Hydrologic context

January 2017
Roger Bales

Topics for class

1. Introduction to California water plan
2. Snapshot of California water conditions
3. History of water development in California

Goals

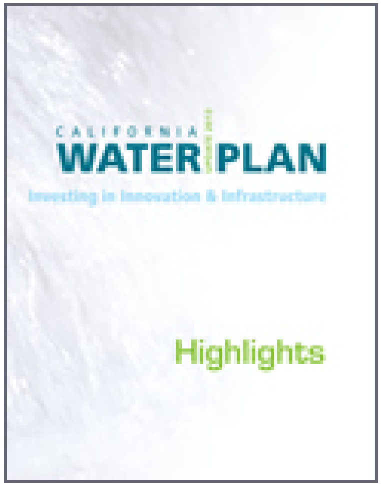
1. Develop an understanding of the multi-faceted and changing objectives of water management in California
2. Place water resources management in the context of hydrologic variability
3. Begin to understand how California's water resources management system has evolved

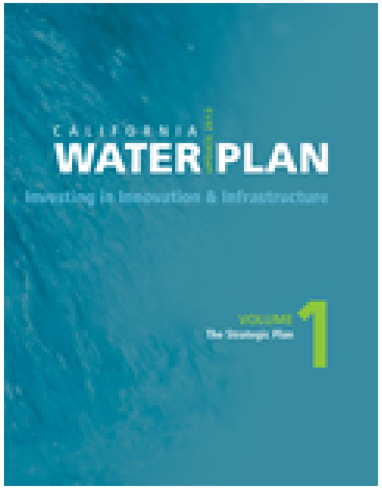
Questions

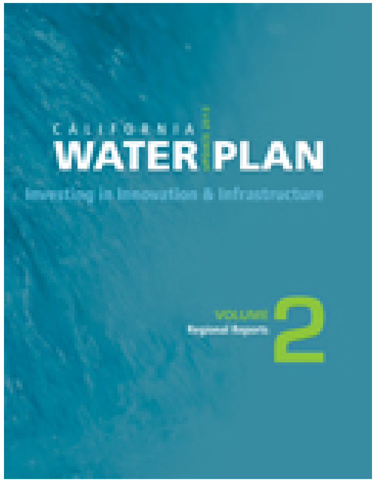
1. Your definition of water security, globally & for California?
2. For California, major areas for conflict? Compromise?
3. Fundamental barriers to water security, social, political, science, engineering?

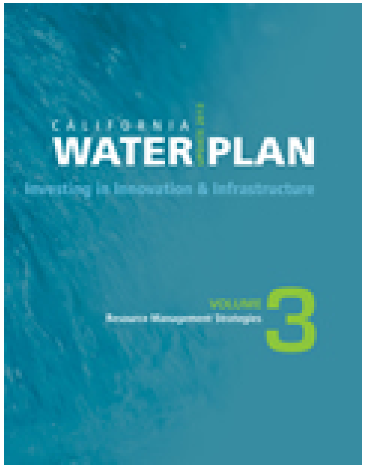
Note: In-class activities & discussion notes accompany these slides

California Water Plan, 2013









http://www.waterplan.water.ca.gov/cwpu2013/

How Our Past Shaped the 21st Century

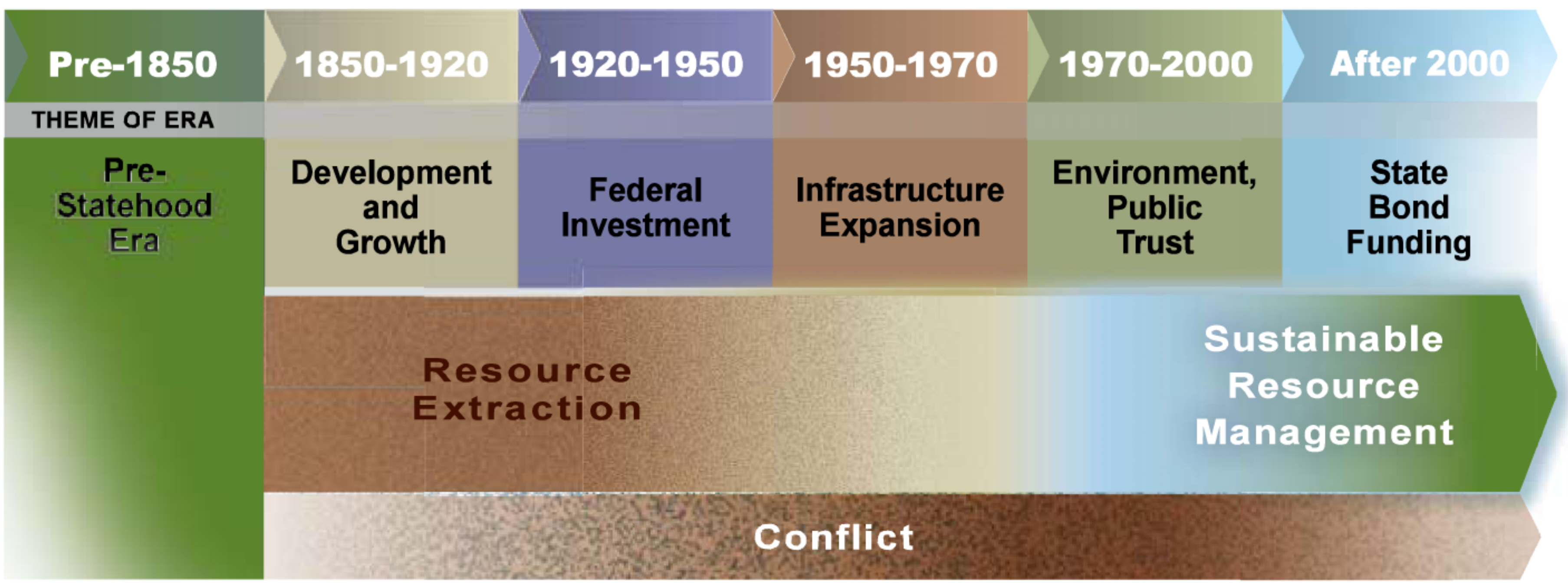
CA Water Plan, 2013

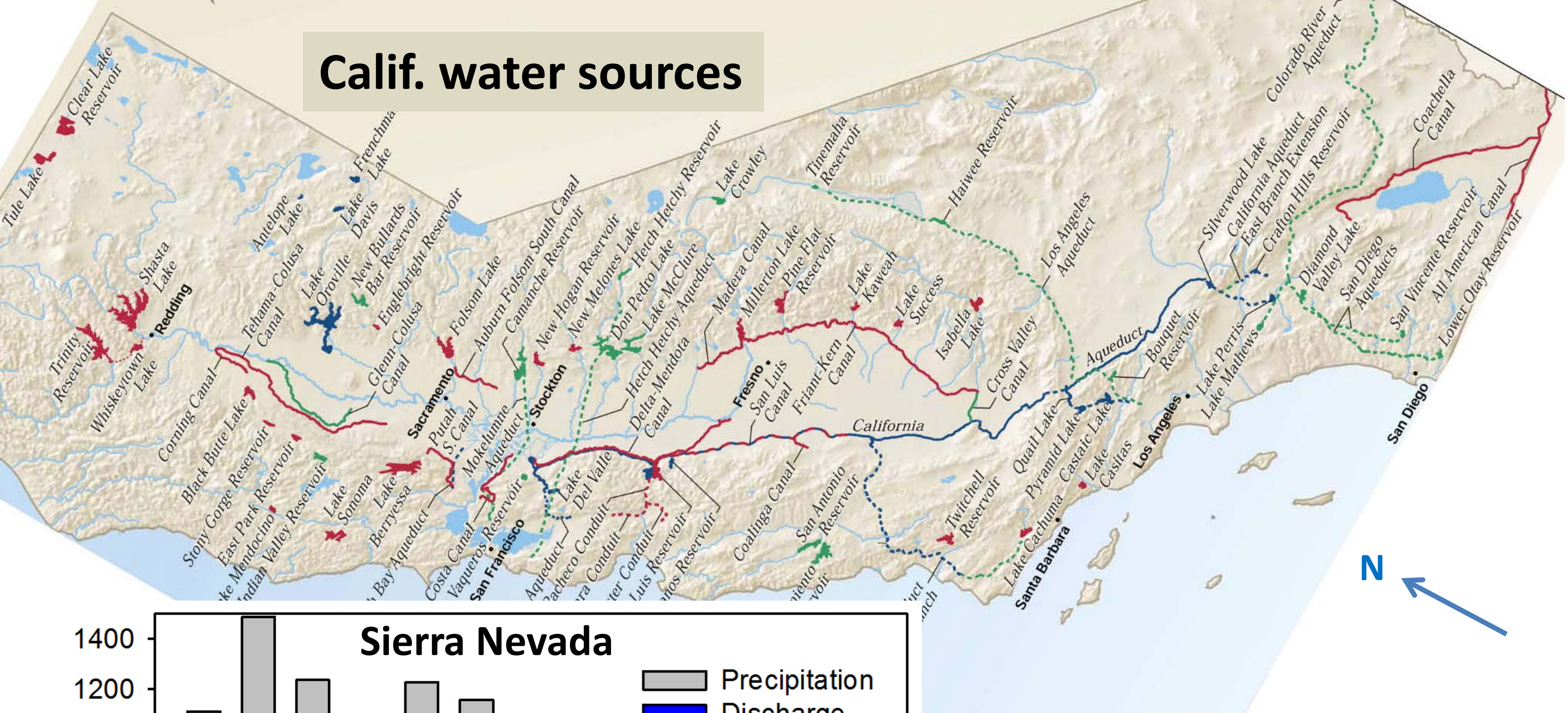
Pre-Statehood: Tribal Practices Promoted Sustainability

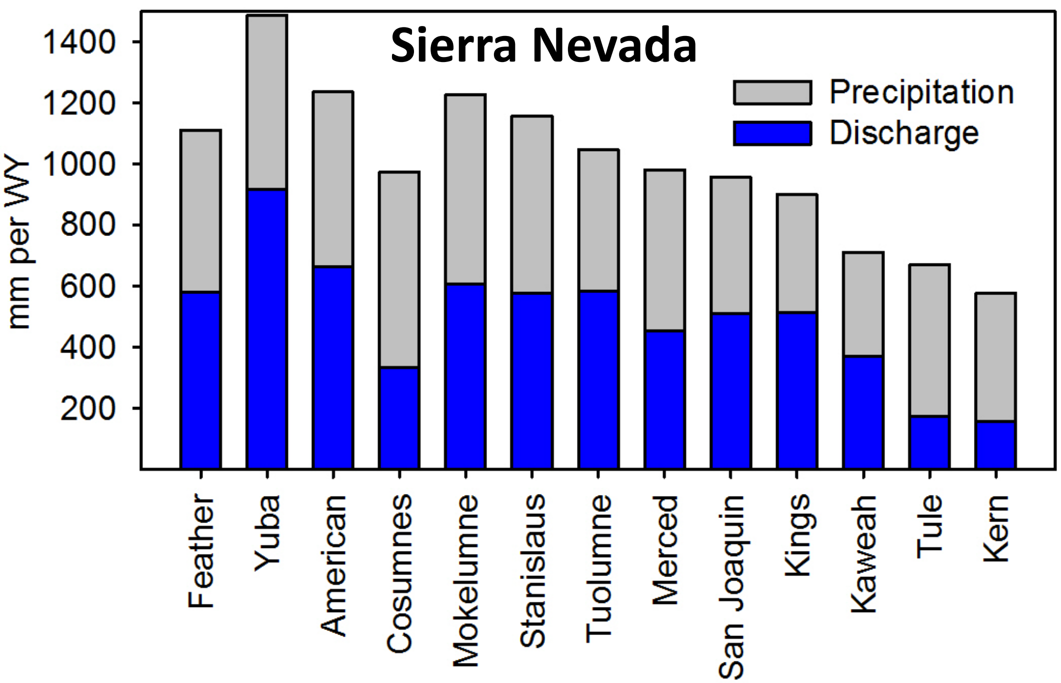
California's natural resources were carefully managed by Native American tribes, promoting sustainability to provide for the people for thousands of years. Tribal watershed management mimicked nature, enhancing the resources in many ways.

19th and 20th Centuries: Infrastructure Investments Promoted Growth and Economic Development

California invested in water and flood management infrastructure to promote growth and economic development in rural, suburban, and urban communities. This involved a period of resource extraction that led to a booming economy with benefits still enjoyed today, while at the same time creating a number of unintended consequences, including environmental degradation. Environmental laws and regulations were enacted in the latter part of the 20th century to help remedy the consequences and restore the environment.





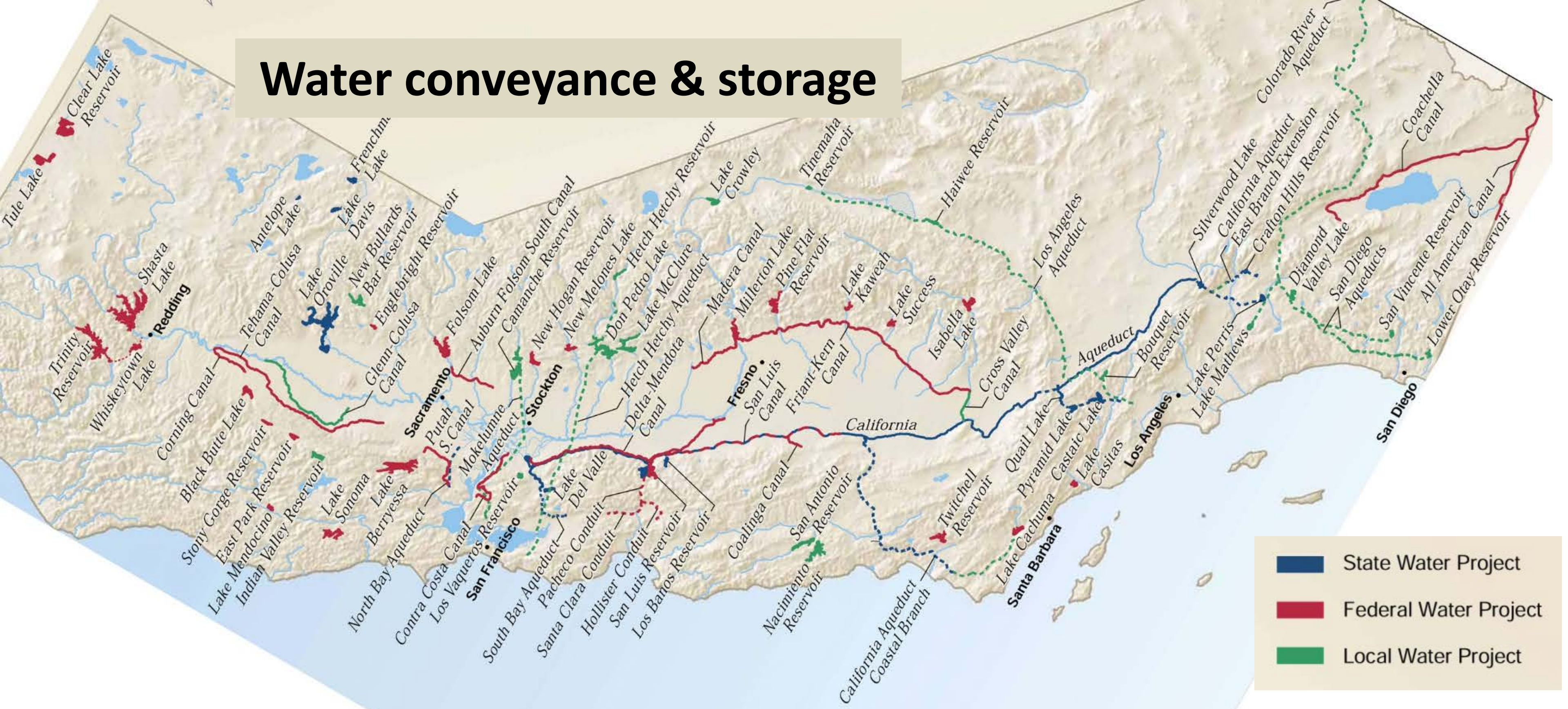


More precipitation & runoff north of Delta

More water use south of Delta

CA Water Plan, 2013

Water conveyance & storage

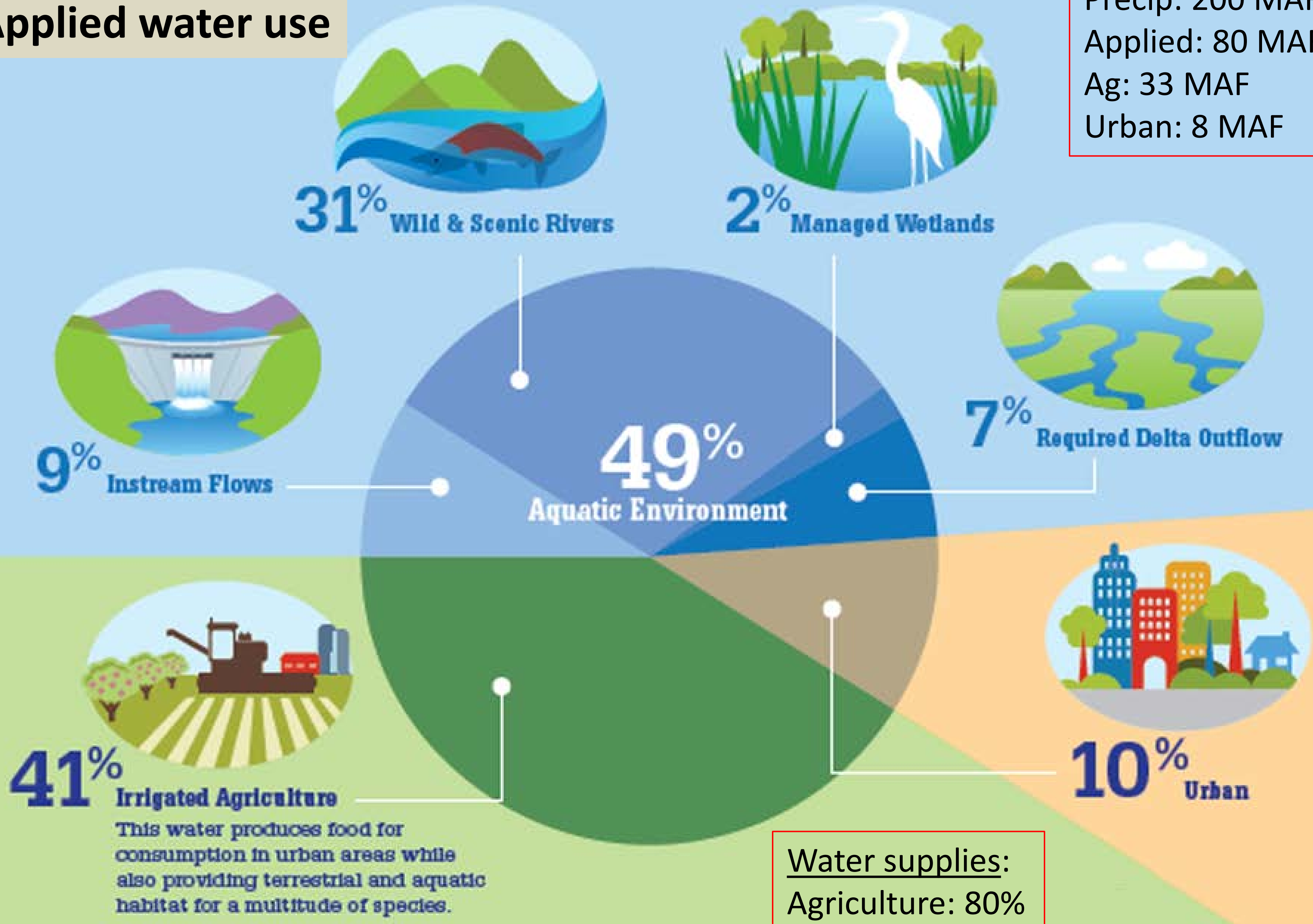


Moving water
north → south
mountains → coast

CA Water Plan, 2013

Applied water use

Precip: 200 MAF
Applied: 80 MAF
Ag: 33 MAF
Urban: 8 MAF

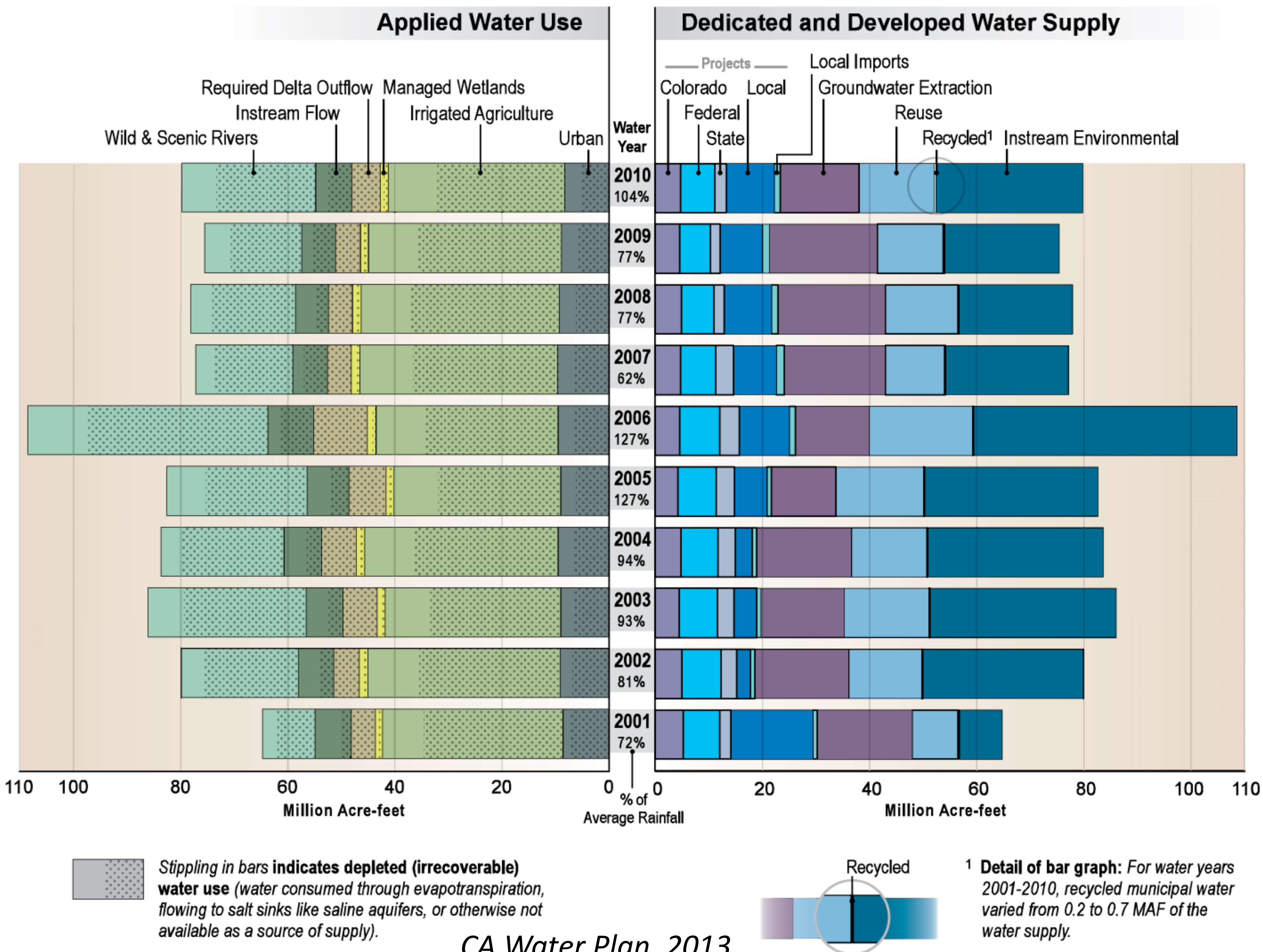


Water supplies:
Agriculture: 80%
Urban 20%

Data from DWR, adapted from Nor. Cal. Water Assn.

How California uses and supplies water

Statewide water uses and supplies are highly variable

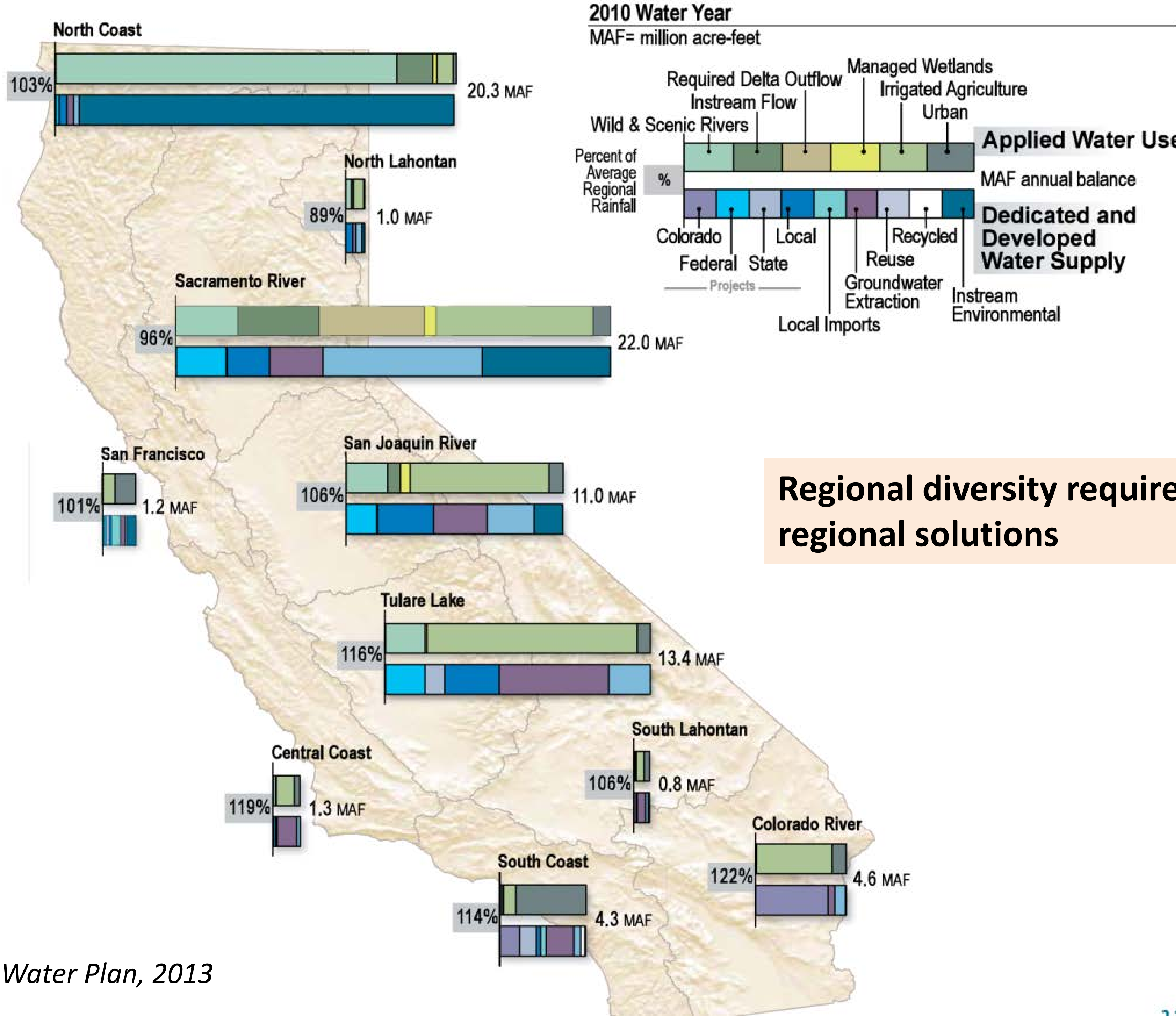


CA Water Plan, 2013

California Water Balance by Water Year Data Table (MAF)

	2001 (72%)	2002 (81%)	2003 (93%)	2004 (94%)	2005 (127%)	2006 (127%)	2007 (62%)	2008 (77%)	2009 (77%)	2010 (104%)
Applied Water Use										
Urban	8.6	9.1	9.0	9.5	9.0	9.5	9.6	9.3	8.9	8.3
Irrigated Agriculture	33.7	35.9	32.8	36.1	31.2	33.3	36.9	37.0	36.0	32.9
Managed Wetlands	1.3	1.6	1.5	1.6	1.4	1.6	1.6	1.6	1.5	1.5
Req Delta Outflow	4.5	4.8	6.4	6.5	7.0	10.1	4.5	4.5	4.7	5.3
Instream Flow	6.8	6.6	6.9	7.0	7.8	8.5	6.5	6.2	6.3	6.8
Wild & Scenic R.	9.8	21.9	29.5	23.0	26.2	44.8	18.1	19.5	18.1	25.1
Total Uses	**64.7**	**79.9**	**86.1**	**83.7**	**82.6**	**107.9**	**77.1**	**78.0**	**75.5**	**79.8**
Depleted Water Use (stippling)										
Urban	7.0	6.7	6.3	6.4	6.1	6.2	6.2	6.1	5.8	5.2
Irrigated Agriculture	26.0	26.2	24.3	26.8	22.7	24.2	27.1	27.6	26.6	23.8
Managed Wetlands	0.9	0.8	0.7	0.8	0.7	0.8	0.9	1.1	0.8	1.0
Req Delta Outflow	4.5	4.8	6.4	6.5	7.0	10.1	4.5	4.5	4.7	5.3
Instream Flow	2.2	2.6	2.7	2.7	3.3	6.1	4.4	2.2	4.1	4.4
Wild & Scenic R.	6.9	17.5	22.8	18.9	18.7	33.8	14.7	15.4	13.2	18.5
Total Uses	**47.5**	**58.6**	**63.2**	**62.1**	**58.5**	**81.3**	**57.8**	**56.8**	**55.2**	**58.3**
Dedicated and Developed Water Supply										
Instream	8.0	29.9	34.7	32.7	32.3	49.2	22.8	21.2	21.4	27.4
Local Projects	15.4	2.6	4.2	3.2	6.0	9.3	8.0	8.8	7.9	8.8
Local Imported Deliveries	0.8	0.8	0.8	0.8	0.9	1.1	1.5	1.2	1.3	1.1
Colorado Project	5.2	5.0	4.5	4.8	4.2	4.6	4.7	4.9	4.6	4.7
Federal Projects	6.8	7.3	7.1	6.9	7.2	7.4	6.6	6.1	5.7	6.4
State Project	2.1	2.9	3.1	3.2	3.4	3.7	3.3	1.9	1.8	2.2
Groundwater Extraction	17.6	17.5	15.5	17.7	12.0	13.1	18.8	20.0	20.1	14.7
Inflow & Storage	0.0	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1
Reuse & Seepage	8.5	13.6	15.8	14.0	16.3	19.2	11.1	13.5	12.3	14.1
Recycled Water	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3
Total Supplies	**64.7**	**79.9**	**86.1**	**83.7**	**82.6**	**107.9**	**77.1**	**78.0**	**75.5**	**79.8**

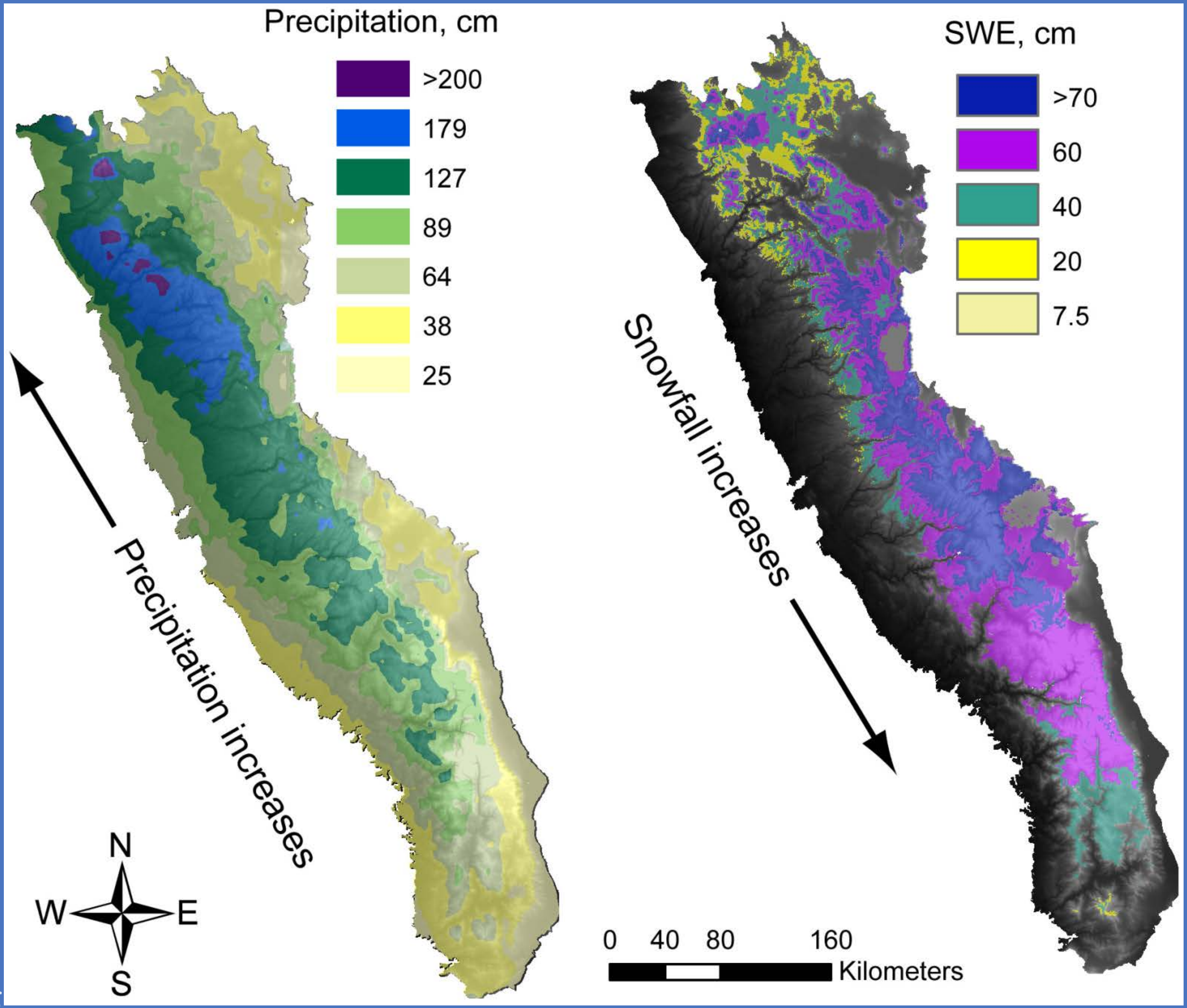
CA Water Plan, 2013



Regional diversity requires regional solutions

CA Water Plan, 2013

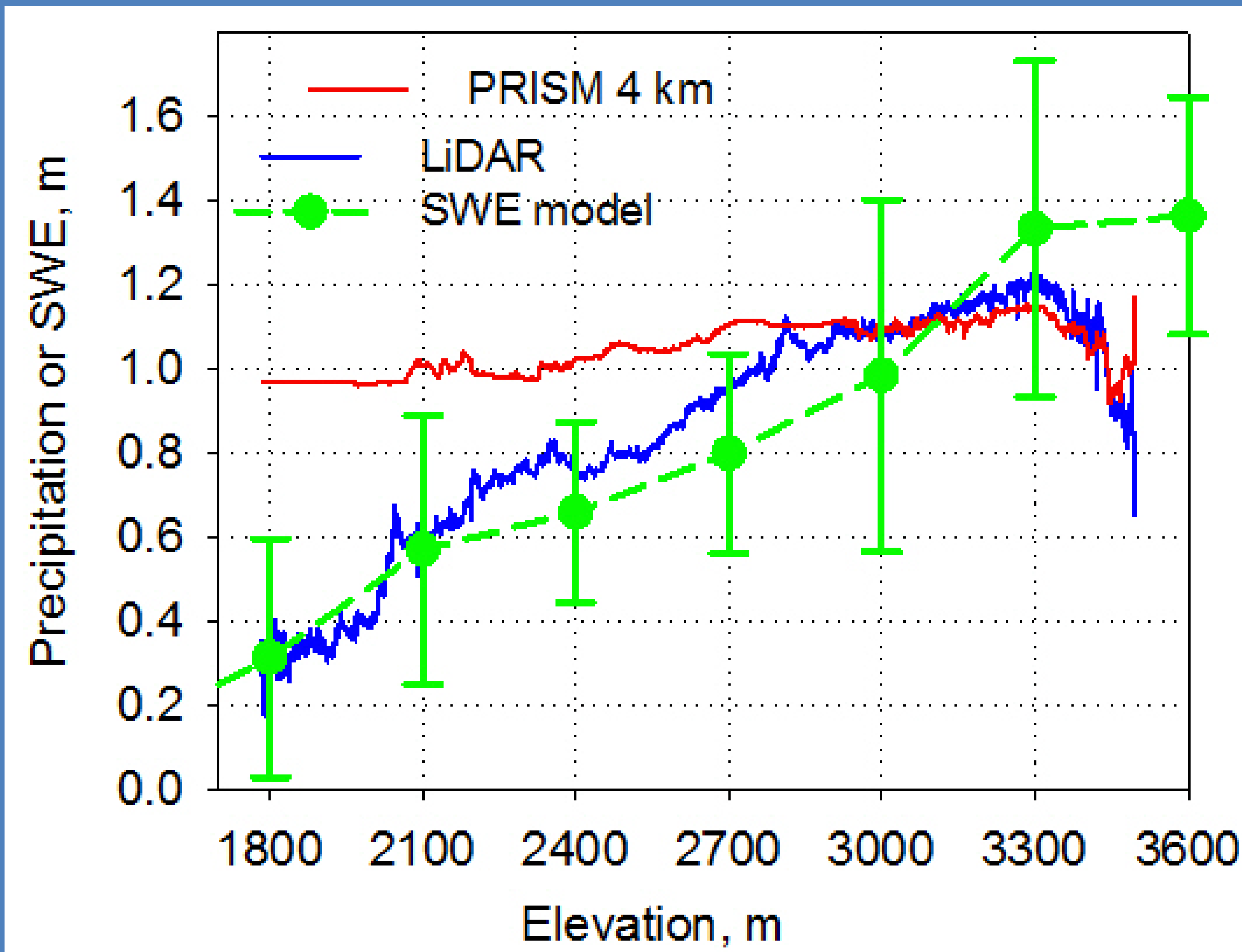
Sierra Nevada precipitation & snow water equivalent (SWE) – climatological estimate



Bales et al., 2006

Comparison of SWE measured by LiDAR w/ indirect estimates of SWE & precipitation, Kaweah R. basin

WY 2010



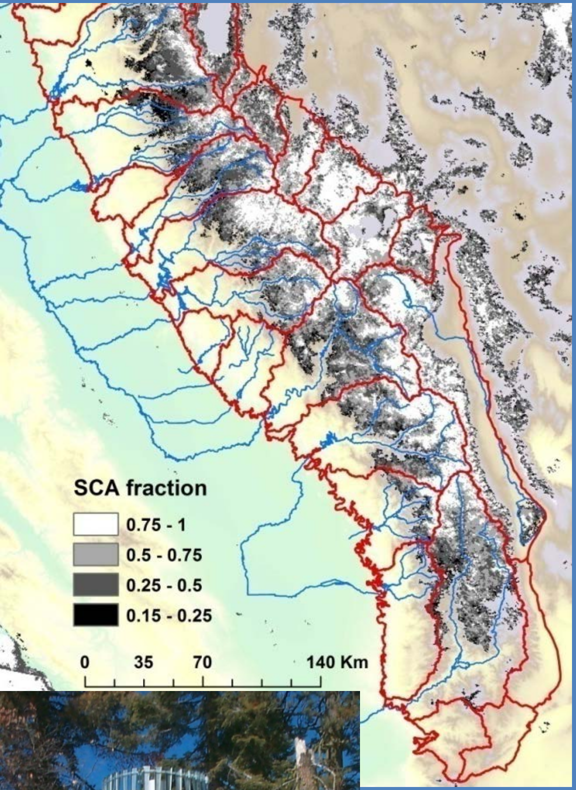
Future: data from distributed, wireless sensor networks, blended w/ remote sensing data

Kirchner et al., 2015.

SWE: Guan et al., 2013

Basic water balance

Precipitation = Evapotranspiration + Runoff



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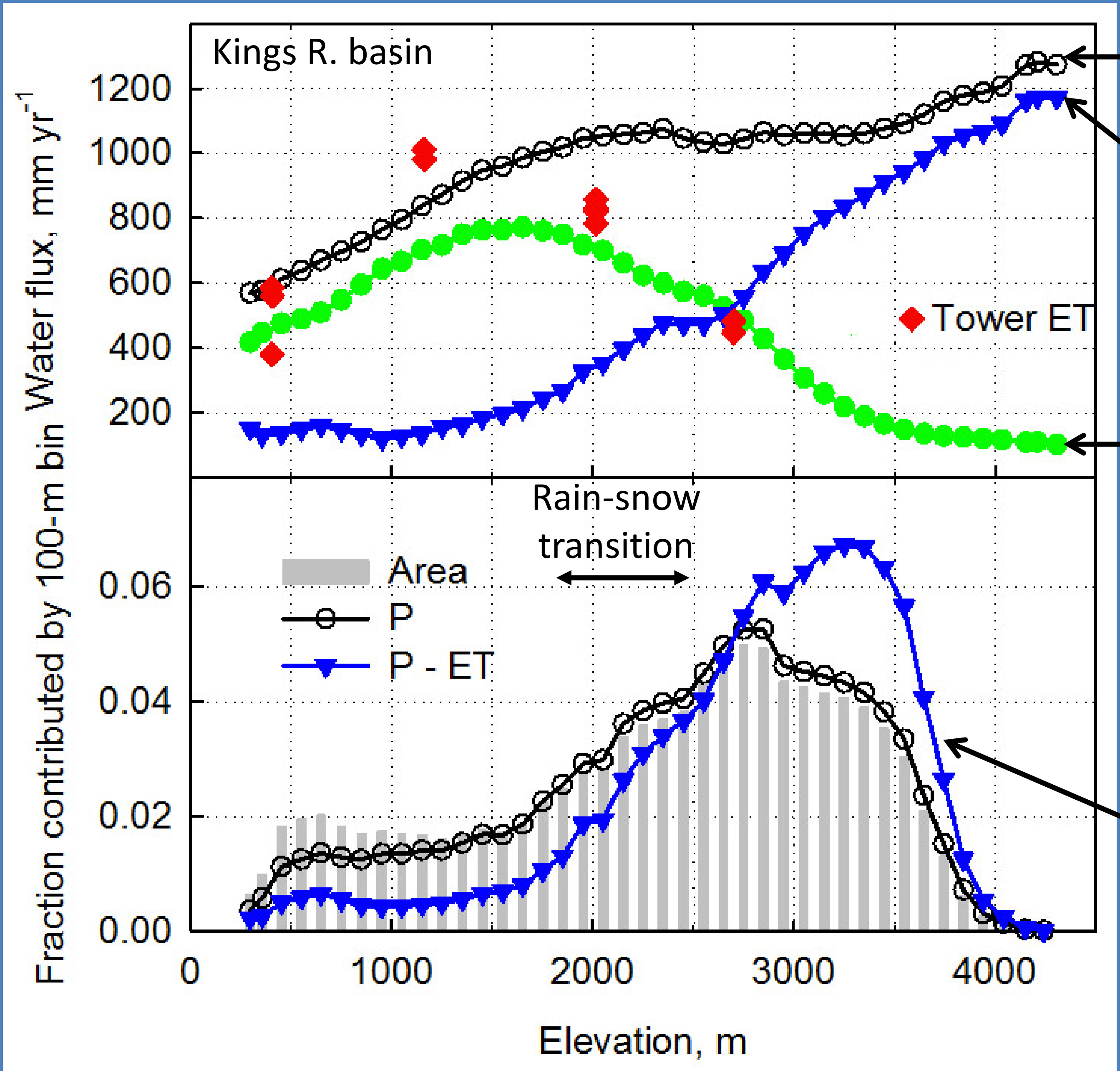
Extending flux-tower results to the basin scale



Precip based on PRISM

Runoff by difference

ET extended using satellite indices

Runoff

IC-2

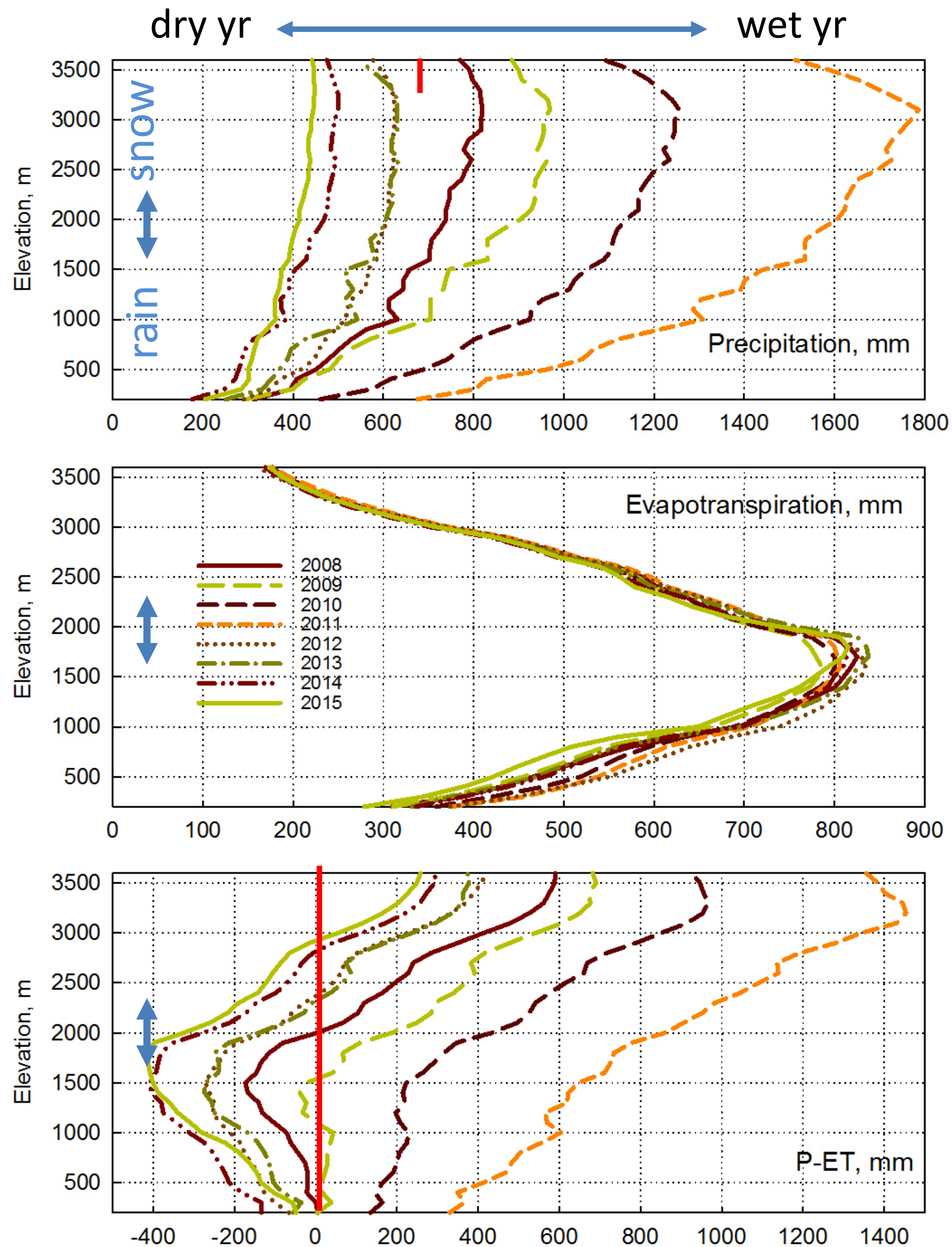
Goulden & Bales, 2014

Southern Sierra averages

Precipitation (P) from PRISM

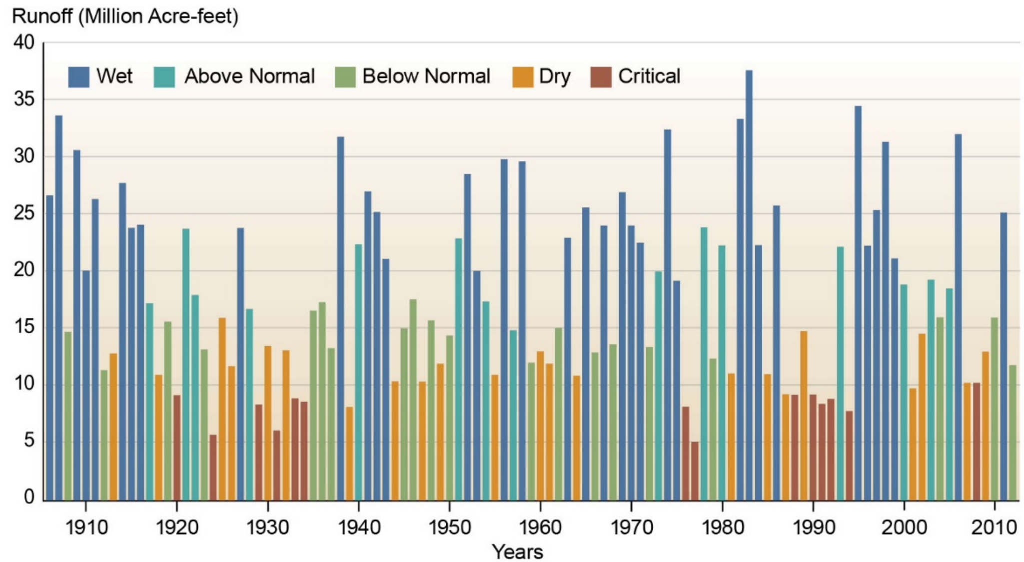
Evapotranspiration (ET) from NDVI: “canopy-acclimated ET”

P – ET is difference



Unimpaired runoff

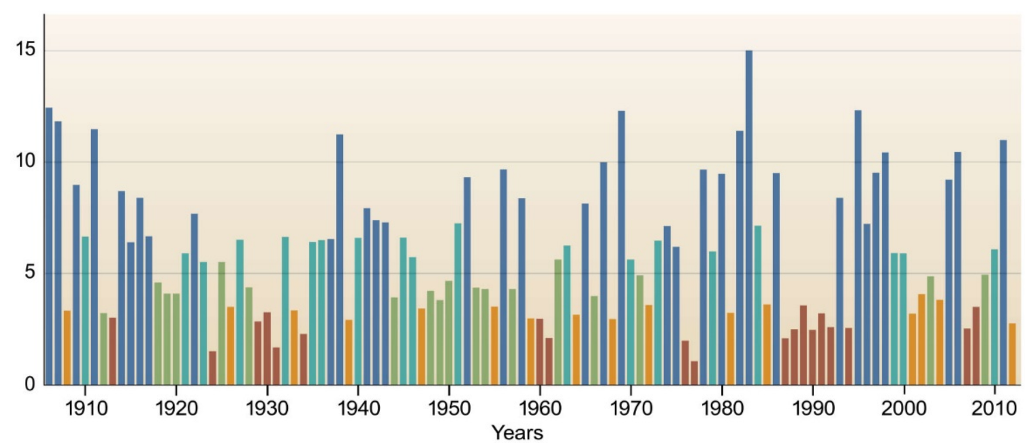
Figure 3-7 Sacramento Four Rivers Unimpaired Runoff, 1906-2012



Note: The Sacramento Four Rivers are Sacramento River above Bend Bridge, near Red Bluff; Feather River inflow to Lake Oroville; Yuba River at Smartville; American River inflow to Folsom Lake.

How frequent are critically dry years?

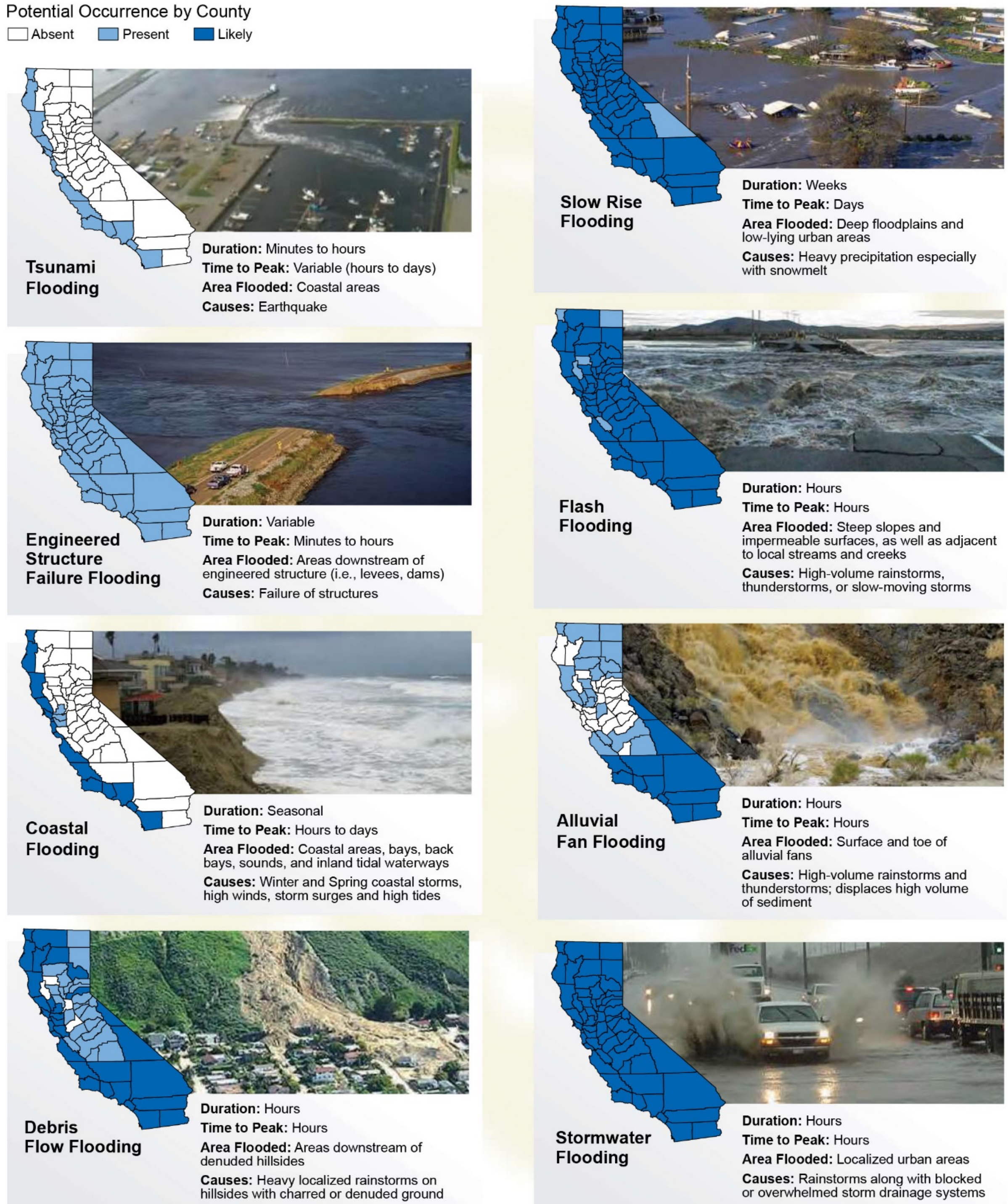
Figure 3-8 San Joaquin Four Rivers Unimpaired Runoff, 1906-2012



Note: The four San Joaquin rivers are Stanislaus River inflow to New Melones Reservoir, Tuolumne River inflow to New Don Pedro Reservoir, Merced River inflow to New Exchequer Reservoir, and San Joaquin River inflow to Millerton Reservoir.

CA Water Plan, 2013

Flooding

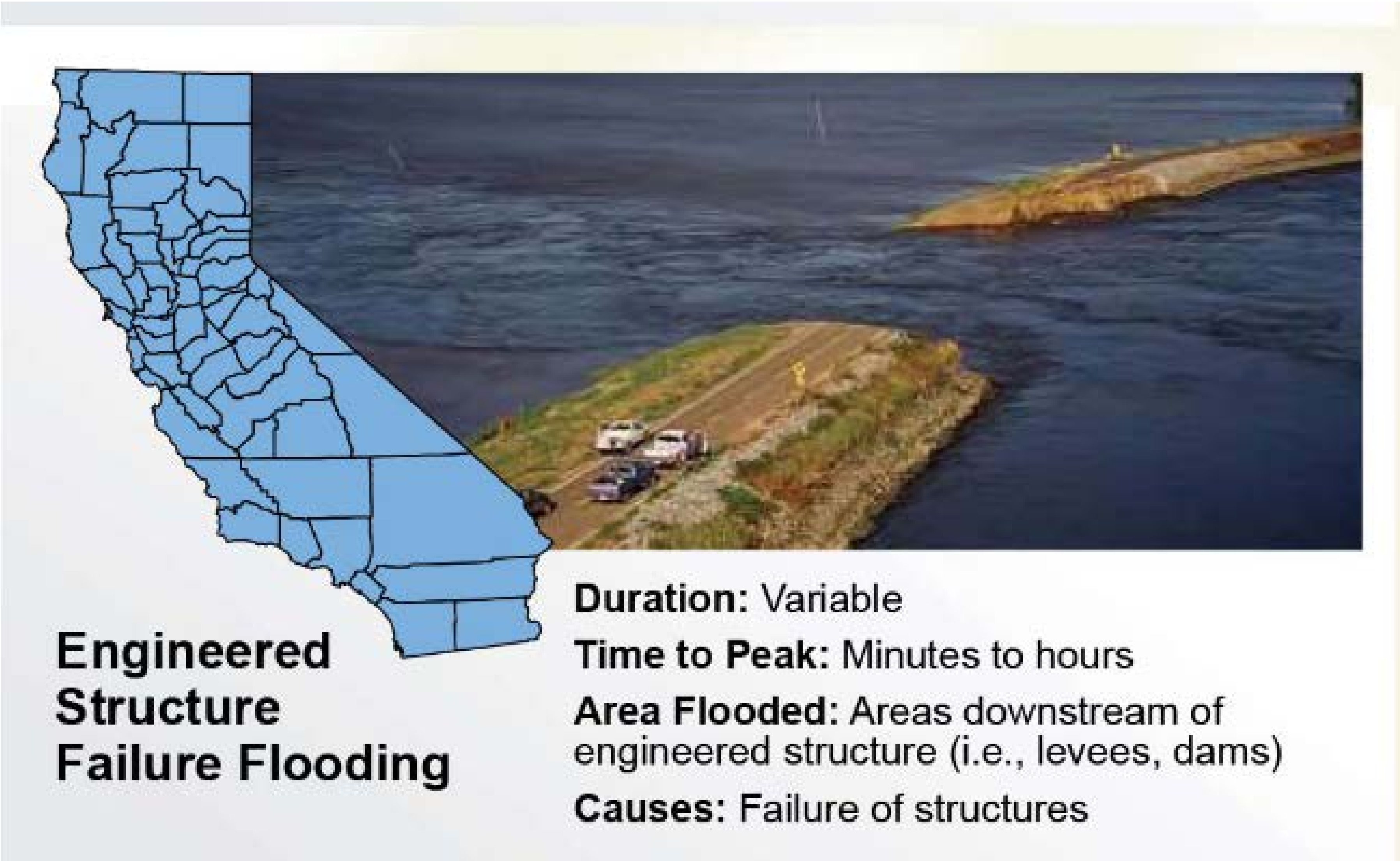


CA Water Plan, 2013

Flooding

CA Water Plan, 2013

Flooding

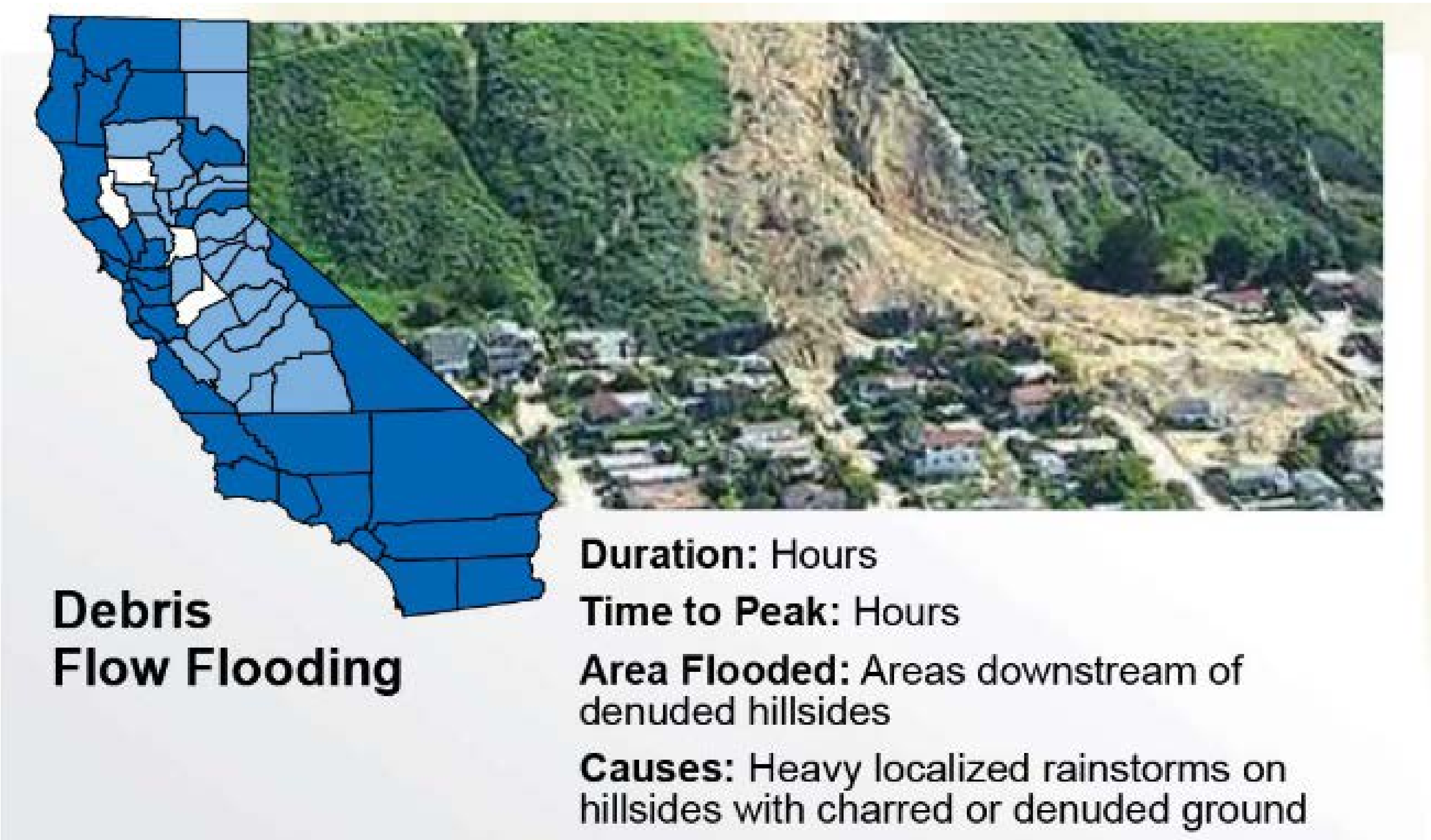


CA Water Plan, 2013

Flooding

CA Water Plan, 2013

Flooding



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Flooding

Slow Rise Flooding

Duration: Weeks

Time to Peak: Days

Area Flooded: Deep floodplains and low-lying urban areas

Causes: Heavy precipitation especially with snowmelt

CA Water Plan, 2013

Flooding

CA Water Plan, 2013

Flooding

Alluvial Fan Flooding

Duration: Hours

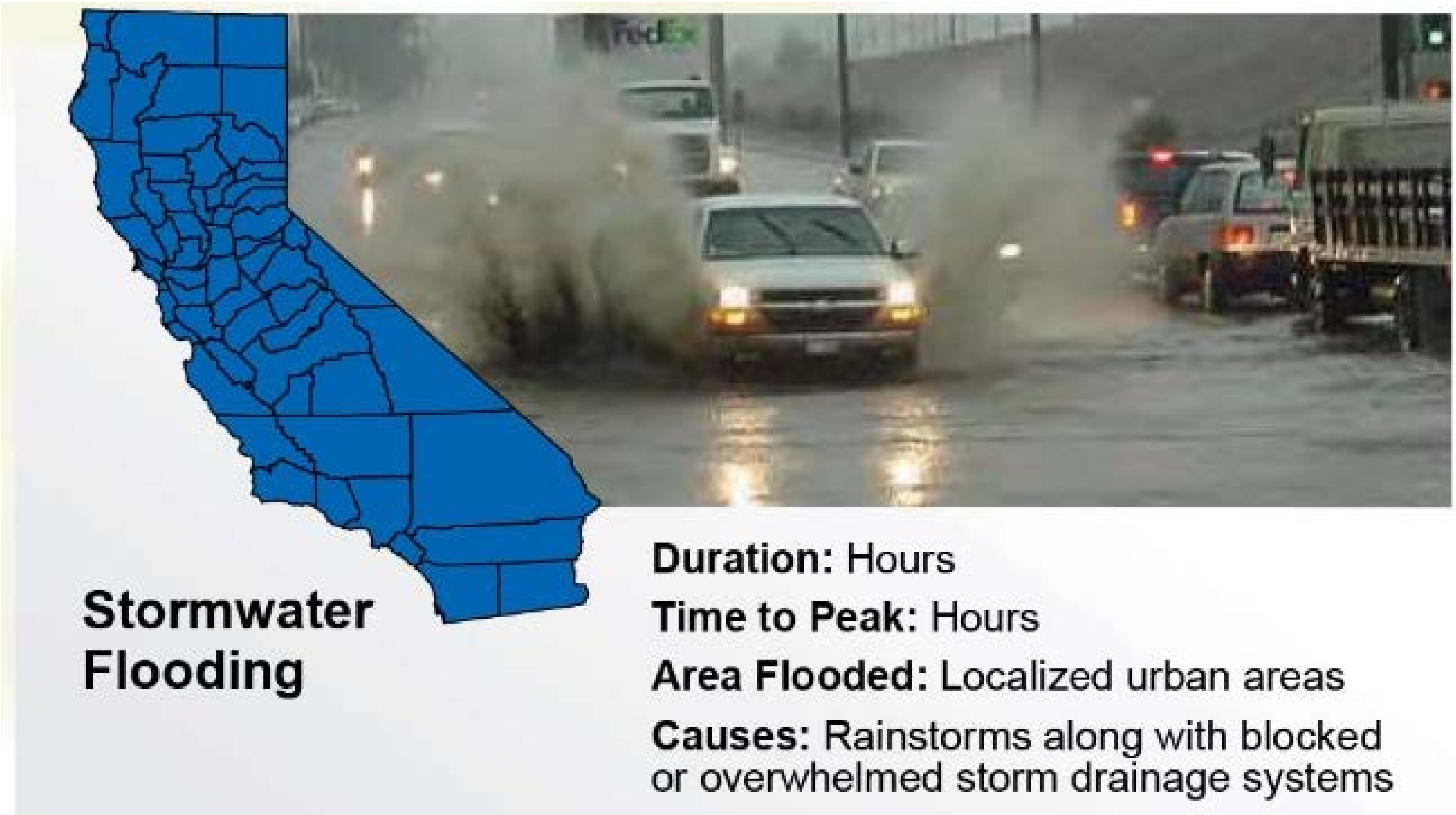
Time to Peak: Hours

Area Flooded: Surface and toe of alluvial fans

Causes: High-volume rainstorms and thunderstorms; displaces high volume of sediment

CA Water Plan, 2013

Flooding

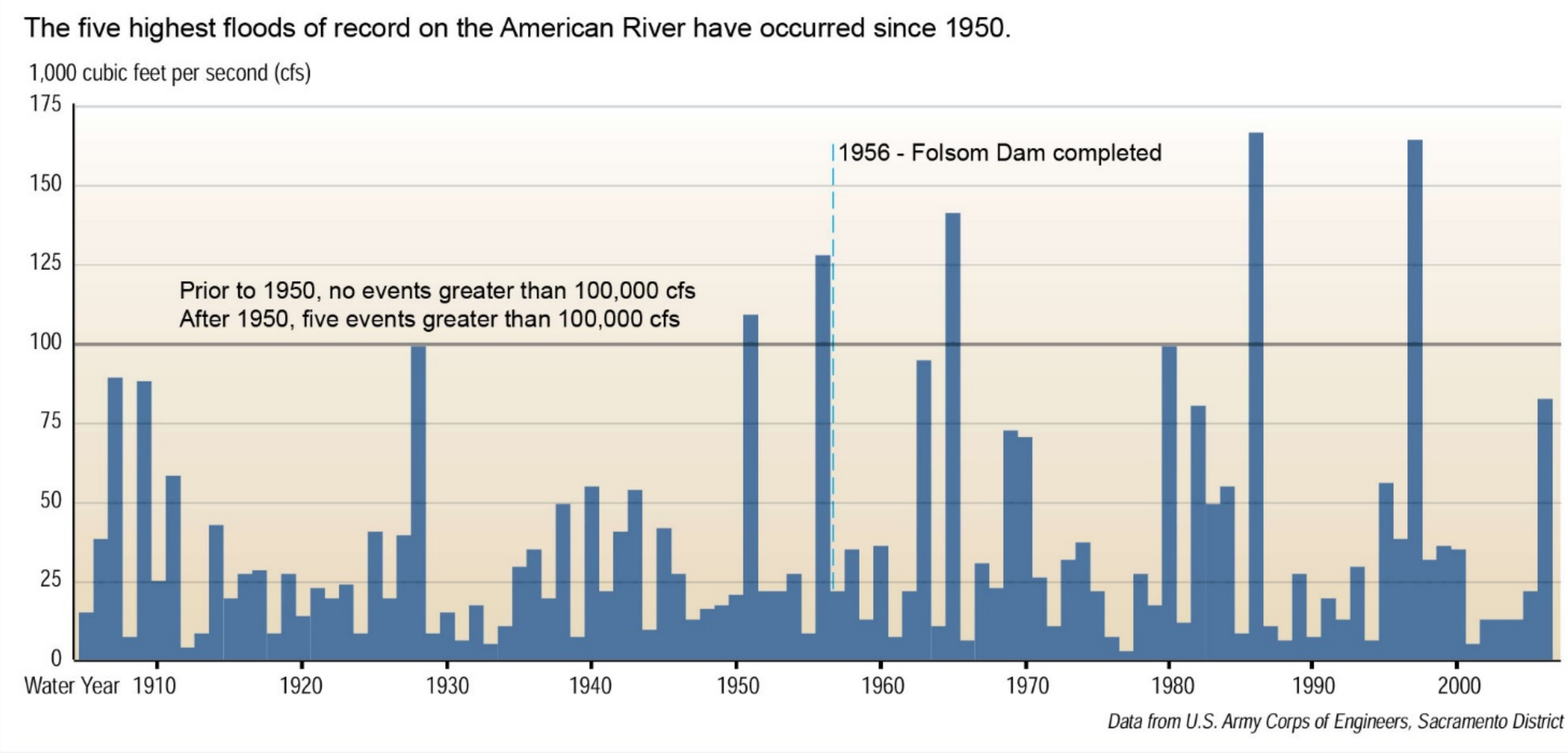


CA Water Plan, 2013

American River floods

Understanding of 100-year flood event magnitude on the American River has changed substantially over time. In the early 1900s, a 100-year flood was estimated to equate to a peak flow of just over 200,000 cubic feet per second (cfs) at what is now Folsom Dam. The estimate with current data is more than 300,000 cfs.

Figure A American River at Folsom Dam



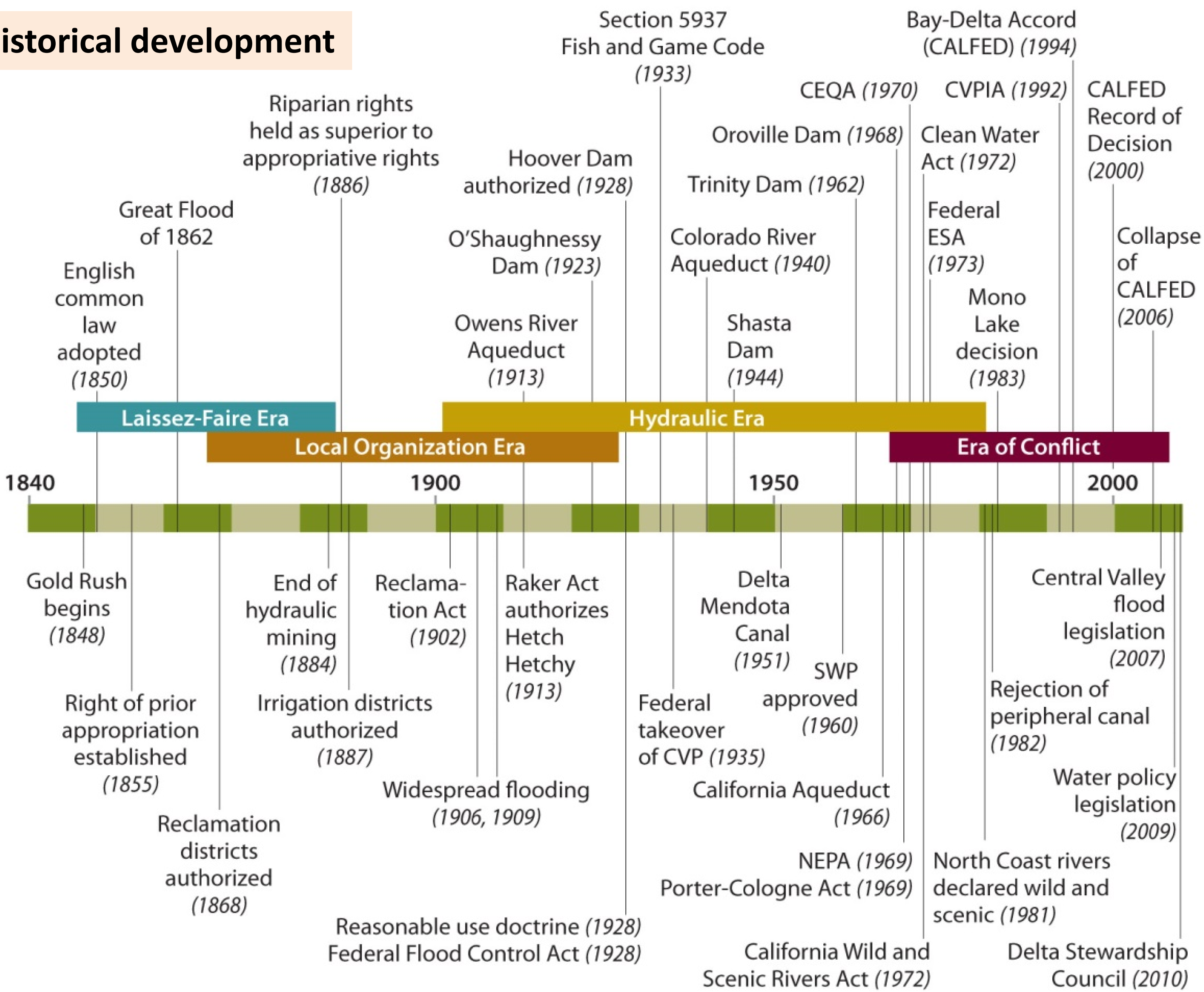
CA Water Plan, 2013

Water development

California’s networks of dams, canals, levees, and water treatment plants, along with the laws, regulations, and institutions that govern them, were not developed in concert as part of a grand vision or plan. Rather, they evolved over the course of more than 160 years, responding to a rapidly growing population, changing demographics and demands, and the occasional drought, flood, and lawsuit.

Hanak, 2011

Historical development

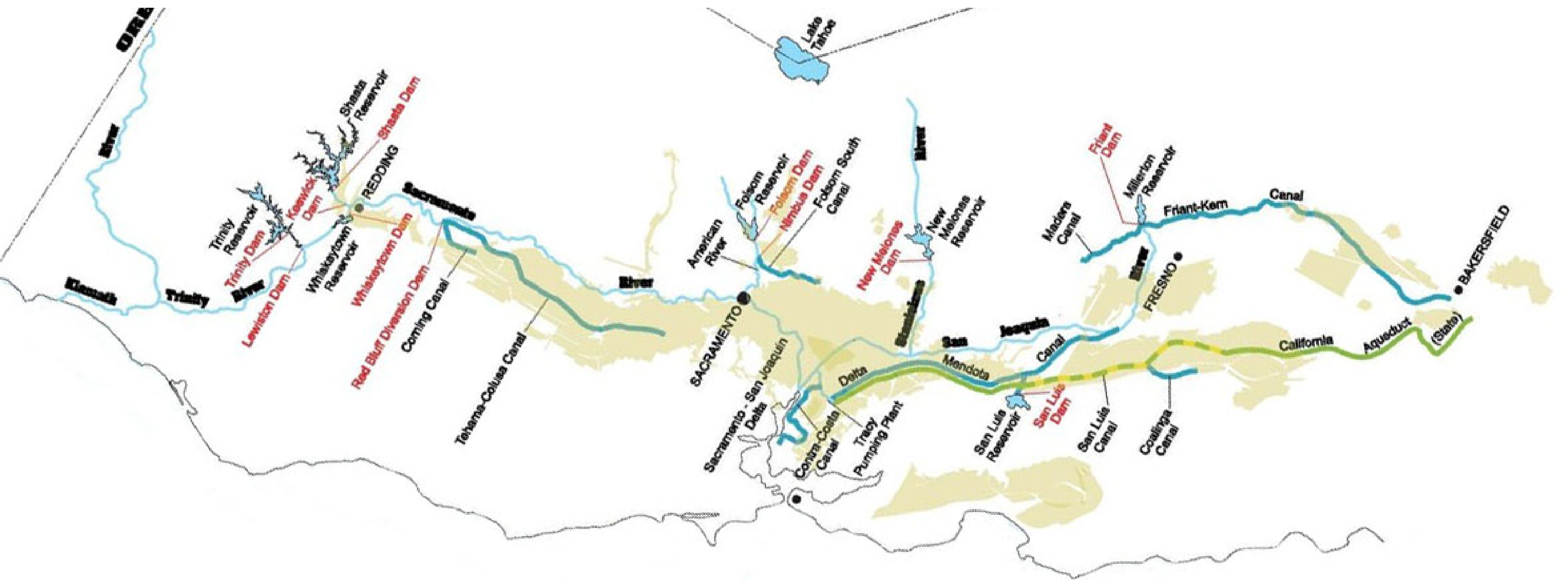


Water conveyance & storage

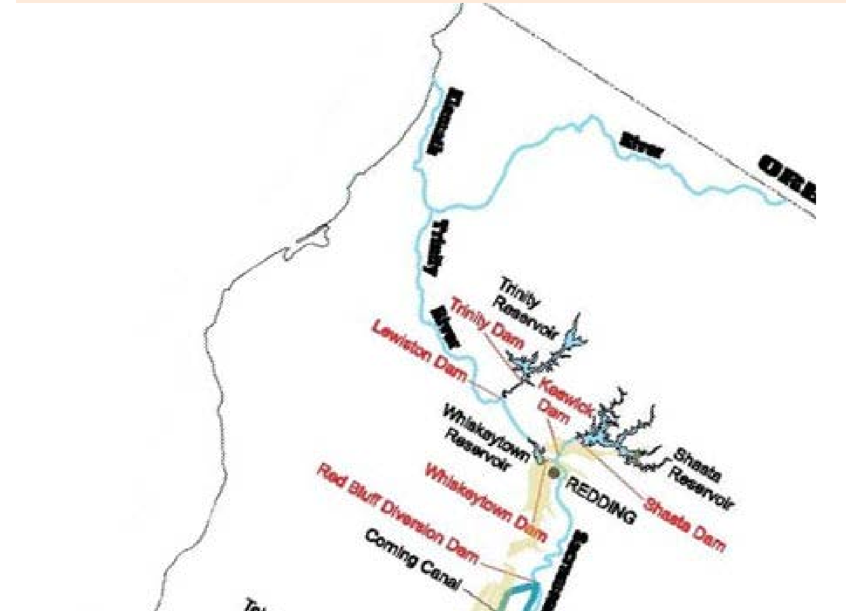
CA Water Plan, 2013

Central Valley Project

The CVP operates 18 dams and reservoirs, 11 power plants, and 500 miles of canals and other facilities between the Cascade Range near Redding and the Tehachapi Mountains near Bakersfield. It serves agricultural, municipal and industrial needs in the Central Valley, urban centers in parts of the San Francisco Bay Area, and is the primary water source for many Central
Valley wildlife refuges. In an average year, the CVP delivers approximately 7 maf of water, for agriculture, urban and wildlife use, irrigating about one-third (3 million acres) of California's agricultural lands and supplying water for nearly one million households



Central Valley Project – Shasta Dam



http://www.shastalake.com/

californiawaterblog.files.wordpress.com

Central Valley Project – Whiskeytown Dam & Trinity Diversion

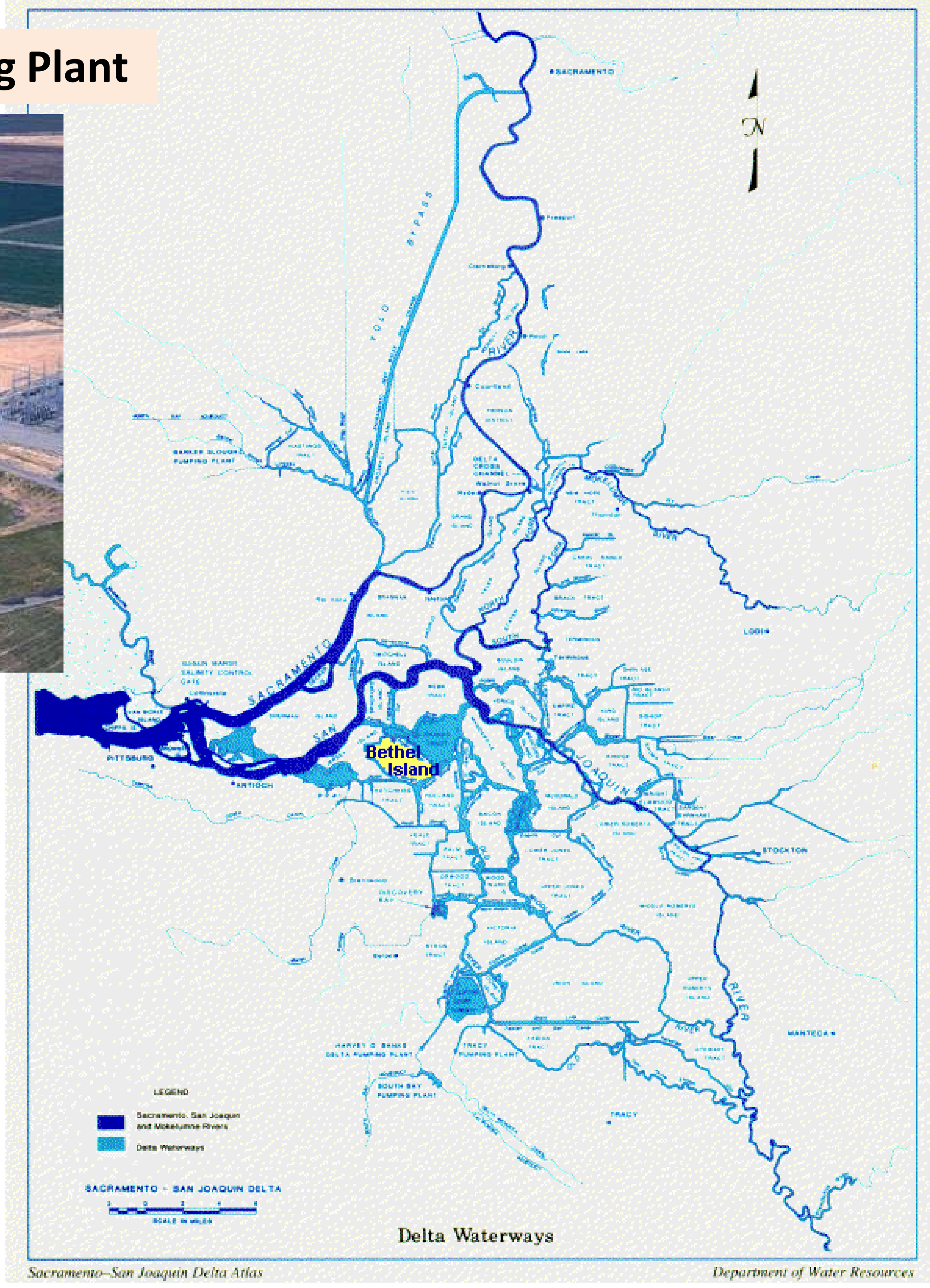
http://www.usbr.gov/

Central Valley Project – Sacramento River

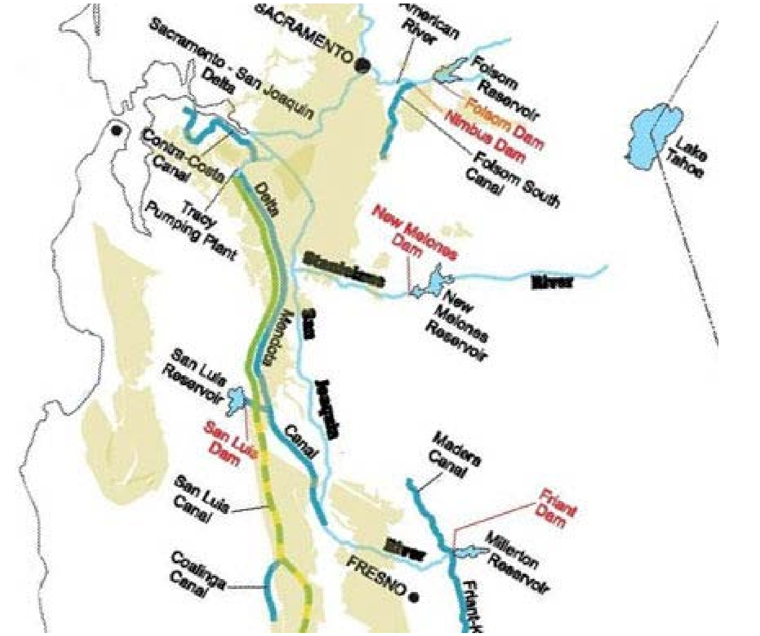
Aerial photograph of the Sacramento River and Redding, Shasta County, California. View to the west.

Central Valley Project – Delta Pumping Plant

http://www.usbr.gov/



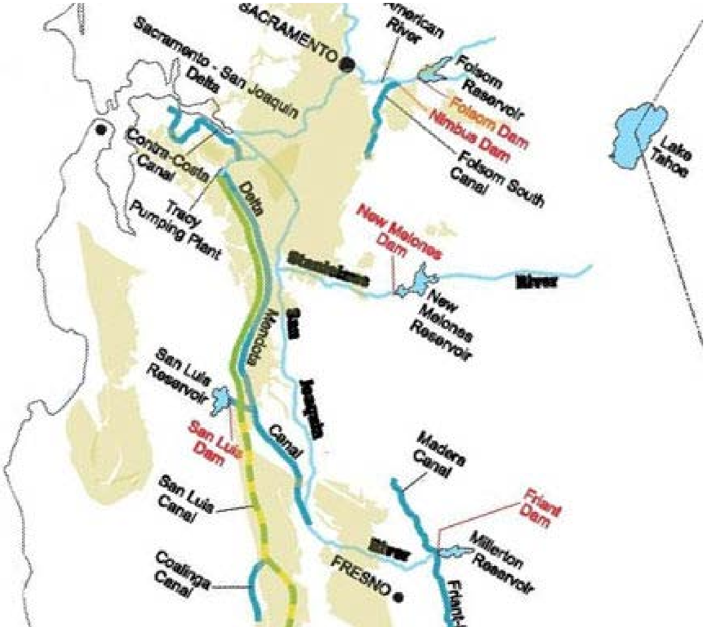
Central Valley Project – Delta-Mendota Canal



http://mavensphotoblog.com/

http://www.usbr.gov/

Central Valley Project – San Luis Reservoir

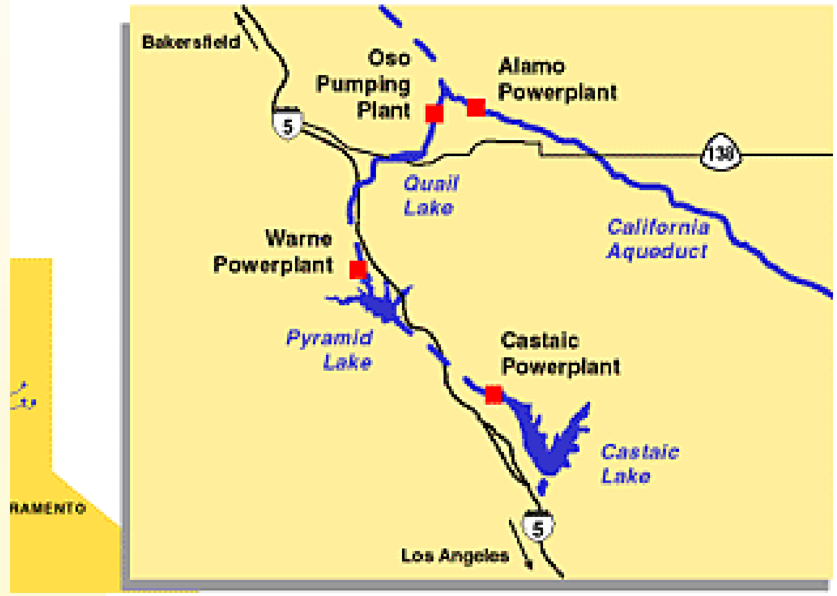


http://www.usbr.gov/

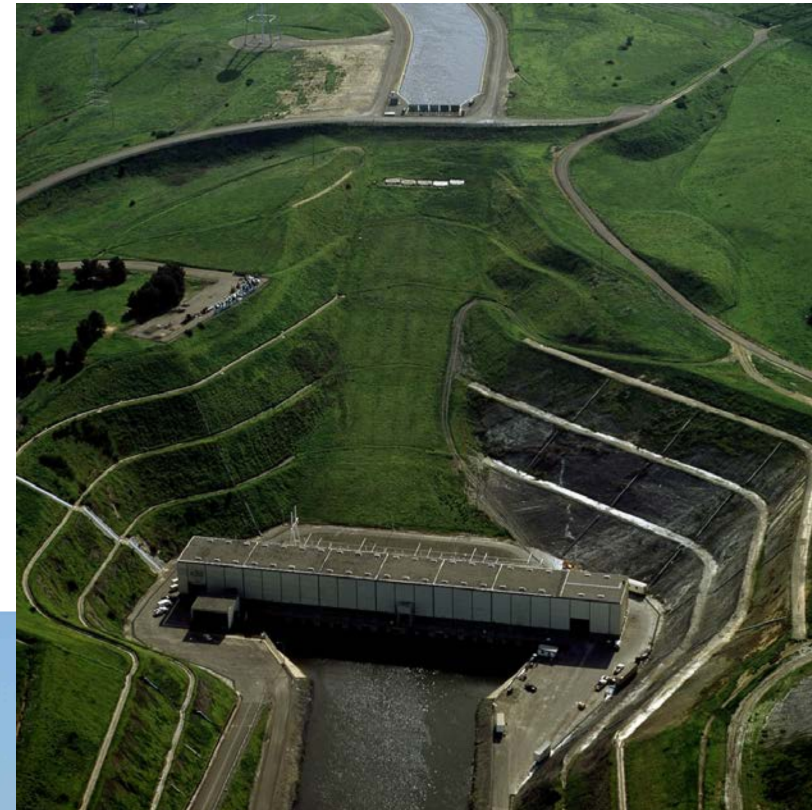
articles.latimes.com

State Water Project

SWP FACILITIES IN THE WEST BRANCH AREA



State Water Project



http://www.water.ca.gov/

Colorado River Supplies

In recent years, Arizona has begun to exercise full use of its basic apportionment, & Nevada has approached full use of its entitlement & surplus allocation

Before 2003, California's annual use of Colorado River water ranged between 4.5-5.2 maf

However …

Therefore …

California has had to reduce its dependence on Colorado R. water to 4.4 maf in average years

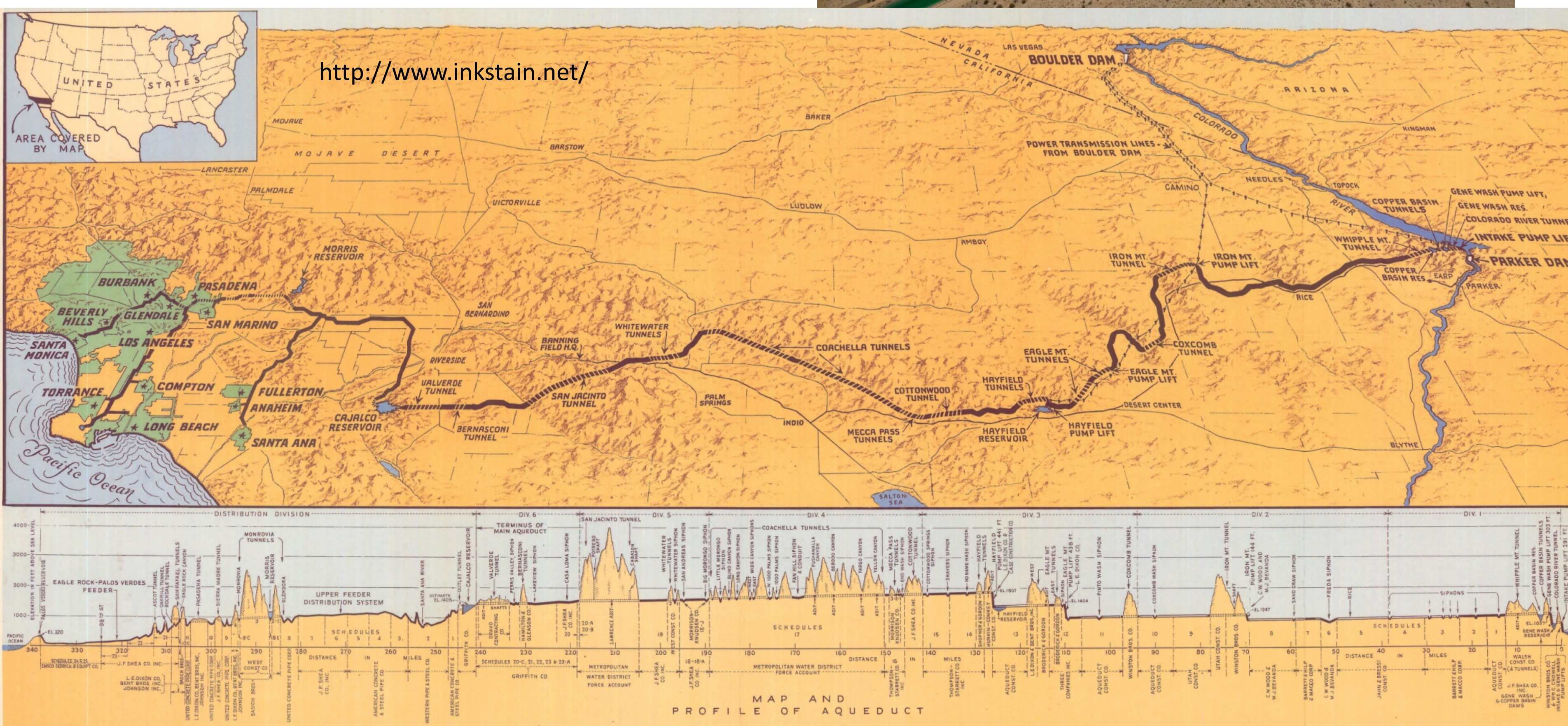
And …

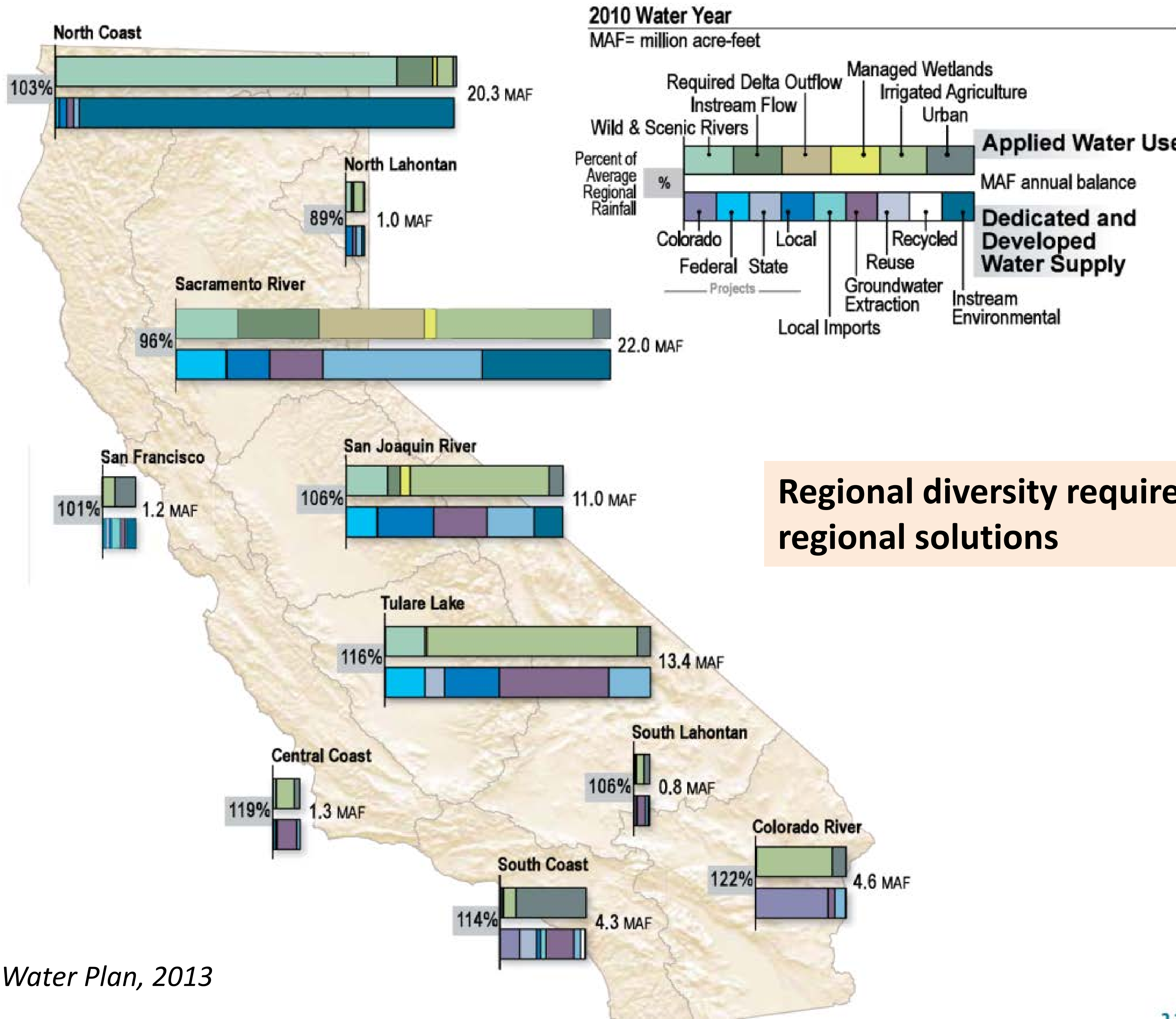
A record 8-yr drought in the Colorado basin has reduced current reservoir storage throughout the river system to just over 50% of total storage capacity

Colorado River Supplies

Glen Canyon Dam, en.wikipedia.org

Colorado River Aqueduct

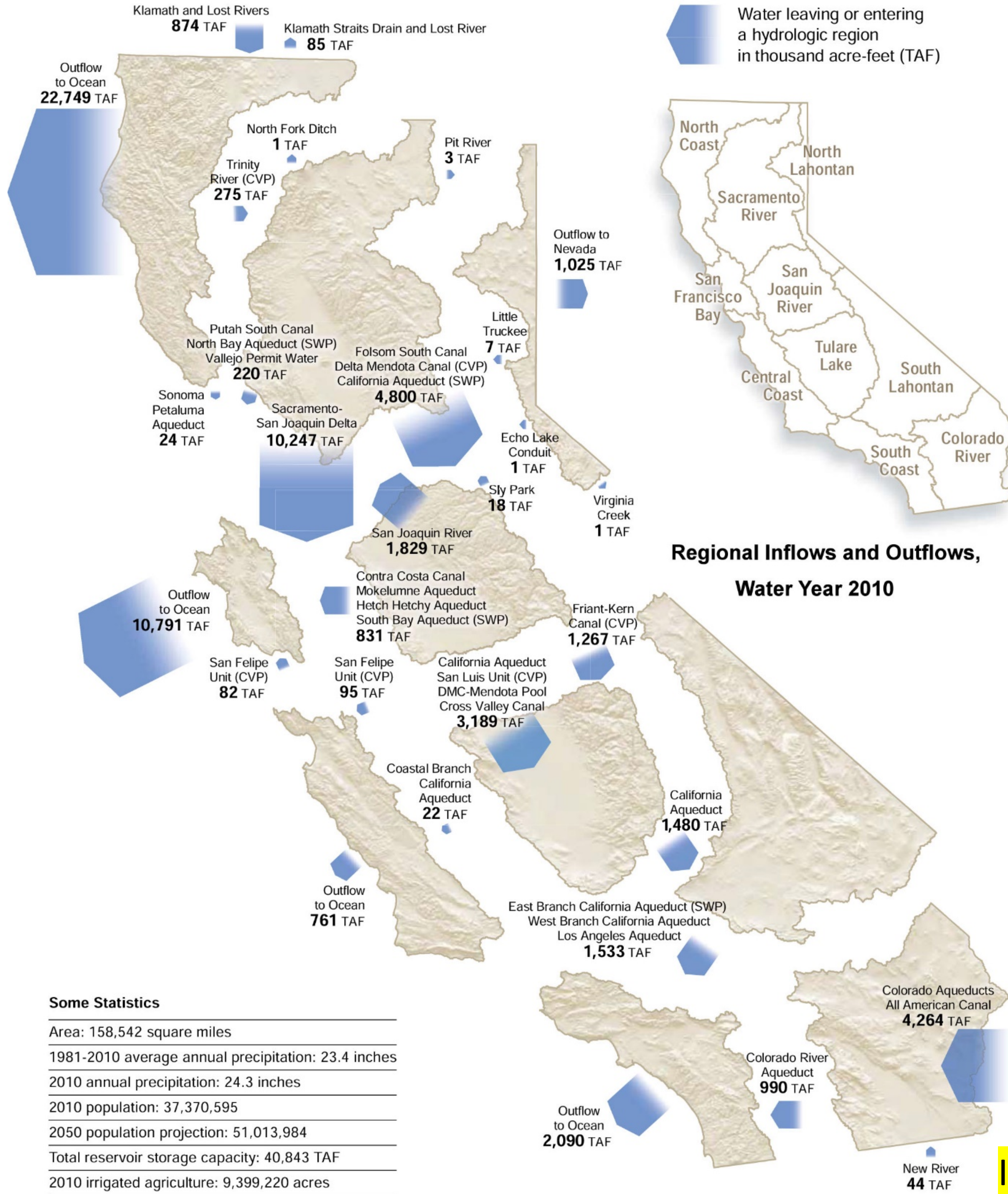




Regional diversity requires regional solutions

CA Water Plan, 2013

Regional redistribution of water



Regional Inflows and Outflows, Water Year 2010

Some Statistics

Area: 158,542 square miles
1981-2010 average annual precipitation: 23.4 inches
2010 annual precipitation: 24.3 inches
2010 population: 37,370,595
2050 population projection: 51,013,984
Total reservoir storage capacity: 40,843 TAF
2010 irrigated agriculture: 9,399,220 acres

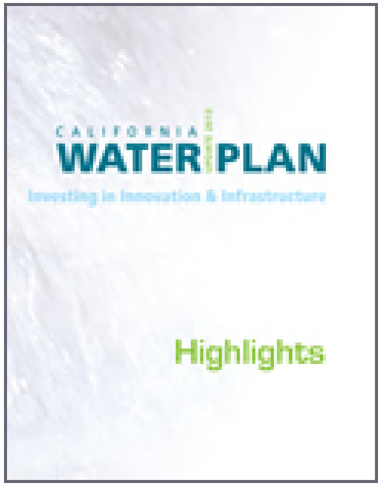
CA Water Plan, 2013

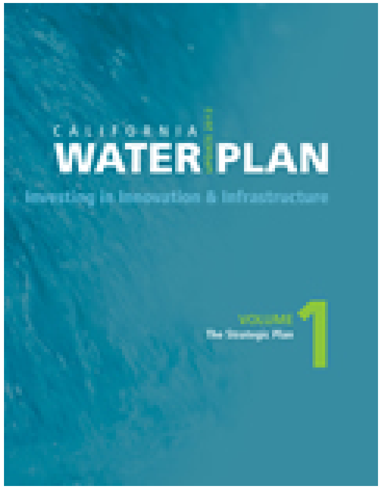
Table 3-2 California Statewide Water Balance for 2001-2010 (in maf)

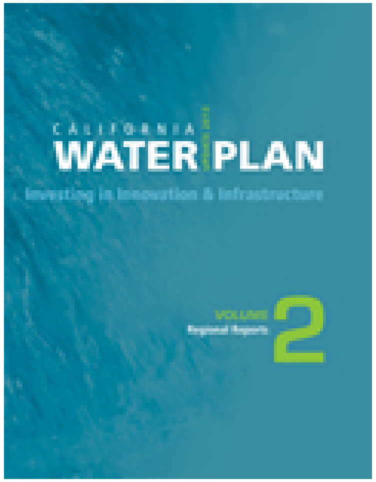
Statewide (maf)	Water Year (Percent of Normal Precipitation)									
	2001 (72%)	2002 (81%)	2003 (93%)	2004 (94%)	2005 (127%)	2006 (127%)	2007 (62%)	2008 (77%)	2009 (77%)	2010 (104%)
WATER ENTERING THE REGION										
Precipitation	139.2	160.1	184.4	186.5	251.9	251.1	123.3	152.2	151.8	205.0
Inflow from Oregon/Mexico	1.1	1.1	1.1	1.1	1.0	2.3	1.2	1.2	1.0	0.9
Inflow from Colorado River	5.2	5.4	4.5	4.8	4.2	4.6	4.7	4.9	4.6	4.7
Imports from Other Regions	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total	**145.5**	**166.6**	**190.0**	**192.4**	**257.1**	**258.0**	**129.2**	**158.3**	**157.4**	**210.6**
WATER LEAVING THE REGION										
Consumptive use of applied water[a] (Ag, M&I, Wetlands)	26.5	27.7	25.7	28.2	23.7	25.6	28.6	29.0	28.1	25.0
Outflow to Oregon/Nevada/ Mexico	0.5	0.8	1.1	0.8	1.4	2.1	0.8	0.9	1.0	1.1
Exports to other regions	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Statutory required outflow to salt sink	12.6	23.1	31.0	26.0	24.6	43.7	20.3	20.6	18.3	24.4
Additional outflow to salt sink	14.8	13.6	18.7	18.1	20.0	48.4	9.2	10.6	8.6	13.8
Evaporation, evapotranspiration of native vegetation, groundwater subsurface outflows, natural and incidental runoff, ag effective precipitation & other outflows	105.4	111.2	118.7	133.2	183.7	142.9	89.8	114.3	113.4	149.2
Total	**159.8**	**176.4**	**195.2**	**206.3**	**253.4**	**262.7**	**148.7**	**175.4**	**169.4**	**213.5**
CHANGE IN SUPPLY										
[+] Water added to storage [-] Water removed from storage										
Surface reservoirs	-4.6	0.1	3.7	-4.1	7.9	1.4	-8.0	-3.9	1.1	5.1
Groundwater[b]	-9.7	-9.6	-8.7	-9.8	-4.1	-6.1	-11.5	-13.1	-13.1	-8.0
Total	**-14.3**	**-9.5**	**-5.0**	**-13.9**	**3.8**	**-4.7**	**-19.5**	**-17.0**	**-12.0**	**-2.9**
Applied water[a] (ag, urban, wetlands) (compare with consumptive use)	43.7	46.6	43.3	47.2	41.6	44.4	48.1	47.9	46.5	42.7

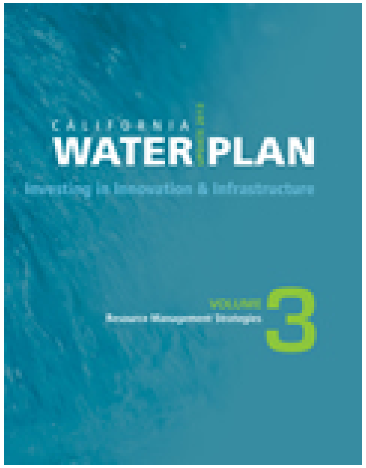
CA Water Plan, 2013

California Water Plan, 2013



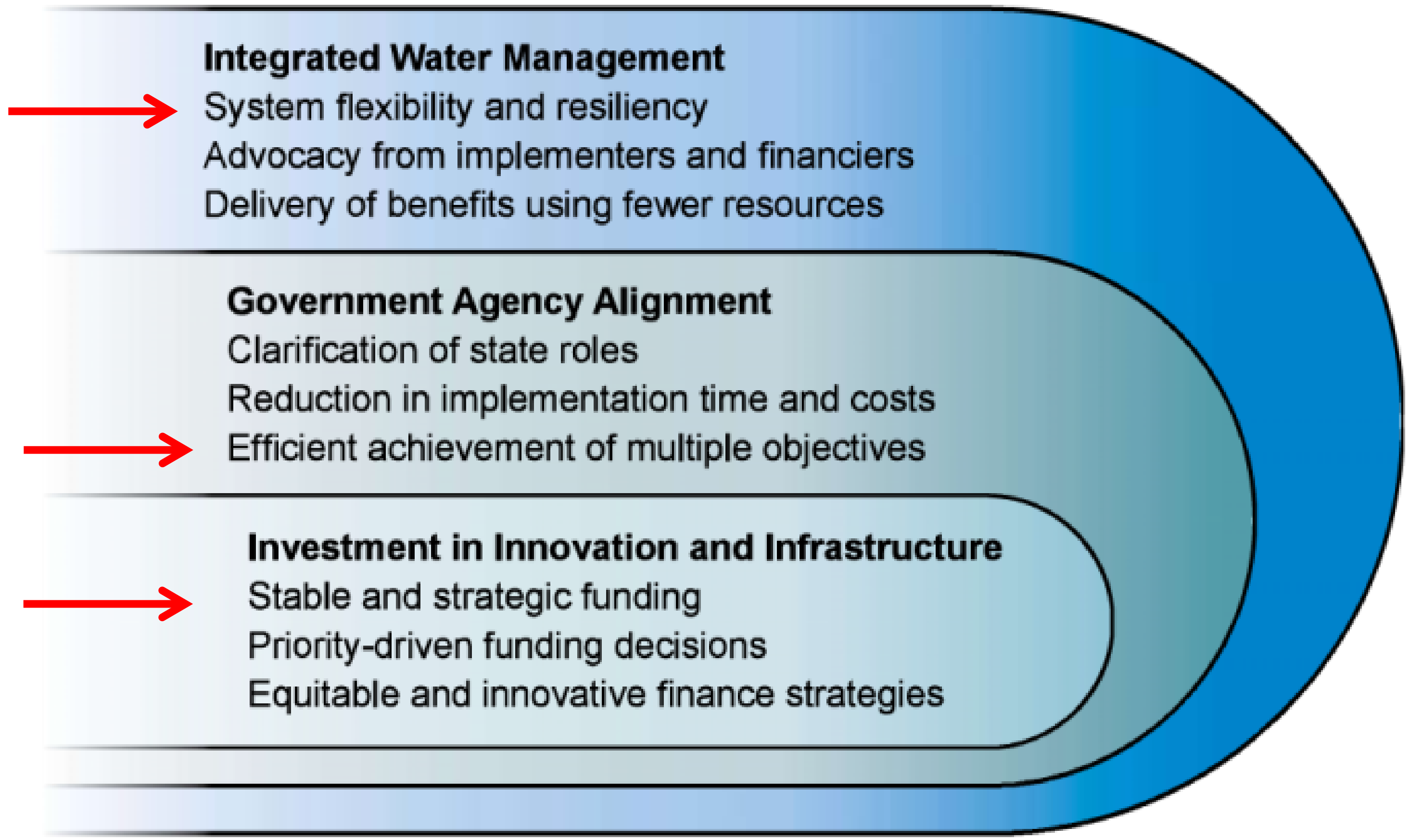






http://www.waterplan.water.ca.gov/cwpu2013/

California Water Plan – themes



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California Water Plan Highlights – summary

California Water Plan Update 2013 | **Highlights**

A Resource for Implementing the Governor's Water Action Plan

This guide links two key State government plans: the Governor's Water Action Plan (Five-Year Plan) and the more long-term Update 2013. Linkages are shown between implementation actions in Update 2013 that advance one or more of the Governor's 10 priorities in the Five-Year Plan. The actions related to the 17 objectives in Update 2013 represent the alignment of nearly 40 State agency plans and are well supported by the State's diverse stakeholder groups and opinion leaders.

Use this table to access more than 300 specific actions in Update 2013. The Update 2013 actions are presented topically by the 17 objectives and related resource management strategies (RMSs) listed in the table. The specific actions behind the objectives and RMSs can be accessed in Volume 1, Chapter 8, "Roadmap for Action," and Volume 3, *Resource Management Strategies*, respectively.

How the 10 Essential Actions Are Advanced in Update 2013

Water Action Plan's 10 Essential Actions	**Make conservation a California way of life**	**Invest in integrated water management and increase regional self-reliance**	**Achieve the coequal goals for the Delta**	**Protect and restore important ecosystems**	**Manage and prepare for dry periods**	**Expand water storage capacity**	**Provide safe drinking water and secure wastewater systems to all communities**	**Increase flood protection**	**Improve operational and regulatory efficiency**	**Identify sustainable and integrated financing opportunities**
Update 2013 Objectives (Volume 1, Chapter 8) *See foldout 11A-11B for an explanation of Update 2013 Objectives*	#2 – Use and Reuse Water More Efficiently	#1 – Strengthen Integrated Regional Water Management Planning #10 – Improve Data, Analysis, and Decision-Support Tools #17 – Improve Integrated Water Management Finance Strategy and Investments	#7 – Manage the Delta to Achieve the Coequal Goals for California	#4 – Protect and Restore Surface Water and Groundwater Quality #5 – Practice Environmental Stewardship #9 – Reduce the Carbon Footprint of Water Systems and Water Uses #14 – Public Access to Waterways, Lakes, and Beaches	#2 – Use and Reuse Water More Efficiently #3 – Expand Conjunctive Management of Multiple Supplies #7 – Manage the Delta to Achieve the Coequal Goals for California #8 – Prepare Prevention, Response, and Recovery Plans	#3 – Expand Conjunctive Management of Multiple Supplies (includes groundwater and surface storage)	#4 – Protect and Restore Surface Water and Groundwater Quality #12 – Strengthen Tribal/State relations and Natural Resources Management #13 – Ensure Equitable Distribution of Benefits	#6 – Improve Flood Management Using an Integrated Water Management Approach	#3 – Expand Conjunctive Management of Multiple Supplies #16 – Strengthen Alignment of Government Processes and Tools	#17 – Improve Integrated Water Management Finance Strategy and Investments
Resource Management Strategies (Volume 3)	• Ag Water Use Efficiency • Urban Water Use Efficiency • Recycled Municipal Water • Outreach and Engagement • Economic Incentives • Water and Culture	All 30+ RMSs can enhance regional self-reliance, depending on where they are implemented and how the benefits are allocated.	All 30+ RMSs have the potential to help meet Delta coequal goals, depending on where they are implemented and how the benefits are allocated.	• Six RMSs involve water quality • Ag Lands Stewardship • Ecosystem Restoration • Forest Mgmt. • Land Use Planning and Mgmt. • Recharge Area Protection • Sediment Mgmt. • Watershed Mgmt. • Water and Culture	(Partial list) • Ag Water Use Efficiency • Urban Water Use Efficiency • Recycled Municipal Water • Conjunctive Mgmt. of Surface and Groundwater • CALFED/Local/ Regional Surface Storage	• Conjunctive Mgmt. of Surface and Groundwater • CALFED Surface Storage • Local/Regional Surface Storage • System Reoperation	Nearly all 30+ RMSs can help provide safe water and wastewater to all communities, depending on where they are implemented and how the benefits are allocated.	• Flood Management • Land Use Planning and Management • Sediment Management • Watershed Management • Urban Stormwater Runoff Management • Forest Management	• Conveyance Delta • Conveyance Regional/Local • System Reoperation • Water Transfers	

Cross-Cutting Objectives (Volume 1, Chapter 8)

- #10 – Improve Data, Analysis, and Decision-Support Tools
- #11 – Invest in Water Technology and Science
- #12 – Strengthen Tribal/State Relations and Natural Resources Management
- #13 – Ensure Equitable Distribution of Benefits
- #15 – Strengthen Alignment of Land Use Planning and Integrated Water Management
- #16 – Strengthen Alignment of Government Processes and Tools
- #17 – Improve Integrated Water Management Finance Strategy and Investments

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Context for water-resources management

The highly diverse population, climate and ecosystems result in many objectives that stakeholders consider important considerations for water-resources management

Examples

- Facilitate access to safe drinking water for disadvantaged communities.
- Achieve environmental-water quality objectives.
- Control invasive species.
- Maintain a reasonably high standard of living and quality of life.
- Enhance economic stability.
- Minimize greenhouse-gas emissions in water management activities.
- Improve water supply reliability.
- Reduce direct property damage resulting from floodwater.
- Reduce high-severity wildfires.
- Many more …

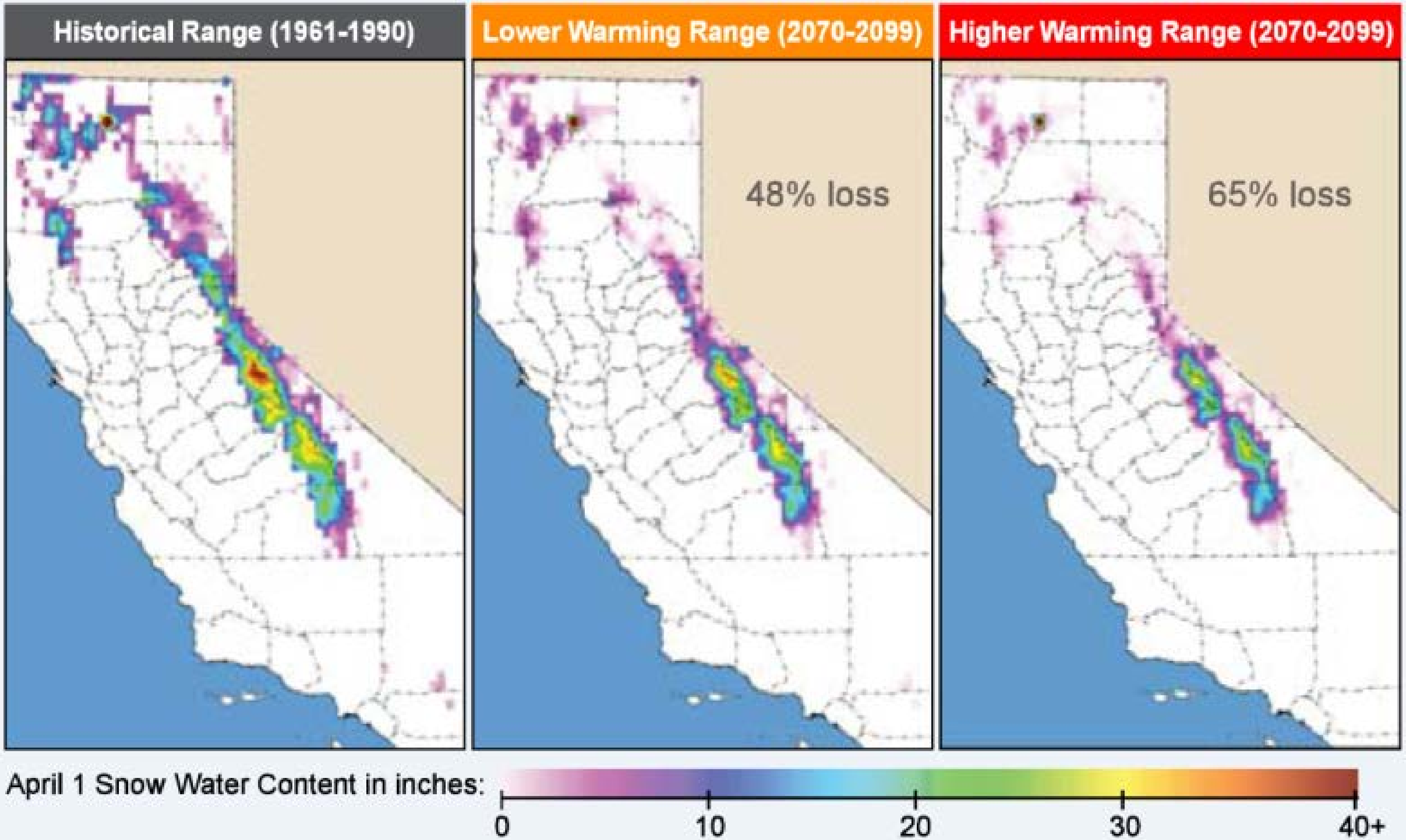
Public lands

USDA Forest Service — 20,741,000 acres.
U.S. Bureau of Land Management — 15,128,485 acres.
National Park Service — 7,559,121 acres.
U.S. Fish and Wildlife Service — 472,338 acres.

All of California is about 100 million acres

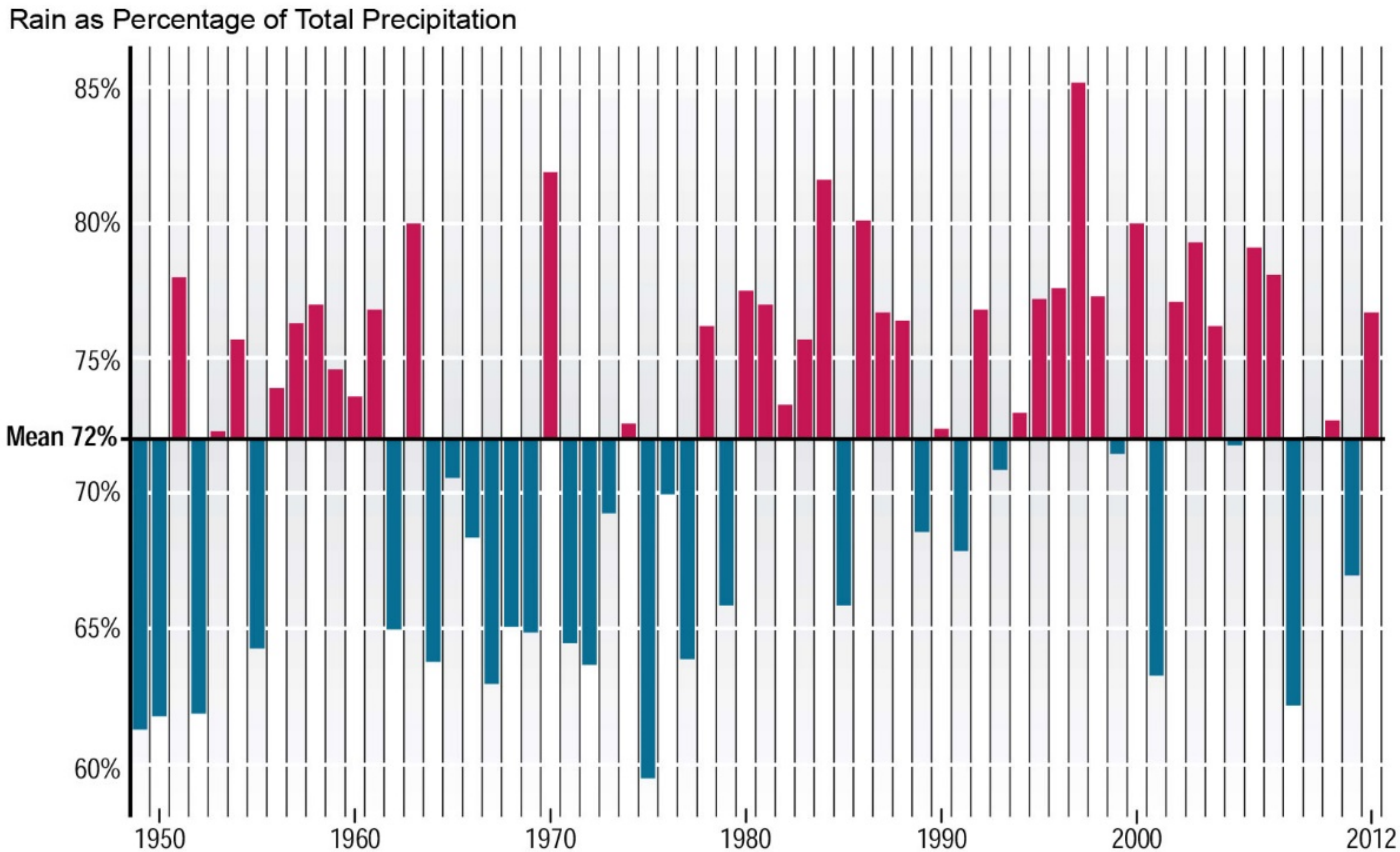
Climate change is affecting California's water

California Is Losing Its Largest Surface Reservoir



Historical and projected April 1 snow water content for the Sierra for lower and higher warming scenarios depicting the effect of human-generated greenhouse gases and aerosols on climate. By the end of this century, the Sierra snowpack is projected to experience a 48 to 65 percent loss from its average at the end of the previous century (Pierce and Cayan 2013).

Rain versus snow

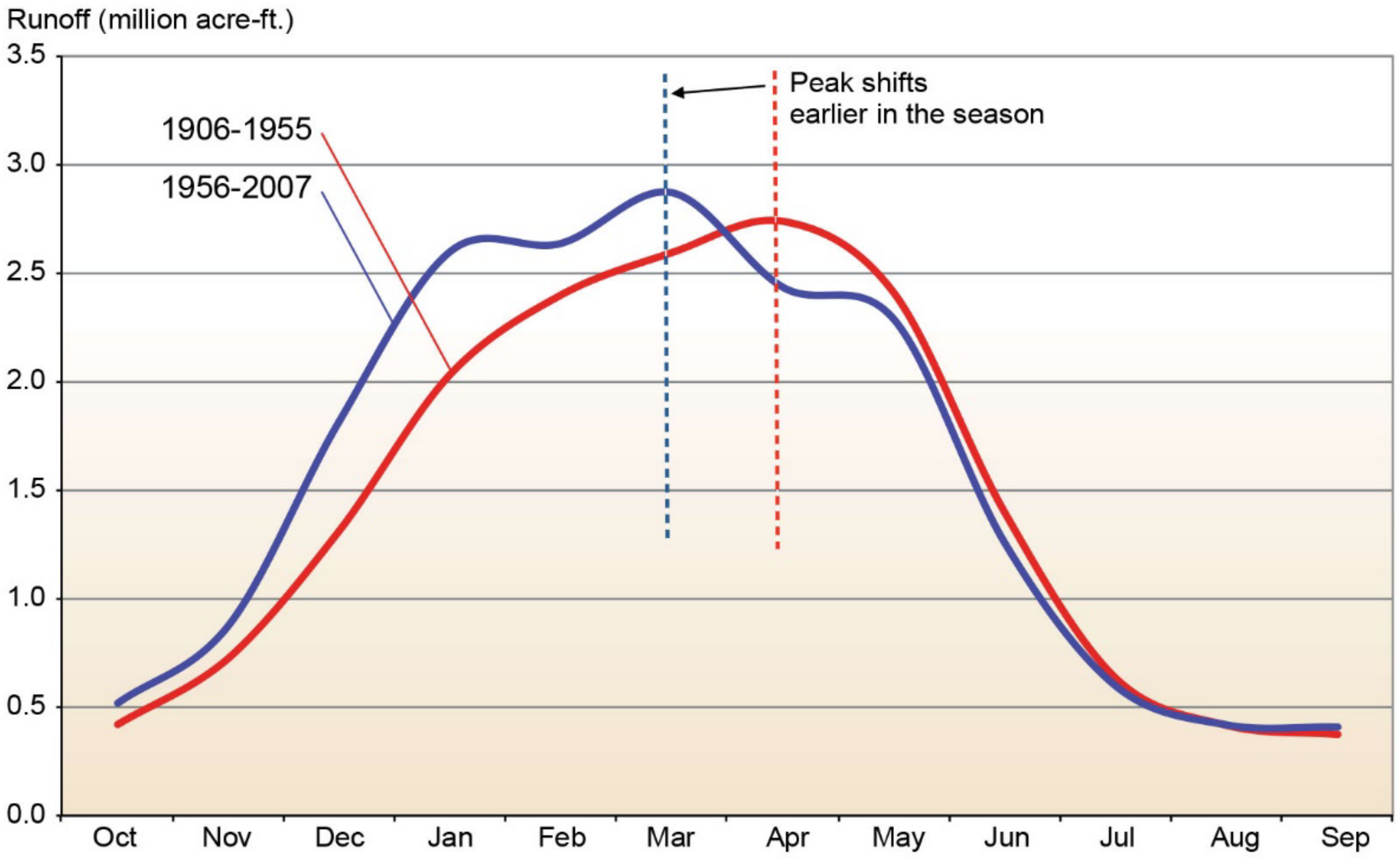


Note: Percentage of precipitation falling as rain over the 33 main water-supply watersheds of the State is shown for water years ending 1949 through 2012 (Oct. 1948-Sept. 2012), using Western Region Climate Center historic precipitation and freezing level re-analysis (http://www.wrcc.dri.edu).

These watersheds experience a mean of 72 percent of precipitation as rain; years with red bars have a higher percentage of rain than the mean, and years with blue bars have a lower percentage of rain than the mean. Years with a higher percentage of rain are more common in the later period of record, in agreement with expectations under a warming climate and previous studies. There is substantial annual variability resulting from climate signals that occur on annual and decadal scales.

CA Water Plan, 2013

Monthly average runoff in Sacramento River system



Note: Average monthly runoff in the Sacramento River System is a critical component of California's water supply. Flood protection and water supply infrastructure have been designed and optimized for historical conditions. However, the timing of peak monthly runoff between 1906-1955 (redline) and 1956-2007 (blue line) has shifted nearly a month earlier, indicating that this key hydrology metric is no longer stationary. Timing is projected to continue to move earlier in the year, further constraining water management by reducing the ability to refill reservoirs after the flood season has passed.

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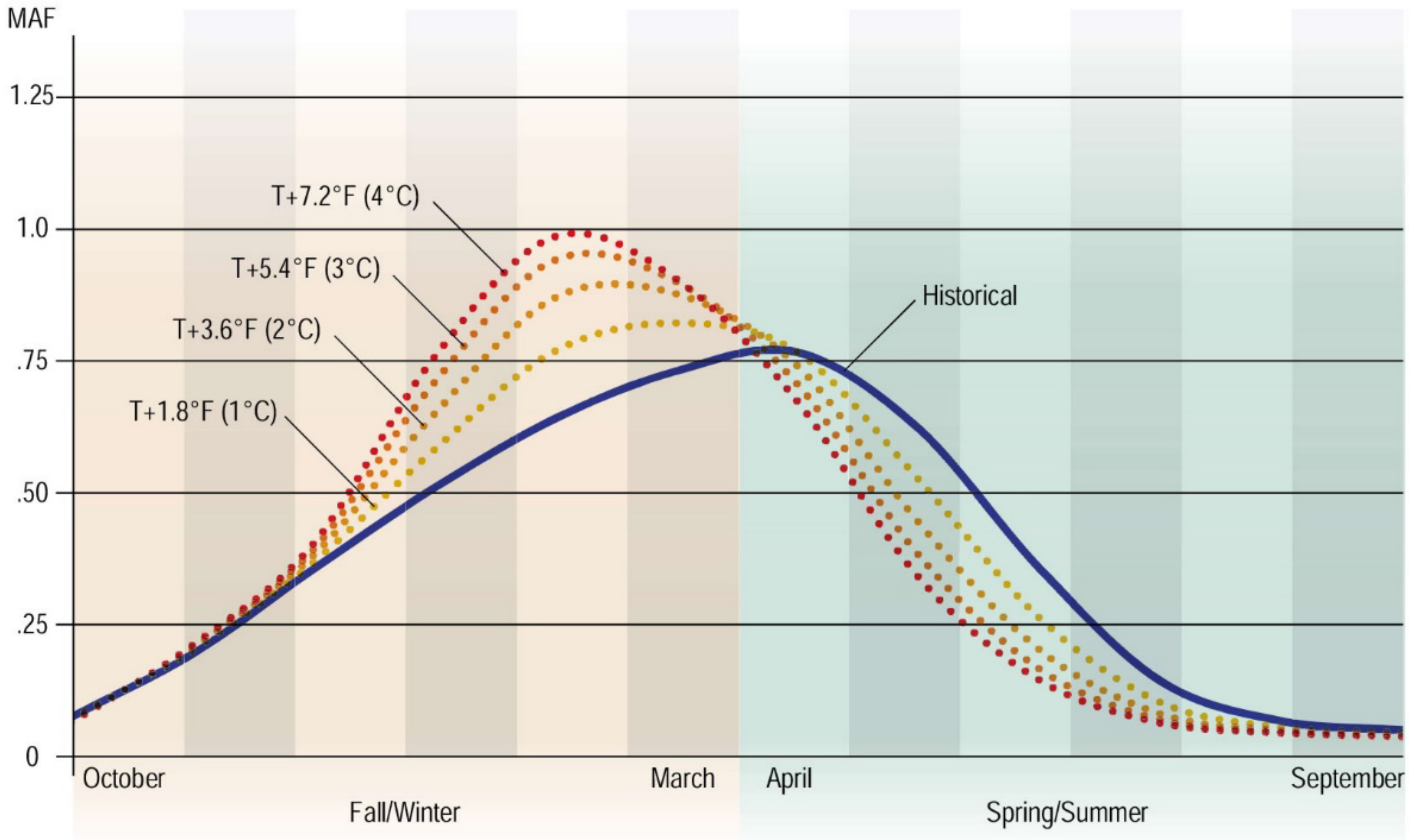
Climate change impacts on State Water Project inflow to Oroville



Note: Climate warming will cause substantial reductions in the natural storage of water in the accumulation and melt of seasonal snowpack. Earlier runoff during the spring snowmelt period will occur. Monthly average natural stream inflows to Lake Oroville (water year 1922-2010), before being regulated by reservoir operation and diversions, were simulated with a rainfall-runoff model (SWAT). The results shown in this figure indicate that the reduction in spring snowmelt runoff for water supply can only be recovered and captured by additional reservoir storage as air temperature increases.

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How earlier runoff affects water availability

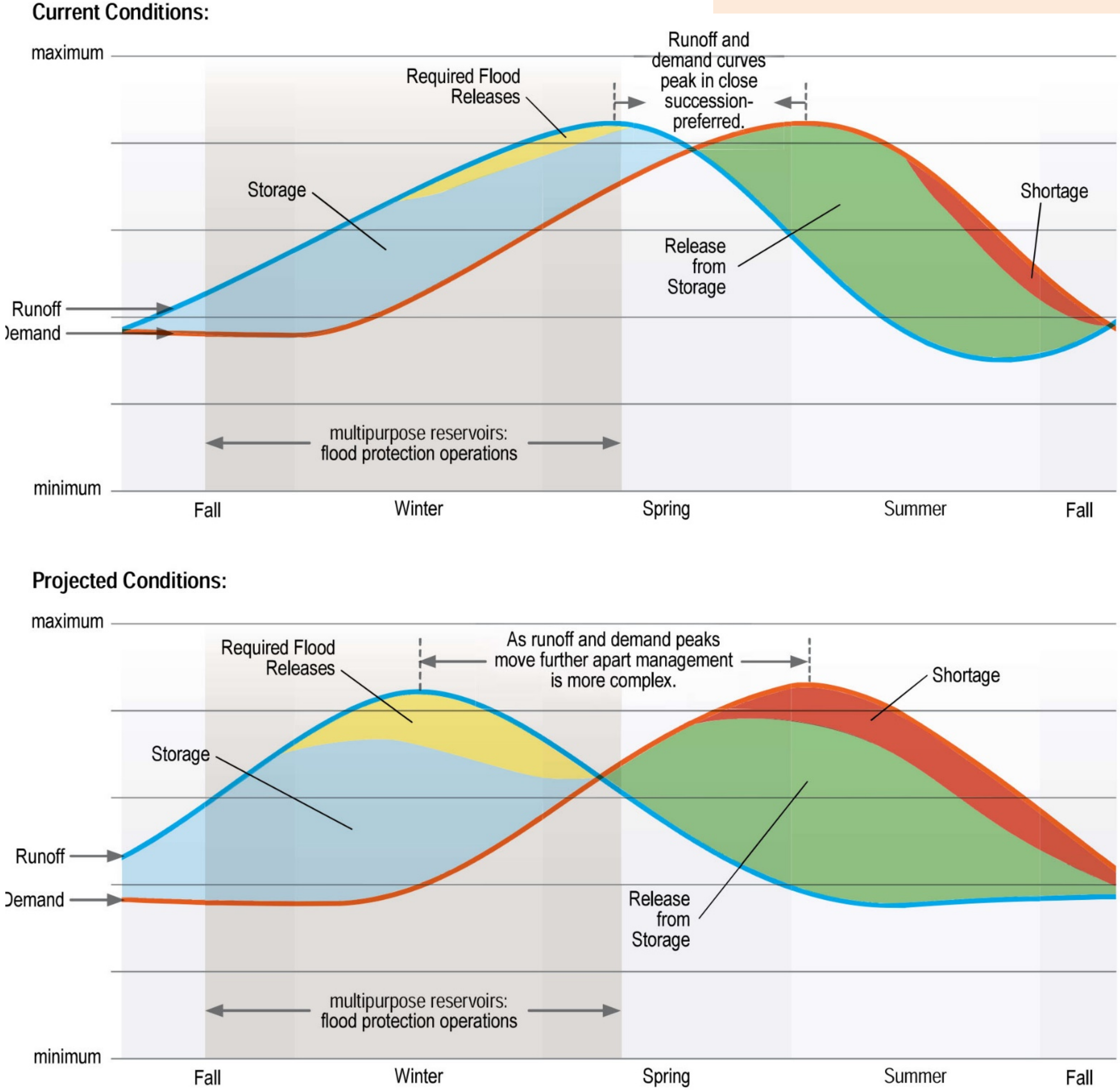

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Table 3-1 California Population Change 2005 to 2010 Statewide and by Hydrologic Region

Hydrologic Region	2005 Population	2010 Population	Growth
North Coast	656,064	671,344	2.3%
San Francisco Bay	6,132,111	6,345,194	3.5%
Central Coast	1,486,250	1,528,708	2.9%
South Coast	19,176,154	19,579,208	2.1%
Sacramento River	2,846,723	2,983,156	4.8%
San Joaquin River	1,999,295	2,104,206	5.2%
Tulare Lake	2,093,865	2,267,335	8.3%
North Lahontan	97,644	96,910	-0.8%
South Lahontan	806,672	930,786	15.4%
Colorado River	690,804	747,109	8.2%
Total	35,985,582	37,253,956	3.5%

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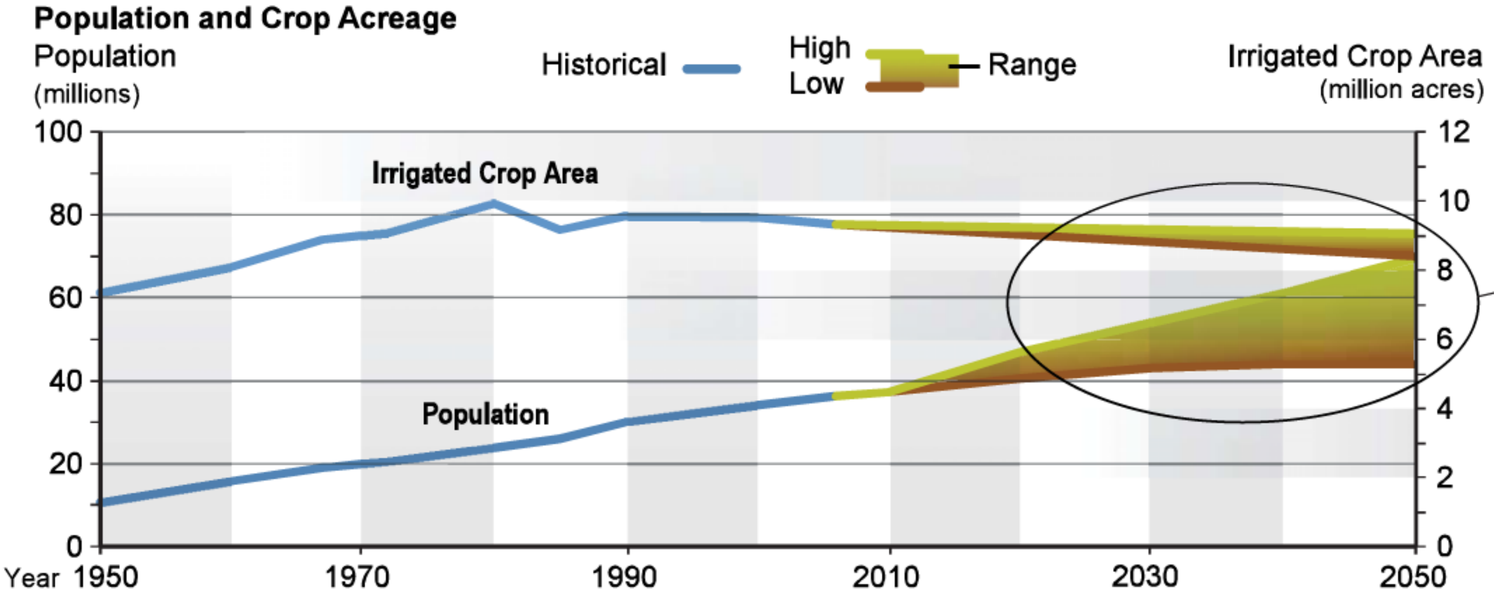
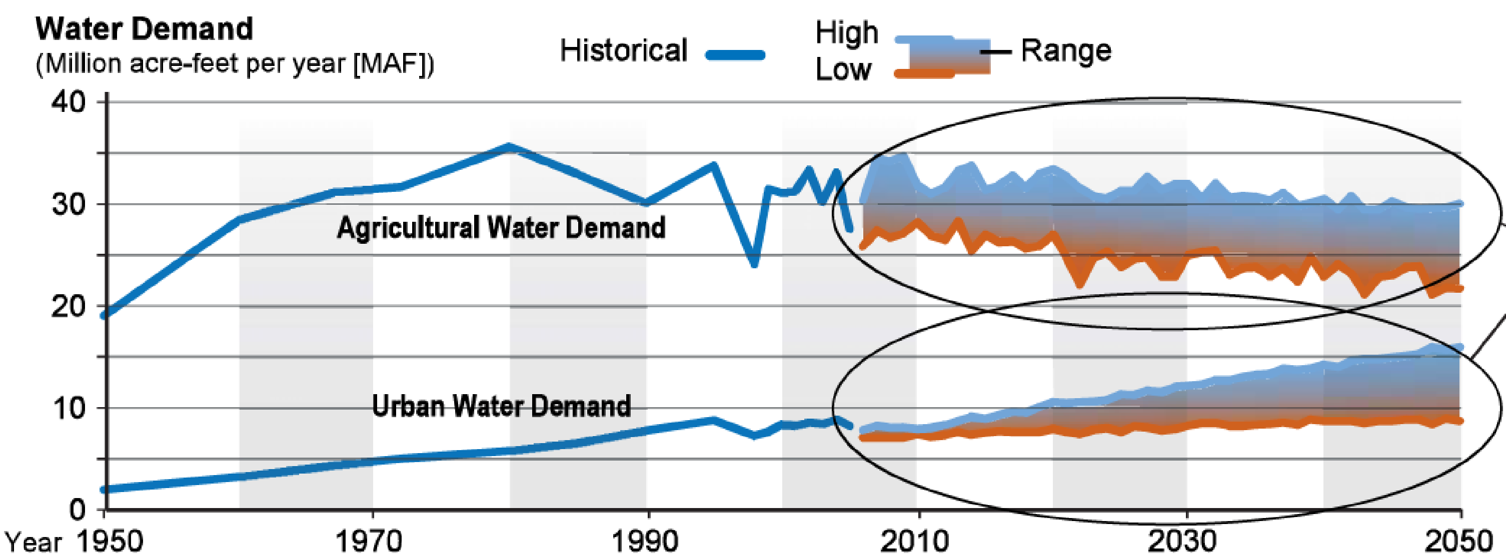
California water futures



Year 2050 scenarios considered population between 43.9 and 69.4 million people and irrigated crop area between 8.4 and 9.2 million acres.*



By 2050, urban water demand could increase by 1.0-6.7 MAF/yr, and agricultural demand could decrease by 2.0-5.9 MAF/yr.*

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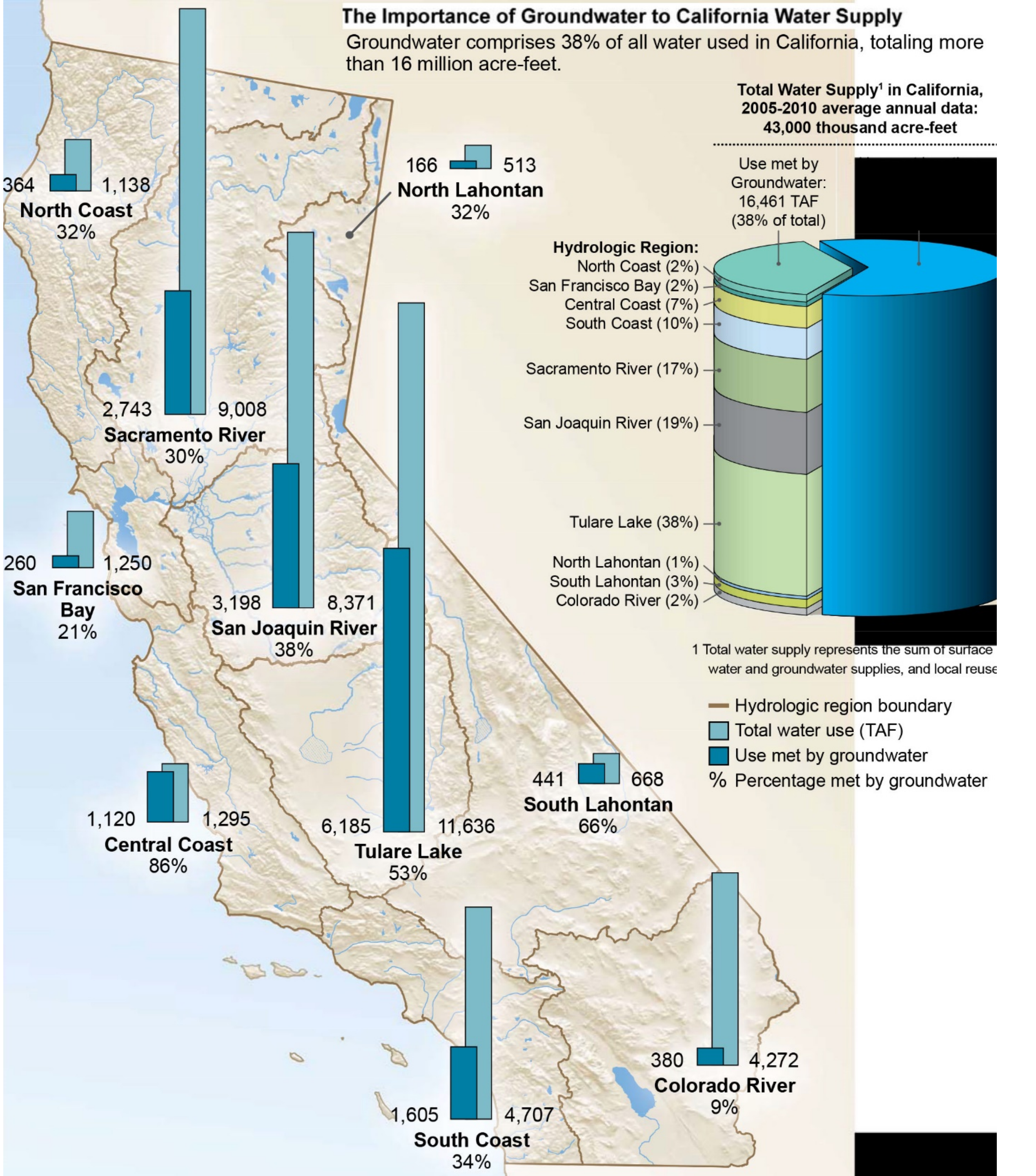
Recent groundwater use



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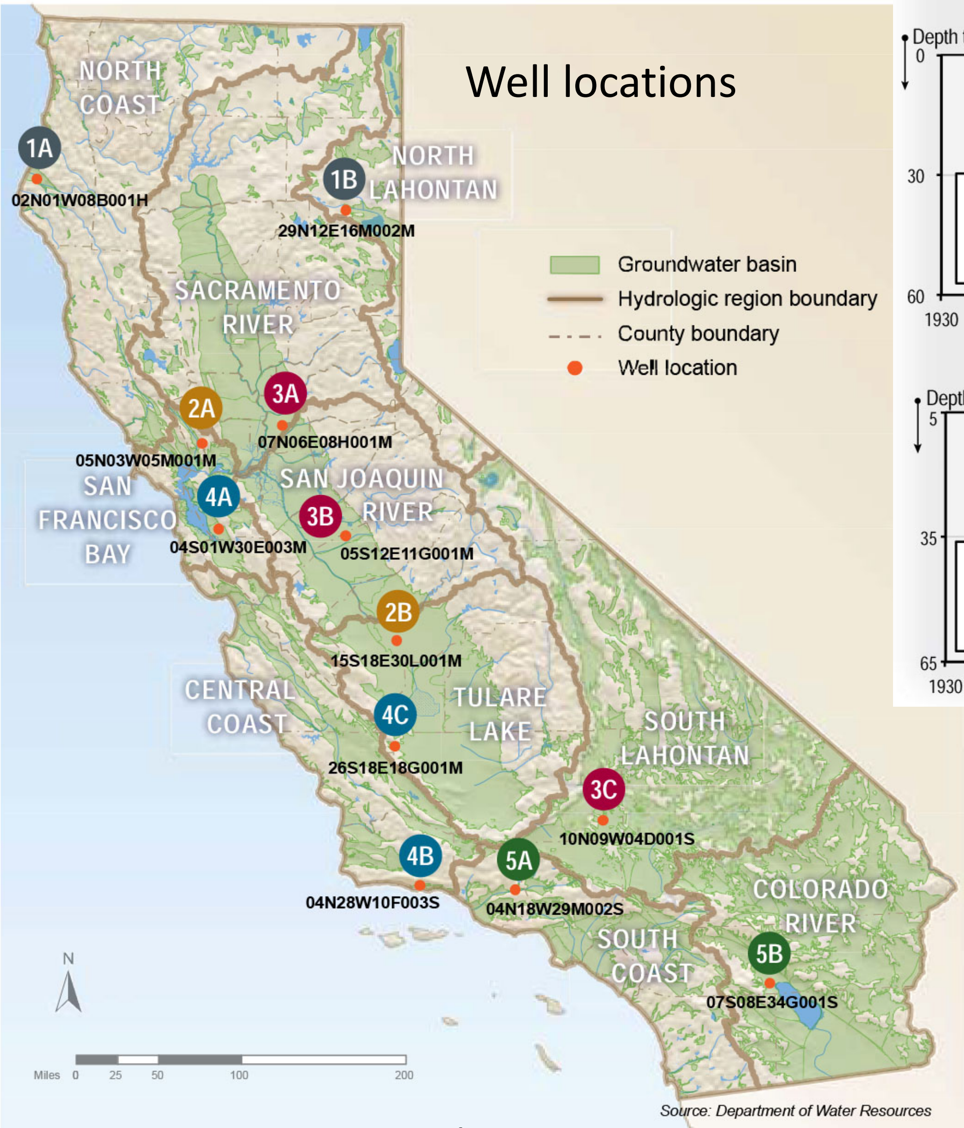
California groundwater level trends

Aquifer response to changing demand & management



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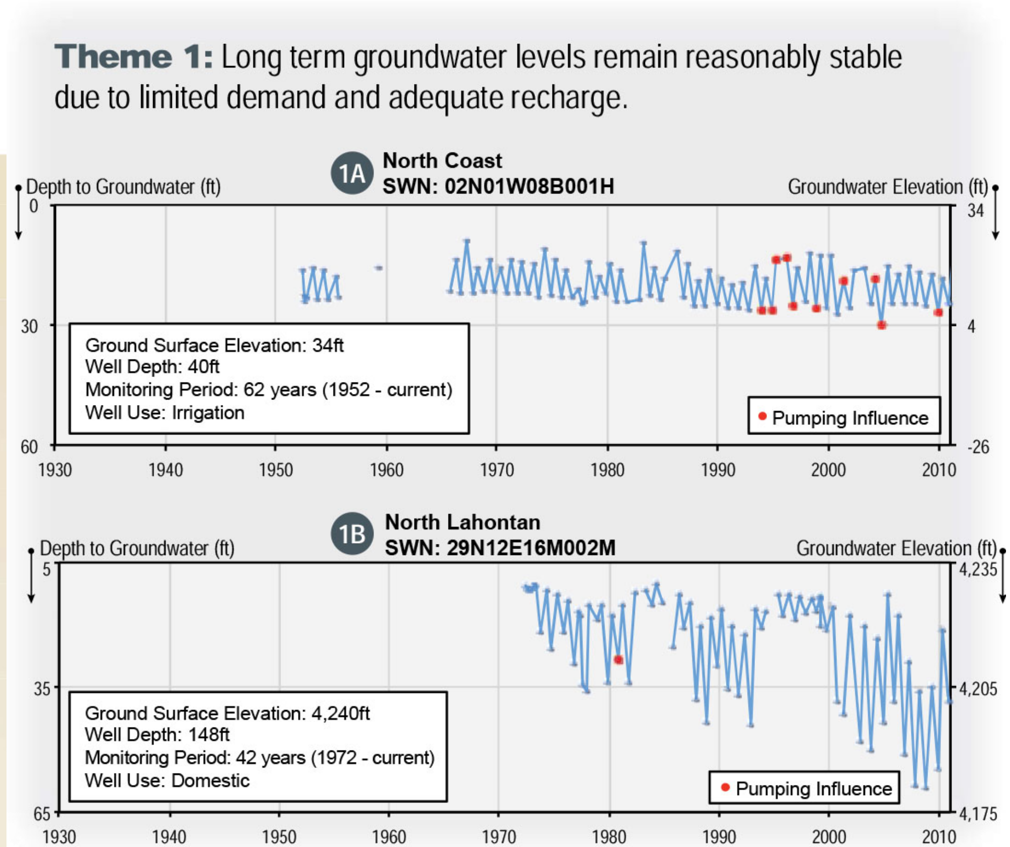
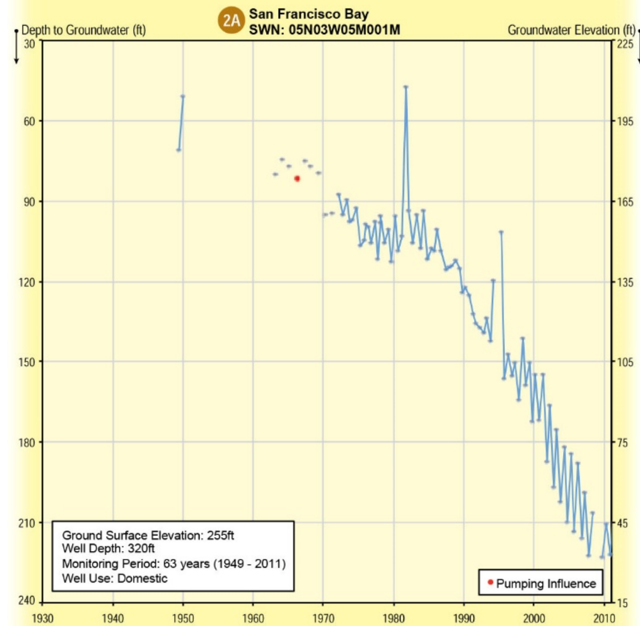


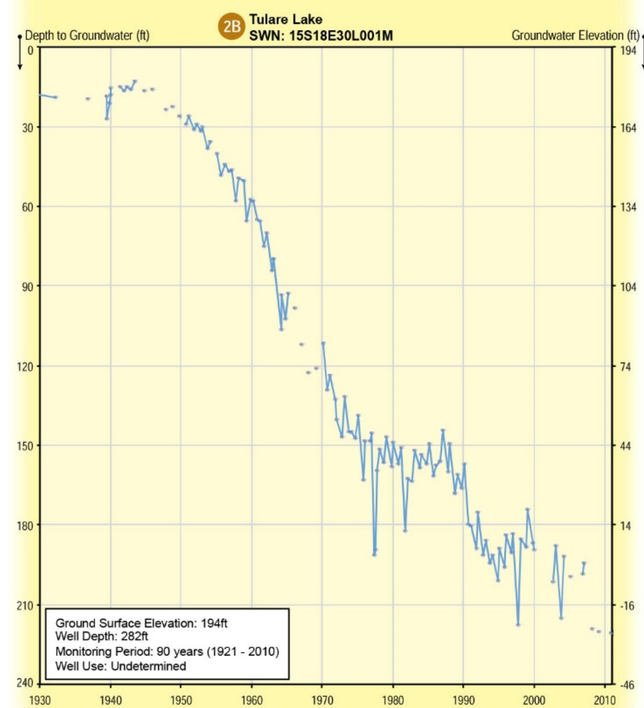
California groundwater level trends

Aquifer response to changing demand & management

CA Water Plan, 2013

Theme 2: Long-term decline in groundwater levels due to annual demand being consistently greater than annual recharge.





California groundwater level trends

Aquifer response to changing demand & management

Well locations

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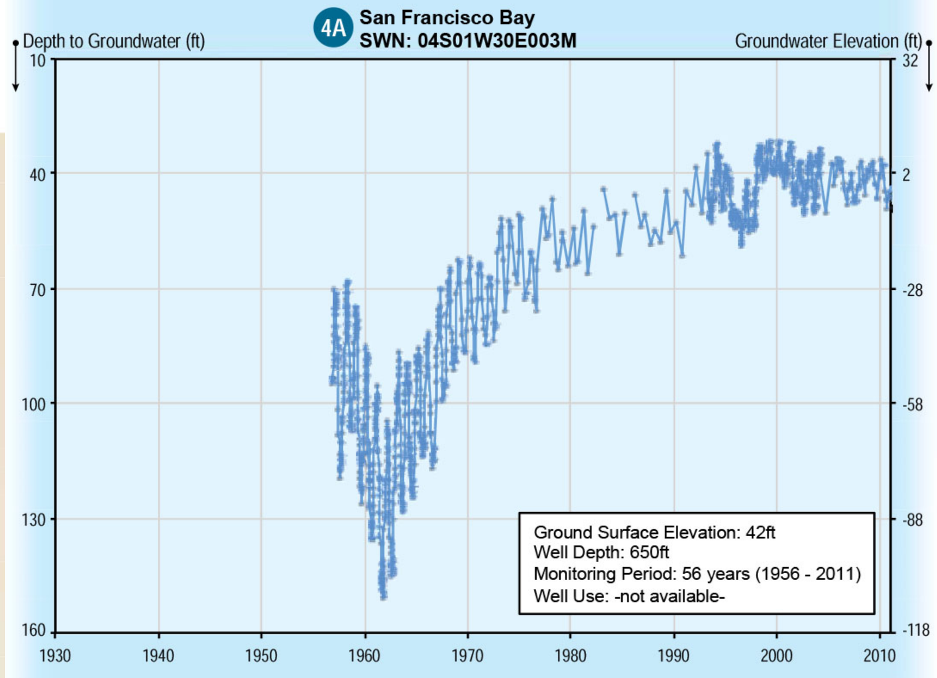
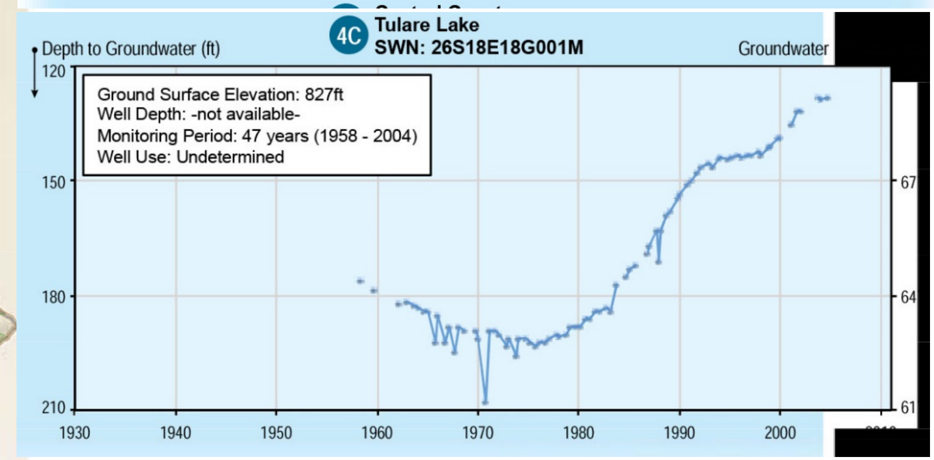
Theme 4: Long-term decline in groundwater levels that have stabilized and improved, due to reduced demand and increased recharge.

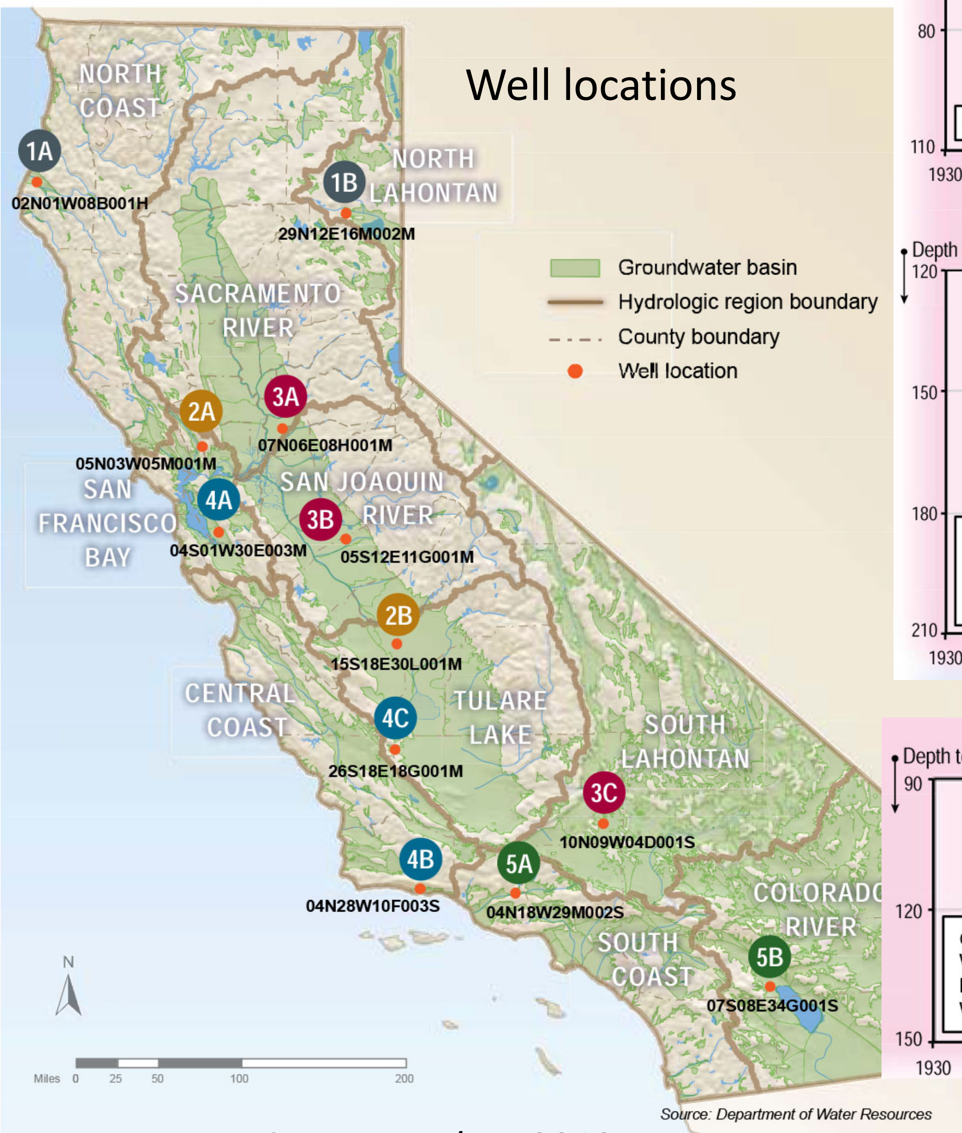




California groundwater level trends

Theme 3: Long-term decline in groundwater levels that have stabilized but not recovered, due to reduced demand.

Aquifer response to changing demand & management



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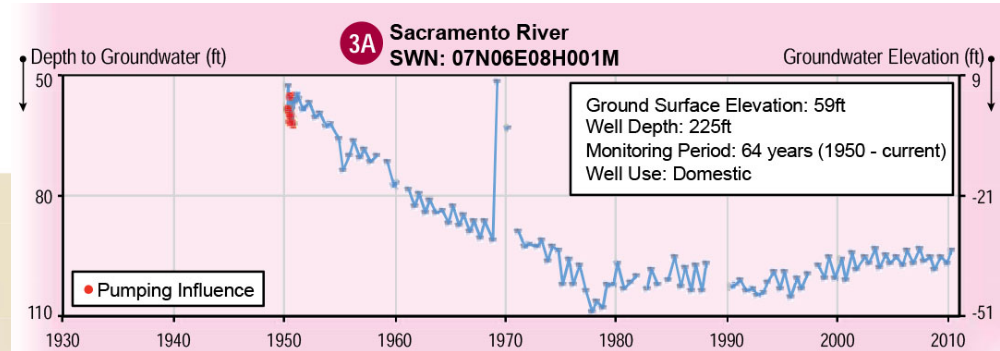
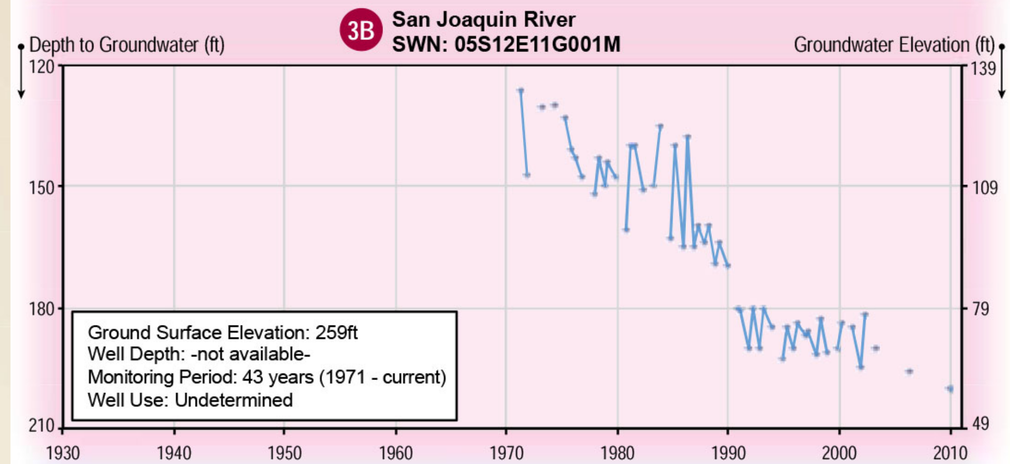
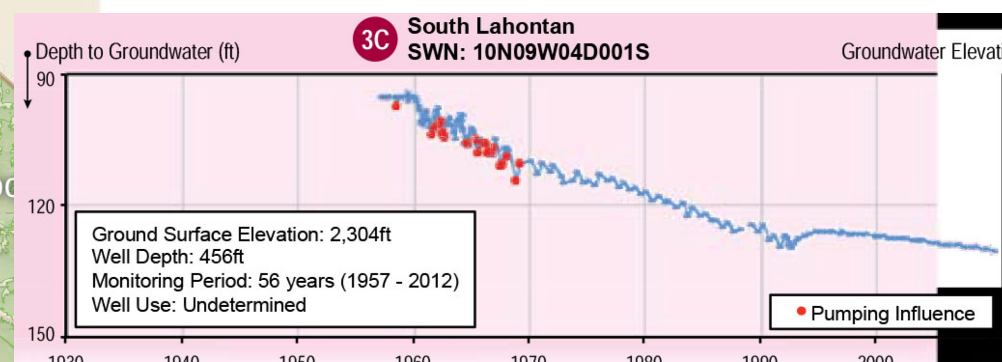
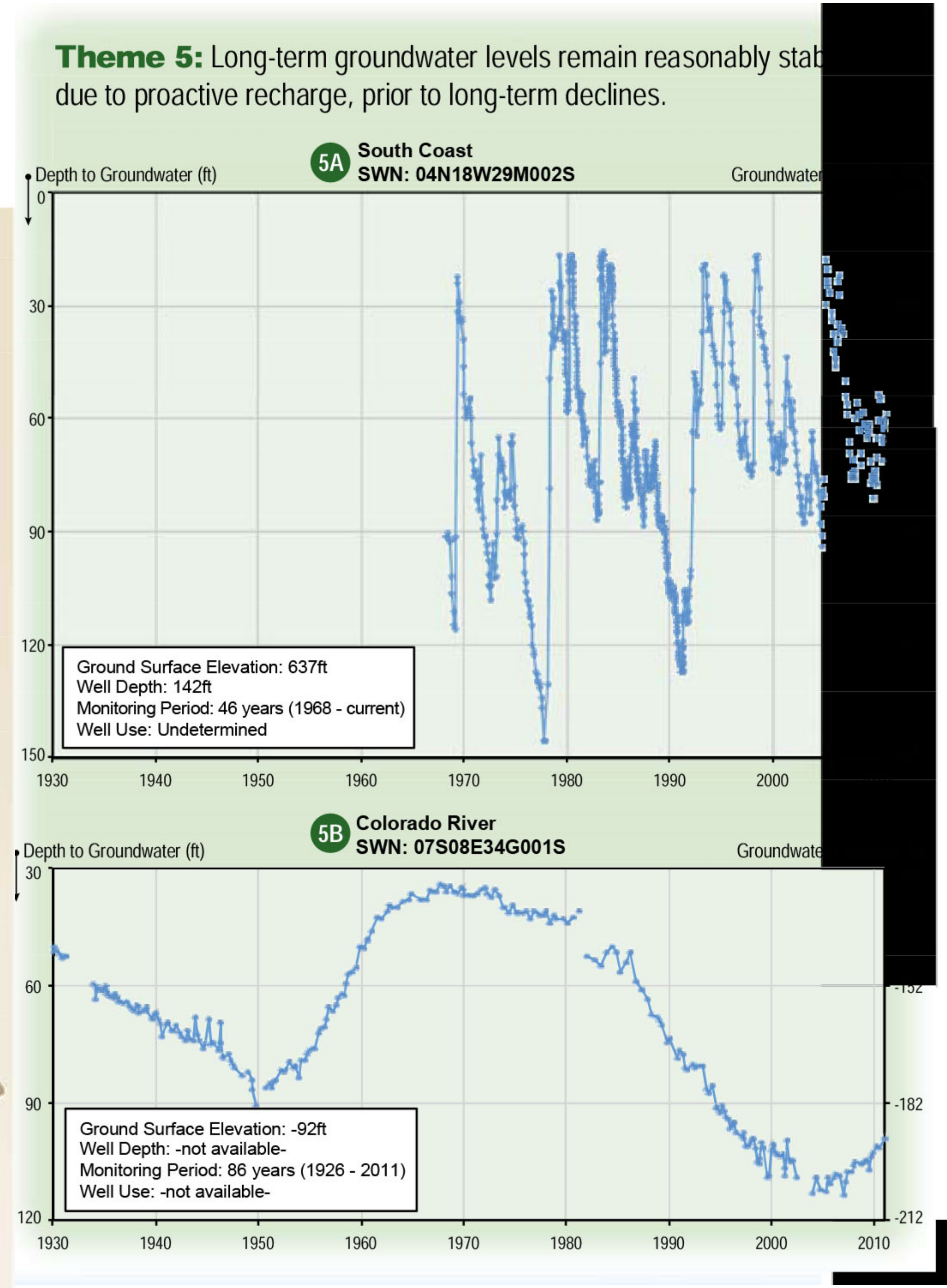






California groundwater level trends

Aquifer response to changing demand & management



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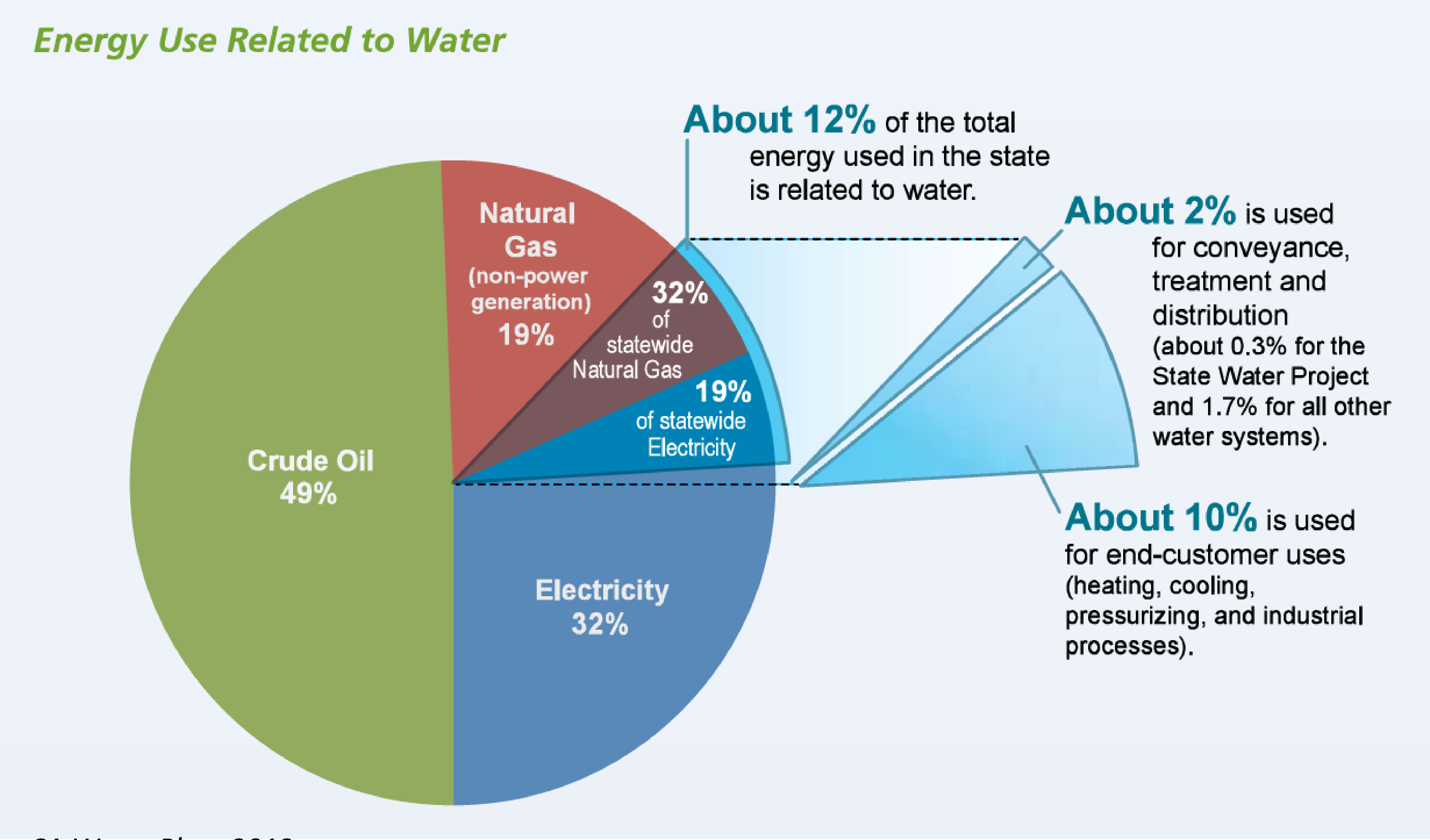
Water-energy nexus



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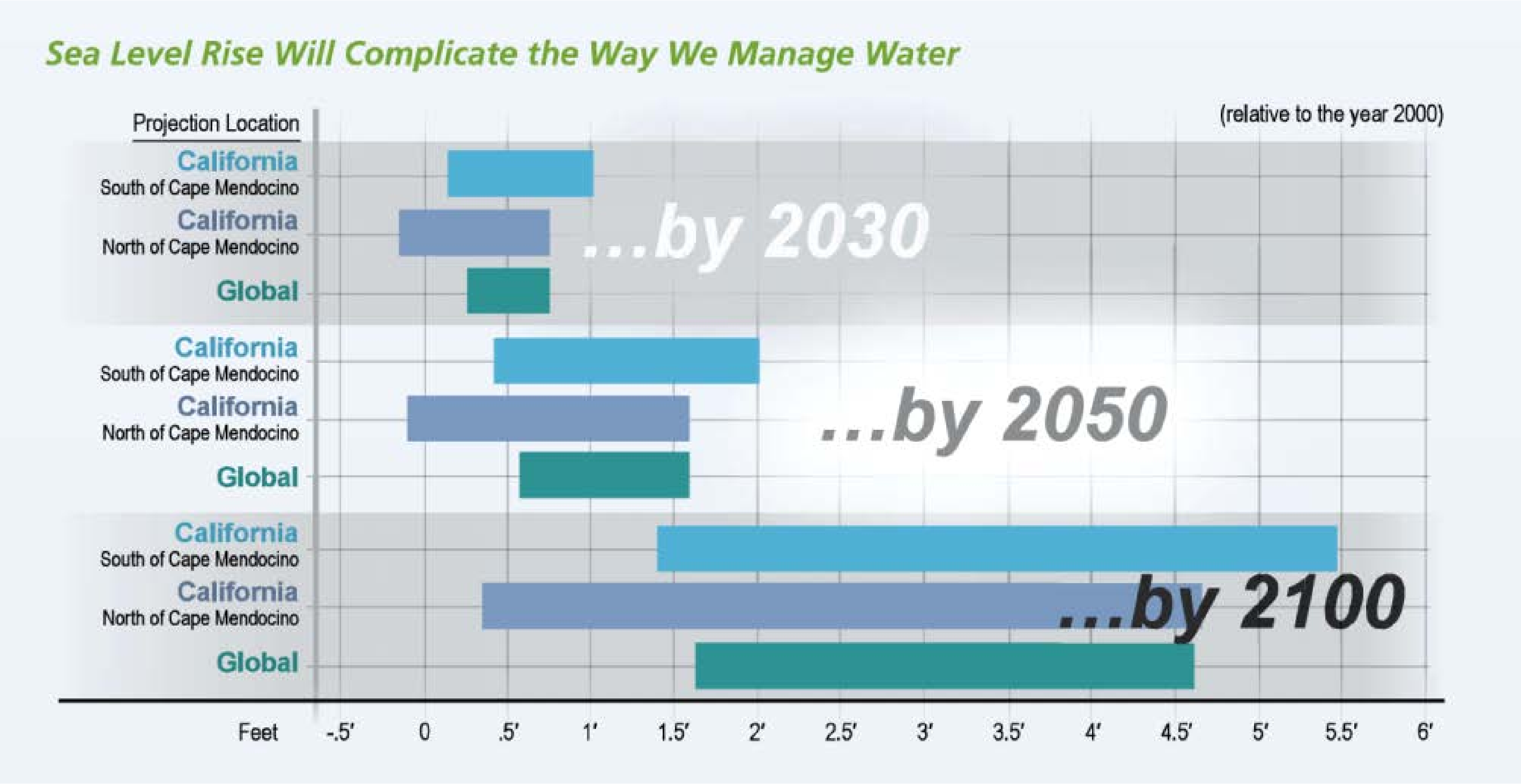
Climate change is affecting California's water



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Investments to increase resilience

Increasing Resilience in the Sacramento Region[1]

Response Package	Urban Supply Reliability	Agricultural Supply Reliability	Change in Ground-water Conditions	Meeting New Ecosystem Flows	Average Annual Cost above Current Plan
Currently Planned	High	High	Medium	Medium	$0
+ Conservation + Recycling + Groundwater Recovery Targets + New Ecosystem Flow Targets	High	High	High-Medium	Medium	$300

Increasing Resilience in the Tulare Lake Region[1]

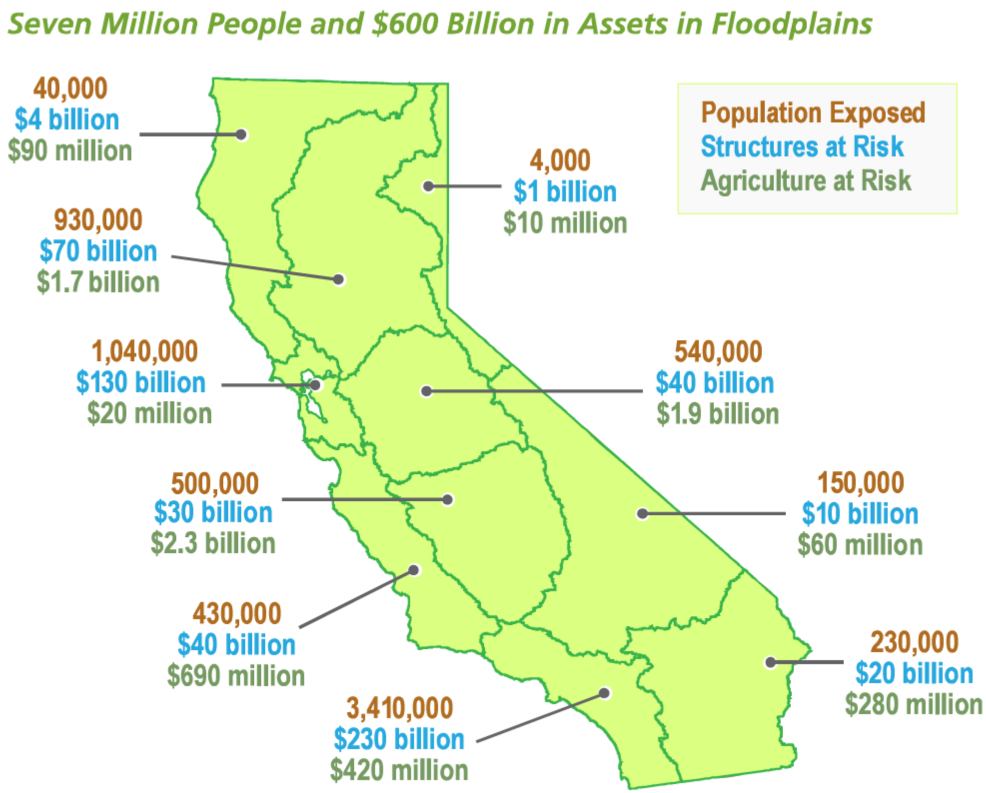
Response Package	Urban Supply Reliability	Agricultural Supply Reliability	Change in Ground-water Conditions	Average Annual Cost above Current Plan
Currently Planned	Medium	Low	Low	$0
+ Conservation + Recycling + Groundwater Banking + Groundwater Recovery Targets	High-Medium	Low	High-Medium	$550

Increasing Resilience in the San Joaquin Region[1]

Response Package	Urban Supply Reliability	Agricultural Supply Reliability	Change in Ground-water Conditions	Meeting New Ecosystem Flows	Average Annual Cost above Current Plan
Currently Planned	High	Medium	High-Medium	Low	$0
+ Conservation + Recycling + Groundwater Banking + Groundwater Recovery Targets + New Ecosystem Flow Targets	High	High	High	High	$400

CA Water Plan, 2013

Costs of inaction



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3 2

1997 flood, Yuba City area

Hydrologic context

January 2015
Roger Bales

Topics for class

1. Introduction to California water plan
2. Snapshot of California water conditions
3. History of water development in California

Goals

1. Develop an understanding of the multi-faceted and changing objectives of water management in California
2. Place water resources management in the context of hydrologic variability
3. Begin to understand how California's water resources management system has evolved

Questions

1. Your definition of water security, globally & for California?
2. For California, major areas for conflict? Compromise?
3. Fundamental barriers to water security, social, political, science, engineering?