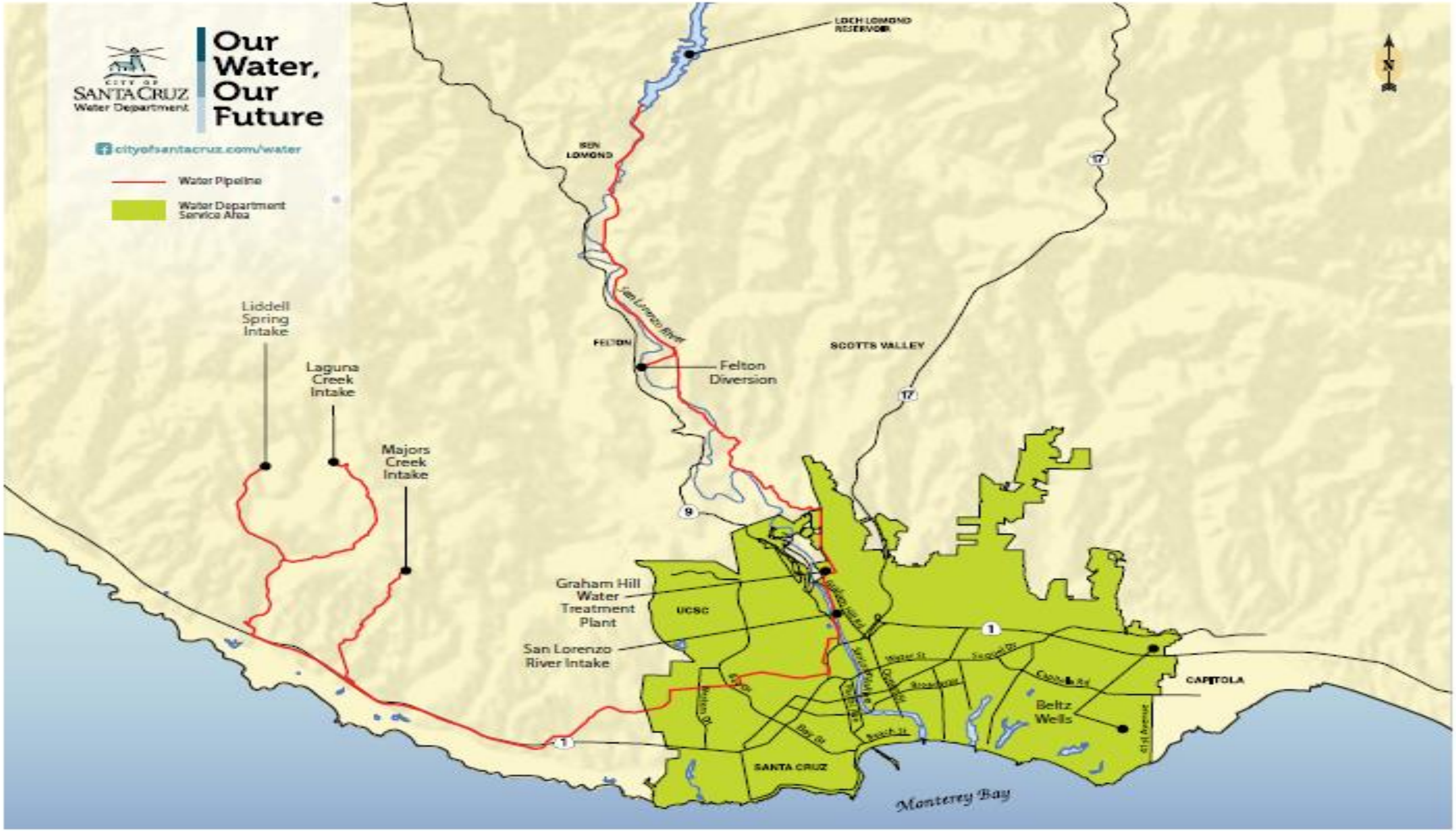
# Santa Cruz Climate Change Scenario Planning

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.

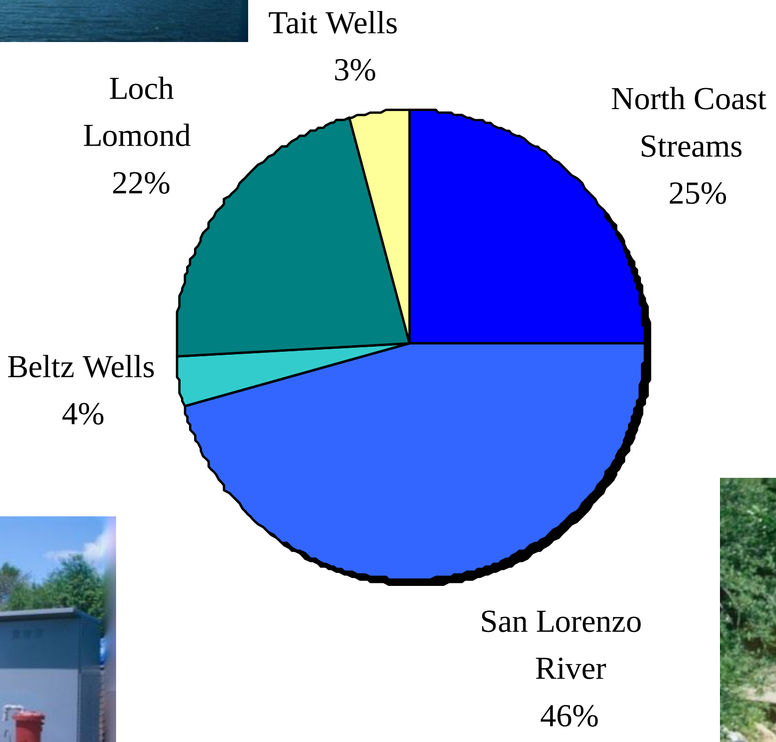



CITY OF SANTA CRUZ
Water Department
Our Water, Our Future
cityofsantacruz.com/water
Water Pipeline
Water Department Service Area
LOCH LOMOND RESERVOIR
BEN LOMOND
San Lorenzo River
FELTON
Felton Diversion
SCOTTS VALLEY
17
Liddell Spring Intake
Laguna Creek Intake
Majors Creek Intake
9
Graham Hill Water Treatment Plant
UCSC
San Lorenzo River Intake
1
Water St
Soquel Dr
Capitola Rd
Broadway
Bay St
Beach St
41st Avenue
CAPITOLA
Beltz Wells
SANTA CRUZ
Monterey Bay

# Santa Cruz's Diverse Sources

Loch Lomond Reservoir
(1960)

North Coast Streams
(1890)



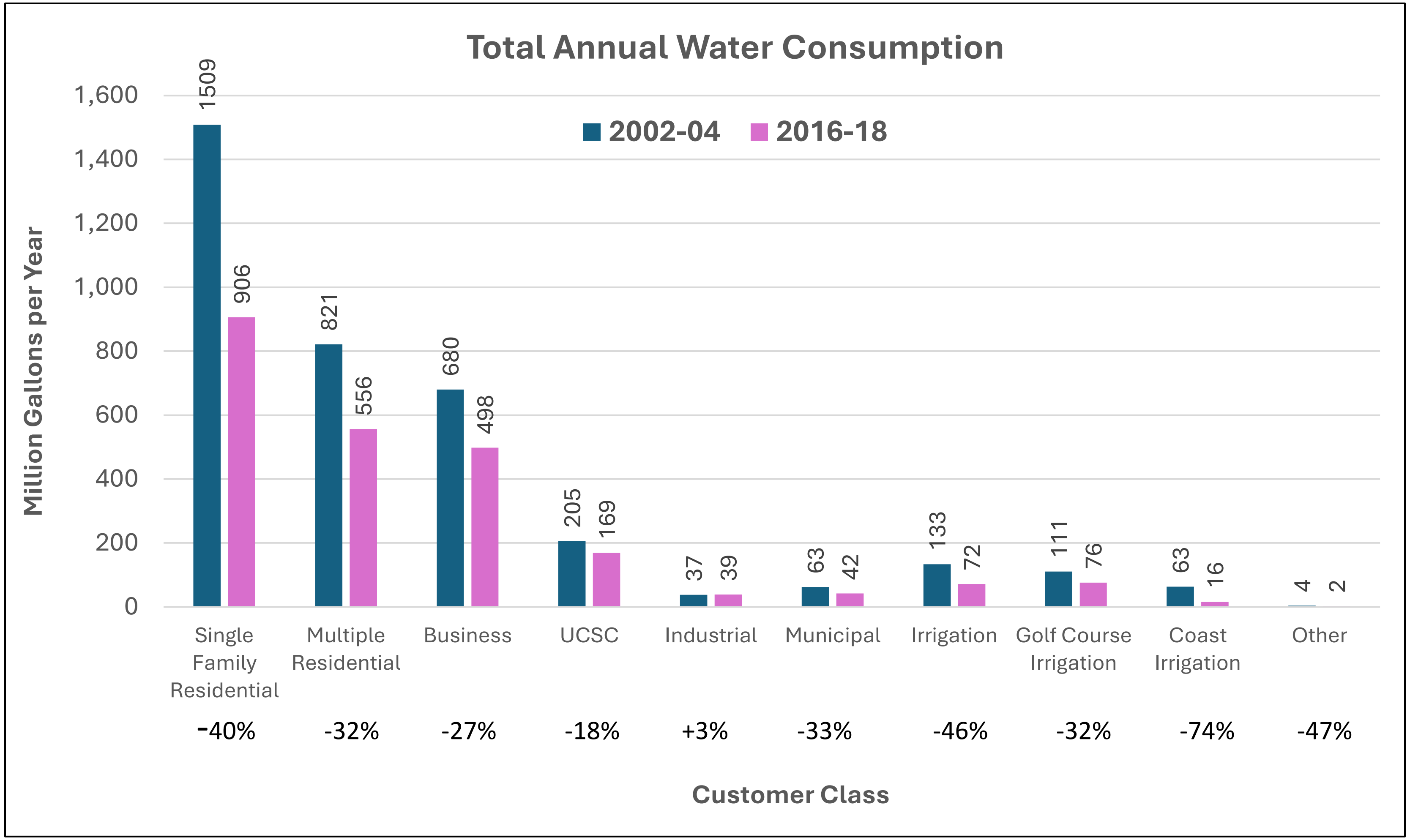

Beltz Wells (1964)

San Lorenzo River
(1924)

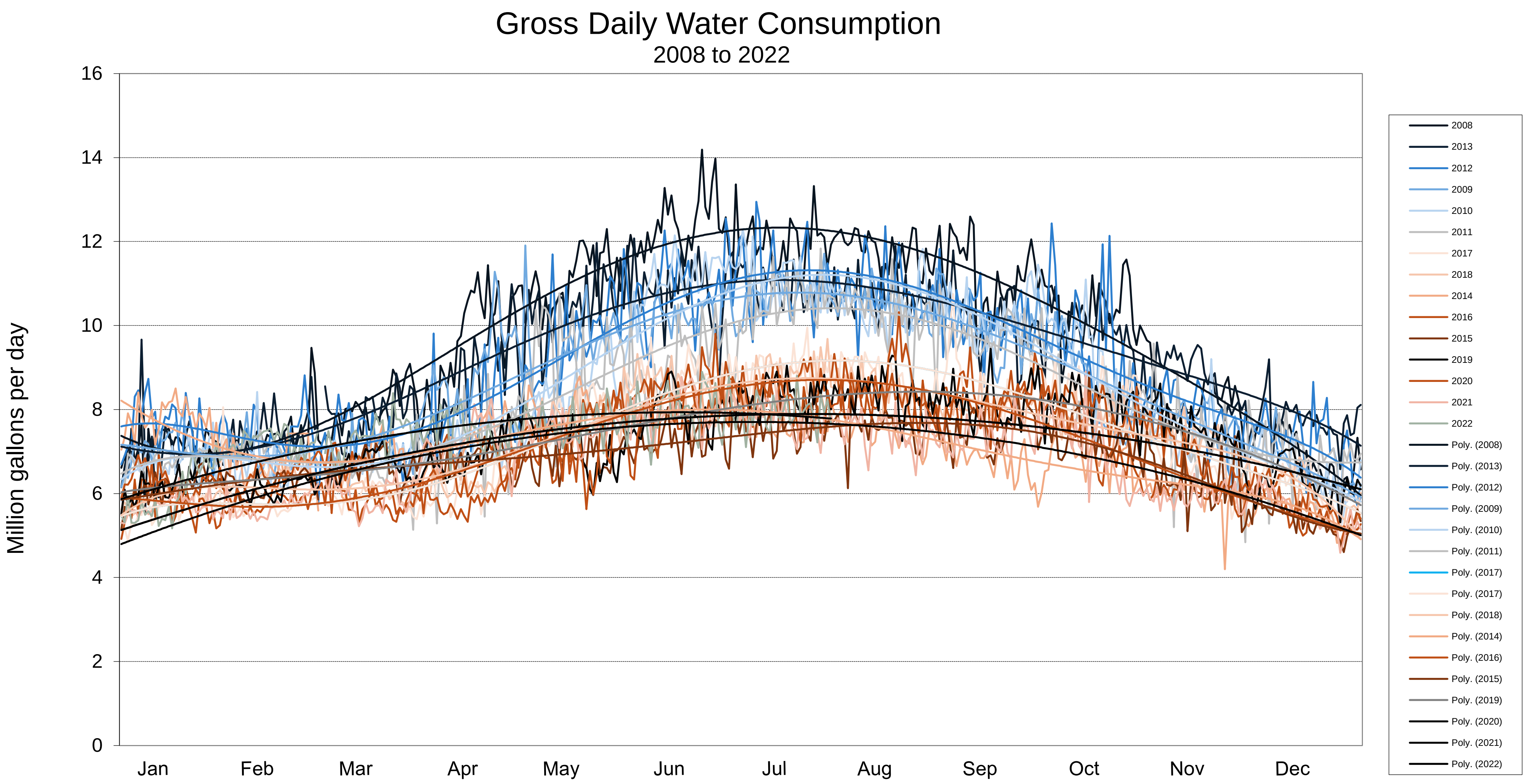
# Water Use Comparison: Then versus Now

| | 2002-2004 | 2016-2018 | Change (Volume) | Percent Change | Direction |
|---|---|---|---|---|---|
| Total annual production (billion gallons) | 3.9 | 2.6 | -1.3 | -33% | ↓ |
| Peak season production (billion gallons) | 2.3 | 1.5 | -0.8 | -35% | ↓ |
| Peak month (million gallons) | 467 | 270 | -197 | -42% | ↓ |
| Peak day (million gallons) | 15.2 | 10.4 | -4.8 | -32% | ↓ |
| Average day during peak season (million gallons) | 12.7 | 8.0 | -4.7 | -37% | ↓ |
| Population | 87,000 | 97,000 | +10,000 | +11% | ↑ |
| Visitors (tourism) | ? | ? | ? | | ↑ |

# Water Use by Customer Class: Then versus Now



# So, What’s Changed about Demand Over Time?



# Water Supply and WSAC

# Council Direction to WSAC:

- Define the problem.
- Evaluate available alternatives.
- Make recommendations.

# The City of Santa Cruz Water Supply Advisory Committee
# April 2014 – October 2015

Small group learning opportunities for Committee members

Scenario planning working groups and presentatio ns

Time for interest group caucuses

conditions)

# 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:

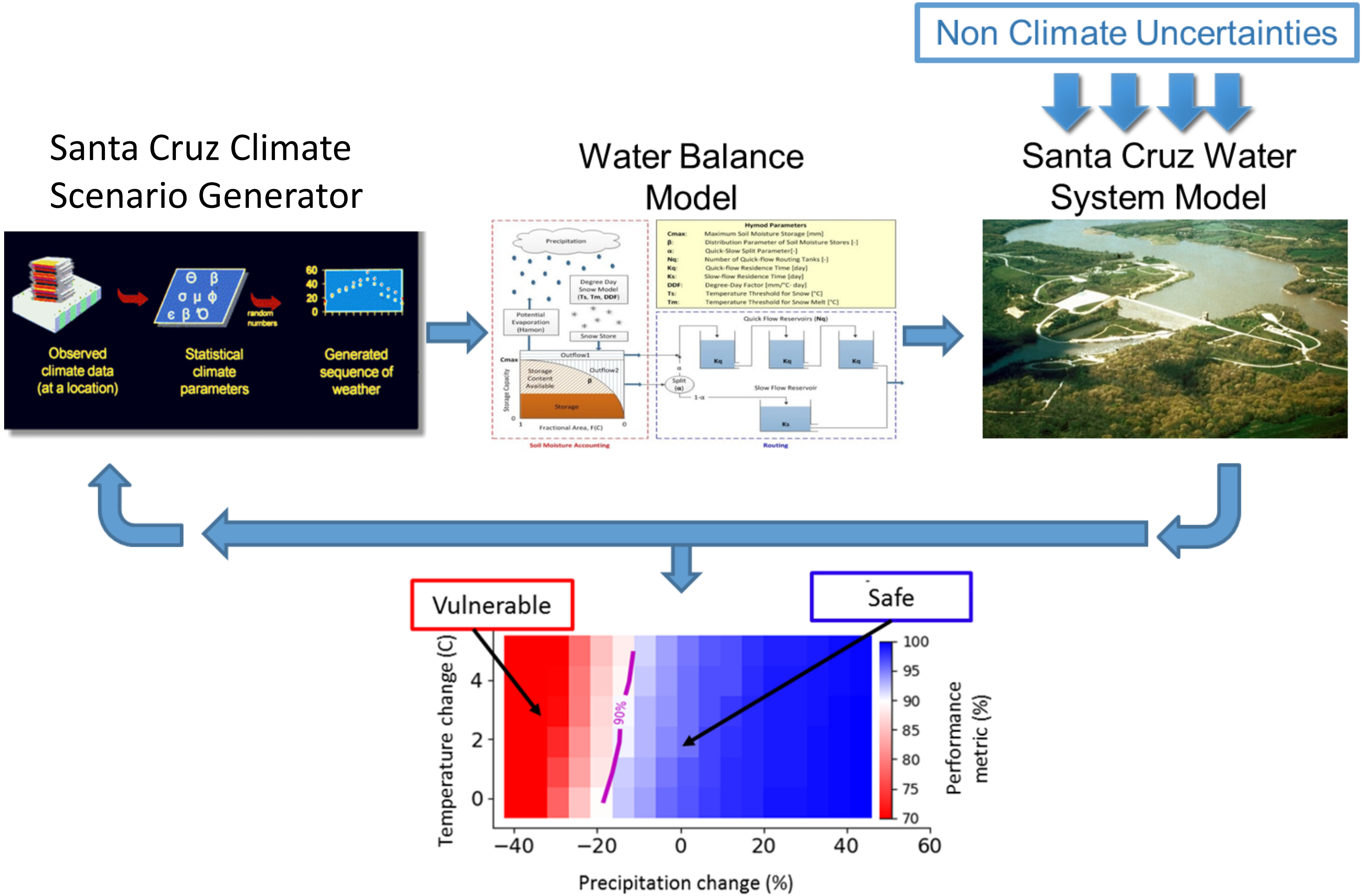
1. We developed the modeling tools to define the water supply deficit that could occur under various climate change scenarios;
2. We conducted technical feasibility analyses work on supply augmentation alternatives that gave us the information we needed to *realistically* assess their ability to improve 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

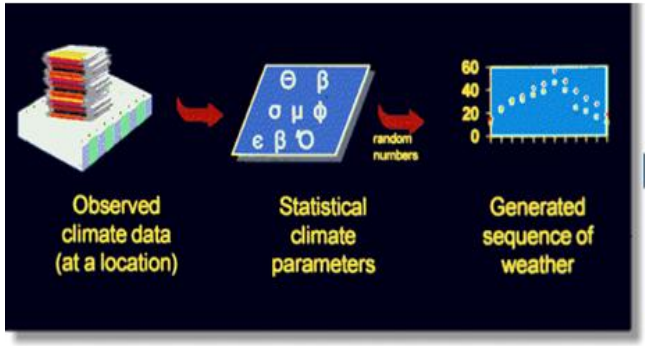


# Weather Generator Model

# Santa Cruz Climate Scenario Generator

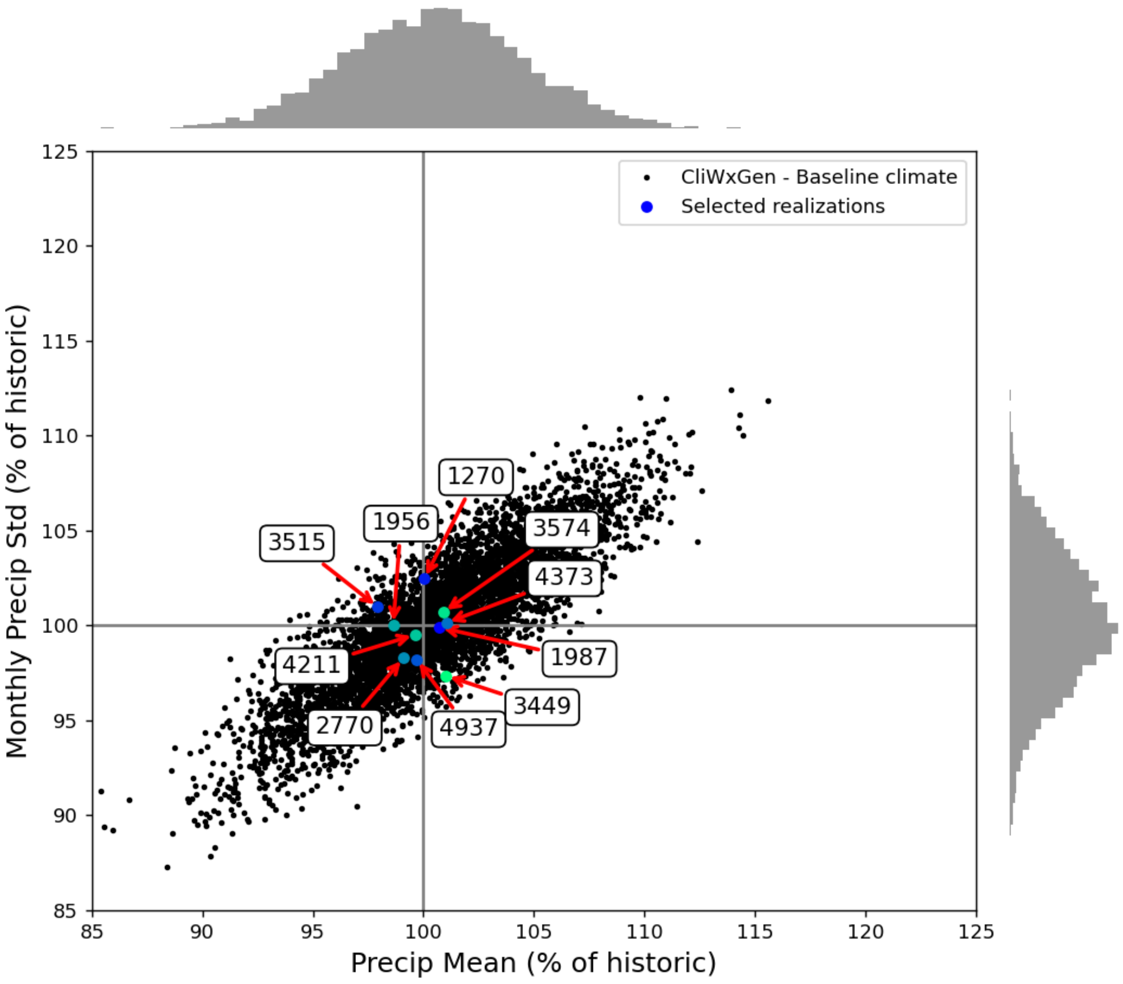
- The **climate scenario generator** is used to create tailored climate change scenarios for stress testing.
- It simulates changes in variability and changes in mean climate.
- Climates Scenarios are designed to be run with the water balance model.
- This allows comprehensive exploration of the climate vulnerability of Santa Cruz Water

Climate/Weather Generator



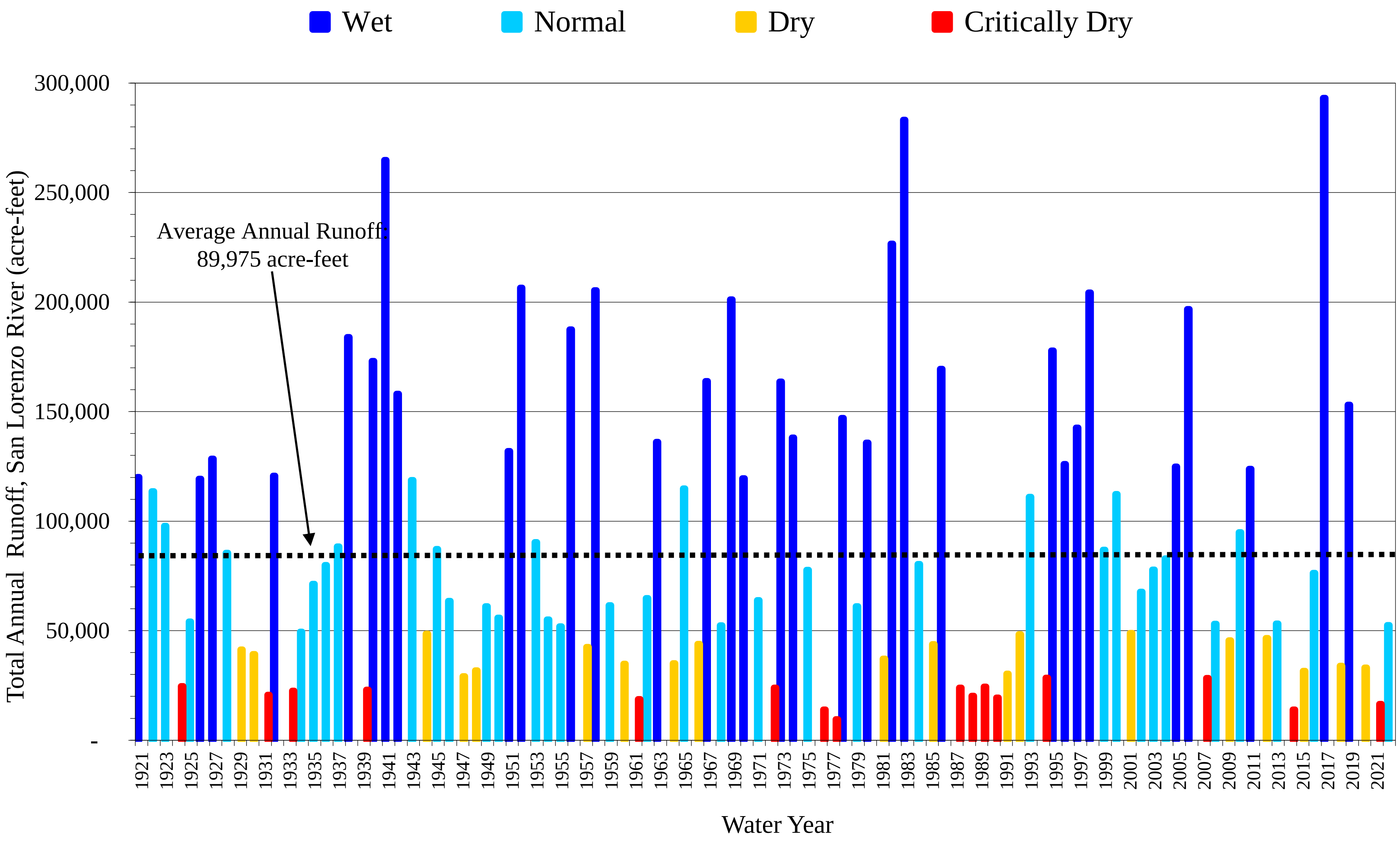
# Climate/Weather Generator: Development Steps

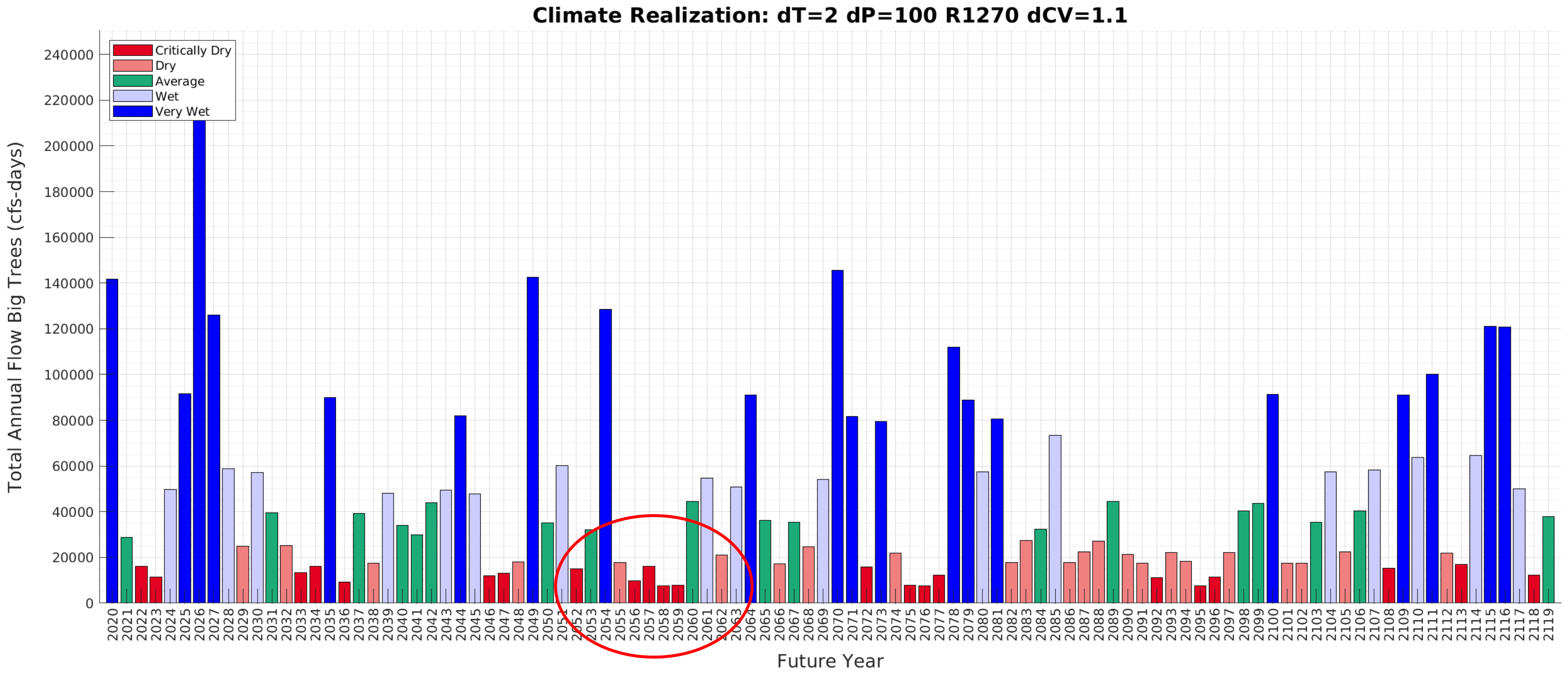
- Weather Data used covered 1936 to 2015.
- Historical characteristics of climate variability diagnosed and used to produce 5,000 new 100-year time series of precipitation and temperature generated based on identified trends in historic climate variability
- Subset of 10 realizations of variability selected for stress testing the system.



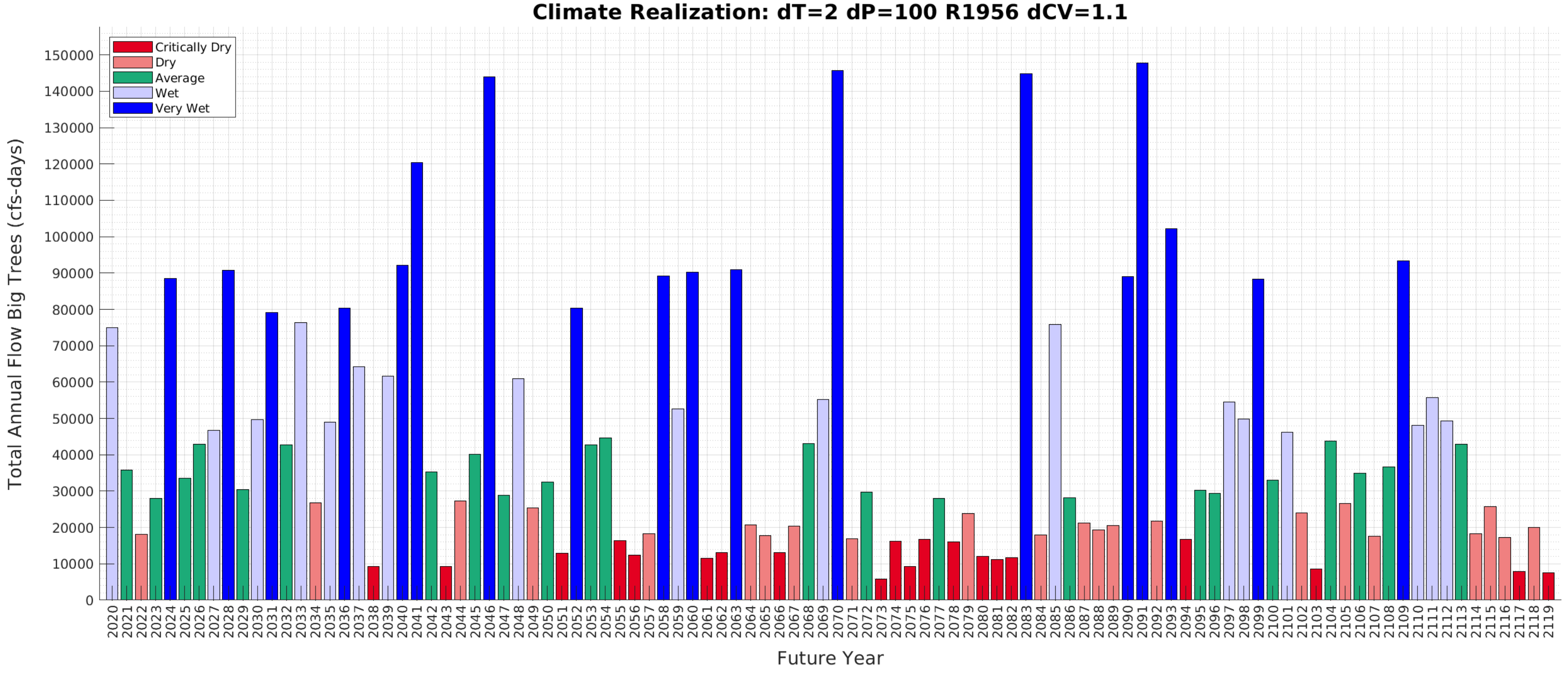
# Water Balance Model

# Water Year Classification System

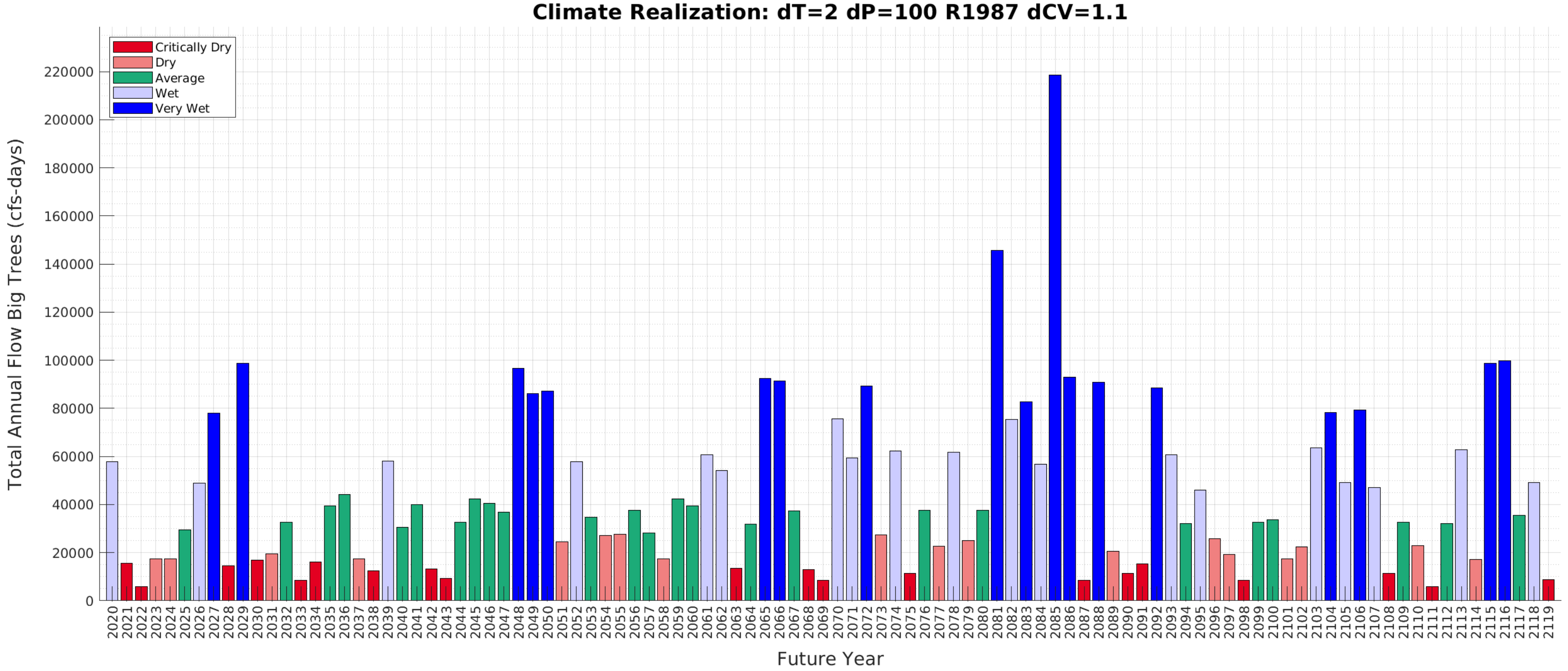




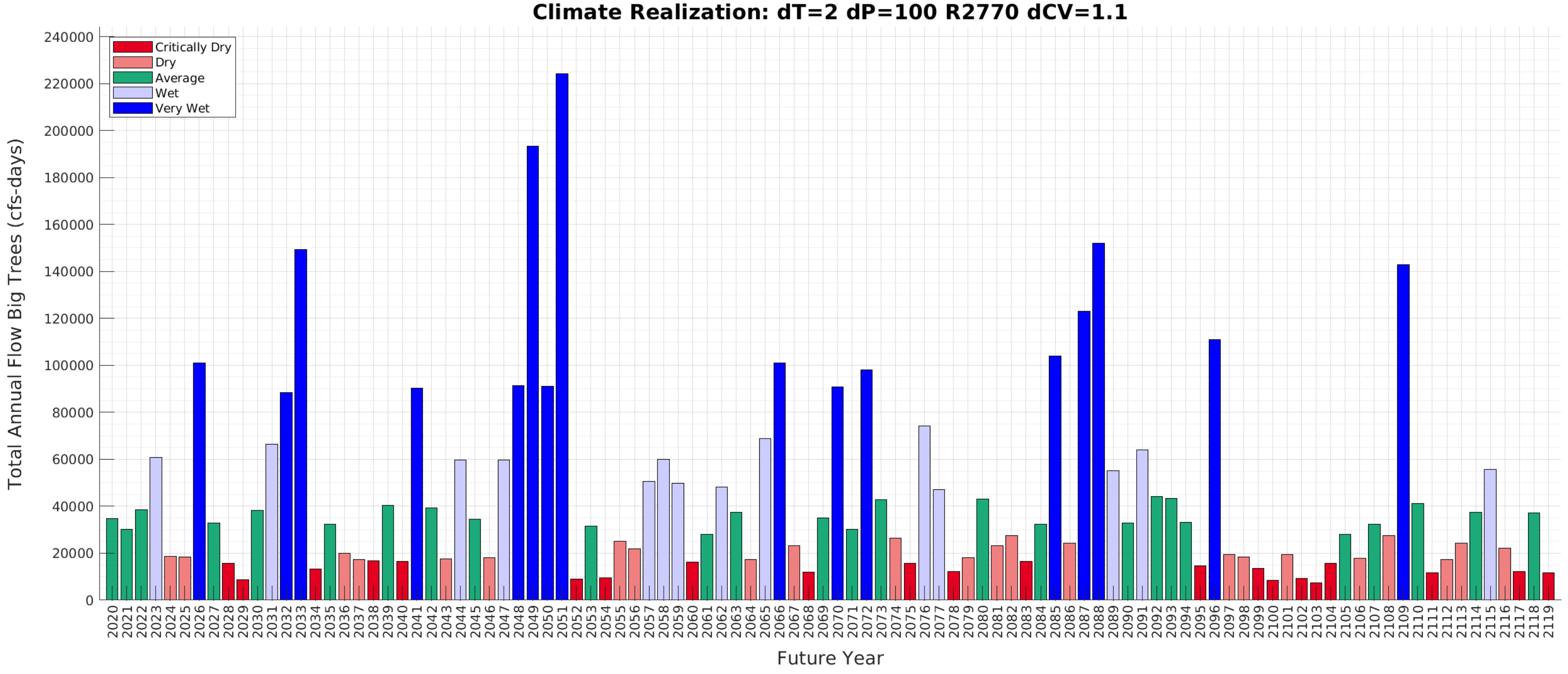
Climate Realization: dT=2 dP=100 R1270 dCV=1.1
Critically Dry
Dry
Average
Wet
Very Wet
Total Annual Flow Big Trees (cfs-days)
Future Year

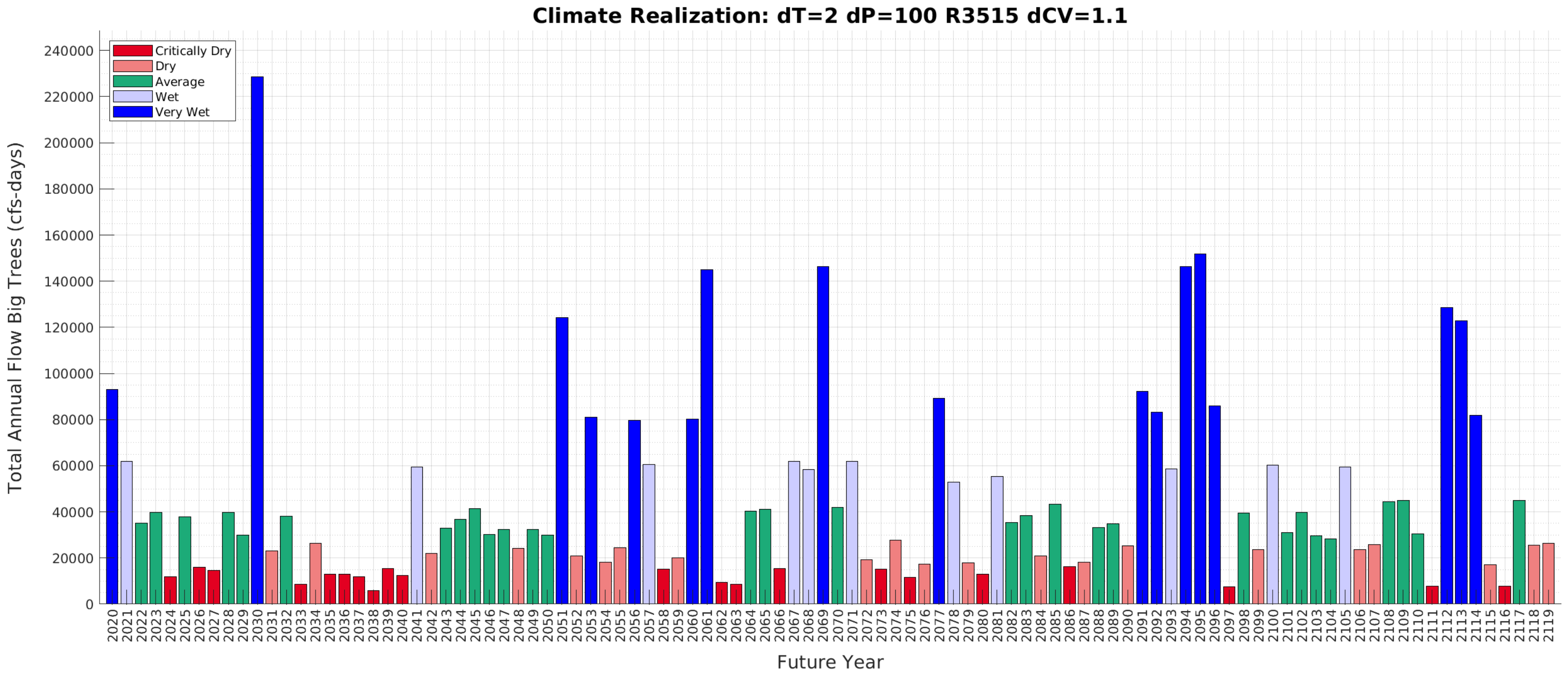


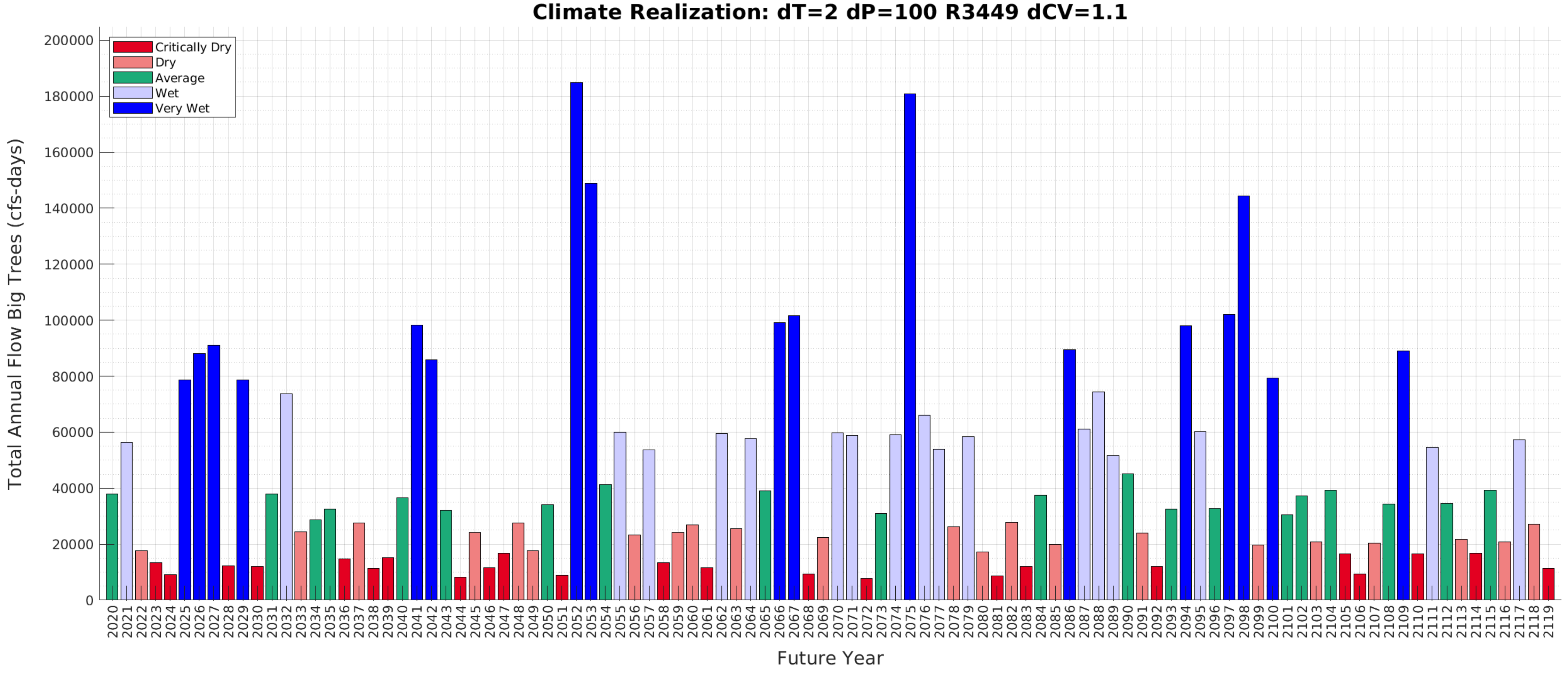
Climate Realization: dT=2 dP=100 R1956 dCV=1.1
Critically Dry
Dry
Average
Wet
Very Wet
Total Annual Flow Big Trees (cfs-days)
Future Year



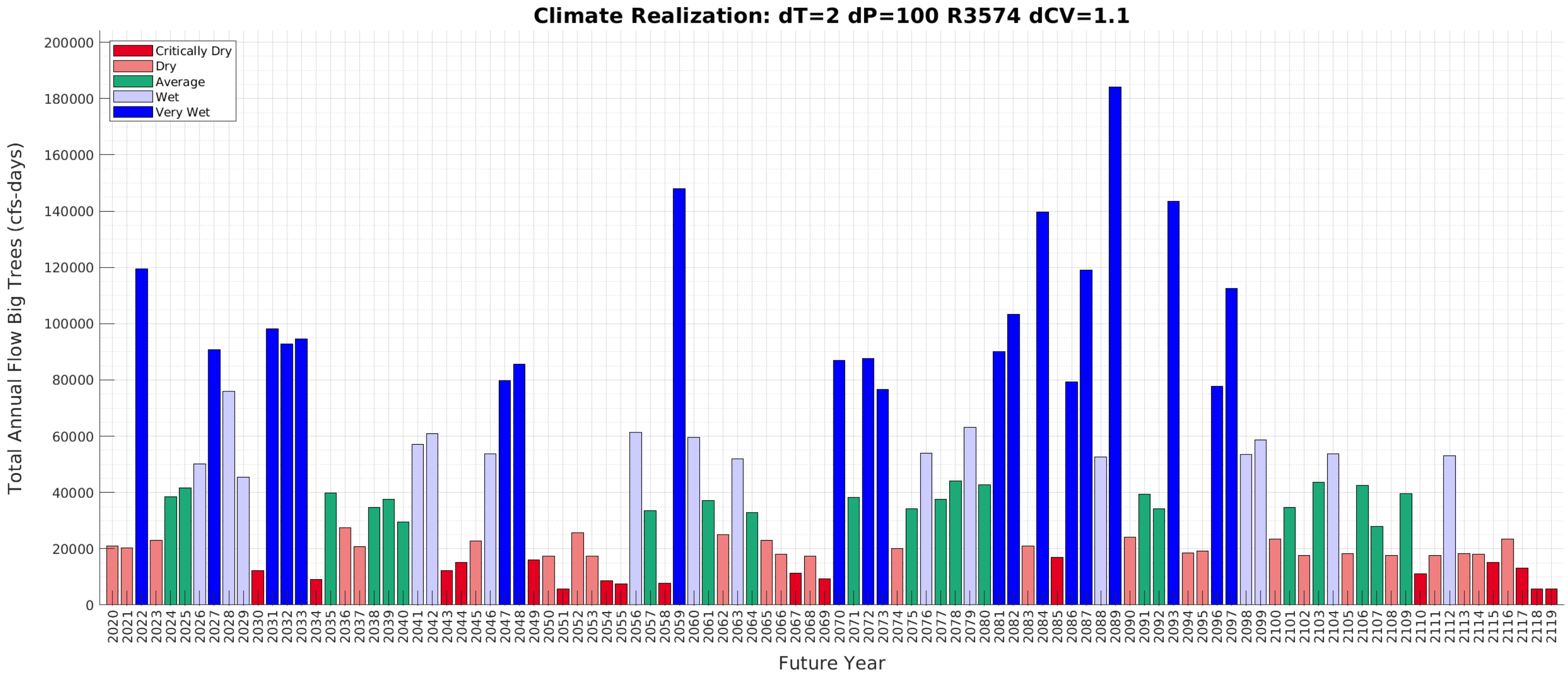
Climate Realization: dT=2 dP=100 R1987 dCV=1.1
Critically Dry
Dry
Average
Wet
Very Wet
Total Annual Flow Big Trees (cfs-days)
Future Year

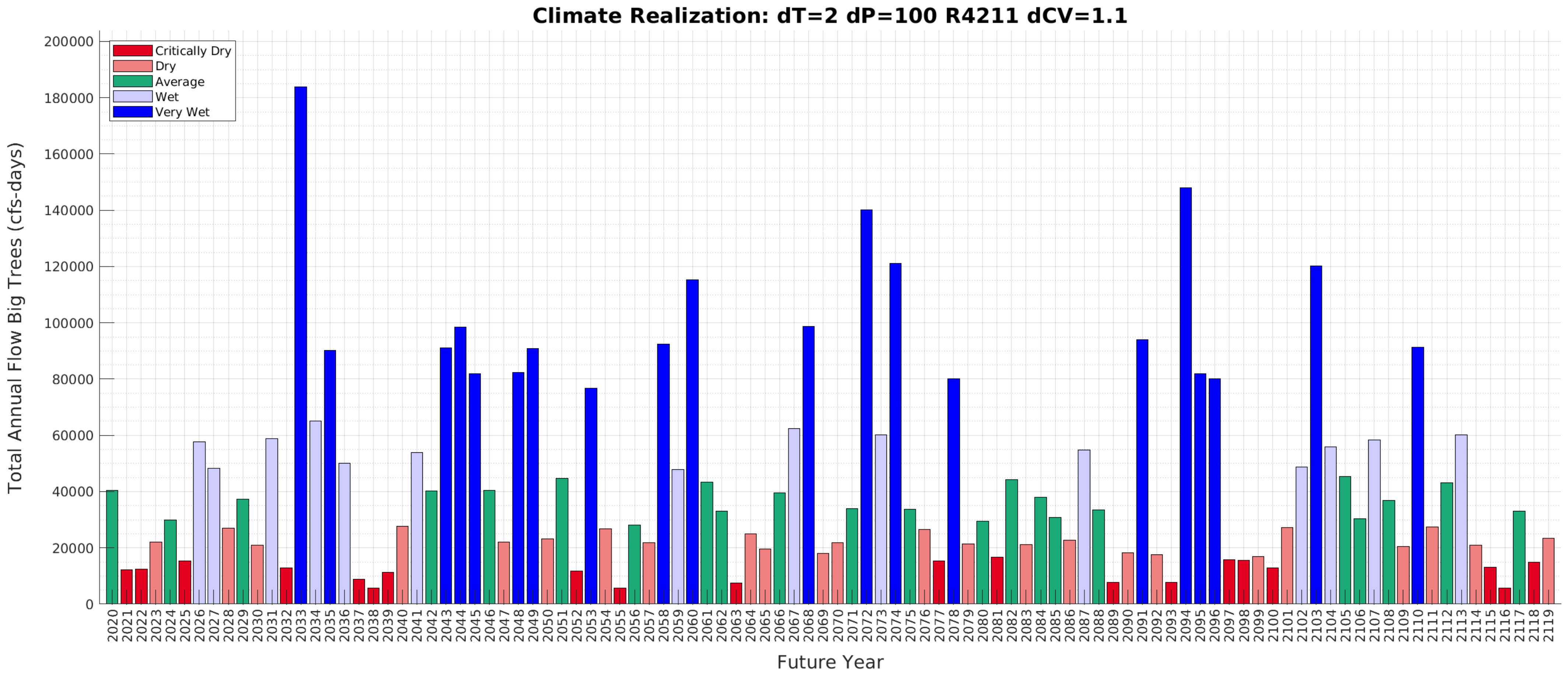

Climate Realization: dT=2 dP=100 R2770 dCV=1.1
Critically Dry
Dry
Average
Wet
Very Wet
Total Annual Flow Big Trees (cfs-days)
Future Year


Climate Realization: dT=2 dP=100 R3515 dCV=1.1
Critically Dry
Dry
Average
Wet
Very Wet
Total Annual Flow Big Trees (cfs-days)
Future Year

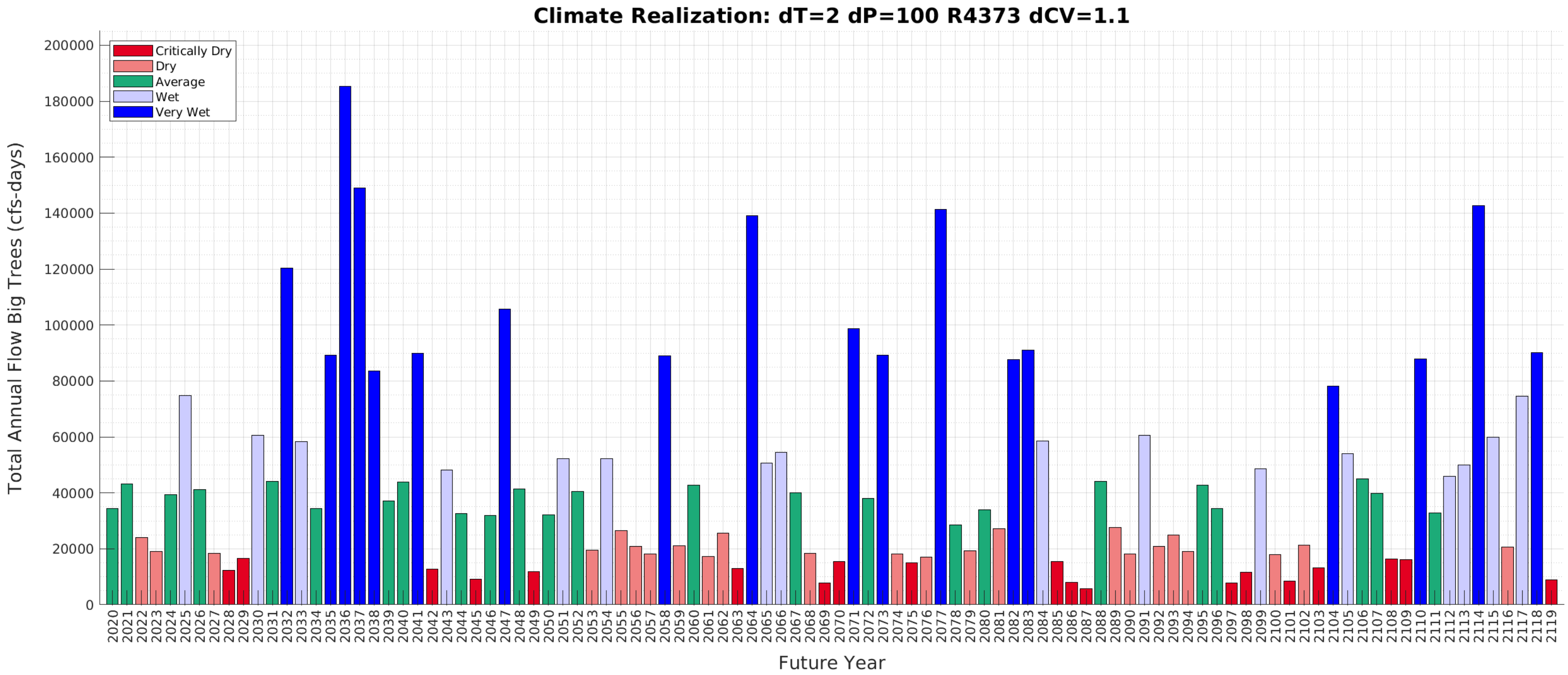


Climate Realization: dT=2 dP=100 R3449 dCV=1.1
Critically Dry
Dry
Average
Wet
Very Wet
Total Annual Flow Big Trees (cfs-days)
Future Year

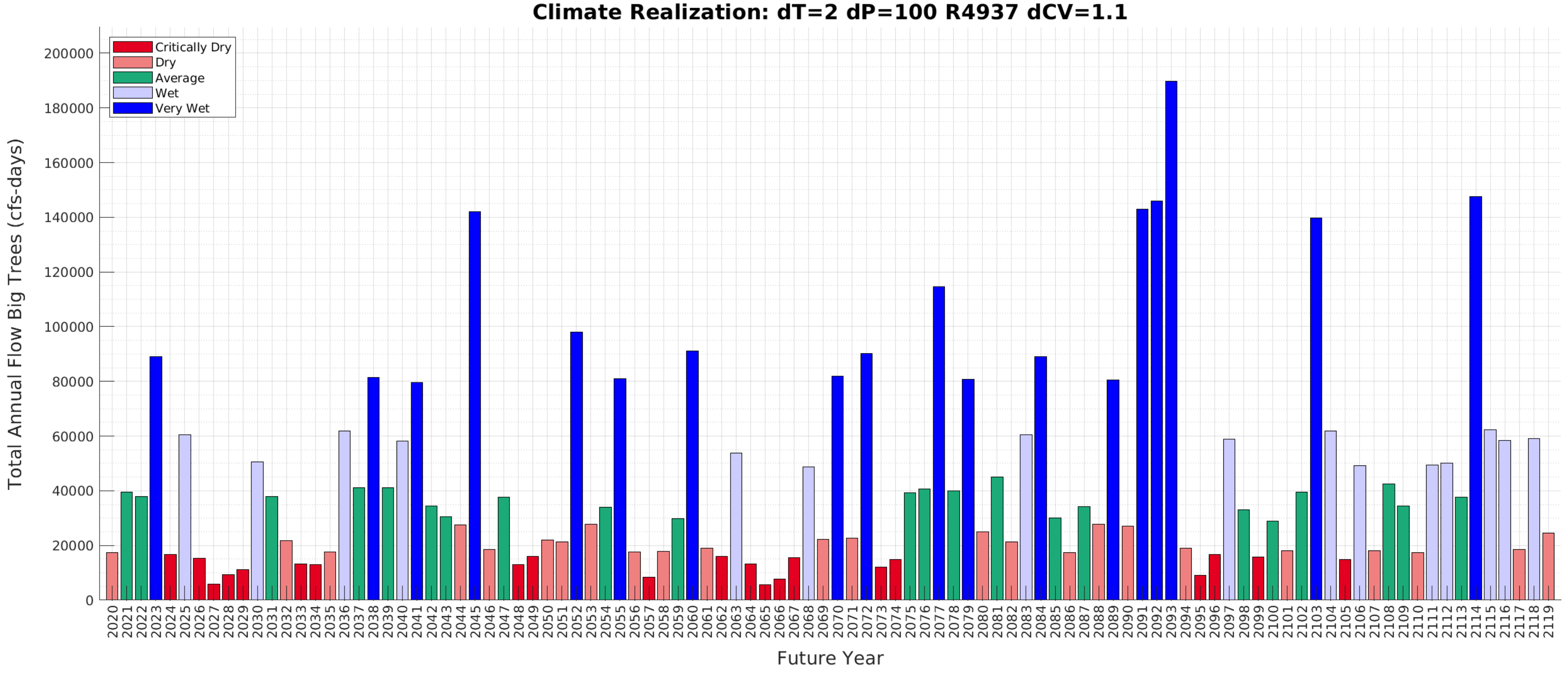

Climate Realization: dT=2 dP=100 R3574 dCV=1.1
Critically Dry
Dry
Average
Wet
Very Wet
Total Annual Flow Big Trees (cfs-days)
Future Year



Climate Realization: dT=2 dP=100 R4211 dCV=1.1
Critically Dry
Dry
Average
Wet
Very Wet
Total Annual Flow Big Trees (cfs-days)
Future Year



Climate Realization: dT=2 dP=100 R4373 dCV=1.1
Critically Dry
Dry
Average
Wet
Very Wet
Total Annual Flow Big Trees (cfs-days)
Future Year

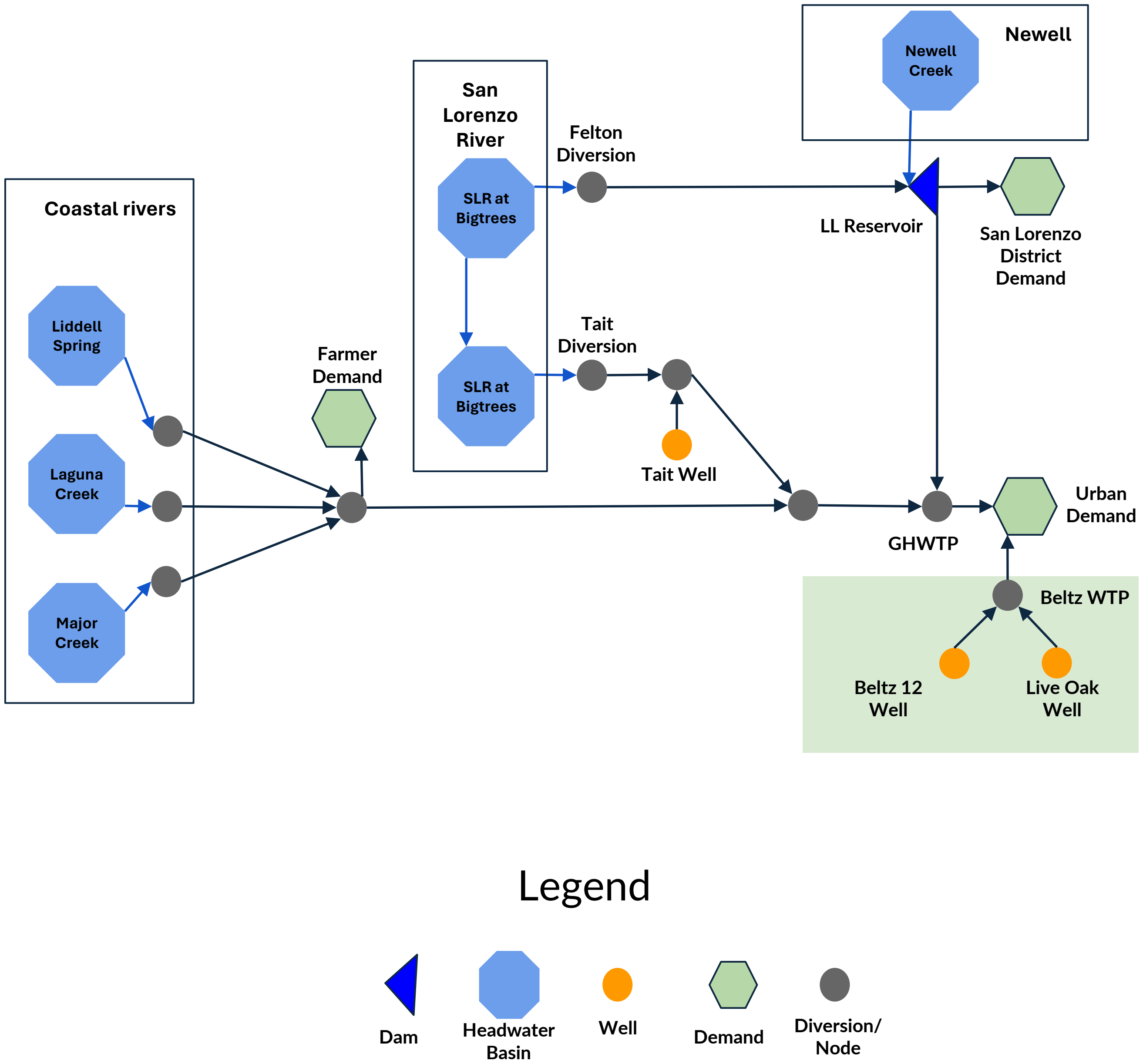

Climate Realization: dT=2 dP=100 R4937 dCV=1.1
Critically Dry
Dry
Average
Wet
Very Wet
Total Annual Flow Big Trees (cfs-days)
Future Year

# Santa Cruz Water System Model

# SCWSM: Model Schematic

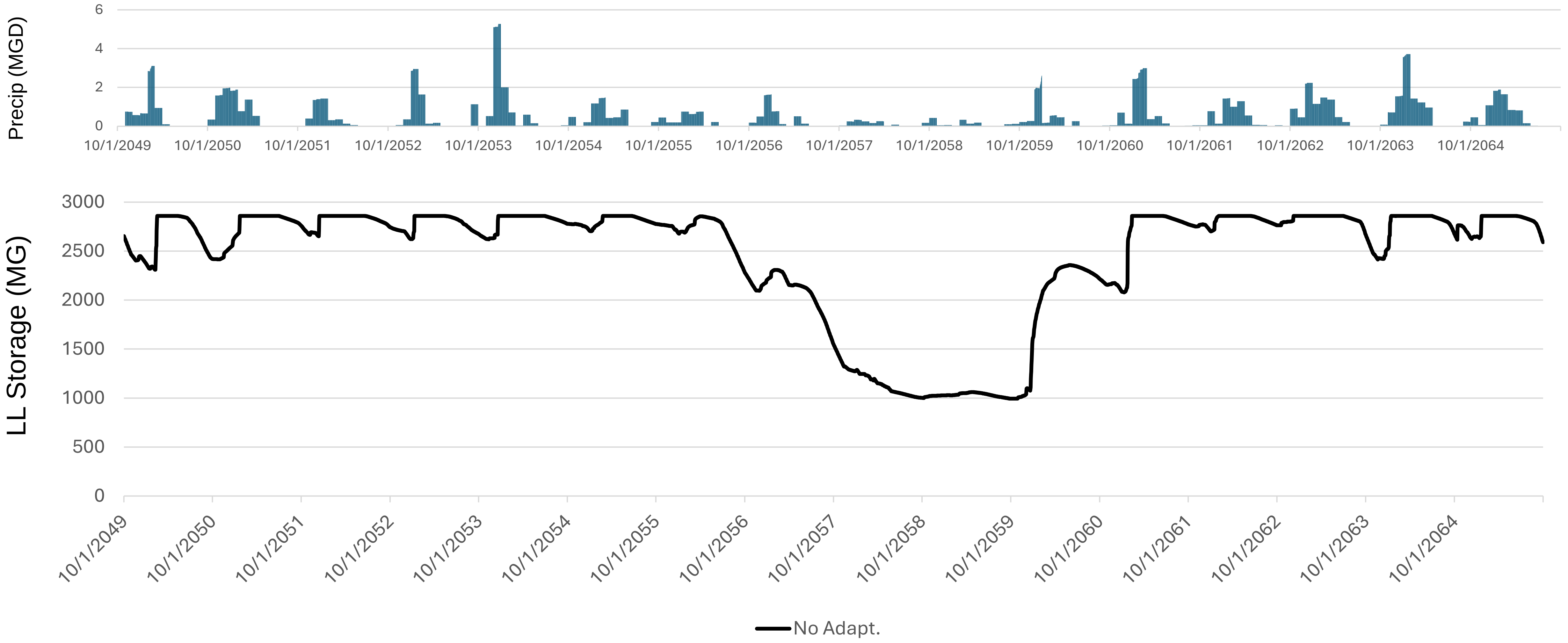
The water sources have the following use priority:

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



# Reservoir Drawdown

# No Climate Change



# 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$^{th}$)
- Two Year Deficit Volume (Max, 98$^{th}$)
- Three Year Deficit Volume (Max, 98$^{th}$)
- Frequency of Deficits and Reliability

# Multi-Year Deficits and Climate Change

- Precipitation change effects with +2C

| Precip Change (%) | 98th Percentile | | | Max | | |
|---|---|---|---|---|---|---|
| | 1-yr deficit (MG) | 2-yr deficit (MG) | 3-yr deficit (MG) | 1-yr deficit (MG) | 2-yr deficit (MG) | 3-yr deficit (MG) |
| -40 | 1222 (47%) | 2026 (78%) | 2731 (104%) | 1743 (67%) | 3005 (115%) | 4229 (162%) |
| -30 | 861 (33%) | 1478 (57%) | 2031 (78%) | 1597 (61%) | 2694 (103%) | 3413 (131%) |
| -20 | 512 (20%) | 1025 (39%) | 1382 (53%) | 1408 (54%) | 2491 (96%) | 2755 (105%) |
| -10 | 243 (9%) | 650 (25%) | 840 (32%) | 1065 (41%) | 2095 (80%) | 2205 (85%) |
| **0** | **63 (2%)** | **247 (9%)** | **421 (16%)** | **923 (35%)** | **1580 (61%)** | **1643 (63%)** |
| +10 | 0 | 0 | 22 (1%) | 664 (25%) | 824 (32%) | 845 (32%) |
| +20 | 0 | 0 | 0 | 188 (7%) | 188 (7%) | 188 (7%) |
| +30 | 0 | 0 | 0 | 0 | 0 | 0 |
| +40 | 0 | 0 | 0 | 0 | 0 | 0 |

# Planning Scenario: Comparing deficits without climate change and with climate change of -10% P and +2 C

(Demand from 2020)

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

# Effect of Increased Demand Over 20 Years of about 300 MGY

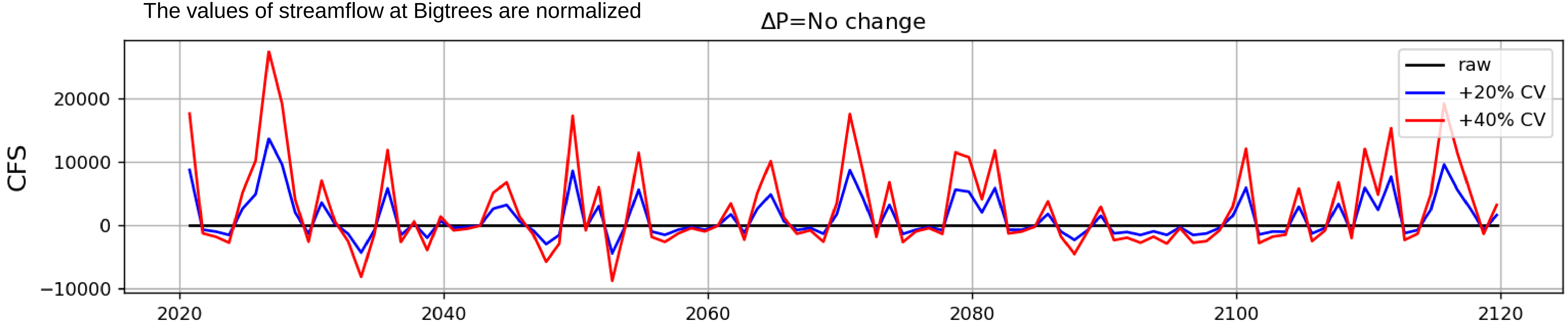
- **1-yr** Deficit from 243 MG under **2020** demand to 361 MG under **2045** demand
- **2-yr** Deficit from 650 MG under **2020** demand to 780 MG under **2045** demand

# 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**.

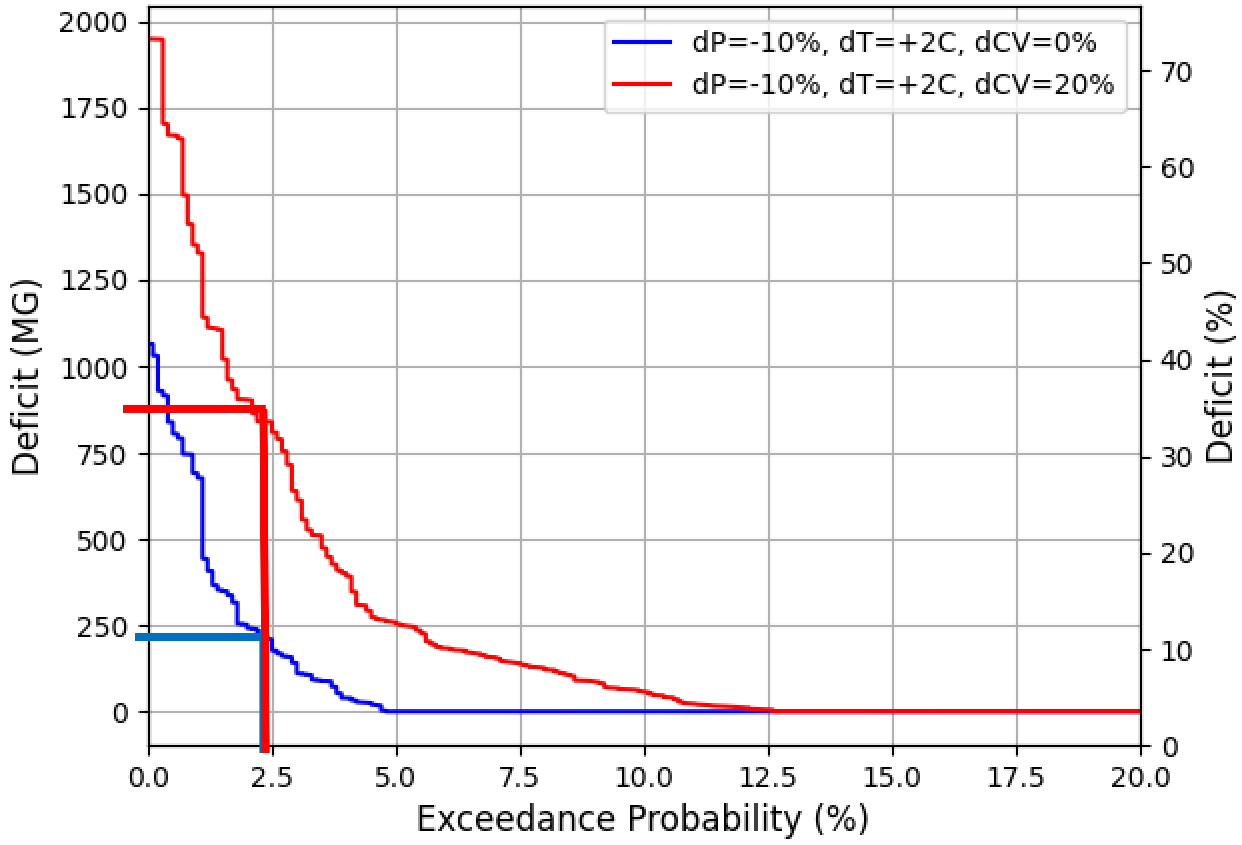
The values of streamflow at Bigtrees are normalized



# 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%)

(dT=+2C , dP=-10%, demand 2020)



# Coefficient of Variation effects on Deficit

(dT=+2C , dP=-10%) (Demand from 2020)

| Change in CV | 98th Percentile | | | Max | | |
|---|---|---|---|---|---|---|
| | 1-yr deficit (MG) | 2-yr deficit (MG) | 3-yr deficit (MG) | 1-yr deficit (MG) | 2-yr deficit (MG) | 3-yr deficit (MG) |
| 0% | 243 (9%) | 650 (25%) | 840 (32%) | 1065 (41%) | 2095 (80%) | 2205 (85%) |
| 10% | 583 (22%) | 1065 (41%) | 1424 (55%) | 1626 (62%) | 2560 (98%) | 2675 (103%) |
| 20% | 904 (35%) | 1484 (57%) | 1999 (77%) | 1949 (75%) | 3278 (126%) | 3278 (126%) |

# Conclusions – Understanding Size and Characteristics of Potential Future Deficits

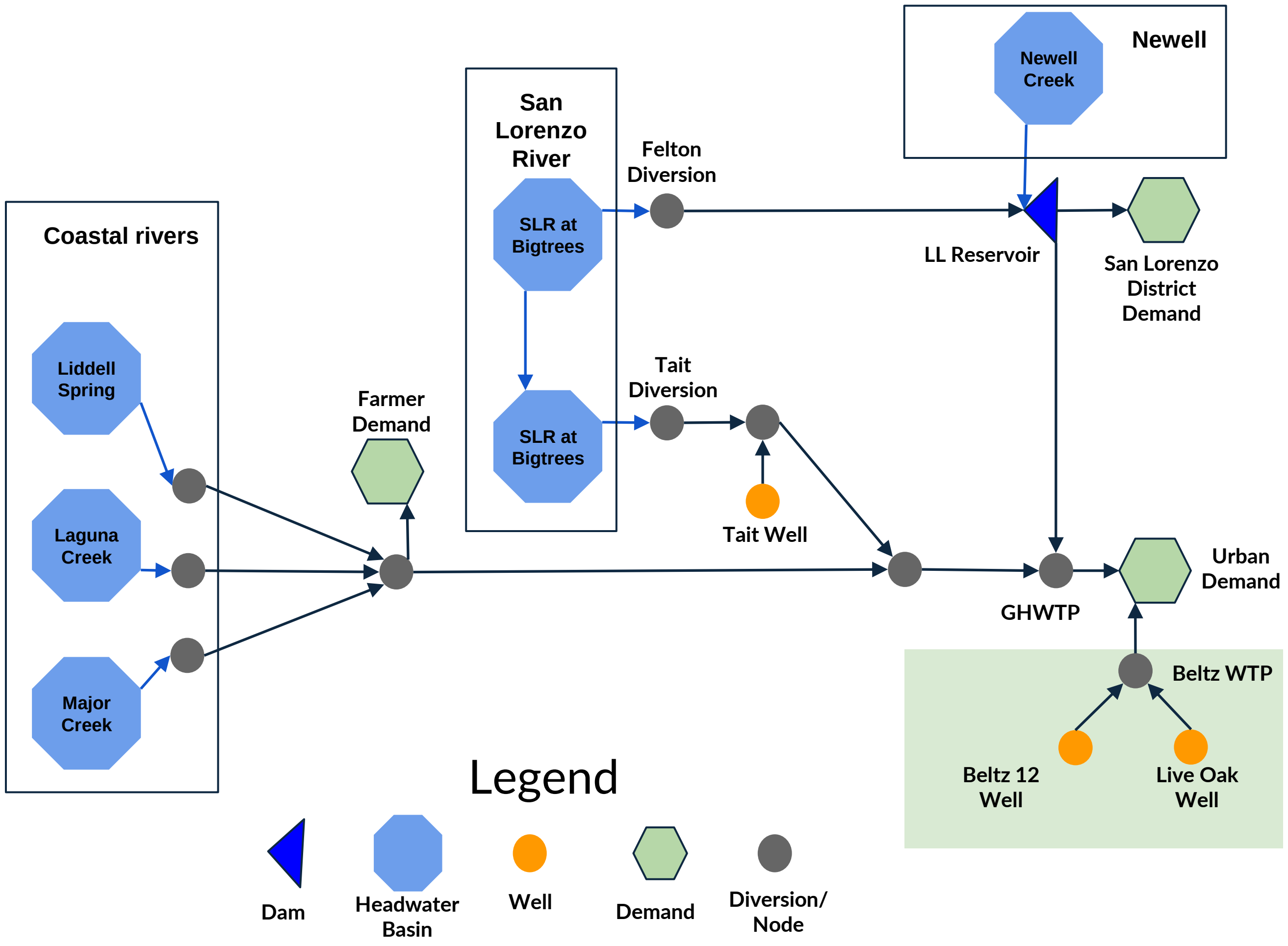
- The Water Supply Deficit is significantly affected by Climate Change
- Many climate projections indicate increase in the water supply deficit
- A 10% precipitation decrease causes a deficit increase of almost 10x (one year deficit) to 3x (3-year deficit)
- The frequency of drought also increases rapidly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

# Evaluating Project Alternatives

# Dispatch Orders

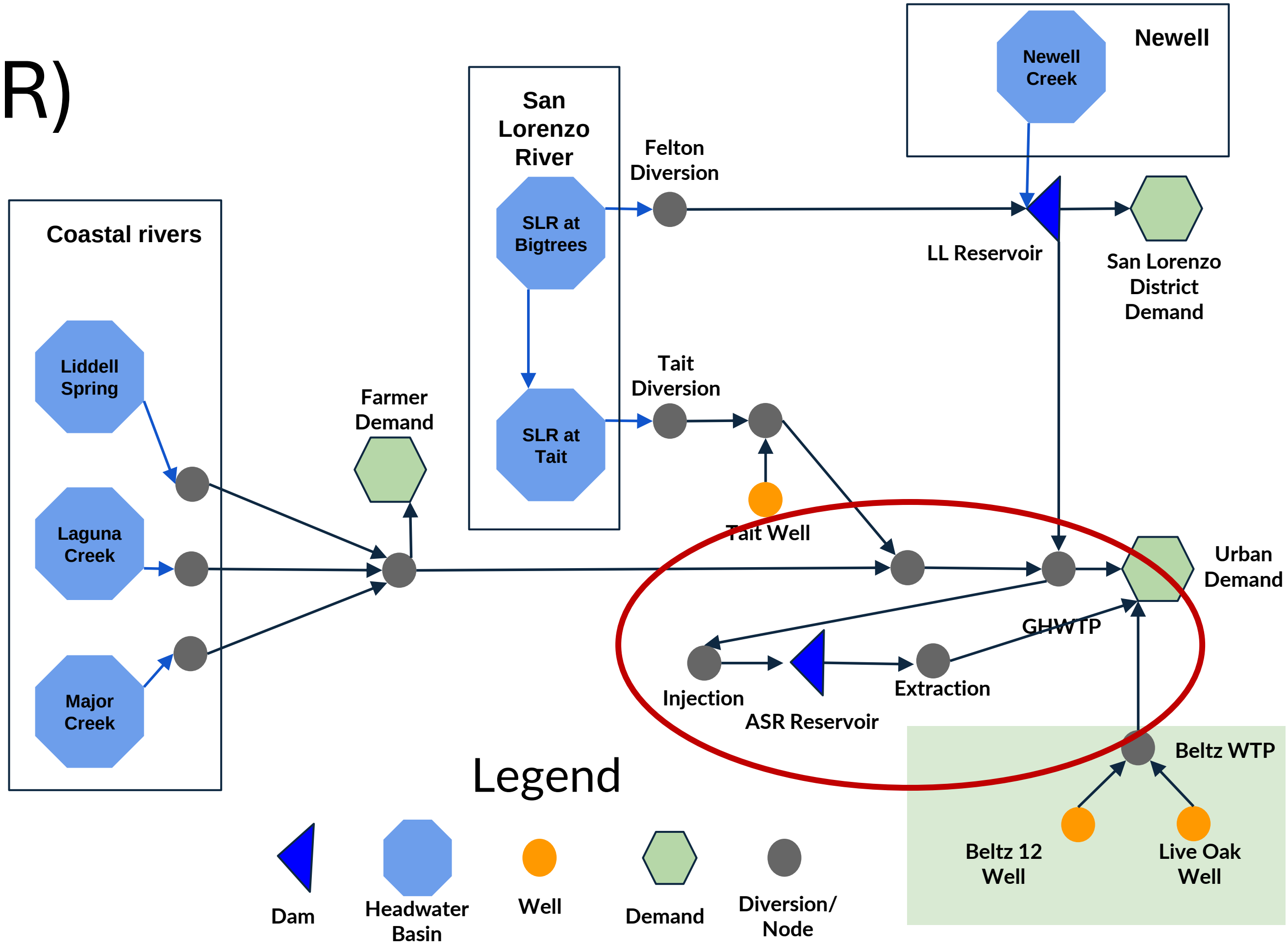
The water sources have the following use priority:

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)

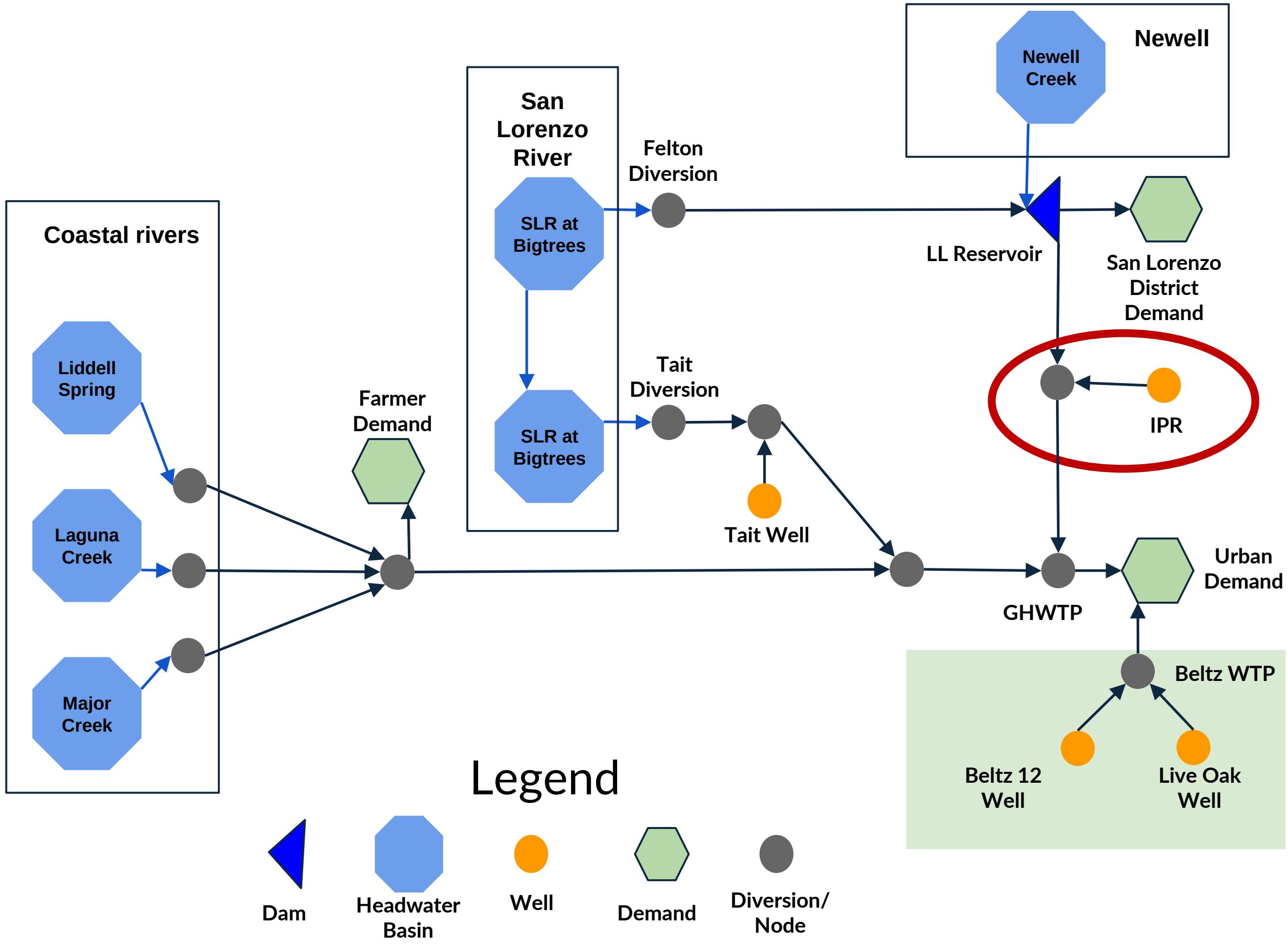
- ASR reservoir has a maximum storage volume of 1.67BG.
- ASR reservoir is filled by injection of ~2 MGD from November to April. Injection rate has a loss of 19%.
- Extraction from the ASR reservoir is ~ 3 MGD and limited to May – October.
- We use an interlocking approach to split water between the 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)

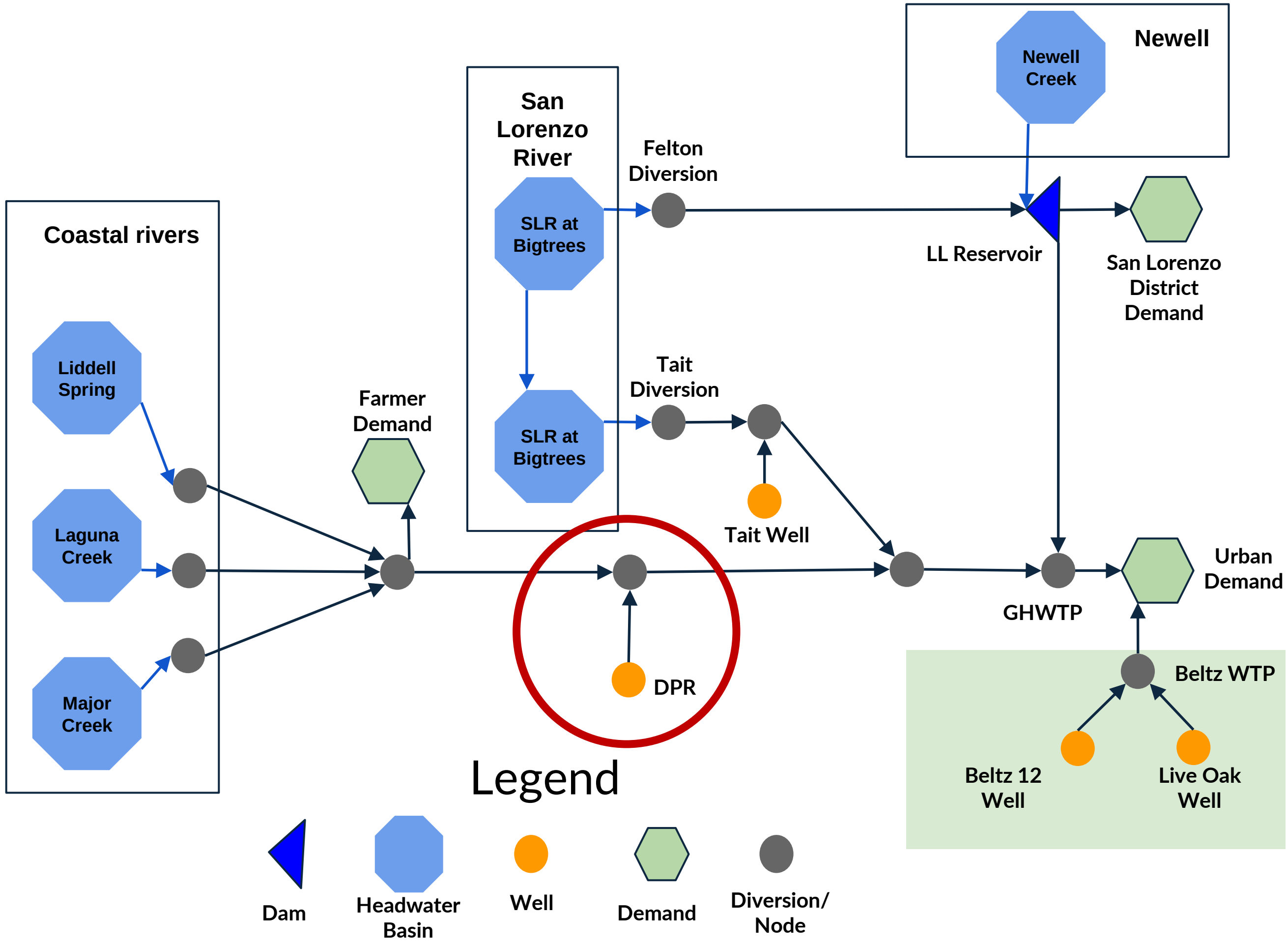
- 0.7 MGD input to water supply system on Nov-April and 1.1 MGD input to water supply system on May-OCT.

- After Tait wells in order of dispatch, before Beltz wells.



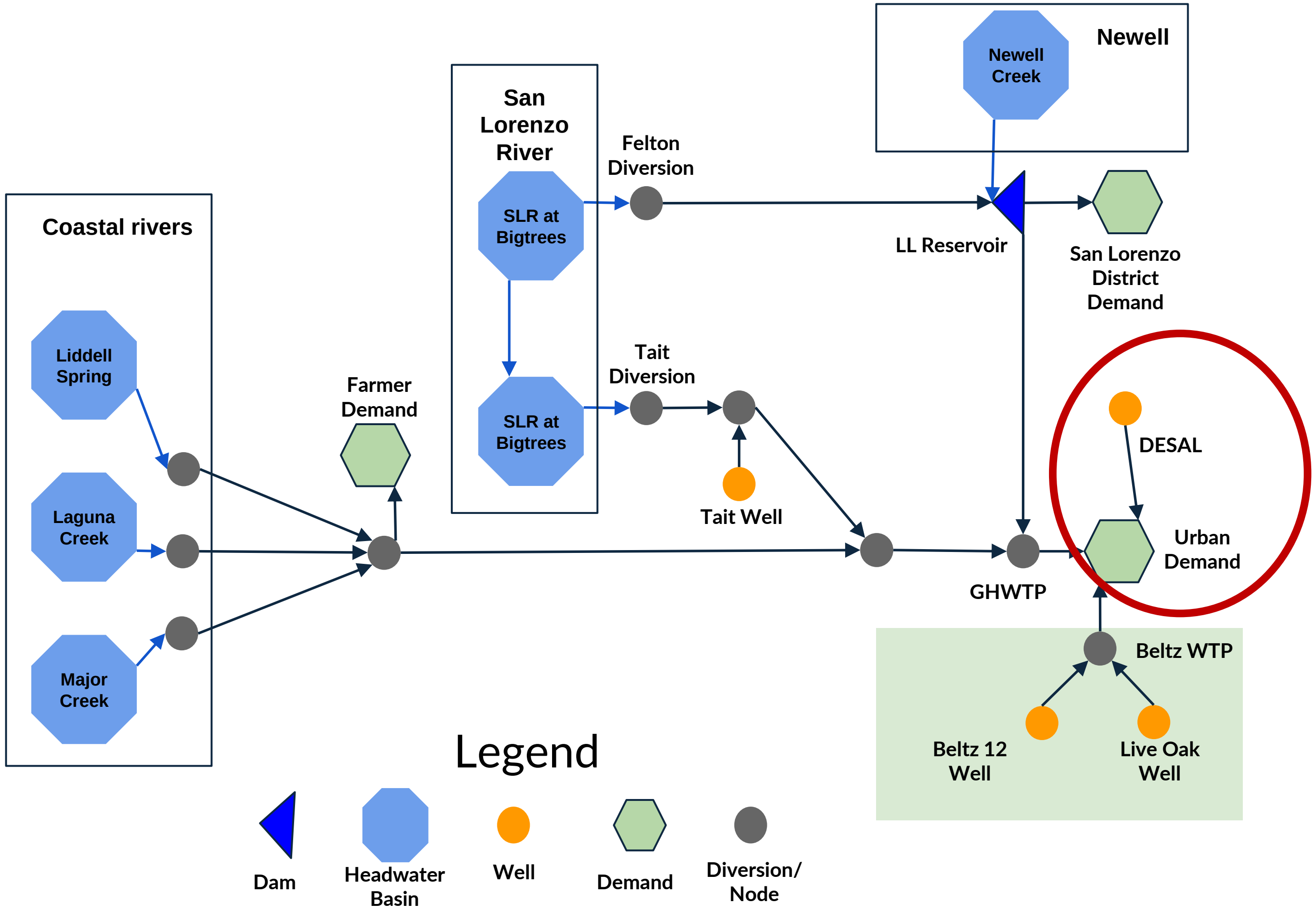
# Direct Potable Reuse (DPR)

- 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.

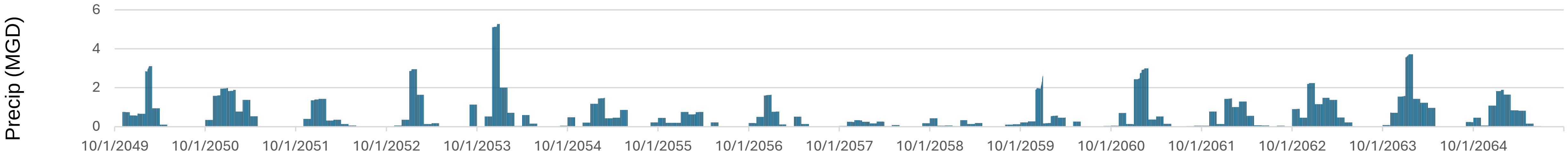


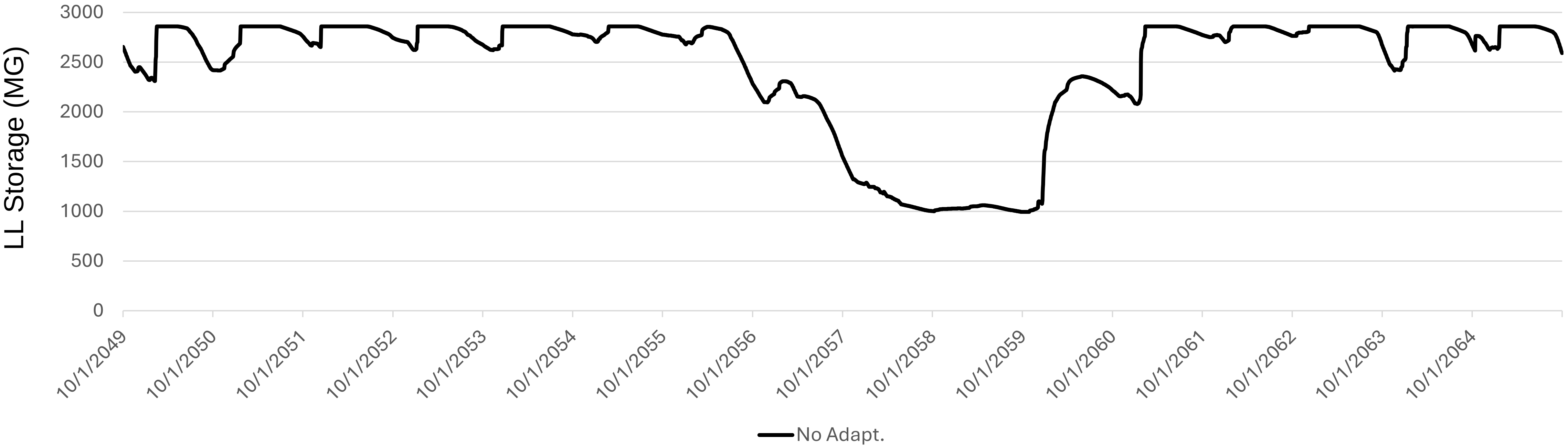
# Results for Worst Drought

# R1270 Sequence -- 2055-2059

# Reservoir Drawdown

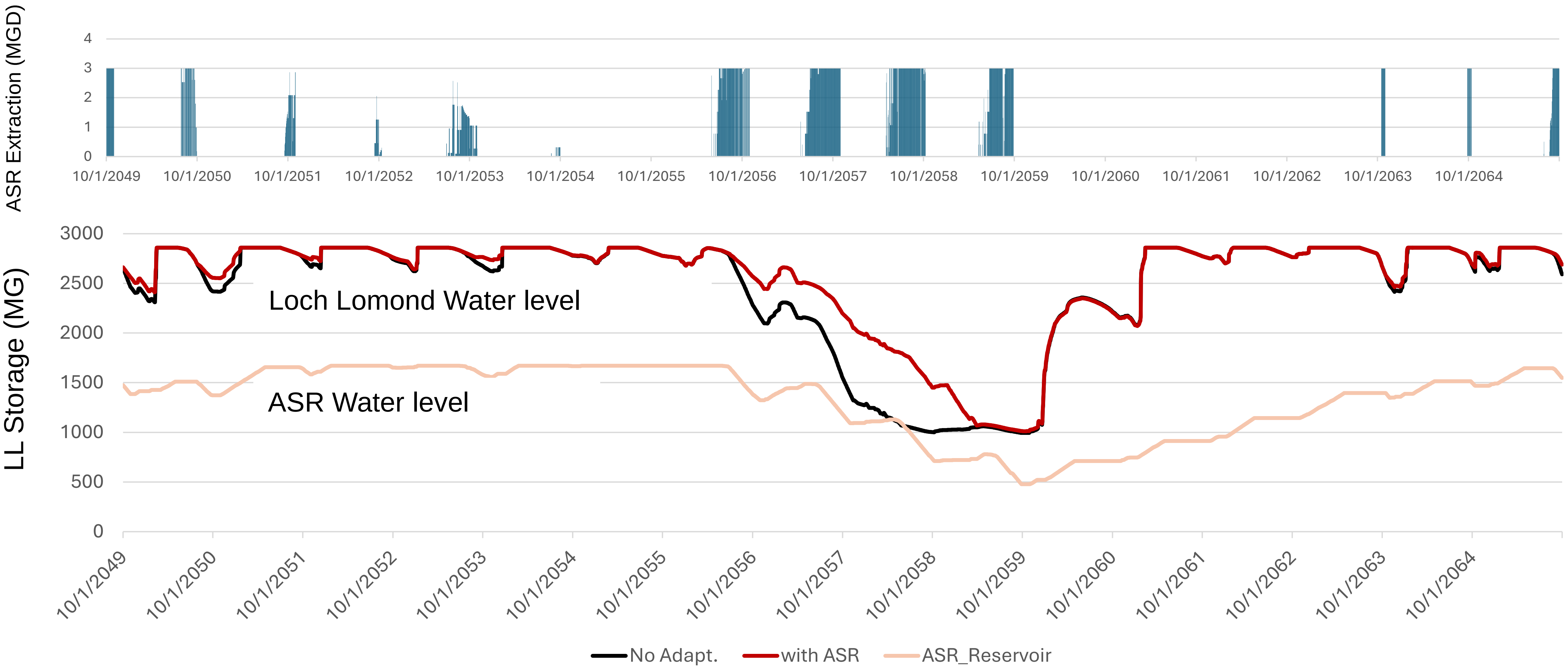
# No Climate Change



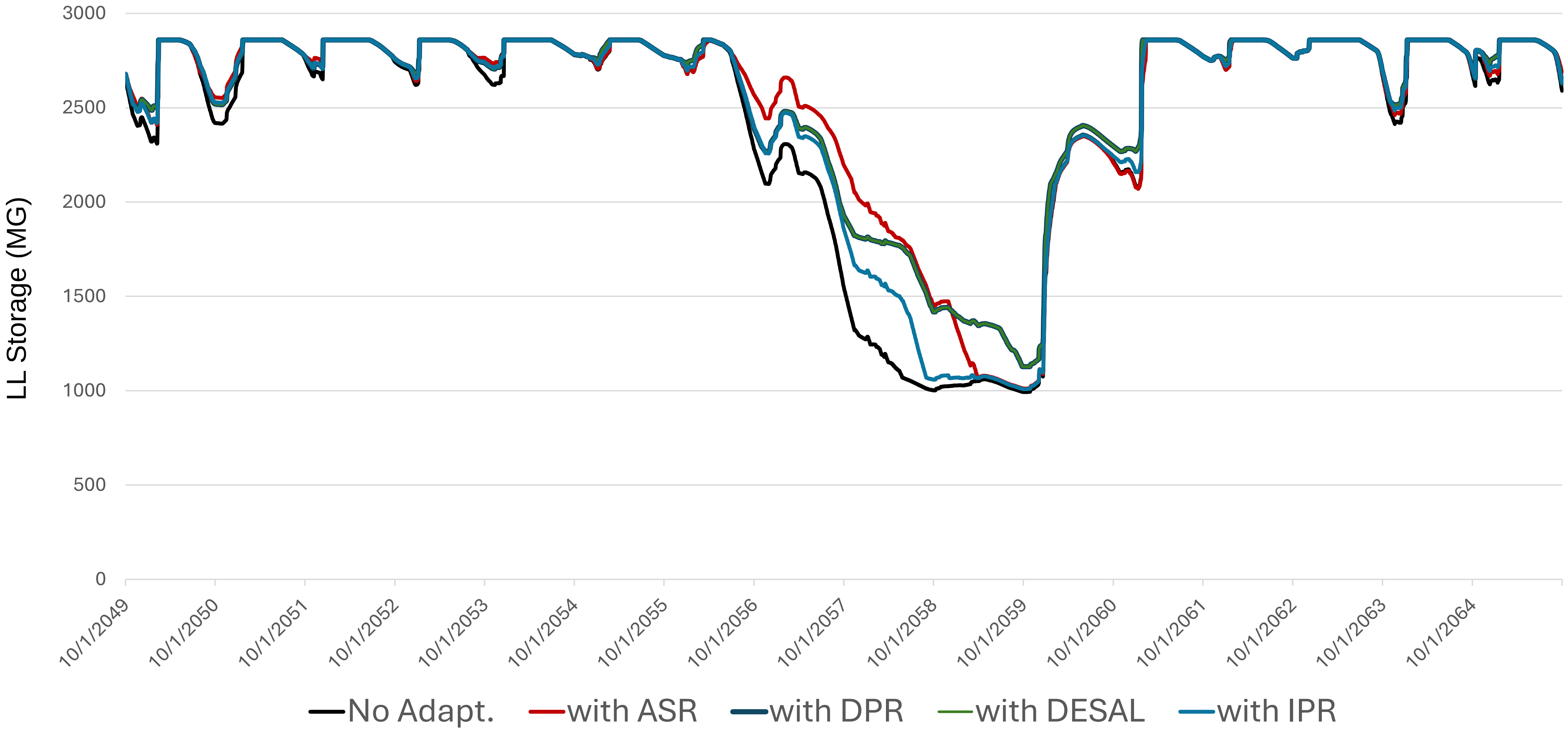
# ASR-Reservoir Drawdown

# No Climate Change



# Reservoir Drawdown

# No Climate Change



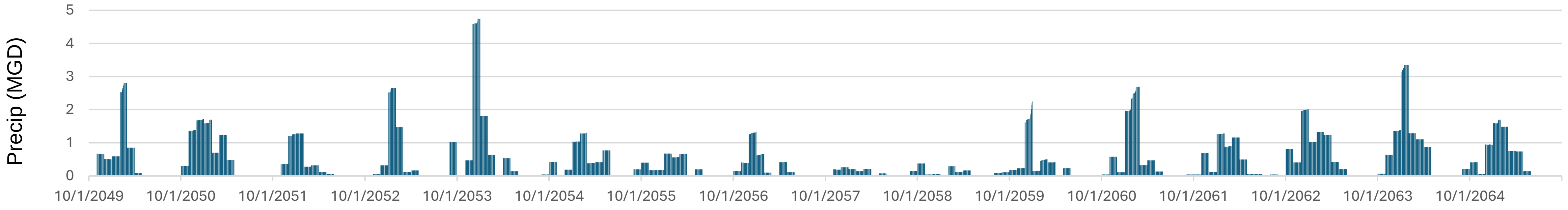
# Change in Deficit

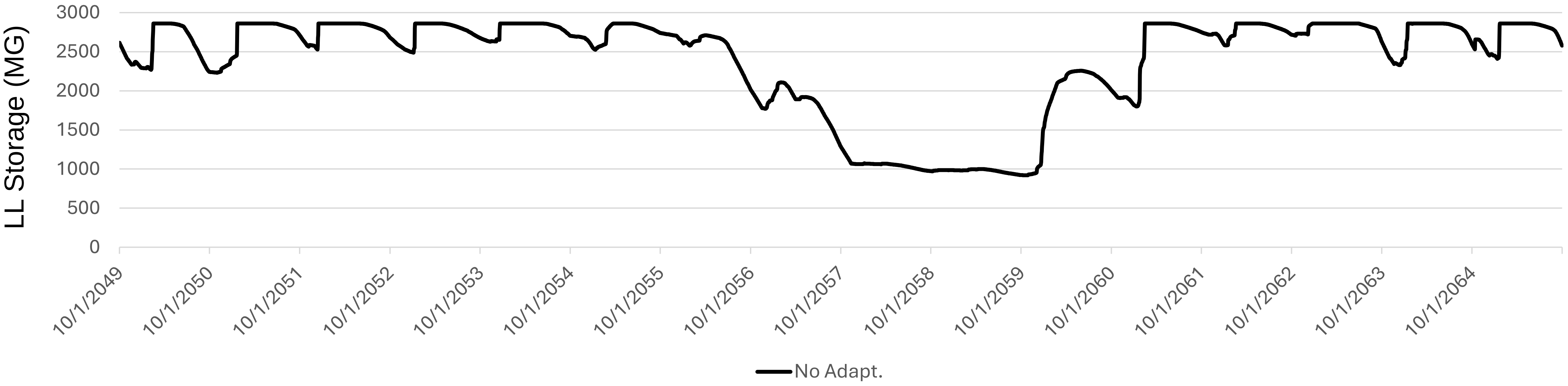
# No Climate Change

- **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.**

| | Max Annual Deficit (MG) | | | |
|---|---|---|---|---|
| | No Adapt. | with ASR | with IPR | with DPR/DESAL |
| 2058 | 610 | - | 130 | - |
| 2059 | 920 | 170 | 670 | - |
| 2060 | 30 | 20 | 20 | - |
| 3-yr Cumulative | 1,560 | 190 | 810 | - |

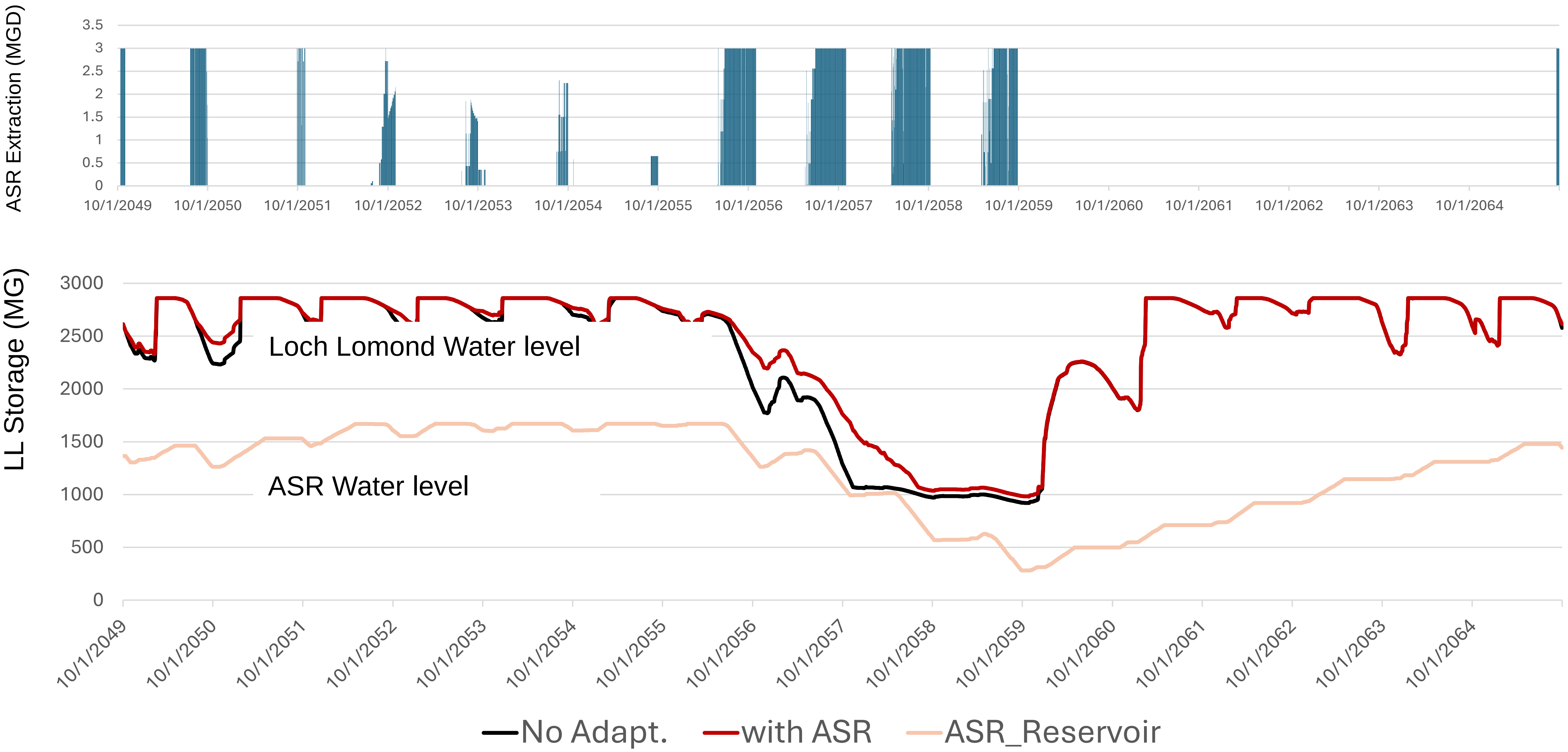
# Reservoir Drawdown Climate Change (P: -10%, T: +2C)



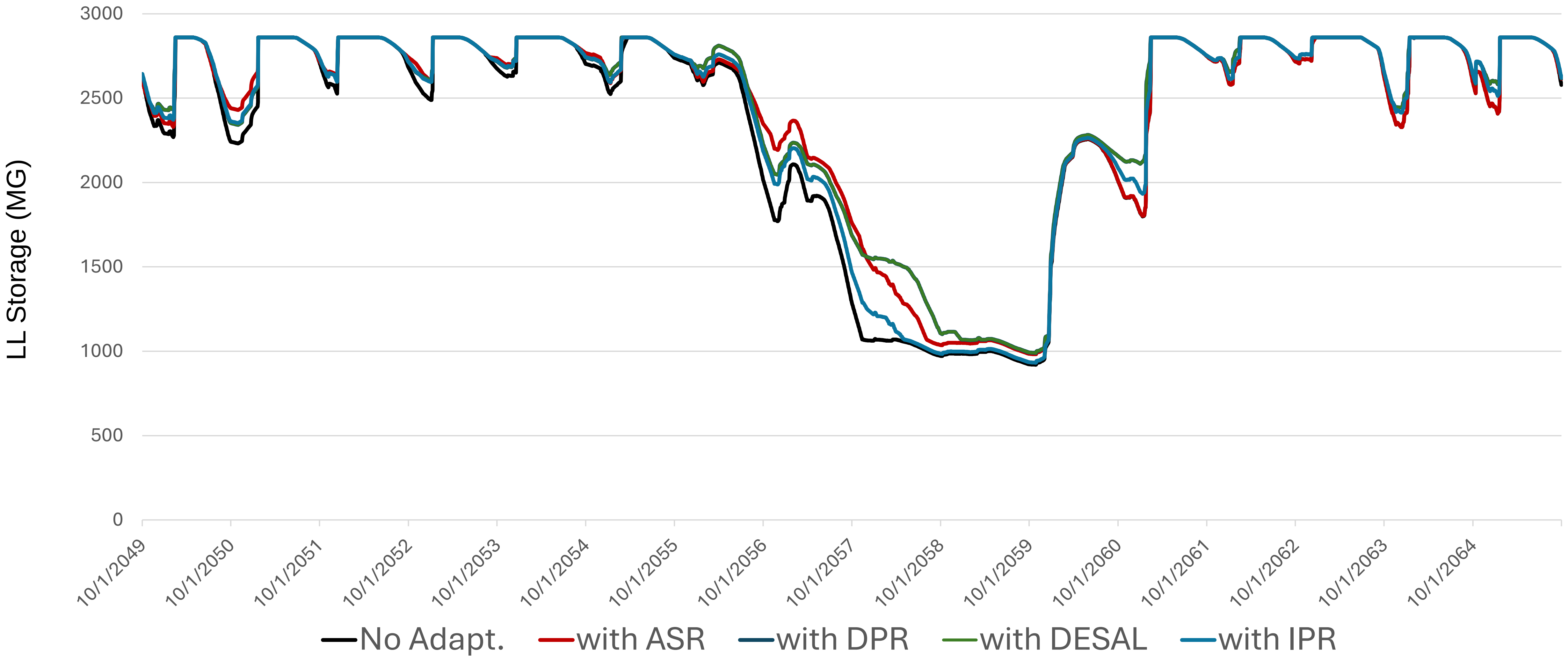
# ASR-Reservoir Drawdown

## Climate Change (P: -10%, T: +2C)



# DPR/DESAL-Reservoir Drawdown

## Climate Change(P:-10%, T:+2C)



# Effects of Climate Change on Deficit - ASR

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

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

Without ASR | With ASR

(Demand from 2020)

| dP / dT | 98th percentile of deficit (MG) | | | | | | Maximum deficit (MG) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0% 0C | | | -10% +2C | | | 0% 0C | | | -10% +2C | | |
| **1-YR** | 30 | 0 | 100% | 240 | 0 | 100% | 920 | 170 | 80% | 1,070 | 690 | 35% |
| **2-YR** | 140 | 0 | 100% | 650 | 0 | 100% | 1,540 | 190 | 85% | 2,100 | 850 | 60% |
| **3-YR** | **260** | **0** | **100%** | **840** | **30** | **95%** | **1,560** | **190** | **85%** | **2,210** | **910** | **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%.

Without ASR | With ASR

(T:+2C , P:-10%) (Demand from 2020)

| Change in CV | 98th Percentile | | | | | | | | | Max | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1-yr deficit (MG) | | | 2-yr deficit (MG) | | | 3-yr deficit (MG) | | | 1-yr deficit (MG) | | | 2-yr deficit (MG) | | | 3-yr deficit (MG) | | |
| 0% | 240 | 0 | 100% | 650 | 0 | 100% | 840 | 30 | **95%** | 1,070 | 700 | 35% | 2,100 | 850 | 60% | 2,210 | 910 | **60%** |
| 20% | 900 | 350 | 60% | 1,480 | 680 | 55% | 2,000 | 950 | **50%** | 1,950 | 1,570 | 20% | 3,280 | 2,150 | 35% | 3,280 | 2,150 | **35%** |