Climate Ready North Bay

Sonoma County Water Agency

Project Overview and Sample Data Products

January 2016

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RCPA regional climate protection authority

Point Blue Conservation Science™

USGS science for a changing world

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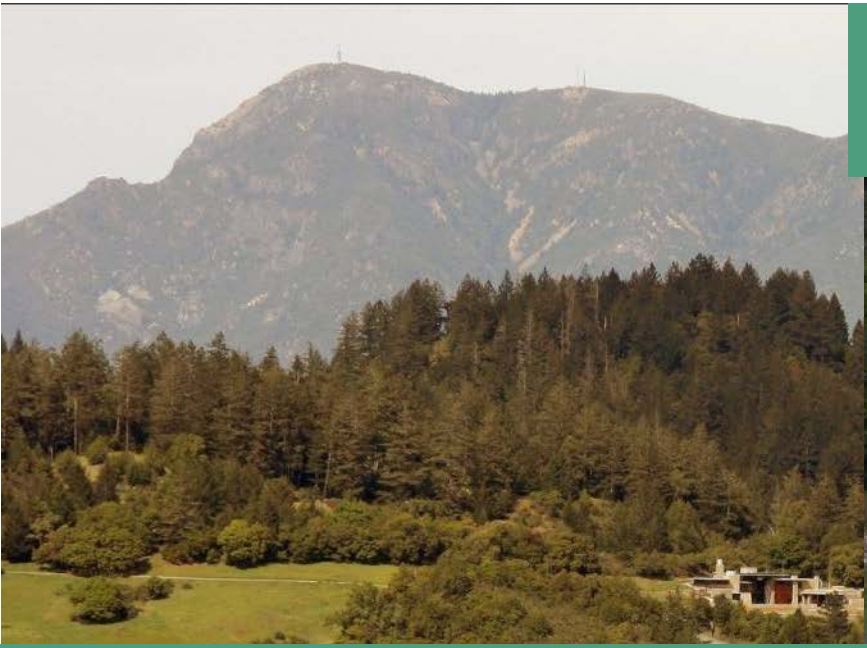
Pepperwood Mission: to advance science-based conservation across our region and beyond

Pepperwood served as project manager of the Climate Ready North Bay vulnerability assessment with TBC3 partners including USGS, Point Blue Conservation Science, and University of California at Berkeley.



3200-acre reserve in Mayacamas, partnered with CA Academy of Sciences

The new Dwight Center for Conservation Science

USGS science for a changing world

Berkeley UNIVERSITY OF CALIFORNIA

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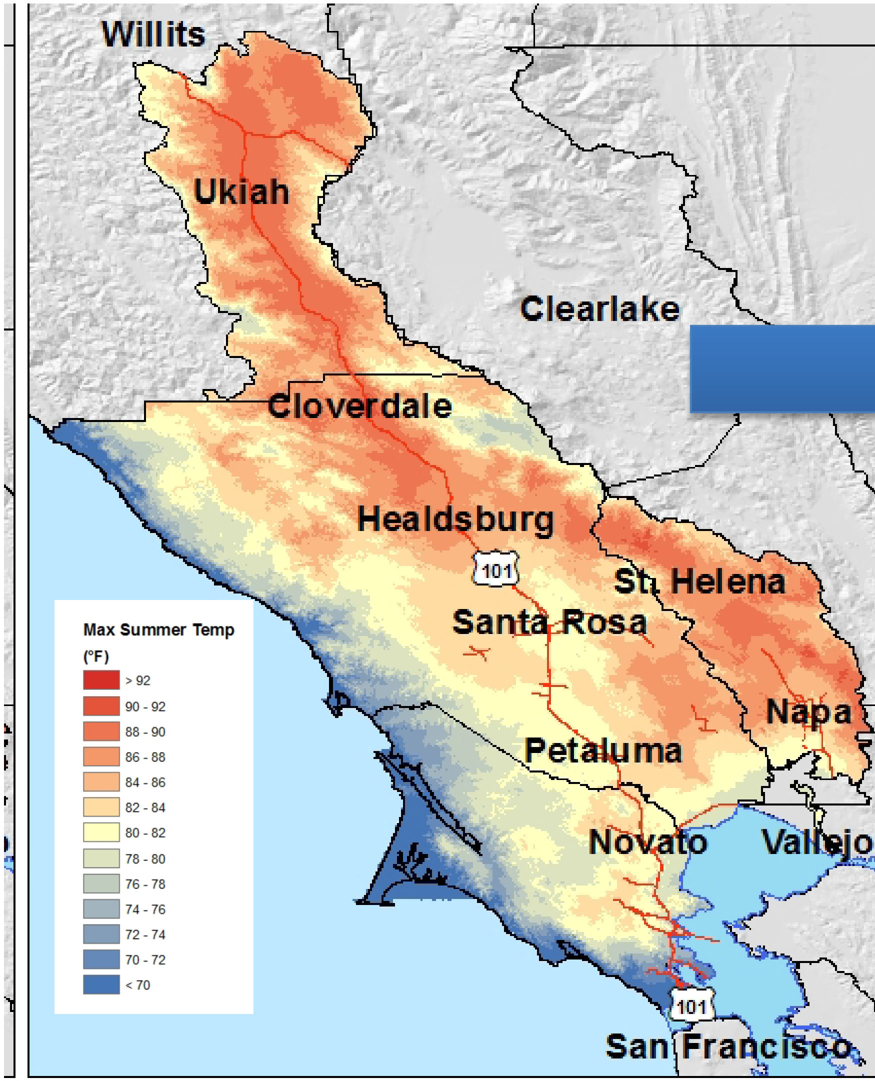
Climate Ready North Bay: translating a landscape-level climate-hydrology database into inputs for long-term planning



Source: Climate Ready North Bay 2015

- Warmer temperatures
- Greater hydrologic variability
- Greater evapo-transpiration
- Increased water demand
- Variable runoff and groundwater recharge
- Shifts in natural vegetation types
- Increased wildfire risk
- (Not sea level rise!)

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North Bay Climate Ready
User Groups and Partners

User Group 1: Sonoma County Water Agency with Mendocino County Water Conservation and Flood District

Domain: Sonoma County plus Russian River Basin of Mendocino County

User Group 2: Sonoma County Agricultural Protection and Open Space District and Sonoma County Regional Parks

Domain: Sonoma County

User Group 3: Napa County, Departments of Planning and Public Works plus the Watershed Protection District

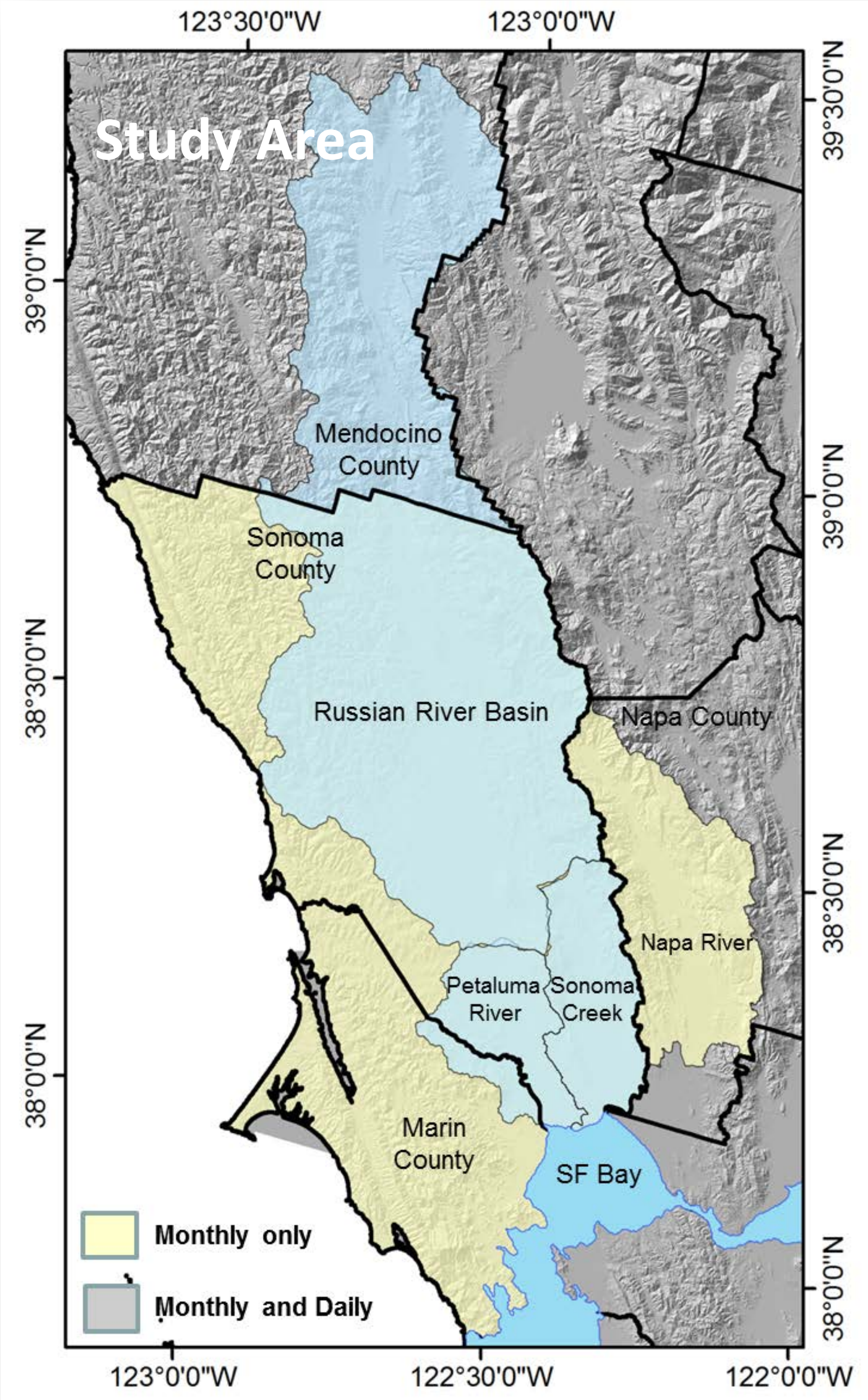
Domain: Napa Valley

User Group 4: Marin Municipal Water District (MMWD)

Domain: Marin County

User Group 5: Regional Climate Protection Authority (RCPA) Municipal Users Group: all nine cities of Sonoma County-public works and planning officers

Domain: Sonoma County and sub-watersheds



project overview

North Bay Climate Ready

Serving natural resource agencies in Marin, Sonoma, Napa and Mendocino Counties

Funding: a *Climate Ready* Coastal Conservancy grant to Sonoma's Regional Climate Protection Authority plus match funds from partners

Pepperwood is the lead analyst on vulnerability assessment with TBC3 members from USGS, and Point Blue Conservation Science, and University of California

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Climate Ready Process

Part 1

Engage managers at the outset: define key management questions for each jurisdiction, and then refine questions through process.

First meeting: based on their concerns, managers selected one set of climate “futures” based on concerns-focus on “worst case” with one “middle of road” and one “mitigated” for entire North Bay region.

Climate Ready Process

Part 2

Managers survey: how does climate variability, including current drought, impact your operations today? What are your concerns for the future?

Agency-specific meetings to introduce our Basin Characterization Model, data menu and sample products, refine data queries based on management questions.

Climate model selection

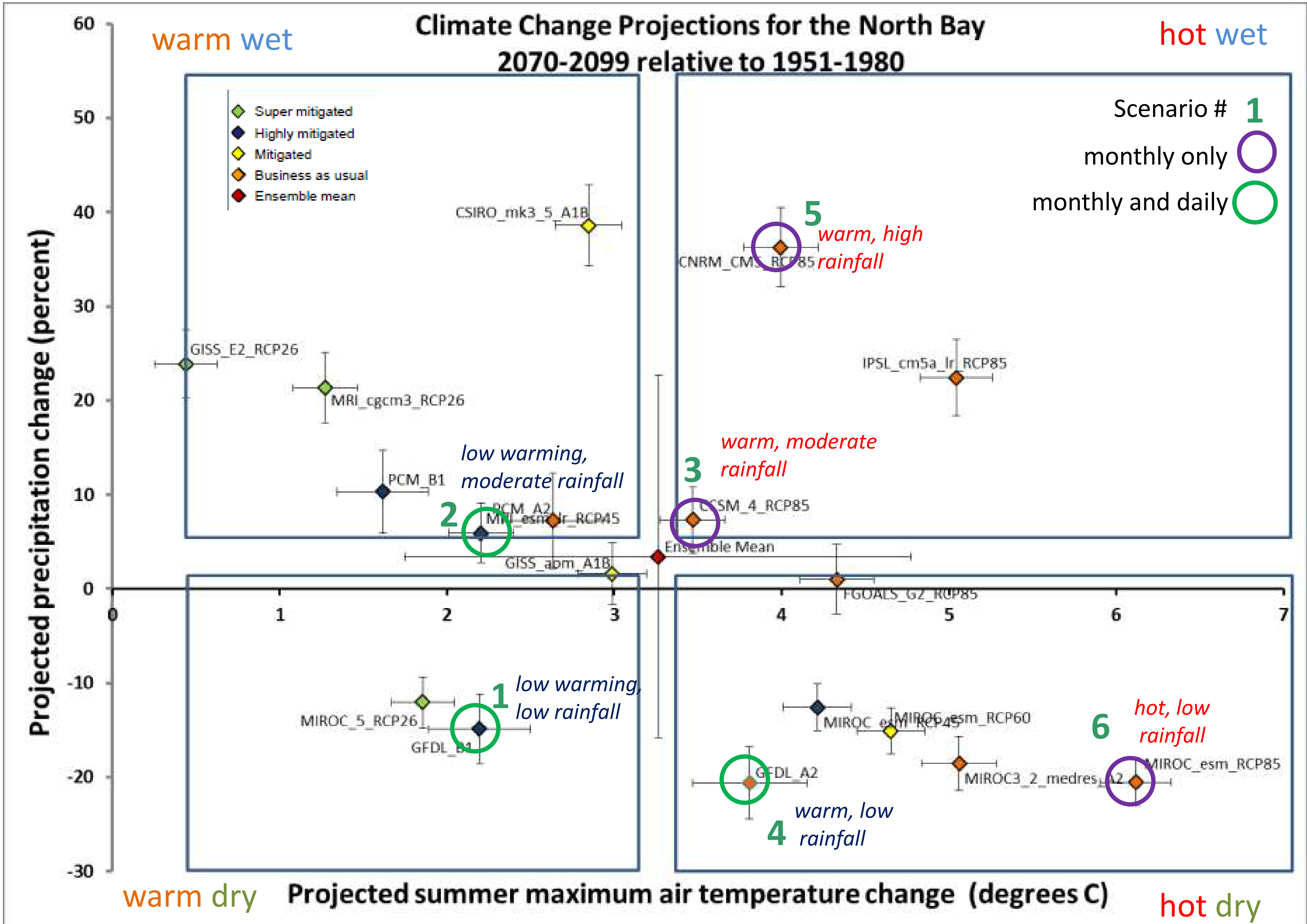
Selected Futures for North Bay Regional Vulnerability Assessment (in yellow)

Scenario #	Model	Emissions Scenario	Assessment Report Vintage	Time Period	Summer Tmax °C	Summer Tmax Increase	Winter Tmin °C	Winter Tmin Increase °C	Annual Precipitation (mm)	% Change Precipitation	% Change Water Deficit
	historic (hst)	N/A	N/A	1951-1980	27.9		3.9		1087		
	current	N/A	N/A	1981-2010	27.9		4.3	0.4	1095	1%	1%
	Assumption: Business as Usual										
6	miroc-esm	rcp85	AR5	2070-2099	34.0	6.1	8.4	4.6	865	-20%	24%
	miroc3_2_mr	A2	AR4	2070-2099	33.0	5.1	7.1	3.2	887	-18%	20%
	ipsl-cm5a-lr	rcp85	AR5	2070-2099	33.0	5.0	9.6	5.7	1325	22%	16%
	fgoals-g2	rcp85	AR5	2070-2099	32.3	4.3	7.1	3.2	1099	1%	22%
5	cnrm-cm5	rcp85	AR5	2070-2099	31.9	4.0	7.7	3.9	1477	36%	12%
4	GFDL	A2	AR4	2070-2099	31.7	3.8	7.7	3.9	861	-21%	21%
3	ccsm4	rcp85	AR5	2070-2099	31.4	3.5	7.1	3.2	1163	7%	12%
2	PCM	A2	AR4	2070-2099	30.6	2.6	6.3	2.4	1159	7%	11%
				Business as Usual Average	**32.2**	**4.3**	**7.6**	**3.7**	**1104**	**2%**	**17%**
	Assumption: Mitigated										
	miroc-esm	rcp60	AR5	2070-2099	32.6	4.7	7.1	3.2	922	-15%	14%
	giss_aom	A1B	AR4	2070-2099	30.9	3.0	6.4	2.5	1104	2%	11%
	csiro_mk3_5	A1B	AR4	2070-2099	30.8	2.8	6.5	2.6	1506	38%	4%
				Mitigated Average	**31.4**	**3.5**	**6.6**	**2.8**	**1177**	**8%**	**10%**
	Assumption: Highly Mitigated										
	mpi-esm-lr	rcp45	AR5	2070-2099	30.1	2.2	5.8	1.9	1148	6%	5%
	miroc-esm	rcp45	AR5	2070-2099	30.1	2.2	6.9	3.0	949	-13%	14%
1	GFDL	B1	AR4	2070-2099	30.1	2.2	6.1	2.2	923	-15%	10%
	PCM	B1	AR4	2070-2099	29.5	1.6	5.5	1.7	1197	10%	5%
				Highly Mitigated Average	**30.0**	**2.1**	**6.1**	**2.2**	**1055**	**-3%**	**8%**
	Assumption: Super Mitigated										
	miroc5	rcp26	AR5	2070-2099	29.8	1.9	5.2	1.3	953	-12%	9%
	mri-cgcm3	rcp26	AR5	2070-2099	29.2	1.3	4.8	0.9	1315	21%	2%
	giss-e2-r	rcp26	AR5	2070-2099	28.4	0.4	4.6	0.7	1344	24%	-4%
				Super Mitigated Average	**29.1**	**1.2**	**4.8**	**1.0**	**1204**	**11%**	**2%**
				ALL Scenarios Average	**31.1**	**3.2**	**6.7**	**2.8**	**1122**	**3%**	**11%**

TBC3 downscaled 18 global climate models selected to represent the full range of IPCC projections. 6 were selected by a consensus of all the managers engaged in Climate Ready. Scenario numbers correlate to chart version of the North Bay TBC3 ensemble.

North Bay Climate Ready: Selected Futures for Regional Vulnerability Assessment

map products in red, daily products available for Russian River basin only



Climate Ready North Bay Scenarios

6 selected futures: monthly values, observed vs mid-century

	Model	Emissions Scenario	IPCC Assessment	Short-hand name	Time Period	Summer Tmax °F	Summer Tmax Increase °F	Winter Tmin °F	Winter Tmin Increase °F	Annual Precipitation (in)	% Change Precipitation	% Change Water Deficit
Observed	historical baseline	N/A	N/A		1951-1980	82.2		39.0		42.8		
	current	N/A	N/A		1981-2010	82.2		39.7	0.7	43.1	1%	1%
Projections												
1	GFDL	B1	AR4	low warming-low rainfall	2040-2069	85.2	2.9	42.7	3.7	42.6	-1%	6%
2	PCM	A2	AR4	low warming-mod rainfal	2040-2069	85.0	2.7	41.1	2.1	43.8	2%	7%
3	CCSM-4	rcp85	AR5	warm-mod rainfall	2040-2069	86.0	3.7	42.0	3.0	42.2	-1%	8%
4	GFDL	A2	AR4	warm-low rainfall	2040-2069	86.3	4.0	43.2	4.2	39.8	-7%	12%
5	CNRM-CM5	rcp85	AR5	warm-high rainfall	2040-2069	86.5	4.2	43.0	4.0	53.8	26%	6%
6	MIROC-ESM	rcp85	AR5	hot-low rainfall	2040-2069	89.2	6.9	41.4	2.4	35.0	-18%	14%
Average						**86.3**	**4.1**	**42.2**	**3.2**	**42.9**	**0%**	**9%**

Climate Ready North Bay Scenarios

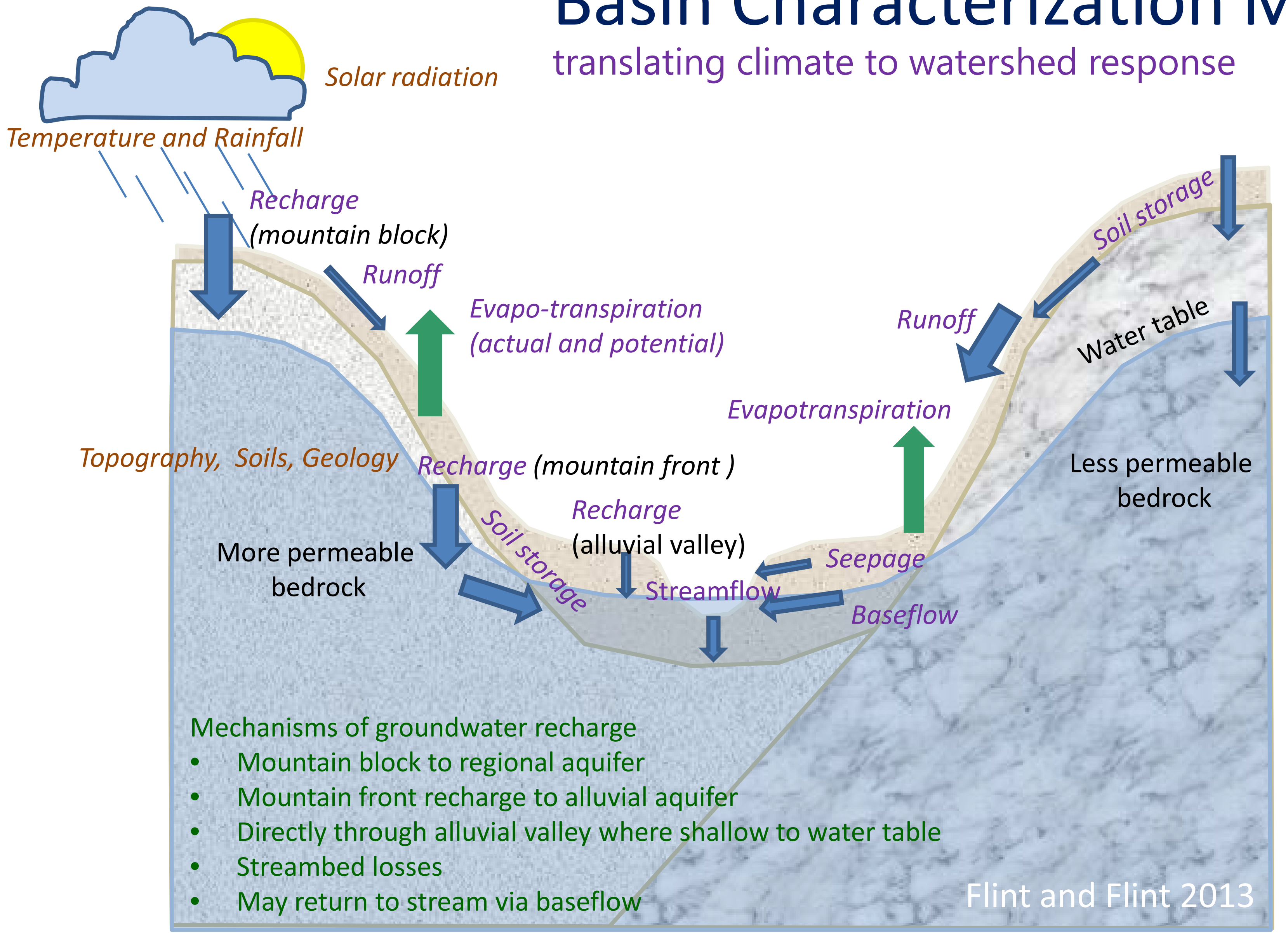
6 selected futures: monthly values, observed vs end-century

	Model	Emissions Scenario	IPCC Assessment	Short-hand name	Time Period	Summer Tmax °F	Summer Tmax Increase °F	Winter Tmin °F	Winter Tmin Increase °F	Annual Precipitation (in)	% Change Precipitation	% Change Water Deficit
Observed	historical baseline	N/A	N/A		1951-1980	82.2		3.9		42.8		
	current	N/A	N/A		1981-2010	82.2		4.3	0.4	43.1	1%	1%
Scenario # Projections												
1	GFDL	B1	AR4	low warming-low rainfall	2070-2099	86.2	4.0	6.1	2.2	36.3	-15%	10%
2	PCM	A2	AR4	low warming-mod rainfal	2070-2099	87.0	4.7	6.3	2.4	45.6	7%	11%
3	CCSM-4	rcp85	AR5	warm-mod rainfall	2070-2099	88.5	6.2	7.1	3.2	45.8	7%	12%
4	GFDL	A2	AR4	warm-low rainfall	2070-2099	89.1	6.9	7.7	3.9	33.9	-21%	21%
5	CNRM-CM5	rcp85	AR5	warm-high rainfall	2070-2099	89.5	7.2	7.7	3.9	58.1	36%	12%
6	MIROC-ESM	rcp85	AR5	hot-low rainfall	2070-2099	93.3	11.0	8.4	4.6	34.0	-20%	24%
Average						88.9	**6.7**	**7.2**	**3.3**	**42**	**0.0**	**15%**

BCM methods

Basin Characterization Model

translating climate to watershed response



Size of arrows reflect relative magnitude of water flow

USGS science for a changing world

Brown text is BCM input, Purple text is BCM output

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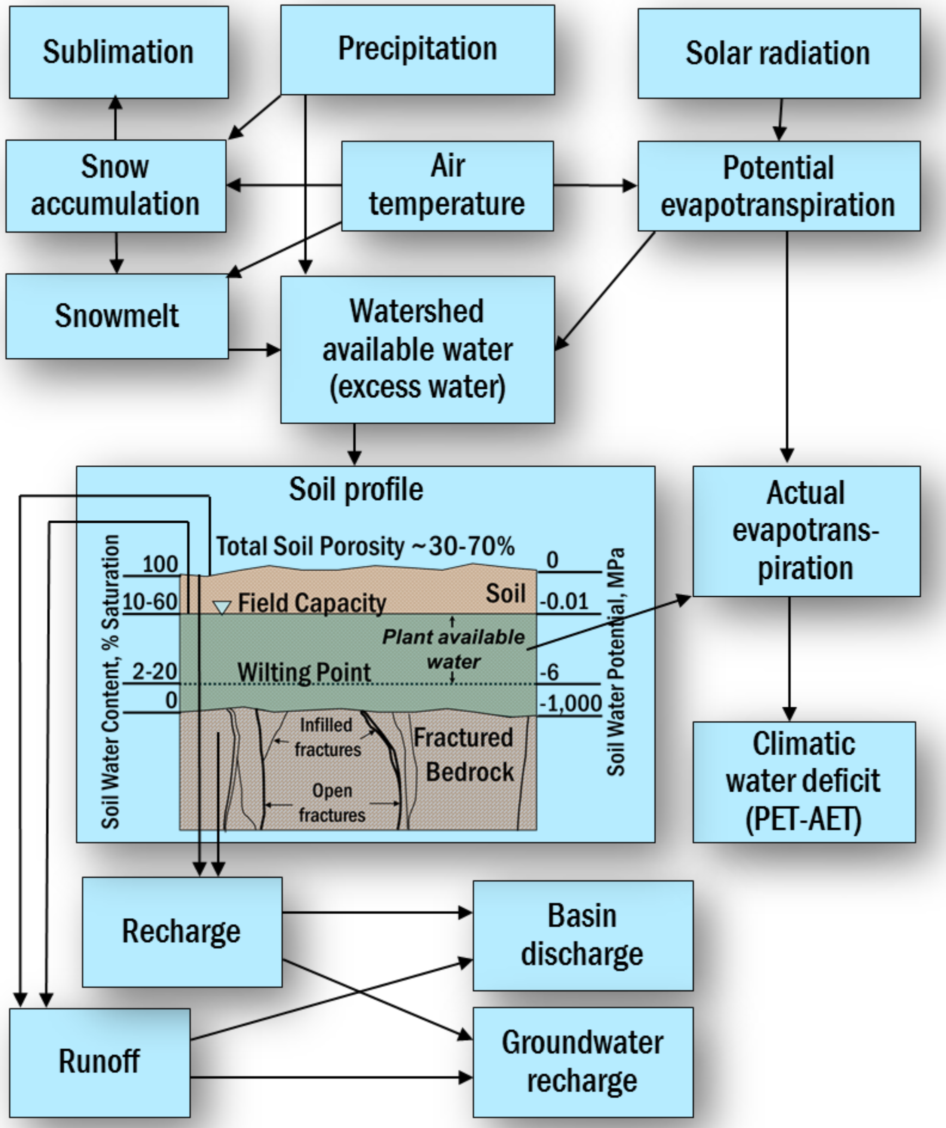
USGS California Basin Characterization Model:

translating climate to watershed response



Flint and Flint 2013

BCM methods

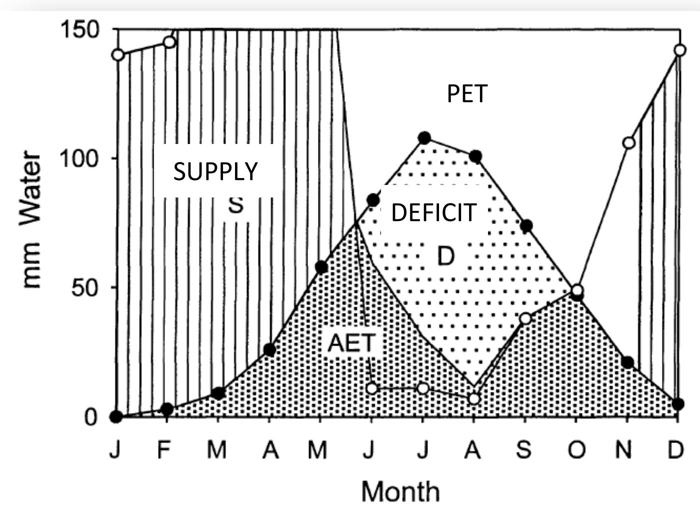
BCM output: Climatic Water Deficit

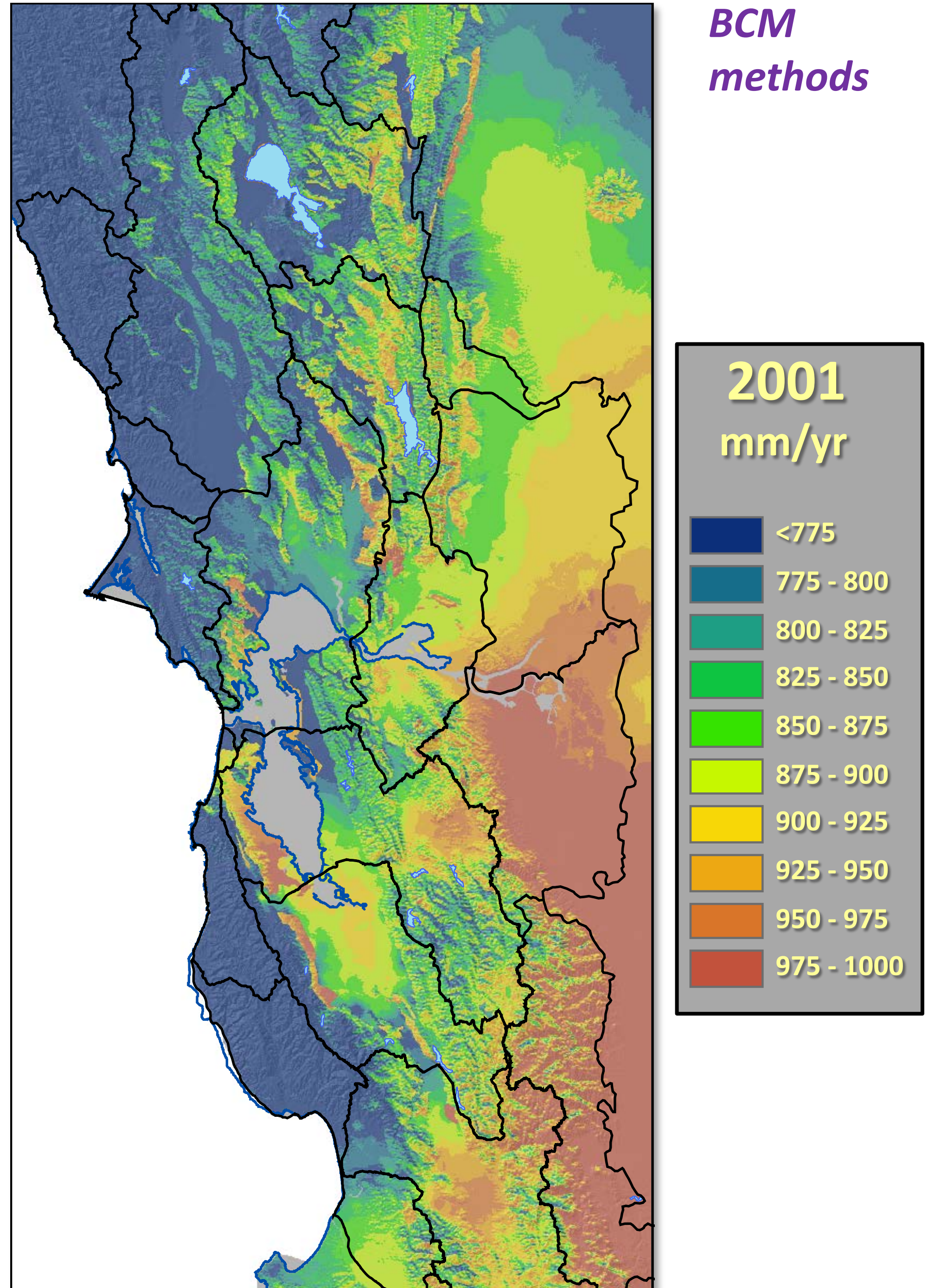
BCM methods

Annual evaporative demand that exceeds available water = drought stress

Potential – Actual Evapotranspiration

- Integrates climate, energy loading, drainage, and available soil moisture storage
- Surrogate for irrigation demand
- Generally increases with all future climate scenarios
- Correlates with vegetation type and fire risk





Data menu

Primary (BCM outputs):

climate and hydology-temperature, rainfall, runoff, groundwater recharge, evapo-transpiration, soil moisture, climatic water deficit

Secondary:

Fire frequency (either percent likelihood of burn or return interval)

Potential native vegetation transitions

Time scales-historical (1910-2010) and projected (2010-2100)

30-y averages

Annual data

Monthly/Seasonal data

Spatial scales

Regional summaries-whole North Bay study area

County Summaries

Sub-regions-watershed, landscape unit, service area

Large parcels

Regional Rainfall and BCM Summary

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Basin Characterization Model: North Bay Region
Trends in 30-year average values, historical-2099

Regional Statistics									
		Historical	Current	Moderate Warming, High Rainfall		Moderate Warming, Moderate Rainfall		Hot, Low Rainfall	
Variable	Units	1951-1980	1981-2010	2040-2069	2070-2099	2040-2069	2070-2099	2040-2069	2070-2099
Ppt	in	43	43	54	58	42	46	35	34
Tmn	Deg F	38.8	39.7	43.0	45.9	41.9	44.8	44.1	47.3
Tmx	Deg F	82.2	82.2	86.4	89.4	86.0	88.5	89.2	93.4
CWD	in	28	28	30	31	30	31	32	35
Rch	in	11	10	13	13	11	11	8	9
Run	in	14	14	23	27	14	17	10	9

				Change from Current					
		Historical	Current	Moderate Warming, High Rainfall		Moderate Warming, Moderate Rainfall		Hot, Low Rainfall	
Variable	Units	1951-1980	1981-2010	2040-2069	2070-2099	2040-2069	2070-2099	2040-2069	2070-2099
Ppt	in	43	43	25%	35%	-2%	6%	-19%	-21%
Tmn	Deg F	38.8	39.7	3.2	6.1	2.2	5.0	4.3	7.6
Tmx	Deg F	82.2	82.2	4.1	7.2	3.8	6.3	7.0	11.2
CWD	in	28	28	5%	10%	7%	11%	12%	22%
Rch	in	11	10	25%	29%	4%	6%	-20%	-17%
Run	in	14	14	61%	90%	-1%	22%	-32%	-34%

VARIABLES: Ppt=precipitation, Tmn=minimum winter temperature (monthly), Tmx=maximum summer temperature (monthly), CWD=climatic water deficit, Rch=recharge, Run=runoff

USGS, Point Blue, Pepperwood 2015

Management Question

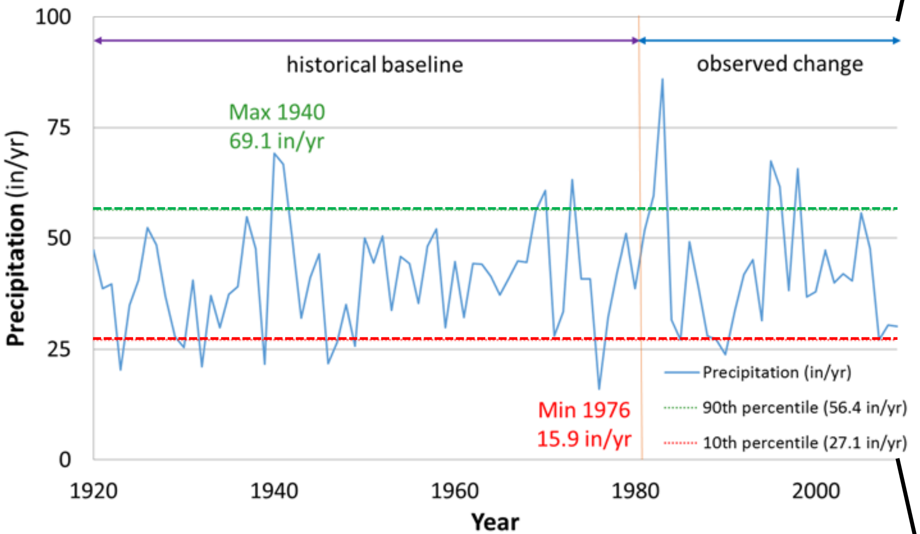
How is climate change projected to impact the variability of regional annual rainfall relative to the historic record?

North Bay Climate Ready

Regional Annual Rainfall: Historical and Projected

(comparison of 90-year periods)

North Bay Annual Rainfall Record (1920-2009)



Extremes (1920-2009)

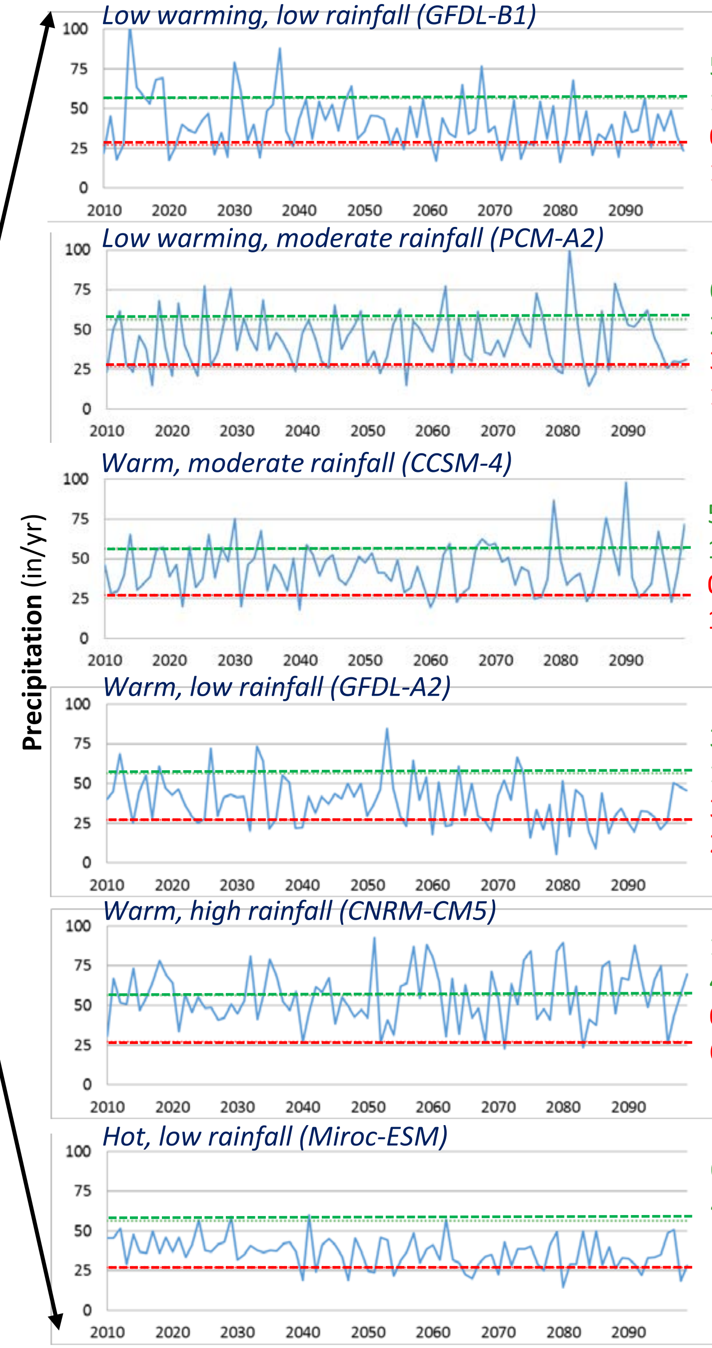
2 events >=1940

9 events >90th % (56.4in/y)*

1 events <=1976

9 events <10th % (27.1 in/y)*

North Bay Annual Rainfall Projections (2010-2099)



Scenario 1
5 events >=1940
13 events >90th %
0 events <=1976
18 events <10th %

Scenario 2
6 events >=1940
23 events >90th %
3 events <=1976
17 events <10th %

Scenario 3
5 events >=1940
19 events >90th %
0 events <=1976
10 events <10th %

Scenario 4
3 events >=1940
10 events >90th %
3 events <=1976
23 events <10th %

Scenario 5
19 events >=1940
41 events >90th %
0 events <=1976
6 events <10th %

Scenario 6
0 events >=1940
4 events >90th %
1 events <=1976
14 events <10th %

* 10th and 90th percentile benchmarks based on 1920-2009 record

Climate Ready North Bay

Annual Rainfall Extremes per Decade

Frequency of extreme annual events per decade

Scenario #	Model	Time Period	Name	Annual Peaks (floods) >=1940 (69.1 in/yr)	Annual Peaks (floods) >90th % (56.4 in/yr)	Annual Lows (droughts) <10th % (27.1 in/yr)	Annual Lows (droughts) <=1976 (15.9 in/yr)
	Historic & Observed Change	1920-2009		0.22	1.00	1.00	0.11
1	GFDL_B1	2010-2099	Low warming, Low rainfall	0.56	1.44	2.00	0.00
2	PCM_A2	2010-2099	Low warming, Mod rainfall	0.67	2.56	1.89	0.33
3	CCSM4_rcp85	2010-2099	Warm, Mod rainfall	0.56	2.11	1.11	0.00
4	GFDL_A2	2010-2099	Warm, Low rainfall	0.33	1.11	2.56	0.33
5	CNRM_rcp85	2010-2099	Warm, High rainfall	2.11	4.56	0.67	0.00
6	MIROC_rcp85	2010-2099	Hot, Low rainfall	0.00	0.44	1.56	0.11

Percent increase or decrease (projected relative to 1920-2009): Frequency extreme annual events per decade

Scenario #	Model	Time Period	Name	Annual Peaks (floods) >=1940 (69.1 in/yr)	Annual Peaks (floods) >90th % (56.4 in/yr)	Annual Lows (droughts) <10th % (27.1 in/yr)	Annual Lows (droughts) <=1976 (15.9 in/yr)
	Historic & Observed Change	1920-2009					
1	GFDL_B1	2010-2099	Low warming, Low rainfall	150%	44%	100%	-100%
2	PCM_A2	2010-2099	Low warming, Mod rainfall	200%	156%	89%	200%
3	CCSM4_rcp85	2010-2099	Warm, Mod rainfall	150%	111%	11%	-100%
4	GFDL_A2	2010-2099	Warm, Low rainfall	50%	11%	156%	200%
5	CNRM_rcp85	2010-2099	Warm, High rainfall	850%	356%	-33%	-100%
6	MIROC_rcp85	2010-2099	Hot, Low rainfall	-100%	-56%	56%	0%
			Average	***217%***	***104%***	***63%***	***17%***

* 10^{th} and 90^{th} percentile benchmarks based on 1920-2009 record

SCWA
Basin Characterization Model
Custom Outputs

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Management Question

How will climate change impact precipitation variability, and in turn, impact water available for supply via surface sources?

Basin Characterization Model: Russian River Basin
Trends in 30-year average values, historical-2099

		Historical	Current	Moderate Warming, High Rainfall		Moderate Warming, Moderate Rainfall		Hot, Low Rainfall	
Variable	**Units**	1951-1980	1981-2010	2040-2069	2070-2099	2040-2069	2070-2099	2040-2069	2070-2099
Precipitation	in	45.4	45.9	56.8	61.0	44.4	47.3	37.5	37.0
Winter minimum temp	Deg F	44.4	45.3	48.8	51.6	48.1	50.9	50.2	53.8
Summer maximum temp	Deg F	71.2	70.9	74.8	78.9	74.3	77.0	76.6	80.4
Climatic water deficit	in	27.5	27.9	29.0	30.5	29.7	30.4	31.0	33.0
Recharge	in	16.9	16.8	21.0	21.0	17.9	17.3	13.5	14.6
Runoff	in	19.1	19.9	32.7	36.5	20.2	23.4	13.5	13.7

Percent Change from Current or Change in Temperature

		Current	Moderate Warming, High Rainfall		Moderate Warming, Moderate Rainfall		Hot, Low Rainfall	
Variable	**Units**	1981-2010	2040-2069	2070-2099	2040-2069	2070-2099	2040-2069	2070-2099
Precipitation	in	45.9	24%	33%	-3%	3%	-18%	-19%
Winter minimum temp	Deg F	45.3	3.5	6.3	2.8	5.6	4.9	8.5
Summer maximum temp	Deg F	70.9	3.9	8.1	3.4	6.1	5.7	9.5
Climatic water deficit	in	27.9	4%	9%	6%	9%	11%	18%
Recharge	in	16.8	25%	25%	7%	3%	-20%	-13%
Runoff	in	19.9	64%	83%	1%	18%	-32%	-31%

Precipitation and Runoff

Management Question

Are projected rainfall amounts different for the upper and lower basins of the Russian River?

Differences in Precipitation between upper and lower Russian River

		Healdsburg to Guerneville		North of Healdsburg	
		Lower River Precipitation		Upper River Precipitation	
Climate	Years	in/yr	% change from current	in/yr	% change from current
Historical	1951-1980	46		45	
Current	1981-2010	47		45	
Moderate Warming, High Rainfall	2040-2069	57	+23	56	+25
	2070-2099	62	+33	60	+33
Moderate Warming, Moderate Rainfall	2040-2069	45	-4	44	-2
	2070-2099	48	+3	47	+3
Hot, Low Rainfall	2040-2069	38	-19	38	-17
	2070-2099	37	-21	37	-18

Management Question

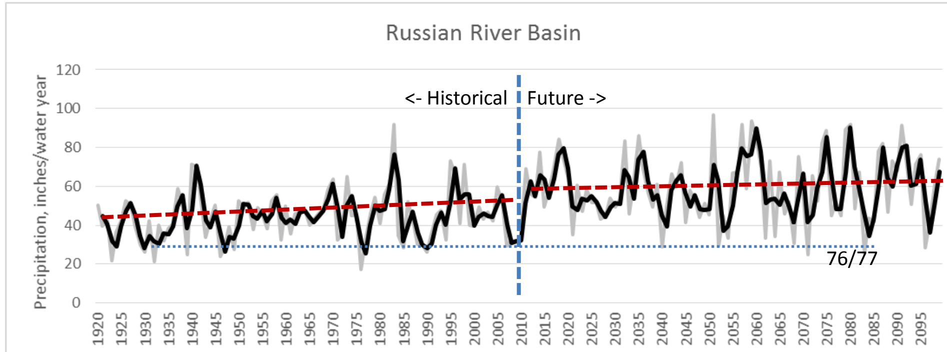
How will climate change impact the variability of annual and spring rainfall in the Russian River basin?

Variability in Annual Precipitation

Russian River Basin

2-year running average values

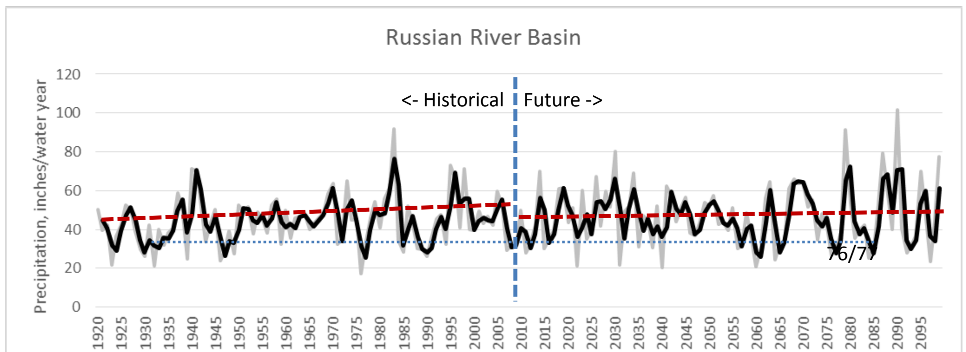
Warm &
High Rainfall



1981-2010 46 in/y

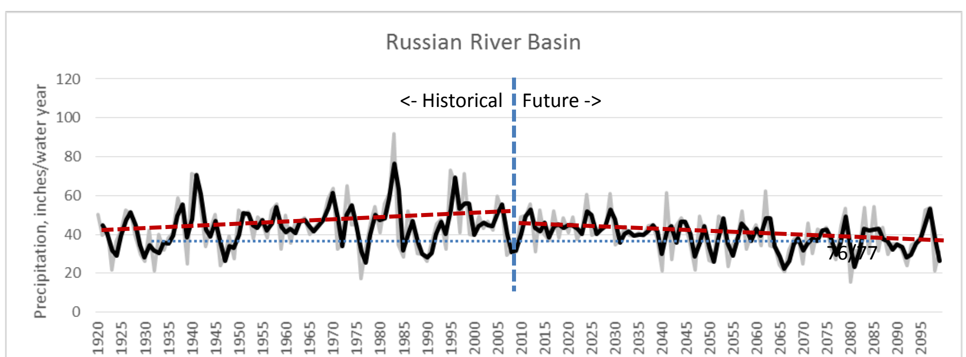
2070-2099 61 in/y

Warm &
Moderate
Rainfall



2070-2099 47 in/y

Hot &
Low Rainfall



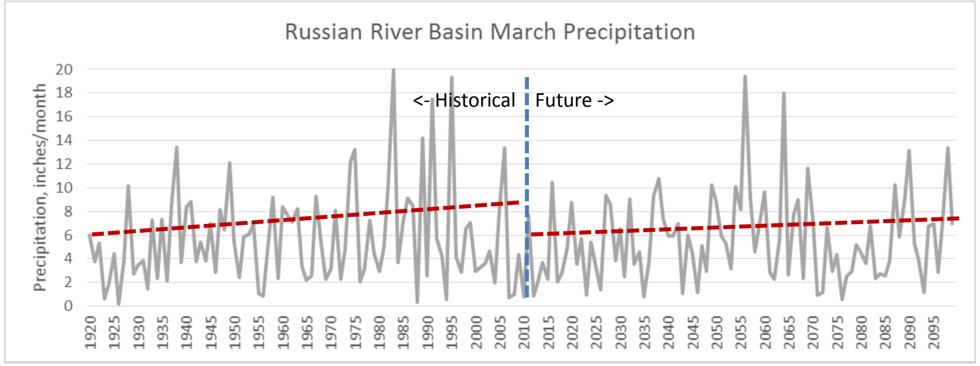
2070-2099 37 in/y

Precipitation across projections show both more extreme peaks and more dry years

Variability in March Precipitation

Russian River Basin

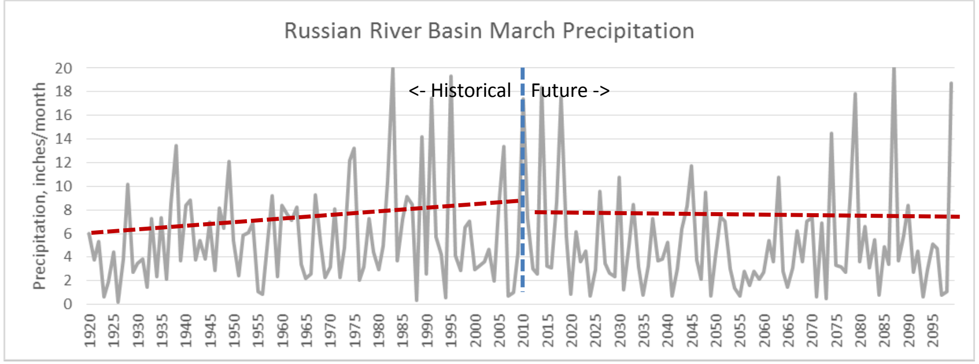
Warm & High Rainfall



Historical 5.8 in/mo

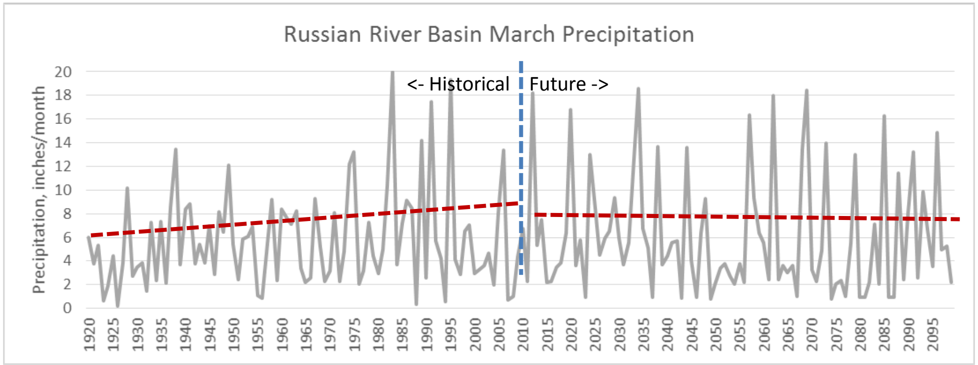
Future 5.6 in/mo

Warm & Moderate Rainfall



Future 5.2 in/mo

Hot & Low Rainfall



Future 6.1 in/mo

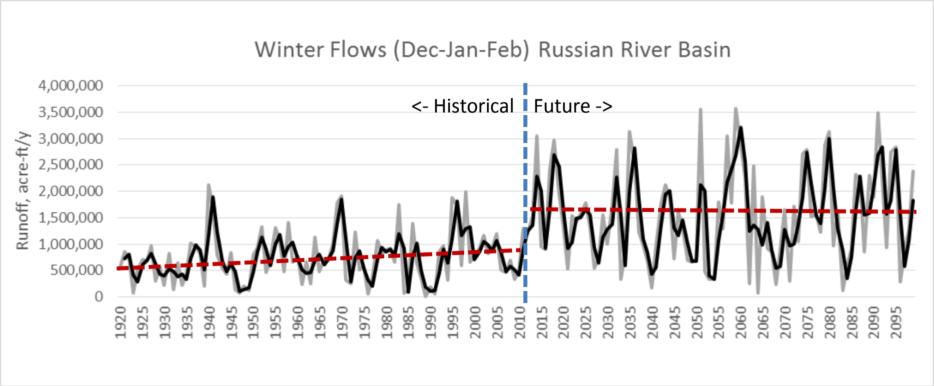
March precipitation doesn't significantly change across futures

Management Question

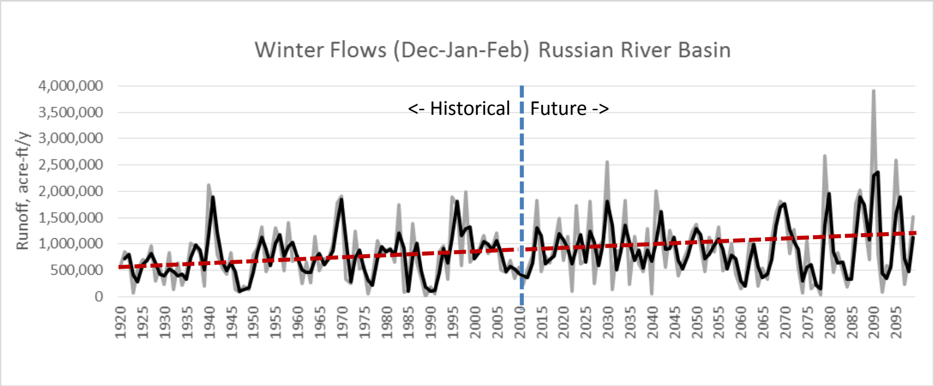
How will climate change impact the variability of winter and dry season runoff in the Russian River basin?

Russian River Basin: Winter Runoff

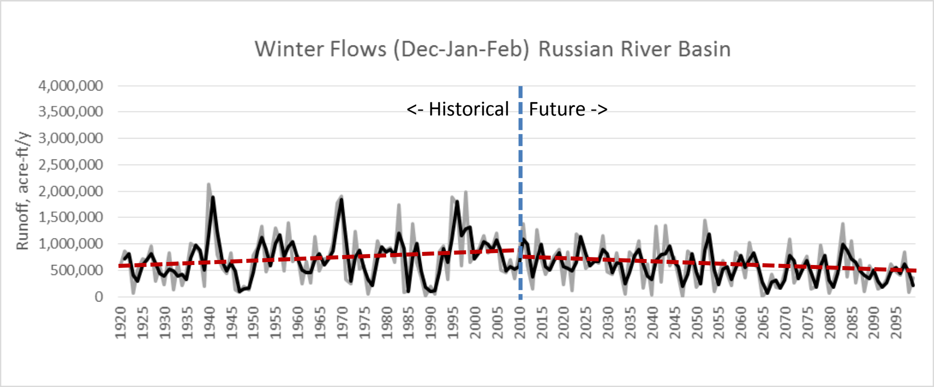
Warm &
High Rainfall



Warm &
Moderate
Rainfall



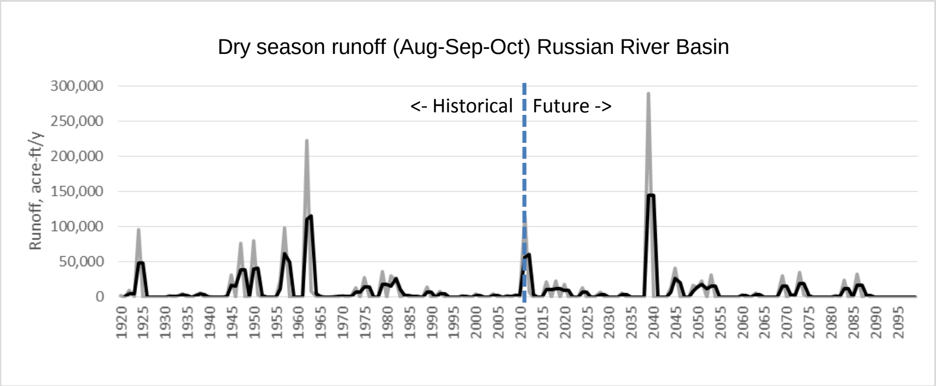
Hot &
Low Rainfall



Winter runoff parallels precipitation patterns across projections, including more extreme peaks and more dry years

Russian River Basin: Runoff available for base flow

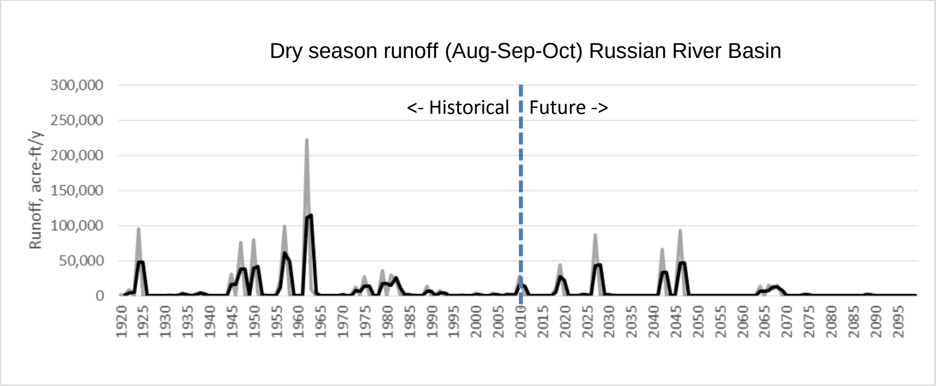
Warm &
High Rainfall



Historical 4423 af/y

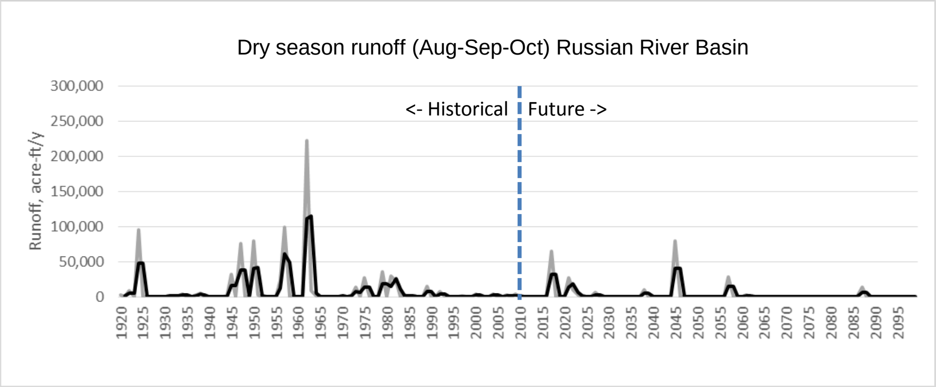
Future 4253 af/y

Warm &
Moderate
Rainfall



Future 1923 af/y

Hot &
Low Rainfall



Future 1204 af/y

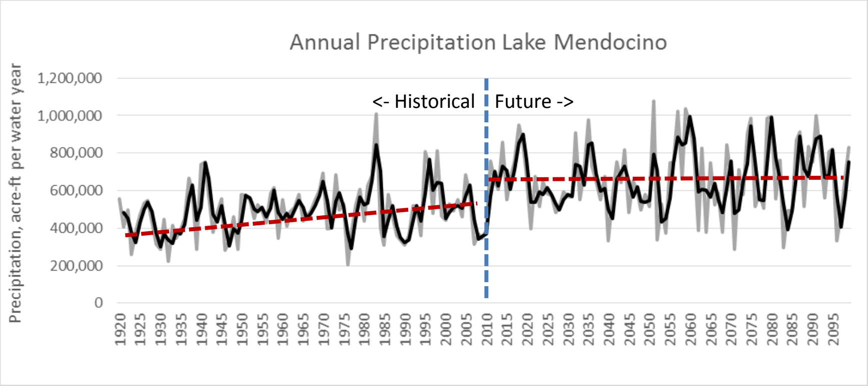
Reservoir Watershed Conditions

Management Question

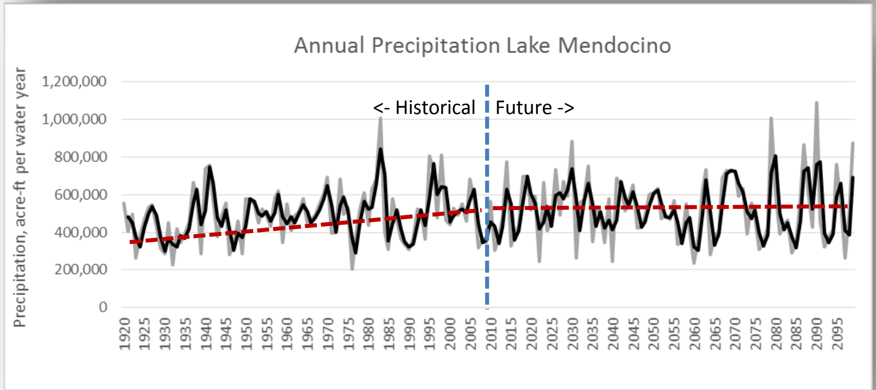
How will climate change impact the variability of annual rainfall in specific reservoir basins?

Lake Mendocino Watershed: Annual Precipitation

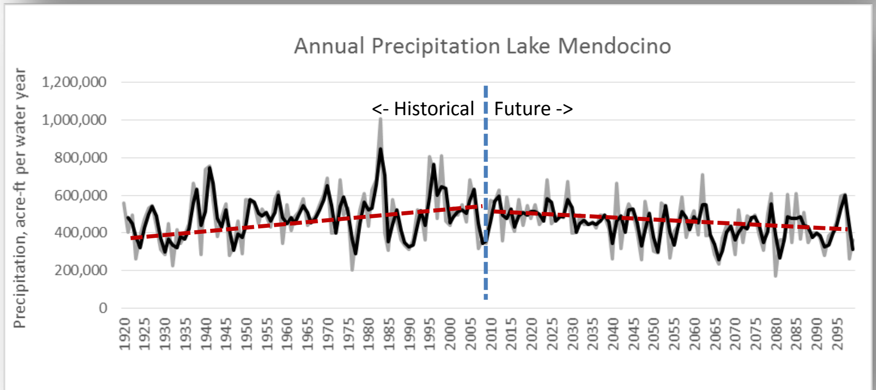
Warm & High Rainfall



Warm & Moderate Rainfall



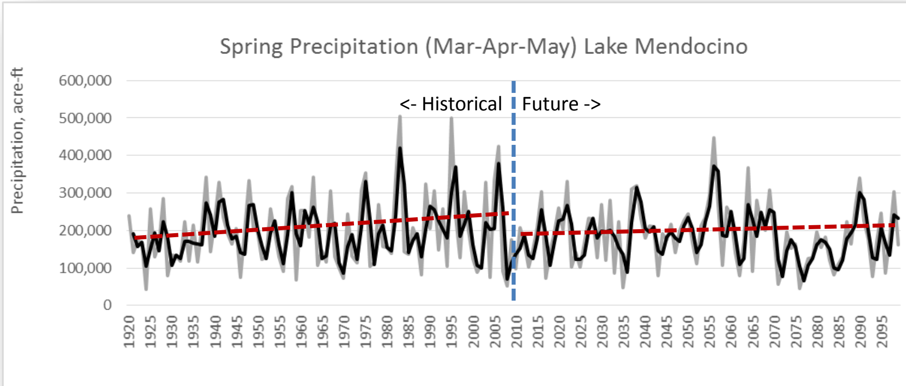
Hot & Low Rainfall



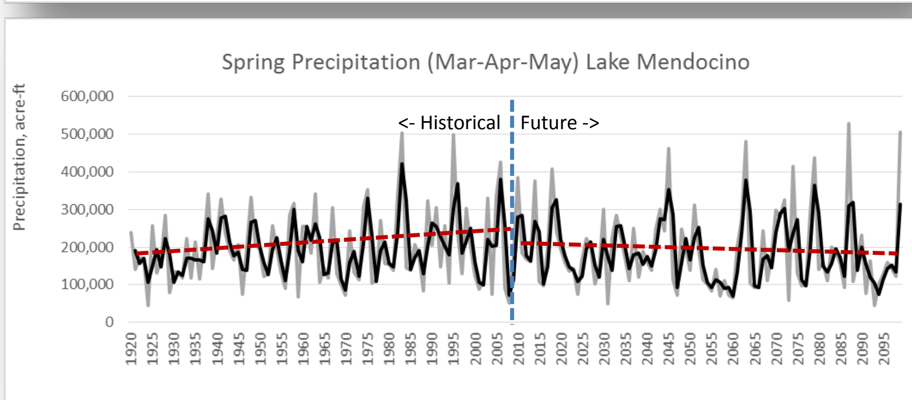
See table "Reservoir precipitation table.xlsx" for seasonal results for 3 reservoir watersheds and 6 futures.

Lake Mendocino Watershed: Spring Precipitation

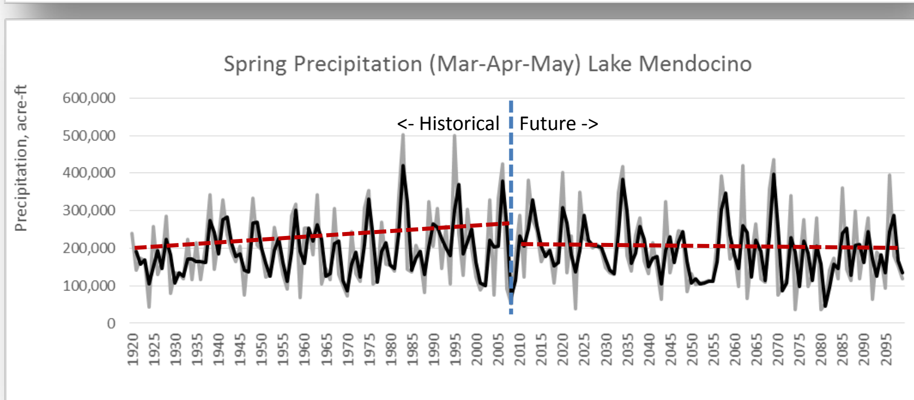
Warm &
High Rainfall



Warm &
Moderate
Rainfall

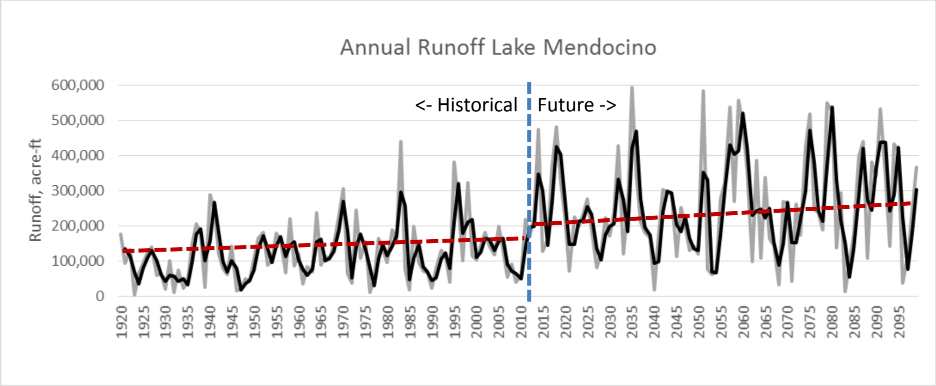


Hot &
Low Rainfall

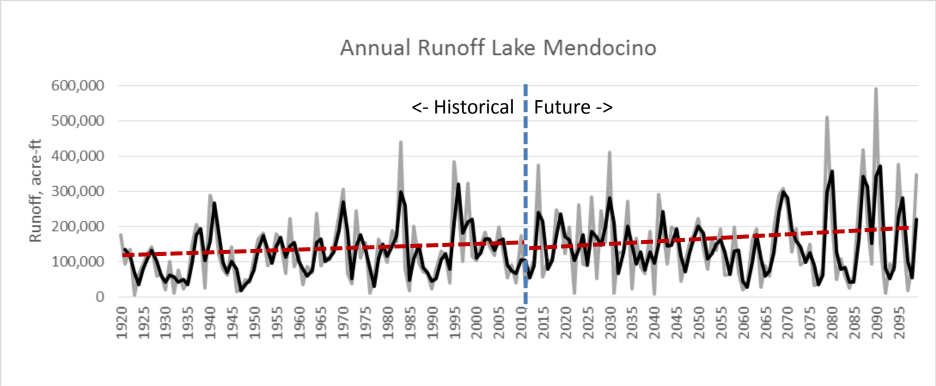


Lake Mendocino Watershed: Annual Runoff

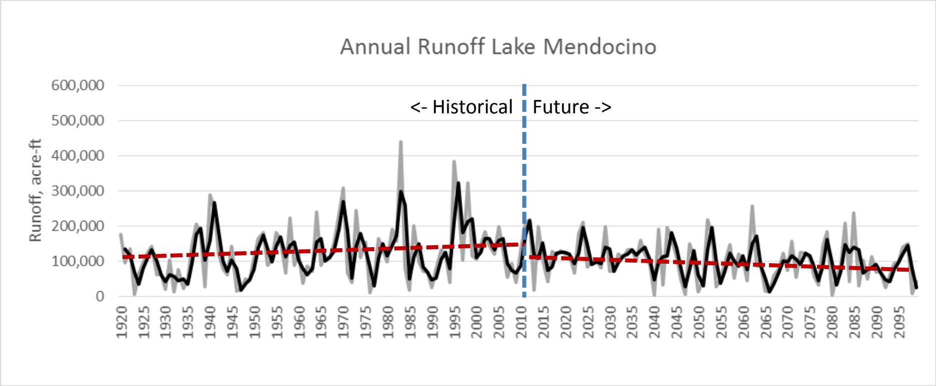
Warm &
High Rainfall



Warm &
Moderate
Rainfall



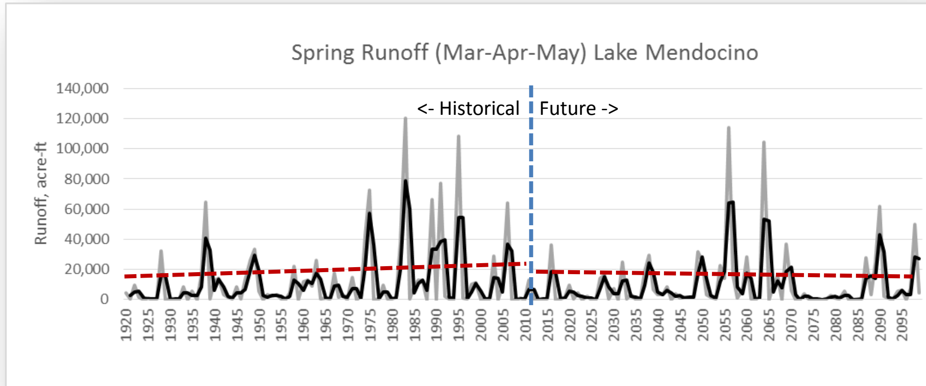
Hot &
Low Rainfall



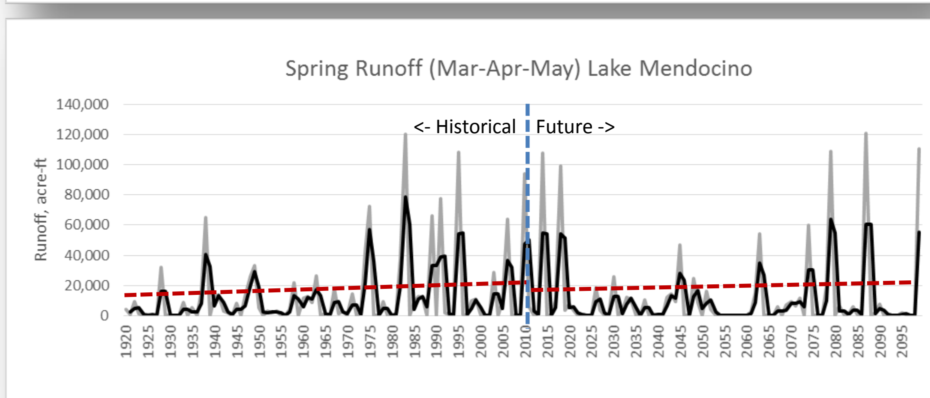
See table “Reservoir runoff table.xlsx” for seasonal results for 3 reservoir watersheds and 6 futures.

Lake Mendocino Watershed: Spring Runoff

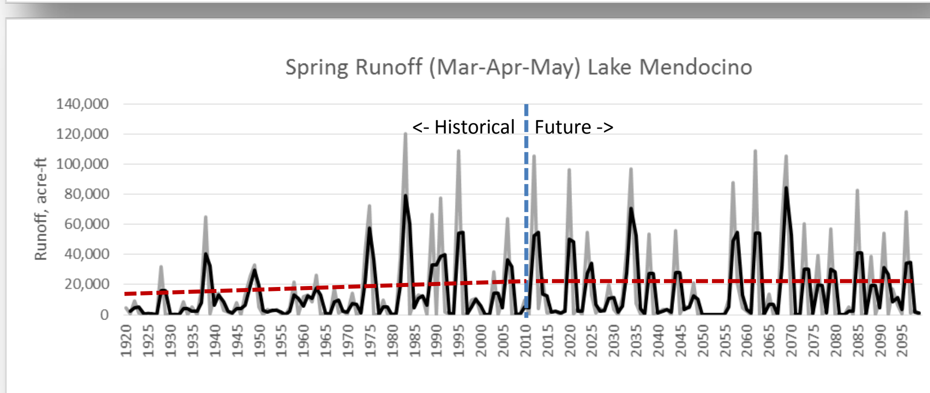
Warm & High Rainfall



Warm & Moderate Rainfall



Hot & Low Rainfall

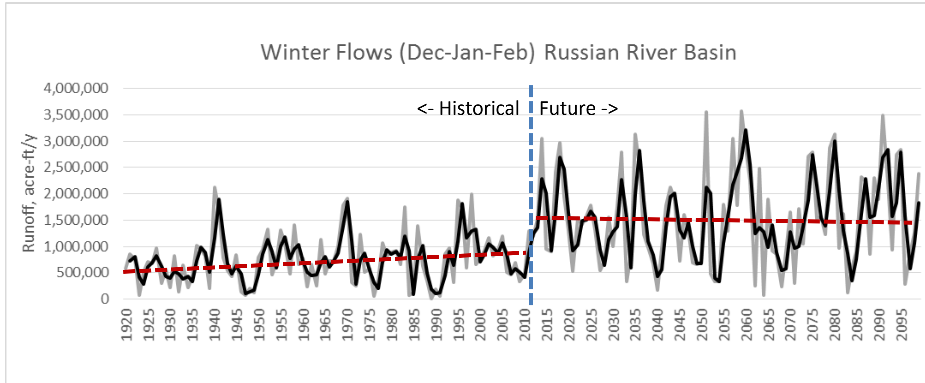


CHECK-are these in right order? ie true that high rainfall has less spring rainfall then low-these look interesting-any summary stats?

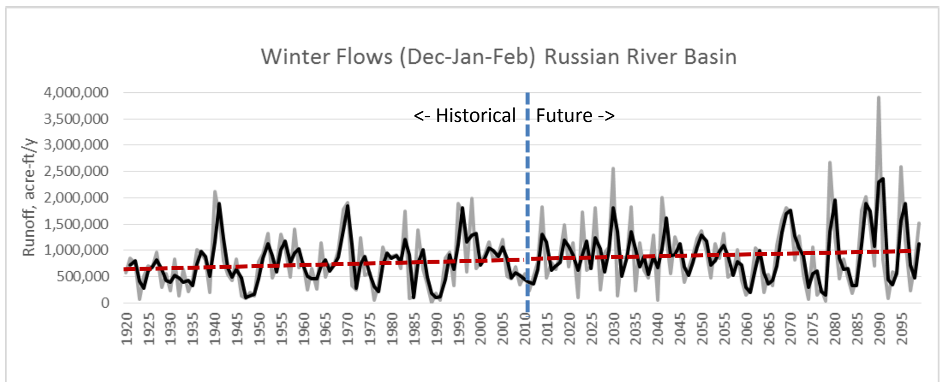
See table "Reservoir runoff table.xlsx" for seasonal results for 3 reservoir watersheds and 6 futures.

Lake Mendocino Watershed: Winter Runoff

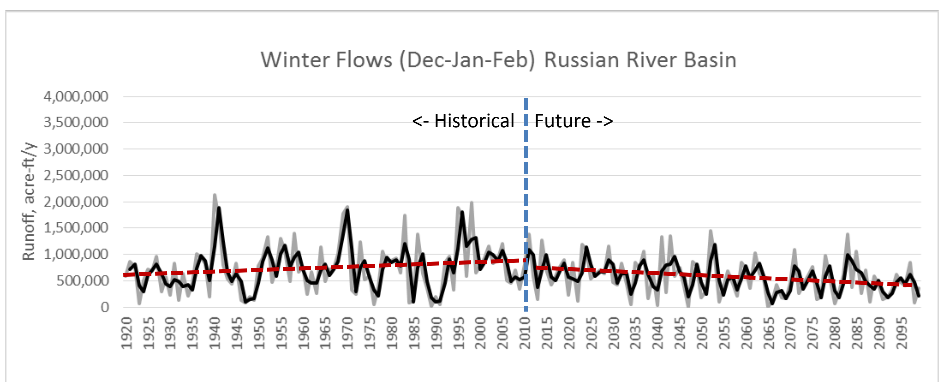
Warm &
High Rainfall



Warm &
Moderate
Rainfall



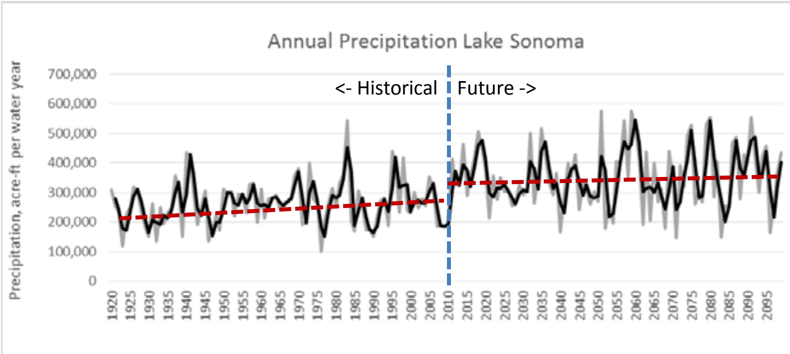
Hot &
Low Rainfall

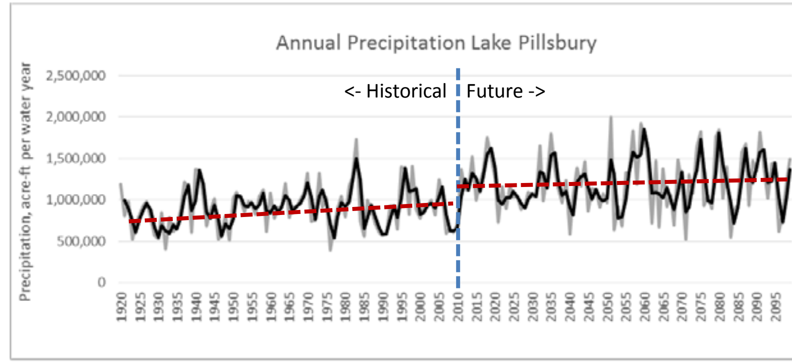


See table "Reservoir runoff table.xlsx" for seasonal results for 3 reservoir watersheds and 6 futures.

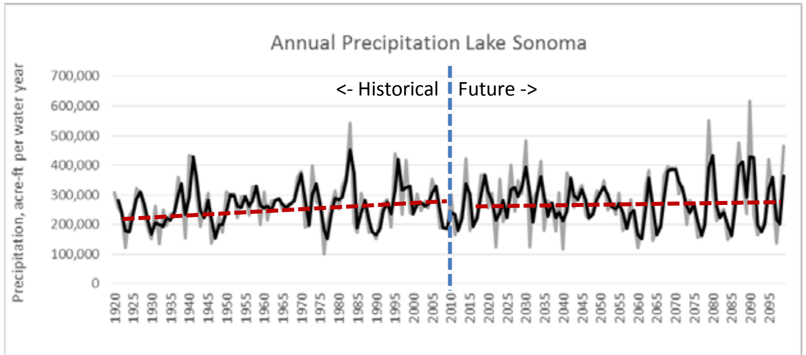
Precipitation in Lakes Sonoma and Pillsbury reservoir watersheds

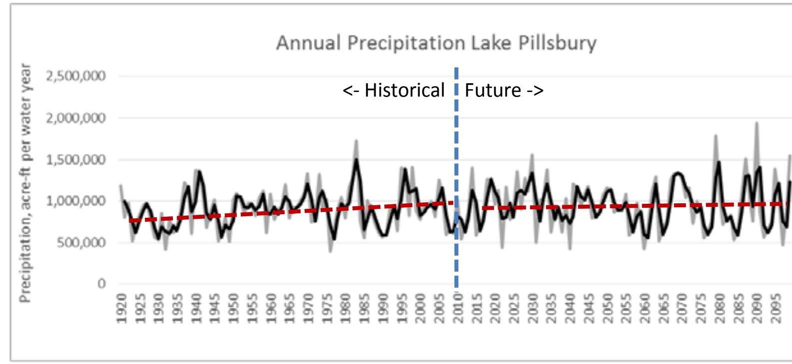
Warm & High Rainfall



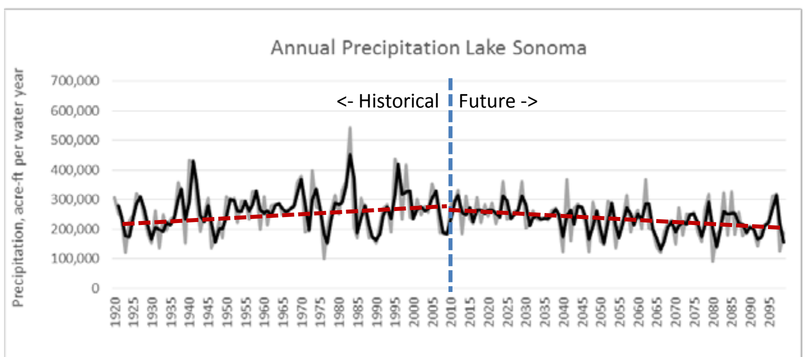


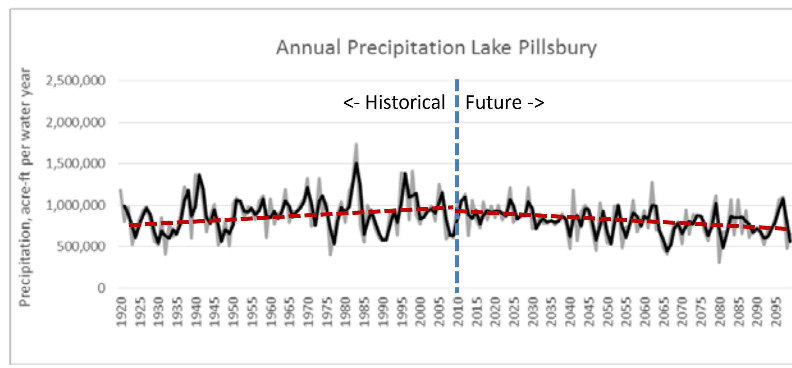
Warm & Moderate Rainfall





Hot & Low Rainfall



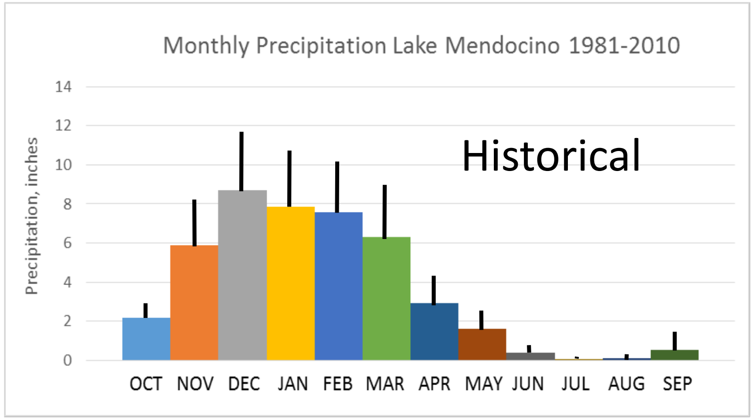


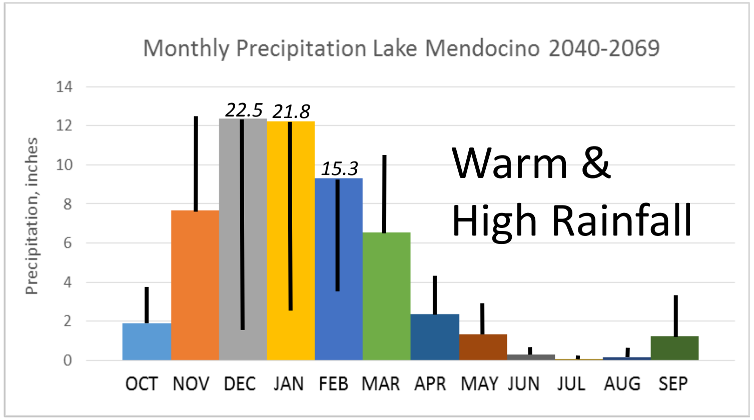
See table "Reservoir precipitation table.xlsx" for seasonal results for 3 reservoir watersheds and 6 futures.

Management Question

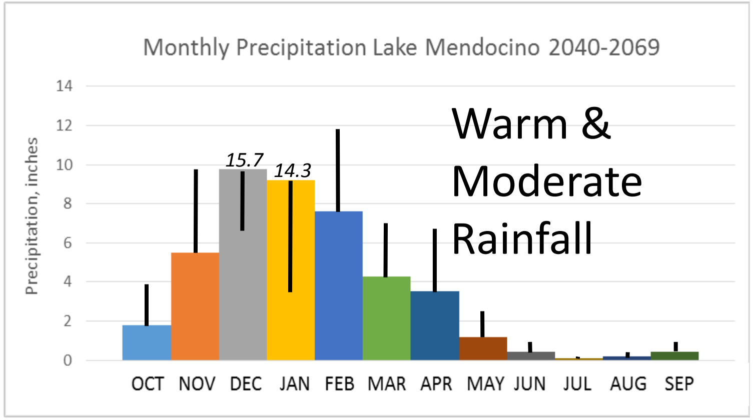
How will climate change impact the seasonality of annual rainfall in the Mendocino Reservoir basin?

Rainfall Seasonality: Lake Mendocino Basin

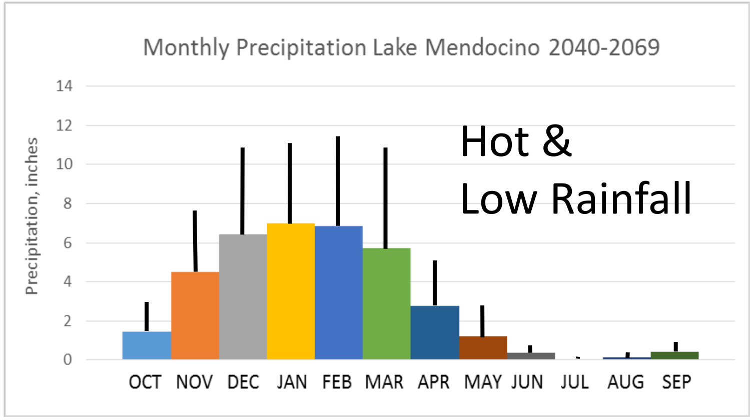




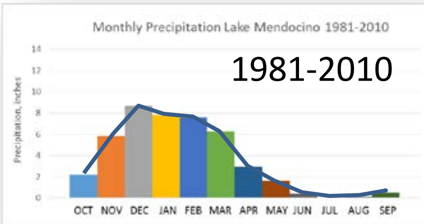
Length of bar is ½ standard deviation of monthly precipitation



- Seasonality of average rainfall doesn't change much for Lake Mendocino watershed by mid-century
- Wet scenario: additional rainfall concentrated in mid-winter
- Dry scenario: reductions in Nov-Dec
- Increases in monthly variability for all scenarios, notably wetter ones



Changes in Seasonality Precipitation



- Black line is historical for comparison on all graphs
- Miroc, GFDL and PCM all shift winter precip to a month later for mid century and to 2 months later for end century
- Miroc, GFDL and PCM all have narrowing of wet season for mid and end century
- CNRM moves wet season forward a month

CNRMrcp85 (warm wettest)

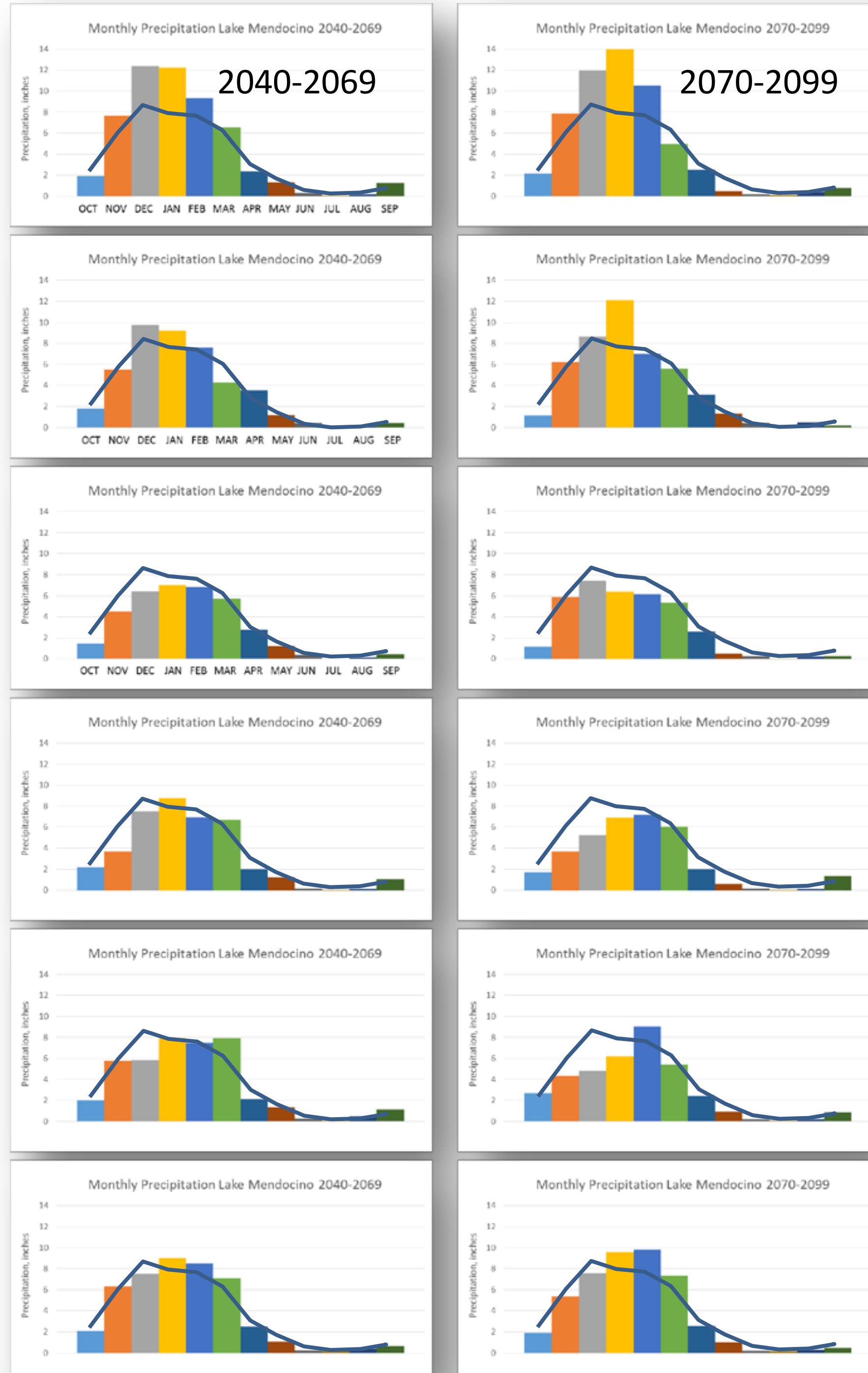
CCSM4rcp85 (warm mod wet)

MIROCrcp85 (hot driest)

GFDL A2 (warm dry)

GFDL B1 (warm wet)

PCM A2 (warm wet)



Daily Flow Analyses

Pepperwood
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Management Question

How will climate change impact the distribution of daily flows on the Russian River?

Management Question

How might climate change increase the risk of flooding in the Russian River Basin?

3-day high flows for Upper River and Lower Russian River (modeled)

3-day flows exceedances of 99.9% threshold (per decade)

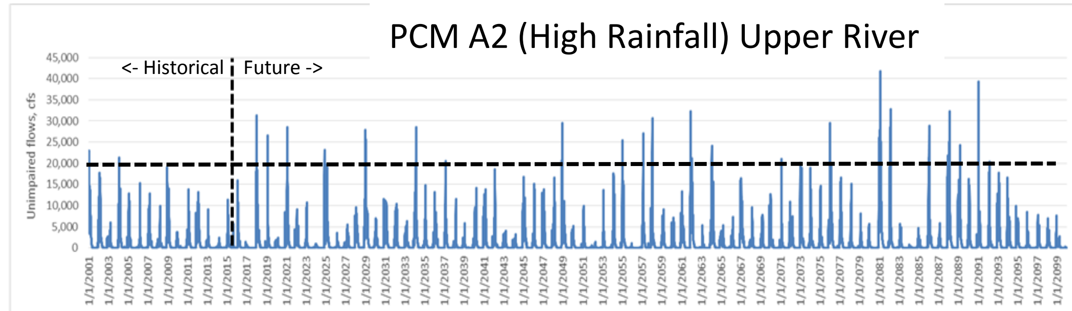
19,298 cfs threshold for upper river
38,902 cfs threshold for lower river

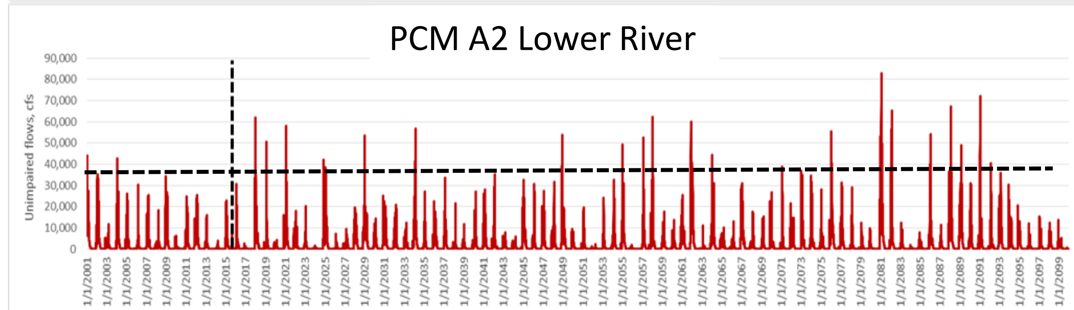
2001-2015 vs 2016-2099
(exceedances per decade)

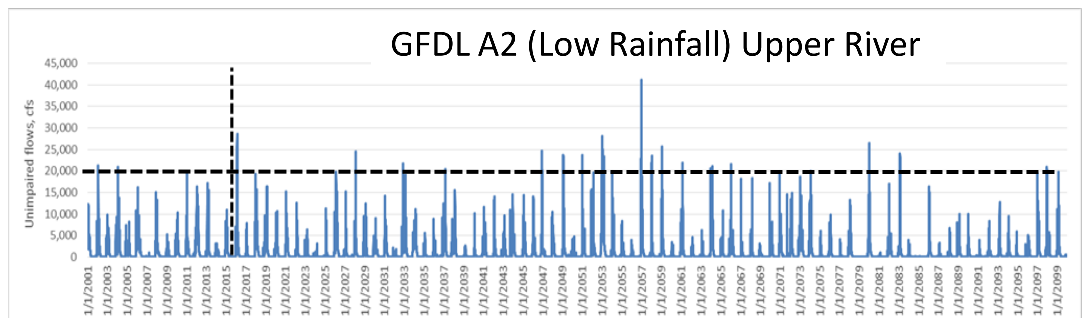
	Upper River: Healdsburg		Lower River: Guerneville	
	Current (2001-15)	Future (2016-99)	Current (2001-15)	Future (2016-99)
Business-as-usual				
PCM A2	1.3	3.9	1.3	3.6
GFDL A2	2.0	3.6	0.7	3.3
Mitigated				
PCM B1	4.0	4.8	3.3	4.6
GFDL B1	2.0	3.7	1.3	3.6

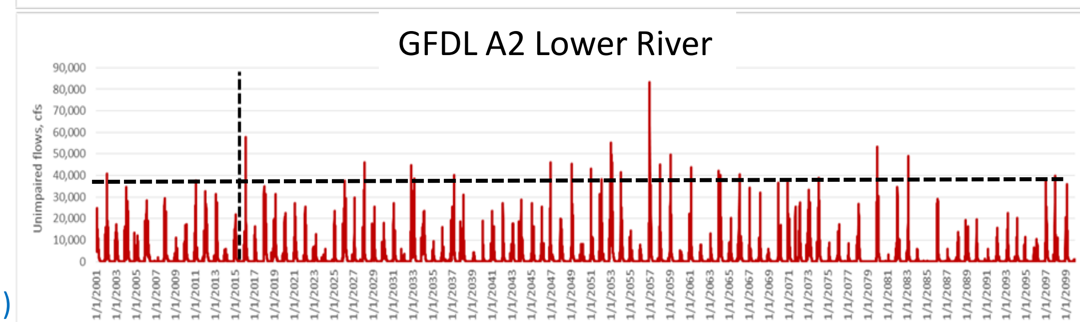
The frequency of 3-day "very high flow" events are up to 3 x more likely to occur than they do currently.

PCM A2 = Scenario 2: Low warming, moderate rainfall
GFDL A2 = Scenario 4: Warm, low rainfall
GFDL B1 = Scenario 1: Low warming, low rainfall (mitigated)









Management Question

How might the effect of climate change on flows impact the value of the Russian River for fisheries?

3-day low flows for Upper River and Lower River (modeled)

Percentage of time future 3-day flows are below the lower 5% of current flows

3.9 cfs threshold for upper river

11.1 cfs threshold for lower river

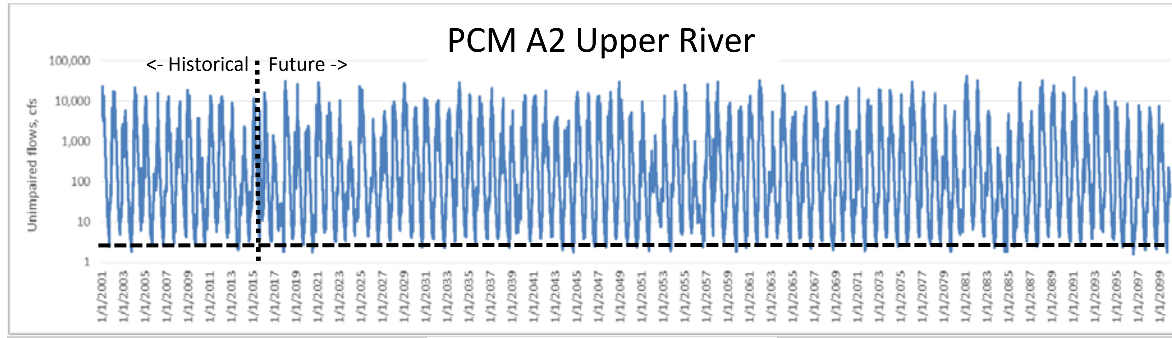
2001-2015 vs 2016-2099

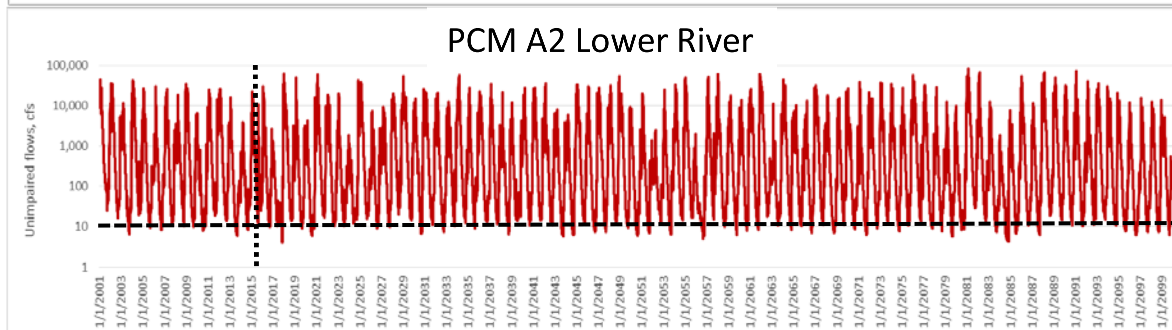
(exceedances per decade)

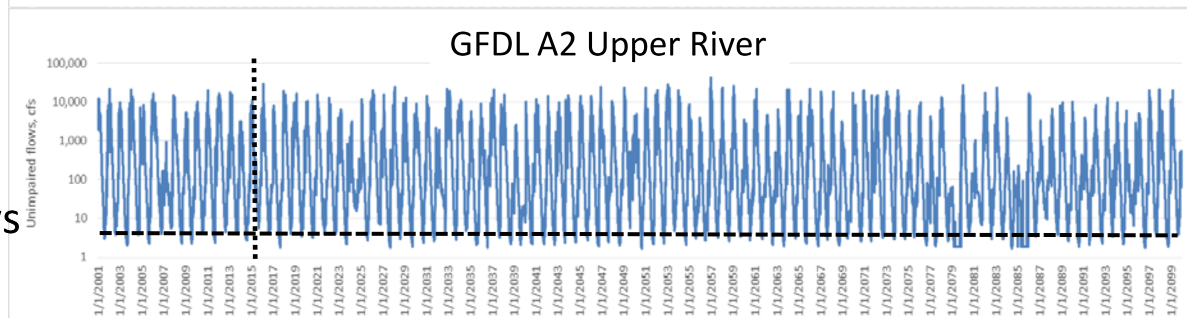
	Upper River: Healdsburg		Lower River: Guerneville	
	Current (2001-15)	Future (2016-99)	Current (2001-15)	Future (2016-99)
Business-as-usual				
PCM A2	2.0	3.3	6.0	6.9
GFDL A2	4.7	8.1	4.7	8.1
Mitigated				
PCM B1	5.3	3.9	6.0	4.9
GFDL B1	4.0	3.9	6.0	7.6

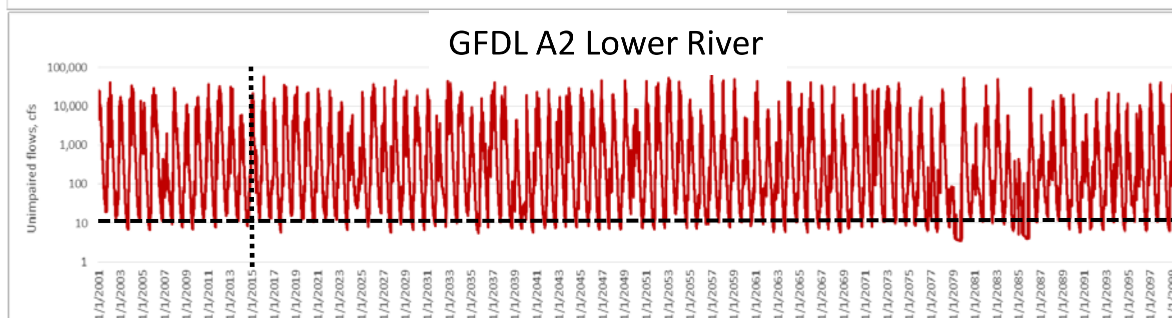
Generally, future 3-day very low flows range from no change or a decline from current for the mitigated scenario, to no difference for the upper river and an increase for the lower river under the BAU scenario.

PCM wet model, GFDL dry model









Daily streamflow data
Evaluation of environmental flow thresholds

- Environmental flow components based on Hydrologic Alteration concepts and TNCs Indicators of Hydrologic Alteration (IHA) software
- These 5 flow components (combined from 33 environmental flow components characterized in IHA) are particularly important to river ecosystem health.
- They can be used to assess ecosystem flow recommendations for post-impact period (e.g. climate change), such as thresholds needed to maintain channel and floodplain habitats, creating fish passage, shallow water habitats, nutrient cycling, wetland maintenance, etc.

Large floods: equal to or greater than the 1- year flood (maintain channel habitats and floodplain topography, enhance nutrient cycling etc.)

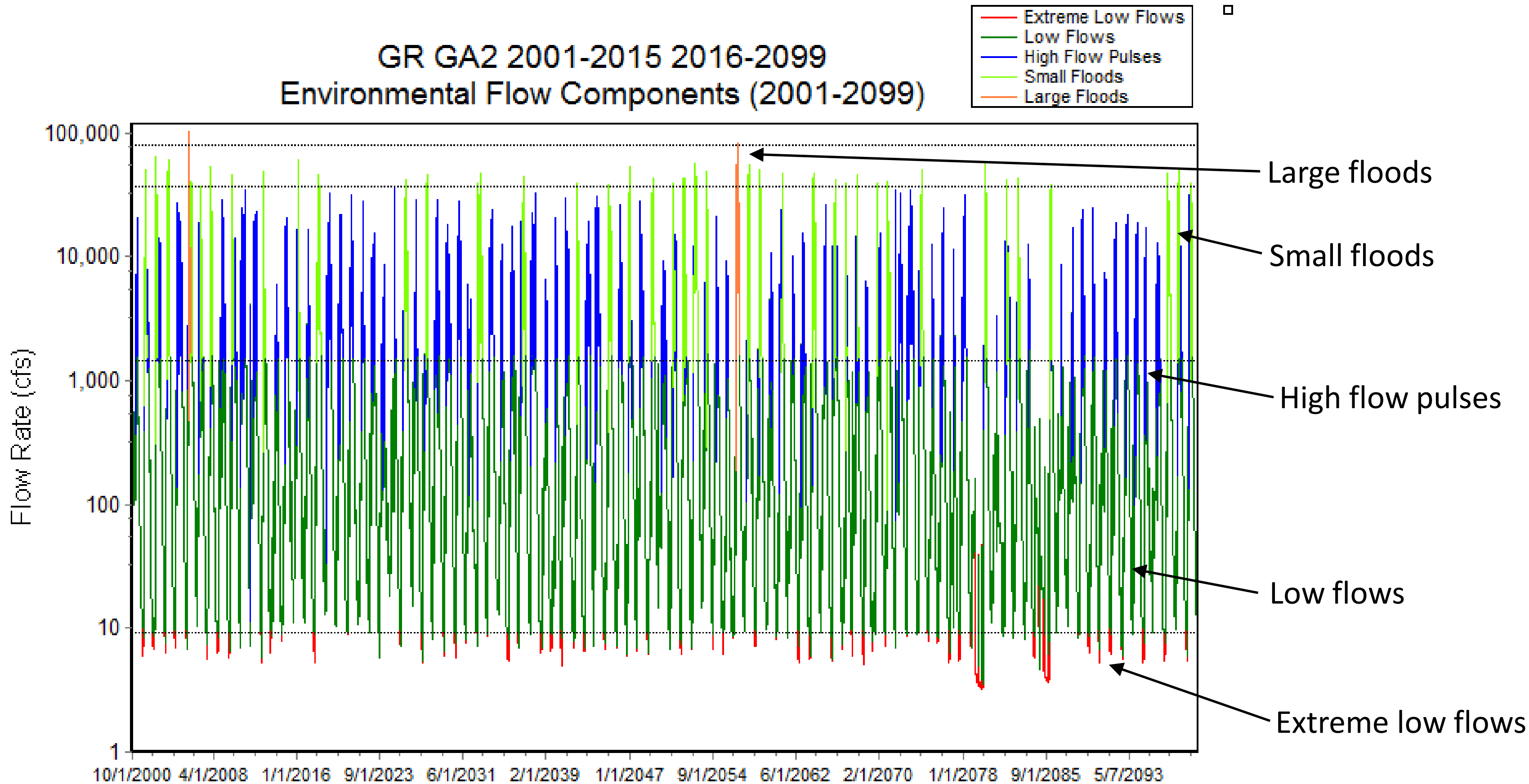
Small floods: exceed bankfull, occurring every 2-10 years (maintain wetlands, control invasives) THIS LOOKS REVERSED TO ME

High flow pulses: flows > low flows and < bankfull (threshold is 5% exceedance of pre-impact period) (transport and dispersal, fish passage etc.)

Low flows: base flow for each month (threshold is 95% exceedance during pre-impact period) (shallow water habitat)

Extreme low flows: occur during droughts (lowest 10th percentile of all low flows) (floodplain drainage and tree recruitment)

Daily streamflow data: environmental flow thresholds



Large floods: equal to or greater than the 1- year flood

Small floods: exceed bankfull, occurring every 2-10 years

High flow pulses: flows > low flows and < bankfull (threshold is 5% exceedance probability during 1981-2010 period

Low flows: base flow for each month (threshold is 95% exceedance probability during 1981-2010 period)

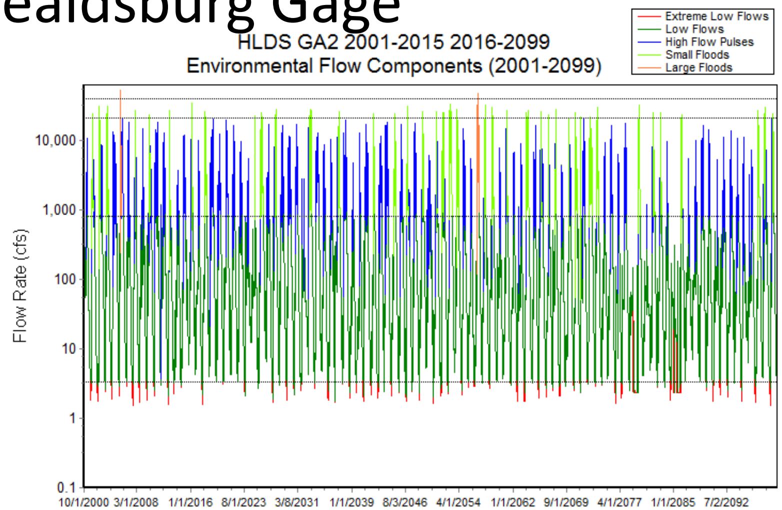
Extreme low flows: occur during droughts (lowest 10th percentile of all low flows)

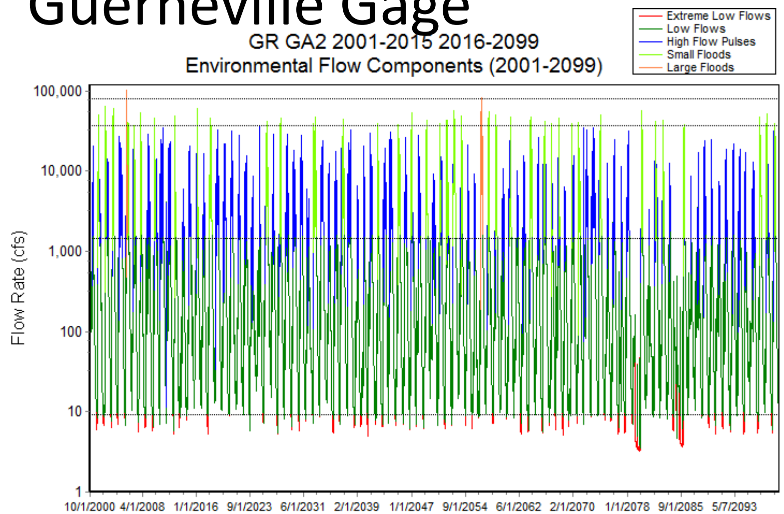
Daily streamflow data: environmental flow thresholds

Daily flow data and futures: thresholds developed from 2001-2015 period

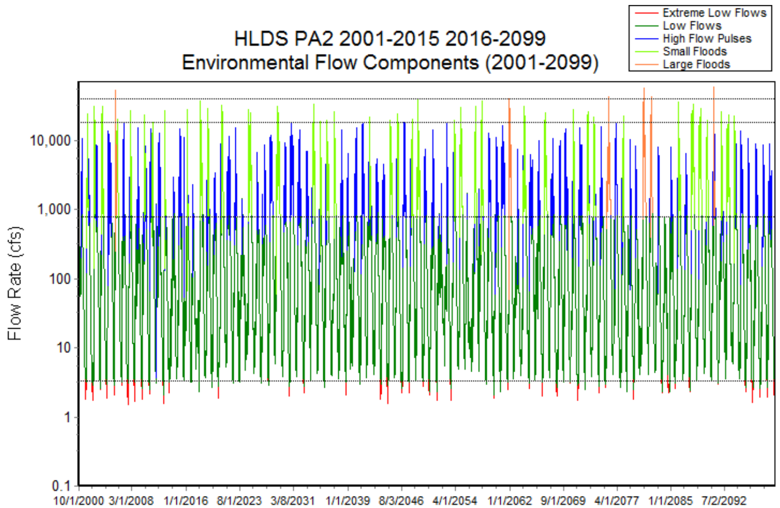
Healdsburg Gage | Guerneville Gage

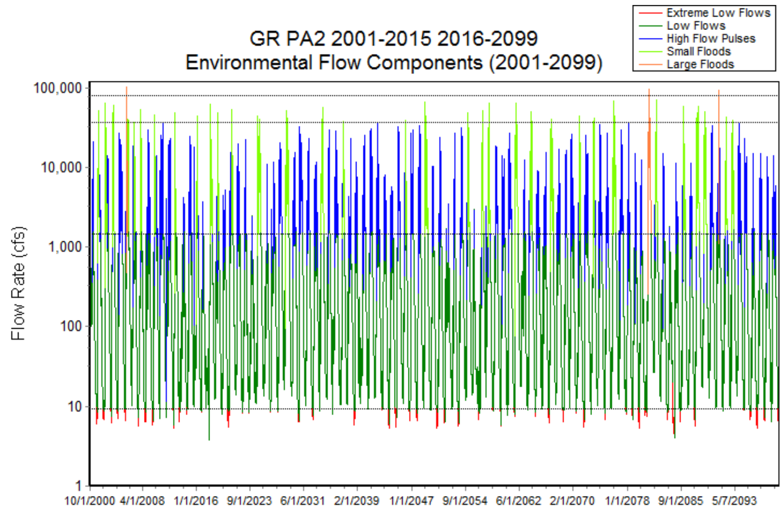
Dry scenario





Wet scenario



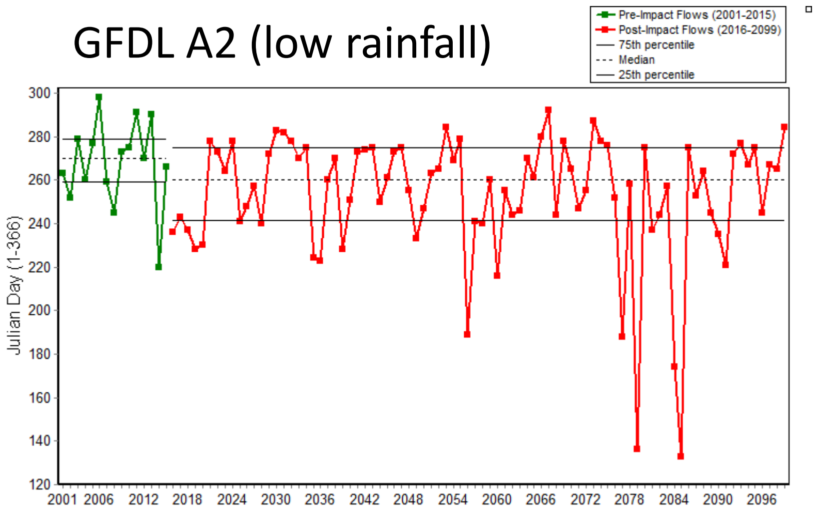


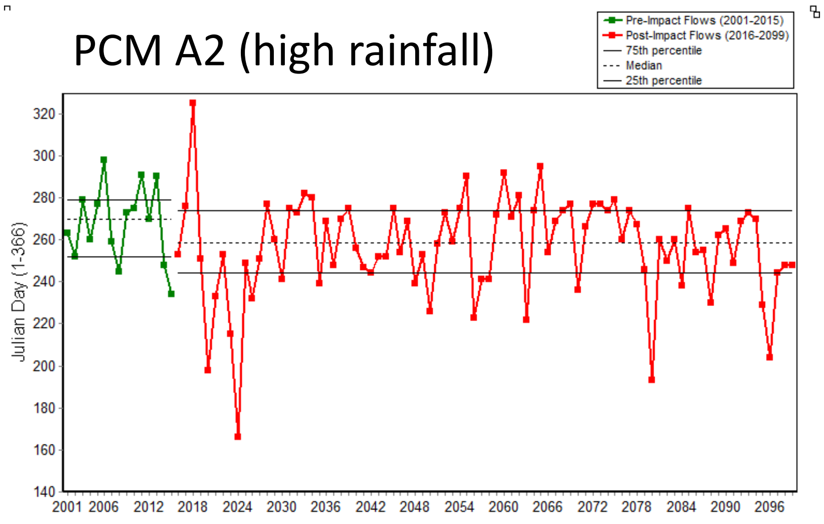
Thresholds differ for gages and flow recommendations can be made for each reach.
Futures can be evaluated to assess likelihood of achieving goals.

Julian Date of Minimum Flow: Russian River

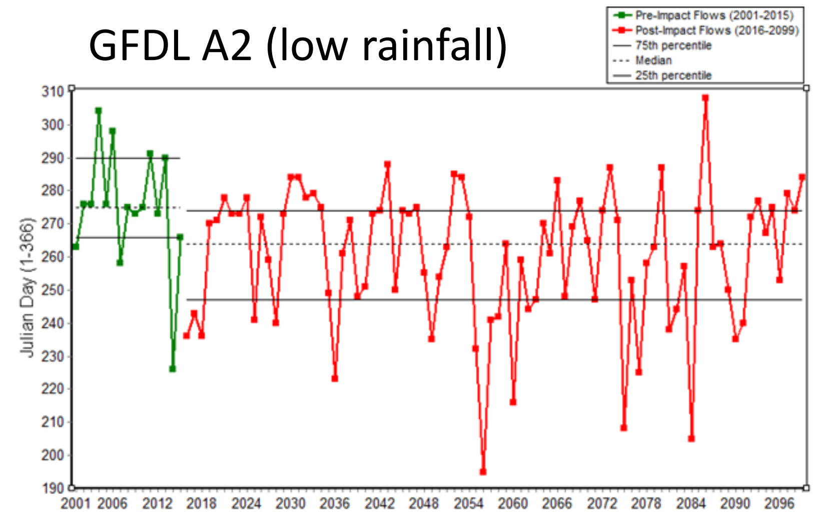
RESULTS
GFDL A2 Average Date of minimum flow (2015-2099) ~ 10 days earlier than 2001-2015 average
PCM A2 Average Date of minimum flow (2015-2099) ~5 to10 days earlier 2001-2015 average

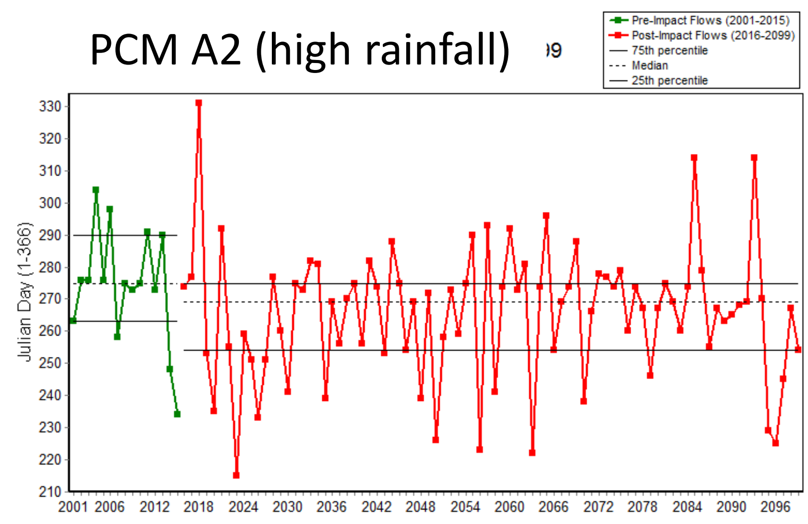
Upper River: Healdsburg Gage





Lower River: Guerneville Gage





Recharge and Local Runoff

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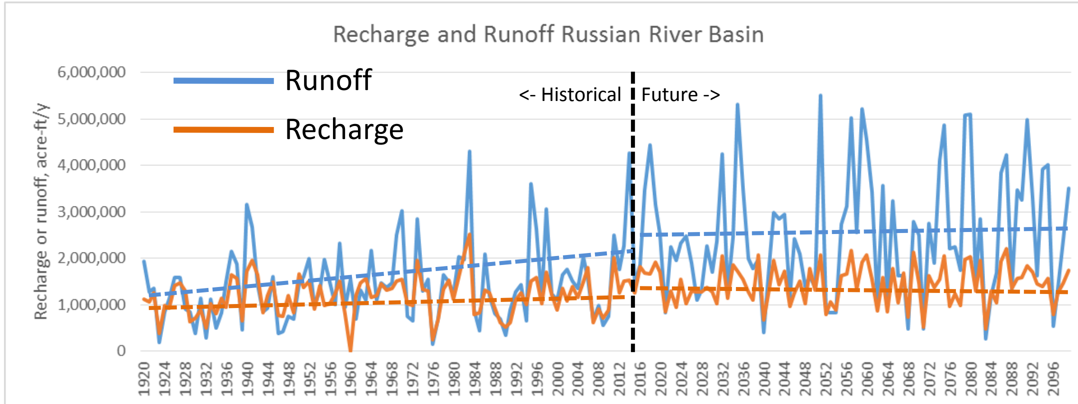
Management Question

What is the relationship of annual recharge rates compared to annual runoff?

Russian River Basin: Annual Runoff and Recharge

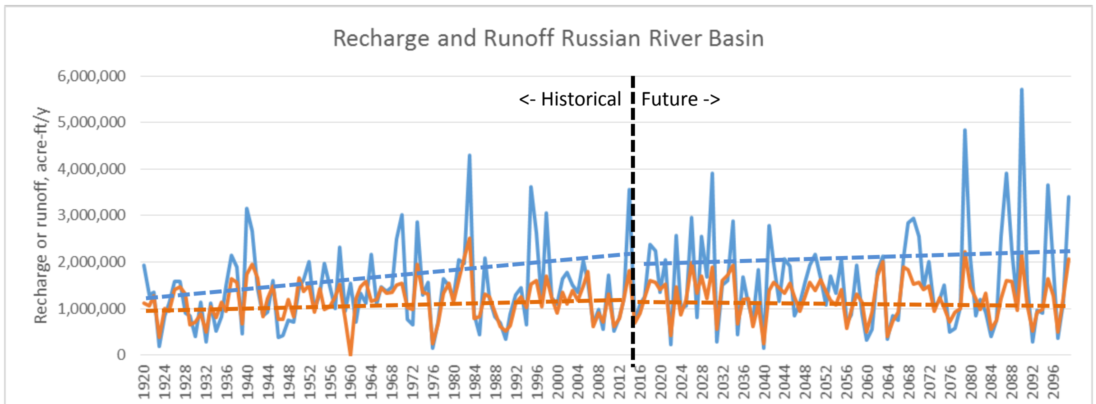
Warm &
High Rainfall



Historical rch 1.4 Maf/y
run 1.9

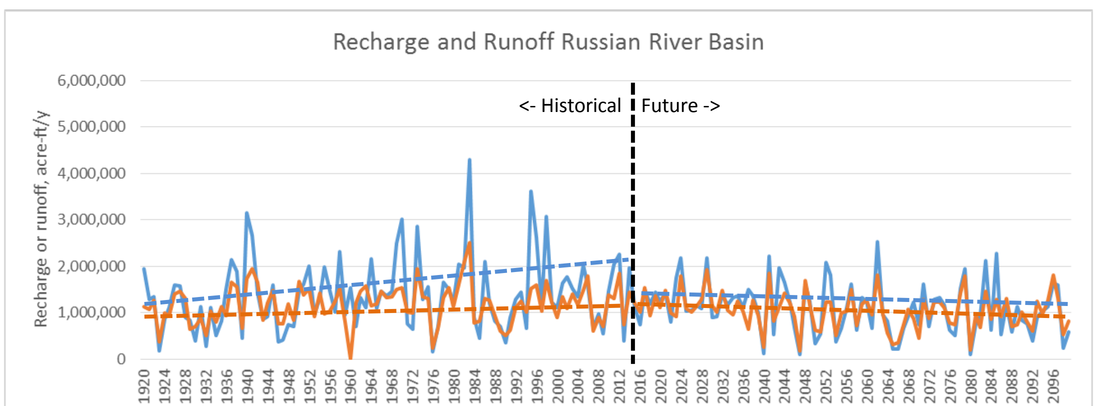
Future rch 1.8 Maf/y
run 3.4

Warm &
Moderate
Rainfall



Future rch 1.5 Maf/y
run 2.2

Hot &
Low Rainfall



Future rch 1.2 Maf/y
run 1.5

UNITS? Was orig af/y
used millions of acre feet-based on graph which meant had to reduce values by factor of 10)

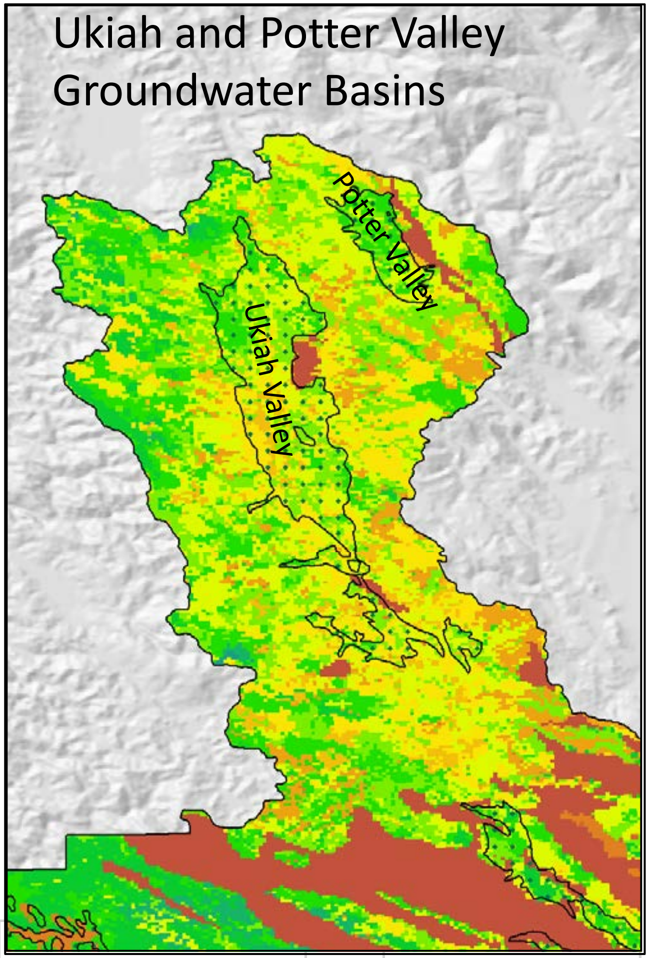
Take home message: Recharge is much less variable than runoff across futures

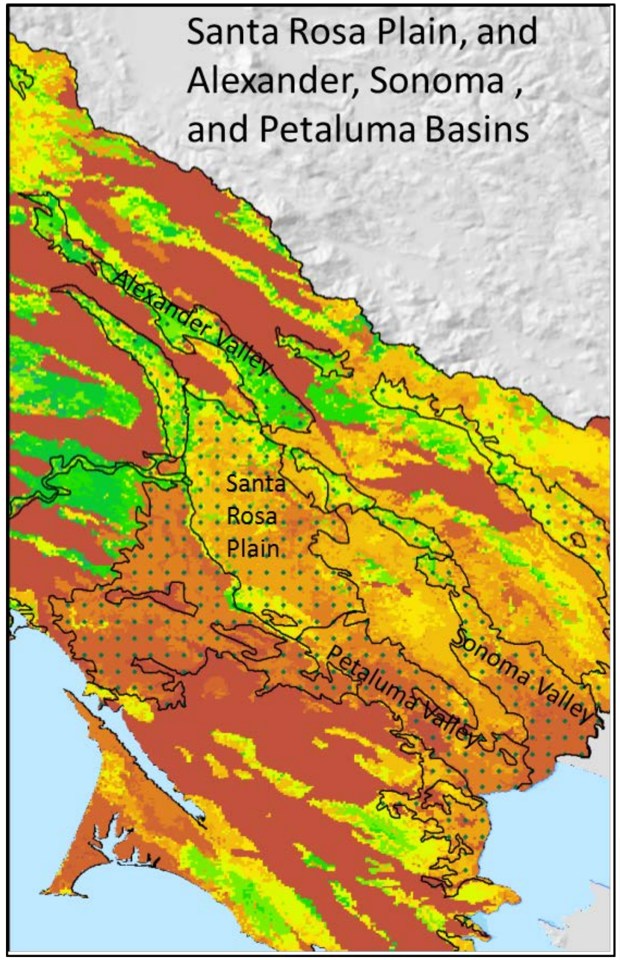
Management Question

What is the spatial variability of runoff and potential groundwater recharge and how might climate change impact these distributions?

Historical Recharge 1981-2010

(inches)





Groundwater basins

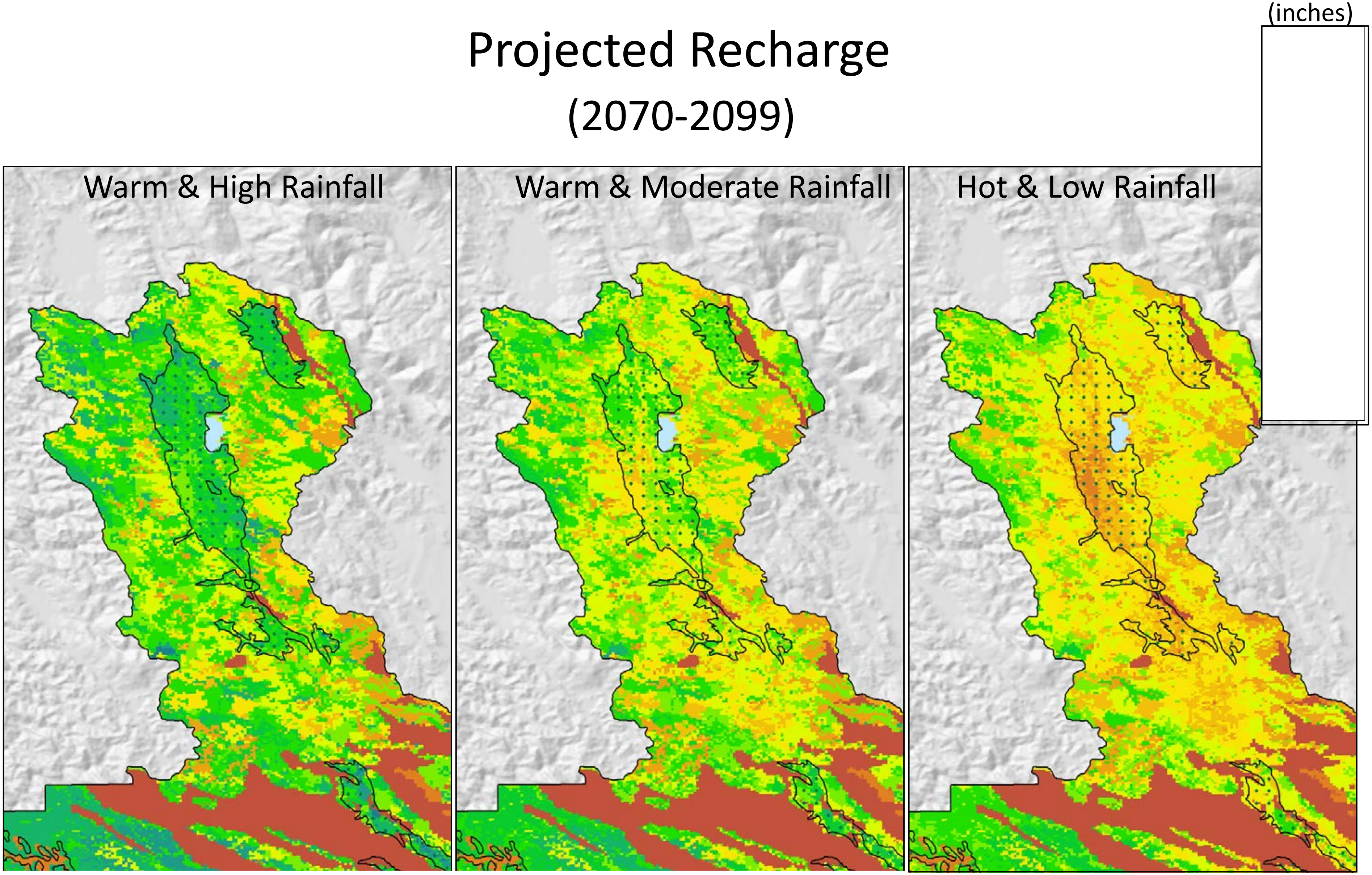
		Current (1981-2010)	
Subbasin	Units	Recharge	Runoff
Ukiah Valley	in	36.1	18.9
East Fork Potter Valley	in	15.7	12.7

Recharge or Runoff for Groundwater Basin Watersheds

		Current (1981-2010)	
Subbasin	Units	Recharge	Runoff
Alexander Valley	in	9.1	19.4
Santa Rosa Plain	in	10.5	9.8
Petaluma Valley	in	10.6	8.5
Sonoma Valley	in	8.6	8.8

Projected Recharge

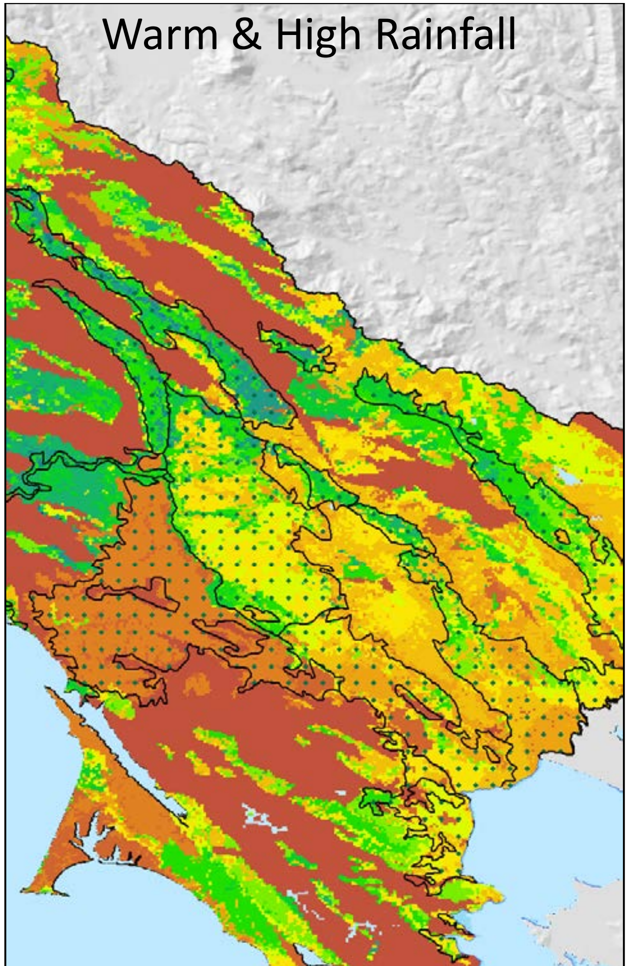
(2070-2099)

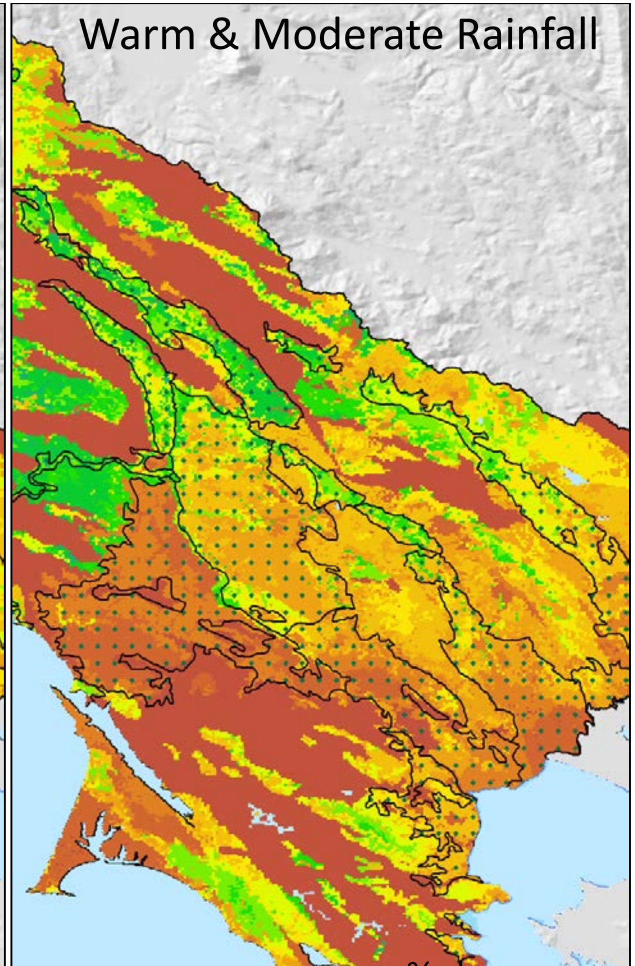


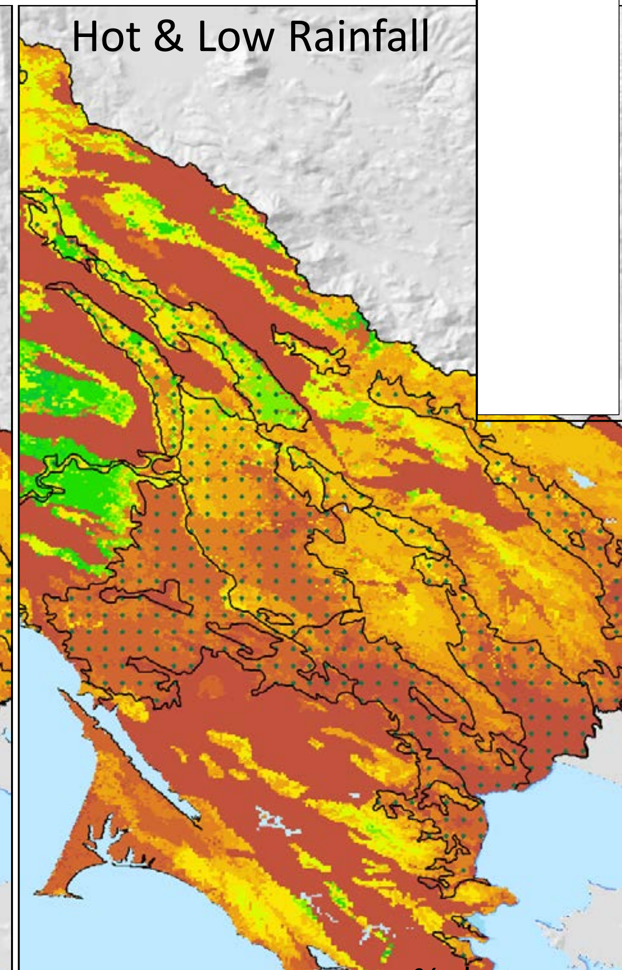
	Warm & High Rainfall % change	Warm & Moderate Rainfall % change	Hot & Low Rainfall % change
Ukiah Valley	22%	0%	-16%
East Fork Potter Valley	15%	-1%	-14%

Projected Recharge
(2070-2099)

(inches)

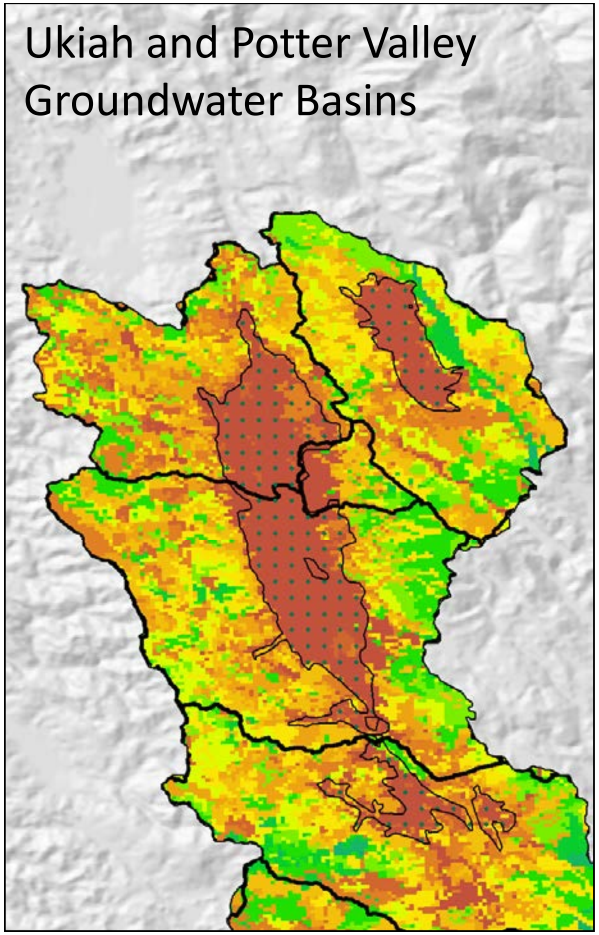


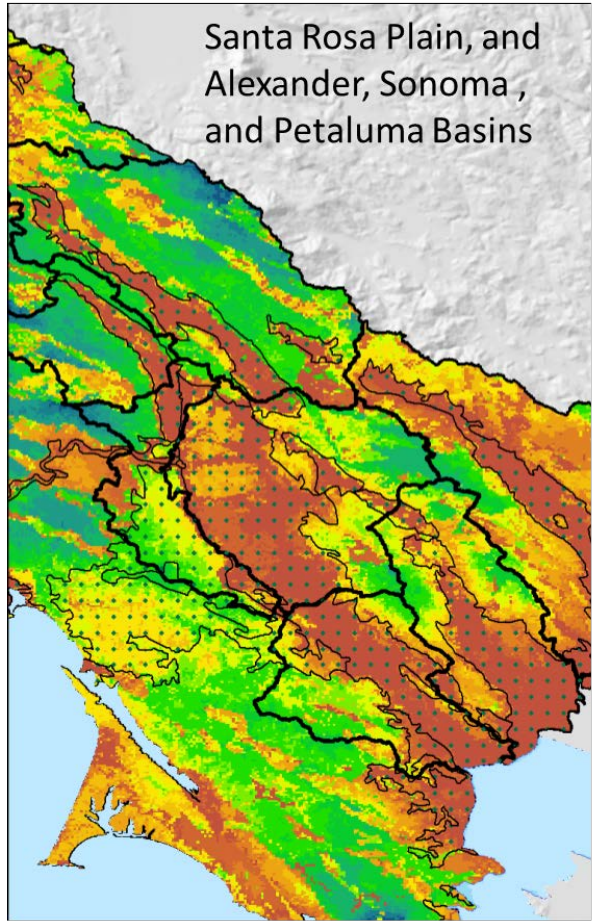




	% change	% change	% change
Alexander Valley	27%	5%	-17%
Santa Rosa Plain	39%	7%	-25%
Petaluma Valley	-21%	-44%	-67%
Sonoma Valley	39%	5%	-28%

Historical Runoff 1981-2010





(inches)

Groundwater basins

		Current (1981-2010)	
Subbasin	Units	Recharge	Runoff
Ukiah Valley	in	36.1	18.9
East Fork Potter Valley	in	15.7	12.7

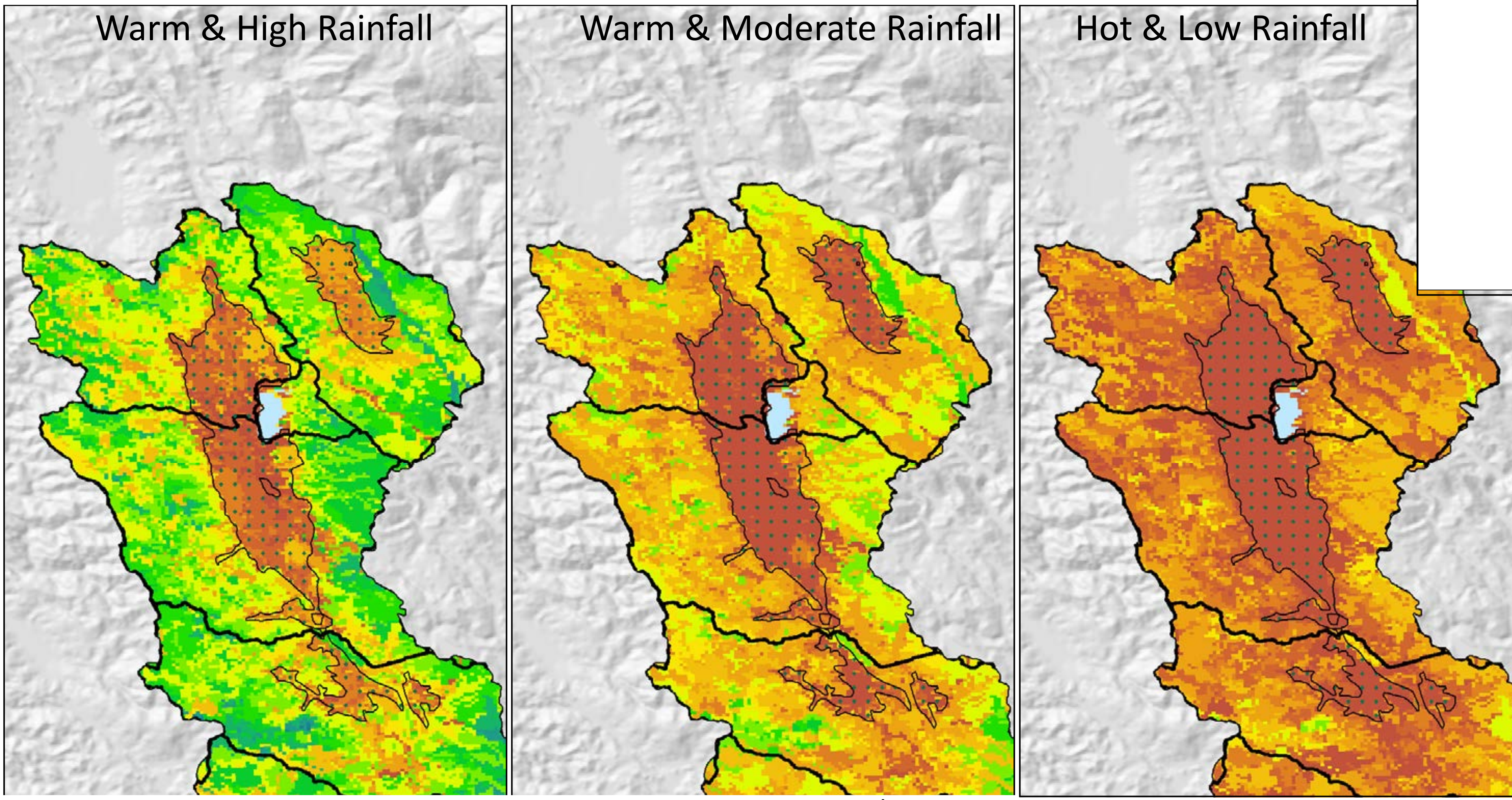
Recharge or Runoff for Groundwater Basin Watersheds

		Current (1981-2010)	
Subbasin	Units	Recharge	Runoff
Alexander Valley	in	9.1	19.4
Santa Rosa Plain	in	10.5	9.8
Petaluma Valley	in	10.6	8.5
Sonoma Valley	in	8.6	8.8

Projected Runoff

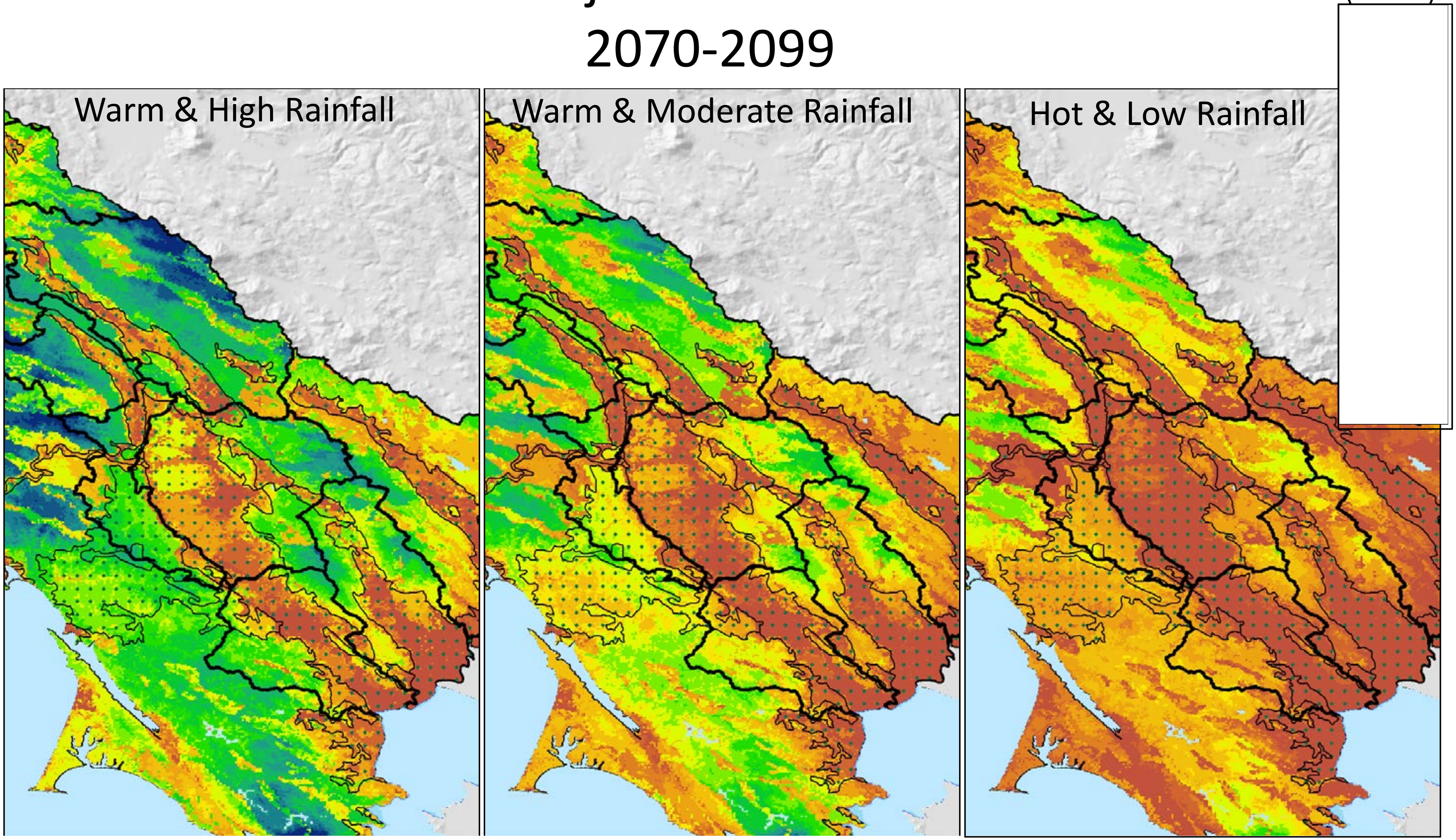
(2070-2099)

(inches)



	Warm & High Rainfall % change	Warm & Moderate Rainfall % change	Hot & Low Rainfall % change
Ukiah Valley	119%	23%	-40%
East Fork Potter Valley	98%	17%	-36%

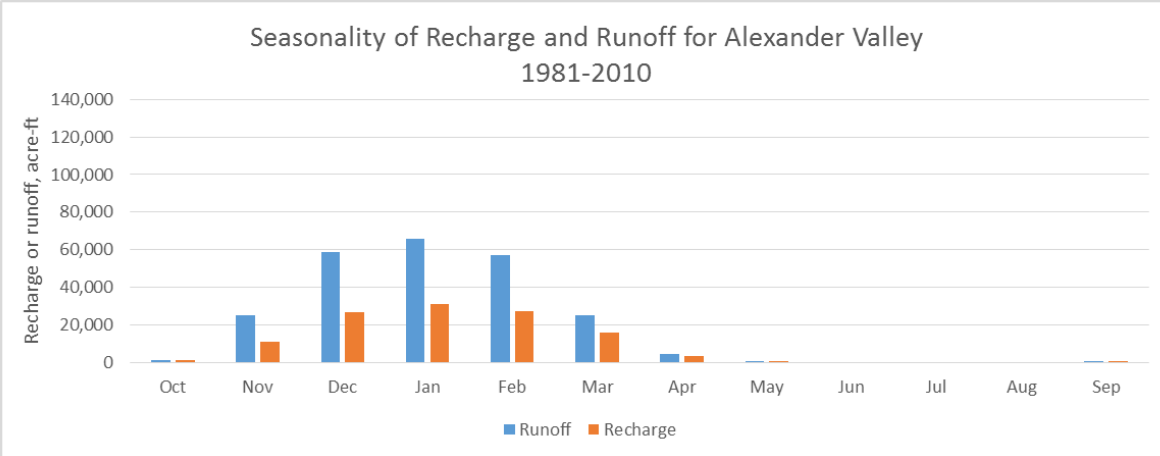
Projected Runoff
2070-2099

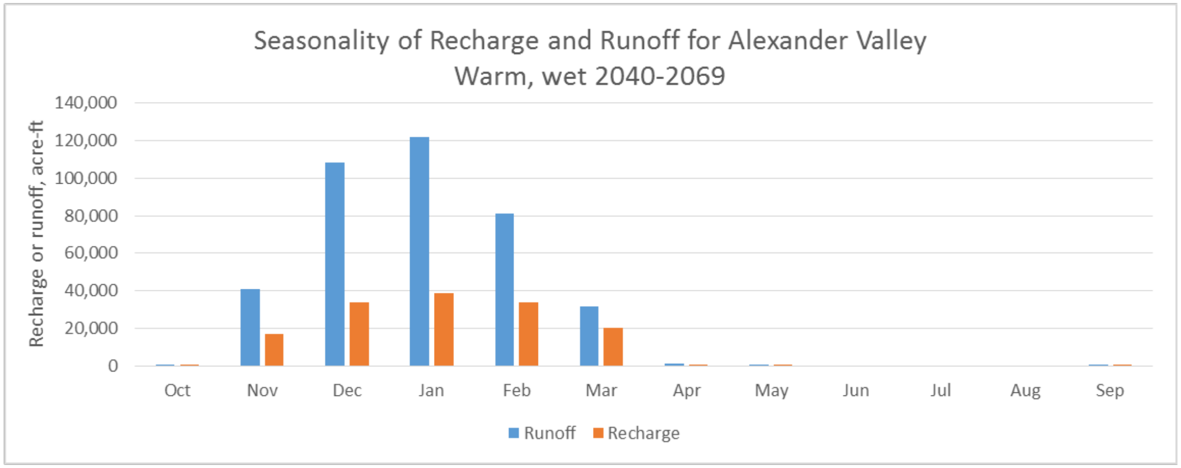


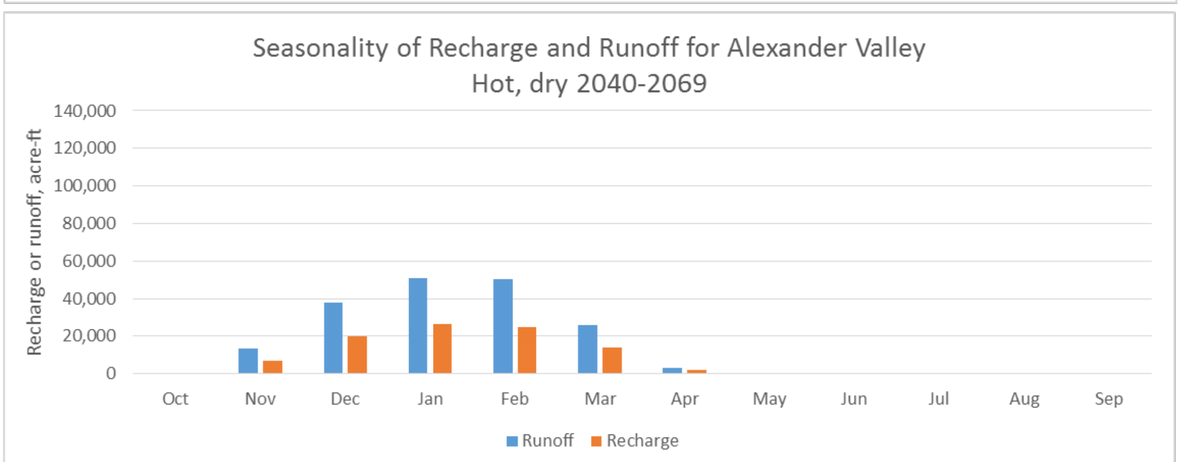
	Warm & High Rainfall % change	Warm & Moderate Rainfall % change	Hot & Low Rainfall % change
Alexander Valley	74%	16%	-29%
Santa Rosa Plain	101%	25%	-40%
Petaluma Valley	94%	21%	-44%
Sonoma Valley	97%	23%	-44%

Management Question

What is the spatial variability of potential groundwater recharge and how might climate change impact recharge rates?







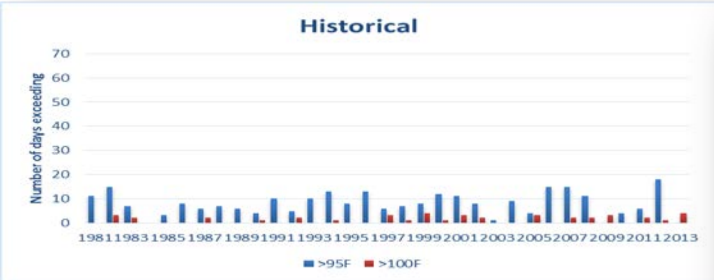
- Relative seasonality of recharge and runoff do not significantly differ among futures
- Runoff changes much more than recharge

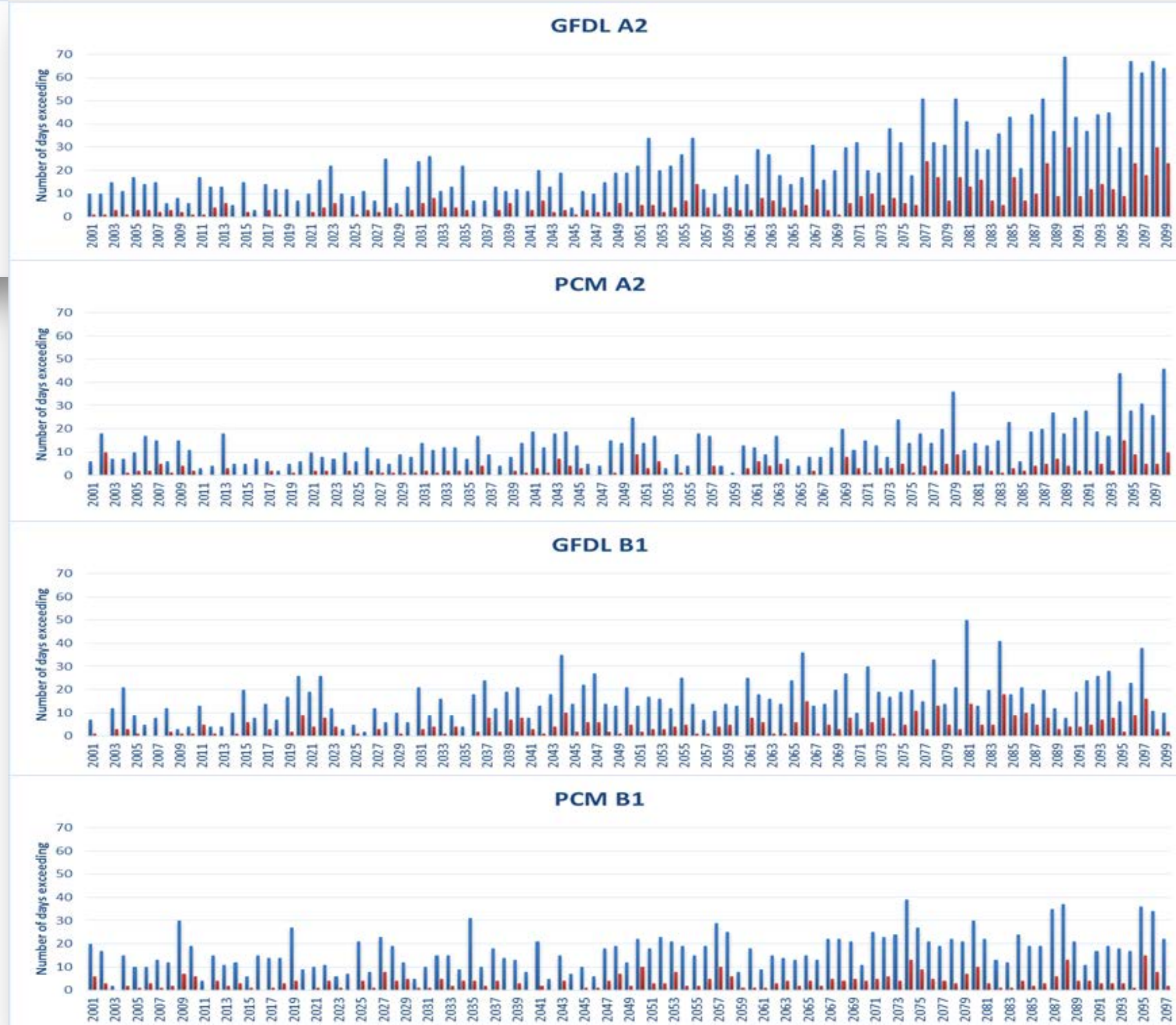
Temperature Extremes

Management Question

How will climate change influence the frequency and intensity of heat events that trigger big upticks in demand for irrigation?

Three-day Heat Waves
Santa Rosa Plain





Number of events of 3 or more days in a row where Tmax exceeds 95F for the Santa Rosa Plain.

	# of events	Tmax	Tmin
1981-2010	26	95.7	93.4
2010-2039	39	96.5	93.3
2040-2069	55	96.4	93.5
2070-2099	148	97.3	93.5

>95F >100F

PCM wet model
GFDL dry model

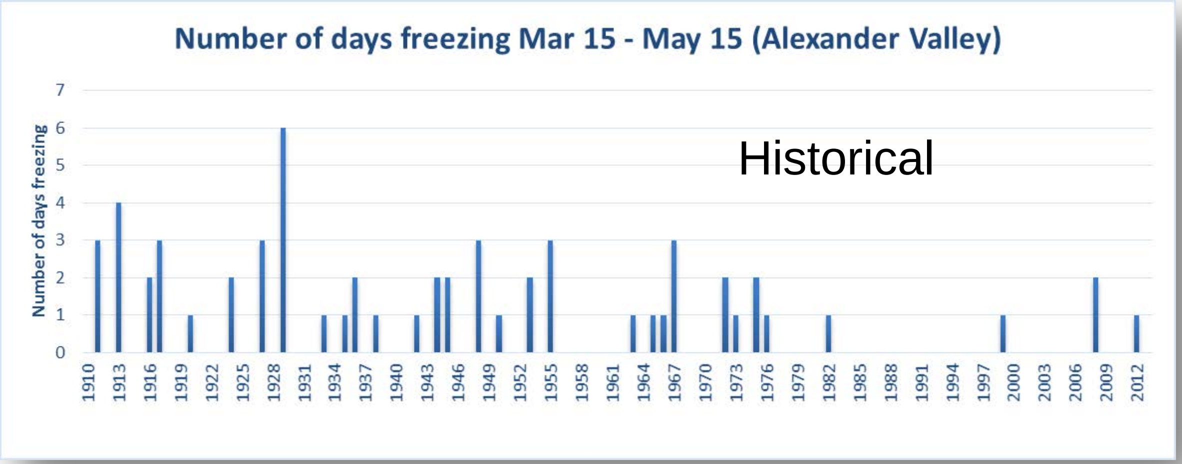
Management Question

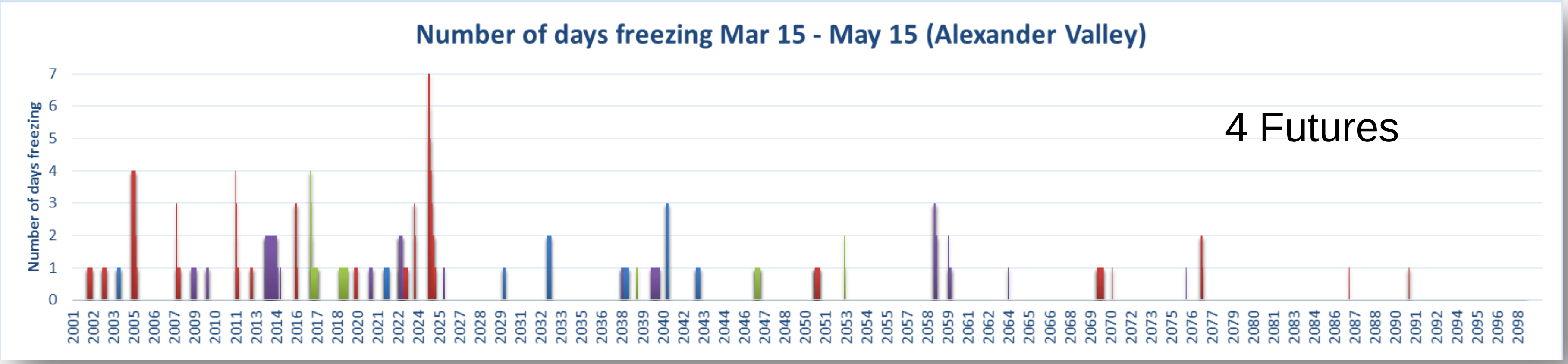
How will climate change influence frost frequency, and in turn, demand for frost protection in agricultural zones?

Number of springtime days at or below freezing: Alexander Valley

(average for valley, does not account for cold air pools)

	Historical 1981-2010		
	February	March	April
	52	8	5
	Future 2040-2069		
	February	March	April
PCM A2	38	5	1
GFDL A2	25	5	1
PCM B1	87	11	1
GFDL B1	24	6	1
average	44	7	1
	Future 2070-2099		
	February	March	April
PCM A2	24	3	0
GFDL A2	18	4	0
PCM B1	34	7	0
GFDL B1	31	6	1
average	27	5	0





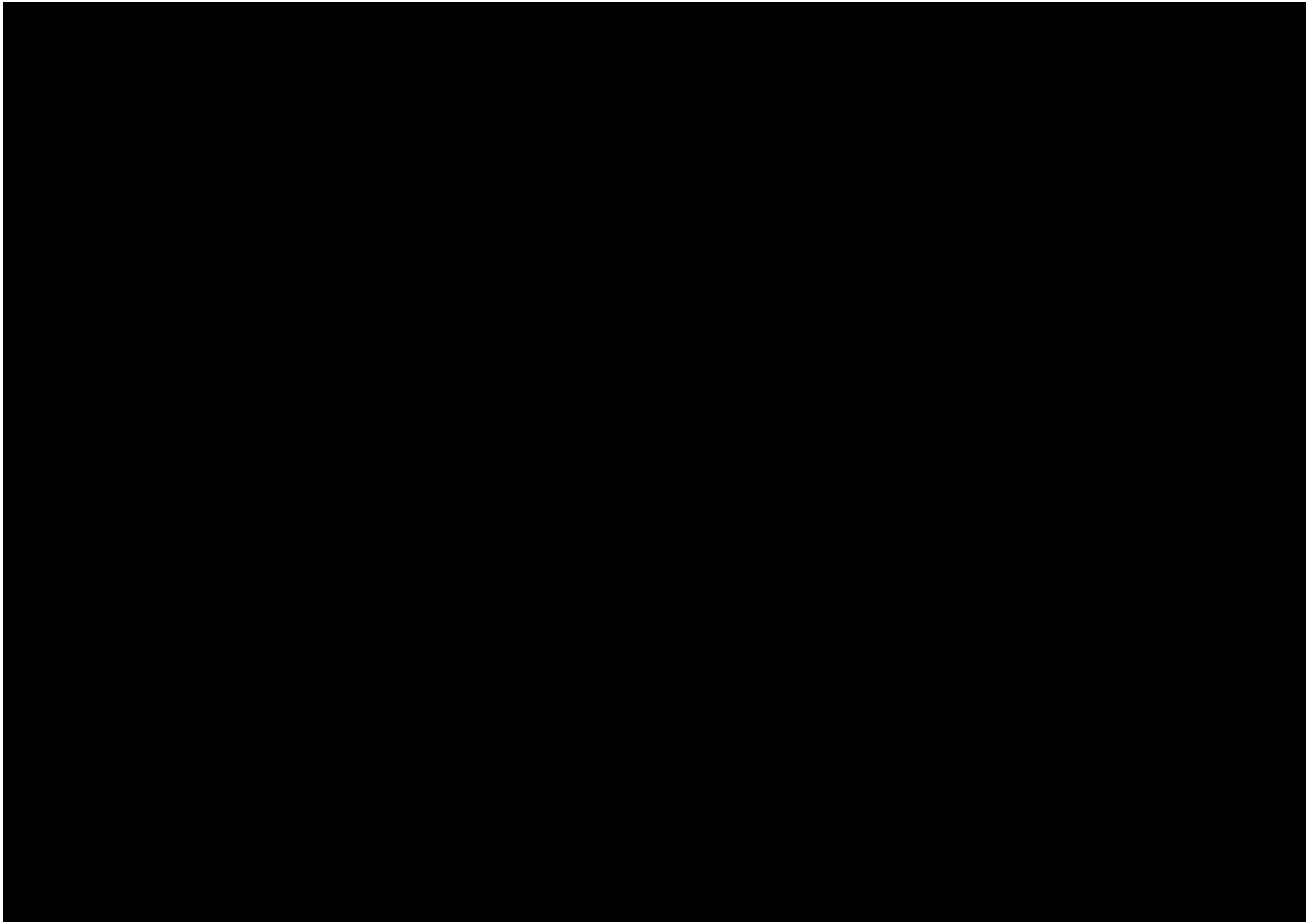
PCM wet model, GFDL dry model

CWD and Landscape Stress

Pepperwood
PRESERVE
Inspiring conservation through science

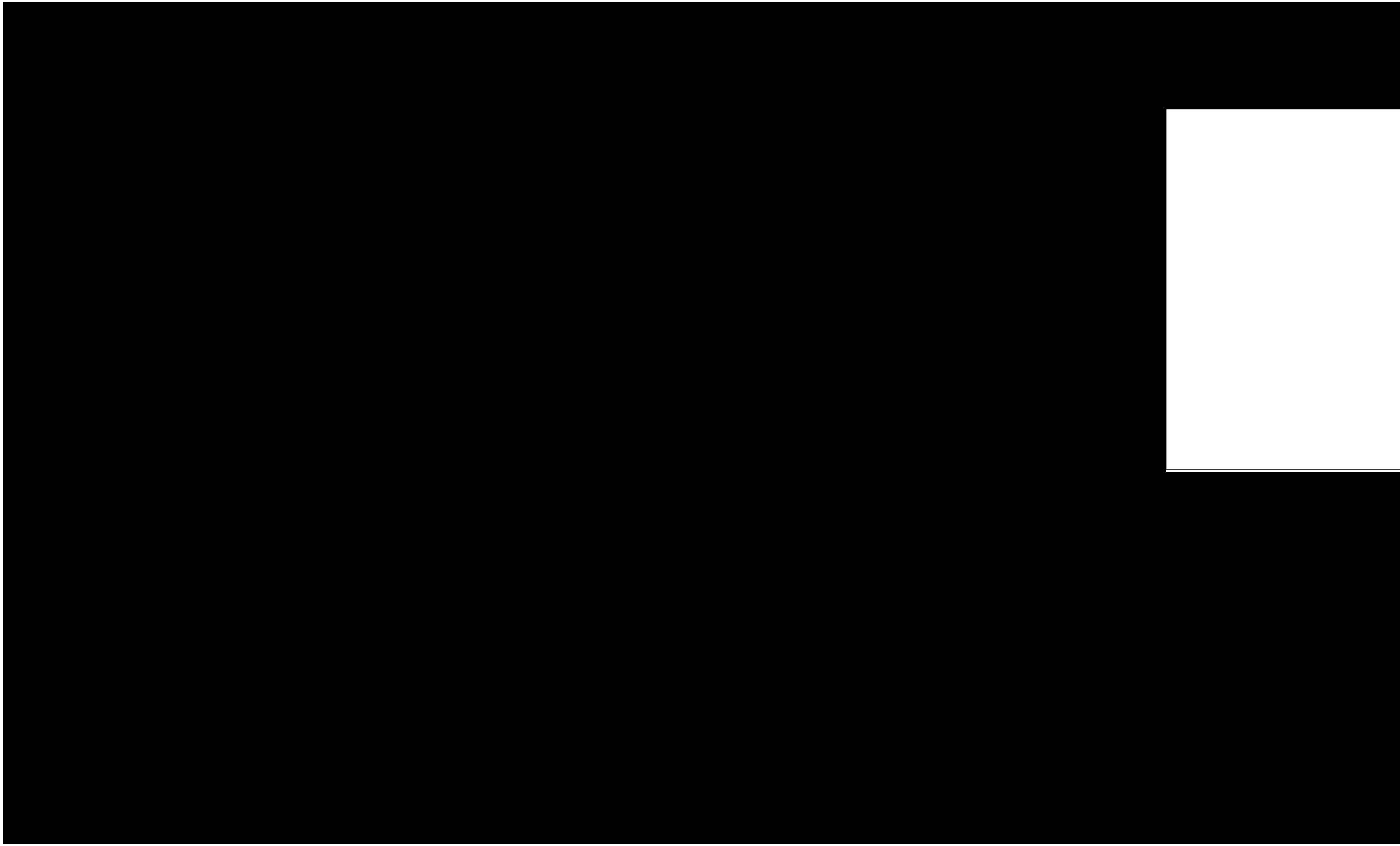
Management Question

How might climate change influence the magnitude of landscape drought stress, estimated as climatic water deficit, across the Russian River basin? Where are the regions where this effect is mitigated by present day fog distributions?



CWD average of 27 in/y

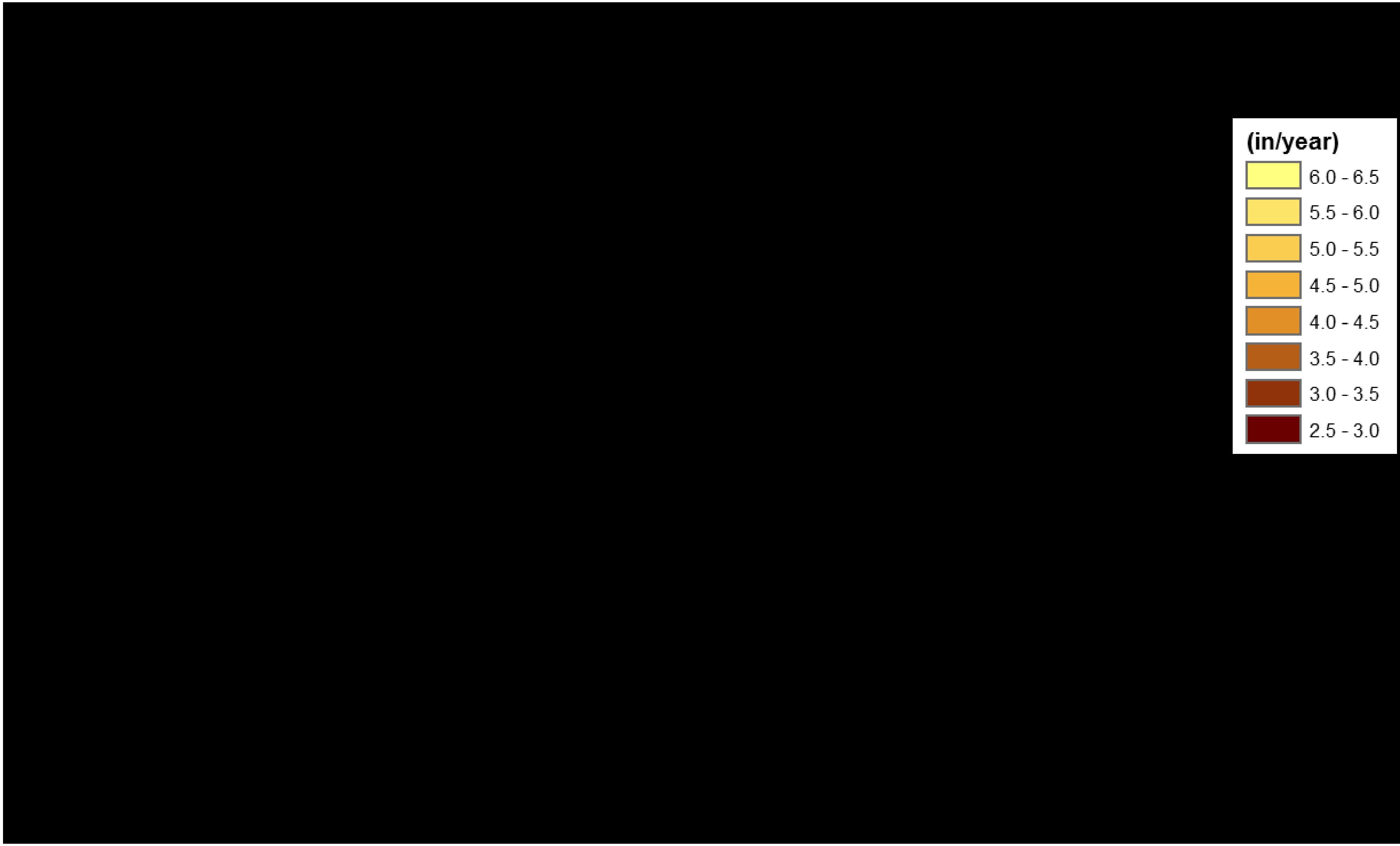
CWD average of 28 in/y



Average CWD 32 in/y
(52 in/y rainfall)

Average CWD 32 in/y
(41 in/y rainfall)

Average CWD 35 in/y average
(29 in/y rainfall)

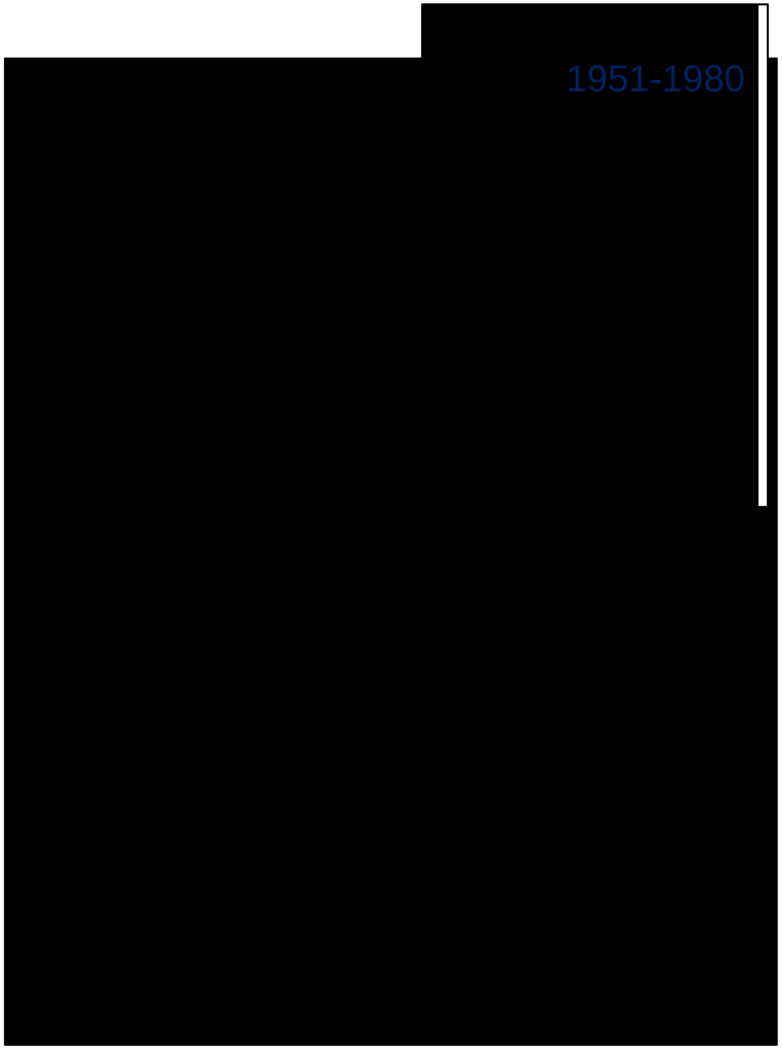


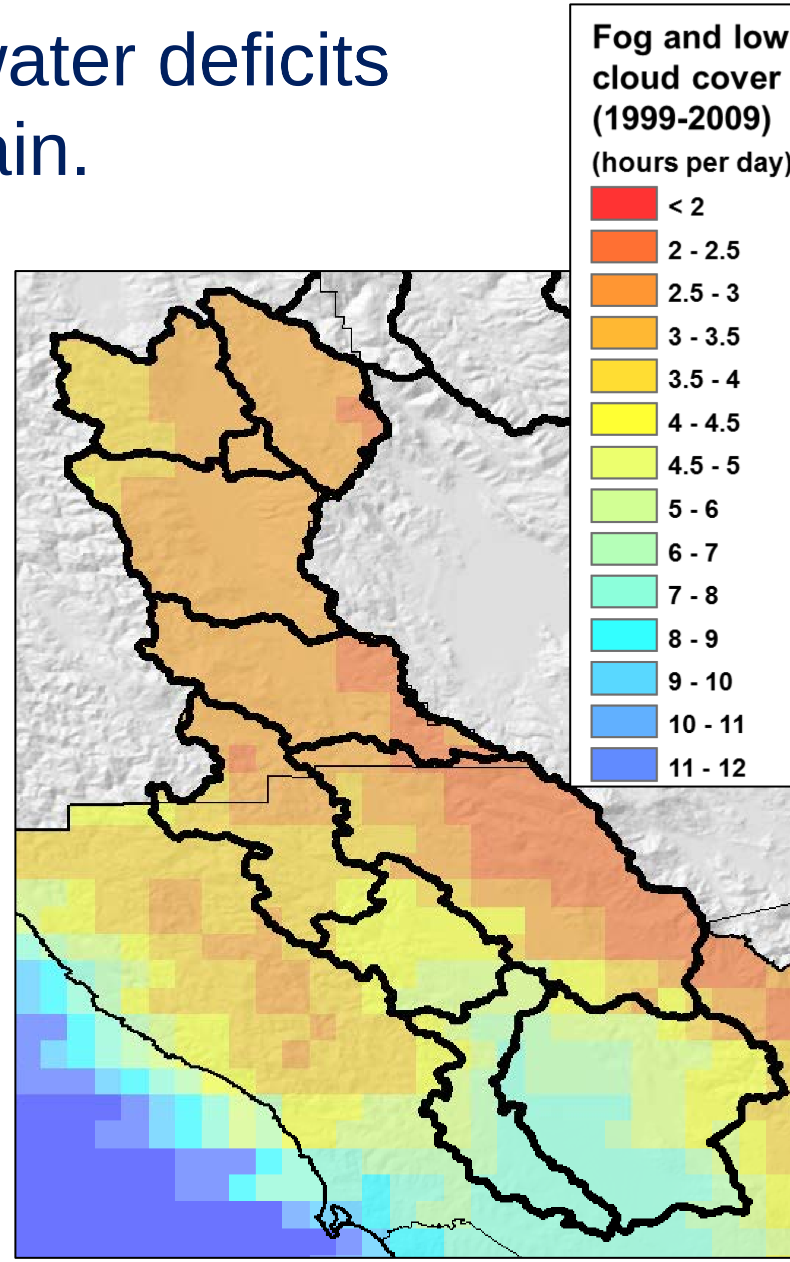
9 % increase in CWD

9 % increase in CWD

18 % increase in CWD

Fog may help counteract water deficits
Future fog patterns uncertain.





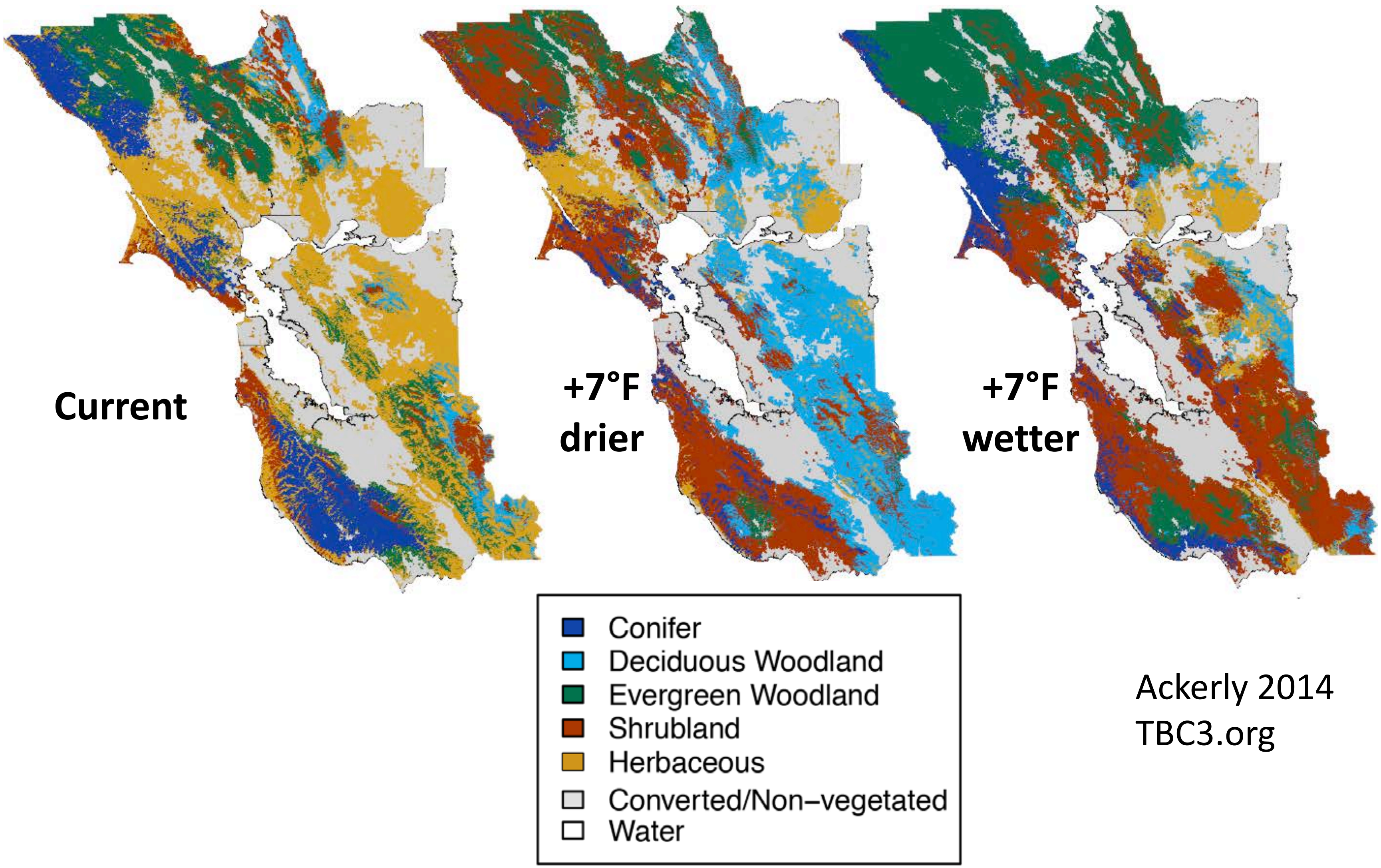
Torregrosa et al in press

Potential native vegetation responses to changing climate

Management Question

How might climate change affect the native vegetation distributions of Sonoma County?

what might the Bay Area vegetation of the future look like?

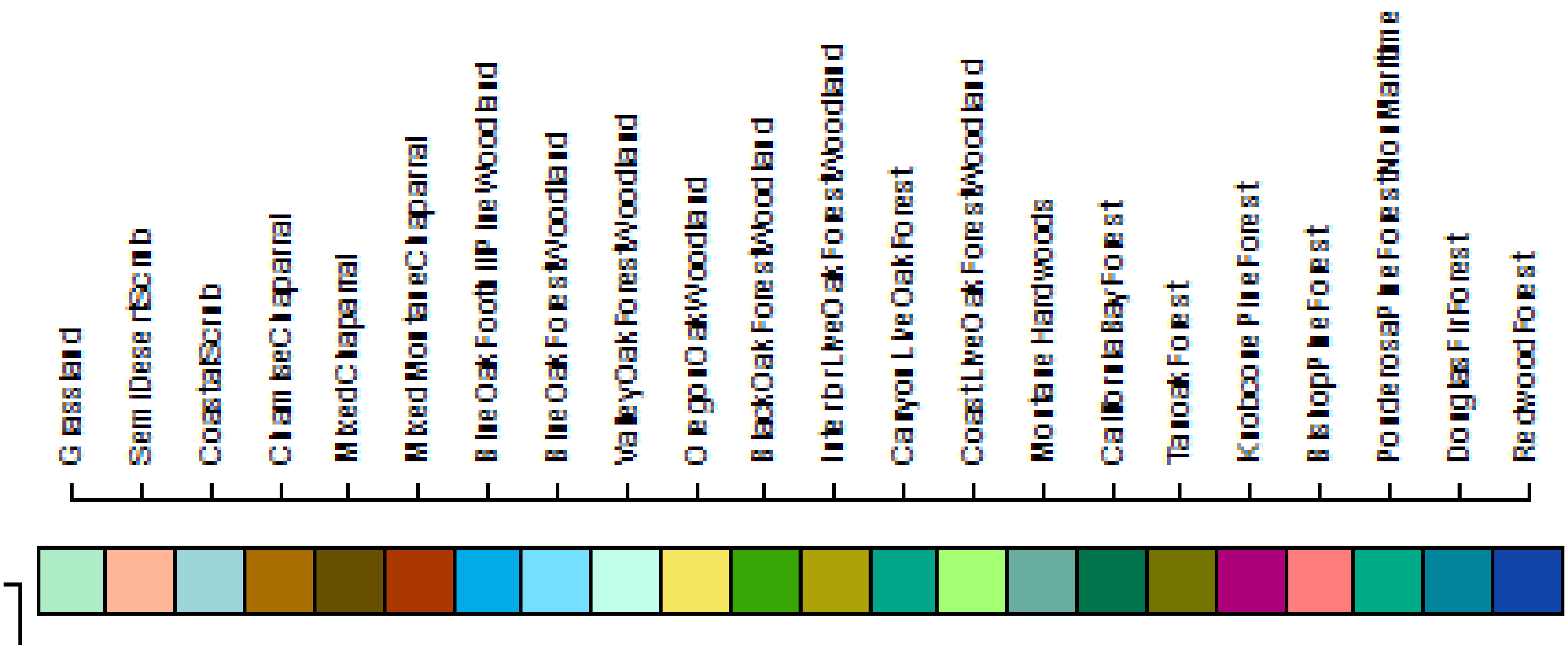


Ackerly 2014
TBC3.org

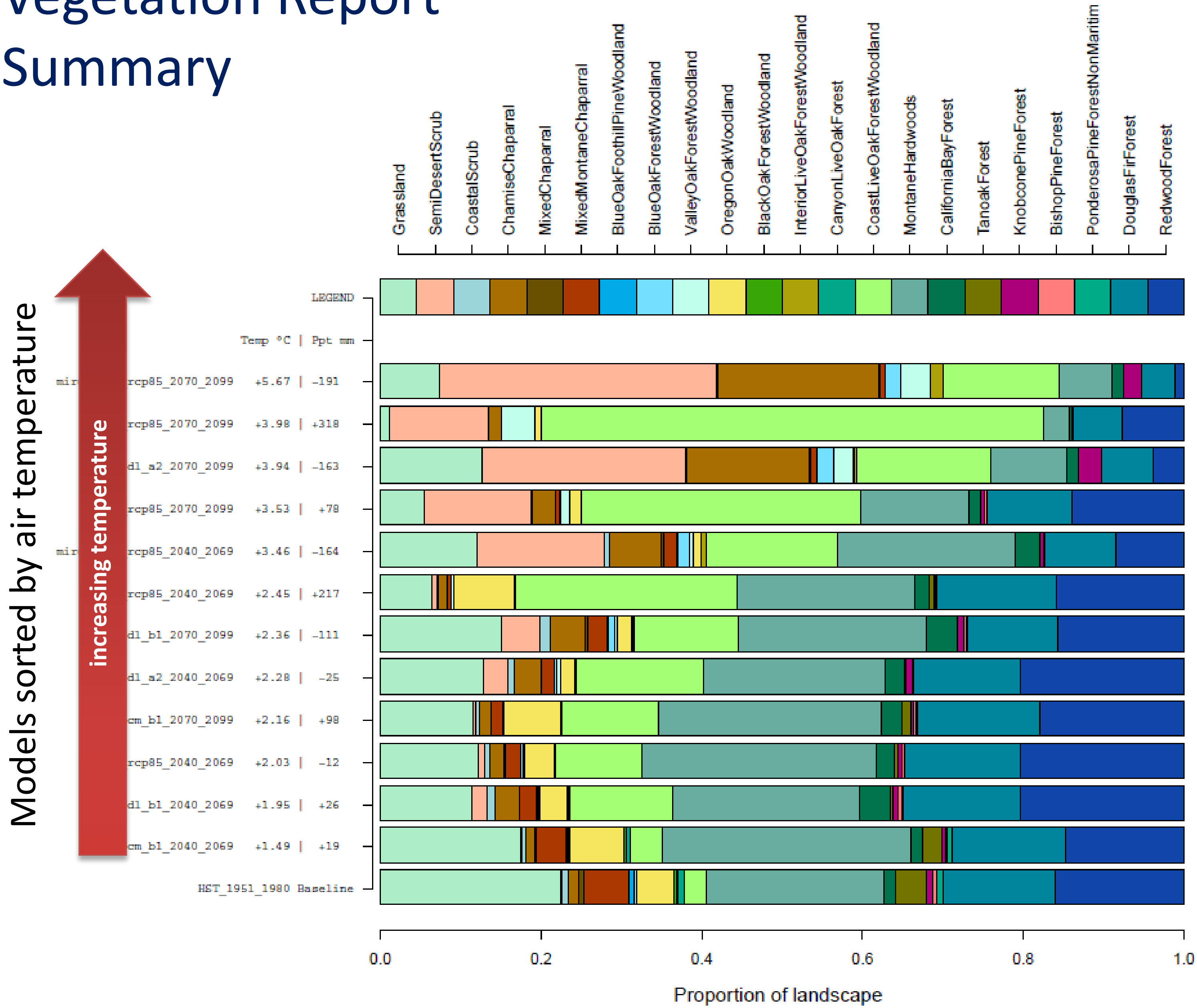
Equilibrium vegetation response to climate change in

The North Bay Climate Ready Region

Projected proportional landscape cover of 22 vegetation types under both historical conditions and six future scenarios, organized from top to bottom by increasing temperature. This is an equilibrium model so this assumes vegetation has had time to adjust to climate conditions. In reality , vegetation turnover will take time. Fires and other disturbance can accelerate shifts. How land is managed will also affect rate of change. For example, grasslands may be maintained by active grazing, burning or mowing. Data from D.D. Ackerly 2015.



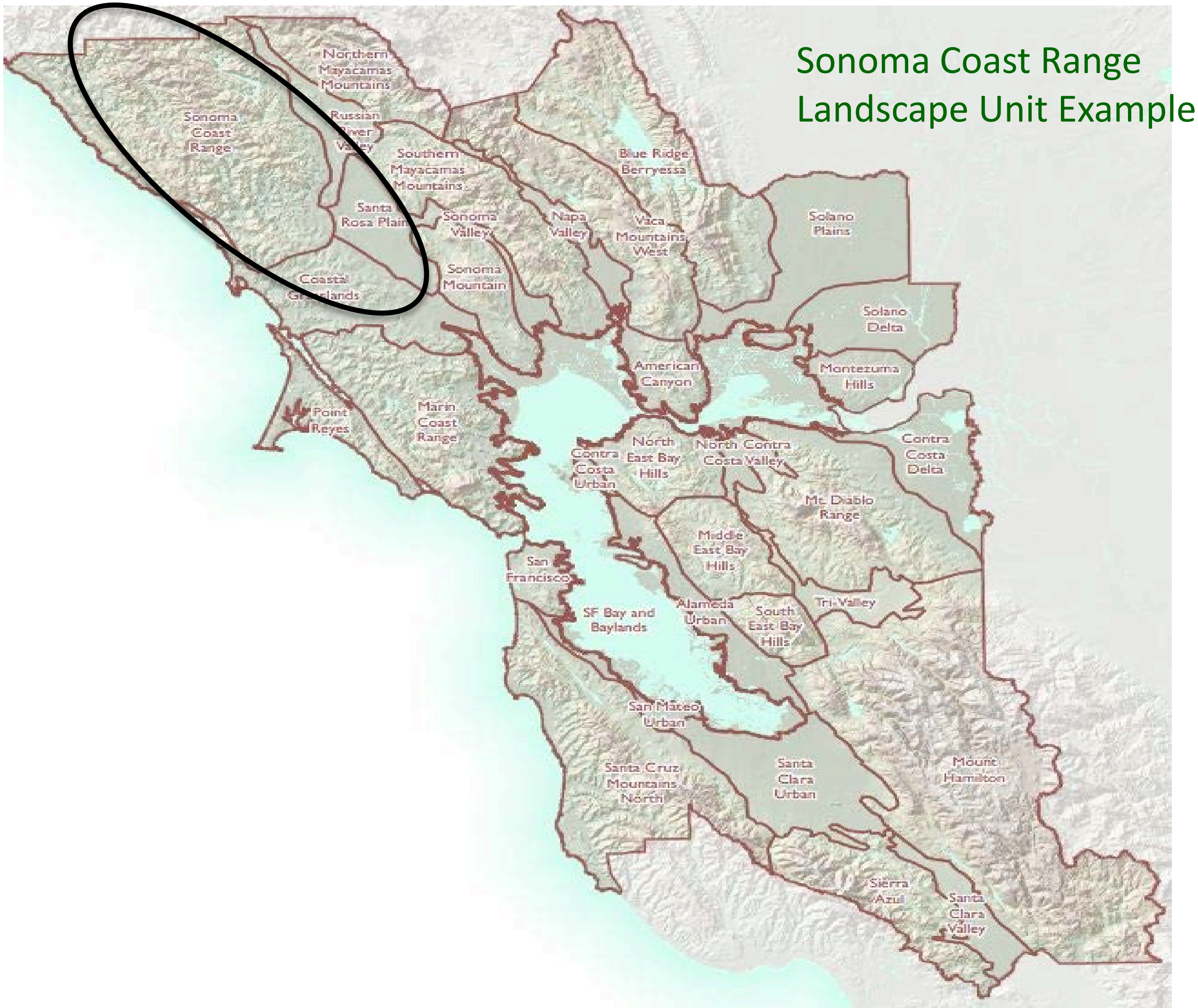
Sonoma County Vegetation Report Summary



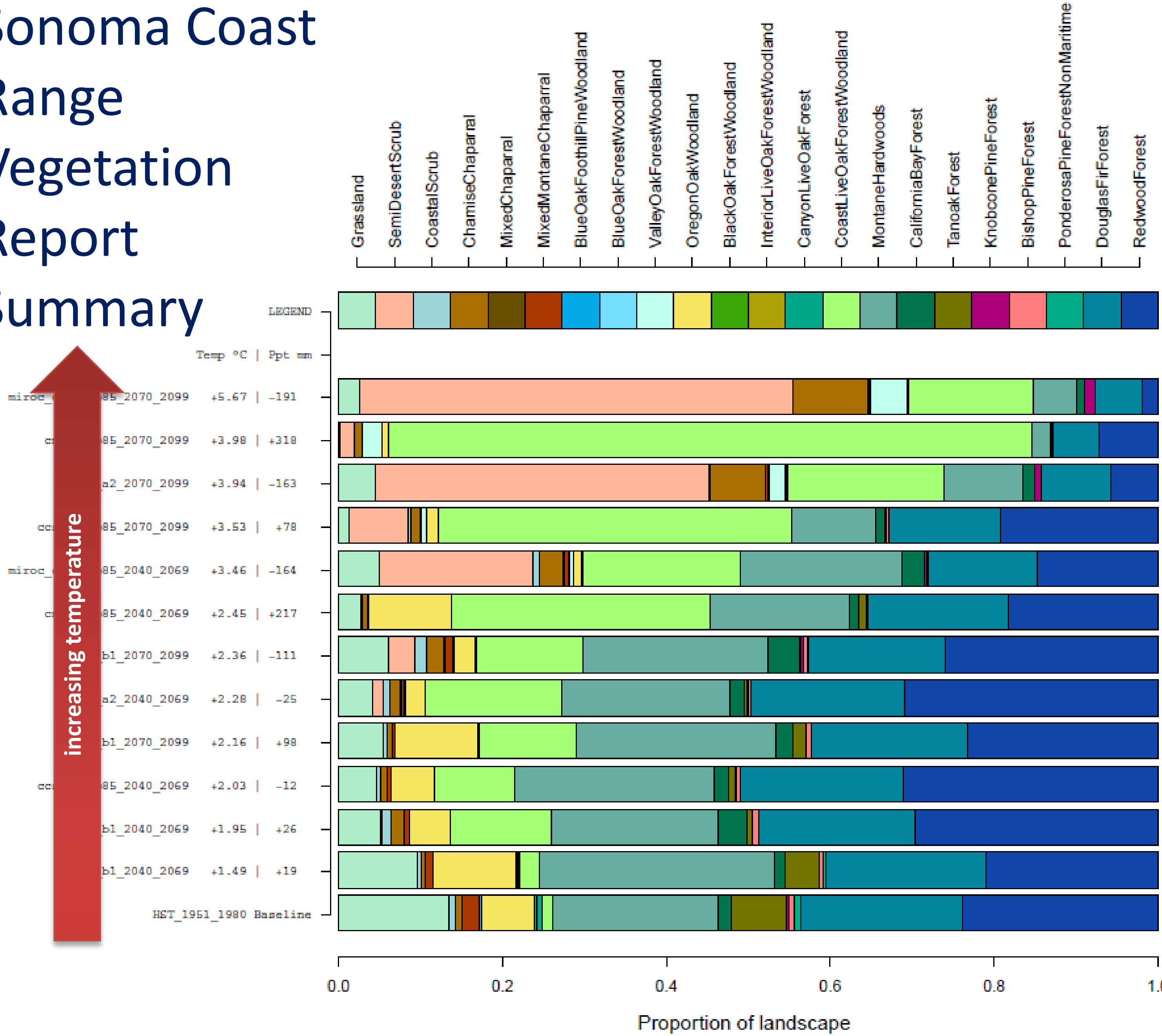
Reduced suitability for redwood, doug fir, and montane hardwoods

Increased suitability for coast live oak, semi-desert scrub, chamise chaparral

Landscape Units defined by Bay Area Upland Habitat Goals Project (2011)



Sonoma Coast Range Vegetation Report Summary



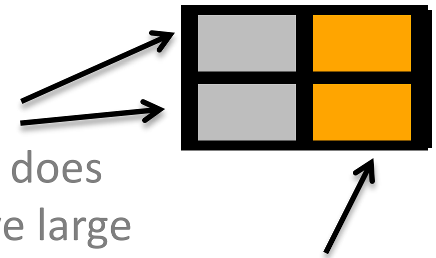
Reduced suitability for redwood, doug fir and montane hardwoods

Increased suitability for coast live oak, semi-desert scrub, chamise chaparral

Another way to look vegetation data:

Four-square diagrams

Example: *Redwood Forest is sensitive to temperature in Sonoma's Coast Range*



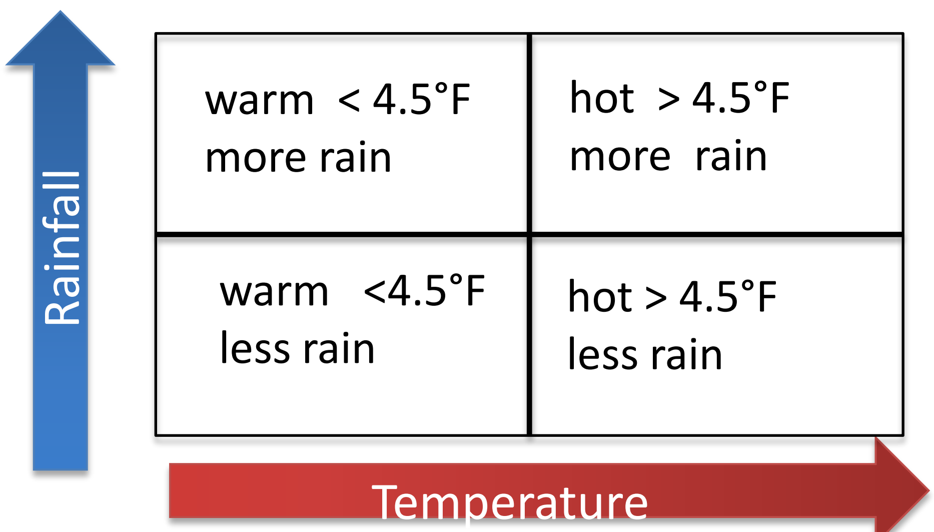
Rainfall does not have large effect

Significant declines emerge at hotter temperatures.

Color-coding the square quadrants shows the direction of change in percent cover in suitable climate for veg type (current to 2050)

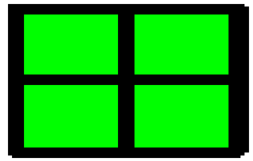
- Red: Dramatic Decline (<25% of current)
- Orange: Moderate Decline (25-75% of current)
- Gray: Relative Stability (75-125% of current)
- Green: Increase (>125% of current)

Each quadrant in the square represents higher or lower temperature and rainfall



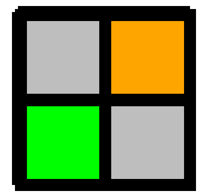
Sonoma Coast Range Species Level Examples

Example: Coast Live Oak



does well in all future scenarios regardless of warming magnitude and rainfall

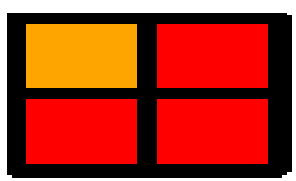
Example: California Bay



does well in moderate scenario, but declines in hot and low rainfall

.

Example: Tan Oak is sensitive to rainfall and temperature



shows declines in all scenarios

Identify potential “winners and losers” by landscape unit

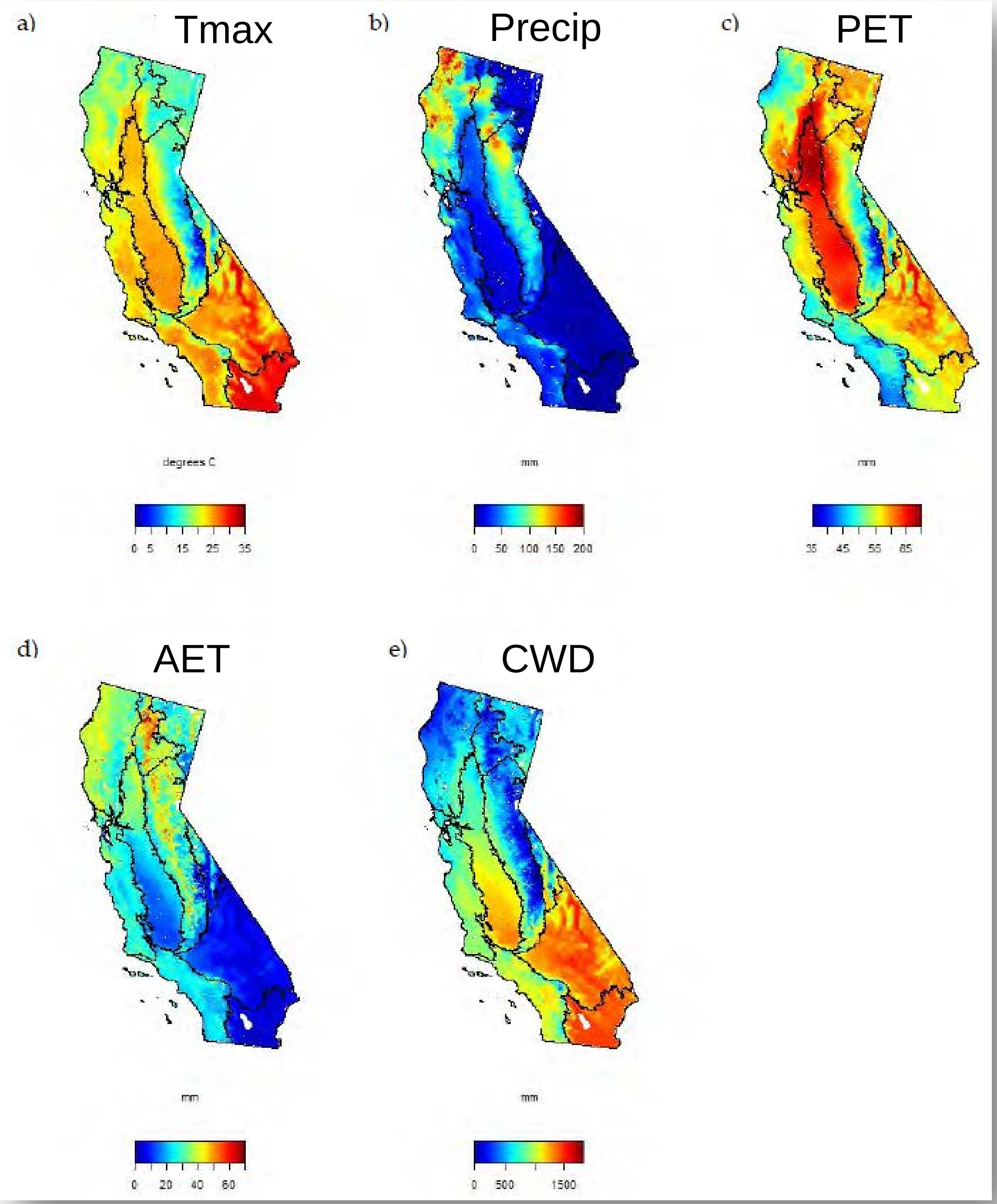
Modeled fire risks
in Russian River Basin

Pepperwood
PRESERVE
Inspiring conservation through science

Management Question

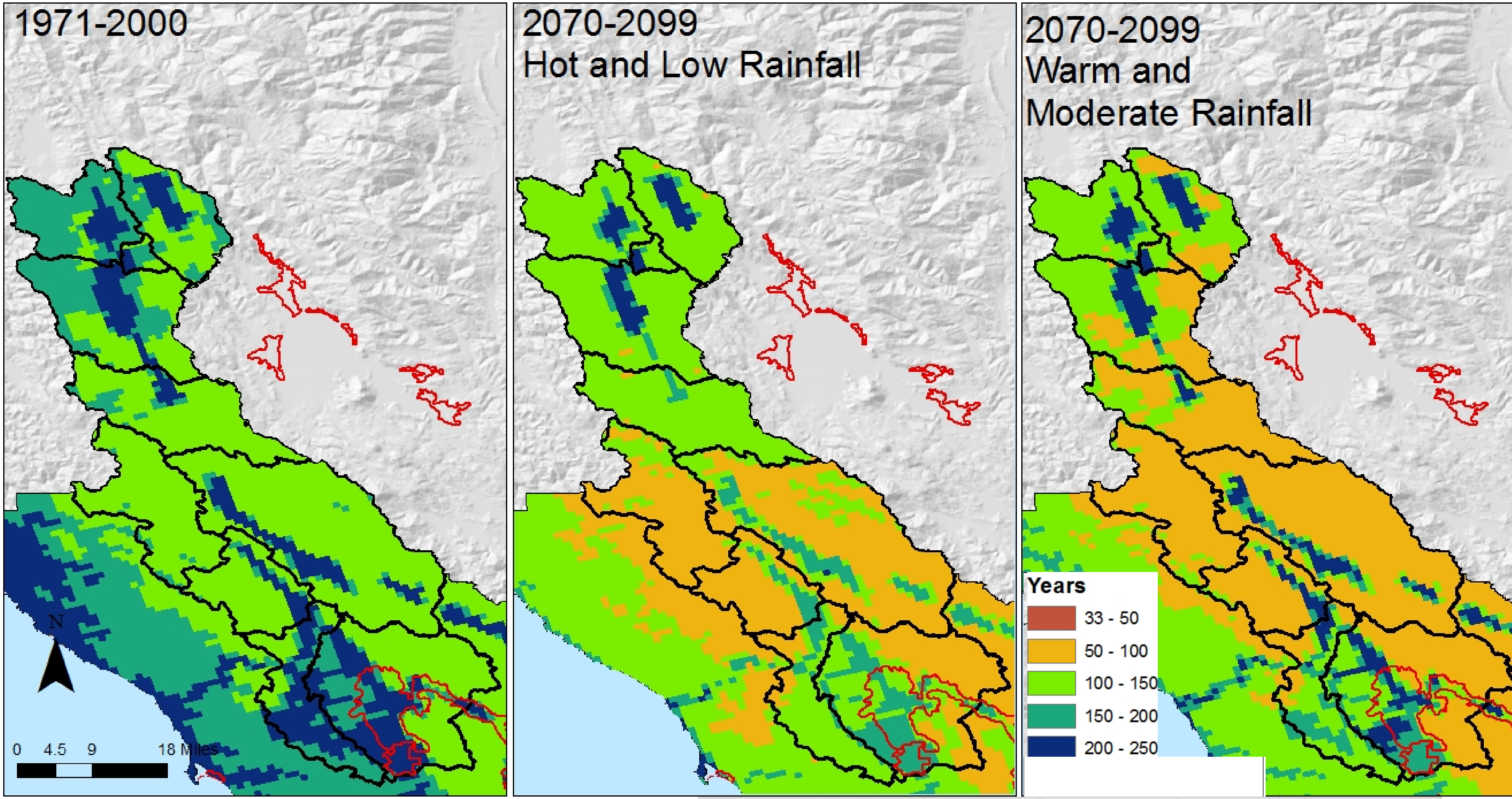
How might climate change affect fire frequency in Sonoma County and the Russian River?

Spatial Patterns in Explanatory Climate Variables 1971–2000



Krawchuk and Moritz 2012 PIER report

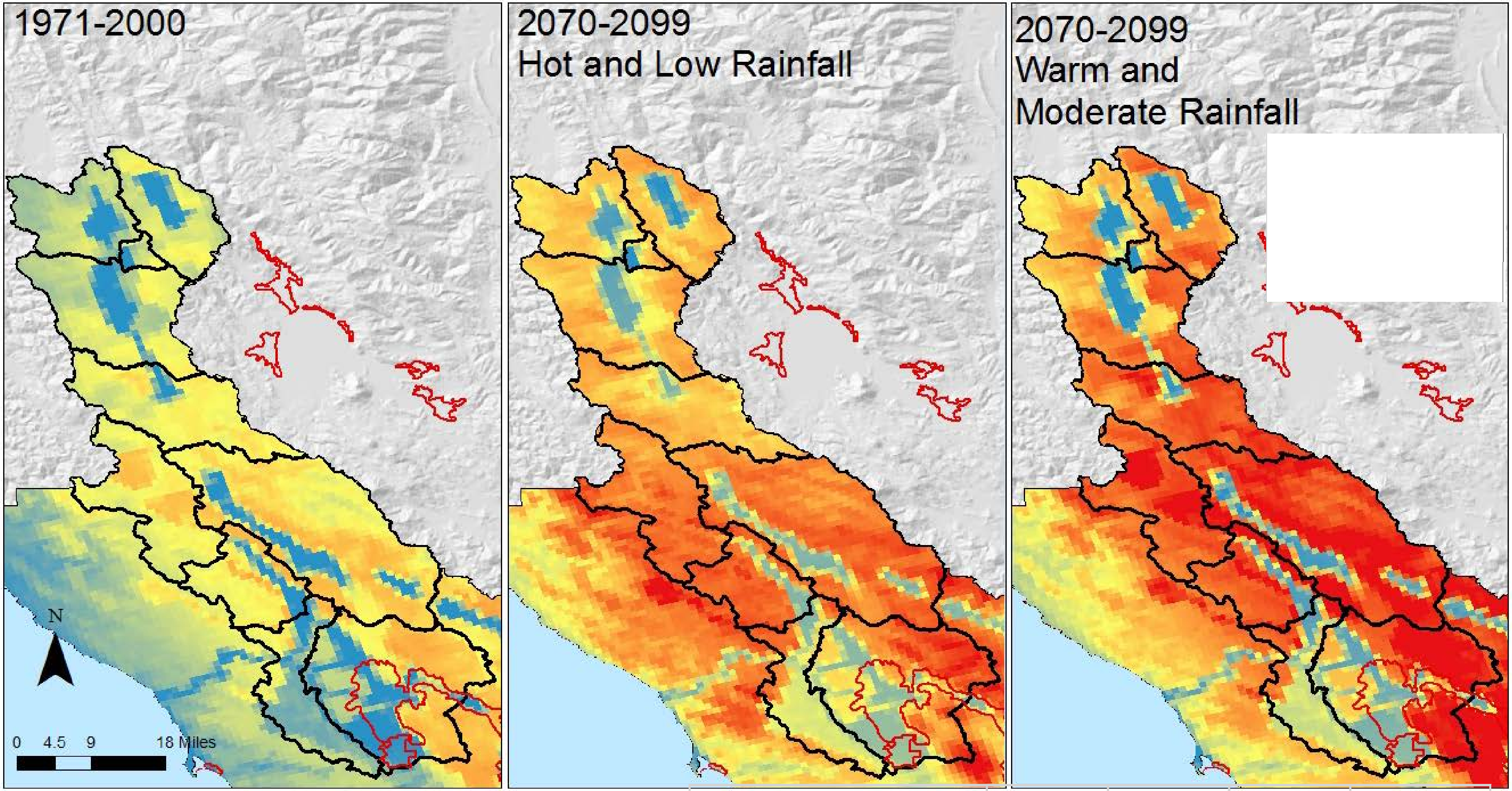
Change in Projected Fire Return Interval



Fire return intervals cut by approximately 25%

		Current	Hot, Low Rainfall	Moderate Rainfall
Variable	Units	1971-2000	2070-2099	2070-2099
Fire return interval	Years	175	152	127
	SD	42	145	35

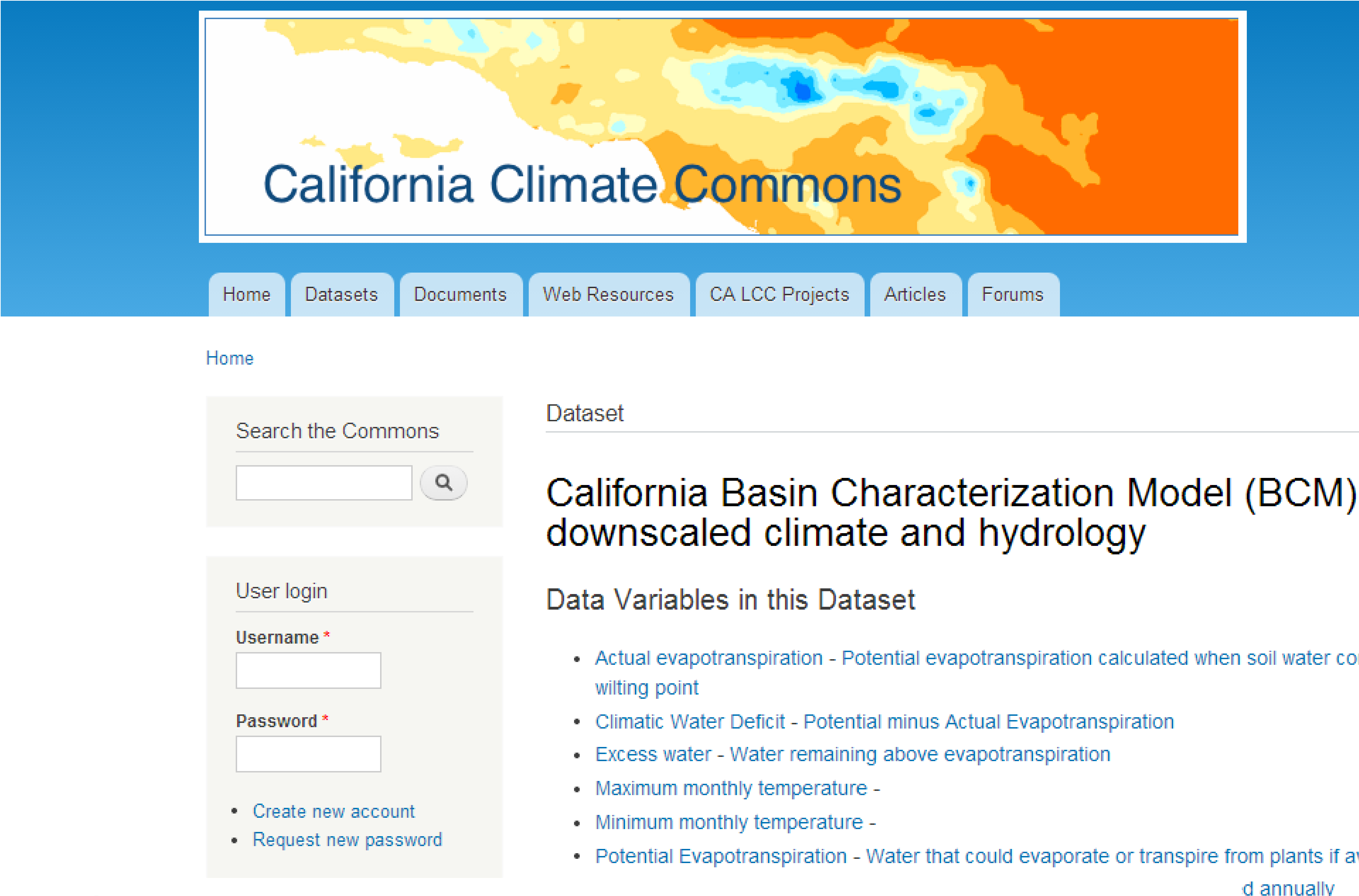
Probability of burning within a 30-year window



Probability of fire doubles in some locations

			Hot, Low Rainfall	Moderate Rainfall
		Current		
Variable	Units	1971-2000	2070-2099	2070-2099
Probability of burning 1 or more times	Percent	16%	21%	22%
	SD	5%	7%	6%

Climate Smart Exchange Page



climate.calcommons.org
will host “Climate Smart Exchange” page for users