Table S1. Summary information for the 100 reservoirs in this study, based on the ResOpsUS and GRanD datasets. The “Observed data” column indicates which reservoir data are available, with 'I' representing inflow, 'O' representing outflow, and 'S' representing storage. Reservoirs marked with an asterisk (*) indicate those without upstream global reservoirs in the WaterGAP model. Data from GRanD, unless the column name includes 'observed'.

GRanD ID	Dam name	Longitude	Latitude	GRanD capacity [km^3]	Observed maximum monthly storage [km^3]	Observed maximum daily storage [km^3]	Commissioning year	primary purpose	Observed data
610	Hoover	-114.73	36.02	36.70	32.90	36.89	1935	supply	OS
753	Garrison	-101.43	47.51	30.22	29.28	36.10	1953	flood	IOS
870	Oahe	-100.40	44.46	29.11	28.08	28.33	1966	flood	IOS
597	Glen Canyon	-110.73	37.37	25.07	31.58	31.69	1963	electricity	IOS
307	Fort Peck	-106.41	48.00	23.56	23.17	23.81	1957	flood	IOS
1753	Kentucky	-88.09	36.27	7.56	2.68	3.67	1944	navigation	IOS
297*	Libby	-115.32	48.41	7.43	6.16	7.17	1973	electricity	IOS
1036	Bull Shoals	-92.57	36.37	6.67	6.57	6.80	1951	flood	IOS
989	Harry S. Truman	-93.41	38.27	6.42	5.19	6.19	1978	electricity	IOS
1135	Denison	-96.57	33.82	6.41	6.47	7.41	1944	flood	OS
1269	Toledo Bend	-93.57	31.18	6.29	5.73	6.04	1966	electricity	OS
1077	Eufaula	-95.36	35.31	4.72	4.29	5.22	1964	flood	OS
1026	Table Rock	-93.31	36.60	4.27	4.21	4.56	1959	flood	IOS
740*	Lower Red	-95.08	48.04	4.23	3.17	3.37	1931	flood	OS
1294	Mansfield	-97.91	30.39	3.98	1.72	2.24	1942	irrigation	OS
1848*	Sardis	-89.79	34.41	3.72	2.13	2.21	1940	flood	IOS
1869*	Grenada	-89.77	33.82	3.36	2.12	2.21	1954	flood	IOS
1863*	Buford	-84.07	34.16	3.15	3.32	3.63	1958	flood	OS
1770*	Norris	-84.09	36.23	3.15	1.34	1.52	1936	flood	OS
965*	Tuttle Creek	-96.60	39.26	2.78	2.24	2.90	1962	flood	OS
1247	Whitney	-97.37	31.87	2.59	1.74	2.44	1951	supply	OS
7313	Canyon Ferry	-111.73	46.65	2.53	2.47	2.53	1953	electricity	IOS
1287	Livingston	-95.02	30.63	2.52	2.32	2.57	1969	flood	OS
1186*	Ferrells Bridge	-94.50	32.75	2.47	0.77	0.86	1958	supply	OS
1042*	Norfork	-92.24	36.25	2.45	2.41	2.50	1944	flood	IOS
884	Big Bend	-99.45	44.04	2.34	2.18	2.26	1963	flood	IOS
1273	Belton	-97.47	31.11	2.31	1.37	1.44	1954	recreation	OS
961*	Clarence Cannon	-91.65	39.53	2.30	1.09	1.31	1983	flood	OS
1144	Millwood	-93.97	33.70	2.29	1.64	1.84	1966	flood	IOS
616	Davis	-114.66	35.47	2.24	2.18	2.23	1952	electricity	OS
911*	Red Rock	-92.98	41.37	2.17	1.98	2.25	1969	flood	OS
1006*	Stockton	-93.77	37.69	2.06	1.58	1.78	1969	flood	IOS
1048	Keystone	-96.26	36.15	2.06	1.74	2.31	1964	flood	IOS
1123	Broken Bow	-94.68	34.15	1.98	1.54	1.68	1967	flood	OS
1032	Oologah	-95.68	36.42	1.92	1.66	2.18	1963	flood	IOS
1774	Cherokee Saddle 1	-83.50	36.17	1.90	0.91	0.96	1941	flood	OS
1781*	Douglas	-83.53	35.96	1.90	0.85	0.94	1943	flood	OS
355	Yellowtail	-108.08	45.23	1.76	1.50	1.68	1965	irrigation	IOS
1101*	Arkabutla	-90.12	34.76	1.71	0.79	0.91	1943	flood	IOS
1023	Kaw	-96.93	36.70	1.64	1.36	1.76	1976	flood	IOS
1060*	Tenkiller	-95.04	35.60	1.52	1.27	1.47	1952	flood	OS
1864*	Enid	-89.73	34.17	1.50	0.93	0.95	1952	flood	IOS
1797	Watts Bar	-84.51	35.83	1.45	0.66	0.80	1942	navigation	OS
305	Albeni Falls	-117.00	48.18	1.42	1.90	1.99	1955	electricity	OS

968	Milford	-96.90	39.08	1.41	1.23	1.66	1967	flood	OS
1019*	Wappapello	-90.29	36.93	1.40	0.69	0.94	1941	flood	OS
1302*	Canyon	-98.20	29.87	1.39	0.88	0.99	1964	supply	OS
1824	Pickwick Landing	-88.25	35.07	1.36	0.63	0.77	1938	navigation	OS
1316*	Choke Canyon	-98.25	28.49	1.34	0.88	0.96	1981	recreation	OS
1835	Wheeler	-87.38	34.81	1.32	0.72	0.98	1936	electricity	OS
1847	Guntersville	-86.39	34.42	1.29	0.69	0.94	1939	navigation	OS
1231*	Blackburn Crossing	-95.44	32.06	1.29	0.55	0.65	1971	supply	OS
1140*	Lake Kemp	-99.15	33.76	1.28	0.40	0.51	1923	irrigation	OS
1296*	Somerville	-96.53	30.32	1.27	0.62	0.68	1967	irrigation	OS
1659*	Lake Shelbyville	-88.78	39.41	1.27	0.59	0.69	1970	flood	OS
1277*	Stillhouse-Hollow	-97.53	31.02	1.25	0.78	0.81	1968	supply	OS
1021*	Great Salt Plains La	-98.14	36.74	1.22	0.12	0.23	1941	flood	IOS
1280	Buchanan	-98.42	30.75	1.21	1.08	1.11	1937	irrigation	OS
1120*	Waurika	-98.05	34.24	1.15	0.37	0.45	1977	flood	IOS
182*	Mormon Island Saddle	-121.12	38.77	1.10	1.20	1.26	1955	irrigation	IOS
7311*	Elk City	-95.80	37.26	1.05	0.28	0.44	1966	Flood	IOS
1755*	Barren River	-86.12	36.90	1.01	0.78	0.84	1964	flood	IOS
1152*	Jim Chapman	-95.62	33.32	0.98	0.50	0.56	1991	supply	OS
1192	Caddo	-93.92	32.71	0.93	0.43	0.91	1914	navigation	IOS
541*	Blue Mesa	-107.18	38.47	0.92	1.01	1.03	1965	electricity	IOS
1822	Chickamauga	-85.23	35.10	0.91	0.42	0.55	1940	navigation	OS
972*	Wilson	-98.49	38.96	0.91	0.80	0.82	1964	flood	OS
613	Cochiti	-106.31	35.62	0.89	0.46	0.49	1975	flood	OS
1086*	Santa Rosa	-104.69	35.03	0.88	0.14	0.15	1979	flood	OS
1295	Conroe	-95.57	30.36	0.87	0.55	0.66	1973	irrigation	OS
1139*	Lake Arrowhead	-98.37	33.76	0.84	0.33	0.35	1966	flood	OS
1862*	Allatoona	-84.73	34.17	0.83	0.72	0.85	1965	flood	OS
629	Parker	-114.14	34.30	0.80	0.75	1.06	1938	supply	OS
1000*	Pomme De Terre	-93.32	37.90	0.80	0.55	0.62	1961	flood	OS
7306	Wilson	-87.50	34.82	0.79	0.39	0.41	1924	electricity	OS
991*	John Redmond	-95.76	38.24	0.77	0.62	0.80	1964	flood	OS
998	John Martin	-102.94	38.07	0.75	0.53	0.56	1943	flood	OS
7317	Tims Ford	-86.27	35.22	0.75	0.34	0.37	1970	Flood	OS
1716*	Rend	-88.96	38.04	0.75	0.40	0.54	1971	flood	IOS
1896	West Point	-85.19	32.92	0.75	0.79	0.91	1974	flood	OS
1883*	Wallace	-83.16	33.35	0.73	0.06	0.15	1980	electricity	IOS
1285*	Granger	-97.33	30.70	0.69	0.30	0.33	1979	recreation	OS
1266*	Sterling C. Robertson	-96.33	31.33	0.69	0.28	0.30	1978	irrigation	OS
1176*	Morris Sheppard	-98.43	32.87	0.69	0.69	0.92	1941	supply	OS
924*	Rathbun	-92.89	40.83	0.68	0.64	0.72	1972	flood	OS
758	Winnibigoshish	-94.17	47.45	0.68	1.02	1.44	1884	supply	OS
1257	Simon Freese	-99.67	31.50	0.67	0.52	0.53	1989	recreation	OS
895	Gavins Point	-97.49	42.85	0.67	0.57	0.69	1958	flood	IOS
1317	Wesley E. Seale	-97.87	28.05	0.66	0.34	0.39	1958	recreation	OS
1242	Red Bluff	-103.91	31.90	0.64	0.35	0.43	1936	irrigation	OS
107*	Lost Creek	-122.65	42.69	0.62	0.57	0.58	1976	flood	OS
1841*	Carters Main	-84.67	34.62	0.58	0.51	0.58	1974	flood	OS
907*	Coralville	-91.53	41.73	0.57	0.57	0.69	1958	flood	OS
80*	Detroit	-122.25	44.72	0.56	0.55	0.56	1953	electricity	OS
981	Kanopolis	-97.97	38.61	0.53	0.29	0.50	1948	flood	OS
1236*	Proctor	-98.48	31.97	0.53	0.39	0.47	1963	supply	OS
1093*	Wister	-94.72	34.94	0.53	0.54	0.71	1949	flood	IOS
1709*	Summersville	-80.89	38.22	0.51	0.25	0.39	1965	flood	IOS
1017*	Clearwater	-90.77	37.14	0.51	0.50	0.55	1942	flood	IOS
1194	Benbrook	-97.47	32.66	0.51	0.22	0.26	1951	supply	OS

Table S2. The ranges for each parameter in each algorithm (formatted as [start: increment rate: end]) along with the total number of parameter sets per algorithm. The number of parameter sets in the CH differs for irrigation and non-irrigation reservoirs due to the fact that a_2 is only applied for irrigation reservoirs.

	Algorithm		
	CH	SA	WA
Range of parameter 1	a1=[0.05:0.05:1]	p1=[0.1:0.1:1; 1.5; 2:1:10]	q1=p1
Range of parameter 2	a2=[0.1:0.1:1]	p2=p1	q2=p1
Range of parameter 3	a3=[0.1:0.05:1; 2:1:10]	p3=p1	q3=p1
Number of parameter sets for irrigation reservoirs	5800	8000	8000
Number of parameter sets for non-irrigation reservoirs	580	8000	8000

Table S3. KGE values and their components for the storage and outflow of Glen Canyon Dam (GranD ID 597) were simulated using the DH, CH, SA, and WA algorithms during the calibration (validation) period. The algorithms were calibrated against outflow, storage, storage anomaly, and estimated storage.

Simulated variable	Calibrated variable	Algorithm	KGE	R_{KGE}	V_{KGE}	B_{KGE}	T_{KGE}
Storage	—	DH	0.17 (0.04)	0.54 (0.75)	1.21 (1.79)	0.76 (0.90)	0.38 (0.52)
	Outflow	CH	0.17 (0.04)	0.54 (0.75)	1.21 (1.79)	0.76 (0.90)	0.38 (0.52)
		SA	-0.08 (-1.28)	0.62 (0.81)	1.60 (3.18)	0.54 (0.56)	0.34 (1.44)
		WA	0.22 (0.22)	0.69 (0.78)	1.12 (1.65)	0.61 (0.70)	0.41 (1.23)
	Storage	CH	0.60 (0.64)	0.79 (0.80)	1.12 (1.19)	0.72 (0.76)	0.84 (1.04)
		SA	0.58 (-0.51)	0.92 (0.20)	1.37 (0.91)	0.84 (0.66)	1.03 (-0.23)
		WA	0.82 (-0.42)	0.92 (0.27)	1.09 (0.93)	0.90 (0.68)	0.92 (-0.17)
	Storage anomaly	CH	0.60 (0.64)	0.79 (0.80)	1.12 (1.19)	0.72 (0.76)	0.84 (1.04)
		SA	0.58 (-0.51)	0.92 (0.20)	1.37 (0.91)	0.84 (0.66)	1.03 (-0.23)
		WA	0.79 (-1.40)	0.92 (0.72)	1.16 (3.16)	0.89 (0.35)	1.00 (1.77)
	Estimated storage	CH	0.15 (0.34)	0.69 (0.80)	1.64 (1.04)	0.54 (0.50)	1.08 (0.63)
		SA	0.30 (-0.74)	0.83 (0.66)	1.61 (2.33)	0.73 (0.58)	0.90 (0.01)
		WA	0.32 (-2.26)	0.91 (0.65)	1.58 (3.12)	0.65 (0.57)	0.99 (3.41)
Outflow		DH	0.45 (-0.03)	0.47 (0.37)	1.13 (1.00)	0.98 (0.90)	0.95 (1.81)
	Outflow	CH	0.45 (-0.03)	0.47 (0.37)	1.13 (1.00)	0.98 (0.90)	0.95 (1.81)
		SA	0.52 (-0.41)	0.53 (-0.11)	1.03 (0.99)	1.01 (0.98)	0.94 (1.87)
		WA	0.48 (-0.41)	0.51 (0.17)	1.17 (2.00)	0.99 (0.95)	0.95 (0.44)
	Storage	CH	0.15 (-1.09)	0.30 (0.02)	1.48 (2.64)	0.99 (0.94)	0.97 (0.15)
		SA	-0.04 (-1.93)	0.34 (0.09)	1.75 (2.93)	1.00 (0.96)	0.72 (-1.01)
		WA	-0.03 (-1.24)	0.36 (0.16)	1.75 (2.90)	1.00 (0.92)	0.69 (0.17)
	Storage anomaly	CH	0.15 (-1.09)	0.30 (0.02)	1.48 (2.64)	0.99 (0.94)	0.97 (0.15)
		SA	-0.04 (-1.93)	0.34 (0.09)	1.75 (2.93)	1.00 (0.96)	0.72 (-1.01)
		WA	-0.04 (-1.63)	0.36 (0.10)	1.74 (2.62)	1.00 (1.08)	0.65 (-0.86)
	Estimated storage	CH	-0.03 (-1.95)	0.28 (0.00)	1.74 (3.27)	1.04 (1.00)	0.96 (-0.60)
		SA	0.24 (-0.01)	0.29 (0.04)	1.21 (1.22)	1.01 (0.95)	0.81 (1.21)
		WA	0.31 (-3.56)	0.36 (0.08)	1.22 (2.35)	1.01 (1.04)	0.86 (-3.25)

Table S4. KGE values and their components (excluding the trend component) for remotely sensed absolute storage estimates from the Global Reservoir Storage (GRS) and the GloLakes dataset, compared with storage data from ResOpsUS for 100 studied reservoirs. GloLakes includes data for only 57 of these 100 reservoirs. The comparison period for GRS is from 1999-2018, and for GloLakes it is from 1984-2019. "NA" denotes that data is not available for that reservoir.

GRanD ID	GRS				GloLakes			
	KGE	R_{KGE}	V_{KGE}	B_{KGE}	KGE	R_{KGE}	V_{KGE}	B_{KGE}
80	0.09	0.75	0.39	0.37	0.59	0.92	0.61	1.08
107	0.54	0.9	0.55	0.96	0.39	0.93	0.44	1.23
182	0.6	0.95	0.61	1.04	0.65	0.94	0.65	1.04
297	0.63	0.78	0.73	1.14	-2.02	0.94	0.46	3.97
305	-43.71	0.6	0.02	45.69	-28.96	0.51	0.07	30.95
307	0.95	0.98	1.05	0.98	NA	NA	NA	NA
355	-0.06	0.64	0.49	0.14	0.33	0.68	0.42	0.9
541	0.52	0.89	0.53	1.01	0.22	0.91	0.47	1.57
597	0.93	0.99	0.95	1.05	0.37	0.99	0.91	0.38
610	0.85	1	0.86	1.05	NA	NA	NA	NA
613	0.06	0.63	1.76	0.59	NA	NA	NA	NA
616	0.54	0.64	0.73	0.91	0.33	0.54	0.54	0.84
629	0.03	0.12	0.64	0.83	-0.13	0	0.58	1.32
740	-0.28	0.23	0.04	0.62	NA	NA	NA	NA
753	0.85	0.95	0.87	0.94	NA	NA	NA	NA
758	-0.65	-0.36	0.41	0.28	NA	NA	NA	NA
870	0.87	0.98	0.88	0.96	NA	NA	NA	NA
884	-0.06	-0.03	1.25	1	NA	NA	NA	NA
895	0.36	0.58	0.7	0.62	NA	NA	NA	NA
907	-0.27	0.22	0.17	0.44	-0.78	0.64	0.12	2.5
911	0.03	0.59	0.18	0.68	-1.02	0.56	0.24	2.82
924	0.4	0.71	0.61	0.65	0.08	0.81	0.48	1.74
961	0.57	0.66	0.79	0.85	-0.13	0.61	0.66	2
965	0.38	0.63	0.54	0.83	-0.56	0.67	0.22	2.31
968	0.56	0.68	0.72	0.89	0.42	0.79	0.51	1.22
972	0.79	0.86	0.86	0.97	0.33	0.62	0.49	0.79
981	0.52	0.85	0.55	0.89	0.09	0.69	0.29	1.49
989	0.43	0.63	0.71	0.67	-1.49	0.68	0.38	3.39
991	-0.01	0.59	0.14	0.66	0.05	0.58	0.15	0.98
998	0.92	0.99	1.05	0.93	0.49	0.98	0.78	0.54
1000	0.22	0.28	0.77	0.79	NA	NA	NA	NA
1006	0.48	0.58	0.71	0.9	0.18	0.61	0.54	1.56
1017	-0.15	0.54	0.14	0.39	NA	NA	NA	NA
1019	-0.01	0.26	0.32	1.02	NA	NA	NA	NA
1021	0.2	0.49	0.86	0.4	NA	NA	NA	NA
1023	0.29	0.68	0.4	0.78	0.16	0.79	0.32	1.46
1026	0.25	0.33	0.99	0.65	NA	NA	NA	NA
1032	0.07	0.48	0.25	0.85	-0.49	0.59	0.27	2.23
1036	-0.03	0.78	0.68	0.04	-0.05	0.8	0.59	1.95
1042	-0.1	0.66	0.64	0.02	-0.1	0.66	0.58	1.96
1048	0.02	0.7	0.07	0.92	-0.07	0.66	0.42	1.83
1060	0.5	0.56	0.81	0.86	0.26	0.6	0.62	1.49
1077	0.28	0.61	0.56	0.58	NA	NA	NA	NA
1086	0.3	0.98	0.88	0.31	0.33	0.97	0.86	0.35
1093	-0.14	0.39	0.14	0.57	NA	NA	NA	NA
1101	-0.13	0.62	0.35	0.16	0.08	0.68	0.32	1.53
1120	0.9	0.95	0.93	0.94	NA	NA	NA	NA
1123	0.43	0.47	0.84	0.86	0.11	0.52	0.66	1.68
1135	0.28	0.62	0.46	0.72	0.08	0.58	0.38	1.54
1139	0.71	0.95	0.81	0.79	NA	NA	NA	NA
1140	0.53	0.96	0.73	0.62	0.42	0.94	0.66	0.53

1144	-0.15	0.29	0.21	0.56	NA	NA	NA	NA
1152	0.21	0.92	0.33	0.59	0.16	0.84	0.37	0.47
1176	0.72	0.93	0.77	0.85	NA	NA	NA	NA
1186	0.3	0.59	0.48	0.79	-0.79	0.56	0.43	2.64
1192	0.37	0.47	0.99	0.66	NA	NA	NA	NA
1194	0.48	0.78	0.53	0.94	0.3	0.73	0.4	0.77
1231	-0.21	0.26	0.48	0.2	NA	NA	NA	NA
1236	0.1	0.63	0.32	0.54	NA	NA	NA	NA
1242	0.53	0.99	1.18	1.43	0.3	0.92	0.66	0.39
1247	0.55	0.8	0.6	1.02	0.22	0.68	0.46	1.46
1257	0.94	0.98	0.96	0.96	0.58	0.98	0.95	0.59
1266	0.5	0.64	0.7	0.84	NA	NA	NA	NA
1269	0.57	0.73	0.67	1	NA	NA	NA	NA
1273	0.38	0.65	0.5	0.87	0.08	0.7	0.34	1.57
1277	0.35	0.6	0.49	0.95	0.35	0.72	0.44	0.81
1280	0.79	0.98	0.8	0.94	0.69	0.97	0.73	0.86
1285	0.22	0.6	0.35	0.83	NA	NA	NA	NA
1287	-0.14	0.29	0.21	0.6	NA	NA	NA	NA
1294	0.84	0.98	0.93	0.85	0.81	0.97	0.82	1.03
1295	0.12	0.53	0.52	0.43	NA	NA	NA	NA
1296	0.51	0.69	0.64	1.13	0.17	0.71	0.28	1.29
1302	0.6	0.8	0.67	0.91	0.55	0.81	0.6	1
1316	0.47	0.96	0.5	0.82	0.31	0.94	0.49	0.53
1317	0.72	0.93	0.73	0.98	0.5	0.84	0.59	1.24
1659	0.22	0.43	0.54	0.73	-0.13	0.58	0.38	1.85
1709	0.25	0.42	0.63	0.71	NA	NA	NA	NA
1716	0.2	0.57	0.4	0.7	0.32	0.62	0.43	0.99
1753	-0.15	0.14	0.59	1.65	NA	NA	NA	NA
1755	0.1	0.42	0.4	0.66	NA	NA	NA	NA
1770	0.01	0.13	0.69	0.65	NA	NA	NA	NA
1774	0.39	0.78	0.53	0.67	-1.94	0.78	0.52	3.89
1781	0.86	0.94	0.94	0.89	-1.64	0.88	0.44	3.58
1797	-0.13	-0.05	1.14	1.39	NA	NA	NA	NA
1822	0.02	0.1	0.71	1.28	NA	NA	NA	NA
1824	-0.49	-0.13	0.04	0.96	-9.86	0	0.7	11.81
1835	-0.23	-0.09	0.47	1.19	NA	NA	NA	NA
1841	-0.75	0.28	2.59	0.82	NA	NA	NA	NA
1847	-2.15	-0.18	3.92	0.98	-6.88	-0.03	2.85	8.59
1848	-0.04	0.82	0.39	0.17	NA	NA	NA	NA
1862	0.23	0.37	0.61	0.82	NA	NA	NA	NA
1863	-0.01	0.5	1.53	0.31	NA	NA	NA	NA
1864	-0.01	0.76	0.42	0.2	-0.18	0.82	0.46	2.03
1869	-0.67	0.84	0.4	2.55	-0.39	0.78	0.49	2.27
1883	-23.35	0.06	0.13	25.32	NA	NA	NA	NA
1896	0.41	0.46	0.96	0.76	NA	NA	NA	NA
7306	-1.25	-0.46	2.45	1.9	NA	NA	NA	NA
7311	-6.62	0.71	0.79	8.61	-0.21	0.74	0.32	1.97
7313	0.29	0.71	0.39	1.2	0.14	0.6	0.44	1.52
7317	-0.57	-0.18	1.7	1.77	NA	NA	NA	NA

Table S5. Number of reservoirs (out of 100) where simulated storage by the SA or WA algorithms reached level(s)—above 70% of capacity, between 70% and 40% of capacity, or below 40% of capacity—in the validation phase that were not observed during calibration.

Operation algorithm	Calibration variable	Number of reservoirs reaching storage level(s) during validation that were not observed during calibration.
SA	Outflow	0
	Storage	4
	Storage anomaly	4
	Estimated storage	4
WA	Outflow	3
	Storage	9
	Storage anomaly	9
	Estimated storage	8

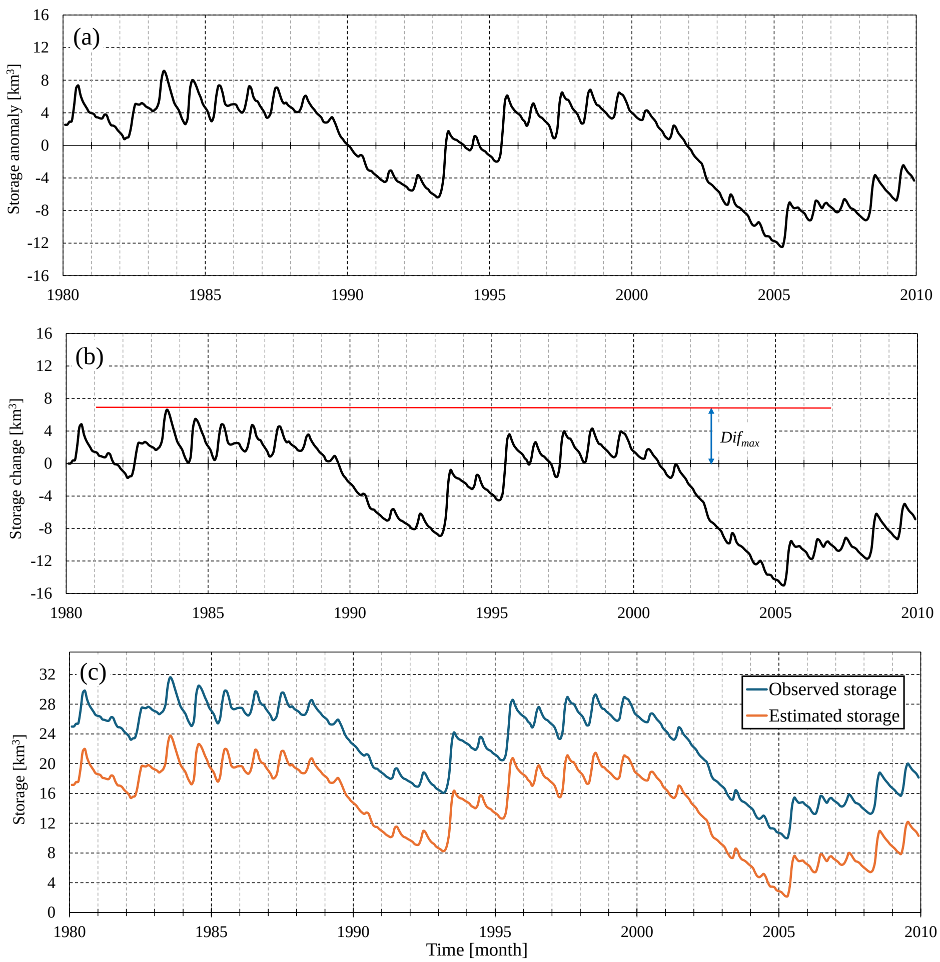

Figure S1. (a) Monthly storage anomaly time series for the Glen Canyon Dam (Lake Powell) from 1980 to 2009; (b) Storage change time series, calculated by subtracting the initial storage anomaly value (2.53 km³) from subsequent monthly storage anomaly values. The maximum storage change (Dif_{max}) at the monthly scale is 6.6 km³, occurring in July 1983. Dif_{max} is scaled by a factor of 1.2 to account for the 20% higher daily maximum storage changes compared to monthly values, resulting in a scaled value of 7.9 km³. Assuming the reservoir reaches maximum capacity at least once between 1980 and 2009, the reservoir's capacity (25.1 km³, as reported by the GRanD dataset) implies an estimated initial storage of 17.2 km³ (25.1 km³ minus 7.9 km³). Storage changes are added to this estimated initial storage to compute the time series of estimated storage; (c) Monthly time series of observed storage and estimated storage for the Glen Canyon Dam. The shift between the observed and estimated storage time series is attributed to the difference between the maximum observed storage (31.6 km³) and the reservoir capacity reported by the GRanD dataset (25.1 km³).

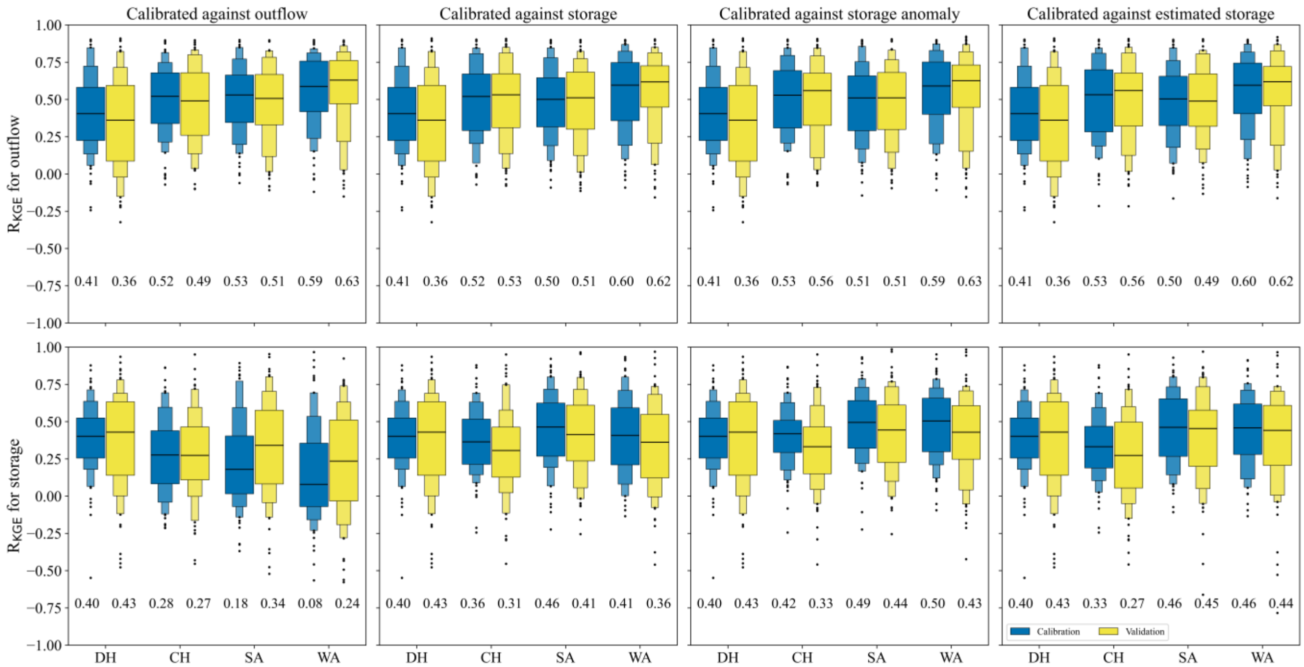

Figure S2. Letter-value plots of R_{KGE} for outflow and storage of 100 studied reservoirs for the DH, CH, SA, and WA algorithms for the calibration period (1980-2009) and validation period (2010-2019). All algorithms are calibrated against outflow (first column), storage (second column), storage anomaly (third column), as well as estimated storage (fourth column) using KGE as the objective function. The values at the bottom of the panels are the median R_{KGE} (indicated by the horizontal line). The widest box contains 50% of the data, the second widest contains 25%, the third widest contains 12.5%, and so on. The inflow data is sourced from the WaterGAP model.

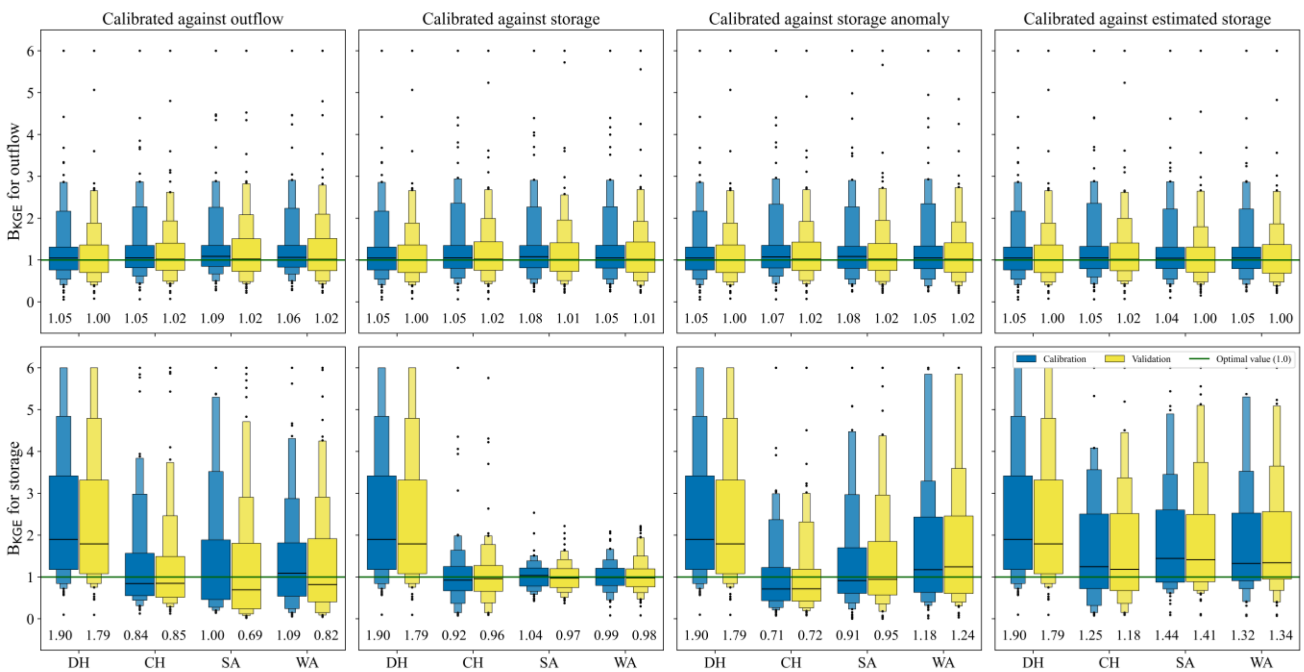

Figure S3. Letter-value plots of B_{KGE} for outflow and storage of 100 studied reservoirs for the DH, CH, SA, and WA algorithms for the calibration period (1980-2009) and validation period (2010-2019). All algorithms are calibrated against outflow (first column), storage (second column), storage anomaly (third column), as well as estimated storage (fourth column) using KGE as the objective function. The green lines represent the optimal value of B_{KGE}. The values at the bottom of the panels are the median B_{KGE} (indicated by the horizontal line). B_{KGE} values greater than 6 are set to 6. The widest box contains 50% of the data, the second widest contains 25%, the third widest contains 12.5%, and so on. The inflow data is sourced from the WaterGAP model.

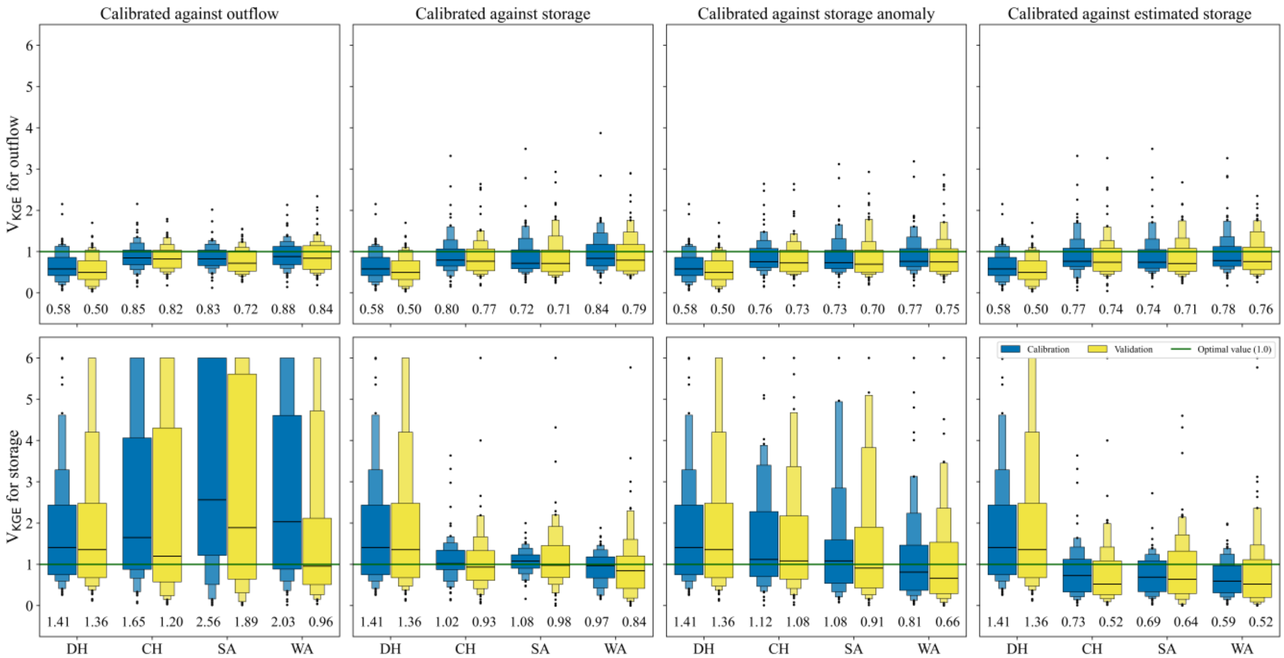

Figure S4. Letter-value plots of V_{KGE} for outflow and storage of 100 studied reservoirs for the DH, CH, SA, and WA algorithms for the calibration period (1980-2009) and validation period (2010-2019). All algorithms are calibrated against outflow (first column), storage (second column), storage anomaly (third column), as well as estimated storage (fourth column) using KGE as the objective function. The green lines represent the optimal value of V_{KGE}. The values at the bottom of the panels are the median V_{KGE} (indicated by the horizontal line). V_{KGE} values greater than 6 are set to 6. The widest box contains 50% of the data, the second widest contains 25%, the third widest contains 12.5%, and so on. The inflow data is sourced from the WaterGAP model.

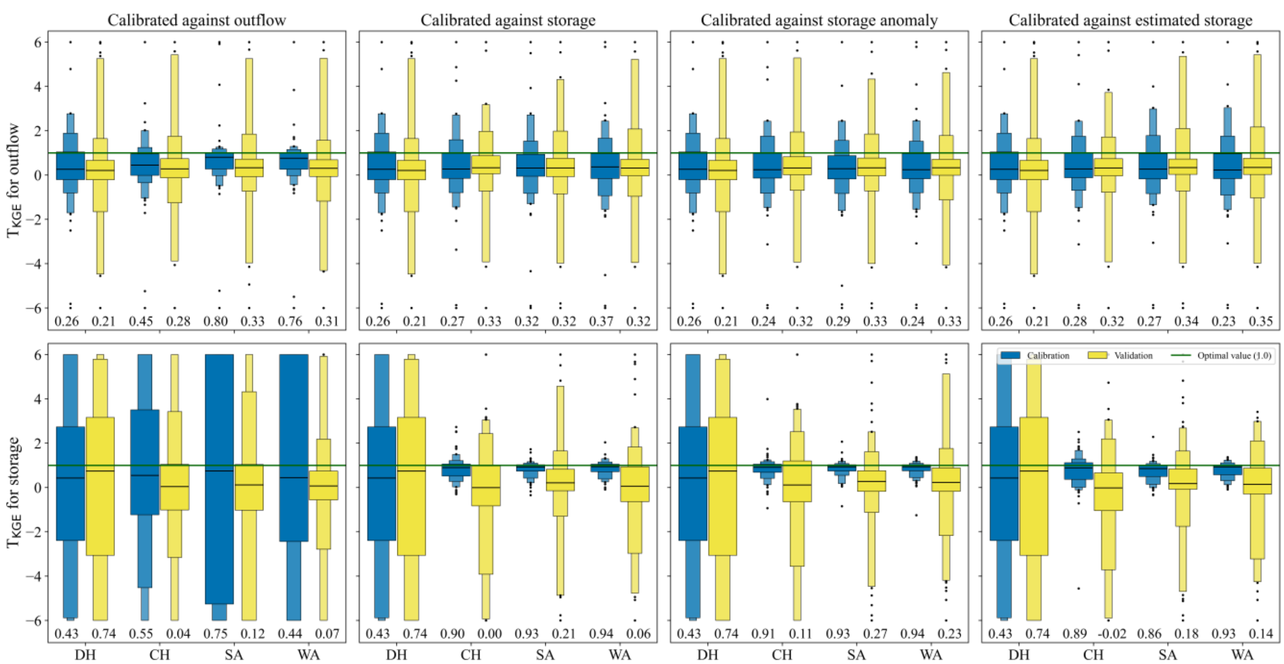

Figure S5. Letter-value plots of T_{KGE} for outflow and storage of 100 studied reservoirs for the DH, CH, SA, and WA algorithms for the calibration period (1980-2009) and validation period (2010-2019). All algorithms are calibrated against outflow (first column), storage (second column), storage anomaly (third column), as well as estimated storage (fourth column) using KGE as the objective function. The green lines represent the optimal value of T_{KGE}. The values at the bottom of the panels are the median T_{KGE} (indicated by the horizontal line). T_{KGE} values greater (less) than 6 (-6) are set to 6 (-6). The widest box contains 50% of the data, the second widest contains 25%, the third widest contains 12.5%, and so on. The inflow data is sourced from the WaterGAP model.

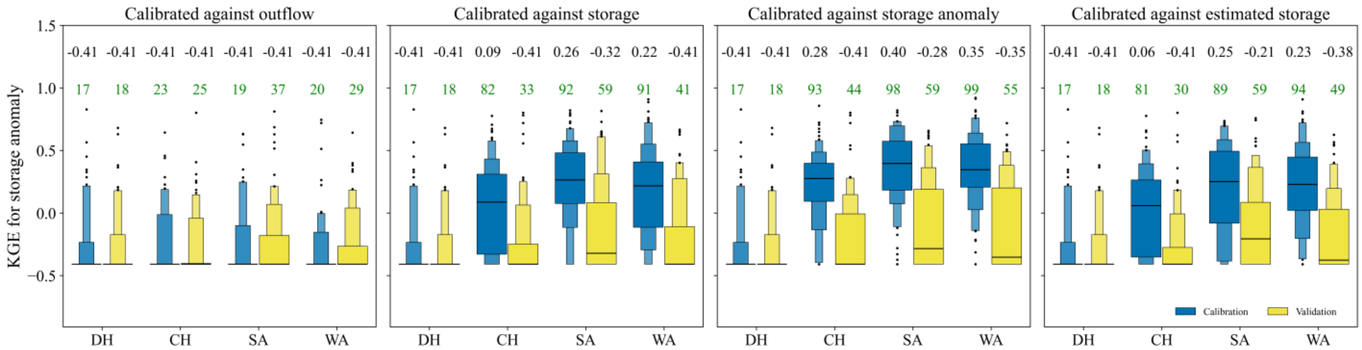

Figure S6. Letter-value plots of KGE for storage anomaly of 100 studied reservoirs for the DH, CH, SA, and WA algorithms for the calibration period (1980-2009, in blue) and validation period (2010-2019, in yellow). All algorithms are calibrated against outflow (first column), storage (second column), storage anomaly (third column), as well as estimated storage (fourth column) using KGE as the objective function. The black and green at the top of the panels represent the median KGE (indicated by the horizontal line) and the number of skillful simulations (KGE > -0.41), respectively. KGE values below the benchmark threshold of -0.41 are set to -0.41. The widest box contains 50% of the 100 data points, the second widest 25% of the data (12.5% in the upper box and 12.5% in the lower box), the third widest 12.5%, and so on. The inflow data is sourced from the WaterGAP model.

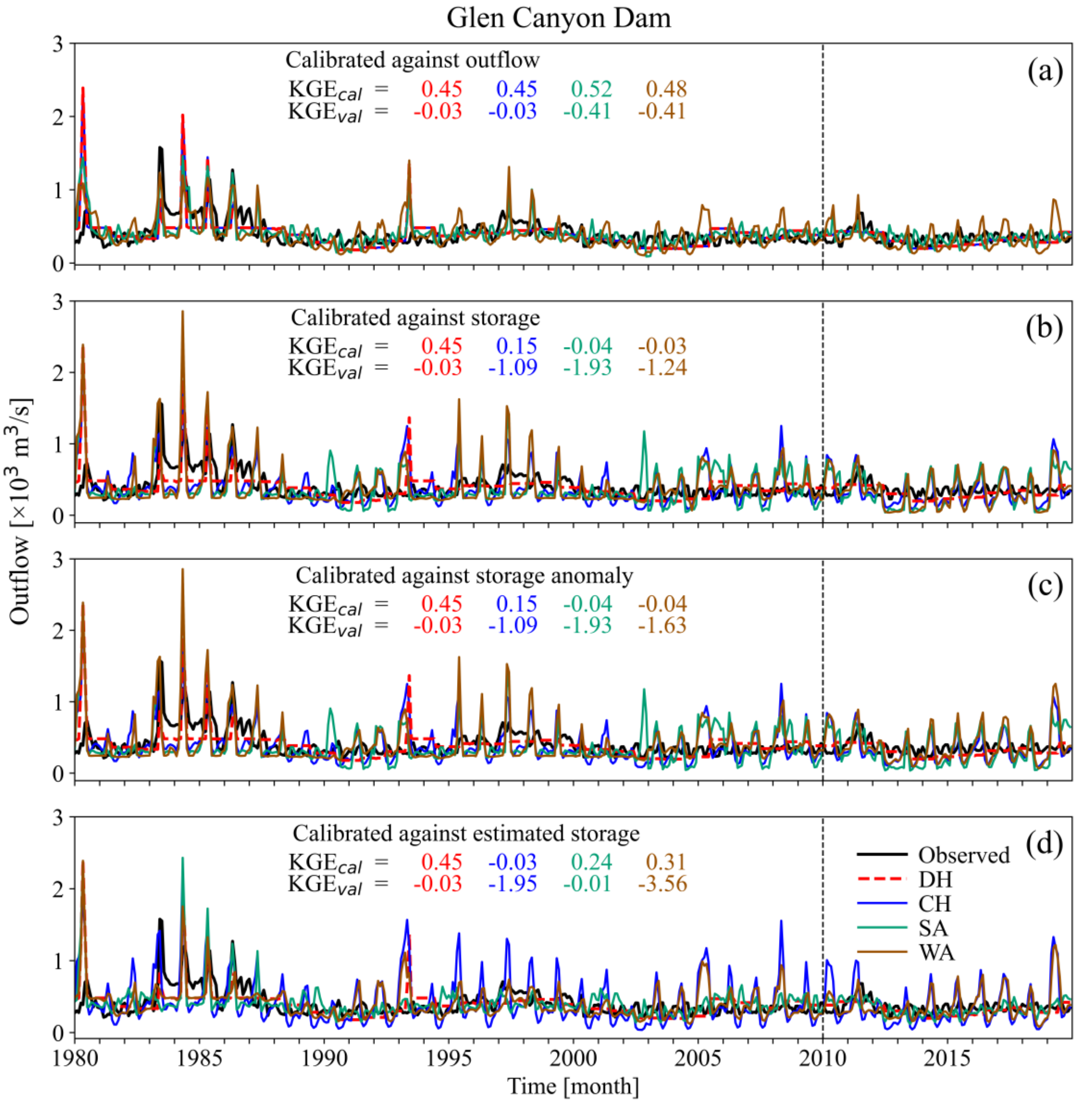

Figure S7. Monthly time series of observed and simulated outflow values from DH, CH, SA, and WA algorithms for Glen Canyon dam, GRanD ID 597, calibrated against (a) outflow, (b) storage, (c) storage anomaly, and (d) estimated storage using KGE as the objective function. The dashed black lines distinguish between the calibration and validation periods. The inflow data is sourced from the WaterGAP model.

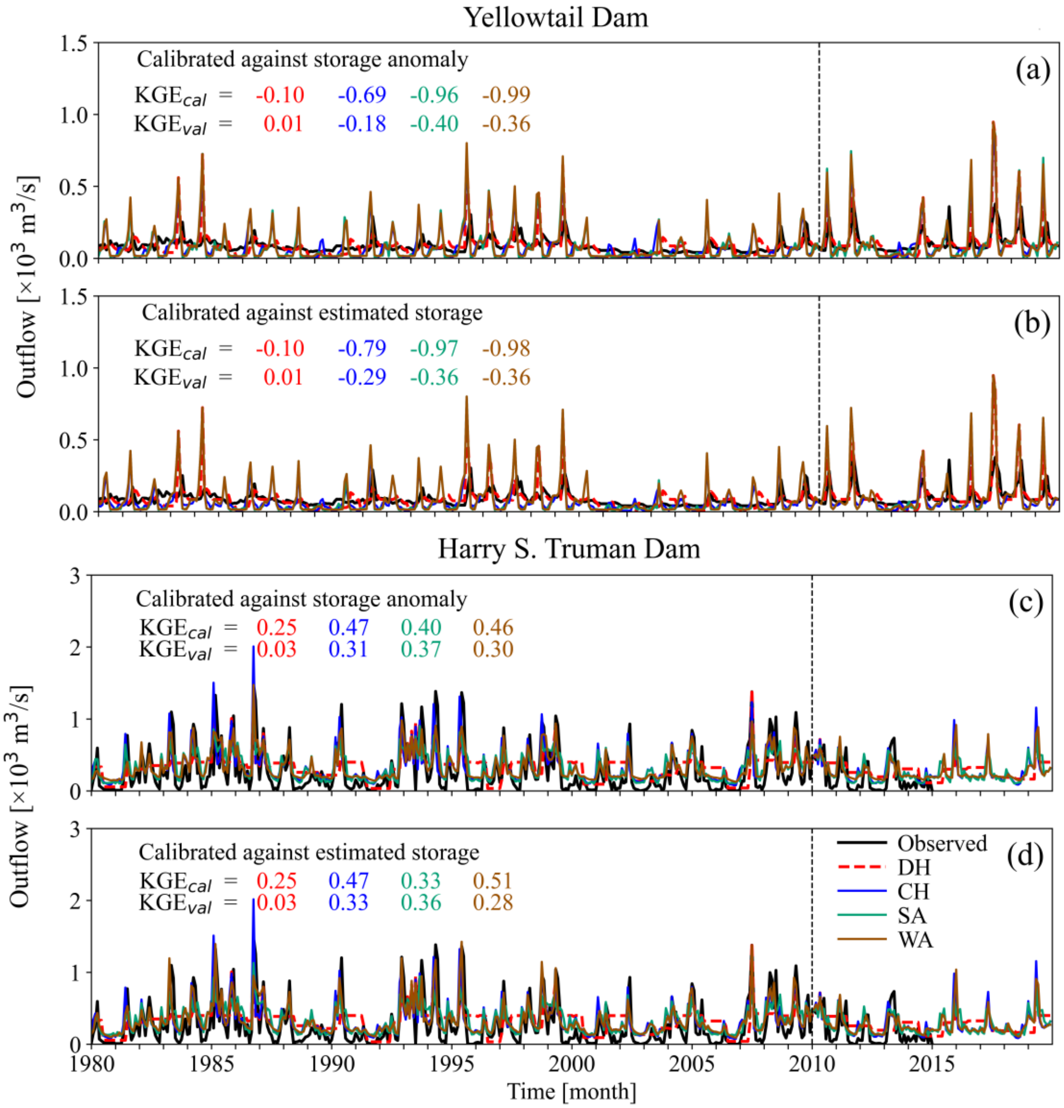

Figure S8. Monthly time series of observed and simulated outflow values from DH, CH, SA, and WA algorithms for Yellowtail/Harry S. Truman reservoirs, GRanD IDs 355/989, calibrated against (a, c) storage anomaly and (b, d) estimated storage using KGE as the objective function. The primary purposes of the Yellowtail Dam and the Harry S. Truman Dam are irrigation and hydropower, respectively. The dashed black lines distinguish between the calibration and validation periods. The inflow data is sourced from the WaterGAP model.

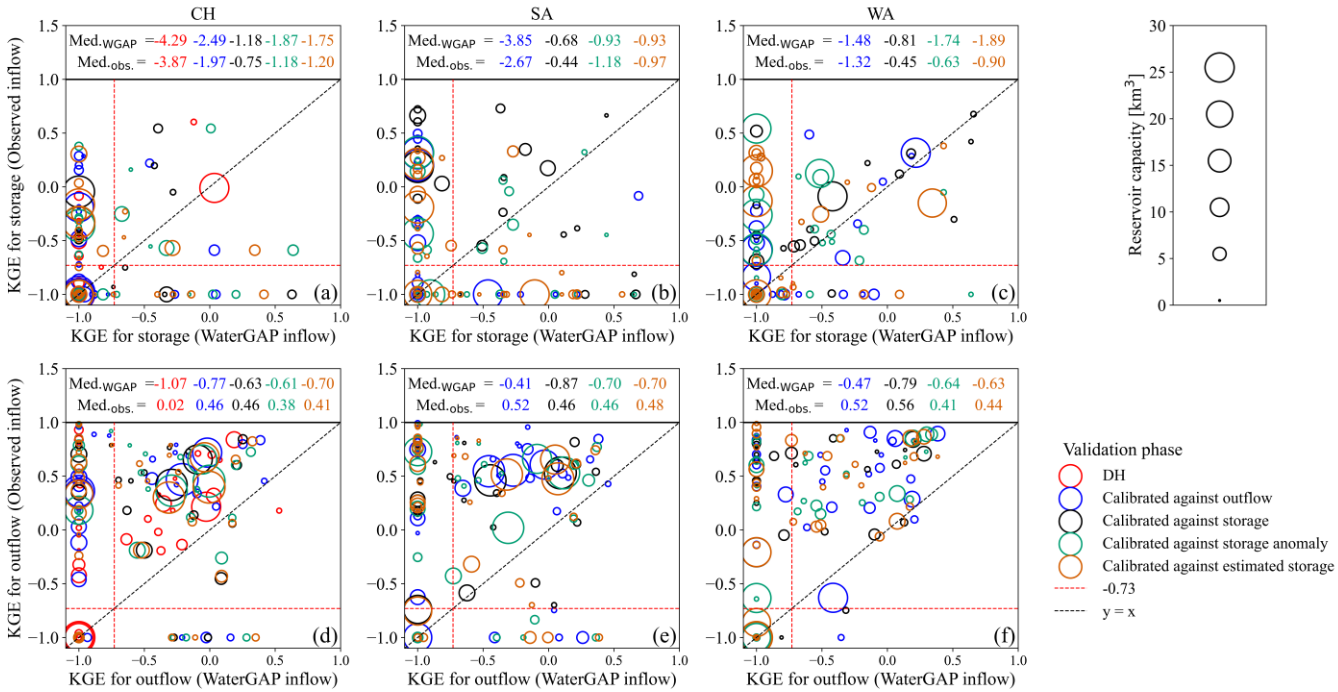

Figure S9. The relationship between KGE of (a-c) storage and (d-f) outflow obtained from modeling reservoirs using WaterGAP inflow and observed inflow for the validation period (2010-2019) for 35 reservoirs with observed inflow out of 100 studied reservoirs. KGE values less than -1 are set to -1. The KGE values for storage anomaly and estimated storage were not shown. The circle size indicates the reservoir capacity. The inner values indicate the median KGE. The dashed red lines indicate the KGE benchmark threshold of -0.73.

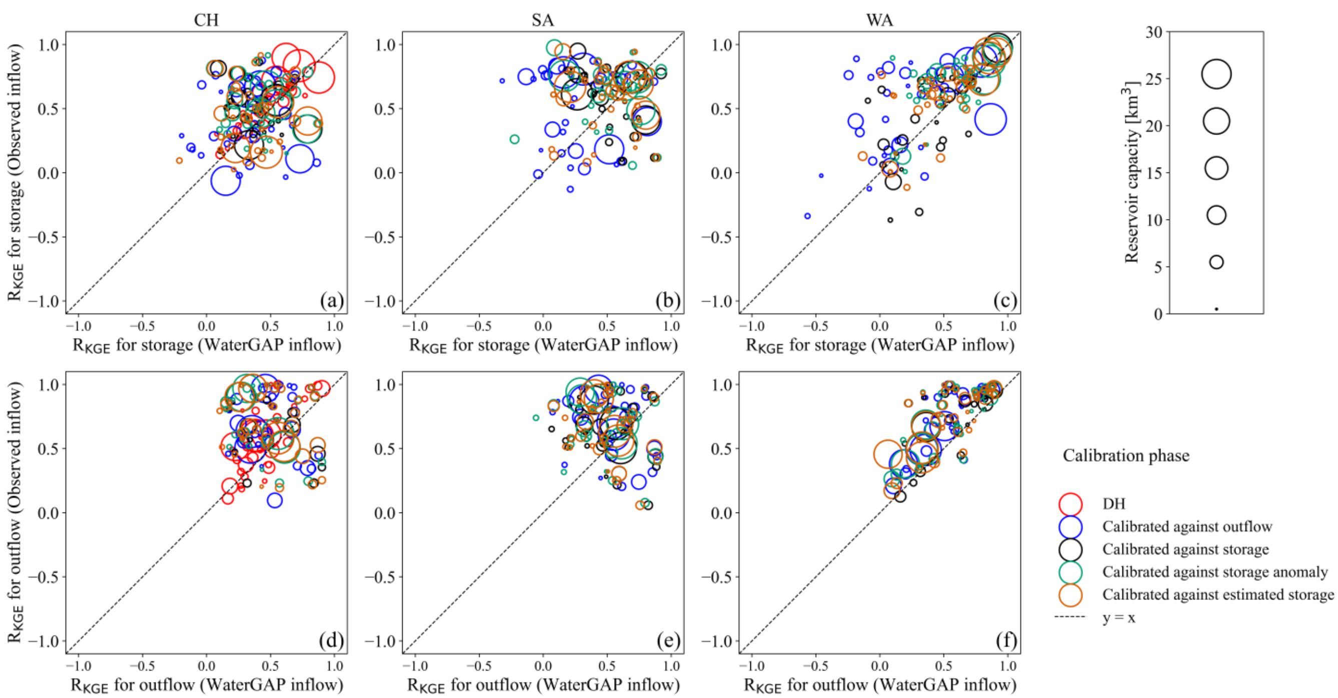

Figure S10. The relationship between R_{KGE} of (a-c) storage and (d-f) outflow obtained from modeling reservoirs using WaterGAP inflow and observed inflow for the calibration period (1980-2009) for 35 reservoirs with observed inflow out of 100 studied reservoirs. The R_{KGE} values for storage anomaly and estimated storage were not shown. The circle size indicates the reservoir capacity.

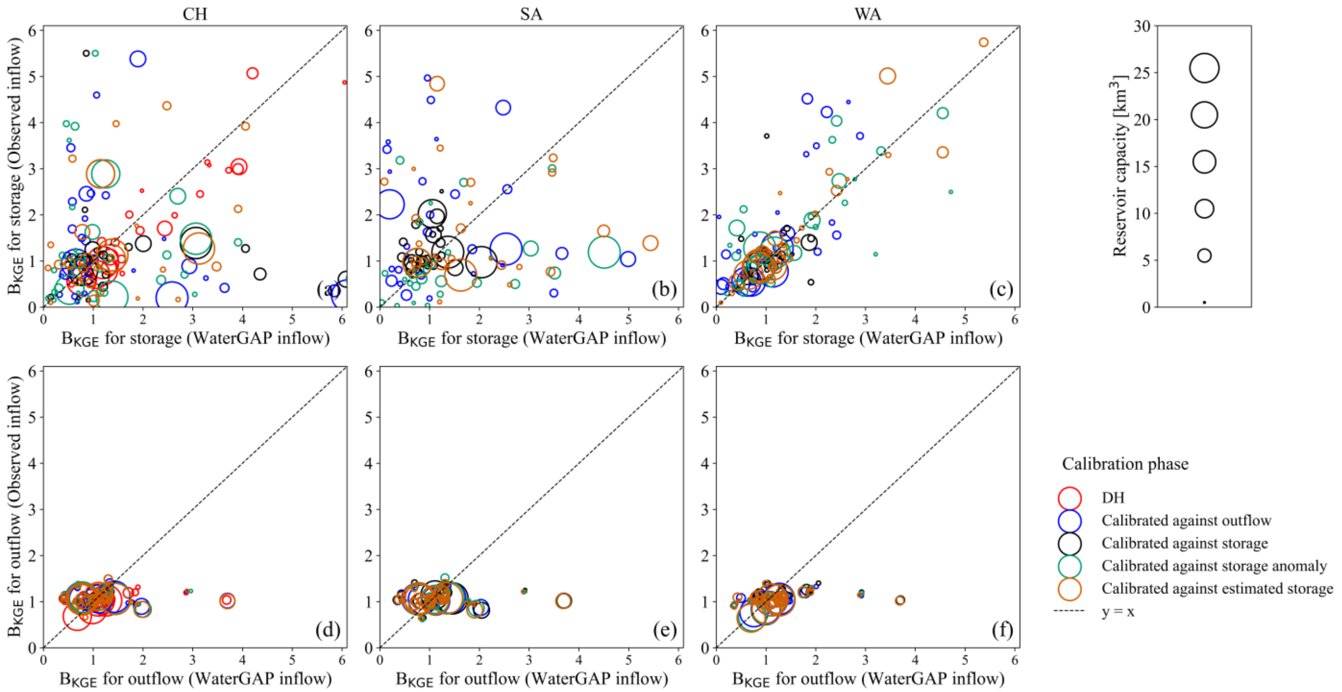

Figure S11. The relationship between B_{KGE} of (a-c) storage and (d-f) outflow obtained from modeling reservoirs using WaterGAP inflow and observed inflow for the calibration period (1980-2009) for 35 reservoirs with observed inflow out of 100 studied reservoirs. B_{KGE} values greater than 6 are set to 6. The B_{KGE} values for storage anomaly and estimated storage were not shown. The circle size indicates the reservoir capacity.

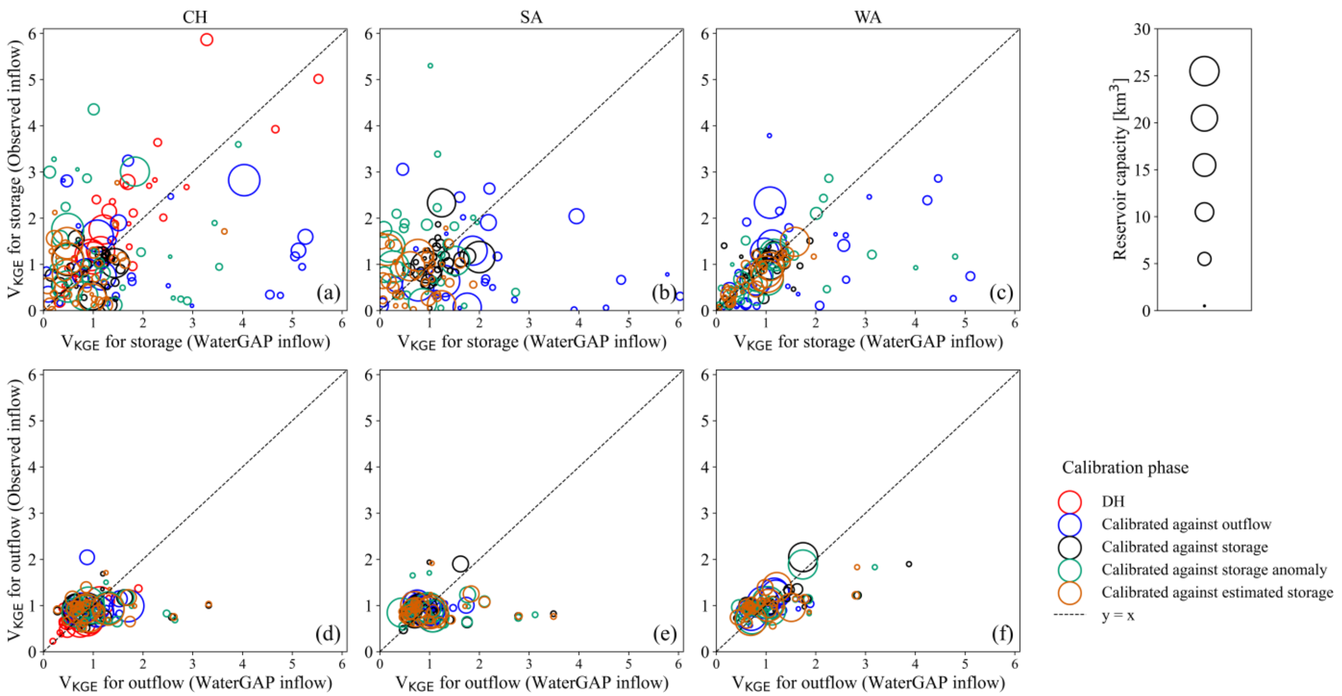

Figure S12. The relationship between V_{KGE} of (a-c) storage and (d-f) outflow obtained from modeling reservoirs using WaterGAP inflow and observed inflow for the calibration period (1980-2009) for 35 reservoirs with observed inflow out of 100 studied reservoirs. V_{KGE} values greater than 6 are set to 6. The V_{KGE} values for storage anomaly and estimated storage were not shown. The circle size indicates the reservoir capacity.

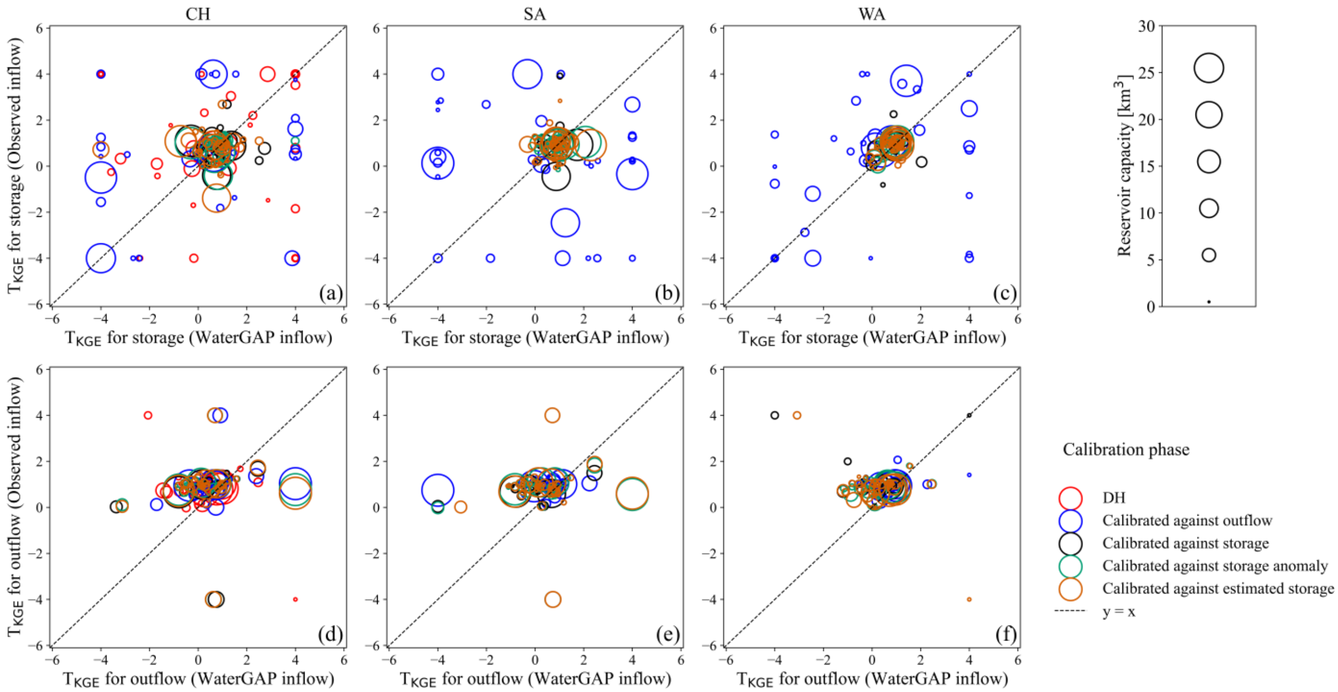

Figure S13. The relationship between T_{KGE} of (a-c) storage and (d-f) outflow obtained from modeling reservoirs using WaterGAP inflow and observed inflow for the calibration period (1980-2009) for 35 reservoirs with observed inflow out of 100 studied reservoirs. T_{KGE} values greater (less) than 6 (-6) are set to 6 (-6). The T_{KGE} values for storage anomaly and estimated storage were not shown. The circle size indicates the reservoir capacity.

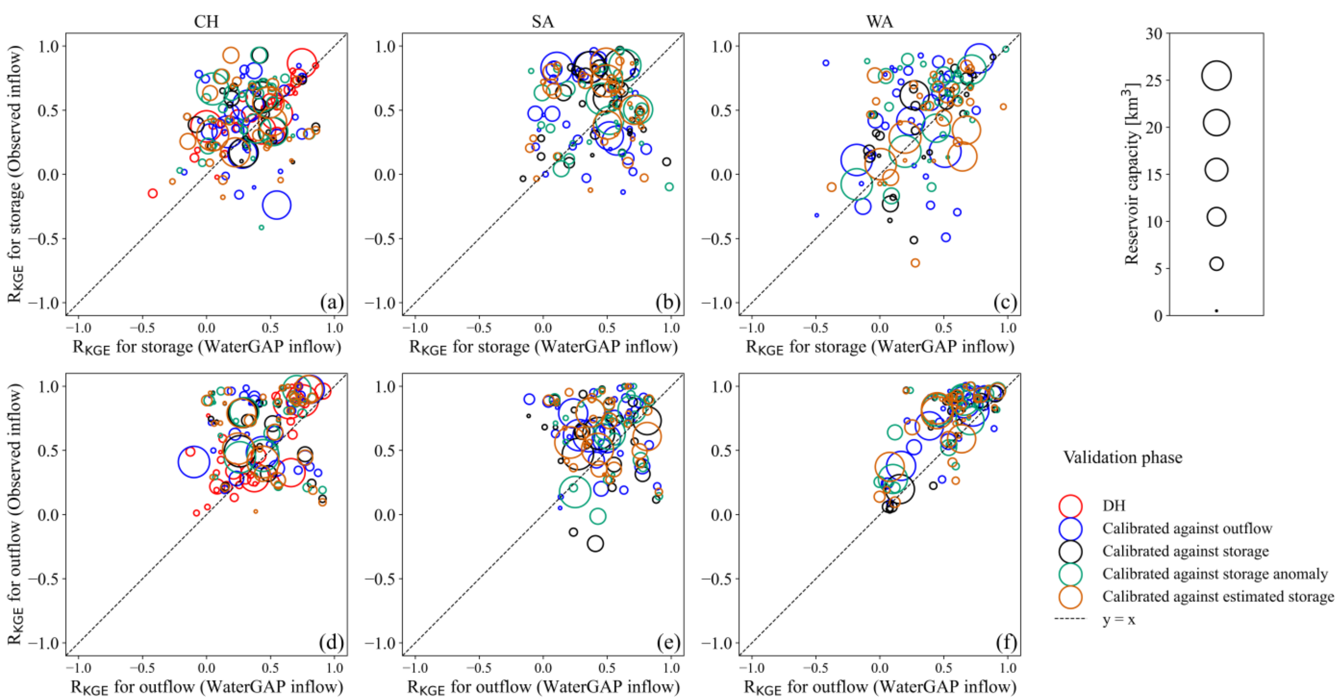

Figure S14. The relationship between R_{KGE} of (a-c) storage and (d-f) outflow obtained from modeling reservoirs using WaterGAP inflow and observed inflow for the validation period (2010-2019) for 35 reservoirs with observed inflow out of 100 studied reservoirs. The R_{KGE} values for storage anomaly and estimated storage were not shown. The circle size indicates the reservoir capacity.

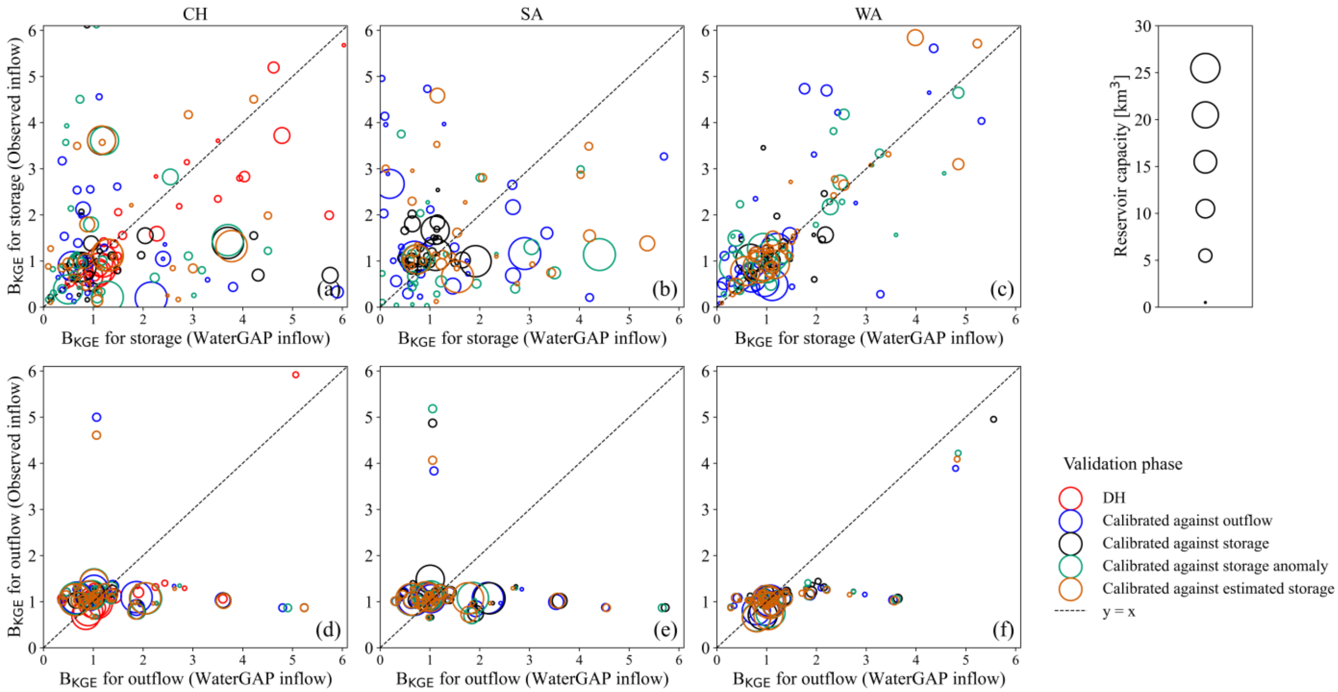

Figure S15. The relationship between B_{KGE} of (a-c) storage and (d-f) outflow obtained from modeling reservoirs using WaterGAP inflow and observed inflow for the validation period (2010-2019) for 35 reservoirs with observed inflow out of 100 studied reservoirs. B_{KGE} values greater than 6 are set to 6. The B_{KGE} values for storage anomaly and estimated storage were not shown. The circle size indicates the reservoir capacity.

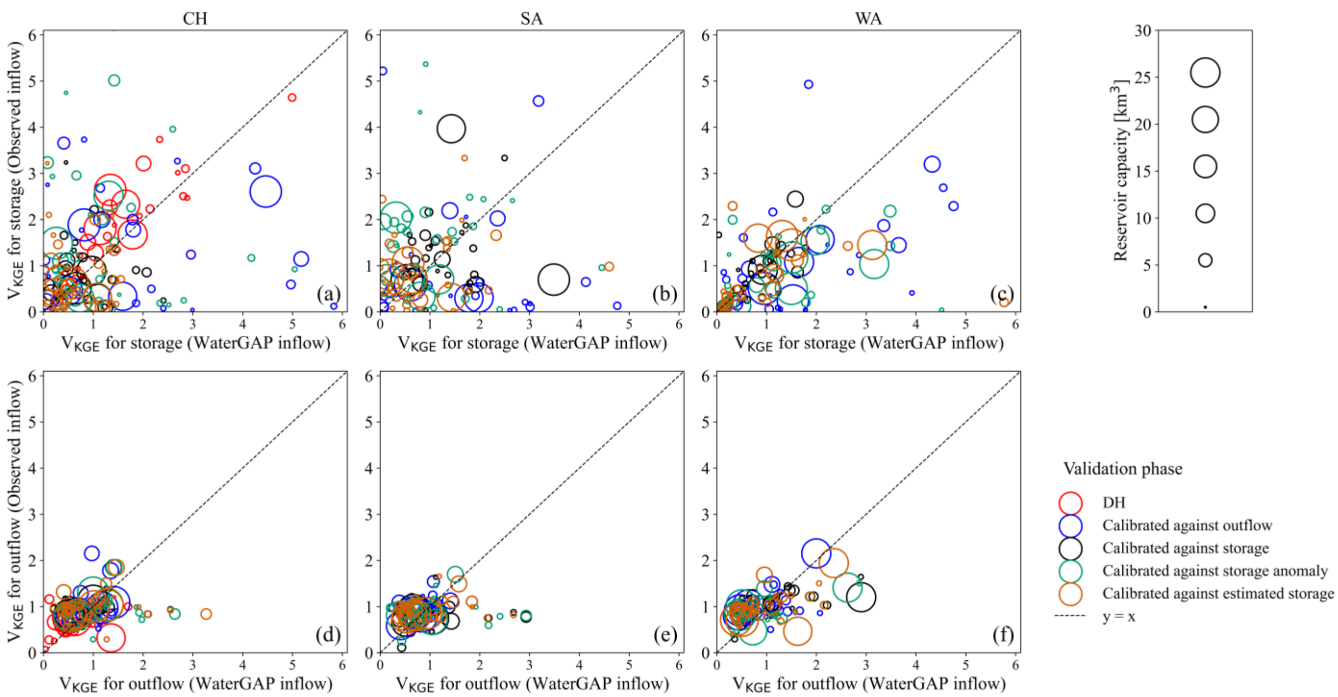

Figure S16. The relationship between V_{KGE} of (a-c) storage and (d-f) outflow obtained from modeling reservoirs using WaterGAP inflow and observed inflow for the validation period (2010-2019) for 35 reservoirs with observed inflow out of 100 studied reservoirs. V_{KGE} values greater than 6 are set to 6. The V_{KGE} values for storage anomaly and estimated storage were not shown. The circle size indicates the reservoir capacity.

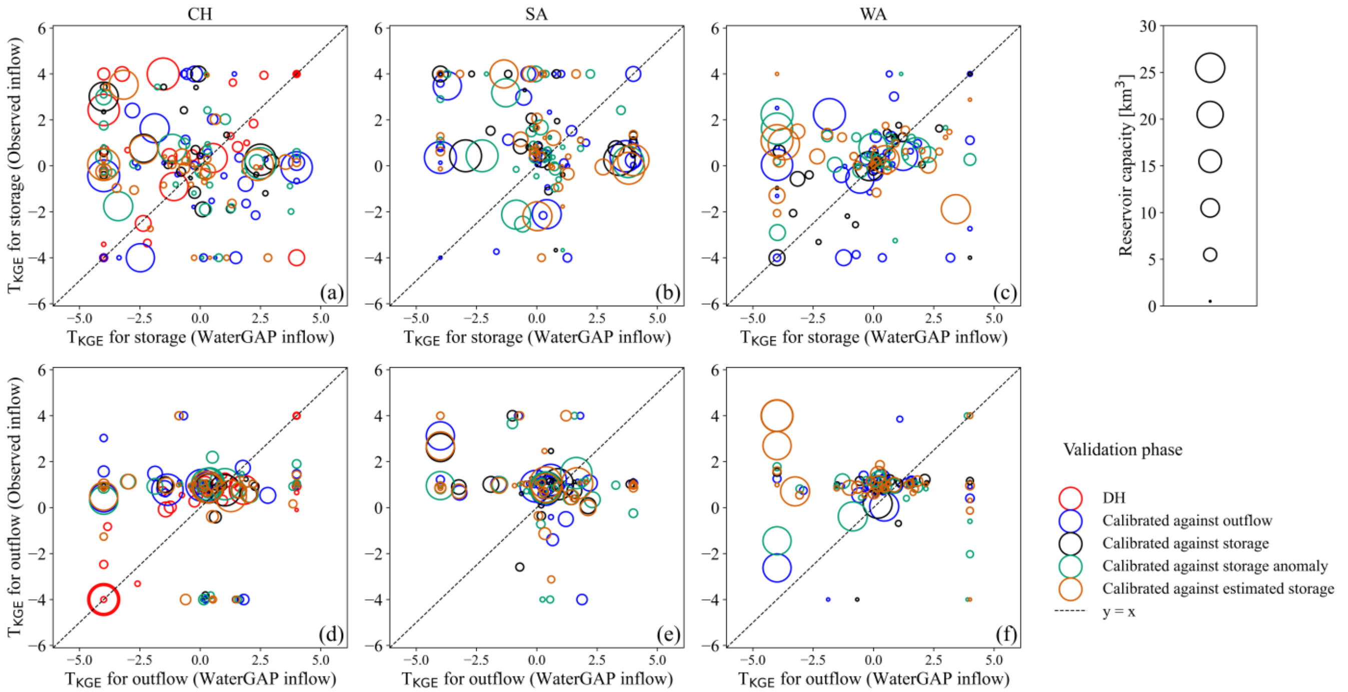

Figure S17. The relationship between T_{KGE} of (a-c) storage and (d-f) outflow obtained from modeling reservoirs using WaterGAP inflow and observed inflow for the validation period (2010-2019) for 35 reservoirs with observed inflow out of 100 studied reservoirs. T_{KGE} values greater (less) than 6 (-6) are set to 6 (-6). The T_{KGE} values for storage anomaly and estimated storage were not shown. The circle size indicates the reservoir capacity.

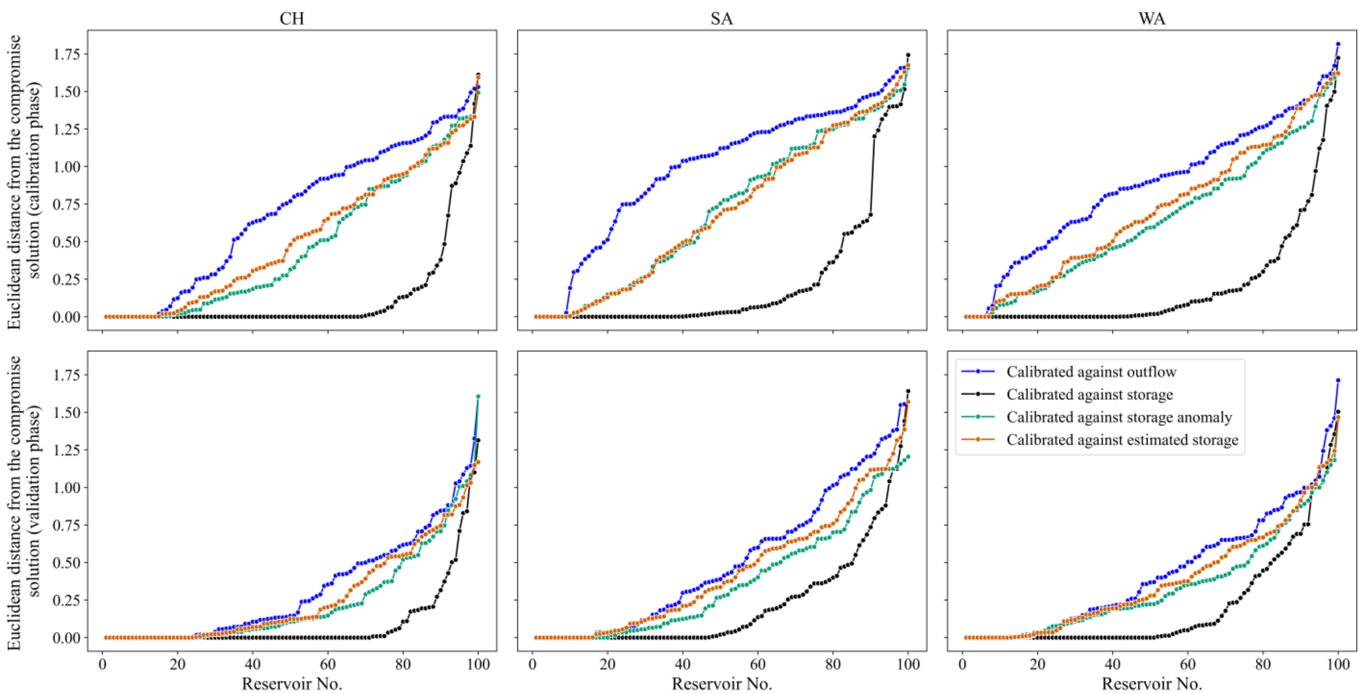

Figure S18. The Euclidean distance between the $KGE_{storage}$ and $KGE_{outflow}$ values obtained from different calibration variants and the $KGE_{storage}$ and $KGE_{outflow}$ values from the compromise solution for each variant, for the calibration period (first row: 1980-2009) and the validation period (second row: 2010-2019) across 100 studied reservoirs. KGE values less than -1 are set to -1 before calculating the distance. The compromise solution is defined as the solution with the minimum Euclidean distance from the optimal KGE value (KGE equals 1) for both storage and outflow. The inflow data is sourced from the WaterGAP model.

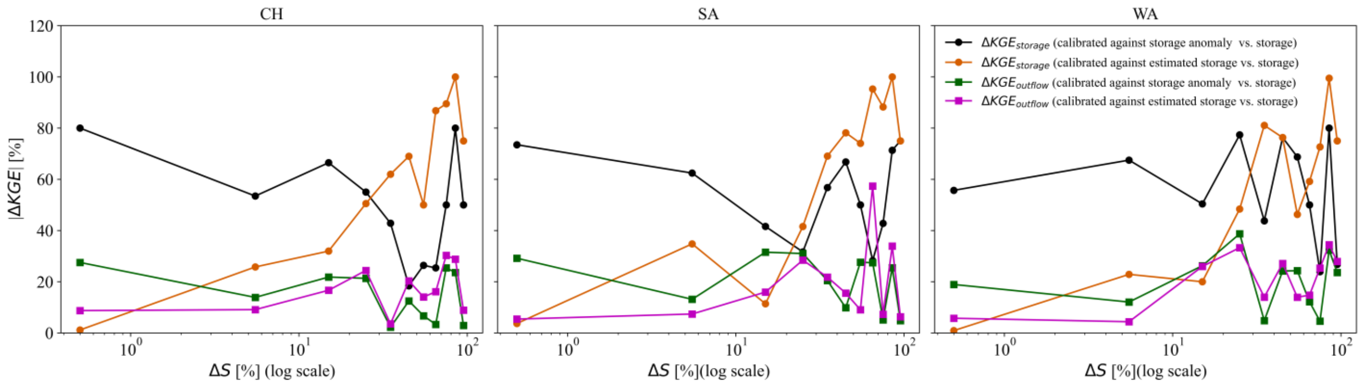

Figure S19. Changes in KGE values when calibrated against storage anomaly/estimated storage compared to actual storage, versus differences between reservoir capacities reported by GRanD and observed maximum daily storage. The ΔKGE is calculated as the absolute difference between the KGE values obtained from calibrating against storage anomaly/estimated storage and those obtained from calibrating against actual storage, divided by the KGE value from calibration against actual storage. ΔS is calculated as the absolute difference between the reservoir capacity and the maximum daily observed storage, divided by the maximum observed daily storage. ΔKGE values are averaged over bins of 10% differences in ΔS, with differences less than 1% treated as a separate bin. The x-axis has a logarithmic scale.

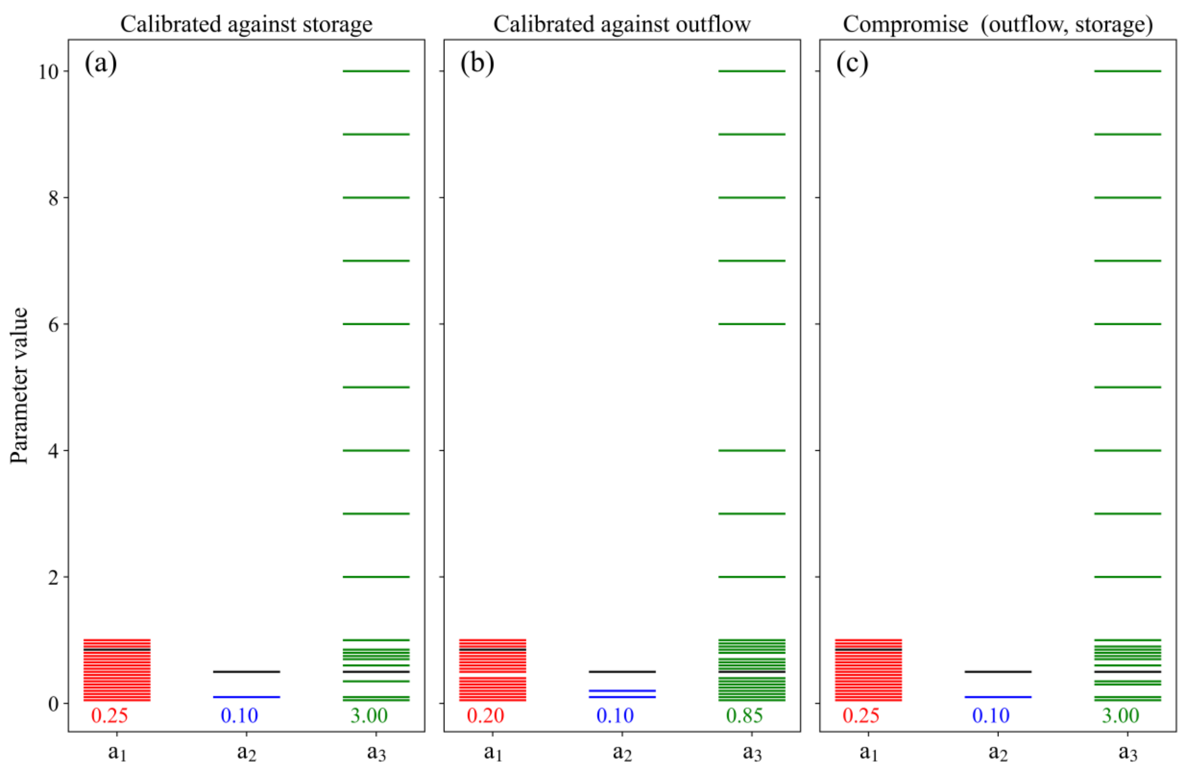

Figure S20. The calibrated parameters for the Hanasaki algorithm are compared to default values based on calibration against (a) outflow, (b) storage, and (c) a compromise between outflow and storage. The default values for a_1, a_2, and a_3 are 0.85, 0.5, and 0.5, respectively. a_2 is only included in irrigation reservoirs. The calibrated parameters $a_1$and a_3 are obtained from 100 reservoirs, while for a_2 is derived from only nine reservoirs primarily used for irrigation. The values at the bottom of the panels indicate the median KGE for the calibrated parameters.

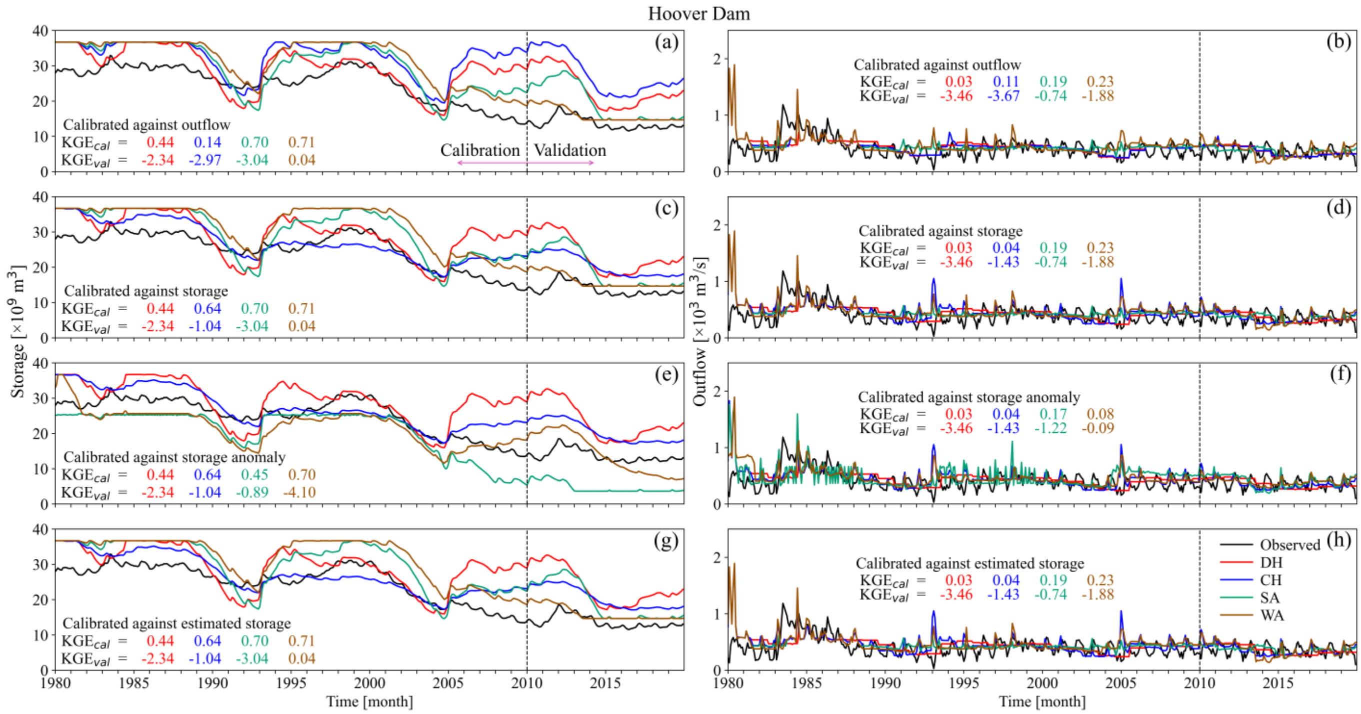

Figure S21. Monthly time series of observed storage and outflow, as well as simulated values from DH, CH, SA, and WA algorithms for Hoover dam, GRanD ID 610, calibrated against (a, b) outflow, (c, d) storage, (e, f) storage anomaly, and (g, h) estimated storage using KGE as the objective function. The dashed black lines distinguish between the calibration and validation periods. The inflow data is sourced from the WaterGAP model.