Using a Simplified Reservoir Simulator for Exploring Climate Change Adaptation in California's Central Valley

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Reservoir Modeling

- Wide variety of existing perspectives:
  - CalSim
  - CRMSS
  - HEC-HMS/HEC-ResSim
- Detailed models with many data requirements and interdependencies

Goals

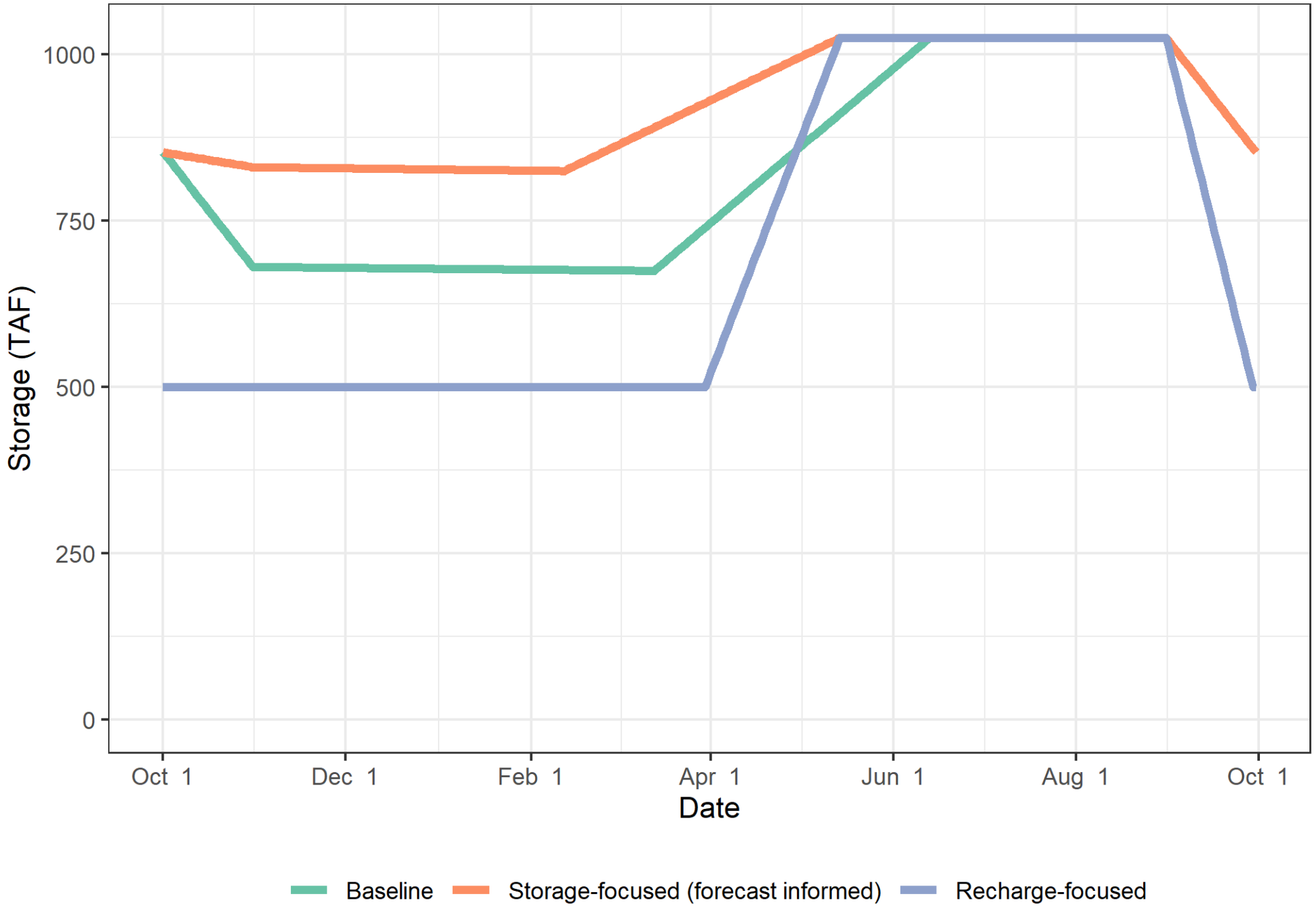
- Had need of a simple screening tool to support varied other projects with mix-and-match approach
- Explore effects of forecast informed reservoir operations (FIRO)
- Quantify groundwater banking projects
- Allow for easy implementation of model climate data runs

How Model Works

- Daily reservoir inflow series, either historical or climate change adjusted
- A single rule curve per scenario: release baseline flow, plus additional flow if storage would be above rule curve
- Heuristics for earmarking releases as groundwater recharge, with maximum rate into storage

Hypothetical storage curves

- Baseline curve estimated from examining historical data
- Forecast-informed curve assumes higher storage capacity due to improved forecasting:
  - Temporarily revert to baseline curve if lookahead shows large upcoming flows
- Recharge-focused curve aggressively releases water and diverts to groundwater banks

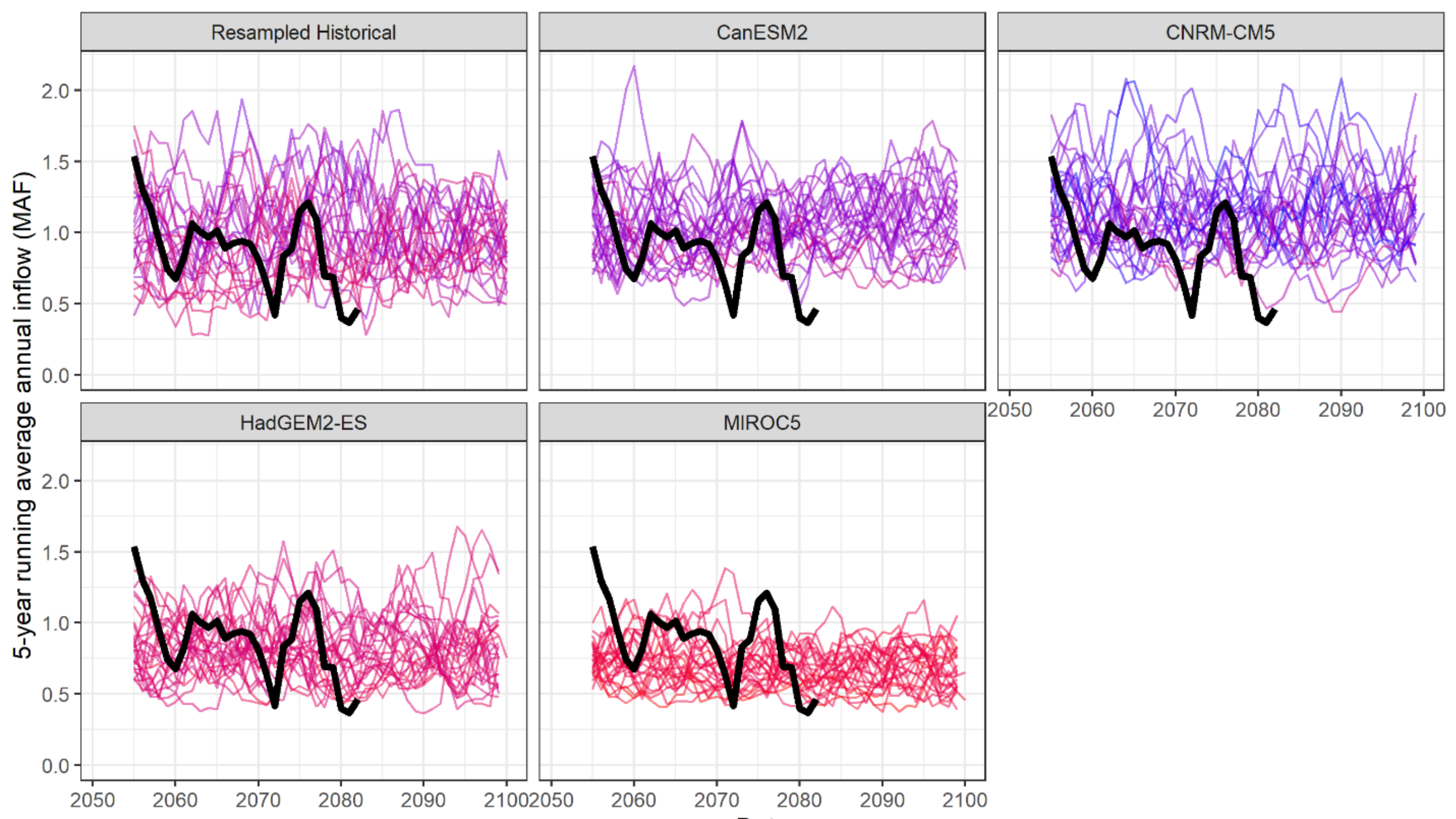

1000
750
500
250
0
Storage (TAF)
Oct 1
Dec 1
Feb 1
Apr 1
Jun 1
Aug 1
Oct 1
Date
Baseline
Storage-focused (forecast informed)
Recharge-focused

Climate Scenarios

- Inflow scenarios accounting for pre-existing climate change runs
- Cal-Adapt had scenarios based on watershed models and downscaled climate runs suited for purpose
- Selected four climate scenarios that span the range of possibilities covered in Cal-Adapt
- Also resample historical data to get 50 year baseline run

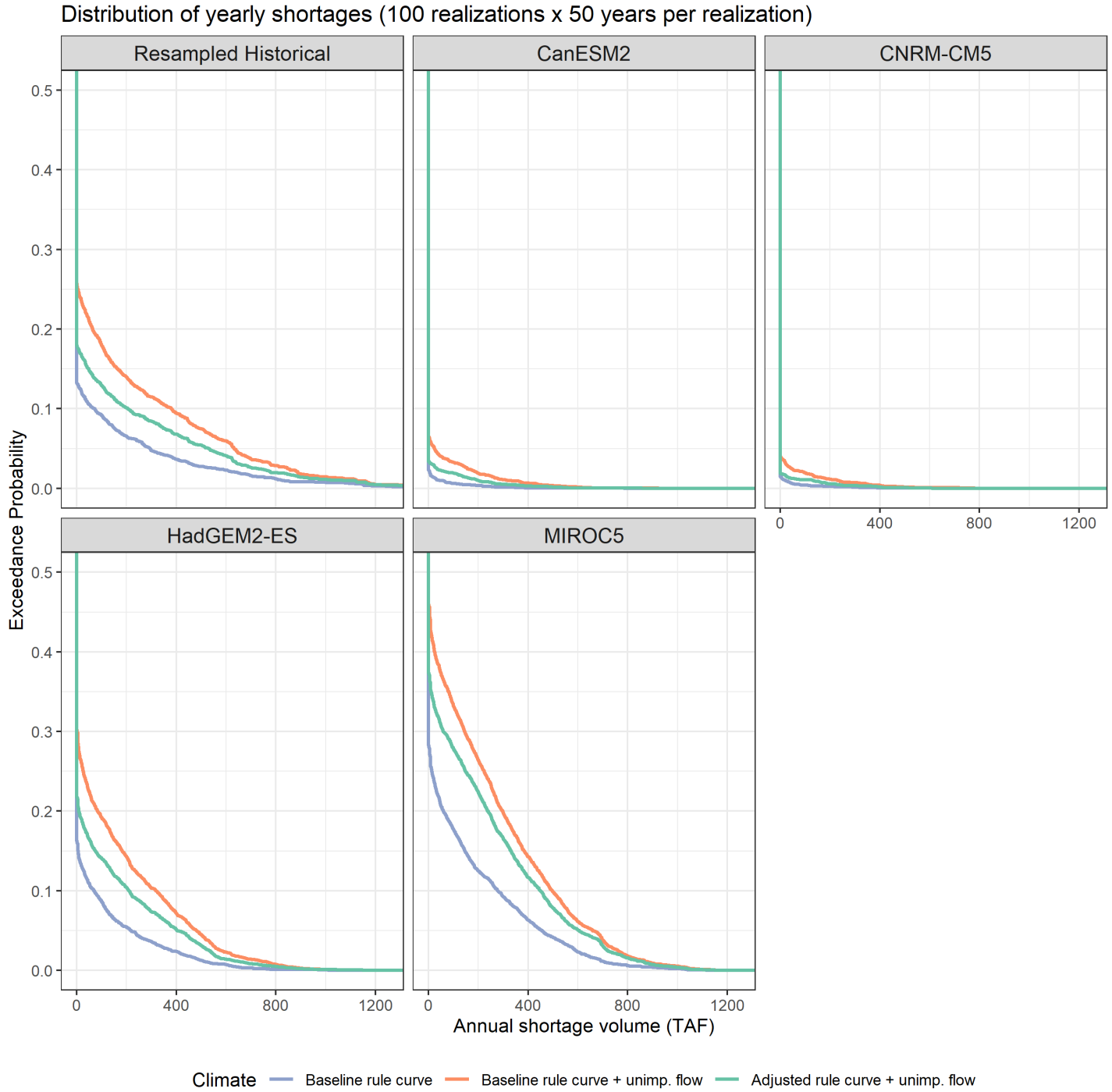
Stochastic resampling scheme

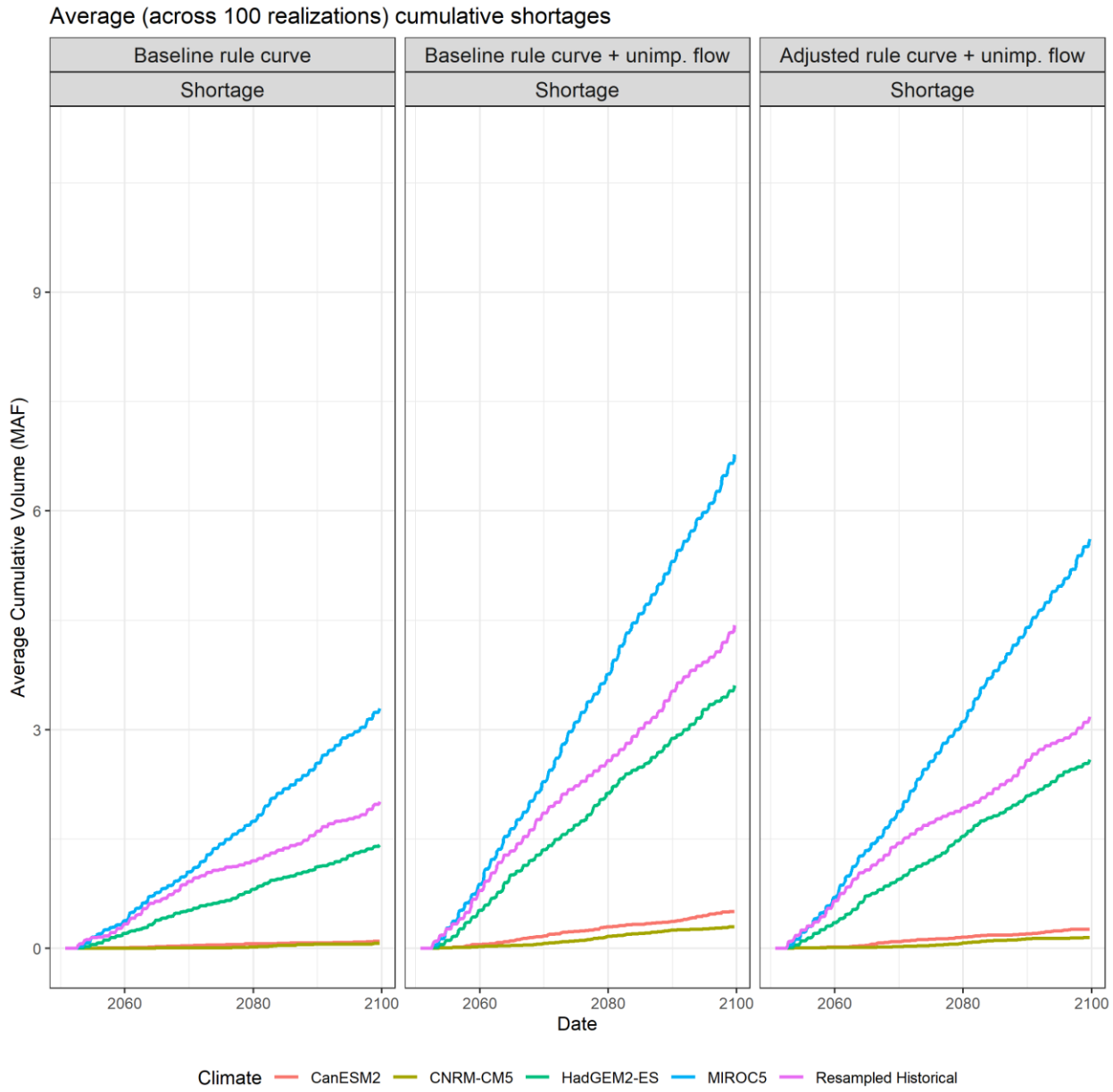
- Reservoir performance depends on specific sequence of inflows:
  - Wet period after drought could be a refilling event vs.
  - Too many large inflows close together results in forced releases
- Randomly permute climate scenarios to get different stochastic realizations of runs of wet/dry periods
- Match a given climate projection month to closest historical month and use that month’s daily inflows

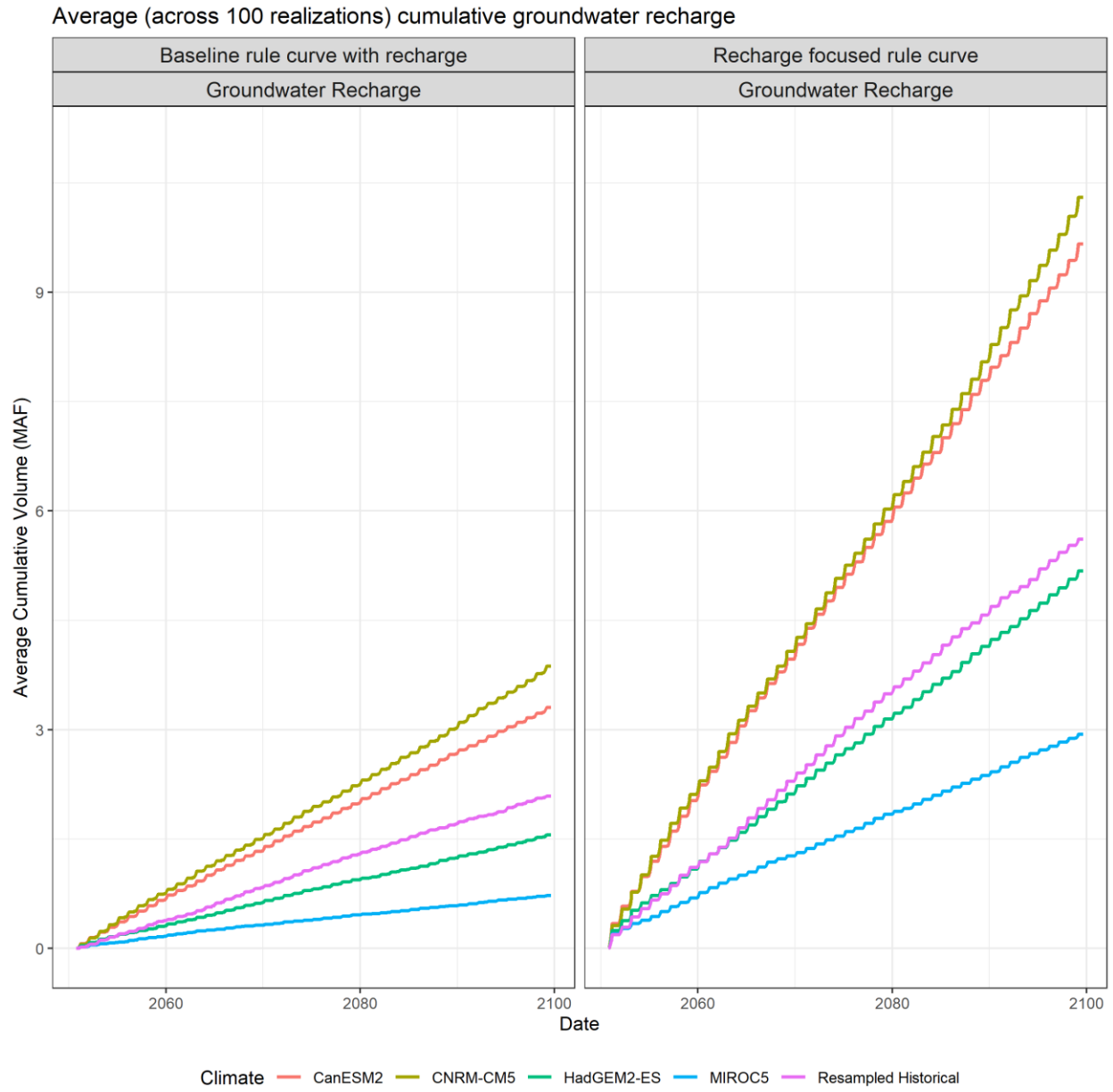

Resampled Historical
CanESM2
CNRM-CM5
HadGEM2-ES
MIROC5
5-year running average annual inflow (MAF)
0.0
0.5
1.0
1.5
2.0
2050
2060
2070
2080
2090
2100

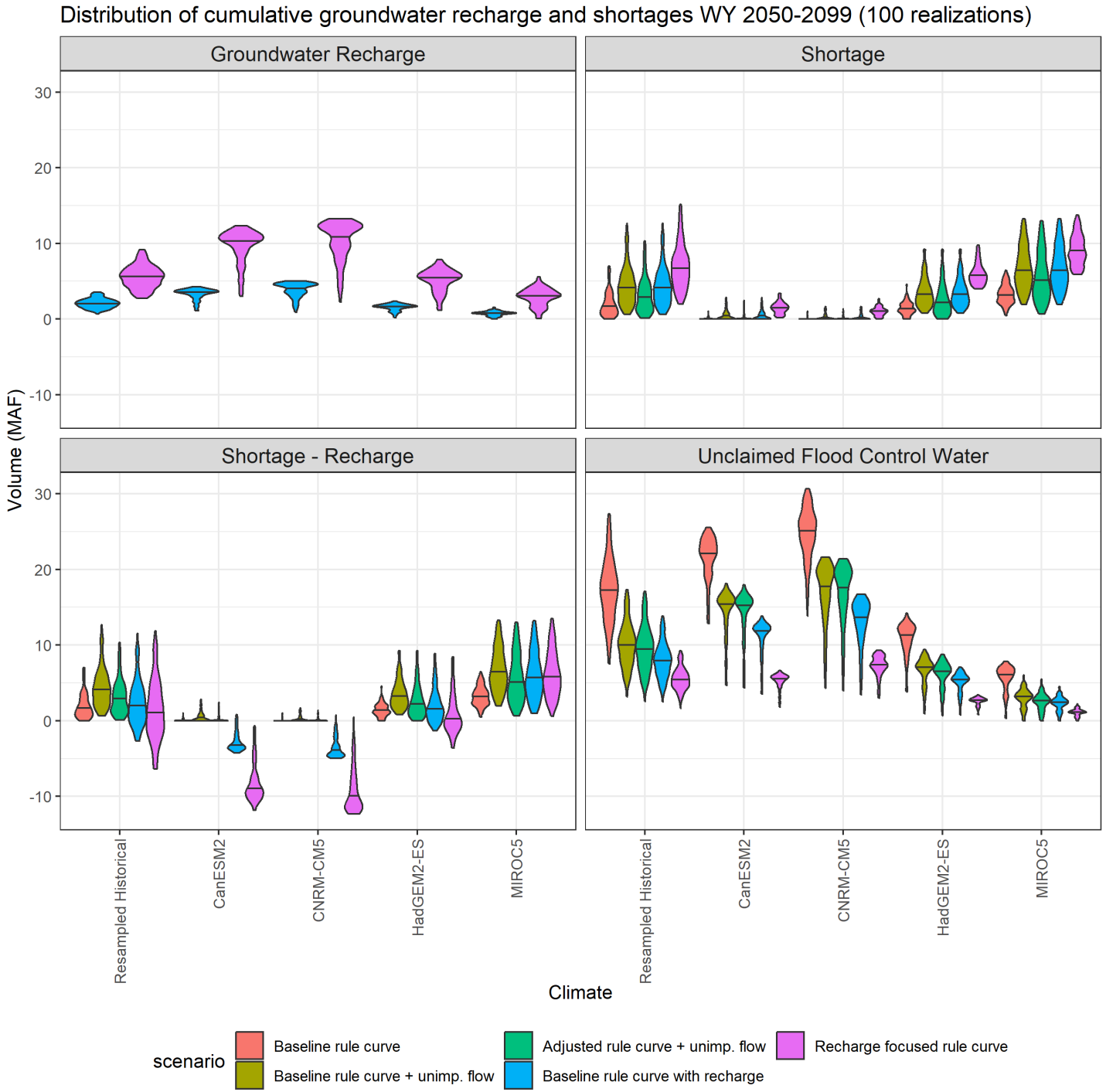
Model operation

- Box model of inflows less outflows and evaporation
- Releases forced to keep storage below rule curve
- Minimum daily outflow
- Request 500,000 AF of releases divided evenly over Apr-Sept; track shortage amount if unable to be supplied
- Hypothetical unimpaired flow rule (Apr-Sept): release if outflow would be less than 35% of full natural flow for a given month
- Groundwater storage (Oct-Mar): any releases above minimum flow can be tracked as GW storage up to a maximum amount


Distribution of yearly shortages (100 realizations x 50 years per realization)
Resampled Historical
CanESM2
CNRM-CM5
HadGEM2-ES
MIROC5
Exceedance Probability
0.0
0.1
0.2
0.3
0.4
0.5
0
400
800
1200
Annual shortage volume (TAF)
Climate
Baseline rule curve
Baseline rule curve + unimp. flow
Adjusted rule curve + unimp. flow


Average (across 100 realizations) cumulative shortages
Baseline rule curve
Baseline rule curve + unimp. flow
Adjusted rule curve + unimp. flow
Shortage
Shortage
Shortage
Average Cumulative Volume (MAF)
0
3
6
9
2060
2080
2100
Date
Climate
CanESM2
CNRM-CM5
HadGEM2-ES
MIROC5
Resampled Historical


Average (across 100 realizations) cumulative groundwater recharge
Baseline rule curve with recharge
Groundwater Recharge
Recharge focused rule curve
Groundwater Recharge
Average Cumulative Volume (MAF)
0
3
6
9
2060
2080
2100
Date
Climate
CanESM2
CNRM-CM5
HadGEM2-ES
MIROC5
Resampled Historical


Distribution of cumulative groundwater recharge and shortages WY 2050-2099 (100 realizations)
Groundwater Recharge
Shortage
Shortage - Recharge
Unclaimed Flood Control Water
Volume (MAF)
30
20
10
0
-10
Resampled Historical
CanESM2
CNRM-CM5
HadGEM2-ES
MIROC5
Climate
scenario
Baseline rule curve
Baseline rule curve + unimp. flow
Adjusted rule curve + unimp. flow
Baseline rule curve with recharge
Recharge focused rule curve

Conclusions

- Shortages vary substantially by climate scenario & stochastic realization
- Unimpaired flow rule increases shortages in some cases
- Rule curve changes are often able to mitigate this, except in driest scenario
- Groundwater banking appears to be a benefit for net shortage, except in driest scenario
- Recharge in particular helps minimize unclaimed flood control water