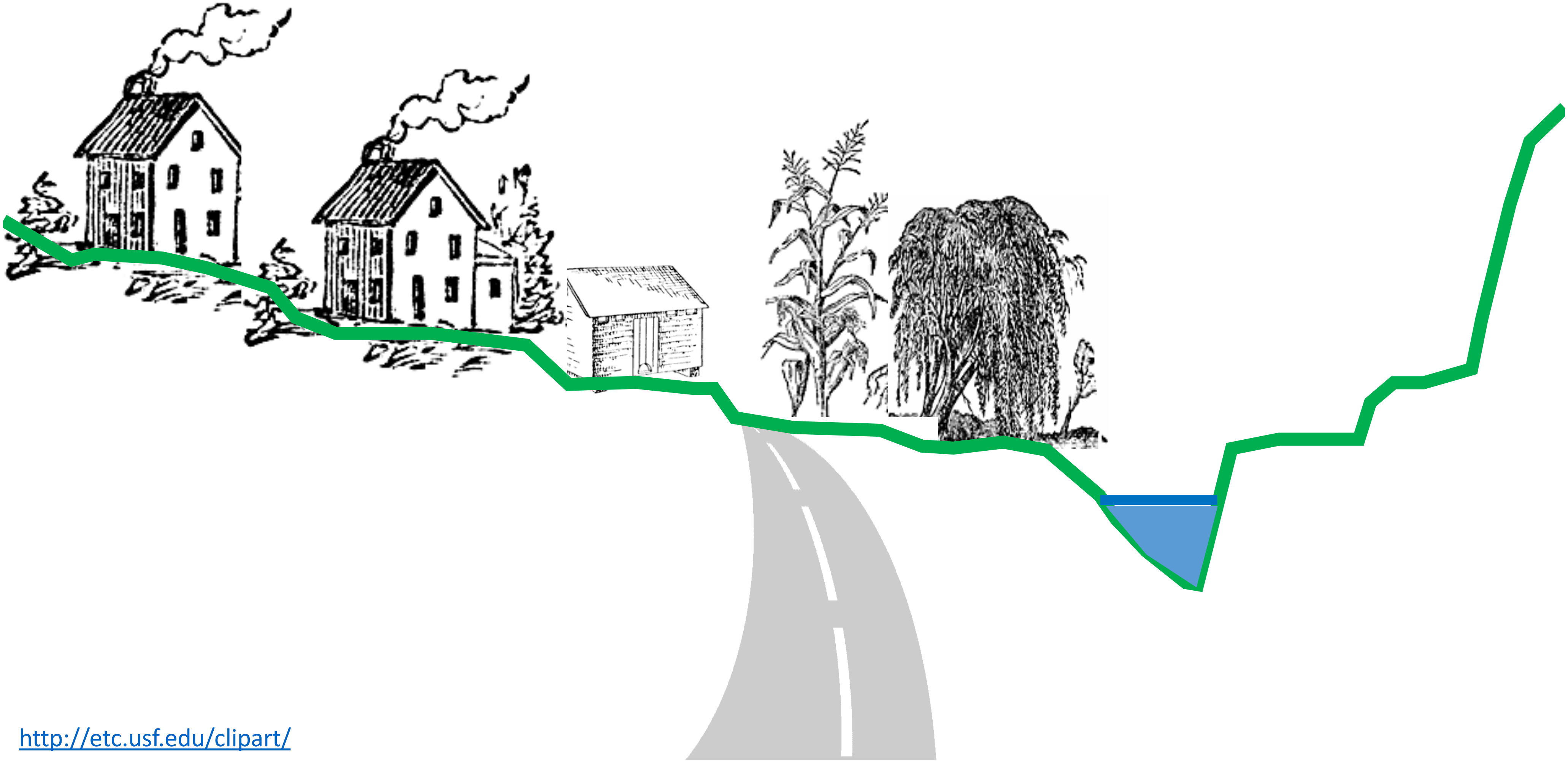
What is a flood?

What is flood frequency?

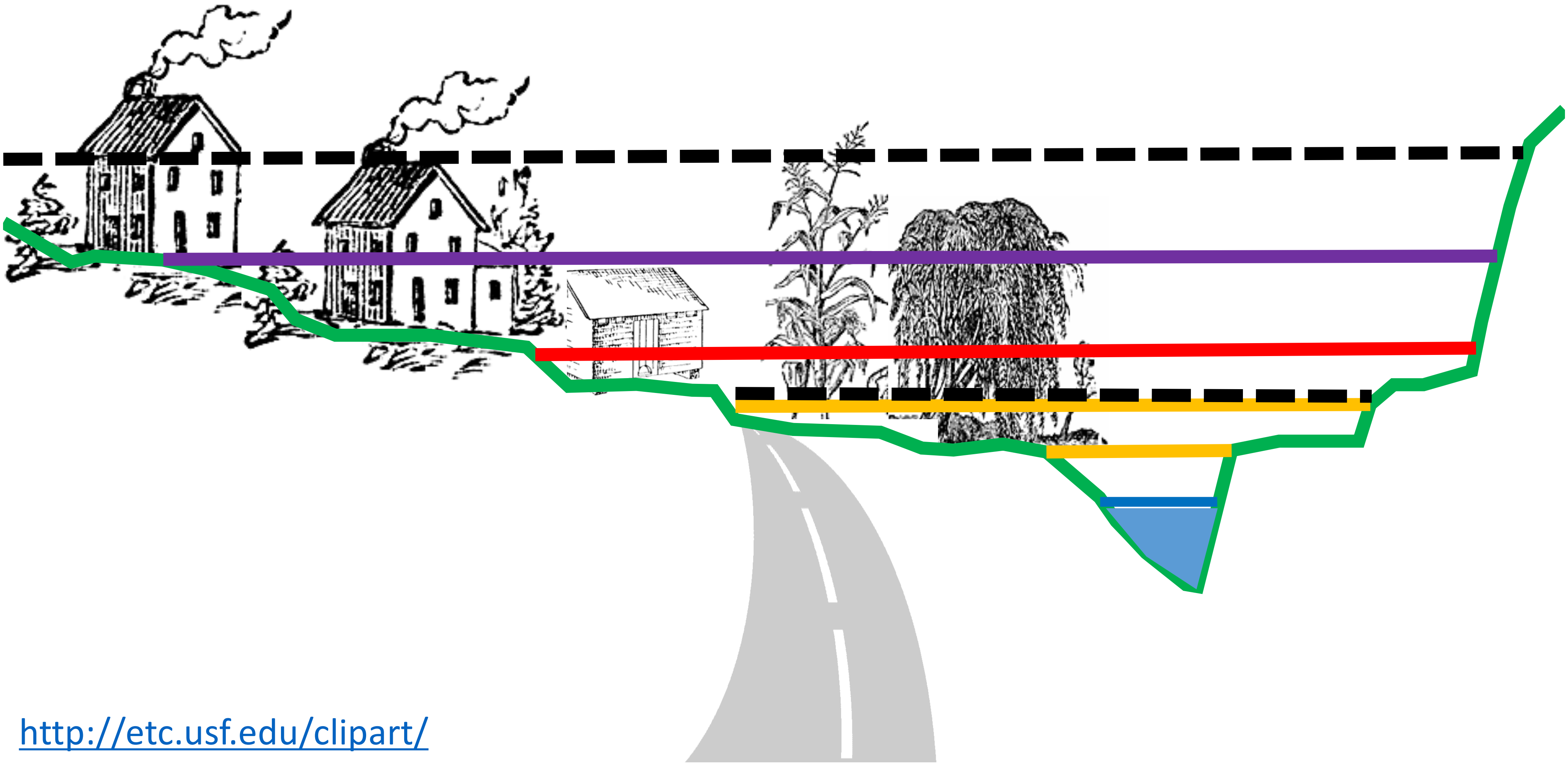


http://etc.usf.edu/clipart/

What is a flood?

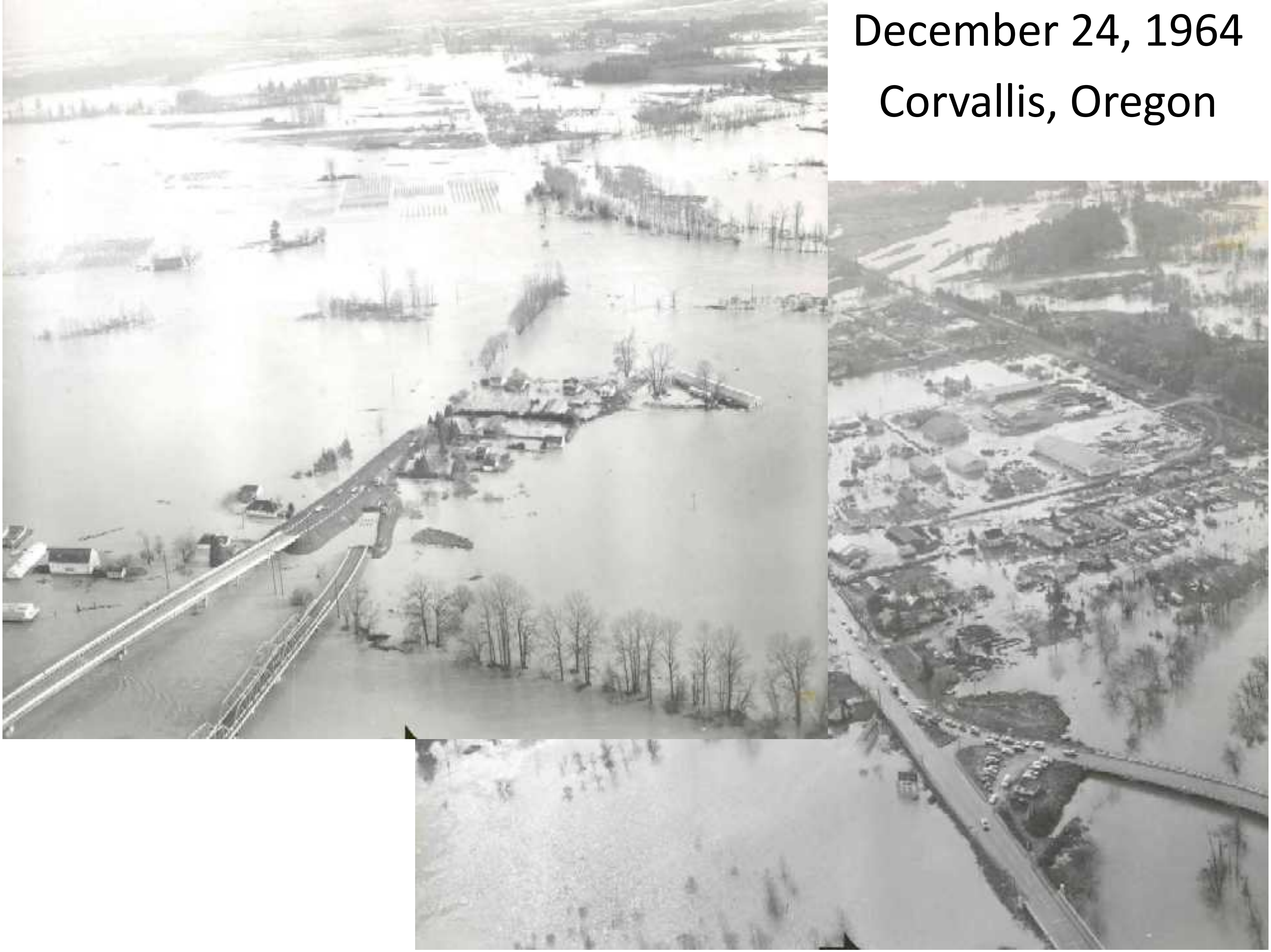
A moderate flood? A major flood? The record flood?

These criteria come from the National Weather Service.



http://etc.usf.edu/clipart/

December 24, 1964
Corvallis, Oregon



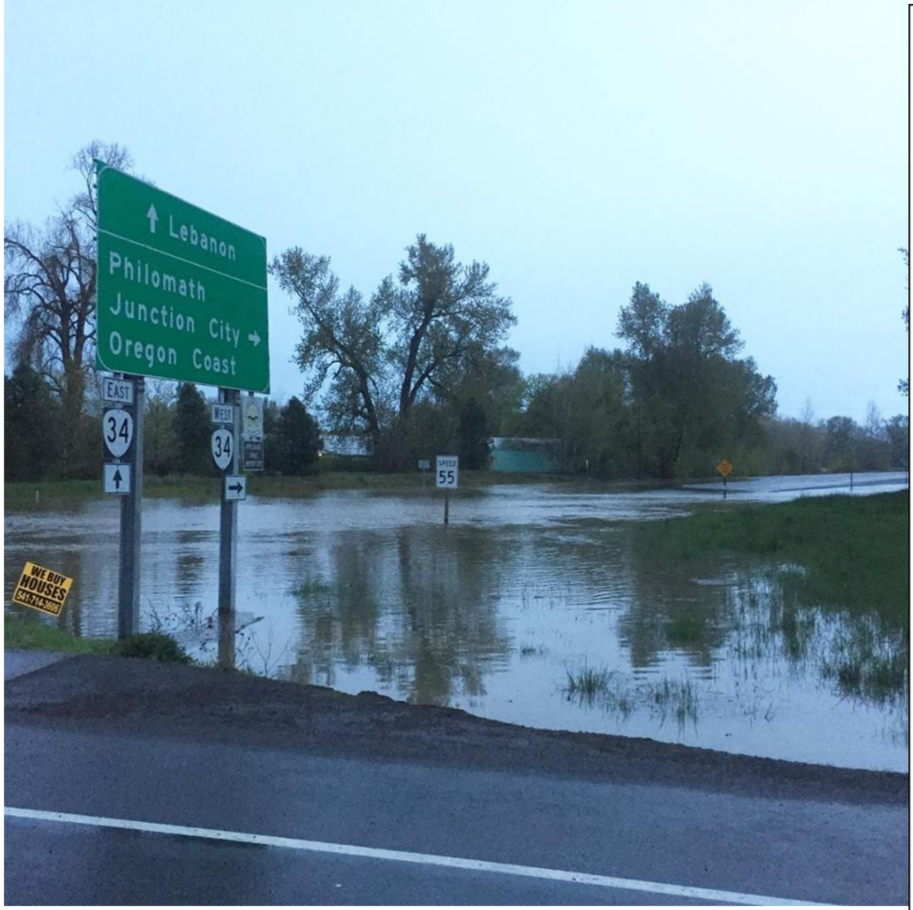
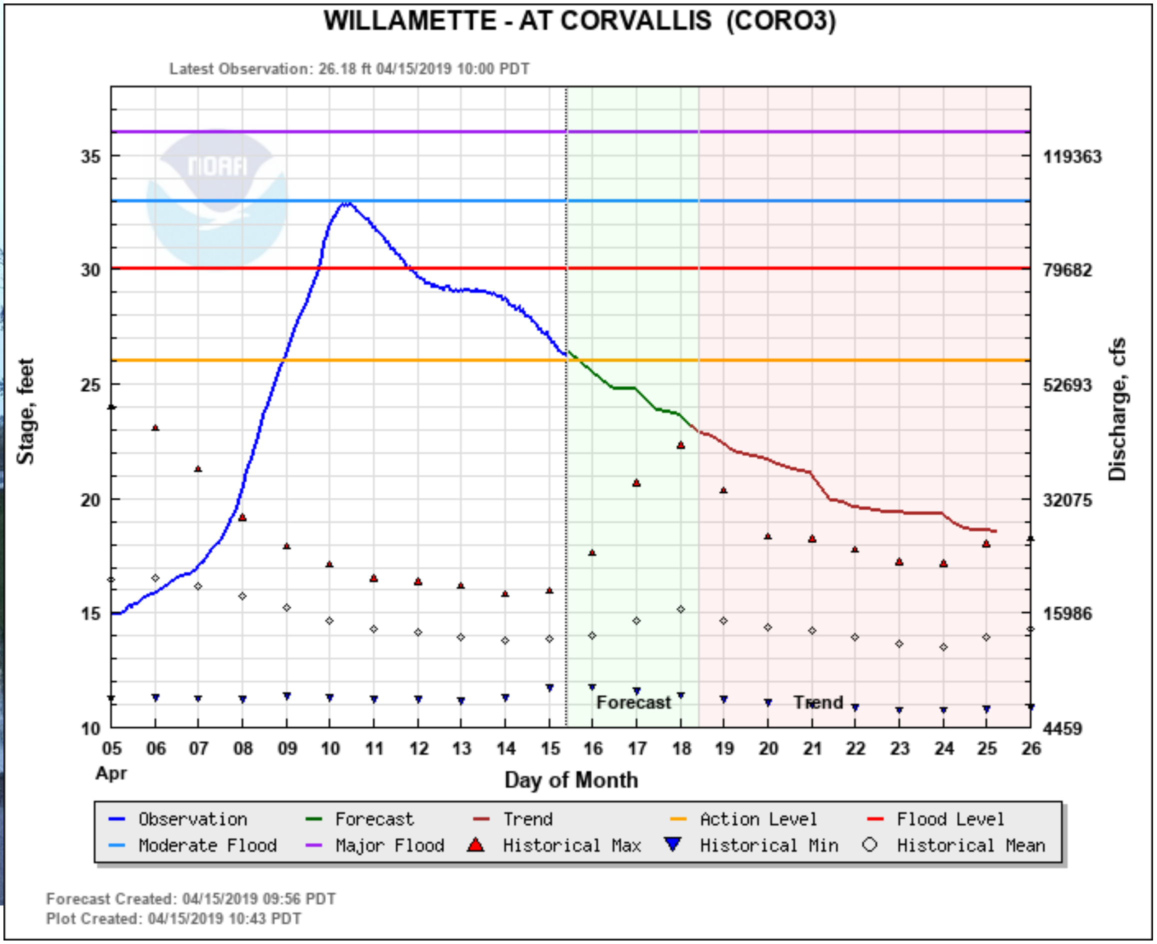
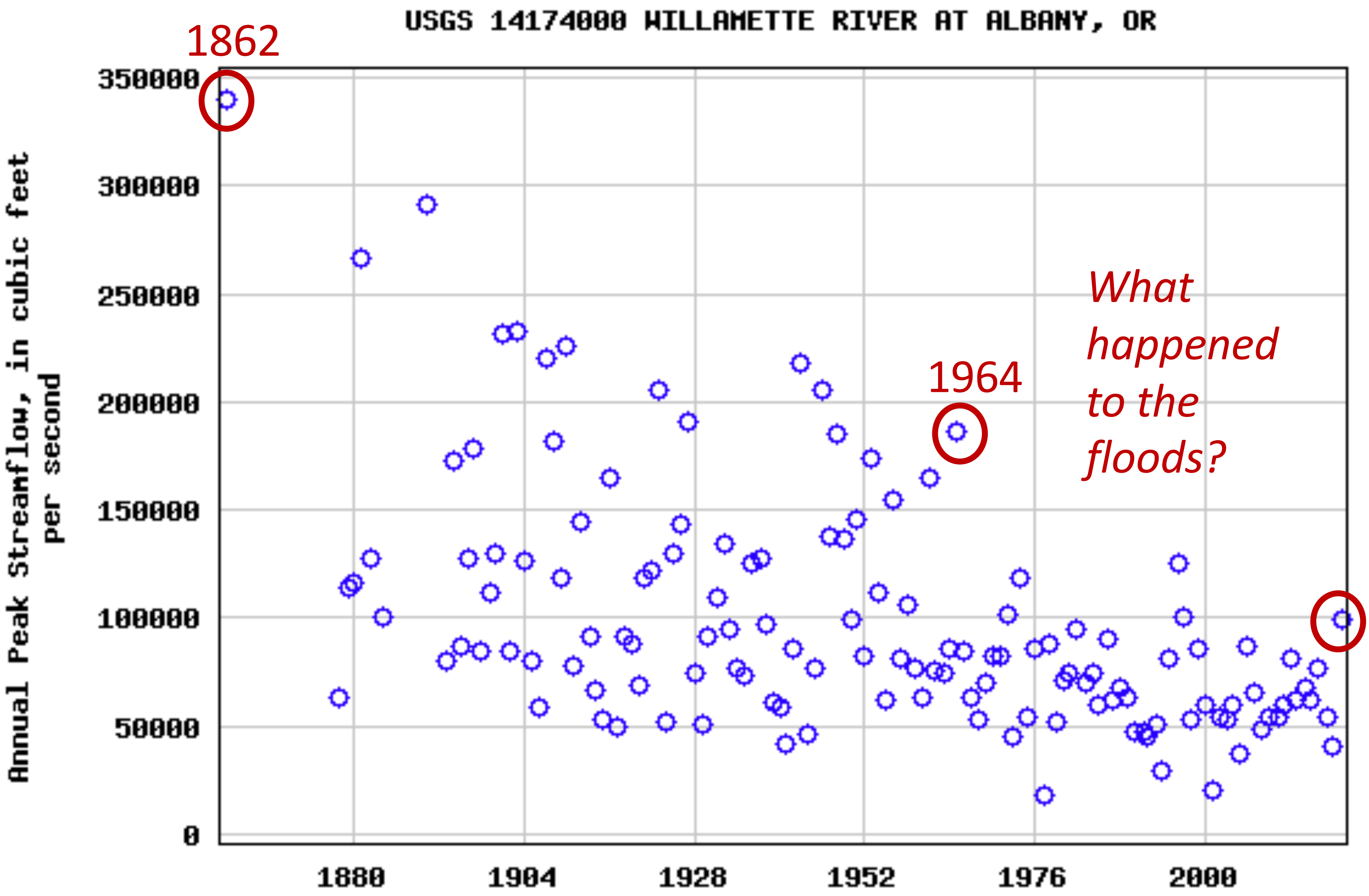


Photo by Sarah Lewis



April 10, 2019
(Willamette River at moderate flood stage)



What happened to the floods?

January 2012: Flooding on rivers and streams tributary to the Willamette River

Benton County declared disaster area

by Jeff Thompson, KGW.com Staff

Posted on January 19, 2012 at 2:02 PM
Updated today at 6:54 AM

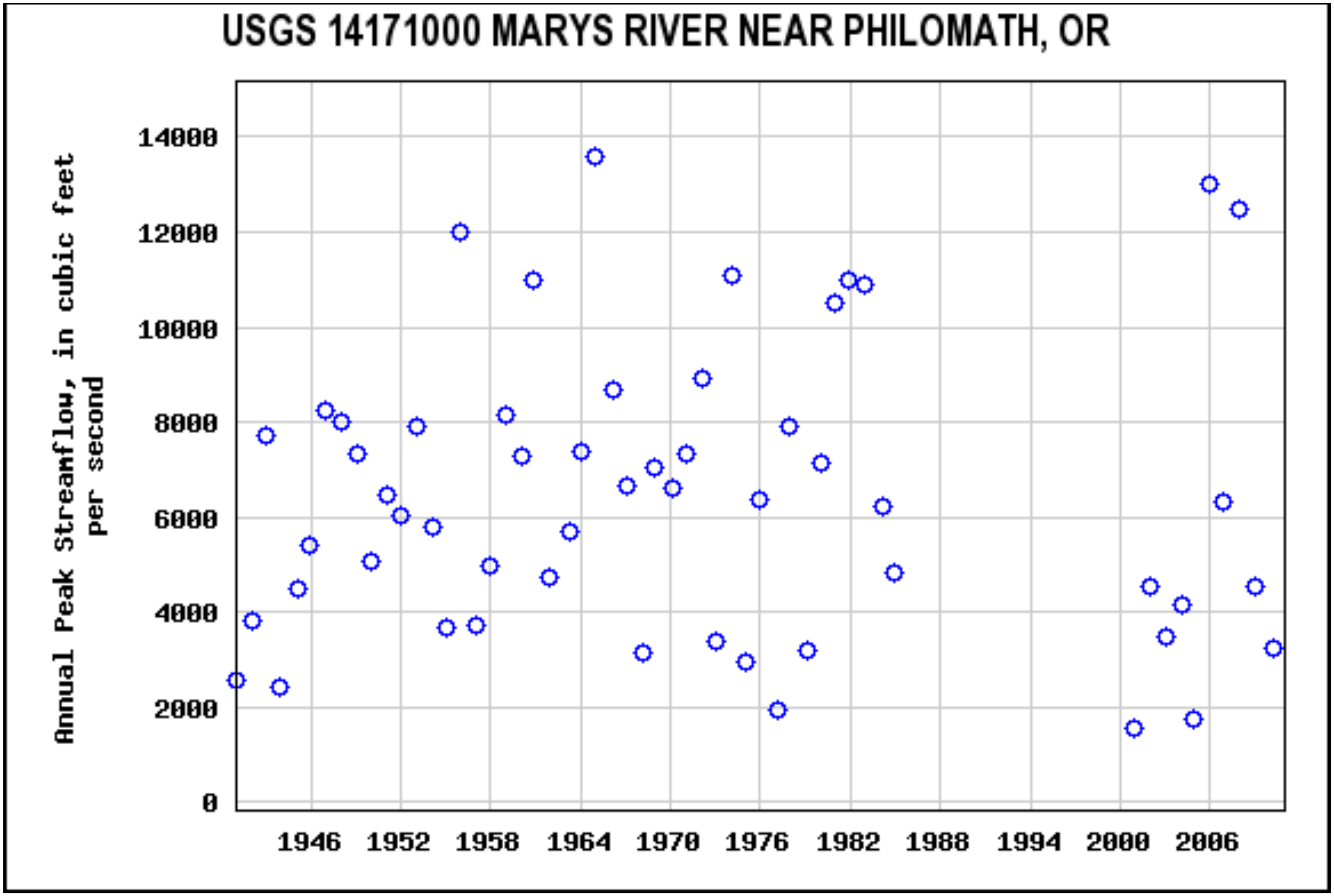
CORVALLIS, Ore. -- Corvallis and

Related:

Photo by R. Lewis, Jan. 18, 2012, flow = 11,700 cfs

Mary’s River near Philomath peaked January 19, 2012, 12:30 pm:
Discharge >13,400 cubic feet/second
How likely was this size flood?

Historical flood records



Annual Peak Streamflow = Based on USGS records of instantaneous peak discharge in a water year

Flood Frequency Analysis

What is the probability of a flood getting that big?

“How often can we expect a flood that big?”

Use historical record to assign probability

$$P = m / n + 1$$

P = probability of exceeding
n = number of data points
m = rank of event

Important questions to ask: Independent and random? Climate change? Land use change? Dams? Multiple causes? Reliability of flow estimates?

Mary’s River Flood Frequency Analysis

Water Year	Discharge (ft^3/s)
2001	1550
2002	4550
2003	3490
2004	4160
2005	1760
2006	13000
2007	6320
2008	12500
2009	4520
2010	3250

Photo by R. Lewis, Jan. 18, 2012, flow = 11,700 cfs

1. Rank (biggest = 1)
2. Apply formula:

$$P = m / n + 1$$

Flood Frequency vs. Recurrence

Discharge (ft^3/s)	m	P	RI (years)
13000	1	0.09	11.0
12500	2	0.18	5.5
6320	3	0.27	3.7
4550	4	0.36	2.8
4520	5	0.45	2.2
4160	6	0.55	1.8
3490	7	0.64	1.6
3250	8	0.73	1.4
1760	9	0.82	1.2
1550	10	0.91	1.1

"100 year flood"

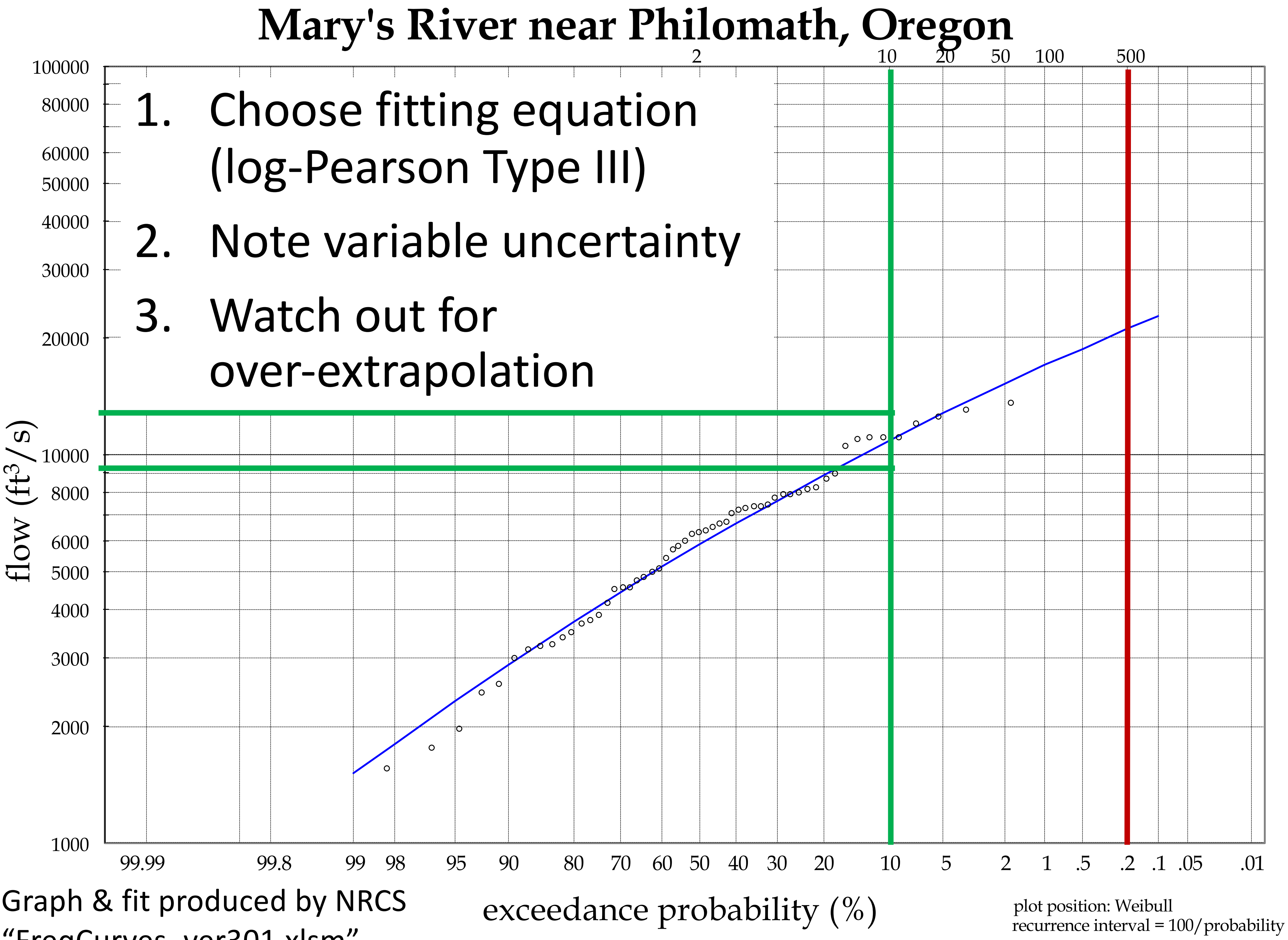
Recurrence Interval

RI = 1/P

average time interval within which a flood of a given size will occur.

NOT a return period.

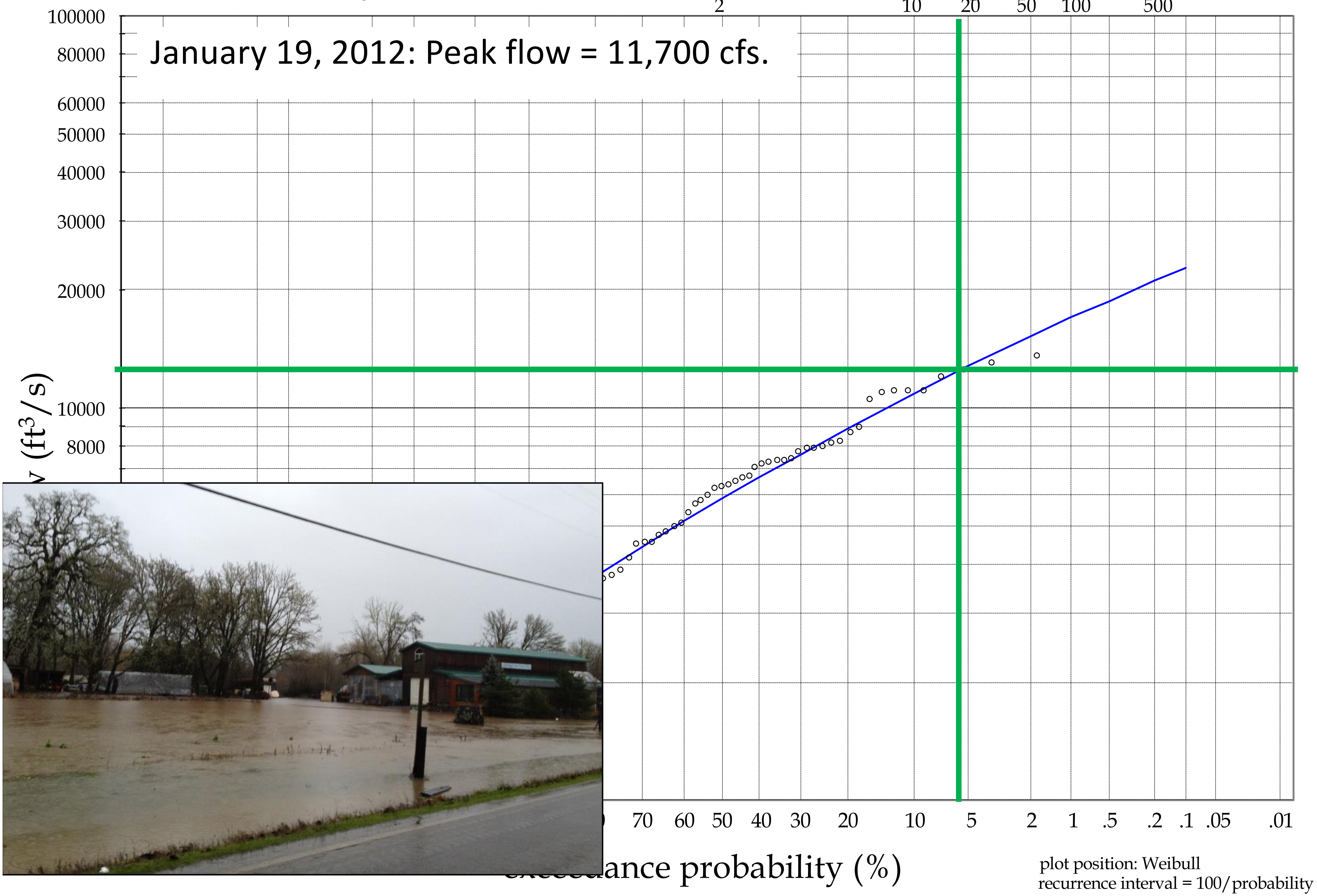
Why you can get a 500-year flood two years in a row: http://all-geo.org/highlyallochthonous/2008/06/why-you-can-get-500-year-floods-two-years-in-a-row/



1. Choose fitting equation (log-Pearson Type III)
2. Note variable uncertainty
3. Watch out for over-extrapolation

Graph & fit produced by NRCS “FreqCurves_ver301.xlsm”

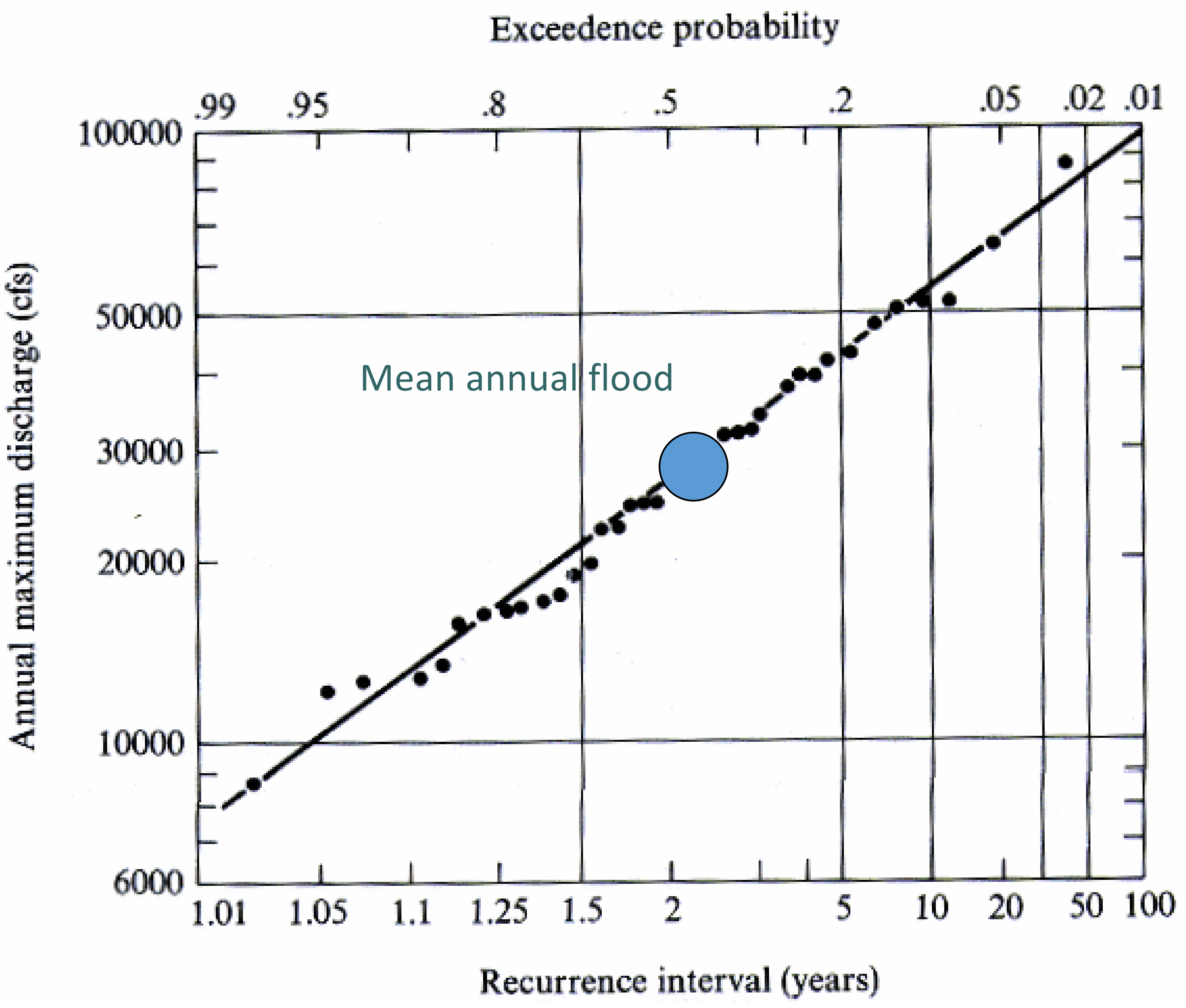
Mary's River near Philomath, Oregon



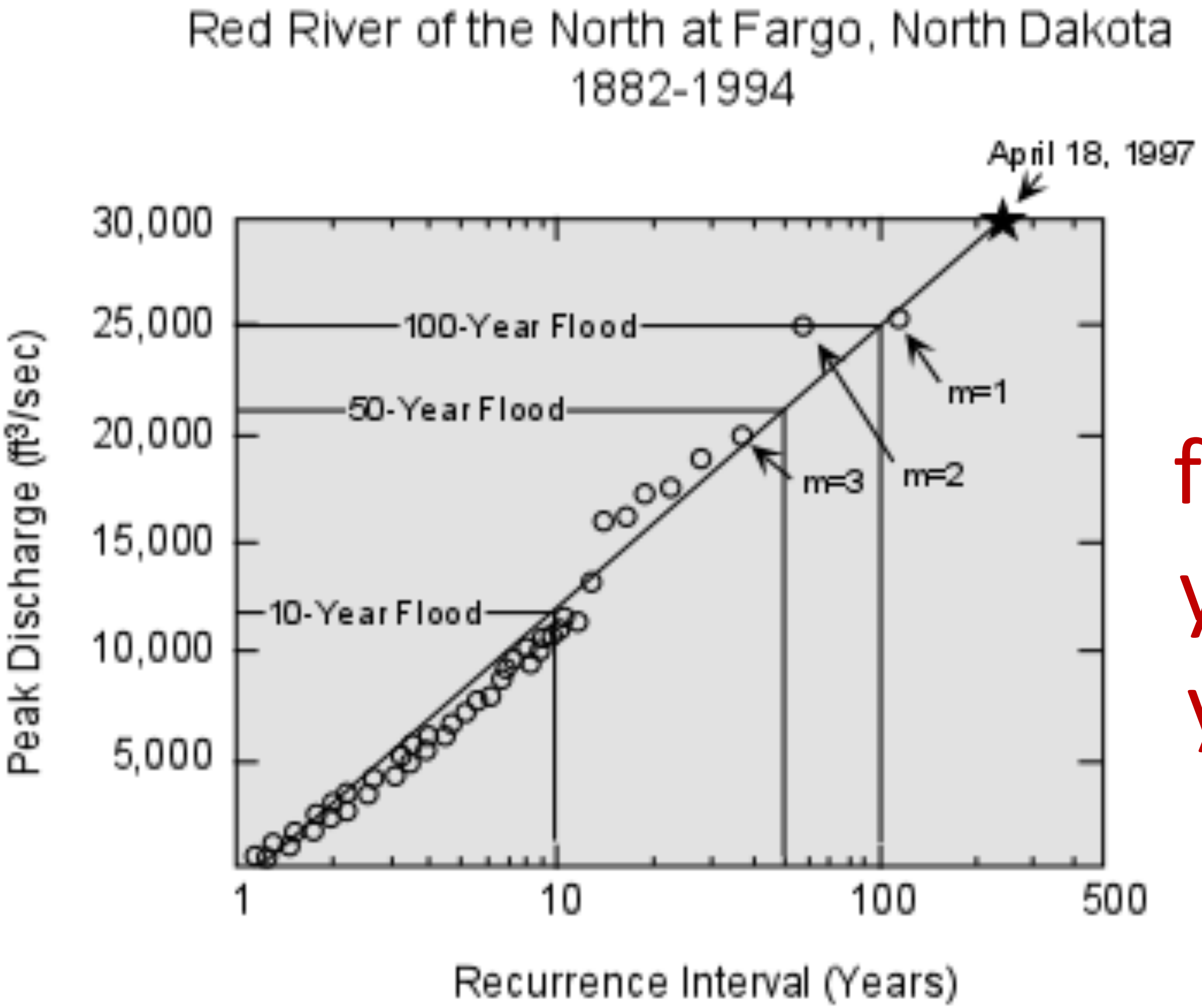
January 19, 2012: Peak flow = 11,700 cfs.

plot position: Weibull
recurrence interval = 100/probability

Photo by R. Lewis, Jan. 18, 2012, flow = 11,700 cfs



The mean annual flood is the arithmetic mean of all annual maximum discharges. Generally has RI of 2.33 years.


Red River of the North at Fargo, North Dakota
1882-1994

Large floods force you to redo your math!

Aerial view of flooding in Grand Forks, ND in 1997

US Army Corps of Engineers photo

For more on flooding on the Red River of the North: http://all-geo.org/highlyallochthonous/2011/04/why-does-the-red-river-of-the-north-have-so-many-floods/

How will flood frequency analysis fare with climate change?

POLICYFORUM

CLIMATE CHANGE

Stationarity Is Dead: Whither Water Management?

Climate change undermines a basic assumption that historically has facilitated management of water supplies, demands, and risks.

P. C. D. Milly,[1]* Julio Betancourt,[2] Malin Falkenmark,[3] Robert M. Hirsch,[4] Zbigniew W. Kundzewicz,[5] Dennis P. Lettenmaier,[6] Ronald J. Stouffer[7]

Systems for management of water throughout the developed world have been designed and operated under the assumption of stationarity. Stationarity—the idea that natural systems fluctuate within an unchanging envelope of variability—is a foundational concept that permeates training and practice in water-resource engineering. It implies that any variable (e.g., annual streamflow or annual flood peak) has a time-invariant (or 1-year–periodic) probability density function (pdf), whose properties can be estimated from the instrument record. Under stationarity, pdf estimation errors are acknowledged, but have been assumed to be reducible by additional observations, more efficient estimators, or regional or paleohydrologic data. The pdfs, in turn, are used to evaluate and manage risks to water supplies, waterworks, and floodplains; annual global investment in water infrastructure exceeds U.S.$500 billion (*1*).

The stationarity assumption has long been compromised by human disturbances in river basins. Flood risk, water supply, and

An uncertain future challenges water planners.

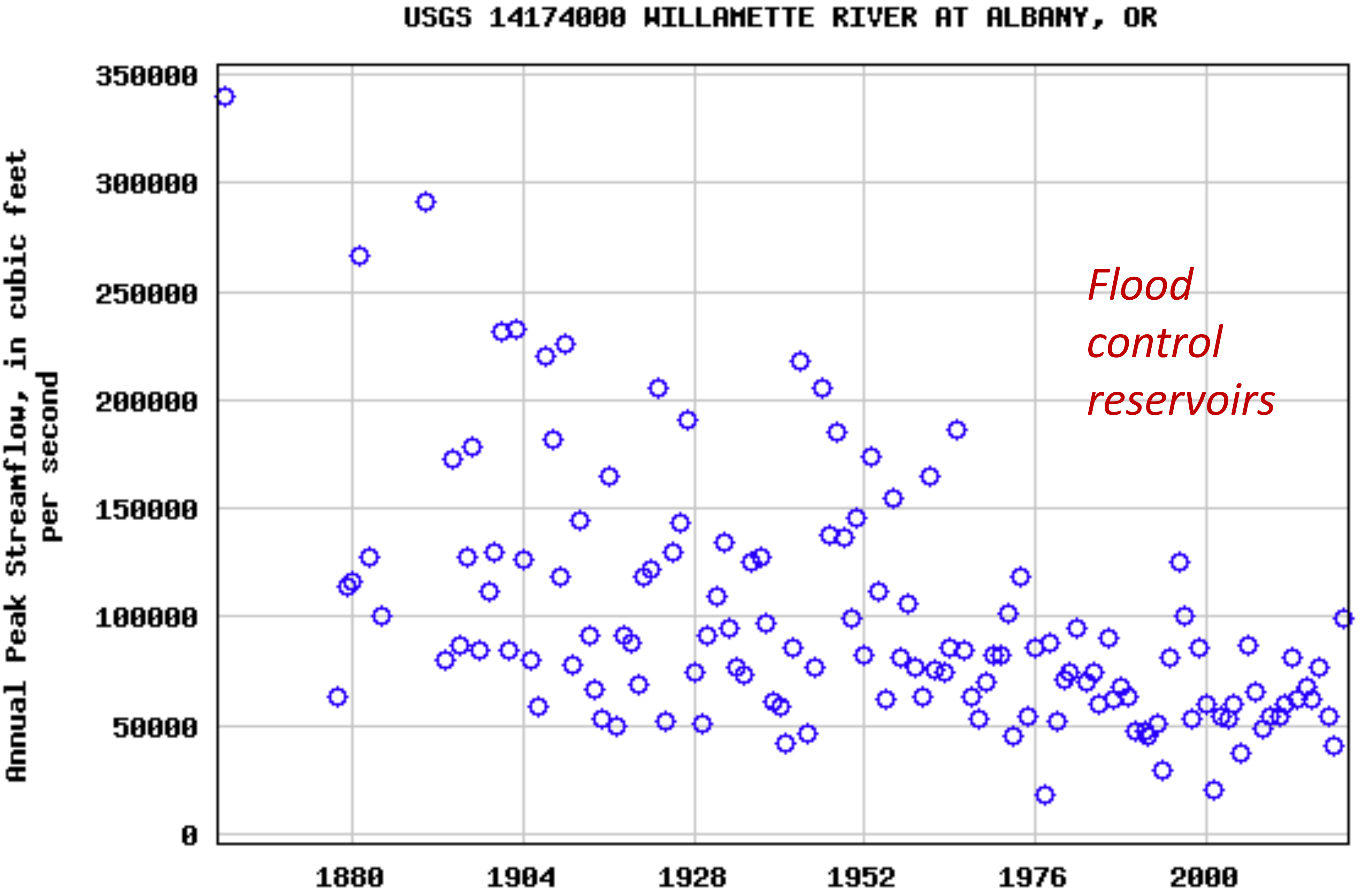
In view of the magnitude and ubiquity of the hydroclimatic change apparently now under way, however, we assert that stationarity is dead and should no longer serve as a central, default assumption in water-resource risk

that has emerged from climate models (see figure, p. 574).

Why now? That anthropogenic climate change affects the water cycle (*9*) and water supply (*10*) is not a new finding. Nevertheless, sensible objections to discarding stationarity have been raised. For a time, hydroclimate had not demonstrably exited the envelope of natural variability and/or the effective range of optimally operated infrastructure (*11*, *12*). Accounting for the substantial uncertainties of climatic parameters estimated from short records (*13*) effectively hedged against small climate changes. Additionally, climate projections were not considered credible (*12*, *14*).

Recent developments have led us to the opinion that the time has come to move beyond the wait-and-see approach. Projections of runoff changes are bolstered by the recently demonstrated retrodictive skill of climate models. The global pattern of observed annual streamflow trends is unlikely to have arisen from unforced variability and is consistent with modeled response to climate forcing (*15*). Paleohydrologic studies suggest that

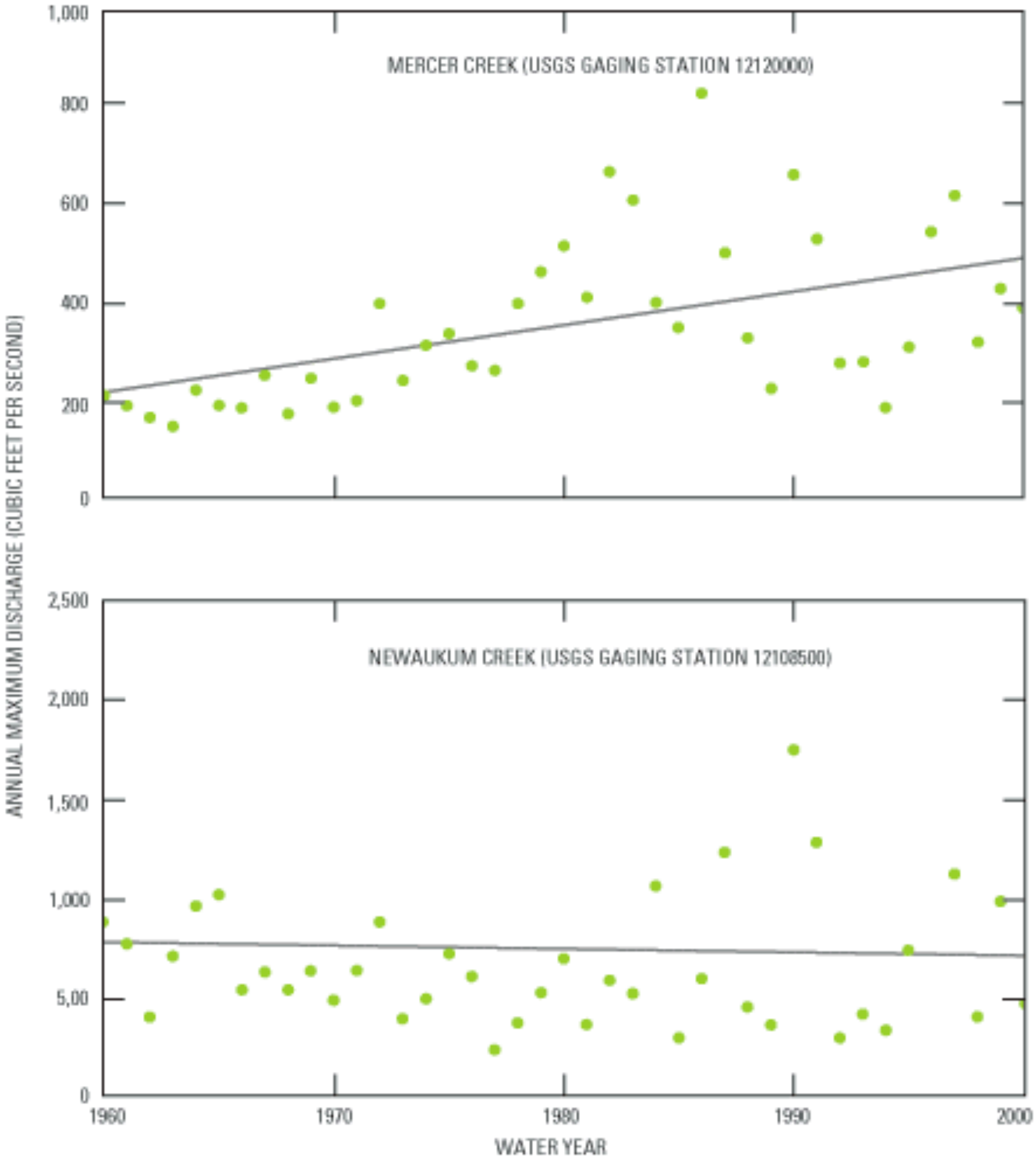
Non-stationarity: Flood control Dams



Non-stationarity: Urbanization

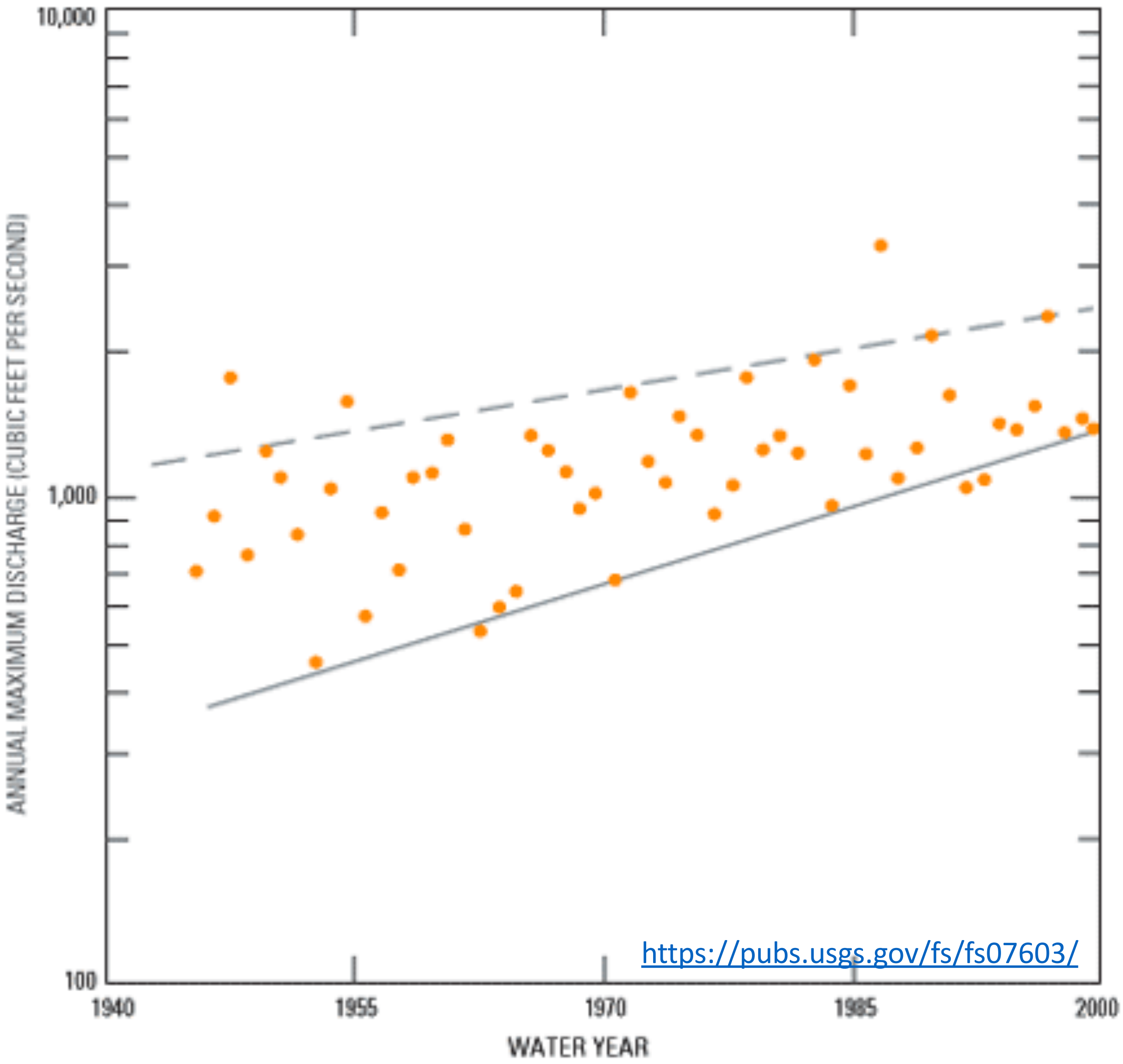
- Peak flows tend to be higher in urban watersheds. *Why?*

- If watersheds urbanize during the streamgage record, the data are not stationary.



https://pubs.usgs.gov/fs/fs07603/

Non-stationarity: Urbanization



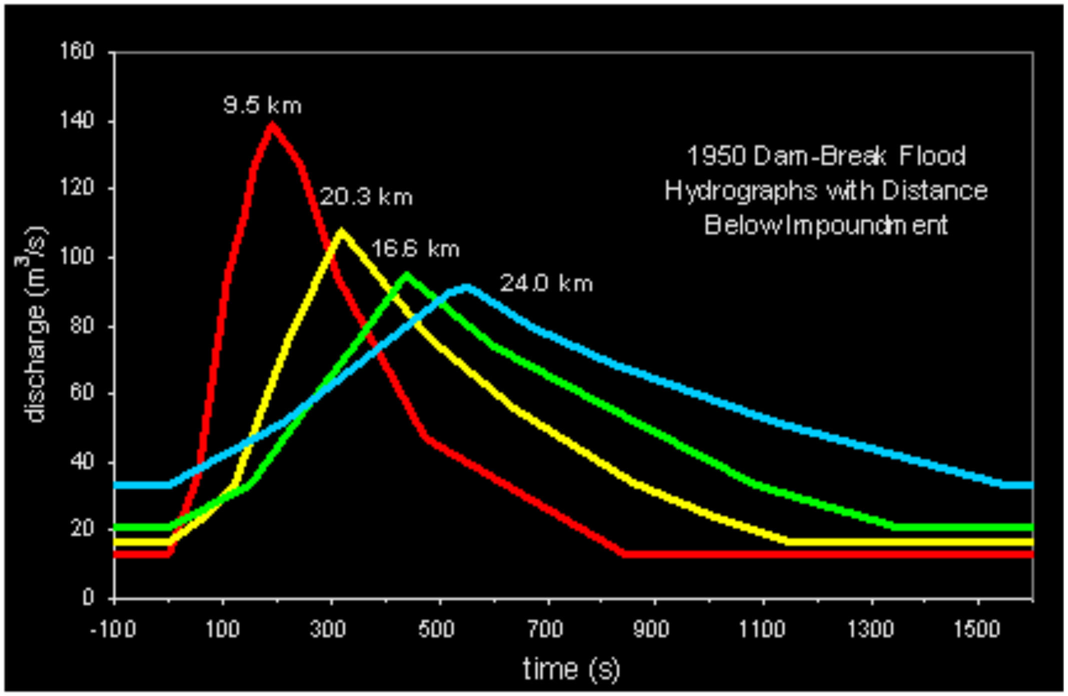
https://pubs.usgs.gov/fs/fs07603/

- Urbanization tends to cause bigger increases in small floods than large floods.
- *Why?*

For more on urbanization and flooding during Hurricane Harvey: http://all-geo.org/highlyallochthonous/2017/09/hurricane-harvey-and-the-houston-flood-did-humans-make-it-worse-part-2-urbanization/

Flood wave transmission

- Translation = wave moves downstream without any change in shape
- Reservoir action = smears out flood wave with temporary storage in channel and valley bottom



Marcus, W.A., Meyer, G.A., Nimmo, D.R., 2001, Geomorphic control of persistent mine impacts in a Yellowstone Park stream and implications for the recovery of fluvial systems: *Geology*, v. 29, no. 4, p. 355-358

- Tributary inflows may not match in timing
- Infiltration loss in arid regions

Large rivers have lower*, longer floods than headwater streams.

*smaller unit Q

What do we do when we don’t have a useable streamgage record for flood frequency analysis?

- Regionalize from the gages we do have
- Use hydrologic and hydraulic models to simulate future flood flows
- Use indirect methods to measure
  floods after they occur