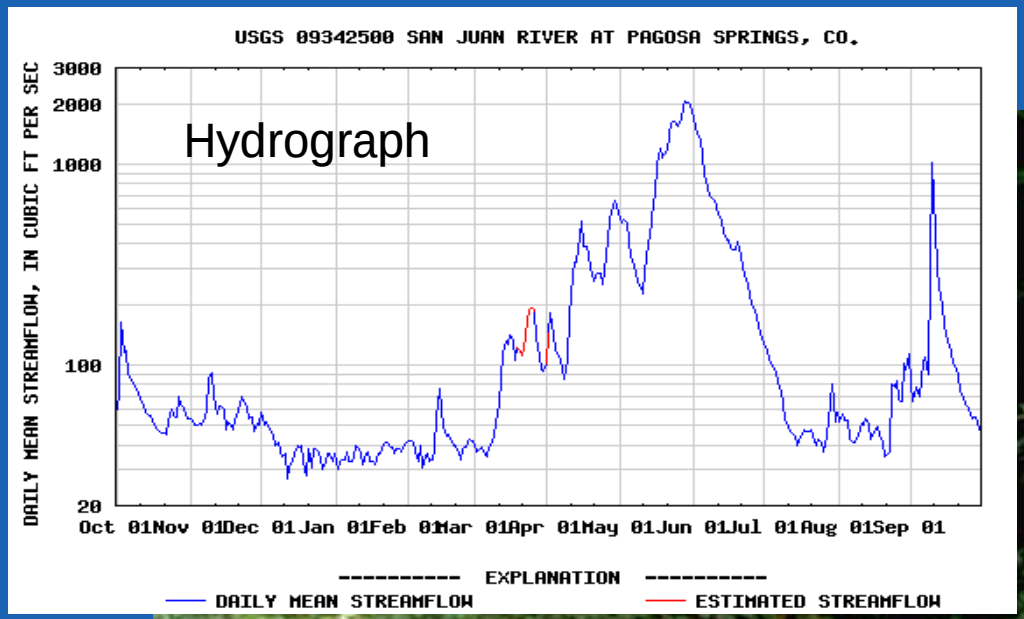
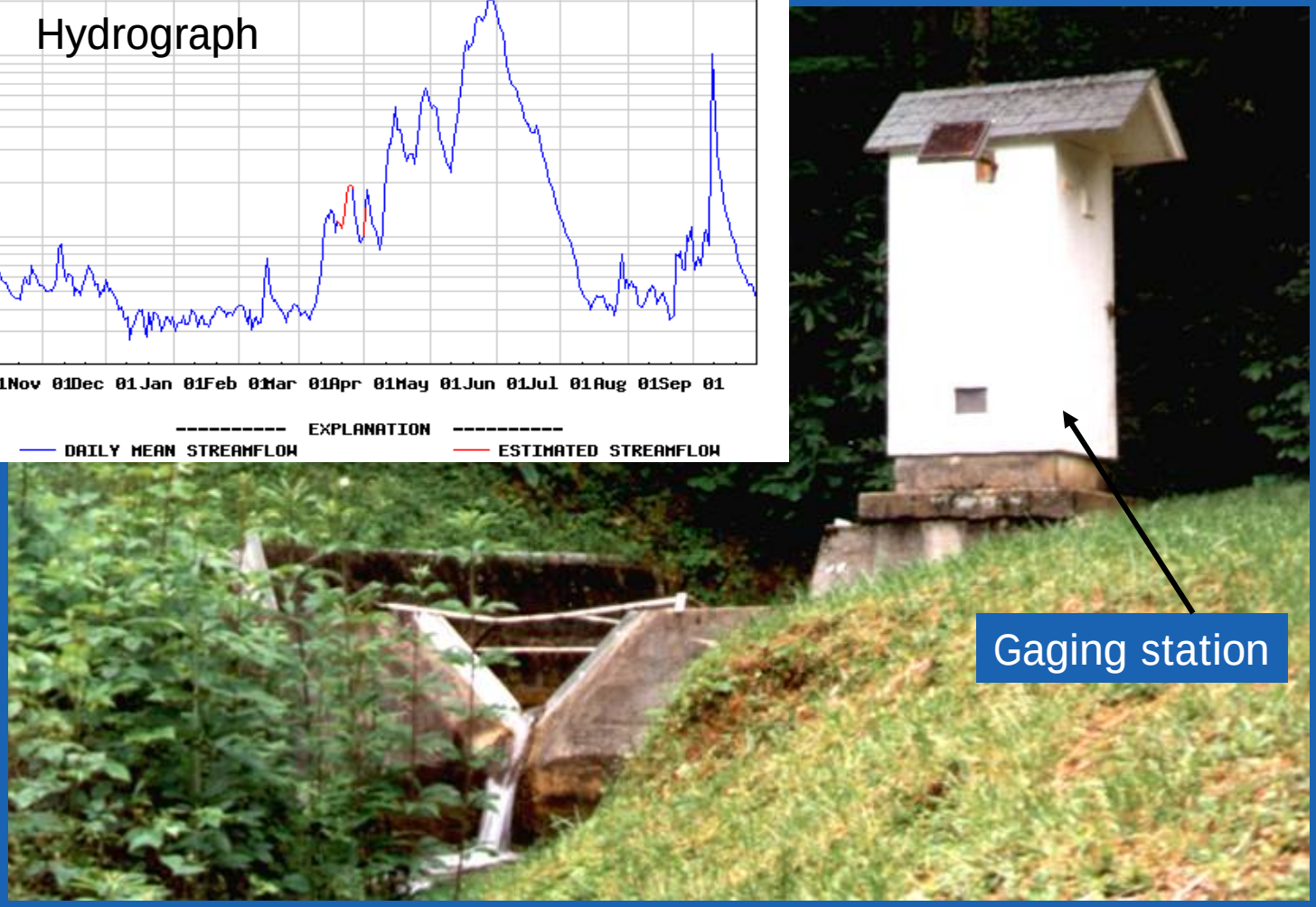
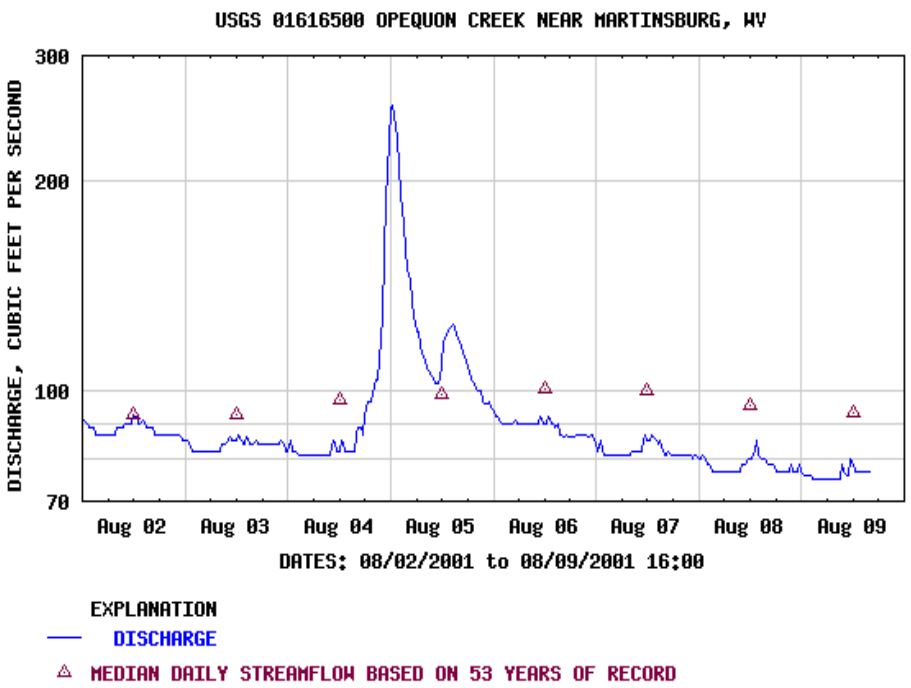

USGS 09342500 SAN JUAN RIVER AT PAGOSA SPRINGS, CO.
Hydrograph
DAILY MEAN STREAMFLOW, IN CUBIC FT PER SEC
3000
2000
1000
100
20
Oct 01
Nov 01
Dec 01
Jan 01
Feb 01
Mar 01
Apr 01
May 01
Jun 01
Jul 01
Aug 01
Sep 01
---------- EXPLANATION ----------
DAILY MEAN STREAMFLOW
ESTIMATED STREAMFLOW


Gaging station

Hydrology

Hydrology Definition

- the patterns of a river's flow on a daily, seasonal, yearly, or multiple-year time frame



Benefits of Hydrology Studies

- Stream classification by hydrologic characteristics
- Characterizing disturbance and the effects on stream ecology (stochastic vs. deterministic, fish spawning patterns, habitat type and availability, etc.)
- Assessing effects of projects on the stream system geomorphology and ecology (e.g., *Indicators of Hydrologic Alteration* software by The Nature Conservancy)
- Flood forecasting

Gaging Stations are Used to Characterize the Long-term Hydrology of a Stream

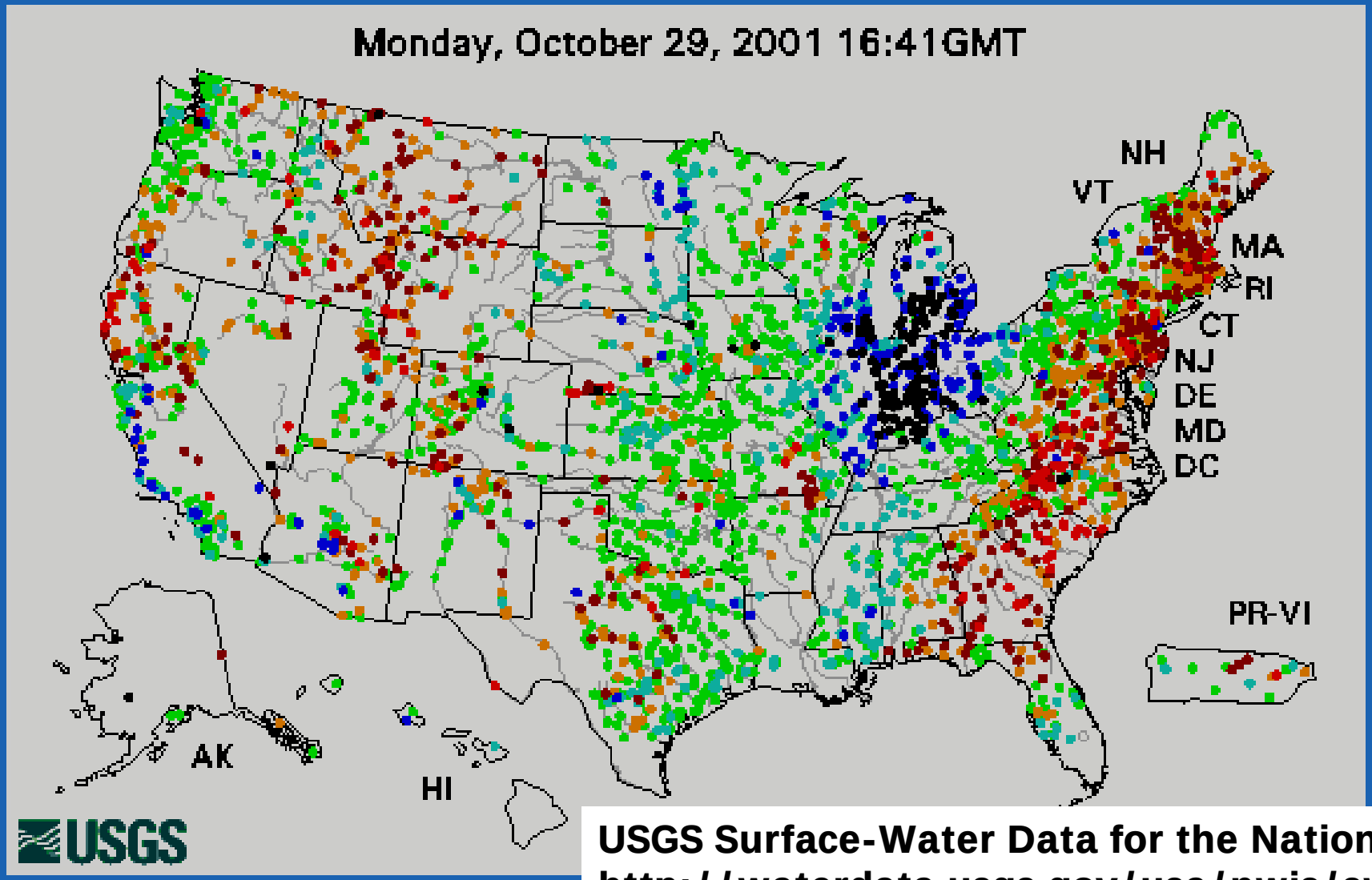
The way a stream gage works-

- The data most often collected are "stage" data. Stage is the height of the water surface above a reference elevation. The most common source of river stage measurement is a gage house.
- Although stage information is useful, it also is necessary to have discharge information about a stream. Discharge is the rate and volume of stream flow. It is usually estimated from stage/discharge relations known as **rating curves**, which are developed by the USGS by comparing field measurements of stage and discharge.

The USGS currently administers 7,725 stream discharge gages in the United States and Puerto Rico.

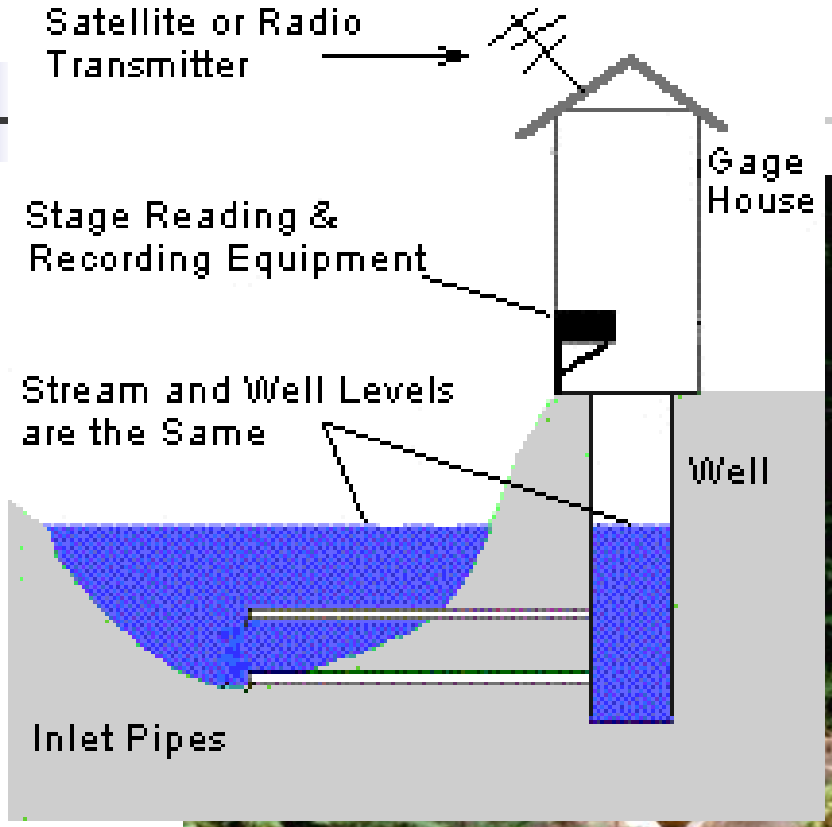
- Data for *selected sites* recorded at 5-60 min interval-- may include surface-water, ground-water, water-quality, and meteorological parameters.
- The data are relayed through the Geostationary Operational Environmental Satellite (GOES) system and is **available on the internet.**

USGS Gaging Stations



USGS Surface-Water Data for the Nation
http://waterdata.usgs.gov/usa/nwis/sw

Gaging Station Components



Gage House

Stage Reading & Recording Equipment

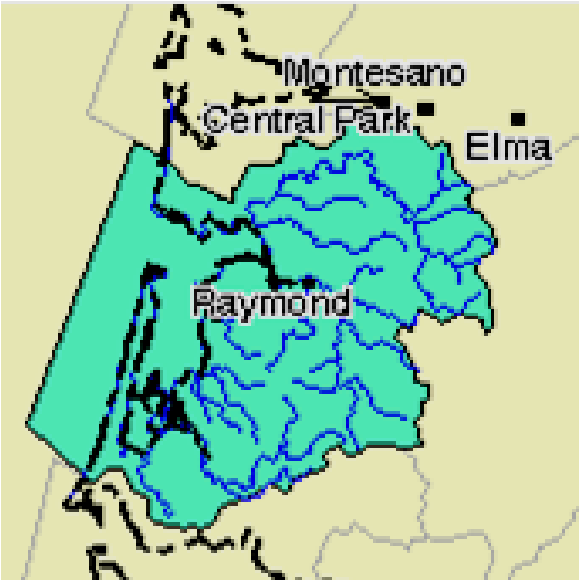
Staff Plate

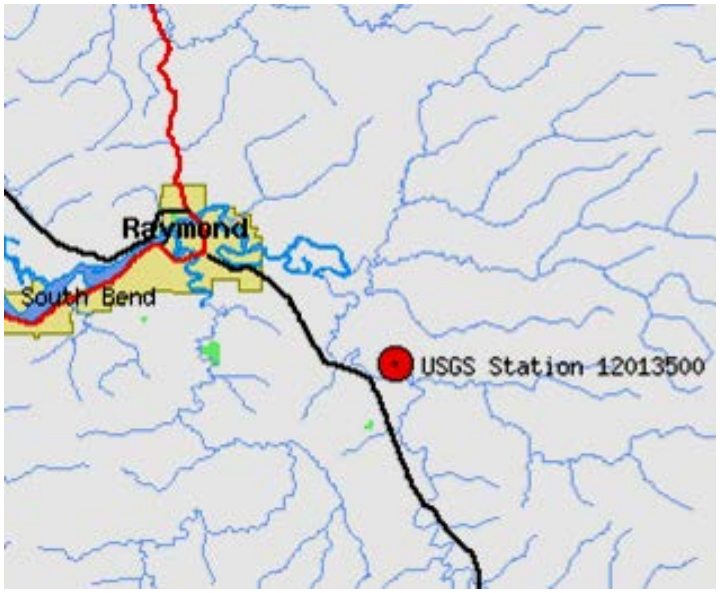
Discharge (Q) Cross-section

Willapa River

@ Willapa, WA

Station # 12013500





Station name: WILLAPA RIVER NR WILLAPA

Latitude (degrees, minutes, and seconds)..... ...463904
Longitude (degrees, minutes, and seconds)..... 1233905
State ..... Washington
County ....Pacific
Hydrologic Unit Code..... 17100106
Drainage Area (square miles)..... .....130.00
Gage Datum (feet above National Geodetic Vertical
Datum)..... 3.57

----Period(s) of Record----
1 1947.08.26-1947.09.30
2 1948.08.01-1954.11.30
3 1961.04.01-Current

EXPANDED RATING TABLE TYPE: LOG

12013500
DATE PROCESSED: 04-26-1995 @ 14:24 BY LAFUSTE

WILLAPA RIVER NR WILLAPA, WA DD: 2 TYPE: 001 RATING NO: 19

OFFSET: 2.70 START DATE/TIME: 10-01-91 (0100)

BASED ON _____ DISCHARGE MEASUREMENTS, NOS _____, AND _____, AND IS _____ WELL DEFINED BETWEEN _____ AND _____ CFS

COMP BY _____ DATE _____ CHK. BY _____ DATE _____

EXTENDED TO 28.00 FT AFTER DEC 94 FLOOD

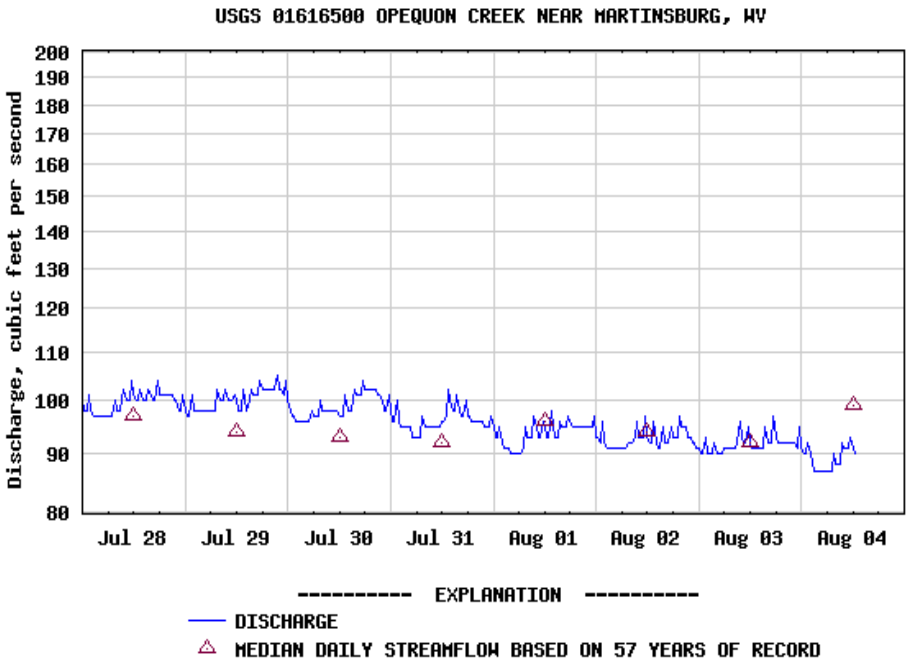
GAGE HEIGHT (FEET)	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09	DIFF IN Q PER TENTH FT
	DISCHARGE IN CUBIC FEET PER SECOND (EXPANDED PRECISION)										
2.90								15.00*	15.53	16.07	5.33
3.00	16.60*	17.18	17.76	18.34	18.92	19.50*	20.12	20.73	21.35	21.98	6.00
3.10	22.60*	23.29	23.99	24.69	25.39	26.10*	26.89	27.68	28.48	29.29	7.50
3.20	30.10*	30.98	31.88	32.78	33.68	34.60*	35.56	36.53	37.51	38.50	9.40
3.30	39.50*	40.51	41.53	42.56	43.60	44.64	45.70	46.76	47.83	48.91	10.50
3.40	50.00*	51.20	52.41	53.63	54.87	56.11	57.37	58.63	59.91	61.20	12.50
3.50	62.50*	63.76	65.03	66.30	67.59	68.88	70.19	71.50	72.83	74.16	13.00
3.60	75.50*	76.81	78.14	79.47	80.80	82.15	83.50	84.87	86.24	87.61	13.50
3.70	89.00*	90.46	91.93	93.40	94.89	96.39	97.89	99.40	100.9	102.5	15.00
3.80	104.0*	105.6	107.1	108.7	110.3	111.9	113.5	115.1	116.7	118.4	16.00
3.90	120.0*	121.7	123.3	125.0	126.7	128.4	130.1	131.8	133.5	135.3	17.00
4.00	137.0*	138.7	140.5	142.2	143.9	145.7	147.5	149.2	151.0	152.8	17.60
4.10	154.6	156.4	158.2	160.0	161.9	163.7	165.5	167.4	169.3	171.1	18.40
4.20	173.0*	174.8	176.6	178.4	180.2	182.0	183.8	185.7	187.5	189.3	18.20
4.30	191.2	193.0	194.9	196.8	198.6	200.5	202.4	204.3	206.2	208.1	18.80
4.40	210.0*	212.1	214.2	216.2	218.3	220.4	222.6	224.7	226.8	229.0	21.10
4.50	231.1	233.3	235.4	237.6	239.8	241.9	244.1	246.3	248.6	250.8	21.90
4.60	253.0*	255.1	257.3	259.4	261.6	263.8	265.9	268.1	270.3	272.5	21.70
4.70	274.7	276.9	279.1	281.3	283.5	285.8	288.0	290.2	292.5	294.7	22.30
4.80	297.0*	299.4	301.8	304.2	306.6	309.0	311.4	313.8	316.2	318.7	24.10
4.90	321.1	323.6	326.0	328.5	331.0	333.5	336.0	338.5	341.0	343.5	24.90
5.00	346.0*	348.5	351.0	353.5	356.1	358.6	361.1	363.7	366.3	368.8	25.40
5.10	371.4	374.0	376.6	379.2	381.8	384.4	387.0	389.6	392.2	394.9	26.10
5.20	397.5	400.1	402.8	405.5	408.1	410.8	413.5	416.2	418.9	421.6	26.80
5.30	424.3	427.0	429.8	432.5	435.2	438.0	440.7	443.5	446.3	449.0	27.50
5.40	451.8	454.6	457.4	460.2	463.0	465.8	468.6	471.5	474.3	477.1	28.20
5.50	480.0*	482.6	485.2	487.9	490.5	493.2	495.8	498.5	501.1	503.8	26.40
5.60	506.4	509.1	511.8	514.5	517.1	519.8	522.5	525.2	527.9	530.6	27.00
5.70	533.4	536.1	538.8	541.5	544.3	547.0	549.7	552.5	555.2	558.0	27.40
5.80	560.8	563.5	566.3	569.1	571.9	574.6	577.4	580.2	583.0	585.8	27.80
5.90	588.6	591.4	594.3	597.1	599.9	602.7	605.6	608.4	611.3	614.1	28.40
6.00	617.0	619.8	622.7	625.6	628.4	631.3	634.2	637.1	640.0	642.9	28.80
6.10	645.8	648.7	651.6	654.5	657.4	660.3	663.2	666.2	669.1	672.1	29.20
6.20	675.0*	678.2	681.5	684.7	688.0	691.2	694.5	697.7	701.0	704.3	32.60
6.30	707.6	710.9	714.2	717.5	720.8	724.1	727.4	730.8	734.1	737.4	33.20
6.40	740.8	744.1	747.5	750.9	754.2	757.6	761.0	764.4	767.8	771.2	33.80
6.50	774.6	778.0	781.4	784.9	788.3	791.7	795.2	798.6	802.1	805.5	34.40

Discharge data, organized by state can be found at:

- http://waterdata.usgs.gov/nwis/current/?type=flow
  - After opening this page go to drop down menu under “Geographic Area” to select your state.
  - Select “Statewide Stream Flow Table” This new page will allow you to organized the real time stream flow data by Major River Basin, County or Hydrologic Unit.

OPEQUON CREEK USGS 01616500 NEAR MARTINSBURG, WV

- The drop down menu for “Available data for this site” includes:
  - Real time data



The drop down menu for “Available data for this site” includes (continued):

- Gage station information
- Daily streamflow

  Daily mean stream flow values from the entire record can be examined or for any period within a record. This data is used to develop flow duration curves for a selected gage site.

  Don’t confuse with Real Time Data which are actual cfs readings throughout the day. The daily mean values are the average discharge over a 24-hour period.

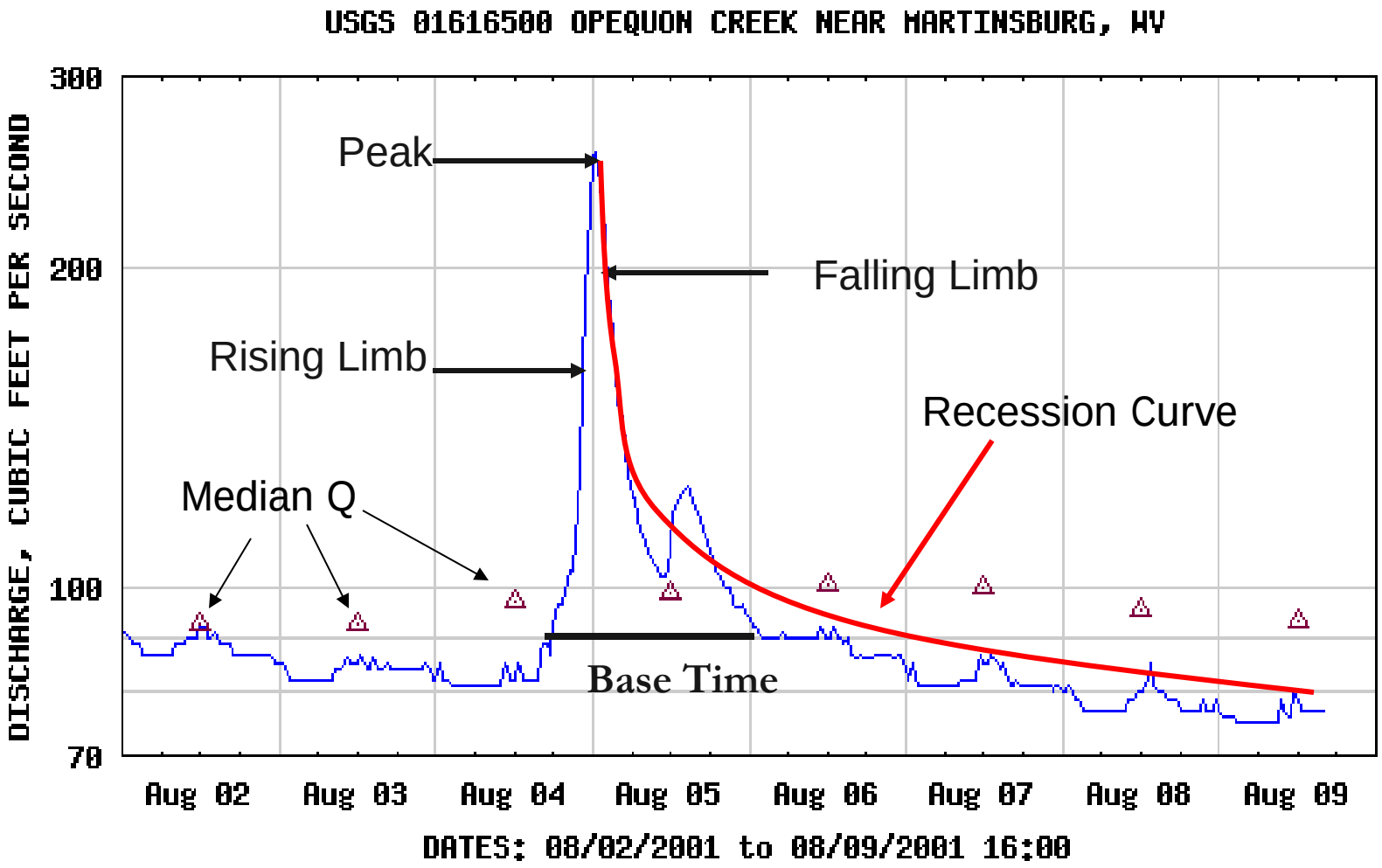
- Stream measurements

Hydrographs

A graph of discharge or depth (stage) versus time

Single Event Hydrograph Terms

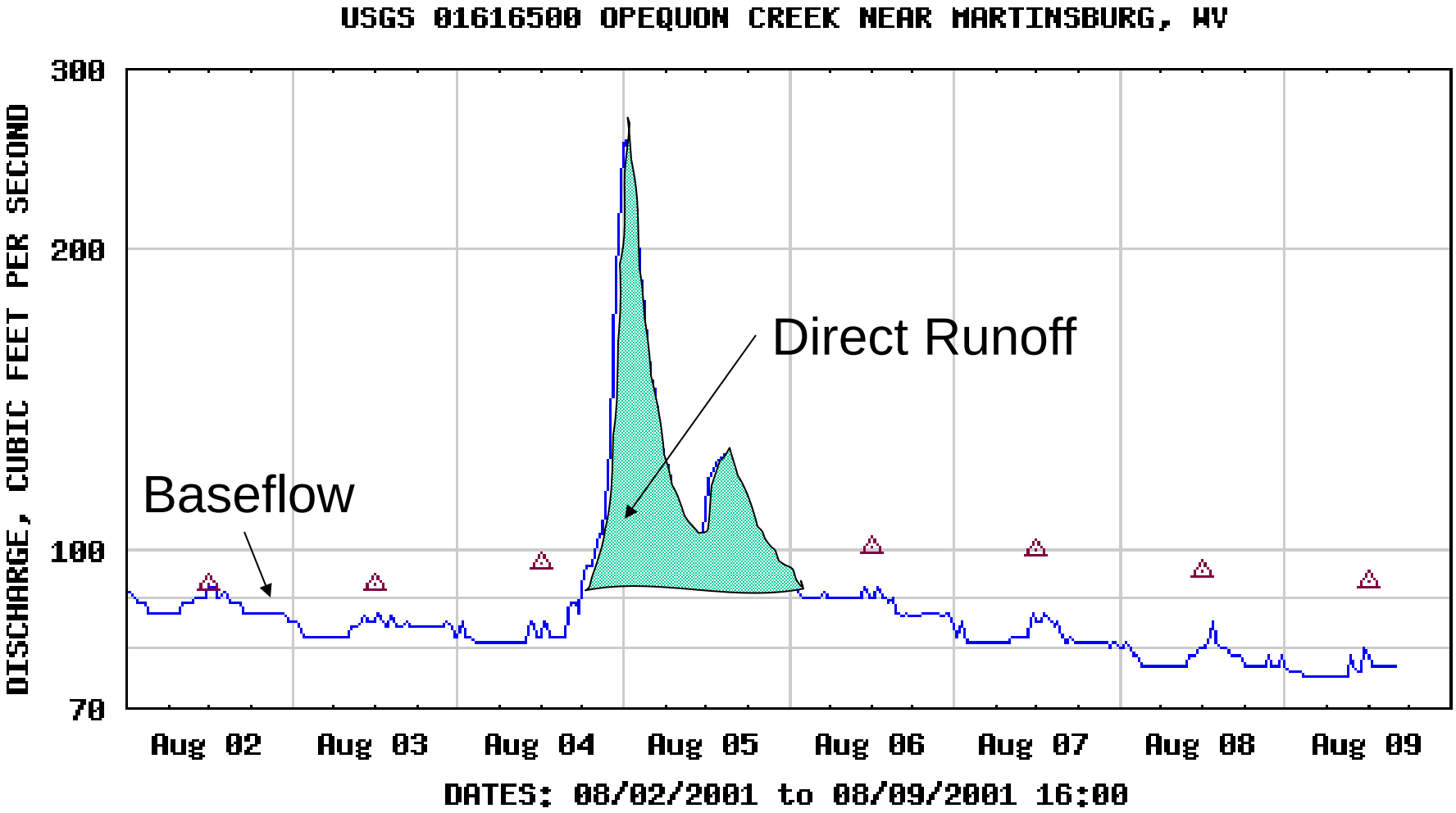
- Rising limb: increasing discharge due to runoff event
- Peak: highest discharge of event
- Falling limb: declining discharge after peak
- Recession curve: discharge after the peak, dominated by groundwater discharge
- Baseflow: groundwater contribution to flow
- Direct runoff: volume of water produced from the precipitation event
- Base time: base width of the direct runoff portion



EXPLANATION

DISCHARGE

MEDIAN DAILY STREAMFLOW BASED ON 53 YEARS OF RECORD

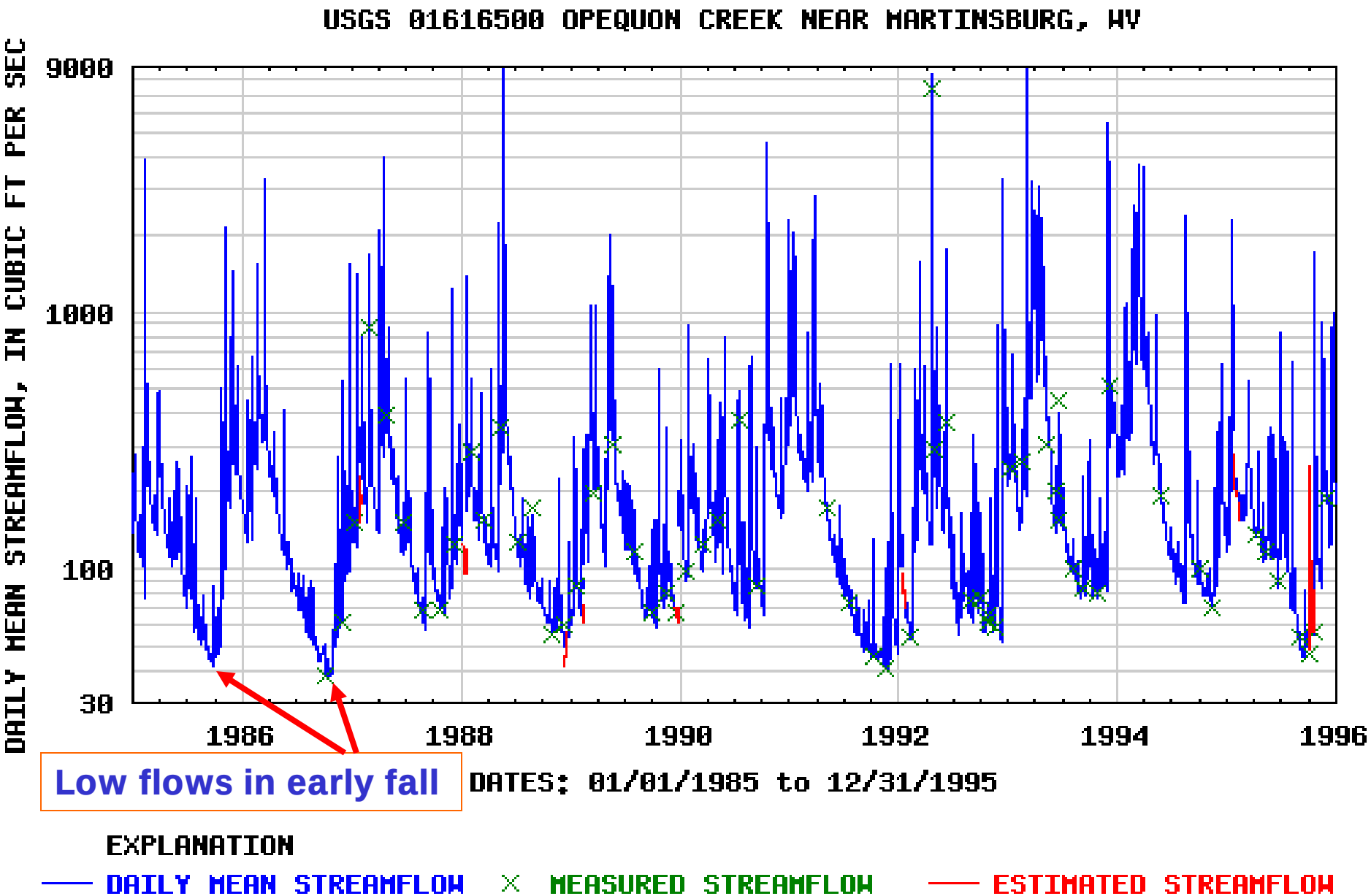


EXPLANATION

DISCHARGE

MEDIAN DAILY STREAMFLOW BASED ON 53 YEARS OF RECORD

Hydrograph Over Multiple Years

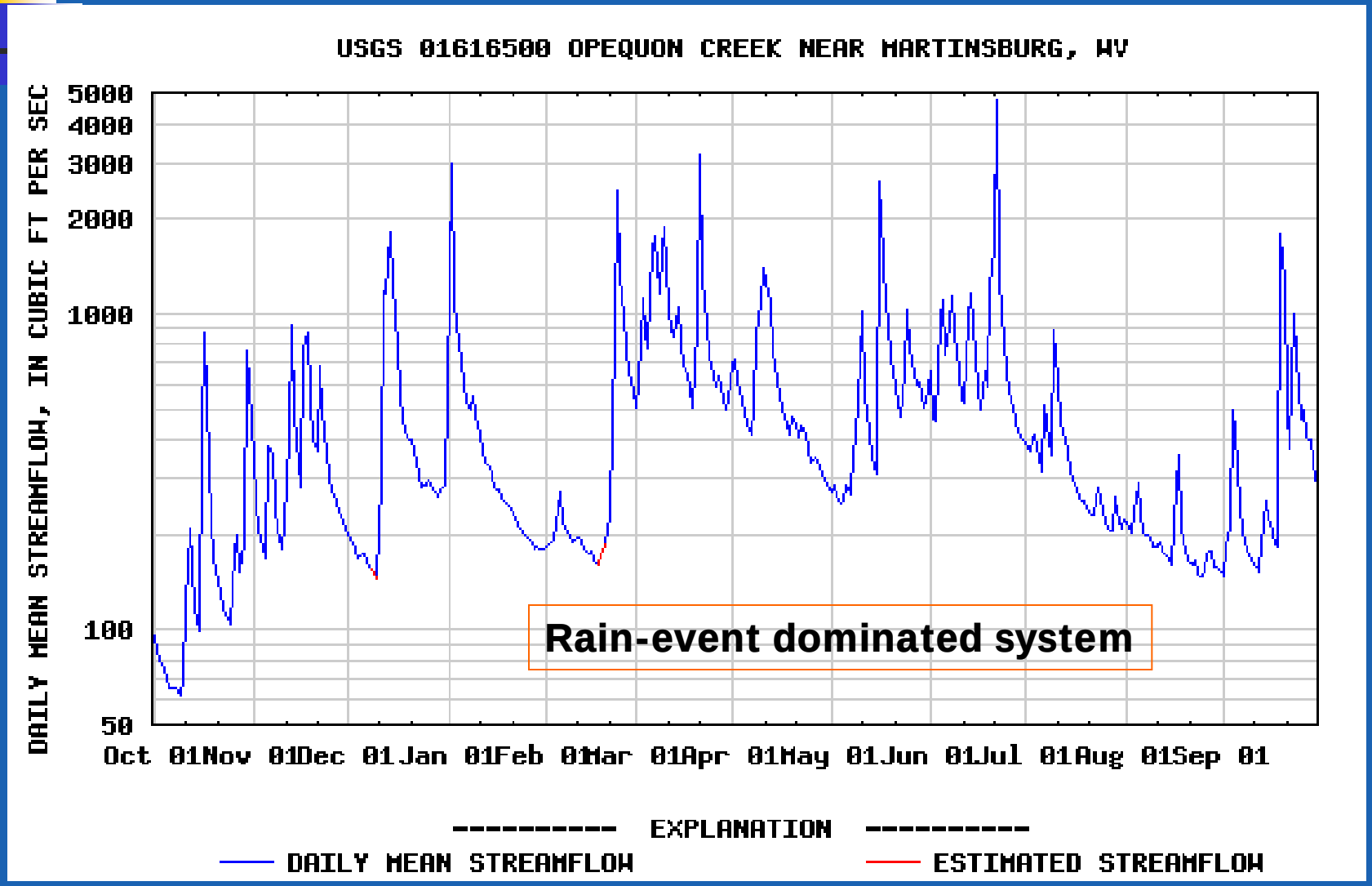


Low flows in early fall

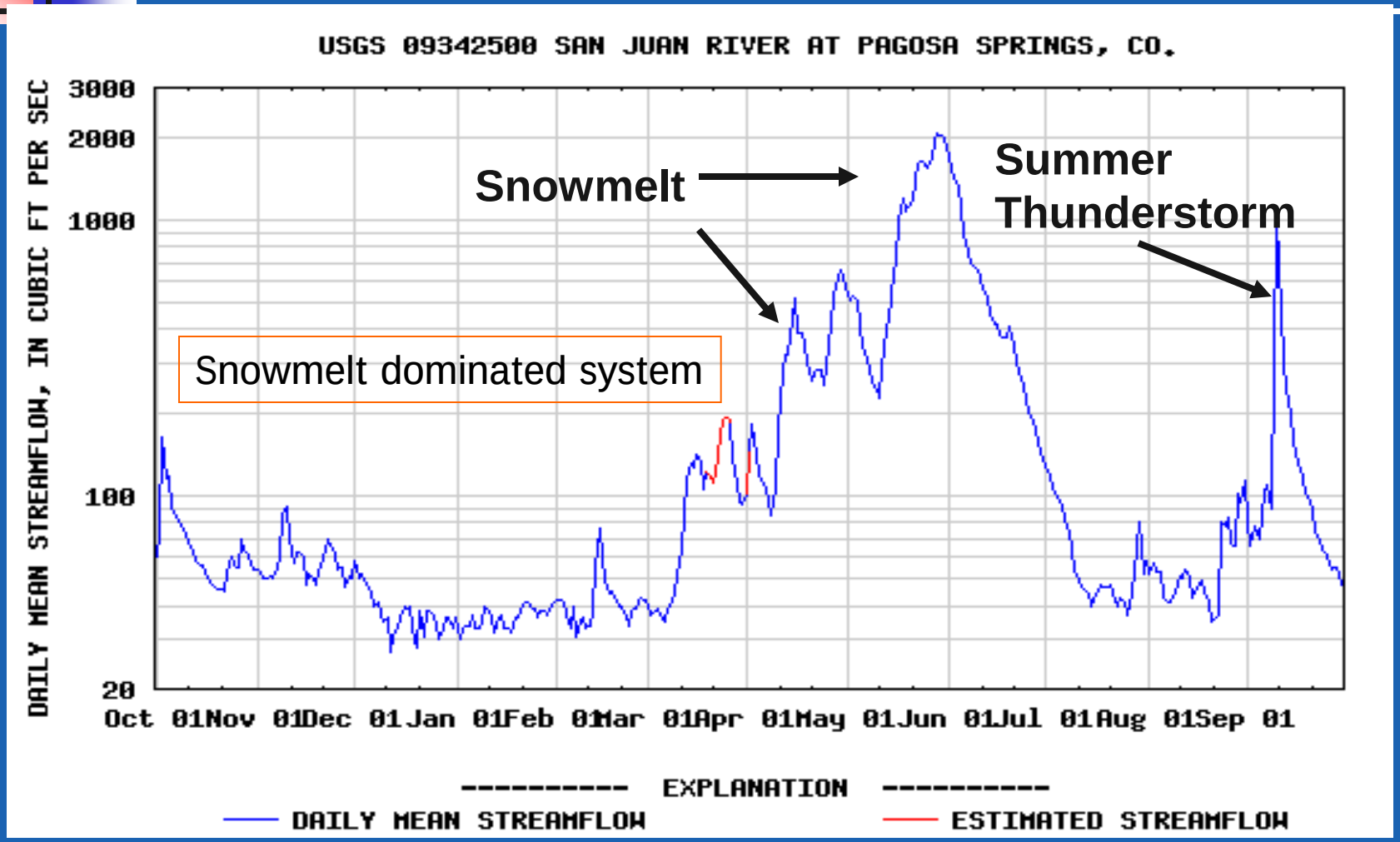
Uses of Multiple-year Hydrograph

- These graphs allow calculation of biologically-relevant hydrologic parameters
  - Magnitude of monthly water conditions (e.g., mean monthly flow)
  - Magnitude and duration of extreme annual flow conditions (e.g., annual minima 7-day means)
  - Timing of annual extreme flow conditions (“predictability”)
  - Frequency and duration of high and low pulses
  - Rate and frequency of water flow changes

Opequon Creek (WV)
Water Year 2003 hydrograph



San Juan River (CO)
Water Year 2003 Hydrograph



Hydrologic Data for Potomac River @ Sheperdstown on August 21, 2005 (69 years of data)

- Discharge: 3,090 CFS
- Minimum: 342 CFS
- Mean: 2,260 CFS
- Maximum: 19,000 CFS
- 80% Exceedence: 989 CFS
- 50% Exceedence: 1,510 CFS
- 20% Exceedence: 2,862 CFS

Flood Flow Frequency Analysis

Flow Frequency Analysis

- A method for assigning probabilities of occurrence to runoff events of a given size
- Use cumulative distribution of flows
- From these distributions, can determine "exceedance" probabilities

Data Needs

- Flood flow frequency analysis uses the highest recorded instantaneous flow recorded for that water year (October through September).
- A.k.a. Annual peak flow
- Only one peak flow per water year is used.
- All data are independent.
- Very important later in determining bankfull discharges from USGS stream gage data!

Streamflow Frequency Analysis

- Rank most extreme events (low or high) of past years in record
- Describe flow data by graphical methods or by fitting data with a theoretical probability distribution (in US, Pearson Type III distribution is standard)
  - The theoretical probability distribution is used to extrapolate data (e.g., 100 year flood Q on a stream having only 70 years of gage station data)
- The fitted curve or distribution can then be used to find probabilities associated with floods or low flows of a given size

Exceedance

- For high flows, probability that a flow is *greater* than some amount

- For low flows, probability that a flow is *less* than a given amount

Plot Annual Peak Discharge Data

- Order data by size (largest value is given a rank of 1, the second largest a rank of 2, with lowest value given a rank equal to N)

- N = total number of data points

Weibull Plotting Position Formulas

- $P = m/(N + 1)$
  - P = probability of exceedance
  - m = rank of the event
  - N = number of years of record

Example

- Determine the probabilities of exceedance for the following annual peak flows (10 years of record total):
  - 463, 286, 301, 3325, 181, 765, 744, 505, 498, 230

Q	Rank	P=m/(N+1)	
3325	1	**0.090909**	
765	2	**0.181818**	
744	3	**0.272727**	
505	4	**0.363636**	
498	5	**0.454545**	
463	6	**0.545455**	
301	7	**0.636364**	
286	8	**0.727273**	
230	9	**0.818182**	
181	10	**0.909091**	

Probability

- Often expressed as “1-in-N-year” chance (e.g., 1-in-100-year flood expected to occur, on average once in every 100 years)

- The 1-in-100-year flood would have a probability of 0.01 or 1% of being equaled <u>or exceeded</u> in any one year

Average Recurrence Intervals

- Average recurrence interval (or return period): average length of time between two floods of a given size or larger.

Weibull Plotting Position Formulas

- $T = (N + 1)/m$

  - T = average recurrence interval
  - m = rank of the event
  - N = number of years of record

How They Relate

- $P = 1/T$
  - Where
    - P = probability of occurrence
    - T = average recurrence interval

Example: if T = 100 years,
P = 1/100 = 0.01

Example

- Determine the average recurrence intervals for the same annual peak flows used in exceedance calculations:

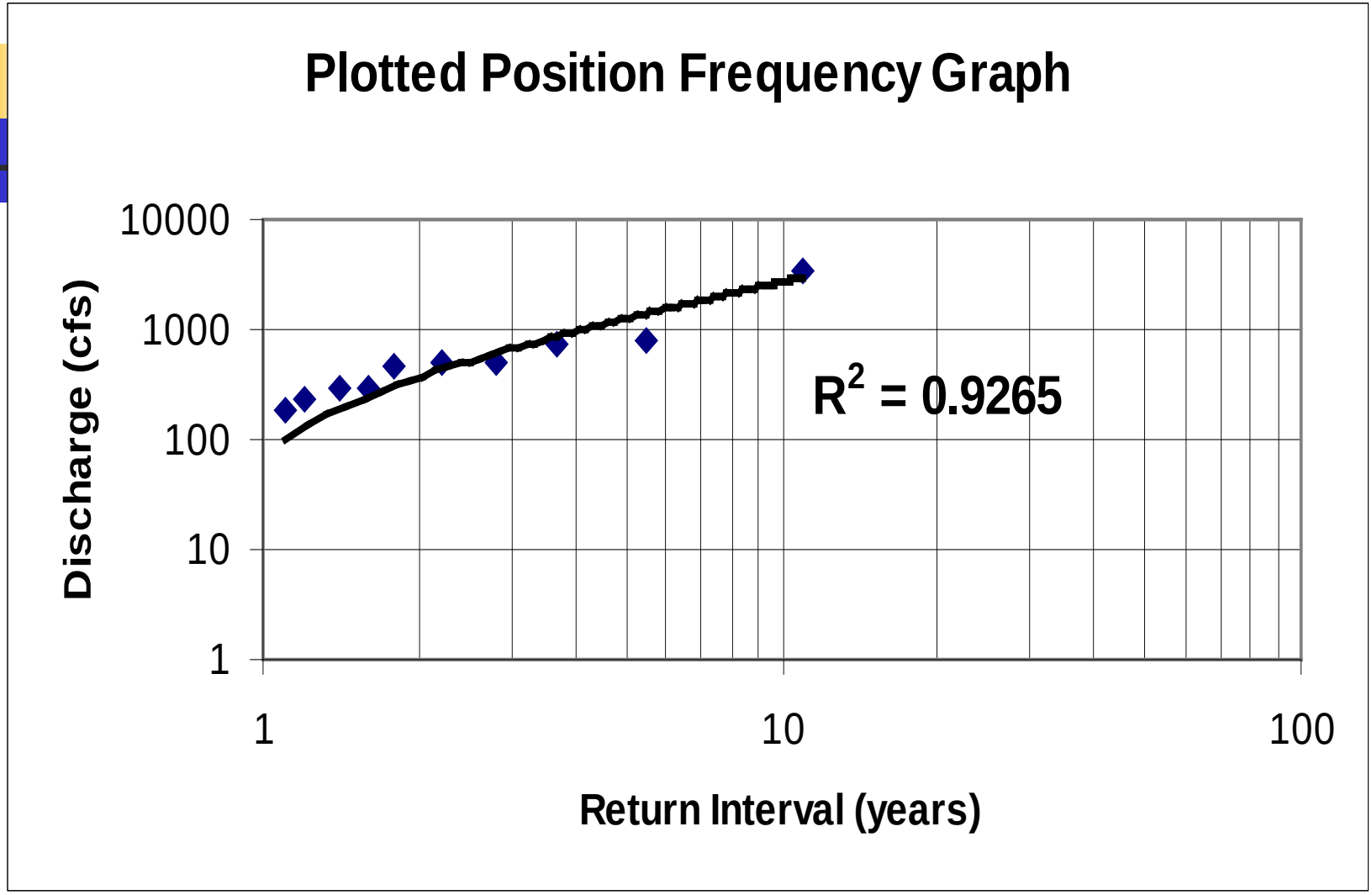
  - 463, 286, 301, 3325, 181, 765, 744, 505, 498, 230

Q	Rank	P = m/(N+1)	T = (N+1)/m
3325	1	0.090909	**11.0**
765	2	0.181818	**5.5**
744	3	0.272727	**3.7**
505	4	0.363636	**2.8**
498	5	0.454545	**2.2**
463	6	0.545455	**1.8**
301	7	0.636364	**1.6**
286	8	0.727273	**1.4**
230	9	0.818182	**1.2**
181	10	0.909091	**1.1**

Bankfull T range

Graphical Methods: The Probability Plot

- The discharges and associated exceedances or recurrence intervals are plotted as points on graph paper and a line is drawn to interpret the points
- This is called a probability plot and the fitted line a flood-frequency curve


Plotted Position Frequency Graph
10000
1000
100
10
1
Discharge (cfs)
1
10
100
Return Interval (years)
R2 = 0.9265

Plot Annual Peak Discharge Data

- Assign a plotting position to each coordinate using plotting position formulas

- Weibull plotting position formulas are most commonly applied in US

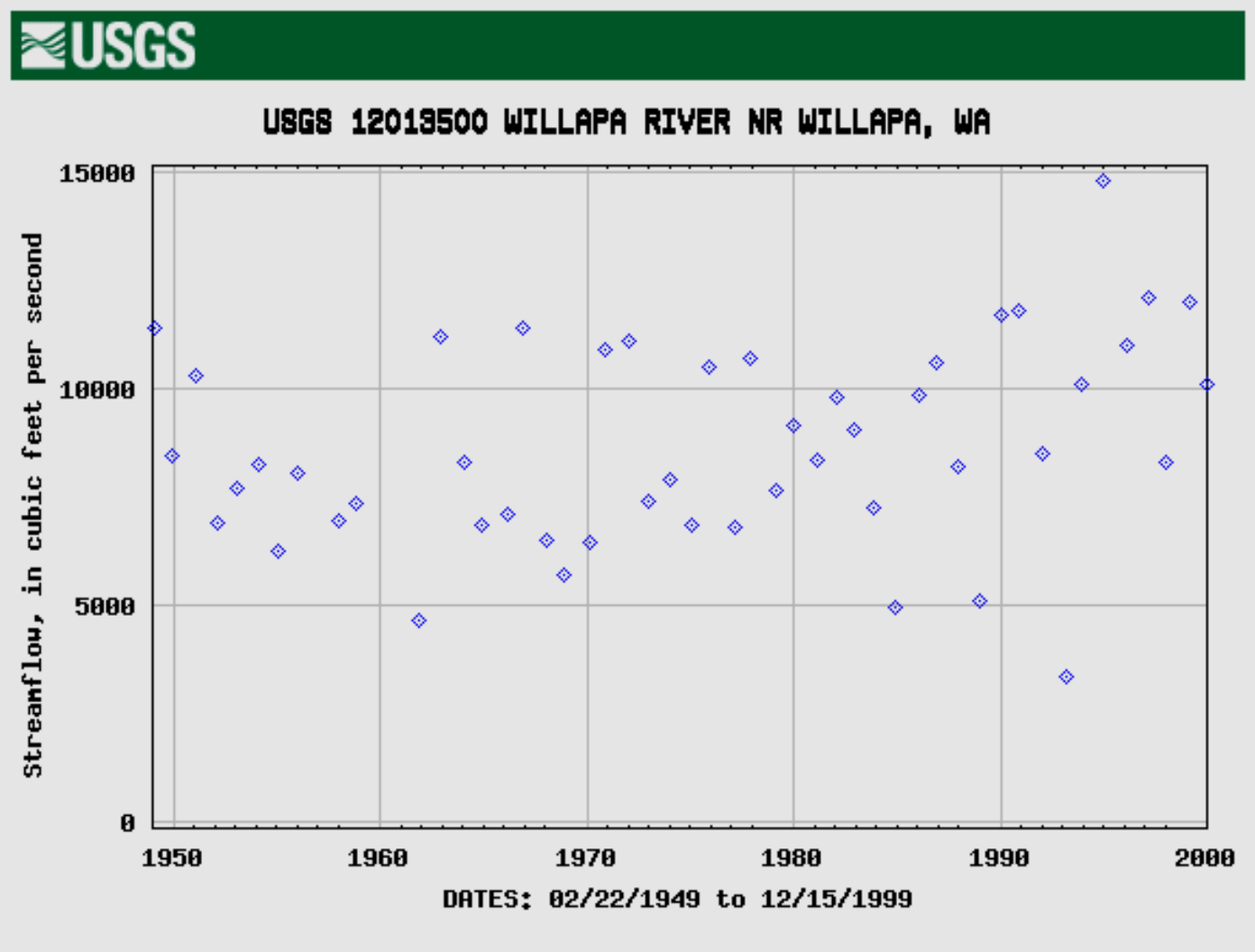
An Actual Example

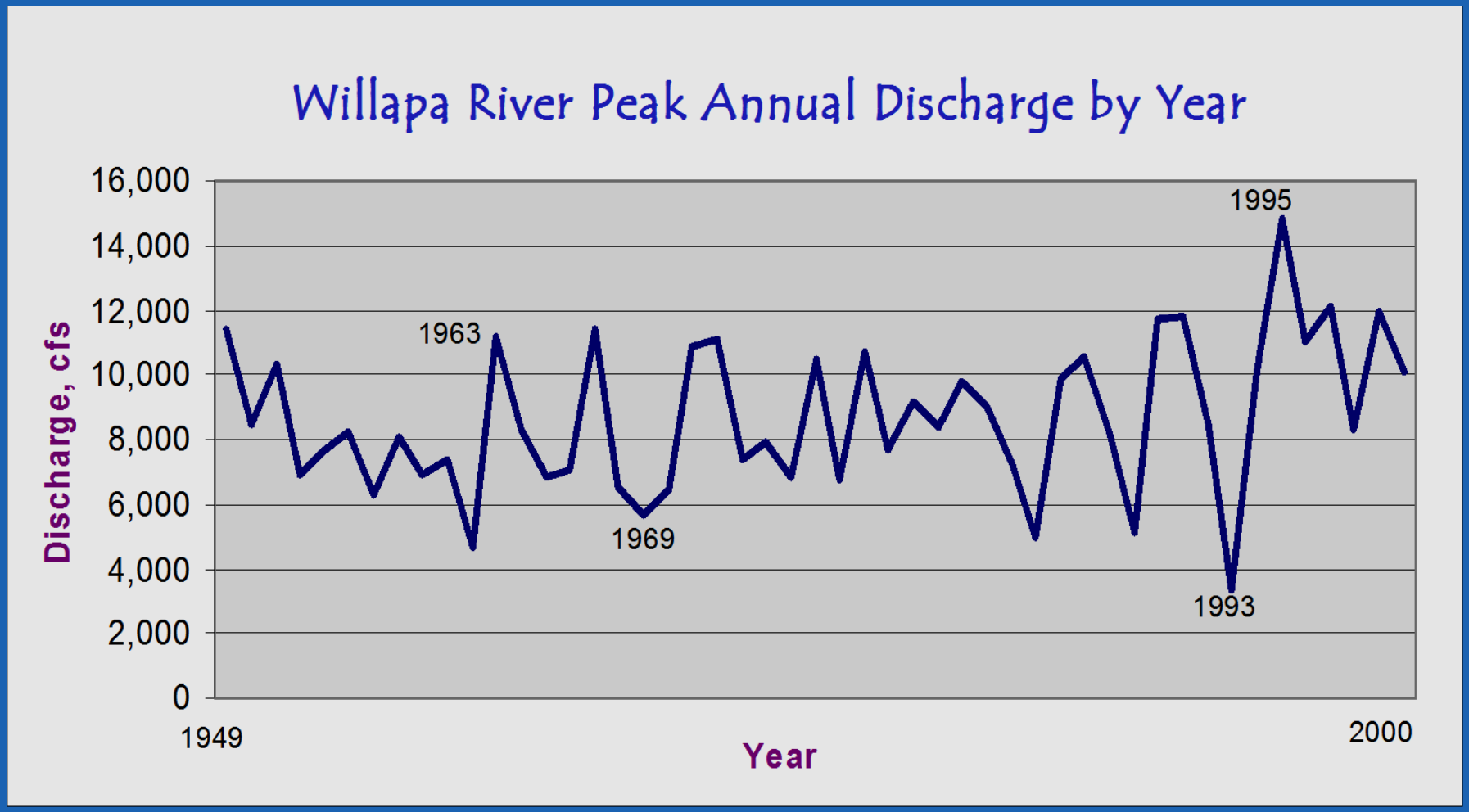
- **Willapa River @ Willapa, WA**
  - **USGS Gaging Station # 12013500**

Willapa River: Peak Flows Ordered by Year

Water Year	Date	Gage Height (feet)	Stream-flow (cfs)	Water Year	Date	Gage Height (feet)	Stream-flow (cfs)
1949	Feb. 22, 1949	24.22	11,400	1976	Dec. 4, 1975	21.49	10,500
1950	Dec. 28, 1949	18.8	8,450	1977	Mar. 7, 1977	16.77	6,780
1951	Feb. 9, 1951	21.86	10,300	1978	Dec. 2, 1977	21.62	10,700
1952	Feb. 4, 1952	17.28	6,900	1979	Mar. 5, 1979	17.88	7,660
1953	Jan. 23, 1953	18.41	7,690	1980	Dec. 18, 1979	19.75	9,160
1954	Feb. 19, 1954	19.2	8,240	1981	Feb. 16, 1981	18.75	8,360
1955	Feb. 8, 1955	16.38	6,270	1982	Jan. 23, 1982	20.52	9,780
1956	Dec. 21, 1955	18.92	8,040	1983	Dec. 4, 1982	20.77	9,040
1958	Dec. 25, 1957	17.36	6,950	1984	Nov. 15, 1983	18.18	7,230
1959	Nov. 18, 1958	17.94	7,360	1985	Nov. 28, 1984	14.85	4,940
1962	Nov. 22, 1961	13.75	4,650	1986	Jan. 19, 1986	21.81	9,850
1963	Nov. 20, 1962	23.04	11,200	1987	Nov. 24, 1986	22.7	10,600
1964	Jan. 25, 1964	19.28	8,300	1988	Dec. 10, 1987	19.66	8,200
1965	Dec. 1, 1964	17.18	6,830	1989	Dec. 30, 1988	15.18	5,090
1966	Mar. 9, 1966	17.57	7,100	1990	Jan. 9, 1990	24.06	11,700
1967	Dec. 13, 1966	23.26	11,400	1991	Nov. 24, 1990	24.21	11,800
1968	Feb. 4, 1968	16.75	6,520	1992	Jan. 28, 1992	20.05	8,480
1969	Dec. 3, 1968	15.47	5,680	1993	Mar. 23, 1993	12.22	3,350
1970	Feb. 16, 1970	16.66	6,460	1994	Dec. 10, 1993	22.08	10,100
1971	Dec. 7, 1970	22.68	10,900	1995	Dec. 20, 1994	27.28	14,800
1972	Jan. 20, 1972	22.93	11,100	1996	Feb. 8, 1996	23.21	11,000
1973	Dec. 21, 1972	18.01	7,410	1997	Mar. 19, 1997	24.53	12,100
1974	Jan. 16, 1974	18.6	7,920	1998	Jan. 14, 1998	19.82	8,310
1975	Feb. 12, 1975	16.89	6,870	1999	Feb. 24, 1999	24.43	12,000
				2000	Dec. 15, 1999	22.01	10,100

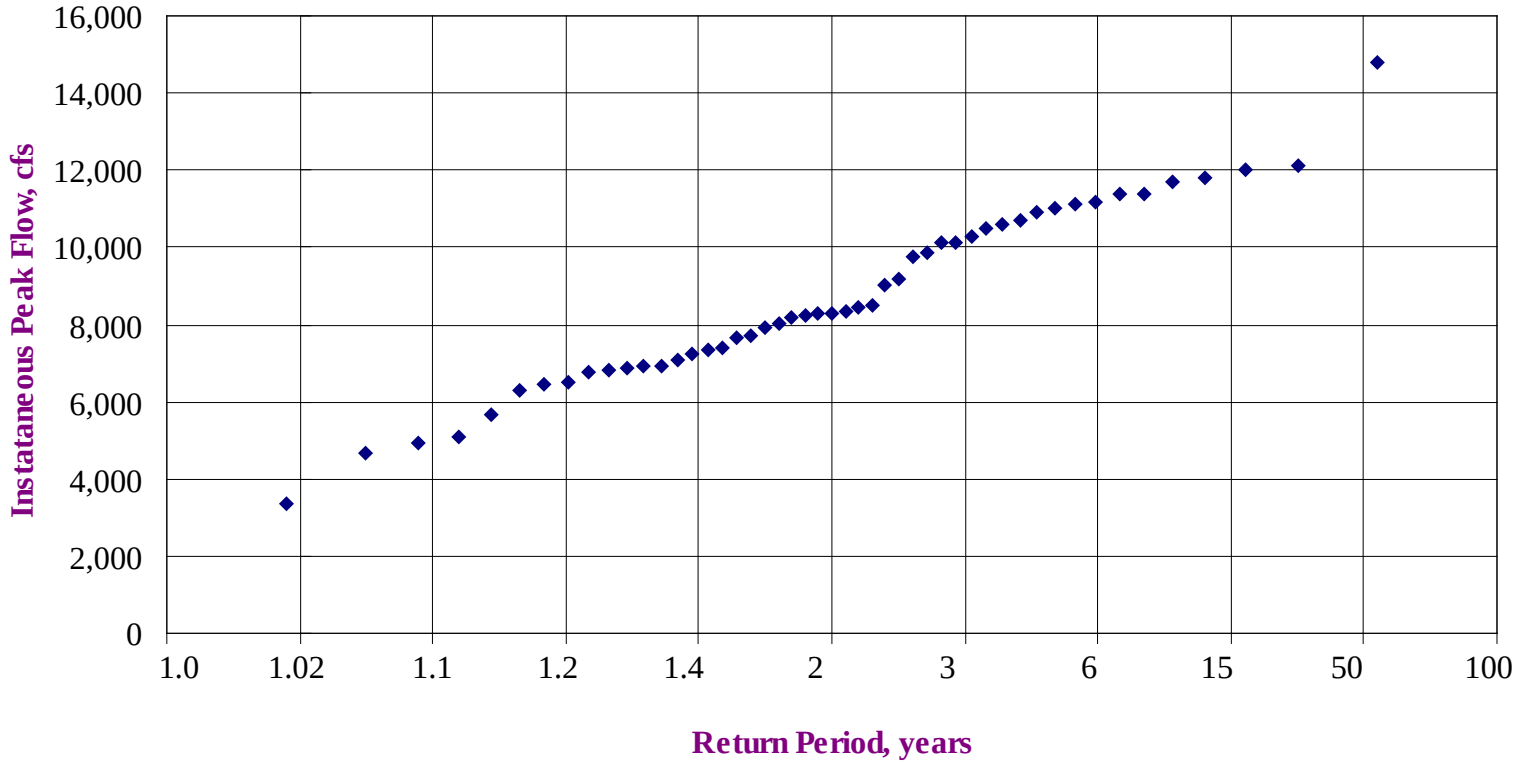
Plot of Peak Annual Discharges by Year

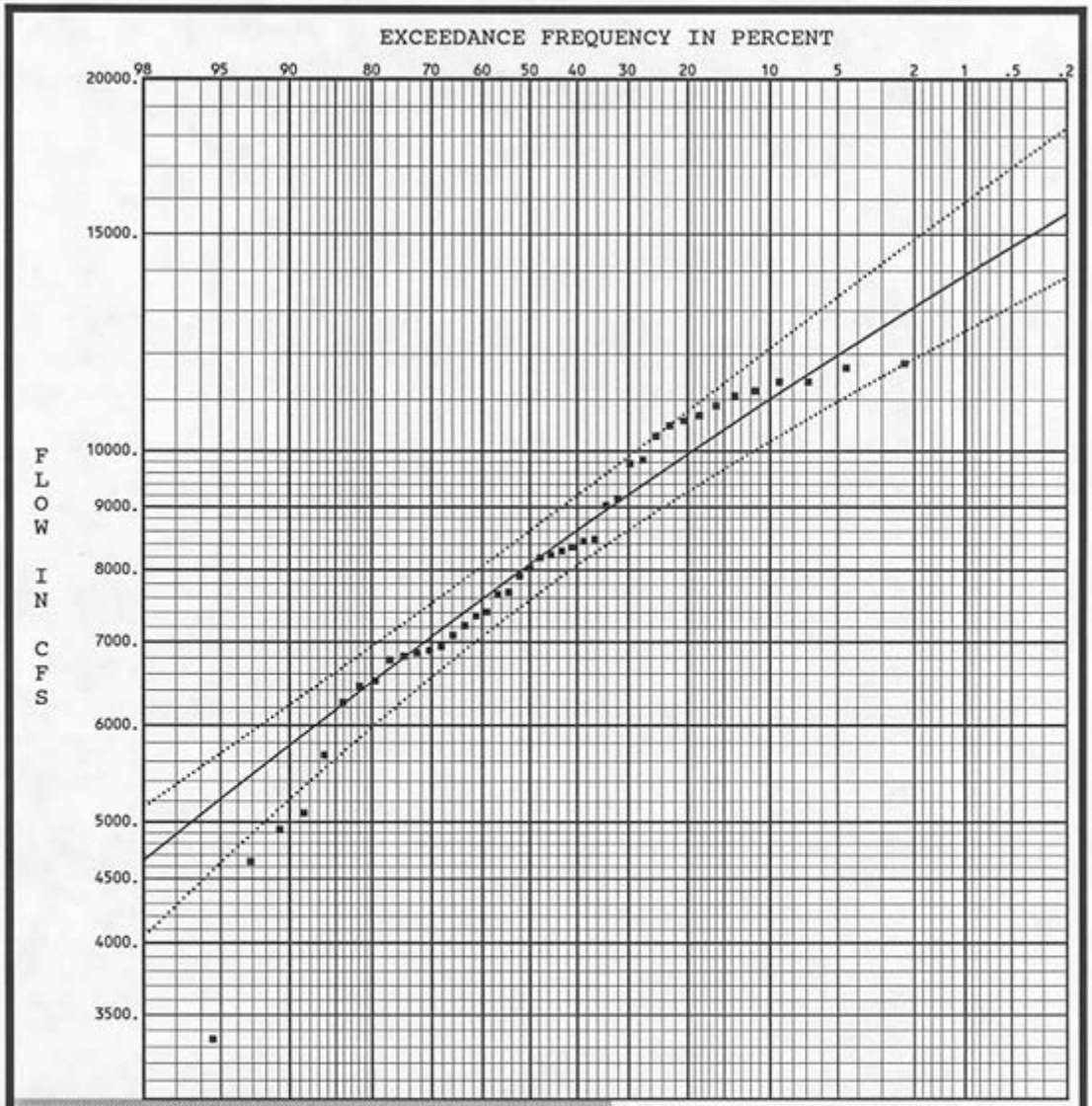



Willapa River Peak Annual Discharge by Year
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Discharge, cfs
1963
1969
1993
1995
1949
2000
Year

Willapa River

Flood Frequency Curve, 1949 to 2000, 130 square mile drainage area





—— Flow Frequency (without Exp. Prob.)
▪ Weibull Plotting Positions
····· 5% and 95% Confidence Limits

FREQUENCY STATISTICS
LOG TRANSFORM OF FLOW, CFS

			NUMBER OF EVENTS
MEAN	3.9043	HISTORIC EVENTS	0
STANDARD DEV	.1096	HIGH OUTLIERS	0
SKEW	-.3189	LOW OUTLIERS	1
REGIONAL SKEW	.0000	ZERO OR MISSING	1
ADOPTED SKEW	-.2000	SYSTEMATIC EVENTS	43

12013500
ANNUAL SERIES
WATER YEARS IN RECORD
43,1949-1956,1958-1959,
1962-1993

Flood Frequency Theoretical Distribution Plotting

- To extend beyond the record, you have to assume something about the total population.
- The population is assumed to have a known distribution. **In U.S., Pearson Type III distribution is standard**
- Remember, this is probability of a flow event in each year, so something could happen as two 100-year storms that occur back to back.

Software for determining a Flow Frequency Curve fitted to a Theoretical Distribution (Program PeakFQ)

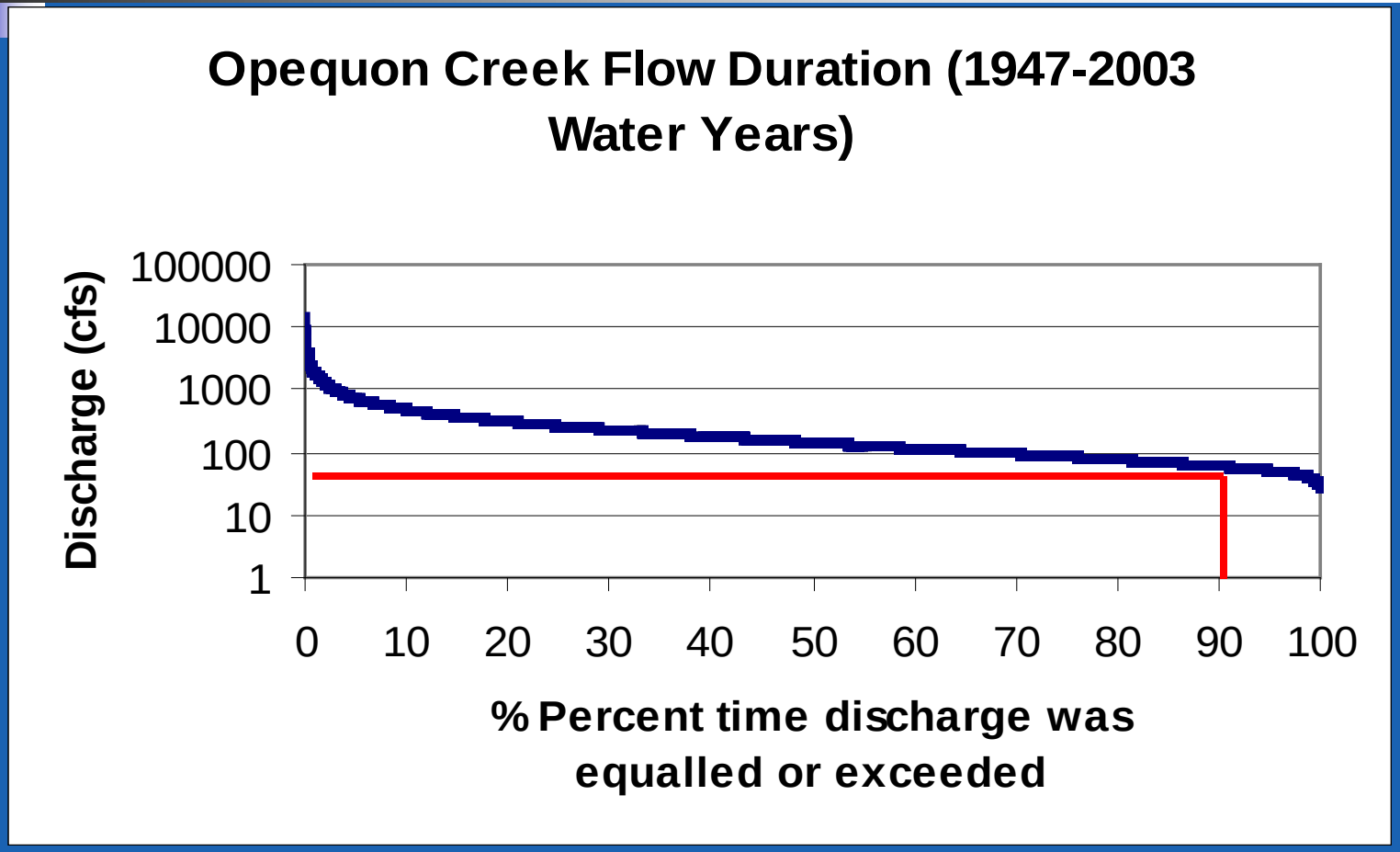
- PeakFQ, Flood Frequency Analysis Based on Bulletin 17B
  http://water.usgs.gov/software/PeakFQ/

- USGS National Water Information System, Peak Streamflow for the Nation (source of annual peak flow data for the USGS gaging stations)
  - http://nwis.waterdata.usgs.gov/nwis/peak?search_criteria=search_station_nm&submitted_form=introduction

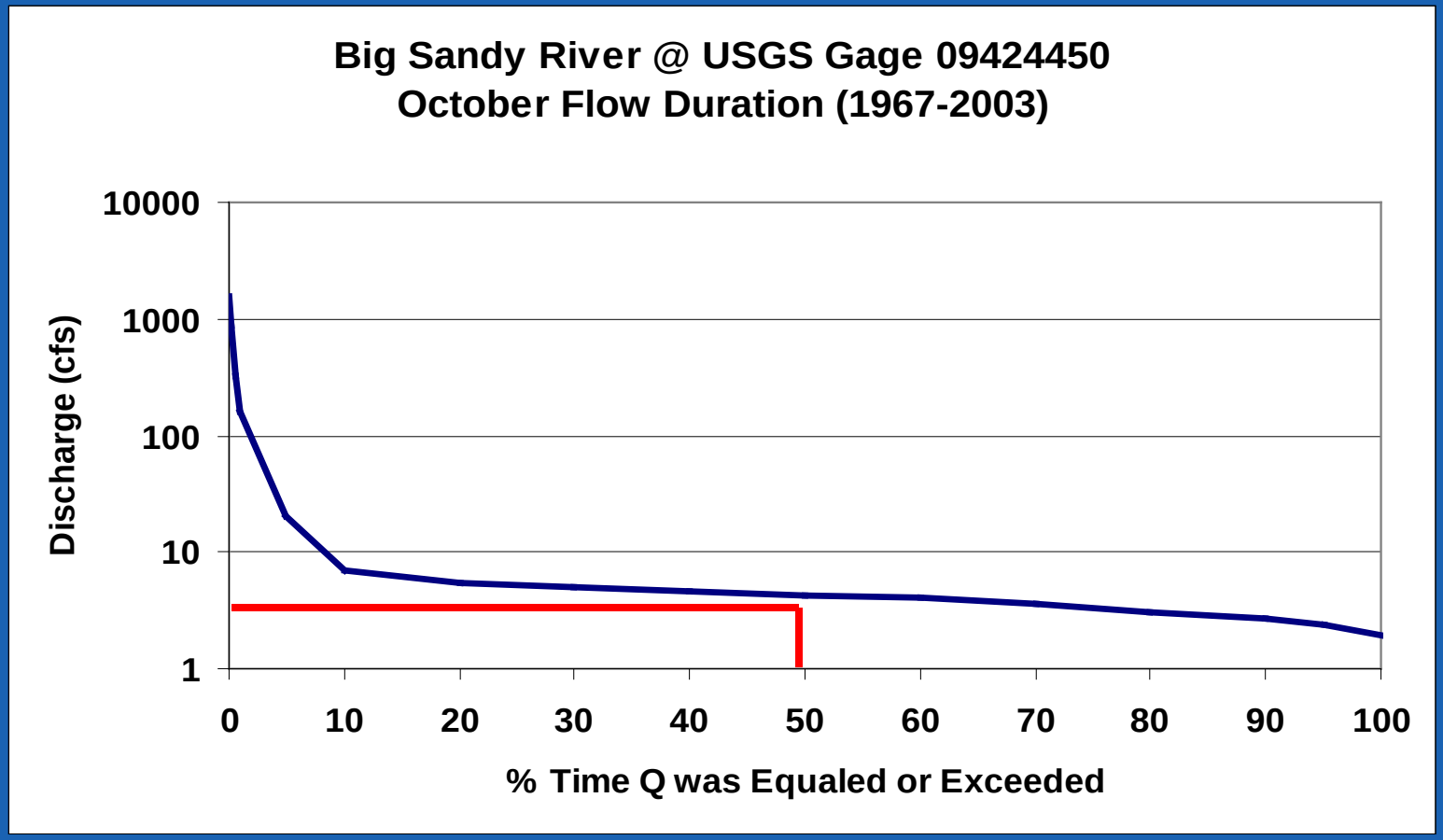
Uses of Flow Duration Curve Examples

Flow duration curves show the percent of time during which a specific discharge were equaled or exceeded in a given period.

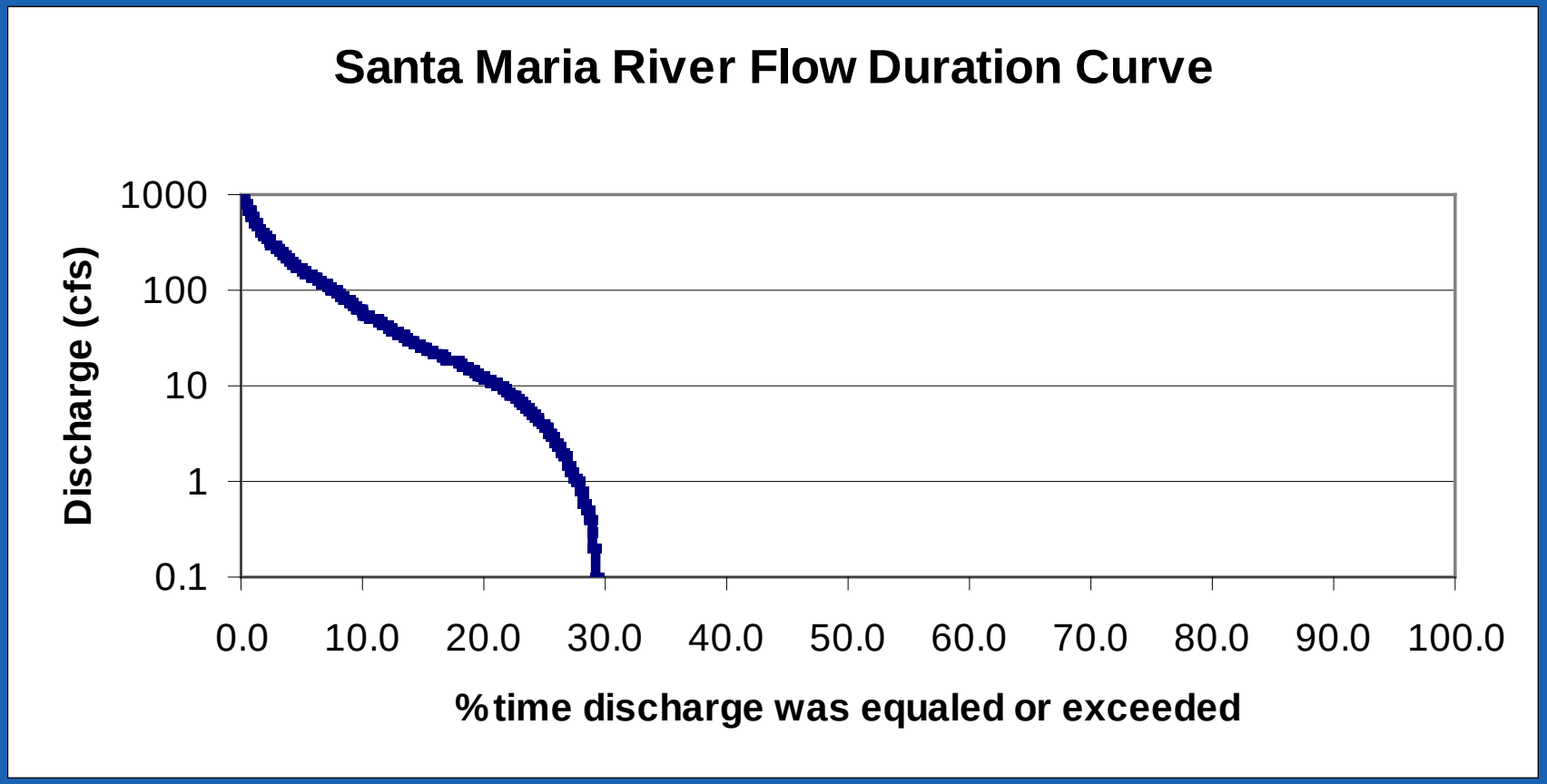
For example, on Opequon Creek (WV), discharge exceeded or equaled 60 cfs for 90% of the period of record.



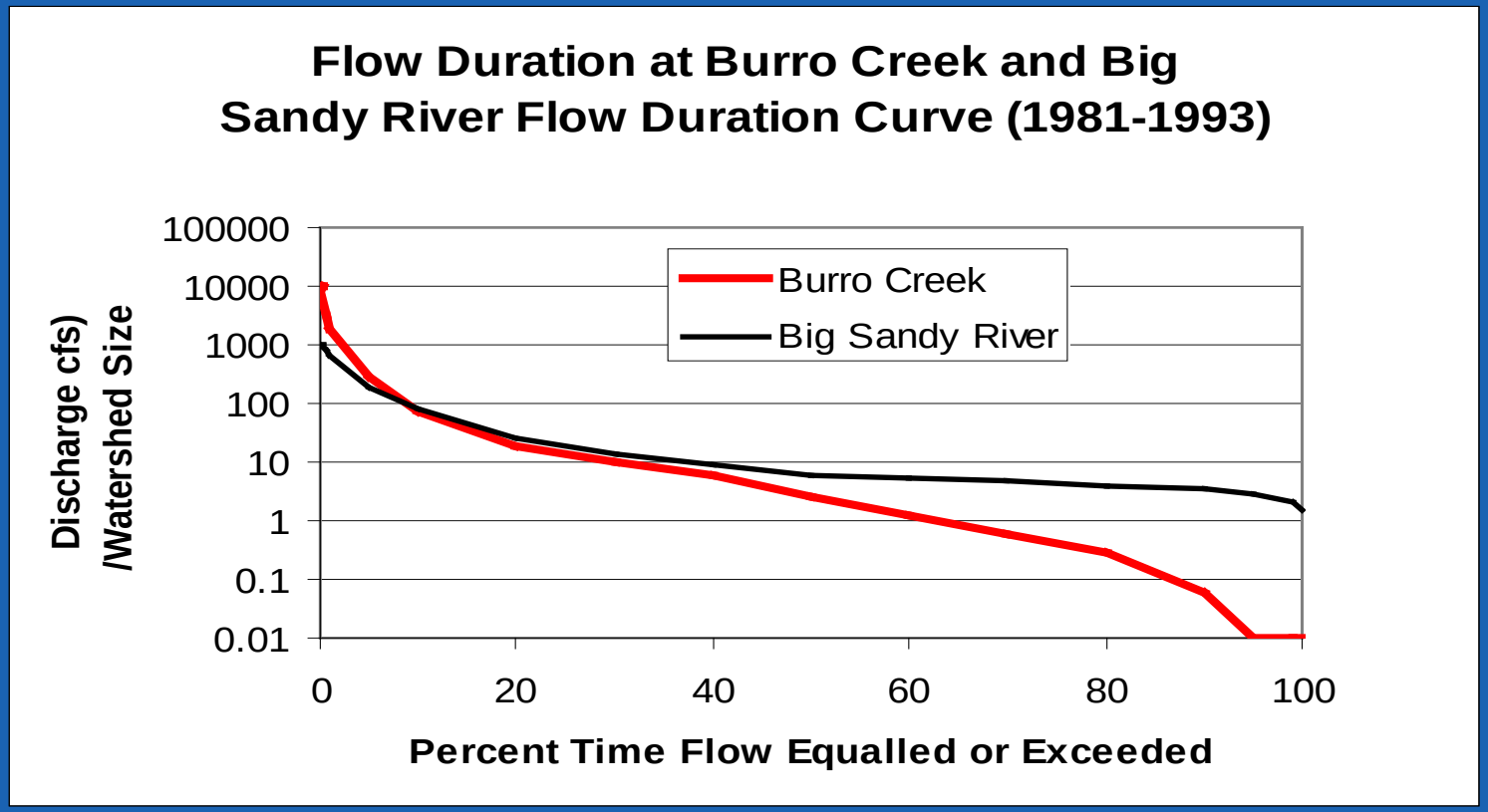
Flow duration curves are used to determine median monthly flow requests as part of instream flow applications. The median flow request for October on the Big Sandy River (AZ) was 4.2 cfs.



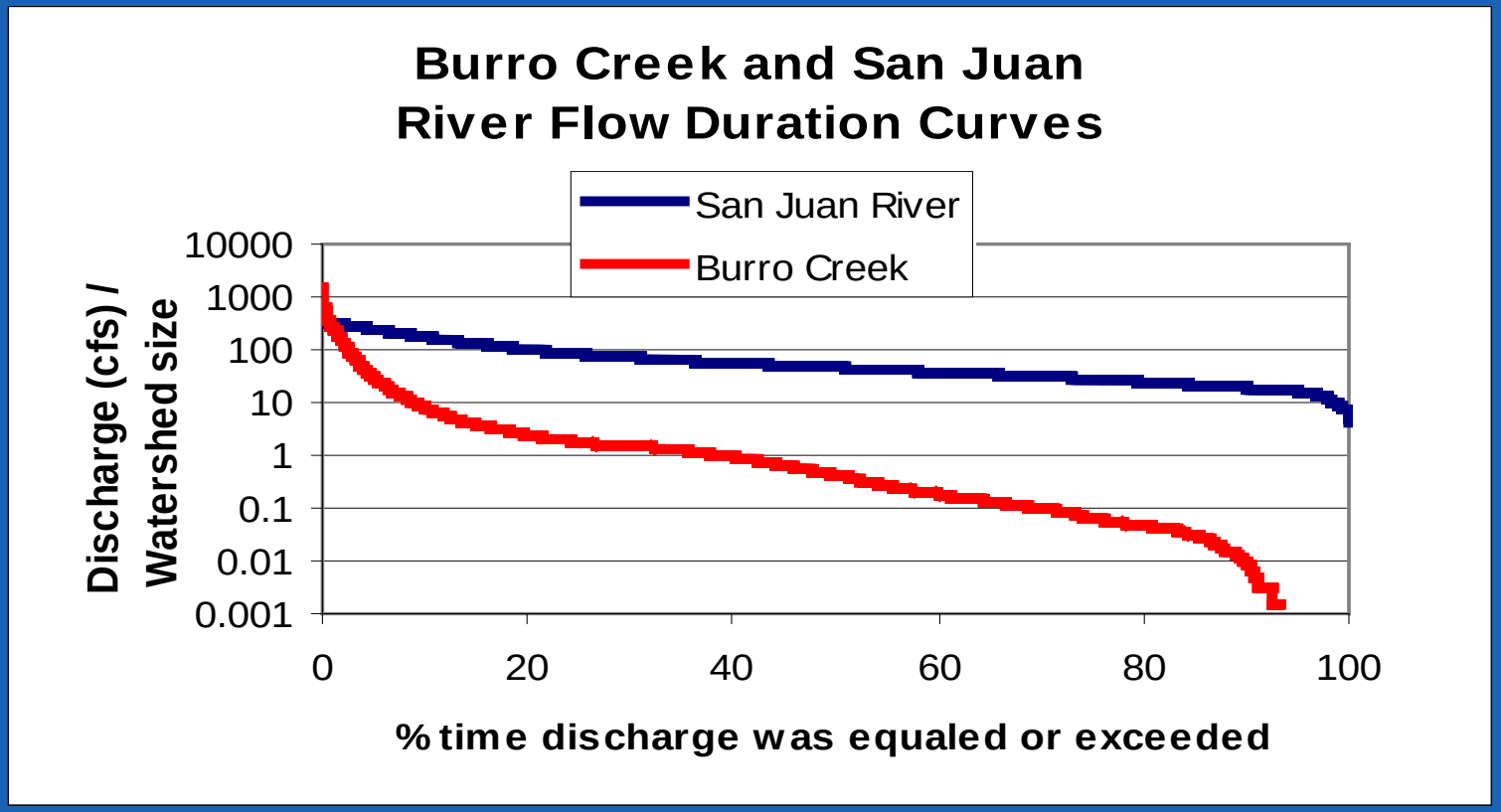
Flow duration curves can also describe a river reaches' potential to support different resources. Since there is no surface flow for 70% of the time on this reach, native fish management isn't a priority on this Arizona river.



Flow duration curves can also be used to compare streams in different geomorphic settings. Burro Creek (AZ), which is confined within a bedrock controlled canyon has high daily mean floods but little bank storage. It's base flow drops to 0 cfs. The Big Sandy River (AZ), located in a deep alluvial valley has lower daily mean flood flows, but has sufficient bank storage to flow year-round.



Streams with different hydrographs can also be examined with flow duration curves. Snow-melt dominated systems, such as the San Juan River (CO) have a flatter curve than flash-flood dominated systems such as Burro Creek (AZ).



HINT - When comparing flow duration curves between two of more sites, be sure to divide discharge by watershed size, then multiply by 100 to adjust for different sized rivers and their watersheds.

Flow Duration Curve Calc.

- Daily Mean discharge values from USGS gage sites on the internet ranked from highest to lowest. The percent of discharge equaled or exceeded during a particular period of record is calculated by:
- P = Rank (1,2,3 or etc.)/N (# of daily discharge readings X 100).
- Given the large data sets used in these calculations, daily mean flow data should be cut and pasted from the USGS website to a spreadsheet.

- For example, discharges equaled or exceeded 11,000 cfs 60% of the period of record.

Rank	P=m/(N+1)*100	Discharge
1	5	35000
2	10	31300
3	15	23000
4	20	18600
5	25	16200
6	30	14900
7	35	14000
8	40	13600
9	45	13000
10	50	12500
11	55	11800
12	**60**	**11000**
13	65	10500
14	70	10400
15	75	10200
16	80	9590
17	85	9490
18	90	9130
19	95	9050
20	100	9000

Bankfull Discharge

- Bankfull discharge is the discharge that maintains the channels' form and stability.
- It is the maximum discharge a stable channel can convey without flowing out onto it's floodplain.
- Separates the processes of river channel formation and floodplain development.

Bankfull Discharge

- It can be used as a surrogate for effective discharge, the discharge that moves the most sediment over time through a river system.
- Effective discharge calculation requires actual measurement of sediment, development of sediment rating curves, etc. This is why bankfull discharge is used.

Bankfull Discharge

- The estimated bankfull discharge has an average return period of approximately 1.5 years with a nominal range of 1.4 to 1.8 years (bankfull Q could be outside this range)

- The channel must be stable if on-site bankfull indicators; appearance of floodplain deposition, top of a point bar, etc, are to be used.

Old floodplain

Newer, forming floodplain

- In an incised or degrading system, if the old floodplain or terrace elevation is used to determine the bankfull channel, bankfull discharge will be over estimated

- Likewise, if a channel is aggrading or filling up with excessive sediment, the decreased bankfull channel cross-sectional area would result in underestimating bankfull discharge.

The goal is to **properly** identify the incipient point of flooding or the location of the floodplain. The identification of the floodplain must be substantiated with streamflow data and geomorphic indicators in the field. It has been observed that people generally “under-estimate” bankfull discharge thus underestimate the size of the bankfull channel. You must do your homework prior to going into the field.

- Bankfull discharge can be determined through USGS streamflow data. Discharge-stage rating curves and flood flow frequency analysis, as shown earlier, can be used to determine bankful discharges and return intervals on gaged streams.

- Measure bankfull elevation at a stream segment containing a gaging station
  - Correlate bankfull elevation to staff plate elevation
  - Use discharge-stage rating curve for the gaging station to determine bankfull discharge
  - Use flood flow frequency curves to determine the return interval of your bankfull discharge
  - Check the “reasonableness” of your recurrence interval estimate

Bankfull Discharge Estimation

- You'll learn how to determine bankfull discharge from surveying a gage site in the Applied Fluvial Geomorphology (Level 1) class.

- For the purposes of this course, we will assume that the recurrence interval is 1.5 years for the bankfull discharge.

First Approximation of Bankfull Discharge

Discharge	Rank	T=(N+1)/m
3325	1	11
765	2	5.5
744	3	3.7
505	4	2.8
498	5	2.2
463	6	1.8
301	7	1.6
286	8	1.4
230	9	1.2
181	10	1.1

- The USGS established numerous stream gages to collect a minimum of 10 years of data to develop some level of flood flow frequency prediction. In some cases these can result in broad range of discharges with similar return intervals. Larger data sets on permanent stream gages allow for a narrower range of predicted bankfull discharges.

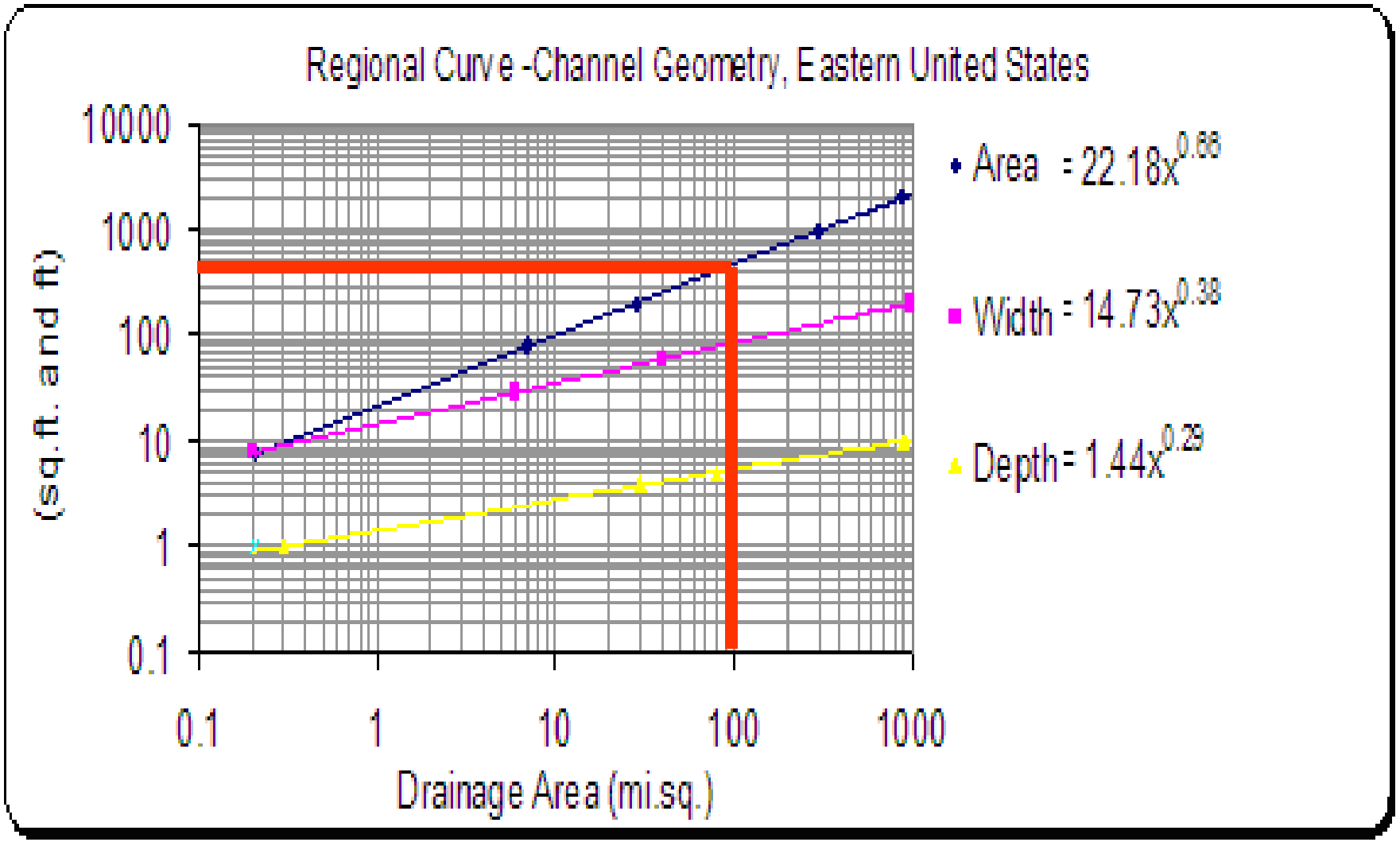
Predict bankfull discharge on un-gaged streams

- USGS stream gage data can be used to predict bankfull discharge on un-gaged streams within the same hydrologic province and/or watershed.
- Determine watershed size for the gaged and un-gaged sites (USGS website has this information for gaged sites). GIS can be used for un-gaged sites.
- Extrapolate bankfull flows for un-gaged sites using the following formula *(assuming Bankfull Q = 1.5 yr. T):*

$$\frac{\text{gaged stream watershed size}}{\text{un-gaged stream watershed size}} = \frac{\text{1.5 year T Q}}{\text{X}}$$

Determining Bankfull Channel Dimensions

- Bankfull channel dimensions can be predicted by:
  - Regional relationships, or regional curves are developed for particular regions or hydrologic provinces. Data collected from numerous gage stations and channel measurements are used to develop regression curves to predict channel dimensions.



Example: a stream segment with a watershed size of 100 mi^2 would have a *bankfull* area, width, and depth as indicated on the y-axis for Eastern U.S. streams.

If regional relationships have not been determined for your region, stream measurements from a gage station can be used to predict the cross-sectional area of the bankfull channel.

USGS hydrologists routinely inspect and calibrate stream gages. Data collected at the gage site includes:

Active channel width, cross-sectional area, mean velocity, gage height, discharge, and a measurement rating (poor, fair, or good).

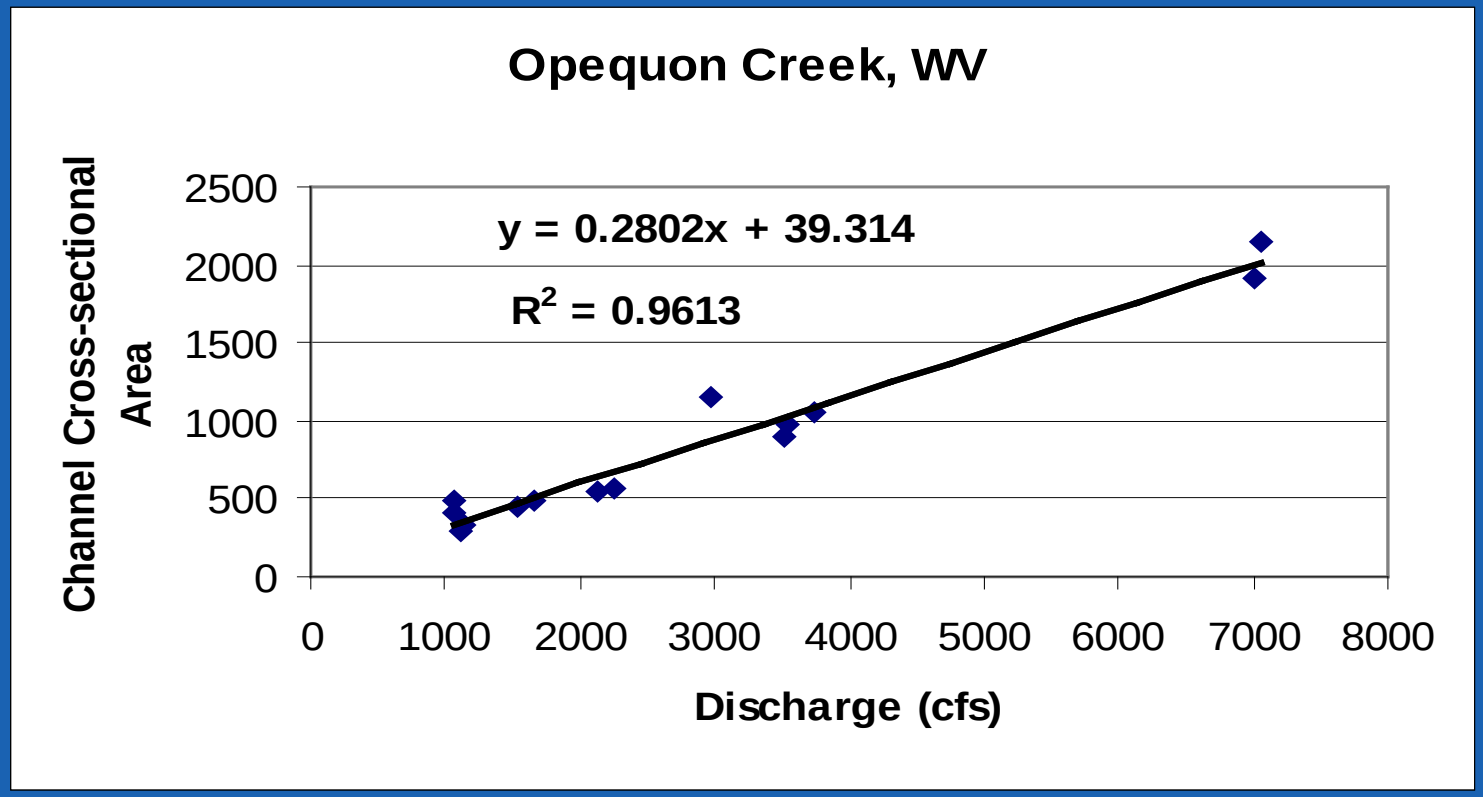
- For example: flood flow frequency information from the 57 year record of Opequon Creek indicates that the 1.5 year return interval flow is 3,030 cfs.

Discharge	Return Interval
3270	1.62
3200	1.57
3190	1.53
3030	1.5
2920	1.46
2910	1.42

- Stream measurement data was collected 14 times at the Opequon gage during discharges measuring over 1,000 cfs.

Discharge	Area (ft^2)
3530	980
2970	1150
7000	1920
1070	412
1070	479
3520	894
1110	298
1530	447
1150	336
3750	1060
7070	2140
1660	479
2130	543
2250	566

- Linear regression analysis between discharge and cross-sectional area can be done, for example, on an Excel spreadsheet. In this case, an active channel with a discharge of 3,030 cfs would be expected to have a cross-sectional area of approximately 890 ft^2

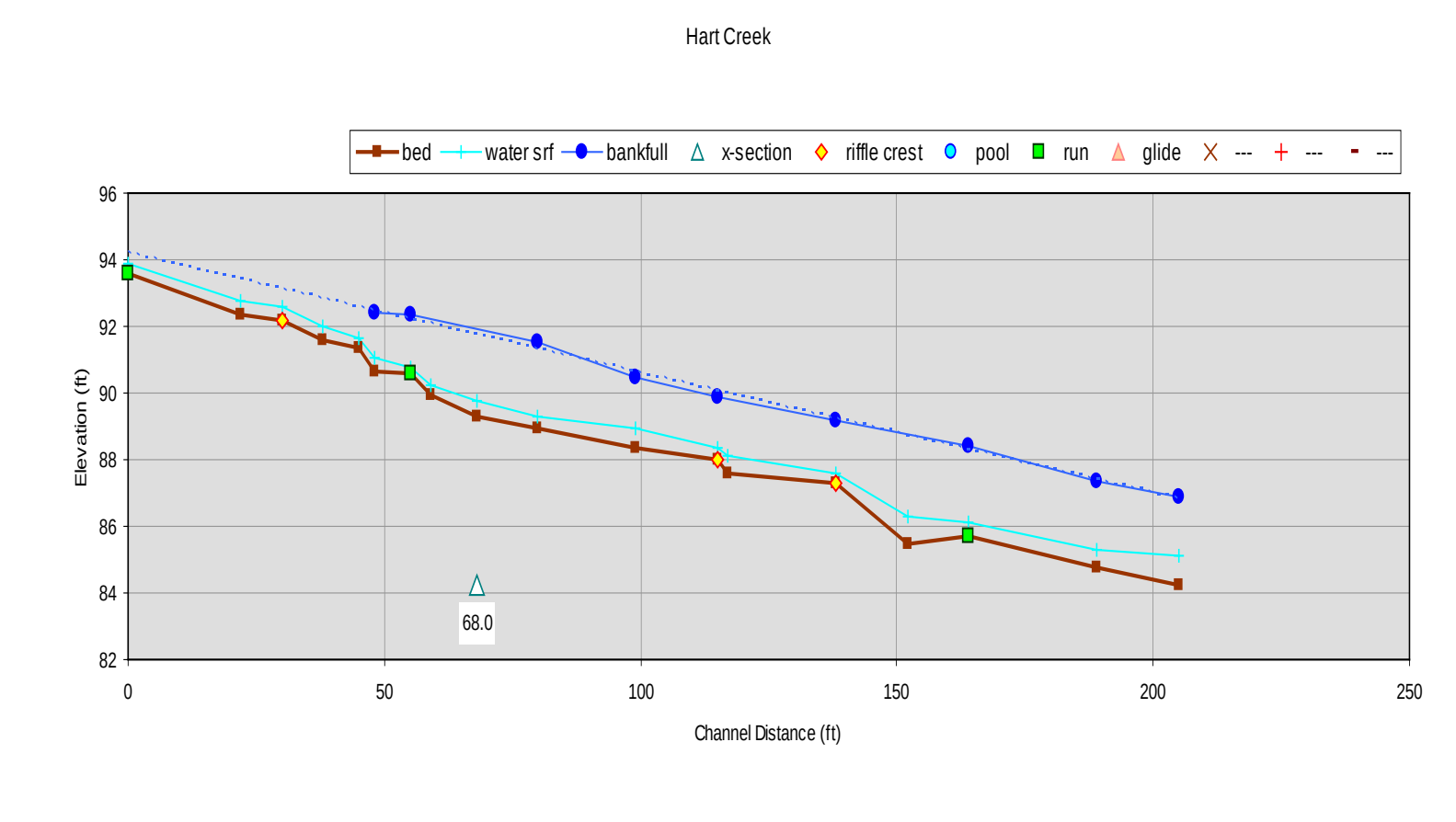


Bankfull Cross-sectional Area Predictions Most Reliable

- The relationship between watershed size and bankfull cross-sectional area usually has the strongest relationship, or highest r^2 value under linear regression.
- There is a weaker relationship between watershed size and bankfull channel width and mean depth because of the effects of channel shape and width-depth ratios.

- These relationships may not be absolute, the identification of the bankfull channel must be supported by field data and observation.
- Bankfull features are built by stream process, therefore they are depositional.
- Confirm bankfull channel identification through channel cross-section measurements at active riffles. Is the cross-sectional area consistent with regional curves or stream measurement data done prior to going in the field.

- Measure a longitudinal profile of the stream reach including thalweg, water surface, low bank or predicted bankfull channel elevations to confirm a consistent bankfull elevation.



- Some References:

USFWS regional curve publications for mid-Atlantic states:
www.fws.gov/chesapeakebay/stream.htm

USGS water publications:
//water.usgs.gov/pubs

Forest Service Stream Team website for bankfull videos, CDs and DVDs:
www.stream/fs/fed.us.index