CE 3354 ENGINEERING HYDROLOGY

LECTURE 7: FLOOD FREQUENCY (BULLETIN 17B)

OUTLINE

- Probability estimation modeling (continued)
- Bulletin 17B

BEARGRASS CREEK EXAMPLE

- Examine concepts using annual peak discharge values for Beargrass Creek
- Data are on class server

BEARGRASS CREEK EXAMPLE

- Take the raw data, and sort small to big

	A	B
1	Peak Discharge - Middle Fork Be	
2		
3	Year	Qp (cfs)
4	1945	1810
5	1946	791
6	1947	839
7	1948	1750
8	1949	898
9	1950	2120
10	1951	1220
11	1952	1290
12	1953	768
13	1954	1570
14	1955	1240
15	1956	1060
16	1957	1490
17	1958	884
18	1959	1320

	A	B	C	D	E
1	Step 1: Sort Data (Small to Big -- Exceedence Probabilities)				
2	Step 2: Compute Empirical Cumulative Probability Estimate by				
3		How Many Entries?		31	<= N
4				32	< N+1
5					
6	Step 3: Plot the Magnitudes versus Cumulative Probability				
7					
8	Rank	Qp (cfs)	Weibull-PP		
9	1	707	0.03125		
10	2	712	0.0625		
11	3	768	0.09375		
12	4	791	0.125		
13	5	839	0.15625		
14	6	874	0.1875		
15	7	884	0.21875		
16	8	898	0.25		
17	9	918	0.28125		
18	10	976	0.3125		
19	11	1060	0.34375		
20	12	1150	0.375		
21	13	1170	0.40625		
22	14	1220	0.4375		
23	15	1240	0.46875		
24	16	1250	0.5		
25	17	1290	0.53125		
26	18	1320	0.5625		
27	19	1450	0.59375		
28	20	1490	0.625		
29	21	1570	0.65625		
30	22	1750	0.6875		
31	23	1810	0.71875		
32	24	2080	0.75		
33	25	2120	0.78125		
34	26	2150	0.8125		
35	27	2270	0.84375		
36	28	2400	0.875		
37	29	3300	0.90625		
38	30	3920	0.9375		
39	31	5200	0.96875		
40					

BEARGRASS CREEK EXAMPLE

- Write the ranks (1,2, … N)

	A	B
1	Peak Discharge - Middle Fork Be	
2		
3	Year	Qp (cfs)
4	1945	1810
5	1946	791
6	1947	839
7	1948	1750
8	1949	898
9	1950	2120
10	1951	1220
11	1952	1290
12	1953	768
13	1954	1570
14	1955	1240
15	1956	1060
16	1957	1490
17	1958	884
18	1959	1320

	A	B	C	D	E
1	Step 1: Sort Data (Small to Big -- Exceedence Probabilities)				
2	Step 2: Compute Empirical Cumulative Probability Estimate by				
3		How Many Entries?		31	<= N
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22	14	1220	0.4375		
23	15	1240	0.46875		
24	16	1250	0.5		
25	17	1290	0.53125		
26	18	1320	0.5625		
27	19	1450	0.59375		
28	20	1490	0.625		
29	21	1570	0.65625		
30	22	1750	0.6875		
31	23	1810	0.71875		
32	24	2080	0.75		
33	25	2120	0.78125		
34	26	2150	0.8125		
35	27	2270	0.84375		
36	28	2400	0.875		
37	29	3300	0.90625		
38	30	3920	0.9375		
39	31	5200	0.96875		
40					

BEARGRASS CREEK EXAMPLE

- Apply Weibull PP Formula

$$PP = \frac{i}{N+1}$$

Chart 5

	A	B	C	D	E
1	Step 1: Sort Data (Small to Big -- Exceedence Probabilities)				
2	Step 2: Compute Empirical Cumulative Probability Estimate by				
3		How Many Entries?		31	<= N
4				32	< N+1
5					
6	Step 3: Plot the Magnitudes versus Cumulative Probability				
7					
8	Rank	Qp (cfs)	Weibull-PP		
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16	8	898	0.25		
17	9	918	0.28125		
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22	14	1220	0.4375		
23	15	1240	0.46875		
24	16	1250	0.5		
25	17	1290	0.53125		
26	18	1320	0.5625		
27	19	1450	0.59375		
28	20	1490	0.625		
29	21	1570	0.65625		
30	22	1750	0.6875		
31	23	1810	0.71875		
32	24	2080	0.75		
33	25	2120	0.78125		
34	26	2150	0.8125		
35	27	2270	0.84375		
36	28	2400	0.875		
37	29	3300	0.90625		
38	30	3920	0.9375		
39	31	5200	0.96875		
40					

BEARGRASS CREEK EXAMPLE

- Build Empirical CDF Plot

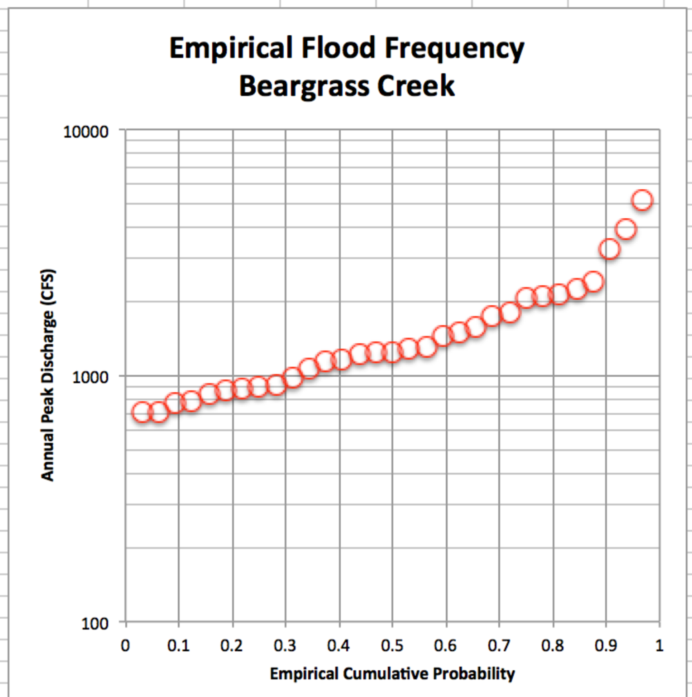
Step 1: Sort Data (Small to Big -- Exceedence Probabilities)

Step 2: Compute Empirical Cumulative Probability Estimate by Weibull Plotting Position Formula (CumProb = Rank/(N+1))

How Many Entries?		31	<= N
		32	< N+1

Step 3: Plot the Magnitudes versus Cumulative Probability

Rank	Qp (cfs)	Weibull-PP
1	707	0.03125
2	712	0.0625
3	768	0.09375
4	791	0.125
5	839	0.15625
6	874	0.1875
7	884	0.21875
8	898	0.25
9	918	0.28125
10	976	0.3125
11	1060	0.34375
12	1150	0.375
13	1170	0.40625
14	1220	0.4375
15	1240	0.46875
16	1250	0.5
17	1290	0.53125
18	1320	0.5625
19	1450	0.59375
20	1490	0.625
21	1570	0.65625
22	1750	0.6875
23	1810	0.71875
24	2080	0.75
25	2120	0.78125
26	2150	0.8125
27	2270	0.84375
28	2400	0.875
29	3300	0.90625
30	3920	0.9375
31	5200	0.96875



BEARGRASS CREEK EXAMPLE

- At this point, can only evaluate the empirical CDF to infer probability and magnitudes within the range of observation (interpolation).
- The next step is to fit a probability distribution to allow extrapolation
  - Normal
  - Gumbell
  - Log-Normal

Beargrass creek example

- Fit Normal Distribution (conventional MOM)
- CMM pp. 363-377

C10

Step 1: Sort Data (Small to Big -- Exceedence Probabilities)

Step 2: Compute Empirical Cumulative Probability Estimate by Weibull Plotting Position Formula (CumProb = Rank/(N+1))

How Many Entries?		31	<= N
		32	< N+1

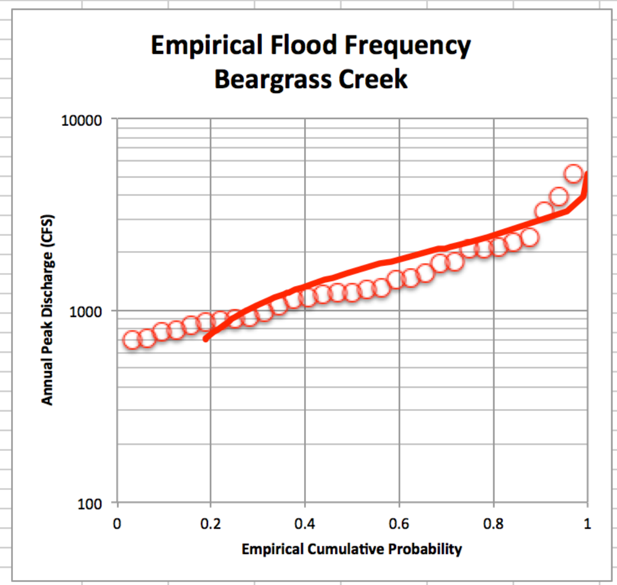
Step 3: Plot the Magnitudes versus Cumulative Probability

Step 4: Compute Normal Distribution Sample Mean, Sample SDEV

Mean		1599.258	<= Mu
		1006.239	<= Sigma

=NORM.DIST(B12,D8,D9,1)

Rank	Qp (cfs)	Weibull-PP	Normal-PP
1	707	0.03125	0.187613
2	712	0.0625	0.188954
3	768	0.09375	0.204373
4	791	0.125	0.210916
5	839	0.15625	0.224961
6	874	0.1875	0.235528
7	884	0.21875	0.238597
8	898	0.25	0.24293
9	918	0.28125	0.249192
10	976	0.3125	0.267829
11	1060	0.34375	0.296009
12	1150	0.375	0.327628
13	1170	0.40625	0.334837
14	1220	0.4375	0.353122
15	1240	0.46875	0.360535
16	1250	0.5	0.364261
17	1290	0.53125	0.379292
18	1320	0.5625	0.390688
19	1450	0.59375	0.44104
20	1490	0.625	0.456768
21	1570	0.65625	0.488402
22	1750	0.6875	0.559542
23	1810	0.71875	0.582946
24	2080	0.75	0.68359
25	2120	0.78125	0.697601
26	2150	0.8125	0.707923
27	2270	0.84375	0.747481
28	2400	0.875	0.786919
29	3300	0.90625	0.954505
30	3920	0.9375	0.989454
31	5200	0.96875	0.999827

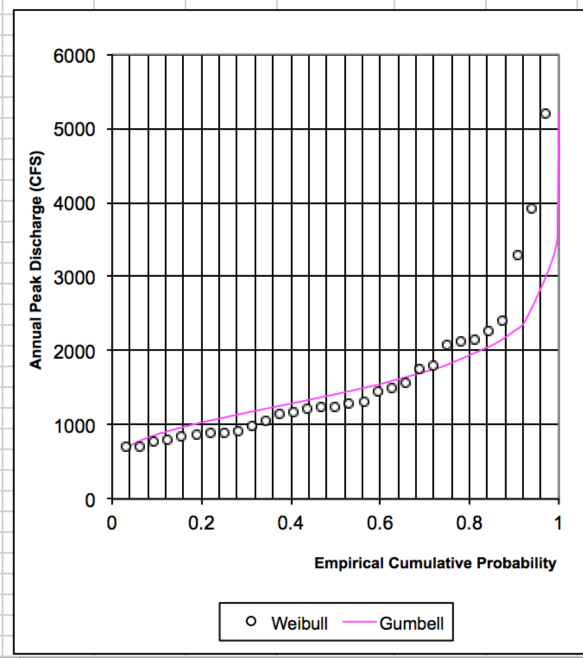


Beargrass creek example

- Fit Gumbell Distribution (conventional MOM)
- CMM pp. 363-377

A	B	C	D	E
Step 1: Sort Data (Small to Big -- Exceedence Probabilities)				
Step 2: Compute Empirical Cumulative Probability Estimate by Weibull Plotting Position Formula (CumProb = Rank/(N+1))				
	How Many Entries?		31	<= N
			32	< N+1
Step 3: Plot the Magnitudes versus Cumulative Probability				
Step 4: Compute Sample Mean, Sample SDEV				
	AVERAGE		1599.258	<= Mu
	STDEV		1006.239	<= Sigma
Step 5: Estimate Gumbell Distribution Parameters				
Parameters:		ALPHA	1246.936	
		BETA	452.8078	
		SSE =>	0.117418	
Ranked	Weibull	Gumbell	error^2	
707	0.03125	0.037067	3.38E-05	
712	0.0625	0.038432	0.000579	
768	0.09375	0.056149	0.001414	
791	0.125	0.064756	0.003629	
839	0.15625	0.085279	0.005037	
874	0.1875	0.102416	0.007239	
884	0.21875	0.107643	0.012345	
898	0.25	0.115201	0.018171	
918	0.28125	0.126476	0.023955	
976	0.3125	0.16217	0.022599	
1060	0.34375	0.220667	0.015149	
1150	0.375	0.289755	0.007267	
1170	0.40625	0.305686	0.010113	
1220	0.4375	0.346008	0.008371	
1240	0.46875	0.362244	0.011343	
1250	0.5	0.370368	0.016804	
1290	0.53125	0.402815	0.016496	
1320	0.5625	0.426993	0.018362	
1450	0.59375	0.528024	0.00432	
1490	0.625	0.557317	0.004581	
1570	0.65625	0.612662	0.0019	
1750	0.6875	0.719475	0.001022	
1810	0.71875	0.749481	0.000944	
2080	0.75	0.853121	0.010634	
2120	0.78125	0.864657	0.006957	
2150	0.8125	0.872755	0.003631	
2270	0.84375	0.900851	0.003261	
2400	0.875	0.924634	0.002464	
3300	0.90625	0.989321	0.006901	
3920	0.9375	0.997273	0.003573	
5200	0.96875	0.999838	0.000966	

$$cdf(x) = \exp(-\exp(\frac{-(x-\alpha)}{\beta}))$$



BEARGRASS CREEK EXAMPLE

- Using the Distribution
- Once Fit, the distribution parameters are used to estimate magnitudes for arbitrary probabilities.
- Estimate discharge for
  20-yr ARI

8	5200	0.96875	0.999838	0.000966		
9						
0	Estimate 20-yr magnitude					
1	Step #1	Probability =1/20		0.05		
2						
3	Step#2	Find value that makes CDF = 1-0.05 = 0.95				
4						
5		Value =	2590	CDF=	0.950	
6						
7						

BEARGRASS CREEK EXAMPLE

- Using the Distribution
- Once Fit, the distribution parameters are used to estimate magnitudes for arbitrary probabilities.
- Estimate discharge for 100-yr ARI

8	5200	0.96875	0.999838	0.000966	
9					
0	Estimate 100-yr magnitude				
1	Step #1	Probability =1/100		0.01	
2					
3	Step#2	Find value that makes CDF = 1-0.01 = 0.99			
4					
5		Value =	3346	CDF=	0.990
6					

Beargrass creek example

- Fit LogNormal Distribution (conventional MOM)
- CMM pp. 363-377

Step 1: Sort Data (Small to Big -- Exceedence Probabilities)

Step 2: Compute Empirical Cumulative Probability Estimate by Weibull Plotting Position Formula (CumProb = Rank/(N+1))

How Many Entries?		31	<= N
		32	< N+1

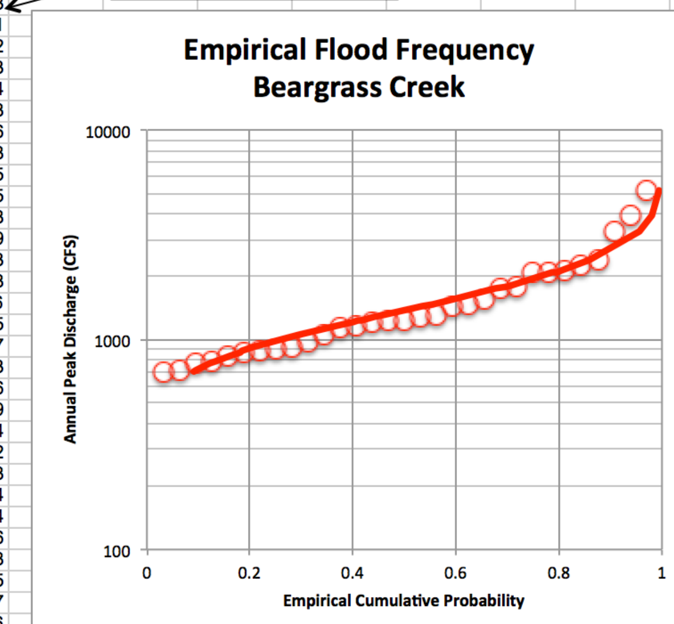
Step 3: Plot the Magnitudes versus Cumulative Probability

Step 4: Compute Normal Distribution Sample Mean, Sample SDEV

Mean		3.143123	<= Mu
		0.220068	<= Sigma

=NORM.DIST(C12,D8,D9,1)

Rank	Qp (cfs)	Log(Qp)	Weibull-PP	Normal-PP
1	707	2.849419	0.03125	0.091003
2	712	2.85248	0.0625	0.093301
3	768	2.885361	0.09375	0.120742
4	791	2.898176	0.125	0.132843
5	839	2.923762	0.15625	0.159434
6	874	2.941511	0.1875	0.179798
7	884	2.946452	0.21875	0.185746
8	898	2.953276	0.25	0.194158
9	918	2.962843	0.28125	0.206335
10	976	2.98945	0.3125	0.242495
11	1060	3.025306	0.34375	0.296198
12	1150	3.060698	0.375	0.353999
13	1170	3.068186	0.40625	0.366733
14	1220	3.08636	0.4375	0.398228
15	1240	3.093422	0.46875	0.41066
16	1250	3.09691	0.5	0.416835
17	1290	3.11059	0.53125	0.441237
18	1320	3.120574	0.5625	0.459193
19	1450	3.161368	0.59375	0.533036
20	1490	3.173186	0.625	0.554329
21	1570	3.1959	0.65625	0.594764
22	1750	3.243038	0.6875	0.675092
23	1810	3.257679	0.71875	0.698658
24	2080	3.318063	0.75	0.786674
25	2120	3.326336	0.78125	0.797444
26	2150	3.332438	0.8125	0.805176
27	2270	3.356026	0.84375	0.833338
28	2400	3.380211	0.875	0.859335
29	3300	3.518514	0.90625	0.955977
30	3920	3.593286	0.9375	0.9796
31	5200	3.716003	0.96875	0.995382



Beargrass creek example

- Using the Distribution
- Once Fit, the distribution parameters are used to estimate magnitudes for arbitrary probabilities.
- Estimate discharge for 20-yr ARI

2	31	5200	3.716003	0.96875	0.995382	
3						
4	Estimate 20-yr magnitude					
5	Step #1	Probability =1/20		0.05		
6						
7	Step#2	Find value that makes CDF = 1-0.05 = 0.95				
8		Q	log10(Q)			
9	Value =	3200	3.50515	CDF=	0.950	
0						

Probability estimation MODELING

- Rank observations
- Compute plotting positions
- Plot Empirical Cumulative Distribution
- Select Probability Model (Normal, Gumbell, …)
- Fit the model to the Empirical Cumulative Distribution
- Use the model to infer magnitudes at desired cumulative probabilities

Bulletin 17B Methods

If the gauging record covers a sufficient period of time, it is possible to develop a flow-frequency relation by statistical analysis of the series of recorded annual maximum flows. The designer can then use the flow-frequency relation in one of two ways:

- If the facility site is near the gauging station on the same stream and watershed, the designer can directly use the discharge obtained from the flow-frequency relation for the design AEP.
- If the facility site is on the same stream, but not proximate to the gauging station, it may be possible to transpose gauge analysis results.

Widely accepted and applied guidelines for statistical analyses of stream gauge data are published in Guidelines for Determining Flood Flow Frequency, Bulletin #17B (IACWD 1982). Procedures from Bulletin #17B, with some Texas-specific refinements, as outlined in this manual, are recommended. They include:

- Obtaining a sufficiently large sample of streamflow data for statistical analysis,
- Using the log-Pearson type III distribution fitting procedure,
- Using a weighted skew value,
- Accommodating outliers,
- Transposing gauge analysis results, if necessary and appropriate.

Bulletin 17B Methods

- Easiest is to use USGS PeakFQ computer program
  - Implements CMM pp 398-405 (with quite a bit of added features)
- The input file is a fixed format “CARD-IMAGE” file
  - Cannot contain TABS, must use whitespace
  - Download from USGS website
- Do an Example with BEARGRASS CREEK to illustrate input file format

BULLETIN 17B Methods

- Bulletin 17B included on server
- PeakFQ user manual included on server (need to get file formats correct)
- Outlier analysis is semi-automated
  - PeakFQ will report if there are high and low outliers above/below criterion
  - User must then flag values (use a minus sign to skip a value) and re-analyze

TRANSPOSITION OF GAGE RESULTS

Transposition of Gauge Analysis Results

If gauge data are not available at the design location, discharge values can be estimated by transposition if a peak flow-frequency curve is available at a nearby gauged location. This method is appropriate for hydrologically similar watersheds that differ in area by less than 50 percent, with outlet locations less than 100 miles apart.

From the research of Asquith and Thompson 2008, an estimate of the desired AEP peak flow at the ungauged site is provided by Equation 4-10:

$$Q_1 = Q_2\sqrt{\frac{A_1}{A_2}}$$

Equation 4-10.

Where:

Q_1 = Estimated AEP discharge at ungauged watershed 1

Q_2 = Known AEP discharge at gauged watershed 2

A_1 = Area of watershed 1

A_2 = Area of watershed 2

SUMMARY

- Probability estimation modeling fits probability distributions to observations
- The fitted distributions are used to extrapolate and estimate magnitudes associated with arbitrary probabilities
- Examples with Normal, LogNormal, and Gumbell in Excel were presented
- Bulletin 17B using PeakFQ was demonstrates as was outlier identification (using the software)
  - Newer software in next few years will replace PeakFQ

NEXT TIME

- Precipitation
- Design Storms
  - TP40
  - HY35
- Intensity-Duration-Frequency
  - NOAA Atlas 14
  - EBDLKUP