Flooding

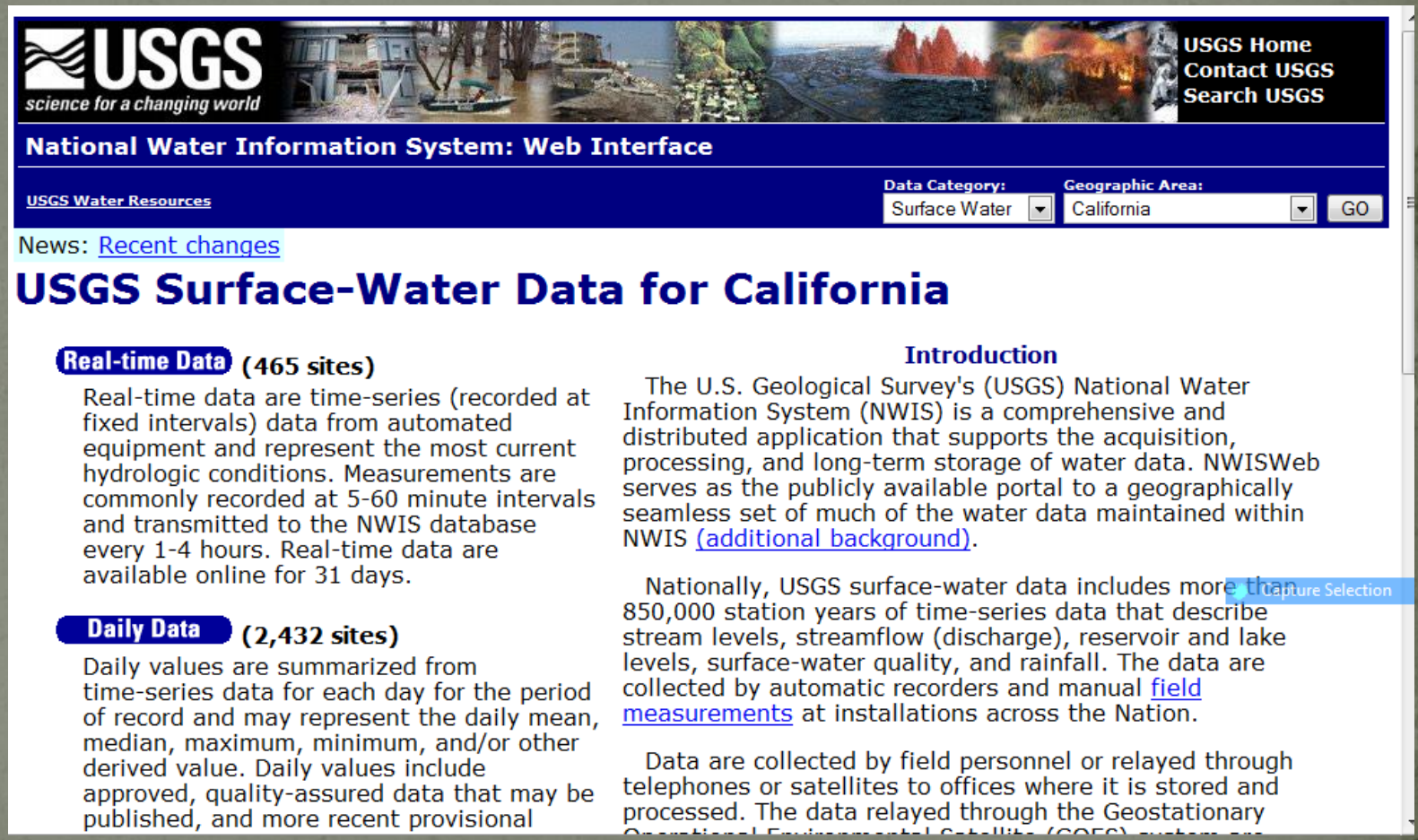
- Definition
- Recurrence Interval
  - The 100 year flood--What it means
- Sacramento flooding issues
- Flood control methods

Flooding

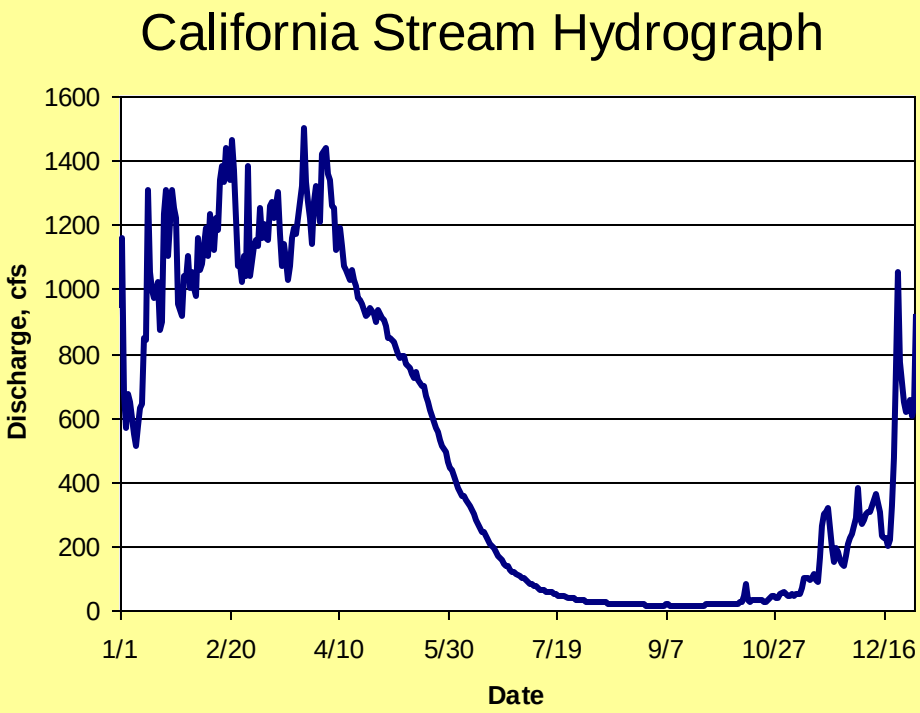
- Occurs when water overtops a stream's banks and spills out onto the flood plain.

Where Can We Get Annual Peak Discharge Data?

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

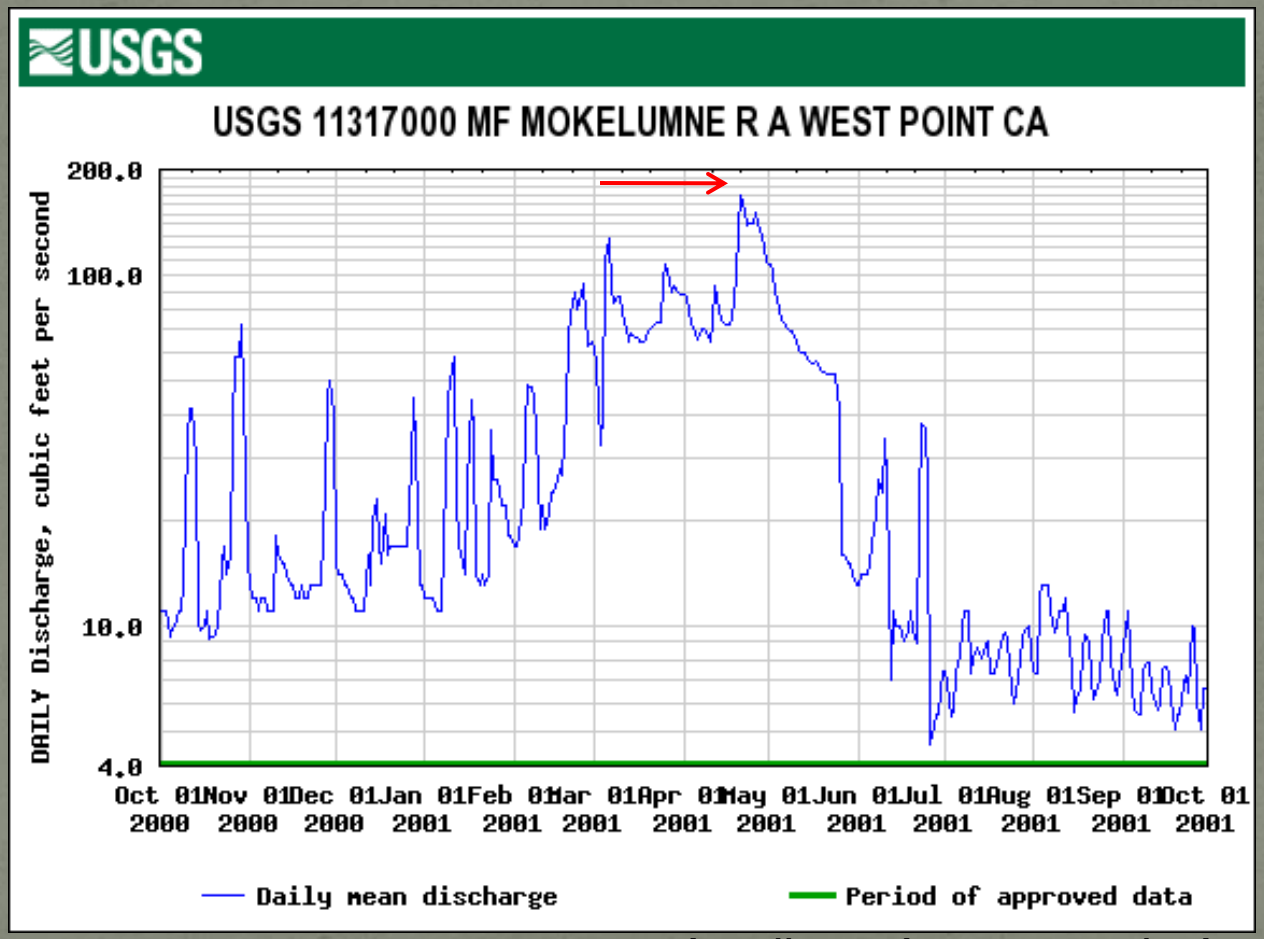


Annual Peak Discharge is the Maximum Instantaneous Stream Discharge During a Water Year (Oct 1 through Sept 30)



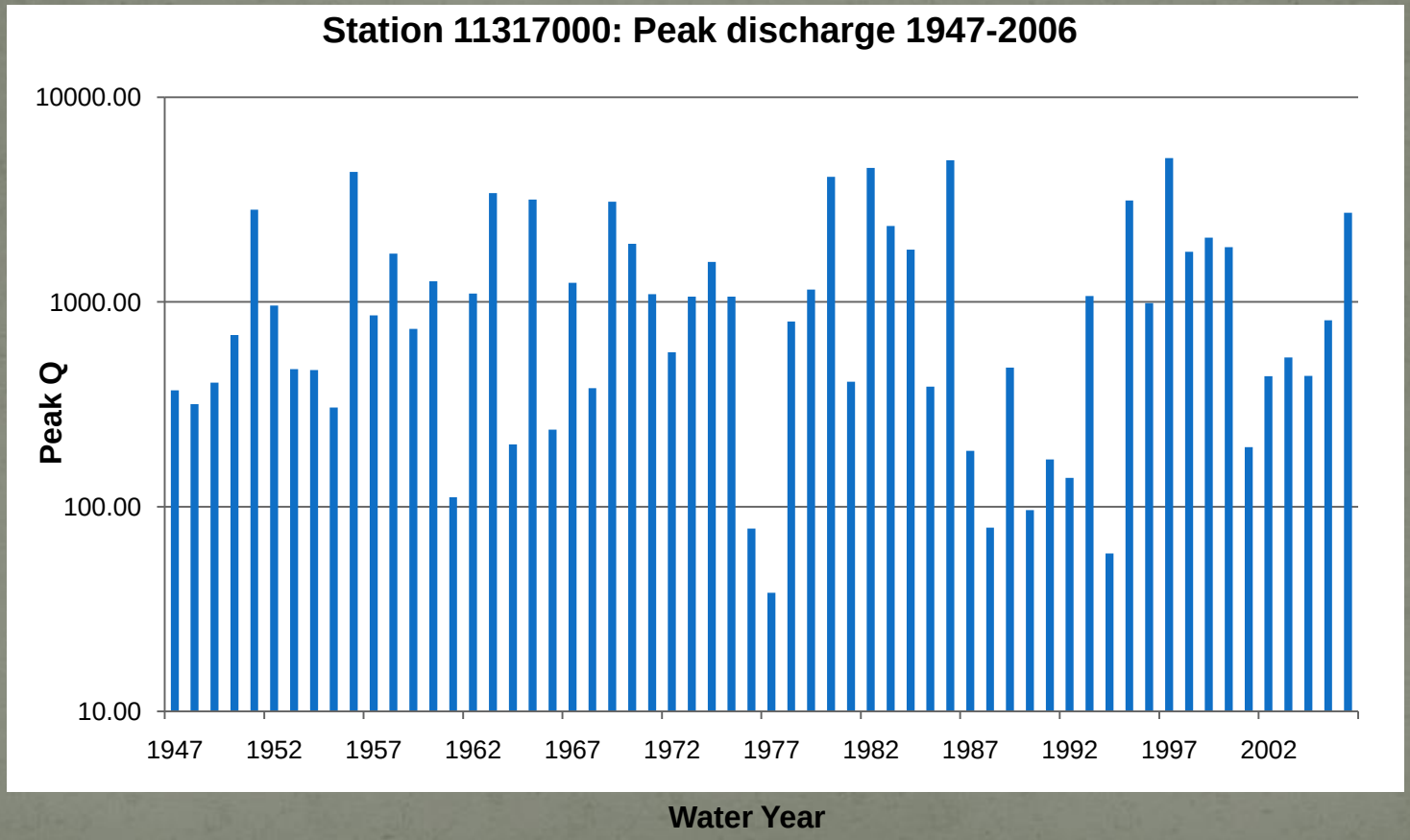
Why Not January 1 through Dec 31?

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

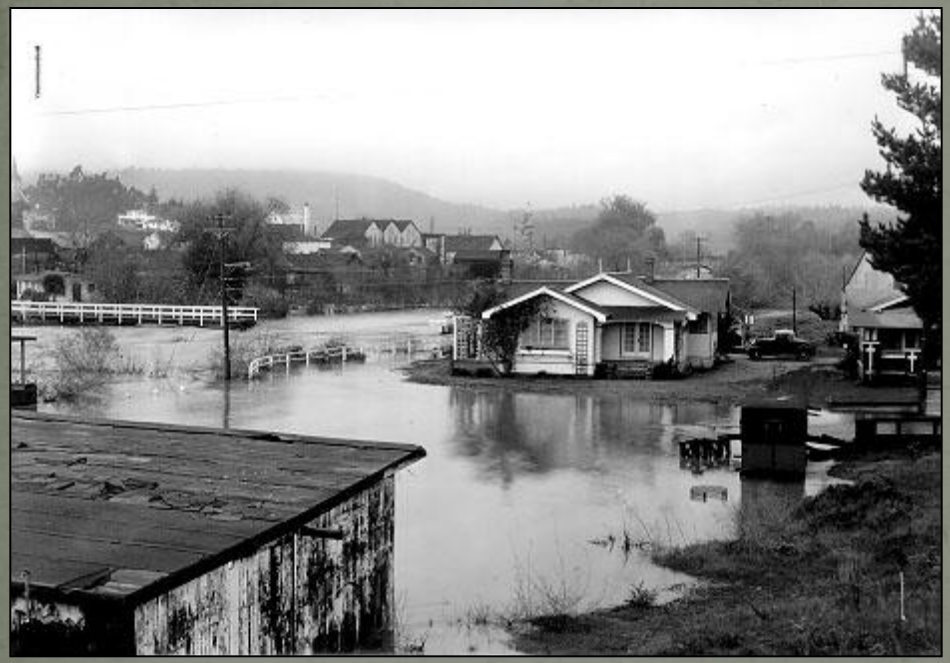


http://waterdata.usgs.gov/nwis

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?

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

USGS site:11413000
N Yuba R Bl 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

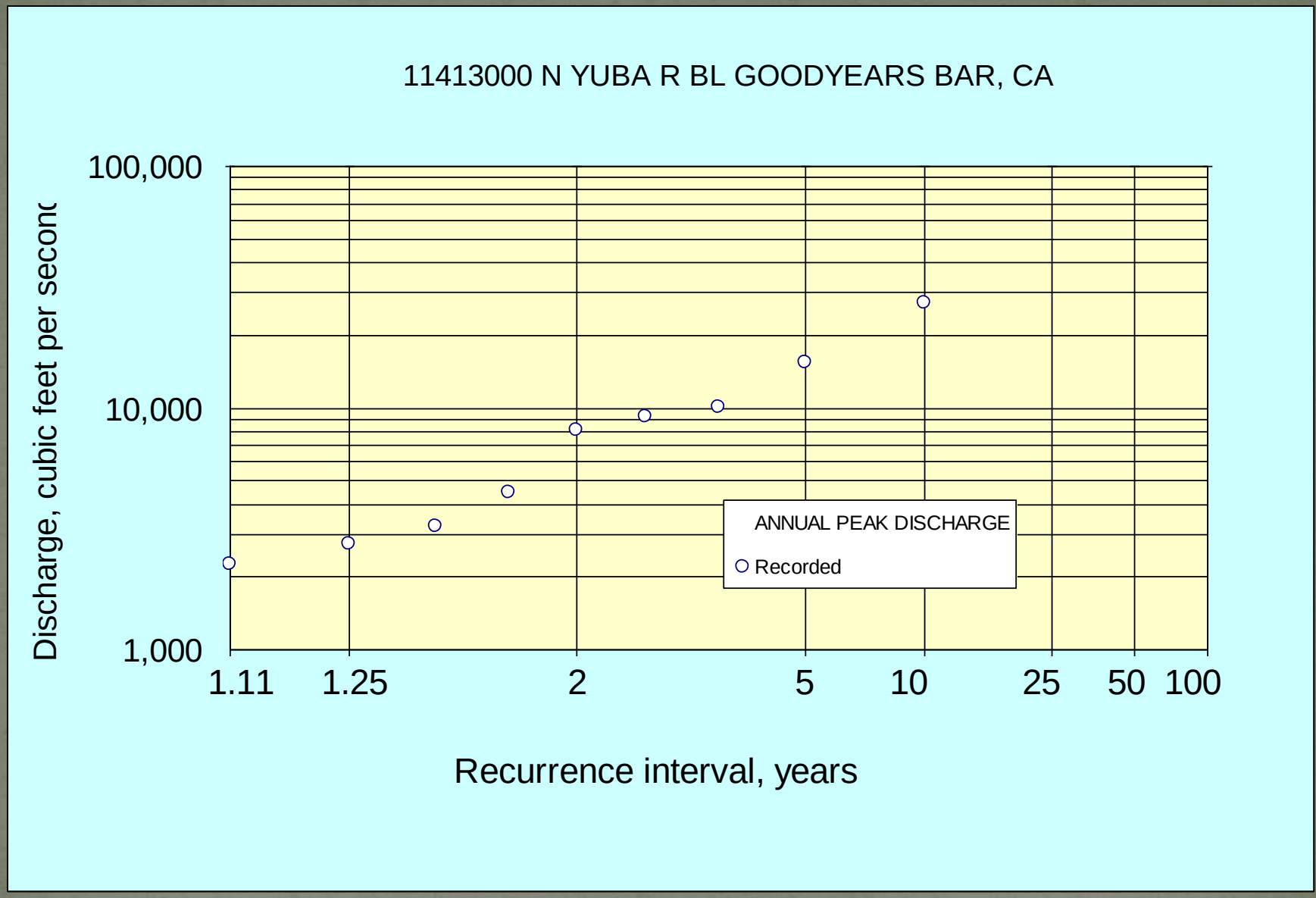
More realistic-- method used by Hydrologists

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

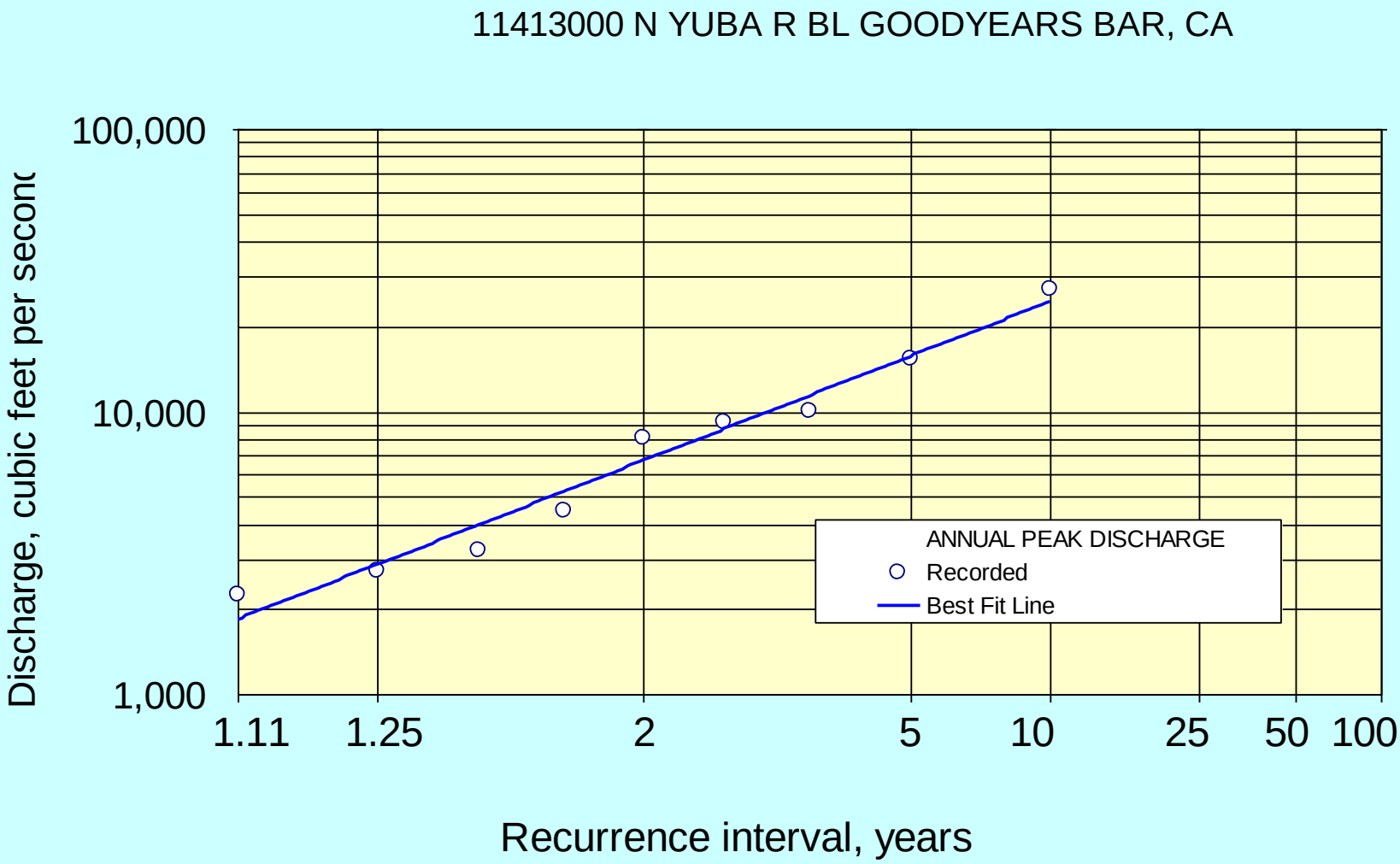
Use your calculator to find the recurrence interval, or can rearrange the recurrence interval equation to:

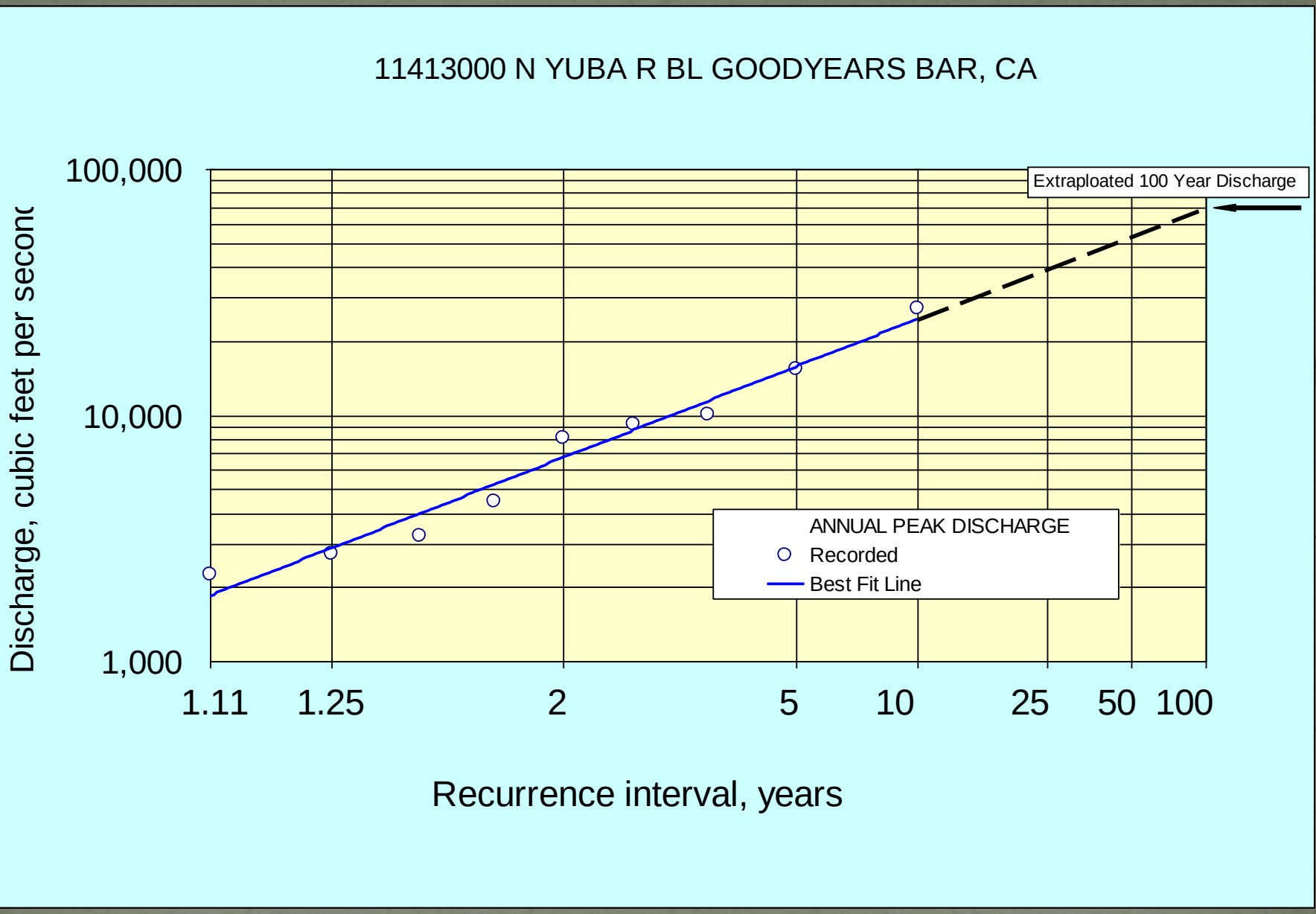
$R = (n+1)/m$

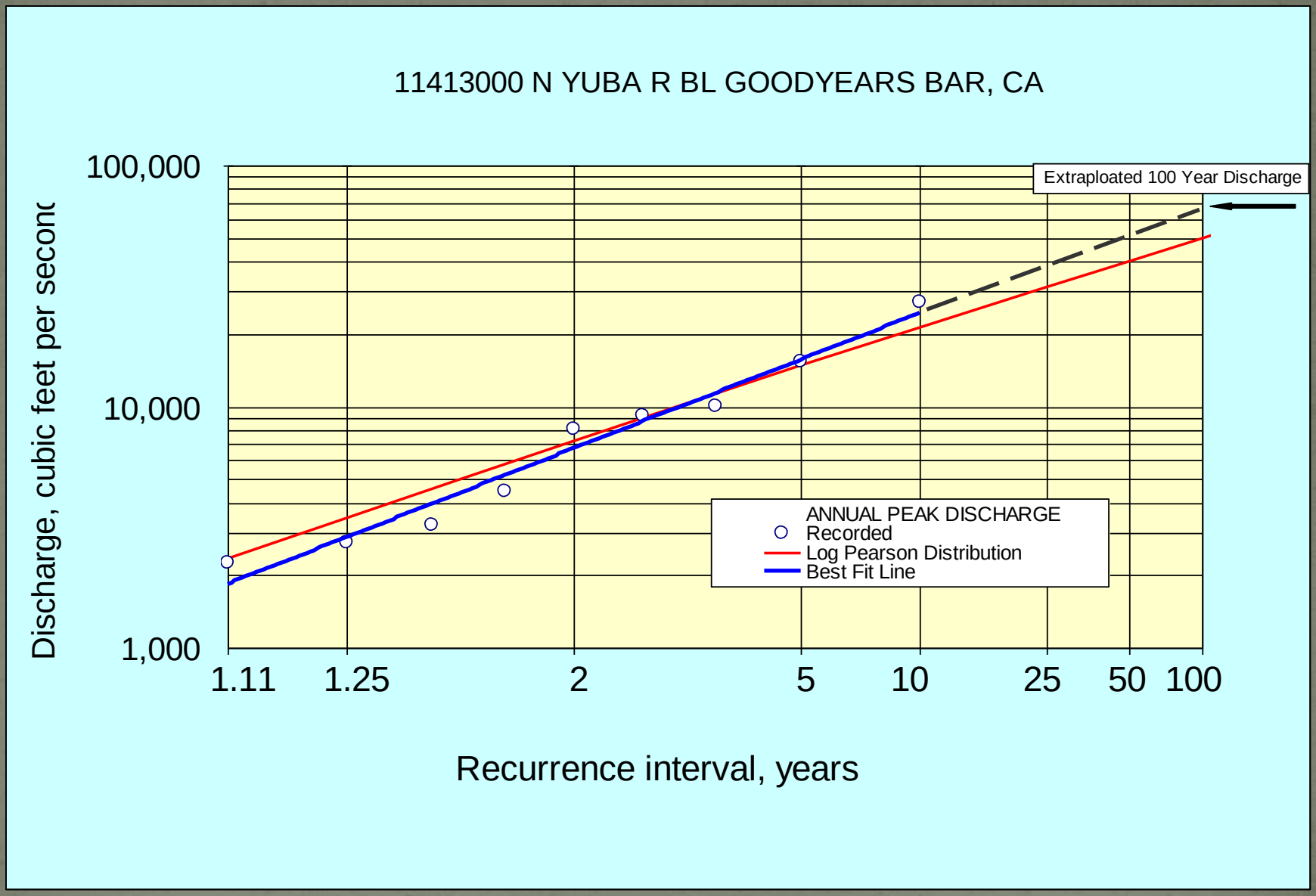
where m= rank



Annual peak Q values plotted on lognormal probability paper


11413000 N YUBA R BL GOODYEARS BAR, CA
Discharge, cubic feet per second
100,000
10,000
1,000
1.11
1.25
2
5
10
25
50
100
Recurrence interval, years
ANNUAL PEAK DISCHARGE
Recorded
Best Fit Line


11413000 N YUBA R BL GOODYEARS BAR, CA
100,000
10,000
1,000
Discharge, cubic feet per second
Extraploated 100 Year Discharge
ANNUAL PEAK DISCHARGE
Recorded
Best Fit Line
1.11
1.25
2
5
10
25
50
100
Recurrence interval, years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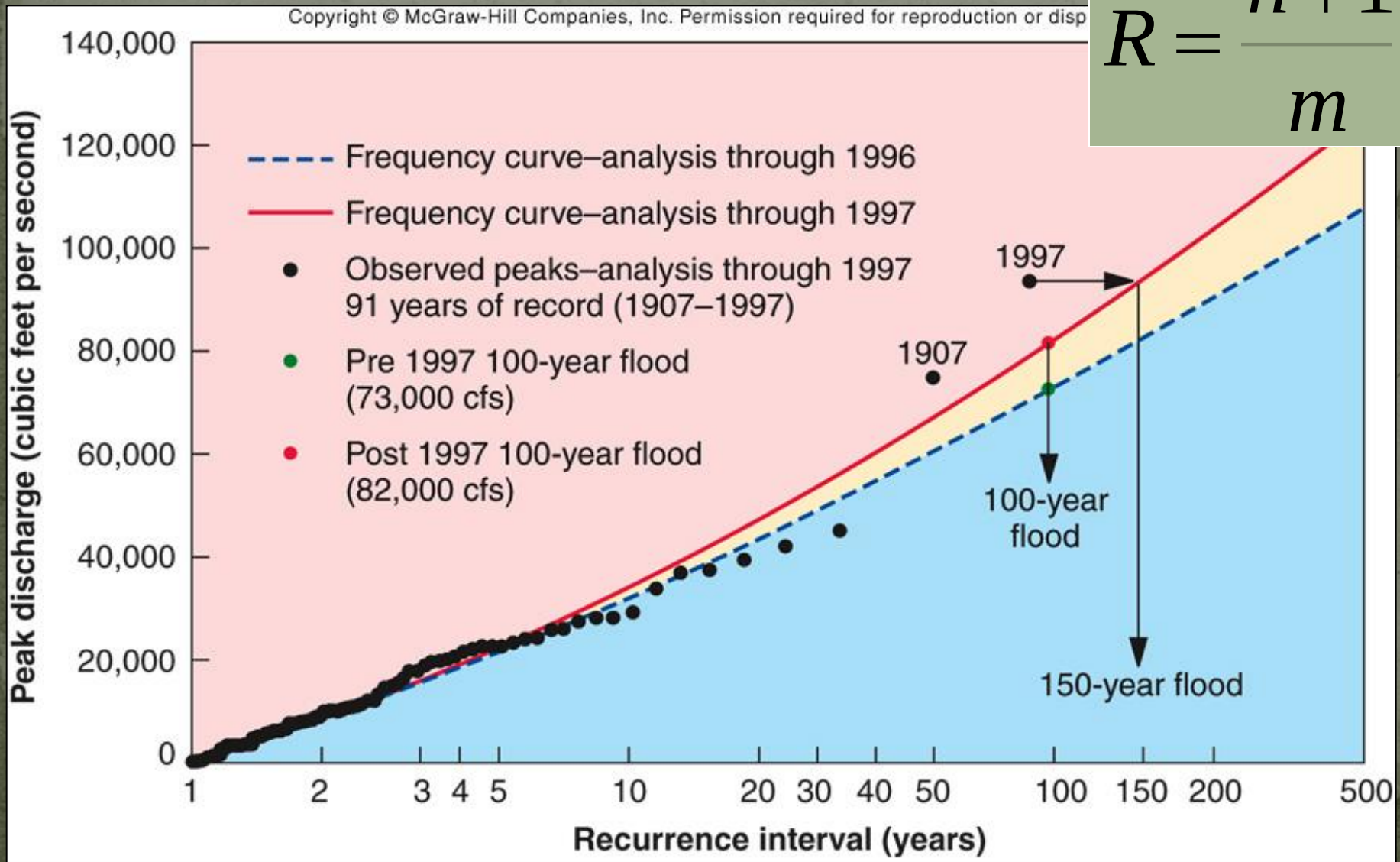
Discharge, cubic feet per second
100,000
10,000
1,000
1.11
1.25
2
5
10
25
50
100
Recurrence interval, years
Extraploated 100 Year Discharge
ANNUAL PEAK DISCHARGE
Recorded
Log Pearson Distribution
Best Fit Line

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

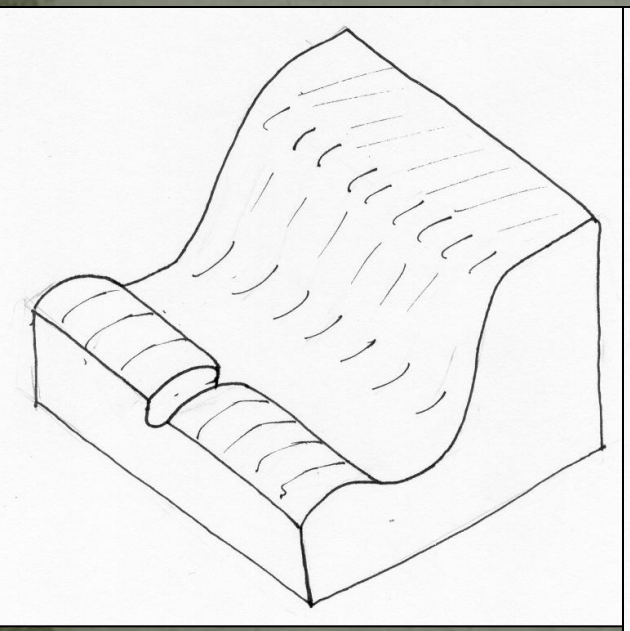
Recurrence Interval

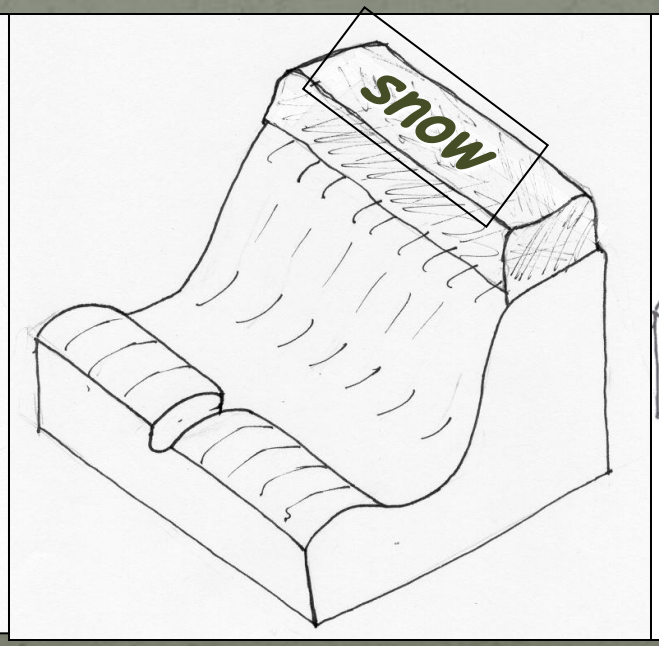
$$R = \frac{n+1}{m}$$

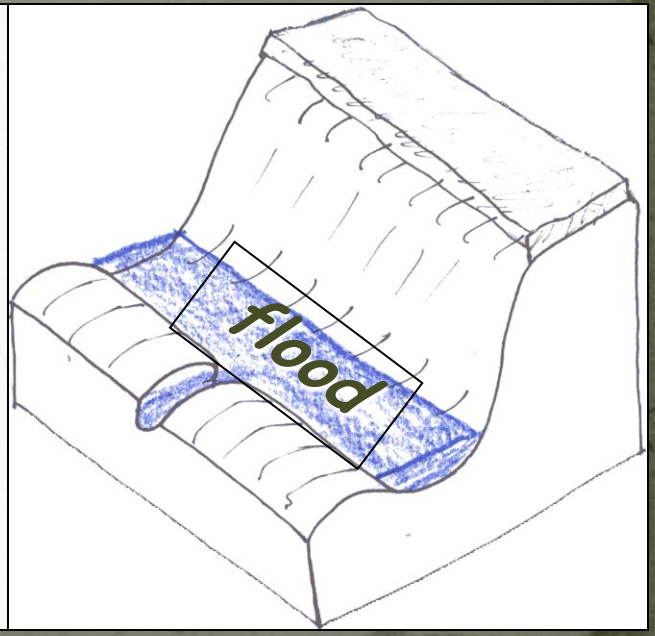


The Perfect Flood Machine

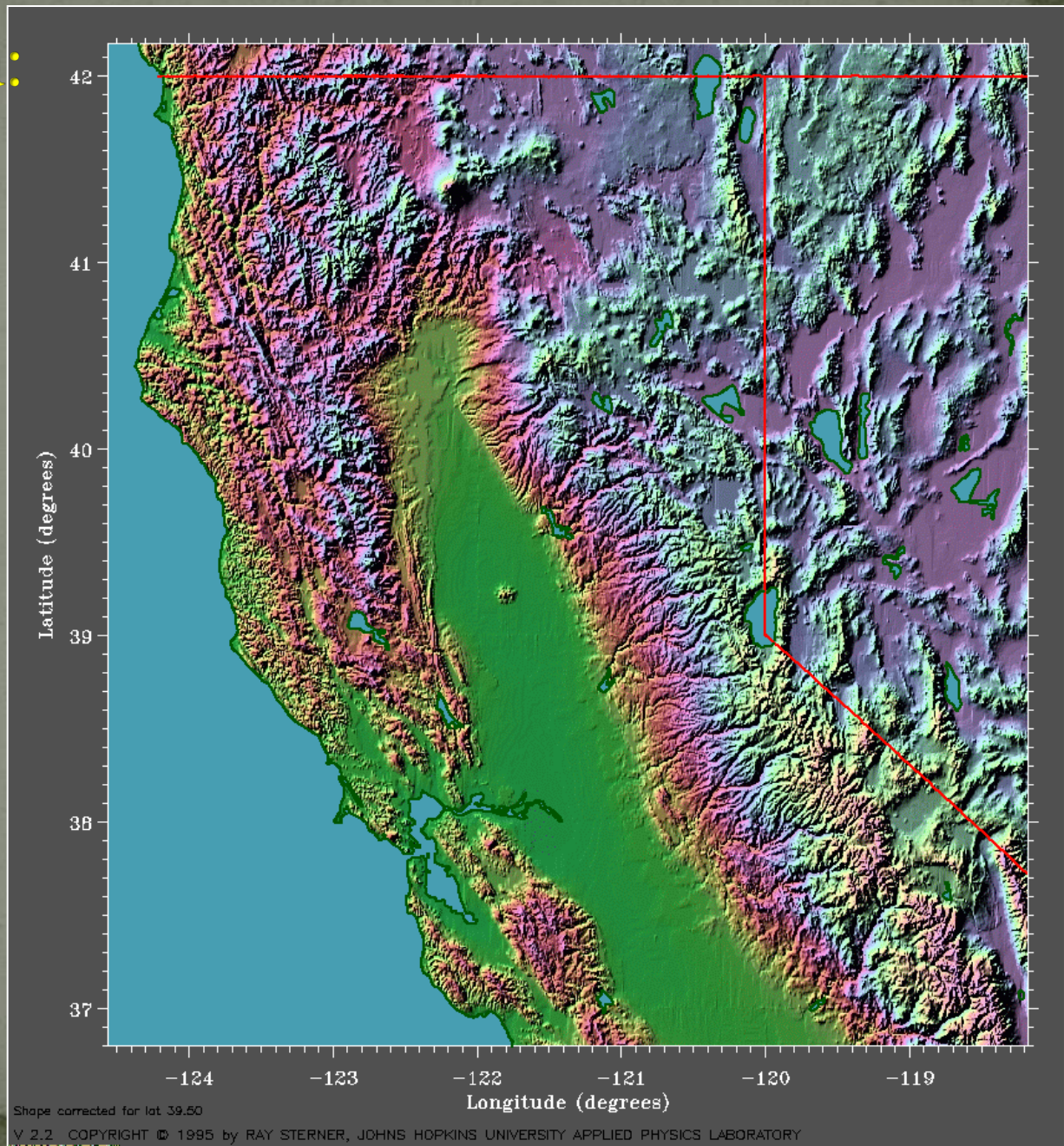
- Store lots of water at high elevation
- Drain water quickly
- Into flat area with a single, narrow outlet



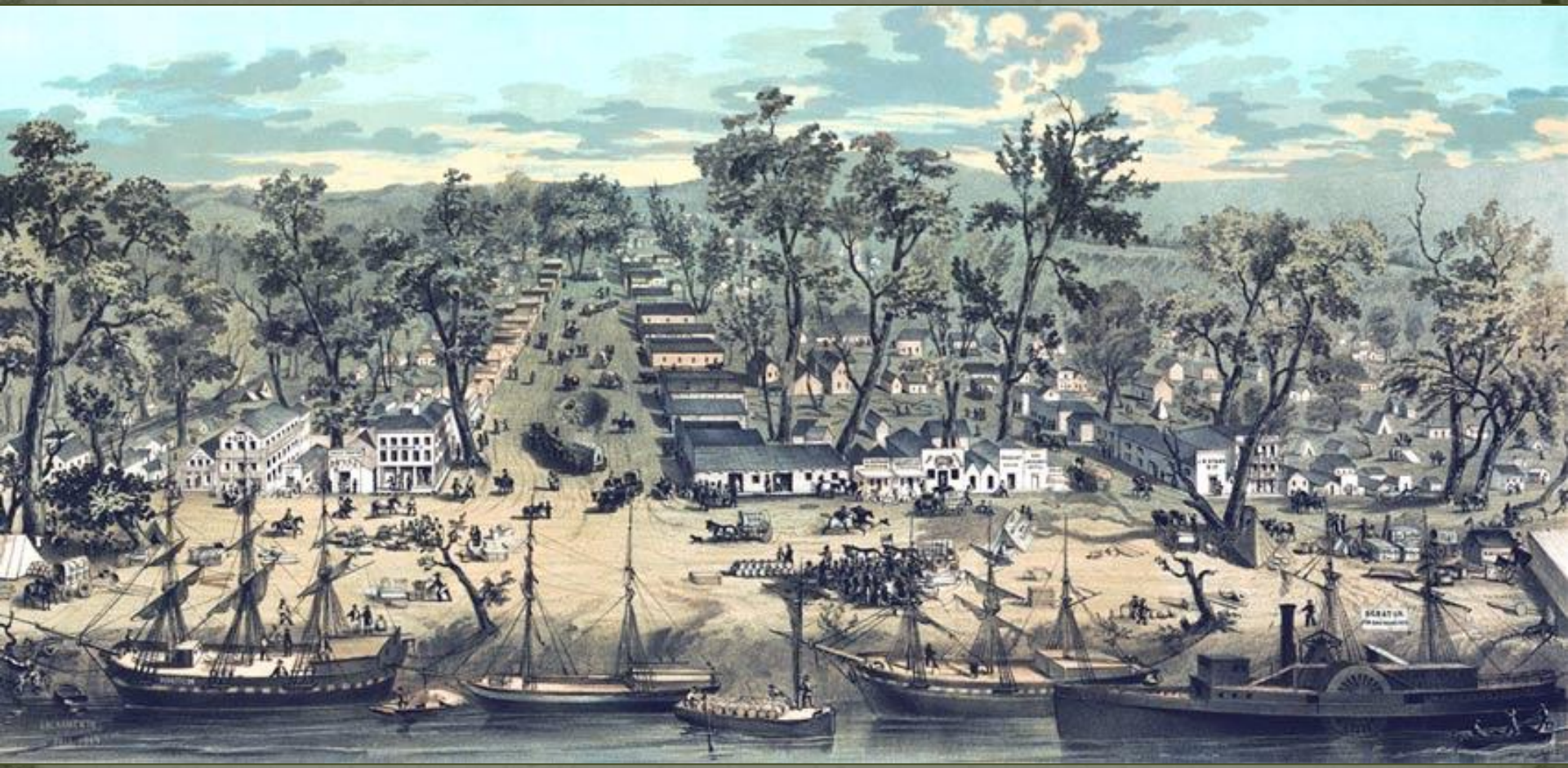




Northern California: The perfect flood machine



Sacramento 1849



Sacramento Flooded
January & December 1862

Flood of 1862

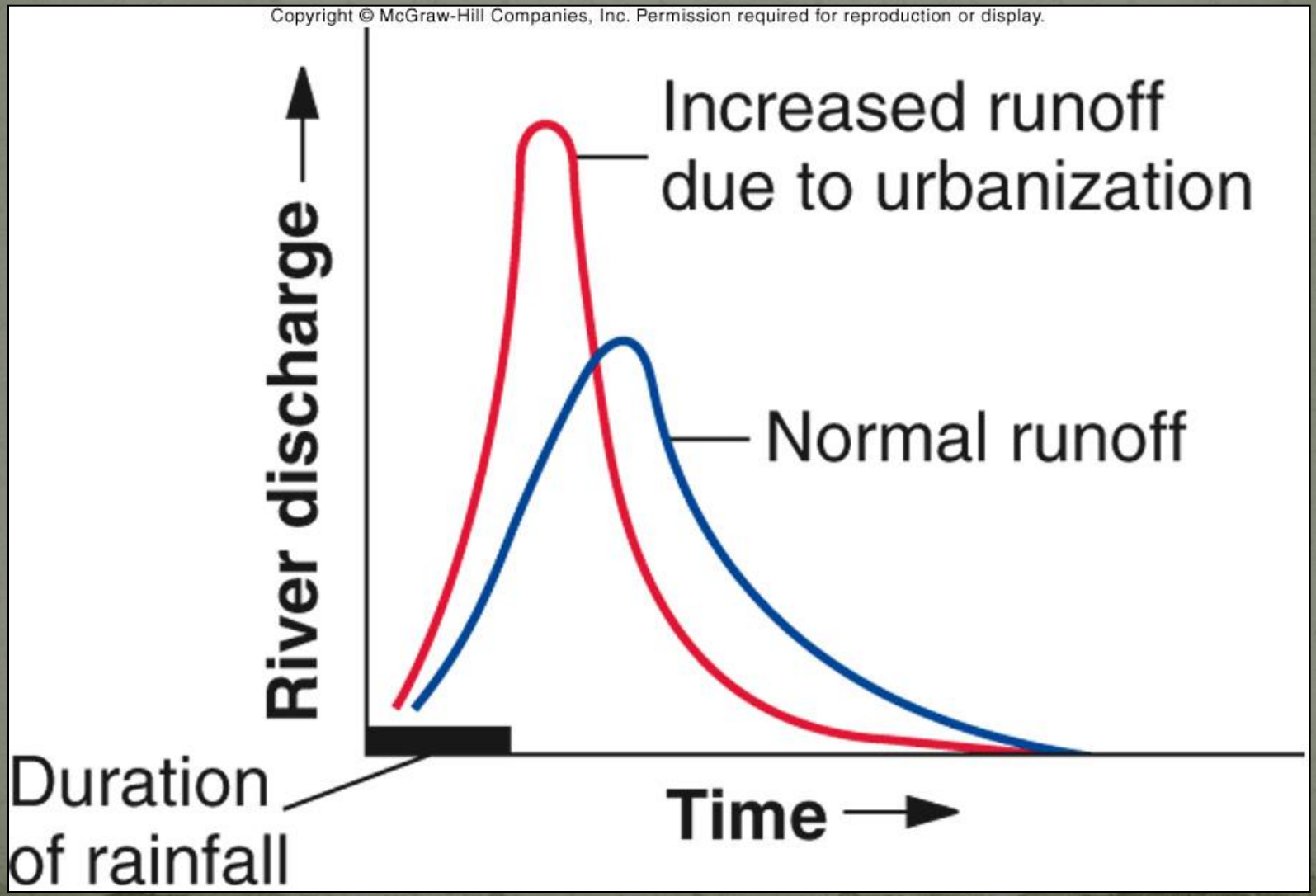
Recent Floods

- 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

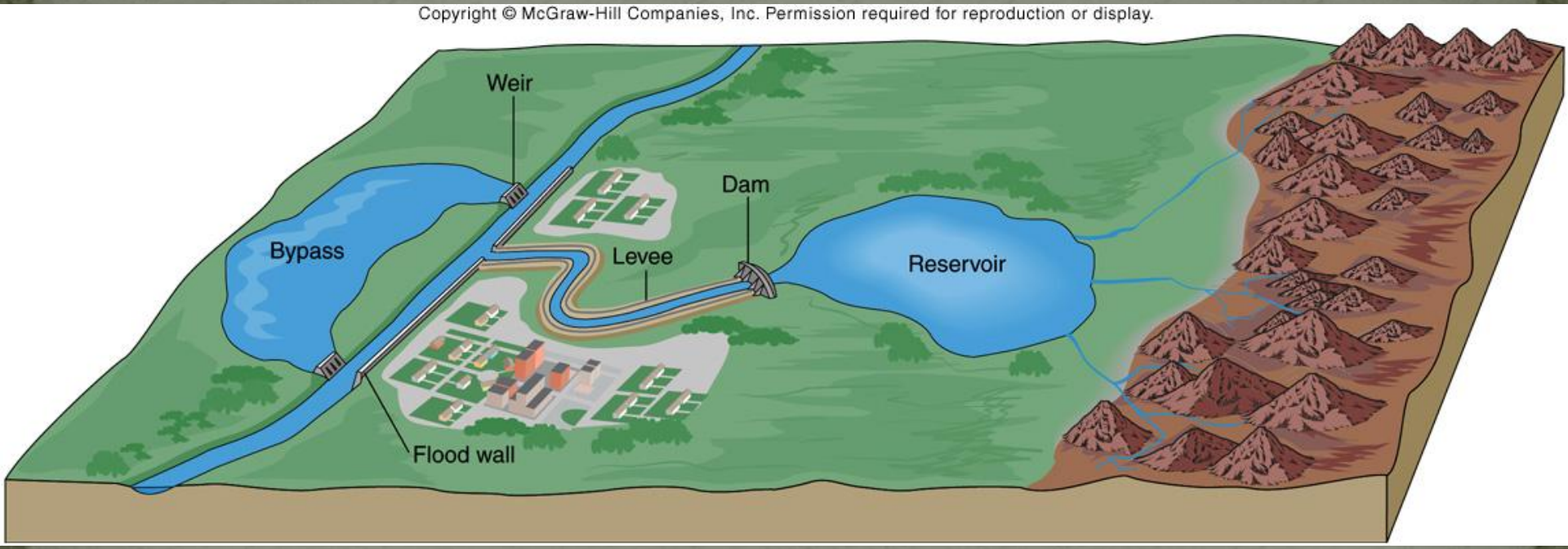
How urbanization affects flood hazard



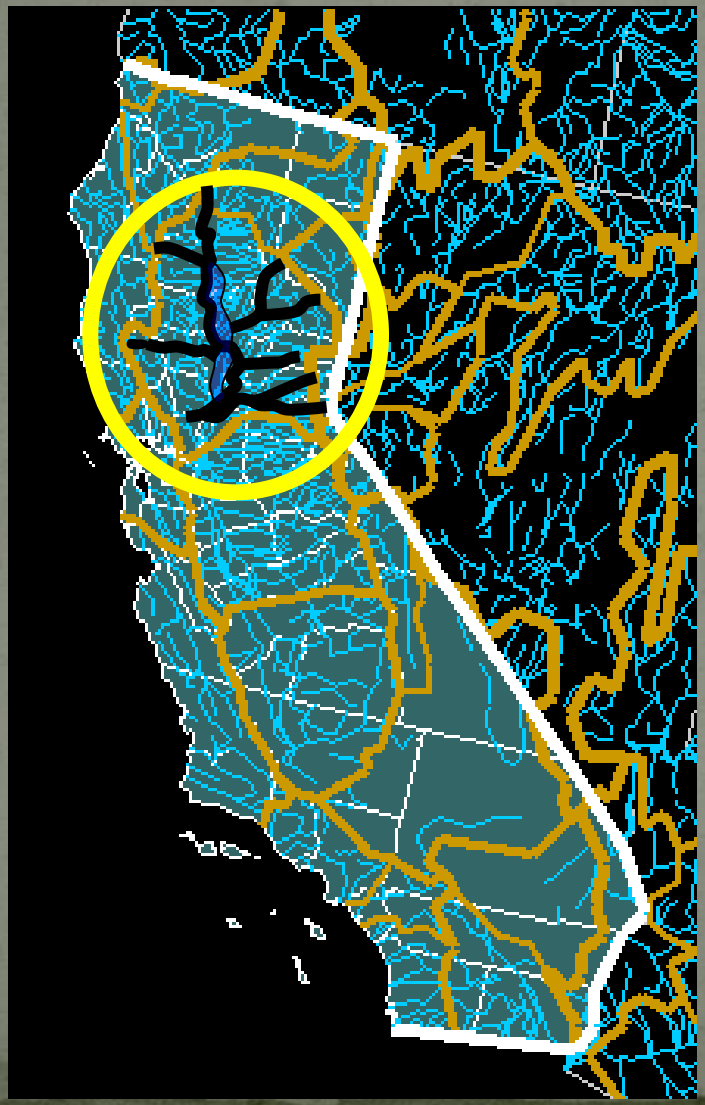
Urbanization and Flooding

- Paving increases amount and rate of surface runoff

Flood Control Structures



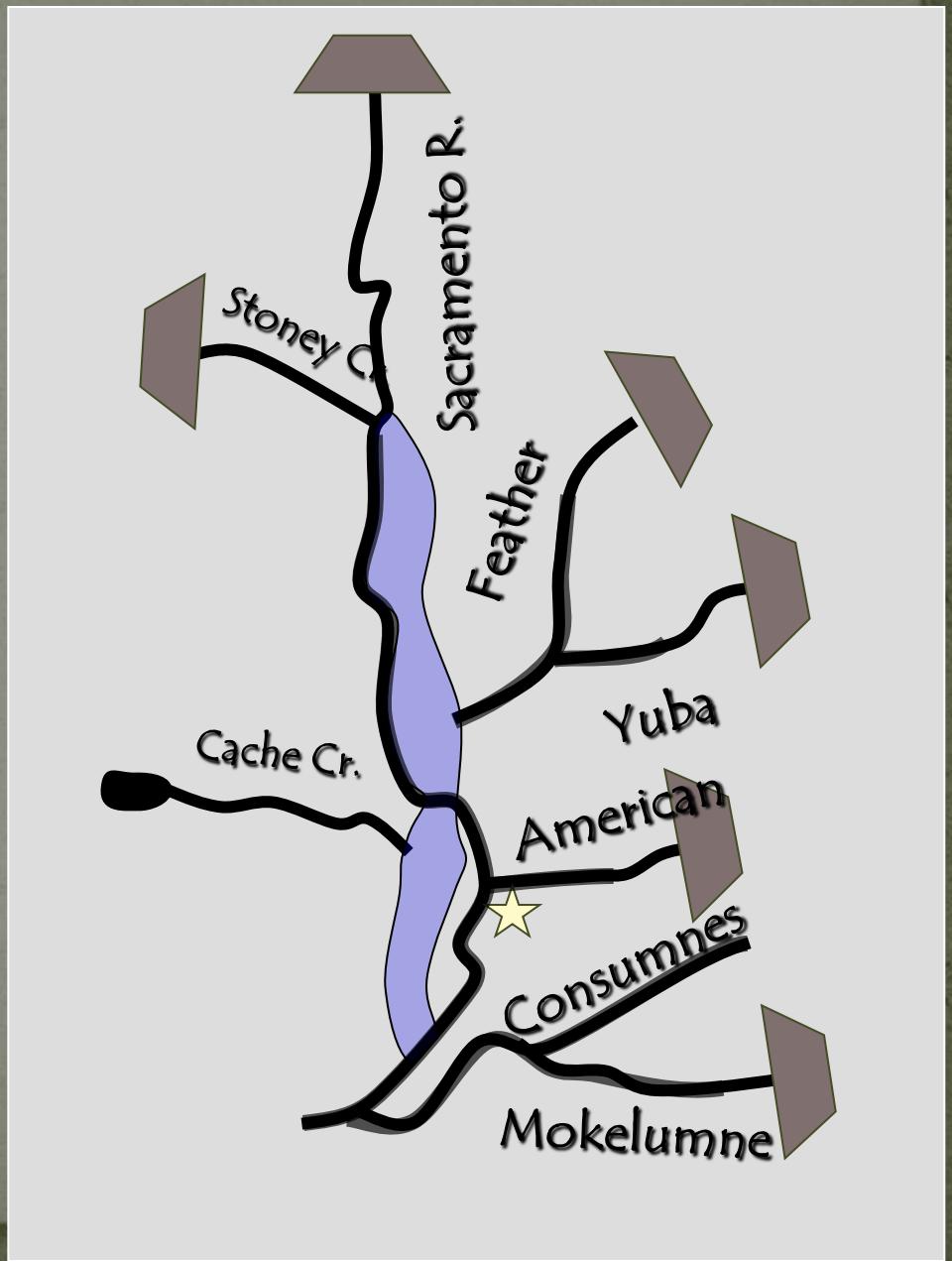
Rivers of the Sacramento Valley



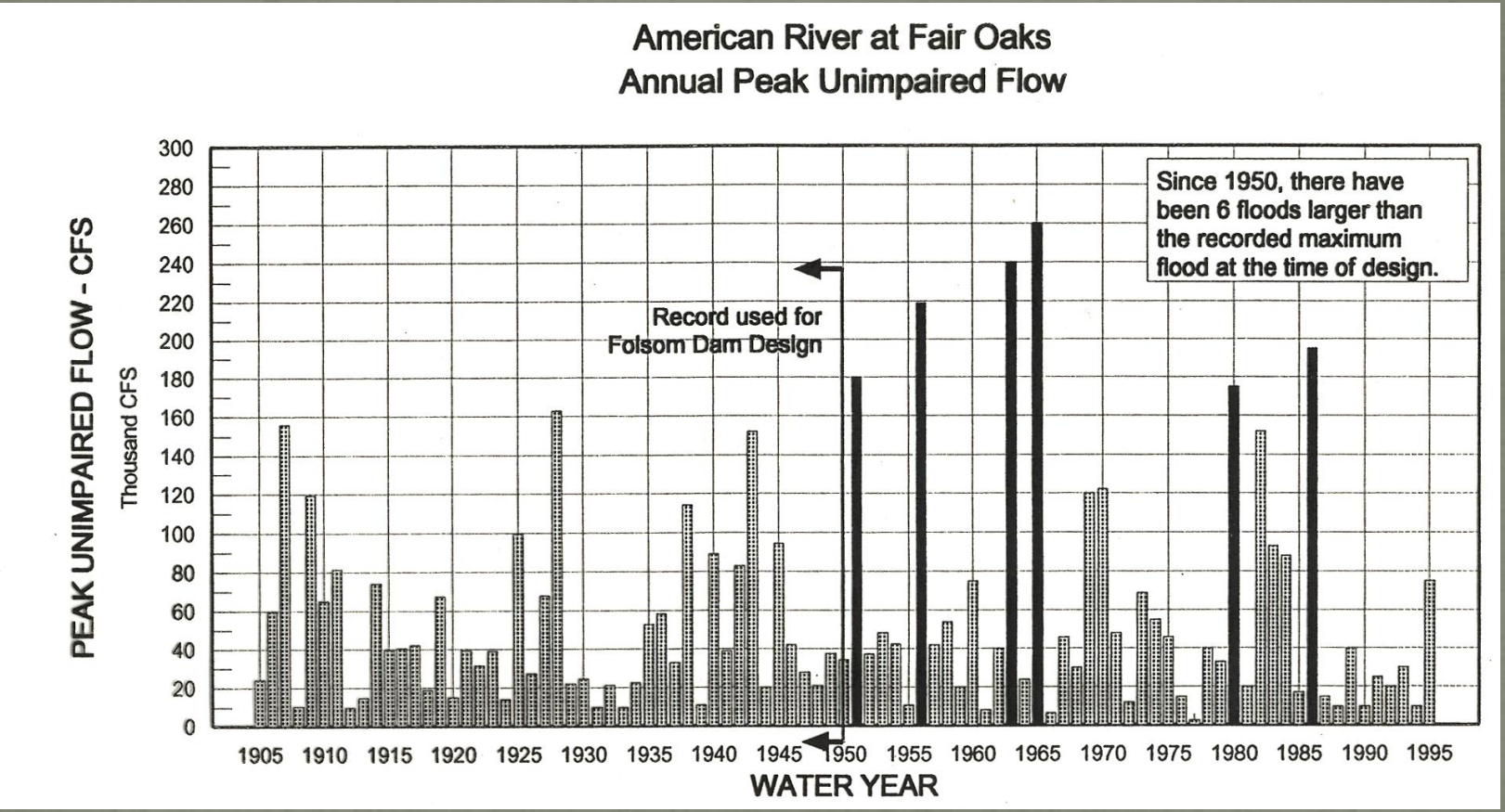
- Sacramento
- Feather
- Yuba
- American
- Consumnes
- Mulkemne
- Stoney Cr.
- Cache Cr.

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?



Cosumnes River Levee Break

Levee Breaks along Dry Creek in Rio Linda

What should be done about to increase flood protection?

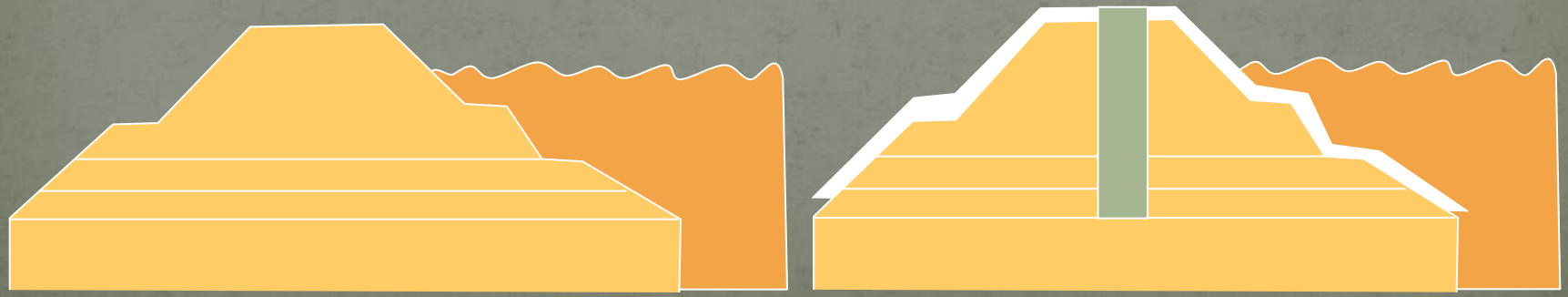
- Auburn Dam
  - Proposed in 1960s
  - Environmental opposition
  - Recently active fault mapped at dam site
- Raise and strengthen levees
- Raise Folsom Dam
- Increase spillways on Folsom Dam

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