Drought, Uncertainty, and the Future of California Water

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No one knows all about water.
Outline

1. California water
2. Climate, drought, & other changes
3. Portfolio management
4. Four big problems
5. Preparing for Future
6. Conclusions
7. Further reading
Most annual rainfall variability in US


NOTES: Dots represent the coefficient of variation of total annual precipitation at weather stations for 1951-2008. Larger values have greater year-to-year variability.
California has lots of droughts

A 200-year drought?

Evidence from tree rings shows that drought was historically much more widespread in the American West than now, while the 20th century was wetter than normal. Percentage of the West affected by drought from 800 A.D. to 2000:

Medieval megadroughts: The West experienced two abnormally dry periods lasting close to 200 years each during the Middle Ages.

1850: California becomes state

Source: E.R. Cook et al., Earth-Science Reviews
Climate, Droughts, & Other Changes

1. Climate is warming and sea level is rising
2. Less snow & runoff, more variability (floods-drought)
3. Less runoff, but more floods for same precipitation
4. Economic structure changes affect water demands
5. Social objectives affect water demands
6. Invasive species also change ecosystems
7. Wildfires

Droughts & floods are pivotal for rebalancing water rules, institutions, and infrastructure

Disasters rebalance local, regional, state, and federal actions, roles, and innovations
Many Drivers of Change

• Climate Changes
  – Sea level rise
  – Warmer temperatures
  – More extremes, wet & dry
  – Precipitation change
  – Wildfires

• Deterioration
  – Aging infrastructure
  – Contaminants – salts, nitrates, etc.
  – Mining legacy
  – Groundwater overdraft
  – Earthquakes
  – Sacramento-San Joaquin Delta

• Economy and Demography
  – State and federal finances
  – Globalization
  – Population growth and urbanization

• Ecosystems
  – New invasive species
  – Wildfire & forests
  – Continued degradation

• Science and technology
  – New chemicals
  – New Technologies
Some Good Changes - California’s economy less agricultural - more robust to drought
Water portfolio management

- California’s water system is more than just storage and conveyance
  - Extensive, diverse, variable, & network encourages portfolio management – “much of the above”

- Portfolio management is successful, but takes time and organized effort.
<table>
<thead>
<tr>
<th>Water supply system portfolio actions</th>
</tr>
</thead>
</table>

### Water supply

<table>
<thead>
<tr>
<th>Water Source availability</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precipitation, streams, groundwater, wastewater, etc.</td>
<td>Existing water and wastewater treatment</td>
</tr>
<tr>
<td>Protection of source water quality</td>
<td>New water and wastewater treatment</td>
</tr>
</tbody>
</table>

**Conveyance capacities**

| Canals, pipelines, aquifers, tankers (sea or land), bottles, etc. | Wastewater reuse |
| Ocean Desalination |
| Contaminated aquifers |

**Storage capacities**

| Surface reservoirs, aquifers and recharge, tanks, snowpack, etc. | Operations |
| Reoperation of storage and conveyance |
| Conjunctive use |

### Water demands and allocation

| Agricultural use efficiencies and reductions | Ecosystem demand management |
| Urban water use efficiencies and reductions | Recreation water use efficiencies |

### Incentives to work well together

| Pricing | Subsidies, taxes |
| Markets, contracts, agreements | Education |
| “Norming”, shaming | Insurance |
Local and Statewide Portfolio

Local Activities:
- Conservation and use efficiency
- Wastewater reuse
- Desalination (brackish & ocean)
- Groundwater use and recharge
- Surface reservoir operations
- Water markets and exchanges

Statewide Activities:
- Inter-regional water conveyance
- Surface reservoir operations
- Plumbing codes & conservation incentives
- Groundwater banking and recharge
- Water market support and conveyance
- Wastewater reuse subsidies

Integrating mix of actions – portfolio planning Foundation for adaptations to the future.
We now rarely die from droughts
Global improvements
<table>
<thead>
<tr>
<th>Group</th>
<th>Grade so far</th>
<th>Comments to parents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban</td>
<td>A-</td>
<td>Excellent preparation, mostly; Next droughts will be harder.</td>
</tr>
<tr>
<td>Agriculture</td>
<td>B+</td>
<td>Good preparation, mostly. Quick learners. Next droughts will be harder.</td>
</tr>
<tr>
<td>Environment</td>
<td>D</td>
<td>Mostly unprepared for tests, or studied for a different test. Must invest for droughts.</td>
</tr>
<tr>
<td>Rural water supply</td>
<td>C</td>
<td>Generally poor preparation. Some improvement. Future tests will be harder.</td>
</tr>
<tr>
<td>Groundwater</td>
<td>C</td>
<td>Grades improving, but tests getting harder.</td>
</tr>
<tr>
<td>Delta</td>
<td>C</td>
<td>Grades improving, but tests getting harder.</td>
</tr>
<tr>
<td>Government agencies</td>
<td>B/C</td>
<td>Must work more closely together. Next test harder.</td>
</tr>
</tbody>
</table>
Ecosystem Problems

1. Most native species declining
2. Disruptions from massive historical land and water development and invasive species
3. Prospects worsen greatly with changing climate
4. Major pollution reductions; substantial prevention/improvements in new water & land developments
5. Failures: Continued declines from legacy dynamics and new activities
6. Im possibility of restoration and difficulties of reconciliation with climate change
7. Ecosystem management lacks business model and agreed objective
Rural drinking water problems

1) ~1-2% of state’s population affected
2) Unsafe rural water systems & wells
3) Small poorer communities
4) Vulnerable to drought draw-down
5) Nitrate and other contaminants
6) Finance & organization
Groundwater Problems

1. Overdraft problems (dry wells, subsidence)
2. Quality problems (nitrate, salinity, others)
3. SGMA shows great promise
4. Need to fallow 0.5 – 2 million acres of irrigated land, mostly in San Joaquin Valley
5. Early progress is promising, and has large implications for other problems
6. How to retire irrigated land responsibly?

Similar to Colorado River overallocation problem.
Problems of the Delta

- Physical instability
  - Land subsidence
  - Sea level rise
  - Floods
  - Earthquakes

- Ecosystem instability
  - Habitat alteration
  - Invasive species

- Economic instability
  - High costs to repair islands
  - Worsening water quality
  - Growing overall water scarcity
Government agencies

1) Important controversial problems become the government’s responsibility.
   • Then we blame the government when the outcome is not what we individually want.
   • So we all dislike the government, even as we need it.

2) Local funding and accountability is fundamental.

3) State and federal regulation for broader social and environmental goods are needed.

4) Success requires government regulations, but not micro-management.

5) Good regulation has: discussion, science & technical-based guidance, motivating local fear of micro-management, and sometimes money.
Floods

1. We do well with most floods today (e.g., 2017)
2. Floods will worsen with climate change
3. Rural town and area problems: no economies of scale/density, development often stymied
4. Opportunities to improve flood preparation and ecosystem management for future – floodplains and wetlands
5. Community flood insurance – Kathy Schaefer
Preparing for uncertainties and surprises

1) Preparing for certain changes - Normal analysis, negotiations, and planning

2) Preparing for uncertain changes - Probabilistic analysis, negotiations, contingency planning and portfolios, reserve and insurance funds

3) Preparing for surprises – Scenario planning and exercises, contingency planning and portfolios, reserve and insurance funds.

Surprises need not catch us unprepared!
# Institutional Capacities

<table>
<thead>
<tr>
<th>Level</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Private</td>
<td>Flexibility, financial discipline</td>
<td>Needs a business model</td>
</tr>
<tr>
<td>NGO</td>
<td>Flexibility, often mission focus</td>
<td>Needs a business model, external discipline</td>
</tr>
<tr>
<td>Local</td>
<td>Local accountability, resources, authorities</td>
<td>Only local accountability</td>
</tr>
<tr>
<td>State</td>
<td>Scale, and technical perspective, state</td>
<td>Can be remote from needs</td>
</tr>
<tr>
<td></td>
<td>accountability</td>
<td></td>
</tr>
<tr>
<td>Federal</td>
<td>Scale, and technical perspective, national</td>
<td>Can be remote from needs</td>
</tr>
<tr>
<td></td>
<td>accountability</td>
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</table>

*Best if these work together, as an institutional portfolio!*
Resistance is Futile

1) Flooding in parts of the Delta
2) Reduced Delta diversions
3) Less irrigated land in the southern Central Valley
4) Less urban water use, more reuse & storm capture
5) Some native species unsustainable in the wild
6) Funding solutions mostly local and regional
7) State’s leverage is mostly regulatory, not funding
8) Nitrate groundwater contamination is inevitable
9) Groundwater will be managed more tightly
10) The Salton Sink will be largely restored

We cannot drought-proof, but we can manage better.
Further Readings


Arax, The Dreamt Land (2019)

CaliforniaWaterBlog.com

Mavensnotebook.com

Pisani (1983), From Family Farms to Agribusiness, UC Press

Hanak et al. (2011) Managing California’s Water, PPIC.org

Hundley (1992), The Great Thirst, UC Press.

Reasons for Hope

1) Human water use peaked?

2) Economy depends less on water abundance

3) Water markets can shift use and civilize change

4) We agree we have a problem

Source: Hanak et al. 2011
CALVIN Water Supply Model

- Optimizes portfolio of many (not all) supply and demand management options and economic values
- Economically optimizes portfolio by month over 83 years of hydrology
- Economic values for Agricultural, Urban, & Hydropower Uses, and operating costs
- Constraints for Environmental Uses and Flows

Forces quantitative understanding of integrated water and economic system
Value of water & infrastructure
Fundamental Water Management Objectives

We often get lost in the weeds...

What should we be managing for:

- Public health
- Prosperity
- Ecosystems
- Social justice

In practice, objectives often become convoluted, but effective management keeps fundamental objectives in mind.
No one knows it all.

"Drought, Uncertainty, and the Future of Water in California"

2-3 sentences:  Water has always shaped California's economy, society, and ecosystems. The talk will briefly review this shaping since the end of the last ice age, with dramatic changes in sea level, temperatures and runoff, through historical developments of small and large scale water management to today's water system. The talk will then examine prospects for further changes in management and water availability due to changes in climate, ecosystem management, and economic structure. Some important policy challenges will be identified.

30-40 minutes

California water overview

Climate change, drought, and other changes

Four big problems:
1. Ecosystems
2. Small communities
3. Groundwater
4. Delta
5. Floods?

Preparing for known uncertainties and surprises

Institutional capacity – local, state, federal, private (comparison Table?)

Conclusions

Further reading
Streamflow and El Nino

Sac. River Annual Runoff, maf

ENSO Index

\[ y = 0.9235x + 18.063 \]

\[ R^2 = 0.0092 \]

2016
Conclusions

1) Statewide water system, with local governance and fragmented regulation

2) Limited State and Federal abilities

3) Local government is most important

4) Complexity enriches possibilities

5) Integrated portfolios are the future

6) Nature and economics eventually prevail over indecision and existing law

7) Eternal changing problems

8) Universities can help
Water Storage Capacity and Uses in California

1. Conclusions

- Groundwater Capacity
- Surface Storage
- Proposed Expansions
Droughts in California

1. California has lots of droughts
2. California has a dynamic society, economy, & climate
3. Globalization eternally important for California water
4. Economic structure drives most management
5. Droughts/pivotal events help water management adjust to changing objectives and conditions
6. Adjustments are technological and institutional
7. Adjustments built on existing institutions and infrastructure
8. Adjustments rebalance portfolio of local, regional, state, and federal roles and innovations
California’s current drought

- An additional dry year could make this drought a whopper.
- Many urban areas are preparing for an additional dry year.
- Long-term preparation gaps:
  - Ecosystems
  - Delta
  - Wildfire

Challenging times for water in California, again.