Climate Change

Elissa Lynn, Aaron Cuthbertson, Andrew Schwarz, Qin Qin Liu, Pete Coombe, Jennifer Morales
CA Department of Water Resources
California Water Plan, Update 2013
Climate Change Content
California Water Plan, Update 2013

Climate Change Content

- Volume 1: CA Water Today
  Statewide Adaptation and Mitigation

- Volume 2: Regional Reports

- Volume 3: Resource Management Strategies
<table>
<thead>
<tr>
<th>Time</th>
<th>Session Title</th>
<th>Presenter(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1:50 PM</td>
<td><strong>WELCOME, AND INTRODUCTIONS</strong> And <strong>SESSION OVERVIEW</strong></td>
<td>Elissa Lynn, DWR Climate Change Program</td>
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<tr>
<td>1:55</td>
<td><strong>SUMMARY OF CLIMATE CHANGE CONTENT in CWP</strong></td>
<td>Elissa Lynn, DWR Climate Change Program</td>
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<tr>
<td></td>
<td>1. Key Features of the Text</td>
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<tr>
<td></td>
<td>2. What is new/different from 2009</td>
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<td>3. What has changed since the last draft</td>
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<td>4. What public input has been received to date</td>
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<td>2:00</td>
<td><strong>CALIFORNIA WATER TODAY</strong></td>
<td>Elissa Lynn, DWR</td>
</tr>
<tr>
<td></td>
<td>1. Intro, Hydrology, SLR and Diagram</td>
<td>Aaron Cuthbertson, DWR</td>
</tr>
<tr>
<td></td>
<td>2. Rain/Snow trends and Diagram</td>
<td>Andrew Schwarz, DWR</td>
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<td></td>
<td>3. Impacts to Water Supply and Diagram</td>
<td>Qinquin Liu, DWR</td>
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<td>4. Water-Energy Nexus and Diagram</td>
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<td><strong>DISCUSSION AND PUBLIC COMMENT</strong></td>
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<td>3:00</td>
<td><strong>REGIONAL REPORTS</strong></td>
<td>Jennifer Morales, DWR</td>
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<tr>
<td></td>
<td>1. Mitigation/Energy Intensity and Diagram</td>
<td>Pete Coombe, DWR</td>
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<tr>
<td></td>
<td>2. Adaptation</td>
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<td><strong>DISCUSSION AND PUBLIC COMMENT</strong></td>
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<td>3:30</td>
<td><strong>RESOURCE MANAGEMENT STRATEGIES</strong></td>
<td>Andrew Schwarz, DWR</td>
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<td>3:45</td>
<td><strong>Next Steps</strong></td>
<td>All</td>
</tr>
<tr>
<td>3:50</td>
<td><strong>ADJOURN</strong></td>
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</table>
California Water Plan, Update 2013

Climate Change Content

- What’s new this year
California Water Plan, Update 2013

Climate Change Content

- What’s new this year

- Public Input received so far:
  - Climate Change Technical Advisory Group
  - Water Energy Subject Matter Experts
California Water Plan, Update 2013

Climate Change Content

- Volume 1: CA Water Today
  Statewide Adaptation and Mitigation
Recent Observations

Warming Trend

Less snow/more rain; changing snow thresholds

Earlier greenup dates; more tree mortalities; enhanced wildfires

Animals moving north

Earlier snowfed streamflow

Mike Dettinger, USGS and SIO/UCSD
Indicators of Climate Change in California

36 indicators

- Decreasing spring snowmelt runoff
- Rising sea levels along the coast
- Shrinking glaciers
- Increasing wildfires
- Warming lakes and ocean waters
- Gradual migration of many plants and animals to higher elevations

Cal EPA and Health Hazards
What Does 4°F (2°C) Mean?

Sacramento
(avg. temp 61°F)

Bakersfield
(avg. temp 65°F)

+7°F degrees makes Sacramento = Las Vegas, NV

+12°F degrees makes Sacramento = Phoenix, AZ
Five Major Impacts to Water Resources in CA

- Shift in runoff patterns resulting in more winter runoff and less spring and early summer runoff.

- Sea level rise with levee and salinity problems in the Delta and low coastal areas.

- Bigger floods due to larger winter rainflood producing areas and more water vapor in storms.

- Somewhat higher crop and landscape water needs.

- Water temperature problems for cold water fish like salmon and steelhead.
Figure 3-22 Global Sea Level Rise: Historic and Projected

Estimated, observed, and projected global sea-level rise from 1800 to 2100. The pre-1900 record is based on geologic evidence, and the observed record is from tide gages (red line) and satellite altimetry (blue line). Example projections of sea-level rise to 2100 are from IPCC (2007) global climate models (pink shaded area), semi-empirical methods (gray shaded area; Rahmstorf, 2007), and NAS report (yellow banded area, 2012). Reprinted with permission from “Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future,” 2012, from the National Academy of Sciences, Courtesy of the National Academies Press, Washington, D.C.
Figure 3-23 West Coast and Global Sea Level Rise Projections

<table>
<thead>
<tr>
<th>projection location</th>
<th>inches</th>
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<tbody>
<tr>
<td>California</td>
<td>7.9</td>
</tr>
<tr>
<td>South of Mendocino</td>
<td>15.7</td>
</tr>
<tr>
<td>California</td>
<td>23.6</td>
</tr>
<tr>
<td>North of Mendocino</td>
<td>31.5</td>
</tr>
<tr>
<td>Global</td>
<td>39</td>
</tr>
<tr>
<td>South of Mendocino</td>
<td>47</td>
</tr>
<tr>
<td>California</td>
<td>55</td>
</tr>
<tr>
<td>North of Mendocino</td>
<td>63</td>
</tr>
<tr>
<td>Global</td>
<td>71</td>
</tr>
</tbody>
</table>

...by 2030
...by 2050
...by 2100


Summary of regional projections of mean sea level rise from a National Academy of Sciences study (NAS, 2102), sponsored by California, Oregon, Washington, and three federal agencies. The highest observed values of sea level rise will occur during winter storms, especially during El Niño years when warmer ocean temperatures result in temporarily increased sea levels. Observed values can be much greater than the mean values shown here. For example, observed California sea levels during winter storms in the 1982-83 El Niño event were similar in magnitude to the mean sea levels now being projected for the end of the 21st century.
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Climate Change Content

- Volume 1: CA Water Today
  Rain/Snow Trends and Diagram

Aaron Cuthbertson
Questions

• For the major watersheds of California,
  • Is the amount of precipitation falling as snow changing?
  • Can a time-series of the rain / total precipitation ratio be estimated?
  • Is there a significant trend in this estimate?
Previous work

• Much previous work on
  • Runoff timing, magnitude
  • Snowpack
  • Total precipitation
  • Snow (or rain) to total precipitation ratios
• This work looks at rain to total precipitation ratios for watersheds of the Sierra Nevada and southern Cascades in California
Methodology

Combines:

• Temporally coarse, spatially fine precipitation and elevation data (PRISM) with

• Data product based on temporally fine, spatially coarse atmospheric data (NCAR/NCEP -> WRCC freezing level tracker)

• Linked by elevation (DEM)
Methodology

Method results in:

• Time series of annual percent of total precipitation falling as rain for each analysis zone and the entire analysis region

• Time series spans from 1949 – 2012 water years
Results – Entire Analysis Area

Percent of Total Annual Precipitation Falling as Rain, All Watersheds

- Blue diamonds: Precipitation Falling as Rain
- Light blue line: 3-year moving average
- Red line: Linear Trend
Conclusions

• Analysis suggests that percent rain is increasing in state, particularly in northern watersheds

• Can we combine low resolution precip phase data with higher resolution precip data? Is there a way to validate the approach?

• What about interdecadal climate variability?
Data – Precipitation Phase

• Obtained from WRCC North American Freezing Level Tracker, Monthly Percent Snow Tool

• Combines modeled data of precipitation and atmospheric temperature and elevation

• Underlying data: NCAR/NCEP global Reanalysis Data
  • 6 hour increments
  • 21 levels of the atmosphere (0-4000m in 200m increments)
  • Coarse 2.5 degree Lat/long grid cell size
Data - PRISM Precipitation Data

- 2.5 ArcMinute Grid (about 2km)
- Monthly data calculated from 1896-2012
- This analysis uses Oct-Sept water years from 1949-2012, corresponding to the reanalysis period data
Data - Elevation

- 2.5 Arcminute Lat/long grid
- Coincides with PRISM monthly precipitation grid data
- DEM ‘binned’ to divide elevations into 21 elevation bands
Data

Coarse Grid - WRCC
% Snow

Fine Grid - PRISM Precip and DEM
Results – Zone A

Percent of Total Annual* Precipitation Falling as Rain, Zone A

* Based on Water Year: October 1 - September 30
Results – Zone B

Percent of Total Annual Precipitation Falling as Rain, Zone B

- Precipitation falling as Rain
- 3-year moving average
- Linear Trend

* Based on Water Year: October 1 - September 30
Results – Zone C

Percent of Total Annual* Precipitation Falling as Rain, Zone C

* Based on Water Year: October 1 - September 30
Results – Zone D

Percent of Total Annual Precipitation Falling as Rain, Zone D

*Based on Water Year: October 1 - September 30
Mann-Kendall Trend Analysis of **Annual Precipitation** by Analysis Zone

H0: No change in Annual Precipitation over time

<table>
<thead>
<tr>
<th>Zone</th>
<th>Kendall’s tau</th>
<th>2-sided p value</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zone A</td>
<td>-0.044</td>
<td>0.614</td>
<td>Fail to reject H₀</td>
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<tr>
<td>Zone B</td>
<td>-0.037</td>
<td>0.672</td>
<td>Fail to reject H₀</td>
</tr>
<tr>
<td>Zone C</td>
<td>0.005</td>
<td>0.958</td>
<td>Fail to reject H₀</td>
</tr>
<tr>
<td>Zone D</td>
<td>0.024</td>
<td>0.785</td>
<td>Fail to reject H₀</td>
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<tr>
<td>Total Analysis Area</td>
<td>-0.020</td>
<td>0.821</td>
<td>Fail to reject H₀</td>
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</table>
Mann-Kendall trend test of **annual snow** by analysis zone

H$_0$: No change in annual snow over time

<table>
<thead>
<tr>
<th>Zone</th>
<th>Kendall’s tau</th>
<th>2-sided p value</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zone A</td>
<td>-0.232</td>
<td>0.007</td>
<td>Reject H$_0$</td>
</tr>
<tr>
<td>Zone B</td>
<td>-0.186</td>
<td>0.031</td>
<td>Reject H$_0$</td>
</tr>
<tr>
<td>Zone C</td>
<td>-0.039</td>
<td>0.656</td>
<td>Fail to reject H$_0$</td>
</tr>
<tr>
<td>Zone D</td>
<td>-0.037</td>
<td>0.672</td>
<td>Fail to reject H$_0$</td>
</tr>
<tr>
<td>Total Analysis Area</td>
<td>-0.104</td>
<td>0.226</td>
<td>Fail to reject H$_0$</td>
</tr>
</tbody>
</table>
Mann-Kendall trend test of **rain as % of total precipitation**, by analysis zone
H0: No change in percent rain over time

<table>
<thead>
<tr>
<th>Zone</th>
<th>Kendall’s tau</th>
<th>2-sided p value</th>
<th>Interpretation</th>
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<tbody>
<tr>
<td>Zone A</td>
<td>0.227</td>
<td>0.008</td>
<td><strong>Reject H₀</strong></td>
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<tr>
<td>Zone B</td>
<td>0.214</td>
<td>0.013</td>
<td><strong>Reject H₀</strong></td>
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<tr>
<td>Zone C</td>
<td>0.132</td>
<td>0.125</td>
<td><strong>Fail to reject H₀</strong></td>
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<tr>
<td>Zone D</td>
<td>0.158</td>
<td>0.066</td>
<td><strong>Fail to reject H₀</strong></td>
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<tr>
<td>Total Analysis Area</td>
<td>0.196</td>
<td>0.022</td>
<td><strong>Reject H₀</strong></td>
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</table>
California Water Plan, Update 2013
Climate Change Content

- Volume 1: CA Water Today
  Impacts to Water Supply and Diagram

Andrew Schwarz
Snowpack Changes:

Evolution of Average Annual Snow Water Equivalent as a Percentage of Average 1995-2005 Values
(effect of temperature changes only: historical P, baseline T from WY 1965-1987)

2030 SWE

2060 SWE

2090 SWE

April SWE: 95%
(of 1995-2005 avg)

April SWE: 64%

April SWE: 48%

(20-year centered avg monthly T anom rel to 1995-2005 monthly avgs from PCM B05.44 run, used to force BDWM with WY65-87 conditions. 6/18/01)
Monthly Average Runoff of Sacramento River System

Flood Protection Operations

Runoff (million acre-ft)

Month

October 1906-1955

NOT a Water Plan FIGURE
Monthly Average Runoff in San Joaquin River System

Flood Protection Operations

NOT a Water Plan FIGURE
Fig. 3-21, How Earlier Runoff Affects Water Availability

Current Conditions:
- Maximum
- Minimum
- Runoff
- Demand
- Storage
- Spill
- Release from Storage
- Multipurpose reservoirs: flood protection operations

Projected Conditions:
- Maximum
- Minimum
- As runoff and demand peaks move further apart, more storage is needed and management is more complex.
California Water Plan, Update 2013
Climate Change Content

❖ Volume 1: CA Water Today
Water-Energy Nexus and Diagram

Qinqin Liu
Objectives

Develop Water-Energy Information Framework

- Water management program portfolios to evaluate different regional water supply options
- Water use efficiency, water system energy efficiency
- Water and energy saving
- GHG reduction and climate change

Facilitate Interagency coordination and public outreach
Fig. 3-24
Water and Energy Connection

Blue circles: Water in Energy
Orange circles: Energy in Water
Water-Energy Related Policy and coordination

• **AB32 scoping plan**
  – Mandated a GHG reduction to 1990 level by 2020;

• **SB7x7**
  – Reduce statewide per capita urban water use by 20% by the year 2020;
  – Agricultural entities required to apply efficient water management practices to reduce water demands.

• **Interagency coordination-WETCAT**
  – The Water-Energy Team (WETCAT) of the Governor’s Climate Action Team
California Statewide Electricity Use

Non-Water related uses 80.9%

Water-Related Uses ~19.1%

Customer End Uses ~11.4%

Wastewater Collection and Treatment 0.8%
Distribution Pumping 0.4%
Potable Treatment 0.1%
Groundwater Supply and Conveyance Pumps 3.9%


Source: CPUC Study 1 and Study 2

NOT a Water Plan FIGURE
Energy in Water

Energy Intensity $EI$
A measure of efficiency in water uses and water systems
Energy used for water transport, distribution or treatment or end uses on a per unit basis (kilowatt hours per acre-foot of water [kWh/AF]).

Energy Embedded in Water
The amount of energy used in water cycles including: conveyance, treatment, and distribution, and wastewater collection, treatment and end use activities
Useful in quantifying energy savings as a result of water savings:
$\text{Embedded energy saved} = \text{water saved} \times EI$
Water in Energy

- Cooling water for thermal generation
- Water for solar thermal energy generation
- Water for energy exploration and extraction: All fossil energy sources require water for exploration and extraction including well drilling, hydraulic fracturing, and mining operations.
- Water used for energy generation from anaerobic digestion at wastewater treatment plants
- Irrigation water for cultivation of biomass fuels
Water in Energy

Background and definition

• Water footprint is used to assess amount of water used for energy production and consumption processes

• Examples: amount of water used in cooling thermoelectric power plants, agricultural and bio-fuel production, and extracting oil and natural gas.

• Current studies and information gaps
Challenges and Future Needs

• Coordination of climate change adaptation and mitigation
• Statewide and regional data
• Tools and standards
• Funding
• Policy alignment and management
• Coordination in water and energy sectors
California Water Plan, Update 2013

Climate Change Content

- Volume 2: Regional Reports
  Mitigation/ Energy Intensity
  Jennifer Morales
Mitigation in the Regional Reports

Climate change mitigation has been added to every Regional Report

(excluding Mountain Counties and the Delta)

- Water-energy connection

- Introduces the Energy Intensity Diagram

- Covers the purpose, exclusions and caveats of the Energy Intensity Diagram

- Embedded energy

- Hydroelectric power in energy intensity calculations
The Goal:
To provide a tool which allows water managers to compare the general energy intensity of the various water sources in their region to aid in decision making.

For this purpose ‘energy intensity’ in defined as the total amount of energy required for the extraction and conveyance of one acre-foot of water

The energy needed for treatment, distribution or end-use was not included.
The Water and Energy Connection

Figure 3.24: The Water and Energy Connection

Key:
- Use energy to facilitate water use
- Use water in the process of energy generation

- Energy for heating and delivering drinking water
- Hydroelectric generation
- Cooling water for thermal generation
- Water for solar thermal energy generation
- Water for water exploration and extraction: All fossil energy sources require water for exploration and extraction including well drilling, hydraulic fracturing, and mining operations.
- Energy for conveying water
- Energy for extraction of groundwater
- Energy for desalination of water
- Energy for advanced treatment and delivery of recycled wastewater
- Water used for energy generation from anaerobic digestion at wastewater treatment plants
- Irrigation water for cultivation of biomass fuels
- Energy for pressuring water for use in drip irrigation systems
Energy Intensity for Water Types
We determined the water sources with...
We determined the energy intensity with Ö.
Energy Intensity Diagram ñ Figure X in each Regional Report

Figure x: South Coast energy intensity per acre foot of water

<table>
<thead>
<tr>
<th>Type of Water</th>
<th>Energy Intensity (yellow bulb = 1-500 kWh/AF)</th>
<th>% of regional water supply</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colorado (Project)</td>
<td>![Energy Intensity Icon] - no hydro</td>
<td>21%</td>
</tr>
<tr>
<td>Federal (Project)</td>
<td>![Energy Intensity Icon] &lt;250 kWh/AF</td>
<td>0%</td>
</tr>
<tr>
<td>State (Project)</td>
<td>![Energy Intensity Icon]</td>
<td>27%</td>
</tr>
<tr>
<td>Local (Project)</td>
<td>![Energy Intensity Icon] &lt;250 kWh/AF</td>
<td>4%</td>
</tr>
<tr>
<td>Local Imports</td>
<td>0*</td>
<td>5%</td>
</tr>
<tr>
<td>Groundwater</td>
<td>![Energy Intensity Icon]</td>
<td>33%</td>
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* LAA is a net energy provider

South Coast Example shown
California Water Plan, Update 2013
Climate Change Content

- Volume 2: Regional Reports
  Adaptation
  Pete Coombe
Climate Change Adaptation

- Regional Report Organization

- Intro- Common Themes in California

- Regional Specific Climate Information
  - Observations
  - Projections and Impacts

- Adaptation
  - Vulnerabilities
  - RMS- Resource Management Strategies
  - IRWM
Common Themes

• *Intro- Common Themes in California*

• State and federal governments have been preparing for the effects of climate change for over 2 decades

---

**Possible Effects of Global Climate Change**

Much concern has been expressed about possible future climate change caused by burning fossil fuel and other modern human activities that increase carbon dioxide and other trace greenhouse gases in the atmosphere. World weather records indicate an overall warming trend during the last century, with a surge of warming prior to 1940 (which cannot be attributed to greenhouse gases) and a more recent rise during the 1980s. The extent to which this latest rise is real or an artifact of instrument location (heat island effect of growing cities) or a temporary anomaly is debated among climatologists. For now, most of the projections of future climate change are derived from computer climate simulation studies. Not yet well-represented in the simulation models are cloud effects, which can have a large influence on the study results.

The studies generally indicate a northwestern change in precipitation distributions due to increased temperatures and a drying of the southeastern United States.
Common Themes

- *Intro- Common Themes in California*
  - State and federal governments have been preparing for the effects of climate change for over 2 decades

- Climate model simulations project increasing temperatures (all models)
Common Themes

• *Intro- Common Themes in California*

• State and federal governments have been preparing for the effects of climate change for over 2 decades

• Climate model simulations project increasing temperatures (all models)

• Precipitation Patterns
  – Changes to surface runoff timing, volume, and type
  – Increase in intensity of Atmospheric Rivers
Regional Observations

- Regional Specific Climate Information
- Observed changes over the past century:
  - Air temperature trends
  - Precipitation trends
  - Shifts in spring snowpack
  - Streamflow trends
  - Sea Level Trends (Coastal Regions)
Regional Observations

- **Regional Specific Climate Information**

- *Observed changes over the past century:*

  Air temperature trends- Evaluated using (WRCC) Western Regional Climate Center Data

[California Climate Data Archive](http://www.calclim.dri.edu/)
Hydrologic Region VS. Climate Region

- **CWP Hydrologic Regions**
  1. North Coast
  2. Sacramento River
  3. North Lahontan
  4. San Francisco Bay
  5. Mountain Counties
  6. San Joaquin River
  7. Central Coast
  8. South Coast
  9. Tulare Lake
  10. South Lahontan
  11. Colorado River

- **WRCC Climate Regions**
  1. North Coast
  2. North Central
  3. Northeast
  4. Sacramento-Delta
  5. Sierra
  6. San Joaquin Valley
  7. Central Coast
  8. South Coast
  9. Southern Interior
  10. Mohave Desert
  11. Sonoran Desert
Regional Observations

- Example: Observed changes over the past century
- Air temperature trends

1. Northern Coastal climate region
2. North Central climate region
3. North East climate region

NOT a Water Plan Figure

North Coast Hydrologic Region

- 0.4 to 1.3 F
- 0.5 to 2.8 F
- 0.8 to 2.0 F
Regional Projections and Impacts

- Regional Specific Climate Information

- Projected future scenarios
  - Air temperature
  - Precipitation trends
  - Spring snowpack simulations
  - Sea level projections (Coastal Regions)

NOT a Water Plan Figure
Regional Projections and Impacts

- **Projected future scenarios**
- Air temperature change 1985–1994 to 2060–2069

*Example: North Coast Region*

Change in Temp
JJA
2.4 to 3.6 deg (C)
4.3 to 6.5 deg (F)

Scripps
Institution of Oceanography, Pierce et al, 2012

*NOT a Water Plan Figure*
Adaptation

- **Key Ideas for Developing Adaptation Strategies**

- Strategies that benefit the region at the present and into the future

- Vulnerabilities are best assessed on a regional basis

- Adaptation to climate change should be both proactive and adaptive

- Loss of "stationarity"

- Climate change adds another layer of uncertainty to water planning
Adaptation

• **Example: Highlights from the North Coast Regional Report**

• **Vulnerabilities**-
  • Diminished snowpack, few significant aquifers, increased potential for water shortages

• **Recommended (RMS) Strategies**-
  • Agricultural/Urban Water Use Efficiency
  • Forest/Watershed Management
California Water Plan, Update 2013
Climate Change Content

Andrew Schwarz
❖ Volume 3: Resource Management Strategies
Climate Change and the RMS’s

• Specific *Climate Change Impacts* related to the RMS

• *Adaptation* - How does the RMS act to make water resources more resilient or adaptable to climate change

• *Mitigation* – Does the RMS act to reduce GHG emissions or does it actually cost carbon/energy to achieve
Example: Urban Water Use Efficiency

Impacts:
- Higher temperatures
- Changing hydrology/storage patterns
- Higher variability—need highly reliable water

Adaptation (+):
- Reduce overall need for water -> prepares water users for reductions in supply.

Mitigation (+):
- Lower water consumption -> Lower Energy -> Lower GHG Emissions
Example: Ag Water Use Efficiency

**Impacts:**
- Higher temperatures — could lead to longer growing seasons, crop shifting
- Changing hydrology/storage patterns
- Higher variability — crop shifting, volatile commodity prices

**Adaptation (+):**
- Reduce overall need for water -> improved ability to meet water needs allow for maximum flexibility in use

**Mitigation (-):**
- Lower water consumption -> Higher Energy -> Higher GHG Emissions
Example: Conjunctive Water Management

**Impacts:**
- Higher temperatures – increased water demand
- Changing hydrology/extreme events
- Higher variability – more floods and droughts
- Greater reliance on groundwater

**Adaptation (+):**
- Improved drought supplies, improved management of flood waters, groundwater recharge, improve storage capacity, system reoperation

**Mitigation (+/-):**
- Increased energy for injection wells and extraction wells, reduced reliance on imported or higher energy supplies, improved groundwater levels (reduced pumping depth)
Desalination and Recycled Water

Energy Intensity Information

• Desal and Recycling are different...
• Lots of variables...
• Energy factors for various types of processes are provided
Next Steps and Comments

- **CA Water Today: Statewide Strategies**
  - Adaptation
  - Water-Energy Nexus

- **Regional Reports**
  - Regionally appropriate Adaptation strategies
  - Energy Intensity of Raw Water Extraction and Conveyance

- **Resource Management Strategies**
  - Assess for Climate Change Adaptation
  - Impact on Greenhouse Gas Emissions (Mitigation)

- **Reference Material**
  Technical and policy background information
Climate Change Contacts

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Andrew Schwarz – aschwarz@water.ca.gov
QinQin Liu – qliu@water.ca.gov
Peter Coombe – peter_coombe@water.ca.gov
Jennifer Morales – jmorales@water.ca.gov
Thank You
Extra Slides
Extra Aaron Slides
Results – Zone A

Percent of Total Annual*Precipitation Falling as Rain, Zone A

* Based on Water Year: October 1 - September 30
Results – Zone B

Percent of Total Annual* Precipitation Falling as Rain, Zone B

* Based on Water Year: October 1 - September 30
Results – Zone C

Percent of Total Annual*Precipitation Falling as Rain, Zone C

* Based on Water Year: October 1 - September 30
Results – Zone D

Percent of Total Annual* Precipitation Falling as Rain, Zone D

* Based on Water Year: October 1 - September 30
Mann-Kendall Trend Analysis of **Annual Precipitation** by Analysis Zone

H0: No change in Annual Precipitation over time

<table>
<thead>
<tr>
<th>Zone</th>
<th>Kendall’s tau</th>
<th>2-sided p value</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zone A</td>
<td>-0.044</td>
<td>0.614</td>
<td>Fail to reject $H_0$</td>
</tr>
<tr>
<td>Zone B</td>
<td>-0.037</td>
<td>0.672</td>
<td>Fail to reject $H_0$</td>
</tr>
<tr>
<td>Zone C</td>
<td>0.005</td>
<td>0.958</td>
<td>Fail to reject $H_0$</td>
</tr>
<tr>
<td>Zone D</td>
<td>0.024</td>
<td>0.785</td>
<td>Fail to reject $H_0$</td>
</tr>
<tr>
<td>Total Analysis Area</td>
<td>-0.020</td>
<td>0.821</td>
<td>Fail to reject $H_0$</td>
</tr>
</tbody>
</table>
Mann-Kendall trend test of **annual snow** by analysis zone

**H₀**: No change in annual snow over time

<table>
<thead>
<tr>
<th>Zone</th>
<th>Kendall’s tau</th>
<th>2-sided p value</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zone A</td>
<td>-0.232</td>
<td>0.007</td>
<td><strong>Reject H₀</strong></td>
</tr>
<tr>
<td>Zone B</td>
<td>-0.186</td>
<td>0.031</td>
<td><strong>Reject H₀</strong></td>
</tr>
<tr>
<td>Zone C</td>
<td>-0.039</td>
<td>0.656</td>
<td><strong>Fail to reject H₀</strong></td>
</tr>
<tr>
<td>Zone D</td>
<td>-0.037</td>
<td>0.672</td>
<td><strong>Fail to reject H₀</strong></td>
</tr>
<tr>
<td><strong>Total Analysis Area</strong></td>
<td>-0.104</td>
<td>0.226</td>
<td><strong>Fail to reject H₀</strong></td>
</tr>
</tbody>
</table>
Mann-Kendall trend test of *rain as % of total precipitation*, by analysis zone

H0: No change in percent rain over time

<table>
<thead>
<tr>
<th>Zone</th>
<th>Kendall’s tau</th>
<th>2-sided p value</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zone A</td>
<td>0.227</td>
<td>0.008</td>
<td>Reject $H_0$</td>
</tr>
<tr>
<td>Zone B</td>
<td>0.214</td>
<td>0.013</td>
<td>Reject $H_0$</td>
</tr>
<tr>
<td>Zone C</td>
<td>0.132</td>
<td>0.125</td>
<td>Fail to reject $H_0$</td>
</tr>
<tr>
<td>Zone D</td>
<td>0.158</td>
<td>0.066</td>
<td>Fail to reject $H_0$</td>
</tr>
<tr>
<td>Total Analysis Area</td>
<td>0.196</td>
<td>0.022</td>
<td>Reject $H_0$</td>
</tr>
</tbody>
</table>
Extra QinQin Slides
CPUC Studies in the Water System

Study 1: Statewide and Regional Water-Energy Relationship

Study 2: Water Agency and Function Component Study and Embedded Energy-Water Load Profiles

Study 3: End-Use Water Demand Profile Study

End Use: Agriculture, Residential, Commercial, Industrial

Source

Supply & Conveyance

Water Treatment

Water Distribution

Recycled Water Treatment

Recycled Water Distribution

Wastewater Treatment

Wastewater Collection

Discharge

Source
10 Hydrologic Regions (plus Delta and Mountain Co.s)
Estimated CA State Wide Water Related Electricity Use 19.1%;
GHG Produced 20.46 Million Tonnes of CO2 equivalent (GHG by electric power 2006/IPCC)

California Statewide Electricity Use

Non-Water related uses 80.9%
Water-Related Uses ~19.1%
Customer End Uses ~11.4%
Water Infrastructure 7.7%

Source: CPUC Study 1 and Study 2
Extra Jennifer Slides
The 2008 water year officially ended Sept. 30. Following a dry 2007, the 2008 water year was designated critically dry. Statewide runoff totaled just 57% of normal for the year. The state’s major reservoirs are at about one-third of capacity at a time when they would typically be at about two-thirds.1

Current Conditions:
- In Northern California, Lakes Shasta, Oroville and Folsom are at or below 30% of capacity. Lakes San Luis and Pine Flat are at 12% of capacity.
- The Colorado River is only at 56% and has seen the lowest 10 year flow average on record, but it is recovering.
- The seven-month period March-September 2008 was the driest on record in the Northern Sierra. Only 3.5” or rainfall was received: merely 23% of average.
- Statewide precipitation for the six-month period March-August 2008 was 31% of average; the driest of 114 years on record.
- Southern California experienced its driest year on record last year.

With all signs pointing to a third dry year for Southern California, water agencies are gearing up for more challenges and the possibility of widespread water shortages.3

Federal Justifications

- **North Coast**- No pumping plants according to FWDEUA map. It has two power plants; Trinity and Lewiston, both operated by BOR.

- **North Lahontan**- No CVP deliveries according to CPUC. It has one power plant; Stampede, operated by BOR.

- **Sacramento River**- No CVP deliveries according to WY2008 Delivery Report. There are small pumps, but have such low EI that they will not be considered. The 15 KWh/ac-ft figure comes from Red Bluff Fish Passage Improvement Project per TCCA.

- **San Francisco**- County of Santa Clara, DAU 44 received 97,639 ac-ft of CVP water. Water comes from the southern tip of the Sacramento-San Joaquin Delta->Jones PMP->DMC-> O’Neill PGP->Pacheco PMP->Coyote PMP. 332.5 KWh/ac-ft (Gianelli removed)
Just because it quacks like a duck and walks like a duck doesn't mean it's not the Delta-Mendota Canal

San Joaquin River Hydrologic Region: 217 KWh/ac-ft weighted average

- DAU 185 (Tracy) -> Jones PMP -> DMC.
- DAU 204 (County of Fresno) -> gravity fed through Friant-Kern Canal.
- DAU 212 (Los Banos) -> Jones PMP -> DMC -> Mendota Pool.
- DAU 213 (Madera County) -> Madera Canal.
- DAU 214 (Counties of Fresno and Madera) -> Millerton lake.
- DAU 215 (Madera County) 64,453 ac-ft; 55,524 ac-ft goes to Columbia Canal Co from DMC, and 7,951 ac-ft goes to Gravelly Ford WD from Millerton Lake.
DAU 216
- Central California ID: Jones->DMC->SJR and Mendota Pool
- Del Puerto WD: Jones->DMC
- City of Dos Palos: Jones->DMC->O’Neill->San Luis Canal
- Eagle Field WD: Jones->DMC
- Firebaugh Canal WD: Jones->DMC->SJR and Mendota Pool
- Grasslands WD: Jones->DMC
- Los Banos WA: Jones->DMC
- Mercy Springs WD: Jones->DMC
- North Grasslands WA: Jones->DMC
- O’Neill Forebay WA: Jones->DMC->O’Neill
- Oro Loma WD: Jones->DMC
- Pacheco CCID: Jones->DMC->O’Neill->San Luis Canal
- Pacheco WD: Jones->DMC->O’Neill->San Luis Canal
- Pacheco WD Ag: Jones->DMC
- Pacheco WD M&I: Jones->DMC
- Patterson WD: Jones->DMC
- San Luis Canal Co: Jones->DMC->SJR and Mendota Pool
- San Luis NWR: Jones->DMC->SJR and Mendota Pool
- San Luis WD Ag: Jones->DMC
- San Luis WD M&I: Jones->DMC
- VA Cemetery: Jones->DMC->O’Neill
- Volta WA: Jones->DMC
- West Stanislaus ID: Jones->DMC
Tulare Lake- 202 KWh/ac-ft
DAU 233- (Fresno County) Friant-Kern Canal and the CVC.
DAU 235- (Fresno County) Jones-> DMC->SJR and Mendota Pool
DAU 237- (Fresno County) Jones-> DMC->SJR and Mendota Pool
DAU 240- (Fresno County) CVC and Friant-Kern Canal
DAU 242- (Kings County, Tulare County) CVC and Friant-Kern Canal
DAU 243- (Tulare County) Friant-Kern Canal
DAU 244- (Fresno County) Jones->DMC->O’Neill->Dos Amigos->San Luis Canal
DAU 245- (Kings County, Fresno County) Jones->DMC->O’Neill->Dos Amigos->Pleasant Valley->San Luis Canal
DAU 254- (Kern County) Friant-Kern Canal
DAU 255- (Kern County) Jones->DMC->O’Neill->Dos Amigos->Pleasant Valley->San Luis Canal
DAU 256- (Kern County) Friant-Kern Canal
DAU 257- (Kern County) Friant- Kern Canal
DAU 258- (Kern County) Friant- Kern Canal
• Central Coast Hydrologic Region
  - DAU 62 County of San Benito: Jones PMP->DMC->O'Neill PGP->Pacheco PMP. 314 KWh/ac-ft

• South Coast
  - No CVP deliveries according to CPUC.

• South Lahontan
  - No CVP deliveries according to CPUC.
Figure x: Tulare Lake energy intensity per acre foot of water

<table>
<thead>
<tr>
<th>Type of Water</th>
<th>Energy Intensity (yellow bulb = 1-500 kWh/AF)</th>
<th>% of regional water supply</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colorado (Project)</td>
<td><em>This type of water not available</em></td>
<td>0%</td>
</tr>
<tr>
<td>Federal (Project)</td>
<td>&lt;250 kWh/AF</td>
<td>15%</td>
</tr>
<tr>
<td>State (Project)</td>
<td></td>
<td>8%</td>
</tr>
<tr>
<td>Local (Project)</td>
<td>&lt;250 kWh/AF</td>
<td>16%</td>
</tr>
<tr>
<td>Local Imports</td>
<td><em>This type of water not available</em></td>
<td>0%</td>
</tr>
<tr>
<td>Groundwater</td>
<td></td>
<td>50%</td>
</tr>
</tbody>
</table>
Figure x: Sacramento River energy intensity per acre foot of water

<table>
<thead>
<tr>
<th>Type of Water</th>
<th>Energy Intensity (yellow bulb = 1-500 kWh/AF)</th>
<th>% of regional water supply</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colorado (Project)</td>
<td><em>This type of water not available</em></td>
<td>0%</td>
</tr>
<tr>
<td>Federal (Project)</td>
<td><img src="image" alt="Energy level" /> &lt;250 kWh/AF</td>
<td>28%</td>
</tr>
<tr>
<td>State (Project)</td>
<td><img src="image" alt="Energy level" /> &lt;250 kWh/AF</td>
<td>0%</td>
</tr>
<tr>
<td>Local (Project)</td>
<td><img src="image" alt="Energy level" /> &lt;250 kWh/AF</td>
<td>30%</td>
</tr>
<tr>
<td>Local Imports</td>
<td><em>This type of water not available</em></td>
<td>0%</td>
</tr>
<tr>
<td>Groundwater</td>
<td><img src="image" alt="Energy level" /> &lt;250 kWh/AF</td>
<td>19%</td>
</tr>
</tbody>
</table>
Figure x: South Lahontan energy intensity per acre foot of water

<table>
<thead>
<tr>
<th>Type of Water</th>
<th>Energy Intensity (yellow bulb = 1-500 kWh/AF)</th>
<th>% of regional water supply</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colorado (Project)</td>
<td><em>This type of water not available</em></td>
<td>0%</td>
</tr>
<tr>
<td>Federal (Project)</td>
<td><em>This type of water not available</em></td>
<td>0%</td>
</tr>
<tr>
<td>State (Project)</td>
<td><img src="image" alt="Yellow bulbs" /></td>
<td>14%</td>
</tr>
<tr>
<td>Local (Project)</td>
<td><img src="image" alt="Yellow bulb" /> &lt;= 250 kWh/AF</td>
<td>7%</td>
</tr>
<tr>
<td>Local Imports</td>
<td><em>This type of water not available</em></td>
<td>0%</td>
</tr>
<tr>
<td>Groundwater</td>
<td><img src="image" alt="Yellow bulb" /></td>
<td>64%</td>
</tr>
</tbody>
</table>
Figure x: San Joaquin energy intensity per acre foot of water

<table>
<thead>
<tr>
<th>Type of Water</th>
<th>Energy Intensity (yellow bulb = 1-500 kWh/AF)</th>
<th>% of regional water supply</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colorado (Project)</td>
<td>This type of water not available</td>
<td>0%</td>
</tr>
<tr>
<td>Federal (Project)</td>
<td>&lt;250 kWh/AF</td>
<td>16%</td>
</tr>
<tr>
<td>State (Project)</td>
<td></td>
<td>0%</td>
</tr>
<tr>
<td>Local (Project)</td>
<td>&lt;250 kWh/AF</td>
<td>29%</td>
</tr>
<tr>
<td>Local Imports</td>
<td>This type of water not available</td>
<td>0%</td>
</tr>
<tr>
<td>Groundwater</td>
<td>&lt;250 kWh/AF</td>
<td>31%</td>
</tr>
</tbody>
</table>
Figure x: San Francisco energy intensity per acre foot of water

<table>
<thead>
<tr>
<th>Type of Water</th>
<th>Energy Intensity (yellow bulb = 1-500 kWh/AF)</th>
<th>% of regional water supply</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colorado (Project)</td>
<td>This type of water not available</td>
<td>0%</td>
</tr>
<tr>
<td>Federal (Project)</td>
<td>![Energy Intensity Icon]</td>
<td>12%</td>
</tr>
<tr>
<td>State (Project)</td>
<td>![Energy Intensity Icon]</td>
<td>12%</td>
</tr>
<tr>
<td>Local (Project)</td>
<td>![Energy Intensity Icon] &lt;250 kWh/AF</td>
<td>15%</td>
</tr>
<tr>
<td>Local Imports</td>
<td>![Energy Intensity Icon] *&lt;250 kWh/AF</td>
<td>38%</td>
</tr>
<tr>
<td>Groundwater</td>
<td>![Energy Intensity Icon]</td>
<td>19%</td>
</tr>
</tbody>
</table>

* Hetch Hetchy is a net energy provider
## Figure x: North Lahontan energy intensity per acre foot of water

<table>
<thead>
<tr>
<th>Type of Water</th>
<th>Energy Intensity (yellow bulb = 1-500 kWh/AF)</th>
<th>% of regional water supply</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colorado (Project)</td>
<td><em>This type of water not available</em></td>
<td>0%</td>
</tr>
<tr>
<td>Federal (Project)</td>
<td><em>This type of water not available</em></td>
<td>0%</td>
</tr>
<tr>
<td>State (Project)</td>
<td><em>This type of water not available</em></td>
<td>0%</td>
</tr>
<tr>
<td>Local (Project)</td>
<td><img src="image" alt="&lt;250 kWh/AF" /></td>
<td>44%</td>
</tr>
<tr>
<td>Local Imports</td>
<td><em>This type of water not available</em></td>
<td>0%</td>
</tr>
<tr>
<td>Groundwater</td>
<td><img src="image" alt="&lt;250 kWh/AF" /></td>
<td>22%</td>
</tr>
<tr>
<td>Type of Water</td>
<td>Energy Intensity (yellow bulb = 1-500 kWh/AF)</td>
<td>% of regional water supply</td>
</tr>
<tr>
<td>---------------</td>
<td>---------------------------------------------</td>
<td>---------------------------</td>
</tr>
<tr>
<td>Colorado (Project)</td>
<td>This type of water not available</td>
<td>0%</td>
</tr>
<tr>
<td>Federal (Project)</td>
<td>&lt;250 kWh/AF</td>
<td>21%</td>
</tr>
<tr>
<td>State (Project)</td>
<td>This type of water not available</td>
<td>0%</td>
</tr>
<tr>
<td>Local (Project)</td>
<td>&lt;250 kWh/AF</td>
<td>27%</td>
</tr>
<tr>
<td>Local Imports</td>
<td>This type of water not available</td>
<td>1%</td>
</tr>
<tr>
<td>Groundwater</td>
<td>&lt;250 kWh/AF</td>
<td>28%</td>
</tr>
<tr>
<td>Type of Water</td>
<td>Energy Intensity (yellow bulb = 1-500 kWh/AF)</td>
<td>% of regional water supply</td>
</tr>
<tr>
<td>--------------------</td>
<td>---------------------------------------------</td>
<td>----------------------------</td>
</tr>
<tr>
<td>Colorado (Project)</td>
<td>&lt;250 kWh/AF</td>
<td>79%</td>
</tr>
<tr>
<td>Federal (Project)</td>
<td>This type of water not available</td>
<td>0%</td>
</tr>
<tr>
<td>State (Project)</td>
<td></td>
<td>1%</td>
</tr>
<tr>
<td>Local (Project)</td>
<td>&lt;250 kWh/AF</td>
<td>0%</td>
</tr>
<tr>
<td>Local Imports</td>
<td>This type of water not available</td>
<td>0%</td>
</tr>
<tr>
<td>Groundwater</td>
<td></td>
<td>9%</td>
</tr>
</tbody>
</table>
Figure x: Central Coast energy intensity per acre foot of water

<table>
<thead>
<tr>
<th>Type of Water</th>
<th>Energy Intensity (yellow bulb = 1-500 kWh/AF)</th>
<th>% of regional water supply</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colorado (Project)</td>
<td>This type of water not available</td>
<td>0%</td>
</tr>
<tr>
<td>Federal (Project)</td>
<td>![Energy Intensity Icon]</td>
<td>7%</td>
</tr>
<tr>
<td>State (Project)</td>
<td>![Energy Intensity Icon]</td>
<td>3%</td>
</tr>
<tr>
<td>Local (Project)</td>
<td>![Energy Intensity Icon] &lt;250 kWh/AF</td>
<td>3%</td>
</tr>
<tr>
<td>Local Imports</td>
<td>This type of water not available</td>
<td>0%</td>
</tr>
<tr>
<td>Groundwater</td>
<td>![Energy Intensity Icon]</td>
<td>79%</td>
</tr>
</tbody>
</table>