Santa Cruz Climate Change Scenario Planning

June 2024
Santa Cruz is located about 75 miles south of San Francisco, with the city water utility serving about 100,000 customers inside and outside the city limits.
Santa Cruz’s Diverse Sources

- Loch Lomond Reservoir (1960)
- Beltz Wells (1964)
- Tait Wells
- North Coast Streams (1890)
- San Lorenzo River (1924)

- Loch Lomond: 22%
- Beltz Wells: 4%
- Tait Wells: 3%
- North Coast Streams: 25%
- San Lorenzo River: 46%
# Water Use Comparison: Then versus Now

<table>
<thead>
<tr>
<th></th>
<th>2002-2004</th>
<th>2016-2018</th>
<th>Change (Volume)</th>
<th>Percent Change</th>
<th>Direction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total annual production</td>
<td>3.9</td>
<td>2.6</td>
<td>-1.3</td>
<td>-33%</td>
<td>↓</td>
</tr>
<tr>
<td>(billion gallons)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peak season production</td>
<td>2.3</td>
<td>1.5</td>
<td>-0.8</td>
<td>-35%</td>
<td>↓</td>
</tr>
<tr>
<td>(billion gallons)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peak month (million gallons)</td>
<td>467</td>
<td>270</td>
<td>-197</td>
<td>-42%</td>
<td>↓</td>
</tr>
<tr>
<td>Peak day (million gallons)</td>
<td>15.2</td>
<td>10.4</td>
<td>-4.8</td>
<td>-32%</td>
<td>↓</td>
</tr>
<tr>
<td>Average day during peak season</td>
<td>12.7</td>
<td>8.0</td>
<td>-4.7</td>
<td>-37%</td>
<td>↓</td>
</tr>
<tr>
<td>(million gallons)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Population</td>
<td>87,000</td>
<td>97,000</td>
<td>+10,000</td>
<td>+11%</td>
<td>↑</td>
</tr>
<tr>
<td>Visitors (tourism)</td>
<td>?</td>
<td>?</td>
<td>?</td>
<td></td>
<td>↑</td>
</tr>
</tbody>
</table>
Water Use by Customer Class: Then versus Now

Total Annual Water Consumption

Customer Class

0 200 400 600 800 1,000 1,200 1,400 1,600
Million Gallons per Year

Single Family Residential
Multiple Residential
Business
UCSC
Industrial
Municipal
Irrigation
Golf Course
Irrigation
Coast Irrigation
Other

-40% -32% -27% -18% +3% -33% -46% -32% -74% -47%
So, What’s Changed about Demand Over Time?

Gross Daily Water Consumption
2008 to 2022

Million gallons per day

Poly. (2008)
Poly. (2009)
Poly. (2010)
Poly. (2011)
Poly. (2012)
Poly. (2013)
Poly. (2014)
Poly. (2016)
Poly. (2017)
Poly. (2019)
Poly. (2020)
Poly. (2021)
Poly. (2022)
Water Supply and WSAC
Council Direction to WSAC:

- Define the problem.
- Evaluate available alternatives.
- Make recommendations.
Small group learning opportunities for Committee members

Time for interest group caucuses

Scenario planning working groups and presentations
WSAC’s Problem Statement:
Our System Is Highly Vulnerable to Drought Caused Shortages Because of:

- Limited storage
- Fish flow requirements
- Highly variable supply

Of these, limited storage is most significant, and Conservation alone cannot solve the problem.

- Climate change is worsening our problem
WSAC Group Agrees to Consensus Recommendations – Early October 2015
WSAC’s Consensus Recommendations

1. Maximize conservation.
2. Commit to near-optimum fish flows for coho salmon and steelhead trout.
3. Share excess winter water (when available) with other local groundwater districts.
4. Store excess winter water in depleted aquifers.
5. Utilize purified recycled water.
6. Utilize desalinated water.

Conduct an analysis of all available alternatives and develop recommendations based on that assessment.
December 3, 2018, “Valve Turning” event for first ever water transfer, which ran until April 30, 2019

Location: O’Neill Ranch well, site of the Soquel Creek- Santa Cruz water system intertie
Supply Alternatives Assessment Work 2015 - present
To Support Scenario Planning Santa Cruz Worked in Three Parallel Paths Over 5 Years:

1. We developed the modeling tools to define the water supply deficit that could occur under various climate change scenarios;

2. We conducted technical feasibility analyses work on supply augmentation alternatives that gave us the information we needed to realistically assess their ability to improve supply reliability; and

3. We used our modeling tools to assess and compare how supply augmentation alternatives performed in improving supply reliability.
Santa Cruz Climate Modeling Tools
Climate Vulnerability Analysis for Surface Water

Vulnerability Analysis tools:
- Santa Cruz Climate Scenario generator (UMass)
- Water Balance Model
- Updated Santa Cruz Water System Model
Weather Generator Model
• The **climate scenario generator** is used to create tailored climate change scenarios for stress testing.

• It simulates changes in variability and changes in mean climate.

• Climates Scenarios are designed to be run with the water balance model.

• This allows comprehensive exploration of the climate vulnerability of Santa Cruz Water
Climate/Weather Generator: Development Steps

- Weather Data used covered 1936 to 2015.
- Historical characteristics of climate variability diagnosed and used to produce 5,000 new 100-year time series of precipitation and temperature generated based on identified trends in historic climate variability.
- Subset of 10 realizations of variability selected for stress testing the system.
Water Balance Model
Average Annual Runoff:
89,975 acre-feet
Climate Realization: \(dT=2\) \(dP=100\) R3574 \(dCV=1.1\)
Santa Cruz Water System Model
The water sources have the following use priority:

1) Coastal rivers (Liddell, Laguna, Majors)
2) SLR through Tait Diversion and Tait wells
3) Beltz Water Treatment Plant
4) Loch Lomond Reservoir
Climate Stress Testing
Climate Stress Test Overview

• Objectives:
  • Simulate widest range of *plausible* futures to understand sensitivity of the system
  • Results will indicate climate changes that are problematic (i.e., climate vulnerabilities)
  • Results will provide the basis for selecting project alternatives using one or more future planning scenario
Performance Metrics to Evaluate Vulnerability

- One Year Deficit Volume (Max, 98\textsuperscript{th})
- Two Year Deficit Volume (Max, 98\textsuperscript{th})
- Three Year Deficit Volume (Max, 98\textsuperscript{th})
- Frequency of Deficits and Reliability
# Multi-Year Deficits and Climate Change

- Precipitation change effects with +2°C

<table>
<thead>
<tr>
<th>Precip Change (%)</th>
<th>98th Percentile</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1-yr deficit (MG)</td>
<td>2-yr deficit (MG)</td>
</tr>
<tr>
<td>-40</td>
<td>1222 (47%)</td>
<td>2026 (78%)</td>
</tr>
<tr>
<td>-30</td>
<td>861 (33%)</td>
<td>1478 (57%)</td>
</tr>
<tr>
<td>-20</td>
<td>512 (20%)</td>
<td>1025 (39%)</td>
</tr>
<tr>
<td>-10</td>
<td>243 (9%)</td>
<td>650 (25%)</td>
</tr>
<tr>
<td>0</td>
<td>63 (2%)</td>
<td>247 (9%)</td>
</tr>
<tr>
<td>+10</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>+20</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>+30</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>+40</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
Planning Scenario: Comparing deficits without climate change and with climate change of -10% P and +2 C

(Demand from 2020)

<table>
<thead>
<tr>
<th></th>
<th>98th percentile of deficit (MG)</th>
<th>Maximum deficit (MG)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>dP</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>dT</td>
<td>0C</td>
<td>-10%</td>
</tr>
<tr>
<td>0C</td>
<td>+2C</td>
<td>-10%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-YR</td>
<td>27 (1%)</td>
<td>923 (35%)</td>
</tr>
<tr>
<td></td>
<td>139 (5%)</td>
<td>1535 (59%)</td>
</tr>
<tr>
<td>2-YR</td>
<td>243 (9%)</td>
<td>1065 (41%)</td>
</tr>
<tr>
<td></td>
<td>650 (25%)</td>
<td>2095 (80%)</td>
</tr>
<tr>
<td>3-YR</td>
<td>257 (10%)</td>
<td>1561 (60%)</td>
</tr>
<tr>
<td></td>
<td>840 (32%)</td>
<td>2205 (85%)</td>
</tr>
</tbody>
</table>

(Demand from 2020)
Effect of Increased Demand Over 20 Years of about 300 MGY

- **1-yr** Deficit from 243 MG under 2020 demand to 361 MG under 2045 demand
- **2-yr** Deficit from 650 MG under 2020 demand to 780 MG under 2045 demand
Climate Stress Test with Variability
Effect of increased CV on streamflow variables.

An increase in Coefficient of Variation (CV) causes dry years that are drier and wet year that are wetter.

The values of streamflow at Bigtrees are normalized.
The Effects of Changes in CV on Planning

- An increased in variability means larger deficits

- No Change: 1-yr deficit: 243 MG (9%)

- +20 Variability: 1-yr deficit: 904 MG (35%)
Coefficient of Variation effects on Deficit

(dT=+2°C, dP=-10%) (Demand from 2020)

<table>
<thead>
<tr>
<th>Change in CV</th>
<th>98th Percentile</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1-yr deficit (MG)</td>
<td>2-yr deficit (MG)</td>
</tr>
<tr>
<td>0%</td>
<td>243 (9%)</td>
<td>650 (25%)</td>
</tr>
<tr>
<td>10%</td>
<td>583 (22%)</td>
<td>1065 (41%)</td>
</tr>
<tr>
<td>20%</td>
<td>904 (35%)</td>
<td>1484 (57%)</td>
</tr>
</tbody>
</table>
Conclusions – Understanding Size and Characteristics of Potential Future Deficits

- The Water Supply Deficit is significantly affected by Climate Change
- Many climate projections indicate increase in the water supply deficit
- A 10% precipitation decrease causes a deficit increase of almost 10x (one year deficit) to 3x (3-year deficit)
- The frequency of drought also increases rapidly with precipitation decreases
- Increases in Variability greatly increase the water supply deficit even with no reduction in precipitation
Evaluating Project Alternatives
The water sources have the following use priority:

1) Coastal streams (Liddell, Laguna, Majors)
2) SLR through Tait Diversion and Tait wells
3) Beltz Water Treatment Plant
4) Loch Lomond Reservoir
Aquifer Storage and Recover (ASR)

- ASR reservoir has a maximum storage volume of 1.67BG.
- ASR reservoir is filled by injection of ~2 MGD from November to April. Injection rate has a loss of 19%.
- Extraction from the ASR reservoir is ~ 3 MGD and limited to May – October.
- We use an interlocking approach to split water between the ASR reservoir and the LL reservoir.
- First use local groundwater (Beltz) and then extract from the ASR reservoir if it is needed.
Indirect Potable Reuse (IPR)

- 0.7 MGD input to water supply system on Nov-April and 1.1 MGD input to water supply system on May-OCT.

- After Tait wells in order of dispatch, before Beltz wells.
Direct Potable Reuse (DPR)

- 1 MGD extracted water into City’s supply on Nov-April, increasing to 2 MGD extracted water into City’s supply from May – Oct during normal years.
- Once the storage at LL reservoir is below 2 BG, increase supply to 3 MGD year-round until LL reservoir reach the maximum storage capacity of 2.8 BG.
- After Tait wells in order of dispatch, before Beltz wells.
Seawater Desalination

- 1 MGD extracted water into City’s supply on Nov-April, increasing to 2 MGD extracted water into City’s supply from May – Oct during normal years.

- Once the storage at LL reservoir is below 2 BG, increase supply to 3 MGD year-round until LL reservoir reach the maximum storage capacity of 2.8 BG.

- After Tait wells in order of dispatch, before Beltz wells.
Results for Worst Drought

R1270 Sequence -- 2055-2059
Reservoir Drawdown

No Climate Change

Precip (MGD)

LL Storage (MG)

No Adapt.
DPR/DESAL, ASR, and IPR can respectively decrease the 3-yr deficit during the worst multi-year drought from 1560 MG to 0, 190, and 810 MG.

<table>
<thead>
<tr>
<th></th>
<th>No Adapt.</th>
<th>with ASR</th>
<th>with IPR</th>
<th>with DPR/DESAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>2058</td>
<td>610</td>
<td>-</td>
<td>130</td>
<td>-</td>
</tr>
<tr>
<td>2059</td>
<td>920</td>
<td>170</td>
<td>670</td>
<td>-</td>
</tr>
<tr>
<td>2060</td>
<td>30</td>
<td>20</td>
<td>20</td>
<td>-</td>
</tr>
<tr>
<td>3-yr Cumulative</td>
<td>1,560</td>
<td>190</td>
<td>810</td>
<td>-</td>
</tr>
</tbody>
</table>
Reservoir Drawdown

Climate Change (P: -10%, T: +2C)
ASR-Reservoir Drawdown

Climate Change (P: -10%, T: +2°C)

No Adapt.  with ASR  ASR_Reservoir

ASR Extraction (MGD)

ASR Water level

Loch Lomond Water level

LL Storage (MG)

ASR_Reservoir

10/1/2049 10/1/2050 10/1/2051 10/1/2052 10/1/2053 10/1/2054 10/1/2055 10/1/2056 10/1/2057 10/1/2058 10/1/2059 10/1/2060 10/1/2061 10/1/2062 10/1/2063 10/1/2064

0 0.5 1 1.5 2 2.5 3 3.5

0 500 1000 1500 2000 2500 3000 3500

10/1/2060 10/1/2061 10/1/2062 10/1/2063 10/1/2064
DPR/DESAL-Reservoir Drawdown

Climate Change (P:-10%, T:+2C)
Effects of Climate Change on Deficit - ASR

- For a 10% decrease in precip, ASR reduction of the 98th percentile of 3-yr deficit decreases from 100% to 95%.

- For a 10% decrease in precip, ASR reduction of the maximum 3-yr deficit decreases from 85% to 60%.

<table>
<thead>
<tr>
<th>dP/dT</th>
<th>98th percentile of deficit (MG)</th>
<th>Maximum deficit (MG)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td></td>
<td>-10%</td>
<td>-10%</td>
</tr>
<tr>
<td></td>
<td>+2C</td>
<td>+2C</td>
</tr>
<tr>
<td>1-YR</td>
<td>30</td>
<td>920</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>170</td>
</tr>
<tr>
<td></td>
<td>100%</td>
<td>80%</td>
</tr>
<tr>
<td></td>
<td>1,070</td>
<td>690</td>
</tr>
<tr>
<td>2-YR</td>
<td>140</td>
<td>1,540</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>190</td>
</tr>
<tr>
<td></td>
<td>100%</td>
<td>85%</td>
</tr>
<tr>
<td></td>
<td>2,100</td>
<td>850</td>
</tr>
<tr>
<td>3-YR</td>
<td>260</td>
<td>1,560</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>190</td>
</tr>
<tr>
<td></td>
<td>95%</td>
<td>85%</td>
</tr>
<tr>
<td></td>
<td>2,210</td>
<td>910</td>
</tr>
</tbody>
</table>

(Demand from 2020)

➢ For a 10% decrease in precip, ASR reduction of the 98th percentile of 3-yr deficit decreases from 100% to 95%.

➢ For a 10% decrease in precip, ASR reduction of the maximum 3-yr deficit decreases from 85% to 60%.
Effects of Variability on Deficit - ASR

- For 20% increase in variability, ASR reduction of 98th percentile of 3-yr deficit decreases from 95% to 50%.
- For 20% increase in variability, ASR reduction of maximum 3-yr deficit decreases from 60% to 35%.

<table>
<thead>
<tr>
<th>Change in CV</th>
<th>98th Percentile</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1-yr deficit (MG)</td>
<td>2-yr deficit (MG)</td>
</tr>
<tr>
<td>0%</td>
<td>240</td>
<td>0</td>
</tr>
<tr>
<td>20%</td>
<td>900</td>
<td>350</td>
</tr>
</tbody>
</table>

(T:+2°C , P:-10%) (Demand from 2020)