A Decision Framework for the California Water Plan
2013 Update

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California Water Plan to Evaluate Uncertain Future Water Management Challenges and Solutions

- How might demand, supply, and other water management conditions change between now and 2050?
- Which uncertain drivers are the most important?
- How can different water management strategies and response packages improve outcomes?
- What are the key tradeoffs among different strategies?
California Water Plan Update 2013 Evaluating Water Demand Under Uncertainty Statewide

Uncertain Future Conditions (Scenarios) → Water Management Model → Outcomes and Performance Metrics

California Water Plan Update 2013 Evaluating Management Strategies for the Central Valley

Uncertain Future Conditions (Scenarios) → Water Management Strategies and Response Packages → Water Management Model → Outcomes and Performance Metrics
Scenarios Reflect Changes in…
How Many People Live in California

- Three population projections by hydrologic region

![Diagram showing Scenarios, Strategies, Model, Metrics connections]

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Scenarios Reflect Changes in…
How Many People Live in California

- Three population projections by hydrologic region

![Graph showing population projections for different years and regions]
Scenarios Reflect Changes in…

Where and How People Live

- Nine demographic scenarios:
  - Population (3)
  - Urban density (3)

2006

2050

Scenarios Reflect Changes in…

How Much Agricultural Land is Irrigated

- Nine scenarios of irrigated agricultural land
  - Conversion from agriculture to urban development
  - Shift towards more high value crops

Central Valley
Scenarios Also Reflect Uncertainty about Future Climate

- Repeat of historical climate patterns

![Graph of temperature and precipitation with marked droughts](image)

5 offsets evaluated
Scenarios Also Reflect Uncertainty about Future Climate

- Repeat of historical climate patterns with climate warming

![Graph showing temperature and precipitation over time](image)

Average Warming by 12 climate models

Global climate model scenarios of temperature and precipitation

Showing projections from 6 of 12 climate simulations
Response Packages Define Combinations of Management Strategies

<table>
<thead>
<tr>
<th>Water Management Response Package</th>
<th>Water use efficiency</th>
<th>Reuse and conjunctive management</th>
<th>Additional environmental flows and groundwater recovery</th>
<th>New surface storage</th>
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</table>
Water Management Models Evaluate System Across Many Scenarios

Statewide Model
- Statewide
- Evaluation of monthly water demands by hydrologic region
- Reflect demographic and climate uncertainty

Central Valley Model
- Sacramento, San Joaquin, and Tulare Lake hydrologic regions
- Simulation of monthly demand, supplies, and management under uncertainty
- Evaluation of water management strategies

Both models built in user-friendly modeling environment to support collaboration
Statewide Model Estimates Future System Performance

- Urban demand
- Agricultural demand
- Additional environmental demands

Central Valley Model Estimates Future System Performance

- Urban unmet demand
  - Reliability
  - Magnitudes of shortages
- Agricultural unmet demand
  - Reliability
  - Magnitudes of shortages
- Environmental performance
  - Reliability of meeting In-stream Flow Requirements
- Groundwater storage
  - Change over time
Summary of Analysis

<table>
<thead>
<tr>
<th>Uncertain Factors (X) and Scenarios</th>
<th>Management Strategies (L) and Response Packages</th>
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<tbody>
<tr>
<td>• Population</td>
<td>Current Management</td>
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<tr>
<td>• Housing density</td>
<td>Additional strategies</td>
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<tr>
<td>• Climate</td>
<td>• Agricultural water use efficiency</td>
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<tr>
<td></td>
<td>• Urban water use efficiency</td>
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<tr>
<td></td>
<td>• New surface storage</td>
</tr>
<tr>
<td></td>
<td>• Conjunctive management &amp; groundwater storage</td>
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<td>• Recycled municipal water</td>
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<td>• Meeting additional flow targets and groundwater recovery goals</td>
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<table>
<thead>
<tr>
<th>Models (R)</th>
<th>Performance Metrics (M)</th>
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<tr>
<td>• UPLAN</td>
<td>• Urban unmet demand</td>
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<tr>
<td>• SWAP</td>
<td>• Agricultural unmet demand</td>
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<tr>
<td>• Statewide Model</td>
<td>• Unmet instream flow requirements and targets</td>
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<td>• Central Valley Model</td>
<td>• Groundwater levels</td>
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Key: Statewide and Central Valley
Central Valley only

Robust Decision Making (RDM) Provides Structure for Identifying Robust Water Management Strategies

- Evaluates water system across numerous scenarios
- Identifies key vulnerabilities
- Defines tradeoffs among different decisions

Revised Structuring

1. Decision Structuring
2. System Simulation
3. Vulnerability Analysis
4. Tradeoff Analysis

Deliberation
Analysis
Deliberation with Analysis

Descriptions of Vulnerabilities
Robust Strategy

Following results from Proof-of-Concept analysis
Under Current Management, Broad Range of Plausible Outcomes Over Scenarios

Urban water supply reliability (%)

Update 2013 California

Agricultural water supply reliability (%)

Update 2013 California

Under Current Management, Broad Range of Plausible Outcomes Over Scenarios

Urban water supply reliability (%)

Update 2013 California

Agricultural water supply reliability (%)

Update 2013 California

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Update 2013 California

Under Current Management, Broad Range of Plausible Outcomes Over Scenarios

Urban water supply reliability (%)

Update 2013 California

Agricultural water supply reliability (%)
Current Management Vulnerable to Many Scenarios

Agricultural water supply reliability (%)

Urban water supply reliability (%)

Update 2013 Califormia

Agricultural water supply reliability (%)

Urban water supply reliability (%)

Update 2013 Califormia

20 out of 39 outcomes below 2 or more thresholds
"Hot and Dry" Vulnerable Scenario Explains Most Bad Outcomes

Vulnerable cases described by "Hot and Dry" scenario

Vulnerabilities Are Reduced With Response Packages

With Response Package

Current Management
Tradeoffs Between Decreasing Vulnerability and Cost and Effort

Initial Vulnerability Results for the Central Valley

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Presentation Goals

- Illustrate preliminary vulnerability analysis results for Central Valley
- Interactively explore:
  - Additional results
  - Effects of analytic choices on results

Current Management System Evaluated Under Many Plausible Futures

<table>
<thead>
<tr>
<th>Growth Scenarios</th>
<th>Climate Scenarios</th>
<th>Total Futures</th>
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<tr>
<td>3 population X 5 Historical ISM</td>
<td>X 5 Historical Drought</td>
<td>X 243</td>
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<tr>
<td>3 urban densities</td>
<td>5 Historical Drought + Steady Warming</td>
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<tr>
<td></td>
<td>12 Downscaled Climate Model</td>
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</table>
WEAP Model Simulates Many Aspects of System Over Time

- Demand (urban and agricultural)
- Supply (urban and agricultural)
- Instream flows
- Unmet demand
- Groundwater and surface water storage
- Many others…

Different Futures Lead to Different Results

Individual Simulation of Urban Supply and Demand

San Joaquin River & Tulare Lakes HRs

Individual Simulation of Agricultural Supply and Demand

Sacramento River HR

San Joaquin River & Tulare Lakes HRs

Historical 1970
Current Trends Population
Current Trends Density

Repeat of 1977

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California Water Plan
Individual Simulation of Agricultural Supply and Demand

Historical 1970
Current Trends Population
Current Trends Density

San Joaquin River & Tulare Lakes HRs

Update 2013
California Water Plan
Individual Simulation of Agricultural Supply and Demand
Low Urban Unmet Demand Across Scenarios in Sacramento River Region

Increasing Urban Demand in San Joaquin River and Tulare Lake Region
Low Agricultural Unmet Demand Across Scenarios in Sacramento River Region

Significant and Increasing Unmet Agricultural Demand in San Joaquin River and Tulare Lake Regions
Stable but Variable Surface and Groundwater in Sacramento River Region

Declining and Highly Variable Surface and Groundwater in San Joaquin River and Tulare Lake Regions
Key Observations of System Performance

- High urban and agricultural reliability in the Sacramento River region across futures
  - Stable groundwater and surface water for most futures
- Modest declines in urban reliability in San Joaquin River and Tulare Lakes regions for some futures
  - Up to 5% shortages in 2040 in some futures
- Degrading agricultural reliability in San Joaquin River and Tulare Lakes regions for most futures
  - Up to 50% shortage by 2040 in some futures
  - Declining groundwater storage amounts

Key Steps to Vulnerability Analysis

1) Review system performance across futures
2) Define vulnerabilities for key metrics
3) Characterize uncertain conditions leading to vulnerabilities
Key Steps to Vulnerability Analysis

1) Review system performance across futures
2) Define vulnerabilities for key metrics
3) Characterize uncertain conditions leading to vulnerabilities

Vulnerability Analysis Focuses on Key Performance Metrics

- Urban unmet demand
- Agricultural unmet demand
- Unmet instream flow requirements
- Groundwater storage

Reliability and maximum shortages
Frequency of unmet requirements
Trends over time
Exceedance Plots Summarize Simulations of Unmet Demand Over Time

Urban Reliability Derived from Exceedance Results

Reliability based on a 99% met demand threshold
Variable Performance Across Supply Metrics and Scenarios

Performance Metrics
- Urban Reliability (SR) (95% threshold)
- Agricultural Reliability (SR) (95% threshold)
- Urban Reliability (SJ/T/L) (99% threshold)
- Agricultural Reliability (SJ/T/L) (80% threshold)

Performance Summary for Groundwater and Instream Flow Requirements

Groundwater
- Groundwater (SR)
- Groundwater (SJ/T/L)

Instream Flow Requirements
- Trinity IFR
- Feather IFR
- American IFR
- Stanislaus IFR
- Merced IFR
- Friant IFR
Vulnerabilities Focus Uncertainty Analysis on What Matters to Management Decisions

- Vulnerabilities are futures in which objectives are not met
  - Defined via thresholds, e.g., Reliability < 95%
- Subsequent steps:
  - define external conditions that lead to vulnerabilities
  - compare how different response packages reduce vulnerable conditions

What Future Conditions Drive Poor Performance?

Urban and Agricultural Reliability

- Urban Reliability (SR)
- Agricultural Reliability (SR)
- Urban Reliability (SJ/TL)
- Agricultural Reliability (SJ/TL)

Urban Reliability Vulnerability
Agricultural Reliability Vulnerability
Analyzed Different Characterizations of Scenarios to Understand What Affects Reliability

- **Climate Conditions**
  - Average temperature (2006-2050, 2030-2050)
  - Average precipitation (2006-2050, 2030-2050)
  - Average precipitation in driest 2 year period
  - Average precipitation in driest 5 year period
  - Year of driest 2 year period
  - Year of driest 5 year period

- **Demographic Conditions**
  - Trends in housing
  - Trends in total irrigated crop area

Two Key Conditions Best Explain Urban and Agricultural Vulnerabilities

1. Average Temperature (2030-2050)
2. Average Precipitation (2030-2050)

Demographic and land use conditions much less important
Agricultural Reliability Vulnerable to All But Coolest Historical and Wettest Climate Scenario

Urban Reliability Is Vulnerable to Futures 12% Drier and 1.5°F Warmer
Declines in Groundwater Storage are Highly Correlated to Low Agricultural Reliability

Key Results from Vulnerability Analysis

- The San Joaquin River and Tulare Lake hydrologic regions vulnerable to some plausible future conditions
  - Urban reliability:
    - Driest and warmest of climate model projections
  - Agricultural reliability:
    - All but the wettest and coolest of historical and climate projections
    - Groundwater conditions vulnerable to similar conditions
Next Steps for Analysis

- Expand vulnerability analysis to additional metrics
- Simulate system with response packages
- Calculate reductions in vulnerability with response packages
- Compare tradeoffs among response packages

Interactive Visualization Software Allows for Exploration of Data and Results

- Interactive visualization software supports data exploration and “what-if” analyses:
  - Explore simulation results
  - Change reliability thresholds
  - Change vulnerability thresholds
  - Change definitions of vulnerable conditions

- Version for stakeholder use to be made available soon