water

MDPI

Supplementary Information

Effects of climate change on streamflow in the Godavari Basin simulated using a conceptual model including CMIP6 dataset

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Table S1. Parameter values by default for the Sacramento model.

Parameter	Description	Default	Min	Max
LZPK	The ratio of water in LZFPM, which drains as base flow each day.	0.01	0.001	0.015
LZSK	The ratio of water in LZFSM which drains as base flow each day.	0.05	0.03	0.2
UZK	The fraction of water in UZFWM, which drains as interflow each day.	0.3	0.2	0.5
UZTWM	Upper Zone Tension Water Maximum.	50	25	125
UZFWM	Upper Zone Free Water Maximum, this storage is the source of water for interflow and the driving force for transferring water to deeper depths.	40	10	75
LZTWM	Lower Zone Tension Water Maximum.	130	75	300
LZFSM	Lower Zone Free Water Supplemental Maximum	25	15	300
LZFPM	Lower Zone Free Water Primary Maximum	60	40	600
PFREE	The minimum proportion of percolation from the upper zone to the lower zone directly available for recharging the lower zone free water stores.	0.06	0	0.5
REXP	An exponent determining the rate of change of the percolation rate with changing lower zone water storage.	1	0	3
ZPERC	The proportional increase in Pbase that defines the maximum percolation rate.	40	0	80
SIDE	The ratio of non-channel baseflow (deep recharge) to channel (visible) baseflow.	0	0	0.8
SSOUT	The volume of the flow which can be conveyed by porous material in the bed of stream.	0	0	0.1
PCTIM	The permanently impervious fraction of the basin contiguous with stream channels, which contributes to direct runoff.	0.01	0	0.05
ADIMP	The additional fraction of the catchment which develops impervious characteristics under soil saturation conditions.	0	0	0.2
SARVA	A decimal fraction representing that portion of the basin normally covered by streams, lakes and vegetation that can deplete stream flow by evapotranspiration.	0	0	0.1
RSERV	Fraction of lower zone free water unavailable for transpiration	0.3	0	0.4
UH1	The first component of the unit hydrograph	1	0	1
UH2	The second component of the unit hydrograph	0	0	1
UH3	The third component of the unit hydrograph	0	0	1
UH4	The fourth component of the unit hydrograph	0	0	1
UH5	The fifth component of the unit hydrograph	0	0	1

Table S2. Parameter values by default for the AWBM model.

Parameter	Description	Default	Min	Max
K_{Surf}	Surface flow recession constant	0.35	0	1
K_{Base}	Base flow recession constant	0.95	0	1
C3	Capacity surface store 3(in mm)	150	0	500
C2	Capacity surface store 2(in mm)	70	0	200
C1	Capacity surface store 1(in mm)	7	0	50
BFI	Base flow index	0.35	0	1
A2	Partial area of surface store 2	0.433	0	1
A1	Partial area of surface store 1	0.134	0	1

Table S3. Parameter values by default for the Tank model.

Parameter	Minimum	Default value	Maximum
First outlet height of the first tank (H_{11}) (in mm)	0	0	500
Second outlet height of first tank (H_{12}) (in mm)	0	0	300
First outlet height of second, third, and fourth tanks (H_{21}, H_{31}, and H_{41}) (in mm)	0	0	100
Coefficient of runoff from various tanks outlets (a_{11}, a_{12}, a_{21}, a_{31}, and a_{41})	0	0.2	1
Coefficient of Evaporation (α)	0	0.1	1
coefficient of infiltration in tanks 1,2, and 3 (b_1, b_2, and b_3)	0	0.2	1
Tanks water level (C_1, C_2, C_3, and C_4) (in mm)	0	20	100

Table S4. Default SimHyd model parameter values.

Parameter	minimum	Default value	maximum
Coefficient of baseflow	0.0	0.3	1.0
Impervious Threshold	0	1	5
Coefficient of Infiltration	0	200	400
Infiltration Shape	0	3	10
Coefficient of Interflow	0.0	0.1	1.0
Pervious Fraction	0.0	0.9	1.0
Rainfall Interception Store Capacity	0.0	1.5	5.0
Coefficient of recharge	0.0	0.2	1.0
Soil Moisture Store Capacity	1	320	500

Sacramento

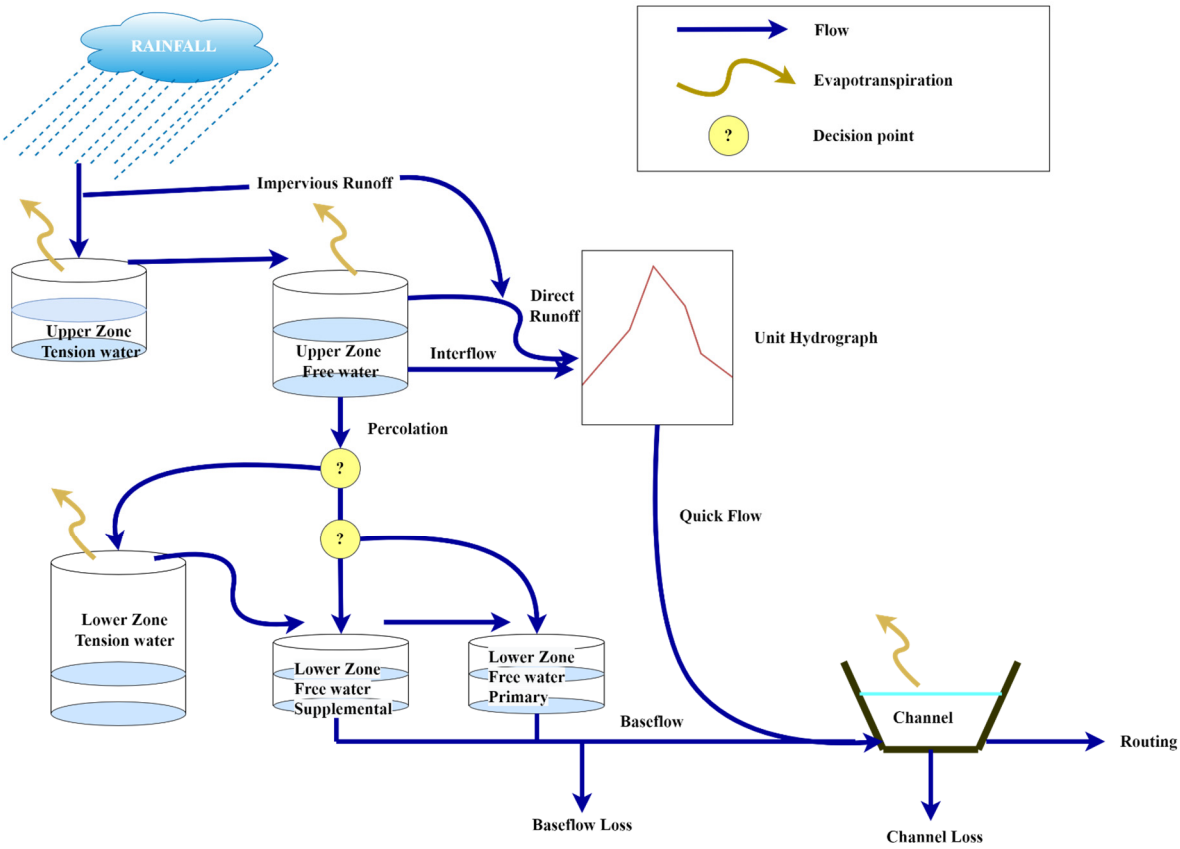

Figure S1. Schematic representation of the Sacramento model (Source: Reddy et al. (2023)).

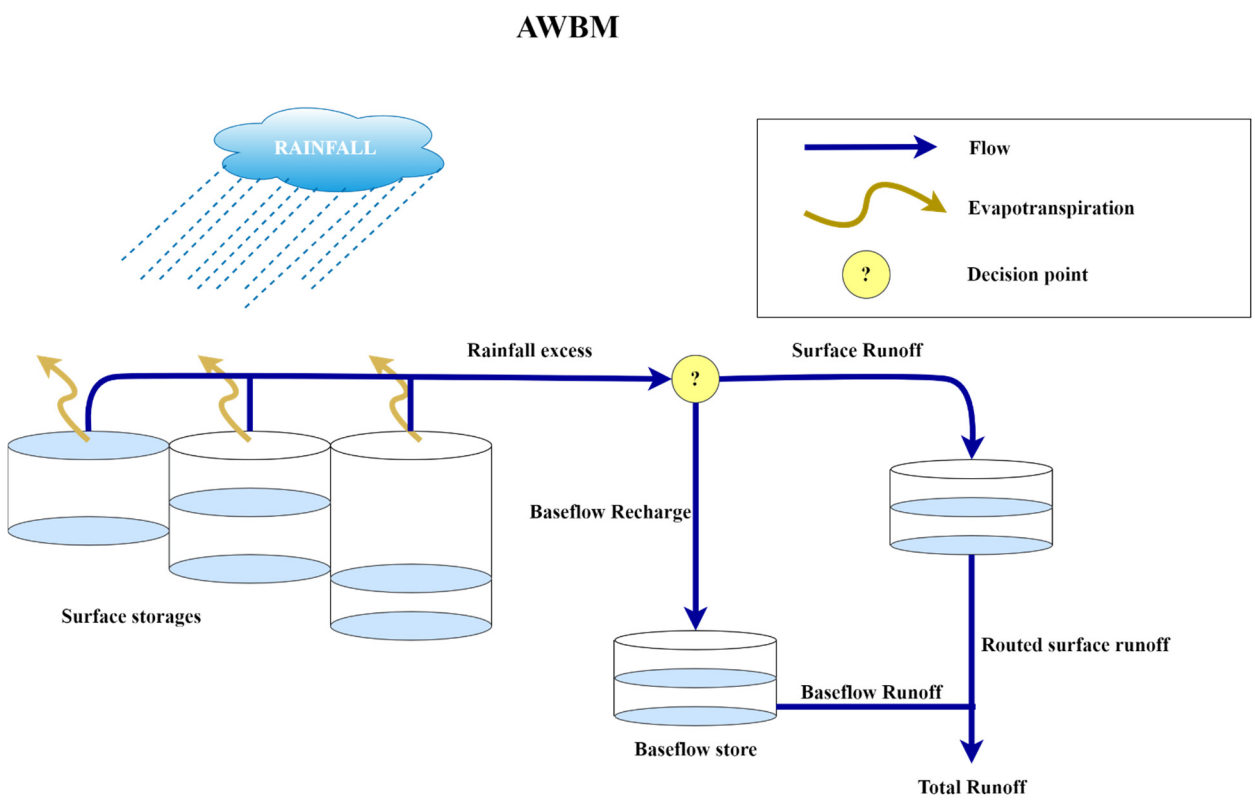

Figure S2. Schematic representation of AWBM model.

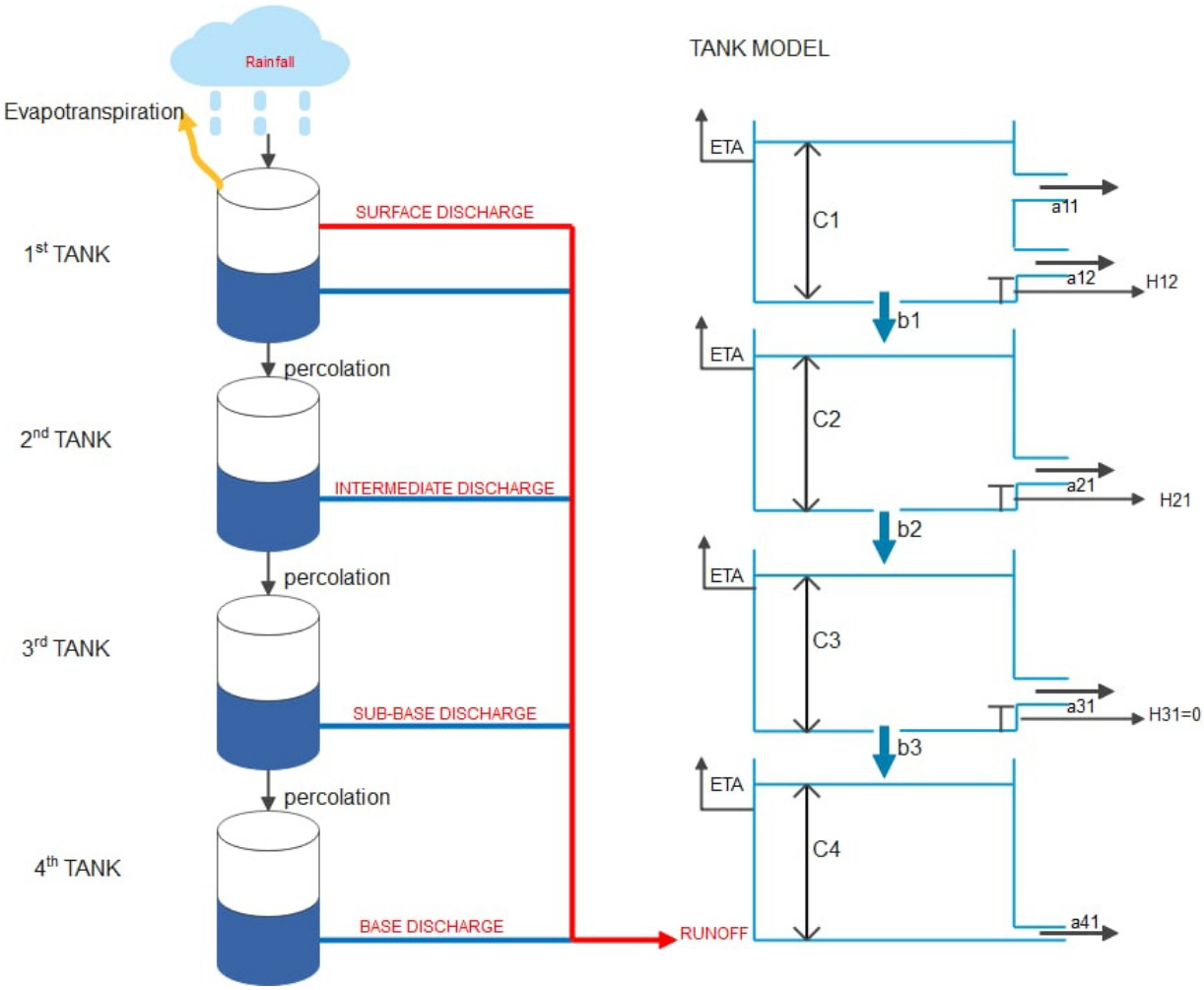

Figure S3. Schematic representation of the TANK model (Source: Reddy et al. (2023b)).

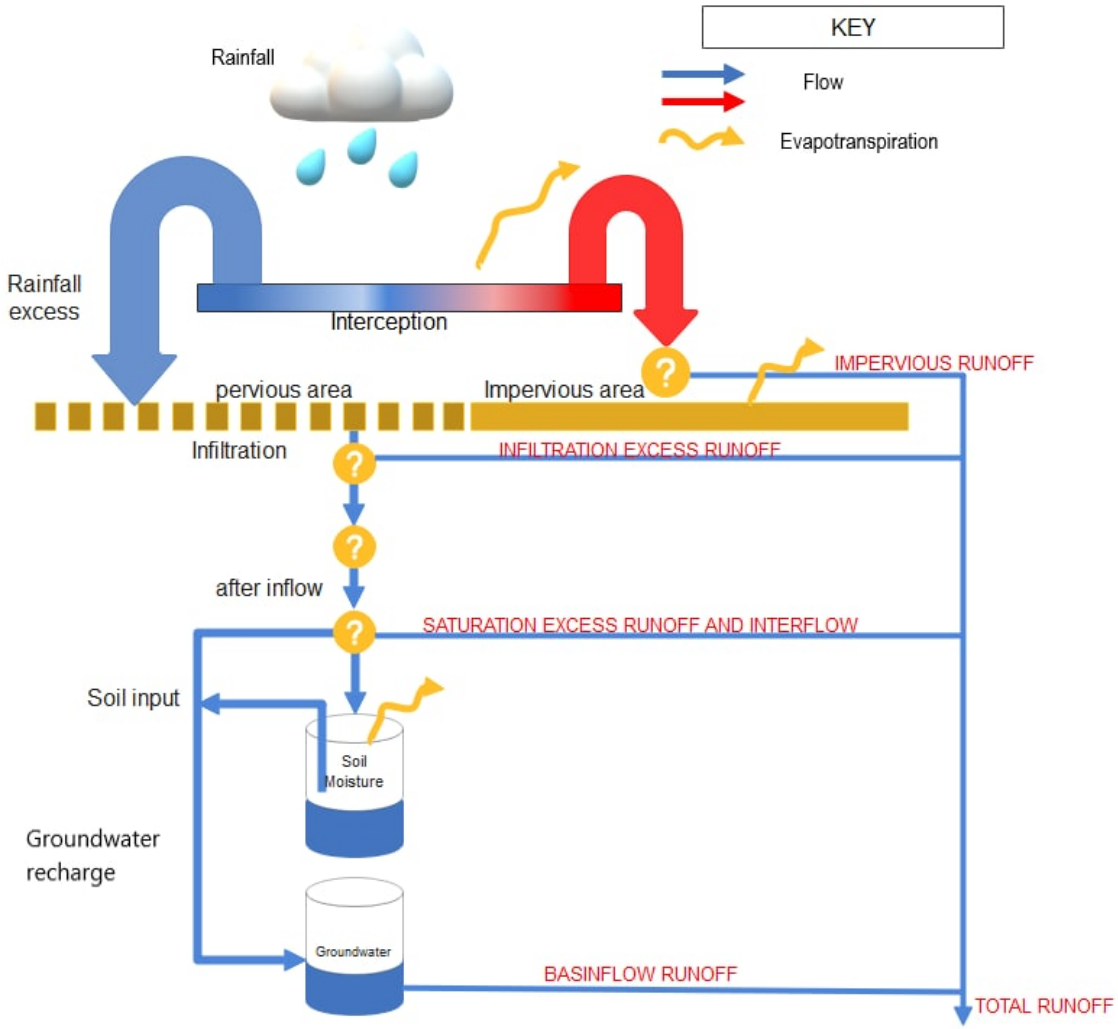

Figure S4. Schematic representation of SIMHYD model.

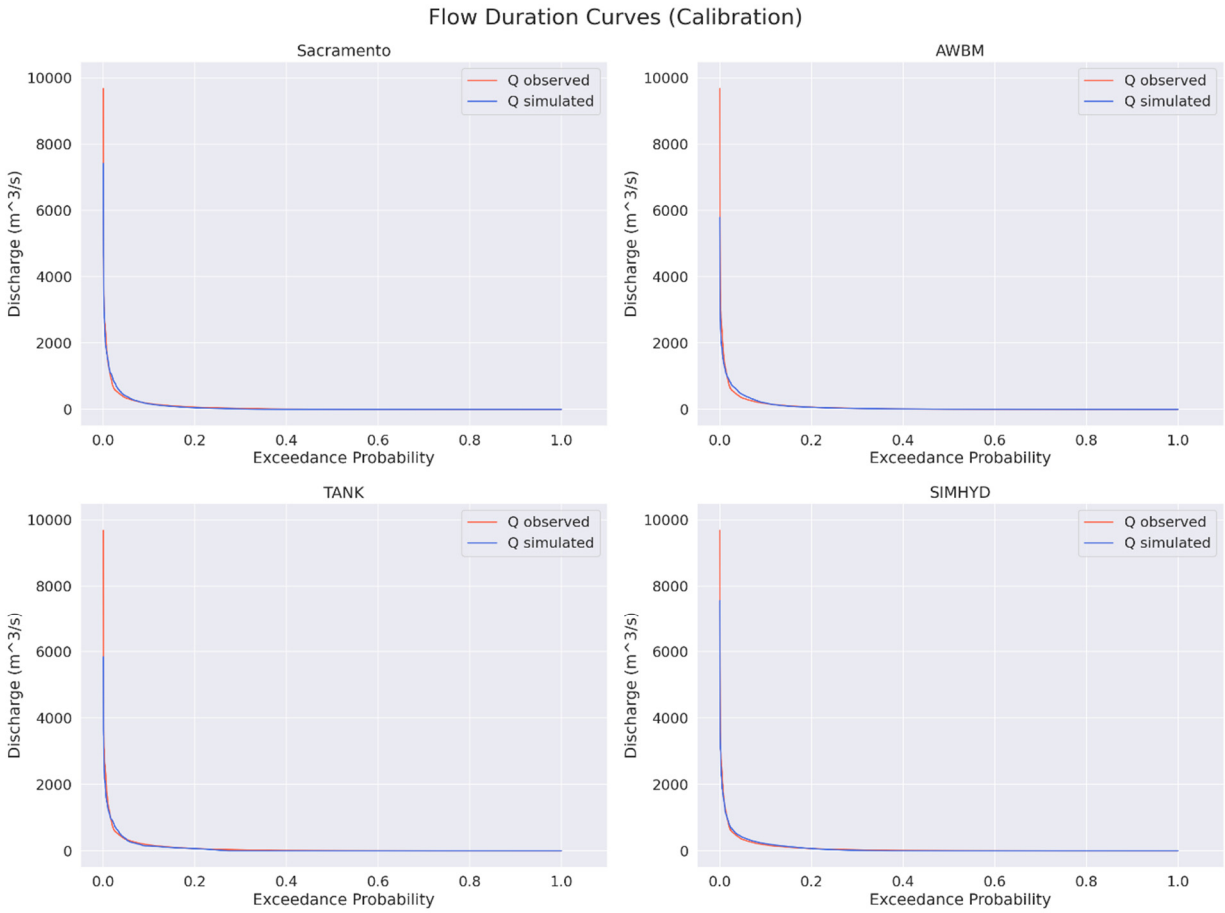

Figure S5. Flow duration curve for Observed vs. simulated streamflow for Sacramento, AWBM, TANK, and SIMHYD models during calibration.

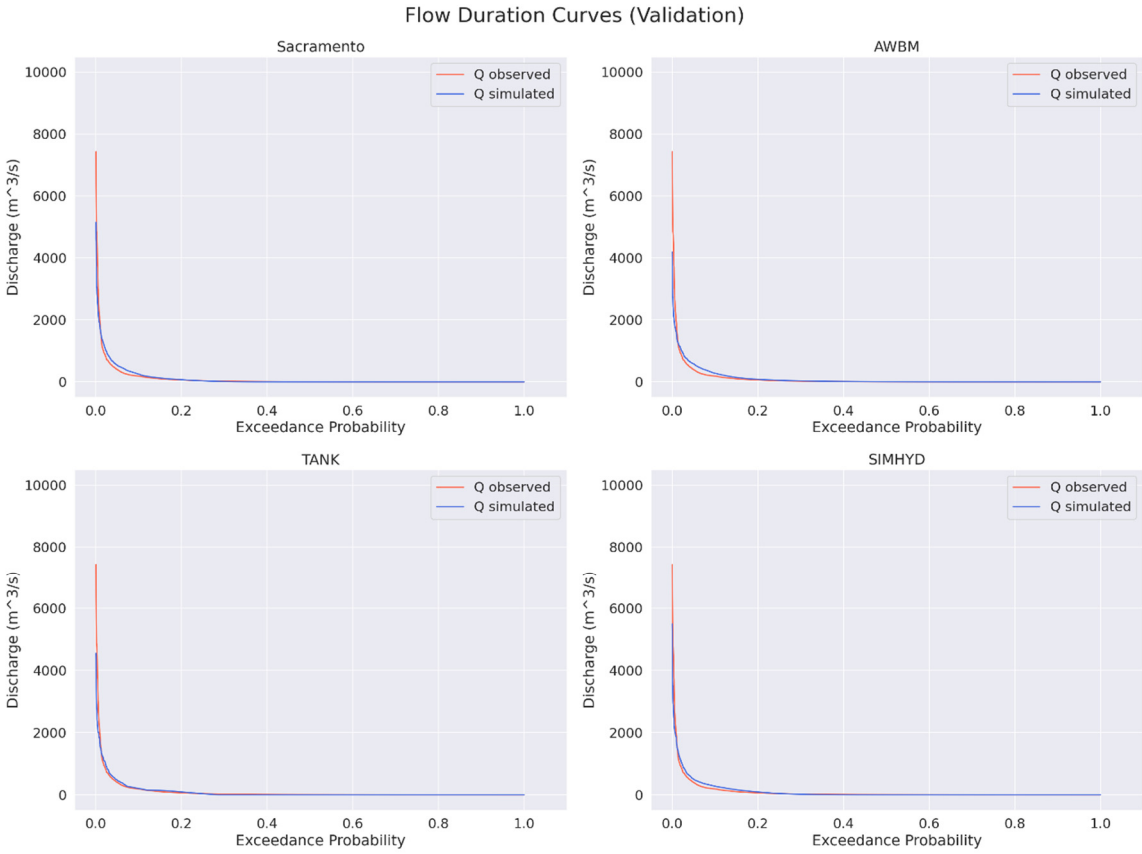

Figure S6. Flow duration curve for Observed vs. simulated streamflow for Sacramento, AWBM, TANK, and SIMHYD models during calibration.

Monthly rainfall projections

Figure 15a shows that the monthly rainfall during historical and SSP126 scenario future projections varies significantly across different time periods. Between January and May, there is not much variation in rainfall. However, in June, there has been a downward trend in precipitation over time, with the historical amount of 177.85 decreasing to 75.26 in the far future. In July, there is mostly no change in the near future, but an increasing trend in the middle and far future. August exhibits an increasing trend, with the Middle Future period having the highest rainfall of 528.83 mm and the Historical period having the lowest at 352.39 mm. September shows an increasing trend, with the Middle Future period having the highest rainfall of 293.24 mm and the Far Future period having the lowest at 265.83 mm. In October, there is a variation, with the Middle Future period having the highest rainfall of 75.77 mm and the Historical period having the lowest at 47.26 mm. In November, there is a variation, with the Middle Future period having the highest rainfall of 30.43 mm and the Historical period having the lowest at 9.27 mm. In December, there is a variation, with the Middle Future period having the highest rainfall of 29.82 mm and the Historical period having the lowest at 7.67 mm.

Figure 15b represents the monthly rainfall during historical and SSP245 scenario future projections. Like the SSP126 scenario, there is not much fluctuation in rainfall between January and May. In June, the Historical era had the maximum rainfall at 177.85 mm and the Near Future the lowest at 70.62 mm. July has the highest Middle Future rainfall at 525.65 mm and the lowest Near Future rainfall at 491.75 mm. August had the greatest middle Future rainfall at 494.69 mm and the lowest Historical rainfall at 352.39 mm. September had the highest far-future rainfall at 300.70 mm and the lowest historical rainfall at 195.66 mm. The Historical era had 47.26 mm of rainfall in October, while the Middle Future had 90.80 mm. In November, rainfall is low in the Historical and Near Future eras

(9.27 mm and 20.60 mm) but high in the Middle and Far Future (19.29 mm and 26.24 mm). In December, the Historical and Near Future eras had 7.67 mm and 20.31 mm of rainfall, respectively, while the Middle and Far Future periods had 24.36 and 41.41 mm.

Figure 15c illustrates the monthly rainfall predictions for both historical data and the SSP370 scenario. There appears to be a slight change in the trend from January to May, but overall, an increase in rainfall is expected. In June, the historical average rainfall is 177.85 mm, which reduces to 56.31 mm in the near future, increases to 106.51 mm in the middle future, and then slightly decreases to 46.80 mm in the far future. In July, there was a decrease to 499.35 mm before rising to 596.27 mm. In August, there is a rise to 526.74 mm in the near future, followed by a drop to 523.24 mm in the middle future and 588.83 mm in the far future. September's historical average rainfall is 195.66 mm, increasing to 282.94 mm in the near future and 351.00 mm in the distant future. In October, there is a rise to 75.36 mm in the near future and 112.96 mm in the far future. In November, the historical average rainfall is 9.27 mm, which rises to 40.70 mm in the near future, drops to 21.51 mm in the intermediate future, and rises again to 46.87 mm in the distant future. Finally, in December, the historical average rainfall is 7.67 mm, which increases to 29.06 mm in the near future and then declines to 27.68 mm in the far future.

Figure 15d displays the monthly rainfall for both historical data and the projected SSP585 scenario estimates. In January, the historical average rainfall is 13.17 mm, increasing to 31.38 mm in the far future. February's historical average is 10.26 mm, which could decrease to 5.15 mm in the near future before increasing to 14.93 mm in the far future. In June, the historical average is 177.85 mm, which decreases significantly to 70.62 mm in the near future before increasing significantly to 140.52 mm in the middle future and slightly decreasing to 58.72 mm in the far future. In July, the historical average is 418.90 mm, which slightly decreases in the near future to 491.75 mm before increasing further to 679.12 mm in the far future. September's historical average is 195.66 mm, significantly increasing to 349.69 mm in the future. Finally, in December, the historical average is 7.67 mm of rainfall, significantly increasing to 41.41 mm in the far future.

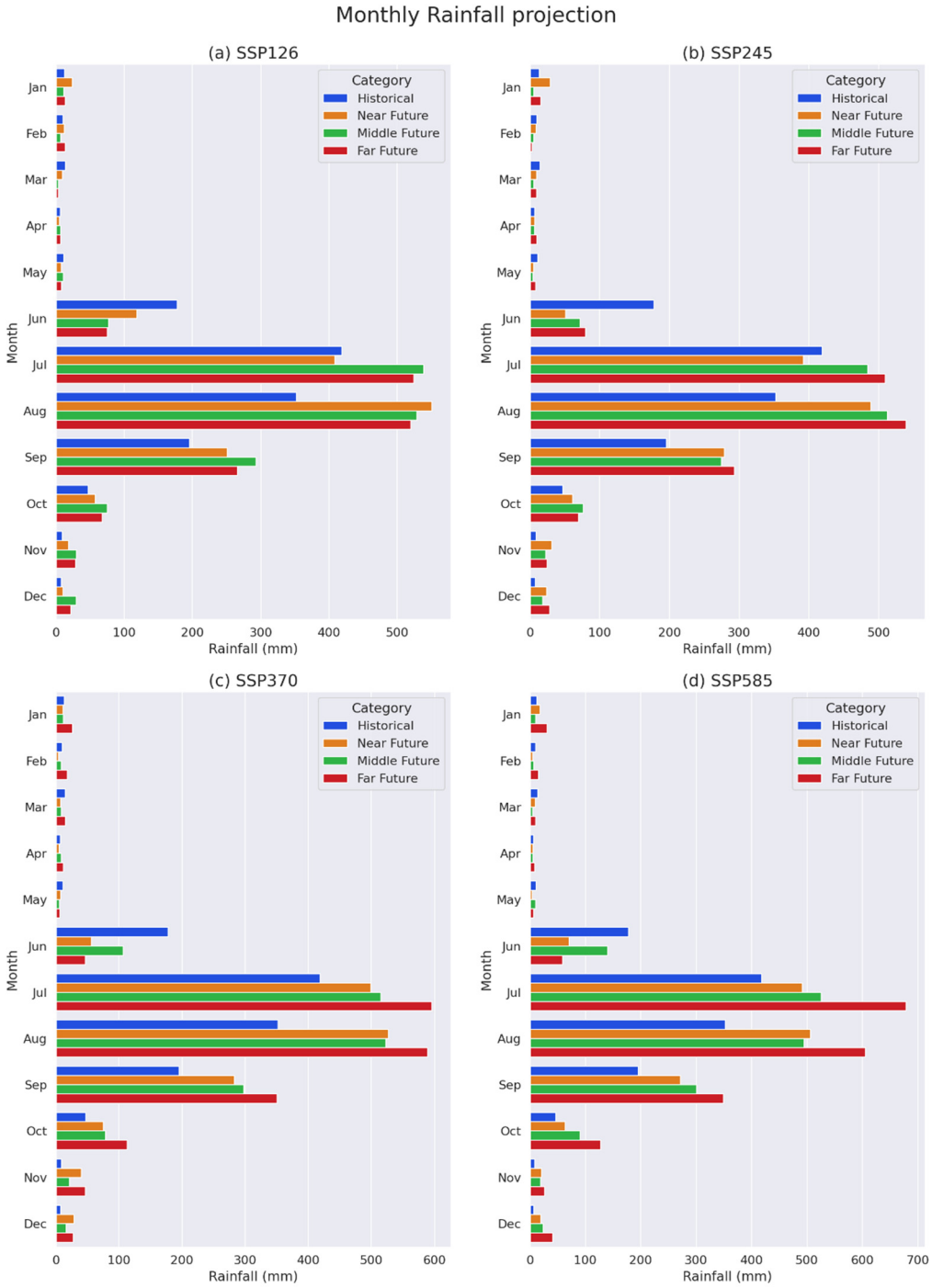

Figure S7. Monthly rainfall projections for SSP126, SSP245, SSP370 and SSP585 scenarios.

Table S5. Descriptive statistics for the dataset during Calibration and Validation.

	Calibration				
	Tmin	***Tmin***	***Precipitation***	***Eto***	***Streamflow***
Mean	19.73577	32.72572	3.470734	4.892049	81.29791
Standard Error	0.061295	0.054857	0.11774	0.014291	3.480582
Median	21.76	31.57691	0	4.467783	5.345
Mode	23.9	31.51	0	3.50683	0
Standard Deviation	5.500849	4.923129	10.5665	1.282557	312.3616
Sample Variance	30.25934	24.2372	111.6509	1.644953	97569.8
Kurtosis	-0.80811	-0.40187	70.74959	-0.61043	202.2821
Skewness	-0.47736	0.632263	6.669793	0.730815	11.24418
Range	27.67	27.27	226.0968	6.166989	9681.6
Minimum	4.55	18.63	0	2.232336	0
Maximum	32.22	45.9	226.0968	8.399326	9681.6
Sum	158951.9	263573	27953.29	39400.56	654773.4
Count	8054	8054	8054	8054	8054
Confidence Level(95.0%)	0.120154	0.107535	0.230802	0.028015	6.822841
	Validation				
	Tmin	***Tmax***	***Precipitation***	***Eto***	***Streamflow***
Mean	19.57438	32.60527	3.432879	4.895996	95.14656
Standard Error	0.089862	0.081061	0.162447	0.02097	6.73403
Median	21.41	31.34	0	4.473222	5
Mode	23.37	31.52	0	3.50683	0
Standard Deviation	5.431293	4.899341	9.818286	1.267422	407.0051
Sample Variance	29.49895	24.00354	96.39874	1.606357	165653.2
Kurtosis	-0.89979	-0.27926	54.41726	-0.52955	115.3684
Skewness	-0.38936	0.685836	6.014272	0.766457	9.647078
Range	26.31	27.68	160.3247	6.098484	7431
Minimum	4.82	18.17	0	2.256467	0
Maximum	31.13	45.85	160.3247	8.354951	7431
Sum	71505.2	119107.1	12540.31	17885.07	347570.4
Count	3653	3653	3653	3653	3653
Confidence Level(95.0%)	0.176186	0.15893	0.318495	0.041114	13.20283

Table S6. Calibrated parameters for all conceptual models.

Sacramento		AWBM		TANK		SIMHYD	
ADIMP	0.031	A1	0.134	H11	119.608	baseflow Coefficient	0.373
LZFPM	49.608	A2	0.433	a11	0.169	impervious Threshold	4.431
LZFSM	49.608	BFI	0.298	a12	0.204	infiltration Coefficient	371.765
LZPK	0.118	C1	1.569	a21	0.812	infiltration Shape	0.196
LZSK	0.729	C2	130.196	a31	0.847	interflow Coefficient	0.000
LZTWM	117.647	C3	252.941	a41	0.478	pervious Fraction	1.000
PCTIM	0.000	K_{Base}	0.561	alpha	1.000	rainfall Interception Capacity	4.569
PFREE	0.184	K_{Surf}	0.627	b1	0.031	recharge Coefficient	0.741
REXP	1.529			b2	0.337	soil Moisture Store Capacity	169.290
RSERV	0.300			b3	0.027		
SARVA	0.010			C1	51.765		
SIDE	0.000			C2	18.824		
SSOUT	0.001			C3	52.549		
UZFWM	79.373			C4	26.667		
UZK	0.737			H12	101.315		
UZTWM	65.098			H21	14.118		
ZPERC	67.765			H31	78.824		
				H41	51.765		