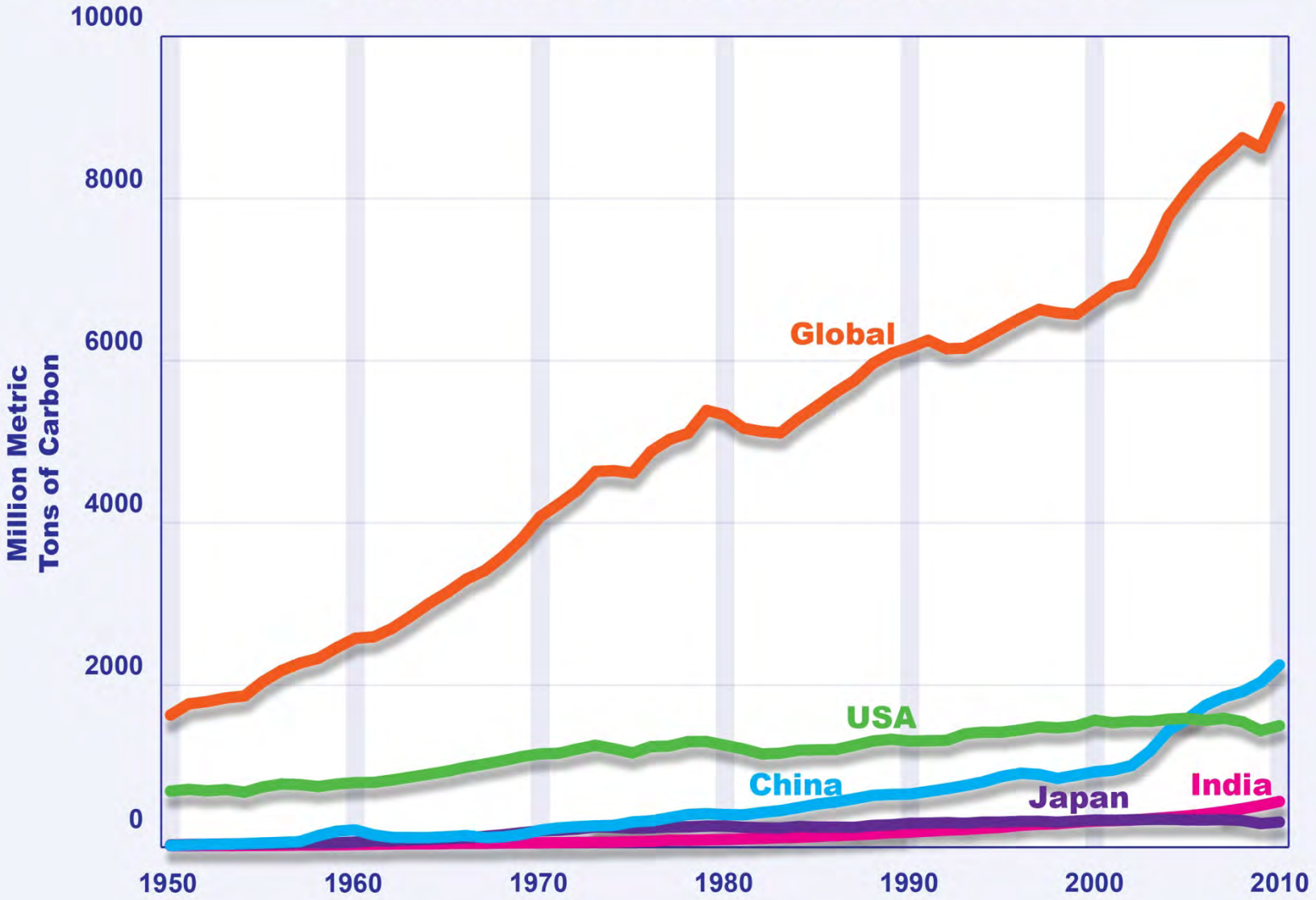
Climate Change, Sea Level and the Delta, and CA Water

by Maurice Roos
CA DWR
(for the Climate Literacy Class)
July, 2012

Five Major Impacts

- Shift in runoff patterns- more winter runoff and less spring and early summer runoff due to smaller snowpacks.
- Sea level rise with levee and salinity problems in the Delta and low coastal areas.
- Bigger floods due to larger winter rainflood producing areas and more water vapor in storms.
- Somewhat higher crop and landscape water needs.
- Water temperature problems for cold water fish like salmon and steelhead.

CO2 Emissions From Fossil Fuel, 1950-2010



Source: G. Marland, T. A Boden and R. J. Andres, CDIAC, Oak Ridge, TN

Major Greenhouse Gases

	Approx Percent	Rel GWP
Carbon dioxide	56	1
Methane	16	23
Nitrous oxide	5	300
Halocarbons	11	140 – 12,000
Trop. ozone	12	N.A.

(Per IPCC 2007)

Water vapor About 2/3 of present GH effect; CO2 is about 25 %

Atmospheric CO_2 at Mauna Loa Observatory

Scripps Institution of Oceanography
NOAA Earth System Research Laboratory

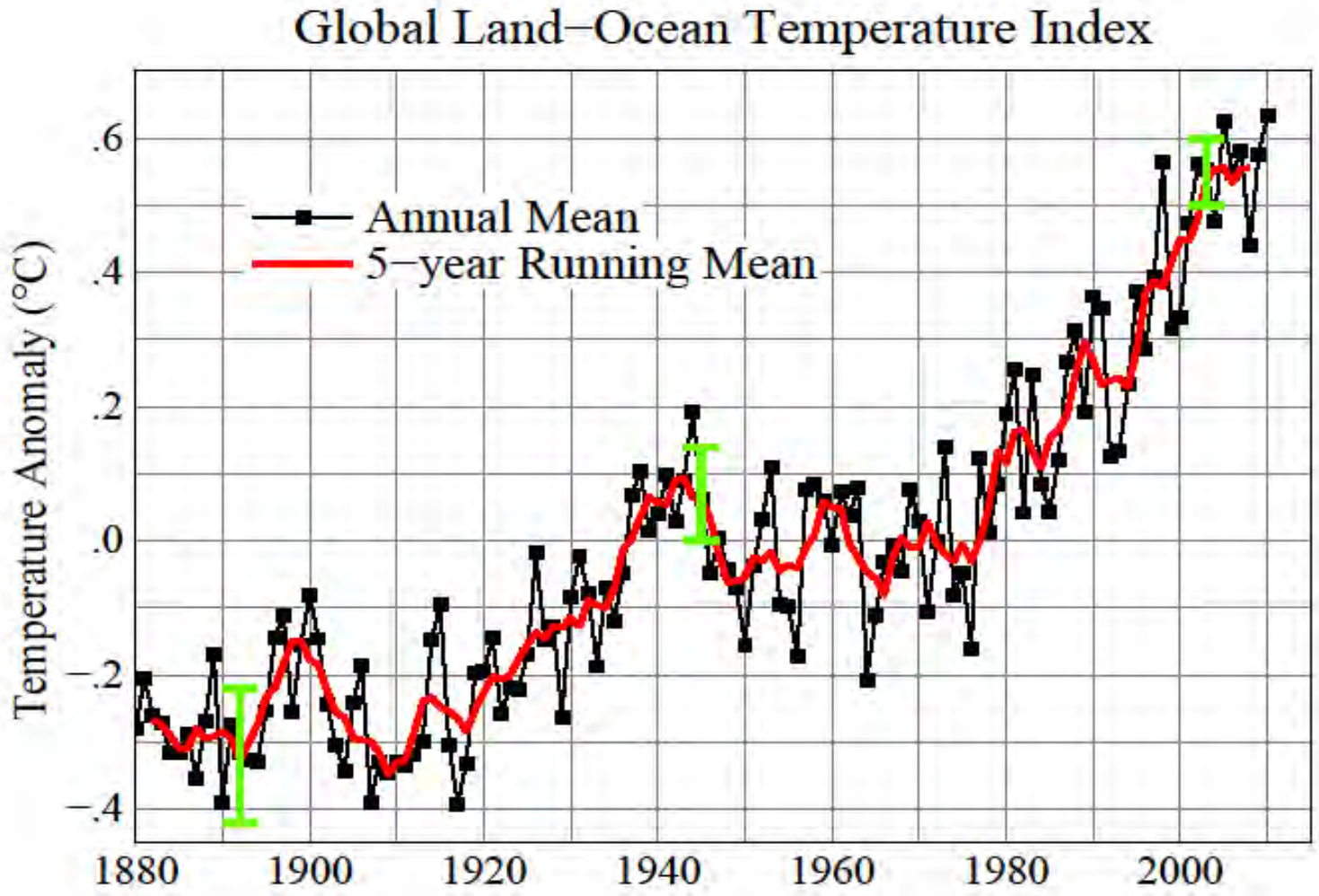
PARTS PER MILLION

380
360
340
320

1960 1970 1980 1990 2000 2010

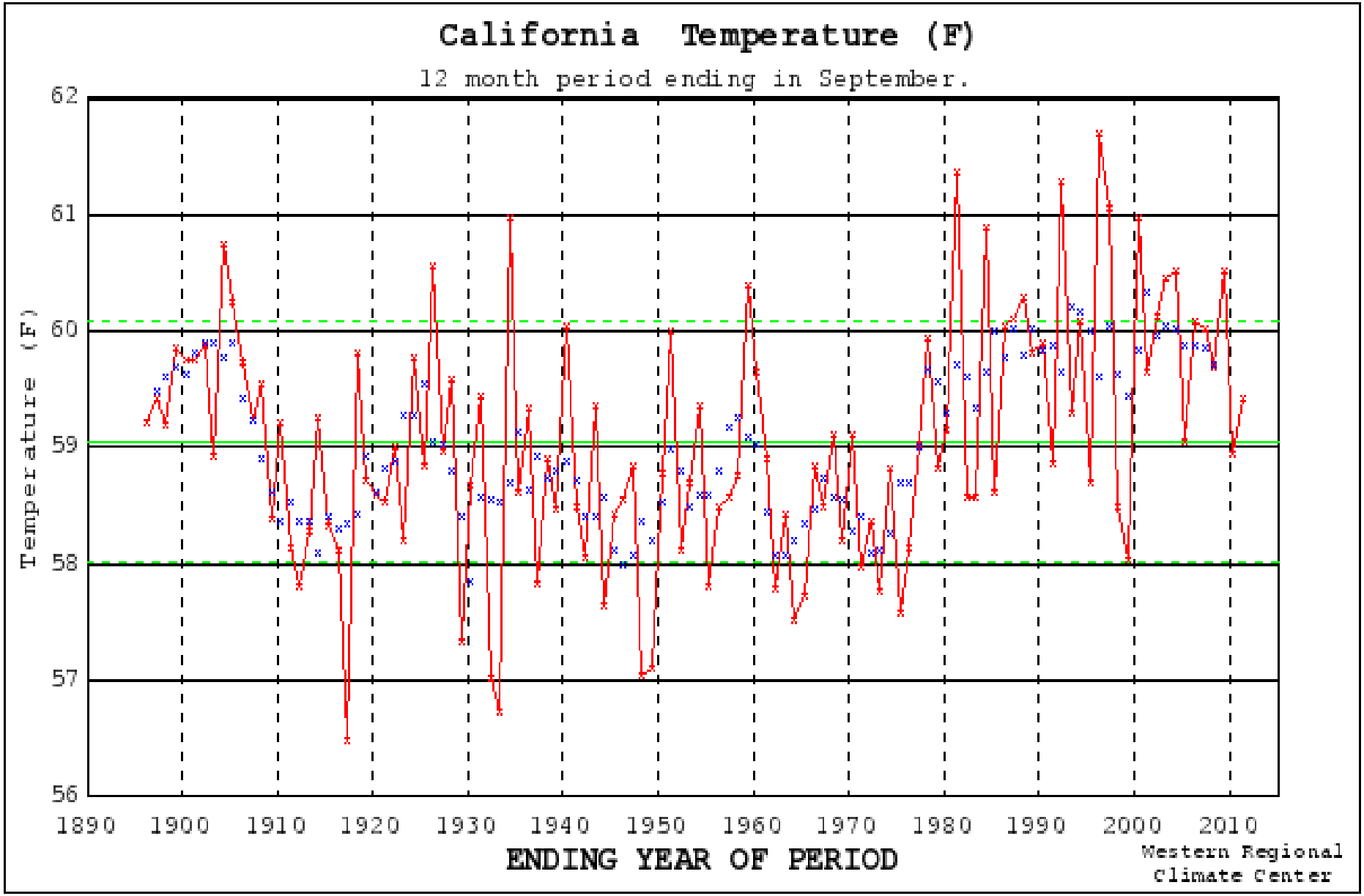
YEAR

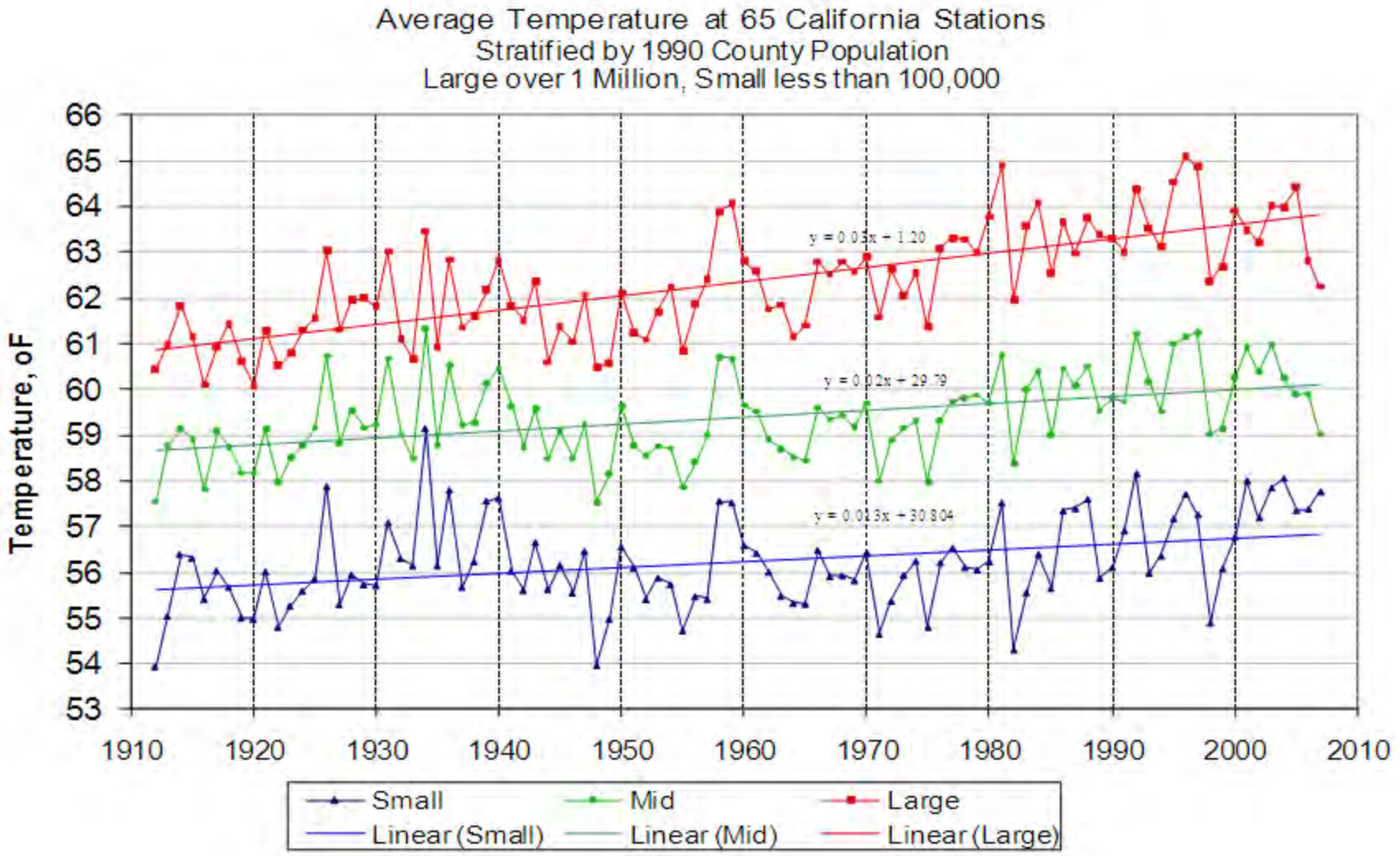
August 2011



GISS analysis of global surface temperature change. Base period = 1951 – 1980. Green vertical bar is estimated 95% confidence range.

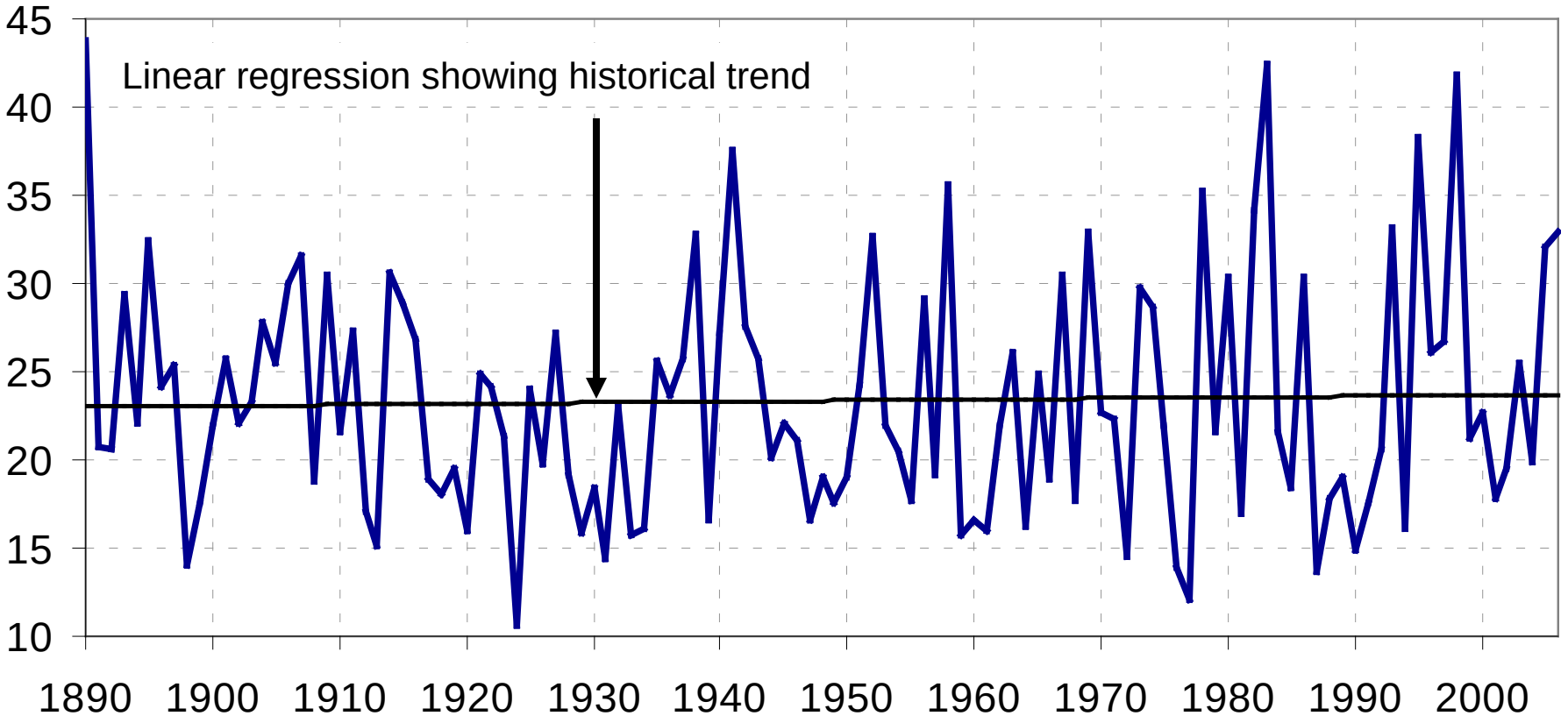
Source: update of Hansen et al., GISS analysis of surface temperature change.


California Temperature (F)
12 month period ending in September.
Temperature (F)
62
61
60
59
58
57
56
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
ENDING YEAR OF PERIOD
Western Regional
Climate Center



Source: James R. Goodridge, updated beyond 2004 by Michael Anderson, DWR with DRI data in 2008.

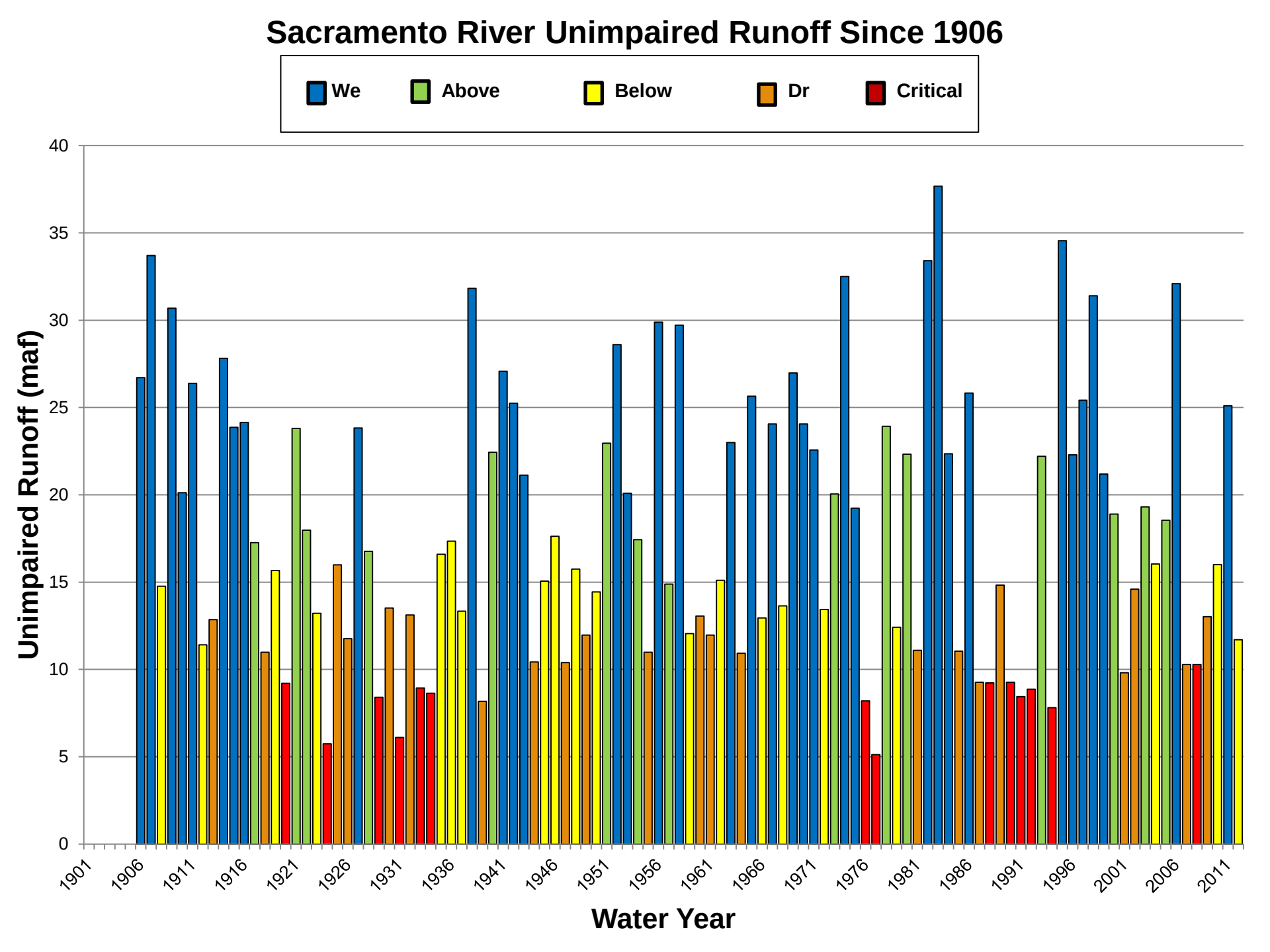
Ca Precipitation Trend



116 year average: 23.88 inches

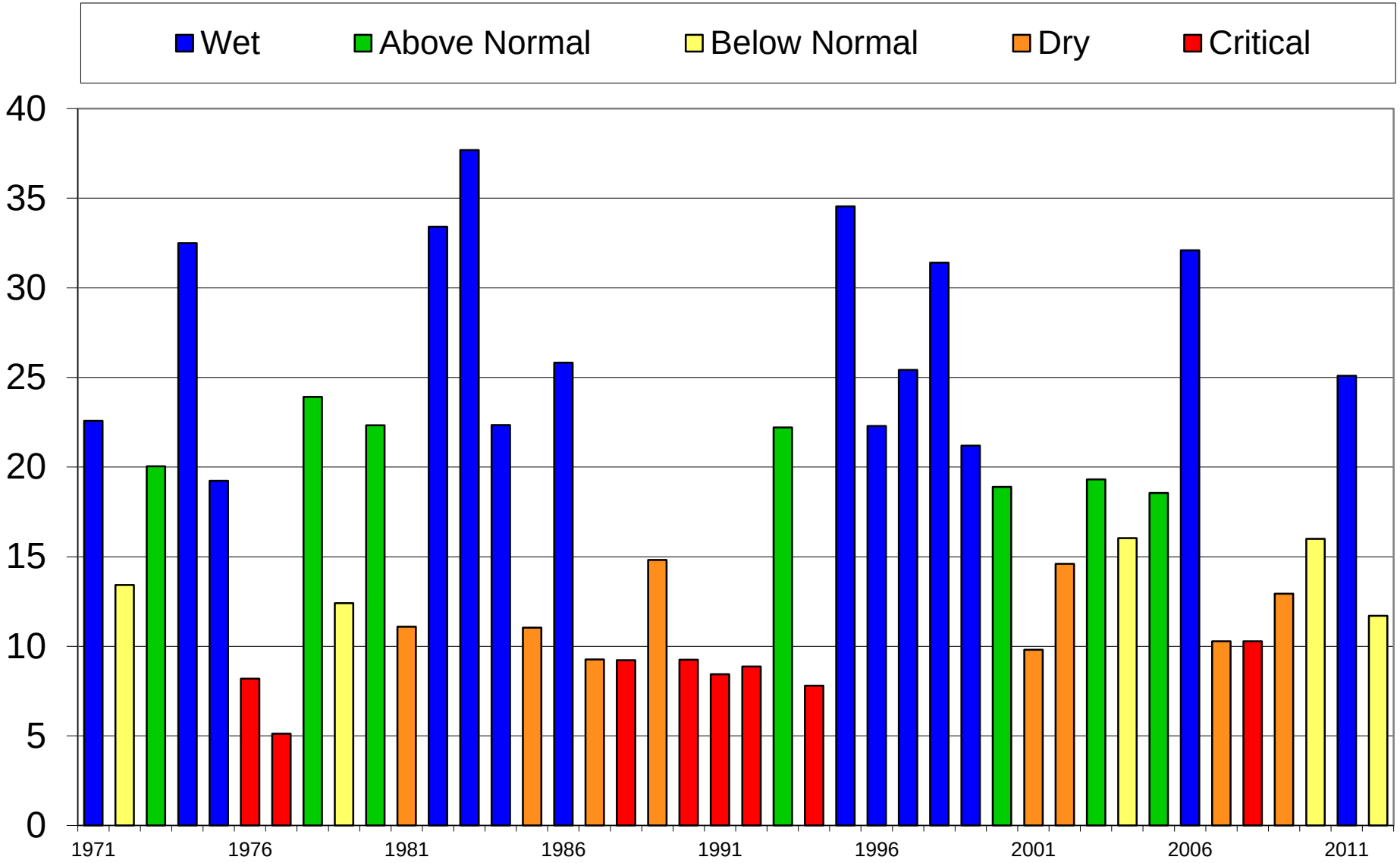
Driest 30 years: 1908-1937 21.28 inches

Wettest 30 years: 1977-2006 24.88 inches


Sacramento River Unimpaired Runoff Since 1906
We
Above
Below
Dr
Critical
Unimpaired Runoff (maf)
0
5
10
15
20
25
30
35
40
1901
1906
1911
1916
1921
1926
1931
1936
1941
1946
1951
1956
1961
1966
1971
1976
1981
1986
1991
1996
2001
2006
2011
Water Year

Sacramento River Unimpaired Runoff Since 1971

In Million Acre Feet



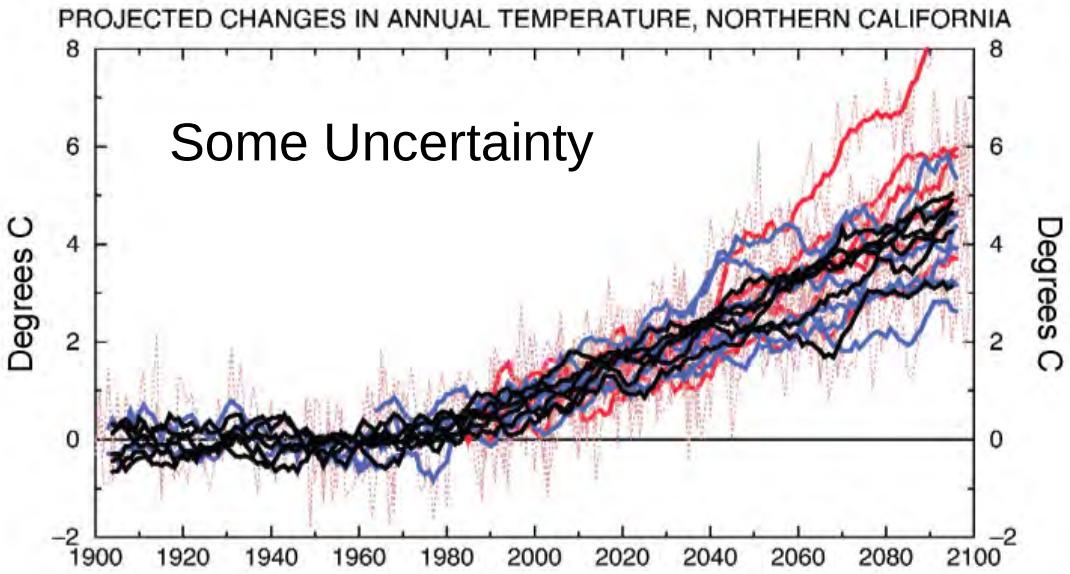
IPCC 2100 Projections

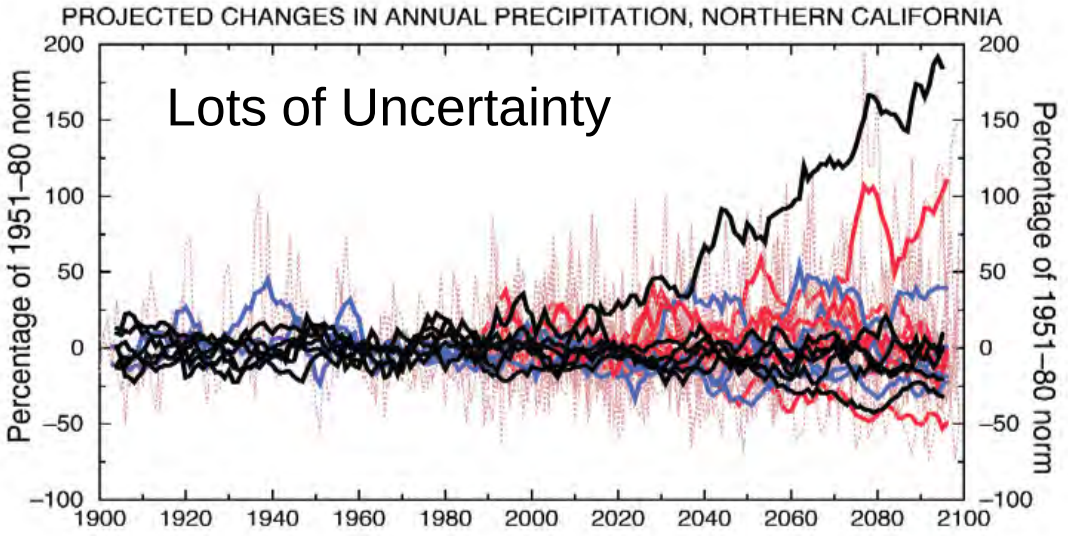
(From 4th Assessment Report 2007)

- Global temp up 1.8 to 4.0 º C (from 1990)
- Sea level rise by .18 to .59 m (.6 to 1.9 ft)

  (with an added .1 to .2 m if Greenland ice melt increases beyond 1993-03 rate)
- Precipitation more uncertain but likely increase at higher latitudes and near equator, less in subtropics
- Extreme events (floods) more likely

CA Temp and Precip Projections





From Dettinger, 2005

Reduced Mountain Snowpack and Change in River Runoff Patterns

- Warmer temperatures mean higher snow levels during winter storms, about 500 feet per degree Celsius.
- If precip about the same, more winter runoff and smaller spring and early summer snowmelt volumes.
- Northern Sierra affected more than higher elevation southern Sierra snowpack.

Snowpack Changes:

Evolution of Average Annual Snow Water Equivalent as a Percentage of Average 1995-2005 Values

(effect of temperature changes only: historical P, baseline T from WY 1965-1987)

Climate Research Division

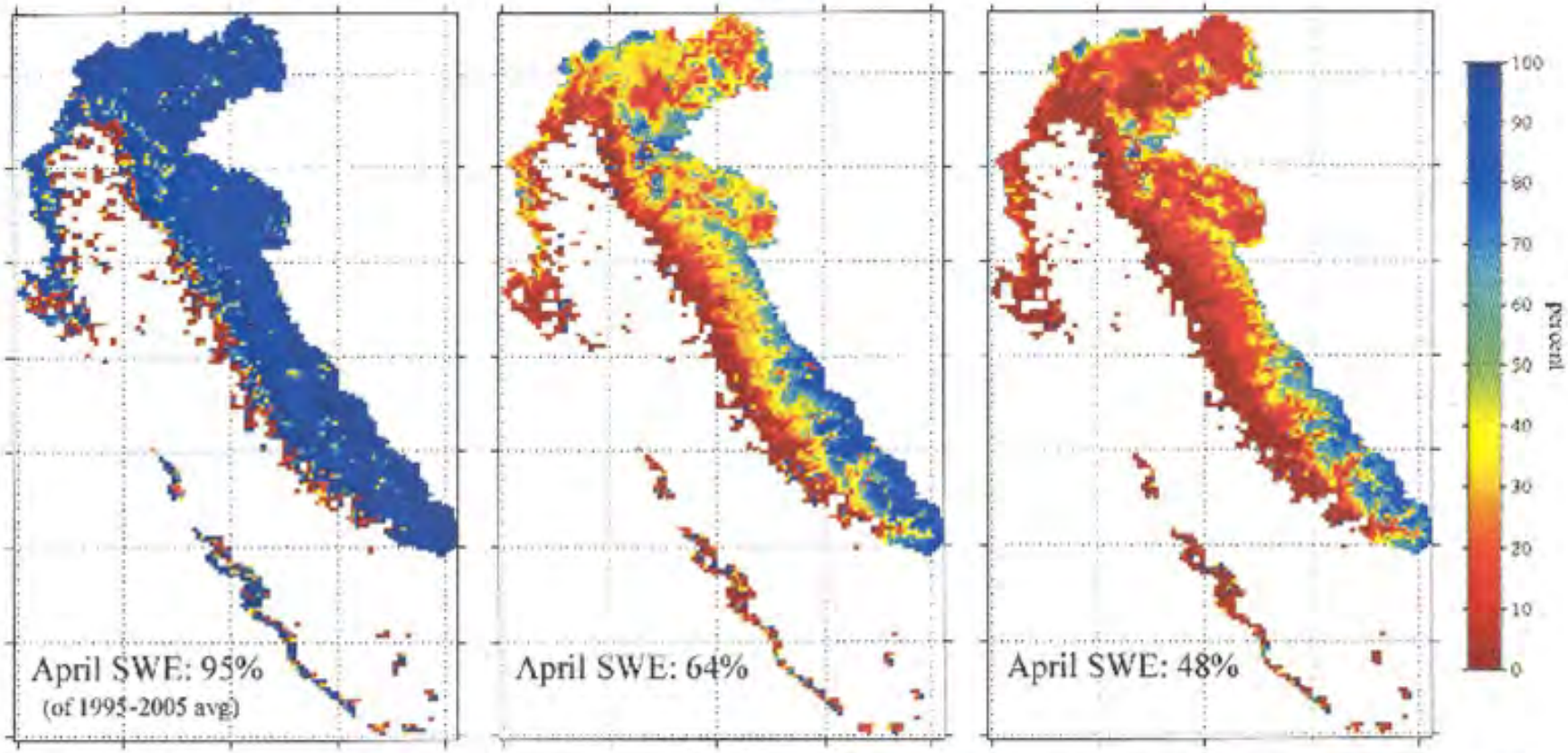
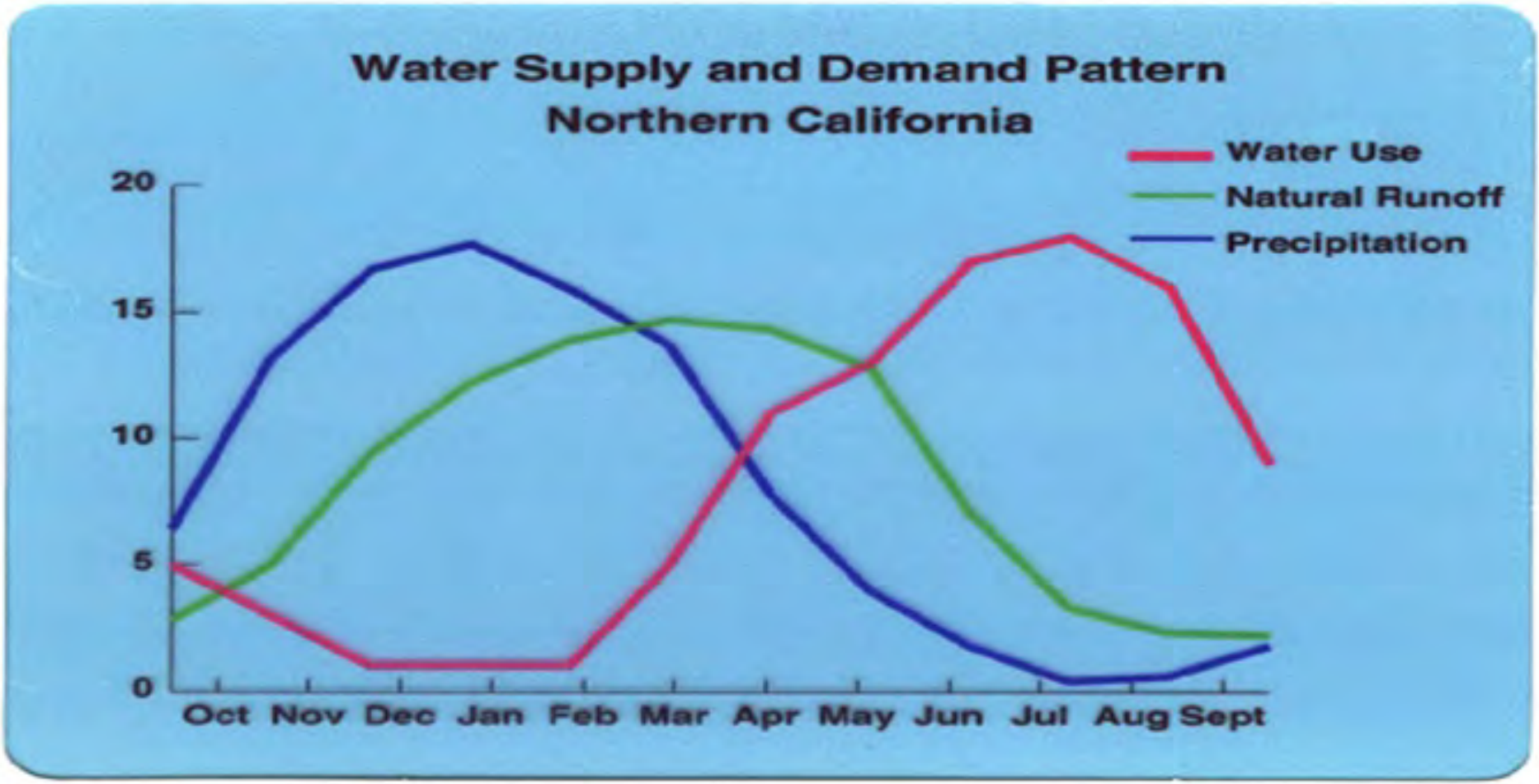


figure by N. Knowles

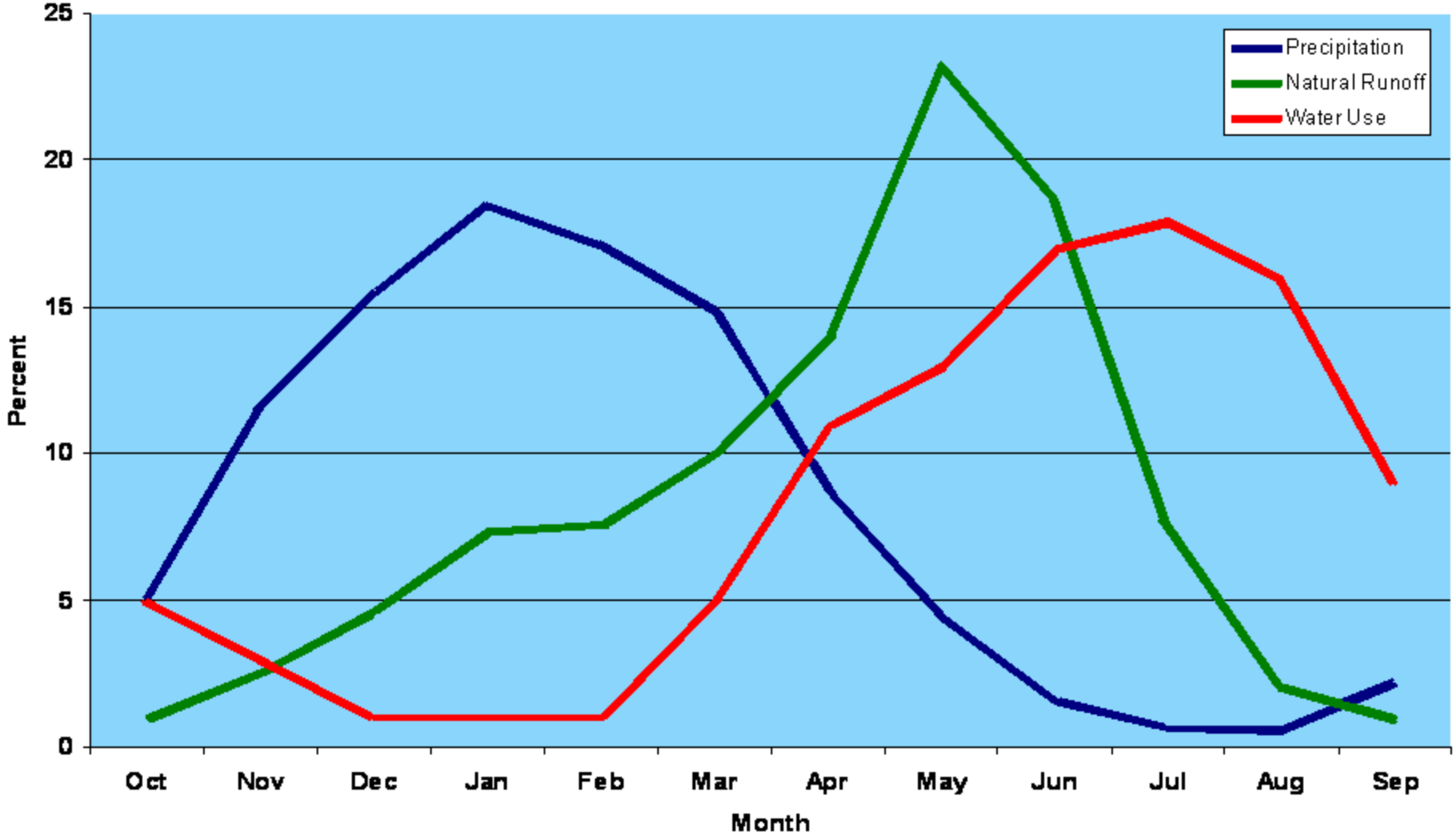
(20-yr cntered avg monthly T anoms rel to 1995-2005 monthly avgs from PCM B09.44 run, used to force BDWM with WY65-87 conditions. 6/15/01)

Loss of Snowpack

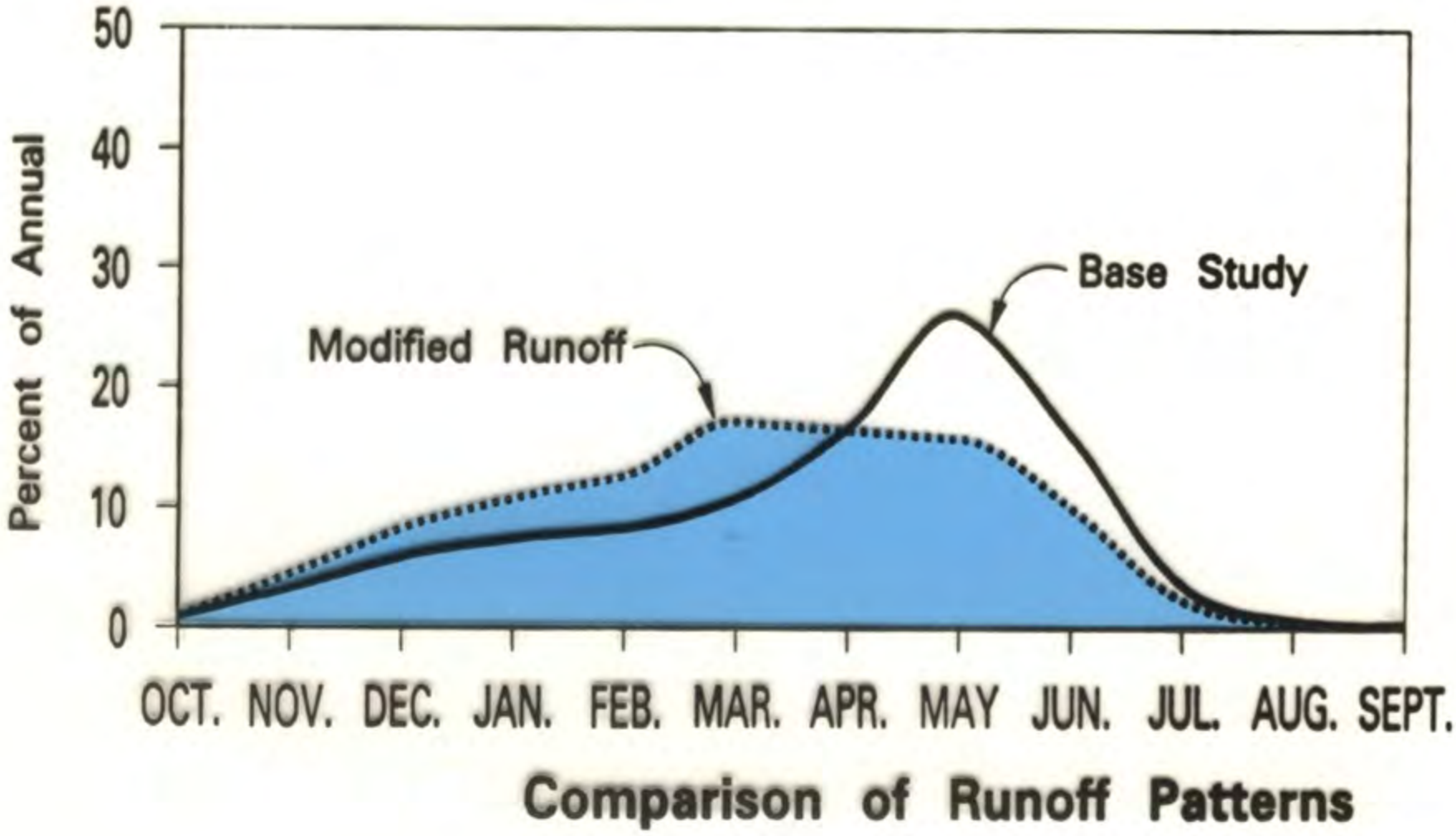
- Knowles & Cayan – 2002 paper
  - **Temp rise** **Pack loss**
  - **0.6 (2030)** **5 percent**
  - **1.6 (2060)** **33 “**
  - **2.1 (2090)** **50 “**
- Hayhoe et al -- 2004 NAS
  - **1.3 – 2.0 (2020-49) 26 -- 40 percent**
  - **2.3 – 5.8 (2070-99) 29 -- 89 “**
- Cayan et al -- 2006 White Paper
  - **0.5 -- 1.5 (2005-34) 6 -- 29 percent**
  - **0.8 -- 2.3 (2035-64) 12 -- 42 “**
  - **1.5 -- 4.5 (2065-99) 32 -- 79 “**

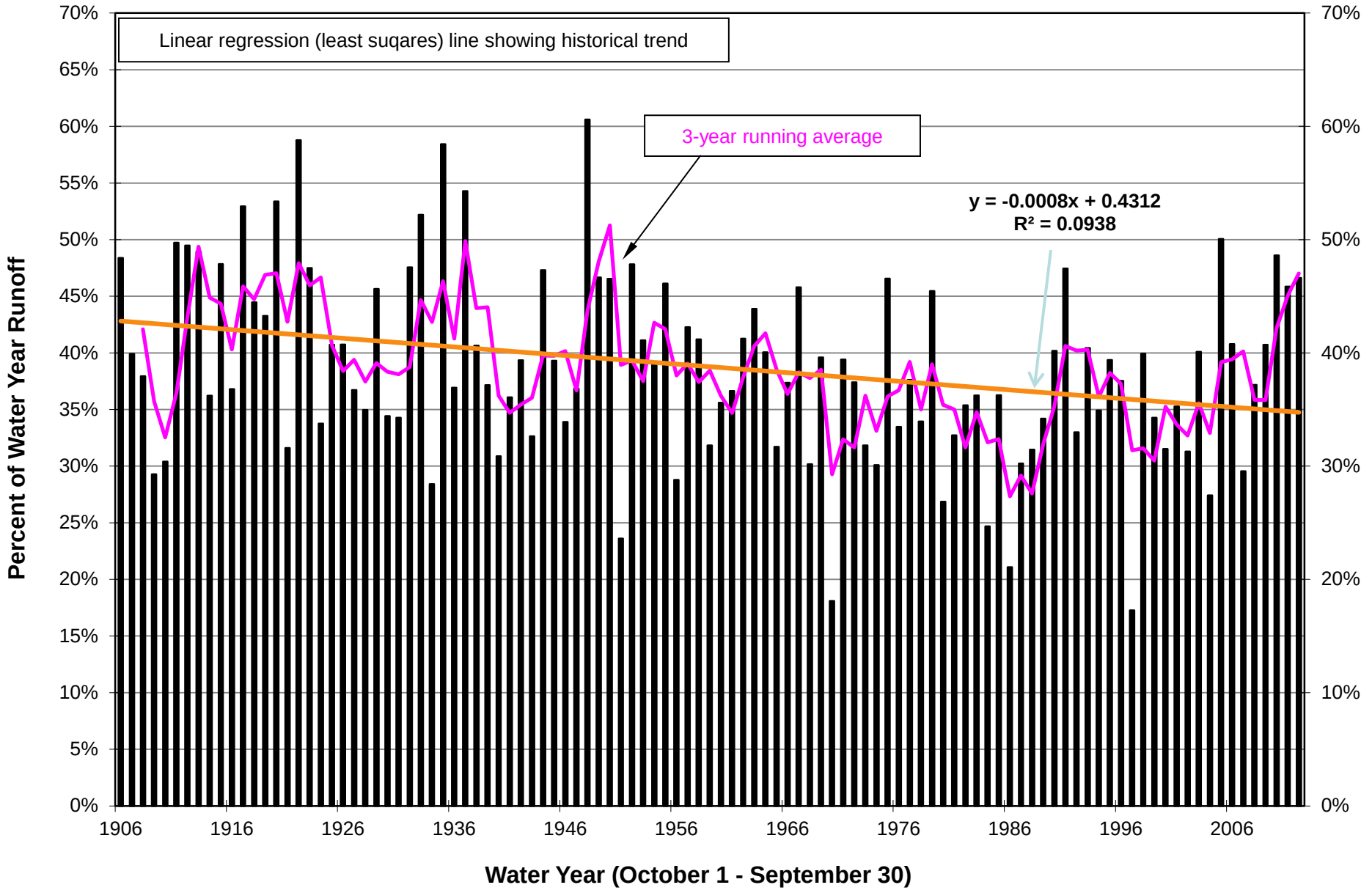

Water Supply and Demand Pattern
Northern California
Water Use
Natural Runoff
Precipitation
20
15
10
5
0
Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sept

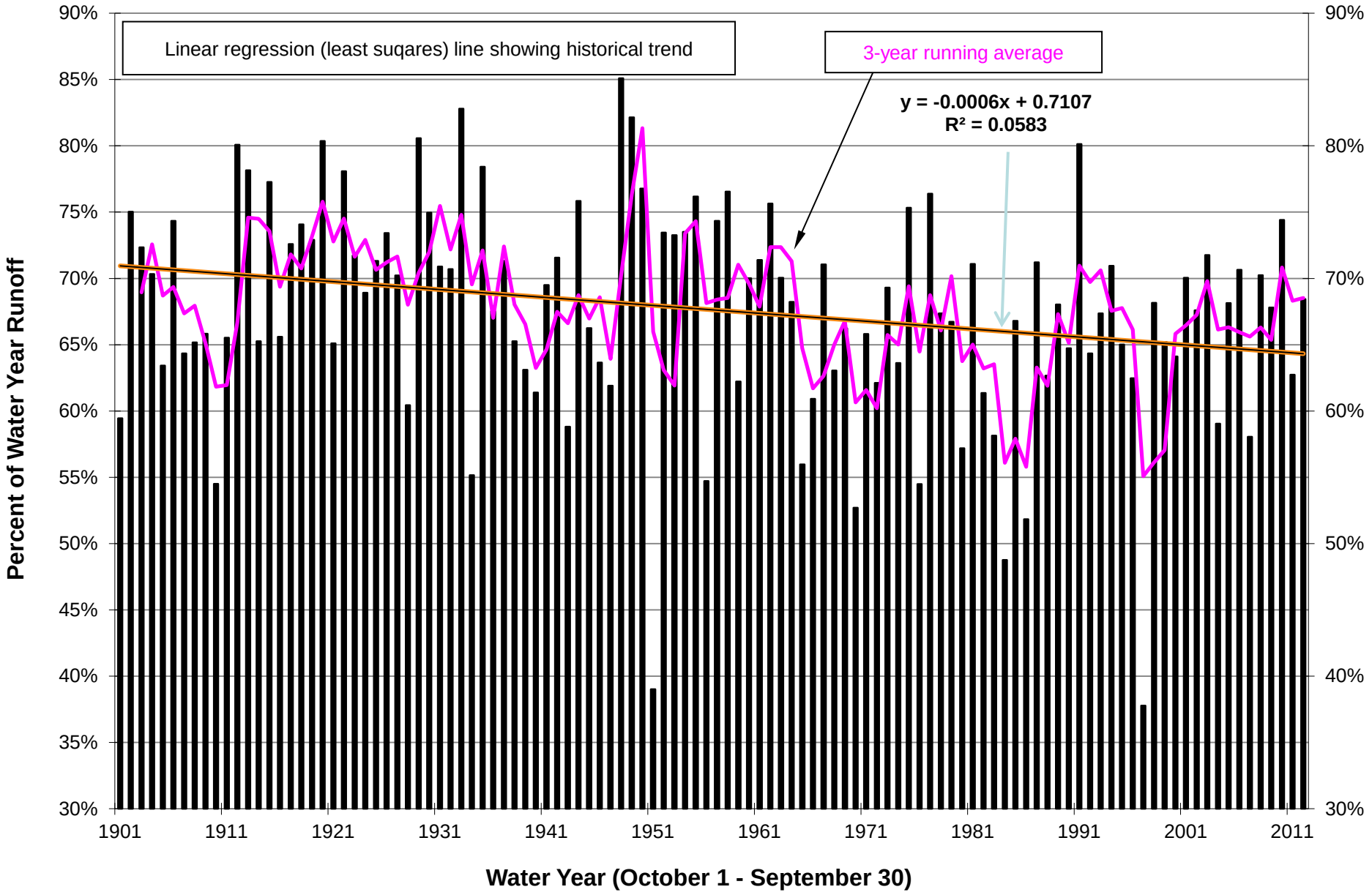
San Joaquin Region 4-River Runoff

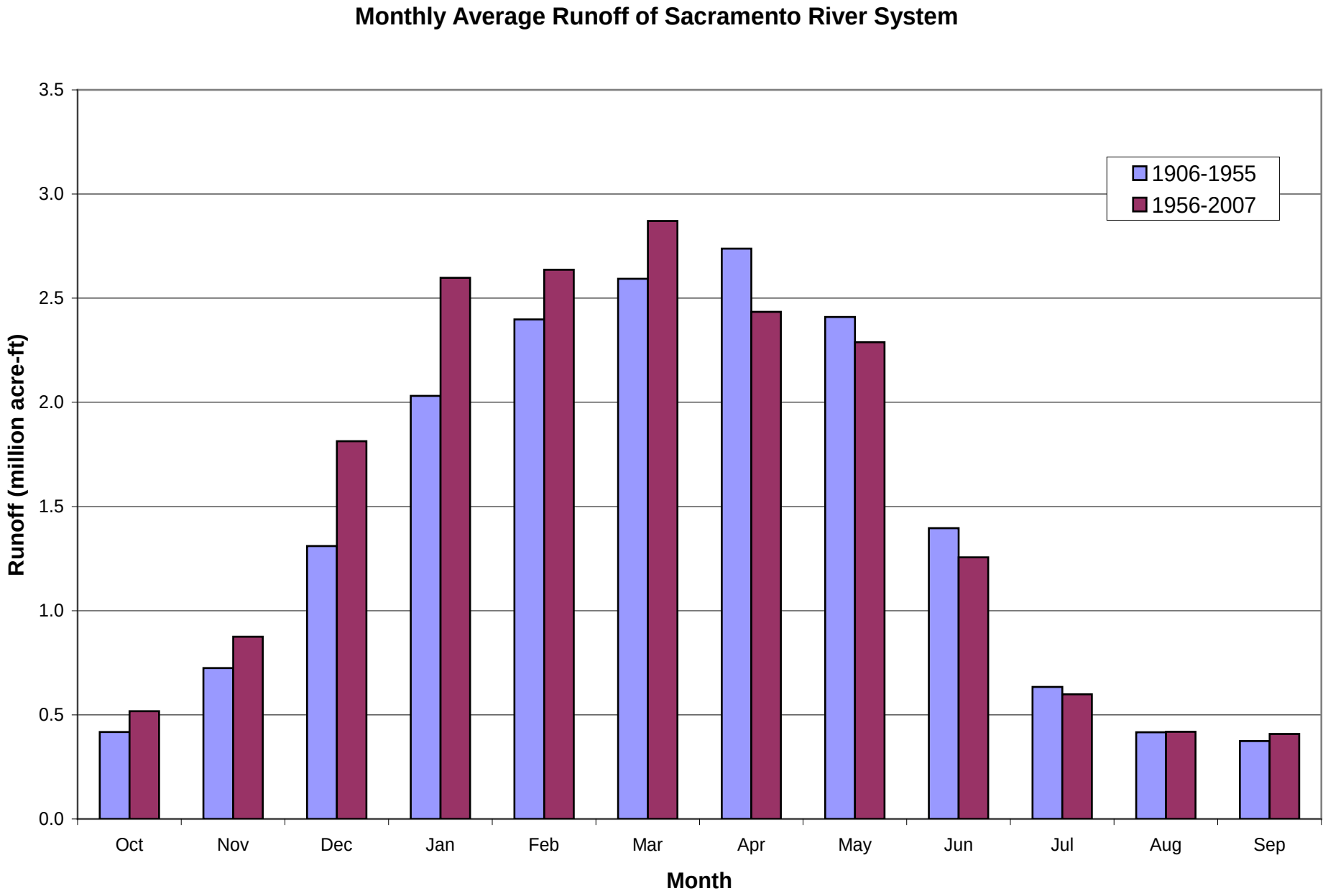


Mokelumne River




Sacramento River (SBB+FTO+YRS+AMF Combined)
April - July Runoff in percent of Water Year Runoff
Linear regression (least suqares) line showing historical trend
3-year running average
y = -0.0008x + 0.4312
R² = 0.0938
Percent of Water Year Runoff
Water Year (October 1 - September 30)
70%
65%
60%
55%
50%
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
1906
1916
1926
1936
1946
1956
1966
1976
1986
1996
2006

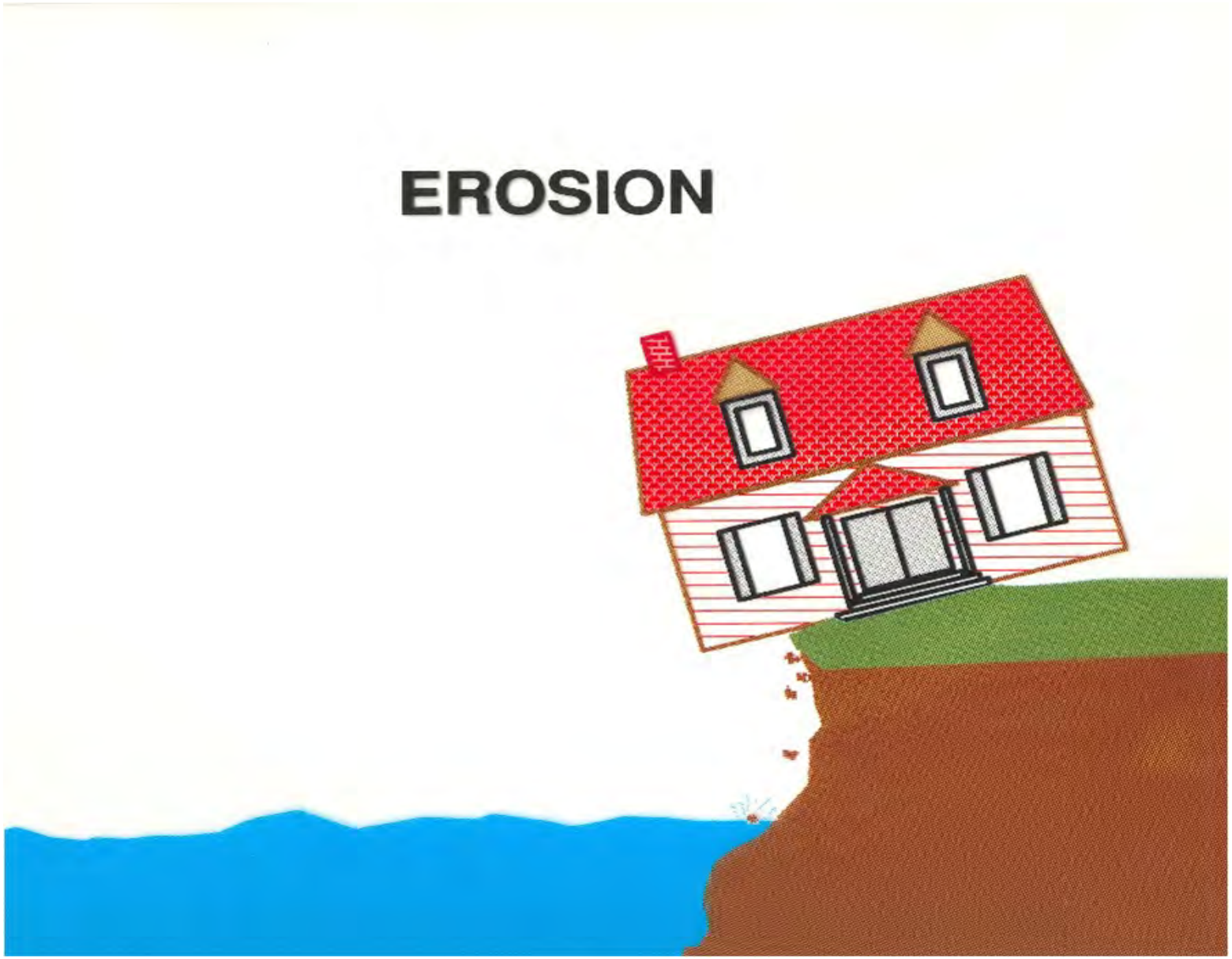

San Joaquin River (SNS, TLG, MRC, and SJF Combined)
April - July Runoff in percent of Water Year Runoff
Linear regression (least suqares) line showing historical trend
3-year running average
y = -0.0006x + 0.7107
R² = 0.0583
Percent of Water Year Runoff
90%
85%
80%
75%
70%
65%
60%
55%
50%
45%
40%
35%
30%
1901
1911
1921
1931
1941
1951
1961
1971
1981
1991
2001
2011
Water Year (October 1 - September 30)


Monthly Average Runoff of Sacramento River System
Runoff (million acre-ft)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
1906-1955
1956-2007
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month

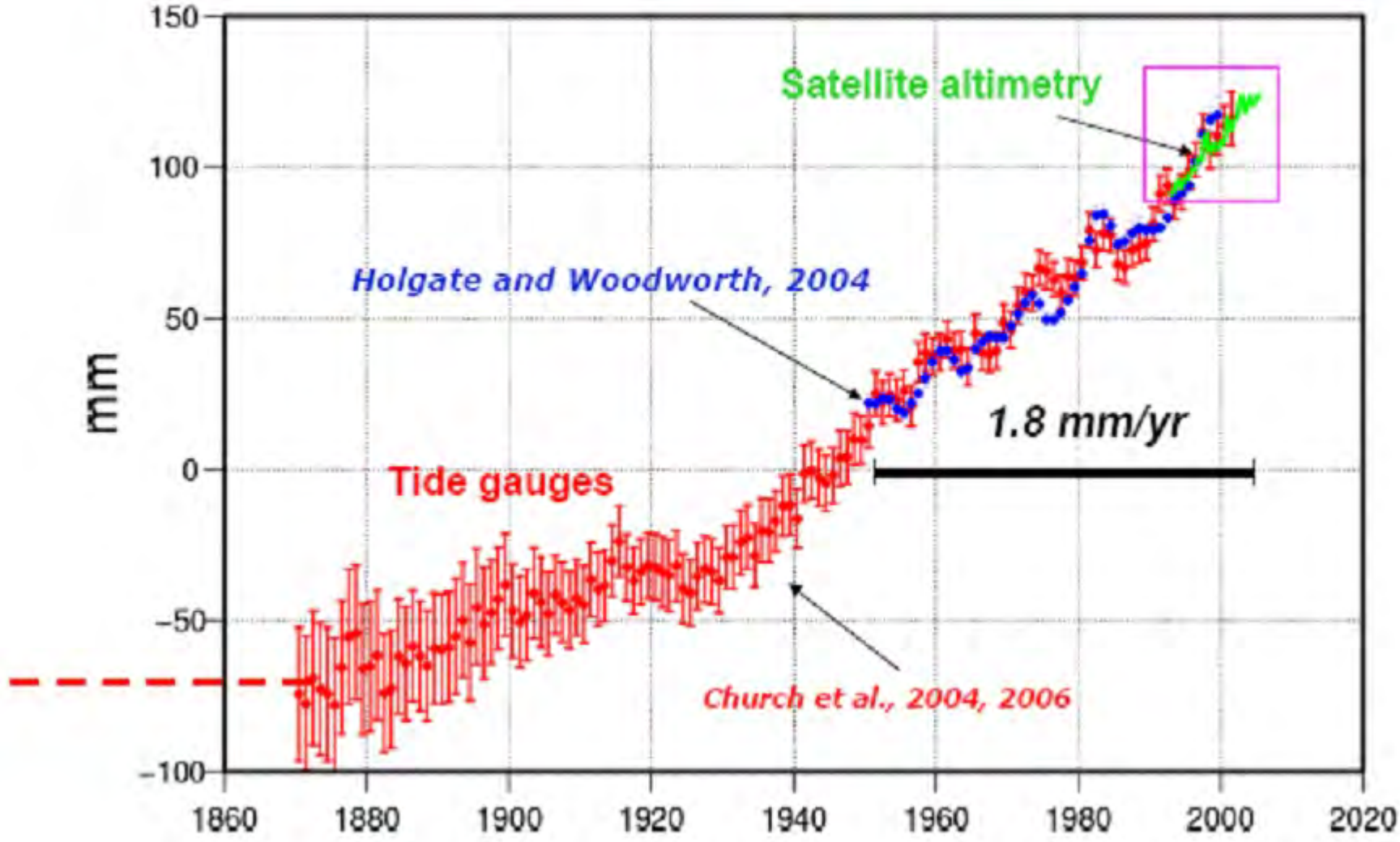
Reduced Snowpack -- Some Increase in Delta Salinity Intrusion

- Most likely to affect the near normal and above normal years, not the dry ones.
- Smaller snowpacks mean less surplus snowmelt runoff at reservoirs and in the Delta in spring.
- Earlier advance of ocean salts into the estuary.
- Longer effective dry season for the Delta will require more freshwater releases to repel ocean salinity and maintain suitable water quality with some additional loss in average export yield.

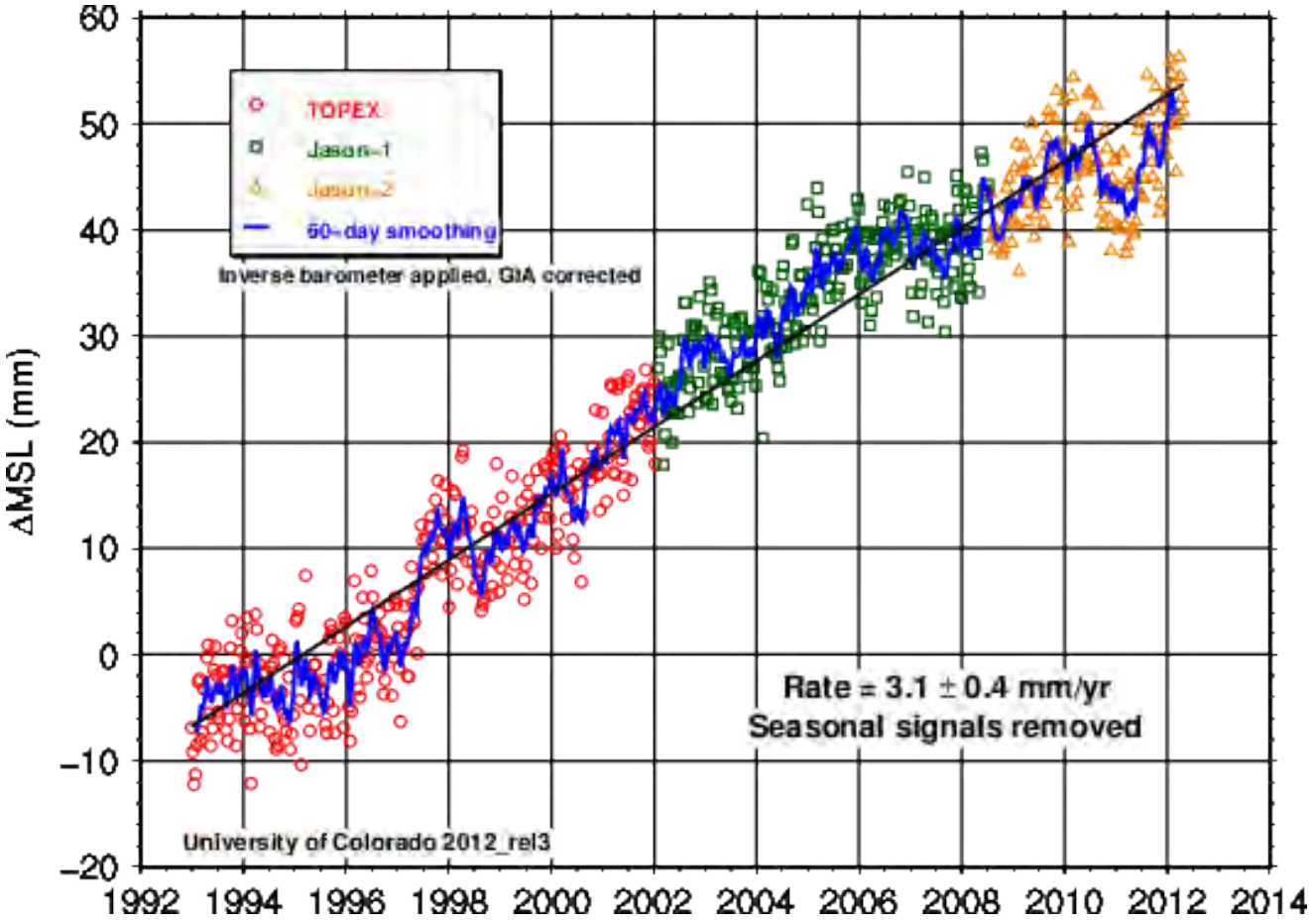
More Coastal Erosion



Global mean sea level rise during the 20th centurry



Global Mean Sea Level From Satellites



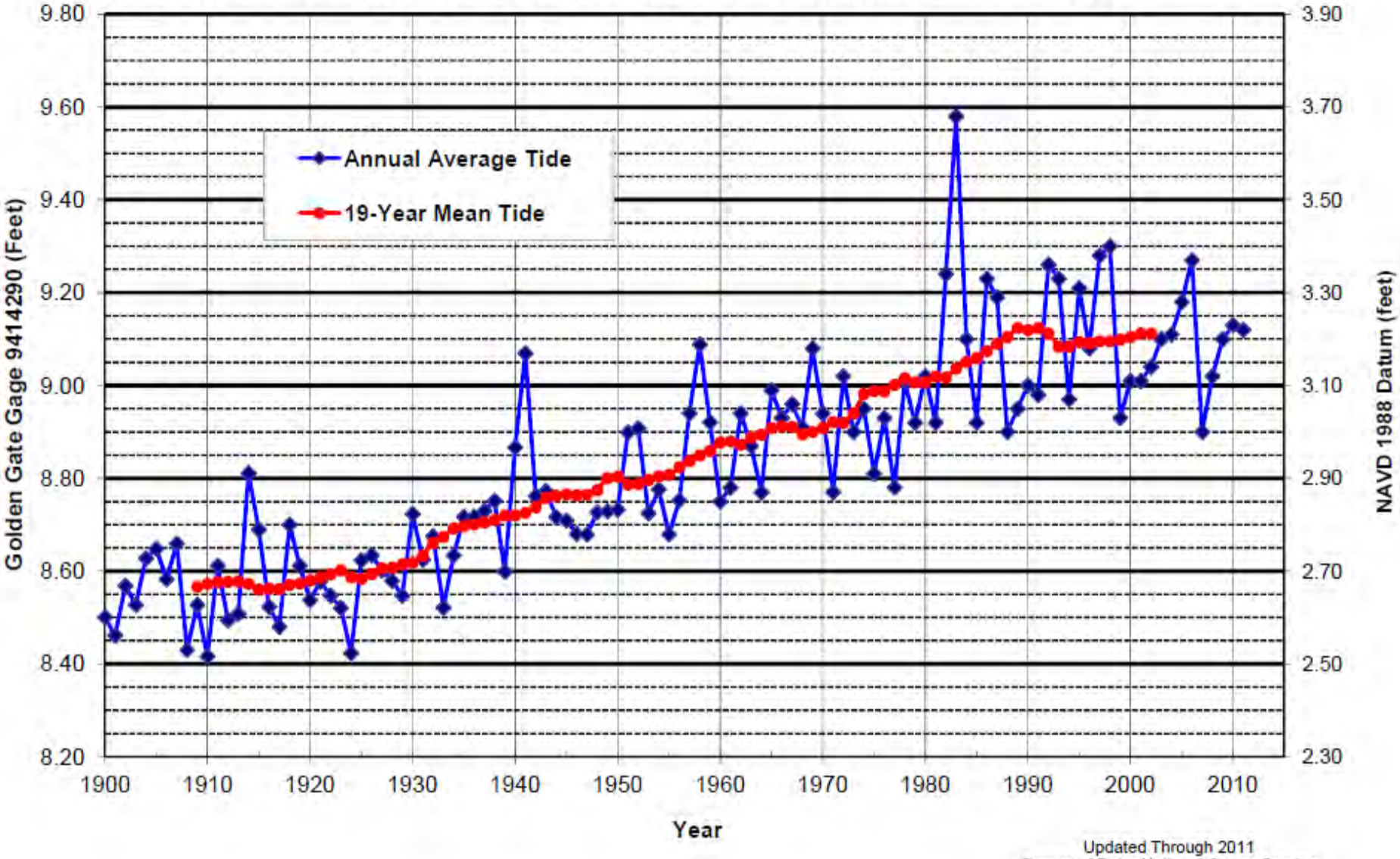
Components of Sea Level Rise, 1993-2003

- Thermal expansion 1.6 mm/yr
- Glaciers and icecaps 0.8 “
- Greenland ice sheet 0.2 “
- Antarctic ice sheet 0.2 “
  - Total 2.8 “

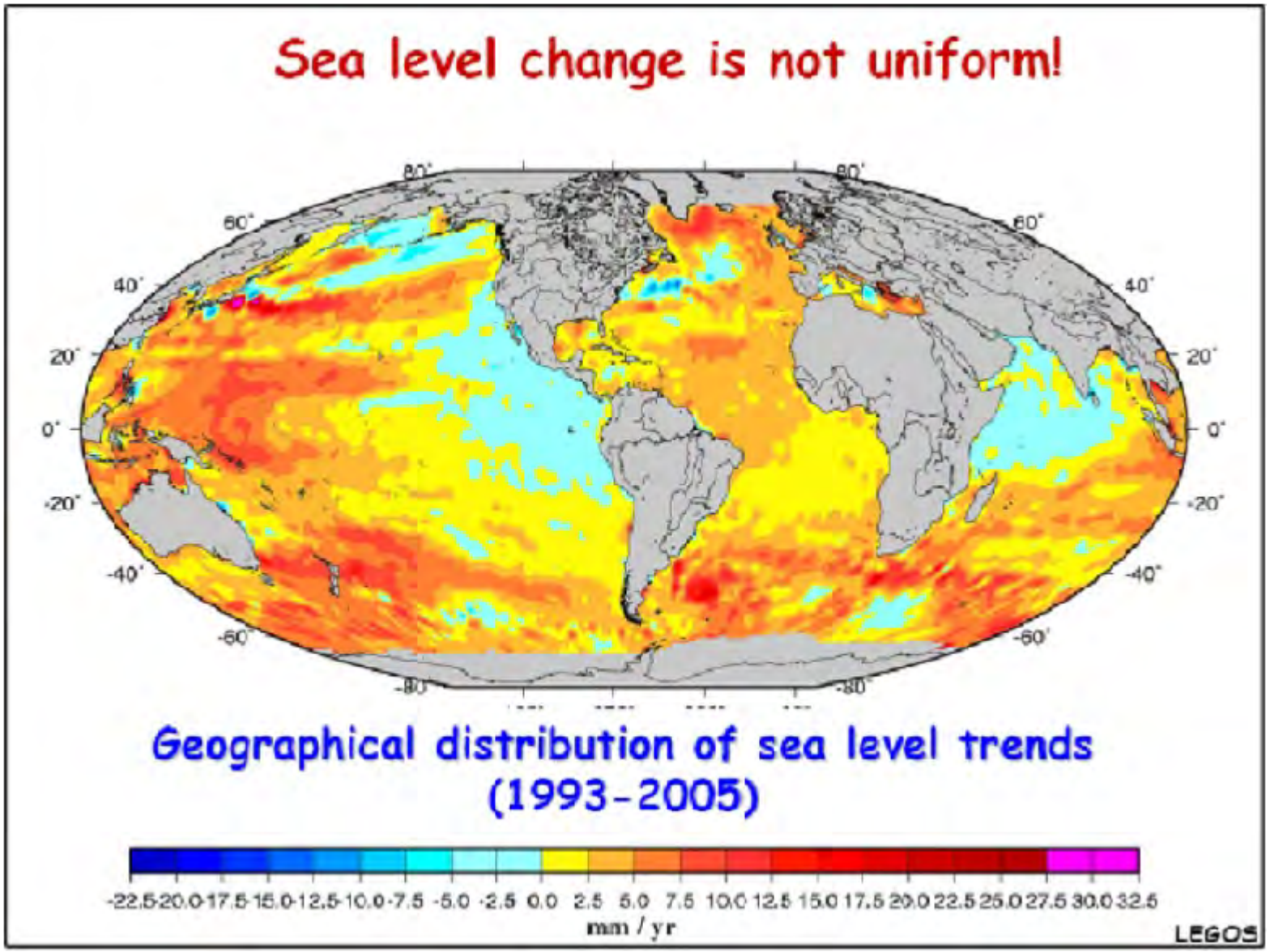
  - Observed 3.1 + or - 0.7

Source: IPCC 2007

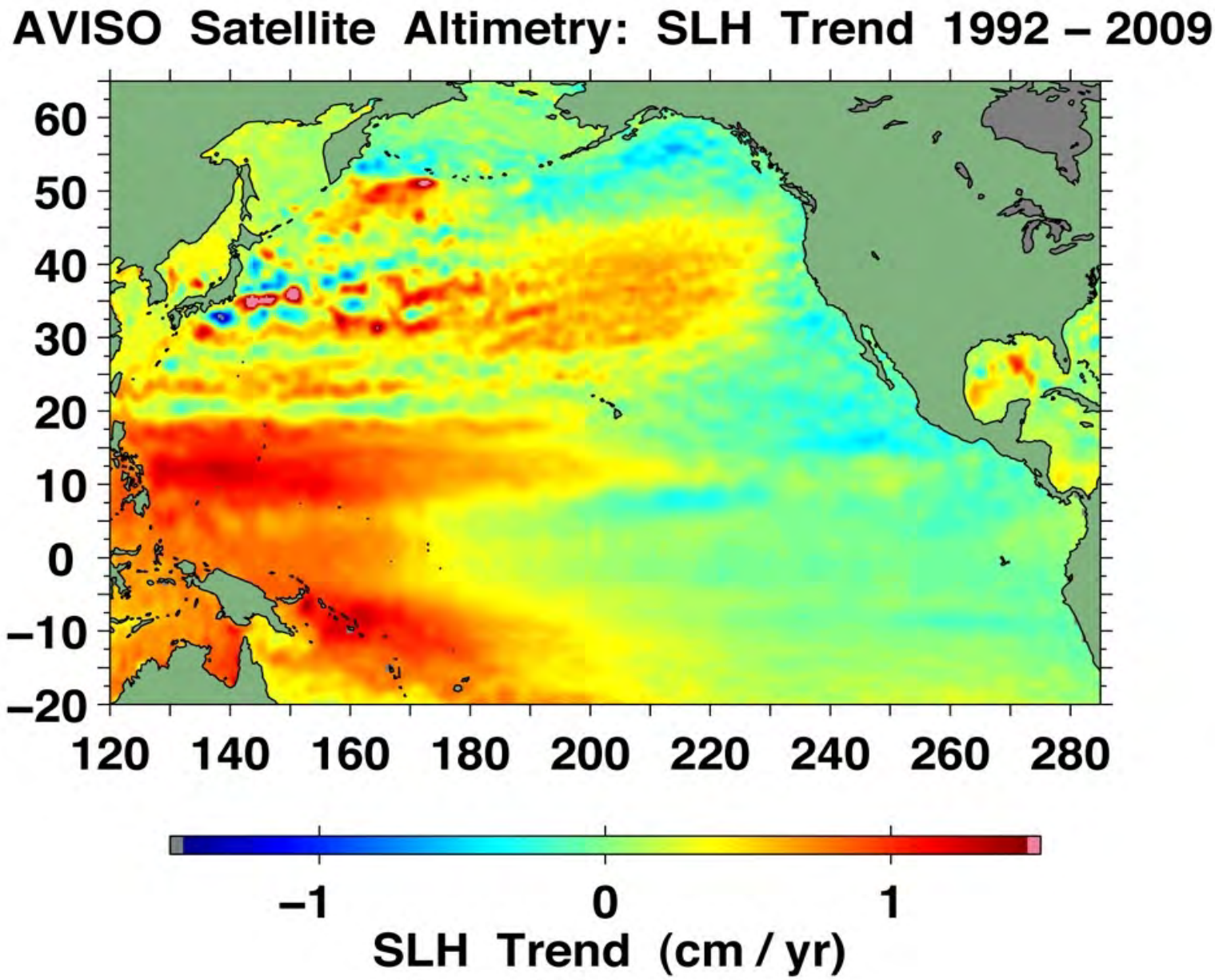
Golden Gate Annual Average and 19-Year Mean Tide Levels



Updated Through 2011
Source of Data: National Ocean Service



From A. Casenave



Bromirski, Miller, Flick and Auad

Sea Level Rise

- IPCC 2007 range from 0.2 to 0.6 m (with an added 0.1 to 0.2 m if Greenland ice melt increases beyond the 1993-2003 rate)
- Historic at GG = 0.2 m per century
- Major water project impacts in Delta:
  - **Increase in salinity intrusion due to higher ocean levels (deeper channels) and longer dry season (less snowmelt runoff). Can be combatted by more outflow.**
  - **More pressure on weak Delta levees with greater risk of inundation in winter floods; higher risk of summer breaks with possible interference with export water transfer.**

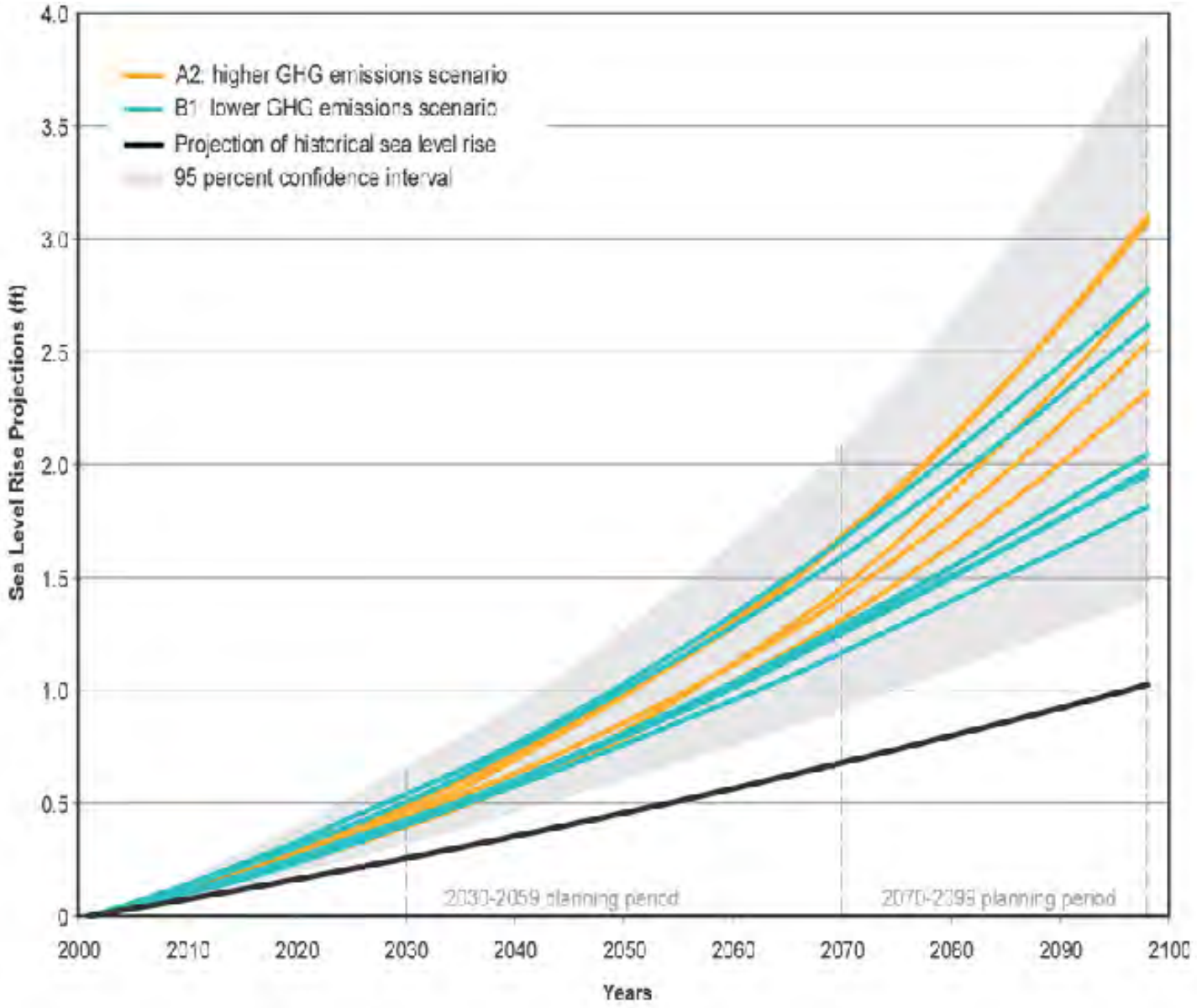
Sea Level Planning Studies Spring 2009

- DWR Staff Recommends a 2050 range of 0.4 to 1.2 feet

- Delta Vision suggests for Delta Planning
  Use 1.3 feet for 2050 and 4.6 feet for 2100

Comment: recent rate of Greenland net ice melt at 200 cubic kilometers is about 0.6 mm/year or a rate of 0.06 m/century (0.2 feet/century).
Sea level will probably continue to rise after 2100.

DWR 2009 PROJECTIONS

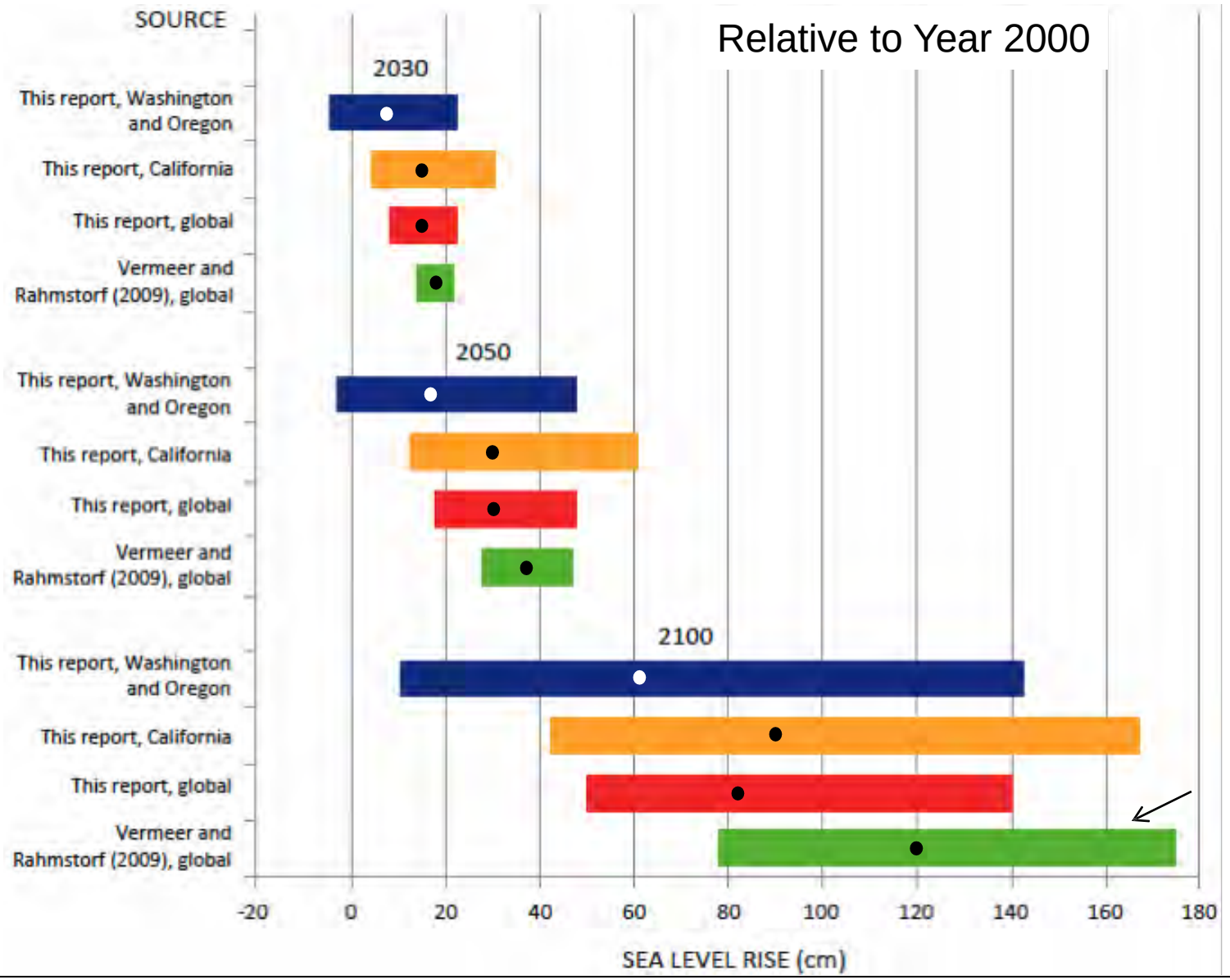


New NRC Sea Level Rise Panel

- 13 experts to provide guidance on long-range rise estimates for planning for 2030, 2050 and 2100
- Evaluate global and local factors
- For CA, OR & WA
- Report done in summer 2012
- Rise projections more than IPCC (2007) but less than Vermeer & Ramsdorf (2009)

Rising seas increase coastal erosion, shoreline retreat, and wetland loss; increases the risk of coastal flooding, and increases coastal damage from storms

NRC PANEL IN 2012



Sea Level Projections and Ranges (cm) for West Coast Cities

City	2030	2050	2100
Seattle	7 (-4 to 23)	17 (-3 to 48)	62 (10 to 143)
Newport	7 (-4 to 23)	17 (-2 to 48)	63 (12 to 142)
San Francisco	14 (4 to 30)	28 (12 to 61)	92 (42 to 166)
Los Angeles	15 (5 to 30)	28 (13 to 61)	93 (44 to 167)

Large north-south difference reflects the change in tectonics
Slight gradient reflects the sea-level fingerprint, which lowers projections, in decreasing amounts, from north to south

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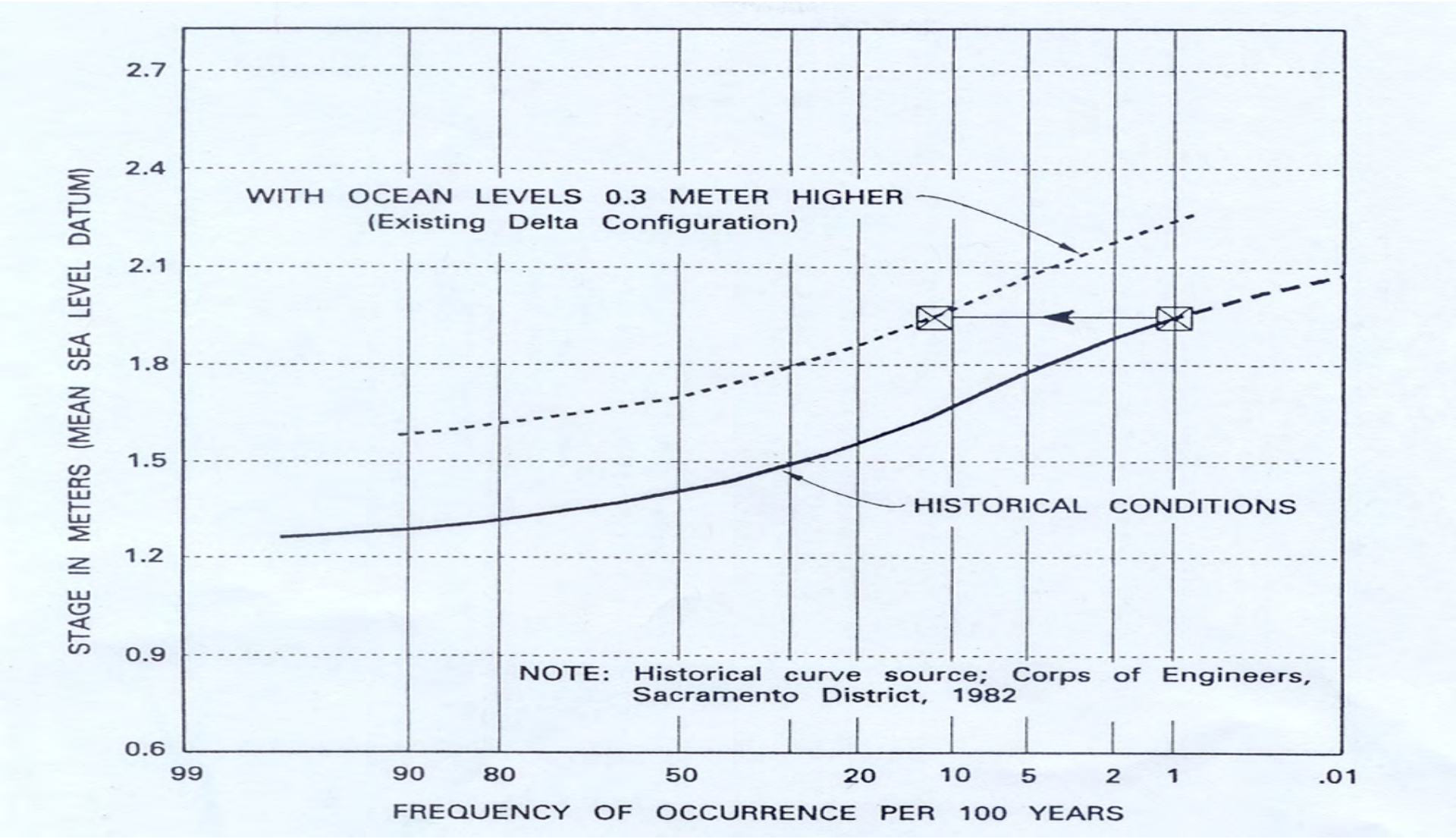
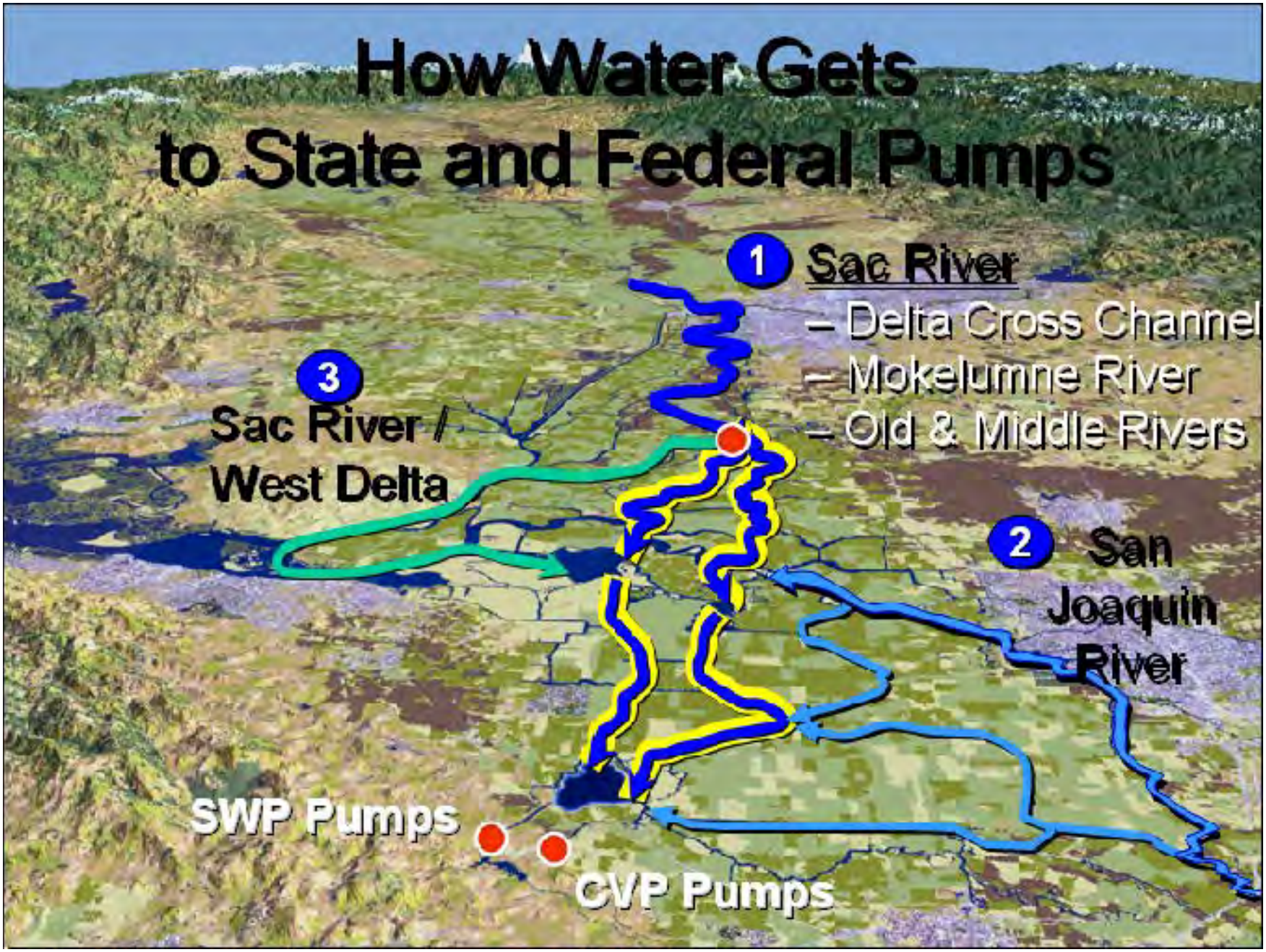
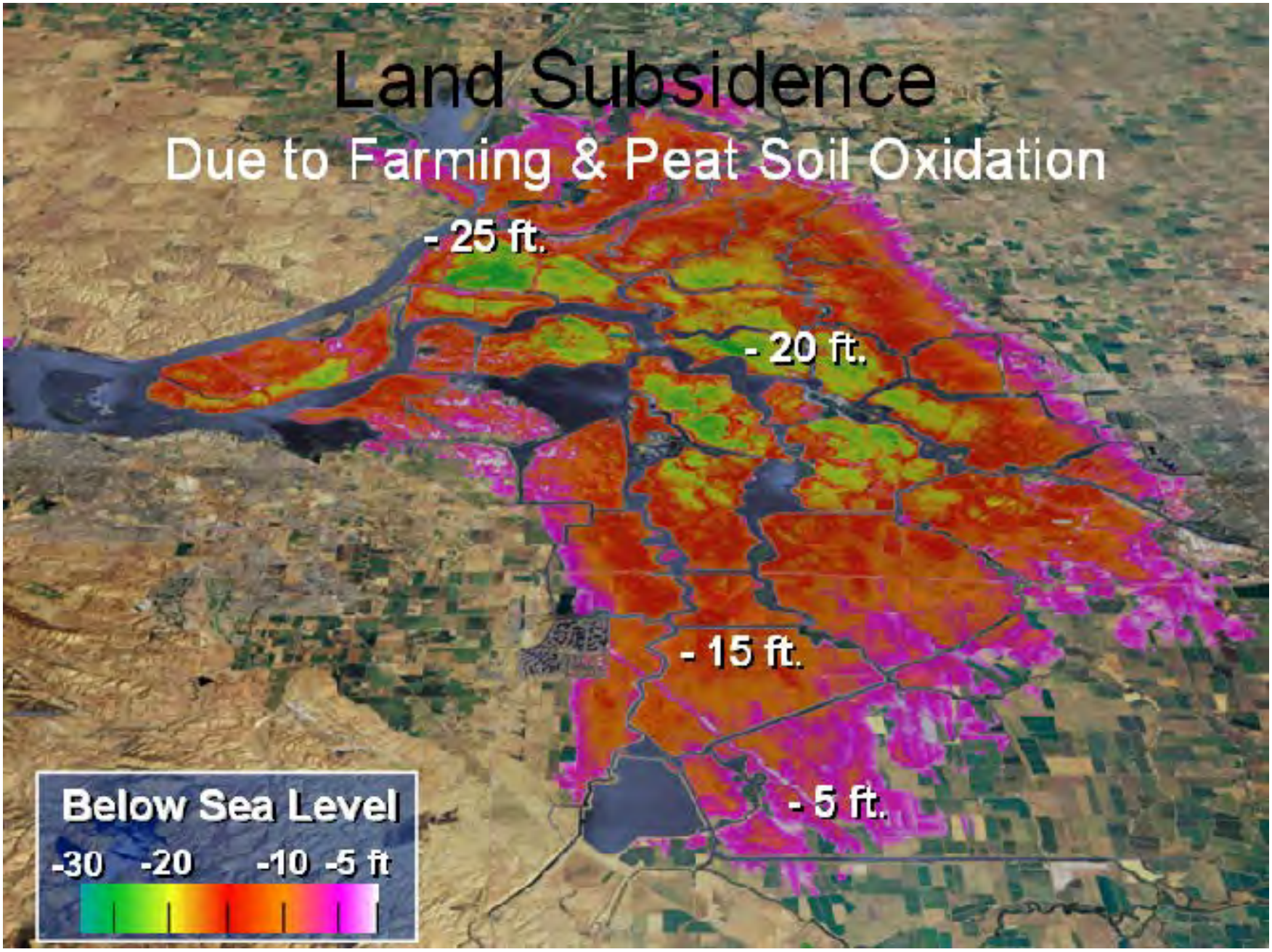
GG
T us
29

Antioch chart




How Water Gets
to State and Federal Pumps
1 Sac River
– Delta Cross Channel
– Mokelumne River
– Old & Middle Rivers
3
Sac River /
West Delta
2 San
Joaquin
River
SWP Pumps
CVP Pumps


Land Subsidence
Due to Farming & Peat Soil Oxidation
- 25 ft.
- 20 ft.
- 15 ft.
- 5 ft.
Below Sea Level
-30 -20 -10 -5 ft

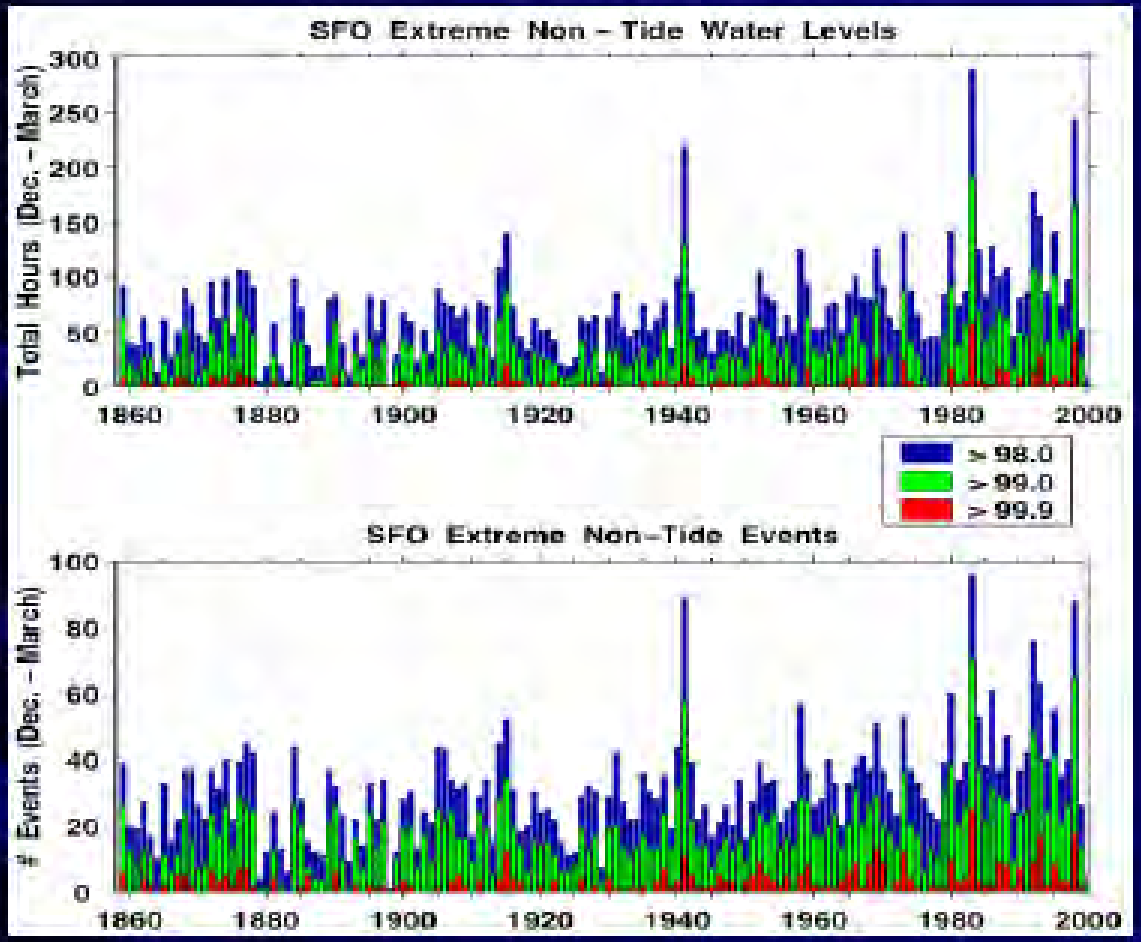
Possible Effect on CVP-SWP Water Exports

- From preliminary 2009 DWR studies for 2050 with twelve scenarios:
  - Average supply change: --7 to --10 percent
  - 6 year dry period change: --7 to –18 percent
  - BUT remember the base has a dry period shortage of around 40 percent already

In California, Mean Sea Level Isn't Everything

From R. Flick

Long-Term Increase in Extreme Sea Levels



Based on the entire SFO tide gauge record, 1858-2000

Underlying MSL trend causes increasing duration and frequency of extreme water level events

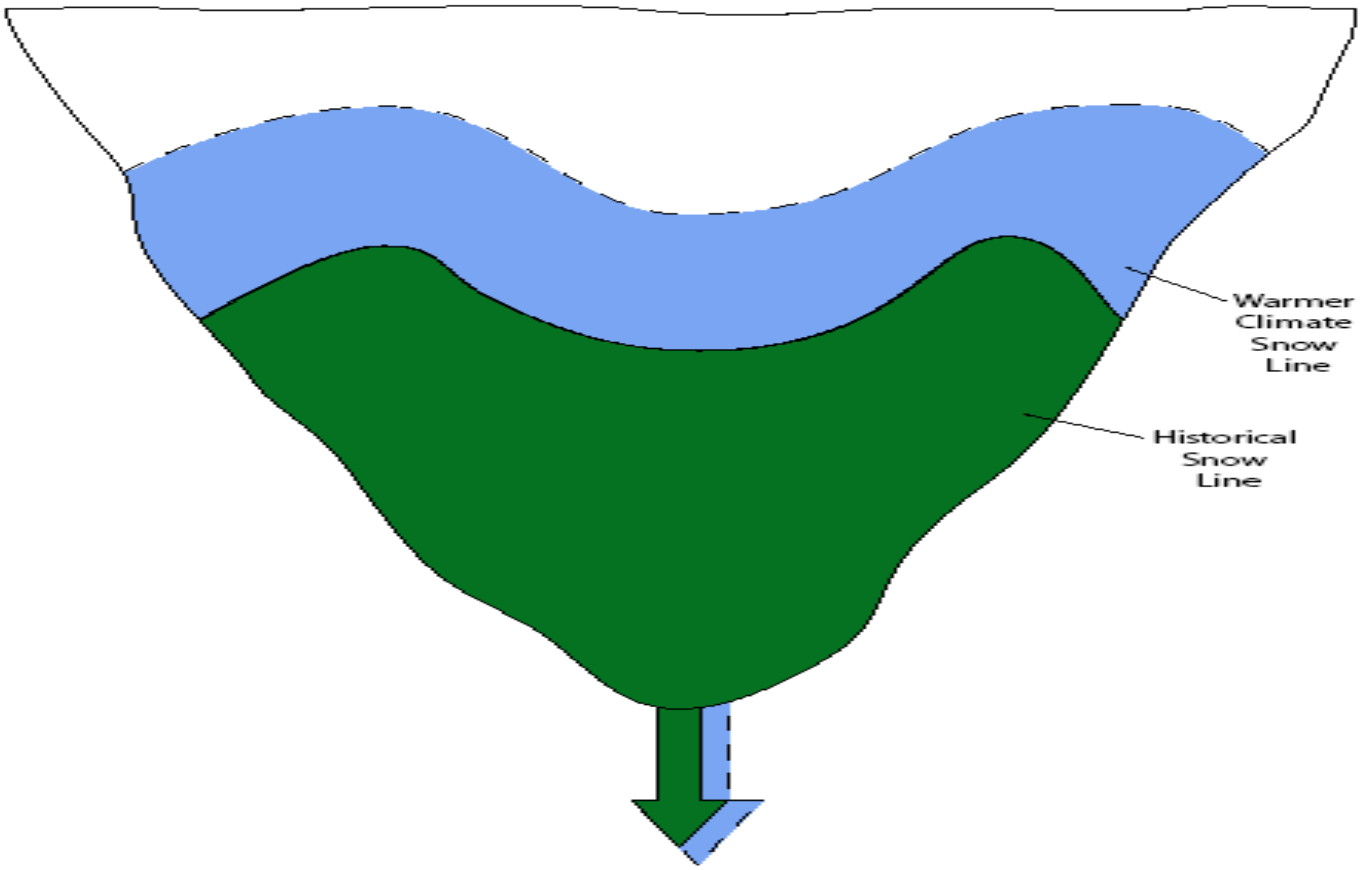
(Bromirski, Flick, and Cayan, 2003, "Storminess variability along the California coast 1858-2000," *Journal of Climate* 16(6))

Best Approach for the Delta

- Spend modest amounts, on the order of 40 million dollars annually, for the next 20 – 30 years to keep pace with the current slow rise in sea level, maintaining the same relative risk as present. Let our children decide what to do then with better information and projections.

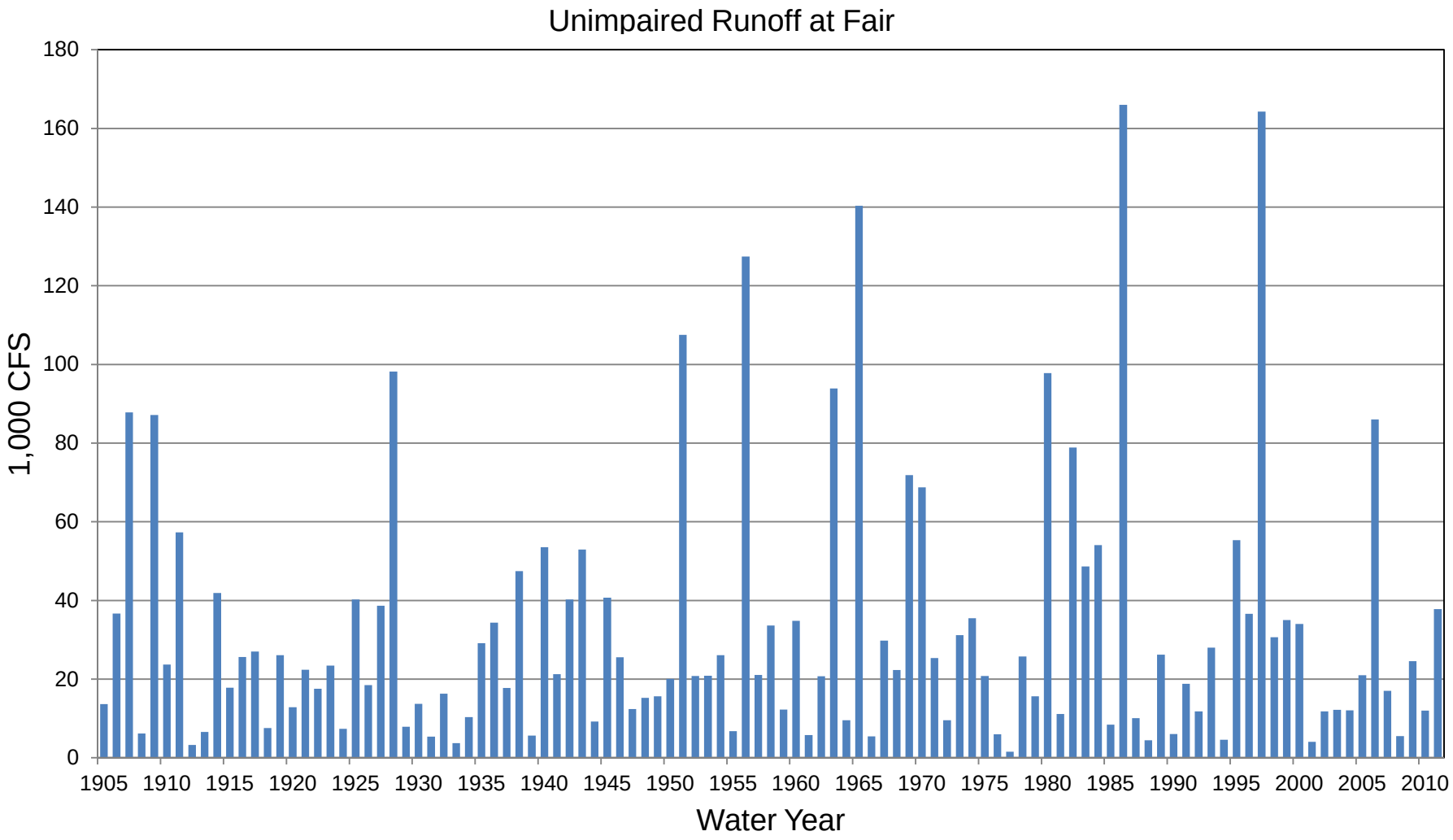
Possible Flood Increase

- For mountain basins, higher snow levels during storms means more rain runoff contributing area.
- Storm rainfall intensity tends to increase with warmer temperatures, other parameters being the same.
- Some indication for storm drainage design of increasing intensity of rainstorms.

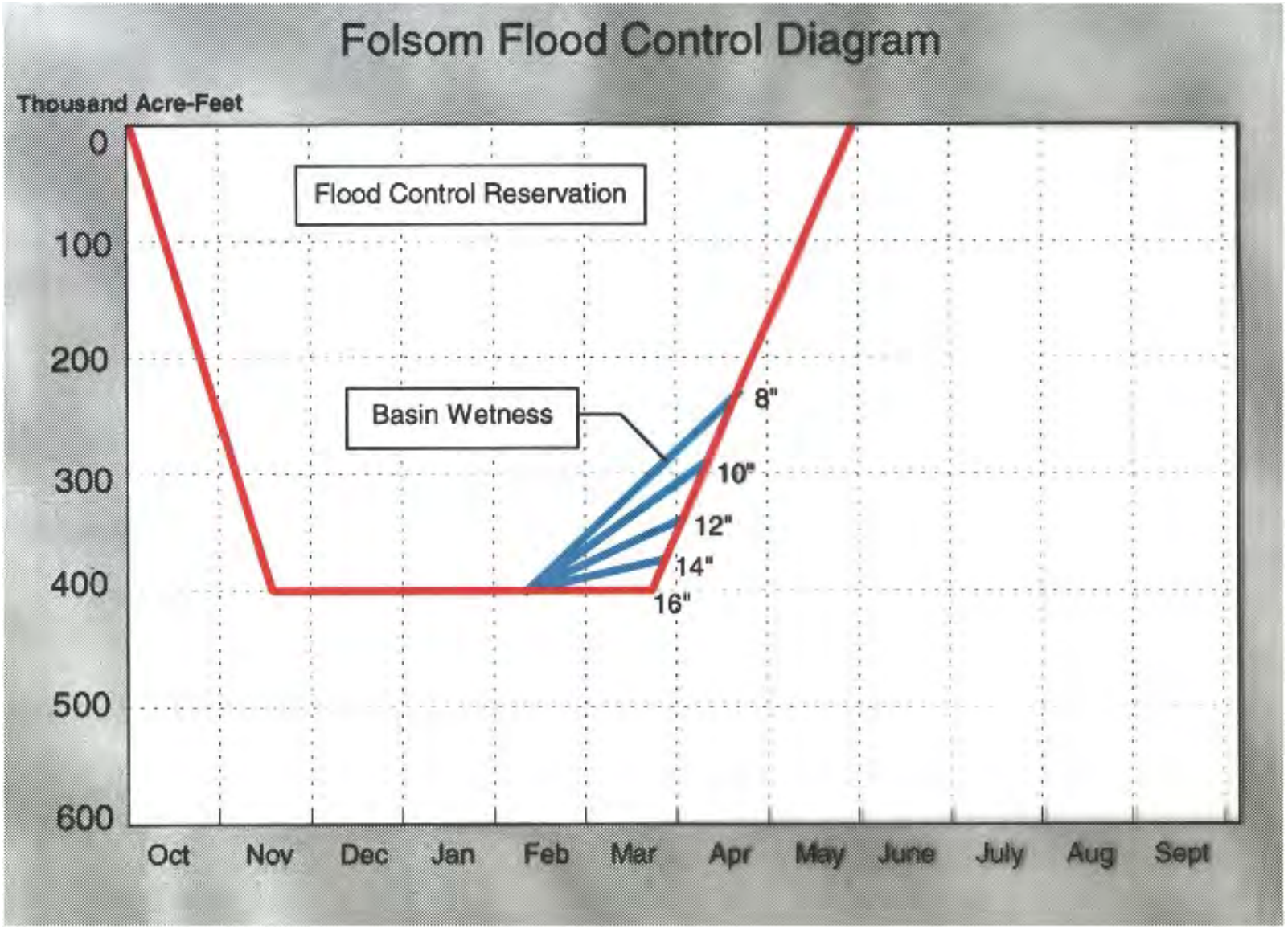


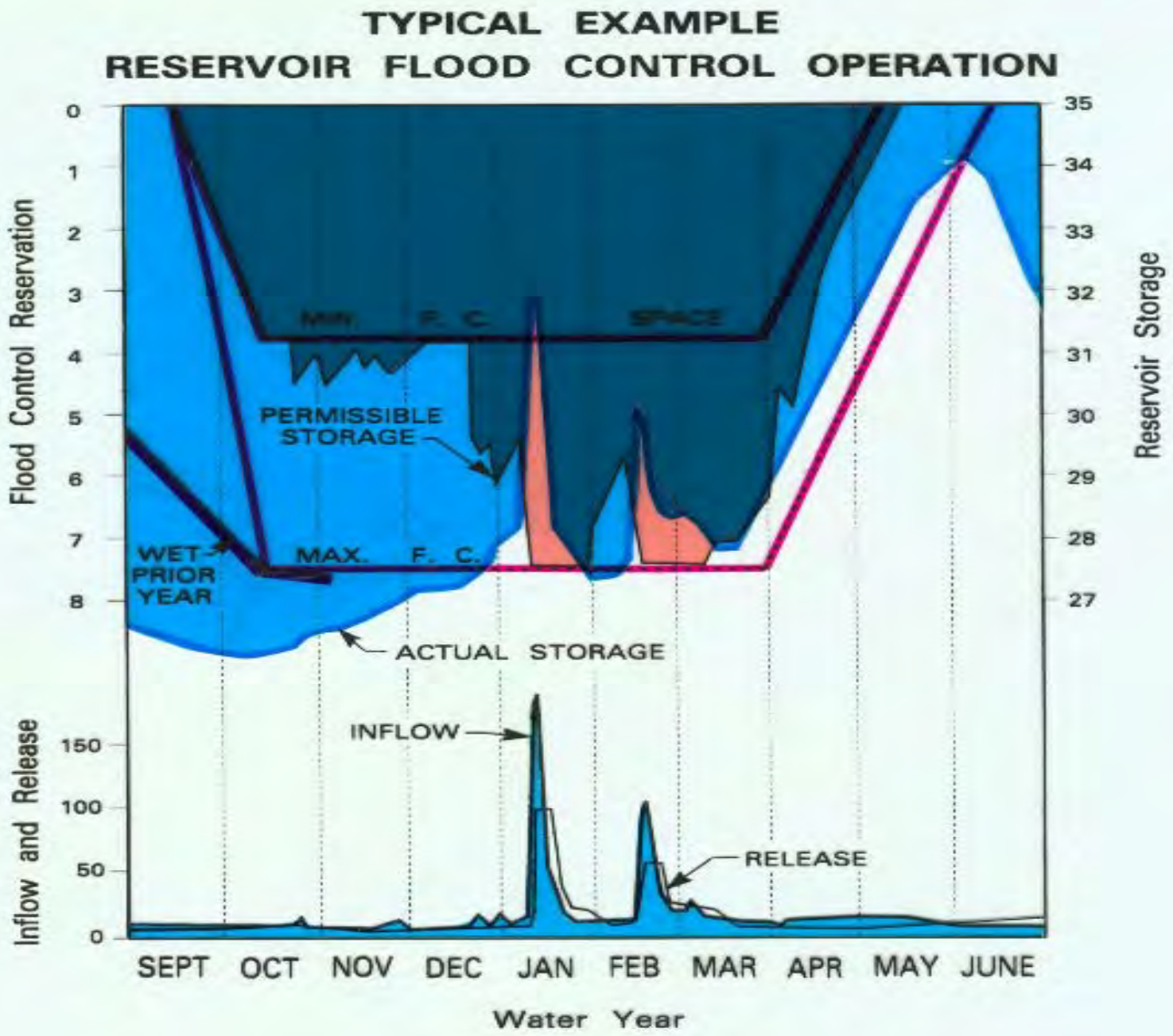
Effect of Warmer Climate on Winter Flood Producing Area

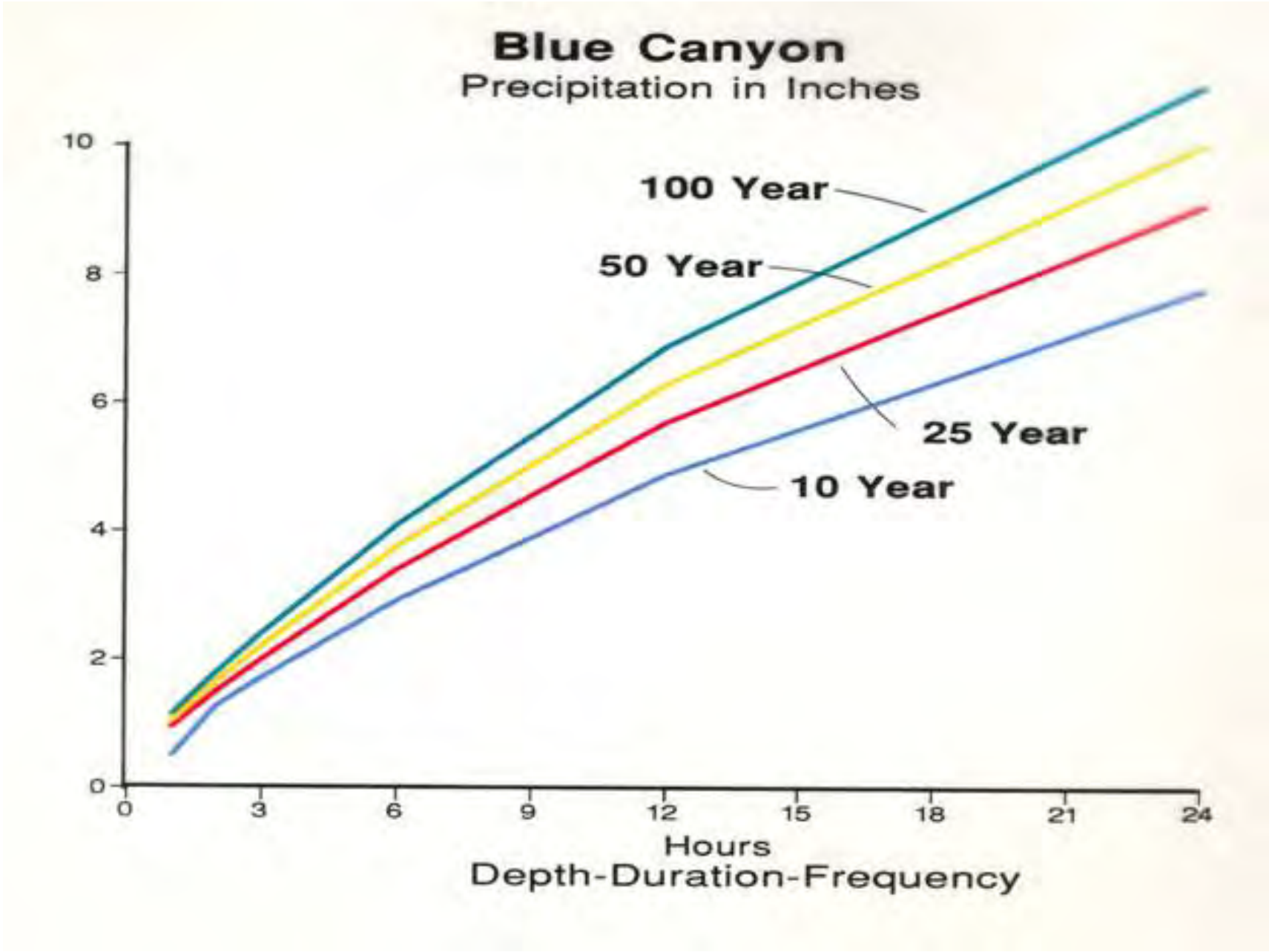
American River Runoff
Annual Maximum 3-Day Flow



Data from Corps of Engineers Sacramento District


Folsom Flood Control Diagram
Thousand Acre-Feet
0
100
200
300
400
500
600
Flood Control Reservation
Basin Wetness
8"
10"
12"
14"
16"
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
June
July
Aug
Sept

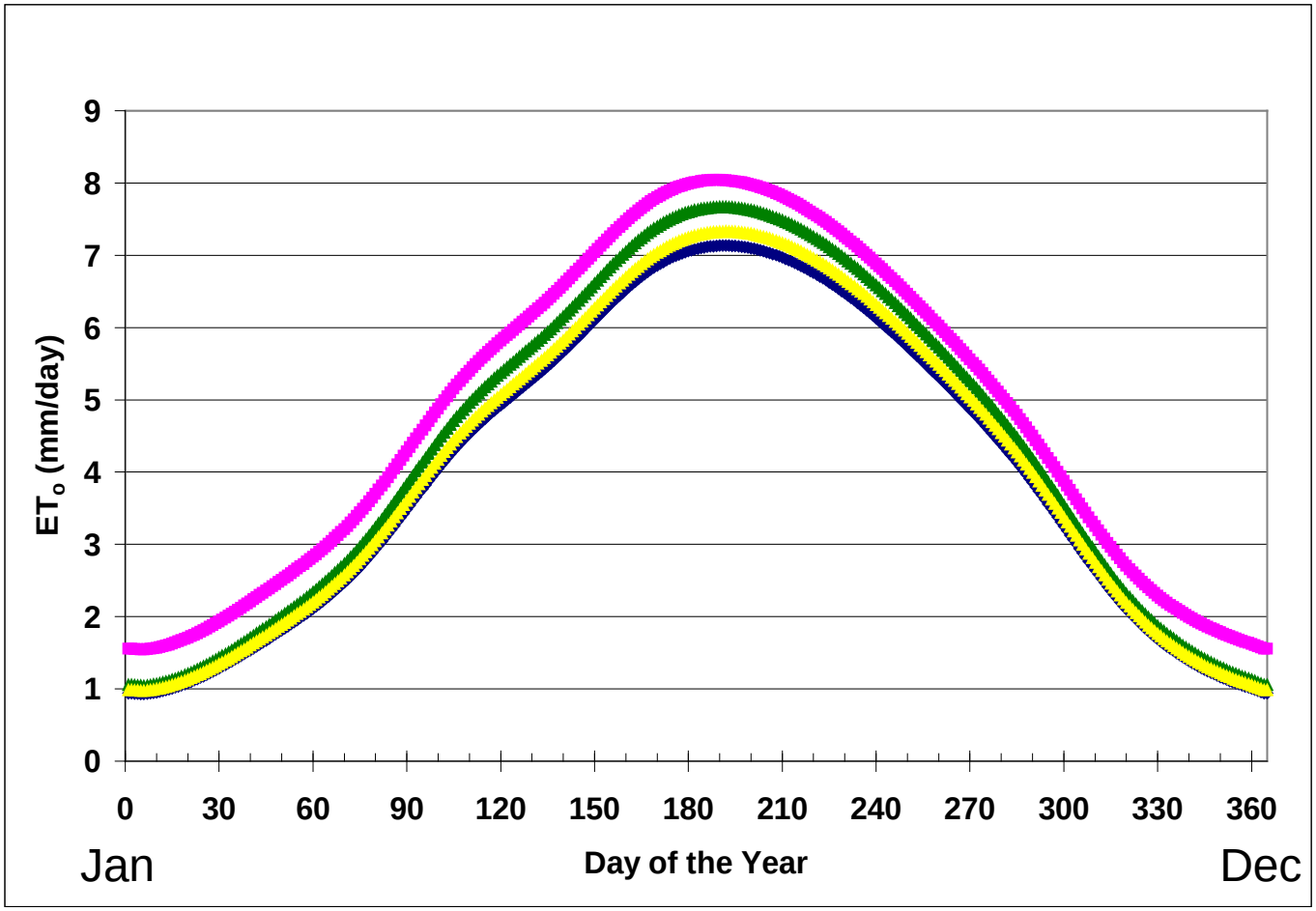

TYPICAL EXAMPLE
RESERVOIR FLOOD CONTROL OPERATION
Flood Control Reservation
0
1
2
3
4
5
6
7
8
35
34
33
32
31
30
29
28
27
Reservoir Storage
MIN. F. C. SPACE
PERMISSIBLE STORAGE
WET PRIOR YEAR
MAX. F. C.
ACTUAL STORAGE
INFLOW
RELEASE
Inflow and Release
150
100
50
0
SEPT OCT NOV DEC JAN FEB MAR APR MAY JUNE
Water Year


Blue Canyon
Precipitation in Inches
100 Year
50 Year
25 Year
10 Year
10
8
6
4
2
0
0
3
6
9
12
15
18
21
24
Hours
Depth-Duration-Frequency

Slightly Higher Water Use

- Farm and landscape water consumption goes up with temperature, around 10 percent for 3º C, other factors constant.
- Higher dewpoints reduce water use
- Higher carbon dioxide reduces water use slightly for most plants.
- With warming, planting dates for annual crops will probably change.

ET simulations slide



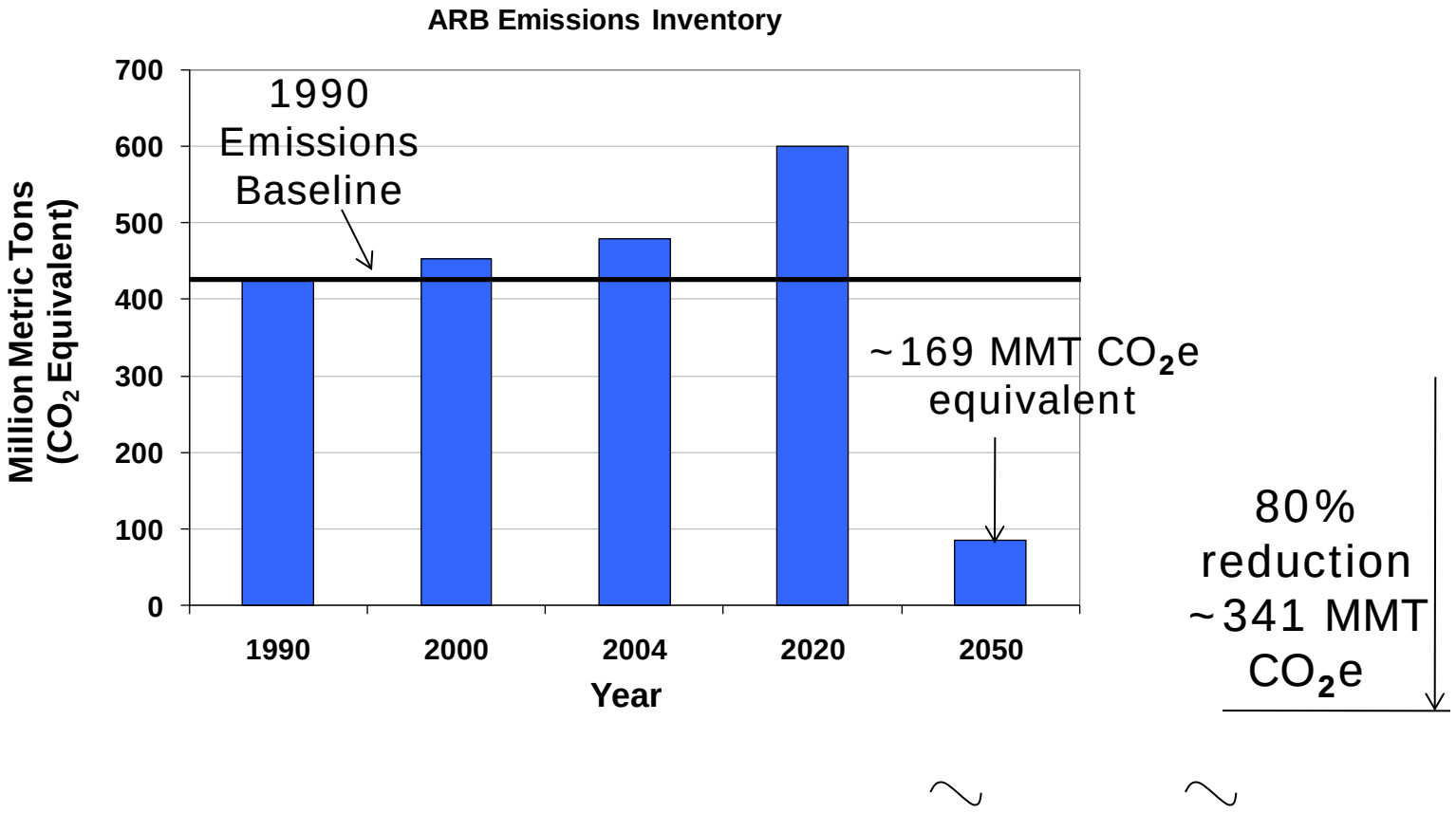
Warmer River Water Temperatures

- There are likely to be more problems for cold water fish like salmon, steelhead and trout from warmer temperatures.
- Warmer air temperatures mean warmer water temperatures.
- Reduced and earlier snowmelt means less cold water pools behind major foothill reservoirs.
- Delta smelt near top of their range now, which is 24 - 25º C, or 75 to 77º F.

Governor's Order and AB 32

- Reduce CA greenhouse gases in 2010 to year 2000 levels.
- Reduce 2020 greenhouse gases to 1990 levels, some 30 percent less than business as usual. (512 to 365 MMTCO2 Equivalent).
- By 2050 reduce GHG 80 % below 1990.
- Air Resources Board in charge of scoping.

MAGNITUDE OF THE CHALLENGE



Ararat Cloud Cap