Groundwater and the Interconnected Climate-Water-Social System
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Ruth Langridge
University of California, Santa Cruz

California’s Water Resources
Groundwater Management: History
Current Challenges
Dedicated water supplies:
Surface water ~70%  Groundwater ~30%, ~40% in dry years
California’s Climate

Wet in winter
Dry in summer

More rain in the north, less in the south

2.5 inches
San Diego

7 inches
Eureka

Heavy spring run off from snow melt
Early California
Development fueled by access to groundwater

1849 - 1910
Population soars after gold rush
Pioneer farmers find ready markets for their crops

1910-1950
Adoption of deep well turbine pump
Groundwater withdrawals increase

Number of pumping units:
1910 ~ 10,000
1930 ~ 50,000
1950 ~ 75,000

(Olmstead and Rhode 1997)
California's Central Valley

CA agricultural production 1950 - $400,000,000

https://giannini.ucop.edu/pdf/
Subsidence

1925-1955

Droughts: 1922-1924, 1929-1934

So much groundwater is pumped from aquifers that half the valley sinks 28 feet near Mendota

New surface storage & transmission systems promoted as a solution
Central Valley Project
1930s

State Water Project
1960s

By 1971, use of imported surface water surpasses use of groundwater,

BUT, groundwater pumping continues

Cotton & rice production expands
Southern San Joaquin Valley - 500,000 new acres come into production
Urban areas expand
Late 1800’s
Water wells pumped by wind power tap into LA groundwater basin
Expansive growth of population & agriculture.

South Coast – Urban – Los Angeles

1931
6th & Los Angeles
http://framework.latimes.com
Early 1900’s
Saltwater invades coastal aquifers
1950s
Basins are adjudicated-West Coast Replenishment District formed
Barrier wells created to inject water into the aquifers to block
further intrusion by building a line of pressure equal to
or exceeding protective elevations
Central Coast - Agriculture - Pajaro Valley

1890s
Apple farming & other cash crops planted
Berries gradually replace apples

Early 1900s
~ 4,000 rail cars of apples left the valley each year, bound for points all over the United States

Photograph: Pajaro Valley Historical Association
1953 - Basin in overdraft - saltwater intrusion
2000 - 54 square miles of basin below sea level

90% of water in Pajaro basin is pumped groundwater

2009
Recycled Water & Coastal Distribution System

2014
Seawater intrusion reduced, not halted
Average shortfall - 12,000 afa
Groundwater pumping increases substantially to compensate for reduced surface supplies.
1976-77 & 1987-92 Droughts

Changes in Farming
Population Growth
Declining Surface Water
Allocations

Triggers a new era of groundwater pumping
"California Drought Deepens as Another Year's Rains Stay Away"

San Jose Mercury News

2014

Northern Sierra 8 Station Precipitation for Water Years 2013 and 2014

Average

2013

2014
California’s Response to Drought

Pump More Groundwater

Rush to drill

Central Valley - 2013

Because surface water is scarce, an increasing number of wells have been drilled in the San Joaquin Valley to provide reliable water supplies. California law gives landowners the right to the water under their property.

Source: The counties

mercurynews.com/drought/ci_25447586/california---drought---san---joaquin---valley---sinking---farmers---race
Volume pumped during droughts generally exceeds replenishment during rains.

Central Valley model simulations

Coastal Pajaro Valley 5-year drought (1987 to 1992) – Water levels fall significantly and do not fully recover.
Additional Responses to Drought

Water Curtailment After a Drought Occurs
Develop Strategies to Generate More Supply

Conservation

Surface Storage

Desalination

Recycled Water
Caution!

Increase Water Supply During Dry Years

In Wet Years, Extra Water Can Lead to More Development

No Reserve and Hardening of Demand Strategies

Increased Vulnerability in Future Droughts

1970s - El Dorado County Irrigation District begins recycling water
2000 - Developers use recycled wastewater to build thousands of new homes

Sac Bee 2014
Groundwater Overdraft

1980
11 basins - critical overdraft;
31 basins - evidence of overdraft;
5 basins - special problems

1990
Groundwater Overdraft by Hydrologic Regions
(Average Water Year -- 1990 Development)

San Joaquin-CV
210,000 ac-ft

Sacramento River -- CV 30,000 ac-ft

Colorado River 60,000 ac-ft

South Lahontan 70,000 ac-ft

Central Coast 240,000 ac-ft

Central California

1990
San Joaquin-CV

Tulare-CV

Lake Tahoe -- CV 650,000 ac-ft

2013
Many of these basins show signs of continued depletion

DWR CA 2013
Climate Change and Water Supply Security:
Managing Groundwater to Increase Drought Resilience

PI - Ruth Langridge*
Co-PIs – Nigel Quinn,** Ben Crow,* Andrew Fisher*
Advisors –Emmanuel Asinas,****Marcelle DuPraw*** Graduate
Students - Kirsten Rudestam, Abigail Brown, Peter Towbin,
Bruce Daniels, Andrew Racz*

*University of California, Santa Cruz, **University of California, Merced and LBL, ***Sacramento State Center for Collaborative Policy, ****California Department of Water Resources
Groundwater as a Critical Resource During Drought

Local Groundwater Drought Reserves

Serve as a buffer during an extreme drought
Reduce overdraft impacts
Less energy intensive
Support groundwater dependent ecosystems

“..it never failed that during the dry years the people forgot about the rich years, and during the wet years they lost all memory of the dry years. It was always that way.” — John Steinbeck
How does our approach differ from current groundwater banking?

Reserves are *Sourced* – *Sited* – *Used* Locally

Goal is to recover groundwater levels to avoid further declines during a drought

Central Valley-Groundwater Storage Trends
10/04 - 10/09
J. S. Famiglietti et. al. (2010)
Our Research

Factors that affect drought resilience

Factors that motivate regions with conflicts over water to reduce groundwater overdraft

Impacts/costs of a groundwater drought reserve versus a no-reserve option

Groundwater pumping & energy use

Tools to assist regions in determining parameters for a reserve

Case Studies
Physical Context
- Sources of water
- Condition of groundwater basin

Legal-Institutional Context
- Water Rights, Governance

Socio-Political Context
- Stakeholder conflicts
- Agency/Board leadership
Legal-Institutional Context

State
No Permit System for Percolating Groundwater

Overlying Landowners
Correlative Rights Doctrine

Local Agencies
Primary Managers of Groundwater

Agencies - City & County Ordinances - Adjudicated Basins
What motivates local management to reduce overdraft and build resilience to water shortages?
Pajaro Valley Water Management Agency

Seawater Intrusion
1998-2011 - 12% increase
Since 1951, ~ sevenfold increase
Largest increases during droughts

Past Stakeholder Conflicts & Litigation

Current Project
Pajaro Valley In-Depth Case Study

Recycled Water Recharge Facilities Coastal Distribution System
The Purisima and Aromas Red Sands Aquifers provide all of SqCWDs water and are at risk for seawater intrusion.
Drought Reserve Project

Collaboration Between Santa Cruz Water Department and Soquel Creek Water District
Scotts Valley Water District

The Santa Margarita Groundwater Basin is sole source of potable water for SVWD

Strategies to Reduce GW Production
Water Conservation
Recycled Water
Gray Water
Rebates

1975-2010: Change in GW Production & Storage
Incorporating drought protection into the determination of Safe (Sustainable) Yield

Metric that specifies extent of groundwater withdrawals that can stop levels declining over time & reduce or avoid overdraft impacts

1. Definition that details assumptions regarding acceptable impacts

2. Calculation of withdrawals to sustain stable groundwater levels that prevent defined acceptable overdraft impacts under normal climatic conditions

3. Calculation of an additional reserve to account for increased withdrawals that accompany a severe drought
   Goal is to avoid groundwater levels trending down over time
Calculating a Drought Reserve for Soquel Creek

Source: Data from Soquel Creek Water District, 2009.
Groundwater level metrics can be converted into acre-feet.
What Local Agencies Are Doing

- Water Neutrality Program
- Rebates for Conservation
- Awards for Demand Reduction
- Promotion of Recharge
- Recycled Water
- Cooperative Partnerships
- Tiered Pricing
Recommendations

- To receive state funding, require local development & implementation of clear overdraft reduction goals & strategies & reserve development

- Develop state-local cooperative structures to establish enforceable standards for groundwater withdrawals
Thank You

http://droughtreserves.ucsc.edu/

"The frog does not drink up the pond in which he lives."
   -American Indian Saying -

"Water and its availability and quality will be the main pressures on, and issues for, societies and the environment under climate change."
   -IPCC, 2007