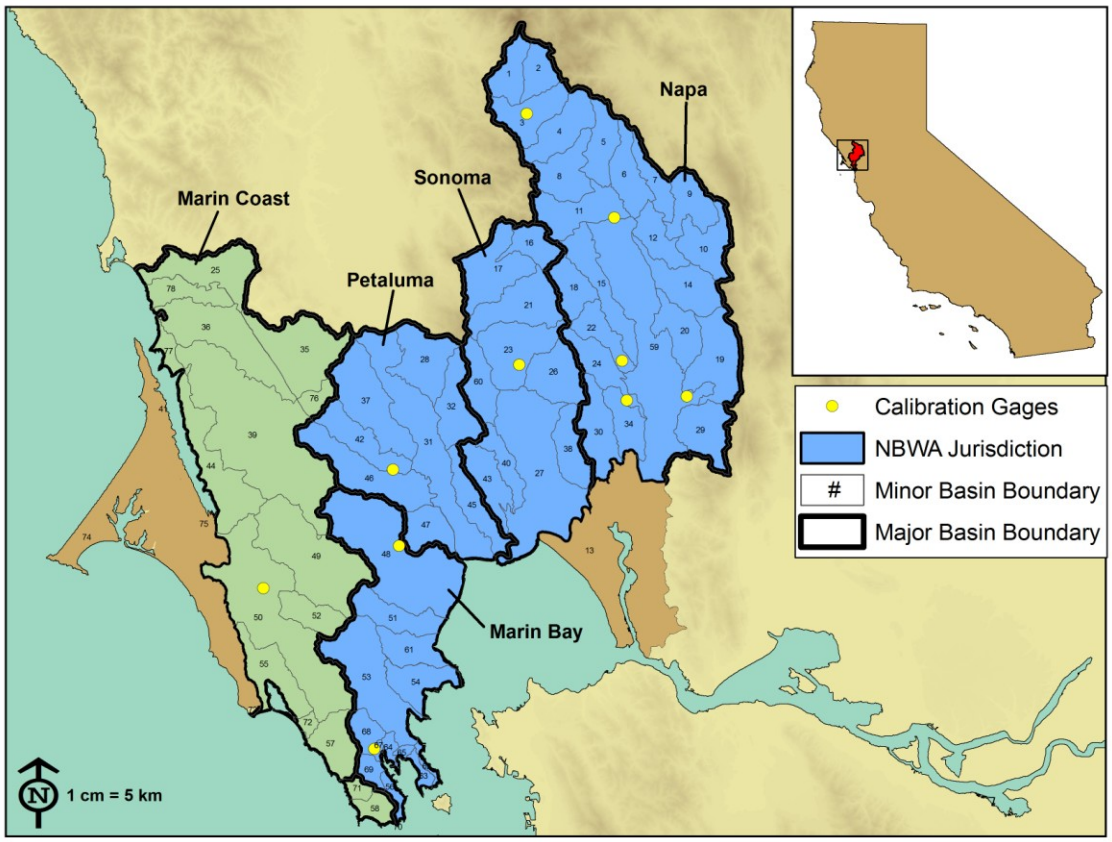
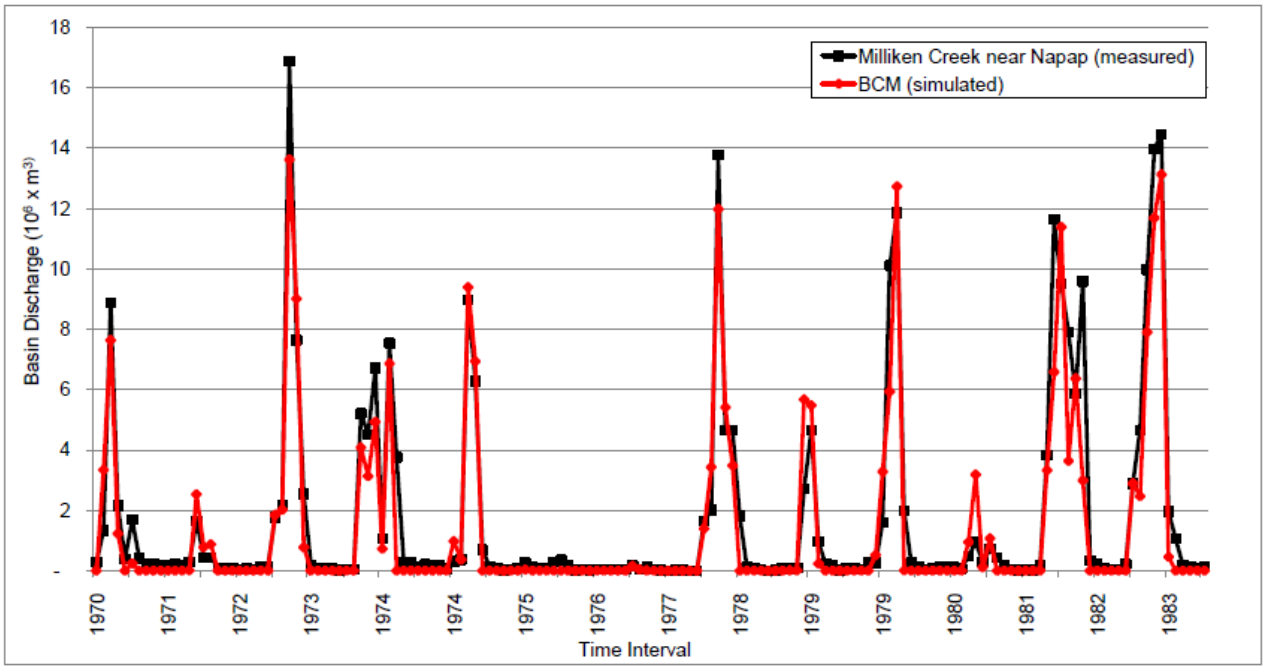
Downscaling future climate scenarios to the watershed scale: a North San Franscisco Bay Estuary case study
FIGURES and TABLES

Figure 1 Site Location



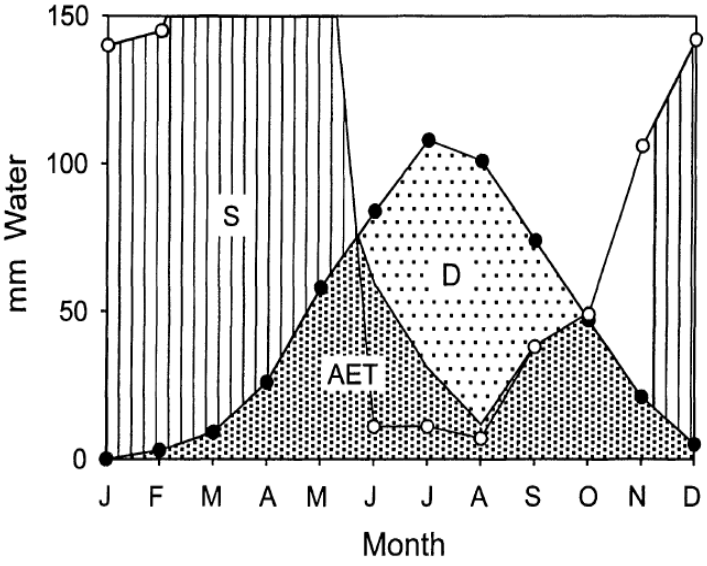
Map of study area delineating major and minor basins analyzed using Basin Characterization Model (BCM). Blue shading defines North Bay Watershed Association (NBWA) jurisdiction which we term "North Bay region" for this study. Labels with arrows identify major basins. Small numbers label minor basins identified by name in Appendix A. Yellow circles show location of USGS gages used for model calibration listed in Table 1.

Figure 2 Model calibration example: comparison of modeled and measured monthly stream discharge, Milliken Creek, Napa River basin, 1970-1983



Monthly stream discharge measured at the USGS gage 11458100 (Milliken Creek near Napa) in black (square labels) compared to Basin Characterization Model (BCM) stream discharge measurements in red (diamond labels) produced via calibration run. Each gage shown in Figure 1 was used for model calibration to ensure the BCM effectively captures magnitude and timing of peaks in monthly discharge.

Figure 3 Climatic water deficit



Climatic water deficit quantifies evaporative demand exceeding available soil moisture, where *S* = soil moisture, *AET* = actual evapotranspiration, *D* =climatic water deficit. After Stephenson 1998.

Figure 4A-C Average annual precipitation and maximum and minimum temperatures, North Bay region, 1971-2000

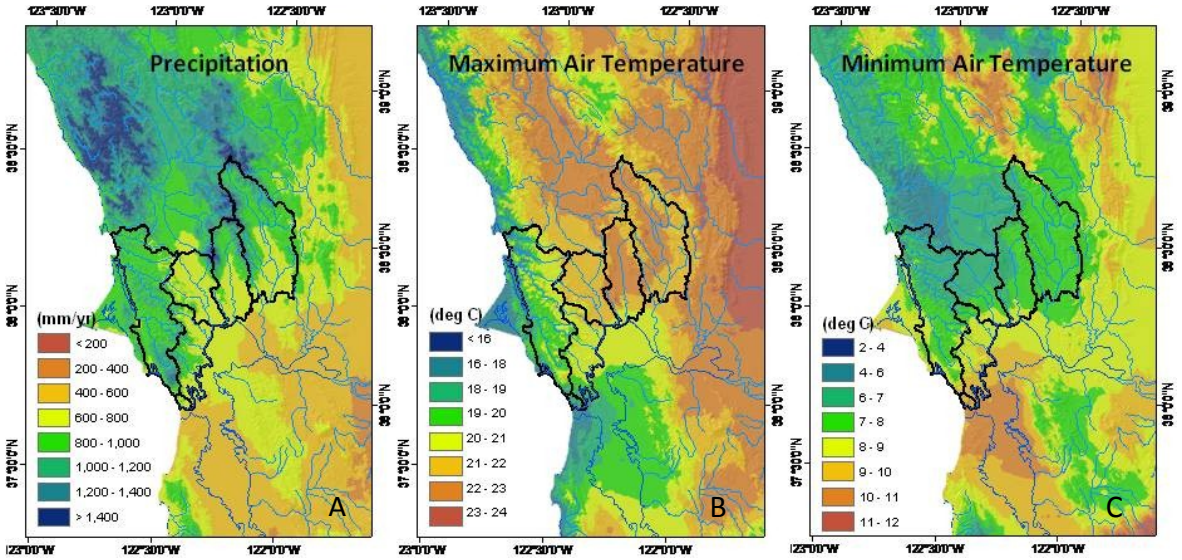
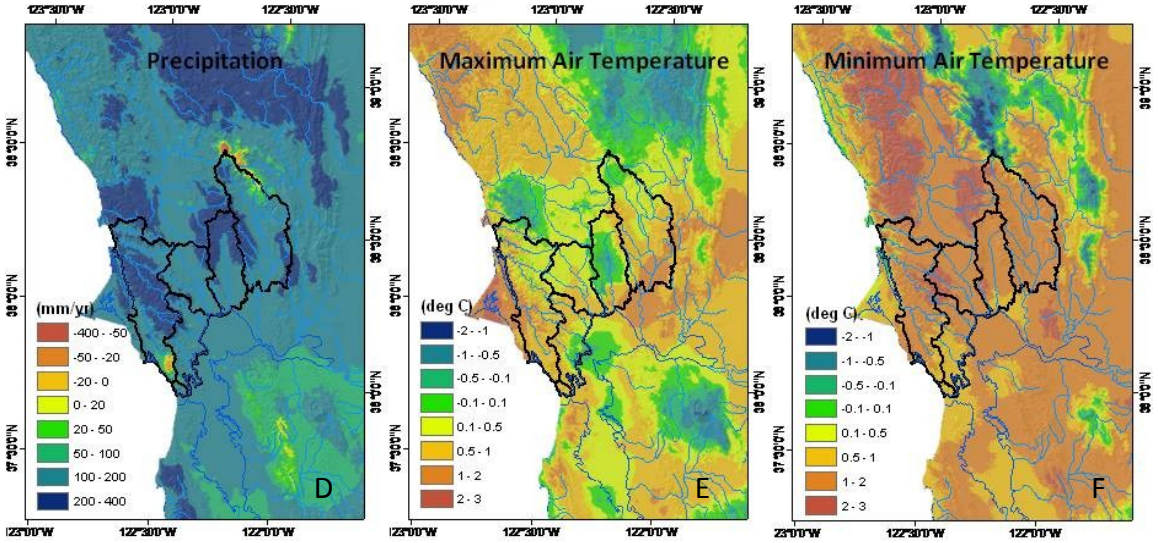


Figure 4D-F Direction and magnitude of change in annual average precipitation and maximum and minimum temperatures, North Bay region, 1971-2000



Trend analysis for precipitation and temperature across North Bay region based on based on monthly PRISM data downscaled to 270 m for 1971-2000. Series A-C shows average annual values and series D-F shows total change for this time period. Major basins are delineated in black outline. A-C display a decreasing precipitation gradient from the coast and montane headwaters to inland valleys, an increasing gradient in maximum temperatures from coast (18-19 °C) to inland (22-23 °C), and relatively consistent trends across the region in minimum temperatures. D-E display an increase of approximately 50-200 mm in precipitation, a variable trend in maximum temperatures, and more intensive increases in minimum temperature (on the order to 1-2 °C) across the region.

Figure 5A Historic (1901-2000) and GCM-projected (2001-2100) maximum temperatures

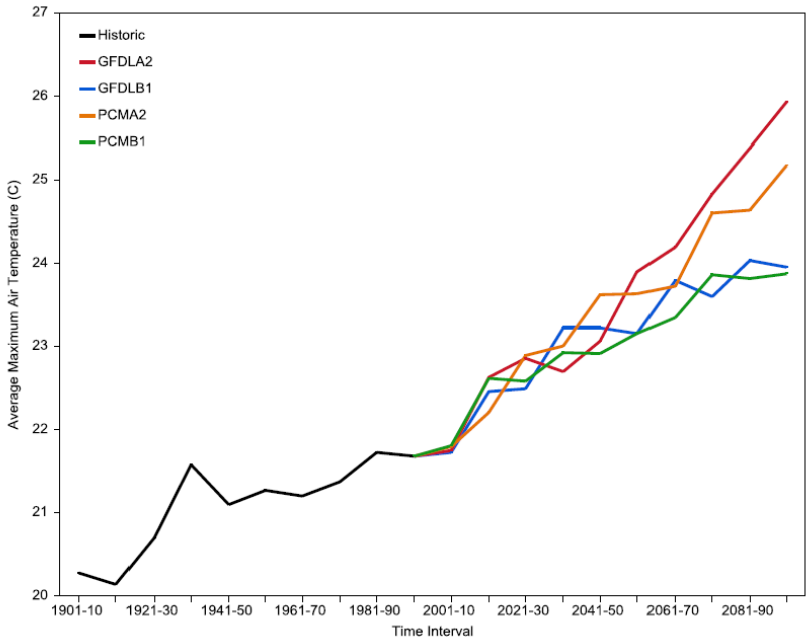
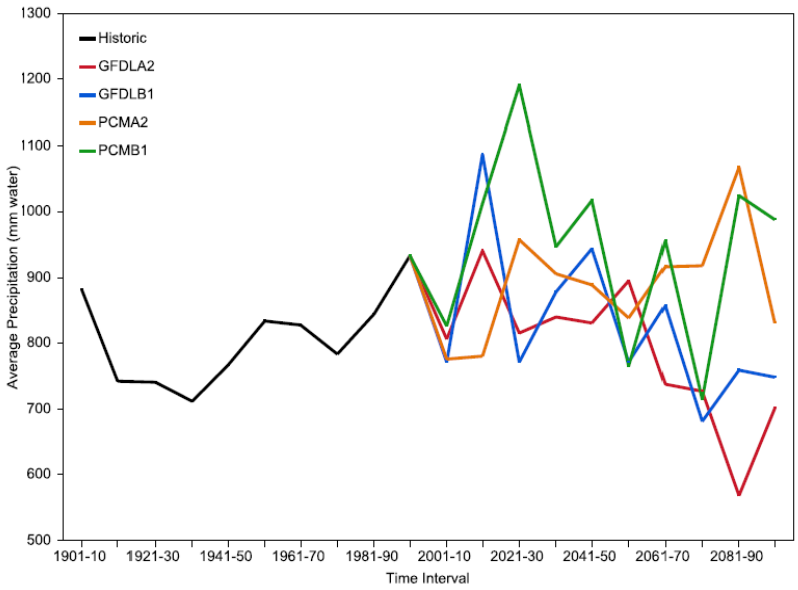
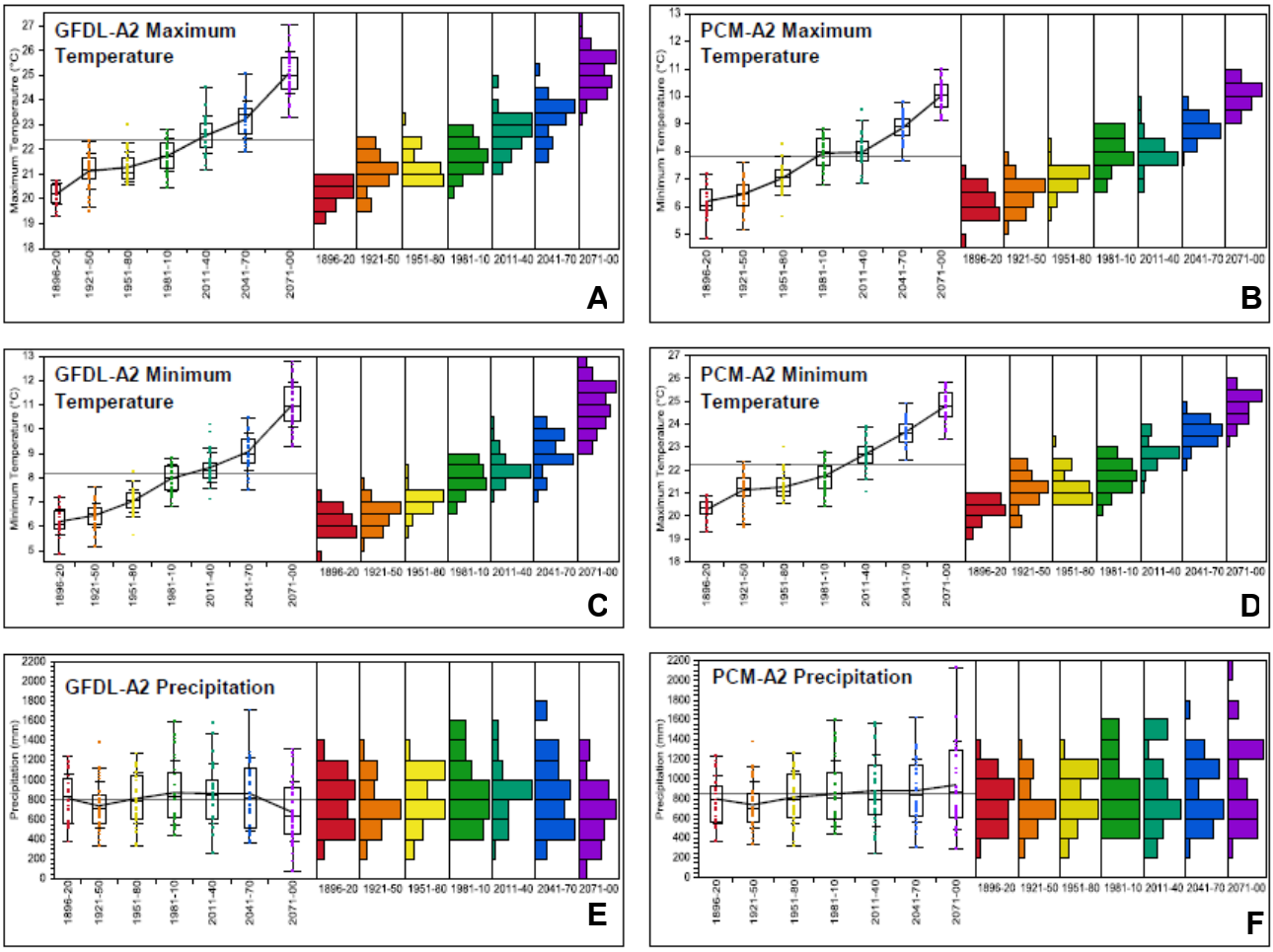


Figure 5B Historic (1901-2000) and GCM-projected (2001-2100) precipitation



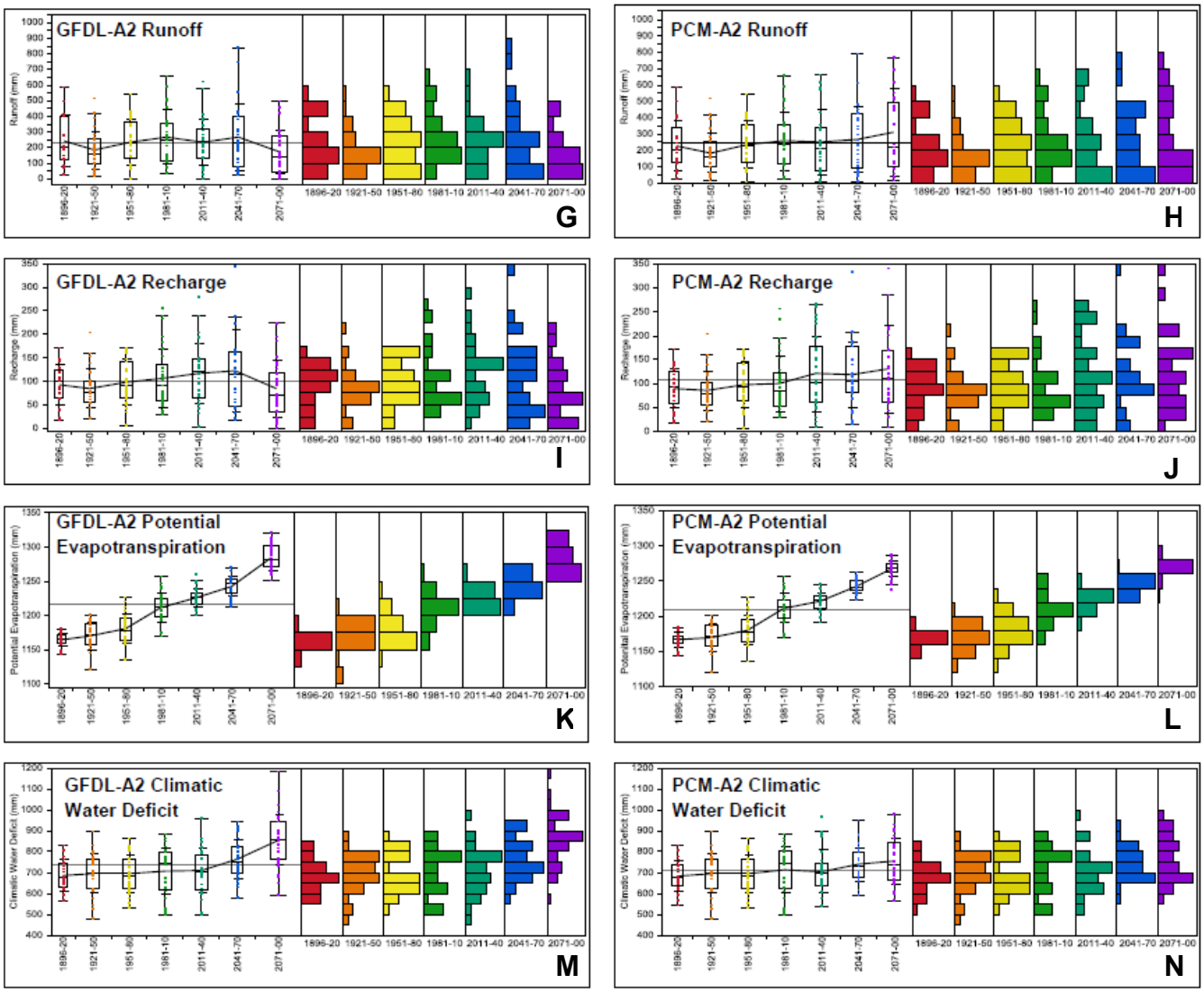
General Circulation Model (GCM) temperature and precipitation outputs downscaled to North Bay region based on monthly values averaged over decade intervals. Historic values derived from PRISM. Projected data series (2001-2100) represent four combinations of GCM model (GFDL or PCM) and emissions scenario (A2 “business as usual”, B1 “mitigated’) as identified in legend.

Figure 6A-F Historic (1896-2009) and projected (2010-2100) temperature and precipitation, North Bay region, GFDL A2 and PCM A2 scenarios



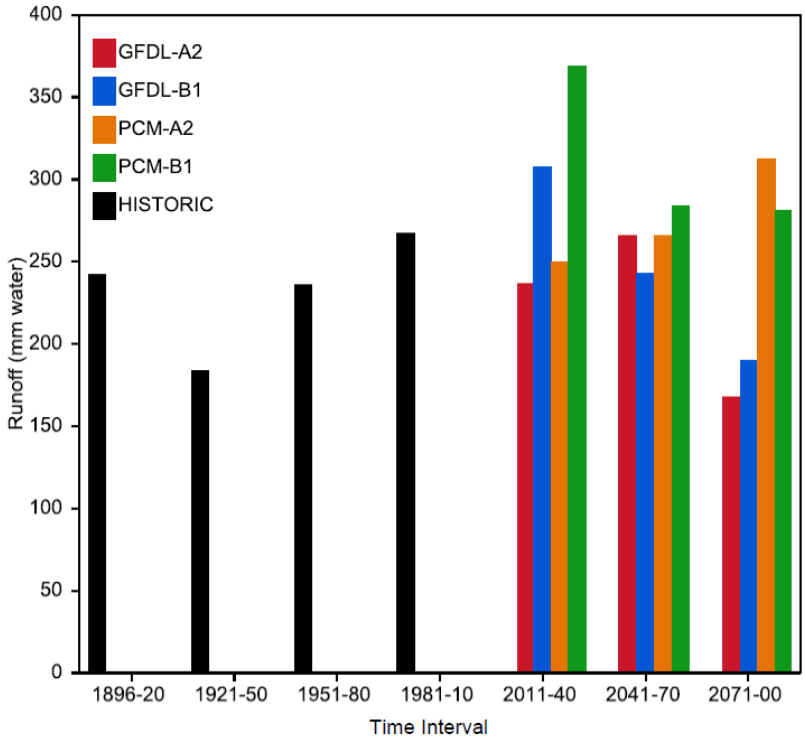
Historic values (1896-2009) for temperature and precipitation derived from PRISM, projected values for temperature and precipitation derived from downscaled GCMs (GFDL A2 “warmer drier” and PCM A2 “warmer wetter” scenarios, 2010-2100). Box plots represent 30-year intervals and are sized to the standard deviation, “whiskers” define the 5-95% confidence interval, and histograms show the frequency distributions of average annual values.

Figure 6G-N Historic (1896-2009) and projected (2010-2100) hydrology, BCM estimates, North Bay region, GFDL-A2 and PCM A-2 scenarios



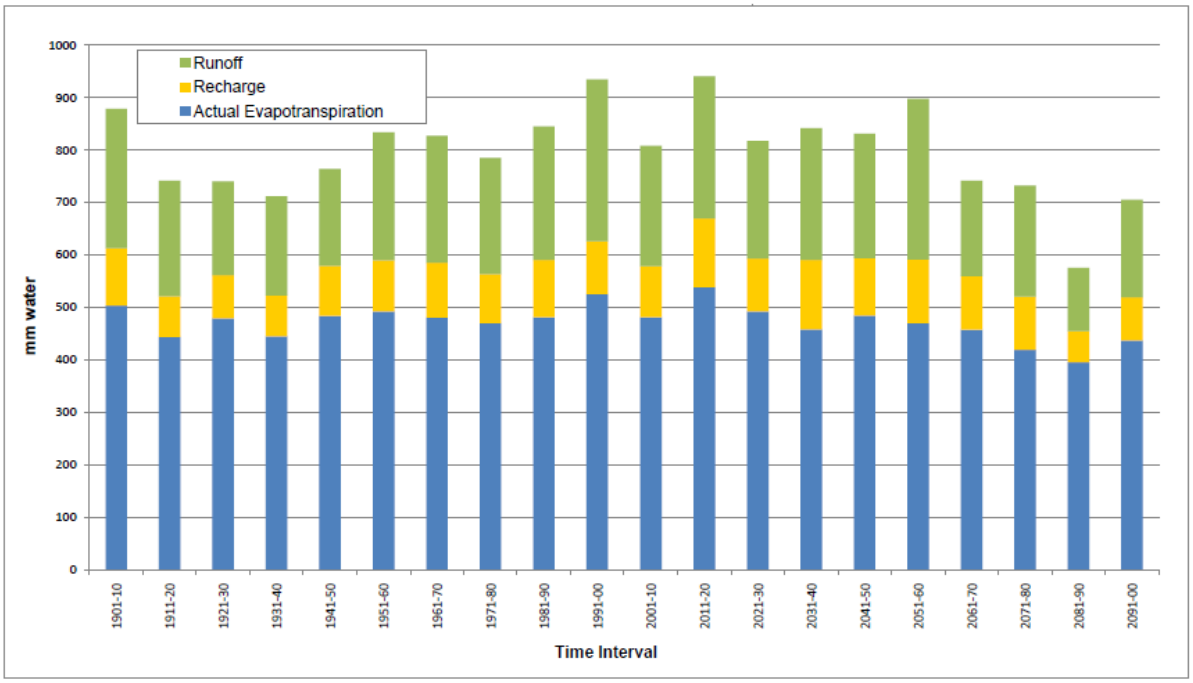
Hydrologic parameters of runoff (G-H), recharge (I-J), evapotranspiration (K-L), and water deficit (M-N) are derived from Basin Characterization Model (BCM) simulations using PRISM data for historic values (1896-2009) and using downscaled GCMs (GFDL A2 “warmer drier” (G, I, K, M) and PCM A2 “warmer wetter” (H, J, L, N)) for future projections (2010-2100). Box plots represent 30-year intervals and are sized to the standard deviation, “whiskers” define the 5-95% confidence interval, and histograms show the frequency distributions of average annual values.

Figure 7 A comparison of historic (1896-2009) to projected (2010-2100) average annual runoff for four future climate scenarios, North Bay region



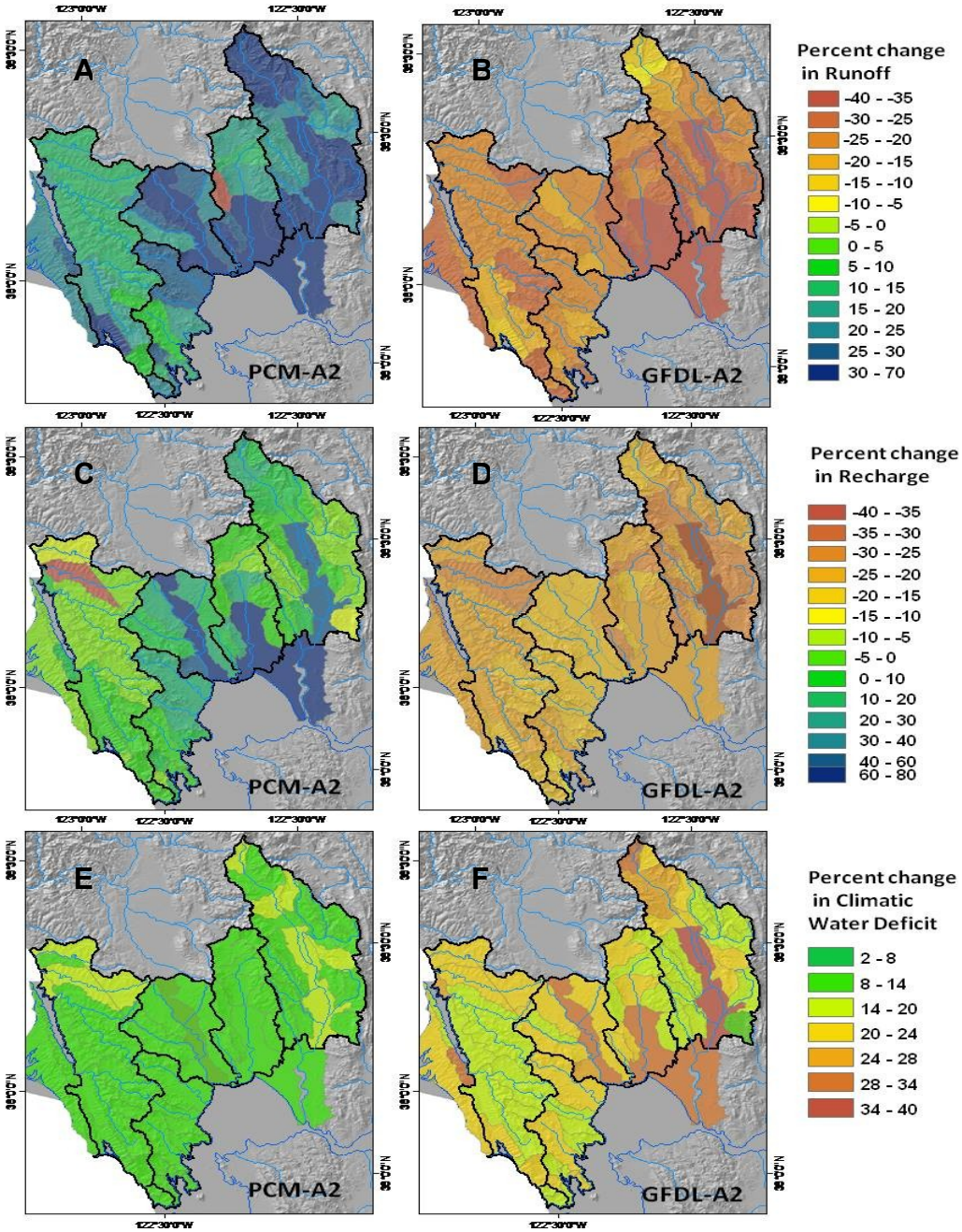
Each bar represents average annual runoff estimated by the Basin Characterization Model (BCM) for the North Bay region (NBWA jurisdiction) over the defined time interval, with black bars derived from PRISM data (1896-2009) and colored bars derived from GCM projections. For the three projected time periods, the first (2011-2040) shows a case where the B1 scenarios are significantly wetter than the A1 scenarios, the second (2041-2070) shows a case where all scenarios are comparable in terms of projected runoff, while the third (2071-2100) demonstrates a case where the PCM projections are significantly wetter than the GFDL projections for both emissions scenarios.

Figure 8 Historic (1896-2009) versus projected (2010-2100) water balance partitioning, North Bay region



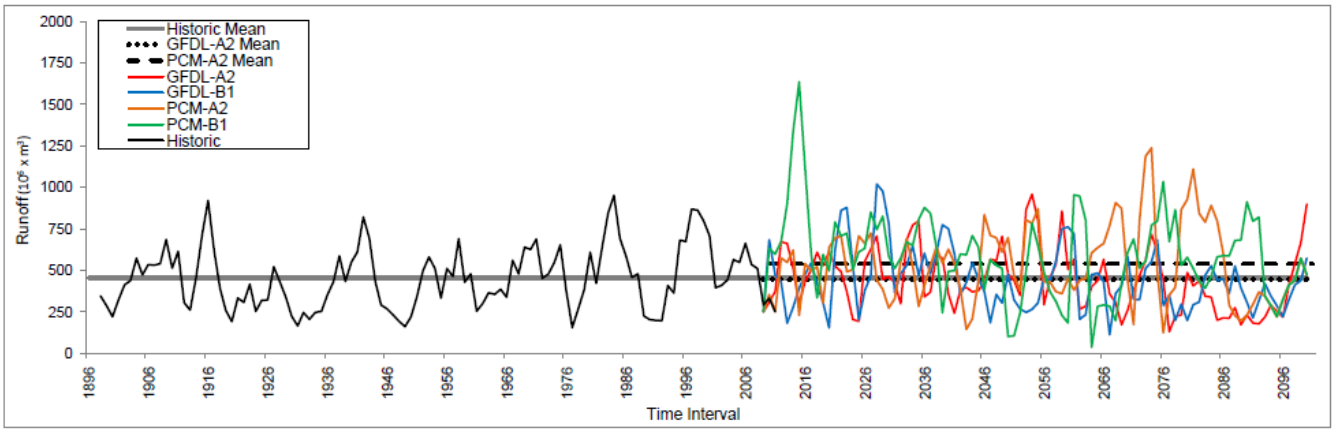
This plot shows estimated water balance distributions for the historic period (1896-2009) and GFDL A2 "warmer drier" scenario (2010-2100) using monthly data averaged over decade intervals. Histograms displaying water balance partitioning between runoff (green), recharge (yellow) and evapotranspiration (blue) show that in low water years proportionally more water is converted to evapotranspiration versus during high water years when proportionally more water is available for recharge and runoff.

Figure 9A-F Spatial distribution of projected climate impacts on hydrology estimated using Basin Characterization Model (BCM), North Bay region



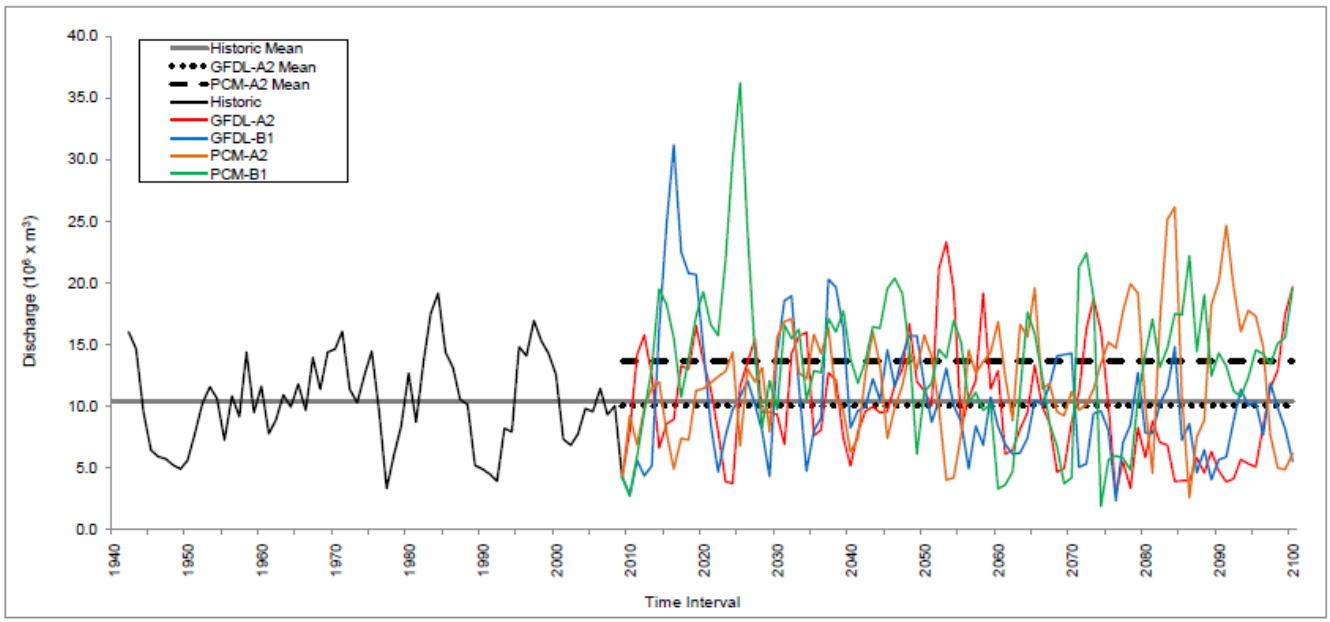
Maps A-F display the diversity of potential hydrologic response to climate change within major basins by showing the spatial distribution of differences between the1971-2000 and 2071-2100 time intervals. A-B displays runoff, C-D displays recharge, and E-F displays water deficit for the PCM A2 "warmer wetter" scenario (A, C, E) and the GFDL A2 "warmer drier" scenario (B, D, F). 270 m grid results are averaged for sub-basins. In general, valley bottoms typified by thick layers of alluvium show the greatest magnitude of potential change due to storage capacity. While runoff and recharge generally trend in opposite directions for the two models (in the positive direction for PCM and the negative direction for GFDL), both models predict increases in water deficit ranging from 8 to greater than 34%.

Figure 10A Historic (1896-2009) and projected (2010-2100) runoff, three-year running average, North Bay region



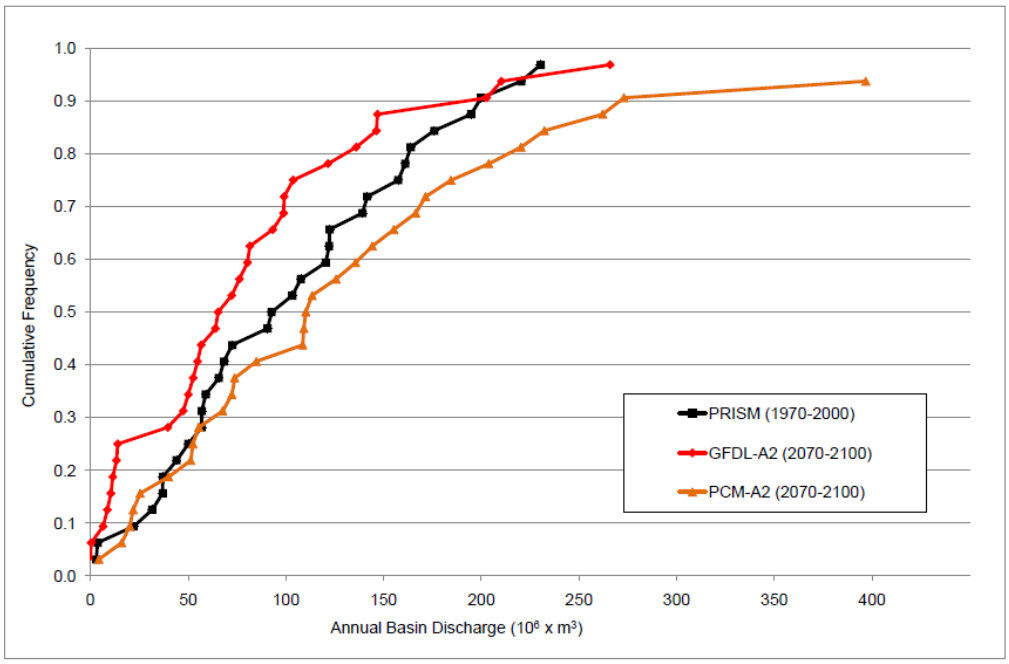
Historic estimated runoff (1896-2009, derived from PRISM data) and projected runoff (2010-2100) for four scenarios (PCM A2 in yellow, GFDL A2 in red, PCM B1 in green, GFDL B1 in blue) for North Bay region (excludes Marin Coast planning basin). Plot shows increased future variability in three-year running average for all scenarios. Trend lines display historic mean (solid), PCMA 2 mean (dashed), and GFDL A2 mean (dotted) values over respective time periods.

Figure 10B Historic (1896-2009) and projected (2010-2100) stream discharge, three-year running average, Napa River at St Helena



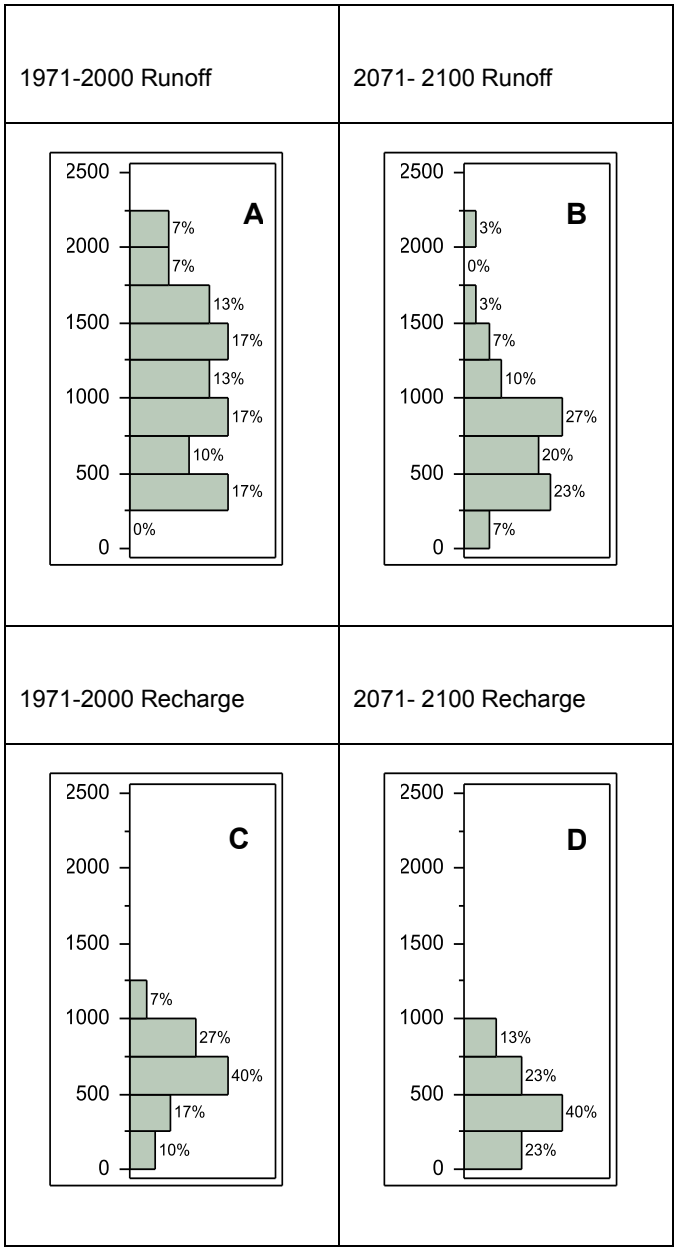
Historic stream discharge (1896-2009, derived from USGS gage data) and projected stream discharge for four scenarios (PCM A2 in yellow, GFDL A2 in red, PCM B1 in green, GFDL B1 in blue) for USGS gage on Napa River at St Helena, #1145600. Plot displays increased future variability in 3-year running average for all scenarios, and trend towards end of current century for more discharge under PCM compared to GFDL scenarios. Trend lines display historic mean (solid), PCM A2 mean (dashed), and GFDL A2 mean (dotted) values.

Figure 11 Historic (1971-2000) versus projected (2071-2100) cumulative probability of annual stream discharge, Napa River at St Helena



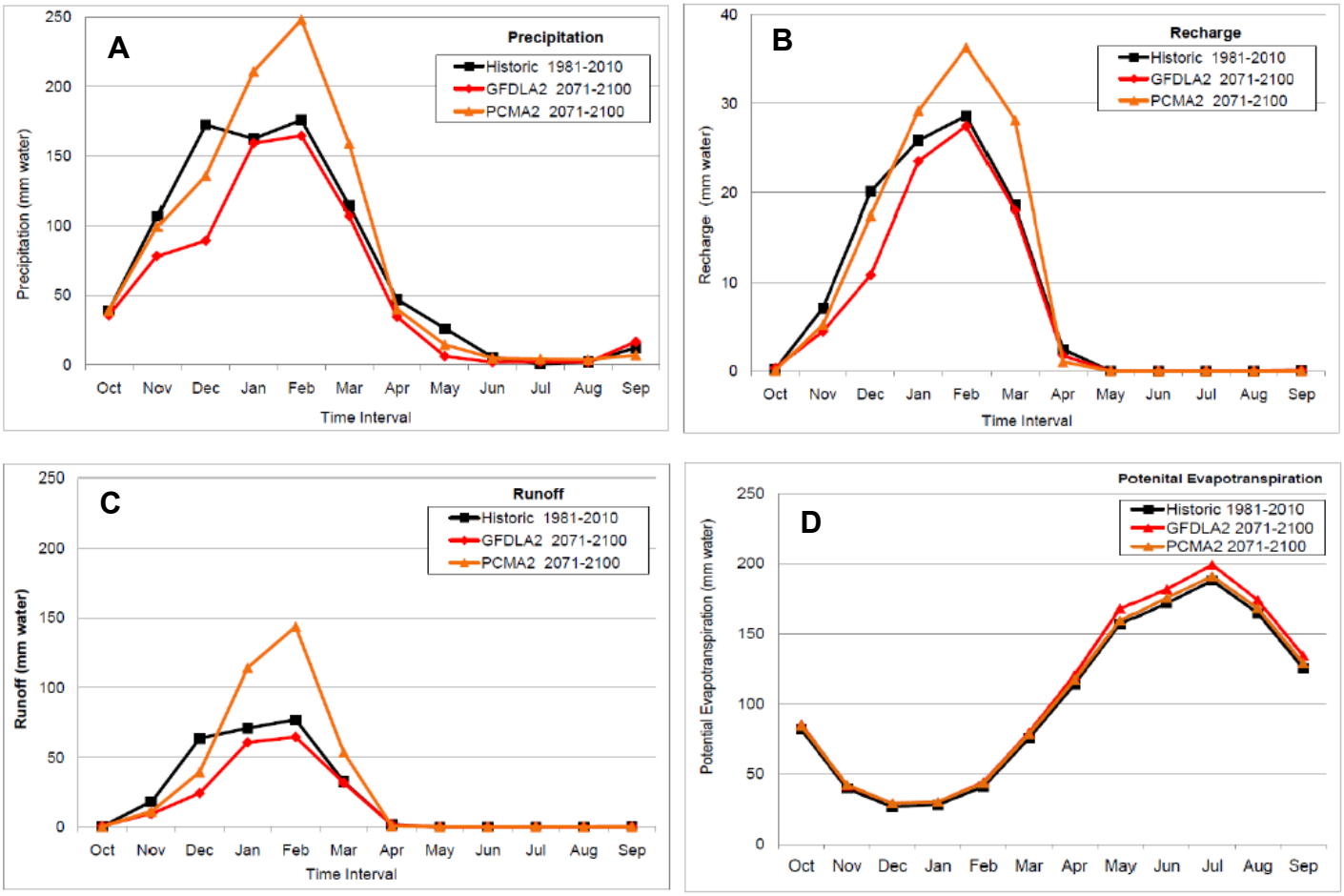
Annual basin discharge versus cumulative frequency for the Napa River at St Helena, where black squares represent historic conditions (1971-2000, derived from USGS gage data), red diamonds represent projected GFDL A2 scenario (2071-2100, BCM simulation), and gold triangles represent projected PCM A2 scenario (2071-2100, BCM simulation).

Figure 12A-D Runoff and recharge, three-year running average values, historic (1971-2000) and GFDL-A2 projections GFDL-A2 (2071-2100), Milliken Creek sub-basin



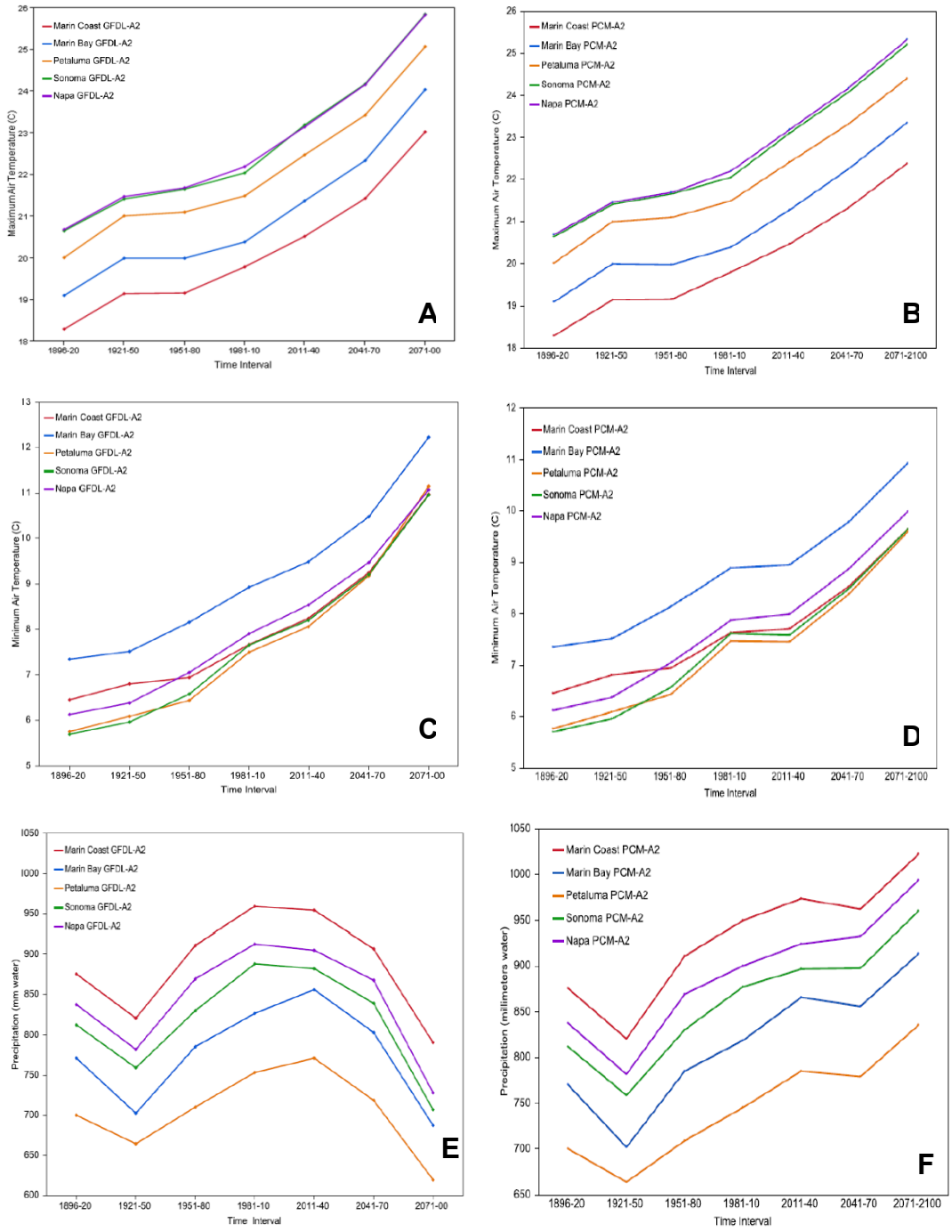
Histograms compare frequency distributions for 1971-2000 (derived from USGS gage data) and 2071-2100 (derived from BCM simulation for GFDL-A2 scenario) in terms of three-year running average values for runoff (A-B) and recharge (C-D). Percent labels show total frequency of values for each histogram interval. Units are 10^3 x m^3 of water.

Figure 13A-D Projected climate impacts on seasonality of climate hydrology parameters, North Bay region



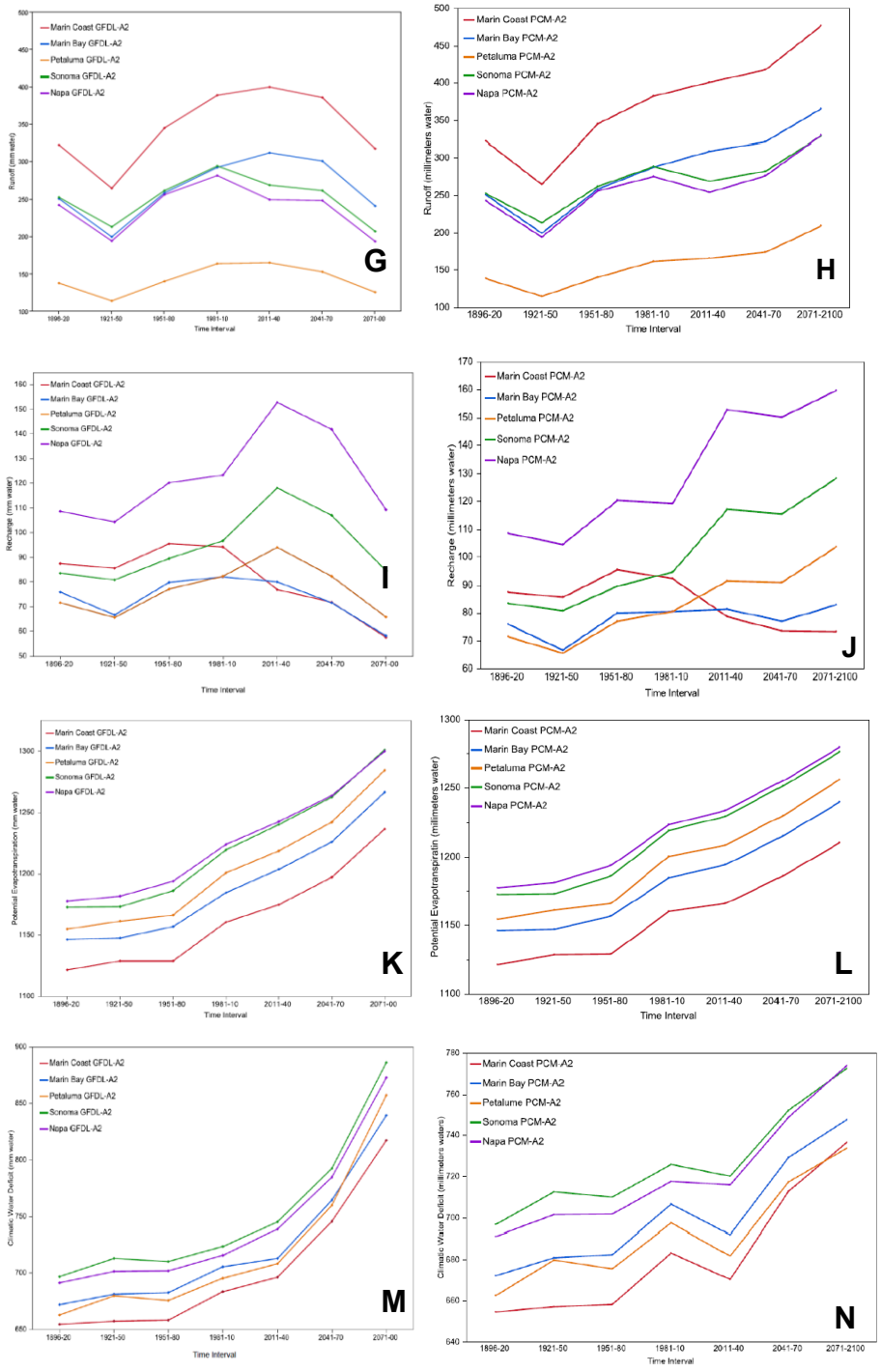
Each plot compares recent (1981-2010) versus projected (2071-2100) monthly average values for individual months of water year for A) precipitation, B) runoff, C) recharge, and D) potential evapotranspiration. Black squares show recent values (derived from PRISM), red diamonds shows projected "warmer-drier" scenario (GFDL A2 scenario, 2071-2100, BCM simulation), gold triangles show "warmer-drier" (PCM A2 scenario, 2071-2100, BCM simulation). Although the PCM A2 model projects unprecedented amounts of precipitation during winter months, it also projects lower water availability by April compared to current conditions. The GFDL A2 model projects significantly less water available in both the early and late months of wet season compared to current conditions.

Figures 14A-F Historic (1896-2009) and projected (2010-2100) maximum and minimum temperatures and precipitation by major basin, North Bay region, GFDL-A2 and PCM-A2 scenarios



Plots compare major basin attributes for maximum temperatures (A-B), minimum temperatures (C-D) and precipitation (E-F) for GFDL A2 and PCM A2 scenarios. Marin Coast shown in purple, Marin Bay shown in blue, Petaluma River basin shown in red, Sonoma Creek basin shown in green, and Napa River basin shown in gold. Appendix B displays results in tabular form.

Figures 14G-N Historic (1896-2009) and projected (2010-2100) hydrology by major basin, North Bay region, GFDL-A2 and PCM-A2 scenarios



Plots compare major basin attributes for runoff, recharge, potential evapotranspiration, and water deficit for GFDL A2 and PCM A2 scenarios. Marin Coast shown in purple, Marin Bay shown in blue, Petaluma River basin shown in red, Sonoma Creek basin shown in green, and Napa River basin shown in gold. Appendix B displays results in tabular form.

Table 1 Stream gages used for Basin Characterization Model calibration

Gage	USGS#	Period of Record	Ratio of Measured to Modeled Runoff
Napa River Near St Helena	11456000	1975-1983	0.983
Novato Creek at Novato	11459500	1960-1990	0.990
Sonoma Creek at Agua Caliente	11458500	1960-1980	0.994
San Antonio Creek near Petaluma	11459300	1975-1981	1.007
Milliken Creek near Napa	11458100	1970-1983	1.009
Dry Creek near Napa	11457000	1959-1966	0.988
Napa River at Calistoga	11455900	1975-1982	0.996
Arroyo Corte Madera at Mill Valley	11460100	1965-1985	1.009

Table 2 Monthly measured climate and simulated hydrologic parameters (1901-2010), averaged per decade

Decade	Maximum air temperature*		Minimum air temperature*		Precipitation*		Runoff**		Recharge**		Potential evapo-transpiration**		Climatic water deficit**	
	°C	SE	°C	SE	mm y-1	SE	mm y-1	SE	mm y-1	SE	mm y-1	SE	mm y-1	SE
1901-10	20.3	0.3	6.4	0.4	796	237	227	132	97	42	1,234	71	757	127
1911-20	20.1	0.5	5.8	0.4	743	295	220	192	78	50	1,160	9	713	74
1921-30	20.7	0.8	6.4	0.5	742	226	179	96	82	32	1,173	11	689	115
1931-40	21.6	0.6	6.4	0.6	712	240	189	137	78	44	1,174	25	725	72
1941-50	21.1	0.5	6.5	0.5	767	267	185	139	95	48	1,163	21	674	89
1951-60	21.3	0.8	6.9	0.6	834	255	244	157	97	46	1,176	27	679	89
1961-70	21.2	0.6	7.0	0.4	828	229	242	128	105	39	1,178	18	693	91
1971-80	21.4	0.5	7.1	0.5	785	317	221	157	93	61	1,187	18	713	98
1981-90	21.7	0.7	7.5	0.4	845	414	255	220	109	79	1,208	23	723	134
1991-00	21.7	0.8	8.0	0.6	934	318	308	181	101	48	1,212	30	683	96
2001-10	21.8	0.5	8.3	0.3	843	244	245	111	110	64	1,215	6	714	108

* Derived from PRISM climate data (Daly and others,2004)

** Simulated from Basin Characterization Model

Table 3 Four scenarios projected climate and hydrology of North Bay Region study area (2011-2100), monthly values averaged per 30-year interval

Model	Time Interval	Maximum air temperature		Minimum air temperature		Precipitation		Runoff		Recharge		Potential evapo-transpiration		Climatic water deficit	
		oC	SE	oC	SE	mm y-1	SE	mm y-1	SE	mm y-1	SE	mm y-1	SE	mm y-1	SE
Historic*	1921-50	21.1	0.1	6.4	0.1	740	43	184	22	85	8	1,170	4	696	17
	1951-80	21.3	0.1	7.0	0.1	816	48	236	26	98	9	1,181	4	695	17
	1981-10	21.7	0.1	7.9	0.1	874	59	269	32	107	11	1,212	4	707	20
GFDL A2**	2011-40	22.6	0.1	8.4	0.1	864	56	236	27	117	12	1,226	3	710	20
	2041-70	23.2	0.1	9.1	0.1	860	68	266	38	122	16	1,242	3	766	17
	2071-00	25.1	0.1	11.0	0.1	699	54	187	27	89	10	1,286	3	855	19
GFDL B1**	2011-40	22.7	0.1	8.6	0.7	913	84	308	49	132	18	1,228	3	750	19
	2041-70	23.4	0.1	9.2	0.5	858	56	243	32	118	12	1,244	2	742	15
	2071-00	23.9	0.1	9.6	0.5	729	52	189	28	86	11	1,253	2	792	16
PCM A2**	2011-40	22.7	0.1	7.9	0.5	882	67	250	37	121	14	1,221	2	706	19
	2041-70	23.7	0.1	8.9	0.5	882	58	266	36	119	13	1,243	2	740	15
	2071-00	24.8	0.1	10.0	0.5	943	82	313	50	131	17	1,268	2	758	21
PCM B1**	2011-40	22.7	0.1	7.9	0.6	1,051	78	369	45	160	18	1,220	2	692	19
	2041-70	23.1	0.1	8.3	0.5	913	77	284	47	121	16	1,229	2	717	20
	2071-00	23.8	0.1	8.9	0.5	907	65	281	39	120	13	1,243	2	732	18

* Derived from PRISM climate data (Daly and others 2004) and Basin Characterization Model watershed simulations for historic time steps

** Derived from referenced General Circulation Models and Basin Characterization Model watershed simulations

APPENDIX A Major and minor basin descriptors derived from CalWater, 1999

MAJOR BASINS

Major Basin Name	Selected Drainages Included	Area (km2)	Area (acres)
Marin Coast	Lagunitas and San Geronimo Creeks, Bolinas	833.7	206,012
Marin Bay	Miller and Corte Madera Creeks	341.5	84,396
Petaluma River	Stage Gulch Creek	384.9	95,114
Napa River	Conn, York, Milliken, Soda and other Creeks	829.2	204,890
Sonoma Creek	Bear, Calabazas, Carriger, and Nathanson Creeks	431.4	106,593

MINOR BASINS

Minor Basin ID (HRC)	Minor Basin (CalWater CDFPWSNAME)	CalWater HANAME	Major Basin	Area (km2)	Area (acres)
1	Upper Napa River	Napa River	Napa River	24.9	6,165
2	Garnett Creek	Napa River	Napa River	20.6	5,088
3	Simmons Canyon	Napa River	Napa River	34.6	8,560
4	Ritchie Creek	Napa River	Napa River	35.5	8,772
5	Bell Canyon	Napa River	Napa River	27.6	6,830
6	Conn Creek	Napa River	Napa River	29.5	7,297
7	Moore Creek	Napa River	Napa River	19.5	4,819
8	York Creek	Napa River	Napa River	34.2	8,451
9	Chiles Creek	Napa River	Napa River	29.5	7,293
10	Fir Canyon	Napa River	Napa River	33.2	8,195
11	Heath Canyon	Napa River	Napa River	41.0	10,139
12	Lake Hennessey	Napa River	Napa River	23.3	5,761
14	Rector Reservation	Napa River	Napa River	37.7	9,325
15	Bear Canyon	Napa River	Napa River	37.9	9,371
18	Upper Dry Creek	Napa River	Napa River	24.7	6,101
19	Milliken Reservoir	Napa River	Napa River	50.3	12,439
20	Soda Creek	Napa River	Napa River	28.6	7,070
22	Lower Dry Creek	Napa River	Napa River	23.0	5,679
24	Redwood Creek	Napa River	Napa River	28.2	6,978
29	Spencer Creek	Napa River	Napa River	36.6	9,039
30	undefined	Napa River	Napa River	38.7	9,565
34	Browns Valley	Napa River	Napa River	24.6	6,068
59	Mouth of Napa	Napa River	Napa River	145.2	35,883
13	Mouth of Napa	Napa River	n/a	174.6	43,146
16	Bear Creek	Sonoma Creek	Sonoma	21.4	5,296
17	Upper Sonoma	Sonoma Creek	Sonoma	49.1	12,140
21	Upper Calabazas	Sonoma Creek	Sonoma	46.8	11,571
23	Lower Calabazas	Sonoma Creek	Sonoma	48.9	12,073
26	Nathanson Creek	Sonoma Creek	Sonoma	37.2	9,183
27	Mouth of Sonoma	Sonoma Creek	Sonoma	122.5	30,259
38	Haraszthy Creek	Sonoma Creek	Sonoma	28.6	7,068
40	Champlin Creek	Sonoma Creek	Sonoma	19.0	4,686
43	undefined	Sonoma Creek	Sonoma	30.4	7,513
60	Mouth of Sonoma	Sonoma Creek	Sonoma	27.5	6,804
28	Lynch Creek	Petaluma River	Petaluma	42.4	10,485
31	undefined	Petaluma River	Petaluma	96.9	23,948
32	Adobe Creek	Petaluma River	Petaluma	36.5	9,016
37	undefined	Petaluma River	Petaluma	60.2	14,869
42	Upper San Antonio	Petaluma River	Petaluma	33.0	8,156
45	Stage Gulch	Petaluma River	Petaluma	30.3	7,476
46	Lower San Antonio	Petaluma River	Petaluma	60.2	14,864
47	undefined	Petaluma River	Petaluma	25.5	6,301
48	Stafford Lake	Novato	Marin Bay	126.0	31,128
51	Miller Creek	Novato	Marin Bay	30.9	7,626
53	San Anselmo Creek	San Rafael	Marin Bay	74.0	18,277

54	San Rafael Creek	San Rafael	Marin Bay	29.3	7,252
56	Old Mill Creek	San Rafael	Marin Bay	8.4	2,081
61	Gallinas Creek	Novato	Marin Bay	26.5	6,549
62	Belvedere Lagoon	San Rafael	Marin Bay	4.8	1,182
63	Belvedere Lagoon	San Rafael	Marin Bay	6.9	1,698
64	Belvedere Lagoon	San Rafael	Marin Bay	5.0	1,246
65	Belvedere Lagoon	San Rafael	Marin Bay	3.7	902
67	Old Mill Creek	San Rafael	Marin Bay	0.8	197
68	Old Mill Creek	San Rafael	Marin Bay	15.7	3,888
69	Old Mill Creek	San Rafael	Marin Bay	9.6	2,378
25	Ebabias Creek	Estero Americano	Marin Coast	50.2	12,393
35	Upper Stemple	Estero San Antonio	Marin Coast	65.5	16,187
36	Lower Stemple	Estero San Antonio	Marin Coast	69.1	17,072
39	Keys Creek	Tomales Bay	Marin Coast	181.2	44,785
44	Nicks Cove	Tomales Bay	Marin Coast	61.9	15,302
49	Nicasio Reservoir	Tomales Bay	Marin Coast	95.7	23,638
50	Tomasini Canyon	Tomales Bay	Marin Coast	138.7	34,273
52	San Geronomo	Tomales Bay	Marin Coast	24.3	6,000
55	Pine Gulch Creek	Bolinas	Marin Coast	40.7	10,066
57	Fern Creek	Bolinas	Marin Coast	31.8	7,869
58	Rodeo Lagoon	Bolinas	Marin Coast	14.3	3,542
71	Rodeo Lagoon	Bolinas	Marin Coast	7.6	1,884
72	Audobon Canyon	Bolinas	Marin Coast	5.8	1,436
73	Pine Gulch Creek	Bolinas	Marin Coast	1.1	284
76	Laguna Lake	Tomales Bay	Marin Coast	11.1	2,747
77	Keys Creek	Tomales Bay	Marin Coast	12.4	3,055
78	Ebabias Creek	Estero Americano	Marin Coast	23.6	5,824
73	Tomales Bay	Keys Creek	n/a	12.4	3,055
74	Estero Americano	Ebabias Creek	n/a	23.6	5,824
75	Napa River	Upper Napa River	n/a	24.9	6,165

APPENDIX B Major Basin Assessments: tabular format

Marin Coast Major Basin

		Tmax		Tmin		PPT		Runoff		Recharge		PET		CWD	
Model	Time Interval	oC	SE	oC	SE	mm y-1	SE	mm y-1	SE	mm y-1	SE	mm y-1	SE	mm y-1	SE
Historic*	1896-20	18.3	0.1	6.5	0.1	876	258	323	43	88	7	1122	2	655	12
	1921-50	19.1	0.1	6.8	0.1	820	260	265	33	86	7	1129	4	657	14
	1951-80	19.2	0.1	6.9	0.1	911	296	346	41	96	8	1129	4	658	13
	1981-10	19.8	0.1	7.7	0.1	960	357	383	49	92	8	1160	4	684	14
GFDL A2**	2011-40	20.5	0.1	8.2	0.1	955	72	400	54	77	8	1175	2	696	15
	2041-70	21.4	0.1	9.2	0.1	907	62	387	52	72	6	1197	3	746	11
	2071-00	23.0	0.1	11.0	0.1	790	72	318	54	58	7	1236	3	818	18
GFDL B1**	2011-40	20.5	0.1	8.3	0.1	998	91	474	72	75	8	1172	2	722	12
	2041-70	21.1	0.1	8.9	0.1	952	59	396	48	78	6	1188	2	710	11
	2071-00	21.6	0.1	9.3	0.1	790	56	287	43	57	7	1197	2	748	11
PCM A2**	2011-40	20.5	0.1	7.7	0.1	974	71	401	56	79	8	1166	2	671	14
	2041-70	21.3	0.1	8.5	0.1	963	65	418	54	74	7	1186	2	713	11
	2071-00	22.4	0.1	9.6	0.1	1023	88	477	72	73	7	1210	2	737	14
PCM B1**	2011-40	20.5	0.1	7.7	0.1	1156	86	586	69	89	8	1164	2	684	15
	2041-70	20.9	0.1	8.0	0.1	1025	82	463	70	74	7	1174	2	685	14
	2071-00	21.5	0.1	8.5	0.1	999	67	446	57	72	7	1186	2	703	13

* Derived from PRISM climate data (Daly and others 2004) and Basin Characterization Model (BCM) watershed simulations for historic time steps

** Derived from referenced General Circulation Models climate projections and Basin Characterization Model (BCM) watershed simulations

Marin Bay Major Basin

		Tmax		Tmin		PPT		Runoff		Recharge		PET		CWD	
Model	Time Interval	oC	SE	oC	SE	mm y-1	SE	mm y-1	SE	mm y-1	SE	mm y-1	SE	mm y-1	SE
Historic*	1896-20	19.1	0.1	7.3	0.1	771	46	251	32	76	34	1,146	2	672	12
	1921-50	20.0	0.1	7.5	0.1	702	42	200	24	67	33	1,148	3	681	14
	1951-80	20.0	0.1	8.2	0.1	786	48	259	30	80	40	1,157	4	682	14
	1981-10	20.4	0.1	8.9	0.1	818	61	289	36	81	49	1,184	3	707	17
GFDL A2**	2011-40	21.4	0.1	9.5	0.1	856	68	313	41	80	11	1,203	10	713	17
	2041-70	22.3	0.1	10.5	0.1	803	56	301	38	72	8	1,226	14	765	12
	2071-00	24.0	0.1	12.2	0.1	687	64	242	40	58	8	1,267	16	839	18
GFDL B1**	2011-40	21.3	0.1	9.5	0.1	879	82	361	54	82	11	1,200	2	738	14
	2041-70	22.0	0.1	10.1	0.1	831	53	299	36	75	8	1,217	2	731	11
	2071-00	22.4	0.1	10.5	0.1	691	50	220	31	55	7	1,225	2	772	12
PCM A2**	2011-40	21.3	0.1	9.0	0.1	866	67	309	43	81	10	1,194	2	692	15
	2041-70	22.2	0.1	9.8	0.1	856	61	321	42	77	9	1,215	2	729	11
	2071-00	23.4	0.1	10.9	0.1	914	80	366	54	83	10	1,240	2	748	16
PCM B1**	2011-40	21.3	0.1	8.9	0.1	1,024	80	442	54	102	12	1,192	2	693	15
	2041-70	21.7	0.1	9.2	0.1	902	75	349	53	81	10	1,202	2	704	14
	2071-00	22.4	0.1	9.8	0.1	879	64	338	45	75	9	1,214	2	721	13

* Derived from PRISM climate data (Daly and others 2004) and Basin Characterization Model (BCM) watershed simulations for historic time steps

** Derived from referenced General Circulation Models climate projections and Basin Characterization Model (BCM) watershed simulations

Petaluma River Major Basin

Model	Time Interval	Tmax		Tmin		PPT		Runoff		Recharge		PET		CWD	
		oC	SE	oC	SE	mm y-1	SE	mm y-1	SE	mm y-1	SE	mm y-1	SE	mm y-1	SE
Historic*	1896-20	20.0	0.1	5.8	0.1	700	42	138	21	72	8	1155	2	663	18
	1921-50	21.0	0.1	6.1	0.1	664	39	115	15	66	7	1161	4	680	19
	1951-80	21.1	0.1	6.4	0.1	710	42	140	17	77	8	1166	4	676	19
	1981-10	21.5	0.1	7.5	0.1	745	54	162	23	80	11	1201	4	698	23
GFDL A2**	2011-40	22.5	0.1	8.1	0.1	771	58	166	23	94	14	1218	2	708	24
	2041-70	23.4	0.1	9.2	0.1	719	49	153	23	82	12	1242	3	760	17
	2071-00	25.1	0.1	11.2	0.2	619	58	126	23	66	12	1284	3	857	26
GFDL B1**	2011-40	22.5	0.1	8.1	0.2	805	73	208	34	108	99	1216	3	728	23
	2041-70	23.1	0.1	8.8	0.1	769	49	167	23	90	63	1233	2	721	18
	2071-00	23.6	0.1	9.3	0.1	649	46	124	20	64	50	1243	2	783	19
PCM A2**	2011-40	22.4	0.1	7.5	0.1	785	58	166	25	91	13	1209	2	682	22
	2041-70	23.3	0.1	8.4	0.1	779	51	174	24	91	13	1230	2	717	18
	2071-00	24.4	0.1	9.6	0.1	836	72	209	36	104	17	1256	2	734	25
PCM B1**	2011-40	22.5	0.1	0.1	0.2	805	73	208	34	108	18	1216	3	728	23
	2041-70	23.1	0.1	0.1	0.1	769	49	167	23	90	11	1233	2	721	18
	2071-00	23.6	0.1	0.1	0.1	649	46	124	20	64	9	1243	2	783	19

* Derived from PRISM climate data (Daly and others 2004) and Basin Characterization Model (BCM) watershed simulations for historic time steps
** Derived from referenced General Circulation Models climate projections and Basin Characterization Model (BCM) watershed simulations

Sonoma Creek Major Basin

Model	Time Interval	Tmax		Tmin		PPT		Runoff		Recharge		PET		CWD	
		oC	SE	oC	SE	mm y-1	SE	mm y-1	SE	mm y-1	SE	mm y-1	SE	mm y-1	SE
Historic	1896-20	20.7	0.1	5.7	0.1	812	48	253	31	84	7	1,173	2	697	16
	1921-50	21.4	0.1	6.0	0.1	759	44	214	23	81	6	1,173	4	713	18
	1951-80	21.7	0.1	6.6	0.1	830	48	262	26	90	8	1,186	4	710	18
	1981-10	22.0	0.1	7.7	0.1	876	62	289	33	94	10	1,220	4	727	23
GFDL A2	2011-40	23.2	0.1	8.2	0.1	883	66	269	33	118	15	1,240	13	746	22
	2041-70	24.2	0.1	9.2	0.1	840	57	262	34	107	12	1,263	15	792	17
	2071-00	25.9	0.1	11.0	0.2	706	65	207	32	85	12	1,301	17	886	24
GFDL B1	2011-40	23.1	0.1	8.4	0.1	931	86	325	49	130	18	1,240	3	764	20
	2041-70	23.8	0.1	9.1	0.1	875	57	261	32	114	12	1,255	2	756	16
	2071-00	24.3	0.1	9.5	0.1	747	53	209	29	84	10	1,265	2	810	18
PCM A2	2011-40	22.1	0.1	7.6	0.1	878	62	289	33	95	10	1,219	4	726	22
	2041-70	23.6	0.1	8.0	0.1	897	45	276	26	116	9	1,241	2	736	13
	2071-00	25.2	0.1	9.6	0.1	961	84	329	50	128	17	1,277	2	773	22
PCM B1	2011-40	23.1	0.1	7.6	0.1	1,073	78	389	44	156	18	1,229	2	701	20
	2041-70	23.6	0.1	7.9	0.1	931	79	300	47	121	16	1,238	2	728	22
	2071-00	24.3	0.1	8.5	0.1	923	65	297	39	116	12	1,252	2	742	19

* Derived from PRISM climate data (Daly and others 2004) and Basin Characterization Model (BCM) watershed simulations for historic time steps
** Derived from referenced General Circulation Models climate projections and Basin Characterization Model (BCM) watershed simulations

Napa River Major Basin

		Tmax		Tmin		PPT		Runoff		Recharge		PET		CWD	
Model	**Time Interval**	**oC**	**SE**	**oC**	**SE**	**mm y-1**	**SE**	**mm y-1**	**SE**	**mm y-1**	**SE**	**mm y-1**	**SE**	**mm y-1**	**SE**
Historic	1896-20	20.7	0.1	6.1	0.1	837	51	243	34	109	9	1178	2	691	15
	1921-50	21.5	0.2	6.4	0.1	782	46	195	25	104	9	1181	4	702	17
	1951-80	21.7	0.1	7.1	0.1	870	50	257	29	120	11	1194	4	702	16
	1981-10	22.2	0.1	7.9	0.1	913	61	282	35	123	12	1224	4	715	20
GFDL A2	2011-40	23.2	0.1	8.5	0.1	905	70	250	36	153	19	1242	3	739	20
	2041-70	24.2	0.1	9.5	0.1	868	61	249	37	142	14	1264	3	785	16
	2071-00	25.8	0.1	11.1	0.1	728	67	194	35	109	15	1300	3	873	23
GFDL B1	2011-40	23.2	0.1	8.4	0.1	967	90	323	54	164	21	1239	3	758	18
	2041-70	23.9	0.1	9.1	0.1	901	59	246	35	151	15	1254	3	749	14
	2071-00	24.3	0.1	9.5	0.1	772	56	197	32	110	13	1264	2	796	16
PCM A2	2011-40	23.2	0.1	8.0	0.1	925	72	254	40	153	18	1234	2	716	19
	2041-70	24.2	0.1	8.9	0.1	932	62	276	40	150	15	1256	2	749	14
	2071-00	25.3	0.1	10.0	0.1	994	88	331	55	160	19	1280	2	774	20
PCM B1	2011-40	23.2	0.1	8.0	0.1	1106	81	382	49	194	19	1233	2	703	18
	2041-70	23.7	0.1	8.3	0.1	955	82	292	51	150	18	1242	2	728	20
	2071-00	24.4	0.1	8.9	0.1	965	71	297	44	153	16	1257	2	740	18

* Derived from PRISM climate data (Daly and others 2004) and Basin Characterization Model (BCM) watershed simulations for historic time steps

** Derived from referenced General Circulation Models climate projections and Basin Characterization Model (BCM) watershed simulations