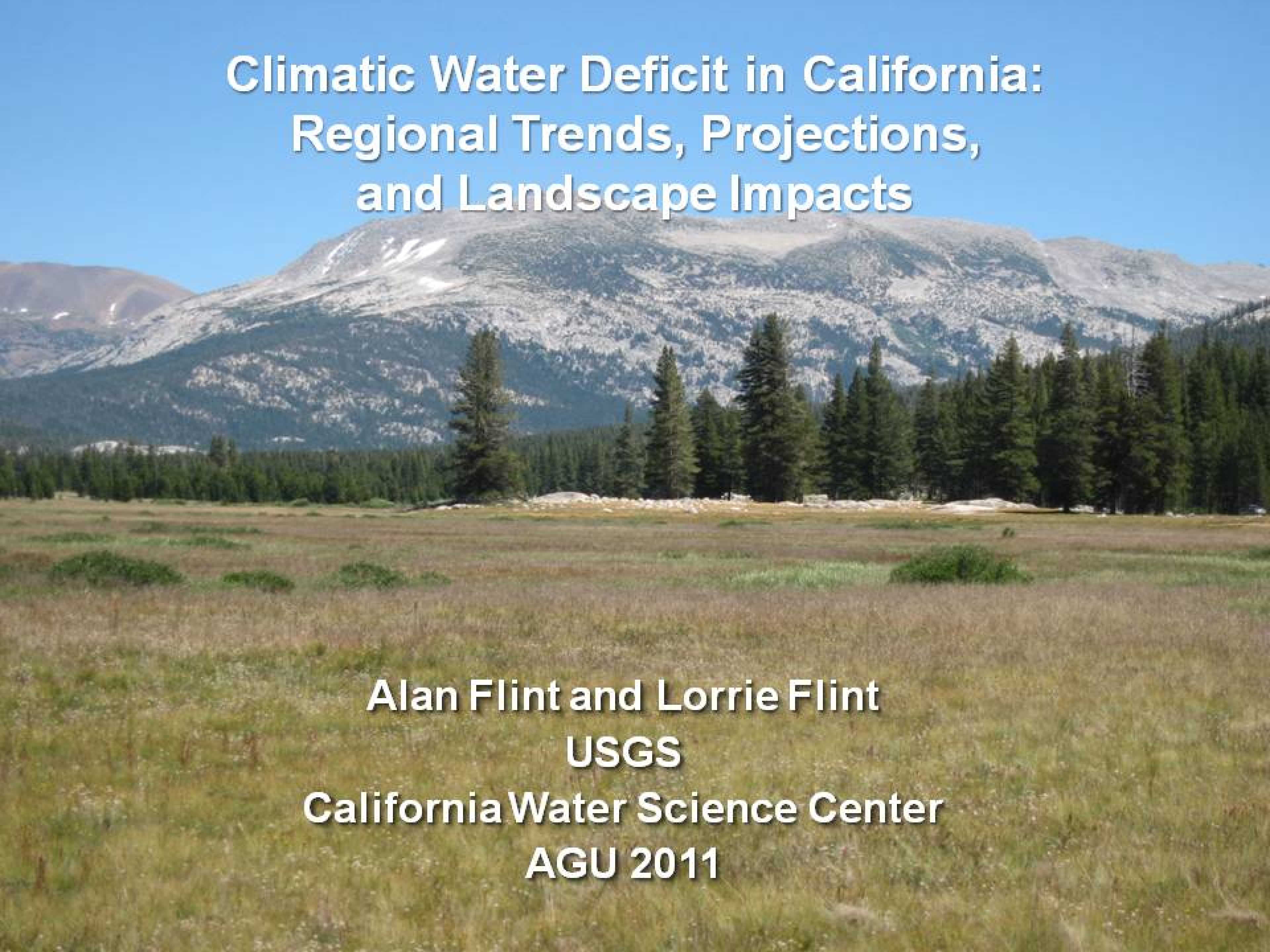

Climatic Water Deficit in California:
Regional Trends, Projections,
and Landscape Impacts
Alan Flint and Lorrie Flint
USGS
California Water Science Center
AGU 2011

Objective

- To calculate climatic water deficit for California on the basis of the water balance
- To illustrate an application of climatic water deficit to evaluate the impacts of changing climate on vegetation
- To demonstrate the efficacy of fine-scale analysis to evaluate habitat resilience to change

Motivation

- Climate is changing, resulting in changes in precipitation and air temperature throughout California
- Global climate models suggest increased variability in precipitation, with a consensus for increased air temperature
- Although climate change may be regional landscapes will respond at the local level


We have to consider the local landscape, such as slope, aspect, elevation, soil depth, and bedrock permeability, which will influence vegetation distributions

Translating climate change to hydrologic response

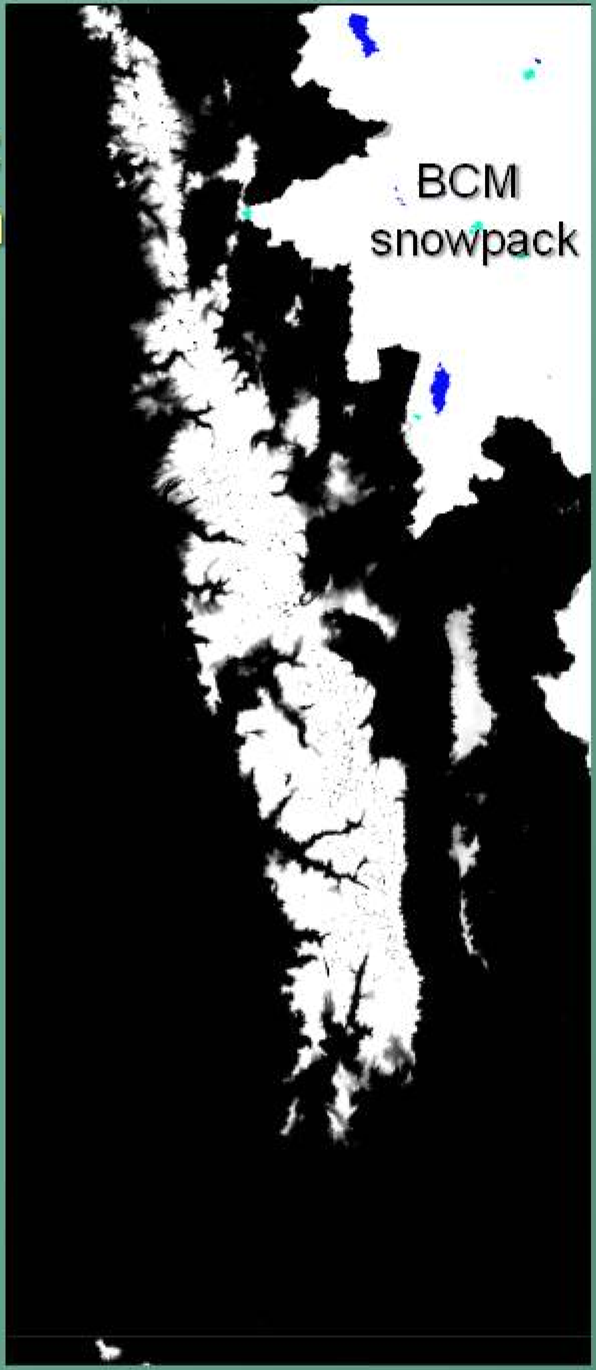
- Statewide analysis
- Two local applications
  - Redwood forest
  - Wine grape growing

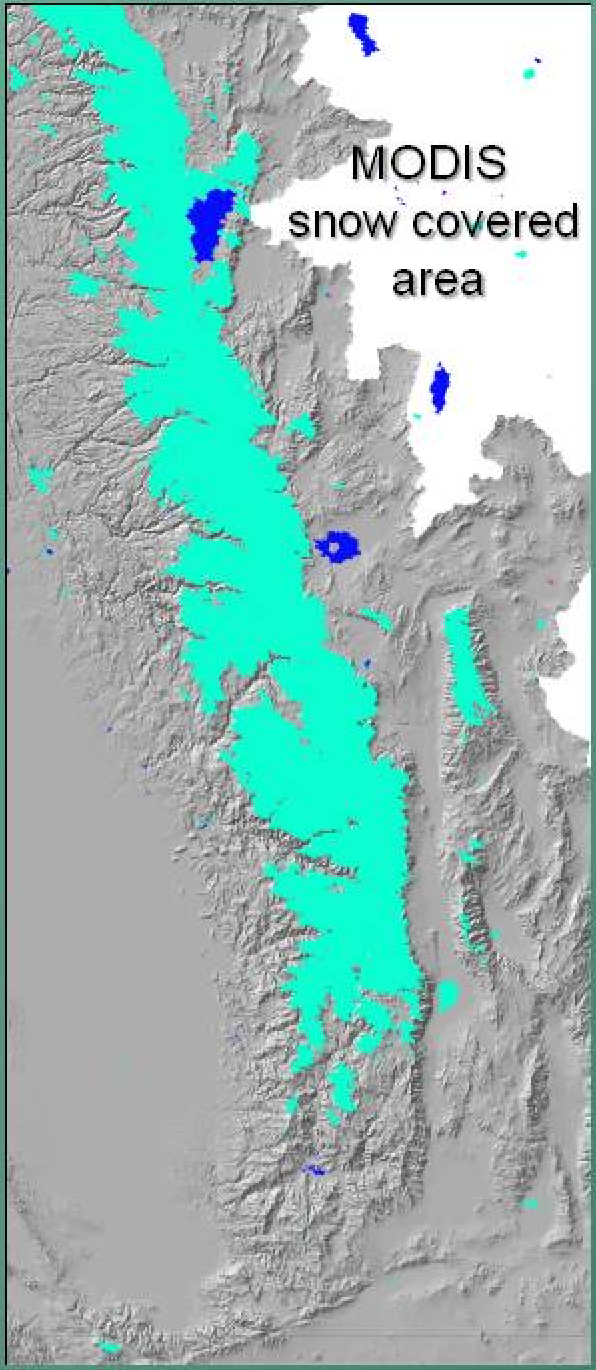
Hydrologic Response Model

- Basin Characterization Model (BCM)
  - grid-based data
  - Monthly or daily time step
  - calculates recharge, runoff, actual ET, climatic water deficit, snow accumulation and melt
- Potential evapotranspiration (Priestley-Taylor)
  - hourly solar radiation model, topographic shading, and cloudiness
- Snow accumulation and melt based on NWS Snow-17 Model
- Soil water storage based on SSURGO soil maps
- Bedrock permeability based on geology
- Climate data from meteorology stations, PRISM, or future projections

Snow Calibration: Distribution and depth

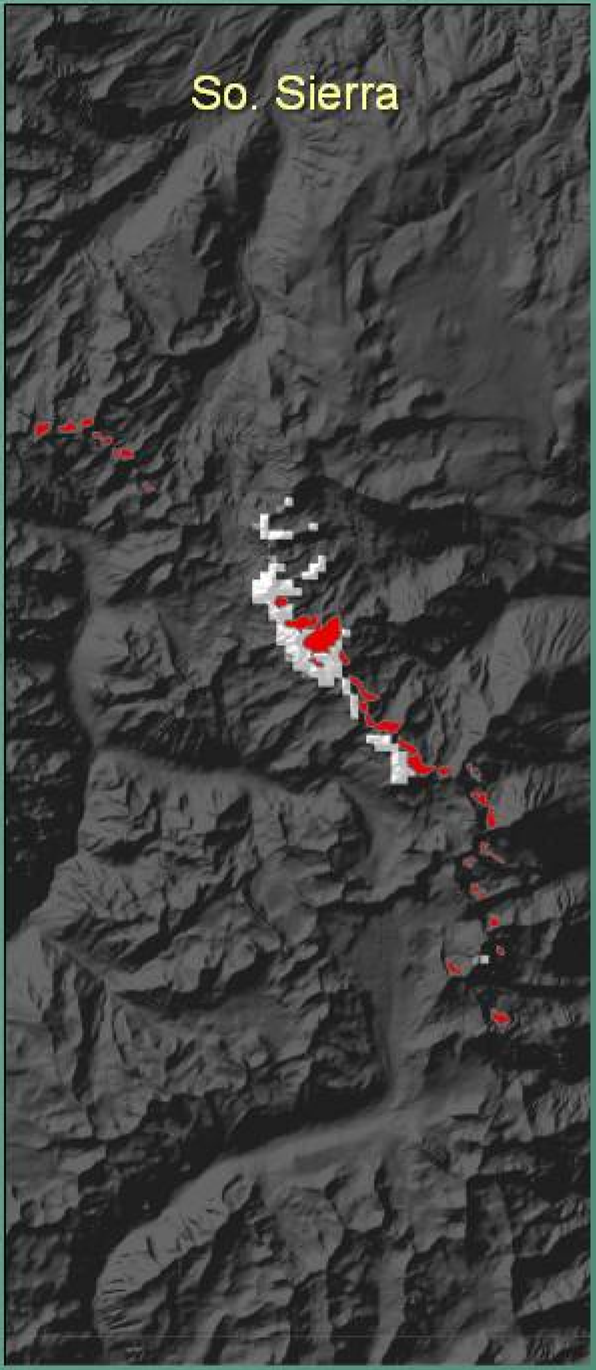
April 2001

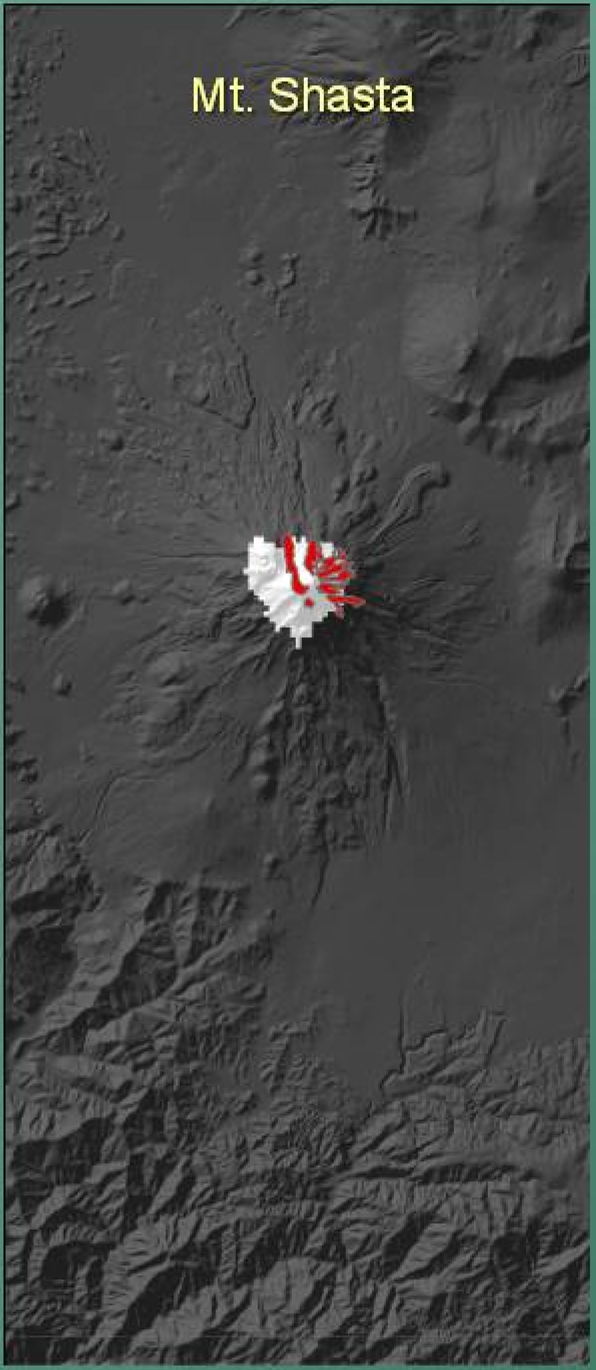




Snow Calibration:

Glaciers

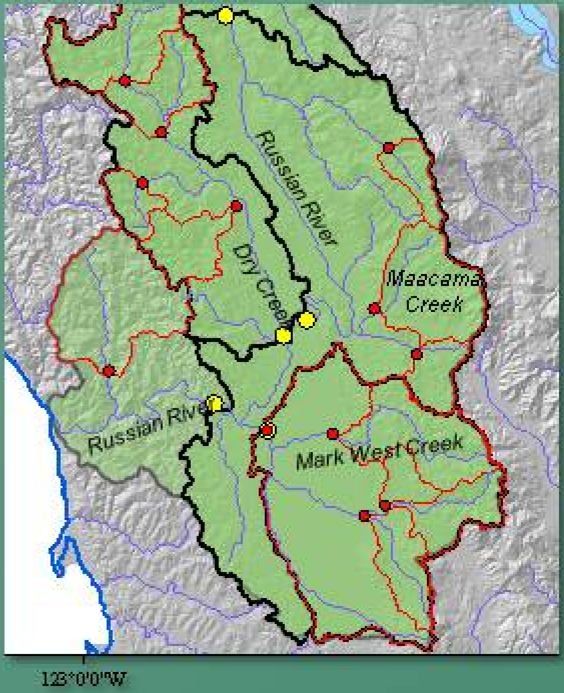


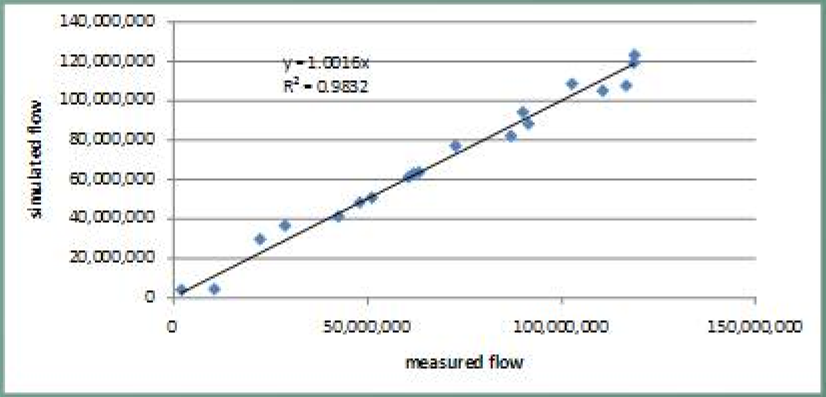


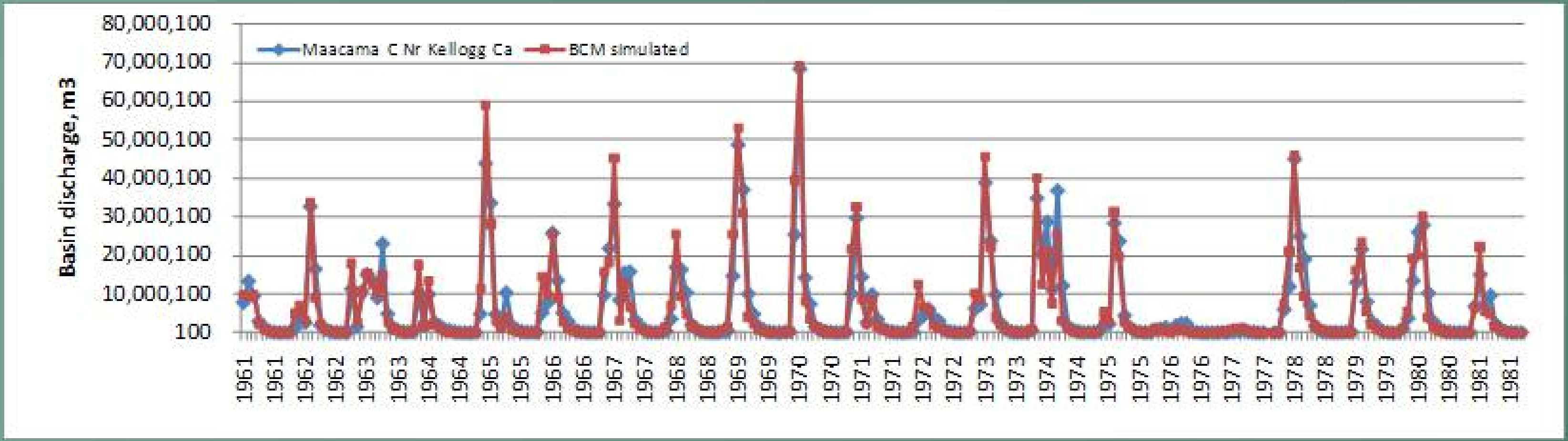
measured

modeled

Calibration Using Discharge Measurements from unimpaired streams





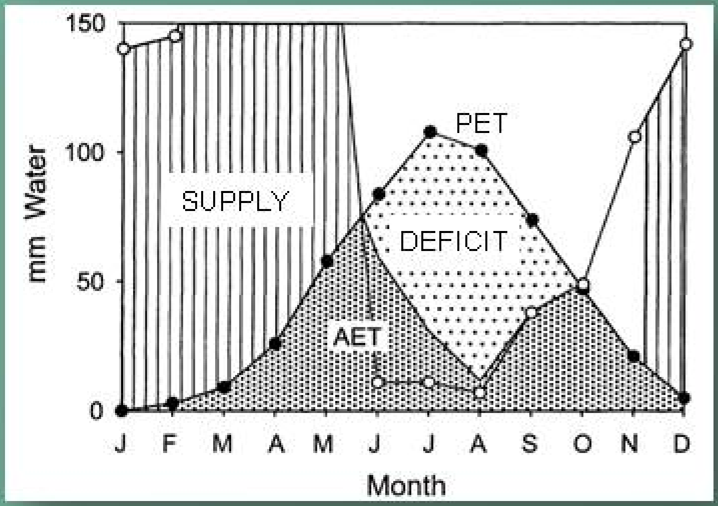


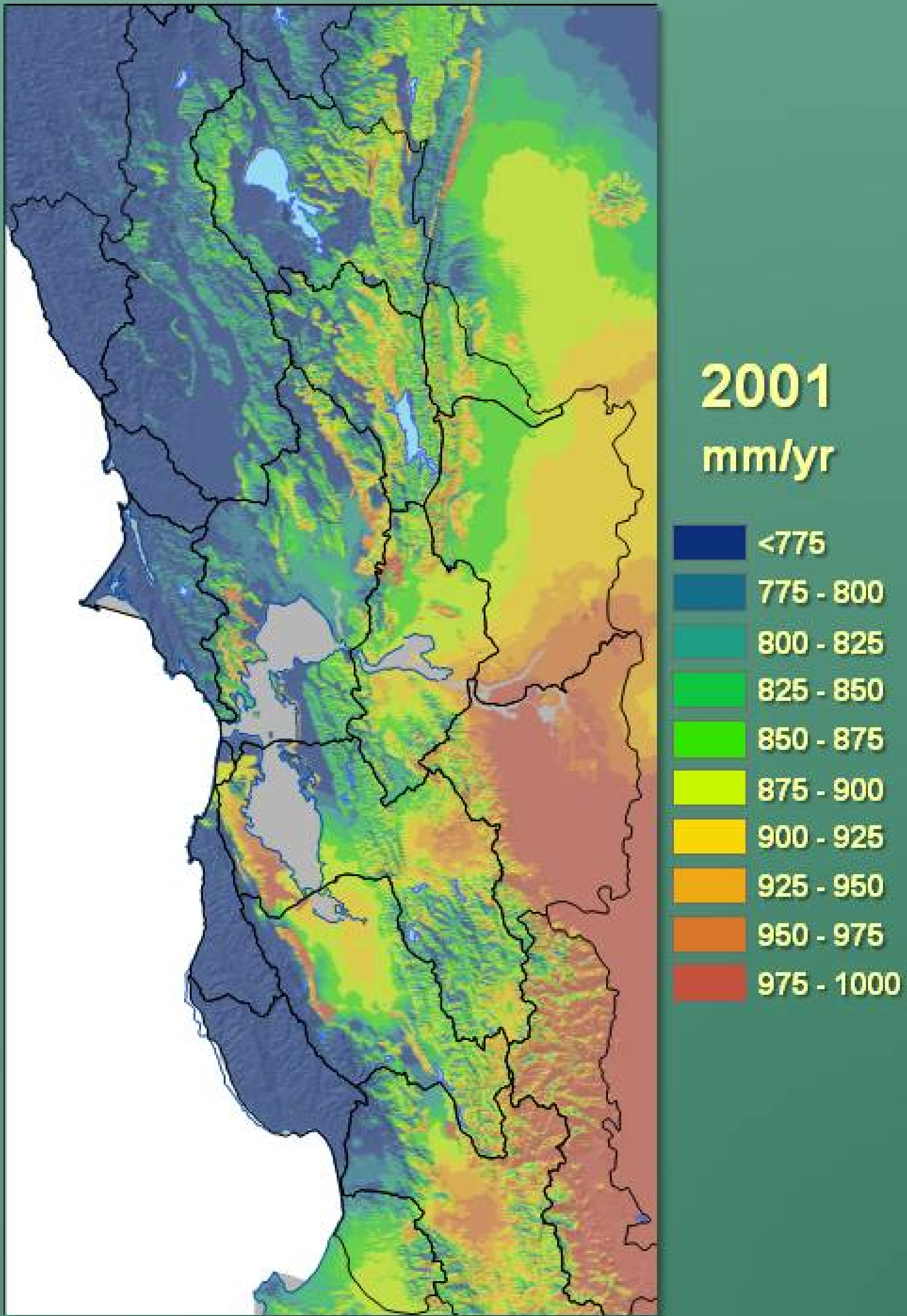
Climatic Water Deficit

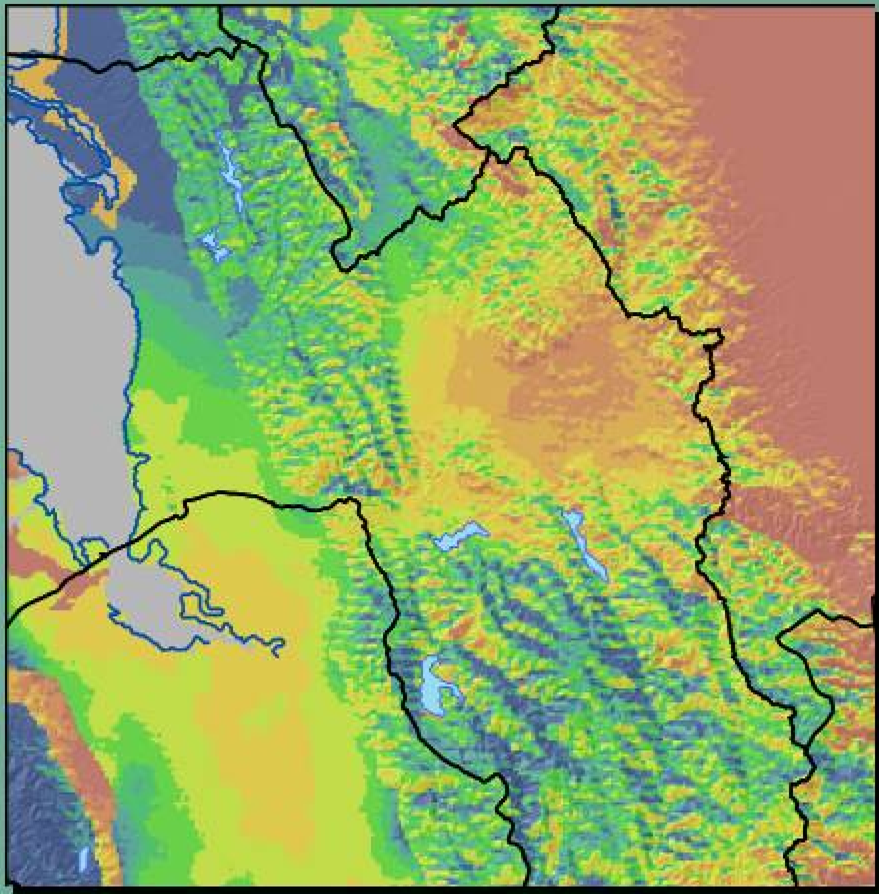
Annual evaporative demand that exceeds available water

Potential – Actual Evapotranspiration

- Integrates climate, energy loading, drainage, and available soil moisture storage
- Vegetation independent (indicator)
- Addresses irrigation demand
- Generally increases with all future climate scenarios







Climatic Water Deficit in South Bay

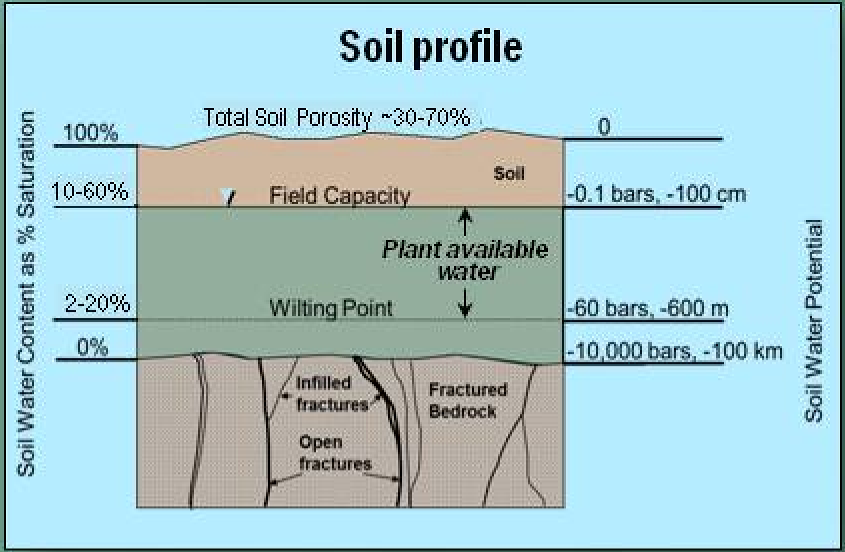
Google Earth Image of South Bay

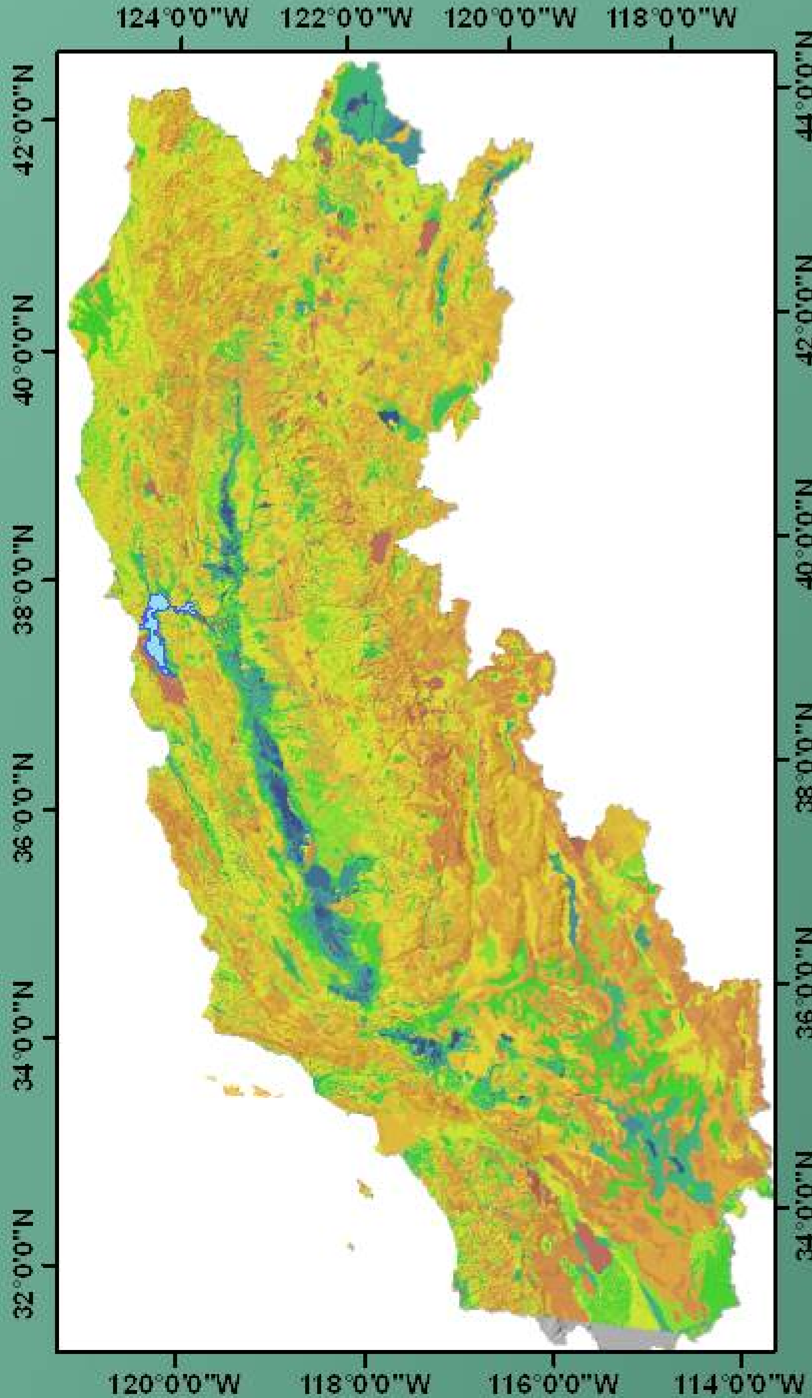
Climatic Water Deficit

Potential (PET) – Actual Evapotranspiration (AET)

Water balance calculation of AET on the basis of plant available water (PAW) and available energy

AET = PET if PAW > 0 and
air temperature > 6 deg C (?) until PAW = 0

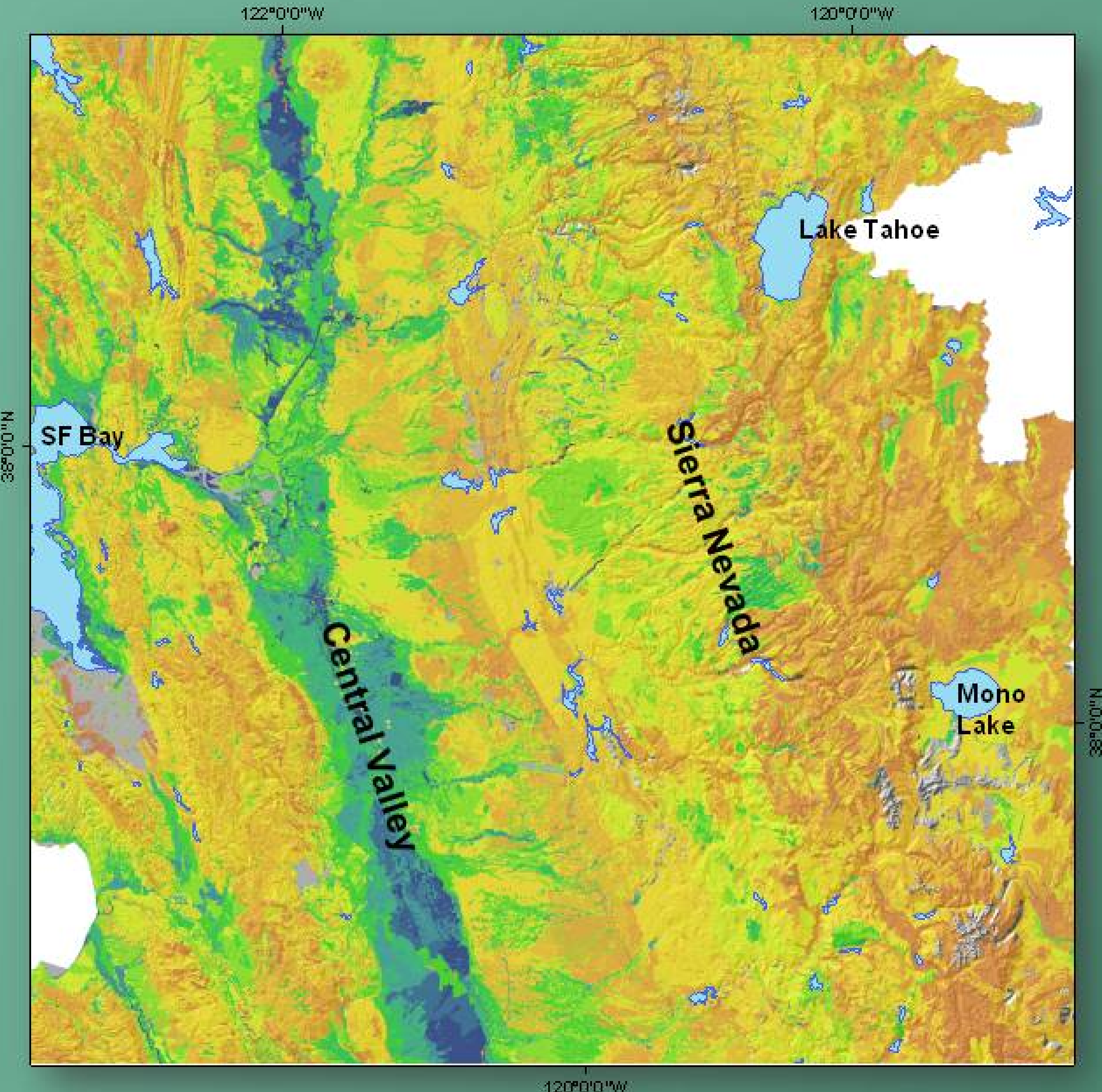




Total Plant Available Soil Water Storage

(Field Capacity – Wilting Point)* Depth
(mm water)

0 - 1
1 - 20
20 - 40
40 - 60
60 - 100
100 - 150
150 - 200
200 - 250
250 - 300
300 - 350
350 - 400
400 - 450
450 - 500
>500

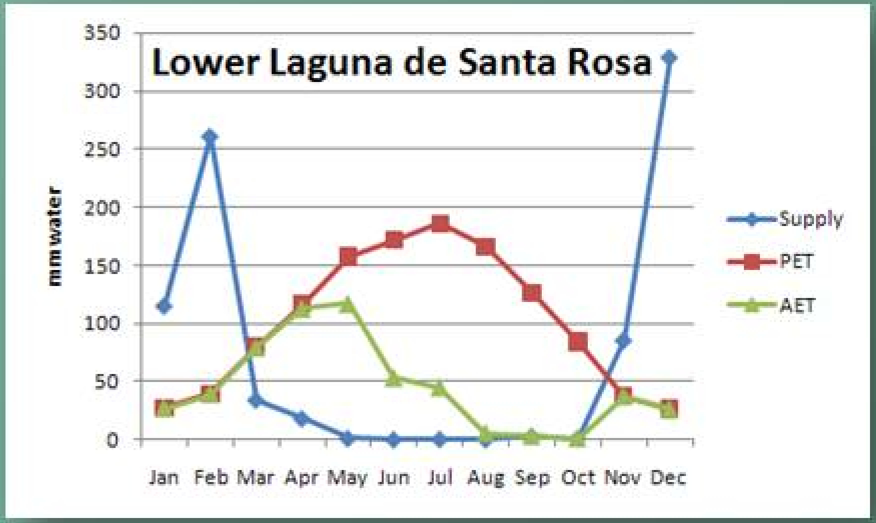


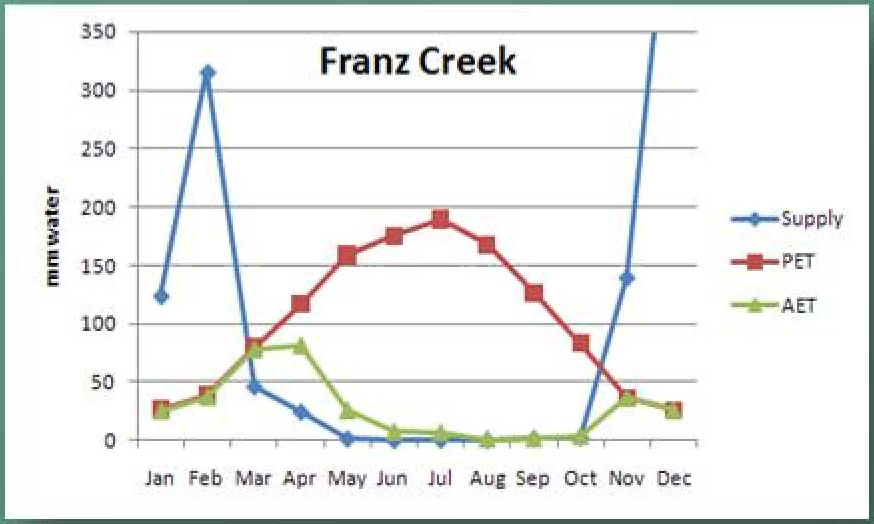
Total Plant Available Soil Water Storage

(mm of water)

- 0 - 1
- 1 - 20
- 20 - 40
- 40 - 60
- 60 - 100
- 100 - 150
- 150 - 200
- 200 - 250
- 250 - 300
- 300 - 350
- 350 - 400
- 400 - 450
- 450 - 500
- >500

Impact of Soil Storage on Climatic Water Deficit





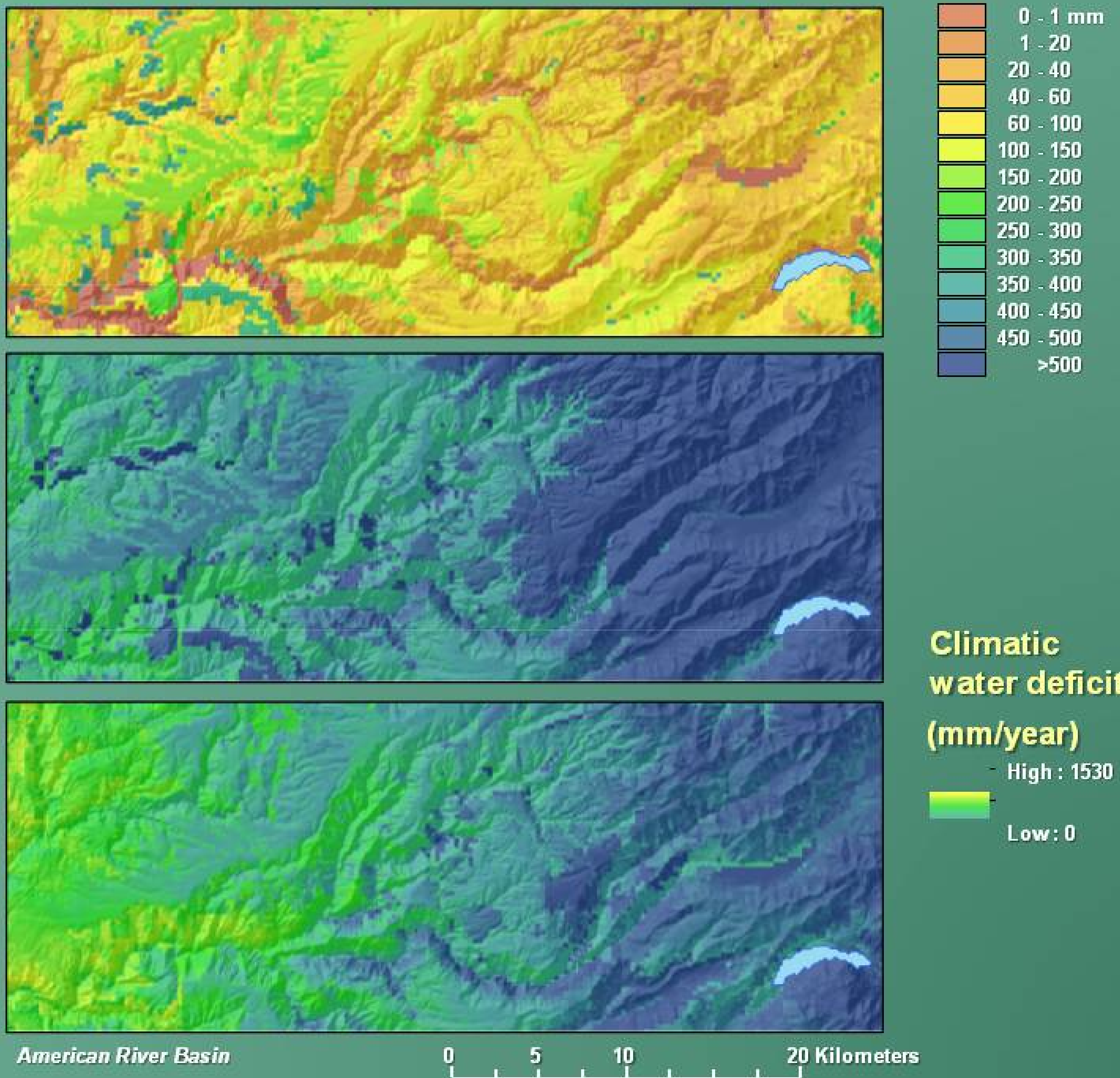
Supply	847 mm/yr
PET	1,218
AET	547
Soil Storage	303
CWD	671

Supply	1,161 mm/yr
PET	1,224
AET	330
Soil Storage	117
CWD	892

Total Soil Water Storage

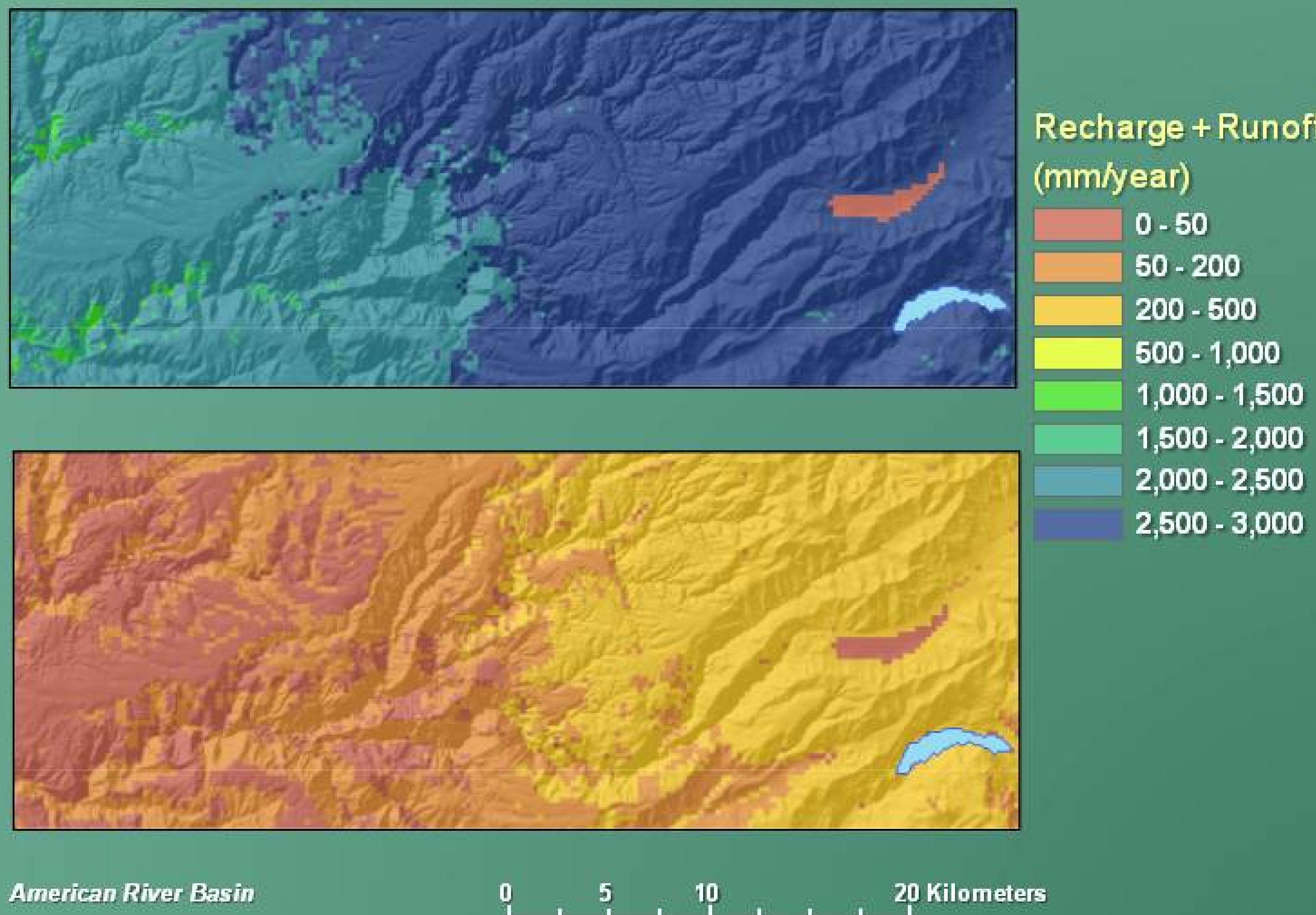
Climatic Water Deficit, wet year 1998

Climatic Water Deficit, dry year 1977

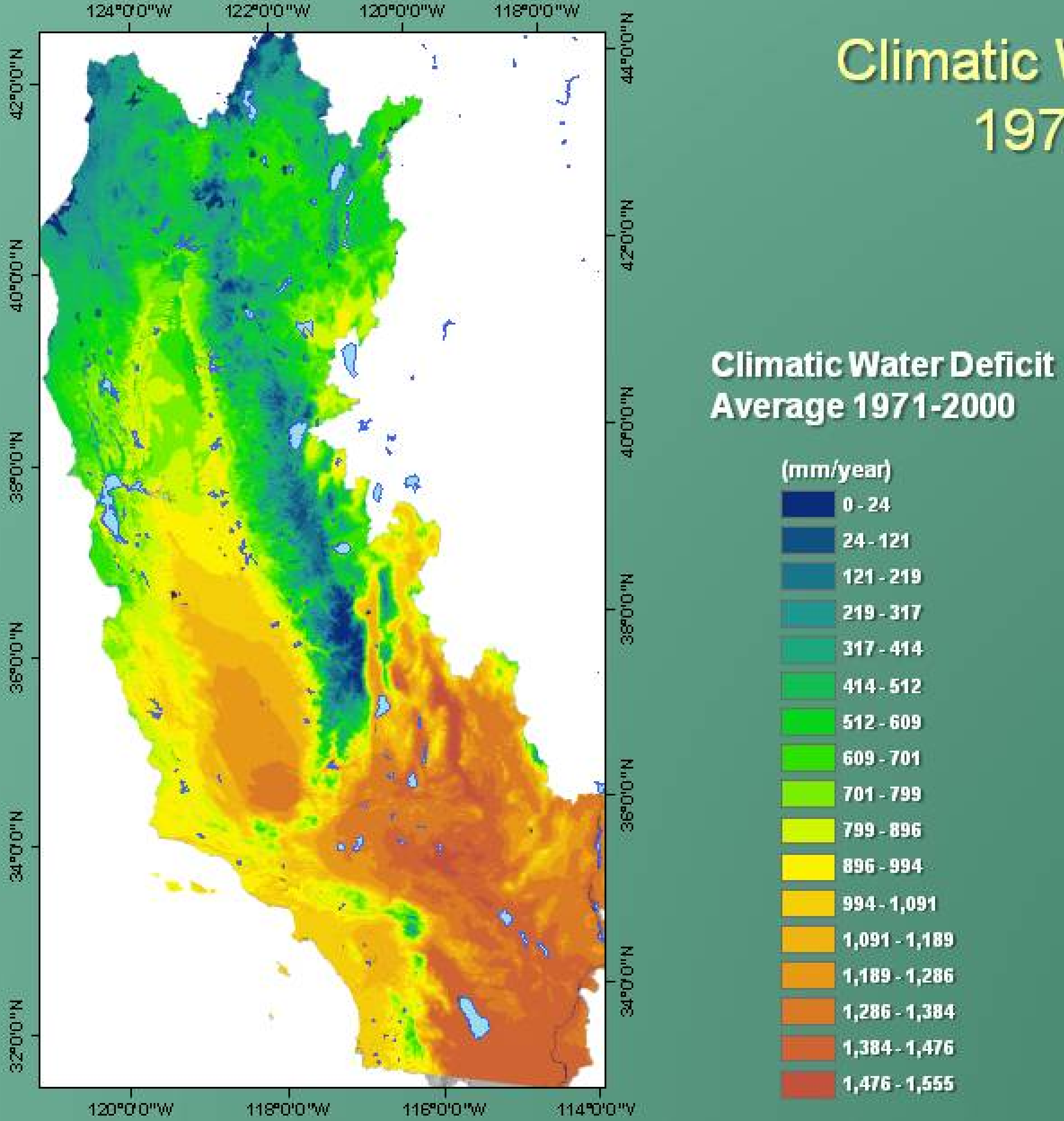


Recharge + Runoff, wet year 1998

Recharge + Runoff, dry year 1977



Climatic Water Deficit 1971-2000



Change in Climatic Water Deficit

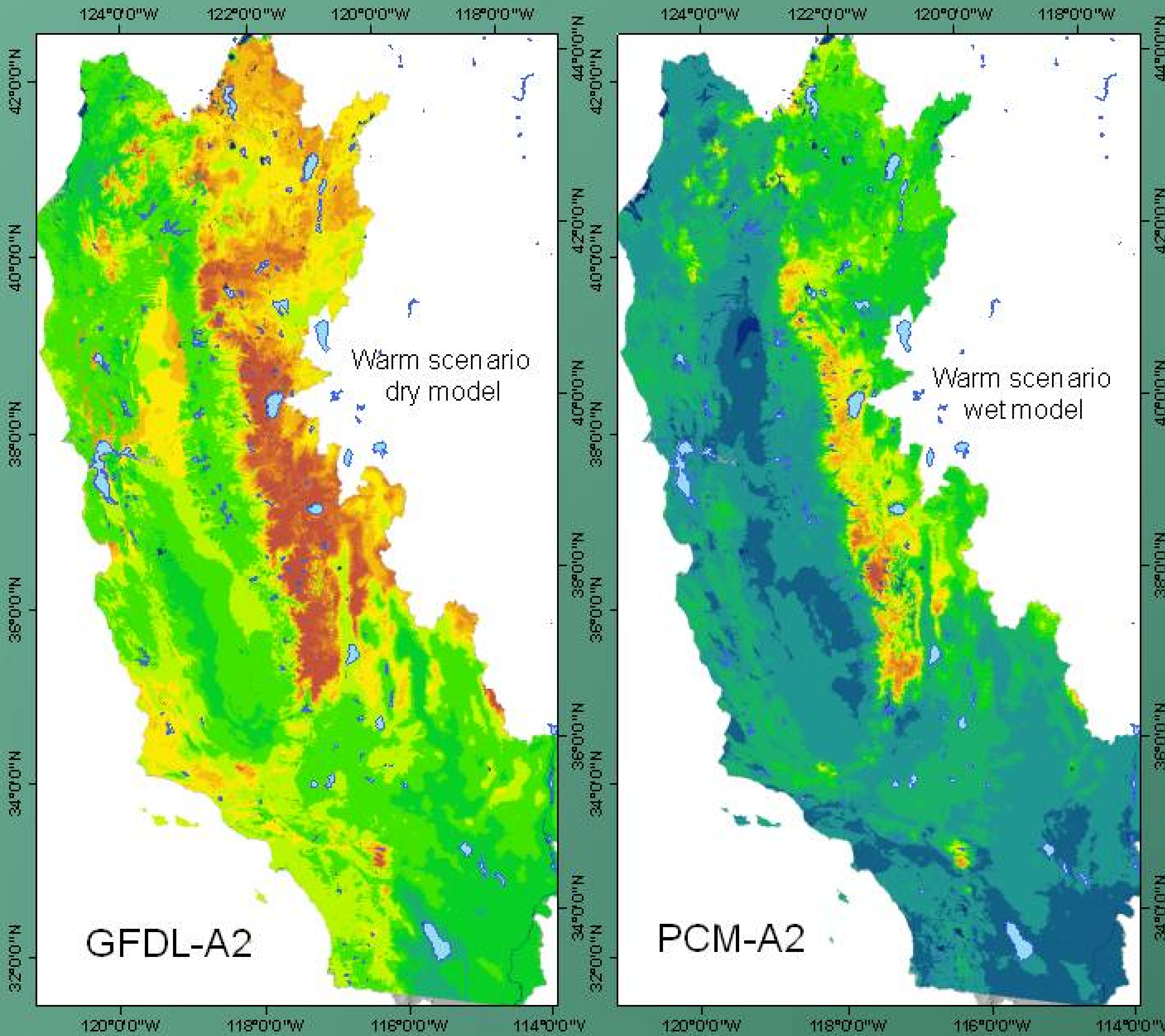
1971-2000

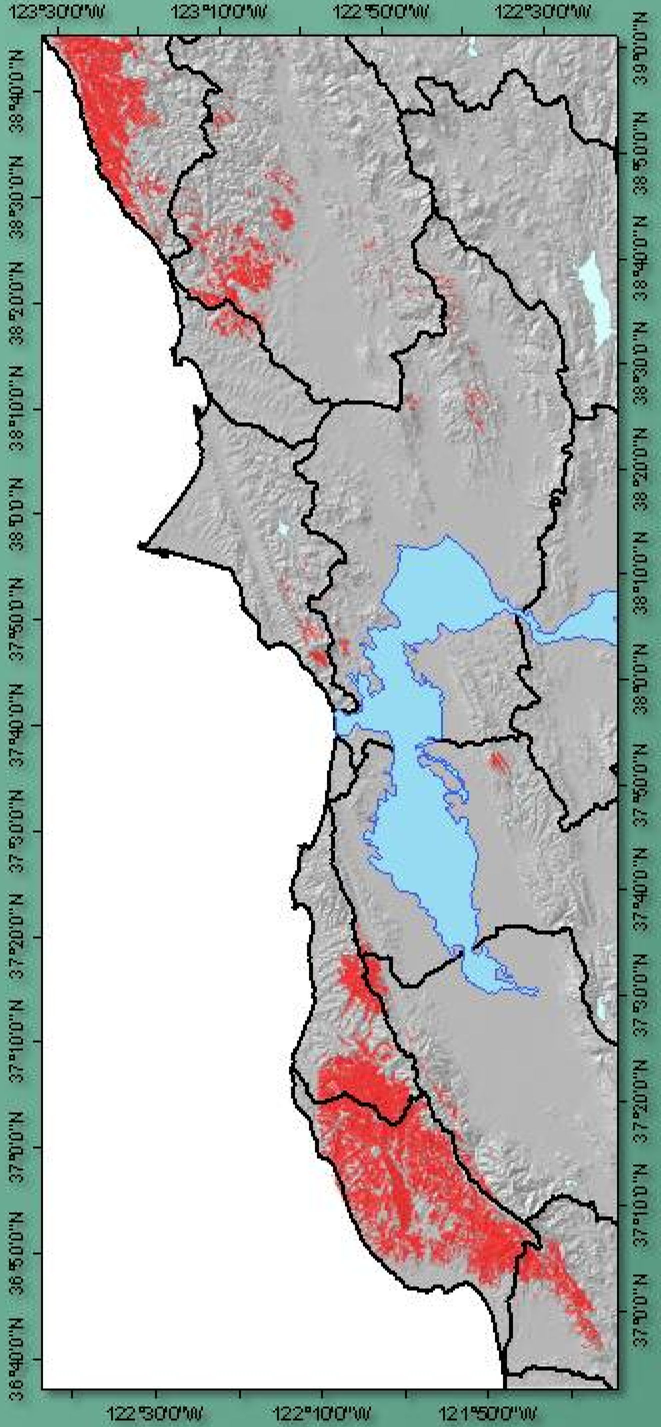
2071-2100

Legend is future minus historical

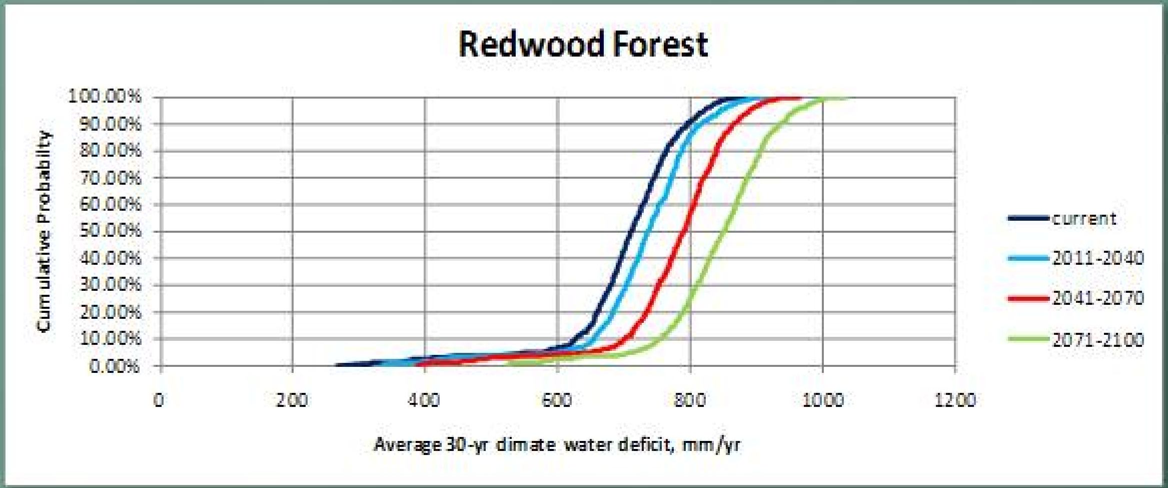
Change (mm/yr)

- -2 - 0
- 0 - 38
- 38 - 68
- 68 - 97
- 97 - 127
- 127 - 156
- 156 - 186
- 186 - 215
- 215 - 245
- 245 - 274
- 274 - 304
- 304 - 513





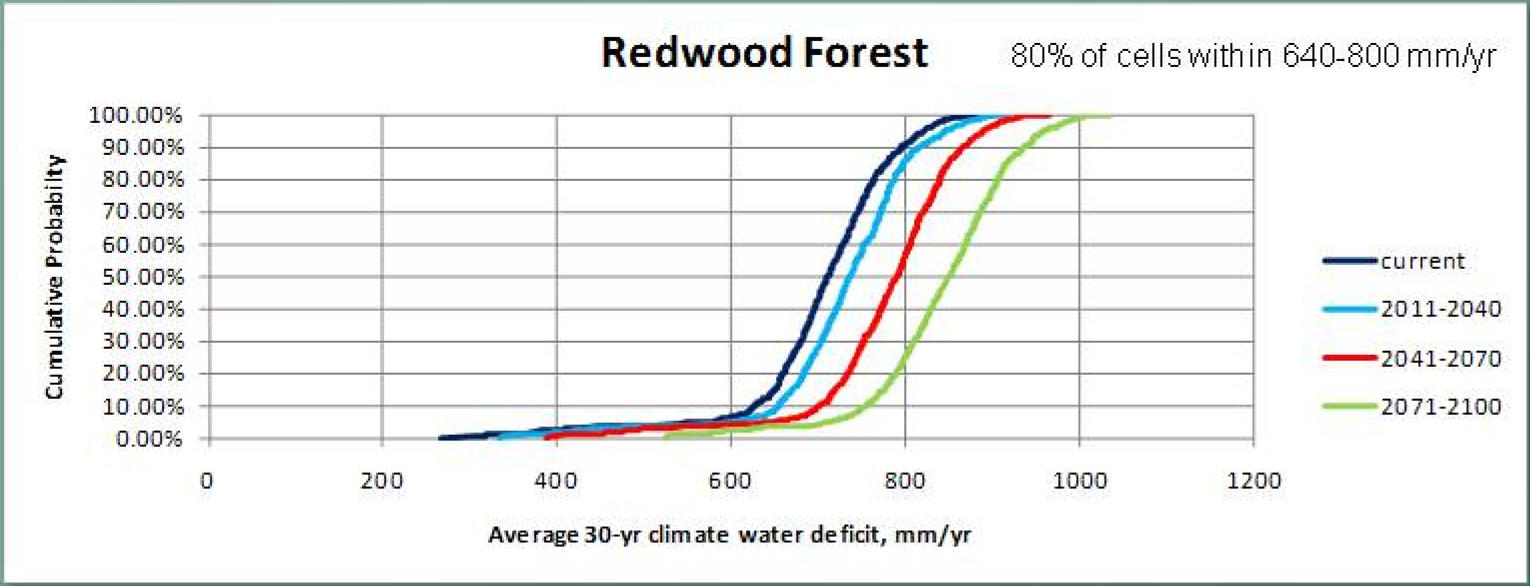
Mapped Locations of Redwood Forest

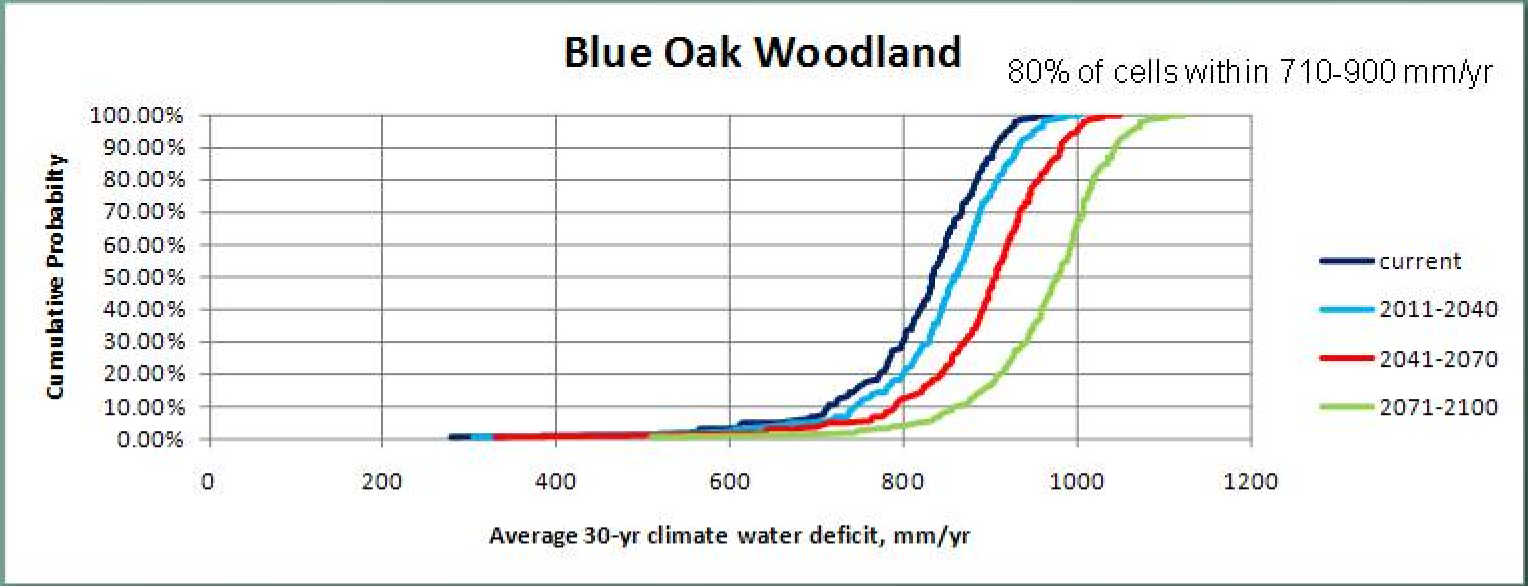


80% of cells for current conditions within 640-800 mm/yr

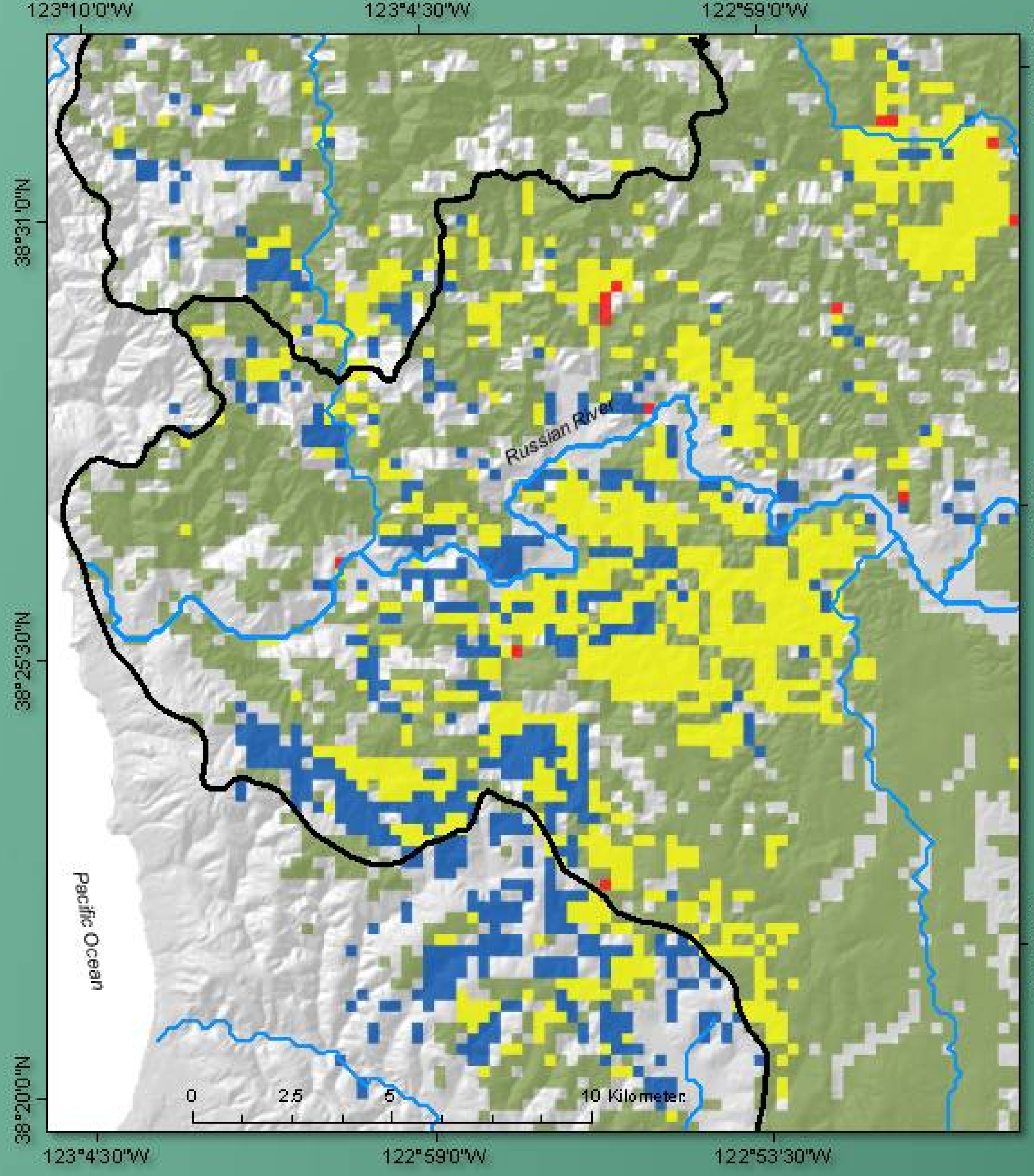
Map Courtesy of Bay Area Open Space Council

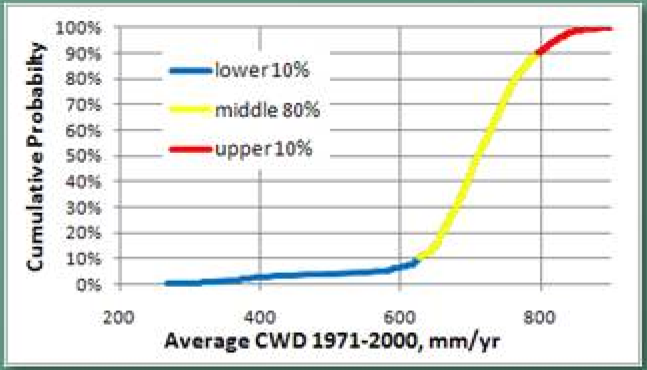
Climatic Water Deficit Distributions





Russian River Valley Distribution of Redwoods





Suitable CWD

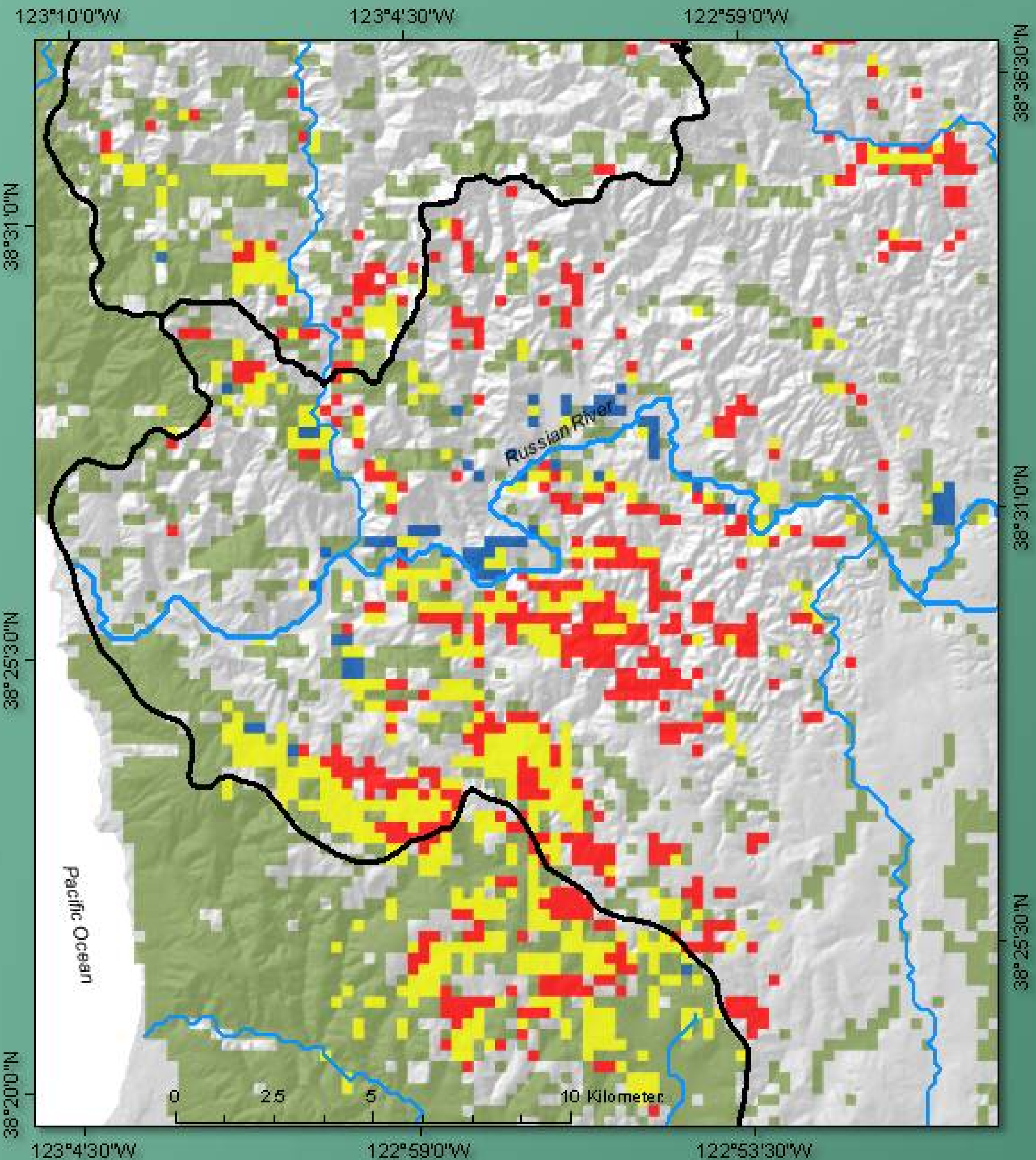
lower 10% (270-640 mm/yr)

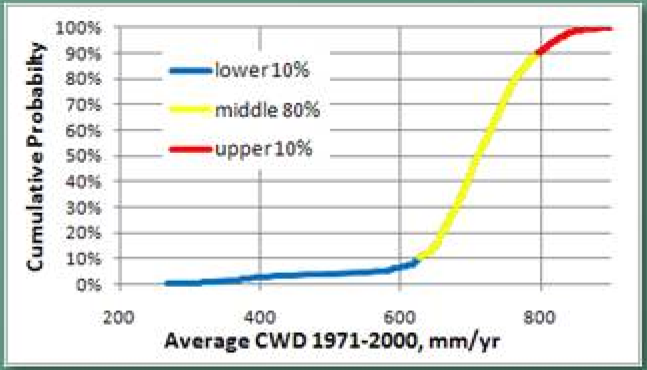
middle 80% (640-800 mm/yr)

upper 10% (800-900 mm/yr)

1971-2000

Russian River Valley and Distribution of Redwoods





Suitable CWD

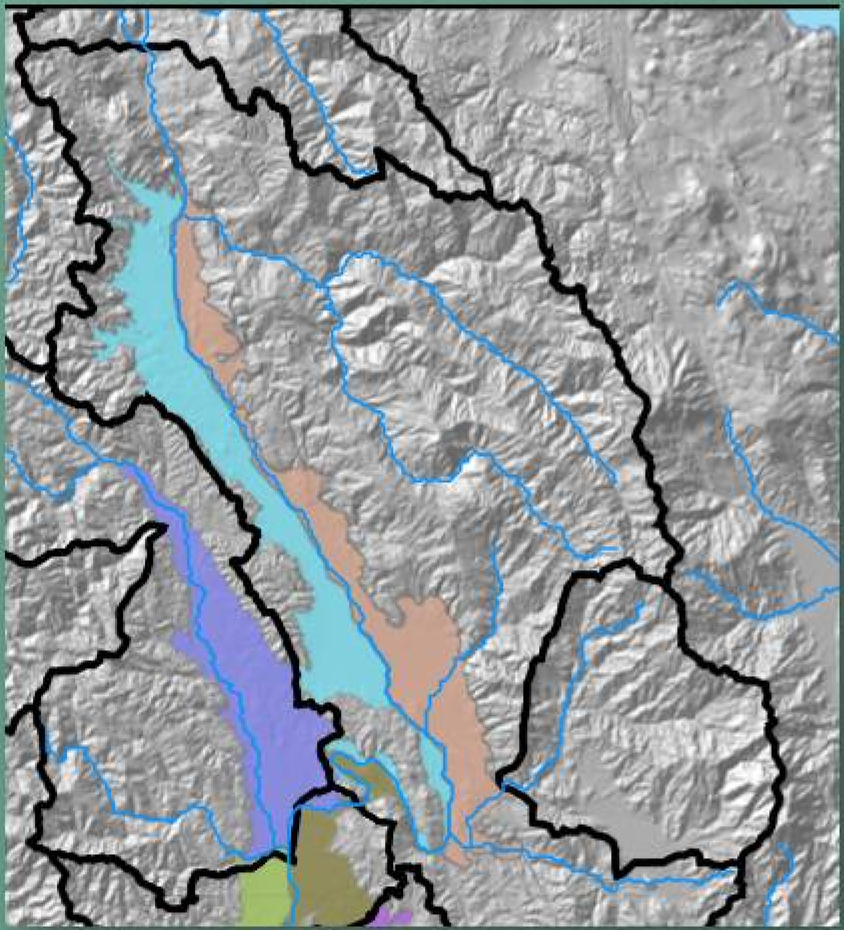
lower 10% (270-640 mm/yr)

middle 80% (640-800 mm/yr)

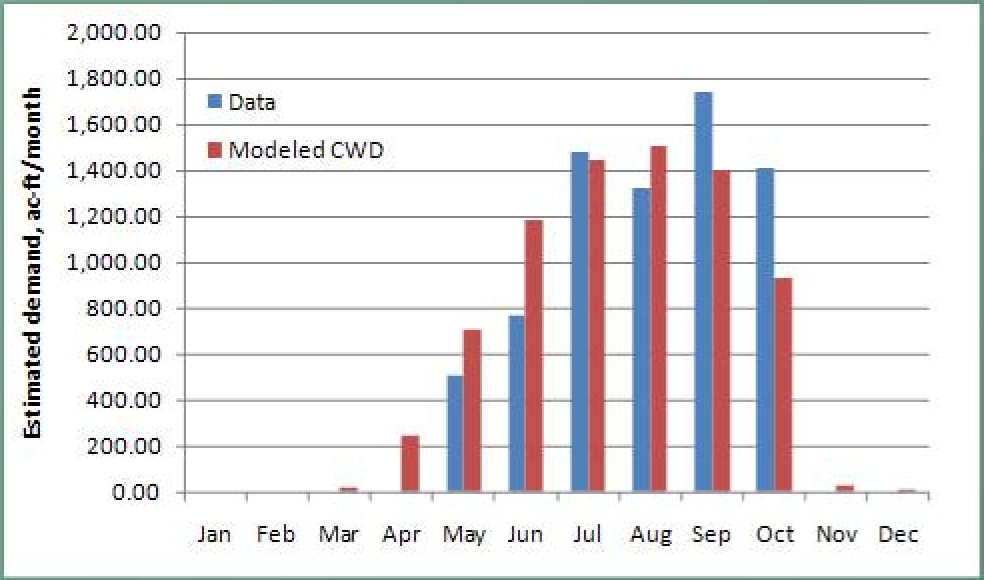
upper 10% (800-900 mm/yr)

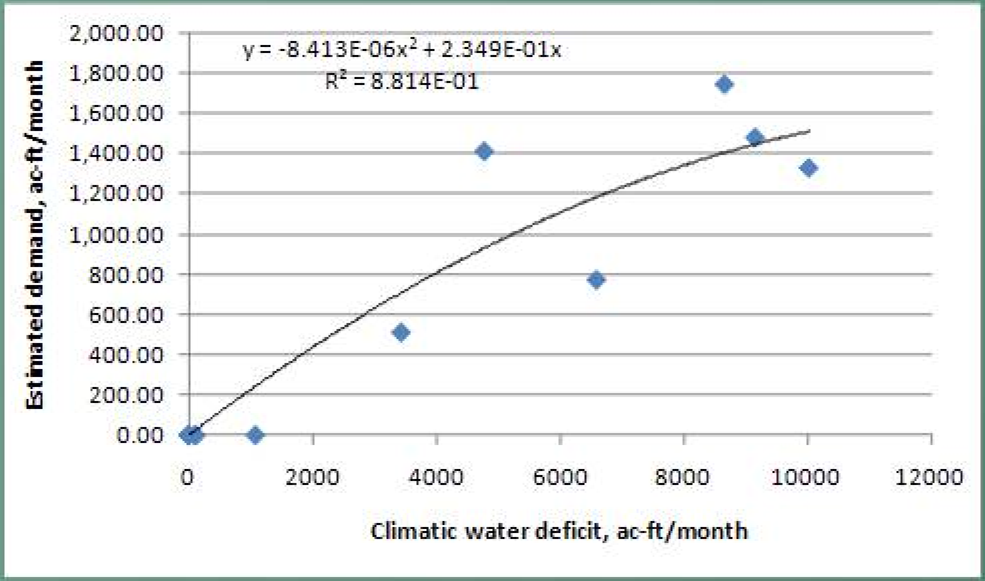
2071-2100
GFDL-A2

Using CWD to Estimate Agricultural Demand

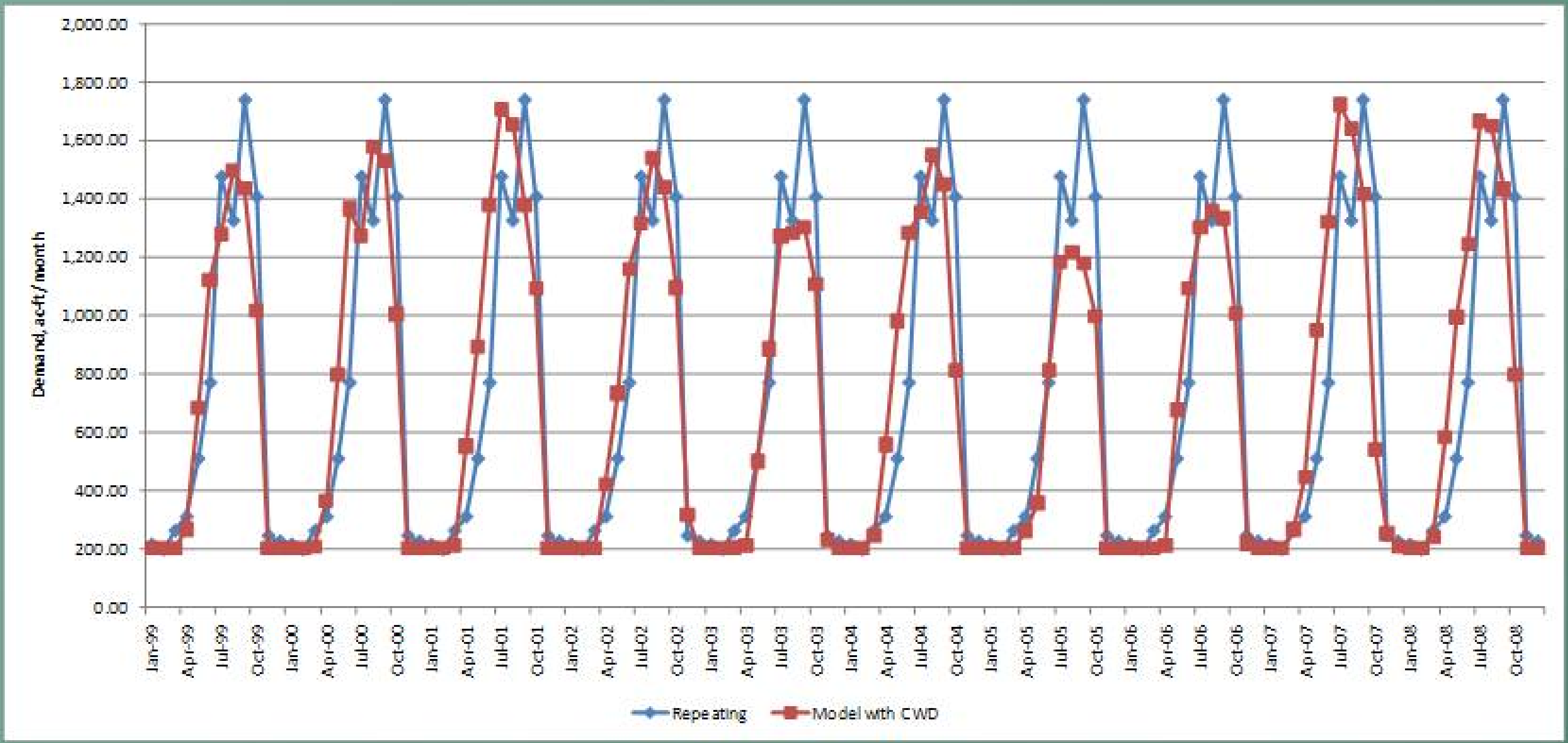


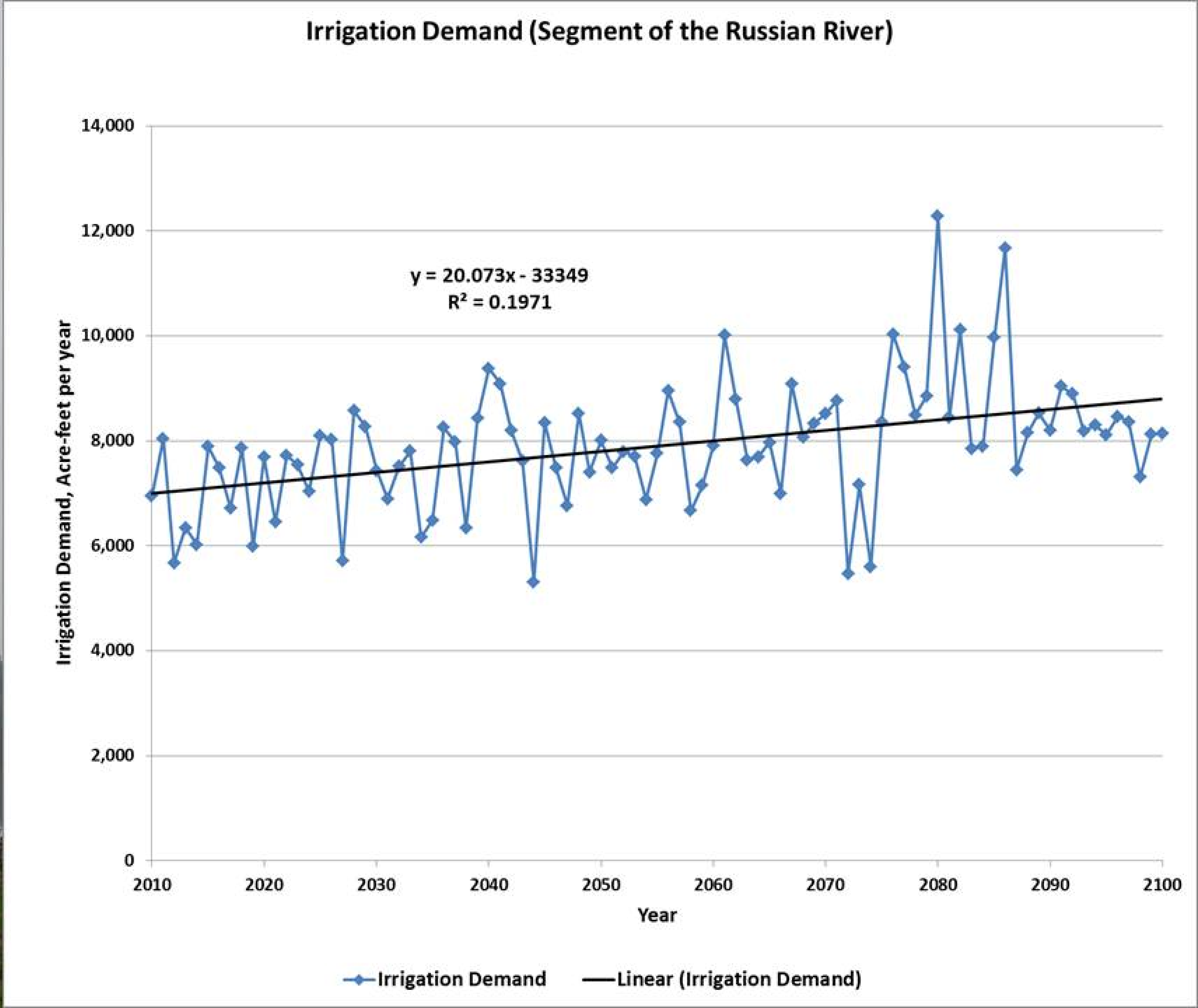
Methodology





Seasonal Demand Estimates Correlated to CWD




Irrigation Demand (Segment of the Russian River)
y = 20.073x - 33349
R² = 0.1971
Irrigation Demand, Acre-feet per year
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
Year
Irrigation Demand
Linear (Irrigation Demand)

Summary and Conclusions

- Statewide analysis of climatic water deficit requires
  - Precipitation
  - Potential evapotranspiration
  - Soil available water holding capacity
- Climatic water deficit correlated to natural vegetation distributions and will influence irrigated agriculture
- Years with excess water yield increases in recharge and runoff but not decreases in climatic water deficit
- Future climate models predict increases in PET, which will increase climatic water deficit regardless of changes in precipitation
- Using fine spatial scales allows us to recognize resiliency in the landscape as local ecologic refugia


photo by Stu Weiss