Statistical Methods Used in Flood Frequency Analysis

Presented by

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Methods

- Frequency Analysis – Bulletin 17B
- Regional Regression Equations
- Purpose: To create relatively simple, accurate and consistent tools we can use to determine flood flows and frequencies

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Frequency Analysis

- Used to infer a flow at a location, with a given probability of exceedance, based on observed values

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Regional Regression Analysis

- Used to estimate a flow, of varying frequency, based on quantifiable characteristics of the watershed in question

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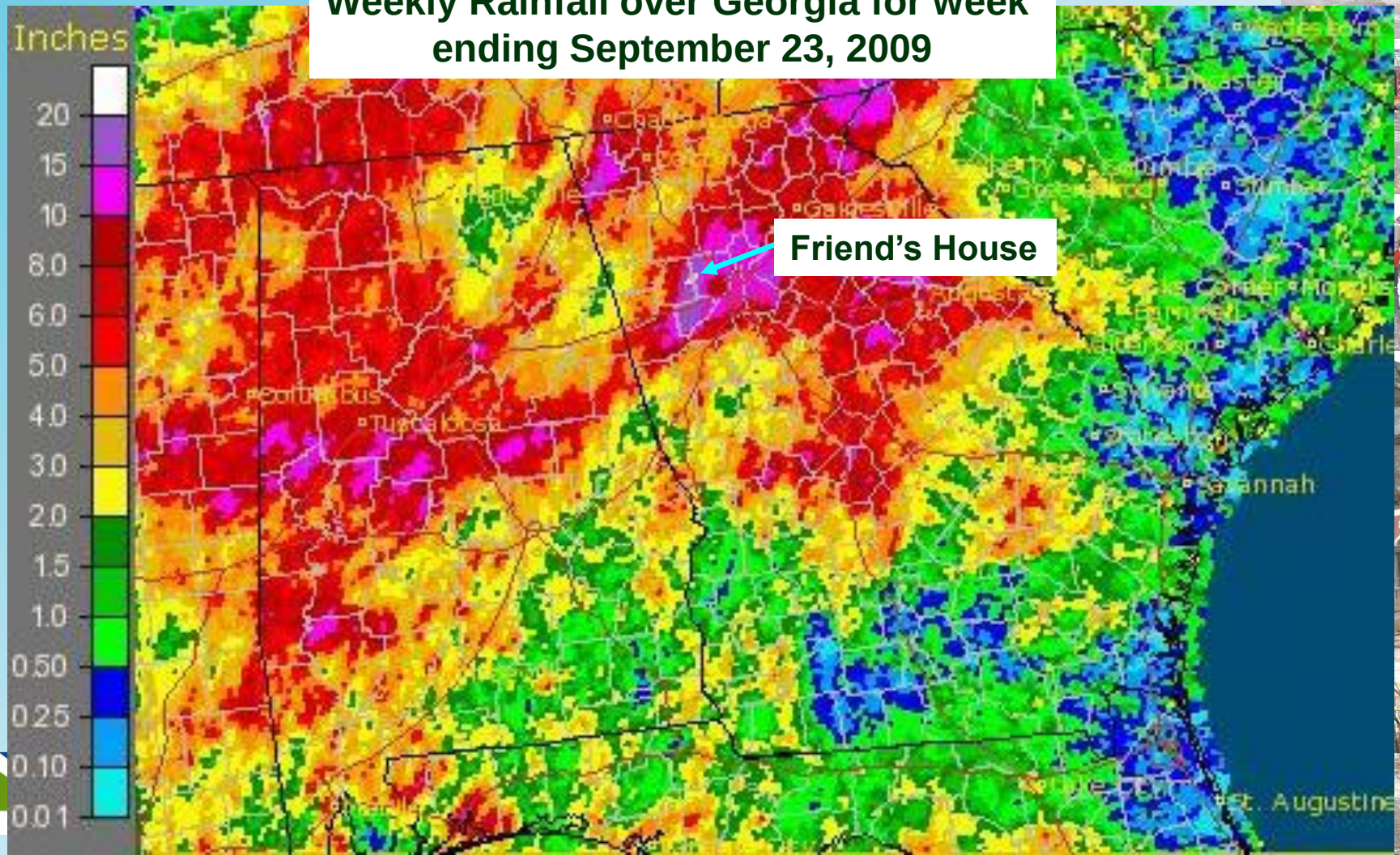
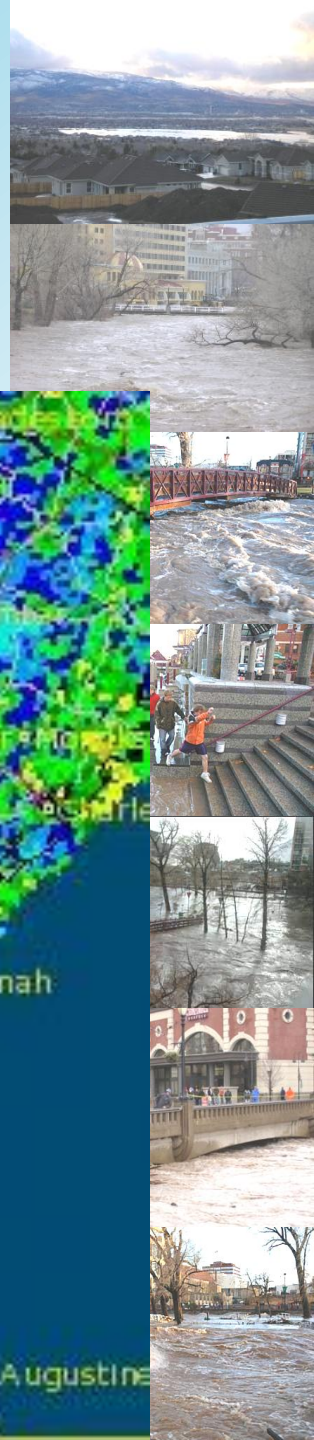
Severe Flooding in Georgia

National Disaster and over $500 million in damages.

Weekly Rainfall over Georgia for week ending September 23, 2009





Severe Flooding in Georgia

- USGS release dated 9/24/2009
  - "*flooding around Atlanta…is one for the record books*"
  - Floods rose over the 500-year flood stage on the Chattahoochee River
  - "*…crews measured the greatest flow ever recorded…on Sweetwater Creek near Austell, Ga.*"

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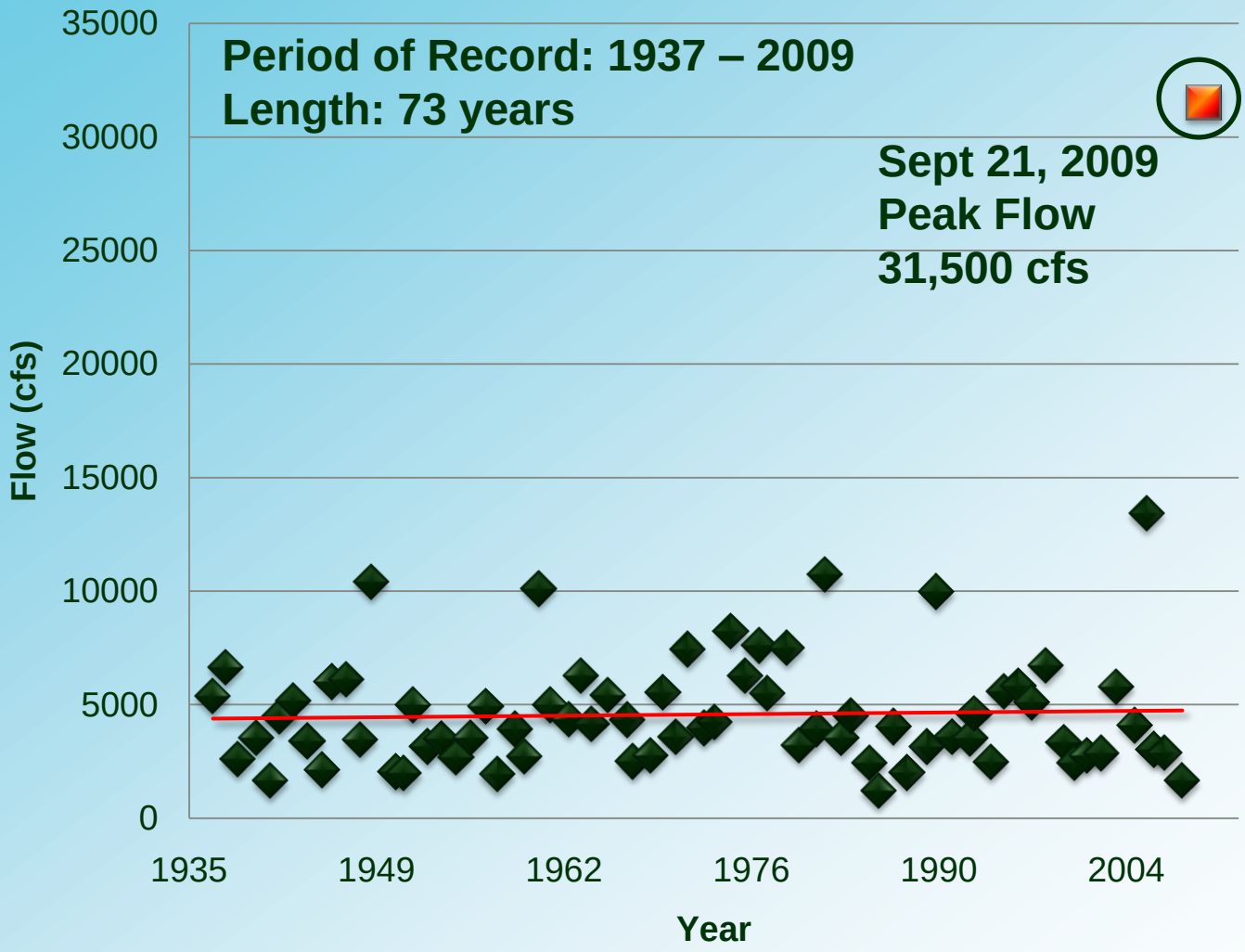
Sweetwater Creek Gage



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What was the return period of the storm?

- Flood Frequency Analysis - Statistical analysis of flood data record to determine return period estimates
- Length of data record vs. expected error (Rule of thumb is 30 years of data!)

Return Interval	±10 % error level (years of record)	±25 % error level (years of record)
10-year	90	18
25-year	105	31
50-year	110	39
100-year	115	48

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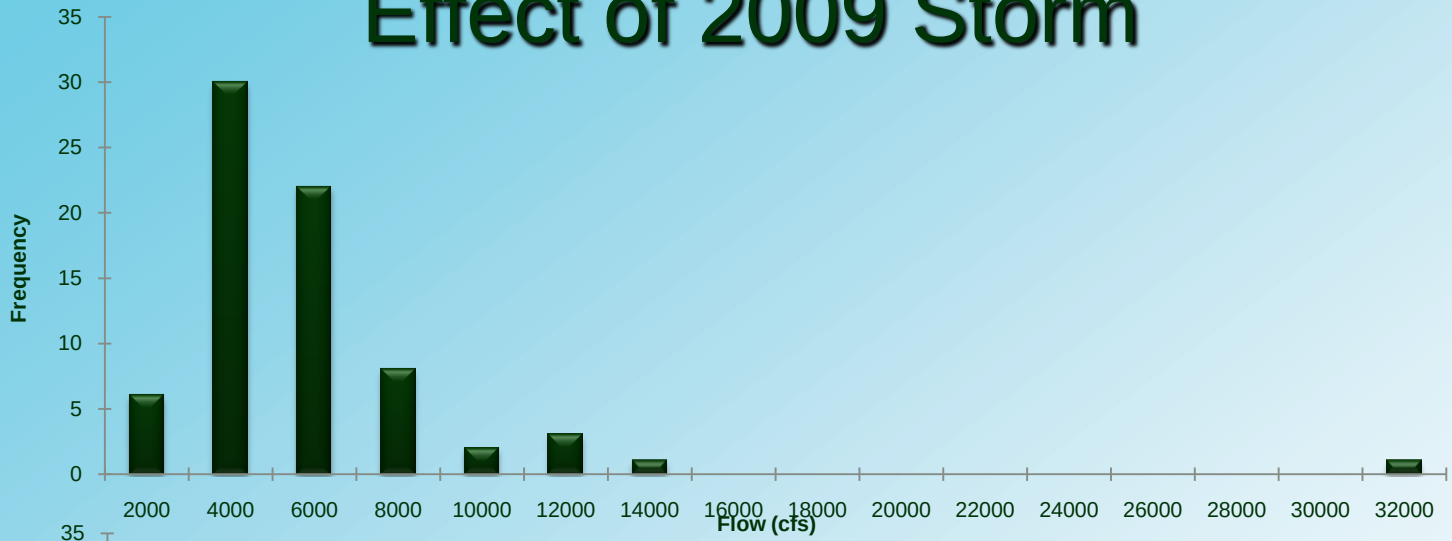
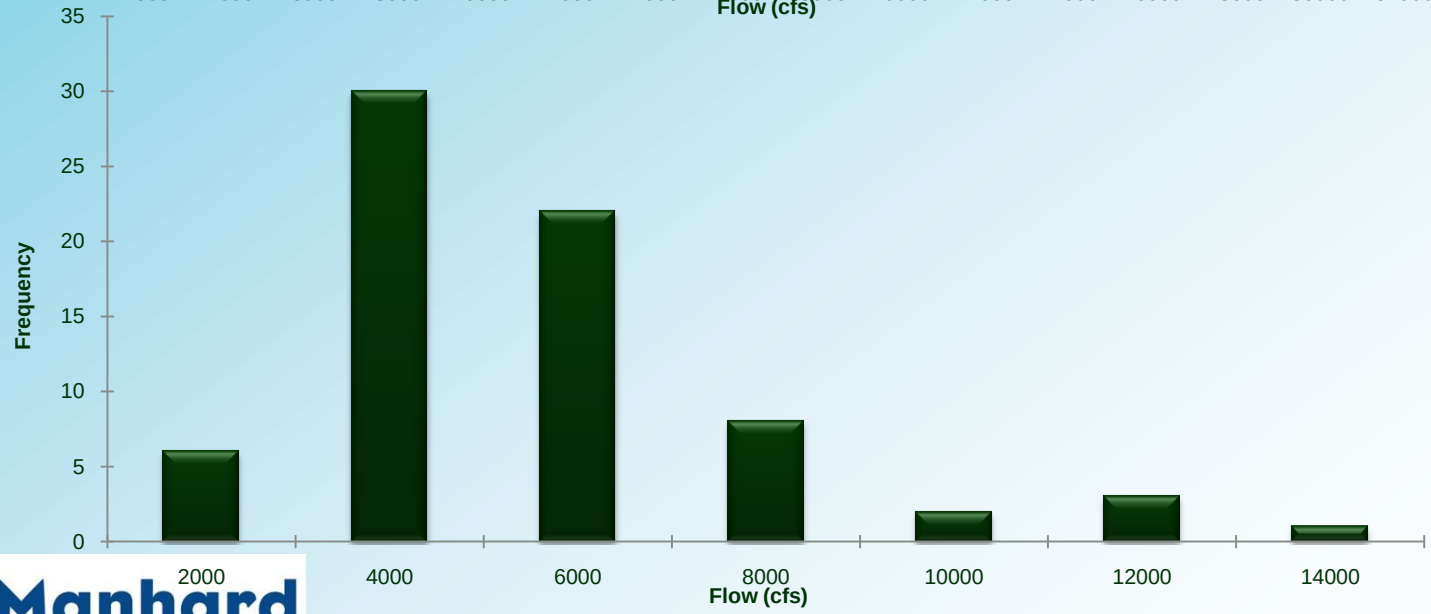
Source: USGS

Histograms of Gage Data
Effect of 2009 Storm





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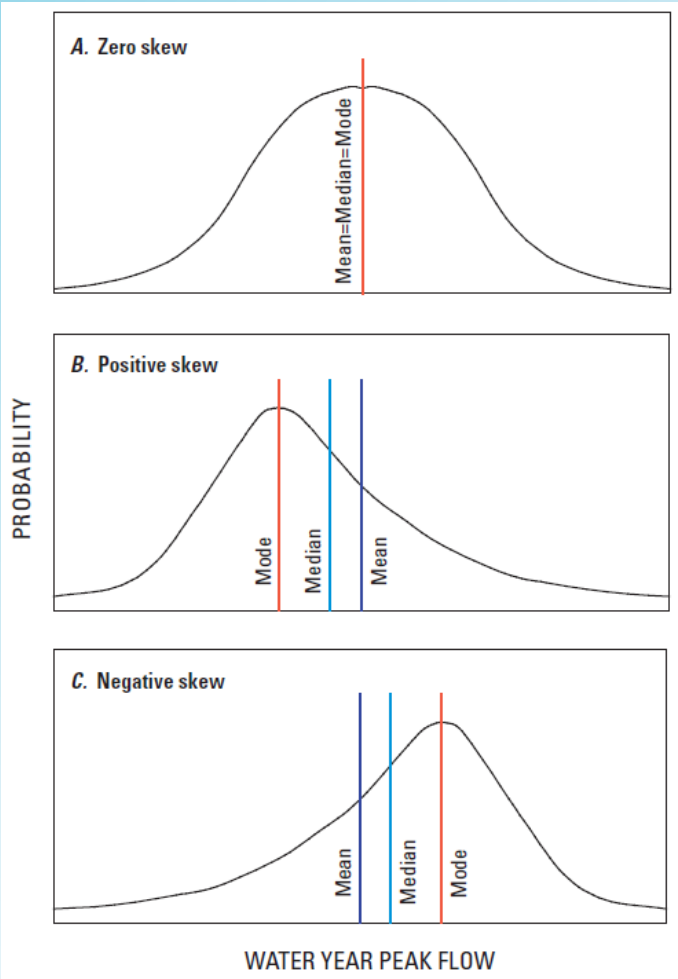
Is the 2009 Peak Flow an Outlier?

- Outliers are points that significantly depart from the remaining data trend
- If station skew high, test for outliers
- Skew is a measure of the asymmetry the data



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Histograms of Gage Data
Effect of 2009 Storm

Question:

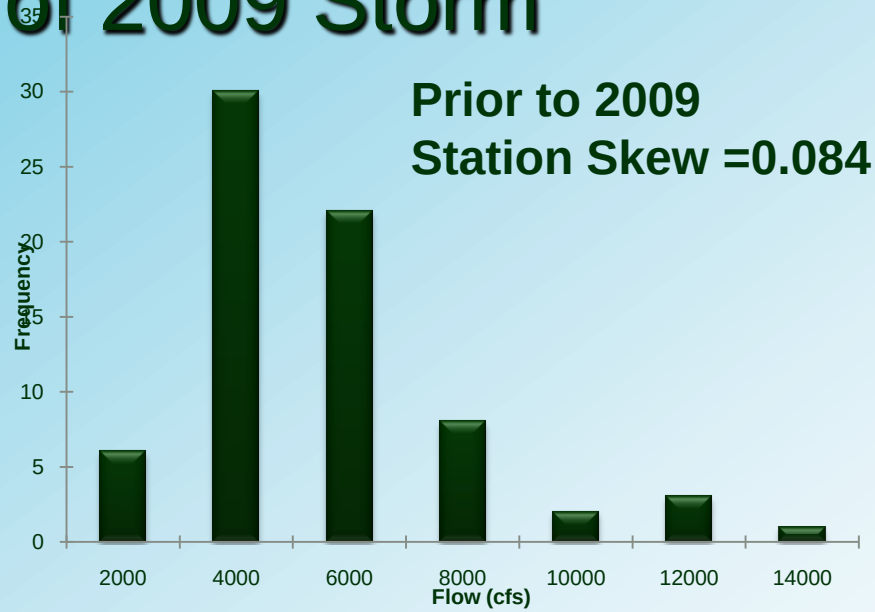
Is the shift solely a result of the outlier, or is it the normal trend of the data?

Flows greater than 10^{X_H} are considered high outliers.

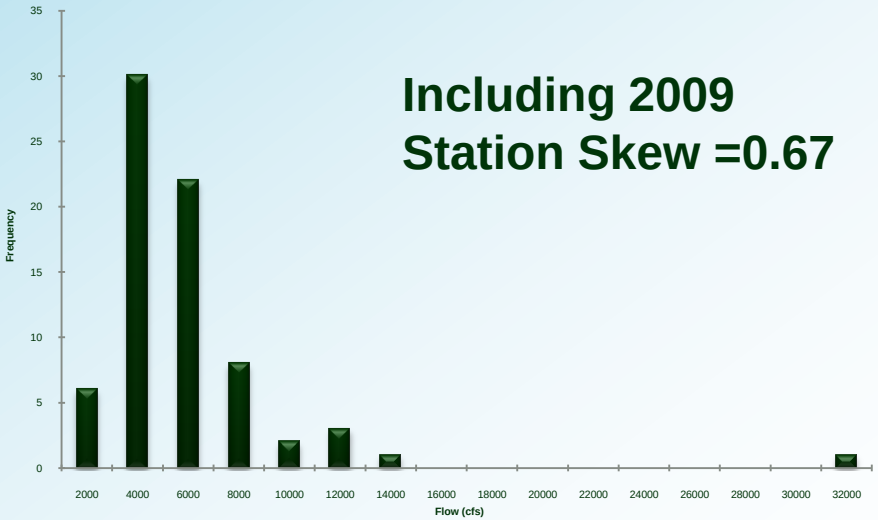
$$X_H = \overline{\log(F_p)} + K_N \sigma_{\log(F_p)}$$

$$10^{X_H} = 20{,}149 \text{ cfs}$$

The 9/21/09 flow (31,500 cfs) is a high outlier



Prior to 2009
Station Skew =0.084



Including 2009
Station Skew =0.67

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Station Skew

- Skew coefficient of the station of record
  - Used in the frequency analysis
  - Very sensitive to extreme events
  - 8 fold increase in skew due to storm!!
- Use a “generalized skew”
  - Weight the station skew with region skew
  - Constant, generalized skew for the south east is –0.019

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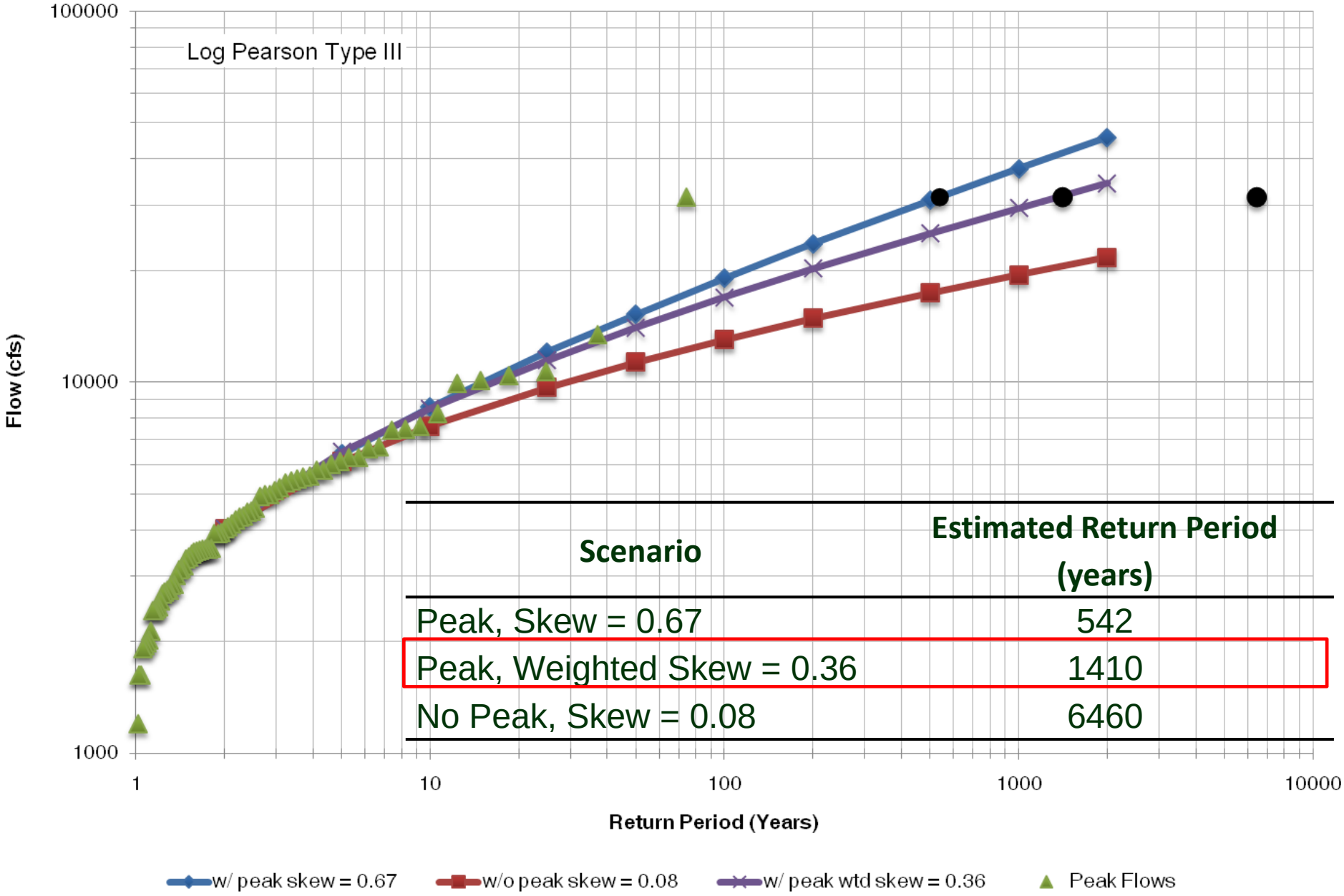
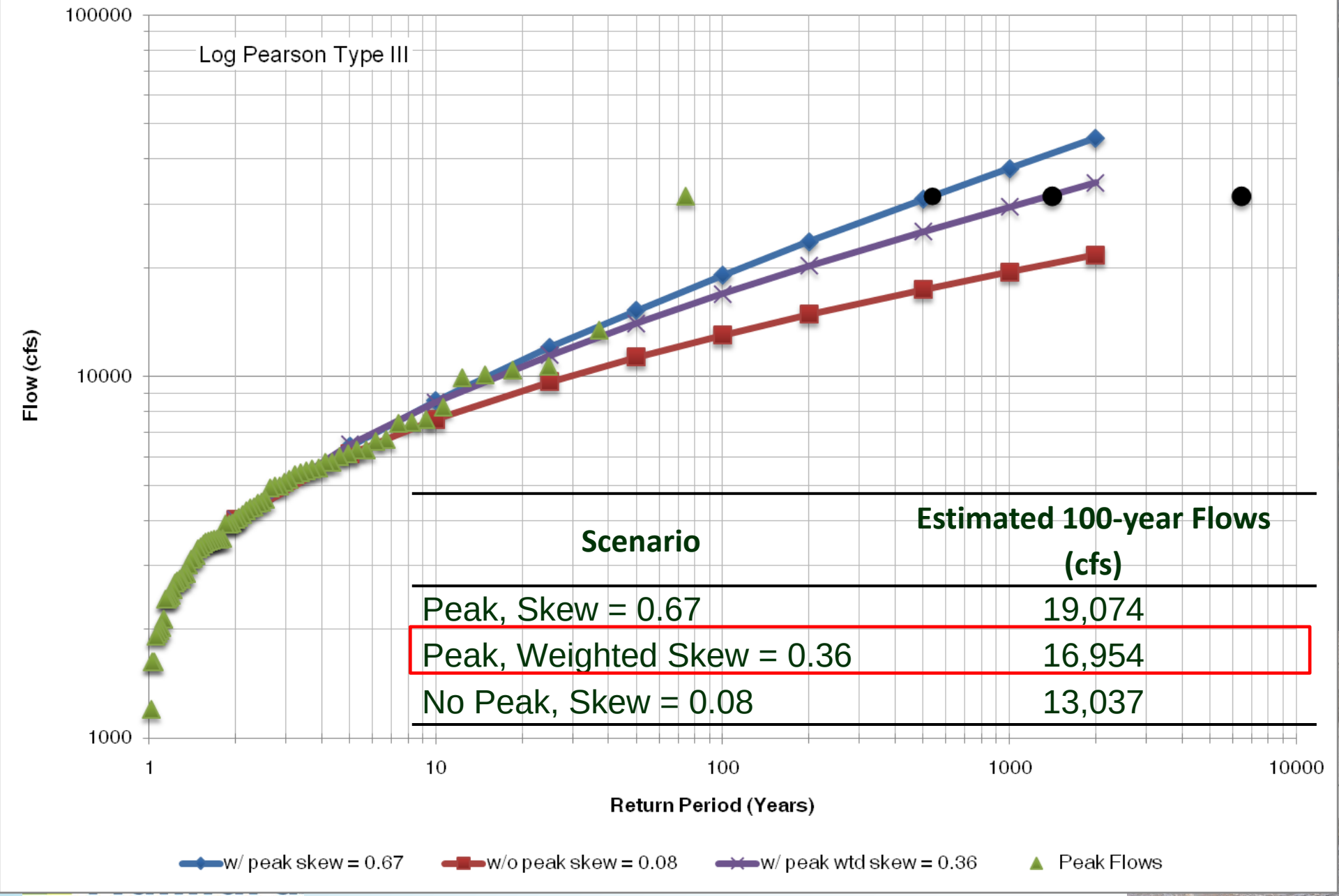
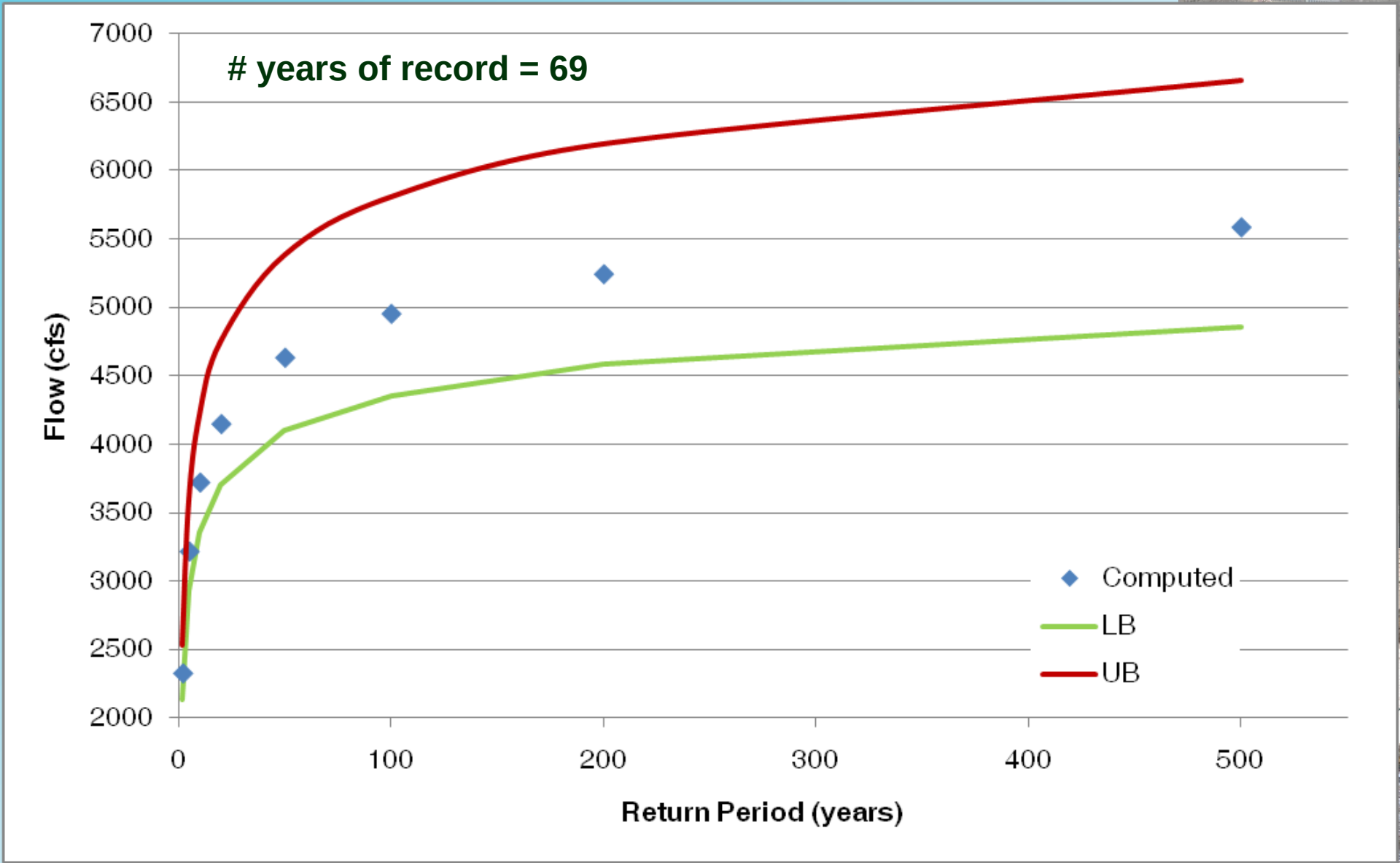


Scenario	Estimated Return Period (years)
Peak, Skew = 0.67	542
Peak, Weighted Skew = 0.36	1410
No Peak, Skew = 0.08	6460



Scenario	Estimated 100-year Flows (cfs)
Peak, Skew = 0.67	19,074
Peak, Weighted Skew = 0.36	16,954
No Peak, Skew = 0.08	13,037

Another Example
95% Confidence Intervals



Using Regression & Frequency Analysis to Validate Model Results

- Location: Carson City, NV
- Hydrologic model results using SWMM

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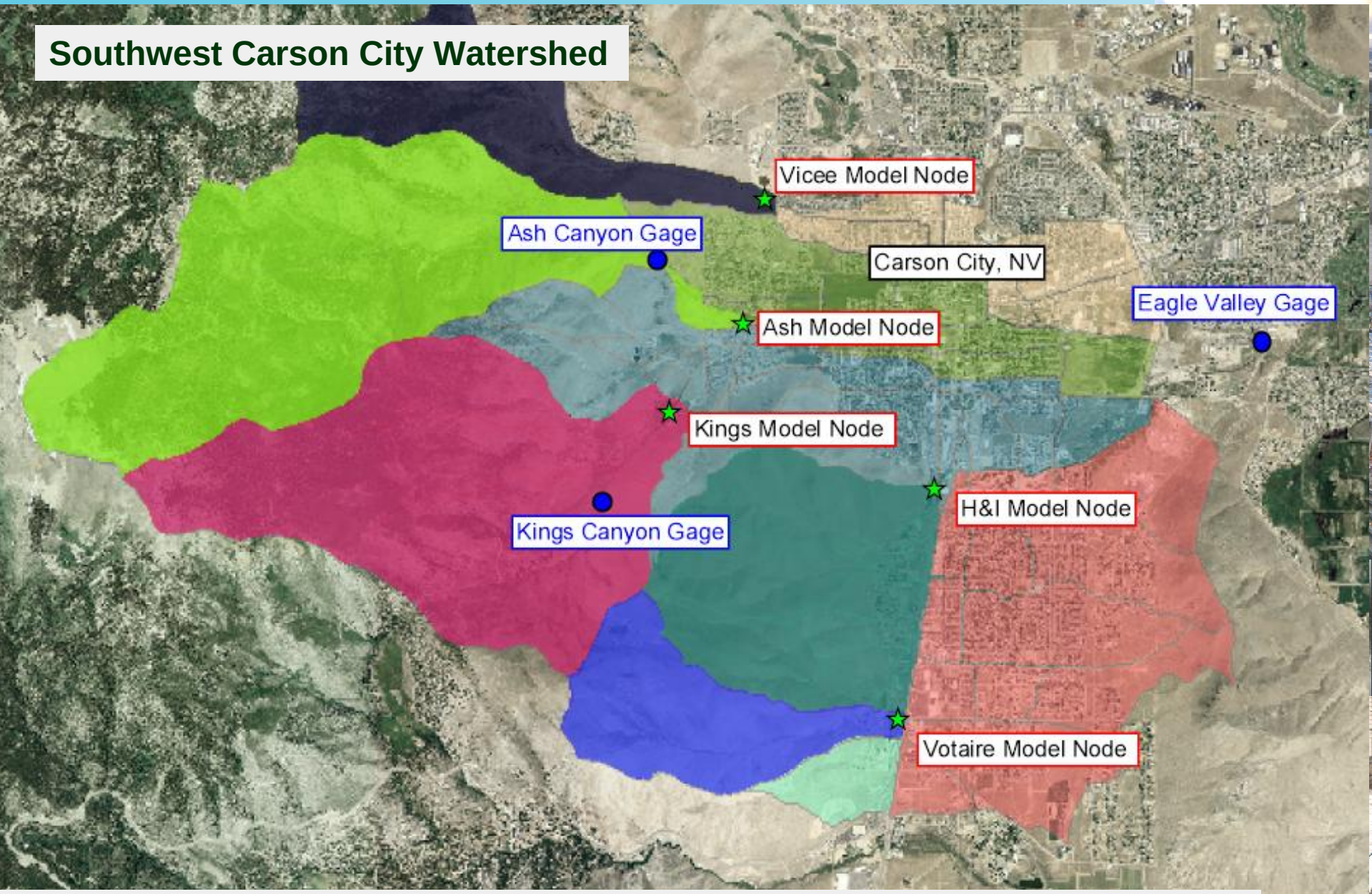
Southwest Carson City Watershed



For model validation:
Compare model results at nodes with gage and regression analysis results

Regression Analysis

- Estimating flood discharges at ungaged sites
- Western Nevada:
  - Thomas, 1994 or Mohr, 1997
- Range of explanatory variables the regression equations are applicable

Drainage Area (mi^2)[1]	Mean Elevation (ft)	Latitude (decimal degrees)
4.1 – 360	5,770 – 10,500	36.44-39.50

[1] For best results, applications should be limited to basins of less than 200 mi^2

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Regression Analysis Variables Used

Location	Drainage Area (mi^2)	Mean Elevation (ft)	NOAA Atlas 14 2yr, 24hr Rainfall (in)	Latitude
Vicee Canyon Creek Retention Basin	1.83	6330	2.21	39.2
Ash Canyon Creek Near Longview Way	5.28	7250	2.57	39.2
Kings Canyon Creek Near Canyon Drive	4.91	6660	2.26	39.2
H&I Tributaries Near Carson Street	2.91	5500	1.68	39.1
Voltaire Canyon Creek Near US 395	1.54	5700	1.80	39.1

Values in red are below the recommended ranges for use in the regression equations.

Regression Analysis Results

Location	100-yr Peak Flow (cfs)	
	Thomas and others (1994)	Mohr (1997)
Vicee Canyon Creek Retention Basin	339	392
Ash Canyon Creek Near Longview Way	577	551
Kings Canyon Creek Near Canyon Drive	656	696
H&I Tributaries Near Carson Street	634	1,112
Voltaire Canyon Creek Near US 395	357	535

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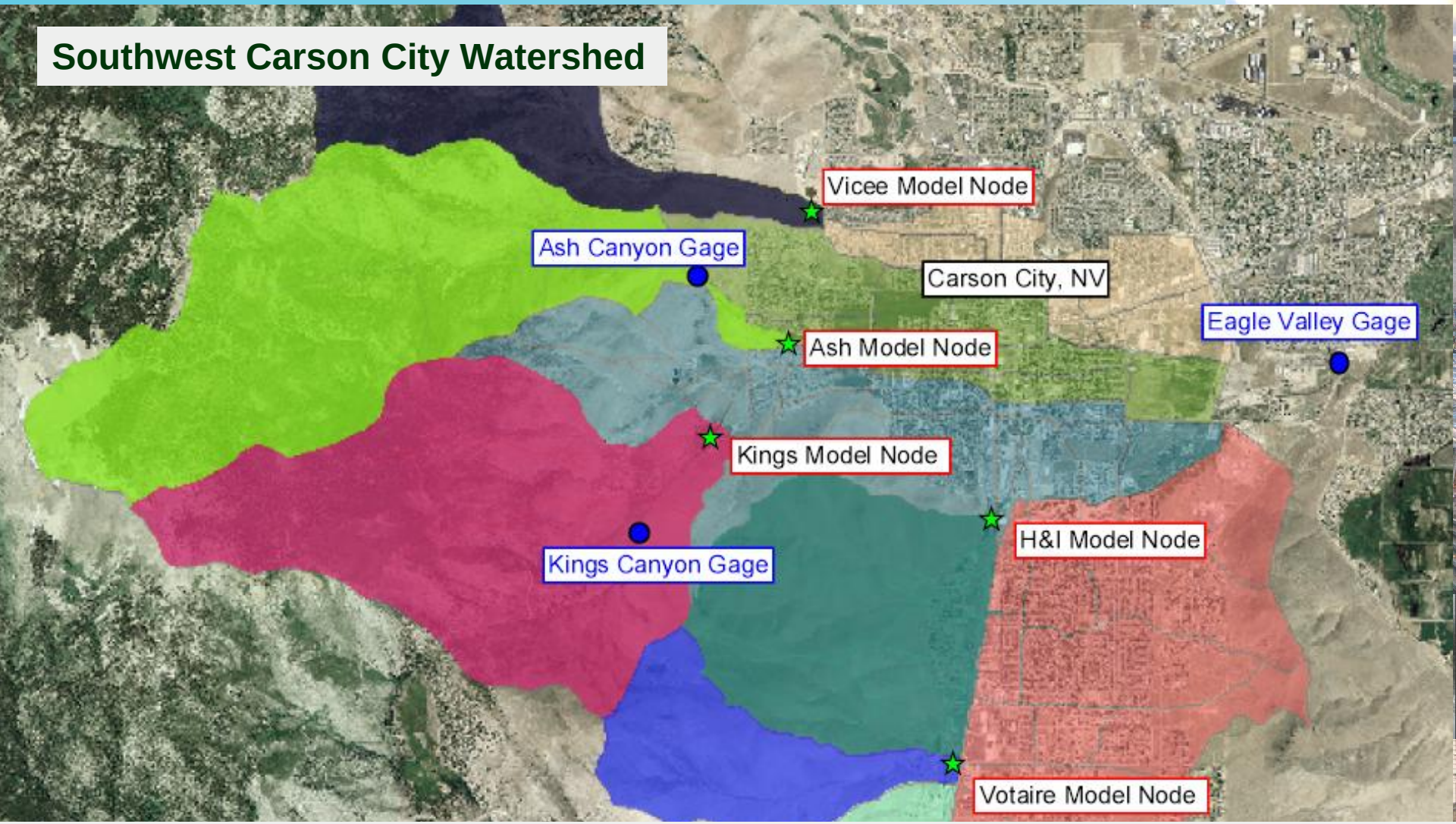
Southwest Carson City Watershed



- Use frequency analysis to estimate 100-year flows at gages
- Gage locations do not coincide with model nodes (ungaged)
- Statistically derived peak flows coinciding with model nodes (ungaged sites) determined using weighted estimates of peak flows at gaged locations
  - USGS Fact Sheet 123-98 (1999) for Nevada

Weighted Estimate Peak Flow

$$\log Q_T(W) = \frac{N \cdot \log Q_T(G) + EQ \cdot \log Q_T(R)}{N + EQ}$$

where

$Q_T(W)$ is the weighted estimate for recurrence interval T at the gaged site,

$Q_T(G)$ **Need frequency analysis results** nalysis of the gage records,

$Q_T(R)$ is the estimate of Q_T derived from application of the regression equation,

N is the number of years of stream gage record, and

EQ is the equivalent years of record

Weighted estimate for ungaged site:

$$Q_T(u) = Q_T(W) \cdot \left(\frac{Area_{ungaged}}{Area_{gaged}} \right)^b,$$

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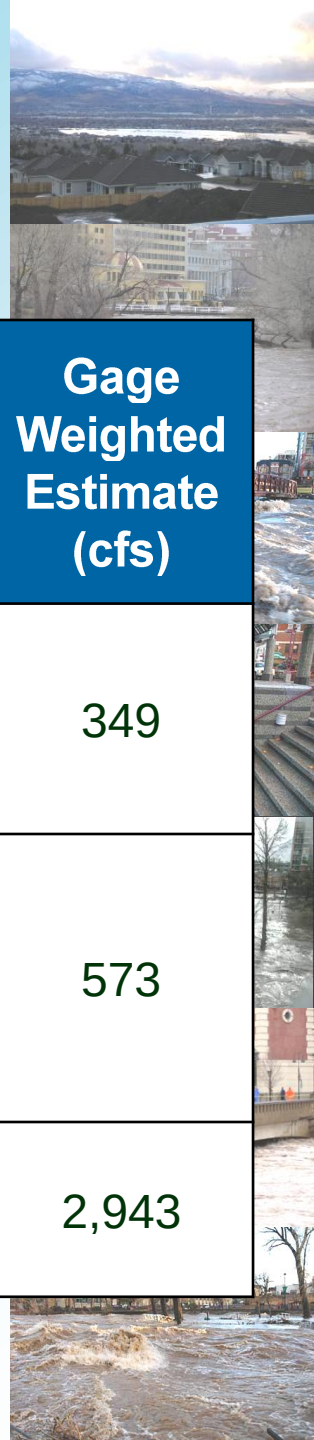
Frequency Analysis Results
100-yr Flows

Gage	Drainage Area (mi^2)	Years	Frequency Analysis (cfs)	Location	Drainage Area (mi^2)	Gage Weighted Estimate (cfs)
Ash Canyon Creek (10311200)	5.18	32	296	Ash Canyon Creek Near Longview Way	5.28	349
Kings Canyon Creek (10311100)	3.86	32	437	Kings Canyon Creek Near Canyon Drive	4.91	573
Eagle Valley Creek (10311300)	45.5	24	3,849	Study Area	28.6	2,943



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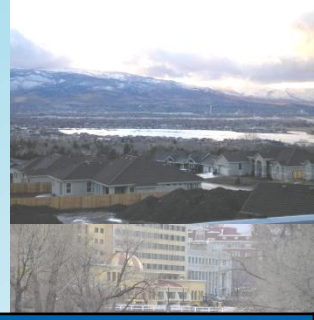
Comparison with Model Results



Location	100-year Peak Flows (cfs)				
	SW Carson SWMM Model	Weighted Gage Estimate	FEMA Effective FIS	Thomas (1994)	Mohr (1997)
Vicee Canyon	370	155[1]	475	339[3]	392[3]
Ash Canyon	1,006	349[2]	1,660	577	551
Kings Canyon	922	573[2]	1,390	656	696
H&I Tributaries	486	246[1]	854	634[3]	1,112[3]
Voltaire Canyon	270	130[1]	690	357[3]	535[3]

[1]Estimate determined from Eagle Valley gage by weighting the watershed areas.
[2]Estimate determined using methods presented in USGS Fact Sheet 123-98, Sept 1999
[3]Outside of range of explanatory variables for which regression equations are applicable

Questions?

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