Challenges in CalSim 3 Historical Rim Inflow Adjustment for Current Climate Condition

Presenter: Z. Richard Chen

Modelling Support Office

Collaborators:

Hongbing Yin, Francis Chung, Andrew Schwarz,

Jianzhong Wang, James Polsinelli, and Hasan Mohammad

CWEMF 2023

Acknowledgement

DWR's Historical Data Adjustment Workgroup met regularly in 2022 on the subject of adjusting historical hydrology to reflect the current climate conditions in California, which let to the work of this presentation. The workgroup analyzed unimpaired flow timeseries of 5 major watersheds in the last 100 years using various statistics, developed metrics and plotting tools for screening different methods, and evaluated several adjusting methods.

Historical Data Adjustment Workgroup

Schwarz, Andrew@DWR;
Reyes, Erik@DWR;
Maendly, Romain@DWR;
Miller, Aaron@DWR;
Yin, Hongbing@DWR;
Chen, Richard (ZhiQiang)@DWR;
Kadir, Tariq@DWR;
Tu, Ming-Yen@DWR;
He, Minxue (Kevin)@DWR;
Anderson, Michael L.@DWR;
Perez, Alejandro@DWR;

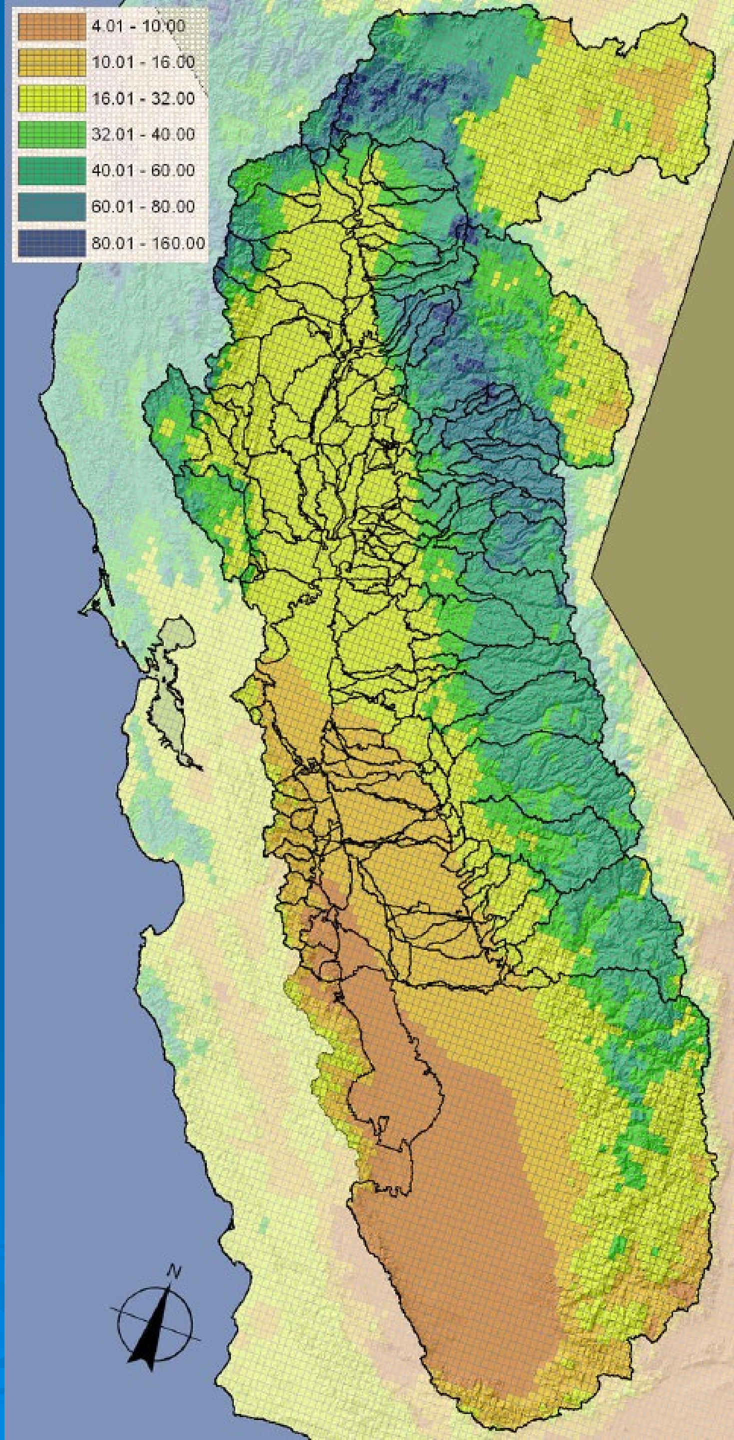
Sandhu, Prabhjot(Nicky)@DWR;
Islam, Nazrul@DWR
Wilde, Jim@DWR
Dhillon, Devinder@DWR
Arnold, Wyatt@DWR
Uecker, Ian@DWR
Das, Tapash/SDO;
Jon Herman;
Loney, Drew A;
Sumer, Derya;
Thielen, Kevin D

Outline

- Background
- CalSim3 rim inflow timeseries
- Methods of adjusting historical rim inflow
- Summary and Discussion

Background

- CalSim3 Simulation
  - Current demands
  - Current supplies
  - Operation constraints
- CalSim3 hydrology inputs
  - Inflow from rim watersheds
  - Precipitation in rim watersheds
  - Valley floor surface runoff
  - Recharge to groundwater aquifer
- Stationary historical hydrology Assumption
  - Current climate is represented by historical meteorological and hydrological data



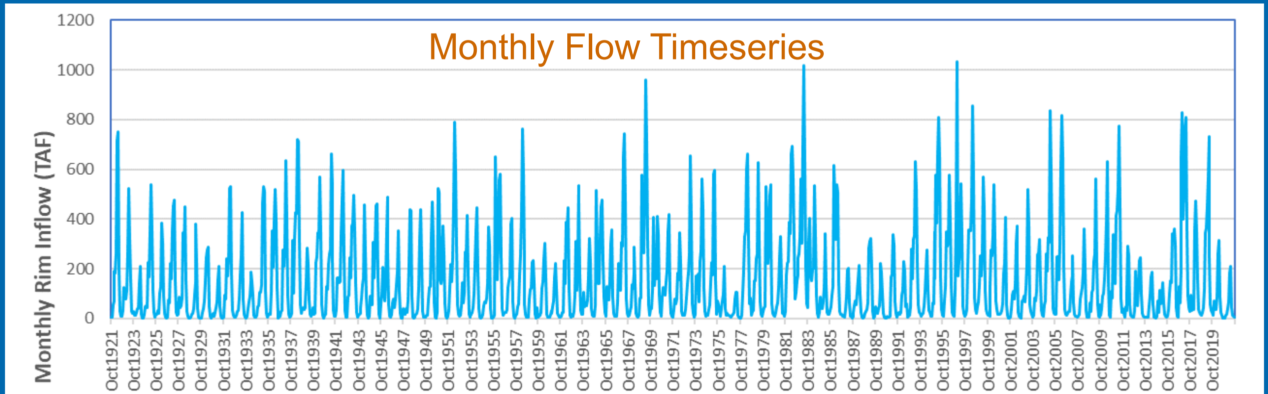
CalSim3 Rim Inflow Timeseries

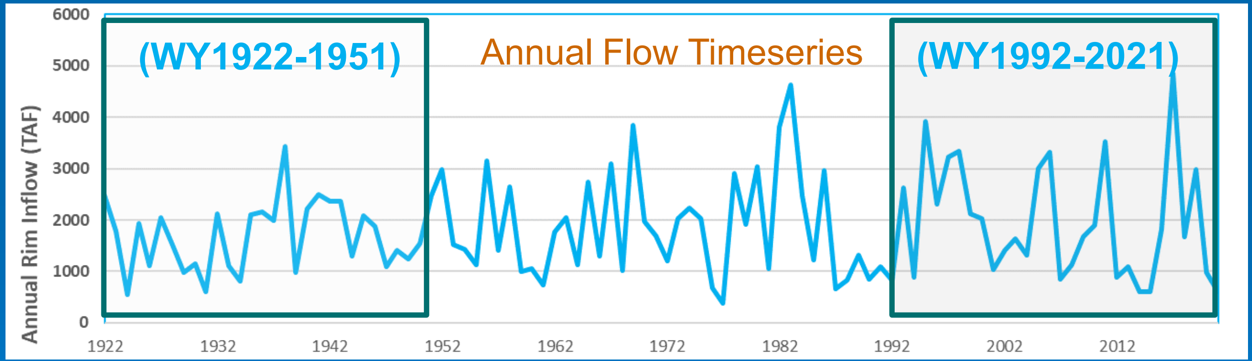
- Unimpaired/impaired stream flow from upper watersheds
  - Historical stream gage
  - Regression based on available historical and model data
  - WY1922-WY2021

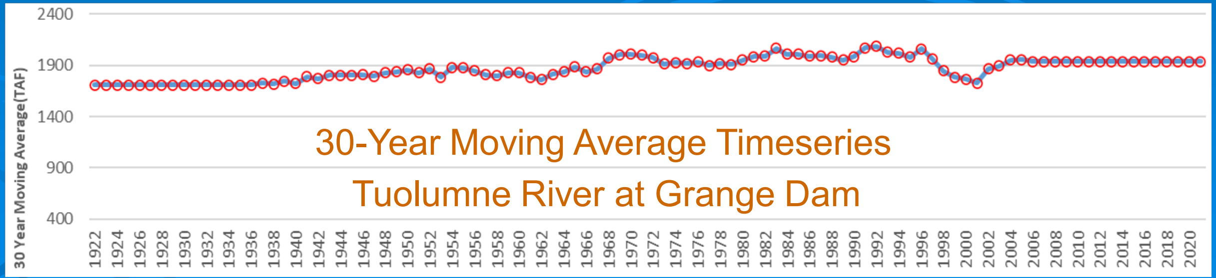
CalSim3 Rim Inflow Timeseries

Different Temporal Scales

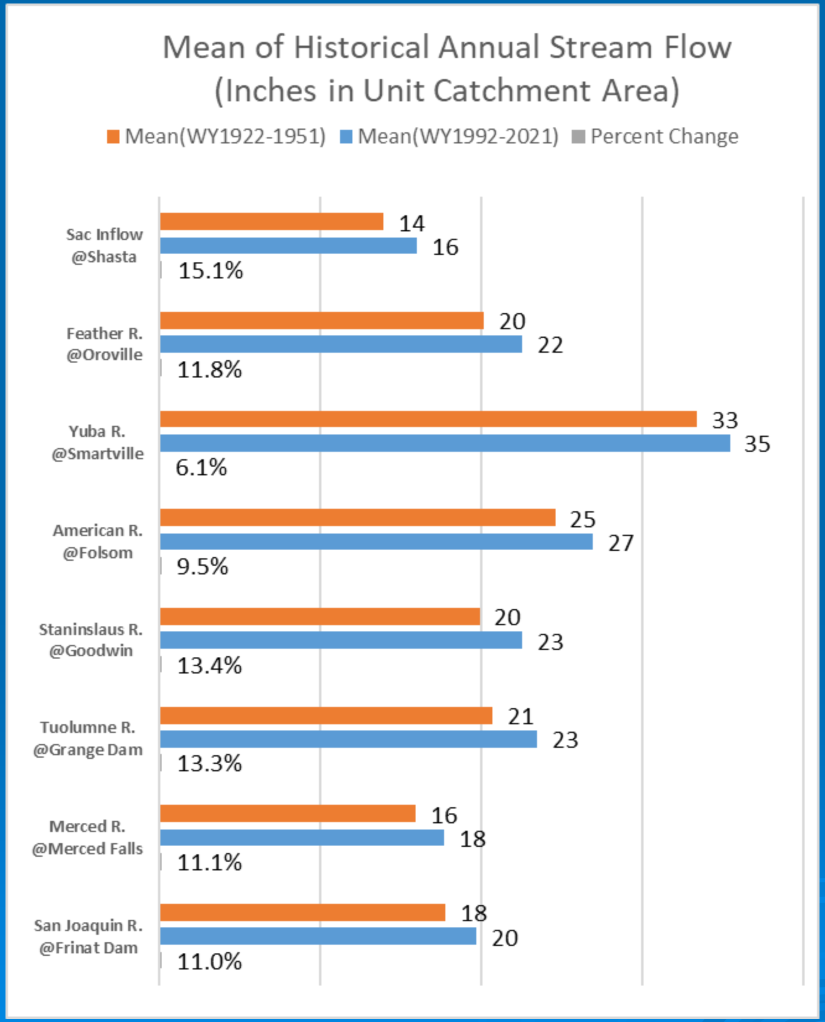
- Monthly
- Annual
- 30-year Moving Average

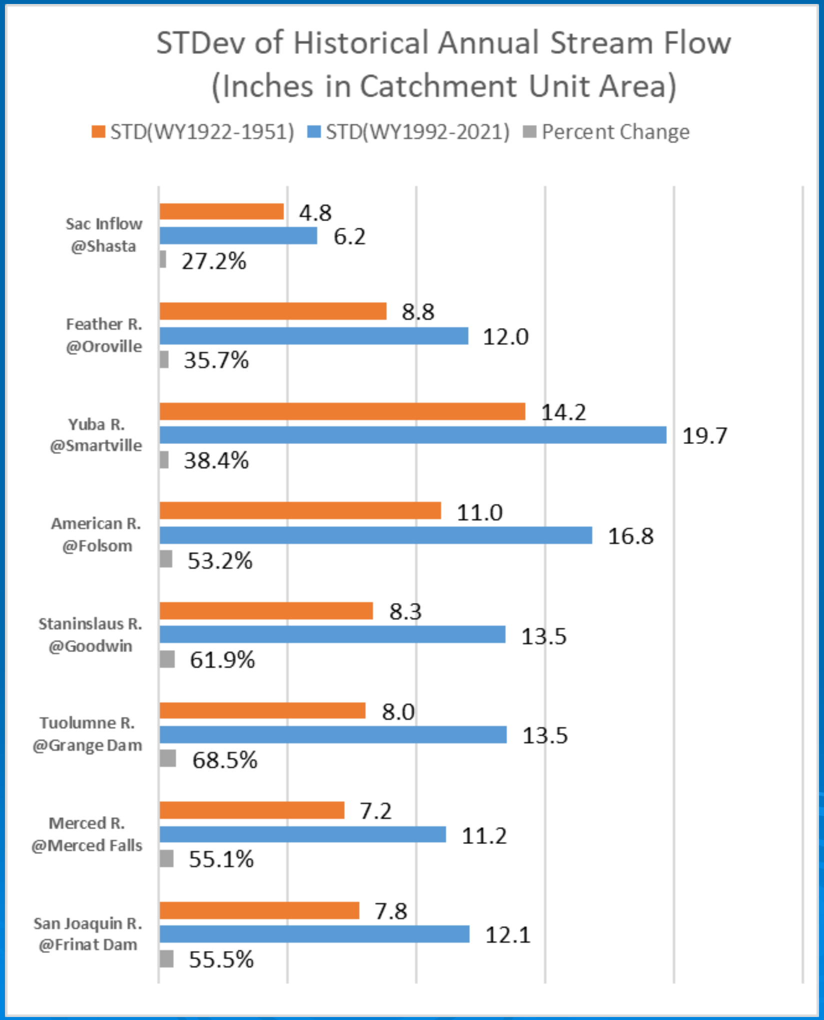


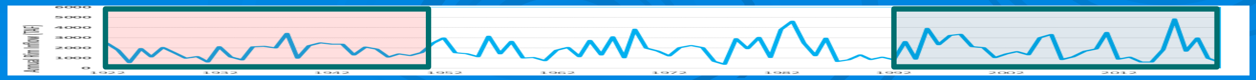




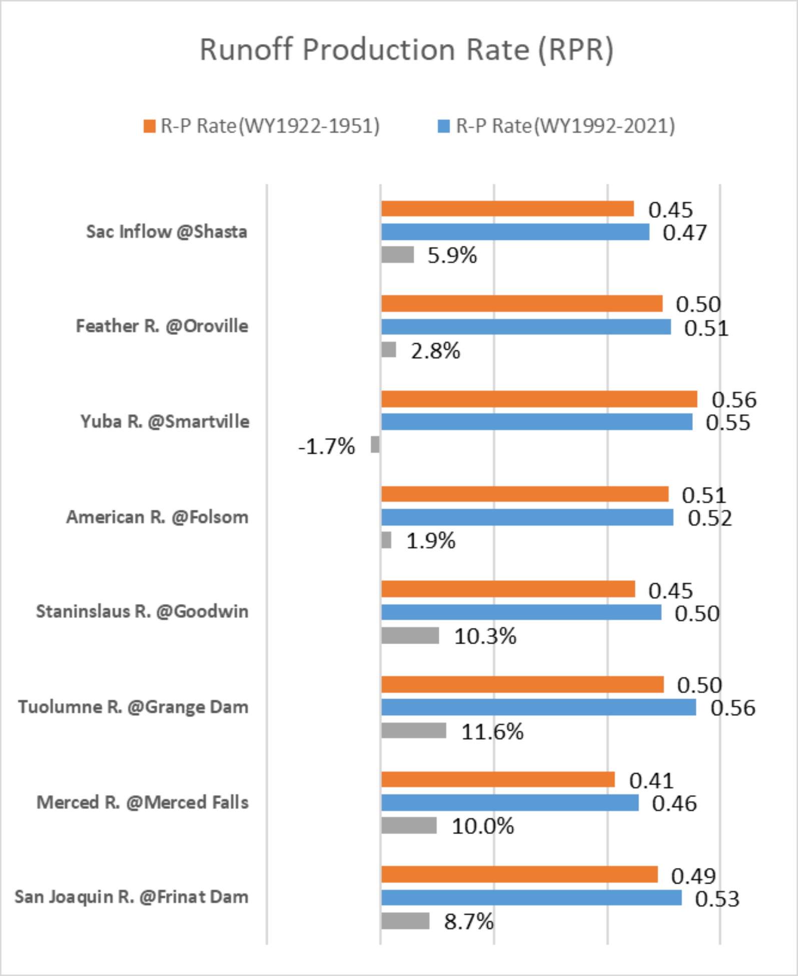
CalSim3 Rim Inflow Timeseries



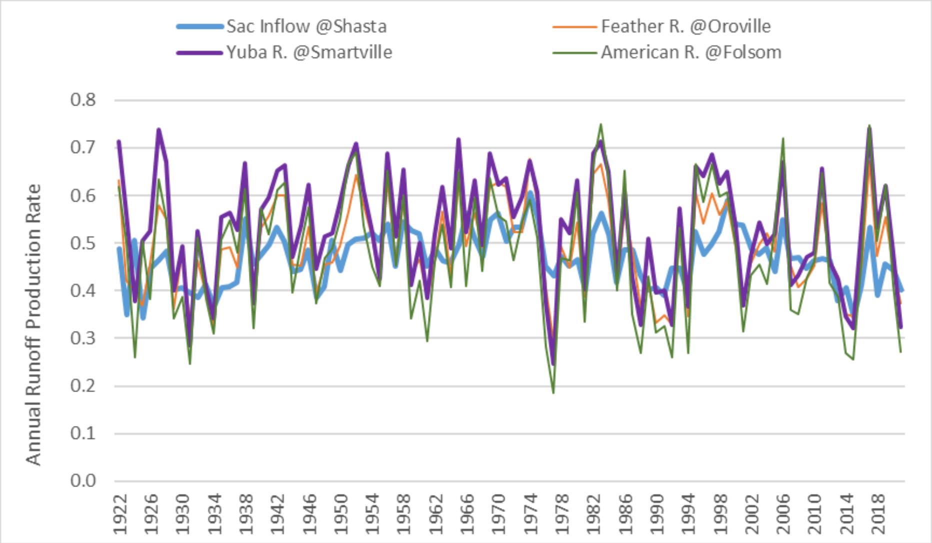


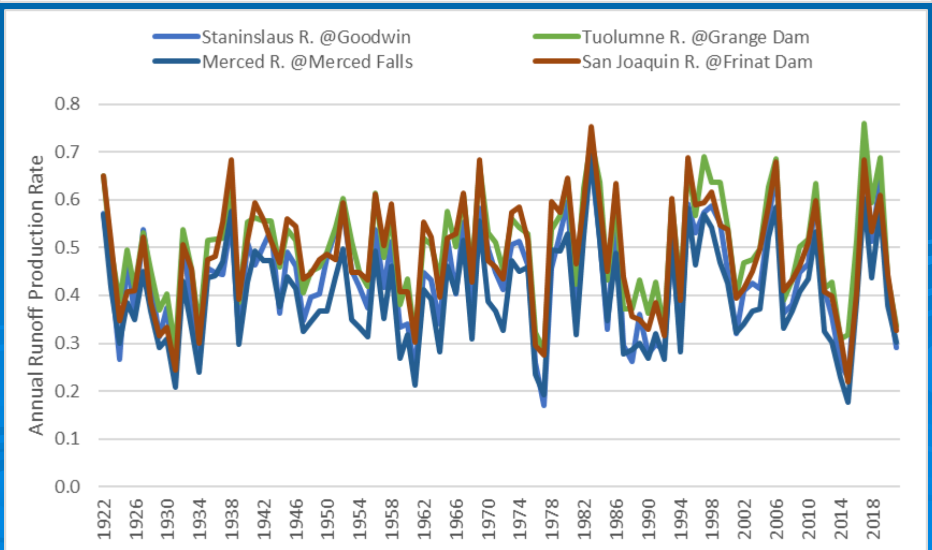


CalSim3 rim inflows



$$RPR = \frac{Stream\ Flow\ Valume}{Precipitation\ Valume}$$





Methods of Adjusting Historical Rim Inflow

Screening and Comparison Approach

Key Screening and Comparison Metrics (M)

- Mean
- Standard Deviation
- Coefficient of Variation

Key Screening and Comparison Data slices -for each of 5 example watersheds (*x*)

- Annual Flow
- Seasonal Flow (AF)
- Seasonal Flow (% of Annual)
- Monthly Flow (AF)
- Monthly Flow (% of Annual)

Minimize the function:

$$\frac{M_{x_{Adj96}} - M_{x_{RefObj}}}{M_{x_{RefObj}}}$$

For all Metrics (M) and data slices (x)

Reference Objective (RefObj)

The reference objective for each comparison is determined by whether or not the Mann-Kendell trend test identifies a significant trend in the historical dataset of the data slice (*x*) from 1922-2021

- If p-value of trend is <0.05 the trend is determined to be significant and the reference 30-year period 1992-2021 is the reference objective
- If p-value of trend is >0.05 the trend fails the significance threshold and the 1922-2015 observed period is the reference objective

Methods of Adjusting Historical Rim Inflow

Screening Tool

Adjustment Method:

- [x] QMSSPLIN_Dry 1922-2015_QMperExt
- [ ] RC-QMperExt
- [ ] Standard-Destandard_QMperExt
- [ ] Standard-Destandard
- [x] RC-YTM
- [x] Observed
- [ ] Reference

Watershed: (Checking more than one watershed will calculate the average of values across checked watersheds)

- [x] Shasta
- [x] Feather
- [x] American
- [x] Tuolumne
- [x] San Joaquin

StDev Weight

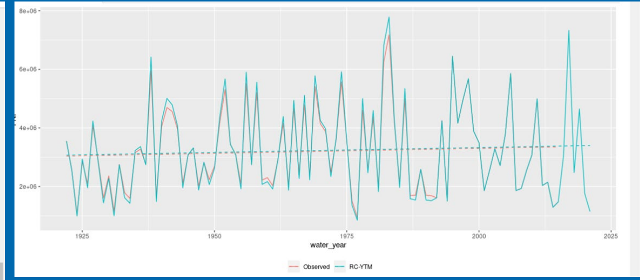
1

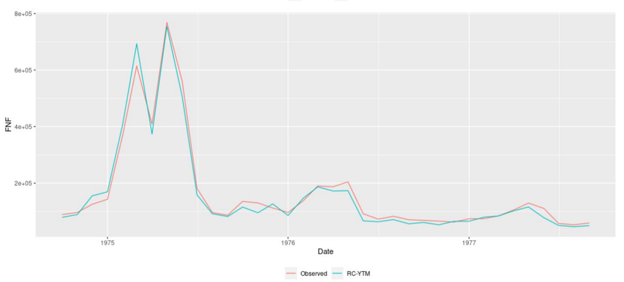
COV Weight

1

Timestep	Dataset	mean_perdiff	SD_perdiff	COV_perdiff	z
Annual	Observed	0.00	-14.10	-11.67	18.30
Annual	QMSSPLIN_Dry 1922-2015_QMperExt	1.53	1.18	2.56	3.20
Month	Observed	-0.46	-0.00	4.32	4.35
Month	QMSSPLIN_Dry 1922-2015_QMperExt	-0.12	10.81	15.47	18.87
Month_Per	Observed	-0.01	6.40	6.59	9.19
Month_Per	QMSSPLIN_Dry 1922-2015_QMperExt	-1.20	5.46	6.87	8.86
Season	Observed	-1.21	-11.20	-9.40	14.67
Season	QMSSPLIN_Dry 1922-2015_QMperExt	-1.90	-0.37	2.34	3.04
Season_Per	Observed	-1.26	7.46	6.24	9.81
Season_Per	QMSSPLIN_Dry 1922-2015_QMperExt	-3.49	-1.09	-0.36	3.67

Dataset	center_mass	center_masss_date
Observed	189.83	April 8
QMSSPLIN_Dry 1922-2015_QMperExt	186.85	April 5
RC-YTM	186.84	April 5

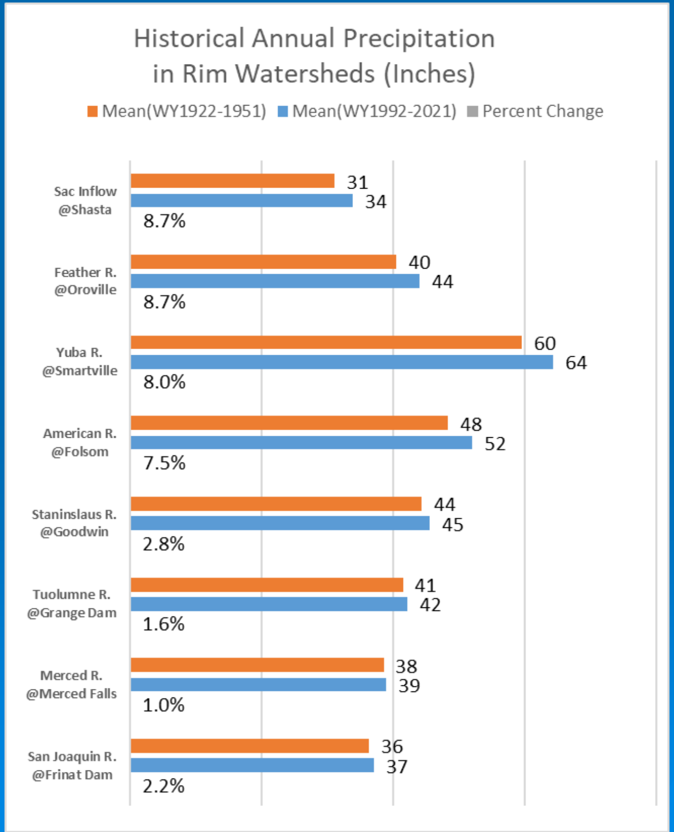


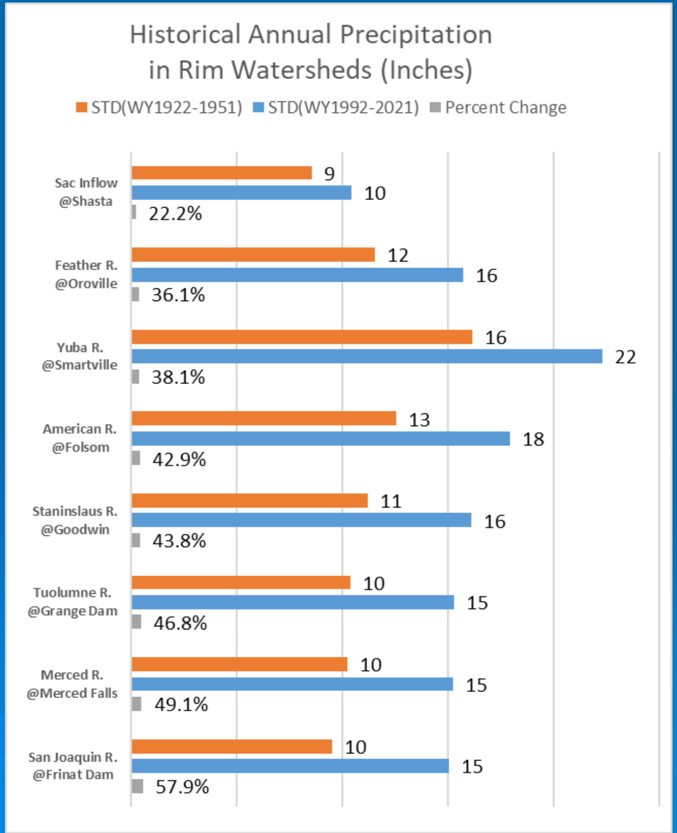


Methods of Adjusting Historical Rim Inflow

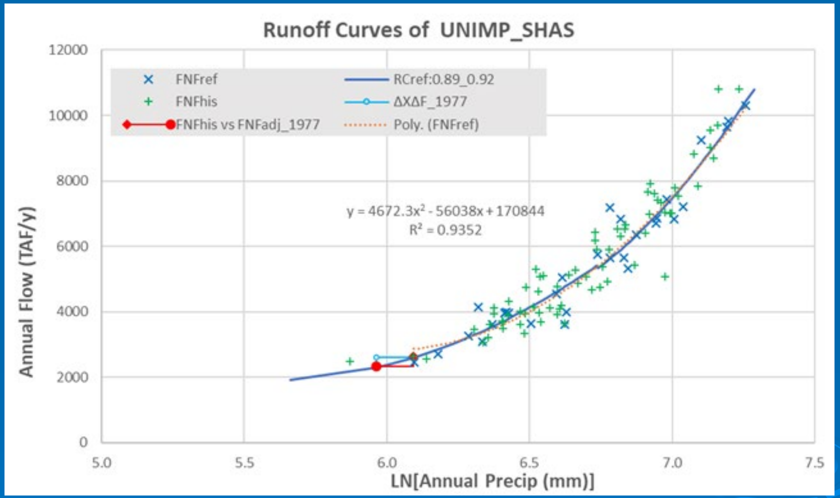
What have caused changes in rim inflow in the past 100 years?

1. Change in precipitation





2. Change in watershed runoff characteristics



Methods of Adjusting Historical Rim Inflow

Mean Distance Scale (MDS)

– method to adjust annual precipitation in the historical period (WY1922-1991) to have the standard deviation in the reference period (WY1992-2021)

Reference Runoff Curve

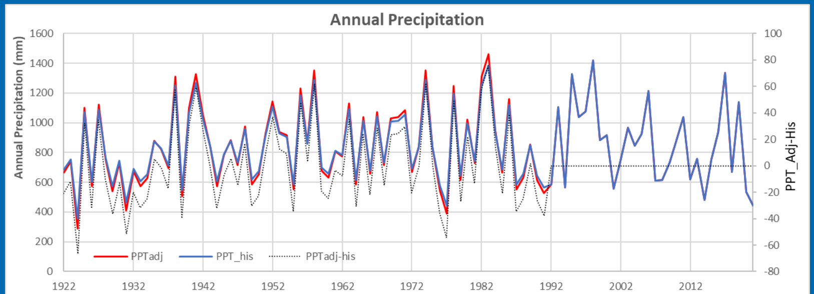
– annual rim inflow as regression function of annual precipitation using data in reference period

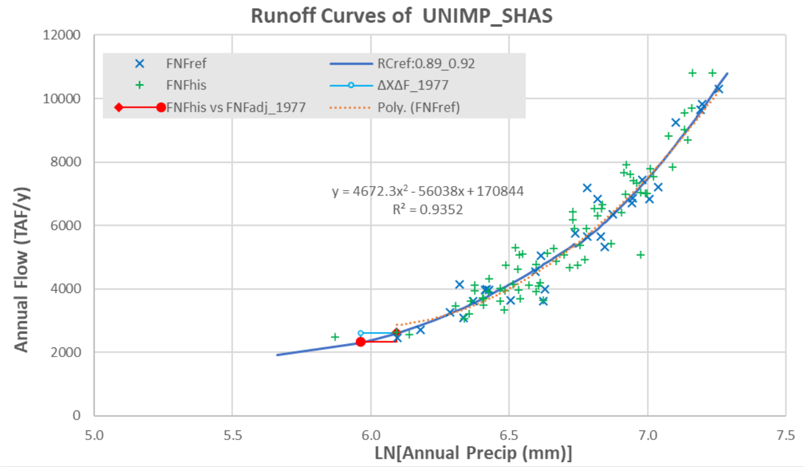
RunoffCurveMDS (RC)

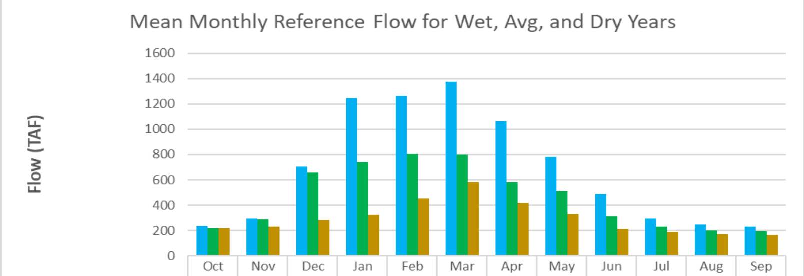
– method to adjust annual rim flow using the flow difference generated by the reference runoff curve with the adjusted annual precipitation.

YTMD (Year-to-Month Distribution) Method

– method to adjust monthly rim inflow distribution patterns using three distributions for WET, AVG and DRY water type years separately in the reference period







	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
WetYrs(WY1992-2021)	234.5	293.0	705.9	1246.7	1263.1	1375.6	1064.4	782.4	487.4	292.2	245.7	229.6
AvgYrs(WY1992-2021)	221.1	289.2	659.2	739.9	804.9	799.5	581.7	510.2	310.8	227.3	200.9	194.4
DryYrs(WY1992-2021)	215.9	232.3	281.7	323.3	451.2	582.4	418.9	332.4	213.6	187.3	168.5	165.7

Methods of Adjusting Historical Rim Inflow

Main Equations

$$P_{wy}^{Adj} = \boldsymbol{\mu}_{his} + \frac{\boldsymbol{\sigma}_{ref}}{\boldsymbol{\sigma}_{his}} \cdot [\boldsymbol{P}_{wy} - \boldsymbol{\mu}_{his}]$$ Annual Precipitation Adjusting Equation

$$F_{wy}^{adj} = F_{wy} + RCV\left[P_{wy}^{adj}\right] - RCV[P_{wy}]$$ Annual Flow Adjusting Equation

$$F_{wy,m}^{adj}(y,m) = \omega_{wy,m}^{adj}(y,m) \cdot F_{wy}^{adj}(y)$$ Monthly Flow Adjusting Equation

$\boldsymbol{\mu}_{his}$ – Mean Annual Precipitation [WY1922 – 1991]

$\boldsymbol{\sigma}_{his}$ – STDev Annual Precipitation [WY1922 – 1991]

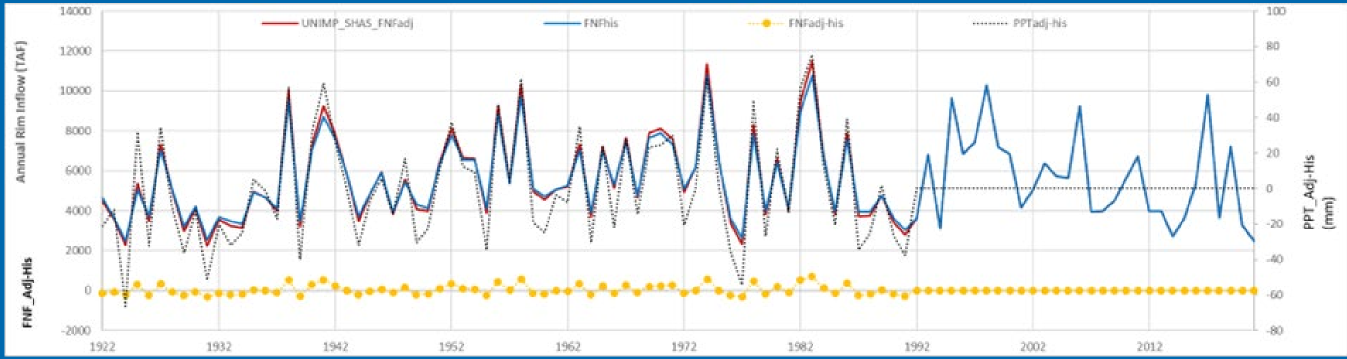
$\boldsymbol{\sigma}_{ref}$ – STDev Annual Precipitation [WY1992 – 2021]

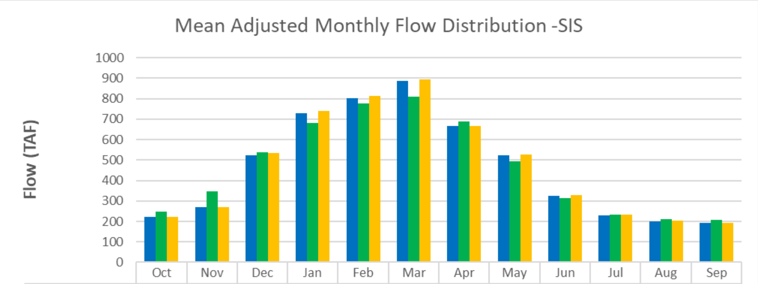
RCV – Reference Runoff Curve Function

$$RCV = a_X^{ref} + b_X^{ref} \cdot \ln\left(P_{wy}(y)\right) + c_X^{ref} \cdot \left[\ln\left(P_{wy}(y)\right)\right]^2$$

$\omega_{wy,m}^{adj}(y,m)$ - Monthly flow pattern parameters

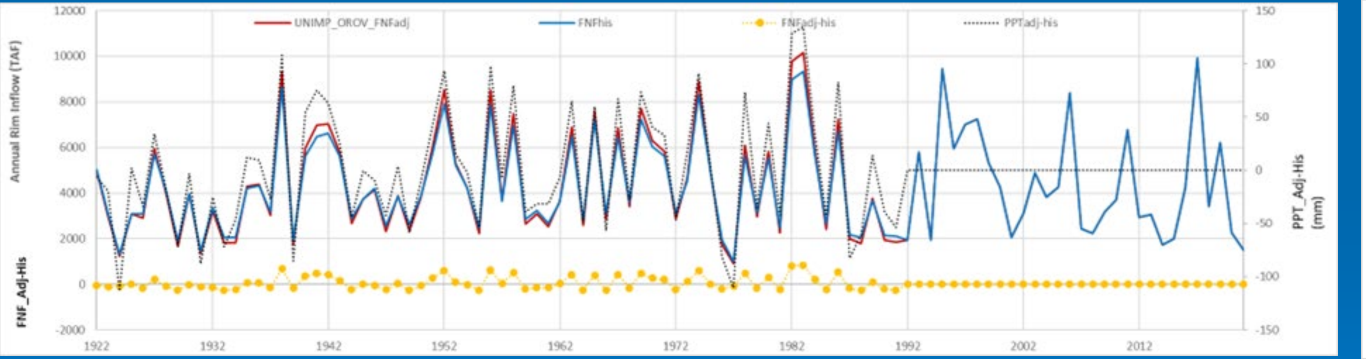
Methods of Adjusting Historical Rim Inflow

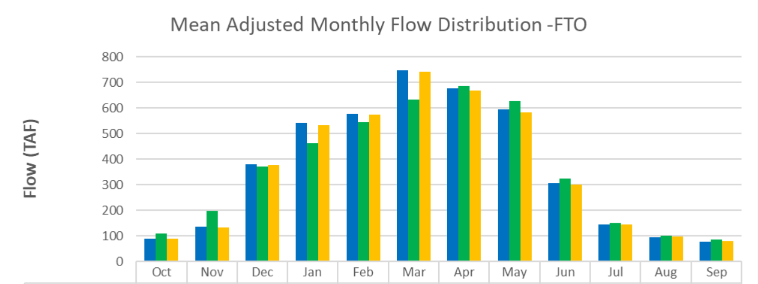




	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Adj(1922_1991)	223	268	524	729	803	888	666	523	326	231	202	194
His(1922_1991)	246	345	538	680	776	811	689	495	315	234	211	207
Ref(1992_2021)	223	270	535	739	813	893	667	527	328	232	202	194

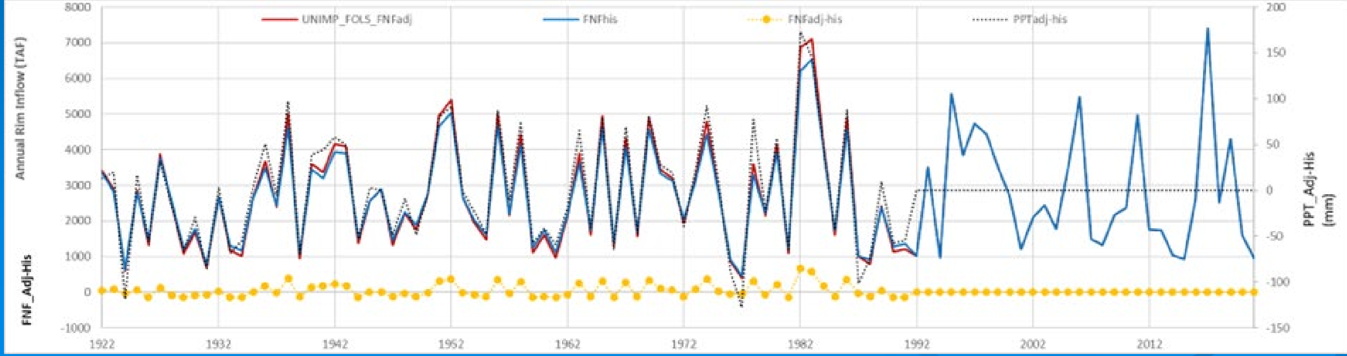
Sac Inflow @Shasta

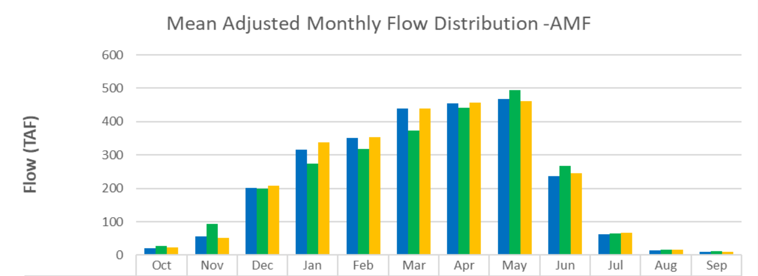




	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Adj(1922_1991)	89	135	381	542	578	746	676	594	306	145	96	79
His(1922_1991)	109	200	371	463	546	633	686	627	325	152	101	88
Ref(1992_2021)	91	135	378	534	573	742	667	581	300	144	97	80

Feather R. @Oroville

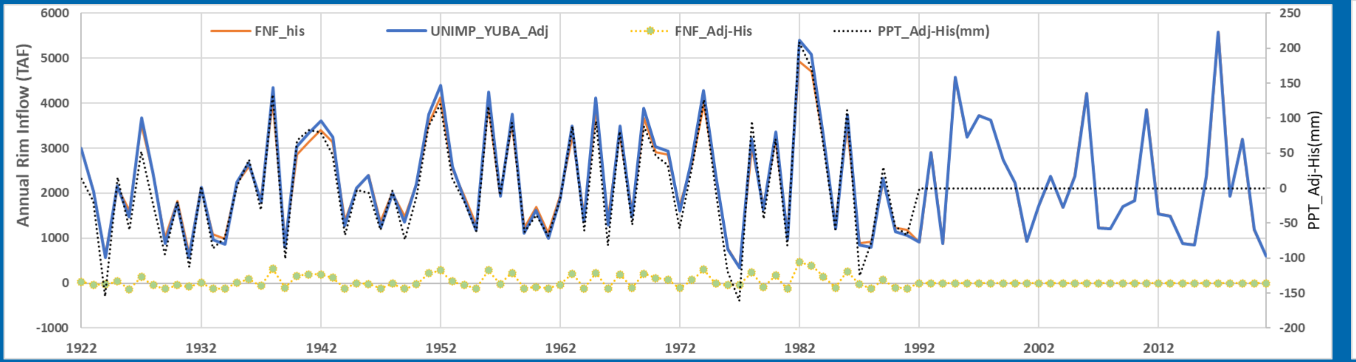


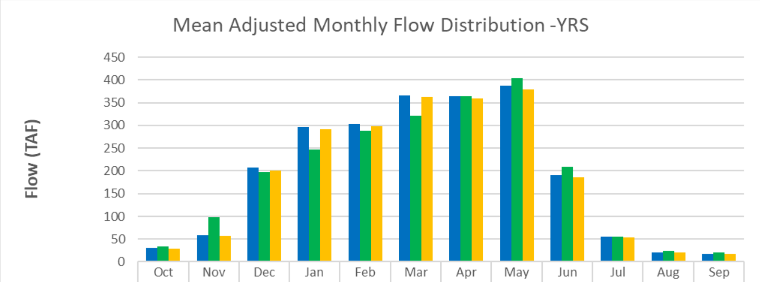


	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Adj(1922_1991)	21	56	201	316	351	440	455	468	238	62	15	10
His(1922_1991)	27	94	200	274	318	373	441	495	267	65	16	12
Ref(1992_2021)	23	52	209	339	354	439	457	462	245	68	16	10

American R. @Folsom

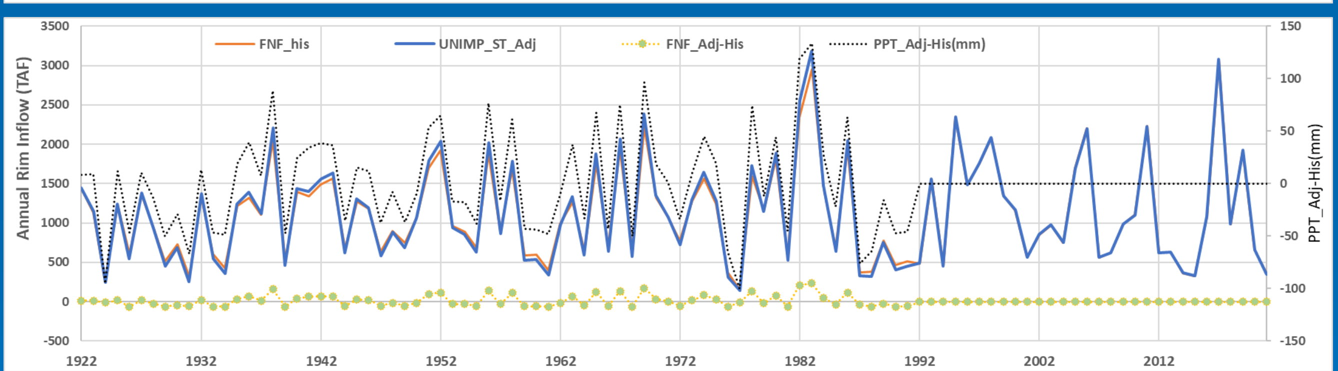
Methods of Adjusting Historical Rim Inflow

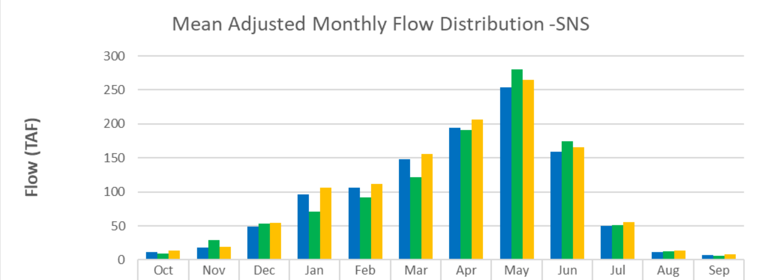




	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Adj(1922_1991)	30	58	207	296	303	365	365	387	191	55	21	17
His(1922_1991)	34	98	197	246	287	321	365	404	209	55	23	20
Ref(1992_2021)	29	57	201	291	298	363	359	379	186	54	21	17

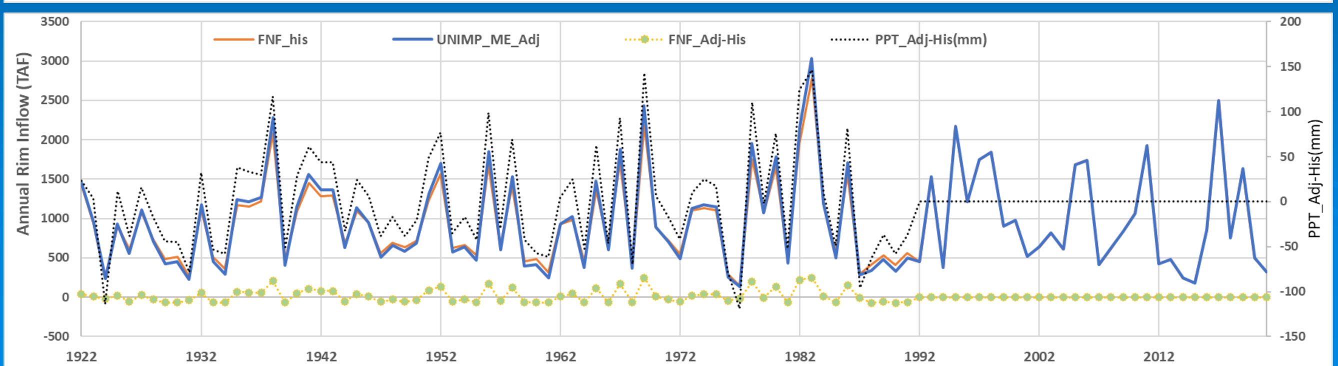
Yuba R.
@Smartville

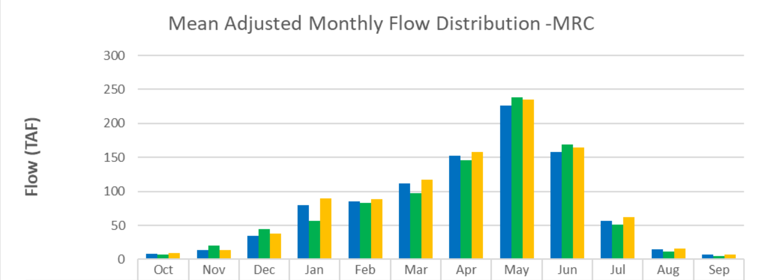




	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Adj(1922_1991)	12	19	49	97	107	148	195	253	159	50	12	7
His(1922_1991)	10	29	54	71	92	122	191	280	174	51	12	6
Ref(1992_2021)	14	19	54	107	112	156	207	265	166	55	13	8

Stanislaus R.
@Goodwin





	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Adj(1922_1991)	9	14	34	80	86	112	152	227	158	57	15	7
His(1922_1991)	7	21	44	57	83	98	146	239	169	52	12	5
Ref(1992_2021)	9	14	38	89	89	117	158	235	165	63	16	7

Merced R.
@Merced Falls

Summary and Discussion

- CalSim3's current condition study has been performed on the assumption that the historical hydrology is stationary.
- Standard deviations of annual rim inflow and precipitation in the 1st 30-year and the last 30-year periods of recent 100 years have increased significantly in watersheds in both Sacramento and San Joaquin basins, which puts the stationarity assumption of historical hydrology in question.
- This study is one attempt to make the conversion of this historical non-stationary hydrology to a stationary time series so that the planning function can continue.
- The proposed adjusting method has made the adjusted rim inflows wetter in wet years drier in dry years.
- Monthly distributions of the adjusted rim inflows do reflect the fact that runoff occurs earlier because of changes in snowmelt and evapotranspiration processes for different type water years and different type watersheds
- Annual adjustment to stream flow is consistent to its annual adjustment to precipitation with the help of reference runoff curve, which is needed for CalSim 3's forecast method

Summary and Discussion

Challenges/Caveats

- One critical dry or wet year may significantly change the standard deviation in the reference 30-year period, which may result very different adjustment.
- Trends in mean of the rim inflows are not adjusted
- Changes in drought frequency are not adjusted
- Quality of the adjusted stream flows depends on the quality of historical precipitation and stream gage data

Question?