BUREAU OF RECLAMATION

Climate Change Data Development Current and Future Efforts

April 19, 2023 CWEMF Annual Meeting

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Collaborators: Steve Micko (Jacobs), Drew Loney & Derya Sumer (USBR), Solmaz Rasoulzadeh (Jacobs)

Modeling Division, Bay Delta Office

DRAFT Subject to Revision

Overview

- Introduction
- Overview approach
- Climate change scenarios development
- Sensitivity scenarios to review range of uncertainty
- Concluding remarks

Future Climate Change Analysis

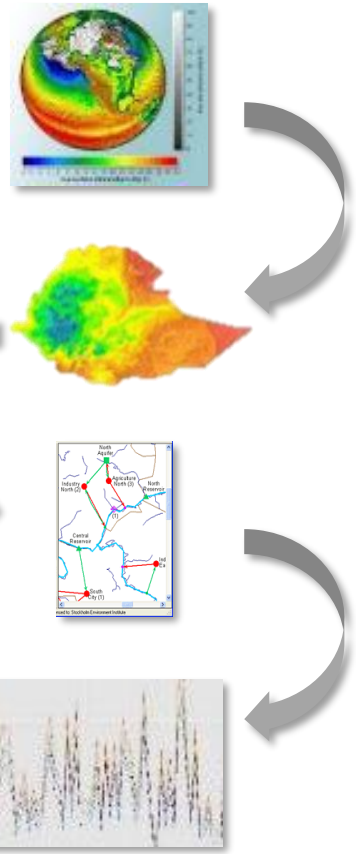
Top Down or Downs-Scaling Approach

Select a Couple of GCM Projections

Downscaling, Hydrologic Modeling

Operations and Planning Models

Conditional System Performance Projections



Bottom Up or Decision-Scaling Approach

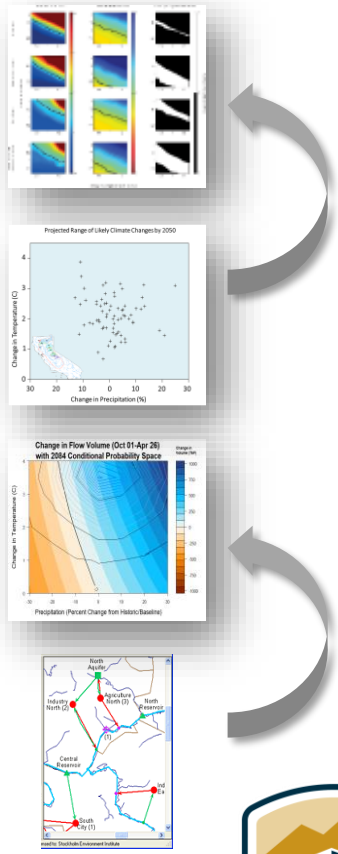
Vulnerability Assessment & Adaptive Planning

Climate Model Ensemble

System Surface Response

Operations and Planning Models

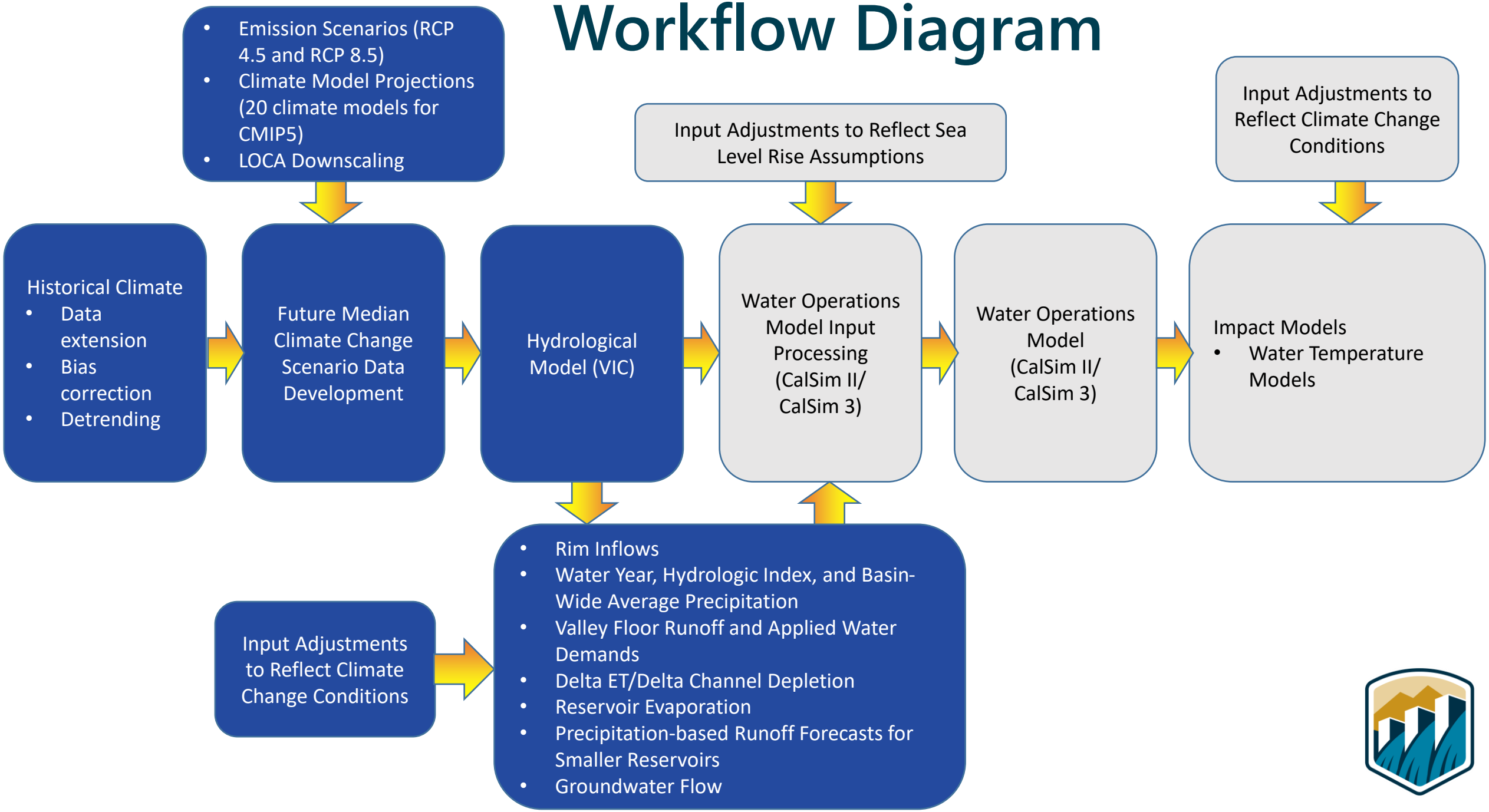
Climate/ Weather Generator

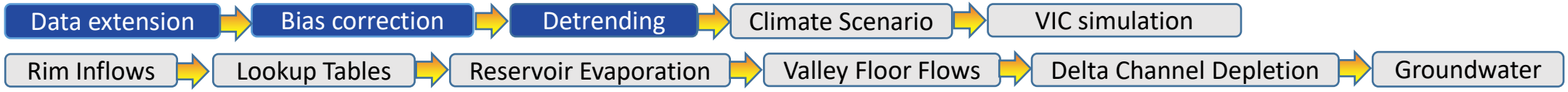


Systematic Climate Perturbations

Source: DWR

Workflow Diagram





Data processing

Data extension

- Historical daily precipitation and temperature data are extended through 2021 using PRISM data.
- Livneh data: 1915-2015
- PRISM data: 2016-2021

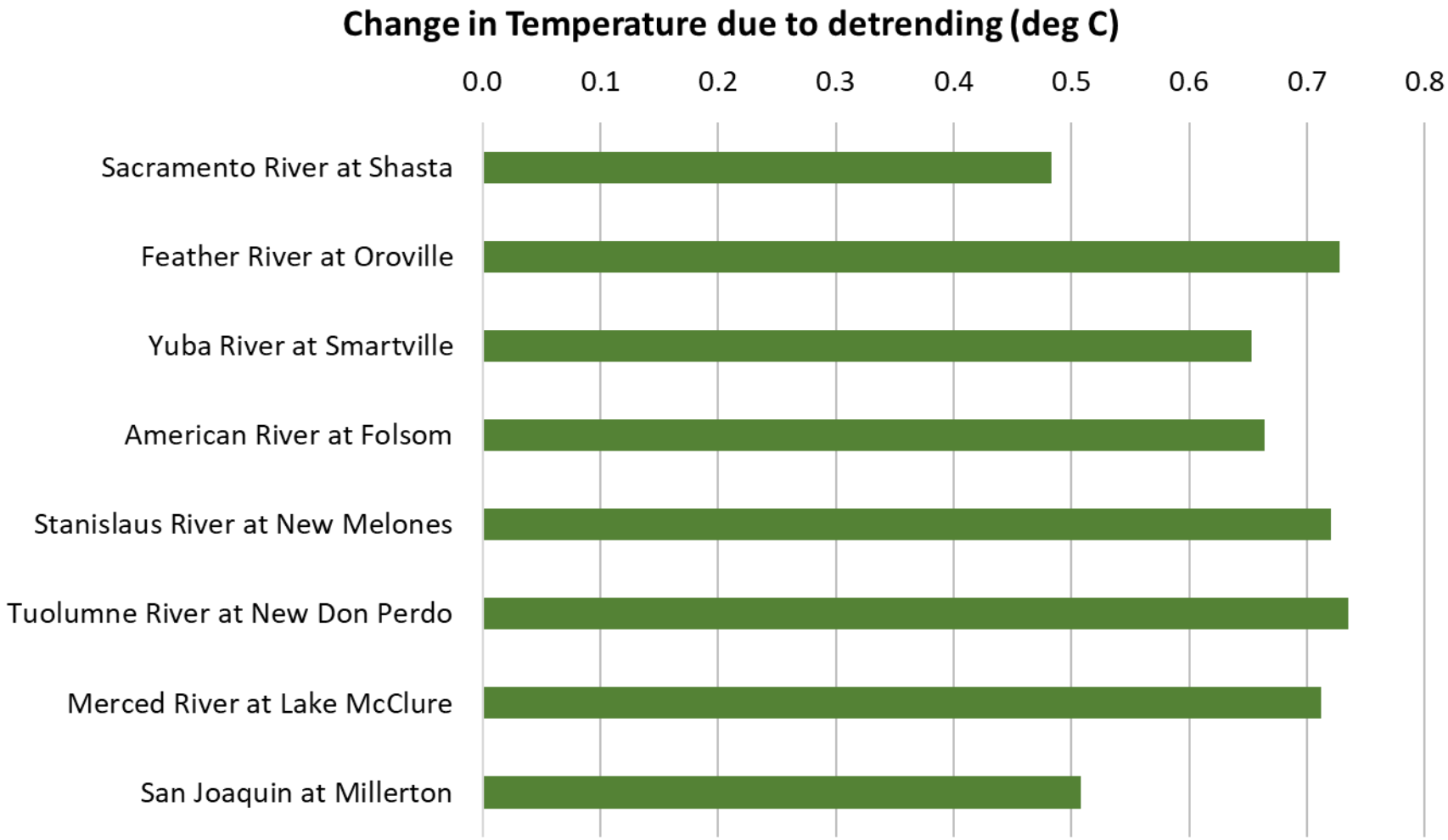
Bias correction

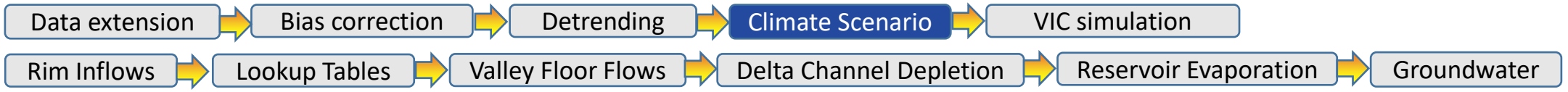
- Extended historical data are bias corrected using monthly PRISM data.

Temperature Detrending

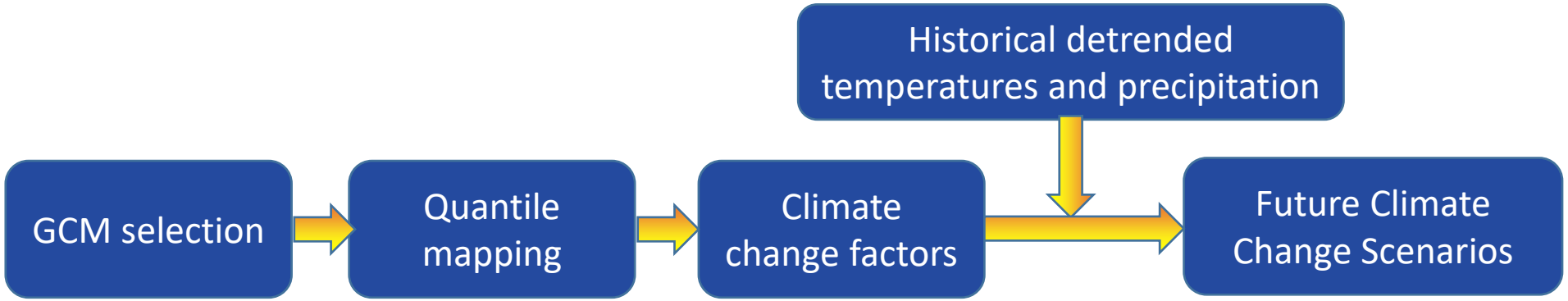
- Bias corrected maximum and minimum temperatures are detrended using Linear Trend Removing Technique.
- Detrended temperatures are anchored using the climatological average over the period 1991 to 2020.

Temperature Detrending





Future Climate Scenarios Development

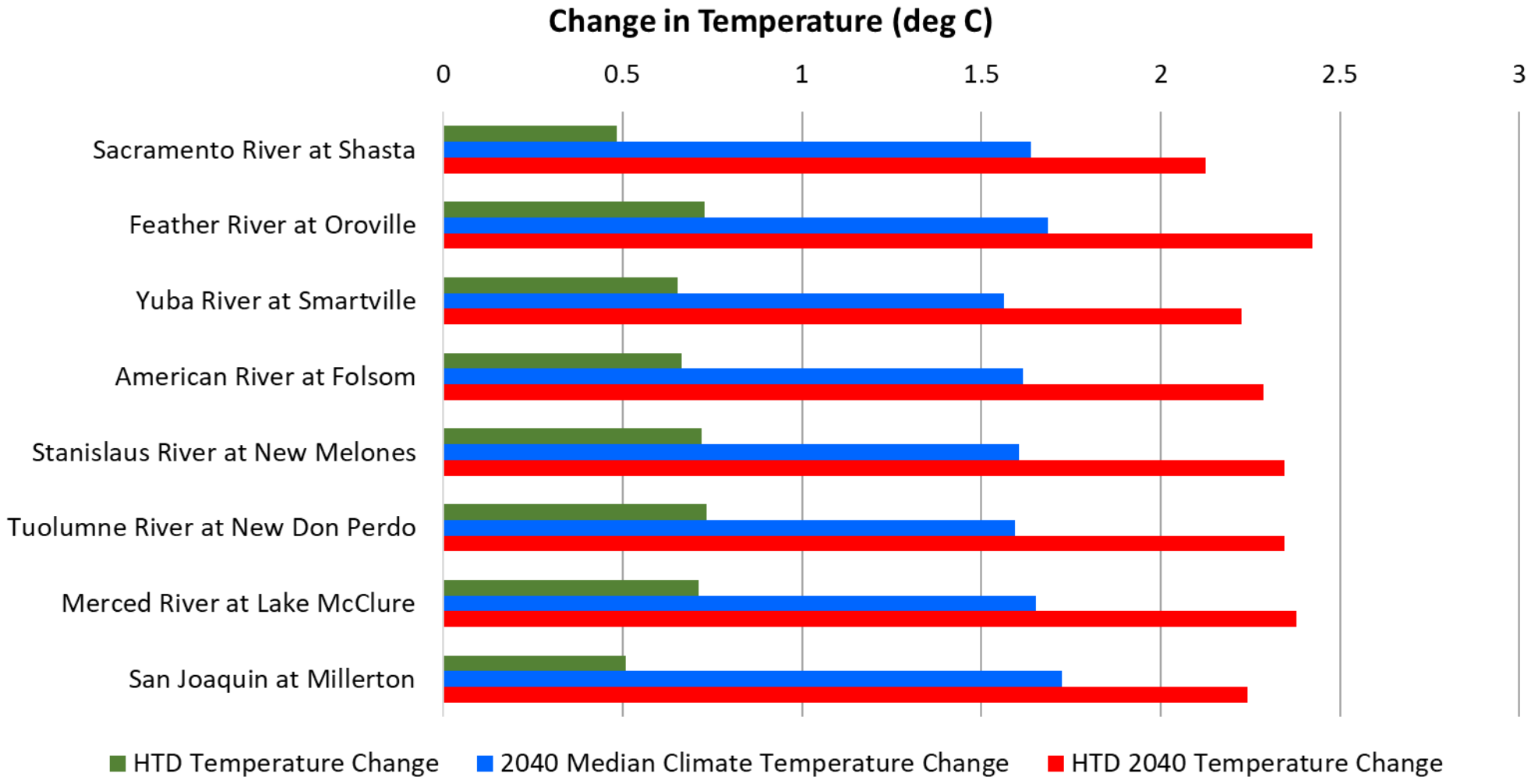


- GCM selection
- Quantile mapping
  - Median climate change scenario centered around 2040 (2026-2055).
  - The reference period is centered around 1995 (1981-2010).
  - Median of the Quantile mapping estimated for 40 climate model projections.
- Superimposing to detrended historical meteorology
- Future Climate Change Scenarios

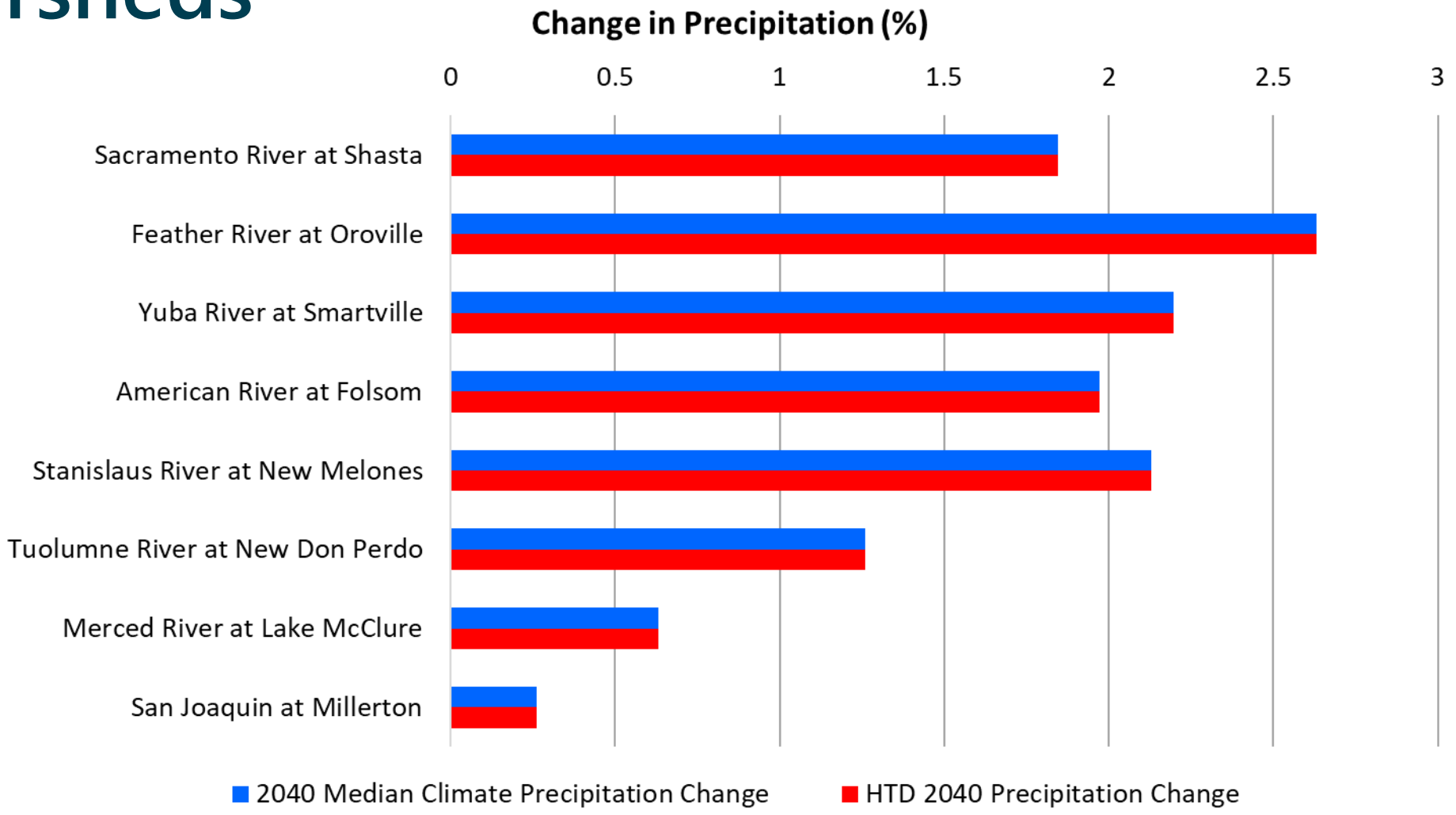
Data extension → Bias correction → Detrending → **Climate Scenario** → VIC simulation

Rim Inflows → Lookup Tables → Reservoir Evaporation → Valley Floor Flows → Delta Channel Depletion → Groundwater

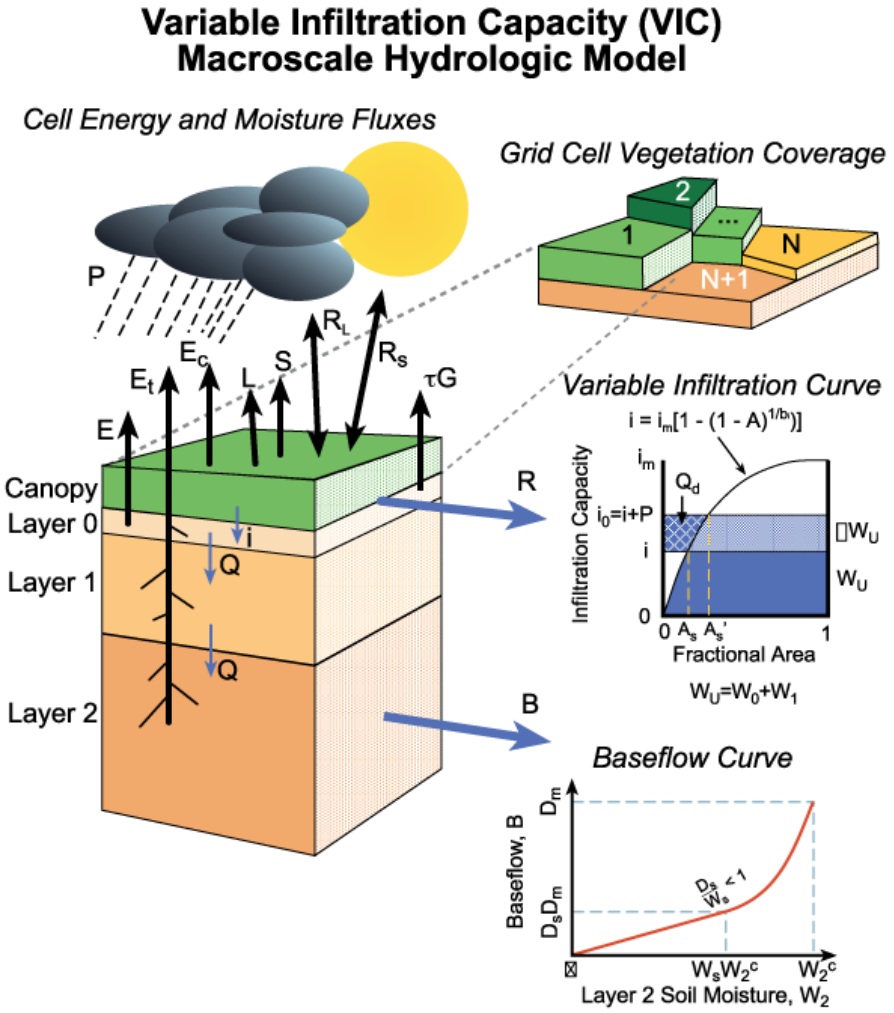
Projected Changes in Average Temperature for Major Watersheds



Projected Changes in Precipitation for Major Watersheds



Hydrological Modeling

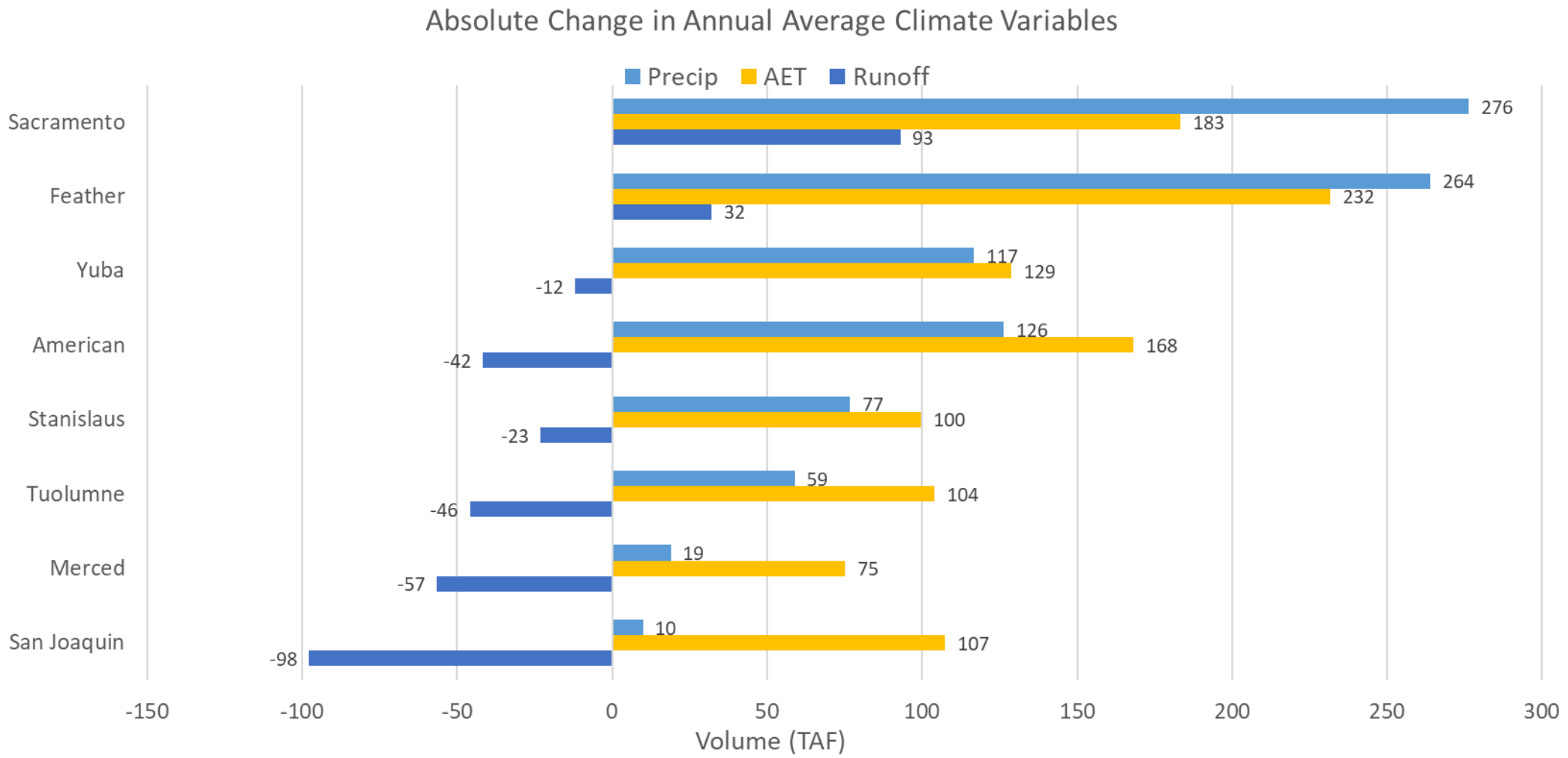


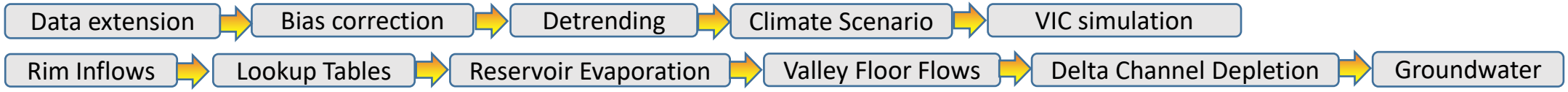
- The VIC model is a large-scale, semi-distributed hydrologic model.
- Land-atmosphere fluxes, and the water and energy balances are simulated at a daily time step.

Data extension → Bias correction → Detrending → Climate Scenario → **VIC simulation**

Rim Inflows → Lookup Tables → Reservoir Evaporation → Valley Floor Flows → Delta Channel Depletion → Groundwater

Projected Absolute Changes in Precipitation, AET, and Runoff for Major Watersheds





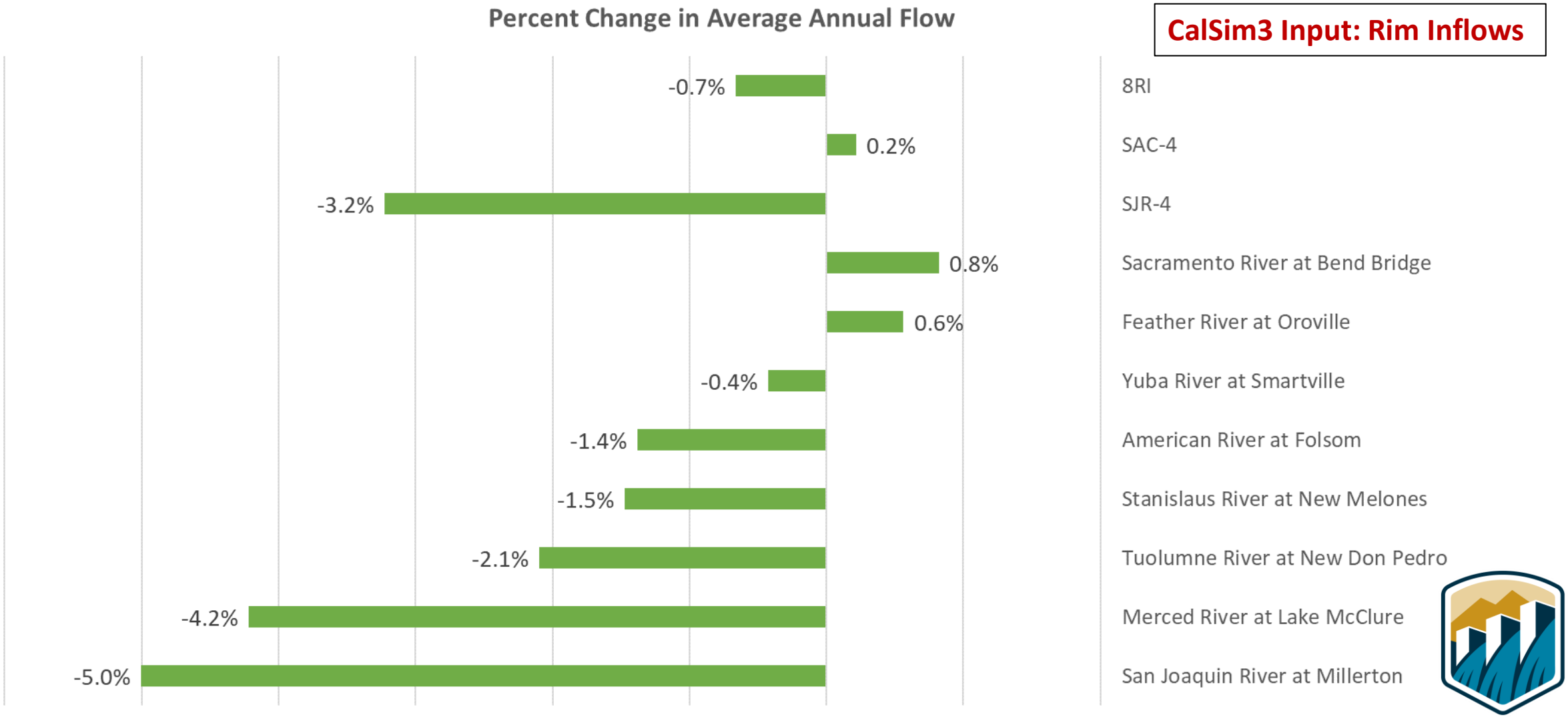
Model Input Adjustments

- CalSim 3:
  - Develop input hydrology for 2040 climate change scenarios
    - Rim Inflows
    - Lookup Tables
    - Reservoir Evaporation
    - Valley Floor Flows and Applied Water Demand
    - Delta Channel Depletion
    - Groundwater

Data extension → Bias correction → Detrending → Climate Scenario → VIC simulation

Rim Inflows → Lookup Tables → Reservoir Evaporation → Valley Floor Flows → Delta Channel Depletion → Groundwater

Projected Changes in Runoff for Major Watersheds



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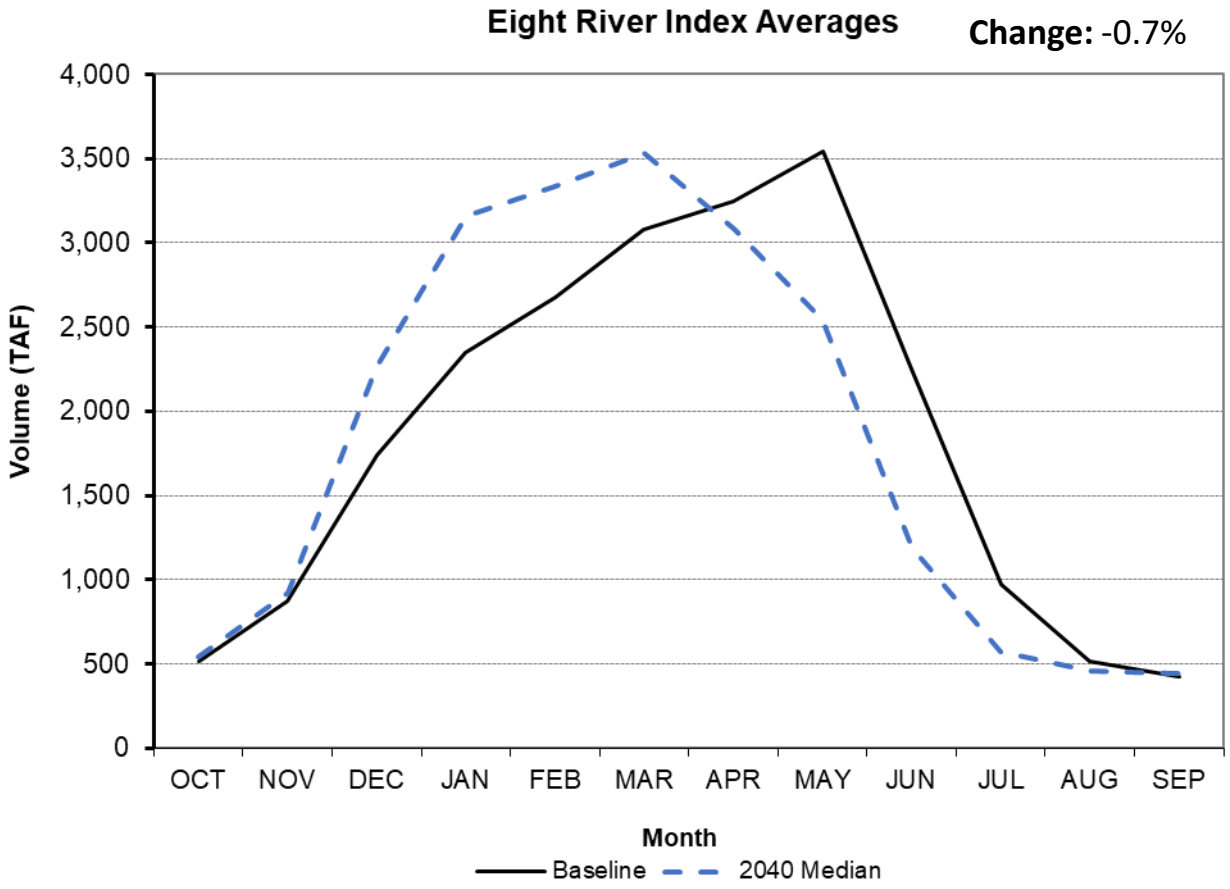
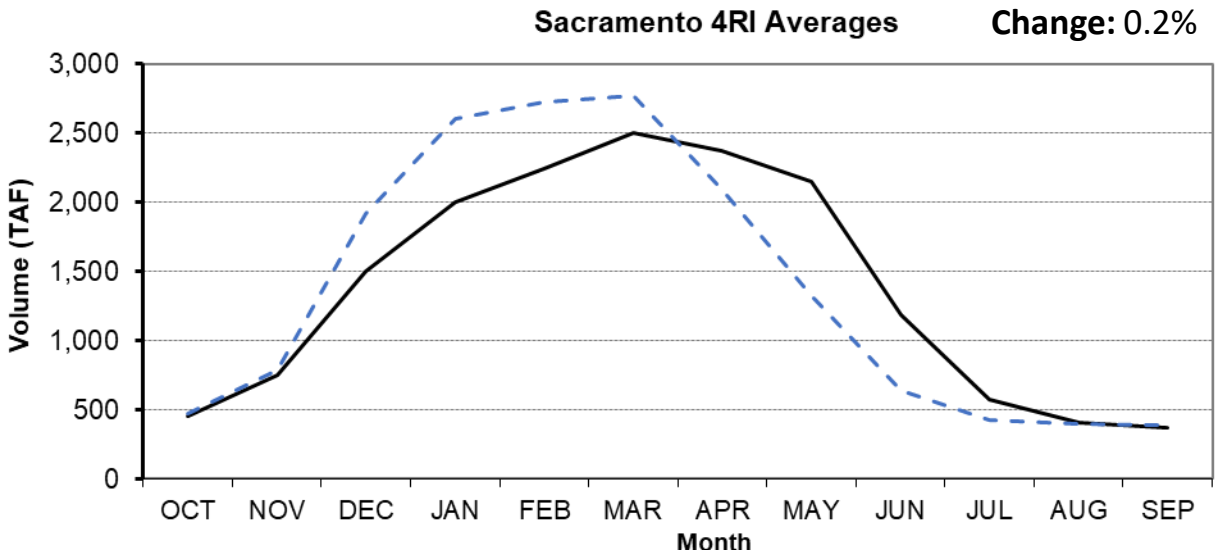
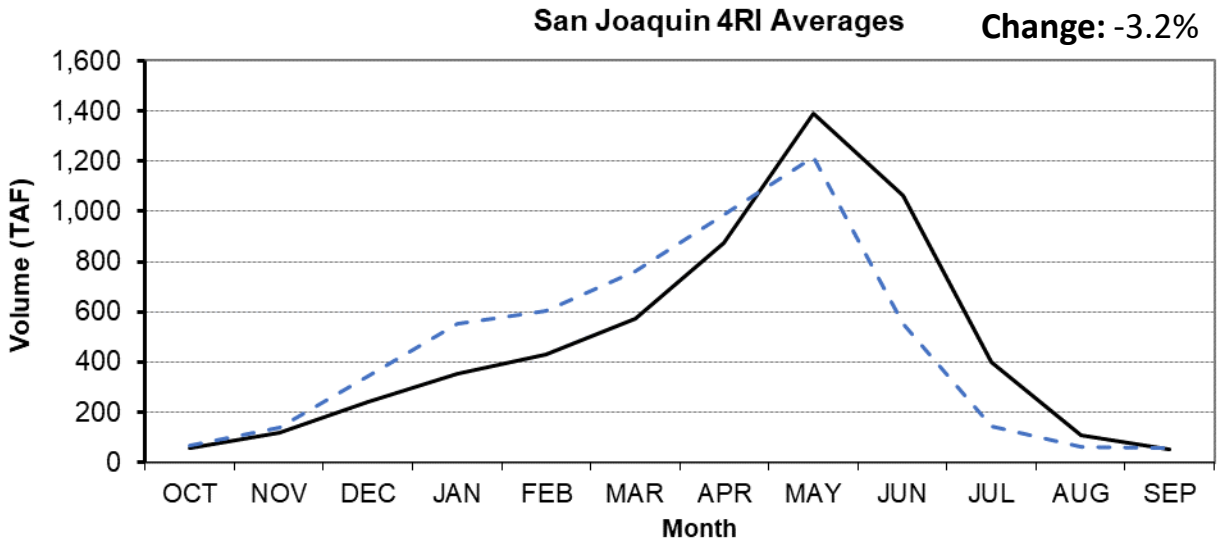
Rim Inflows → Lookup Tables → Reservoir Evaporation → Valley Floor Flows → Delta Channel Depletion → Groundwater

Projected Changes in Monthly Pattern of Runoff



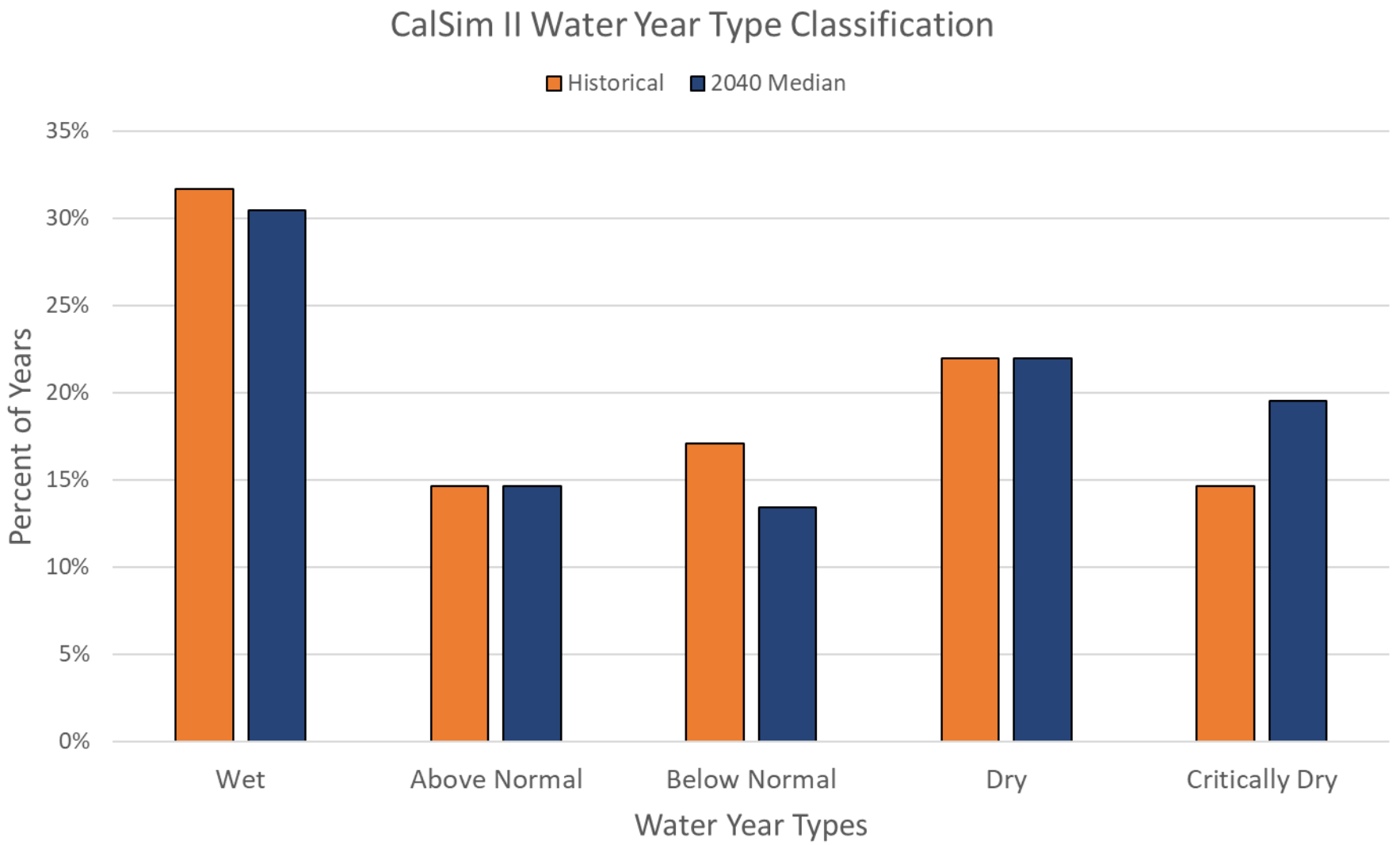




Data extension → Bias correction → Detrending → Climate Scenario → VIC simulation

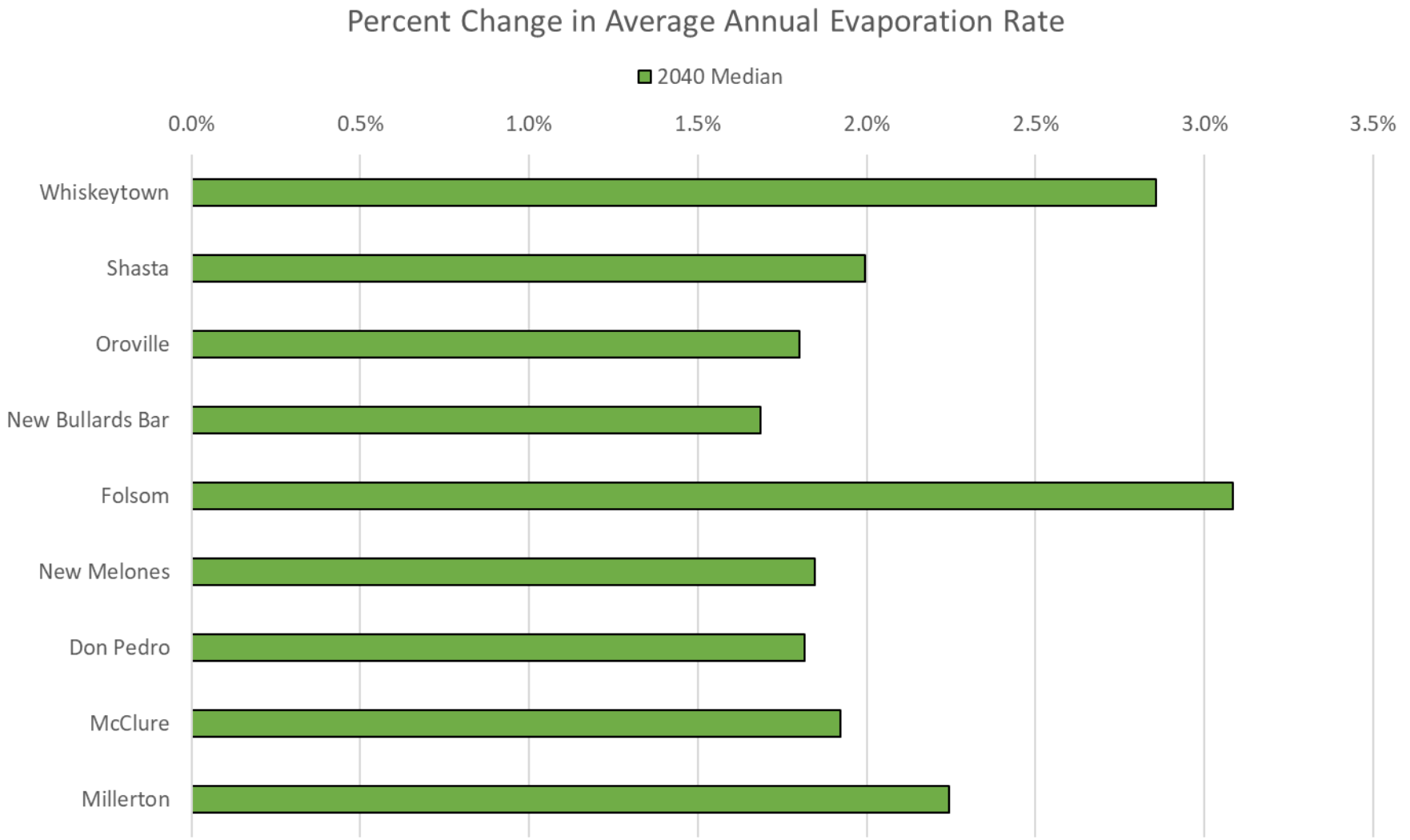
Rim Inflows → **Lookup Tables** → Reservoir Evaporation → Valley Floor Flows → Delta Channel Depletion → Groundwater

Water Year Type



Reservoir Evaporation

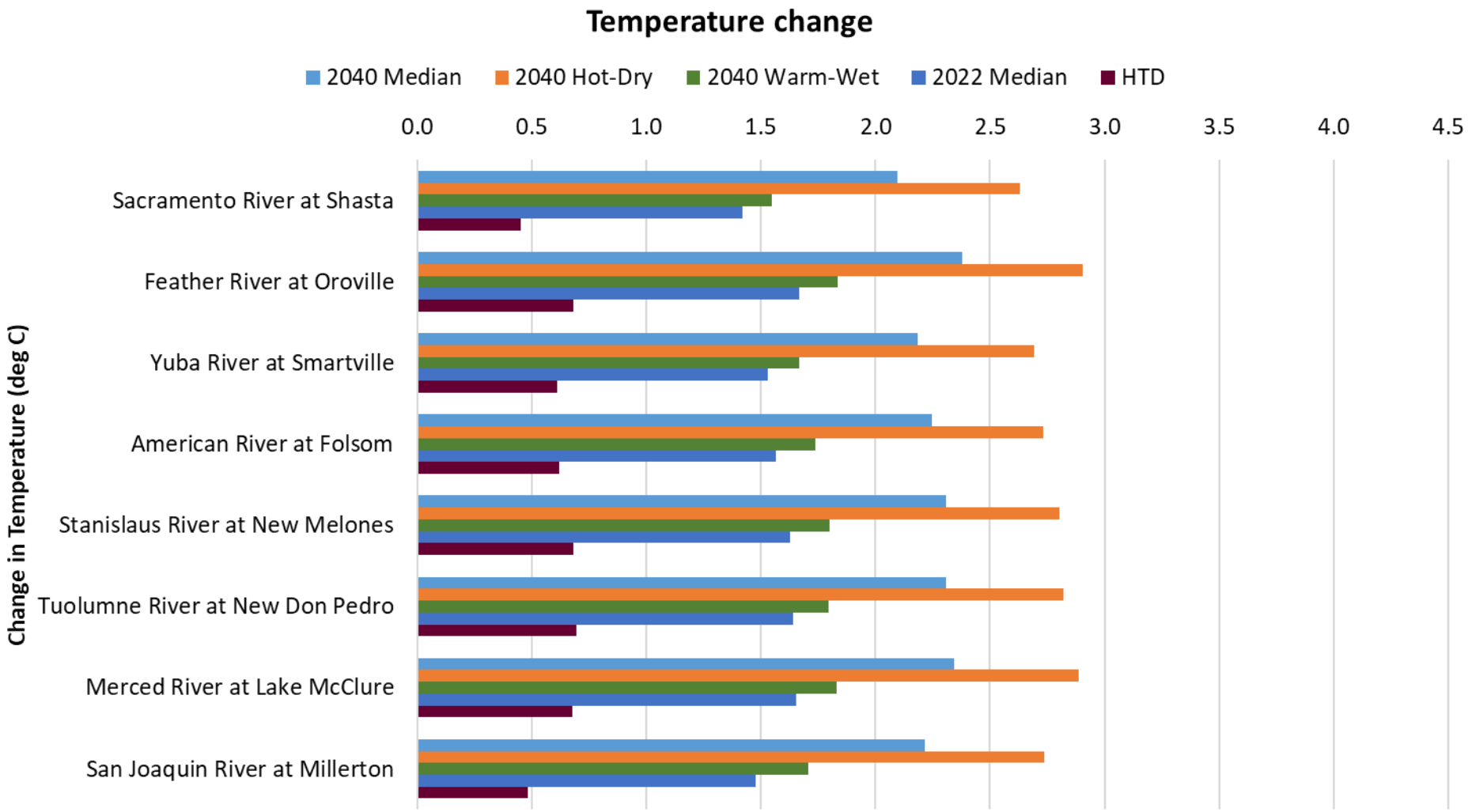
CalSim3 Input: Reservoir Evaporation



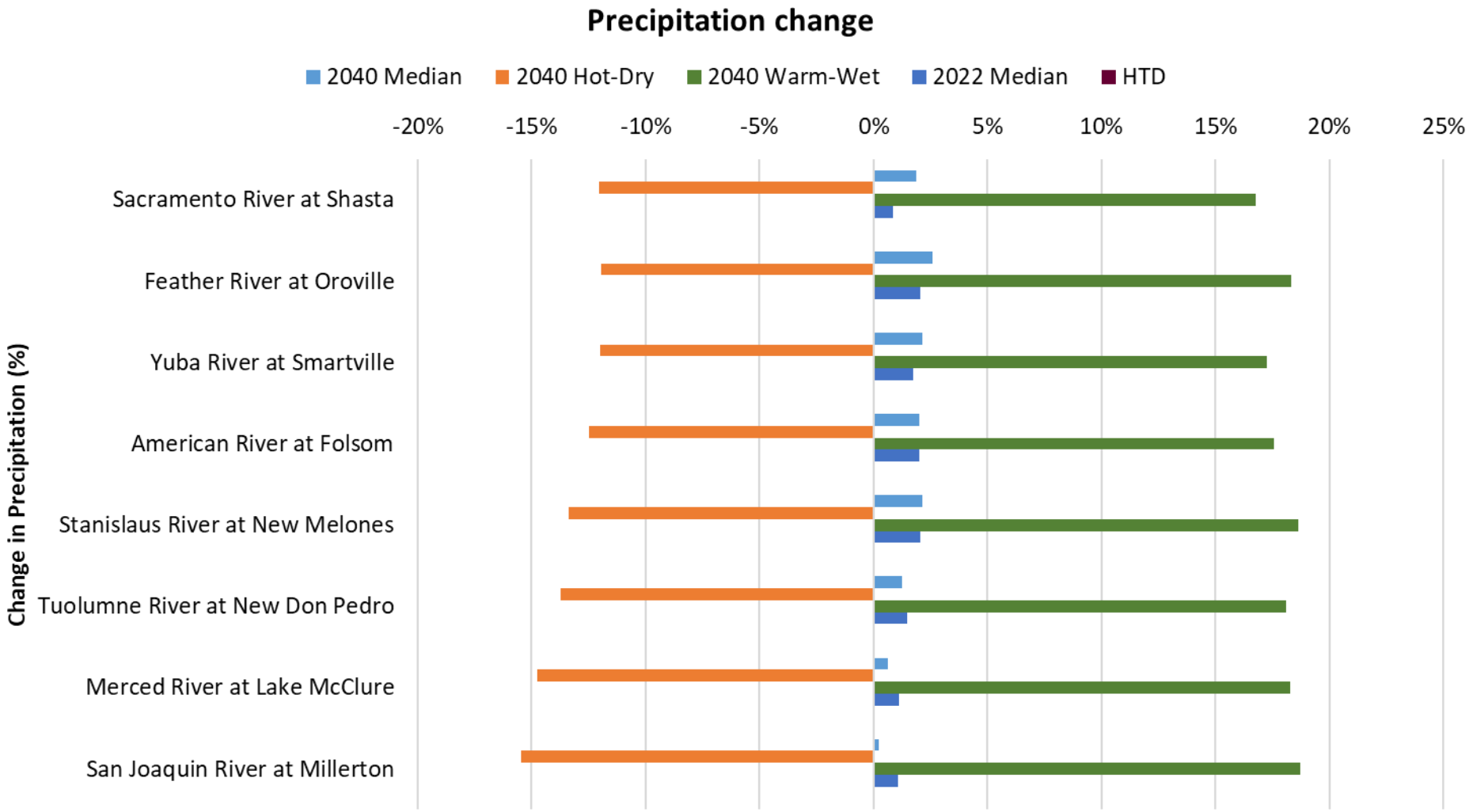
Climate Change Scenarios

- Future climate condition centered on 2040 (50th-ile T & 50th-ile P)
- Analysis are being mainly based on the median climate change scenario
- Sensitivity scenarios to review range of uncertainty
  - Hot and dry (75th-ile T & 25th-ile P)
  - Warm and wet (25th-ile T & 75th-ile P)
  - Extreme heat and dry (95th-ile T & 5th-ile P)
- Additional sensitivity scenarios to be considered
  - 2022 median climate change (50th-ile T & 50th-ile P)
  - Historical Temperature Detrended

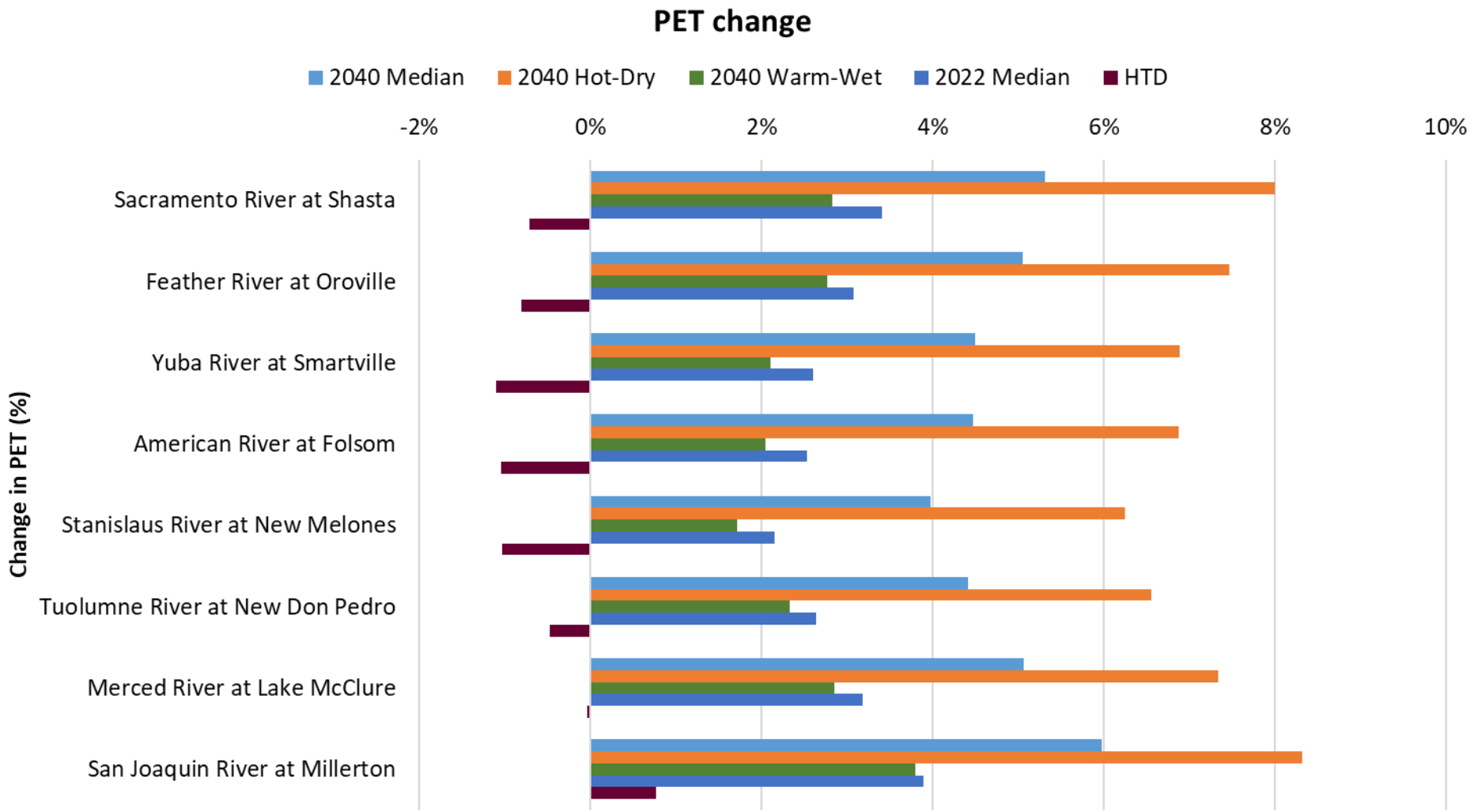
Temperature Change



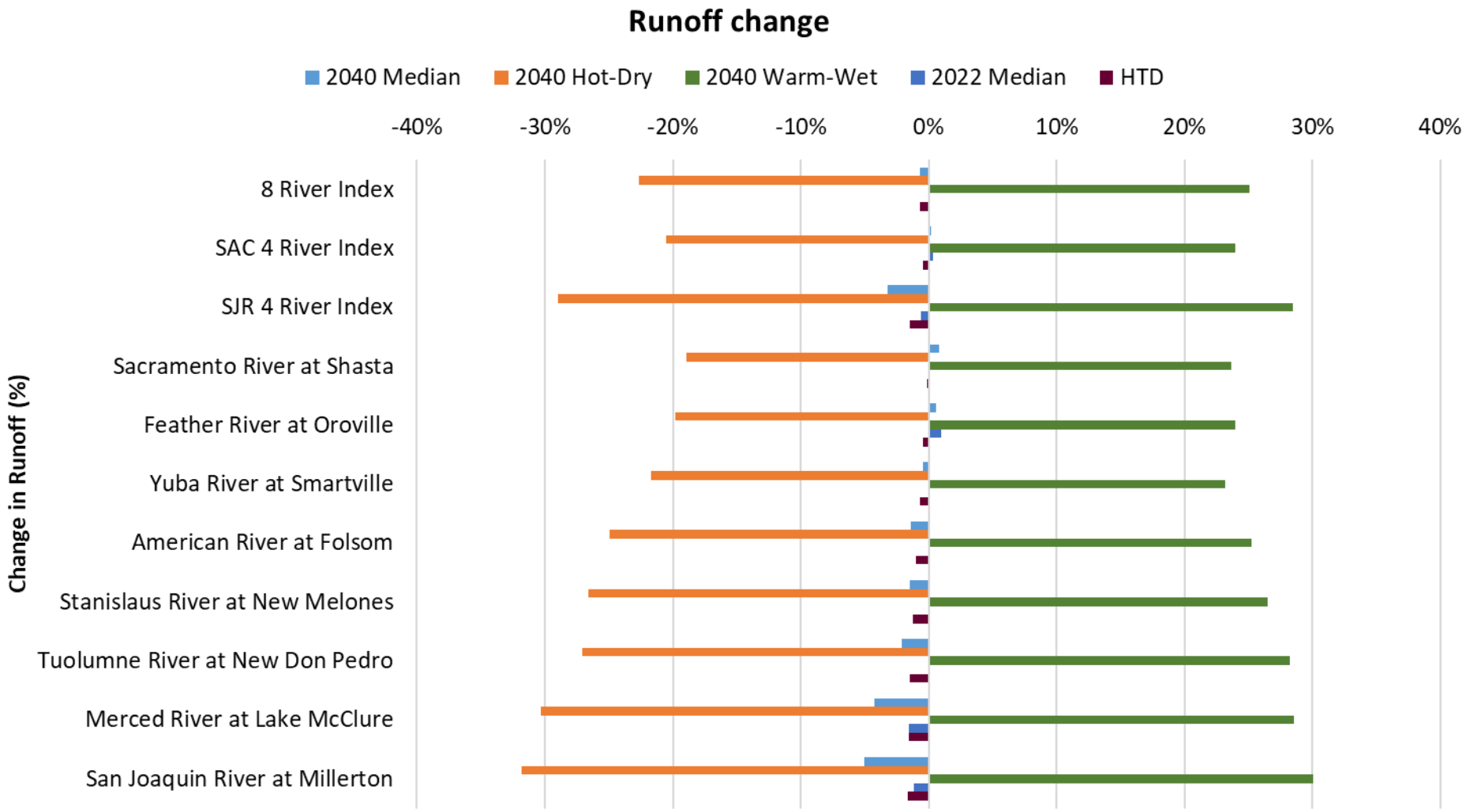
Precipitation Change



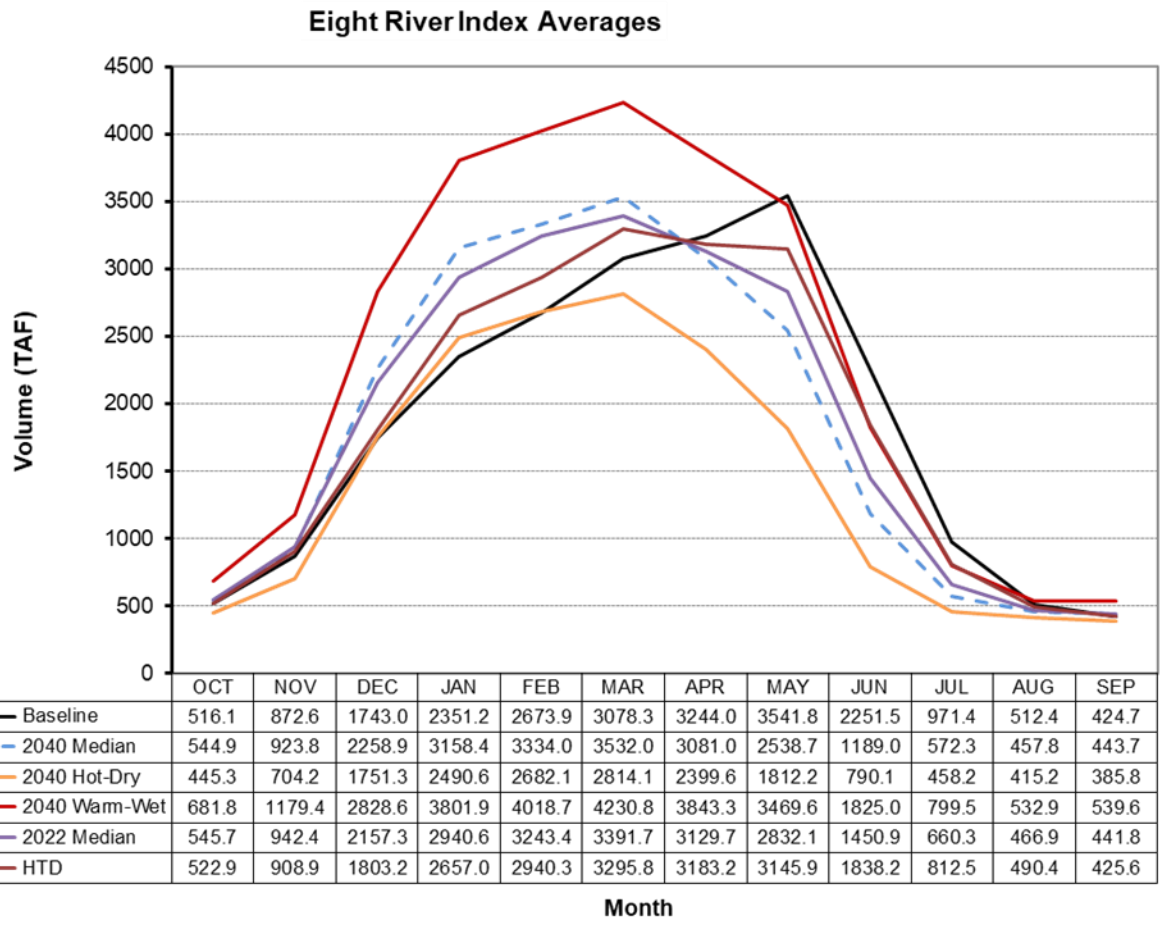
Potential ET Change



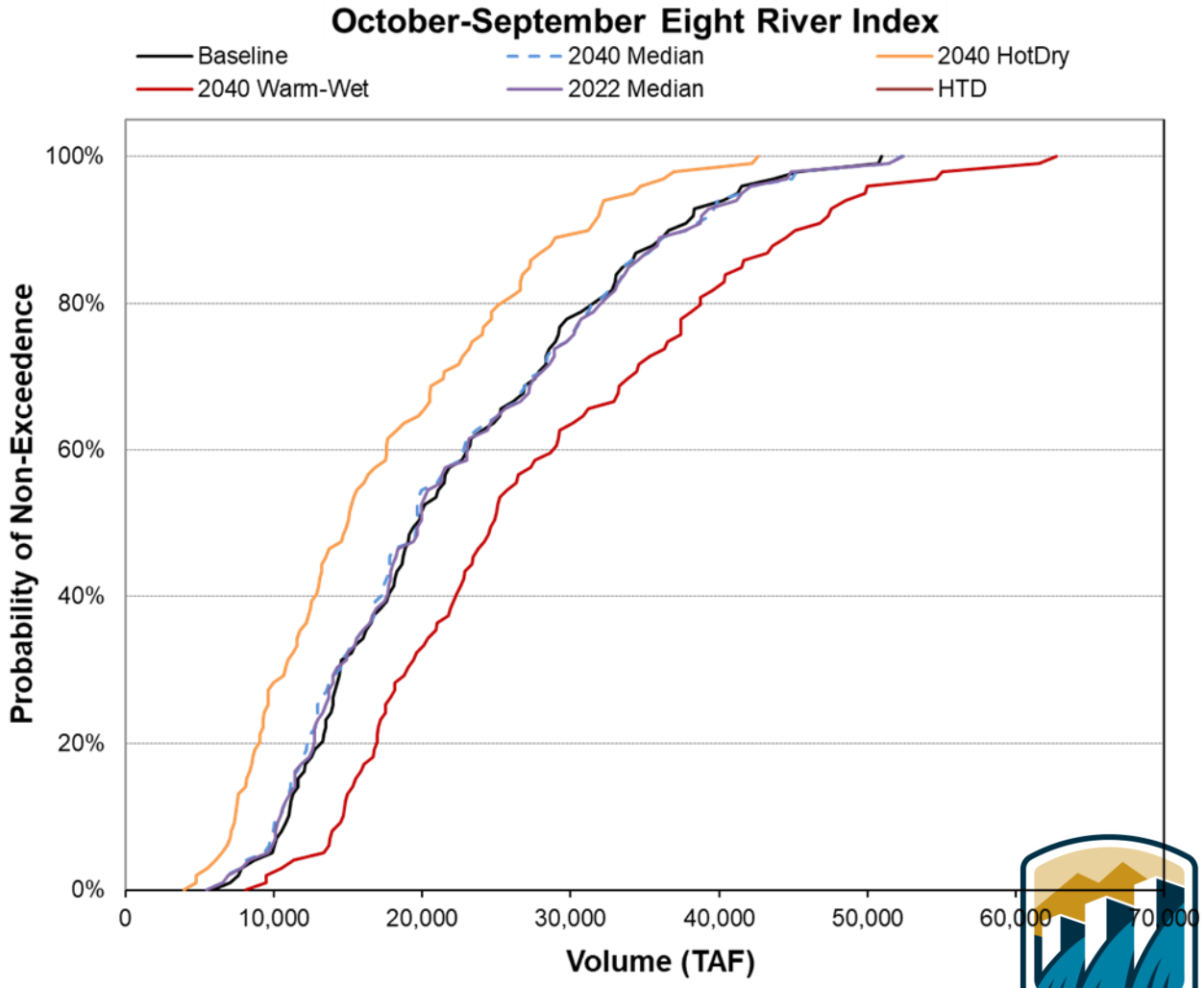
Runoff Change



Runoff: 8 River Index



	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Baseline	516.1	872.6	1743.0	2351.2	2673.9	3078.3	3244.0	3541.8	2251.5	971.4	512.4	424.7
2040 Median	544.9	923.8	2258.9	3158.4	3334.0	3532.0	3081.0	2538.7	1189.0	572.3	457.8	443.7
2040 Hot-Dry	445.3	704.2	1751.3	2490.6	2682.1	2814.1	2399.6	1812.2	790.1	458.2	415.2	385.8
2040 Warm-Wet	681.8	1179.4	2828.6	3801.9	4018.7	4230.8	3843.3	3469.6	1825.0	799.5	532.9	539.6
2022 Median	545.7	942.4	2157.3	2940.6	3243.4	3391.7	3129.7	2832.1	1450.9	660.3	466.9	441.8
HTD	522.9	908.9	1803.2	2657.0	2940.3	3295.8	3183.2	3145.9	1838.2	812.5	490.4	425.6



Concluding Remarks

- Future median climate conditions centered on 2040 was developed.
- CalSim 3 and CalSim II meteorologic and hydrologic boundary conditions were updated to represent future climate conditions.
- Climate change analysis for LTO analysis are mainly based on 2040 median climate change conditions.
- A set of sensitivity scenarios are being developed to review range of uncertainty under future climate conditions.
- Workflow has been developed to generate future climate change scenarios using ensemble-informed approach and can also support for a large ensemble or decision-scaling/hybrid approach.

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Thank you!

Acknowledgement: Modeling Division, Bay Delta Office

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Extra Slides

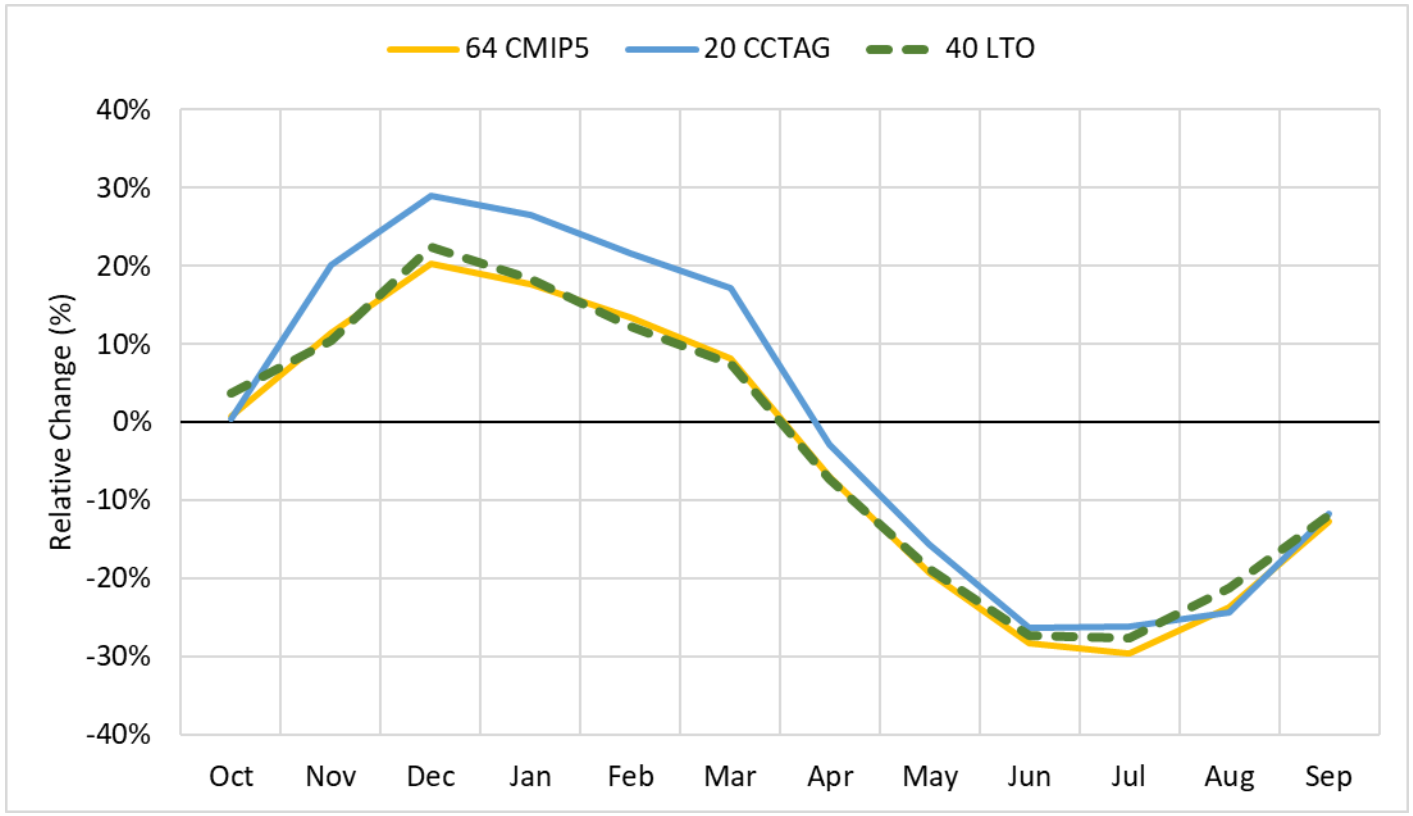
GCM Selection

- 20 of 32 GCMs were selected through this process
  - Uses both RCP 4.5 and RCP 8.5 emission scenarios
- Includes 5 GCMs selected by CCTAG

VIC Routed Runoff Statistics for 8 RI

Selection	Relative Annual Change in Runoff	Relative Change in Standard Deviation of Runoff
64 GCM Projections	-1.4%	10.3%
20 CCTAG Projections	4.7%	16.6%
40 LTO Projections	-1.0%	10.8%

Projected Changes in Runoff - 8RI



Selection	Relative Annual Change
20 CCTAG Mean	4.7%
64 CMIP5 Mean	-1.4%
40 LTO Mean	-1.0%

Data extension → Bias correction → Detrending → Climate Scenario → VIC simulation

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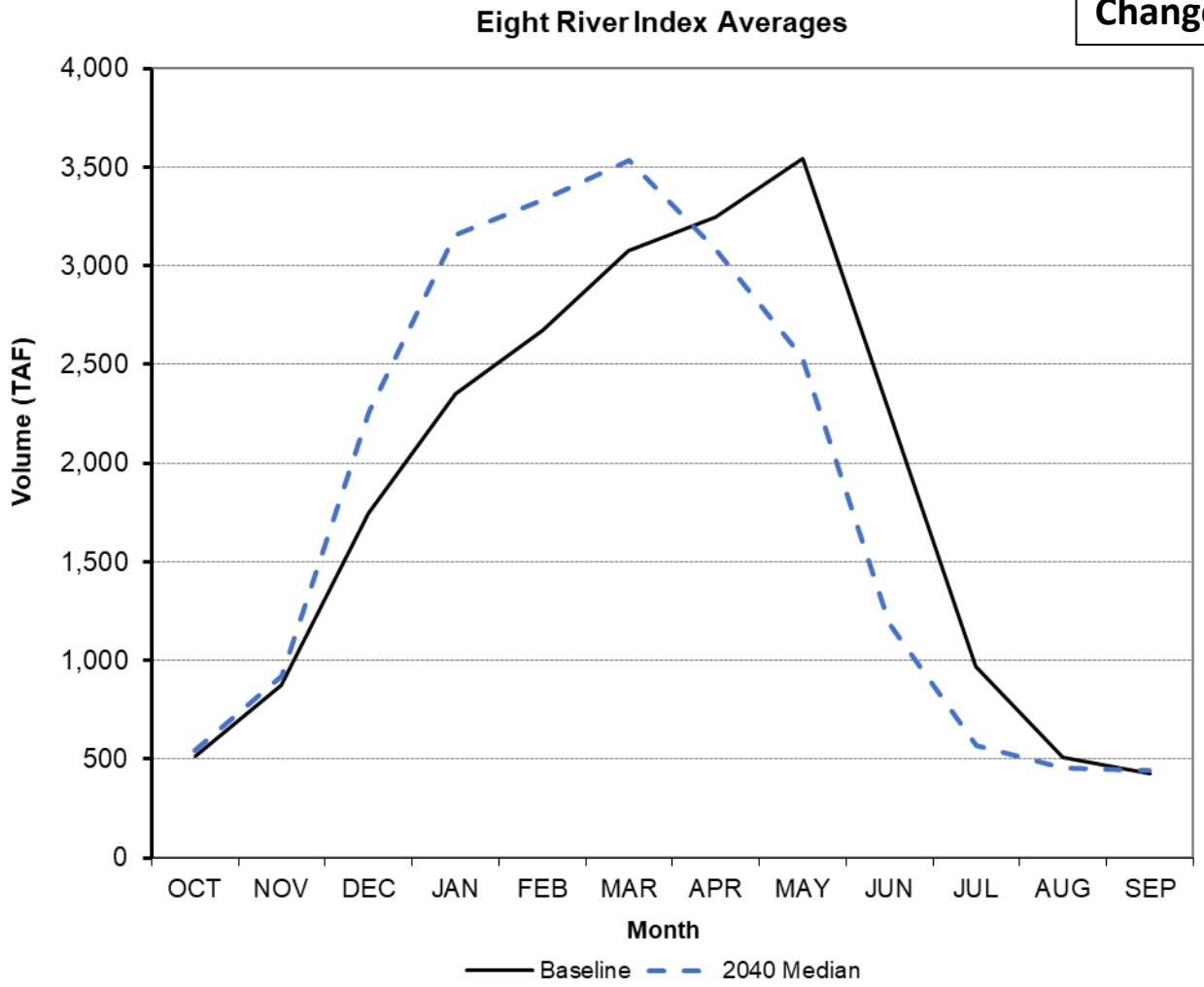
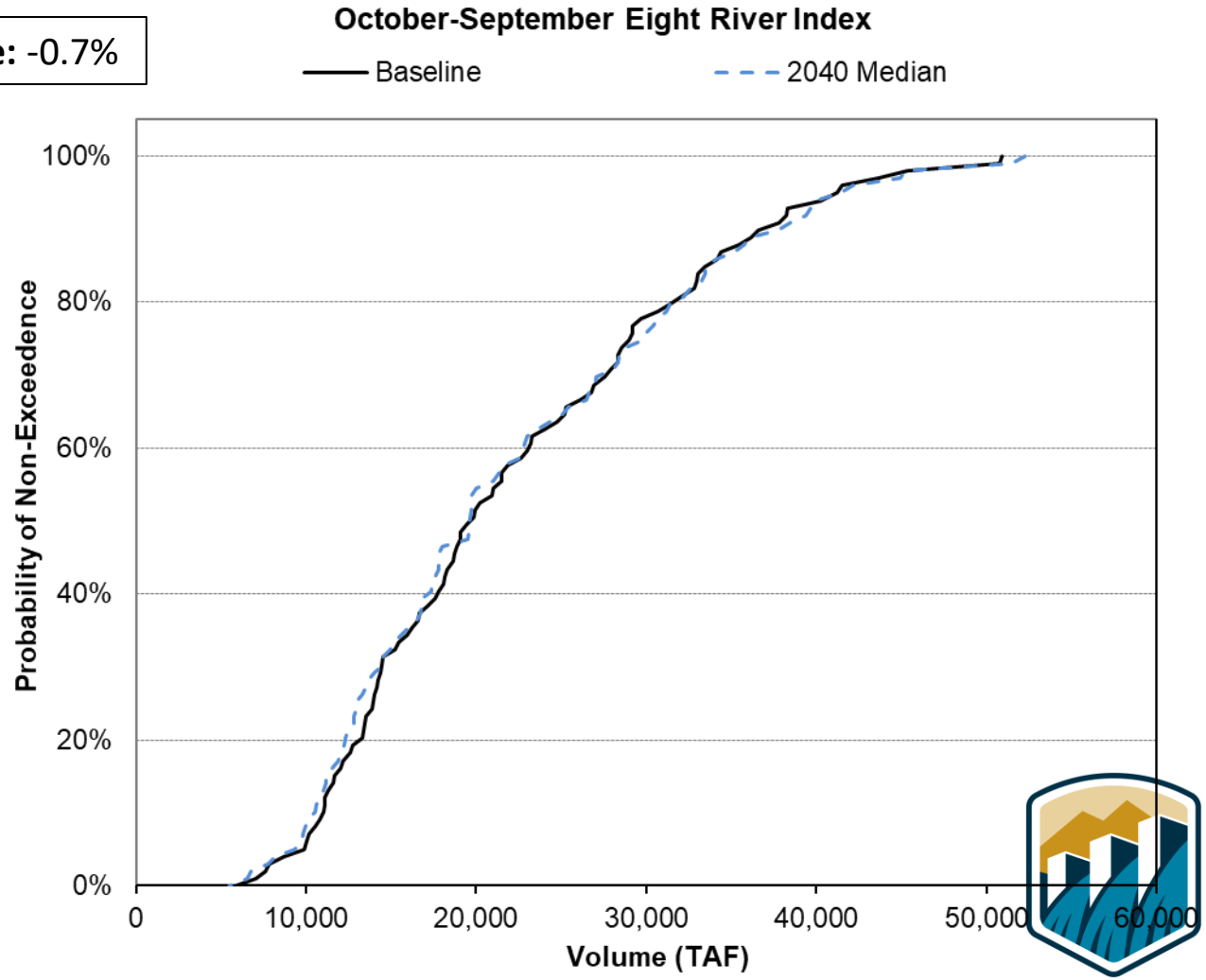
Projected Changes in Monthly Pattern of Runoff for the Eight River Basin

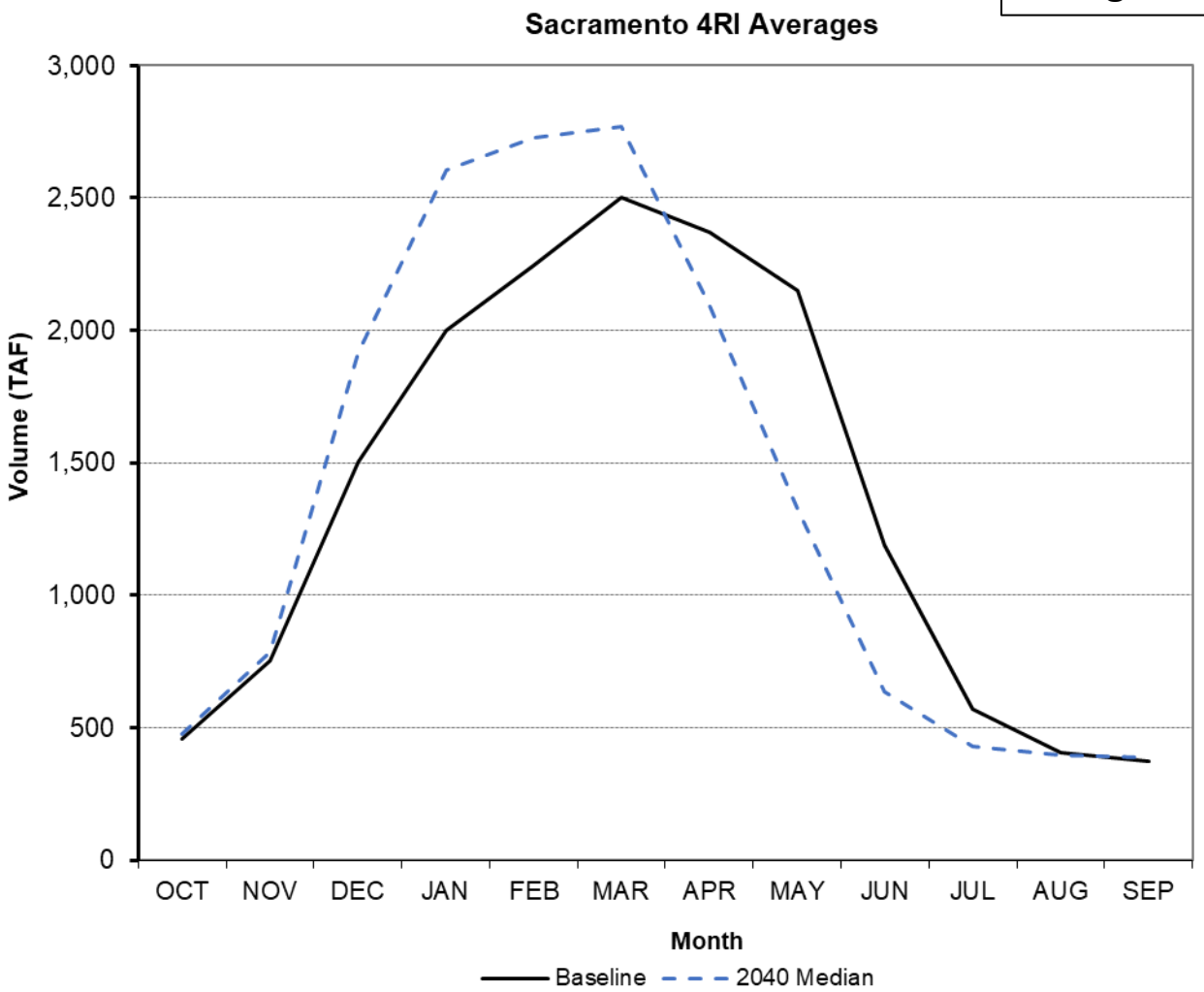
Change: -0.7%

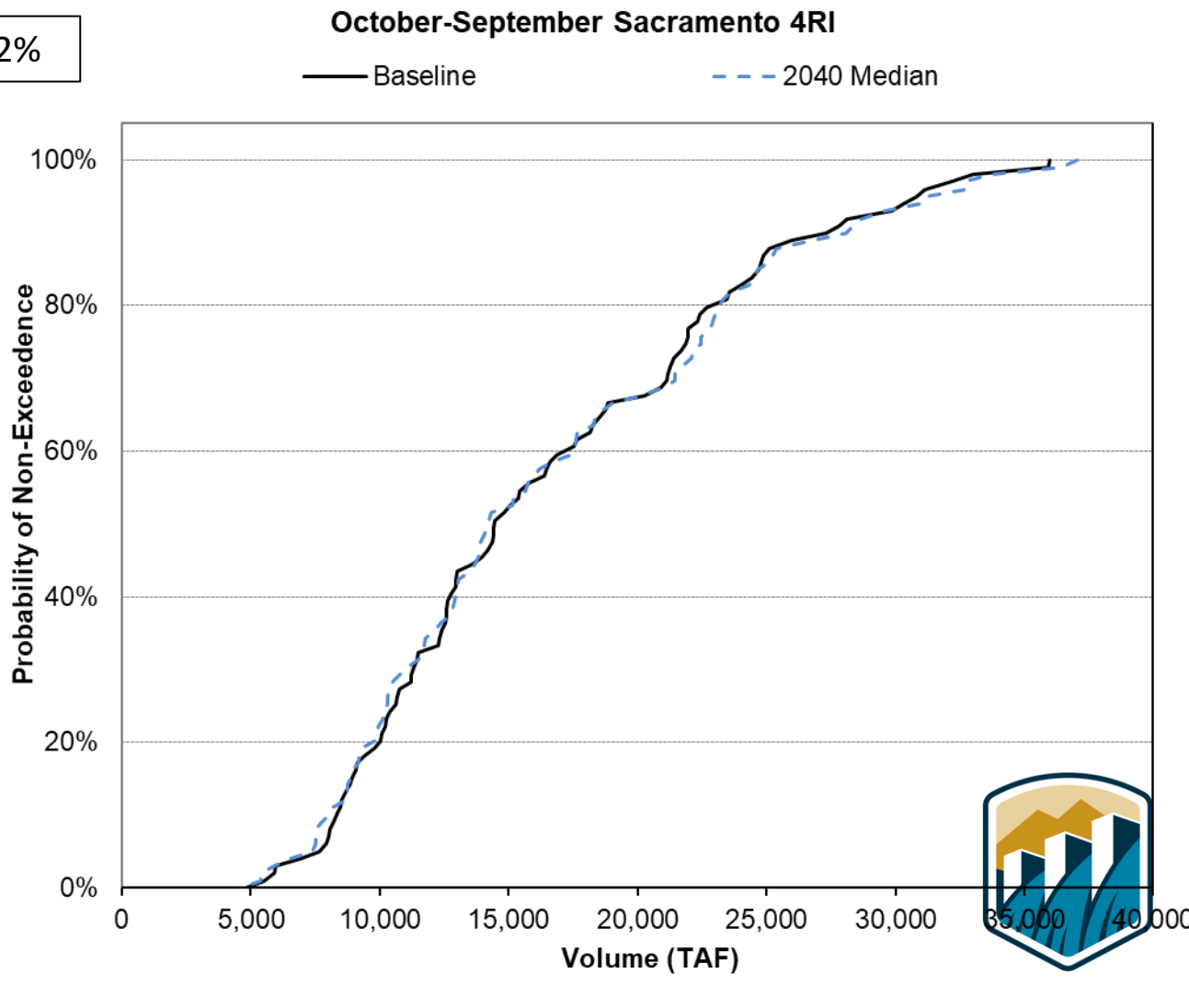




Projected Changes in Monthly Pattern of Runoff for the Sacramento 4RI

Change: 0.2%





Data extension → Bias correction → Detrending → Climate Scenario → VIC simulation

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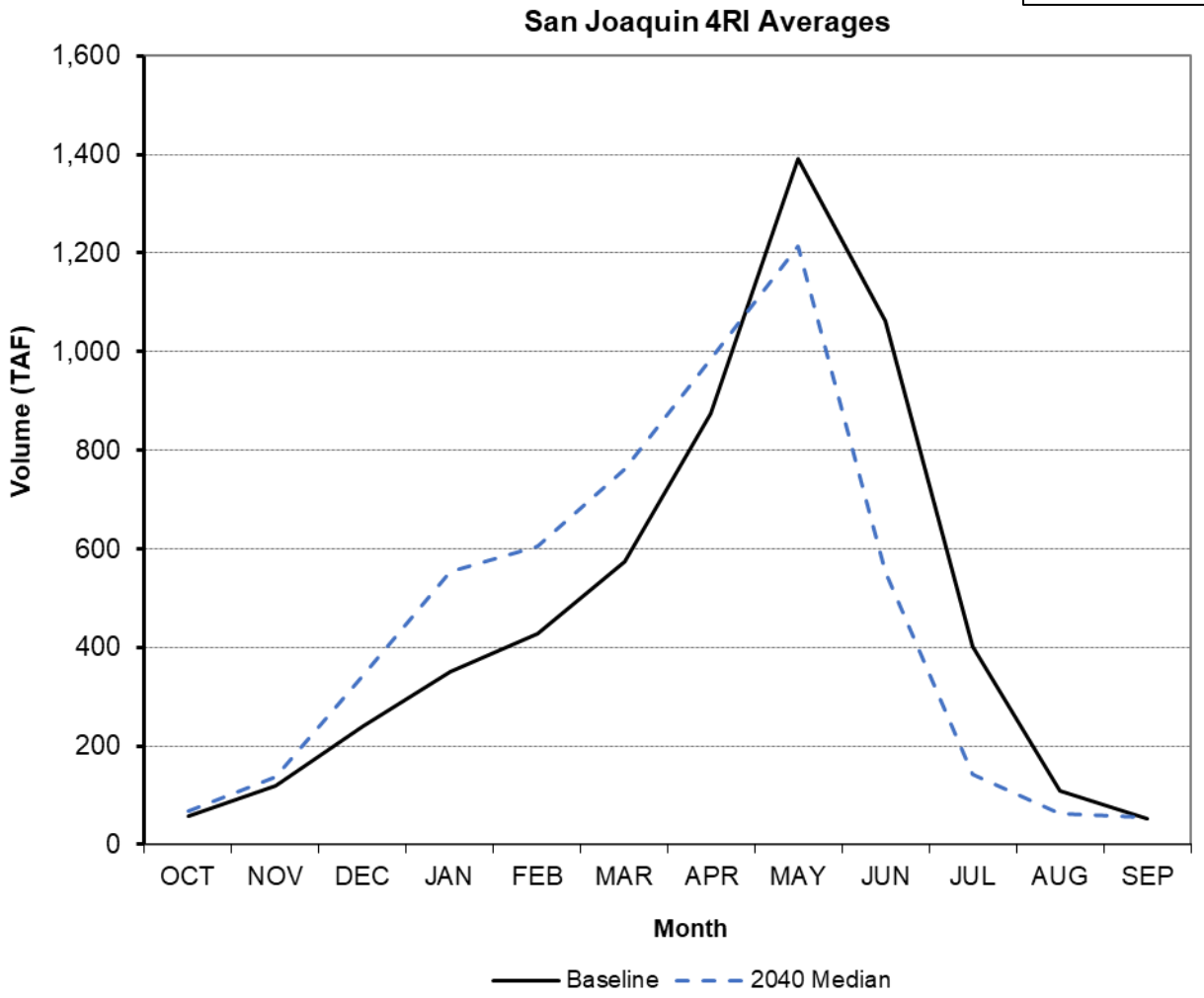
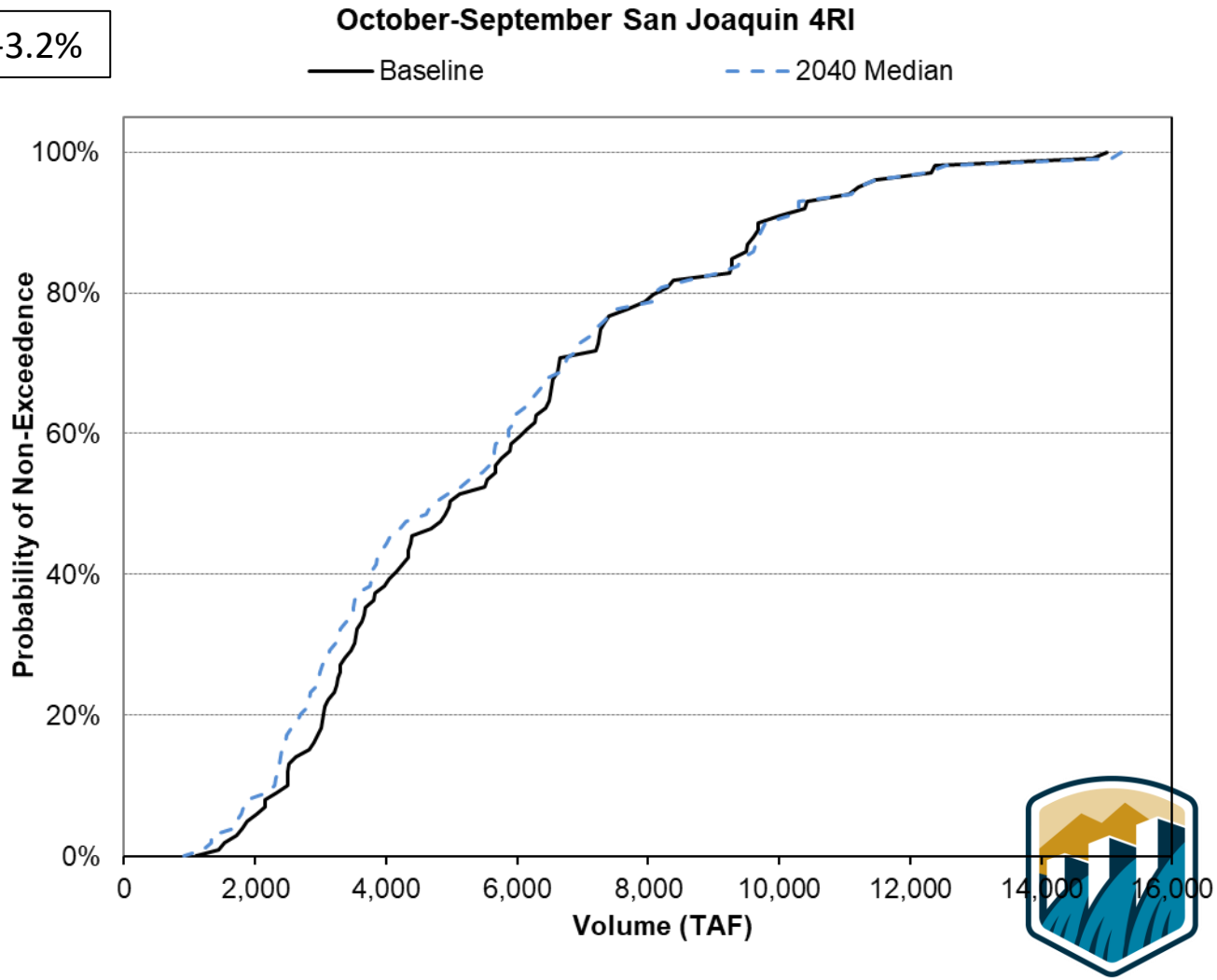
Projected Changes in Monthly Pattern of Runoff for the San Joaquin 4RI

Change: -3.2%





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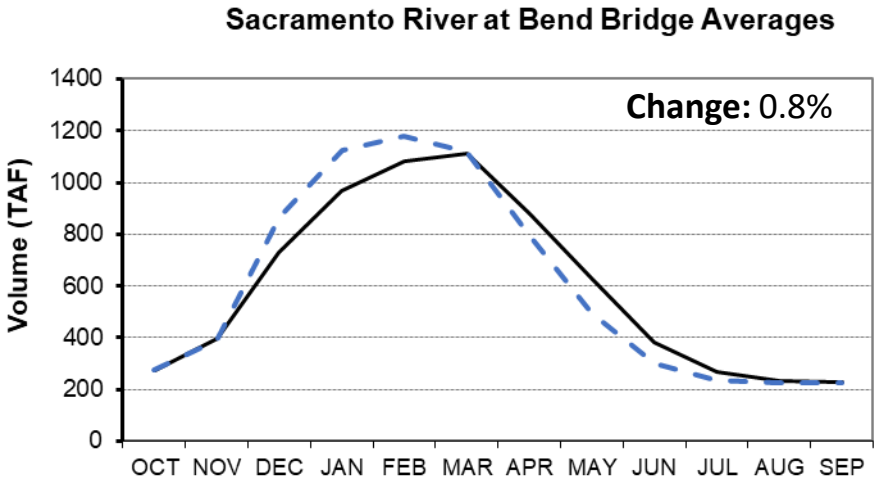
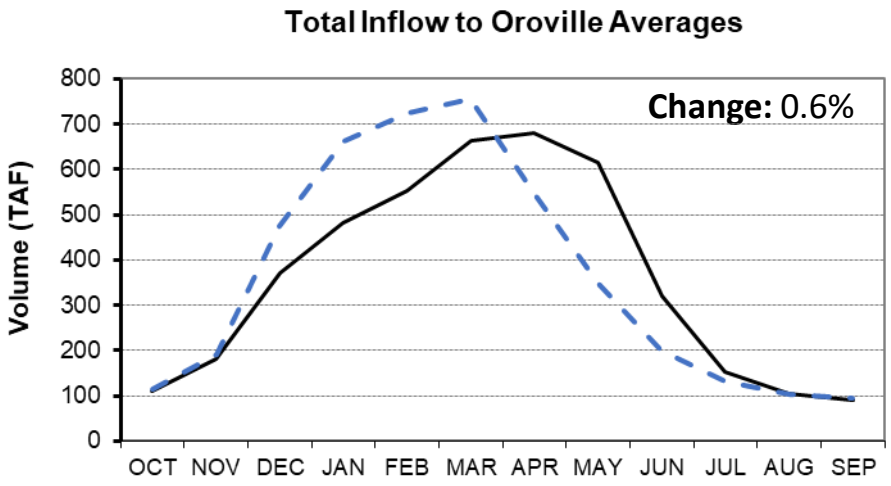
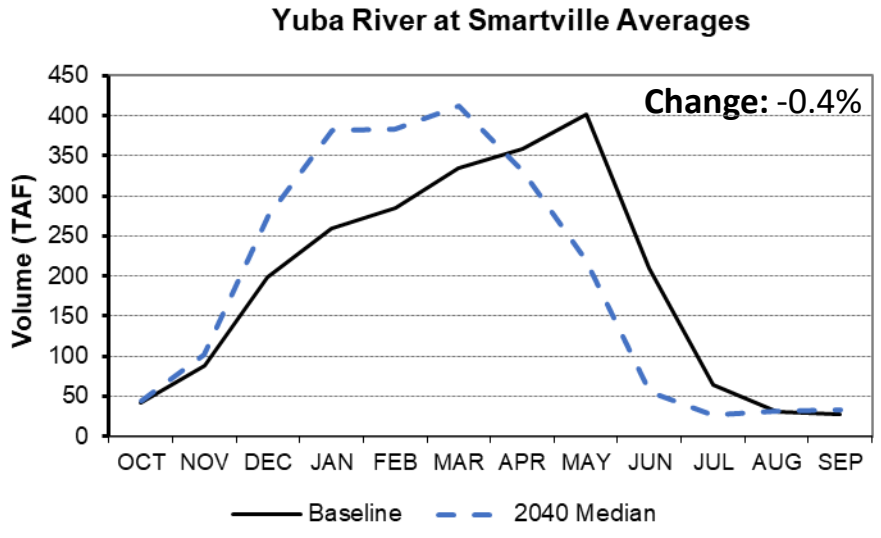
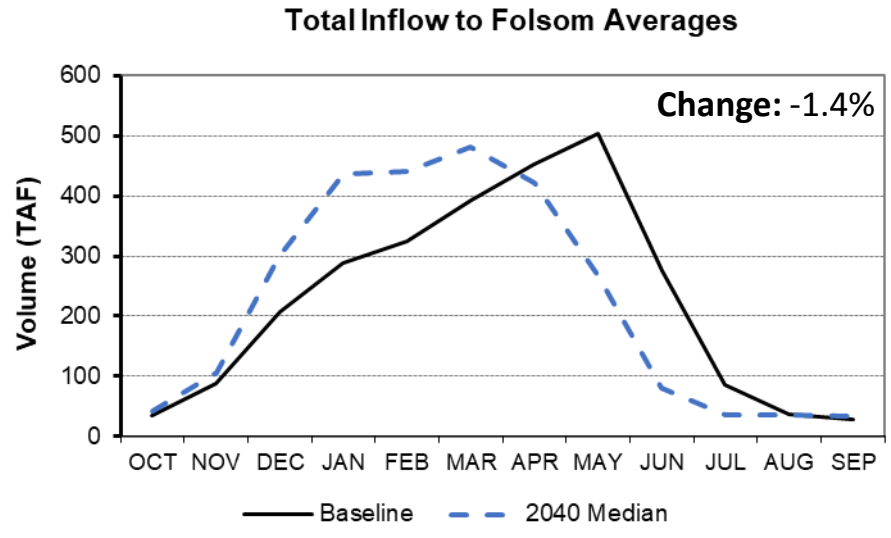
Projected Changes in Monthly Pattern of Runoff for the Sacramento 4RI









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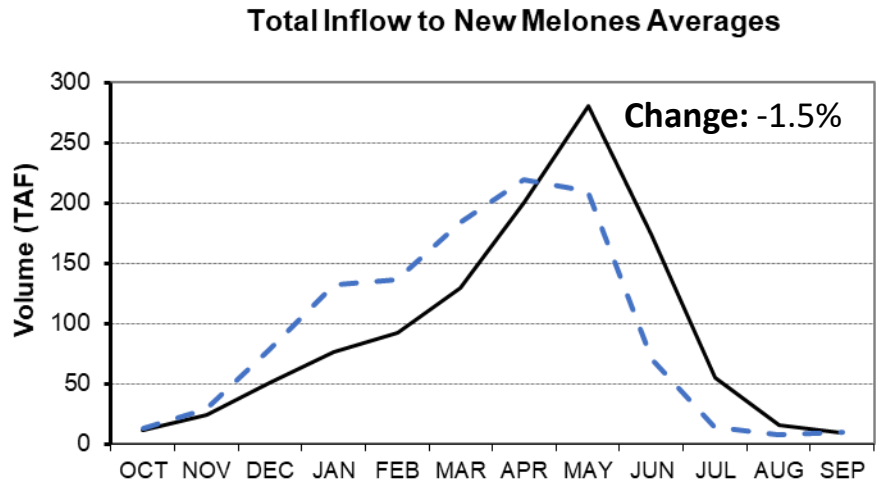
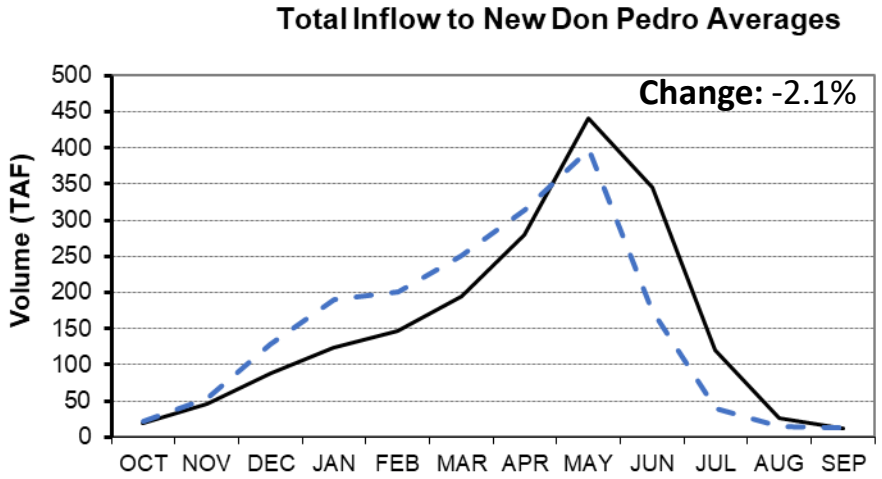
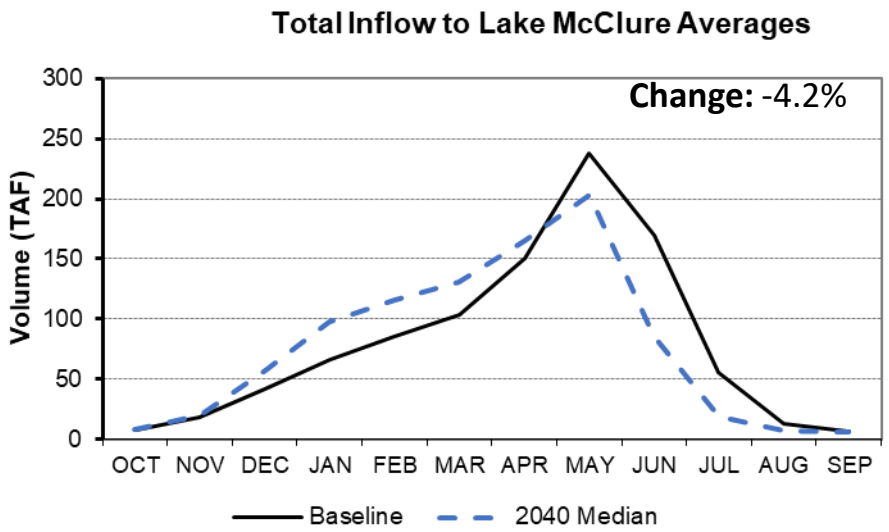
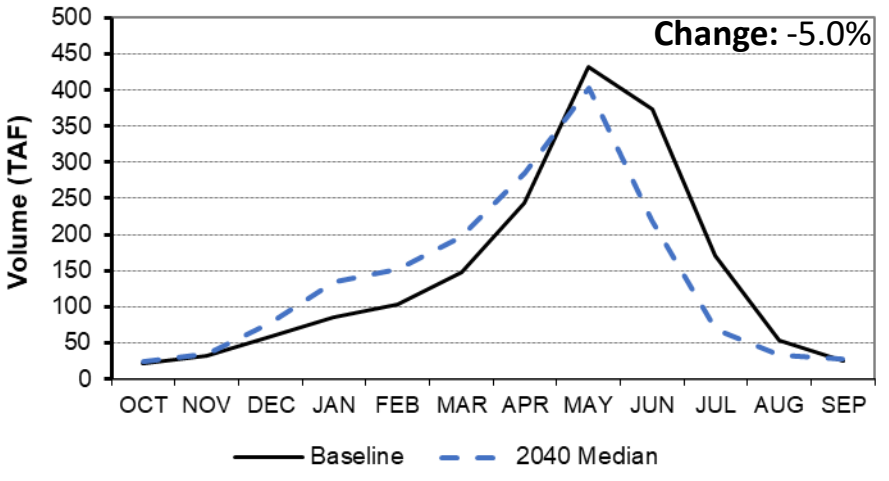
Projected Changes in Monthly Pattern of Runoff for the San Joaquin 4RI

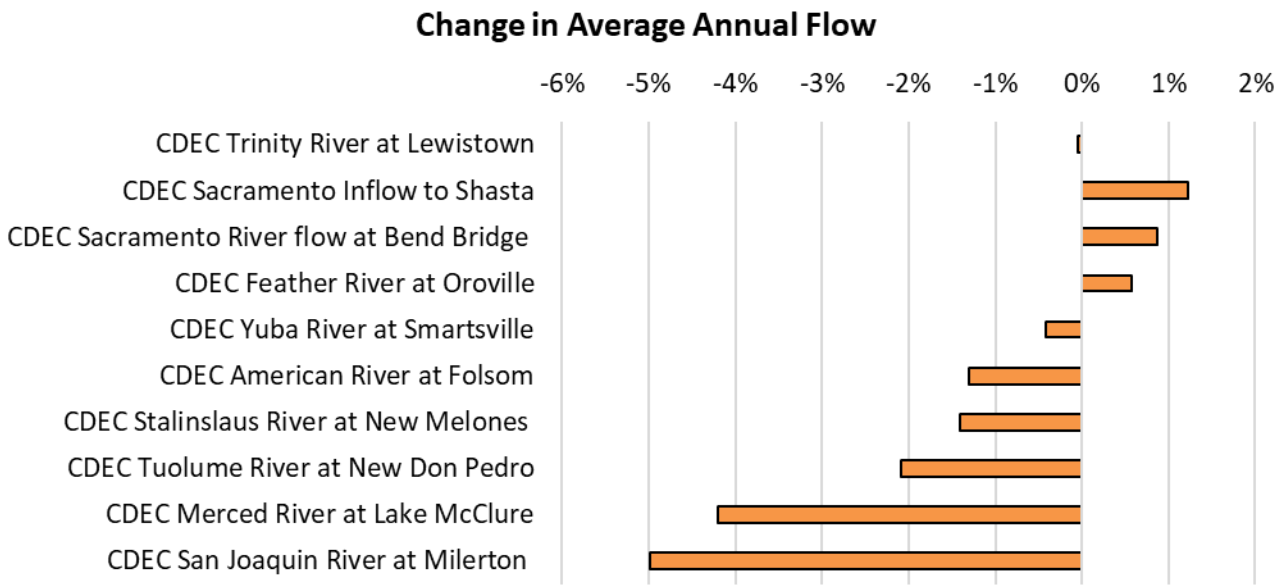


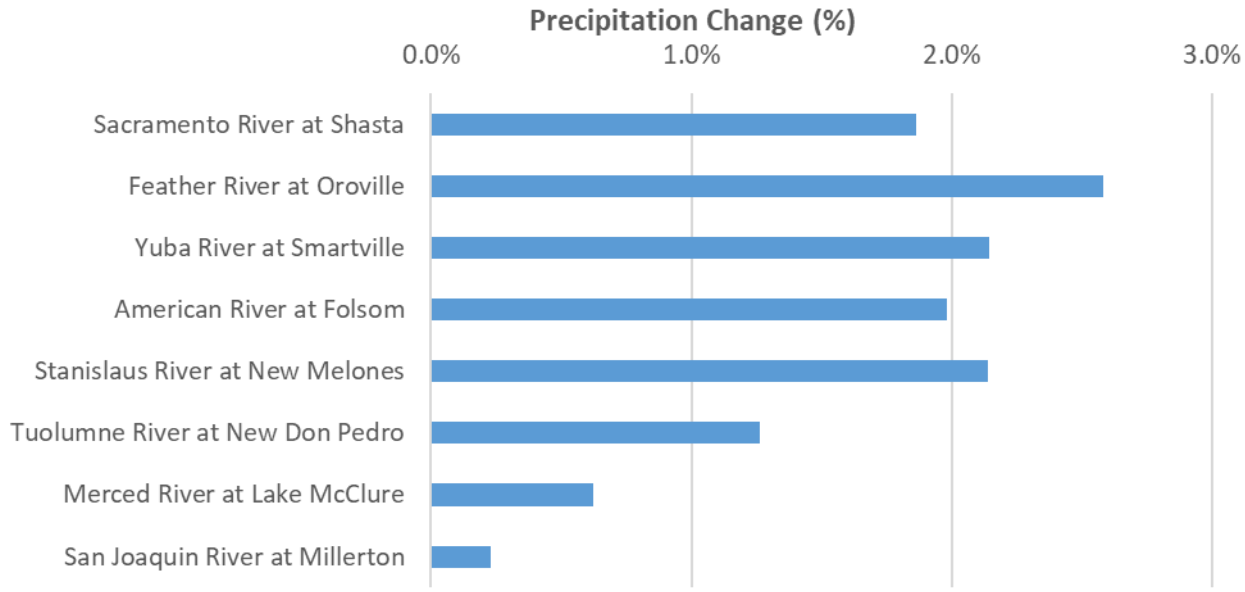






Lookup Tables





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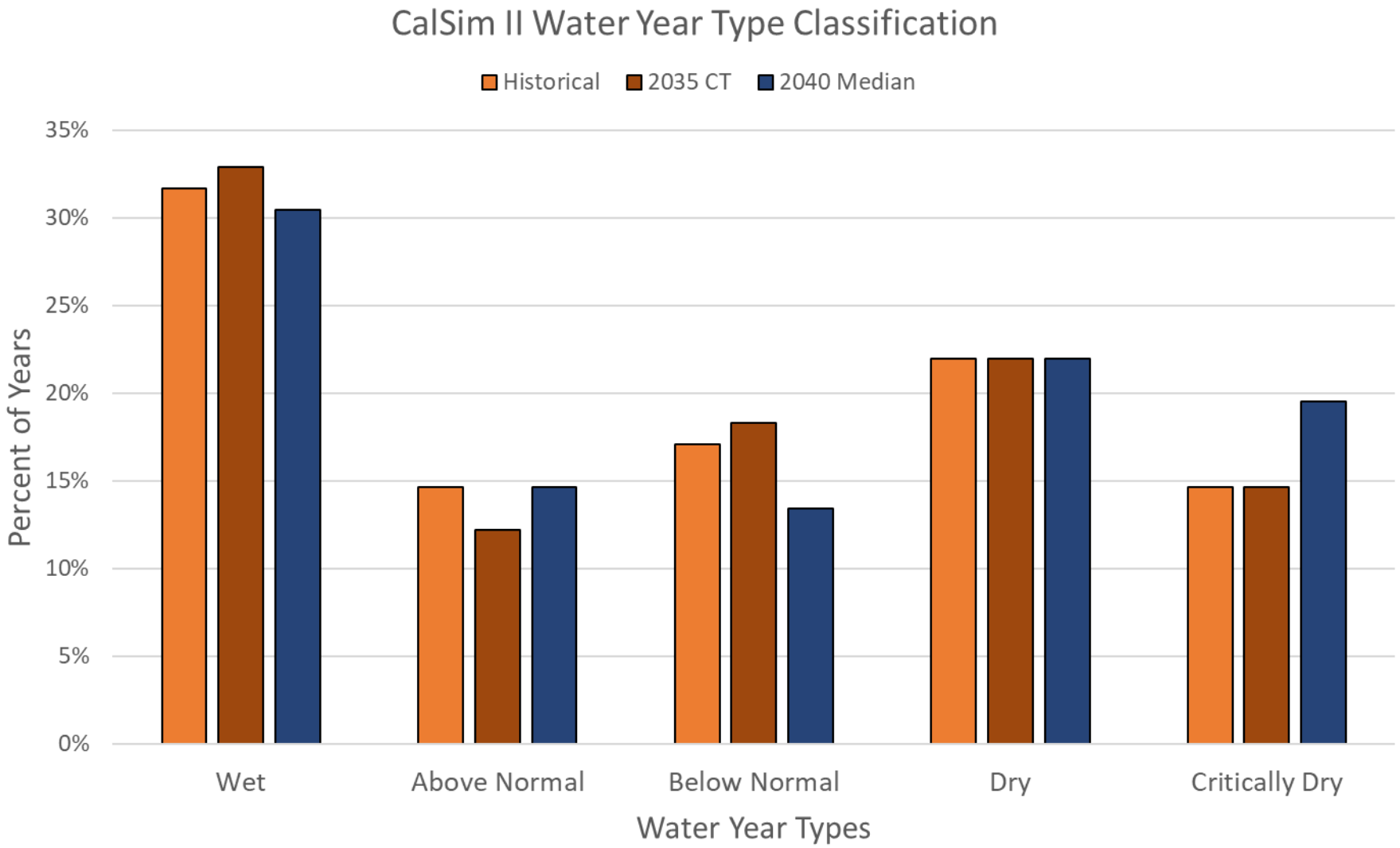
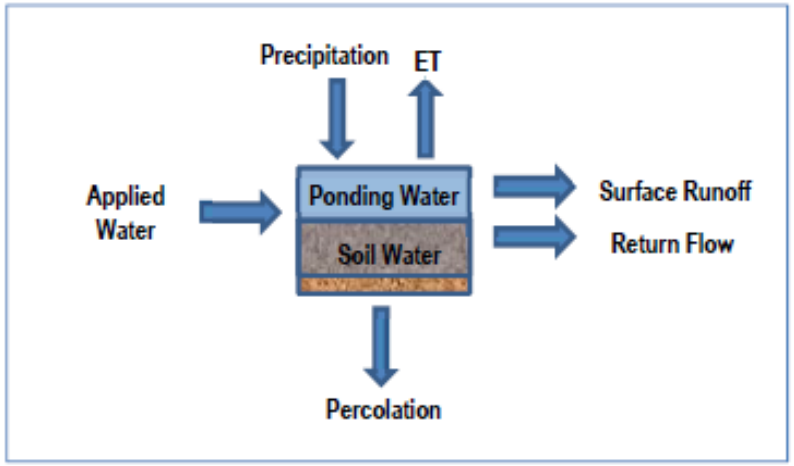
Rim Inflows → **Lookup Tables** → Reservoir Evaporation → Valley Floor Flows → Delta Channel Depletion → Groundwater

Water Year Type



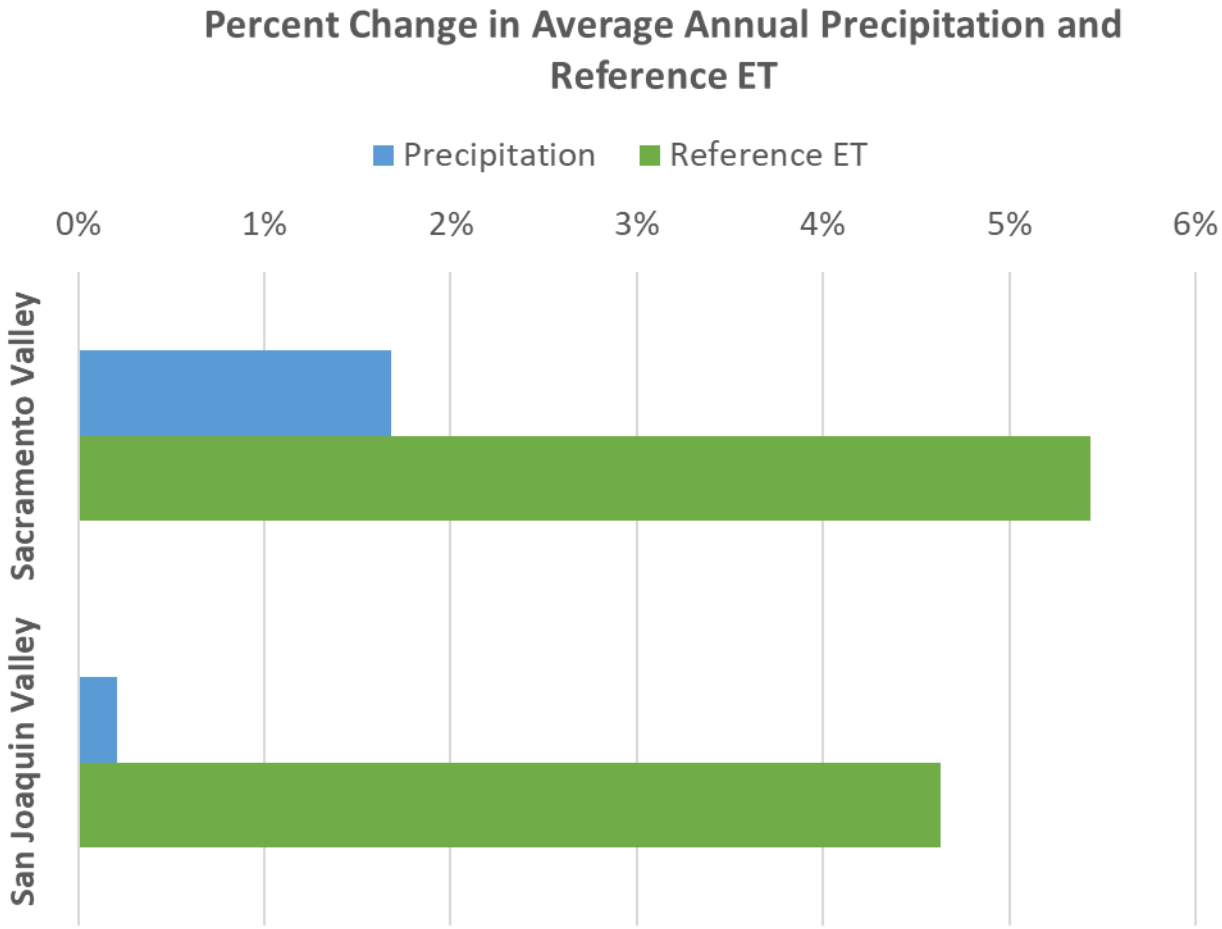
Valley Floor Flows

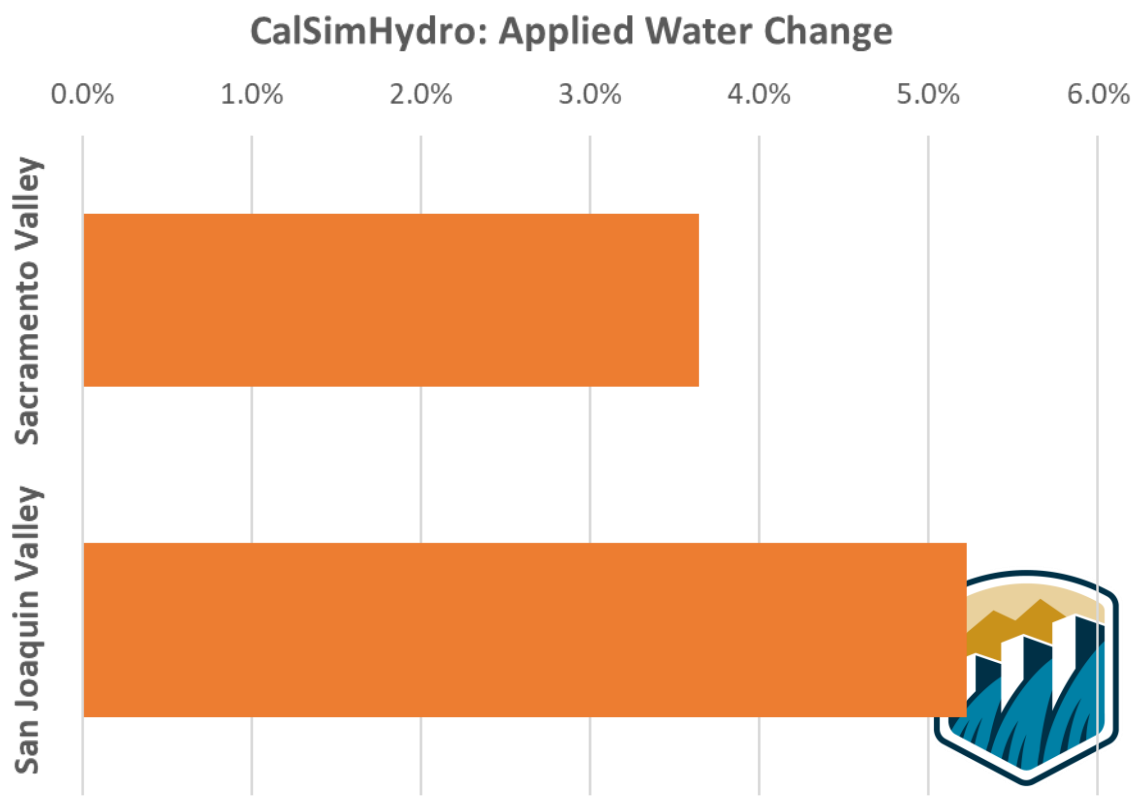


CalSimHydro Mass Balance Diagram

Projected Changes for Sacramento and San Joaquin Valleys

CalSim3 Input: Applied Water, Surface Runoff, Tailwater, Wastewater, and Deep Percolation



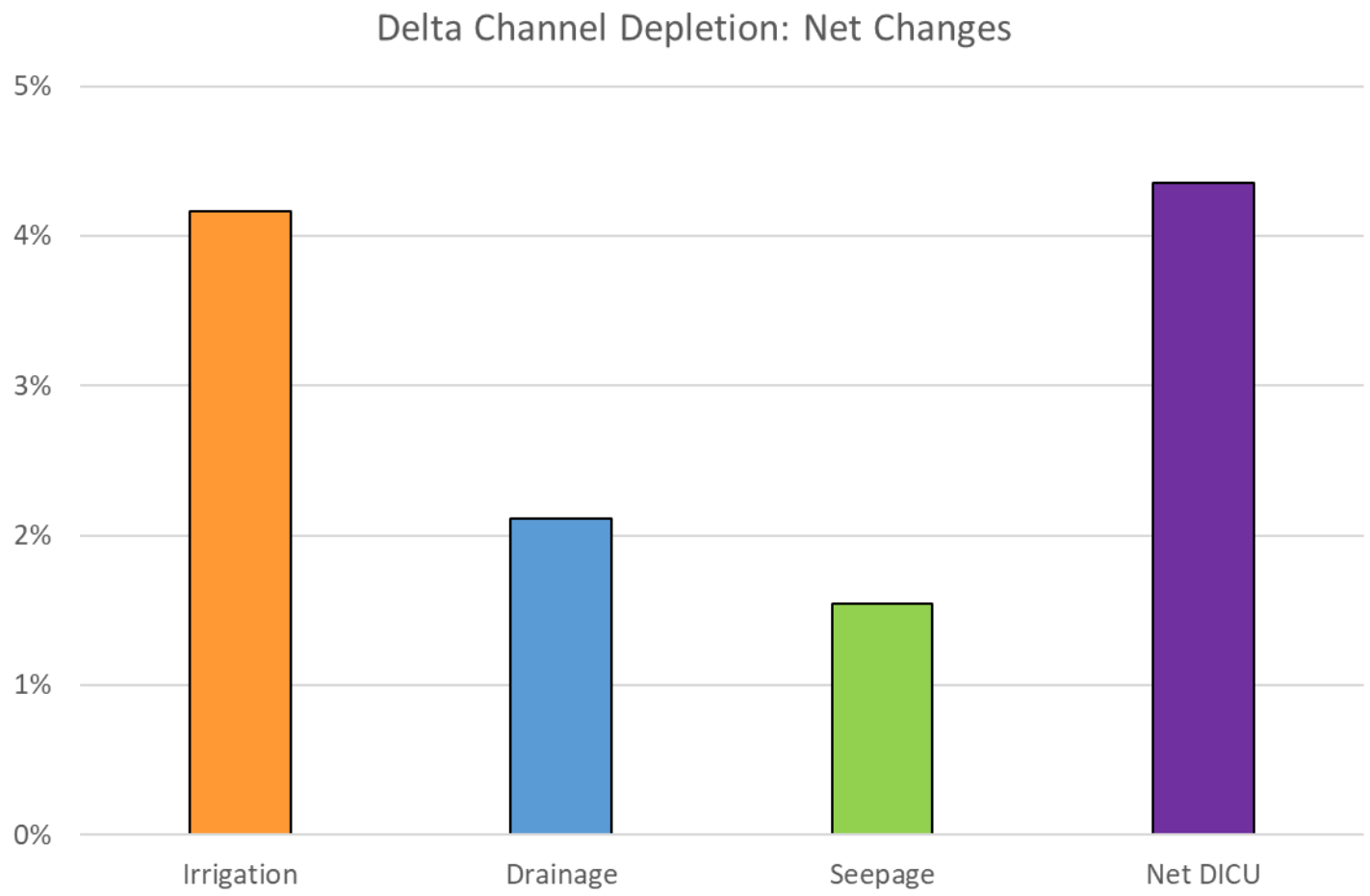


Data extension → Bias correction → Detrending → Climate Scenario → VIC simulation

Rim Inflows → Lookup Tables → Reservoir Evaporation → Valley Floor Flows → **Delta Channel Depletion** → Groundwater

Delta Channel Depletion

CalSim3 Input: Delta Island Irrigation, Drainage and Seepage

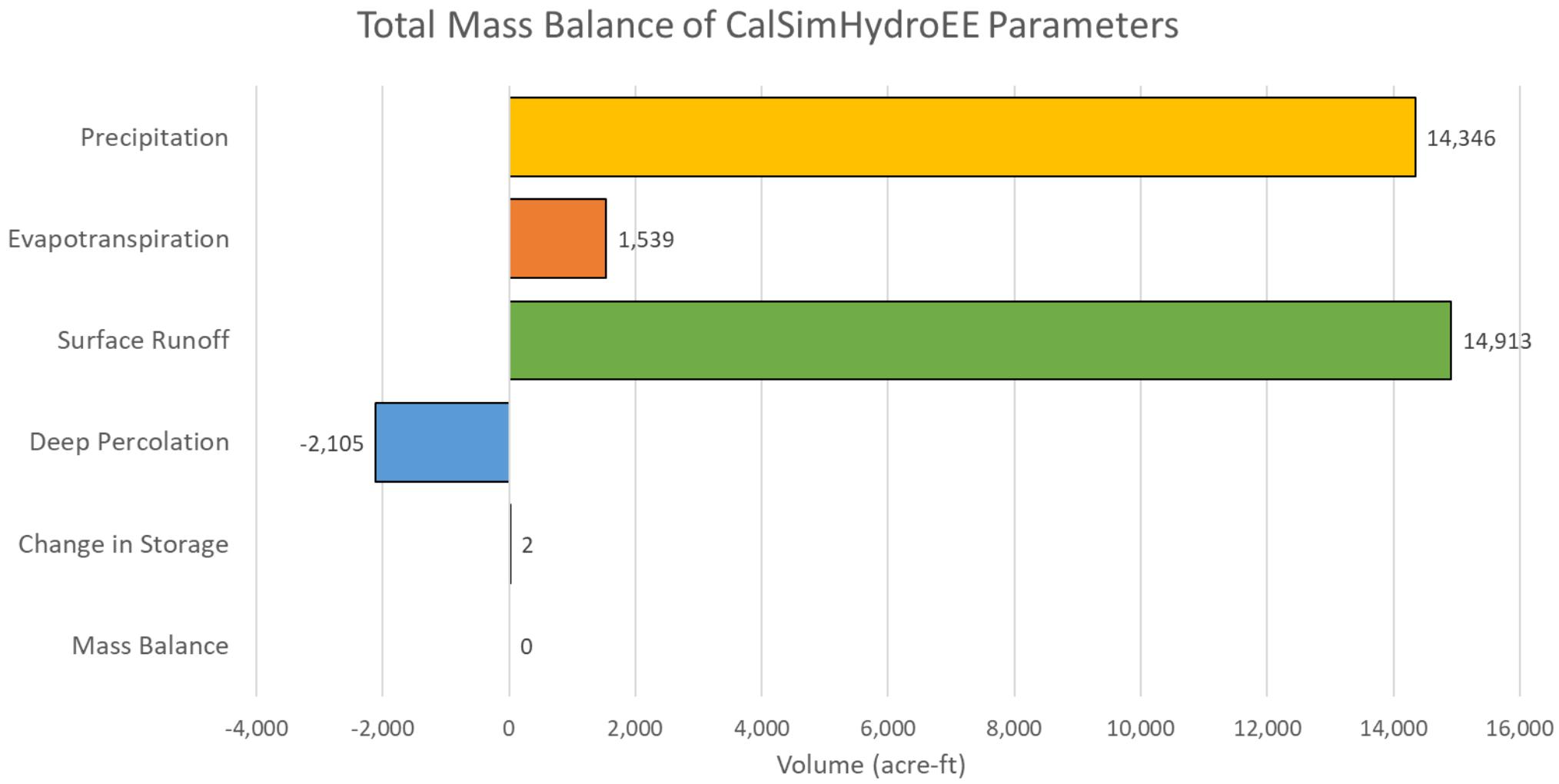


Data extension → Bias correction → Detrending → Climate Scenario → VIC simulation

Rim Inflows → Lookup Tables → Reservoir Evaporation → Valley Floor Flows → Delta Channel Depletion → Groundwater

CalSimHydroEE

CalSim3 Input: Deep Percolation (DP)

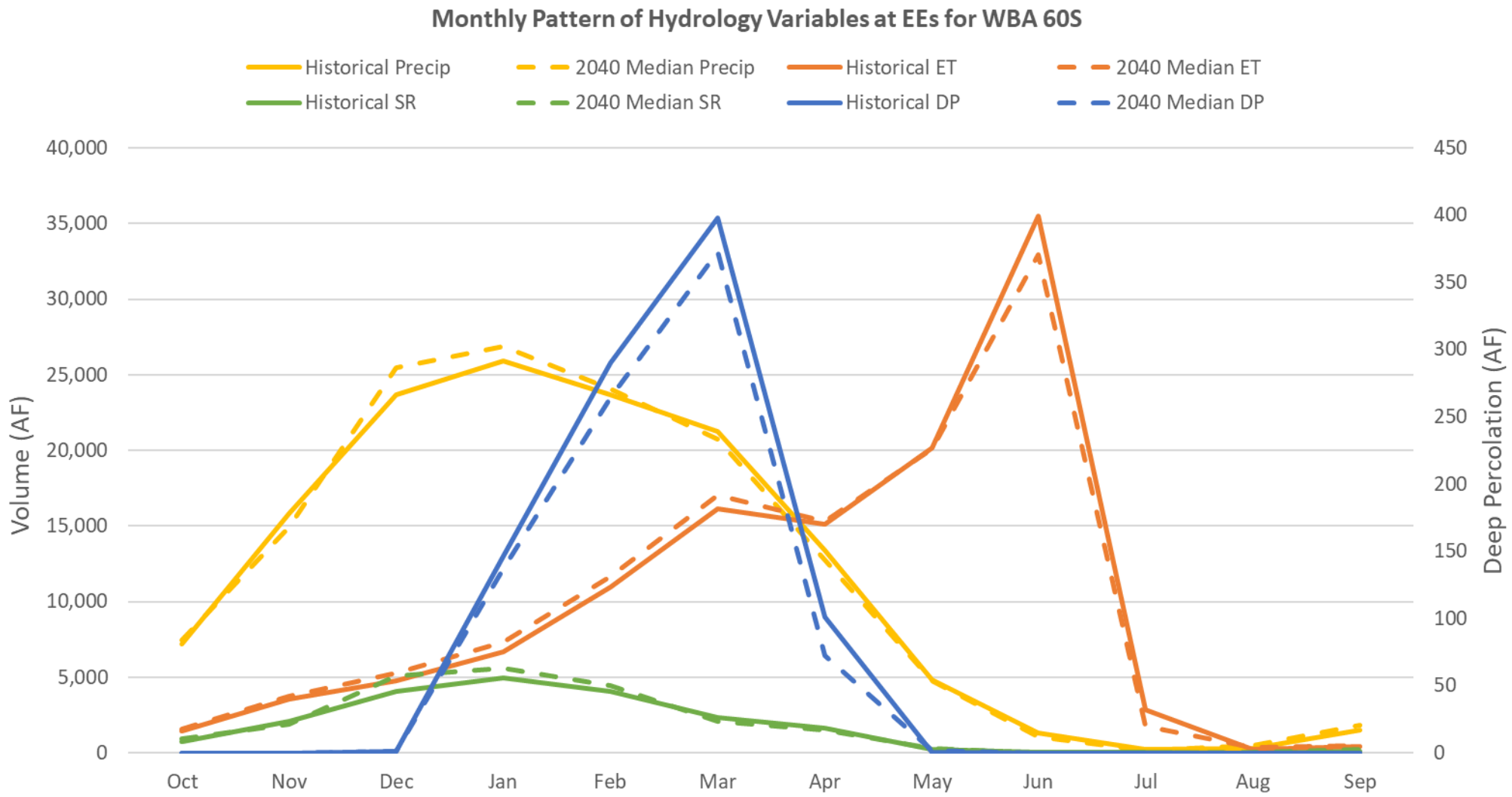


Data extension → Bias correction → Detrending → Climate Scenario → VIC simulation

Rim Inflows → Lookup Tables → Reservoir Evaporation → Valley Floor Flows → Delta Channel Depletion → Groundwater

CalSimHydroEE

CalSim3 Input: Deep Percolation (DP)

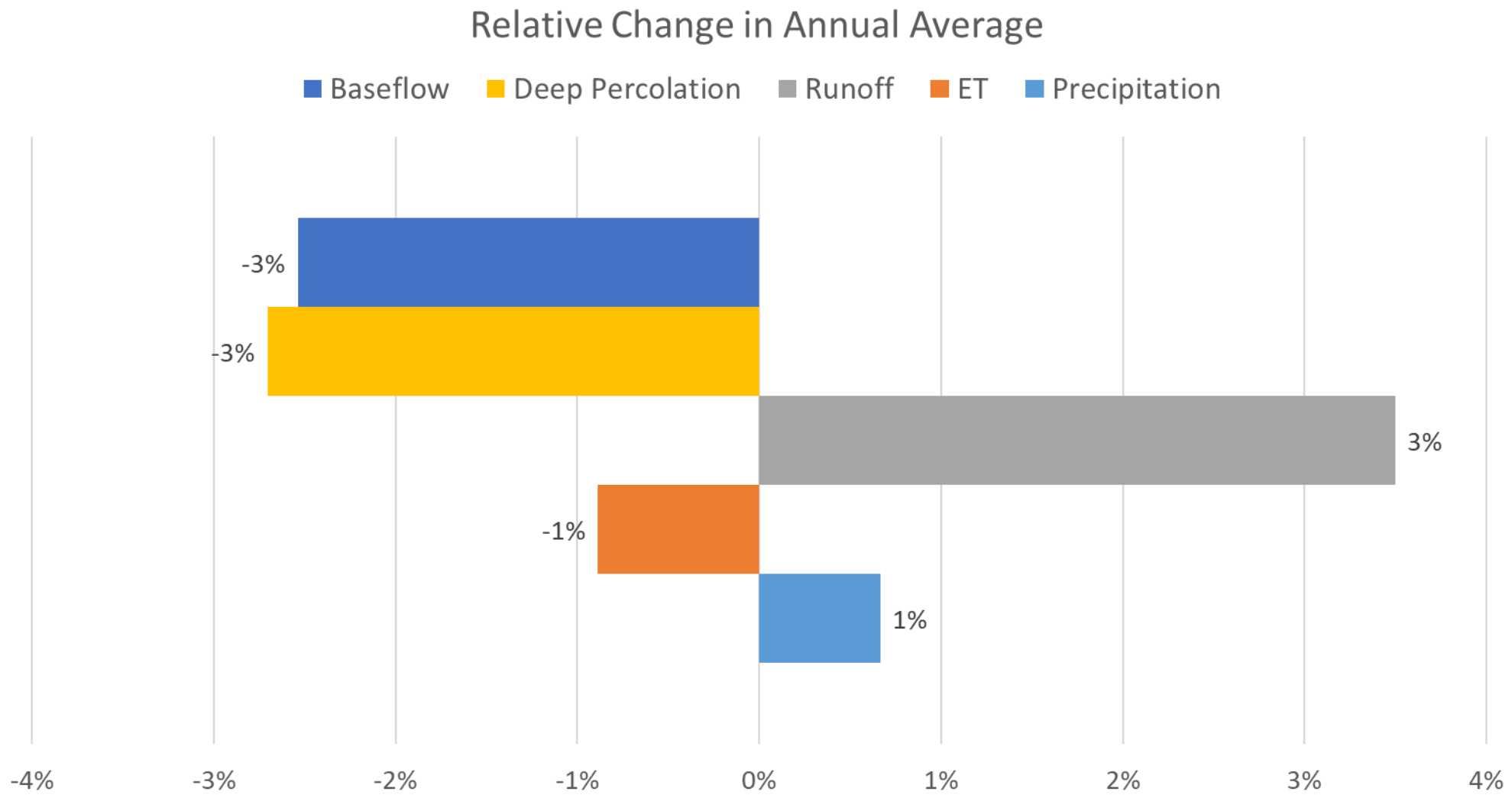


Data extension → Bias correction → Detrending → Climate Scenario → VIC simulation

Rim Inflows → Lookup Tables → Reservoir Evaporation → Valley Floor Flows → Delta Channel Depletion → **Groundwater**

Smallwatersheds

CalSim3 Input: Baseflow

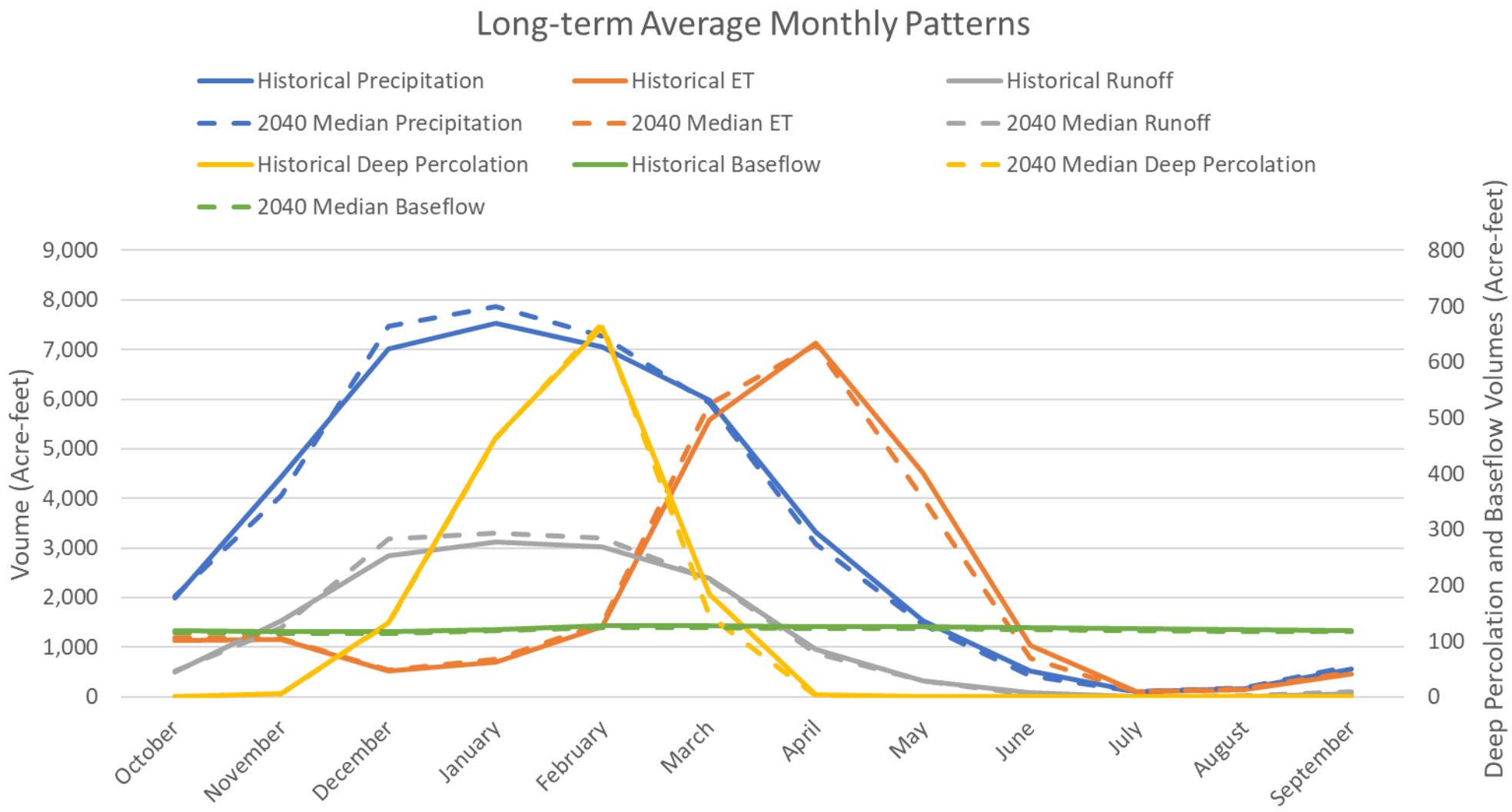


Data extension → Bias correction → Detrending → Climate Scenario → VIC simulation

Rim Inflows → Lookup Tables → Reservoir Evaporation → Valley Floor Flows → Delta Channel Depletion → **Groundwater**

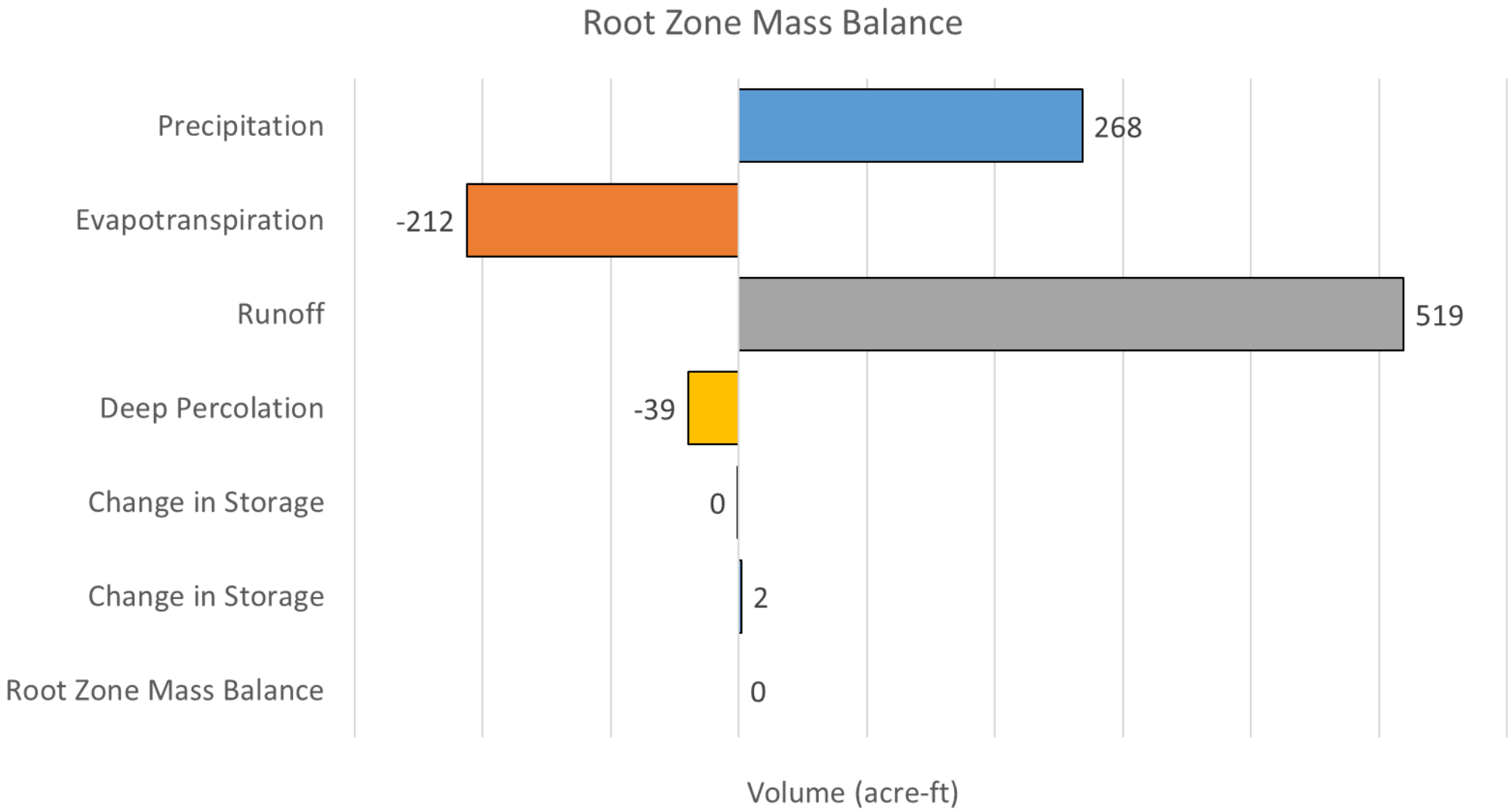
Smallwatersheds

CalSim3 Input: Baseflow



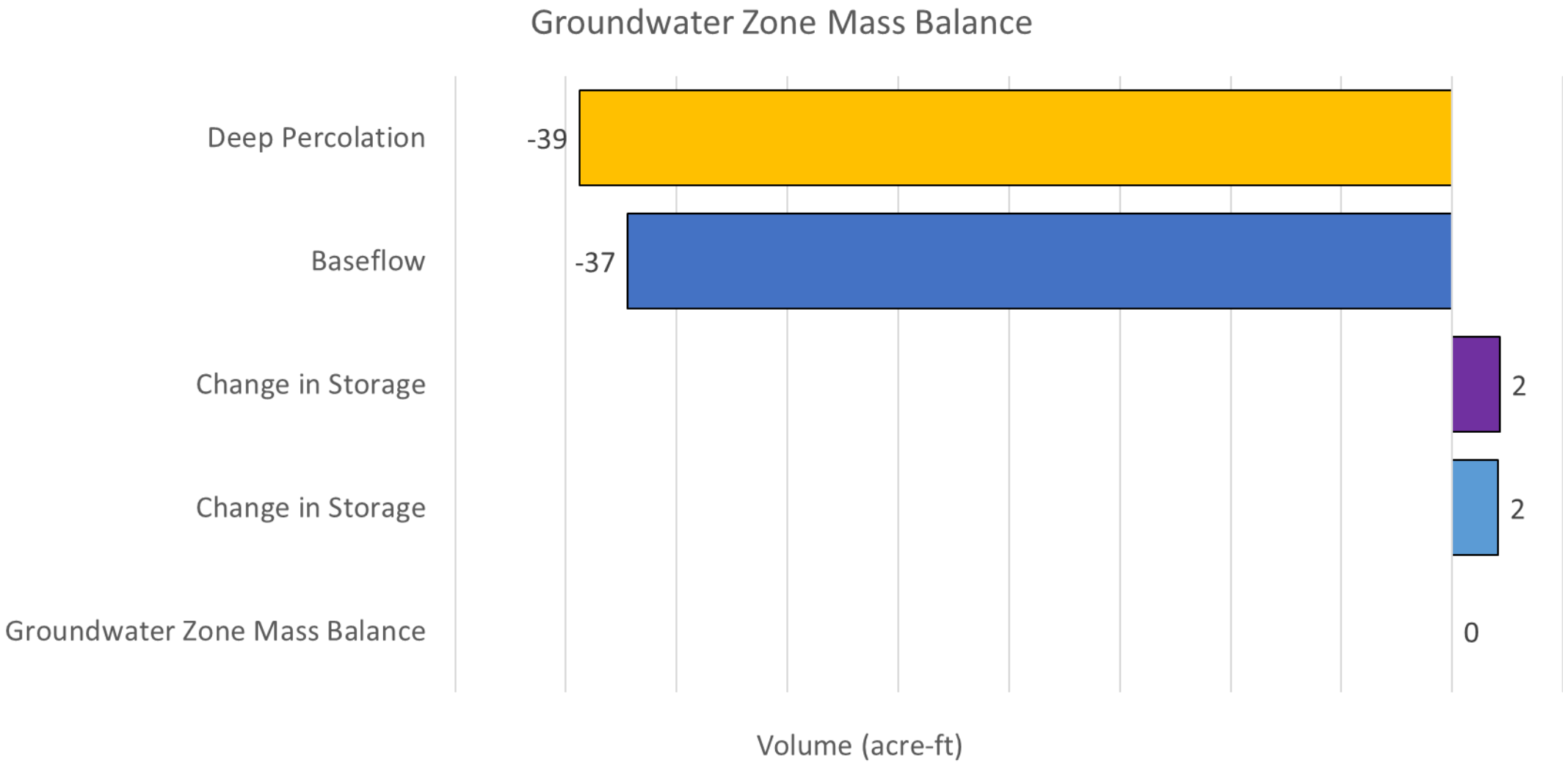
Smallwatersheds

CalSim3 Input: Baseflow



Smallwatersheds

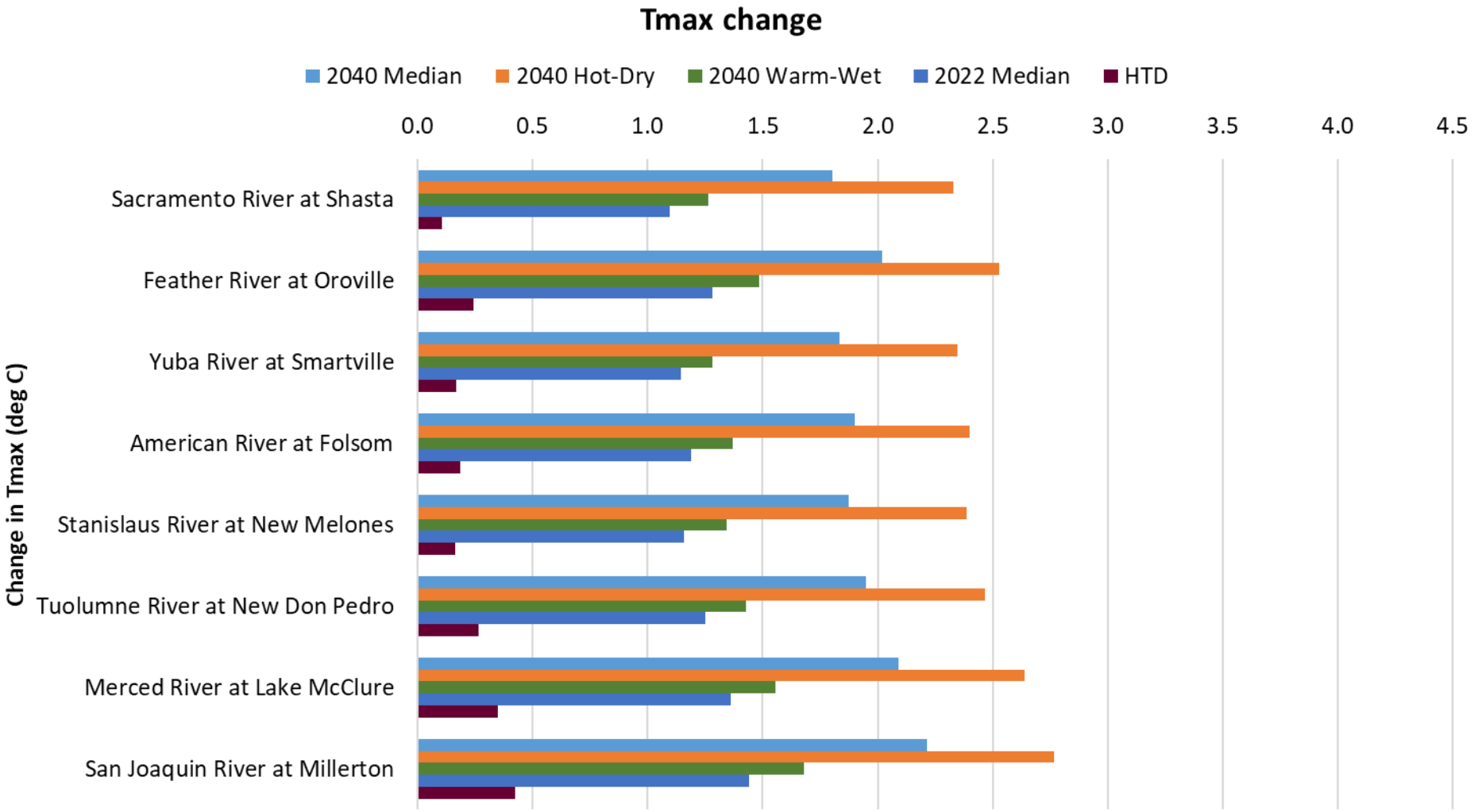
CalSim3 Input: Baseflow



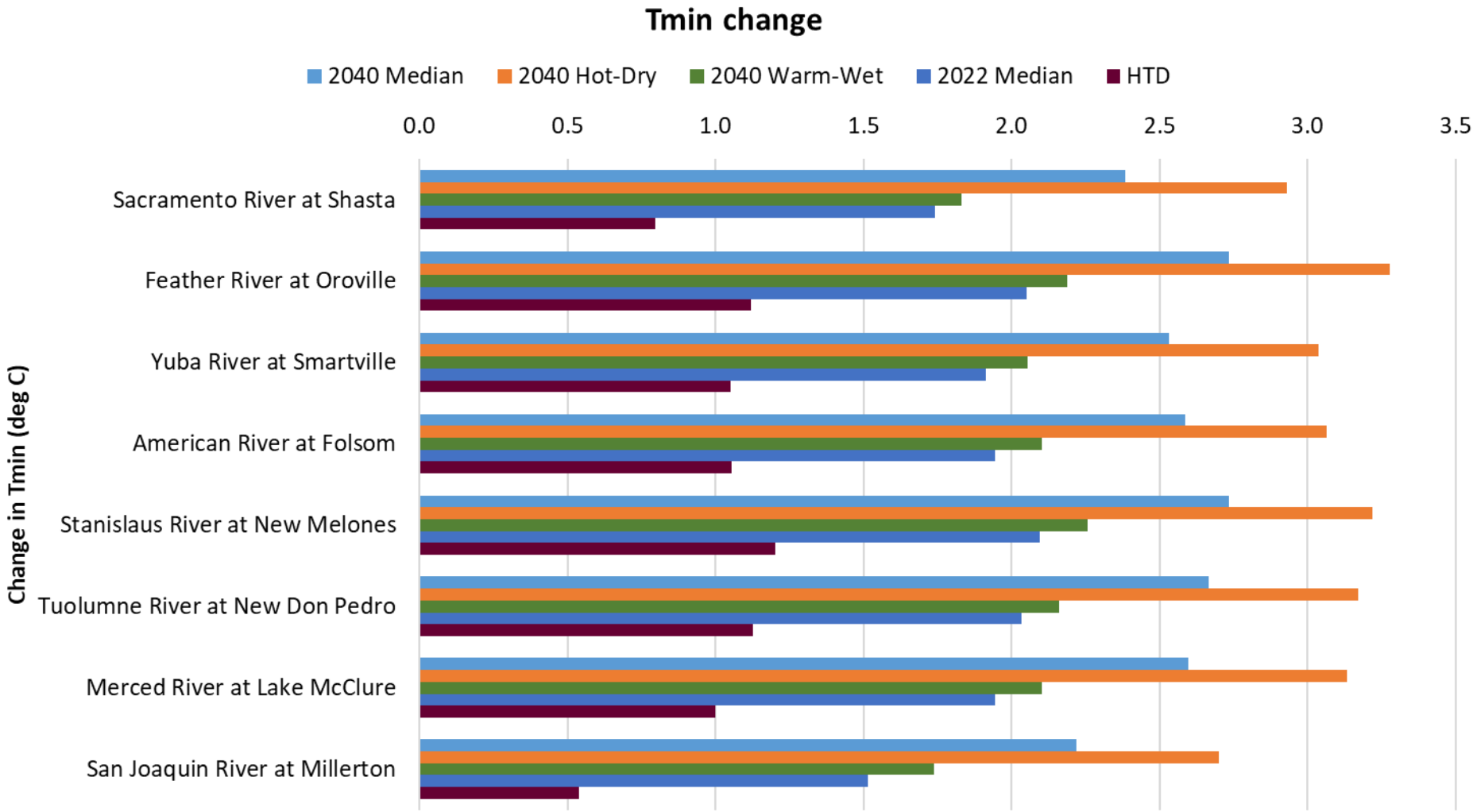
Climate Change Scenarios

1. 2040 Median
    a. 50th percentile of temperature
    b. 50th percentile of precipitation
2. 2040 Hot and Dry
    a. 75th percentile of temperature
    b. 25th percentile of precipitation
3. 2040 Warm and Wet
    a. 25th percentile of temperature
    b. 75th percentile of precipitation
4. 2040 Extreme Heat and Dry
    a. 95th percentile of temperature
    b. 5th percentile of precipitation

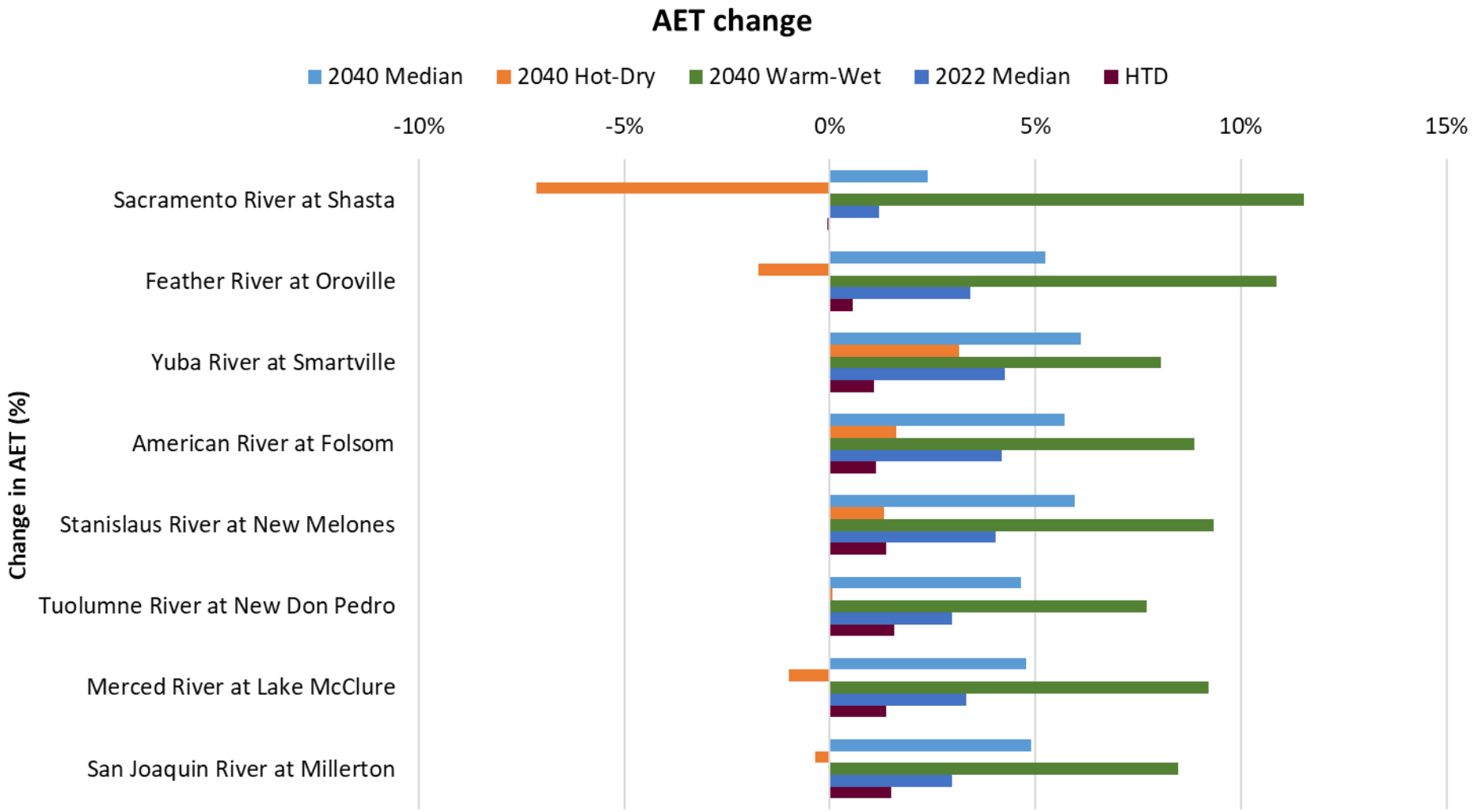
Maximum Temperature Change



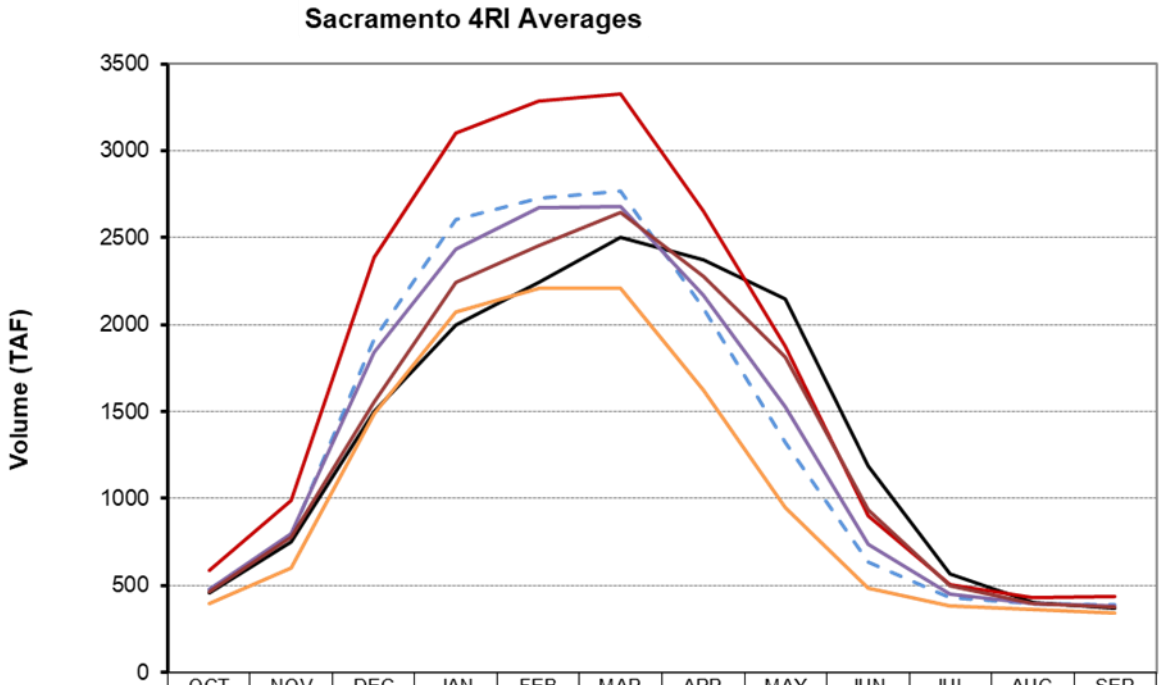
Minimum Temperature Change



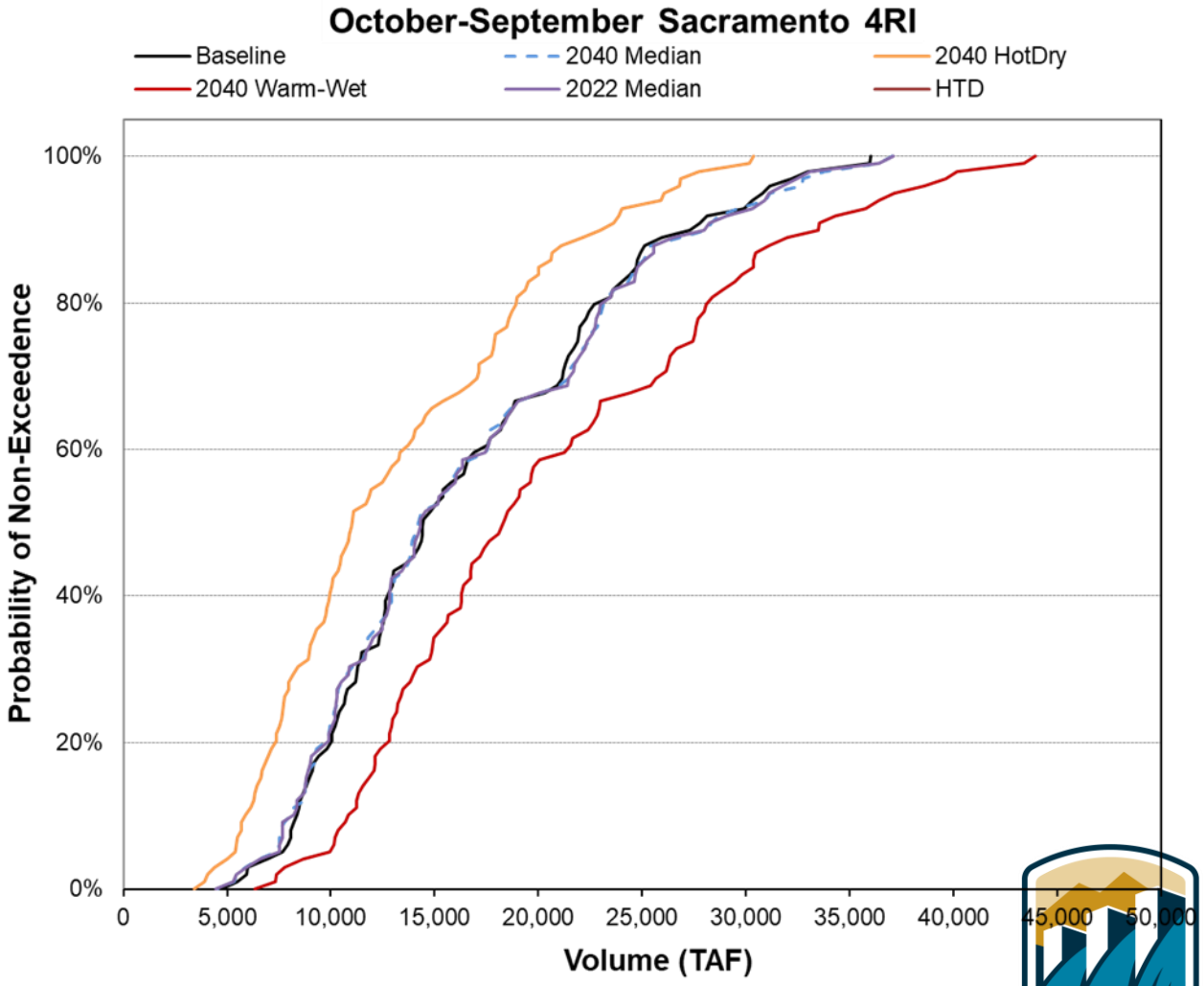
Actual ET Change



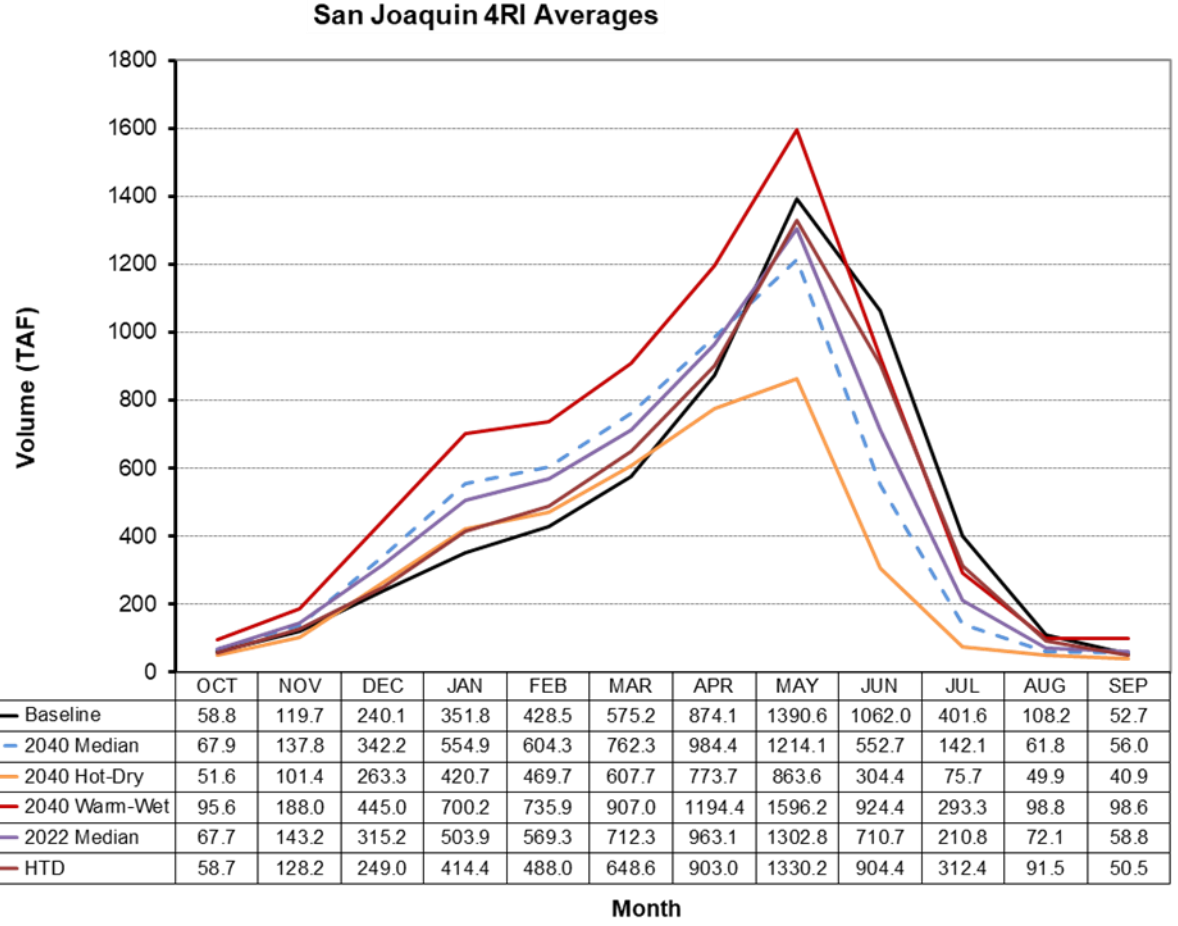
Runoff: Sacramento 4 River Index



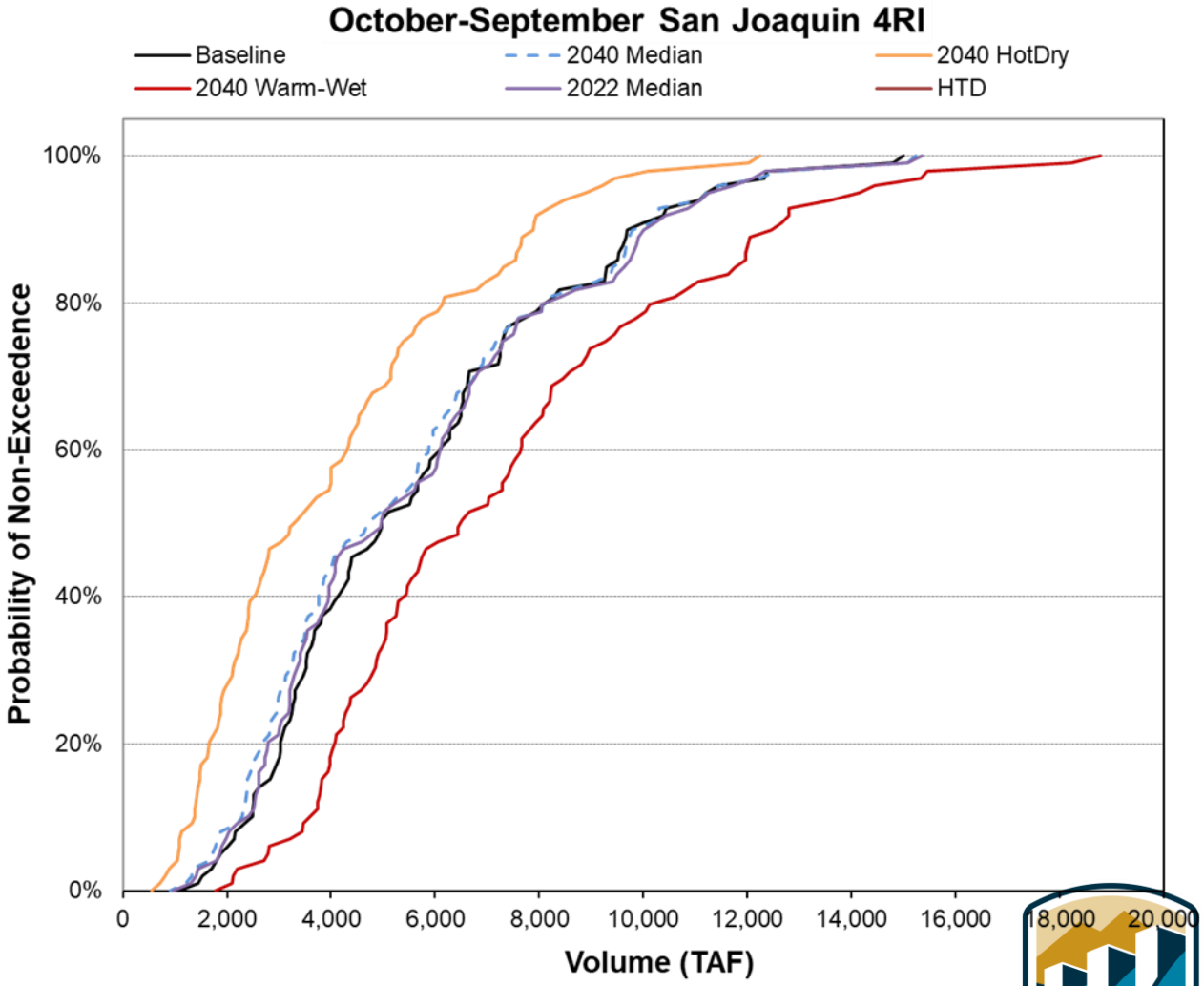
	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Baseline	457.3	752.9	1502.9	1999.4	2245.3	2503.2	2369.9	2151.2	1189.5	569.8	404.2	372.0
2040 Median	477.0	786.0	1916.6	2603.5	2729.7	2769.7	2096.6	1324.6	636.3	430.2	396.0	387.7
2040 Hot-Dry	393.7	602.8	1488.0	2069.9	2212.4	2206.3	1625.9	948.6	485.7	382.5	365.3	344.9
2040 Warm-Wet	586.3	991.4	2383.6	3101.7	3282.8	3323.8	2649.0	1873.4	900.5	506.3	434.1	441.0
2022 Median	478.0	799.3	1842.1	2436.6	2674.1	2679.4	2166.7	1529.3	740.2	449.6	394.8	383.0
HTD	464.2	780.6	1554.3	2242.6	2452.3	2647.3	2280.2	1815.7	933.8	500.1	398.9	375.1



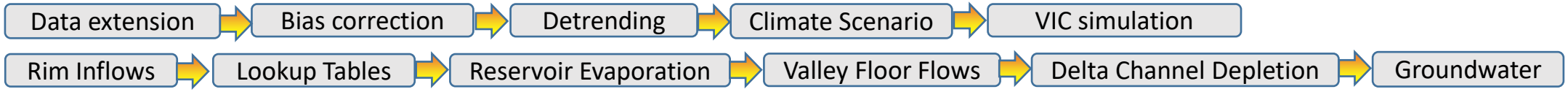
Runoff: San Joaquin 4 River Index



	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Baseline	58.8	119.7	240.1	351.8	428.5	575.2	874.1	1390.6	1062.0	401.6	108.2	52.7
2040 Median	67.9	137.8	342.2	554.9	604.3	762.3	984.4	1214.1	552.7	142.1	61.8	56.0
2040 Hot-Dry	51.6	101.4	263.3	420.7	469.7	607.7	773.7	863.6	304.4	75.7	49.9	40.9
2040 Warm-Wet	95.6	188.0	445.0	700.2	735.9	907.0	1194.4	1596.2	924.4	293.3	98.8	98.6
2022 Median	67.7	143.2	315.2	503.9	569.3	712.3	963.1	1302.8	710.7	210.8	72.1	58.8
HTD	58.7	128.2	249.0	414.4	488.0	648.6	903.0	1330.2	904.4	312.4	91.5	50.5



Approach

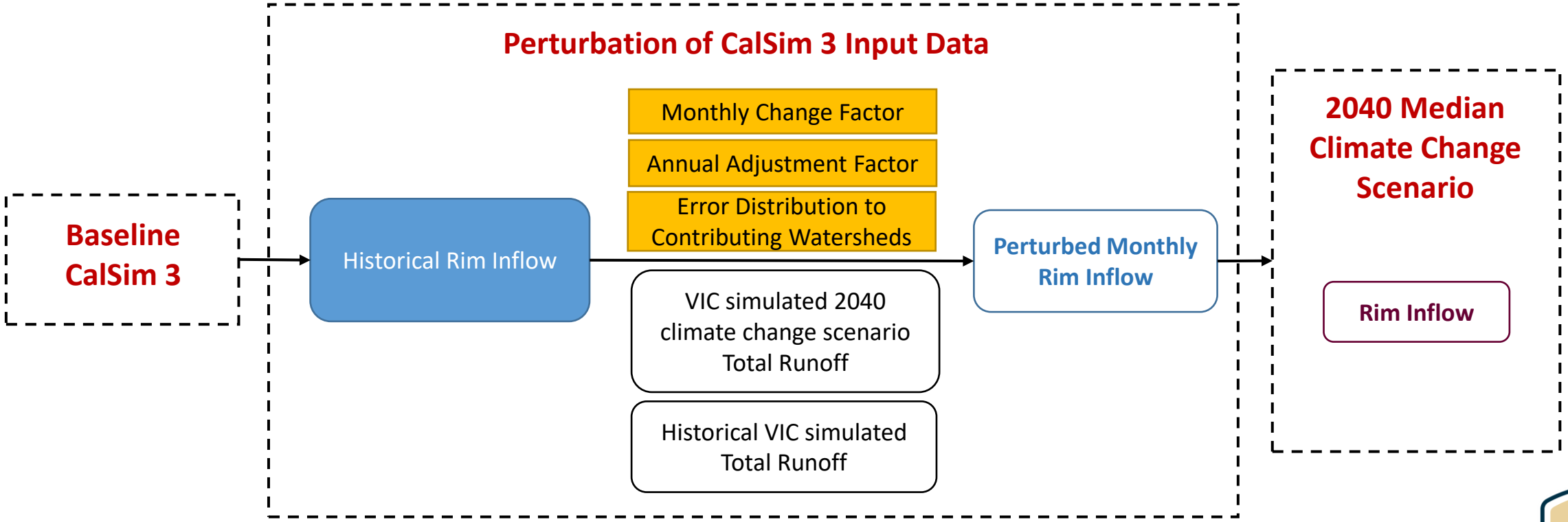


Approach Summary

Process/Variable	Approach
Data Extension	Merging Datasets
Bias Correction	Statistical Bias Correction Method
Temperature Detrending	Average Trend Removing Technique
Climate Scenario	Quantile Mapping
VIC simulation	Hydrological Modeling
Rim Inflows	Monthly and Annual Adjustment with error distribution
Lookup Tables	Monthly and Annual Adjustment
Reservoir Evaporation	Monthly and Annual Adjustment
Valley Floor Flows	Monthly and Annual Adjustment
Delta Channel Depletion	Monthly and Annual Adjustment
Groundwater	Monthly and Annual Adjustment

Rim Inflows

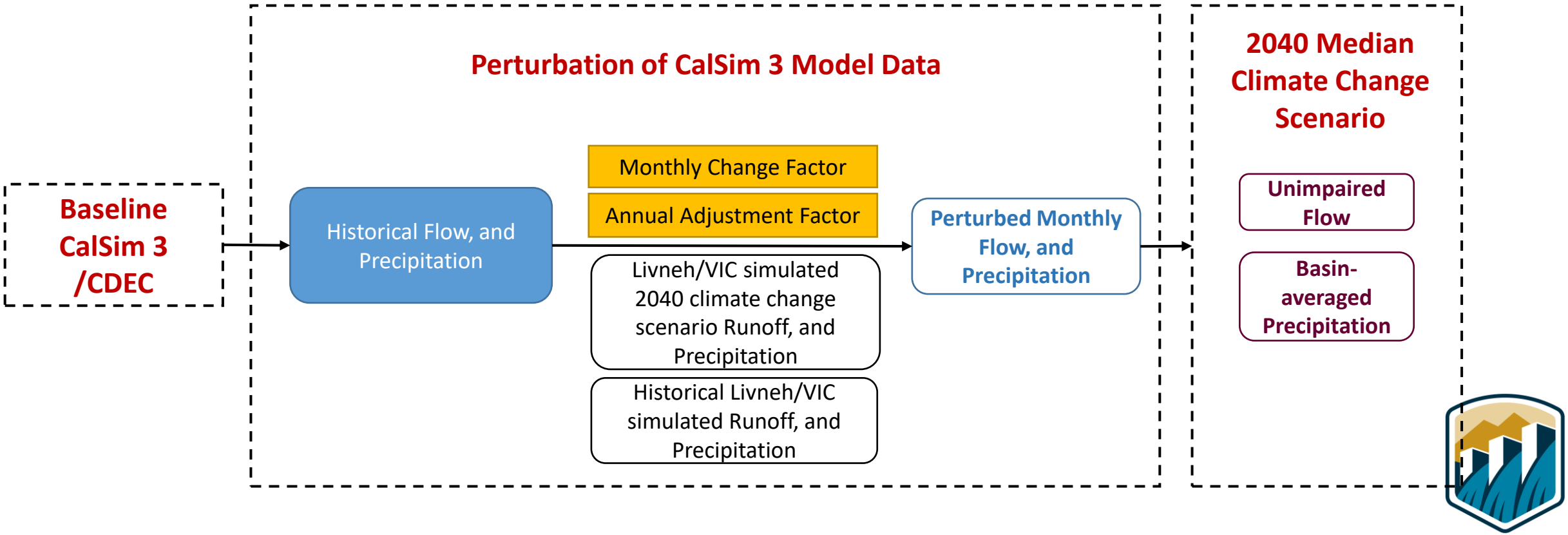
Variables to be adjusted: 1. Rim Inflows (Monthly)



Lookup Tables

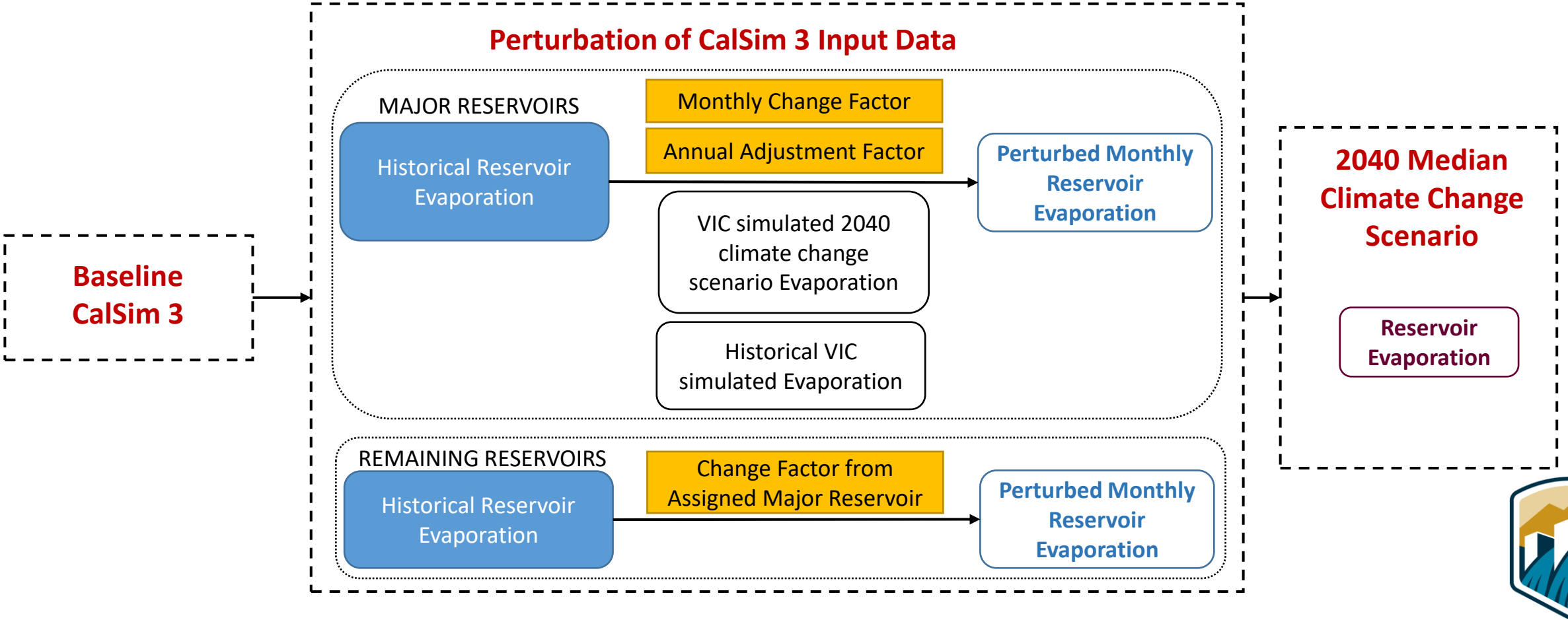
Variables to be adjusted:

1. Unimpaired flow (Monthly),
2. Basin-averaged precipitation (Monthly)



Reservoir Evaporation

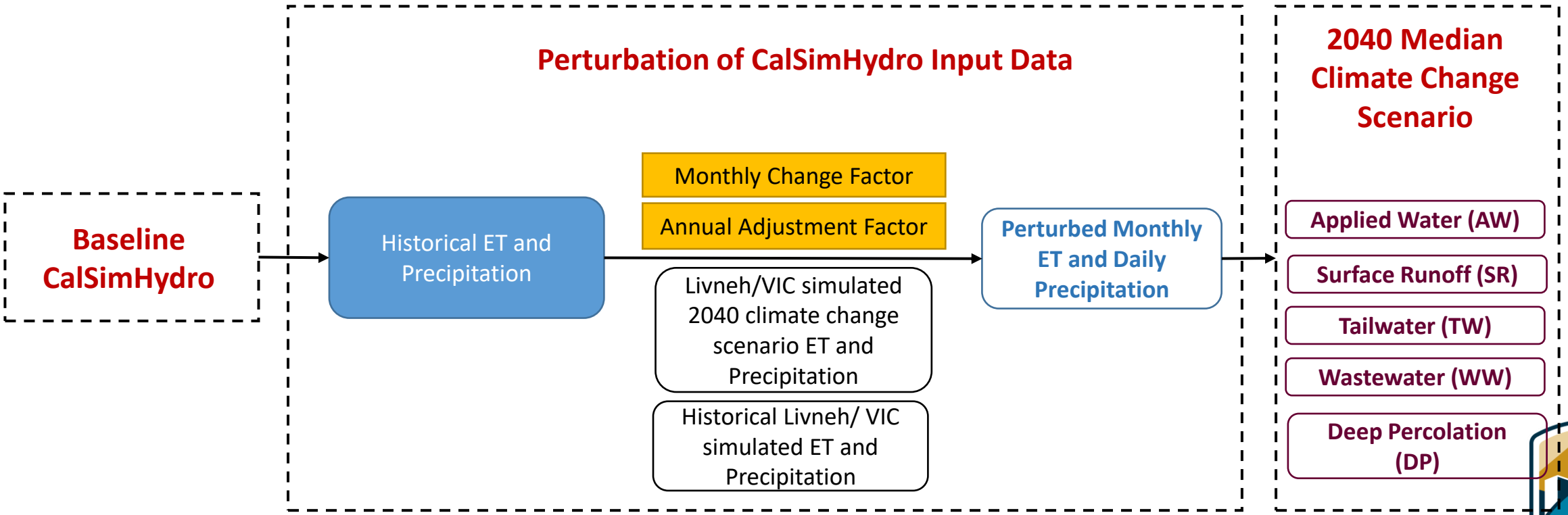
Variables to be adjusted: 1. Reservoir Evaporation (Monthly)



Valley Floor Flows (CalSimHydro)

Variables to be adjusted:

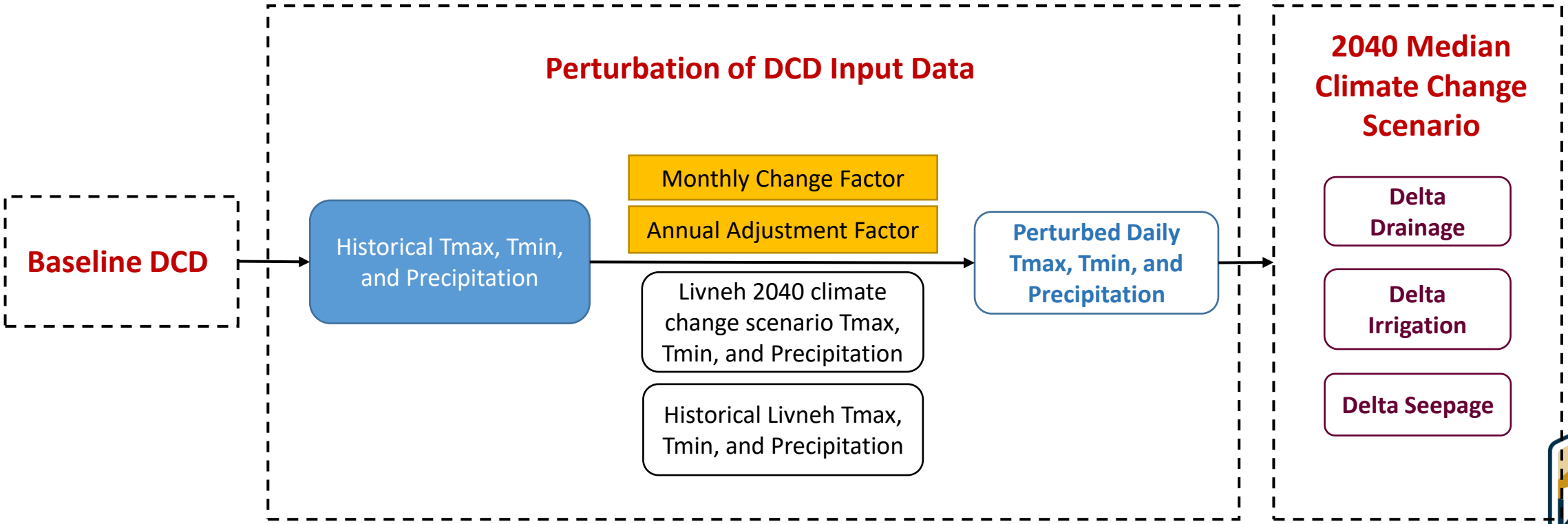
1. Precipitation (Daily) and
2. Evapotranspiration (Monthly)



Delta Channel Depletion

Variables to be adjusted:

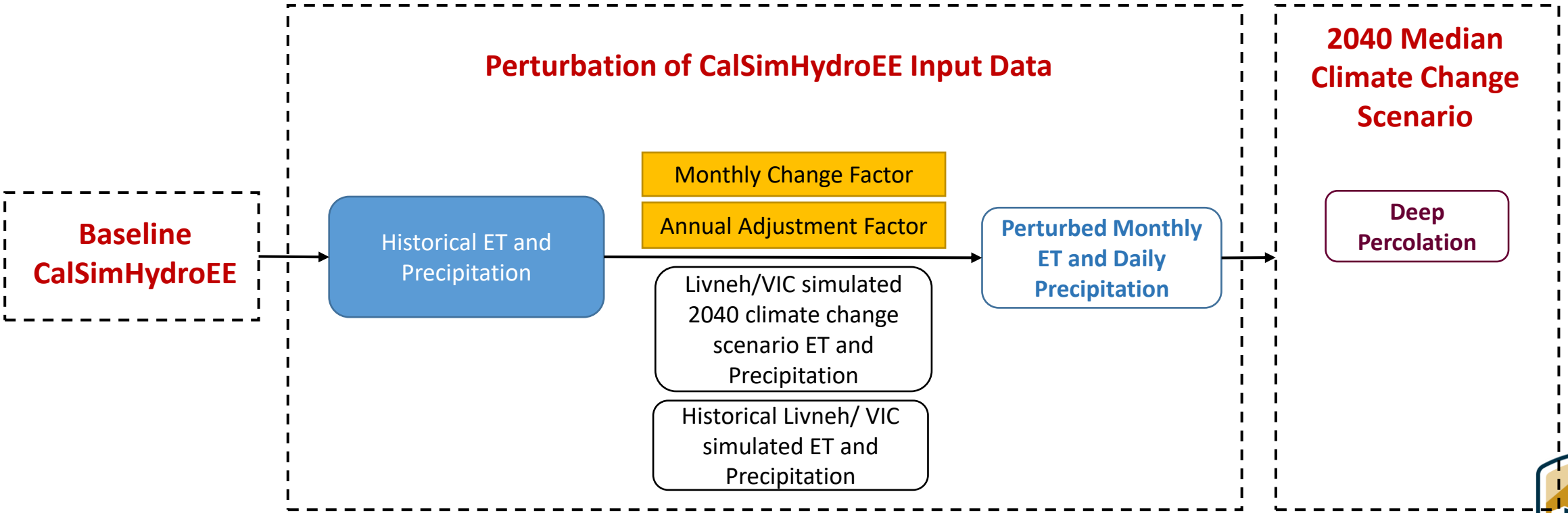
1. Precipitation (Daily),
2. Maximum Temperature (Daily), and
3. Minimum Temperature (Daily)



Groundwater (CalSimHydroEE)

Variables to be adjusted:

1. Precipitation (Daily) and
2. Evapotranspiration (Monthly)



Groundwater (SmallWatersheds)

Variables to be adjusted:

1. Precipitation (Daily) and
2. Evapotranspiration (Monthly)