

# Flooding

- Definition
- Recurrence Interval
  - The 100 year flood--What it means
- Sacramento flooding issues
- Flood control methods



# Flooding



- Occurs when water overtops a stream's banks and spills out onto the flood plain.





# Where Can We Get Annual Peak Discharge Data?

<http://waterdata.usgs.gov/ca/nwi>



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**National Water Information System: Web Interface**

[USGS Water Resources](#)

**Data Category:**  
Surface Water

**Geographic Area:**  
California

GO

News: [Recent changes](#)

## USGS Surface-Water Data for California

**Real-time Data (465 sites)**

Real-time data are time-series (recorded at fixed intervals) data from automated equipment and represent the most current hydrologic conditions. Measurements are commonly recorded at 5-60 minute intervals and transmitted to the NWIS database every 1-4 hours. Real-time data are available online for 31 days.

**Daily Data (2,432 sites)**

Daily values are summarized from time-series data for each day for the period of record and may represent the daily mean, median, maximum, minimum, and/or other derived value. Daily values include approved, quality-assured data that may be published, and more recent provisional

**Introduction**

The U.S. Geological Survey's (USGS) National Water Information System (NWIS) is a comprehensive and distributed application that supports the acquisition, processing, and long-term storage of water data. NWISWeb serves as the publicly available portal to a geographically seamless set of much of the water data maintained within NWIS ([additional background](#)).

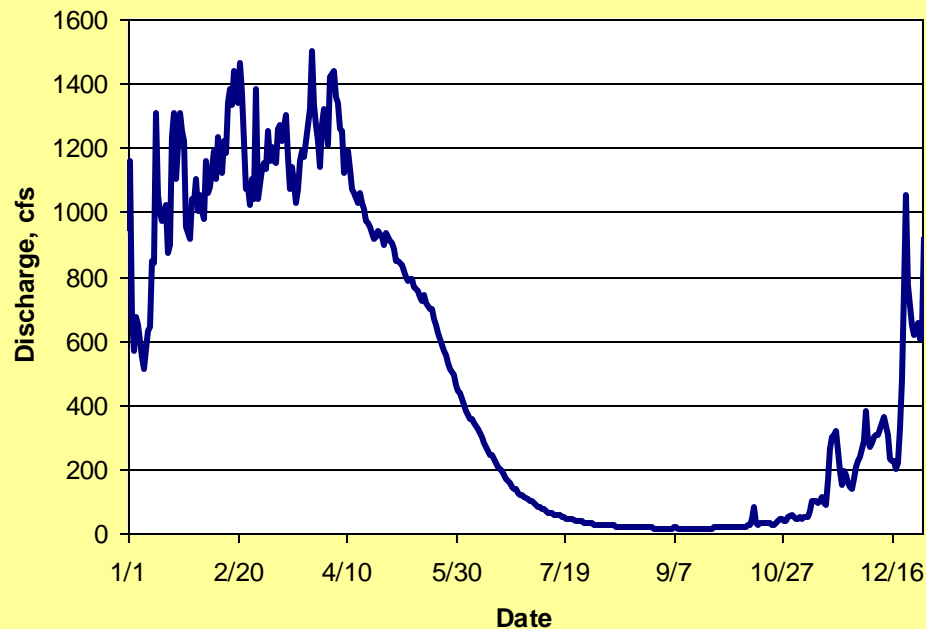
Nationally, USGS surface-water data includes more than 850,000 station years of time-series data that describe stream levels, streamflow (discharge), reservoir and lake levels, surface-water quality, and rainfall. The data are collected by automatic recorders and manual [field measurements](#) at installations across the Nation.

Data are collected by field personnel or relayed through telephones or satellites to offices where it is stored and processed. The data relayed through the Geostationary Operational Environmental Satellite (GOES) system are

Capture Selection

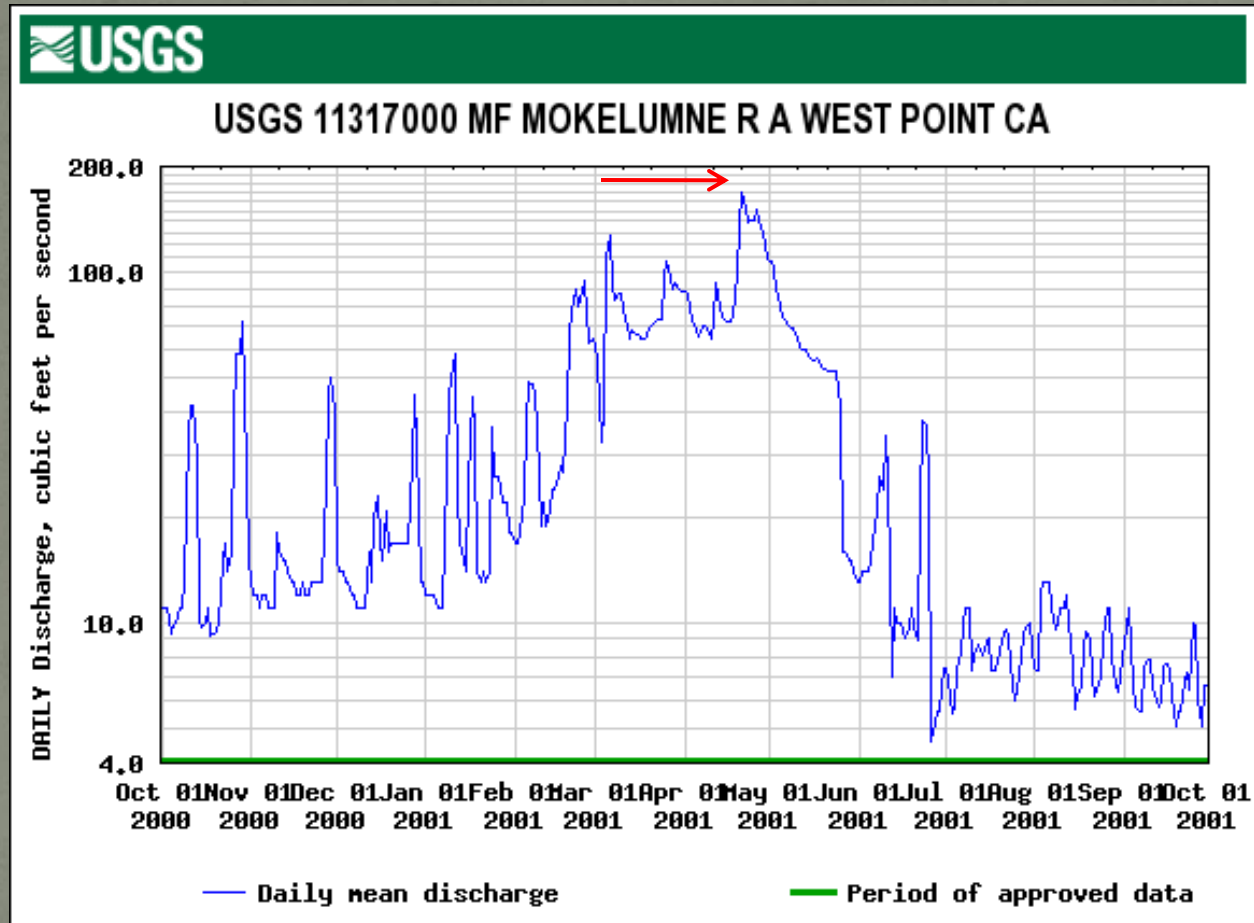
Annual Peak Discharge is the Maximum Instantaneous Stream Discharge During a Water Year (Oct 1 through Sept 30)

California Stream Hydrograph



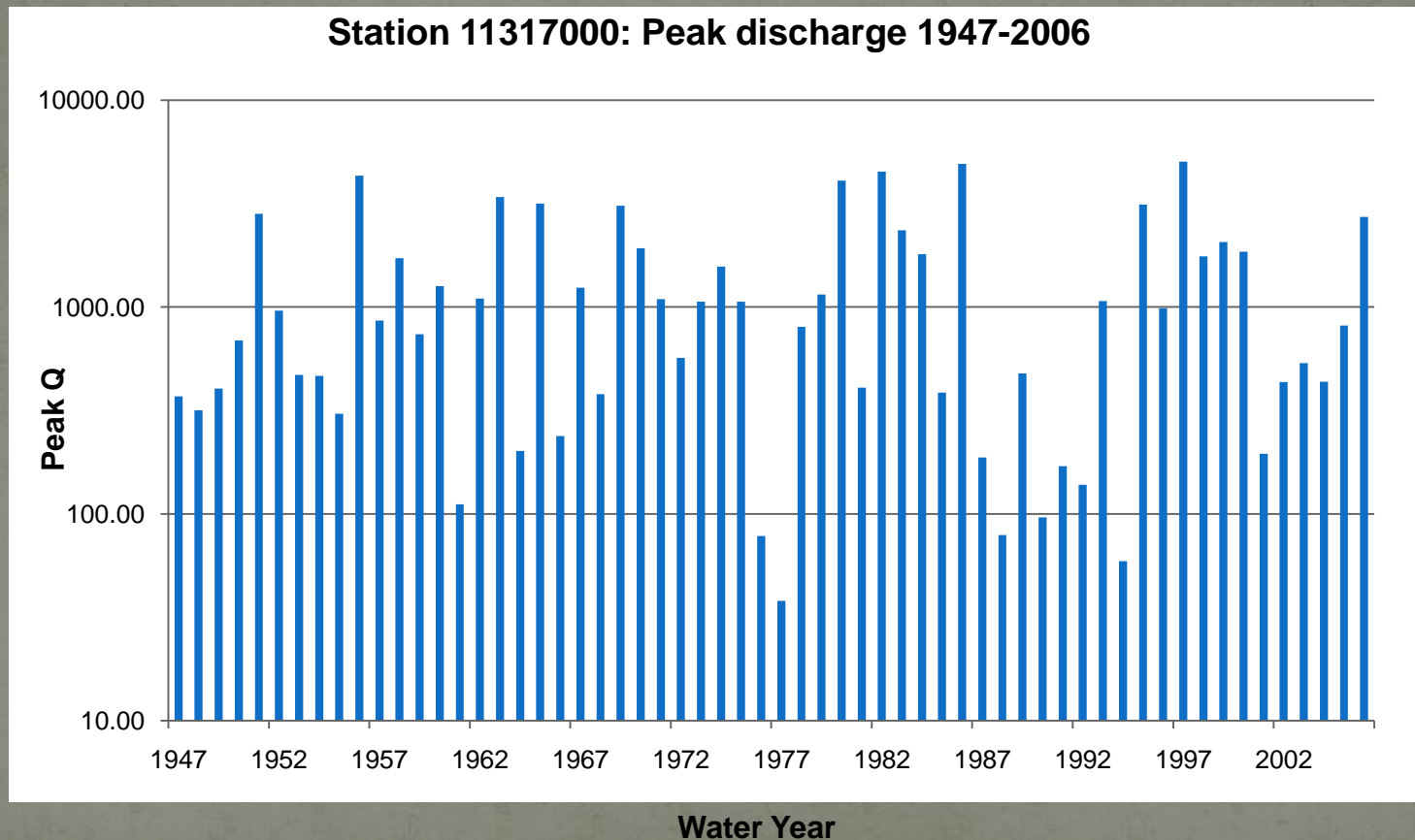
***Why Not January 1 through Dec 31?***

Annual Peak discharges: maximum momentary peak discharge (Q),  
in cubic feet/second (cfs), in each year of record



<http://waterdata.usgs.gov/nwis>

## Annual flood series: a list of annual floods





# Flood Frequency – Associating Stream Discharge with Probability of Exceedance



We need a measure of flooding for which we can associate a probability.

If we use the maximum instantaneous streamflow during an annual period, we can determine an annual exceedance probability.

# Flood Frequency – Associating Stream Discharge with Probability of Exceedance

If we have a record of 10 (or 50 or 100 or..) annual peak flows on a stream, can we use those 10 (or 50 or 100 or ..) recorded values to say something about how likely it will be next year (or any year) to have an annual peak bigger than the largest recorded value?





<b>Year</b>	<b>Discharge (cfs)</b>
<b>1998</b>	<b>9140</b>
<b>1999</b>	<b>8130</b>
<b>2000</b>	<b>10,100</b>
<b>2001</b>	<b>2240</b>
<b>2002</b>	<b>2740</b>
<b>2003</b>	<b>4460</b>
<b>2004</b>	<b>3250</b>
<b>2005</b>	<b>15,400</b>
<b>2006</b>	<b>27,200</b>

**USGS site:11413000**  
**N Yuba R BI Goodyears Bar, CA**

Year	Discharge (cfs)	Rank
2006	27,200	1
2005	15,400	2
2000	10,100	3
1998	9140	4
1999	8130	5
2003	4460	6
2004	3250	7
2002	2740	8
2001	2240	9

**Hydrologists list the discharges in descending order and rank them**

Discharge (cfs)	Rank	Probability of Exceedance
27,200	1	
15,400	2	
10,100	3	
9140	4	
8130	5	
4460	6	
3250	7	
2740	8	
2240	9	

**Next we need to find the probability that in any given year the instantaneous discharge will exceed the recorded discharge value**



Discharge (cfs)	Rank	Probability of Exceedance
27,200	1	1/9= 11%
15,400	2	2/9= 22%
10,100	3	3/9= 33%
9140	4	4/9= 44%
8130	5	5/9= 56%
4460	6	6/9= 67%
3250	7	7/9= 78%
2740	8	8/9= 89%
2240	9	9/9= 100%

**Are these probabilities realistic?**

Discharge (cfs)	Rank	Probability: (rank/ (n+1))
27,200	1	1/10= 0.1
15,400	2	2/10= 0.2
10,100	3	3/10= 0.3
9140	4	4/10= 0.4
8130	5	5/10= 0.5
4460	6	6/10= 0.6
3250	7	7/10= 0.7
2740	8	8/10= 0.8
2240	9	9/10=0.9

**More realistic--  
method used by  
Hydrologists**

Probability: (rank/ (n+1))	Recurrence Interval ( $R=1/P$ ) in years
1/10= 0.1	1/ 0.1 = 10
2/10= 0.2	1/ 0.2 = 5
3/10= 0.3	1/ 0.3 = 3.3
4/10= 0.4	1/ 0.4 = 2.5
5/10= 0.5	1/ 0.5 = 2.0
6/10= 0.6	1/ 0.6 = 1.7
7/10= 0.7	1/ 0.7 = 1.4
8/10= 0.8	1/ 0.8 = 1.3
9/10=0.9	1/ 0.9 = 1.1

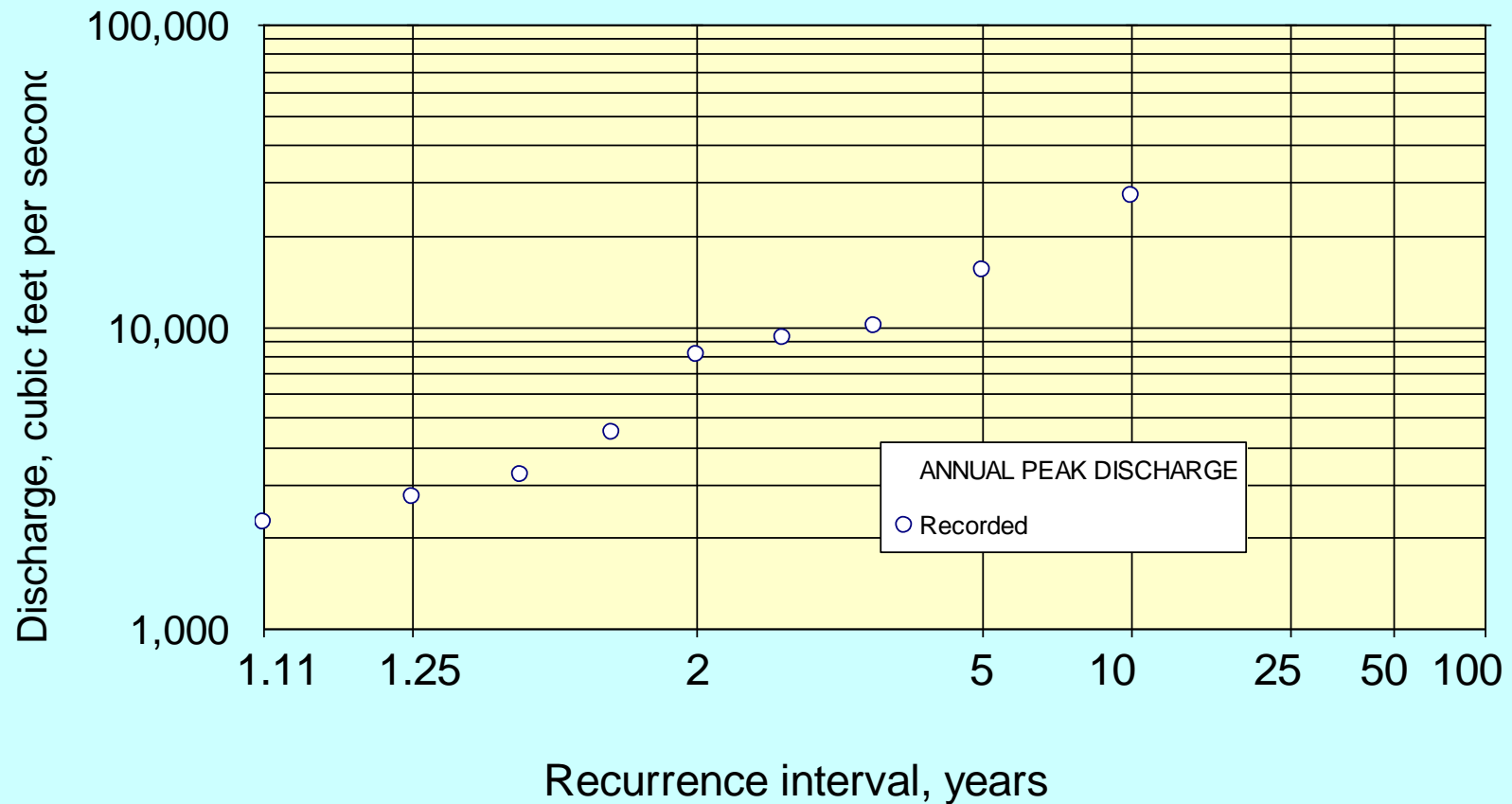
Use your calculator to find the recurrence interval, or can rearrange the recurrence interval equation to:

$$R = (n+1)/m$$

where m= rank

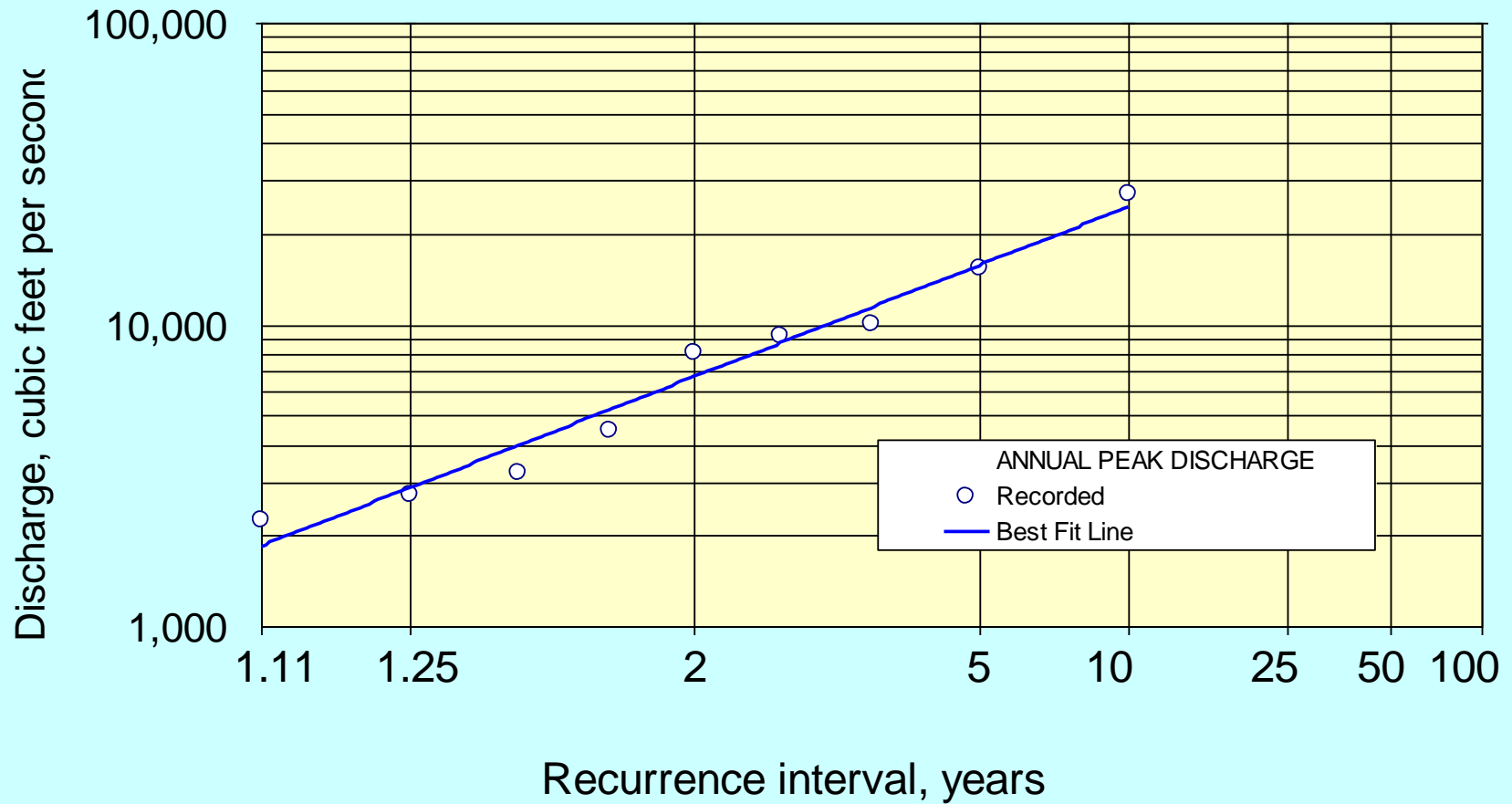


11413000 N YUBA R BL GOODYEARS BAR, CA

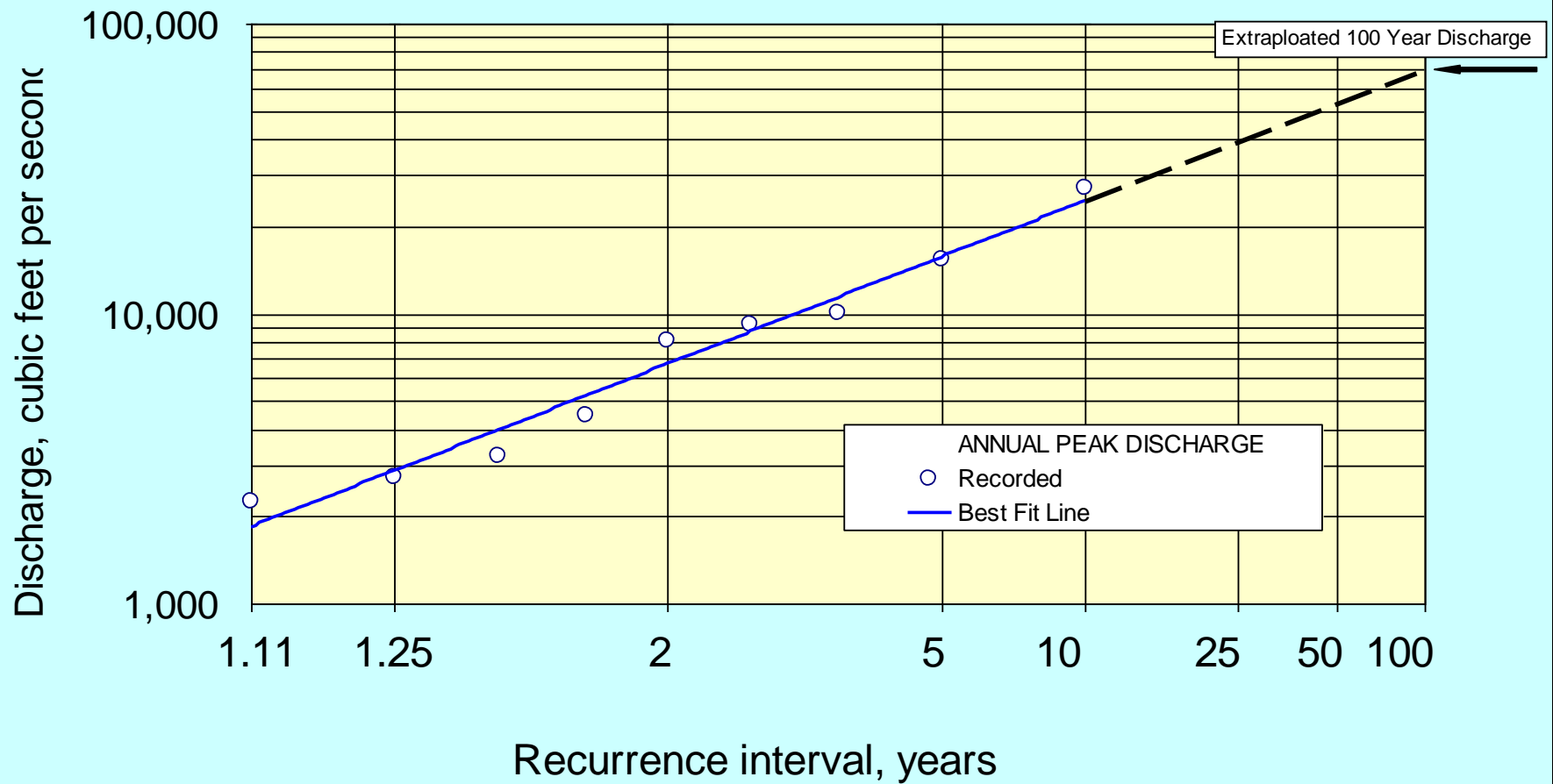


Annual peak Q values plotted on lognormal probability paper

# 11413000 N YUBA R BL GOODYEARS BAR, CA

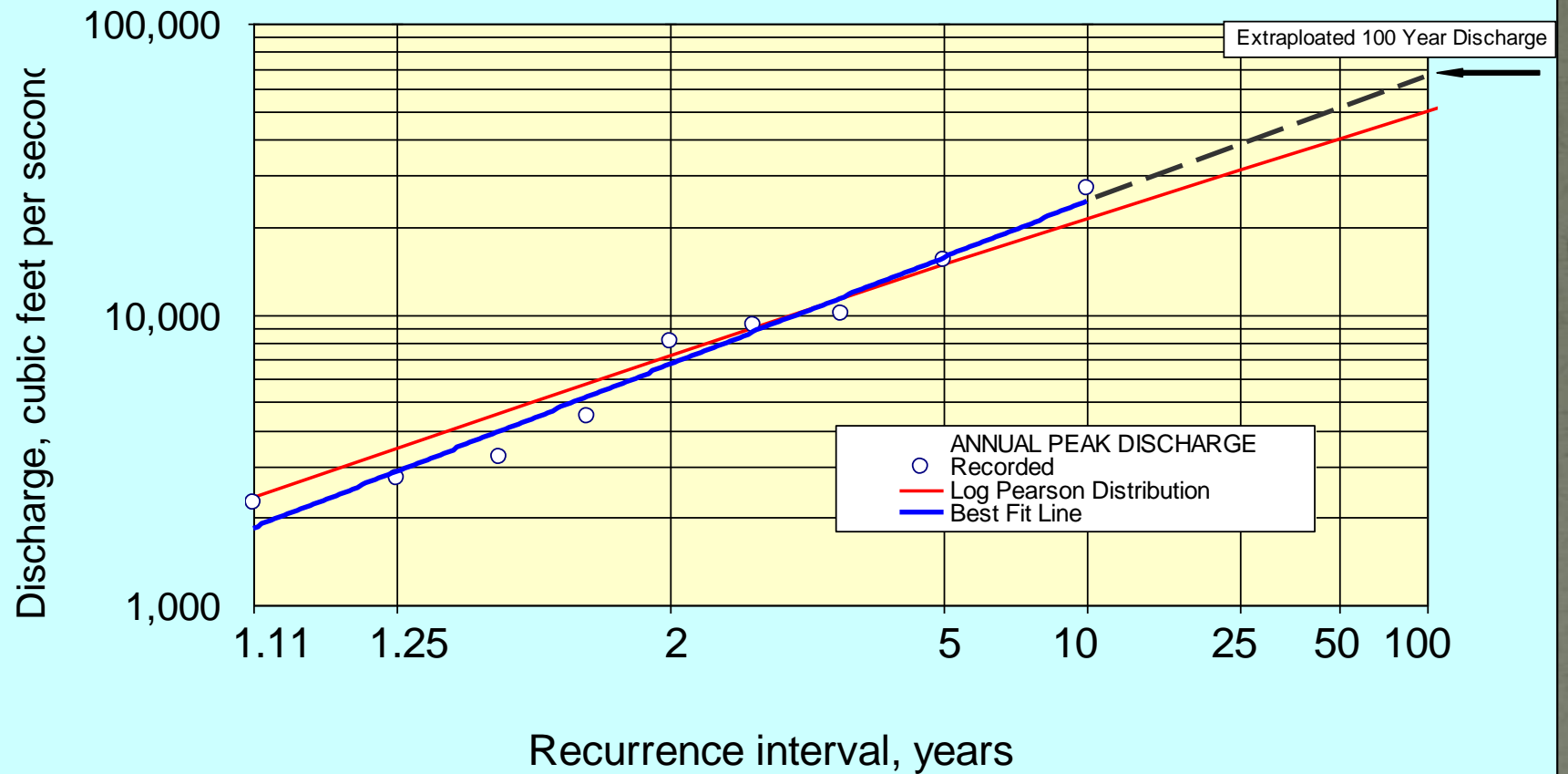


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# 11413000 N YUBA R BL GOODYEARS BAR, CA



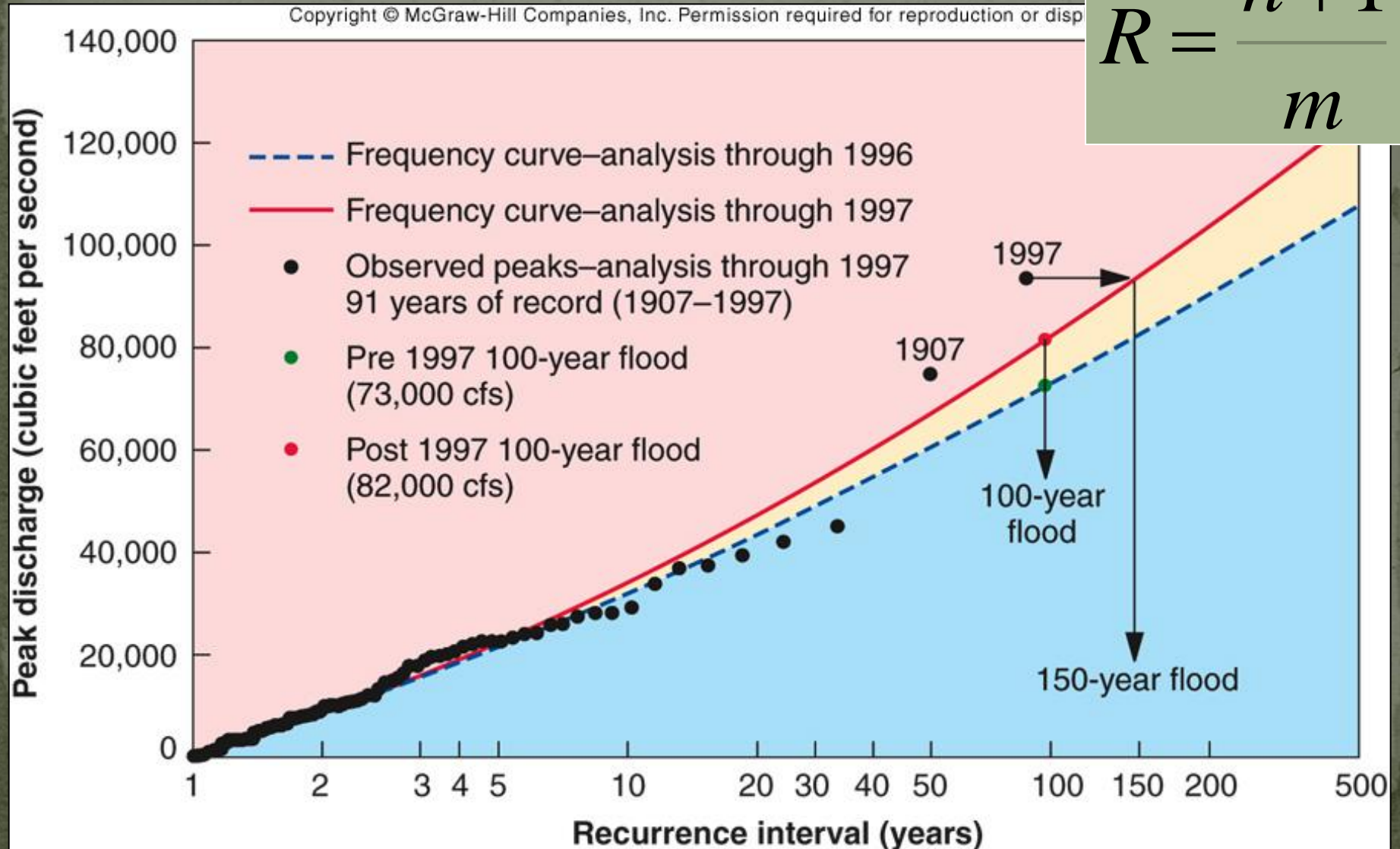
## Limitations:

- Extrapolating too far past the data;  
USGS rule of thumb—don't extrapolate past twice the record length
- Not using the appropriate scales to plot probabilities and recurrence intervals
- Sometimes other probability methods may be more appropriate



# Recurrence Interval

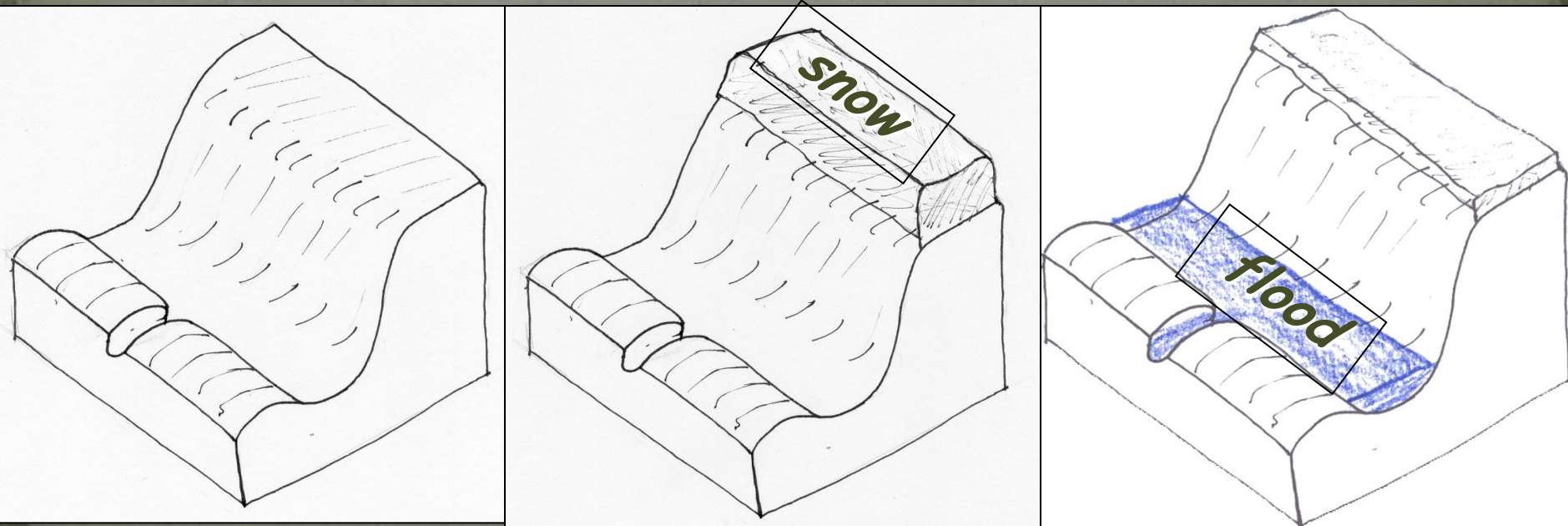
$$R = \frac{n + 1}{m}$$





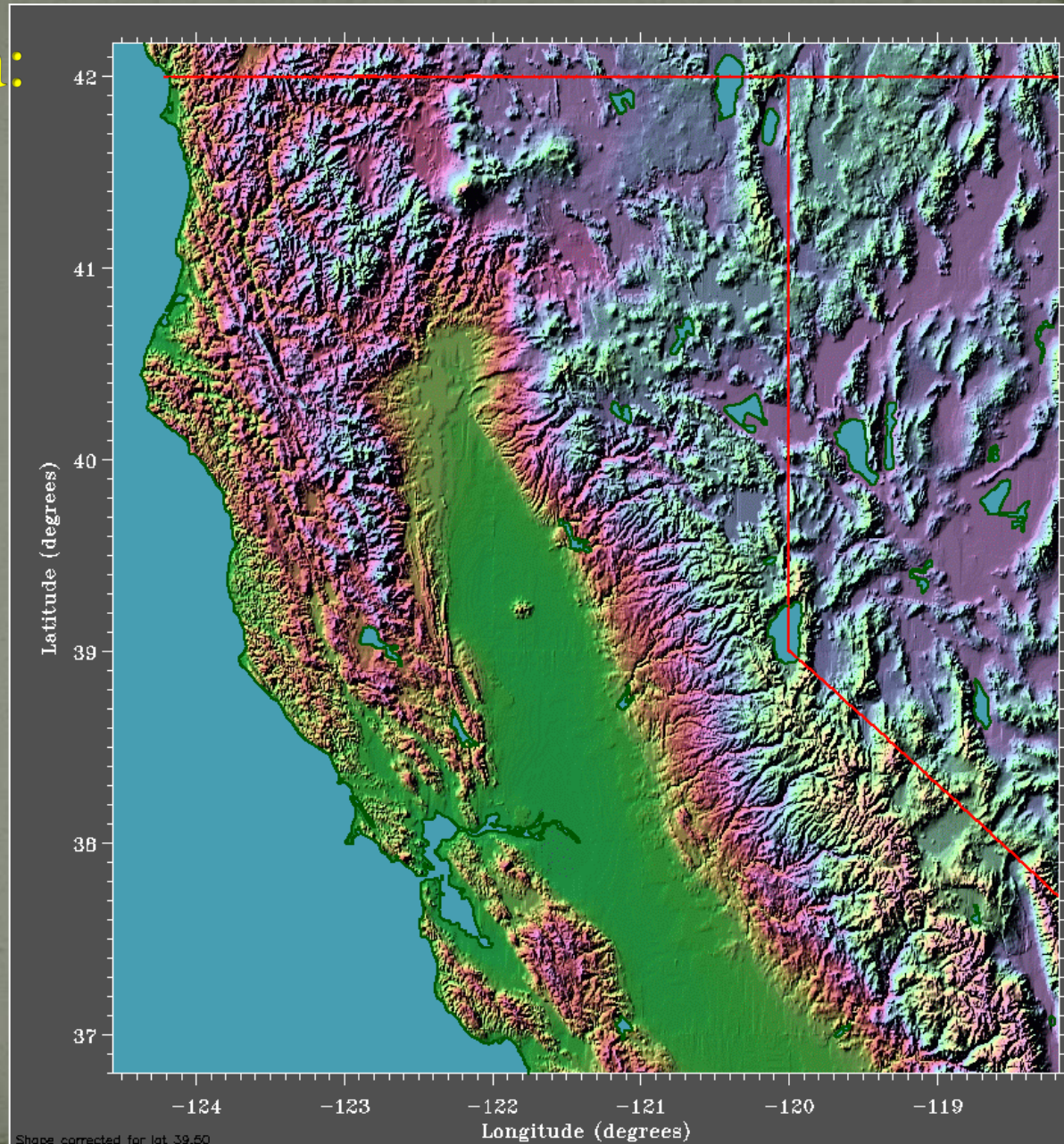
# The Perfect Flood Machine

- Store lots of water at high elevation
- Drain water quickly
- Into flat area with a single, narrow outlet



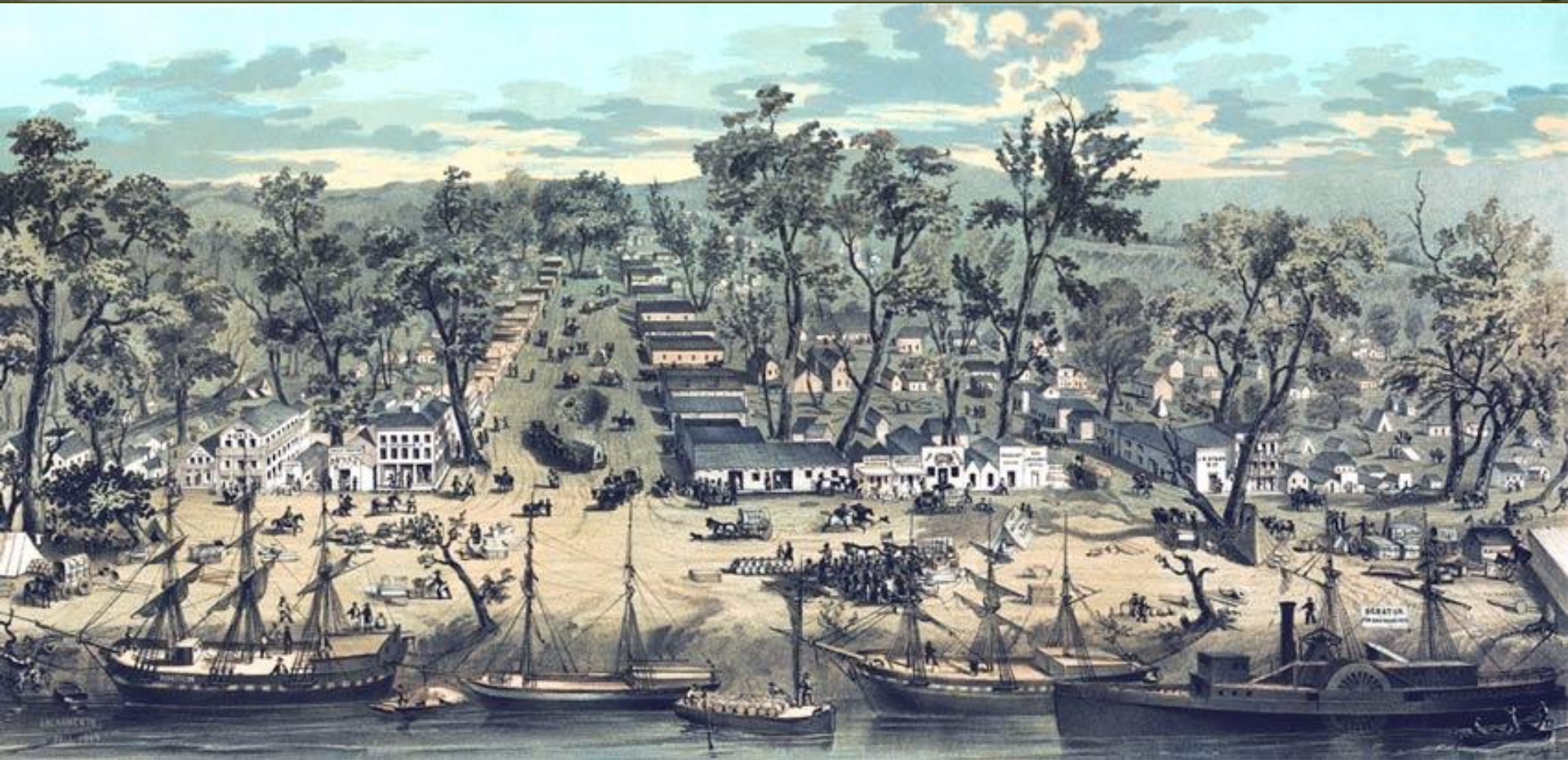


# Northern California: The perfect flood machine





# Sacramento 1849





# Sacramento Flooded January & December 1862





## Flood of



# Recent Floods

- 1986
  - 10 inches rain in 11 days
  - Folsom Lake exceeds designed capacity
  - Record releases from Folsom Dam
  - Folsom Dam protection downgraded to about 70 year flood
- 1997
  - Record Flow Rates
  - Sacramento spared from flooding
    - Modesto hit hard



February 1986... 135,000 cfs



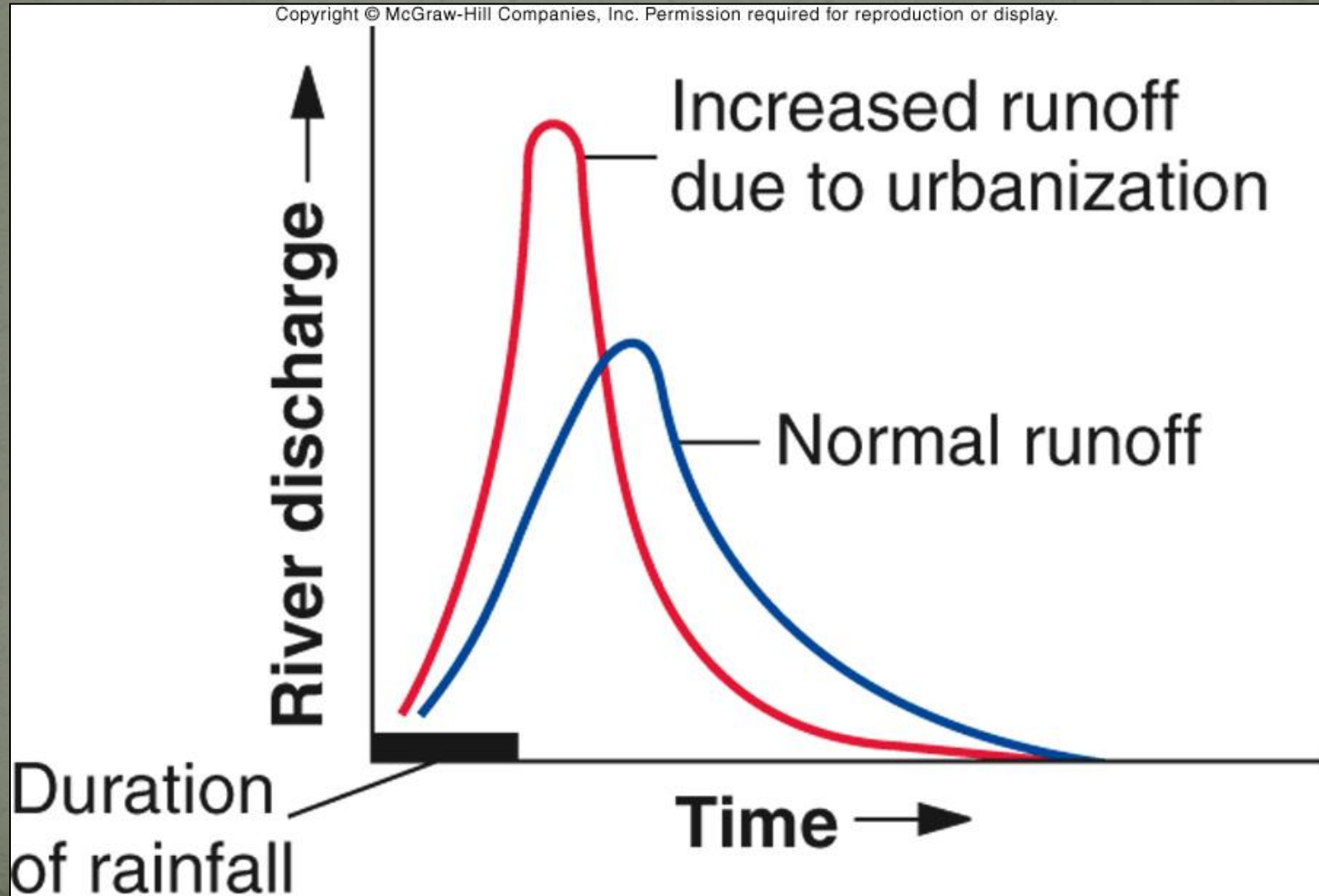
# Nimbus Dam and Hazel Avenue Bridge





# How urbanization affects flood hazard

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# Urbanization and Flooding

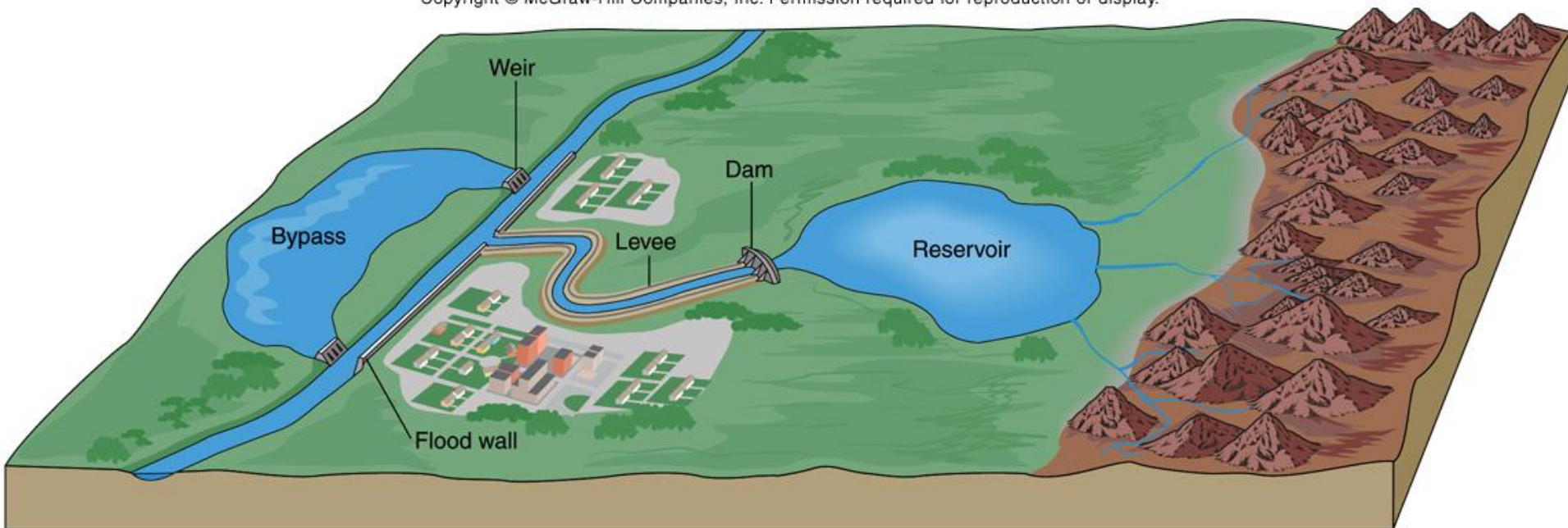
- Paving increases amount and rate of surface runoff



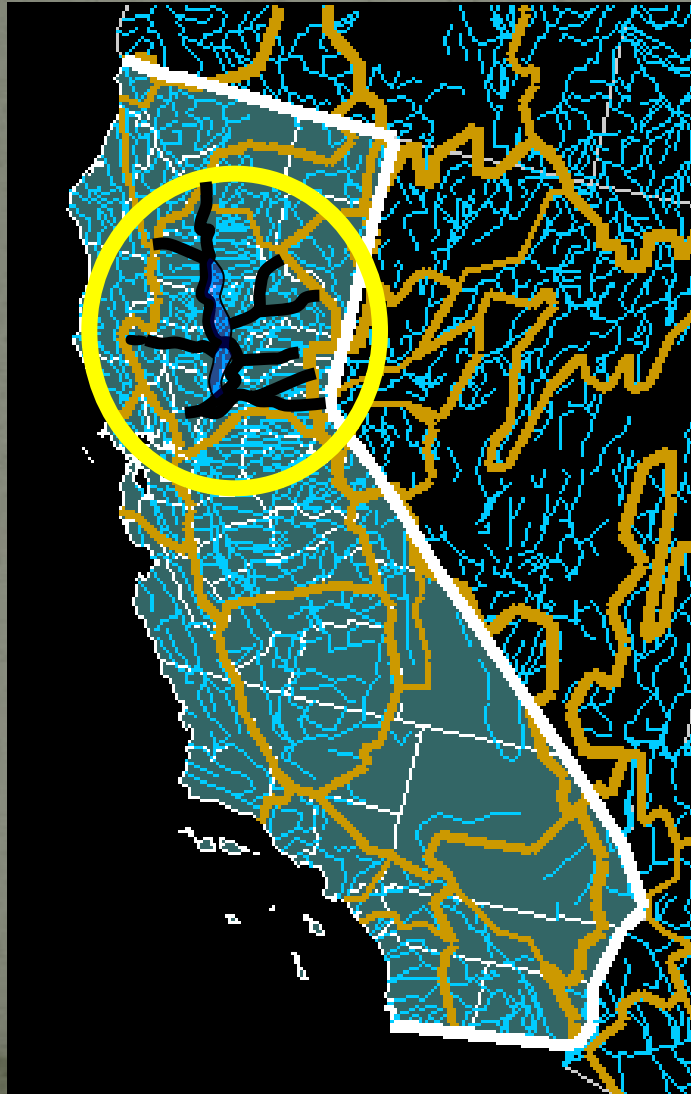


# Flood Control Structures

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# Rivers of the Sacramento Valley

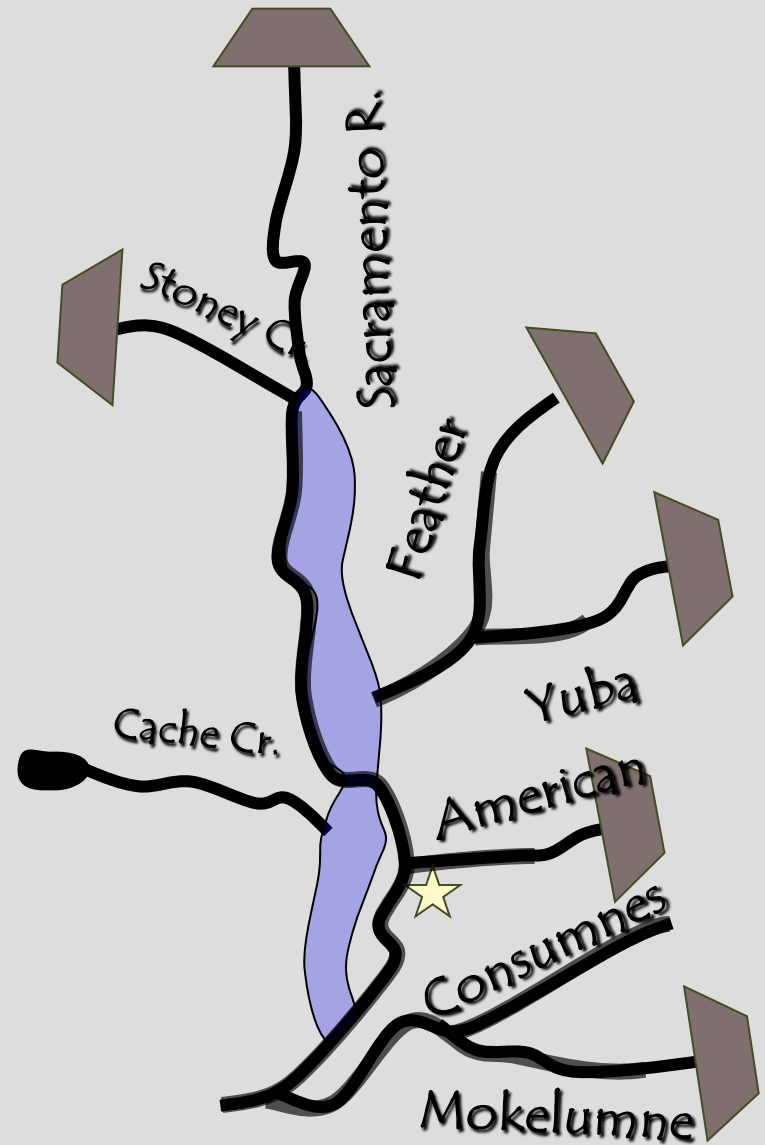


- Sacramento
- Feather
- Yuba
- American
- Consumnes
- Mulkemne
- Stoney Cr.
- Cache Cr.



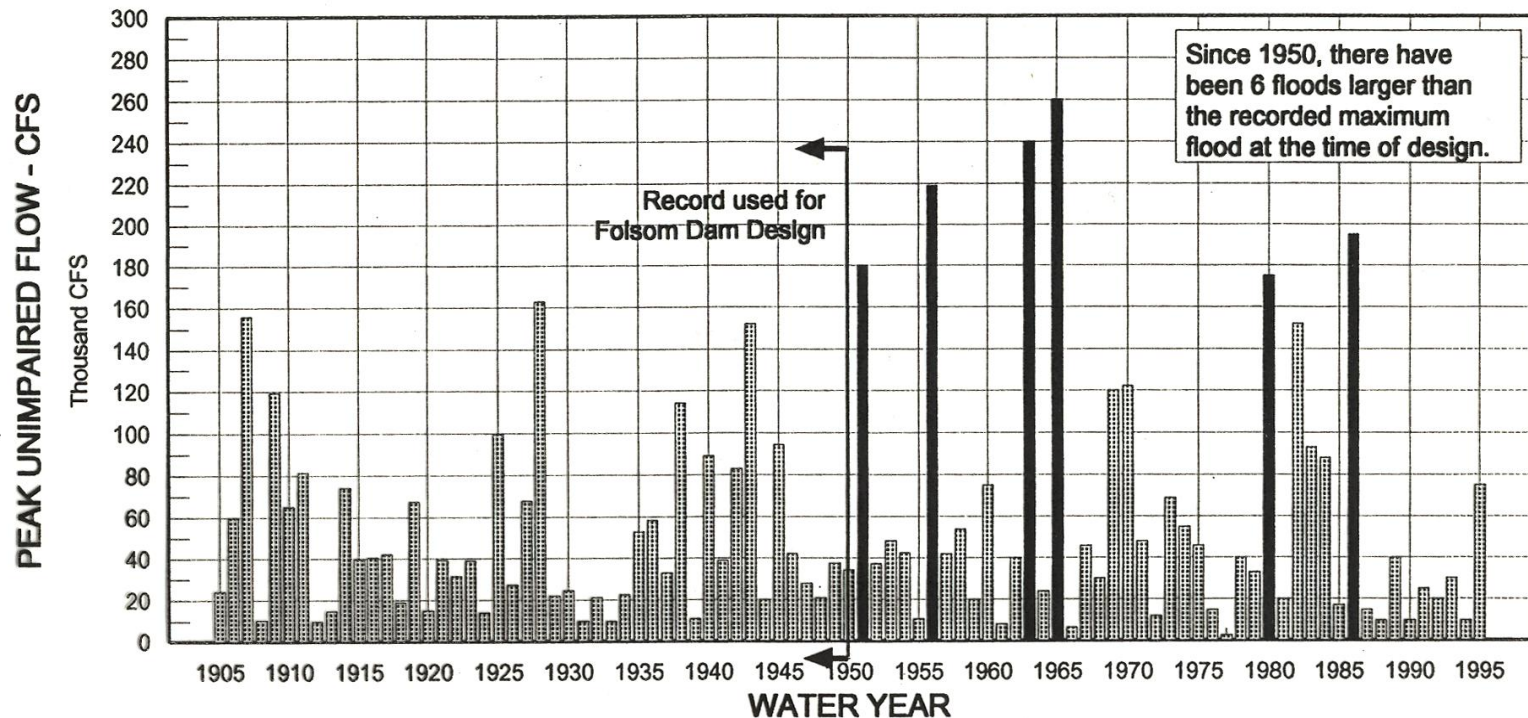
# Flood Control in Sacramento Valley

- Dams upstream
  - 26 dams
- Levees
- River “bypasses”
  - Hold 75% of Sac. River Water during floods



Flood frequency estimates are derived from recorded samples...could conditions change?

American River at Fair Oaks  
Annual Peak Unimpaired Flow





# Cosumnes River Levee Break





# Levee Breaks along Dry Creek in Rio Linda





# What should be done about to increase flood protection?

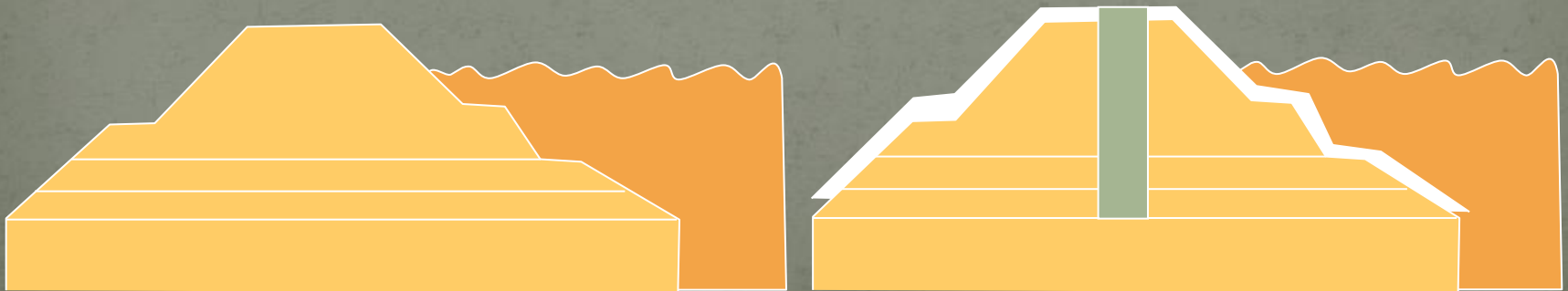
- Auburn Dam
  - Proposed in 1960s
  - Environmental opposition
  - Recently active fault mapped at dam site
- Raise and strengthen levees
- Raise Folsom Dam
- Increase spillways on Folsom Dam

# What should be done about decreased flood protection?

- Auburn Dam
  - Proposed in 1950s
  - Environmental opposition
- Raise and strengthen levees
- Raise Folsom Dam
- Increase spillways on Folsom Dam

# Re-engineer levees

- 1999 US Congress Appropriated funds to improve Folsom Dam
- 2000 Sacramento voters approved an increase in property taxes to improve flood control





# Folsom Dam Spillway Gate Failure 1995

- July 17
- Drained 40% of Folsom Lake
  - 40,000 cfs
- \$20 M repair cost
- Fresh water in SF Bay
  - Salmon and Bass fooled into beginning fall migration

