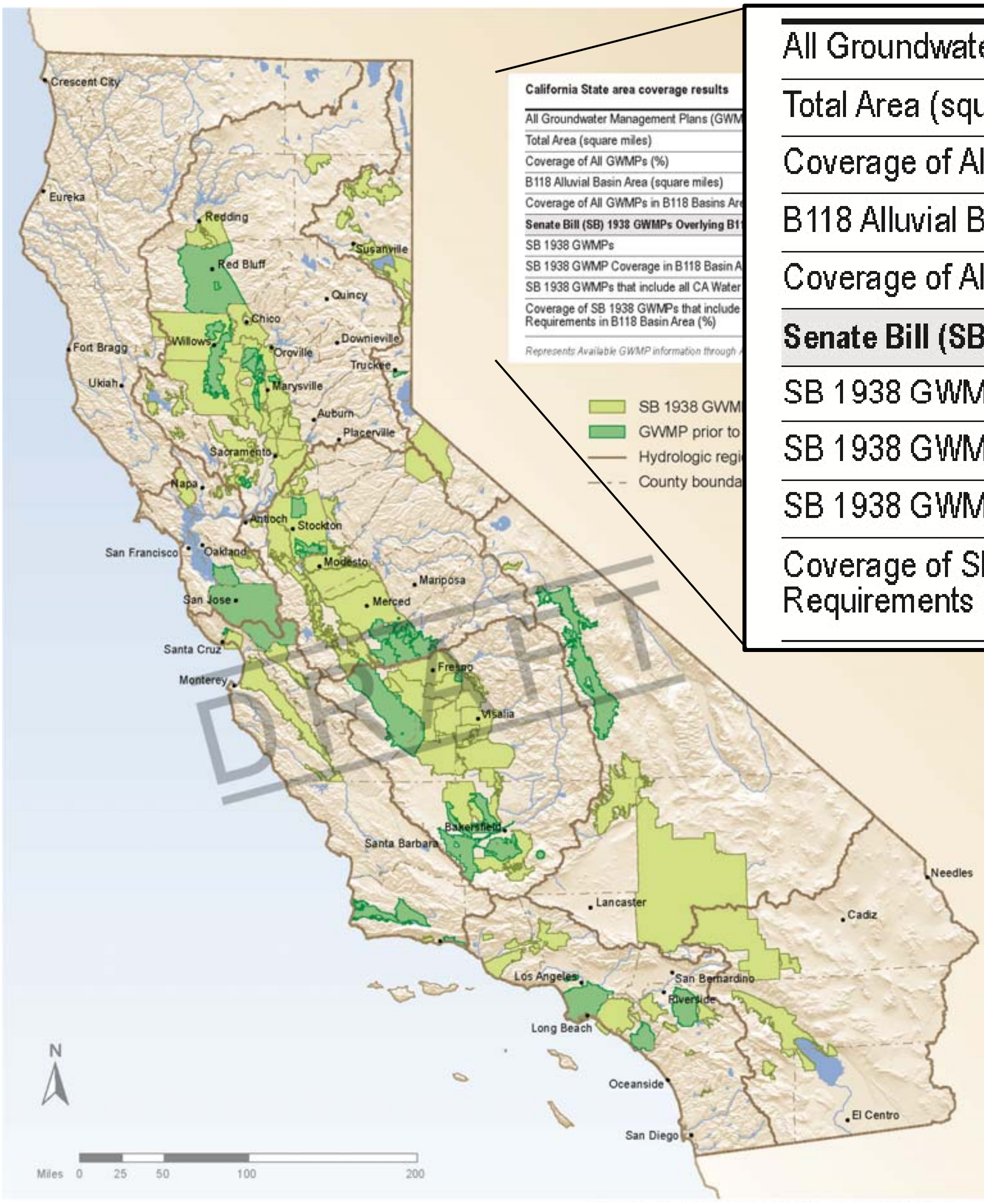


Statewide Groundwater Basin Prioritization Summary

Basin Ranking	Basin Count per Rank	Percent of Total for Hydrologic Region	
		GW Use	Overlying Population
High	46	68%	67%
Medium	80	24%	22%
Low	35	6%	1%
Very Low	354	2%	10%
Totals	515	100%	100%

Basin Prioritization results as of Dec. 1, 2013

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



Source: Department of Water Resources, CWP 2013

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%

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
  - NEW special acts districts (created by legislature, then CEQA, LAFCO, public vote) => Paso Robles

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

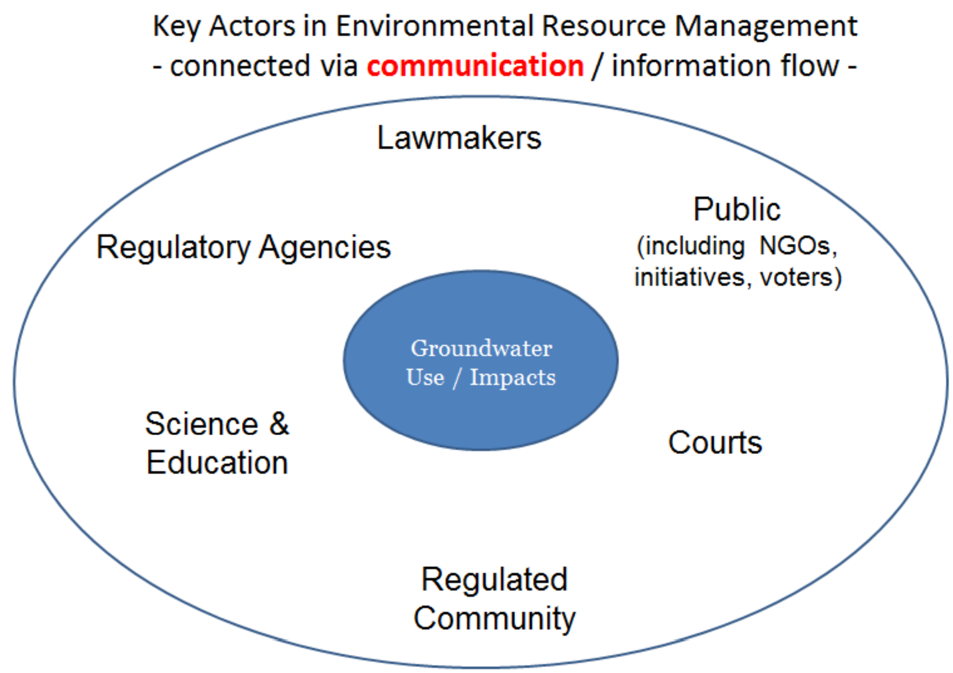
- Stimulate dialogue / communication among local agencies, key stakeholders (e.g., Farm Bureau)
- Engage broad range of interested parties
- Gather information about the basin / find out where the information is / what is available
- Understand what Groundwater Sustainability Planning entails
- Consider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

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

- 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 Organizations:
Key Action Areas for Innovative Thinking

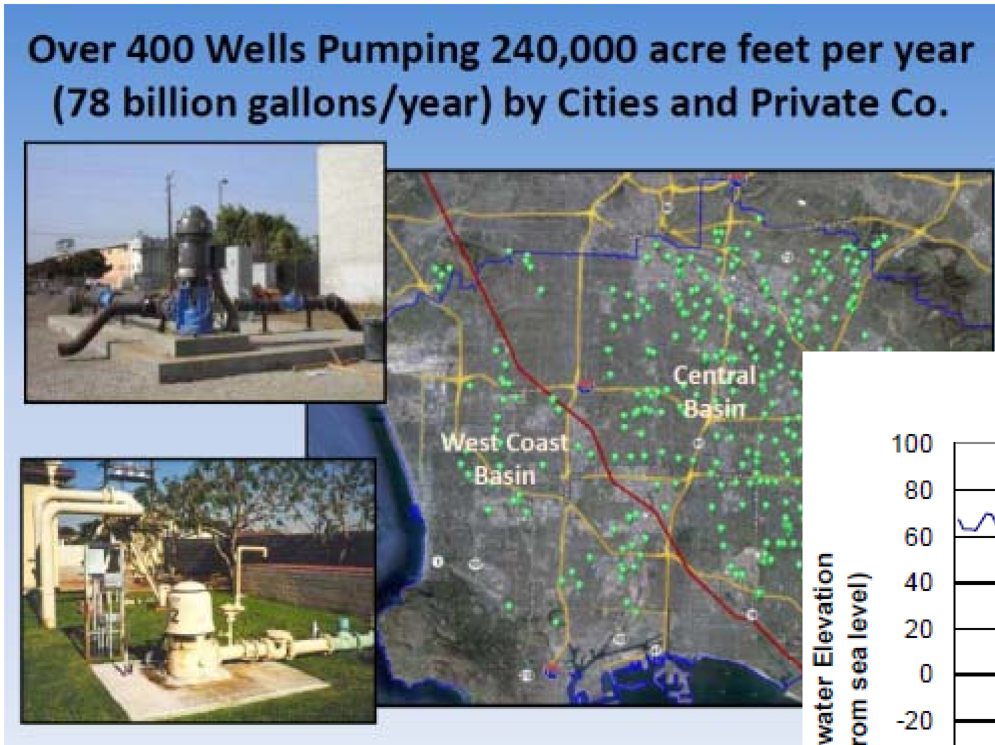
- Planning process
  - Governance structures
  - Finding agreement on goals, reporting, enforcement, cooperation with neighboring agencies
- Cooperation and stakeholder involvement
  - Identifying and engaging participants / stakeholders
  - Structures for involving stakeholders
  - Avoiding / resolving 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

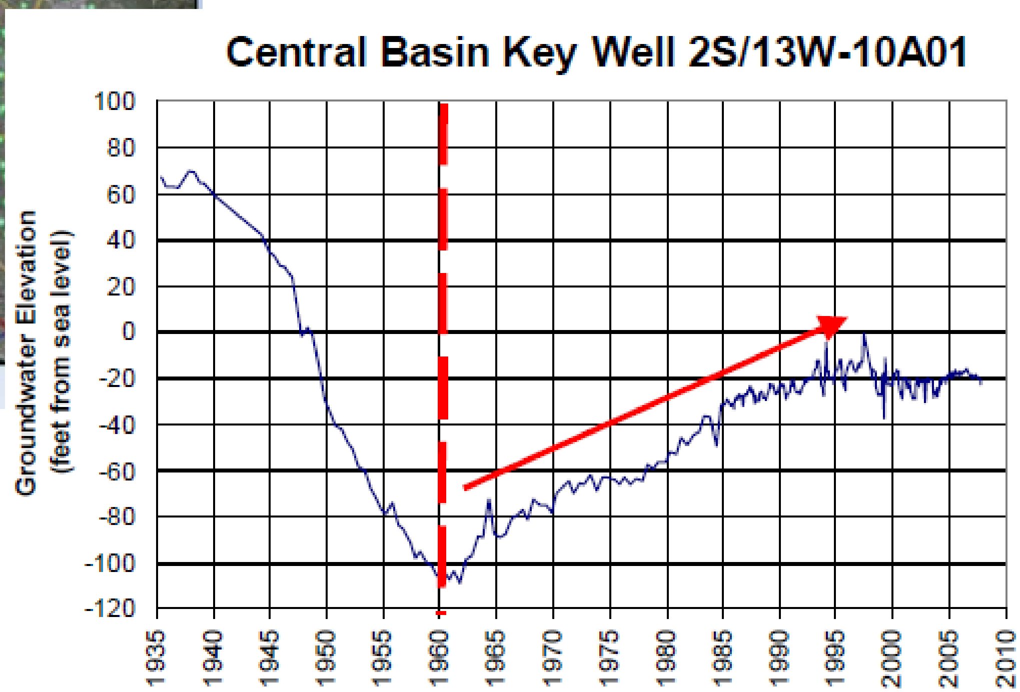
From: Nelson, Innovative GW Management, Stanford 2011

Groundwater Management Portfolio: Overview

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

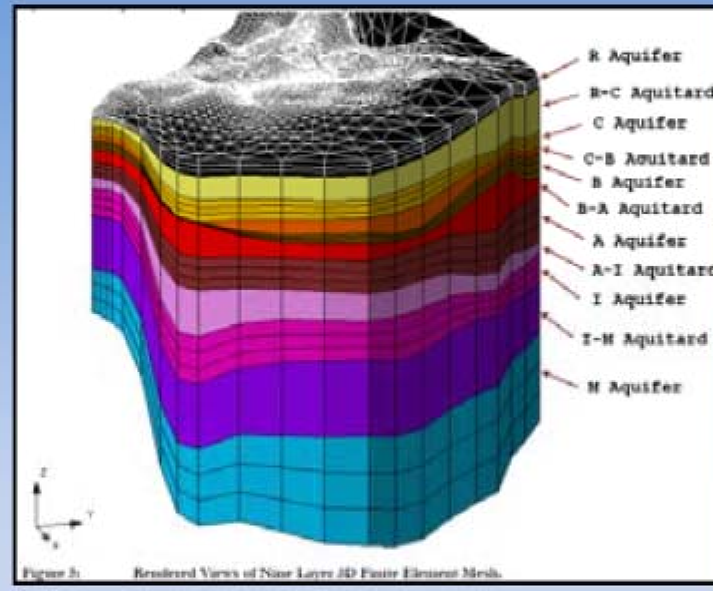
Storage for Local Use:
Water Replenishment District of So. Cal. (founded in 1959)



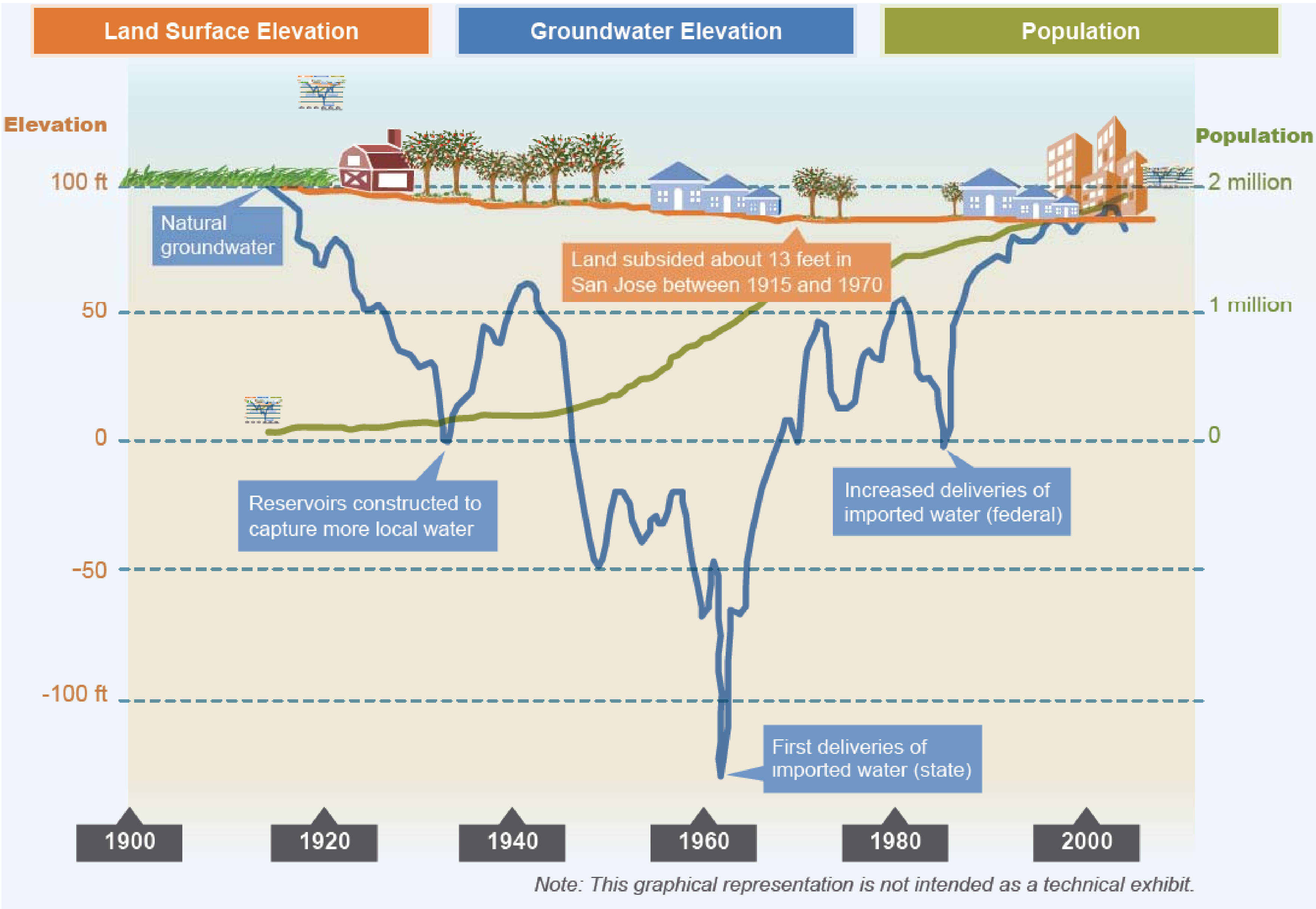


=> also to prevent seawater intrusion!

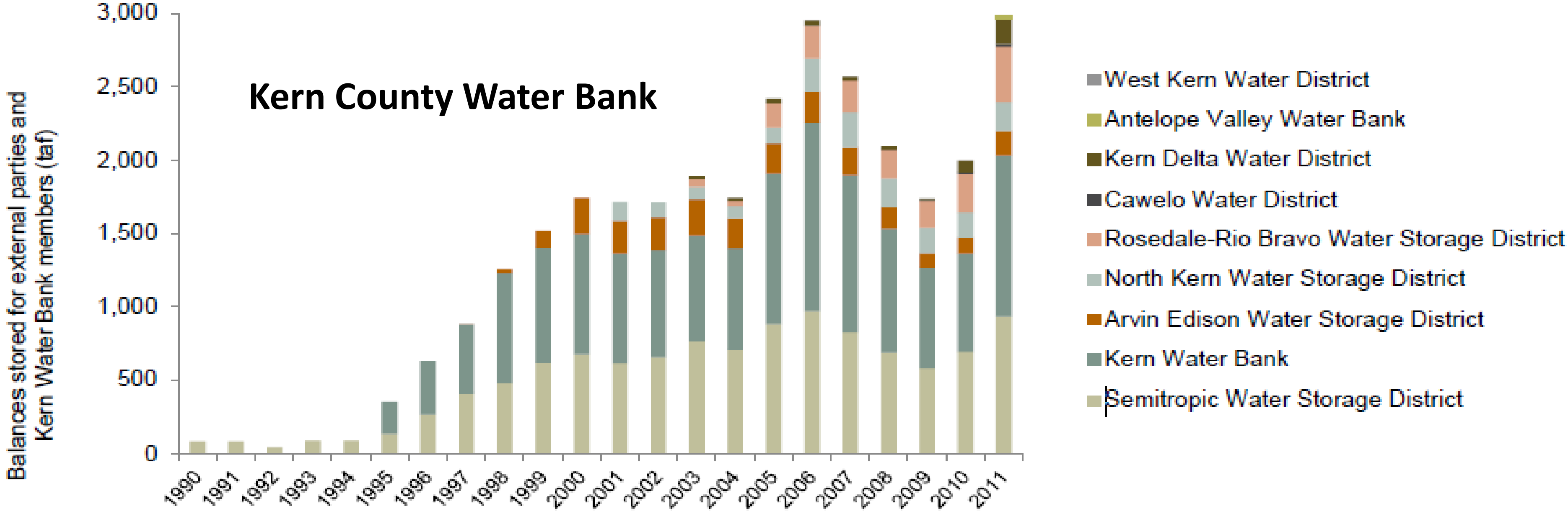
WRD Monitoring and Modeling Programs

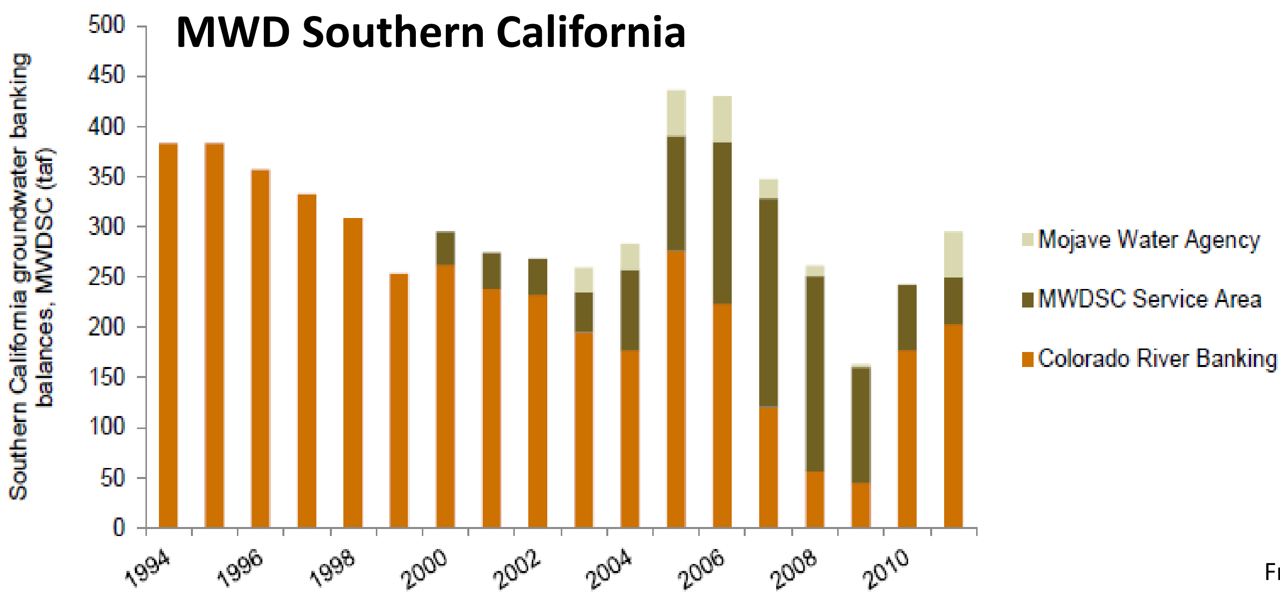


Storage for Local Use: Santa Clara Valley Water District



Long-Term Storage via Import/Export: Groundwater Bank

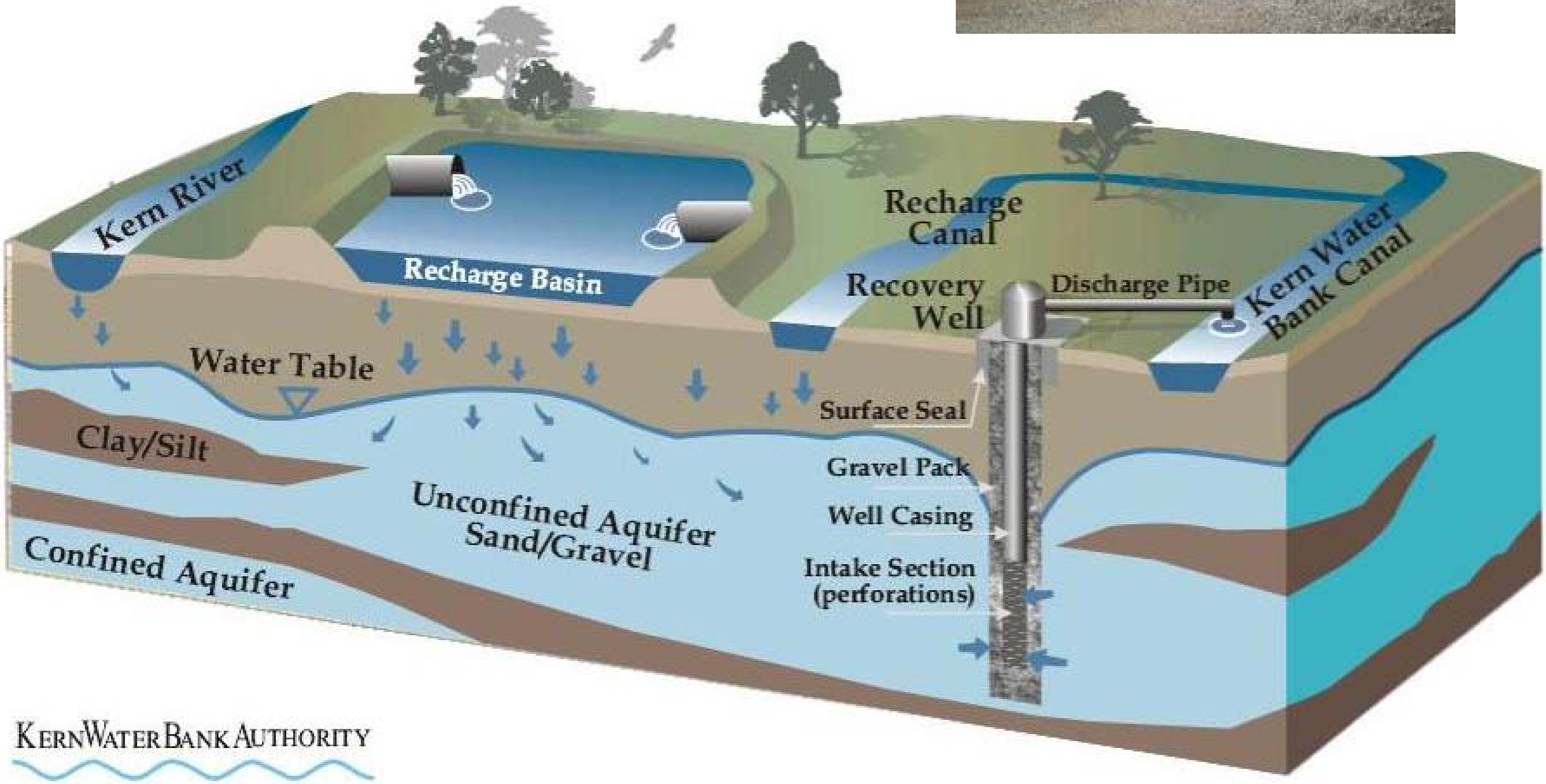




From: Hanak et al., PPIC 2012

From: Ted Johnson, WRD 2013

DWR, California Water Plan Update 2013



KERN WATER BANK AUTHORITY

Groundwater Management Tools for Regional Organization

- SUPPLY SIDE: 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
- DEMAND SIDE: 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
- Communication and networking measures
  - Facilitate stakeholder participation
  - Education
  - Data analysis and reporting
  - Secure funding (grants, project applications,….)

Groundwater Modeling: Central to Planning Effort

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

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**

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**

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  - 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

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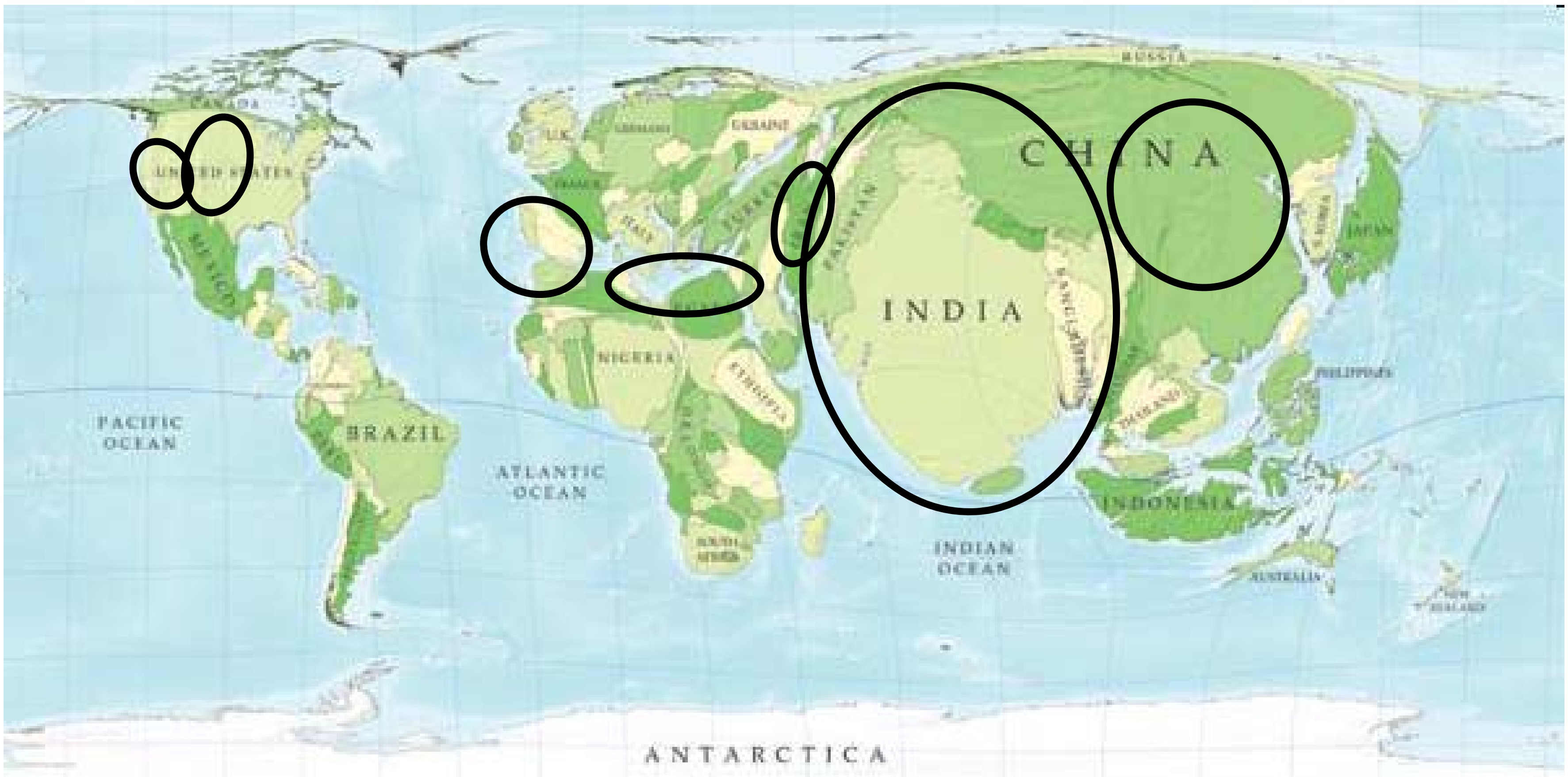
  - Sustainable Groundwater Management Act of 2014: mandatory & expanded local control
- => if local/regional control fails: State Water Resources Control Board
- **The Courts**
  - **Streamlined adjudication (legislation in 2015?)**

Key Challenges for Salinas Valley

- Managing groundwater overdraft to avoid seawater intrusion
  - Option 1: redistribution of groundwater pumping (away from the coast)
  - Option 2: pumping deep aquifer while recharging 180 ft and 400 ft aquifer (feasibility study needed)
- Implementing nutrient management requirements under Ag Order
  - Decreasing leaching fraction
  - Decreasing nitrogen losses to groundwater
  - Increasing clean groundwater recharge within irrigated landscape

Population Map of the World
& Major GW Withdrawal Centers



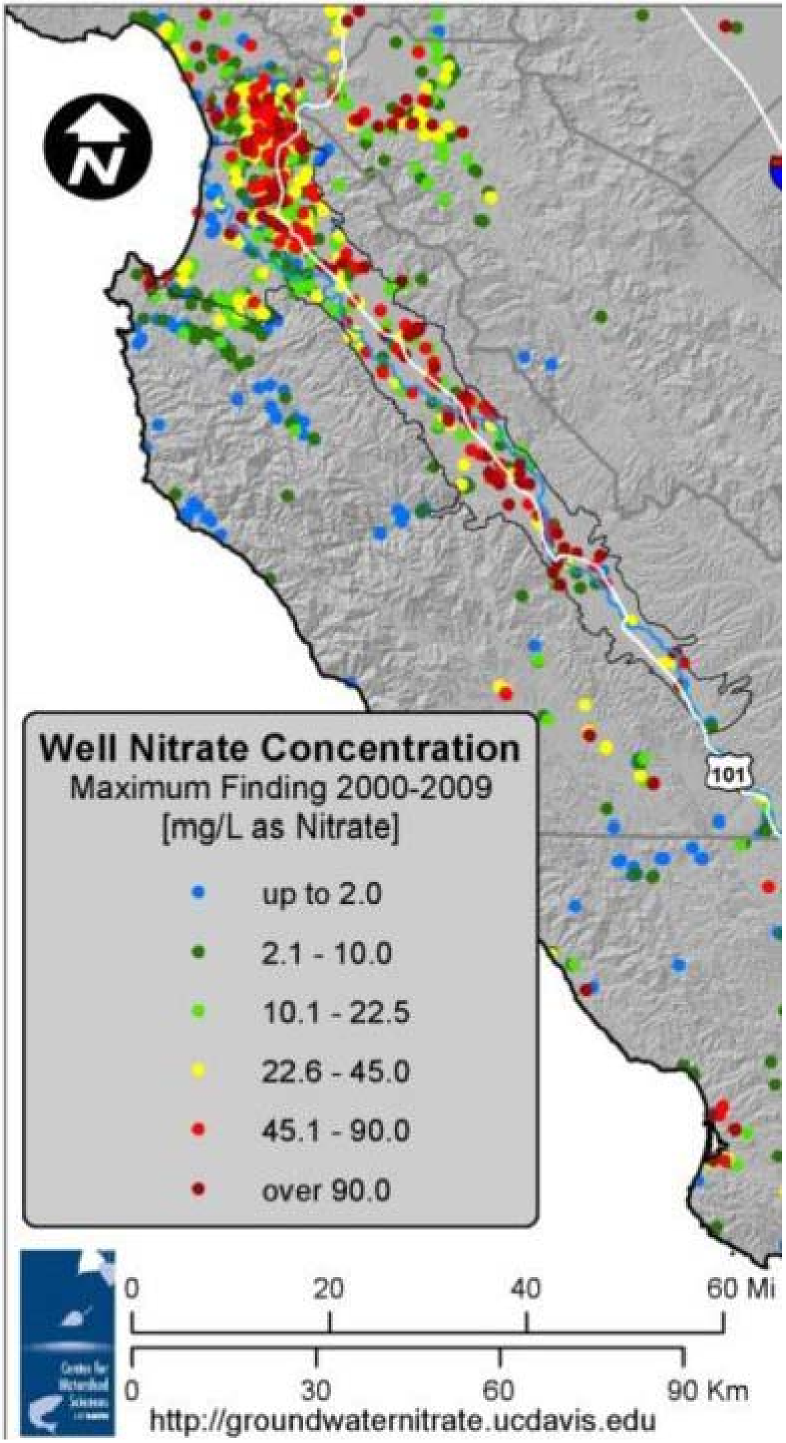
Modified with world population map from: Nature **439**, 800 (16 February 2006) | doi:10.1038/439800a

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

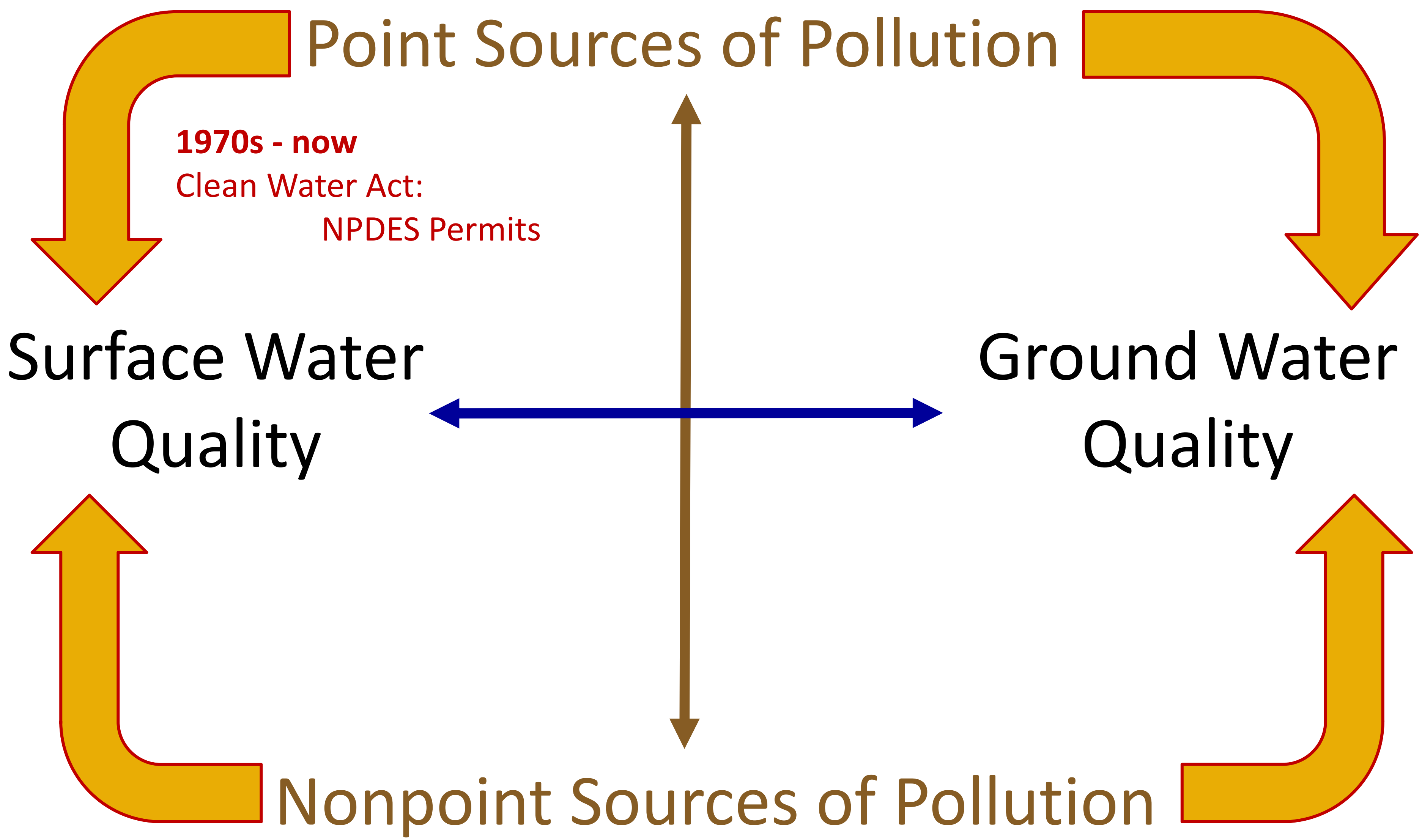
Nitrate: Impacted regions within the Salinas Valley

red dots: wells above MCL for nitrate

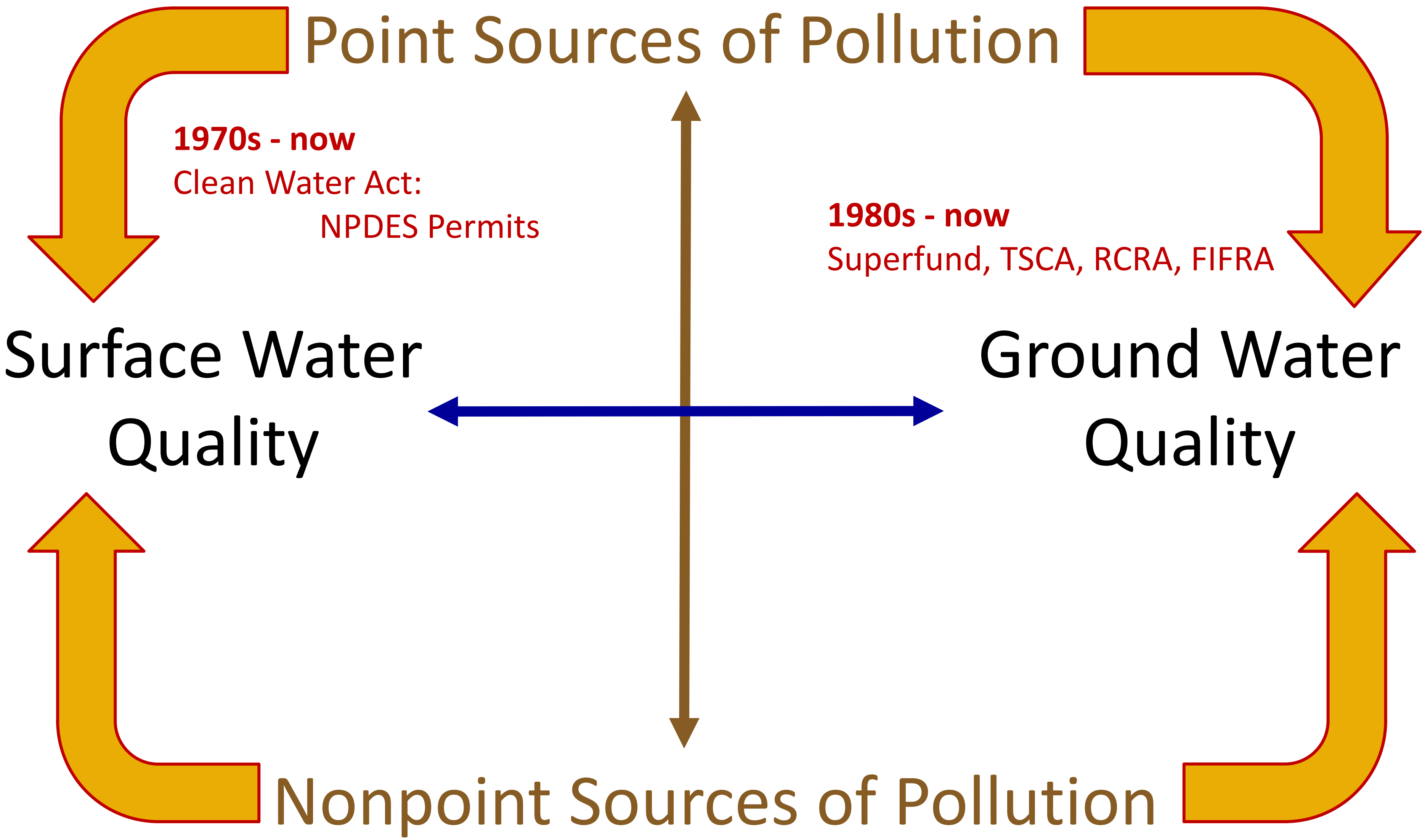


Boyle et al., 2012, http://groundwaternitrate.ucdavis.edu, Figure 42

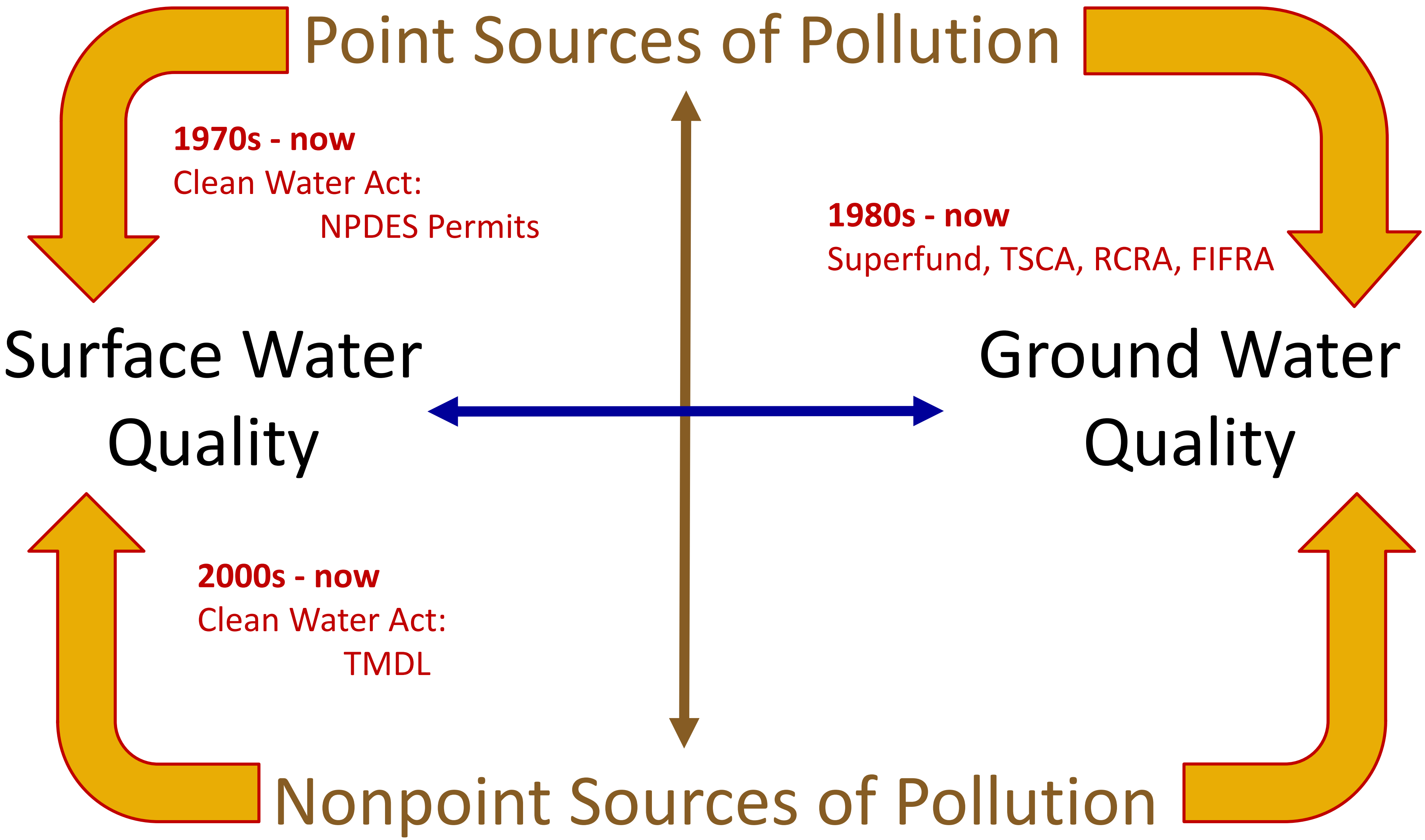
Regulating Water Pollution Sources



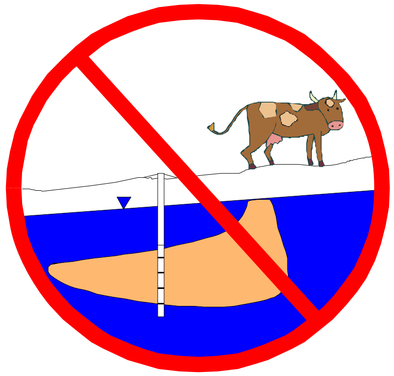
Regulating Water Pollution Sources



Regulating Water Pollution Sources



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

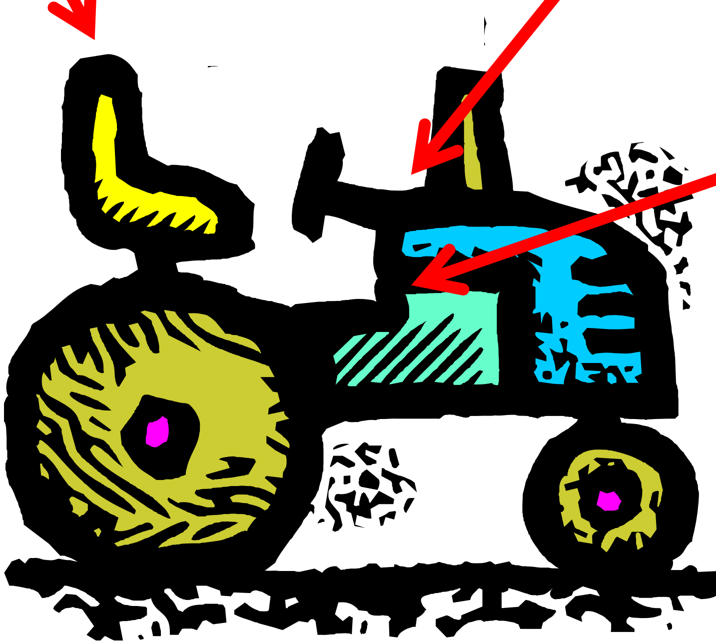
Example of Working with a Regulation: Speed Limit

Responsible Party:
Driver

Feedback:
Speedometer

Management Tool:
Brakes

Enforcement:
Radar Controls



Focus: Enforcement Monitoring

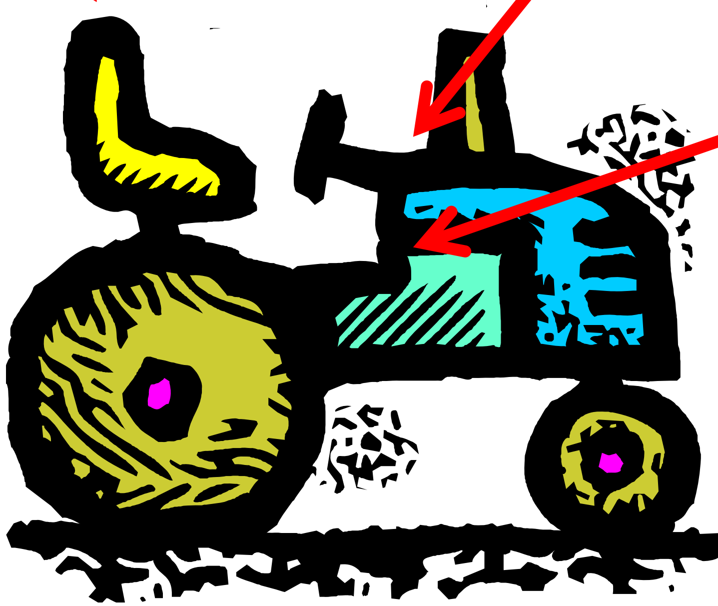
Applying Point Source Approach to Nonpoint Source:

Responsible Party:
Landowner

Feedback:
missing

Management Tool:
$$$ "agronomic"

Enforcement:
Monitoring Wells



Focus: Enforcement Monitoring

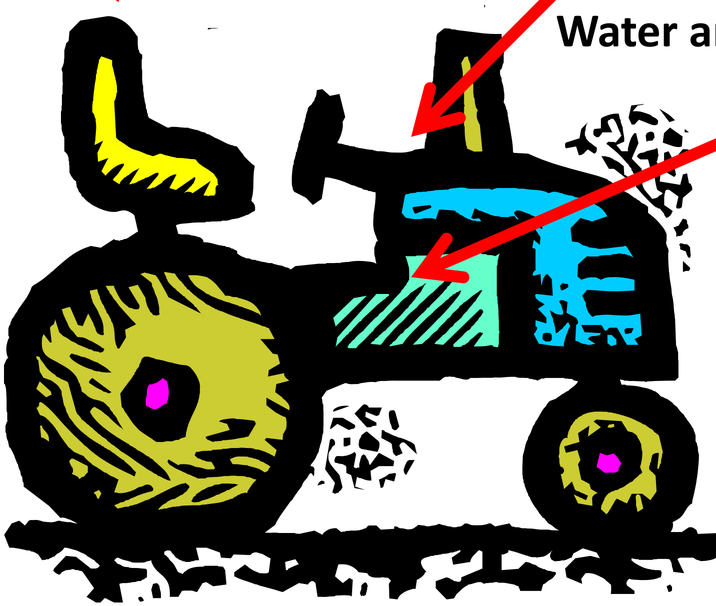
Alternative Monitoring Approach to Nonpoint Source:

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

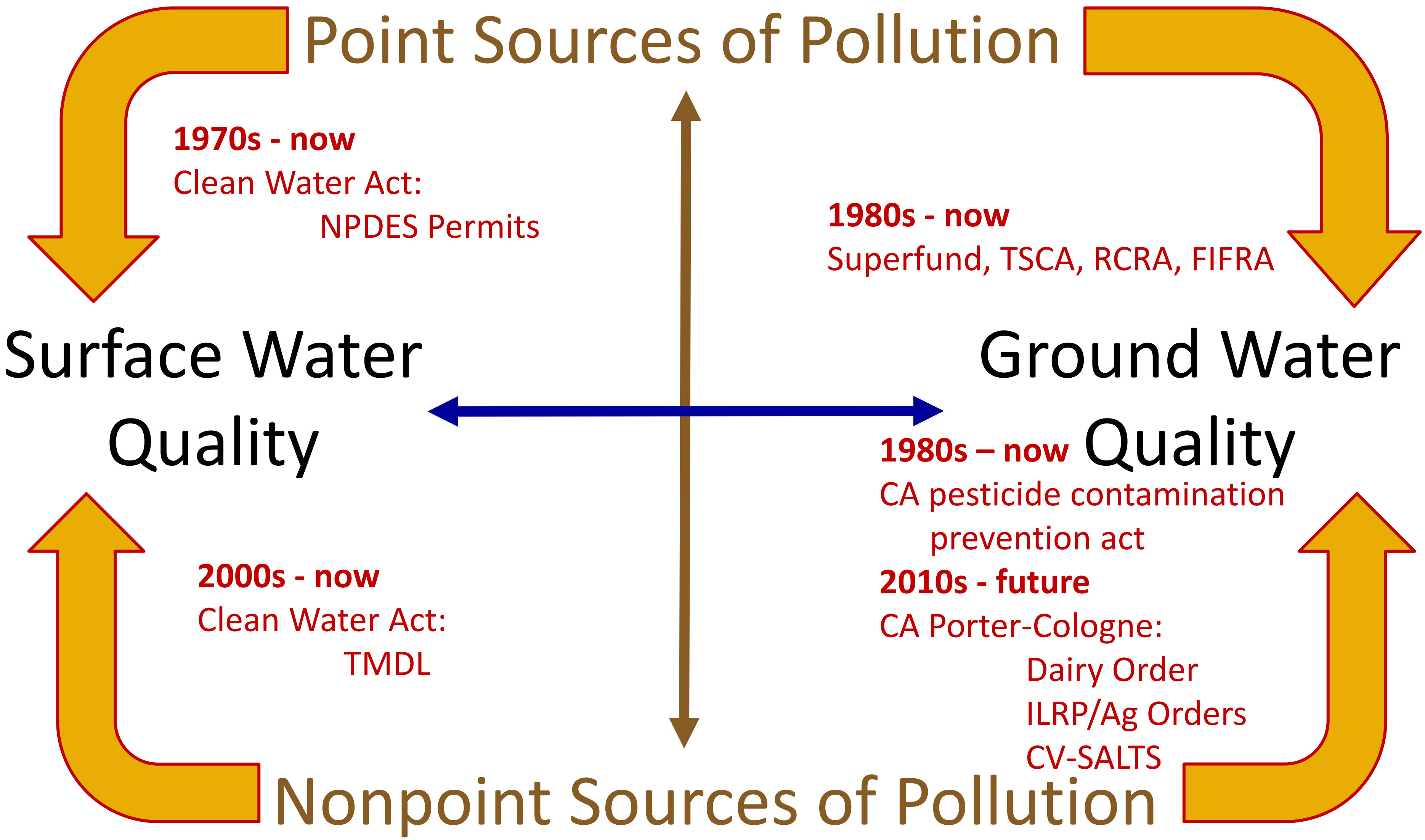
Responsible Party:
Landowner

Feedback:
Nutrient/Water Monitoring & Assessment

Management Tool:
Water and Nutrient Management



Regulating Water Pollution Sources



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

Future of Groundwater Management in Agricultural Regions:

Opportunity for creative solutions to **simultaneously** address

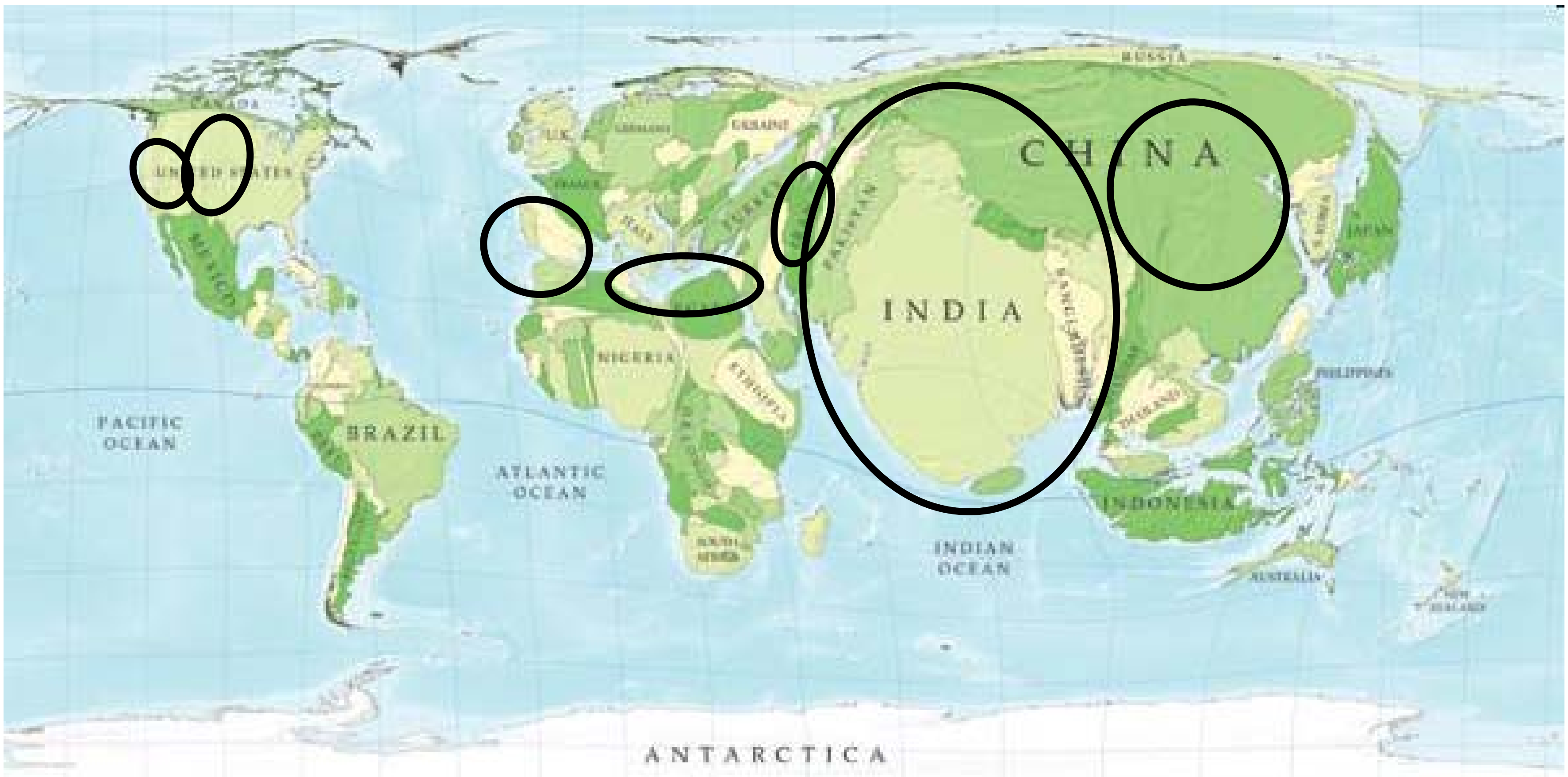
- groundwater supply enhancement
- groundwater quality improvement
- drinking water protection
- economic viability of agriculture

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

Key Challenges for Salinas Valley

- Managing groundwater overdraft to avoid seawater intrusion
  - Option 1: redistribution of groundwater pumping (away from the coast)
  - Option 2: pumping deep aquifer while recharging 180 ft and 400 ft aquifer (feasibility study needed)
- Implementing nutrient management requirements under Ag Order
  - Decreasing leaching fraction
  - Decreasing nitrogen losses to groundwater
  - Increasing clean groundwater recharge within irrigated landscape

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

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